A geomorphological characterisation of the coastal environment of the West Coast Region, South Island

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ABSTRACT

A methodology has been developed for a geomorphological assessment of coastal environments in the West Coast Region. The aim is to provide technical input for the West Coast Regional Council in their work to define the nature and extent of the West Coast coastal environment.

In this desktop assessment, 1:250,000-scale geological and topographic map digital datasets were used to derive geomorphological maps as a foundation for interpretations. The resources developed were a nominally 7-km wide geomorphological ‘strip map’ along the landward side of the coast, and three narrow strip maps (0.5-km-wide) landward of the coastline. The narrow maps, approximating a ‘thick line’ along the coast, highlight single-factor geomorphic considerations; (i) the nature of the shoreface sediments, (ii) the general type of shoreline landform, and (iii) the long-term tectonic environment (uplift versus stability). We also produced an interpretive map of former shoreline positions, based on topographic and geomorphological information.

From this information, we developed two perspectives of the coastal environment. One perspective delineates the inland extent of preserved young coastal landforms, including dune fields, beach plains, estuaries, and near-coastal swamps and lakes. Another perspective takes a broader view of the geomorphological coastal environment, that delineates the general area that has been subject to coast-related processes since present sea level was attained, ~6,500 years ago.

Wider geological and geomorphological considerations bear upon understanding the modern coastal environment of the West Coast. Global glacial-interglacial climate cycles of ~100,000-year average duration produced ~100 m amplitude natural sea level changes. The geometry of the continental shelf seaward of the present coast has a marked influence on river and glacier behaviour that may be manifested in various ways, along with the role of advance and retreat of ice-age glaciers sourced from the Southern Alps. There is a strong imprint of tectonic movements on coastal geomorphology, with the position of the modern, and previous, interglacial shorelines closely related to the positions of major active faults in the coastal area, both onshore and offshore. Some sections of the coast are influenced more by vertical tectonic land movements, others more by glacial and interglacial cycles and sediment supply.

The geomorphological evidence points to considerable natural changes in the coastline over the past ~6,500 years. In many places, there has been a consistent story of erosion and cliff formation followed by progradation/building out of the coastal plain. The geomorphological coastal environment has a predictable array of ongoing natural processes, including erosion and sedimentation. These factors also bear upon the local hazardscape in relation to questions such as earthquake-induced liquefaction, alluvial fan flooding and debris flows, and sediment build-up.

KEYWORDS

West Coast; coastal environment; sea level; Geomorphology; Holocene; shorelines

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1.0 INTRODUCTION

West Coast Regional Council (WCRC) is leading the preparation of a combined district plan for the West Coast region. A joint committee has been established to prepare, consult on, adopt, monitor and review the Te Taio Poutini combined district plan. The committee consists of the three West Coast district councils – Buller, Grey and Westland, WCRC, Te Rūnanga o Ngāti Waewae and Te Rūnanga o Makaawhio. The Te Tai o Poutini Plan will include specific provisions for the coastal environment, particularly in relation to the New Zealand Coastal Policy Statement (NZCPS) 2010. A key aspect is to define an extent for the coastal environment that is to be addressed in the plan. This presents a challenge because differing extents may be indicated, depending on what aspects of the environment are being considered. For example, a delineation of coastal vegetation extent may differ from a delineation of coastal landform extent. This is specifically recognised in Policy 1 of the NZCPS (Figure 1.1).

Policy 1 Extent and characteristics of the coastal environment

(1) Recognise that the extent and characteristics of the coastal environment vary from region to region and locality to locality; and the issues that arise may have different effects in different localities.

(2) Recognise that the coastal environment includes:

(a) the coastal marine area;

(b) islands within the coastal marine area;

(c) areas where coastal processes, influences or qualities are significant, including coastal lakes, lagoons, tidal estuaries, saltmarshes, coastal wetlands, and the margins of these;

(d) areas at risk from coastal hazards;

(e) coastal vegetation and the habitat of indigenous coastal species including migratory birds;

(f) elements and features that contribute to the natural character, landscape, visual qualities or amenity values;

(g) items of cultural and historic heritage in the coastal marine area or on the coast;

(h) inter-related coastal marine and terrestrial systems, including the intertidal zone; and

(i) physical resources and built facilities, including infrastructure, that have modified the coastal environment.

Figure 1.1 Extract from New Zealand Coastal Policy Statement 2010 – Policy 1 outlines the extent and characteristics of how agencies may define the 'coastal environment'.

Councils around Aotearoa New Zealand have taken different approaches to mapping (or not mapping) the coastal environment. Many mapped coastal environments relate to technical reports that delineate an inland extent for the coastal environment based on natural character or landscape values. In order to gain additional perspective on the coastal environment in relation to geomorphology (landforms), WCRC has partnered with the Institute of Geological and Nuclear Sciences (GNS Science) for advice on geomorphological considerations. The work was funded from an Envirolink grant (advice grant 2201-WCRC200) and the GNS Science Strategic Science Investment Fund research programme 'Global Change though Time', 'Integrated Coastal Dynamics' project).

This geomorphological assessment involved the following steps:

1. Review of available information on coastal processes and geomorphological character for the West Coast Region coastal area (Figure 1.2);
2. Design of a methodology for a geomorphological assessment for the West Coast Region coastal area, including criteria for identifying significant coastal process influences or qualities within the near-coastal landscape;
3. Compilation of digital geospatial map datasets to characterise the distribution of coastal geomorphological features within the coastal landform environment;
4. Documentation of the assessment in this report.

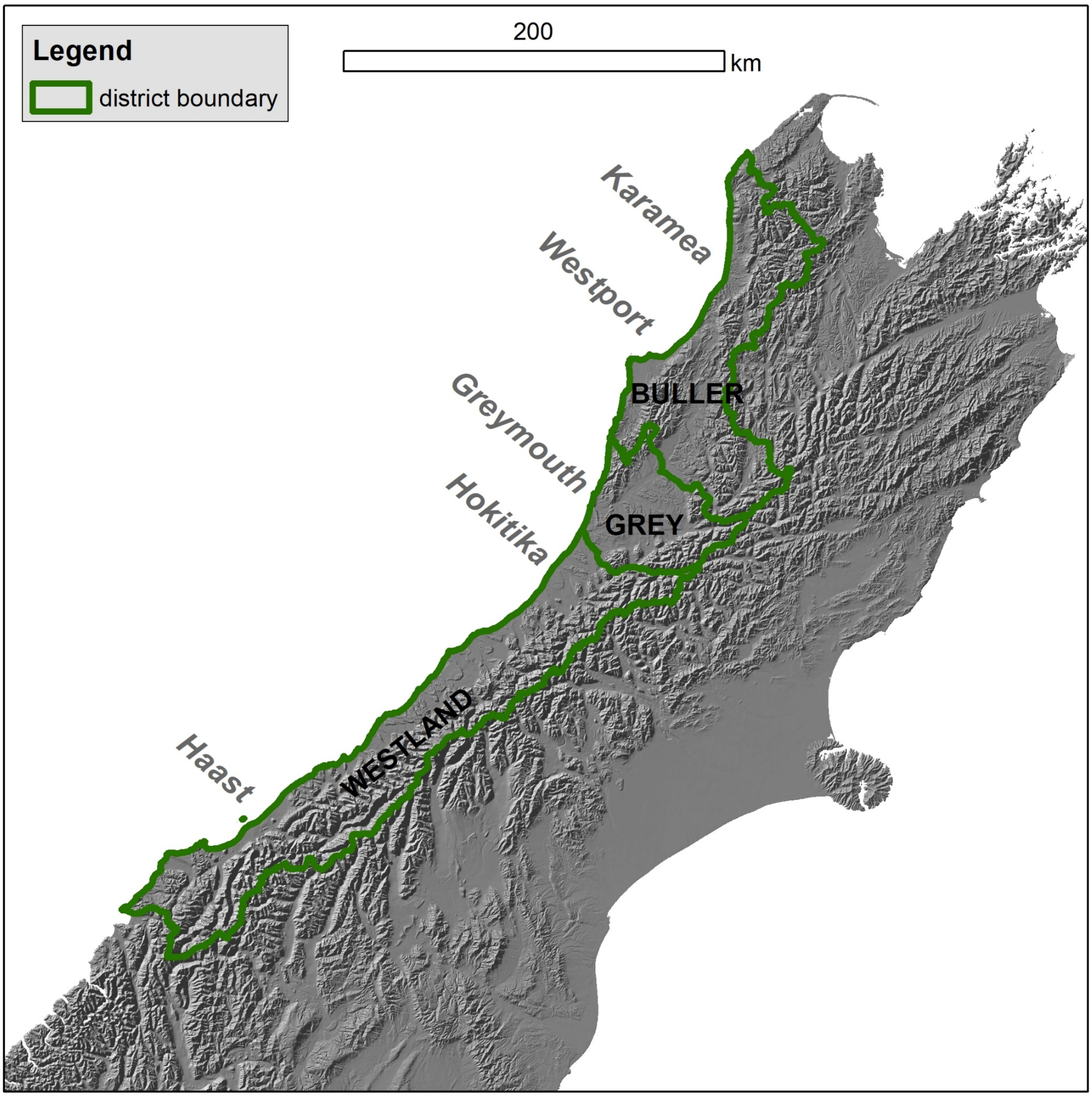


Figure 1.2 Location of the West Coast Region and its three constituent districts.

2.0 METHODOLOGY

2.1 Approach

The data sets compiled for this project are derived from existing digital geospatial information, using the QMAP 1:250,000-scale geological map dataset (Quarter-million-scale MAP) curated by GNS Science, and the Topo 250 1:250,000-scale topographic map dataset from Land Information New Zealand (LINZ). The work was done in a Geographic Information System (GIS) environment, using ArcGIS software. The information presented and discussed in this report is a desktop compilation. No field surveys were undertaken as part of this project, although the project team includes people who are well familiar with West Coast geology and geomorphology, having undertaken field work there over many years.

As part of this project, we compiled a map of geologically recent shoreline positions for the West Coast region, using a range of geological, geomorphological, topographic and bathymetric information and considerations. This was done to provide a longer-term geomorphological context for this assessment.

2.2 Input Data and Data Processing

Compilation of the QMAP geological map was undertaken in the West Coast region between the late 1990s and 2010, and originally published as a cut-up mosaic of maps, with explanatory texts (Nelson sheet – Rattenbury et al. (1998); Greymouth sheet – Nathan et al. (2002); Aoraki sheet – Cox and Barrell (2007); Haast sheet – Rattenbury et al. (2010)). The individual maps were subsequently joined into a ‘seamless’ dataset, of which the latest edition (Heron 2020) was used for this project.

The QMAP geology polygon dataset shows the distribution of different geological units, whether various types of rocks or poorly consolidated near-surface geological deposits. The latter were formed during the Quaternary time period (the past 2.58 million years), and in the West Coast region include various types and ages of sediments deposited by rivers or streams (alluvial), glaciers (glacial) or by coastal processes. The Quaternary geological units are mapped largely on the basis of their landform expression. In other words, they were mapped using geomorphology, from which their geological character was inferred. This makes it a straightforward and logical step to re-classify the geological map polygons as geomorphological map polygons, and this is what has been done for this project. The QMAP polygon dataset does not include water bodies, such as lakes and estuaries, and we have incorporated and attributed water polygons from the Topo 250 digital dataset.

From these digital information sources, we compiled derivative datasets pertaining to coastal geomorphology and relevant coastal geomorphic processes. We made a geomorphological map (Coastal_geomorphology) by clipping the QMAP geology polygons in a 7-km wide strip, inland from the Topo 250 coastline, using geoprocessing tools in ArcGIS (Figure 2.1). In most places, this strip adequately encompasses all features of coastal relevance for geomorphological assessments, except in several parts of South Westland, where we have extended it a little farther inland. In the strip map, we have amalgamated all of the mapped pre-Quaternary rock units into a geomorphological polygon called ‘hill terrain’, which is appropriate as they mainly occur in hill landscapes. The Quaternary deposit units are re-classified as to their landform setting, such as marine terrace, river plain, alluvial fan, glacier moraine belt, etc. We have maintained a generalised QMAP age attribute in the unit name, where we distinguish between Holocene and Pleistocene landforms (deposits).

In the data attributes, the Indicative_age field holds more detailed information about the unit age, including post-1850 AD, Holocene, Late Pleistocene, Middle Pleistocene, Early Pleistocene, composite age, and unspecified.

We also created a 0.5 km wide strip polygon on the landward side of the Topo 250 coastline. We took versions of that polygon to quantify three interpretive datasets:

- Geomorphological nature of the coastline, based on the geomorphological strip map;
- Nature of the modern beach zone (shoreface), based on Topo 250 information;
- Tectonic environment, to highlight the pattern of long-term (e.g. 100,000-year-timeframe) tectonic change (especially uplift) close to the coast.

These 0.5-km-wide strip maps (see Section 3) are provided as an alternative to presenting that information as a line map, which would not properly convey that the mapping represents generalised, broad-scale information about the coast. These maps approximate a thick line.

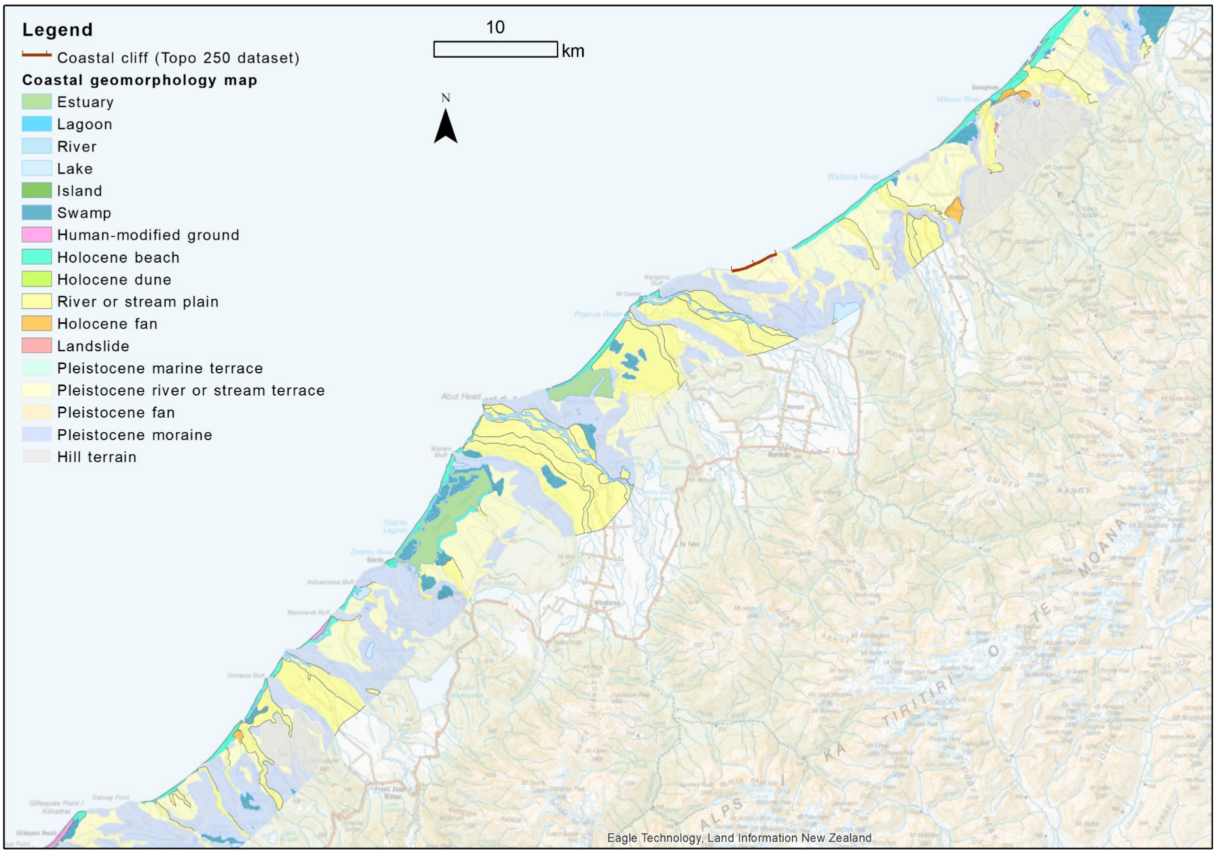


Figure 2.1 Example of the 7-km geomorphological strip map for the Whataroa-Harihari area, based on a subset of the 1:250,000-scale geological information in Heron (2020).

3.0 DATA DESCRIPTION AND LIMITATIONS

The QMAP nationwide geological map is designed for depiction at 1:250,000 scale, which is typically regarded as being of “regional” precision. Considerable generalisation of detail has been performed to achieve legibility for this scale. The QMAP illustrates the geological character in a general location but is not accurate at detailed site-specific scales. This proviso also applies to the derivative geomorphological dataset described in this report. The geomorphological map units are summarised in Table 3.1.

Table 3.1 Geomorphology units in the 7-km geomorphological map (Coastal_geomorphology polygon dataset). Extent of water bodies and islands taken from LINZ Topo 250 data. The River or stream plain unit includes rivers and streams that are not differentiated in the LINZ Topo 250 water dataset.

Data Field: UnitName	QMAP-equivalent unit(s) 1	Geomorphic expression
Estuary	n/a	Coastal water body open to the sea
Lagoon	n/a	Coastal water body separated from the sea by a sediment barrier
River	n/a	Body of running fresh water
Lake	n/a	Body of standing fresh water
Island	n/a	Offshore islands and rocks
Swamp	Swamp deposits	Swampy ground, typically with wetland vegetation
Human-modified ground	Anthropogenic deposits, such as mine tailings	Irregular ground produced by human activity, usually in flat areas
Holocene beach	Beach deposits younger than 11.7 ka	Wave-deposited sand and gravel ridges; typically, parallel to a coastline; commonly includes minor areas of dunes and swamps
Holocene dune	Sand dunes younger than 11.7 ka	Accumulations of wind-blown sand, usually close to the coastline
River or stream plain	Alluvial deposits younger than 11.7 ka	River or stream valley floor and adjacent low-level terraces. Includes recent floodplains
Holocene fan	Alluvial fan deposits younger than 11.7 ka	Fan-shaped accumulations of stream sediment extending from hill-terrain streams or gullies onto adjacent lowlands
Landslide	Deposits of disturbed material emplaced by slope movement	Irregular ground associated with slope instability in the recent geological past
Pleistocene marine terrace	Beach deposits older than 11.7 ka	Isolated remnant of former coastal plain well above present sea level
Pleistocene river or stream terrace	Alluvial deposits older than 11.7 ka	Remnant river or stream plain or terrace well above modern flood level. Includes glacial outwash terraces or plains
Pleistocene fan	Alluvial fan deposits older than 11.7 ka	Fan-shaped accumulations of stream sediments extending from hill-terrain streams or gullies onto adjacent lowlands. Usually somewhat dissected by gullying
Pleistocene moraine	Till and associated ice-contact deposits older than 11.7 ka	Ridge, terrace or bench formed at side or terminus of former glacier; typically, with irregular ground surface
Hill terrain	Pre-Pleistocene rocks (>2.6 Ma)	Typically, moderate to steep hilly topography dissected by valleys or gullies

[1] 1 ka = one thousand years before present (kilo annum); 1 Ma = one million years before present (Mega annum).

The 0.5 km wide strip polygon maps are intended to highlight relevant aspects of the coastline. To highlight the generalised nature of these maps, each polygon encompasses no less than ~1-km length of coastline. These three polygon map datasets should be treated as highly generalised and are not intended to be used for any site-specific purposes.

The main units of the coastal type map are given in Table 3.2 and an example is shown in Figure 3.1. Within the GIS dataset, there is an attribute field that, for each polygon, gives the dominant geomorphological map unit adjacent to that polygon.

Table 3.2 Units of the coastal type map (coastal_character polygon dataset).

Coastal Type unit	Description
Coastal plain	Broad beach plain inland of the coast
Lagoon barrier	Beach or dune barrier protecting inland lagoon
Barrier dunes	Coastal sand dunes where no lagoon exists
Swamp barrier	Beach or dune barrier protecting inland swamp
Alluvial floodplain	River mouths open to the sea, generally with little or no beach/dune barrier
Steep	Topography rising rapidly behind narrow coastal plain; no cliff in Topo 250 data
Cliff	Steep to cliffed topography fronting directly onto the coast; cliff in Topo 250 data

The shoreface type map illustrates the nature of the active beach zone using a simple four-fold classification of ‘rocky’, ‘sandy’, ‘shingle’, or ‘not specified’ (Figure 3.2), based on LINZ Topo 250 data.

The tectonic environment map uses a three-fold classification of ‘uplifting’, ‘probably uplifting’ and ‘probably stable’ (Figure 3.3). This map is based on a nationwide vertical land movement assessment by Beavan and Litchfield (2012), with minor modifications. Uplift is demonstrated where former shoreline landforms now stand higher than the elevations at which they formed. Probable uplift is indicated along sections of coast abutting rugged hill terrain, even if Pleistocene marine terrace landforms are not preserved. Areas of lowland terrain lacking elevated former shoreline landforms are classed as probably stable. Saltwater Lagoon in South Westland is a good example, where Pleistocene moraines more than 130,000 years old (Almond et al. 2001; Cox and Barrell 2007; Barrell et al. 2011, 2013) are preserved just above modern sea level. This indicates there has been no uplift, and probably no subsidence because otherwise those moraines would have been buried by younger deposits. Burial of older deposits by progressively younger ones is diagnostic of subsidence, and is well documented under eastern Christchurch, for example (Begg et al. 2015). No burial sequence like that has been identified in the West Coast coastal area, and therefore there are no indications of subsidence. An updated nationwide set of New Zealand vertical land motion data, produced by the NZ SeaRise research programme, is scheduled for release in February 2022 (R. Levy, GNS Science, pers. comm.).

The former shoreline map is intended to give context to changes that the coastline has undergone in the past few thousand years (Figure 3.4). The dataset depicts the likely position of the shoreline approximately 6,500 years ago, when the rising global post-glacial sea-level stabilised at approximately its modern height, and any prominent, now-abandoned coastal cliffs were cut. Most stretches of coastline against hill terrain are cliffed, and the 6,500-year shoreline is inferred to have lain a short distance off the coast, about where the water depth reaches ~10 m. In some valleys, lagoons and low-lying coastal plains, the sea is interpreted to have extended some distance inland of where the coast now lies. Where Pleistocene glacier or river terrace landforms lie at the present coast, a published 1:100,000-scale geomorphological map (Barrell et al. 2011, 2013) was used to aid interpretations. The river landforms (i.e. terraces and floodplains) have predictable gradients that were extrapolated seawards to identify where they would have intersected the 6,500-year sea level (0 m). The belts of lateral moraine that formed alongside each glacier have less predictable gradients and were extrapolated seawards as a best estimate. Now-abandoned cliff lines were mapped with the aid of the LINZ detailed Topo 50 1:50,000-scale topographic map, and further assisted by examination of Google Earth imagery.

Based on the geomorphological map, we have delineated the inland extent of preserved coastal landforms associated with development of the coastal area since ~6,500 years ago (Figure 3.5). A schematic illustration of typical relationships between near-coastal landform features of the West Coast is presented in Figure 3.6.

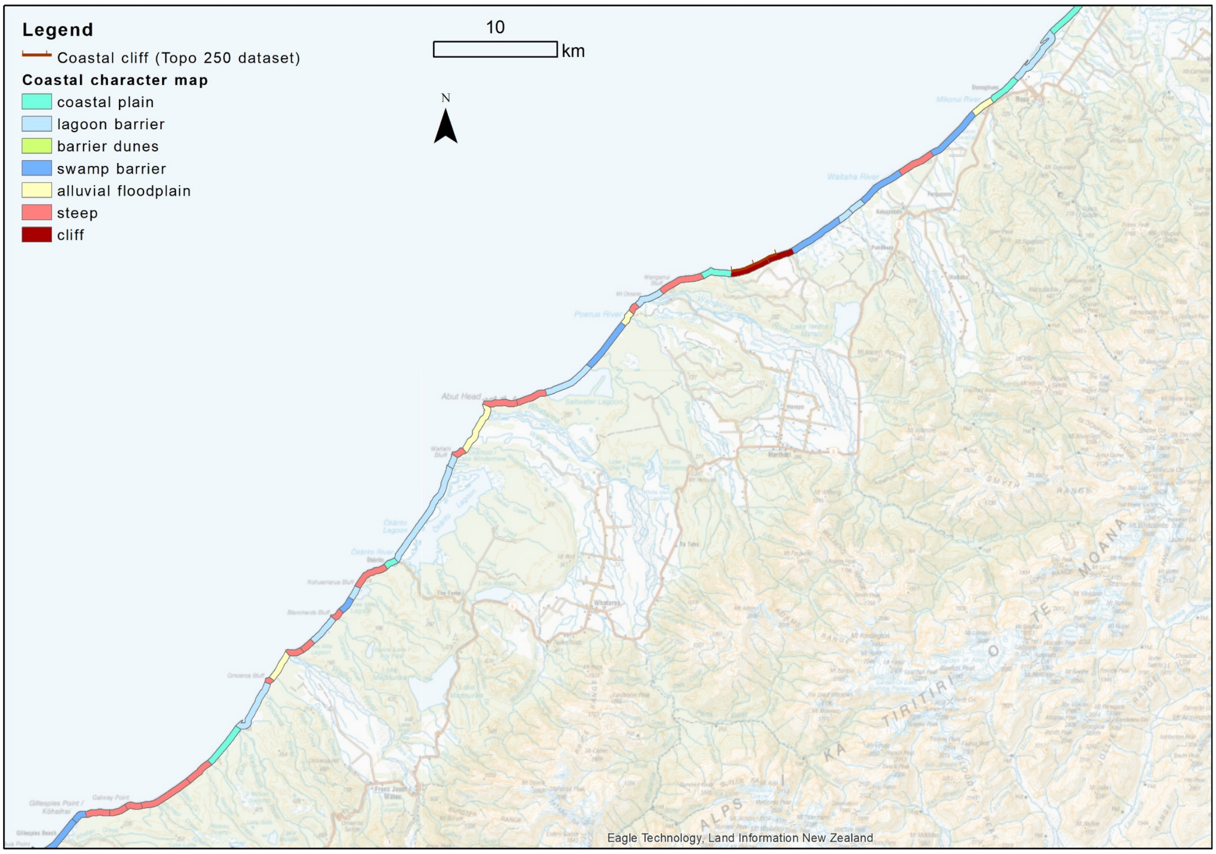


Figure 3.1 An example of the 0.5-km-wide coastal type map (coastal_character polygon dataset) for the Whataroa-Harihari area. See Table 3.2 for more information.

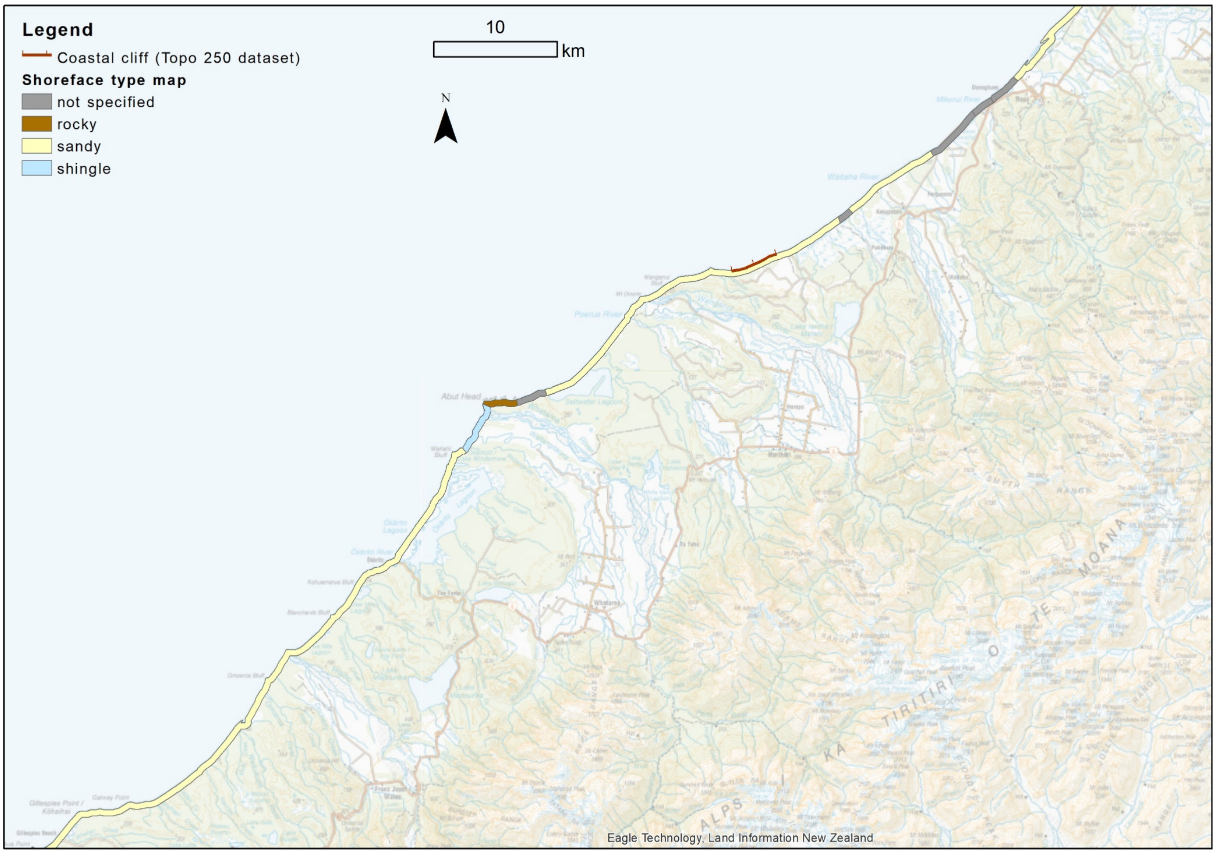


Figure 3.2 An example of the 0.5-km-wide shoreface type map (shoreface_type polygon dataset) for the Whataroa-Harihari area.

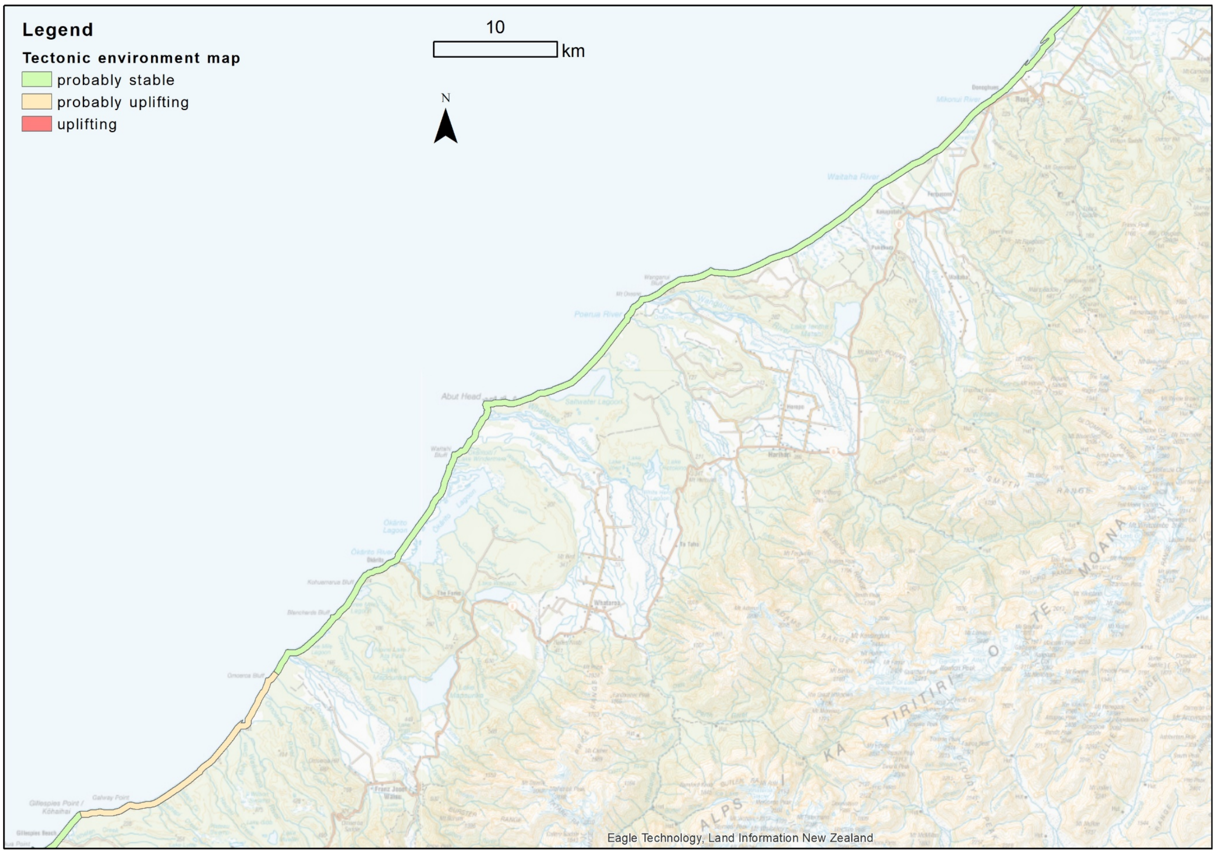


Figure 3.3 An example of the 0.5-km-wide tectonic environment map (tectonic_environment polygon dataset) for the Whataroa-Harihari area.

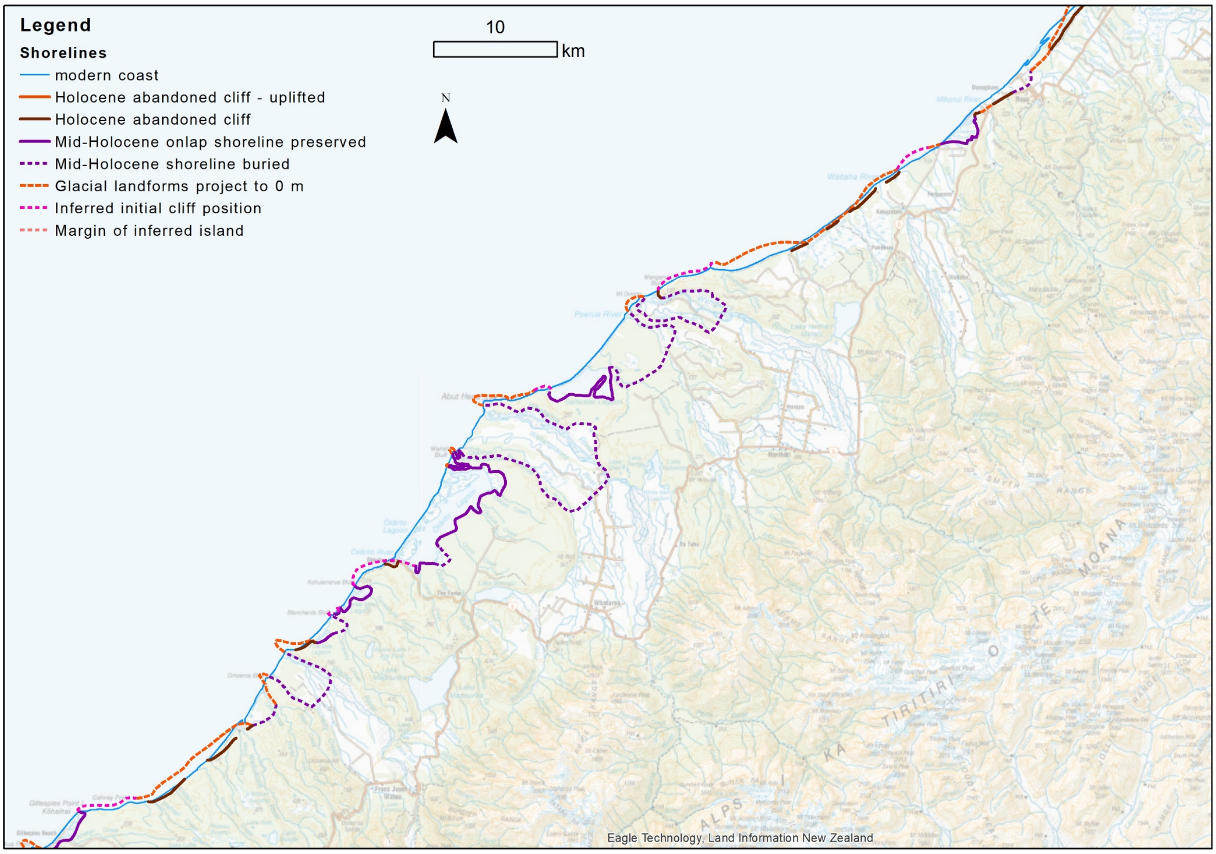


Figure 3.4 An example of the former shorelines map (West_Coast_6500y_shoreline line dataset) for the Whataroa-Harihari area.

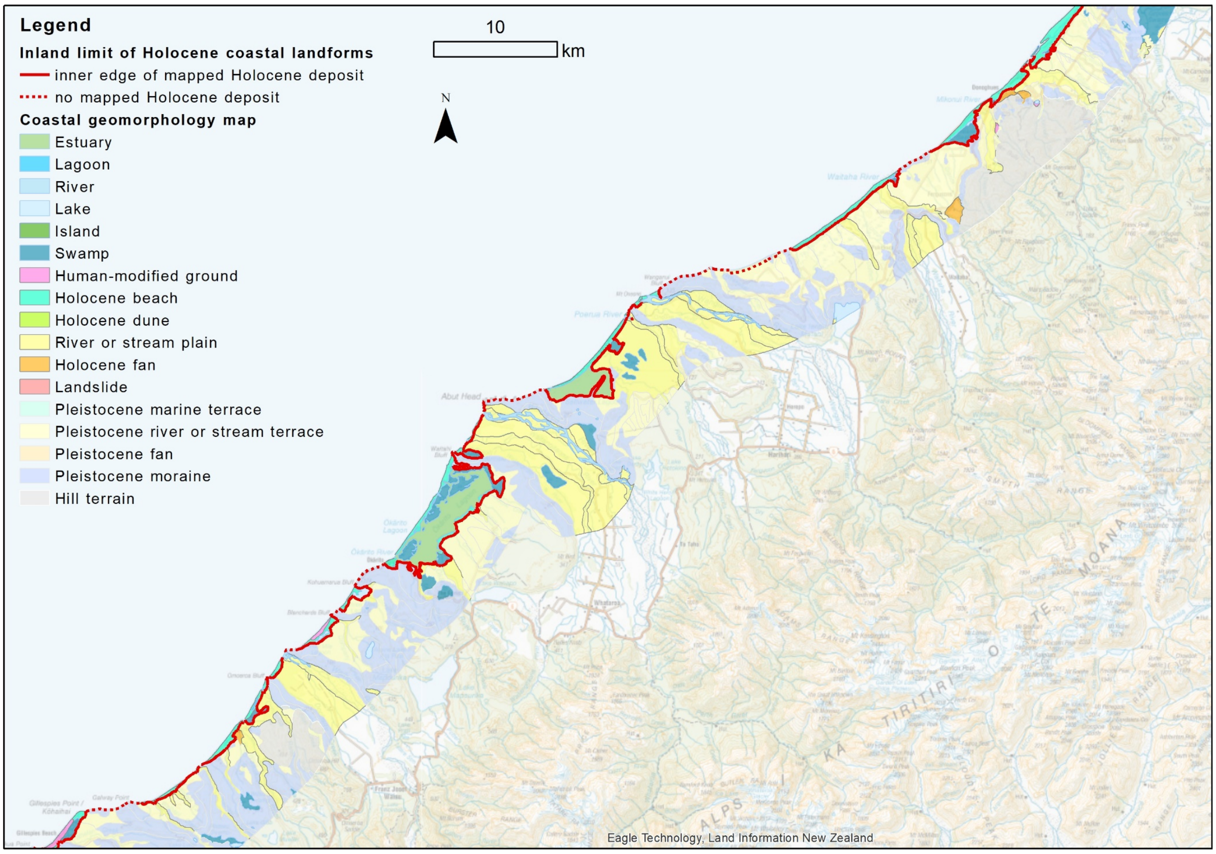


Figure 3.5 An example of the inland extent of preserved coastal landforms in the Whataroa-Harihari area (red line).

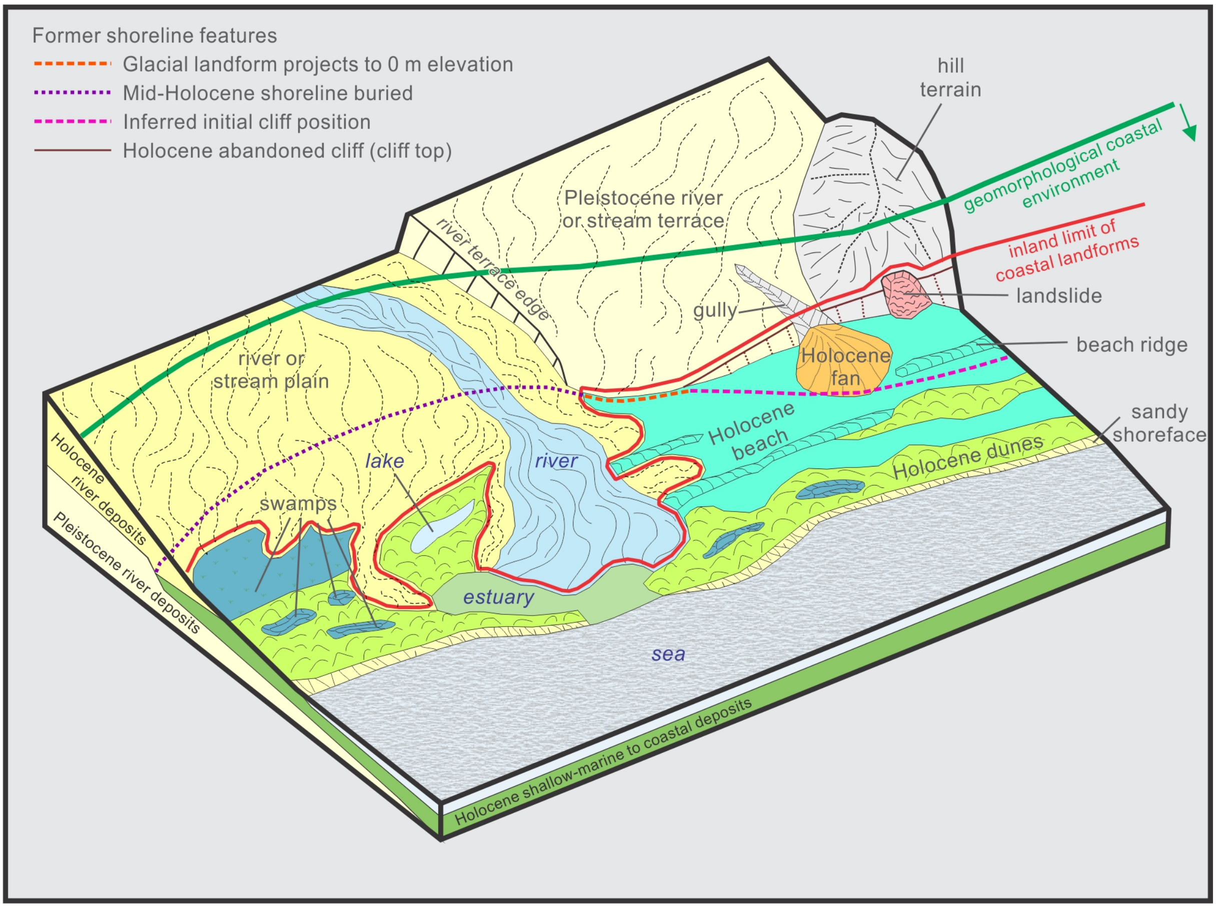


Figure 3.6 Cartoon 3-D block diagram illustrating typical examples of the setting and interrelationships of the geomorphological map units. The diagram highlights the conceptual difference between the inland extent of coastal landforms and associated water bodies (red line), and the geomorphological coastal environment (green line) which encompasses the area influenced by coast-related processes of the recent geological past. The context of geological deposits underlying the landforms is depicted along the front and side of the block diagram. The diagram does not represent any particular location and is not to scale.

4.0 COASTAL ENVIRONMENT INTERPRETATION

4.1 Geomorphological Setting of the West Coast Region

The West Coast occupies the western flank of the rapidly uplifting and eroding Southern Alps, the coastal lowlands along the Southern Alps and, from Greymouth north, an array of uplifted mountain ranges, such as the Paparoa Range. The landscape has strong imprints of the interplay between tectonic uplift and erosion over time, and the effects of a 100,000-year cycling between episodes of ice-age climate (glacials) and warm climate such as today (interglacials). Globally, glacial climates saw massive ice sheets grow on Northern Hemisphere continents. The ice sheets held so much water that the global sea dropped by between ~70 and ~120 m during glacials (Siddall et al. 2003). About 20,000 years ago, the sea was 120 m lower than today, with the shoreline well out on the continental shelf (Figure 4.1).

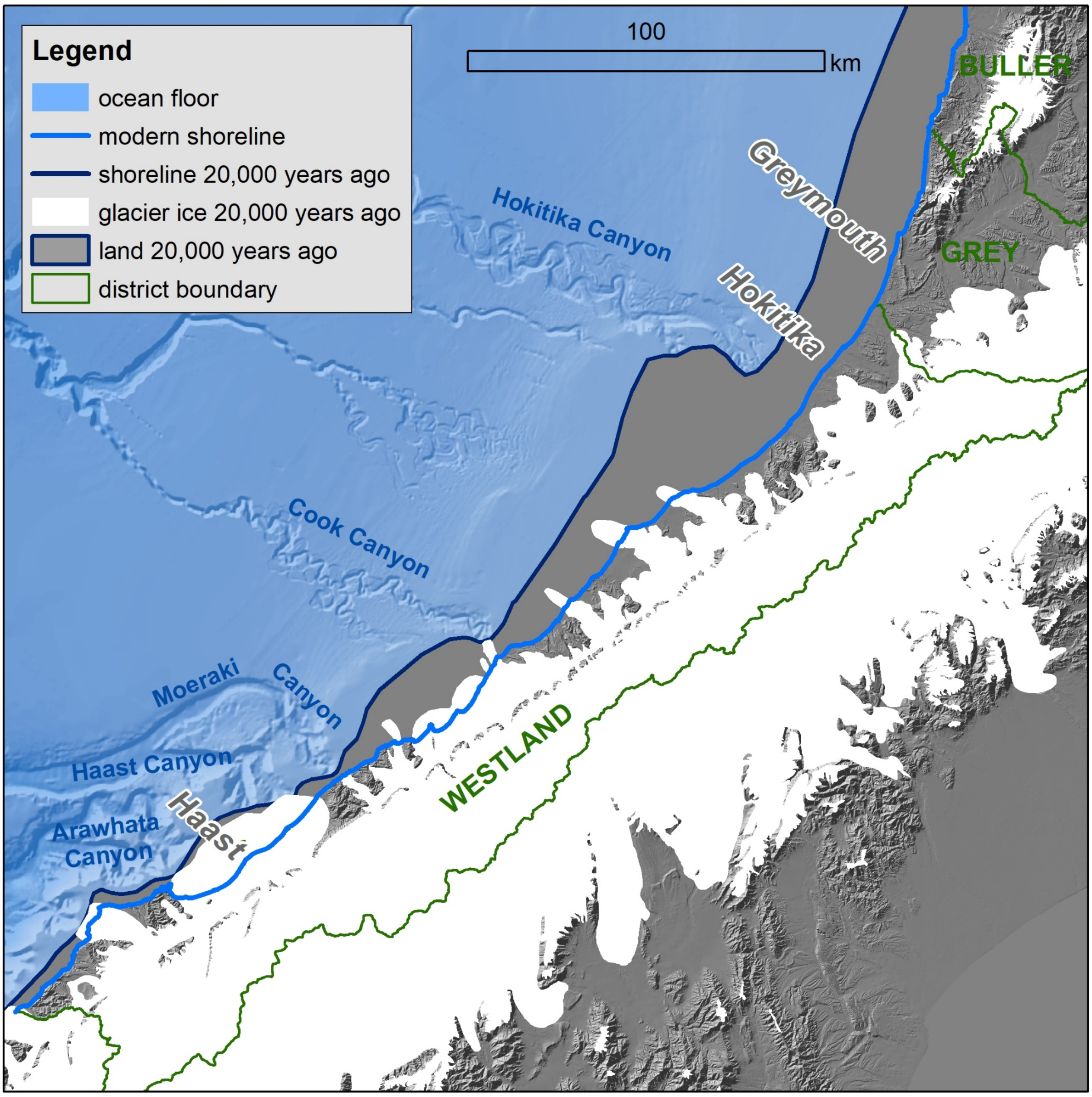


Figure 4.1 Overview map of the extents of land and glaciers 20,000 years ago (after Barrell 2011), plus modern coastline. The ocean floor has river-like channels, set in deep submarine canyons, formed by underwater density-current flows fed by some of the onland ice-age glaciers and glacial rivers.

The last glacial ended ~18,000 years ago and the sea rose progressively, on average ~1 m per century, attaining its modern level ~6,500 years ago. From a geological perspective, sea level has changed hardly at all around New Zealand in the past 6,500 years (Clement et al. 2016), and 6,500 years ago marks the geomorphic onset of the modern West Coast coastal story. Since then, the geomorphologic record shows that in places the coastline has progressively eroded, in other places we see evidence for an episode of erosion, followed by seaward outbuilding of beach deposits. These contrasts highlight the dynamic nature of the West Coast coastal area.

Tectonic processes also have an important bearing on West Coast coastal geomorphology. Much of the present land/sea boundary is closely linked to major active near-coastal faults (Figure 4.2). These issues are discussed in subsequent sections of the report.

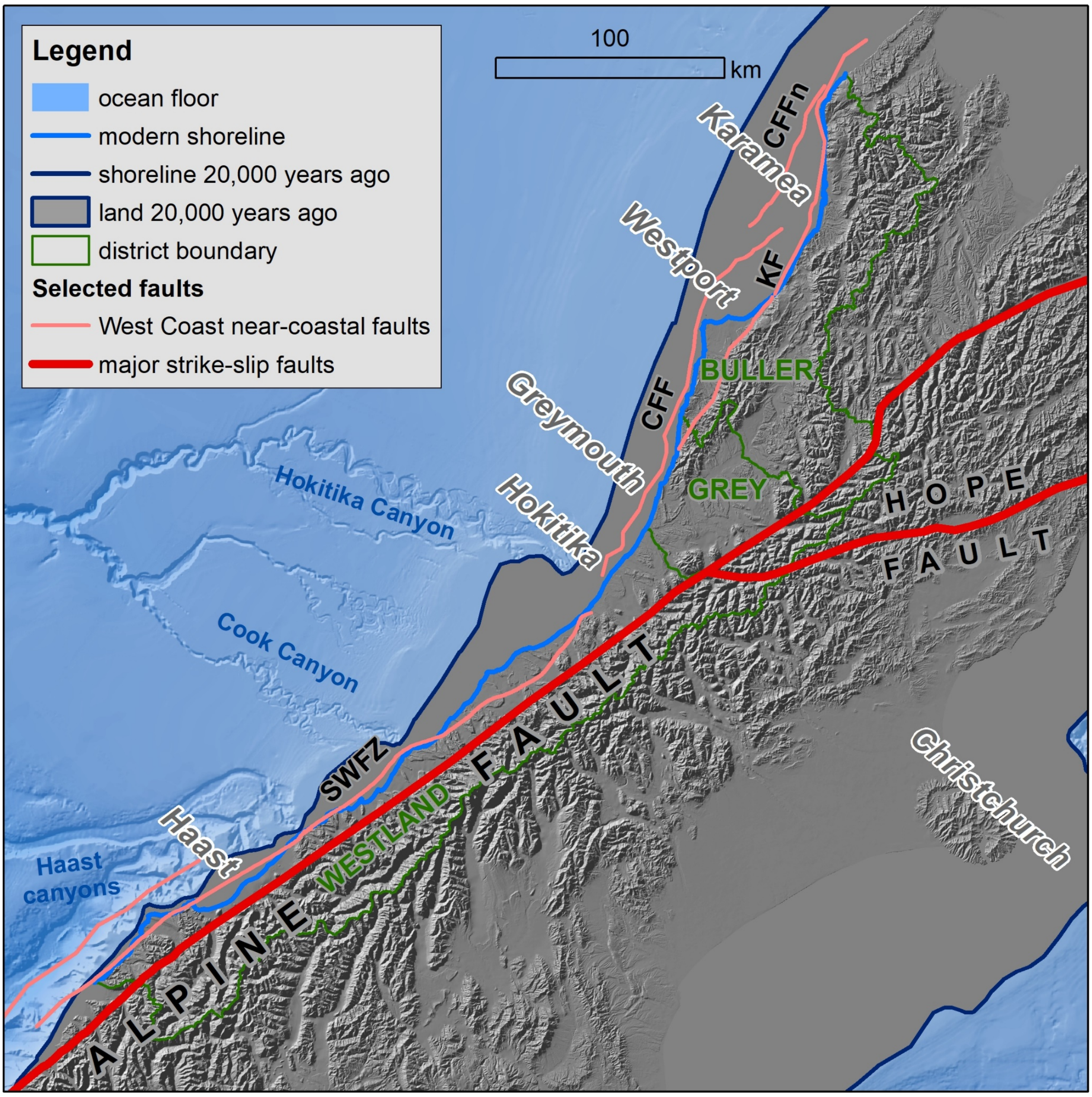


Figure 4.2 Overview map of the selected tectonic features in the western South Island, The selected near-coastal faults (from the NZ Community Fault Model; Van Dissen et al. 2021) are major contractional (reverse) structures, with overall vertical throws typically more than 1 km. CFFn = Cape Foulwind Fault (north); CFF = Cape Foulwind Fault; KF = Kongahu Fault (including the Paparoa (West) Fault south of Westport); SWFZ = South Westland Fault Zone. For these faults, the labels are placed on the downthrown side.

4.2 Delineation of the Coastal Environment Using Geomorphological Criteria

We use the geomorphological information to present two ways for delineating the coastal environment, from a geomorphological perspective. One way encompasses drawing a line at the inland margin of the mapped coastal landforms (deposits), including currently active beach and dune systems, as well as those formed in the past few thousand years, and presently stabilised. This limit is shown by the red line in a series of four overlapping maps encompassing the whole coastal sector of the West Coast region (Figures 4.3, 4.4, 4.5 and 4.6). The other way is to consider the area encompassing the interpreted position of the 6,500-year-old shoreline, and the lower slopes of hills and valley sides near that shoreline. This can be regarded as the geomorphological coastal environment and is the locus of coastal process activity of the past few thousand years (green line in Figures 4.3, 4.4, 4.5 and 4.6). Figure 4.7 to Figure 4.14 are annotated aerial photos illustrating the mapped landform features as they appear in the landscape.

4.2.1 Inland extent of coastal landforms

The inland extent of the red line highlights the limit of prominent coastal landforms. It is drawn at the landward edge of polygons depicting Holocene “coastal” deposits (beach, dune, and adjacent or contiguous swamps and lagoons). Thus, the coastal environment excludes alluvial fans and terraces, and anywhere that Pleistocene or older deposits are mapped. Where steep hill terrain abuts the shoreline directly, such as areas of steep and rocky coastline, the mapped inland extent is coincident with the Topo 250 coastline unless there is a cliff mapped, in which case the line “bends” inland to include the area below the cliff.

4.2.2 Geomorphological coastal environment

The wider area that has been subject to coastal geomorphological processes (the green line) encompasses the area where coast-related events have occurred in the recent geological past and will be reflected in a variety of coast-related environmental considerations. Sediment build-up since 6,500 years ago has pushed the sea back, creating new land, but land that is likely underlain by soft sediments with a high groundwater table, and likely to be particularly susceptible to liquefaction. In addition, sediment brought in from adjacent slopes has formed alluvial fans, thus presenting hotspots for alluvial fan-related hazards, including flash-flooding and, potentially, debris flows. These areas of relatively new land, seaward of the 6,500-year shoreline, may have distinctive soils that may support important near-coastal ecosystems. Furthermore, these areas of relatively low-lying land may be particularly susceptible to consequences from projected anthropogenic sea level rise. From a geomorphological perspective, the NZCPS provides minimal guidance on coastal environment extent. Our methods represent a new approach that bases an improved understanding of the coastal environment on its geological inheritance and geomorphic qualities.

It should be noted that neither the inland extent of coastal landforms (red line) nor the geomorphic coastal environment (green line) represents a particular topographic contour line. Further detailed work (including field investigations) would be required to delineate these boundaries with greater accuracy than is intended in this report, i.e., for usage at map scales more detailed than 1:250,000.

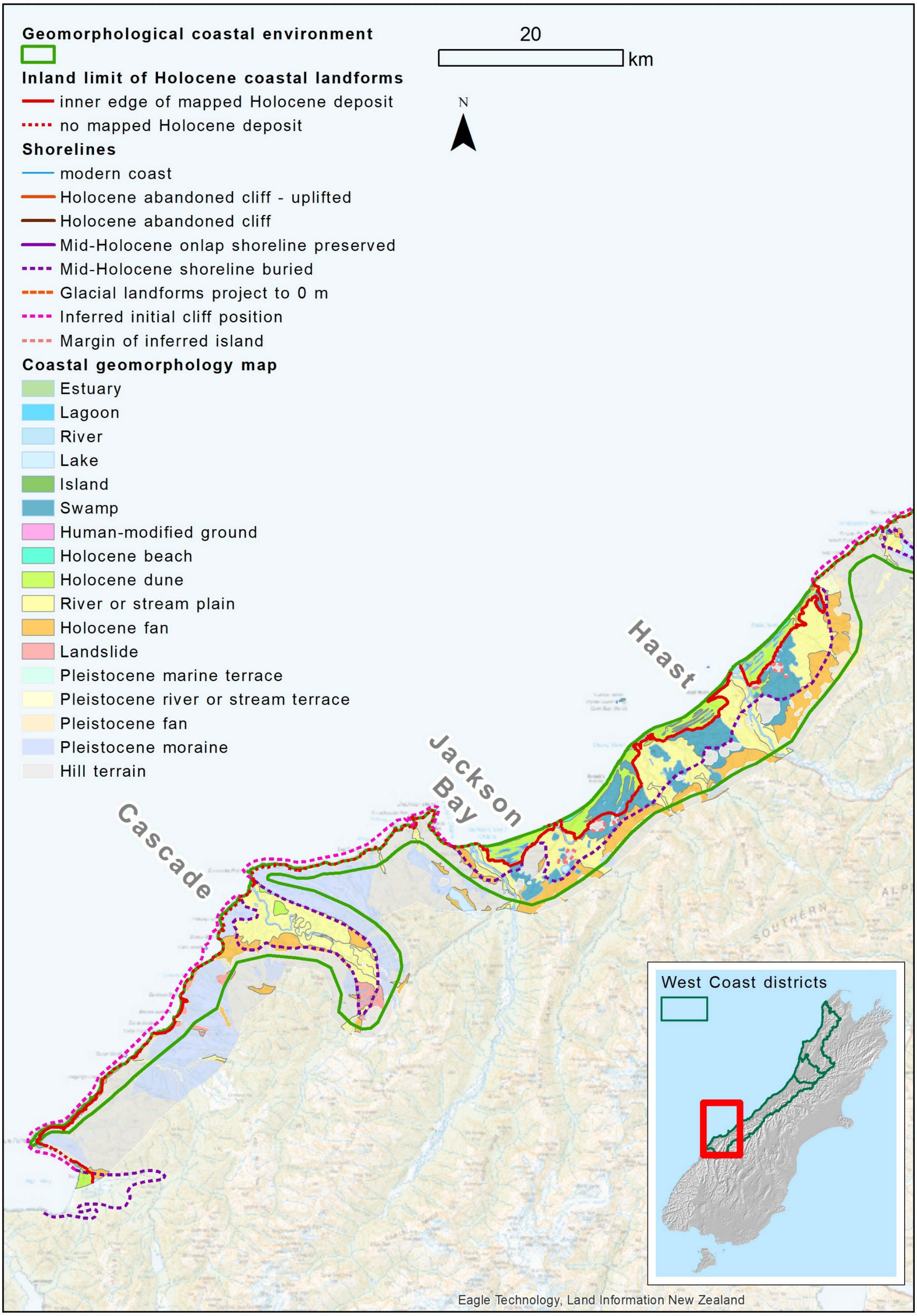
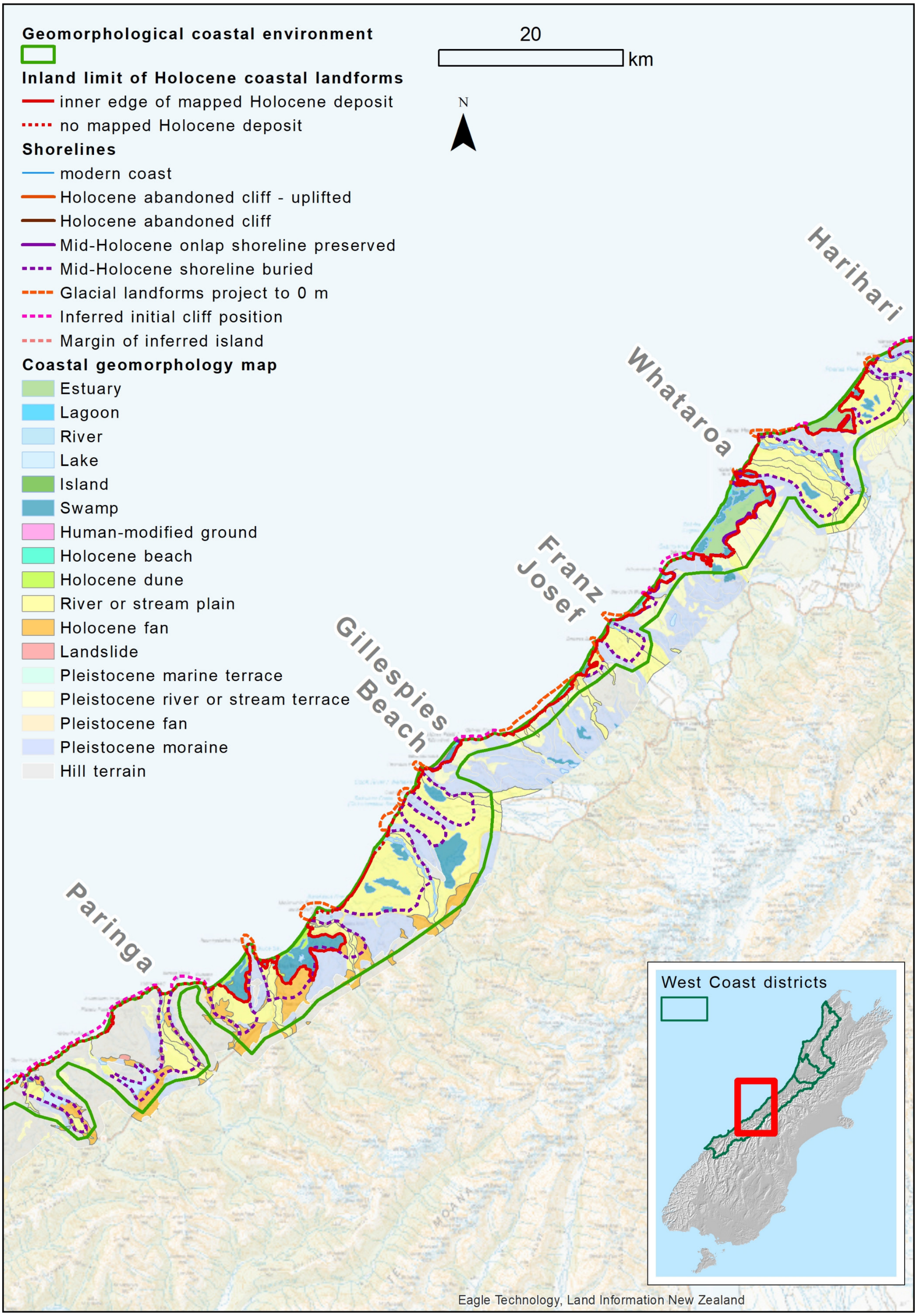


Figure 4.3 Map of geomorphic classifications of coastal environment (four overlapping views). The inland limit of preserved young coastal landforms is in red, while the limit of the geomorphologically-defined coastal environment is in green.



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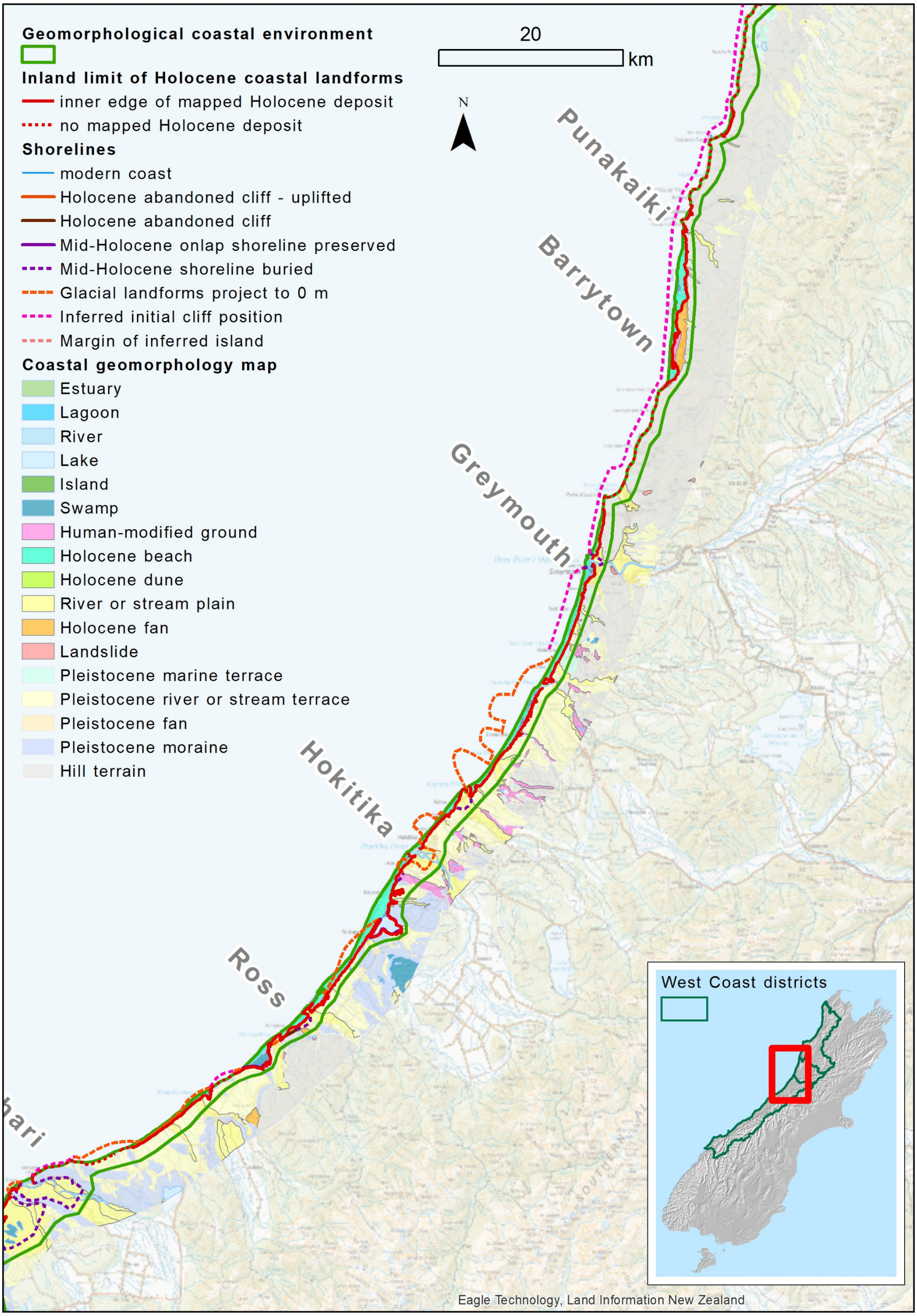

Figure 4.5 Map of geomorphic classifications of coastal environment (four overlapping views). Inland limit of preserved young coastal landforms in red. Limit of the geomorphologically-defined coastal environment in green.

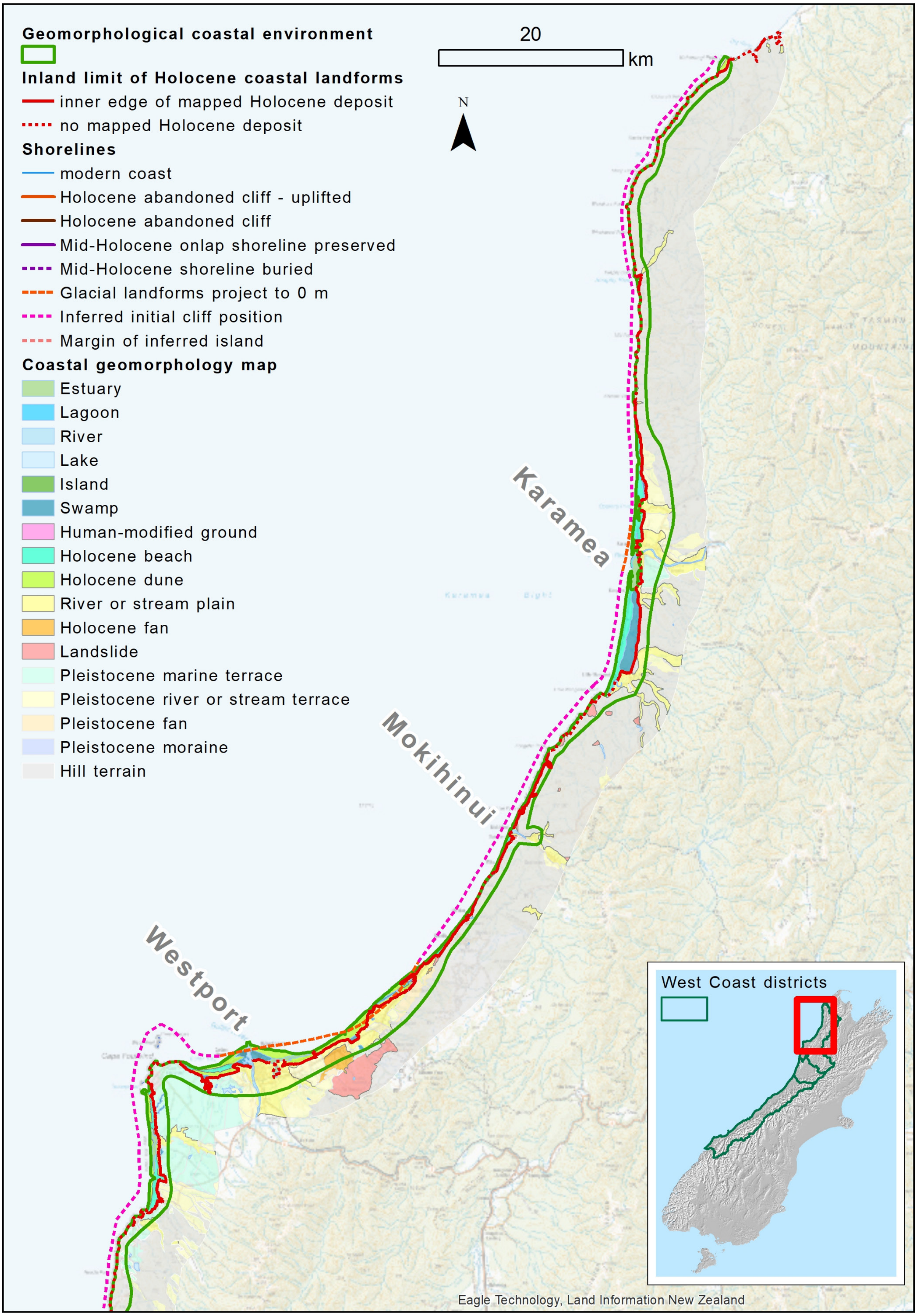

Figure 4.6 Map of geomorphic classifications of coastal environment (four overlapping views). Inland limit of preserved young coastal landforms in red. Limit of the geomorphologically-defined coastal environment in green.

4.3 Illustrations of Coastal Geomorphological Features

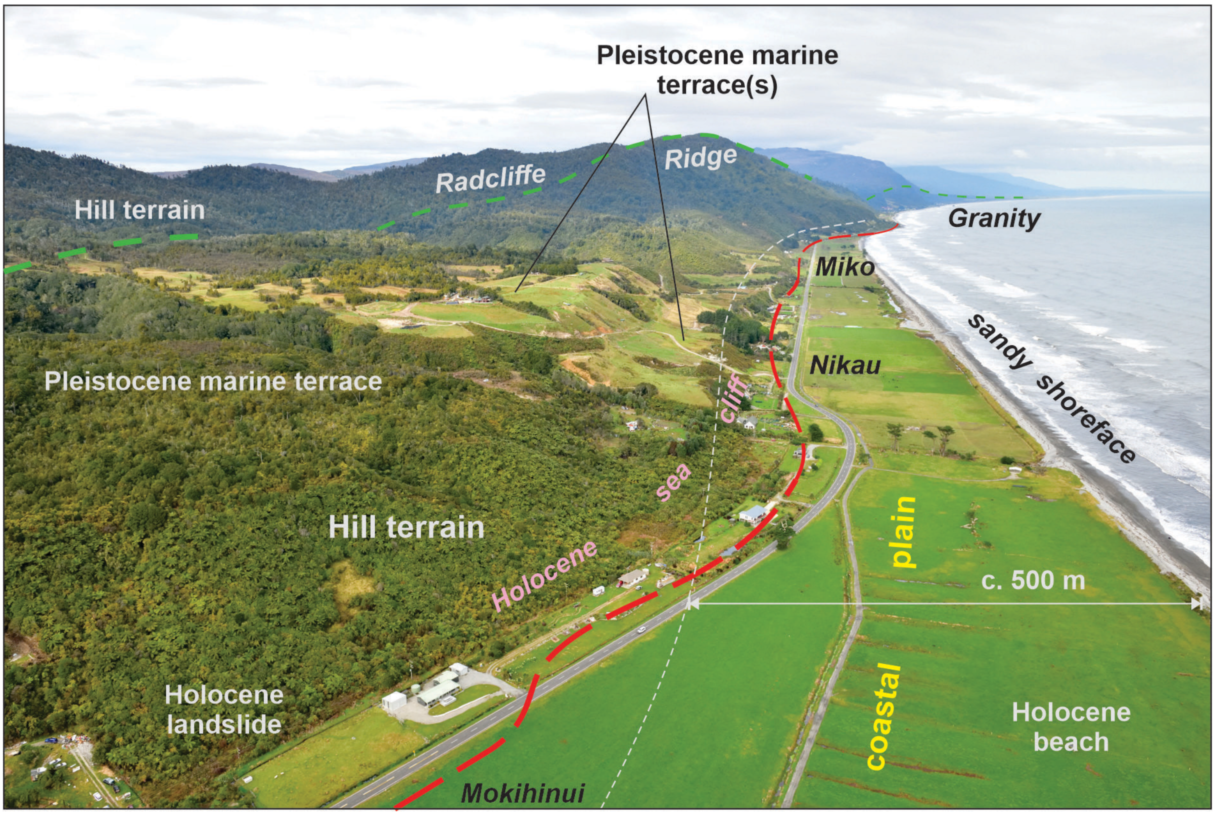

Figure 4.7 Overview of the geomorphic coastal environment just south of Mokihinui, between Westport and Karamea. The approximate inland extent of mapped Holocene coastal deposits is shown by the red dashed line, and the green line marks the inland limit of the geomorphological coastal environment. Representative location names and coastal geomorphology unit names are shown for context. The 0.5 km wide coastal strip map extent is indicated by the white dashed line, and coastal type terms (as in Table 3.2) are in yellow text. The location of the Holocene sea cliff is also indicated. Photo D. Townsend, July 2021. VML ID: 259912.

Figure 4.8 Overview of costal environment at Granity, north of Westport. See Figure 4.7 for explanation of symbols and terms. The entire scene is within the 0.5 km coastal strip. Photo D. Townsend, July 2021. VML ID: 259913.

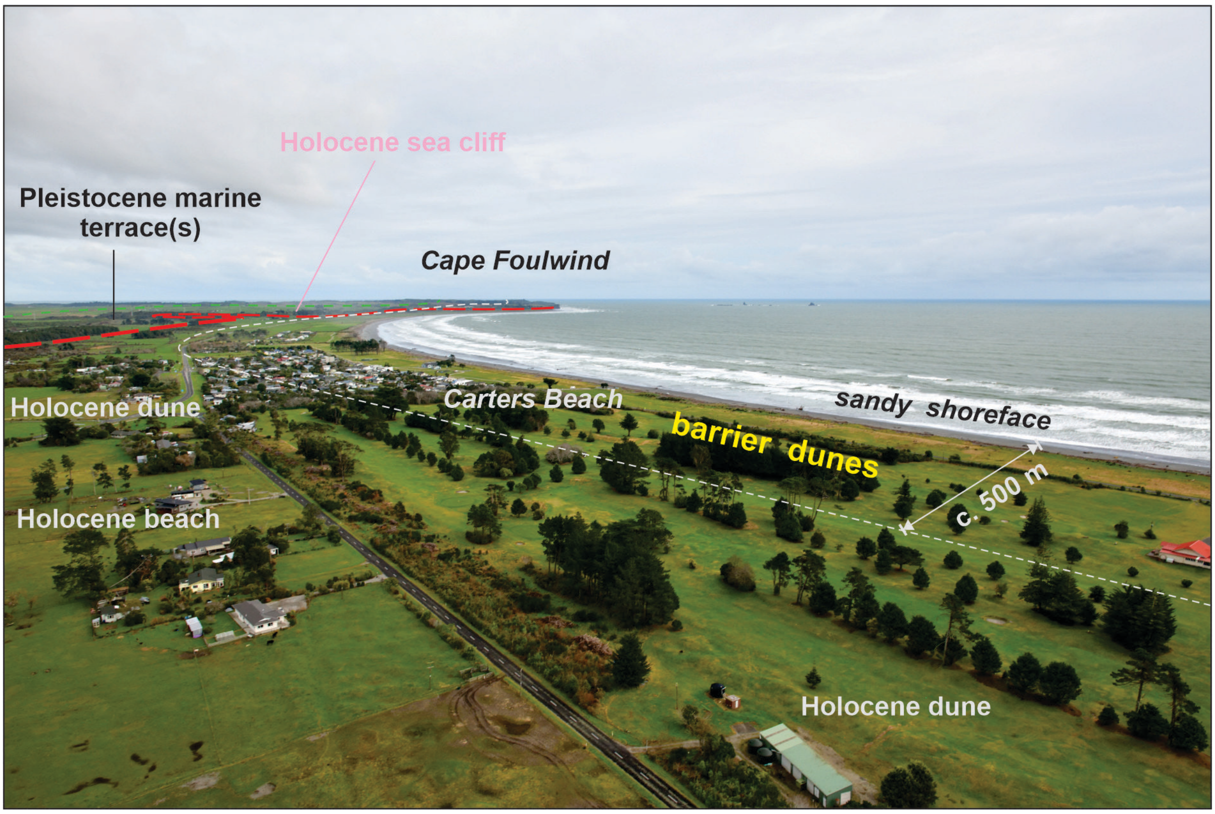

Figure 4.9 Overview of coastal environment at Carters Beach, west of Westport. See Figure 4.7 for explanation of symbols and terms. Photo D. Townsend, July 2021. VML ID: 259914.

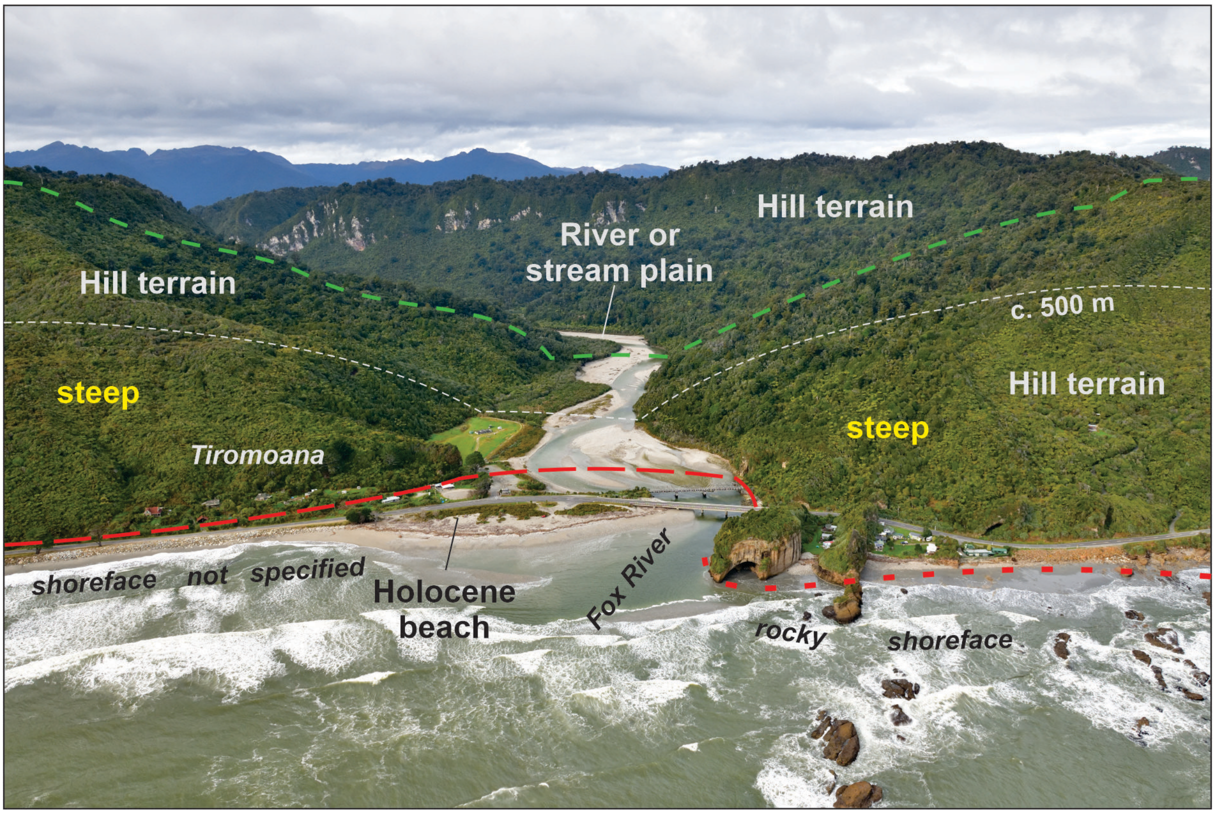

Figure 4.10 Overview of coastal environment at Fox River mouth, between Westport and Greymouth. See Figure 4.7 for explanation of symbols and terms. Photo D. Townsend, July 2021. VML ID: 259915.

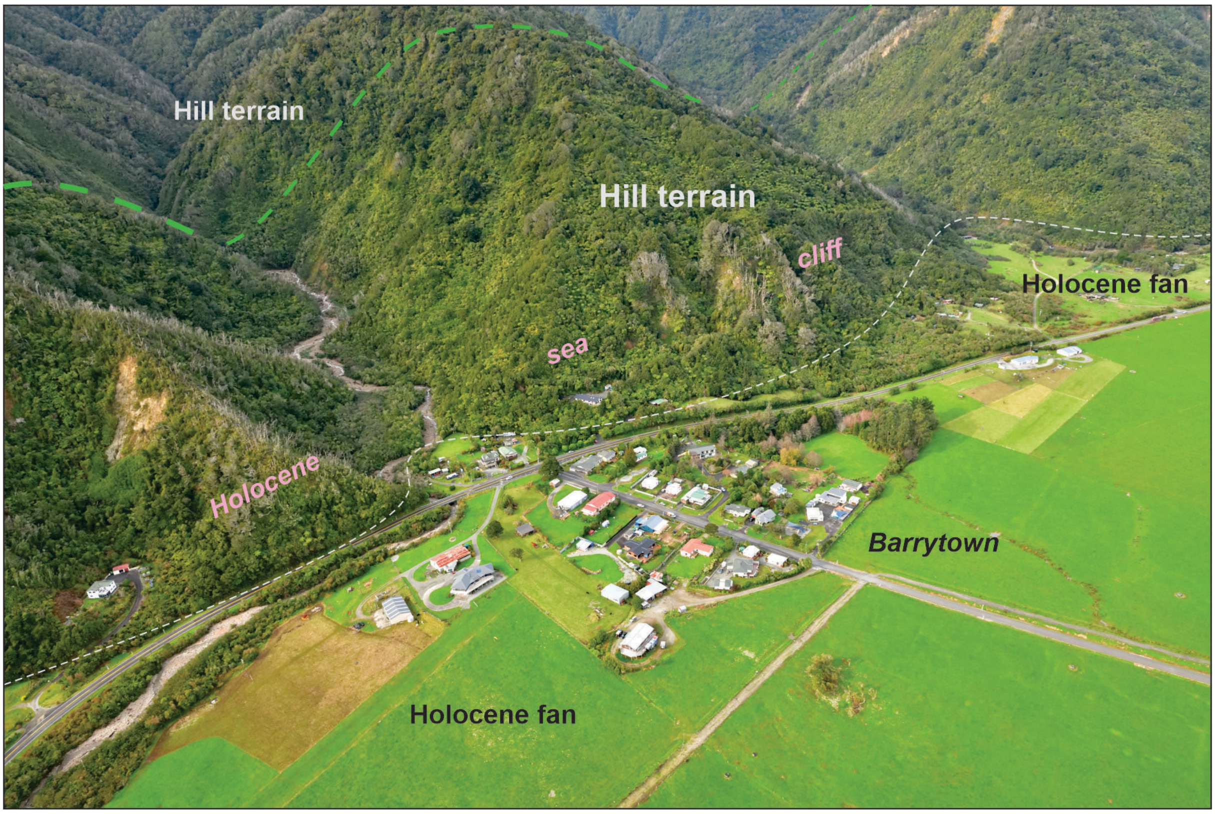

Figure 4.11 Overview of near-coastal environment at Barrytown, north of Greymouth, looking south. See Figure 4.7 for explanation of symbols and terms. Photo D. Townsend, July 2021. VML ID: 259916.

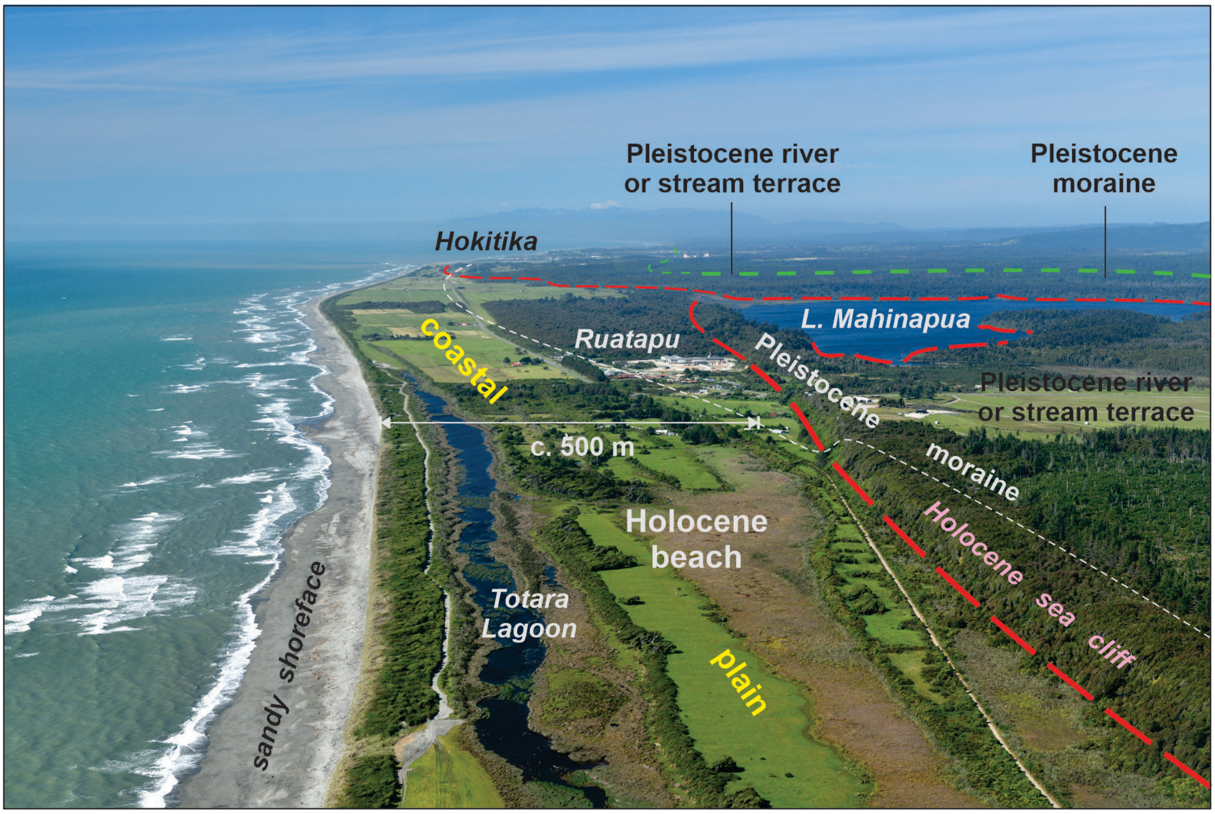

Figure 4.12 Overview of coastal environment near Lake Mahinapua, south of Hokitika. See Figure 4.7 for explanation of symbols and terms. Photo D. Townsend, December 2019. VML ID: 259911.

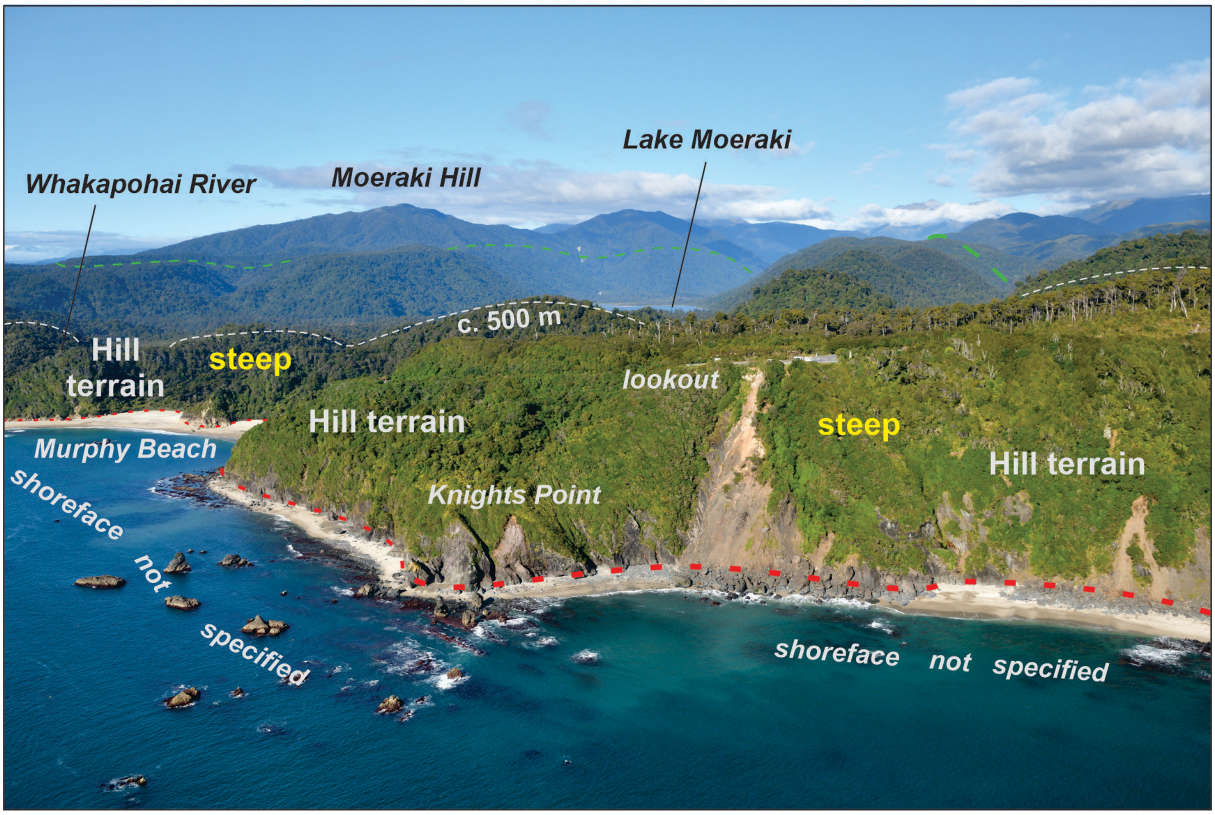

Figure 4.13 Overview of coastal environment at Knights Point, north of Haast. See Figure 4.7 for explanation of symbols and terms. Photo D. Townsend, April 2019. VML ID: 259910.

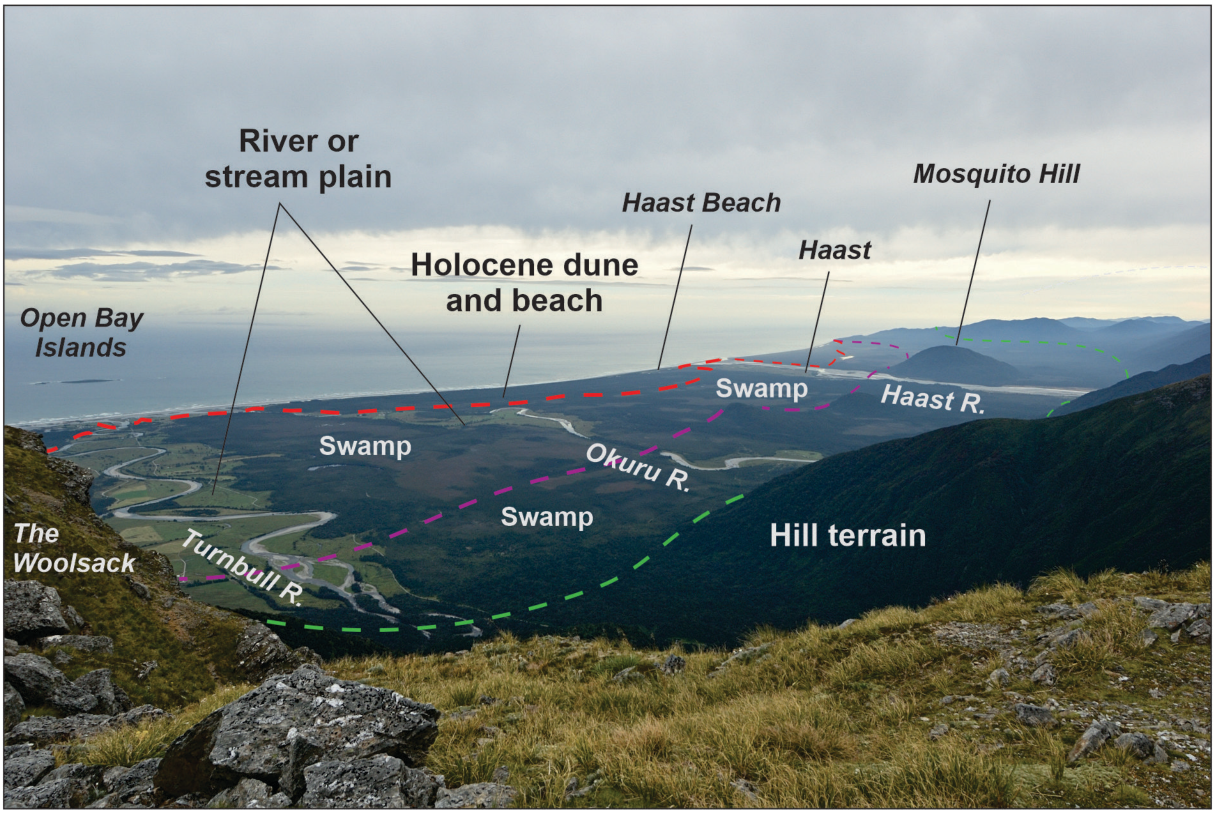

Figure 4.14 Overview of coastal environment near Haast. See Figure 4.7 for explanation of symbols and terms. The purple line marks the interpreted position of the ~6,500-year shoreline. Photo D. Townsend, February 2008. VML ID: 259909.

4.4 Summary Description of Coastal Geomorphology at Selected Coastal Population Centres

4.4.1 Karamea

The settlement of Karamea lies on a Holocene coastal plain that extends for about 30 km northeast from the Little Wanganui River. The coastal plain is backed by a former sea cliff that is now protected from wave action by accumulations of beach sediments that form the up-to-2-km-wide coastal plain. At the Karamea River, seaward-projected gradients of Pleistocene river terraces intersect present sea level only a few hundred metres off the modern coast. This provides an indication of how much coastal change has occurred since ~6,500 years ago. As much as 2 km of coastal erosion cut the sea cliff that now backs the coastal plain. Much of that coastal retreat was subsequently reclaimed naturally by beach sediment accumulation that formed the coastal plain. Features of the Karamea geomorphological coastal environment include the estuarine to tidally influenced lower reaches of the main rivers (Ōpārara, Karamea and Little Wanganui), the coastal beach plain and swamps, and the build-up of fans along the hillslope margins of the plain. In this setting, ongoing net build-up of river and stream sediments is to be expected, and there may be susceptibility to earthquake-induced liquefaction in low-lying areas underlain by shallow-marine or swampy sediments.

The tectonic environment is likely one of uplift (Beavan and Litchfield 2012), with a raised Pleistocene marine terrace preserved just south of the Karamea River. The Kongahu Fault (Figure 4.2) runs parallel to the coast and lies ~2 to 4 km seaward of the modern coastline (Barnes and Ghisetti 2016). Upward movement on the eastern side of this major fault has likely controlled the uplift of land along this part of the Buller coast over time, with the generally rugged coastline cut into the uplifted hill terrain. It is possible that uplift may have played a role in the abandonment of the Holocene sea cliff at the back of the coastal plain.

4.4.2 Westport

Westport lies on a Holocene coastal plain at the mouth of the Buller River, in a landscape dominated by terrace landforms on the western flank of the uplifted Paparoa Range (and its continuation north of the Buller River). Pleistocene beach terraces dominate the landscape around Cape Foulwind (Figure 4.9). At the Buller River, seaward-projected gradients of Pleistocene river terraces intersect present sea level at or close to the modern coast. In most places, those Pleistocene river or stream terraces were trimmed back by coastal erosion, prior to the accumulation of beach, dune and swamp sediments that form the Holocene coastal plain (Figure 4.9). The modern coast in some cases now lies seaward of its inferred initial ~6,500-year position, near the Buller River mouth and between ~10 and ~20 km northeast of Westport in the Waimangaroa area. These landform relationships illustrate how much coastal change has occurred since ~6,500 years ago. As much as 2 km of coastal erosion cut the sea cliff that now backs the coastal plain. Much, and in some cases all, of that coastal retreat was subsequently reclaimed naturally by beach sediment accumulation that formed the coastal plain.

Features of the Westport geomorphological coastal environment include the tidally influenced lower reaches of the Buller River and the fully estuarine Orowaiti Lagoon on the eastern side of the town. The broad, flat coastal plain provides an ideal setting for ongoing accumulation of river or stream sediments, associated with the main river floodplains, or alluvial fans constructed from minor streams or gullies draining onto the landward margin of the plain. The coastal plain area may be susceptible to earthquake-induced liquefaction due to its underlying shallow-marine or swampy sediments, in places now capped with alluvial sediments.

The tectonic environment is undoubtedly one of uplift in the Cape Foulwind area, illustrated by raised Pleistocene marine terraces, and uplifted Holocene wave-cut platforms and cliffs west of about Carters Beach and around Cape Foulwind to Tauranga Bay. This uplift is most likely related to movement on the Cape Foulwind Fault (Figure 4.2), which lies about 2 km off the modern coast, west of the cape (Barnes and Ghisetti 2016). It is possible that uplift may have played a role in the abandonment of the sea cliff at the back of the Westport area coastal plain, especially to the west of Westport township.

4.4.3 Greymouth

Greymouth lies on a terraced to hilly landscape at the mouth of the Grey River, on the western flank of the southwest end of the uplifted Paparoa Range. A narrow coastal plain is developed seaward of an abandoned Holocene sea cliff. There are at least three terrace levels in the coastal plain, the highest about 12 m above sea level, reflecting Holocene uplift(s) of at least several metres (Suggate 1992; Suggate and Waight 1999). The initial position of the 6,500-year shoreline is estimated to have lain ~1 km seaward of the present coast, close to the position of the offshore Cape Foulwind Fault (Figure 4.2).

A fairly straight coastal cliff was then cut to a position a few hundred metres inland from the modern coast, after which the coast was pushed out seaward as the coastal plain sediments accumulated. Uplift may have been a factor in shifting the coast seaward.

Features of the Greymouth geomorphological coastal environment include the locally uplifted coastal plain, the abandoned Holocene sea cliff cut into Pleistocene marine and river terraces, and adjoining hill terrain, the latter especially north of Greymouth. The lower-lying parts of the coastal plain may be susceptible to earthquake-induced liquefaction due to its underlying shallow-marine or swampy sediments, in places now capped with alluvial sediments.

The tectonic environment is undoubtedly one of uplift, with a long-term rate estimated at ~0.5 mm per year (Suggate 1992). The uplift is most likely related to movement of the Cape Foulwind Fault, which lies a few kilometres offshore of Greymouth (Barnes and Ghisetti 2016).

4.4.4 Hokitika

Hokitika lies in predominantly terraced landscape, close to an intersection zone between Pleistocene-age glacial landforms and the Holocene coast. There is a several-hundred-metre wide coastal plain seaward of a sea cliff cut into the glacial moraines and outwash plains. To the south adjacent to Lake Mahinapua, the coastal plain reaches a maximum of more than 1.5 km wide (Figure 4.12). These accumulated sediments now protect the cliff from wave action. These relationships illustrate that there was an episode of coastal erosion that cut the cliff after ~6,500 years ago. The outwash plains were eroded back several hundred metres at Hokitika, and as much as 2 km near Seaview, just north of Hokitika. There was then a change to coastal accretion, with beach sediment build-up that has naturally reclaimed part of the coastal area.

The youngest glacial outwash terraces in the Hokitika valley have steeper gradients than the modern river, and these terraces intersect, and are overtopped by, the modern river floodplain near Kaniere, about 4 km from the present coast. This circumstance is due to the Hokitika undersea canyon (Figure 4.1), whose head lies only ~15 km offshore of the present coast. At the lowest glacial sea level ~20,000 years ago, the Hokitika River would have locked into the head of the canyon, steepening the river system’s gradient and causing general downcutting of the valley. This effect is also evident at Lake Mahinapua, which lies in the drowned valley of several minor streams that would also have drained to the canyon head. Post-glacial sea level rise would have invaded the over-steepened river and stream valleys. We tentatively infer that the 6,500-year-old shoreline may have extended a short distance up the Hokitika River, and undoubtedly extended into the Mahinapua valley. The modern lake is the remnant of that marine inlet, now cut off from the sea by the coastal plain sediments, and sea water replaced by fresh water.

The tectonic environment, at least from Hokitika northwards, is one of uplift, as evidenced by raised Pleistocene marine terraces there, documented by Suggate (1992), with long-term uplift rate estimated at ~0.5 mm per year. South from Hokitika, there are no preserved Pleistocene marine terraces, and the tectonic environment is probably stable (neither uplifting nor subsiding). It is possible that uplift may have played a role in the abandonment of the sea cliff north of Hokitika. The uplift is most likely related to movement of the Cape Foulwind Fault, the southern end of which lies a few kilometres offshore of Hokitika (Barnes and Ghisetti 2016).

4.4.5 Haast

The settlements of Haast and Haast Beach lie on the Haast coastal plain (Figure 4.14), in an area that was overwhelmed by the ice-age Haast Glacier, fed by ice tongues from all the valleys emerging from the Southern Alps in this area. This glacier is interpreted to have extended out to the shelf edge adjacent to the deep water of the Haast and Arawhata undersea canyon system (Figure 4.1). After the ice retreated, the sea rose over the former glacier bed, which is studded by ice-scoured knobs of hard bedrock that protrude from the coastal plain. A sequence of coastal sand dune ridges, with minor intervening swampy depressions, extend as much as ~3 km inland from the present coast (Dickinson and Mark 1994). Their presence highlights a general migration of the coast seawards in response to sediment accumulation along the coast (Wells and Goff 2006, 2007). On topographic and geomorphological grounds, we infer that the shoreline ~6,500 years ago lay between about 4 and 6 km inland of the modern coast. We infer that Haast township lies at about the location of the 6,500-year shoreline. The smaller rivers of the coastal plain (Waiatoto, Turnbull and Okuru) have meandering lower reaches, and we interpret that channel pattern as having developed over the area that was formerly part of the ~6,500-year sea floor. The former seabed was reclaimed naturally by river sediment accumulation. In contrast, the large rivers (Haast and Arawhata) have braided gravel beds extending to the coast, reflecting their greater power and sediment load that has allowed them to maintain a more uniform gradient to the sea. Near the Arawhata River, the inland part of Sponge Swamp has been in existence for at least ~7,000 years, based on radiocarbon dating of a 7-m deep peat core south of Mt McLean, ~4 km from the present coast (Li et al. 2008). This illustrates that the 6,500-year old shoreline did not extend around the inland (southeast) margin of Mt McLean, but rather a swamp environment prevailed there at that time.

Features of the Haast geomorphological coastal environment include the extensive dune systems and swamps of the lowland, and the build-up of fans along the hillslope margins of the plain. In this setting, ongoing net build-up of river and stream sediments is to be expected, and there may be susceptibility to earthquake-induced liquefaction in low-lying areas underlain by shallow-marine or swampy sediments. The Alpine Fault runs along the south-eastern margin of the coastal plain. Movement is mostly strike-slip (sideways) with a recurrence interval for large earthquakes of ~300 years and the last big earthquake on the Haast part of the Alpine Fault is pinpointed at about AD1717 (Berryman et al. 2012; Cochran et al. 2017; Howarth et al. 2018). The absence of raised topography, or high-level Pleistocene moraines at either end of the Haast coastal plain is interpreted to mean that this stretch of the coast (northwest of the Alpine Fault) is probably stable tectonically, neither rising nor subsiding (Beavan and Litchfield 2012).

4.5 Discussion

On the broadest scale, tectonics have played an important role in determining the position of the West Coast Region shoreline. Several northeast-southwest aligned major contractional fault systems lying northwest of the Australian/Pacific plate boundary at the Alpine Fault have, on timescales of the order of a million years, experienced movements that have uplifted the south-eastern sides of these faults. These movements have created elevated ground, in some cases elevated plateaux, such as the Cape Foulwind area, or fully mountainous terrain such as the Paparoa Range. The shorelines formed during episodes of interglacial climate, with high sea level such as today, and including the modern coastline, are cut into the margins of these fault-uplifted blocks. Times of glacial low sea level saw the coastline retreat well out onto the continental shelf. We envision that during shifts from glacial to interglacial climate, the rising sea lapped across the shelf, and upon meeting each of the major faults, recommenced cliff-cutting into their uplifted sides. Over the course of a ~100,000-year glacial-interglacial cycle, the uplift during a period of low sea level appears to have been sufficient to have raised the former interglacial coastline features by typically several tens of metres, and thus above the influence of the succeeding episode of high sea level. This has produced the distinctive flights of interglacial terraces that characterise the coastline, north of Hokitika in particular.

Also significant in big-picture West Coast coastal geomorphology is the interplay of land and marine processes. The width, and therefore gradient, of the continental shelf, in relation to the gradient of river (and glacier) valleys is particularly important. Adjacent to a narrow, steep shelf, glacial sea level fall will steepen the lower reaches of rivers (or glaciers), promoting erosion and incision of valley floors. In contrast, where the shelf is wide and gentle, sea level fall will tend to induce sedimentation and aggradation in the valleys. Post-glacial sea rise will tend to drown the lower reaches of incised valleys (e.g. Lake Mahinapua valley), creating accommodation space for sediment accumulation. Resulting valley filling will reduce sediment delivery to the coast, until valley gradient equilibrium is re-established, after which time the usual sediment supply to the coast will resume. These are just examples of the sorts of process-interrelationships that are relevant to a comprehensive understanding of the geomorphological coastal environment of the West Coast.

Local variations in how the coastline has changed since ~6,500 years ago may reflect the influence of different geomorphological factors. The Haast coastal plain primarily occupies the bed of a former, large, ice-age glacier. The glacier-floor setting provided a zone with space for accommodating coastal and fluvial sediment deposition, reflected in seaward expansion of the coastal plain over time. In contrast, the sectors of coastal plain between the Hokitika and Greymouth areas, near Westport and near Karamea, have a distinctive character, with an earlier phase of coastal erosion with formation of prominent sea cliff, followed by a phase of net sediment accumulation that has seen the land expand seawards, in some cases by more than a kilometre. While it is conceivable that tectonic uplift has been a factor in promoting this change, it is fruitful to consider other environment factors.

One potentially important factor may be changes in sediment supply to the coast by rivers, particularly from Hokitika southwards, where most rivers occupy former glacier valleys. It is possible that the rivers have been continuing to adjust to post-glacial changes in their gradients and states of equilibrium. Major earthquakes have also been suggested as a cause of variations in sediment supply within river systems (e.g. Wells and Goff 2006, 2007; Howarth et al. 2012, 2018). A rich body of paleoseismological investigation data shows that large to great earthquakes occur on the Alpine Fault once every 300 years on average, although with some variability in the exact time between earthquakes, and in the length of the Alpine Fault that ruptures in one go (Howarth et al. 2018). The last rupture of the entire fault has been pinpointed at about AD1717, but it has recently been discovered that the central and perhaps northern part of the fault ruptured again, sometime between AD1813 and AD1848 (Langridge et al. 2021). Nevertheless, the Alpine Fault is close to the end of its present inter-rupture cycle, and the supply of sediment to rivers, related to Alpine Fault earthquakes, is currently at a minimum (Sutherland et al. 2007).

Another factor may be more directly climatic. There may have been changes in wave energy, linked to variations in the locus and strength of the prevailing westerly wind flow. Such changes have been postulated to have involved sustained shifts in the westerlies on multi-thousand-year timescales (e.g. Hinojosa et al. 2017; Anderson et al. 2018; Denton et al. 2021), though the detail is a matter of ongoing research.

Overall, we highlight the following key points relevant to West Coast coastal geomorphology and planning considerations:

- There is some natural dynamism in the coast, illustrated by recent erosion problems at places like Hokitika, Carters Beach and Granity. The wider view of coastal geomorphology shows that these represent very minor adjustments in shoreline position compared with substantial natural shifts over the past few thousand years.
- Areas of coastal lowland seaward of the 6,500-year shoreline are integral components of the geomorphological coastal environment and are natural sediment traps. Alluvial fan and river flood sediments will tend to keep building up over time (e.g. at Barrytown; Figure 4.11), unless managed appropriately, and where possible. It should also be expected that there may be enhanced potential for earthquake-induced liquefaction and poor foundation conditions in these areas of poorly consolidated sediments.
- Sea-level rise is likely to have a range of consequences in the dynamic West Coast Region coastal environment. Inundation from sea level rise will tend to create accommodation space for sedimentation on the coastal plains and lower reaches of valleys, which in turn may encourage upstream aggradation.

5.0 CONCLUSIONS

A methodology has been developed for a geomorphological assessment of coastal environments in the West Coast Region. The aim is to provide technical input for the West Coast Regional Council in their work to define the nature and extent of the West Coast coastal environment.

The work was a desktop assessment, in which 1:250,000-scale geological and topographic map digital datasets were used to derive geomorphological maps as a foundation for our assessment. The main resource is a nominally 7-km wide geomorphological 'strip map' along the landward side of the coast. We produced three narrow strip maps (0.5-km-wide) landward of the coastline to highlight single-factor geomorphic considerations; (i) the nature of the shoreface sediments, (ii) the general type of shoreline landform, and (iii) the long-term tectonic environment (uplift versus stability). We also produced an interpretive map of former shoreline positions, based on topographic and geomorphological information.

From this information, we arrived at an interpretation based on two perspectives of the coastal environment. One perspective delineates the inland extent of preserved young coastal landforms, including dune fields, beach plains, estuaries, and near-coastal swamps and lakes. Another perspective takes a broader view of the geomorphological coastal environment and delineates the general area that has been subject to coast-related processes since present sea level was attained, ~6,500 years ago.

Wider geological and geomorphological considerations have a bearing on understanding the modern coastal environment of the West Coast. We highlight global glacial-interglacial climate cycles of ~100,000-year average duration, which produced ~100 m amplitude natural sea level changes, the geometry of the continental shelf seaward of the present coast, and the role of advance and retreat of ice-age glaciers in the Southern Alps. There is also a strong imprint of tectonic movements, with the position of the modern, and previous interglacial, shorelines, closely related to major active faults in the coastal area. Some sections of the coast are influenced more by vertical tectonic land movements, others more by glacial and interglacial cycles and sediment supply.

The geomorphological evidence points to considerable natural changes in the coastline over the past ~6,500 years. In many places, there has been a consistent story of erosion and cliff formation followed by progradation/building out of the coastal plain. Natural variation in the position of the shoreline over the last 6,500 years has been greater than that observed since human occupation.

6.0 ACKNOWLEDGMENTS

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