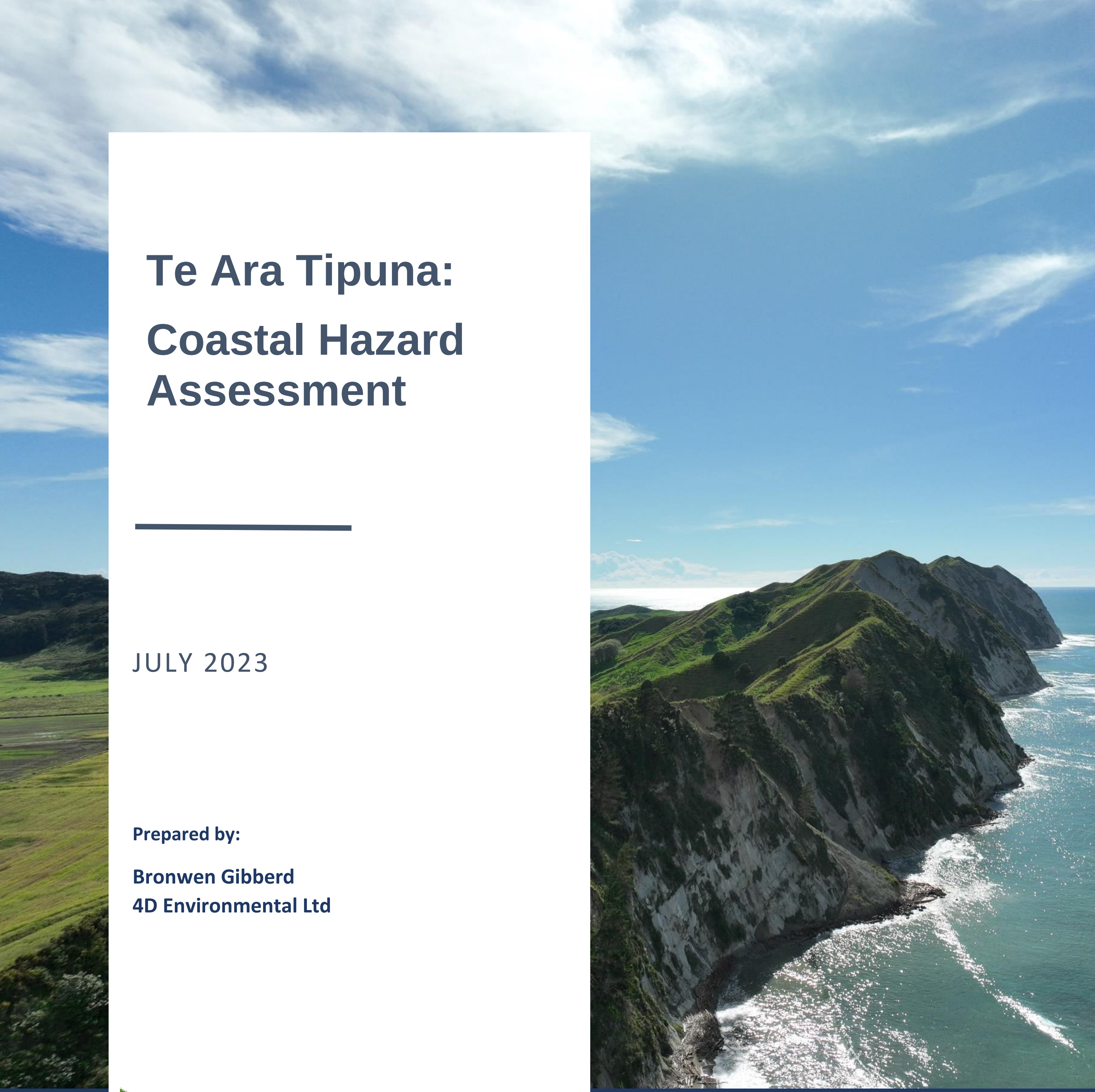

Te Ara Tipuna:

Coastal Hazard Assessment

JULY 2023

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Project Background

The Te Ara Tipuna project aims to establish a continuous interconnected network of walking, cycling and bridle trails around the East Cape, from Gisborne to Ōpōtiki. The objective is to provide a network of accessways for local communities and visitors, and to promote the regeneration of Ngati Porou and Te Whanau-a-Apanui through physical and cultural connections and economic opportunities.

The proposal includes approximately 500 km of trail, including roadside, cliff top, beach, farm and forest sections. The proposed trail is close to the coast at many of the beaches, and in places the walking and bridle trail follow the beach or dunes (Figure 1).

This assessment considers what is known about coastal processes and hazards on the Gisborne and Ōpōtiki District shorelines and evaluates the potential effects of the trail for the purposes of the consent application. The report also highlights potential coastal issues where consents may not be required, including safety for trail users, potential risk to the trail due to erosion, public access and coastal flooding.

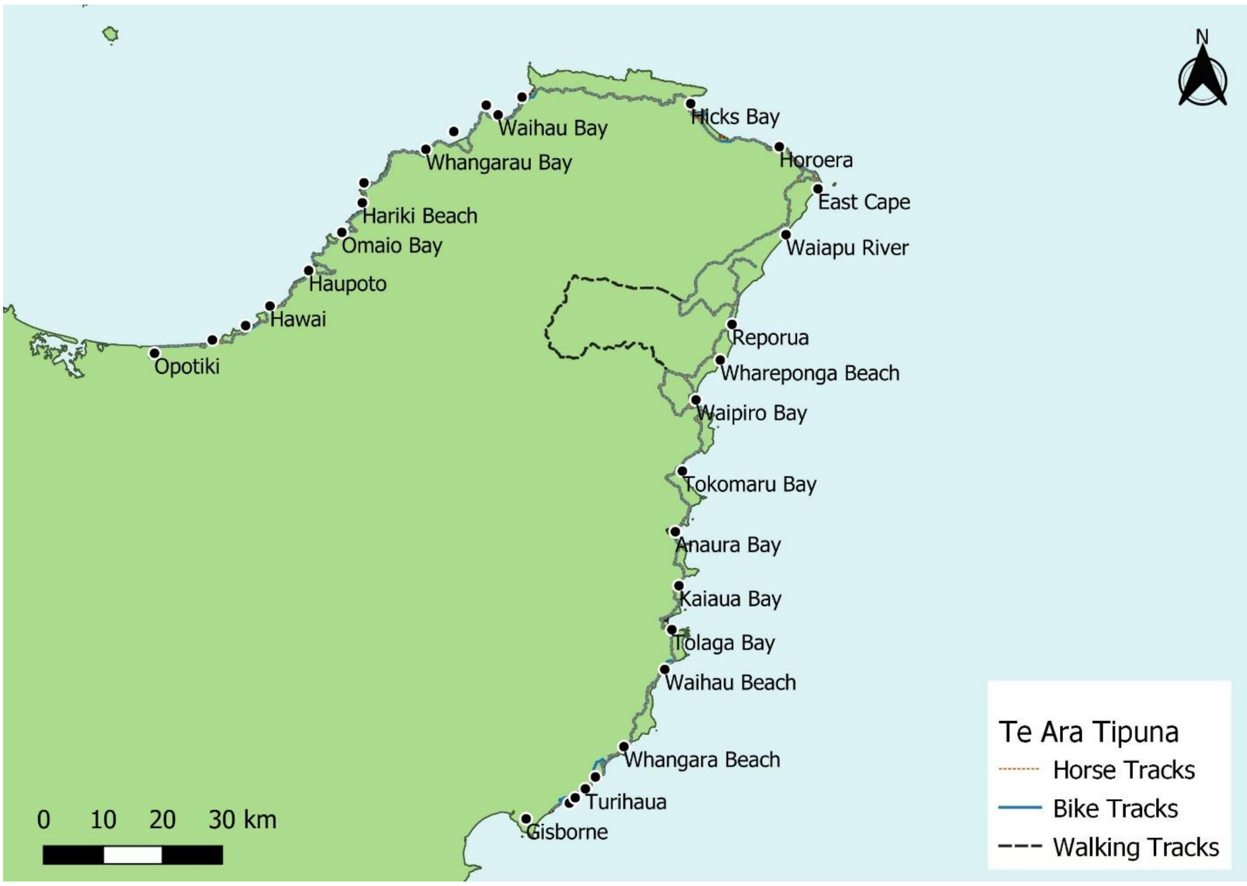

Figure 1: Proposed route of Te Ara Tipuna, with key coastal locations.

Project Details

The shared walk, cycle and bridle trail will be approximately 4.5 m wide and is constructed in most areas as a grassed or compacted dirt/lime track marked with way finder posts. In a small number of locations (to be determined), the trail will be constructed to a higher standard, for example:

- raised wooden boardwalk for walkers and cyclists, with adjacent track for horses,
- ground level boardwalk for walkers and cyclists, compacted lime track for horses, or
- compacted gravel track (4.5 m wide).

The width and construction of the trail will be modified to suit the local setting. In coastal environments, the following assumptions are made when considering the likely effects of the proposed works:

- in dune areas the trail will be a simple track clearly marked with way finders to manage access
- where the width of the coastal reserve is not sufficient to provide for the full width (4.5 m) of shared trail, the width of the trail will be reduced
- on low volume roads, the road corridor maybe used where there is not sufficient width of land or beach to construct a full trail seaward of the road.

The trail utilises existing tracks where it is practicable to do so. There are some stretches of existing track that are potentially vulnerable to coastal hazards. Construction of new track in coastal hazard areas has been avoided where there is a suitable alternative alignment.

This report applies existing knowledge. The coastline between Gisborne and Ōpōtiki has been the focus of many coastal hazard assessments. There has been no additional investigation made to further quantify coastal hazards, except for observations of historic photography where it has been useful. Extreme weather events and roading damage in the summer of 2023 prevented inspection of the proposed route, so this assessment has been undertaken as a desktop exercise, supported by field observations made by those who were able to access the coast.

Coastal hazards change over time at any given location. The landward extent of a coastal erosion hazard is influenced by long term shoreline change trends, and increasingly by the impact of accelerating sea level rise. Coastal inundation hazard is also expected to increase over time with projected sea level rise. This assessment assumes a trail lifespan of 50 years for the consideration of coastal hazards.

Coastal Processes and Environment

Large stretches of Tairāwhiti coastline are characterised by high cliffs (up to 100 m) formed from weak sedimentary rocks. Rock properties and bedding angles vary greatly, which influences erosion rates, landslide susceptibility and slope angle development. Extensive sand beach systems exist between cliff headlands, with numerous river and stream entrances. These beaches are dynamic shorelines and in many areas are experiencing slow ongoing erosion. Beaches are backed by dune systems or low-lying coastal plains of varied width and steeply rising land. The coastal margin is fronted by a rocky shore platform in some areas (including Tokomaru Bay and the East Cape area). The shore platform is covered in some areas by a narrow beach and backed by a low-lying coastal plain.

The Ōpōtiki coastline is also highly varied, with a mixture of exposed sandy beaches backed by wide coastal plains, narrow sand/gravel beaches with rocky shore platforms, and mixed sand gravel barriers. Multiple rivers supply large volumes of sediment to the coastline. Beaches are separated by sedimentary rocky outcrops.

Small settlements exist at many of the beaches, but most of the Tairāwhiti shoreline is backed by coastal reserve and road, or by rural land. Significant townships exist at Tolaga Bay and Tokomaru Bay. The Ōpōtiki shoreline is also largely undeveloped, with numerous small settlements located on the coast but no major urban centres.

The following sections describe the main shoreline types and broadly summarise the key processes affecting these environments, as well as their likely response to future sea level rise. Appendix 1 provides an outline of current national recommendations for future sea level rise projections in New Zealand.

Sandy Beaches

Beaches are dynamic mobile shorelines that are constantly responding and adjusting to coastal processes and are particularly sensitive to the effects of human activities that influence sediment movement or hydrodynamics. Sandy beach shorelines undergo dynamic changes driven by storms, seasonal changes, river mouth dynamics and fluctuations in sediment supply. During storm events, sand is eroded from the beach and (sometimes) the dune and deposited offshore. During calm periods, this sediment is slowly worked back onto the beach by natural coastal processes. As a high tide beach is reformed, sand is blown from the beach and captured by vegetation to rebuild the dune.

Dunes are part of the active beach system and provide a buffer against erosion as well as often serving as a natural defence against coastal inundation. Dune environments are fragile and rely on vegetation to catch and hold wind-blown sand to remain stable and to rebuild following a period of erosion. In many developed areas, these environments are heavily degraded, and this can adversely affect the natural balance of the dynamic beach environment. Dunes are particularly sensitive to disturbance from earthworks and from increased foot traffic.

Natural climatic cycles and variability can alter weather patterns and the frequency and severity of storm events over decadal and multidecadal timeframes. This can drive cycles of erosion and accretion that are larger than that seen from individual storms. Studies of shoreline change on the Tairāwhiti coastline have indicated that sandy beach systems typically undergo dynamic fluctuations of 10-30 m over periods of years to decades, with larger fluctuations near stream and river mouths. Similar multidecadal dynamic changes are seen at beaches on the Ōpōtiki coastline.

Natural and human factors such as net sediment budget and interruptions to sediment transport can drive longer-term progressive shoreline change (erosion or shoreline advance). Many Tairāwhiti beaches are dynamically stable, undergoing shoreline fluctuations over decadal time scales with little net change. At some sites, there is a long-term trend (typically less than 1 m per year) for shoreline retreat or progradation.

Ōpōtiki studies have noted an overall trend for erosion along the coast from Hikuwai to Opape. Most of the mixed sand gravel barriers showed a long-term accretionary trend due to the local sediment supply from the adjacent river mouths. The narrow, mixed sand gravel beaches typically have much less sediment supply and are relatively stable, though in some areas are experiencing long term erosion.

Future Sea Level Rise Effects

The impact of future accelerating sea level rise on beaches will depend on local dynamics, and particularly on sediment supply. In the absence of a strongly positive sediment budget, accelerated sea level rise is expected to slow or even reverse long term accretion. Sea level rise is likely to exacerbate erosion rates on currently retreating shorelines. While there are many possible factors influencing the way that a coastline might respond, the most broadly accepted conceptual model is that the active beach profile (including the nearshore, beach and dune) will translate and reform upwards and landwards in response to sea level rise. The horizontal movement in the shoreline depends on the natural beach slope and is expected to be more significant on wide dissipative sand beaches than steeper narrow beaches. This pattern of change may not occur where there is a large sediment supply, strong alongshore sediment transport or other complicating factors such as the presence of a rocky shore platform.

Gravel Beaches and Barriers

Gravel beaches differ from sandy beaches in terms of morphological features and mechanisms of erosion. Gravel and mixed sand-gravel beaches are typically backed by a "storm berm" which is formed when high energy waves deposit material at the top of the beach slope. Waves overtop the storm berm during extreme events and sediments are deposited on the landward side in a process is known as "rollover". Some gravel is also eroded from the beach face and deposited low on the beach profile. During calm conditions, gravel can be transported up the beach face and form small berms. Although gravel beaches do experience dynamic fluctuations in shoreline position, these tend to be smaller than those observed at exposed sandy beaches. Where gravel beach barriers enclose river mouths these areas can be highly dynamic and complex.

In some areas, narrow mixed sand gravel beaches are seen landward of a rock reef, usually perched on a rocky platform and backed by higher grassed banks formed from sand and gravel deposits. These beaches are somewhat sheltered by the offshore reef and are less dynamic but are generally located away from major sediment supply and can be slowly eroding.

Future Sea Level Rise Effects

Coastal hazard assessments have assumed that accelerating sea level rise will drive shoreline retreat at gravel beaches due to berm rollover. Due to the relatively steep beach profile of mixed sand/gravel and gravel beaches, the horizontal retreat of these shorelines in response to sea level rise is likely to be less than at sandy beaches. Many factors will influence the response of coastlines close to major river entrances to future sea level rise, including changes in catchment management, rainfall, storm patterns and sediment supply.

Cliffs

Cliffs erode as a slow and continual process and do not undergo periods of episodic erosion and rebuilding like unconsolidated beach shorelines. Cliffs erosion has two components; gradual retreat of the cliff toe and face by marine and weathering processes, and episodic slope failures that relate to cliff lithology and geological structure.

Rates of erosion at the toe depend on the geology and exposure and vary considerably on the Tairāwhiti coastline but are typically 0.1-0.3 m/yr (Tonkin & Taylor, 2016). Stable slope angle is influenced by geology and structure and is also highly variable. There is no detailed information about rates of cliff erosion on the Ōpōtiki coastline.

Future Sea Level Rise Effects

The response of a cliff to rising sea level depends on the resistance of the geology and exposure to wave action. As more wave energy meets the base of the cliff due to rising sea level, the erosion of relatively "soft" cliffs is likely to increase. The erosion response will be further influenced by the presence (or absence) of a protective beach at the toe of the cliff.

A broadly accepted approach to estimating future cliff erosion rates is to assume that future toe erosion rates will increase in a way that is influenced by the relationship between past and future rates of sea level rise. The latest coastal erosion hazard assessment by Tonkin & Taylor (2016) has estimated future cliff erosion rates using this approach, which uses a generalised expression that relates past rates of erosion and sea level rise to projected future rates.

Coastal Hazards

Tides and Coastal Inundation

Spring tidal range is approximately 1.7 m on the Gisborne and Ōpōtiki coast, with a MHWS[7] level of 1.07 m (GVD-26) (Table 1).

Table 1: Tidal components at Gisborne and Ōpōtiki (GVD-26 and MVD-53 respectively). Source: https://www.linz.govt.nz/sea/tides/tide-predictions/standard-port-tidal-levels, datum corrections supplied in Tonkin & Taylor (2016), Tonkin & Taylor (2021).

	MHWS	MLWS (m)	Mean spring range (m)	Mean sea level (m)
Gisborne (GVD-26)	1.07	-0.65	1.72	0.21
Ōpōtiki (MVD-53)	0.84	-0.86	1.70	0.04

Water levels at the coast can become significantly elevated during storm events, due to the inverse barometer effect[1] and wind and wave set-up against the coast. Wave overtopping also further exacerbates coastal flooding. The tidal range in Tairāwhiti and Ōpōtiki is relatively small compared with other parts of New Zealand. This means that coastal inundation is heavily influenced by wave effects, which vary considerably with the physical setting and local geomorphology.

As the underlying mean sea level rises in the future, an increasing percentage of normal tides will exceed any given elevation. The same effect will occur with storm tides. Storm tide frequency distributions are such that a relatively small change in base mean sea level can greatly influence the frequency of flooding at any given elevation. For example, NIWA (2020) notes that what is now a relatively frequent 1 in 5-year event would reach the same elevation as a current 500-year ARI storm tide with just 0.16 m of sea level rise. Therefore, events that are currently very rare are expected to occur much more frequently in coming decades.

Extreme sea-levels from storm-tides and waves have most recently been assessed along the Tairāwhiti and Ōpōtiki coastlines by Stephens et al. (2014) and Tonkin & Taylor (2021). Tonkin & Taylor (2016) note that a 1% AEP storm tide is estimated at 1.4 m (GVD-26) in the south of Tairāwhiti District, to 1.5 m (GVD-26) in the north, based on data provided by Stephens et al. (2014). On the Ōpōtiki coast, 1% AEP storm tide levels are approximately 2.0 m (MVD-53) (Tonkin & Taylor, 2021). These figures do not include an allowance for wave run-up, which is variable depending on the physical setting and exposure of the site.

Coastal inundation analysis and mapping has recently been undertaken for the Ōpōtiki District, and the data is due to be released in the second half of 2023. This information will help to guide ongoing management of the trail by providing more detailed information about the storm tide hazard and highlighting areas susceptible to coastal inundation. This information can be used to guide the placing and design of the trail, and potentially to inform trail users about potential coastal hazards.

[1] When there is low atmospheric pressure over the ocean, the water level increases by 10 mm for every 1 hPa fall in atmospheric pressure.

Coastal Erosion

Numerous studies have investigated coastal erosion and the outcomes of these are reflected in the Tairāwhiti Resource Management Plan and the Ōpōtiki District Plan as Areas Susceptible to Coastal Hazards, or "ASCH". The ASCH identify the width of coastal margin potentially vulnerable to coastal hazards over a 100-year timeframe and are based on numerous coastal hazard studies (Gibb, 1994; Dahm & Kench, 2007, Eco Nomos, 2016). ASCH areas have been established with a relatively precautionary approach to provide a method to "screen" proposed activities and highlight the need for more detailed coastal hazard assessments. ASCH may therefore overstate the hazard in many areas.

Detailed hazards assessment at four key sites (Tolaga Bay, Anaura Bay, Wainui Beach and Tokomaru Bay) were completed by Coastal Management Consultants between 1994 and 2008. These hazard zones have been recognised and adopted in the Tairāwhiti Resource Management Plan ("TRMP"):

- Extreme risk: likely to be subject to adverse effects from short-term dune line fluctuations and storm cut (20-year to 30-year timeframe).
- High risk: likely to be subject to net shoreline retreat from historical long-term retreat and sea level rise by 2050.
- Moderate risk: likely to be subject to net shoreline retreat from historical long-term retreat and sea level rise by 2100.
- Safety buffer: likely to be affected in longer term (beyond 2100).

The TRMP includes controls on activities that may impact dunes and other sensitive coastal environments within the identified hazard zones.

The ASCH area was updated and refine by Tonkin & Taylor (2016) along remaining areas of the coastline. This more recent study identifies "ASCE" (Areas Susceptible to Coastal Erosion). The ASCE are calculated at 10-yearly increments from 2015-2115. Planning maps have been produced for present day, 2065 and 2115 timeframes, and include the expected impact of future accelerated sea level rise.

Dahm and Kench (2007) undertook a more detailed study to update the 1994 ASCH areas at priority sites in the Ōpōtiki District and this was again reviewed and updated by Eco Nomos (2016). Tonkin and Taylor have recently completed an updated coastal erosion hazard assessment for sand and gravel beaches and river mouths in the Ōpōtiki District (Tonkin & Taylor, 2021). The report and associated hazard areas are not yet publicly available, but the report was provided to the author to aid with this assessment. Coastal erosion and coastal inundation hazard reports and associated maps are expected to be publicly available in the second half of 2023.

Potential Effects of Trail Construction and Use

As the proposed trail is generally a low-profile track, and in many coastal areas an unformed track, the construction and presence of the trail is unlikely to have significant adverse effects on the coastline or coastal hazards. However, inappropriate positioning, construction or management of the trail could exacerbate the existing coastal hazard risk, including:

- earthworks and associated vegetation disturbance on sensitive dune and coastal margin environments
- damage to dunes and coastal margins from increased pedestrian and horse access
- increased coastal hazard risk due to placement of assets (including the trail and associated structures) within high-risk areas.

These potential effects are discussed below.

Earthworks

Earthworks have the potential to expose highly erodible (non-cohesive) soils in dune environments. Dune sediments are easily damaged both by direct physical disturbance, and by accelerated or chronic wind and coastal erosion if native vegetation is lost. Beaches and associated dunes are easily eroded and particularly vulnerable to projected sea level rise. Retention of natural dune volume is important for coastal resilience. Disturbance of these coastal margin sediments can exacerbate erosion rates, particularly in areas where the coastline has an existing erosion trend.

Where sections of the trail traverse dune environments, earthworks and vegetation disturbance should consider the vulnerability of the environment. The intent in these areas is to simply identify the trail using way finder markers, which will be used to clearly direct walkers to a defined trail. The alignment and location of the pathway should avoid the sensitive frontal dune where possible.

Pedestrian and Horse Access to the Coast

There are currently no structures proposed to provide beach access as part of the trail development. Although therefore not a direct consenting issue, the location and design of the trail should also be managed to mitigate the physical disturbance associated with pedestrians and horses accessing the beach. Increased pedestrian and horse traffic could degrade fragile coastal margins in some areas. It is expected that the "passport" system will provide trail users with information about the importance of using formed accessways and respecting the coastal margin.

In some environments the coast cannot adjust landward as it would naturally in response to sea level rise. This may be due to coastal protection structures, existing infrastructure or development, or natural geomorphology (erosion resistant and/or steeply rising land). In these cases, accessible beaches may become pinched out over time. This will threaten the sustainability of beach sections of the walk at higher stages of the tide and alternative solutions may be required. It is difficult to predict the timeframes over which this access may be lost, due to natural fluctuations and the inherent uncertainty associated with predicting both sea level rise rates and the shoreline's response to sea level rise.

Increased Coastal Hazard Risk

Coastal hazard risk is the product of the coastal hazard and the consequence of that hazard occurring. The establishment of the trail at the coastal margin could increase the consequences of natural coastal erosion and therefore increase the total coastal erosion hazard risk. This is particularly relevant where the trail is to include physical structures (e.g. boardwalks).

The trail alignment has been located as much as practicable to avoid areas likely to be impacted by coastal erosion hazard over the next 50 years. New stretches of trail on cliff shorelines have been aligned to avoid areas likely to be impacted by coastal cliff instability. Slope instability in cliff areas has been addressed in more detail in the geotechnical assessment.

Although effort has been made to minimise coastal hazards, there are sections of the trail where there is no option but to locate it within the identified coastal hazard area. In these areas, the width of the trail will be adapted, and the construction methods/materials limited to avoid large investment within the hazard area and ensure adaptability (i.e. simple path design). In many of these areas, the trail is directly adjacent to (or directly utilising) existing infrastructure that is at risk from coastal hazards.

Placement of toilet and shelter buildings within an area vulnerable to coastal erosion or inundation could cause disturbance to sensitive coastal environments and add to coastal hazard risk. The location of all proposed new buildings and bridges on the Tairāwhiti coast has been reviewed against the identified coastal erosion hazard areas (Tonkin & Taylor, 2016), and all are located outside of coastal erosion areas likely to be vulnerable over the next 50 years.

There are two toilet structures proposed on the Ōpōtiki coastline (at Omaio and Hawai) within the area identified as potentially susceptible to coastal hazards (ASCH). The ASCH have been identified with a broad scale and precautionary approach (i.e. the hazard may be overstated in some areas), and is based on a 100 year timeframe. Based on the information and analysis presented in the available coastal hazard reports and consideration of the coastal setting, the risk to these two buildings is very low.

The most significant potential adverse impact of the proposed works on the physical coastal environment is the possible construction of erosion protection works that may be deemed necessary in the future to protect the trail where it is threated or damaged by coastal erosion. Coastal protection structures can cause adverse effects in the coastal environment, including accelerated lowering of the beach profile, exacerbated erosion on adjacent shorelines ("end effects") and loss of amenity values. These effects can exacerbate coastal hazard risk in the long term. There is currently no expectation that the trail will be protected with physical works in the short term, and there are no coastal protection works proposed as part of the current resource consent application.

Medium to long-term management of the trail will almost certainly require decisions to be made about protecting or adjusting the trail alignment. This assessment assumes that the key focus will be on avoidance of hazards and resilience through adaptation wherever possible. Any future physical works that may be required to protect the trail will be the subject of a separate process and will require resource consent. In many areas this will be linked with the management of the adjacent road. Such a process will require a detailed (site-specific) assessment of the potential effects.

Management Recommendations

The proposed walking, cycling and horse-riding trails traverse many coastal areas, including sand dunes, narrow coastal reserves, low lying coastal plains and coastal cliffs. This report has reviewed the available coastal hazard information to evaluate stretches of the proposed trail that may be vulnerable to coastal hazard over the next 50 years, including short term fluctuations and long-term trends in shoreline change, coastal inundation, and the potential effect of projected sea level rise.

The establishment of Te Ara Tipuna will have little or no effect on existing coastal hazards, based on the following conclusions and assumptions:

- the trail will be marked with simple way finding posts and earthworks will be minimised in sand dunes, unless for the purposes of dune restoration or improvement of dune stability
- the trail itself does not create a barrier to natural coastal processes
- if the trail is threatened or damaged by coastal erosion, management actions will prioritise avoidance and adaptation of the trail alignment over the construction of protection works
- the trail does not include lowering of sand dunes or significant earthworks in coastal inundation areas, and will either avoid or be designed to withstand occasional coastal inundation in low-lying coastal margins
- coastal hazard risk is minimised by locating proposed structures (toilets, shelters and boardwalks) mostly outside coastal hazard areas, and any remaining coastal hazard risk can be mitigated through an adaptive management approach.

Although the establishment of the trail is unlikely to affect coastal hazard processes, users of the trail could be impacted by coastal hazards, and there is a risk of physical damage to the trail over time in some places. There are sections of the trail located close to erosional coastlines, and in some areas the road and/or other land-based assets are already threatened by coastal erosion, with little space to align the trail further landward. In most of these areas, the trail follows existing roads, and its maintenance will likely be integrated with the management of the road.

Predicting each of the many components of coastal erosion hazard comes with considerable uncertainty, particularly the long-term rate and effect of future sea level rise. The likely lifespan of a section of trail close to the coast cannot be accurately predicted. Coastal erosion hazard could be managed using an adaptive management approach, with monitoring and a range of triggers and actions that relate to the coastal hazard risk profile over time. This approach would provide for coastal sections of the trail to be utilised while conditions allow, while planning for future actions to adapt to an increasing hazard risk over time and ensuring the objectives of Te Ara Tipuna are met in terms of resilience.

In low lying areas (particularly Tokomaru Bay and Tolaga Bay), the trail may be periodically inundated during coastal storm events, either directly by storm surge, or by wave run-up and overwash close to the coast. This is only likely during rare and extreme events but is expected to become more frequent over time with projected sea level rise.

A "passport" system has been proposed, to provide trail users with information about appropriate behaviour and sensitive habitats or features (e.g. culturally significant sites, high value ecosystems etc). This system will include information about coastal hazards, including:

- avoiding unnecessary damage in sand dune environments, by using defined accessways and trails
- awareness of tides and storm surge (i.e. some portions of the trail may not be safe during high stages of the tide, or during storm or high wave events)
- basic awareness of tsunami hazard (i.e. signs and actions)

Conclusions

The impact of the establishment of the proposed Te Ara Tipuna coastal trail on coastal processes and coastal hazards is likely to be less than minor. This assessment assumes that the construction and management of the trail reflects the potentially sensitive coastal margin, and an adaptive approach is taken to management of the trail over time in hazardous areas. This judgement also assumes that significant earthworks and major structures will be undertaken outside areas of sensitive coastal margins and identified coastal hazard areas.

Significant stretches of the trail are located very close to the coastline and are potentially vulnerable to damage from coastal erosion in the future, particularly with future sea level rise. In many of these areas, other existing infrastructure is already at risk. Future actions to protect at risk parts of the trail could have significant adverse effects on the coastal environment. It is not practicable to avoid all potential coastal hazard areas, and there will be a need to undertake an adaptive management approach to minimise these impacts and to integrate management of the trail with coastal hazard management of other at-risk infrastructure.

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Appendix 1: Sea Level Rise

Sea level has been rising at approximately 2 mm per year for the last 100 years. Recent historical trends are therefore occurring with this rate of sea level rise. The average level of the sea is expected to continue to increase at an accelerating rate for the foreseeable future. This will have a significant impact on both coastal erosion and coastal inundation hazard in the future.

The Ministry for the Environment provides projections for future sea level rise around New Zealand and recommendations for the use of sea level rise projections for managing coastal areas (MfE, 2022). The guidelines recommend that a range of future sea level rise scenarios are considered to reflect the uncertainty in predicting future sea level rise rates. Five "plausible" Shared Socioeconomic Pathways (known as SSP scenarios) are recommended for coastal planning in New Zealand, which are based on the most recent International Panel on Climate Change (IPCC) report (IPCC, 2021):

- SSP1-2.6 M – "Sustainability"
- SSP2-4.5 M – "Middle of the Road"
- SSP3-7.0 M – "Regional Rivalry"
- SSP5-8.5 M – "Fossil-fuel Development"
- SSP5-8.5 H+ - 83rd percentile (top of shaded "likely range" of SSP5-8.5)

Projected sea level rise for each of the SSP scenarios are shown in Figure 2. The range of projections indicates that sea level rise is likely to be between 0.3 m and 0.5 m over the next 50 years and 0.5 m and 1.1 m over the next 100 years. Sea level rise is expected to continue to increase beyond that time.

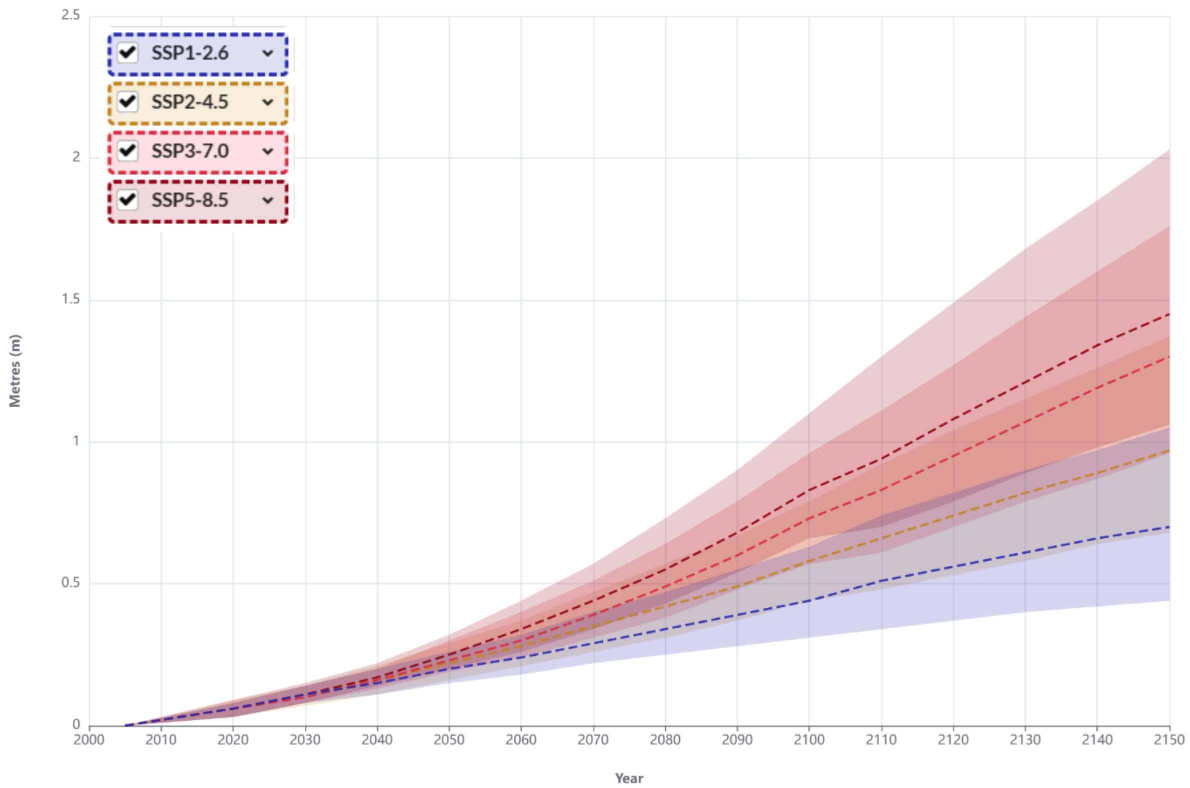

Figure 2: Potential future sea level rise scenarios for the period out to 2150 based on present interim national guidance (solid lines). Shaded areas indicate the likely confidence intervals. Source: Figure 1, MfE (2022).

The amount of sea level rise experienced at any given location can also be influenced by vertical land movement (uplift or subsidence). If land is dropping (subsidence) then sea level rise rates will be effectively increased relative to the land. The NZSeaRise Programme[2] provides sea-level rise projections around New Zealand that include estimated vertical land movement.

NIWA (2020) concludes that NZ-wide sea level rise scenarios should be applied in the Tairāwhiti Region as available data indicates relatively small rates of subsidence and uplift are presently occurring, and that there is uncertainty about whether they will persist for decades. The NZSeaRise Programme provides relative sea-level rise projections around New Zealand, which include consideration of vertical land movement. The NZ SeaRise data suggests a vertical land movement of +/- 1.5 mm/yr in the Gisborne and eastern Bay of Plenty Regions. There is considerable uncertainty in defining these vertical land movement rates away from long term monitoring sites as much of the data is based on a relatively short satellite record.

[2] https://www.searise.nz/