COASTAL MANAGEMENT CONSULTANCY LIMITED

APPLICATION OF GEOLOGY AND PHYSICAL OCEANOGRAPHY TO MARINE RESERVE DETERMINATION, IPIPIRI, EASTERN BAY OF ISLANDS, NORTHLAND, NEW ZEALAND

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" Man cannot discover
new oceans

Until he has courage
to lose sight
of the shore"

Anon

TABLE OF CONTENTS

PART I - BACKGROUND

PART II - FACTS FOUND

PART III - MARINE RESERVE DETERMINATION

APPENDIX A

ADDENDUM April 2013

EXECUTIVE SUMMARY

Knowledge of both geology and physical oceanography is essential when assessing a site for a potential Marine Reserve. Together, both sciences provide the necessary descriptions of typical and unique habitats for marine life. In this study, the site is located in the Eastern B.O.I and includes the sea, foreshore and seabed surrounding Okahu and Waewaetorea Islands, and the northwestern part of Urupukapuka Island.

Although only 3-5 km from the mainland shore, the dominantly Shelly Sand of the seafloor of the site is accumulating at an order of magnitude less than the muddy inlets of the B.O.I., and is free of mainland Mud. Year-round water visibility is some 12-15m, the site benefiting from the subtropical waters of the East Auckland Current and regular flushing by tidal currents. The site features two tidal channels and both sheltered and exposed coasts from the effects of wave action.

The basement rocks are mostly very hard greywacke sandstone laid down when “Zealandia” (New Zealand) was part of the super-continent, Gondwana, prior to splitting off some 83 million years ago to form the Tasman Sea and Southern Ocean. The site includes very rare beds of white marble, red-brown mudstone with equally rare lumps of pink limestone and coral, plus red and green chert.

Although the seacoast is mostly rocky, it includes a diverse range of pocket beaches from; Fine Shelly Sand, Medium Shelly Sand, Pebbles, and Cobbles. The bold seacliffs are often fringed by wave-cut shore-platforms dissected by caves, tunnels, canyons, and crevices, cut along ancient faults and fractures, extending from the coast out onto both shore-connected and offshore reefs on the seabed. Extensive areas of clean Fine to Coarse Shelly Sand that feed the beaches and collectively, form a diverse range of habitats for marine life, separate the reefs.

The site has long been recognized as special by the public with at least 4 attempts to establish a Marine Reserve there in the 1970s, 1985, 1993 and 2003, all of which failed. In this study, a new design for a Marine Reserve is proposed, based on the identified physical attributes of the site. The area proposed is 835ha and is enclosed by five boundary lines established by practical navigation techniques. The proposed area equates to 2.06% of the B.O.I. sea area and is regarded here as an absolute minimum for protection.

Although the scientific evidence on the geology and physical oceanography presented in this study is reasonably comprehensive, further work is required to describe the scientific attributes of the marine flora and fauna of the site. Robust scientific evidence of the geology, physical oceanography and marine life, may collectively, increase the design area of 2.06% of the Marine Reserve proposed in this study, whilst providing a solid basis for an Application to establish lasting protection of this outstanding site.

APPLICATION OF GEOLOGY AND PHYSICAL OCEANOGRAPHY TO MARINE RESERVE DETERMINATION, IPIPIRI, EASTERN BAY OF ISLANDS, NORTHLAND, NEW ZEALAND

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PART I - BACKGROUND

1 INTRODUCTION

Geology is the study of the Earth and oceanography the study of the seas. To a geologist, a rock is more than an aggregate of minerals, but a page of the earth's autobiography with a story to unfold if only he or she can read the language in which the record is written. The fundamental principle in reading the meanings in rocks and landforms was first enunciated by James Hutton in 1785, when he declared that; "*the present is the key to the past*," meaning that, "*the past history of the globe must be explained by what can be seen to be happening now.*" Hutton, the founder of modern geology, insisted that the ways and means of Nature could only be discovered by observation (Holmes 1965).

Based on observations underpinned by research, this study presents information on the physical attributes of the coastal environment of a simply stunning area (the site) in the Eastern Bay of Islands (B.O.I.). The site was classified in the DoC Northland Coastal Resource Inventory as part of an "*Area of International Significance*" (Shaw & Maingay (1990). In a "*Fish Forever*"(BOIMP Inc.) survey in 2010-2011, the general public identified the site as a priority area to establish a Marine Reserve.

It should be noted that this is not the first time that a Marine Reserve has been proposed for this site. Various groups put forward proposals in the 1970s, 1985, 1993 and in 2003, none of which succeeded (Derry Godbert & David Clarkson, Kerikeri, *pers comm*., Aug. 2012). It is however, the first time that both geology and physical oceanography have been considered for a Marine Reserve determination within the B.O.I.

1.1 Report Structure

The purpose of this report is to present relevant information on the geology and physical oceanography, in the context of the Marine Reserves Act 1971, that will contribute to the long-term protection of the site as a Marine Reserve. Based on this information plus practical navigation techniques, a design of a potential Marine Reserve is presented which in the context of the B.O.I., is regarded here as an absolute minimum sea area.

The report is divided into three parts. Part 1 covers the "*Background*" underpinning this study; Part 2 covers "*Facts Found*" about the geology and physical oceanography of the Ipipiri area; Part 3 covers the "*Marine Reserve Determination*" for part of the area and a proposed Marine Reserve design. Unless otherwise stated, the author took all the photographs for the figures in this study between 2008 and 2012.

1.2 The Site

The site in general, is shown in Figures 1 and 2 and includes the coastal environment extending toward Whale Rock to the NW, Okahu Island, Waewaetorea Island, and the NW part of Urupukapuka Island. From NW to SE, the site particularly includes Motungarara (Cliff Island), Okahu Channel, Waewaetorea (Otawake) Channel, Entico Bay, Whanga-apau Islands, Te Hoanga Point, and all the unnamed reefs and rocks associated with the three main islands (Fig. 1).

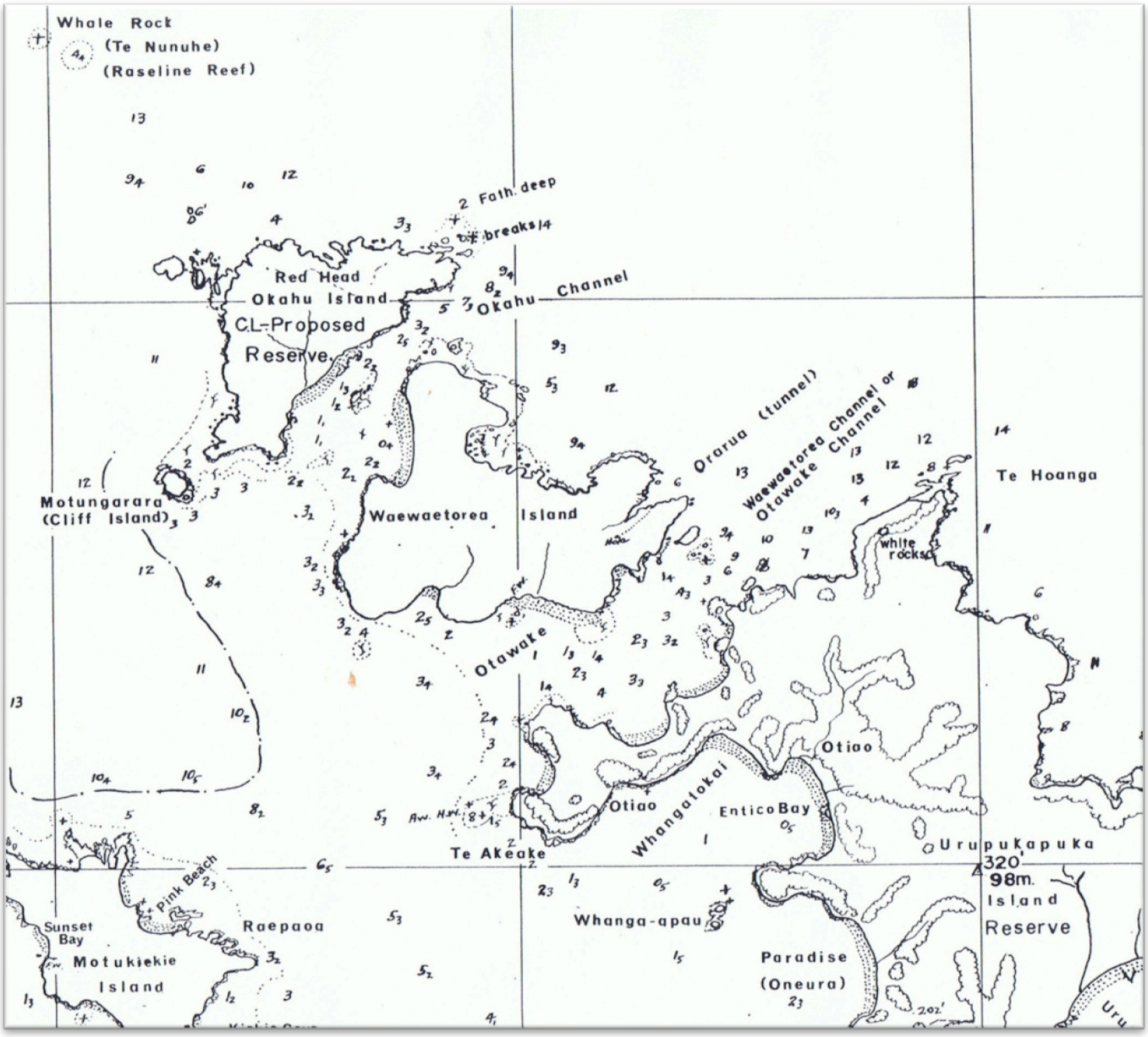


FIGURE 1: Part of Chart 19 from the Pickmere Atlas showing place names adopted by Hereward Pickmere FNZIS, relevant to the site. Soundings in fathoms below Chart Datum (Source Watkins 1974).

1.3 Place Names

For the site, place names were adopted from Chart 19 from the Pickmere Atlas on the grounds that Hereward Pickmere FNZIS, gained “*many authentic names*” from Maori elders and ”*much local knowledge*” from local residents during his detailed surveys of the Northland coast in the 1930s-1940s (Watkins 1974). Modern charts and topographic maps have either deleted or altered the spelling of many place names used on the early Pickmere charts which is confusing (e.g. Otaio for Otiao; Indico for Entico etc.). The Pickmere place names are shown on Figure 1. Note that Entico Bay is adopted here for the bay N of Oneura (Paradise) Bay.

2 RELEVANT LEGISLATION

The Marine Reserves Act 1971 (the Act), provides for the setting up and management of areas of the “*Sea, Seabed and Foreshore”* around New Zealand as Marine Reserves *“…for the purpose of preserving them in their natural state as the habitat of marine life for scientific study*.“

With respect to the physical attributes of a potential site for protection, the Act states that such areas must; “*contain underwater scenery, natural features … of such distinctive quality, or so typical, or beautiful, or unique, that their continued preservation is in the national interest.*” [Sect. 3(1)].

Collectively, the rocks, sediments, landforms, structure, etc. of the foreshore and seabed, plus water clarity, currents, waves, tides, etc., of the sea covering a potential site, are the important physical components of the “... *habitat of marine life*.” In fact, without geology and the sea there are no habitats for marine life. Hence, an understanding of both geology and physical oceanography are essential in the establishment of coastal sites as Marine Reserves.

3 METHODS

Between 2008 and 2012, both Jeremy and Anne Gibb (CMCL) made several field trips to the site on their vessels’ “*Sea Hawk*” and “*Storm Surge*”. The field trips involved observing, photographing and recording the outcropping coastal rocks, landforms, beaches, the sea and coastal processes from both the sea and the land. In addition, beach sediment properties were recorded in the field at 20 representative stations from 15 pocket beaches (Fig.2), using sampling techniques developed by Gibb (1977).

Grain size terminology and sediment nomenclature were classified in the field after Folk *et al.* (1970), as summarised in Tables 1-A and 2-A (Appendix A). Following fieldwork, relevant published literature and charts listed in Section 9 of this report were researched. Of particular relevance, are the recent published works on the geology (Edbrooke & Brook 2009), oceanography and marine geology (NIWA 2010), and global sea-level changes during the past century (Church & White 2011).

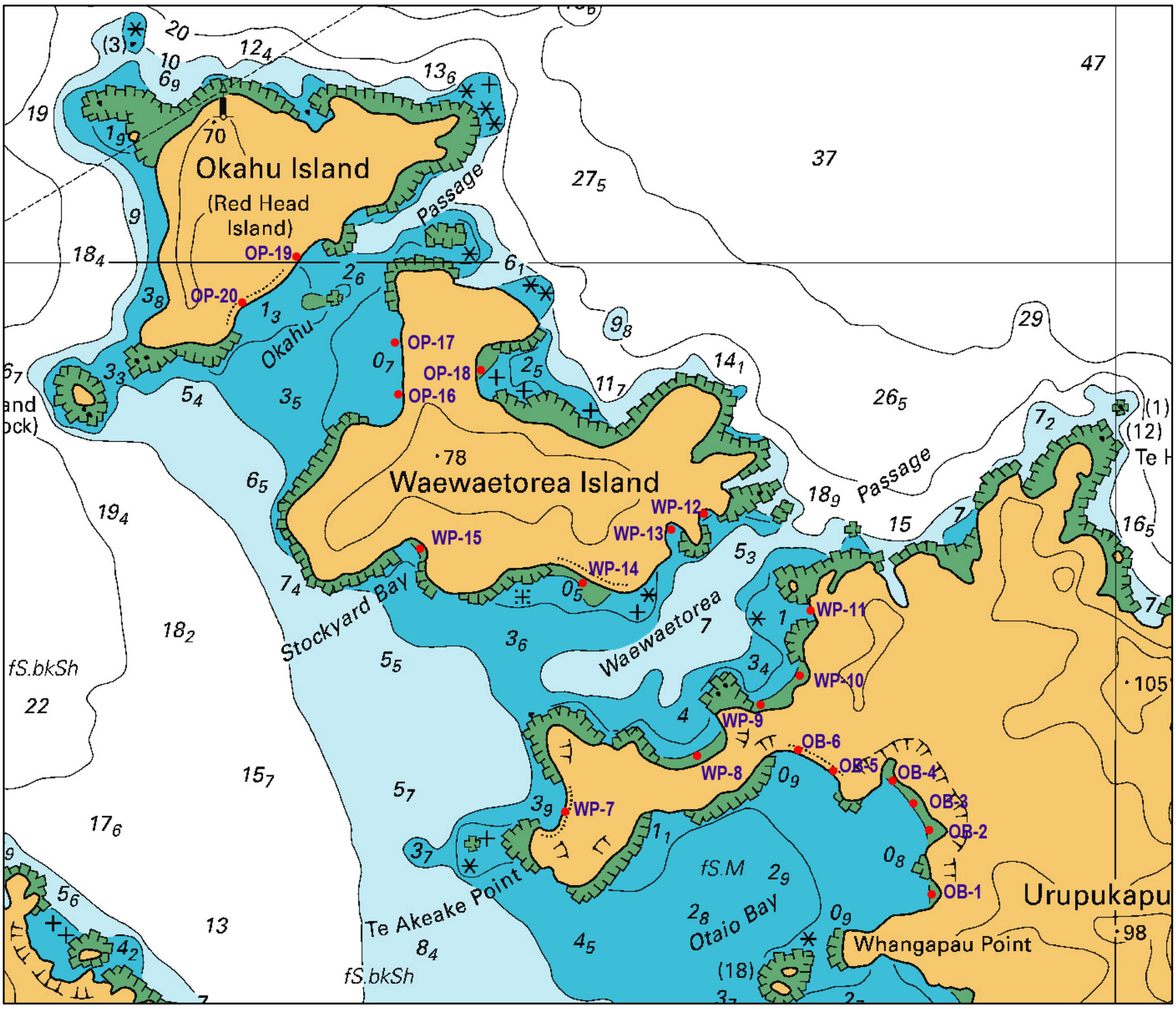


FIGURE 2: Chart of the study area showing locations of the 20 sediment stations labeled alphanumerically from OB-1 to OP-20, sampled in March-April 2012, where OB is Otaio (Entico) Bay, WP is Waewaetorea Passage, and OP is Okahu Passage. Soundings in metres below Chart Datum (Source LINZ 2007).

PART II - FACTS FOUND

4 GEOLOGY

1. Basement rocks of the site belong to the Waipapa Group, consisting predominantly of massive metasandstone (greywacke), with subsidiary interbedded green and red chert, red mudstone and marble. The greywacke (Fig.3) is estimated to form 80-90% by volume of the Waipapa Group sequence (Moore 1981).

2. On the N side of Okahu Island a prominent band of red-brown mudstone crops out in the seacliffs and likely gives this area the name, "*Red Head*"(Fig.1). The mudstone contains abundant clasts of orange, green and red-brown chert, chunks of pink limestone up to 0.3m diameter, and rare lumps of coral (Moore 1981).

3. A prominent lens of white marble (metamorphosed limestone), up to 7-8m thick and about 50m long, crops out on the N side of Te Hoanga Point, Urupukapuka Island (Fig.1). The exact origin of the very pure marble interbedded within the greywacke is unknown, but it must predate the greywacke (Moore 1981).

4.1 Journey From the Motherland

FIGURE 3: Photo of locally derived greywacke sandstone beach cobbles at Station OP-18 (Fig.2) on Waewaetorea Island which is representative of the greywacke gravels found on the beaches of the site.

4. The Waipapa Group of rocks was laid down during the Triassic to Late Jurassic Periods 251-145.5 Ma (million years ago), when New Zealand or Zealandia as it was called, was part of the super-continent Gondwana (Fig.4), often described by geologists as our "*ancient motherland*" (Graham 2008; Edbrooke & Brook 2009).

5. Minerals within the greywacke reveal that the sand was originally supplied from multiple volcanic and other sources within Gondwana, along the E margin of Australia and Antarctica and deposited offshore in deep water by bottom turbidity currents. During deposition, the older marble was emplaced into the enclosing sediment layers.

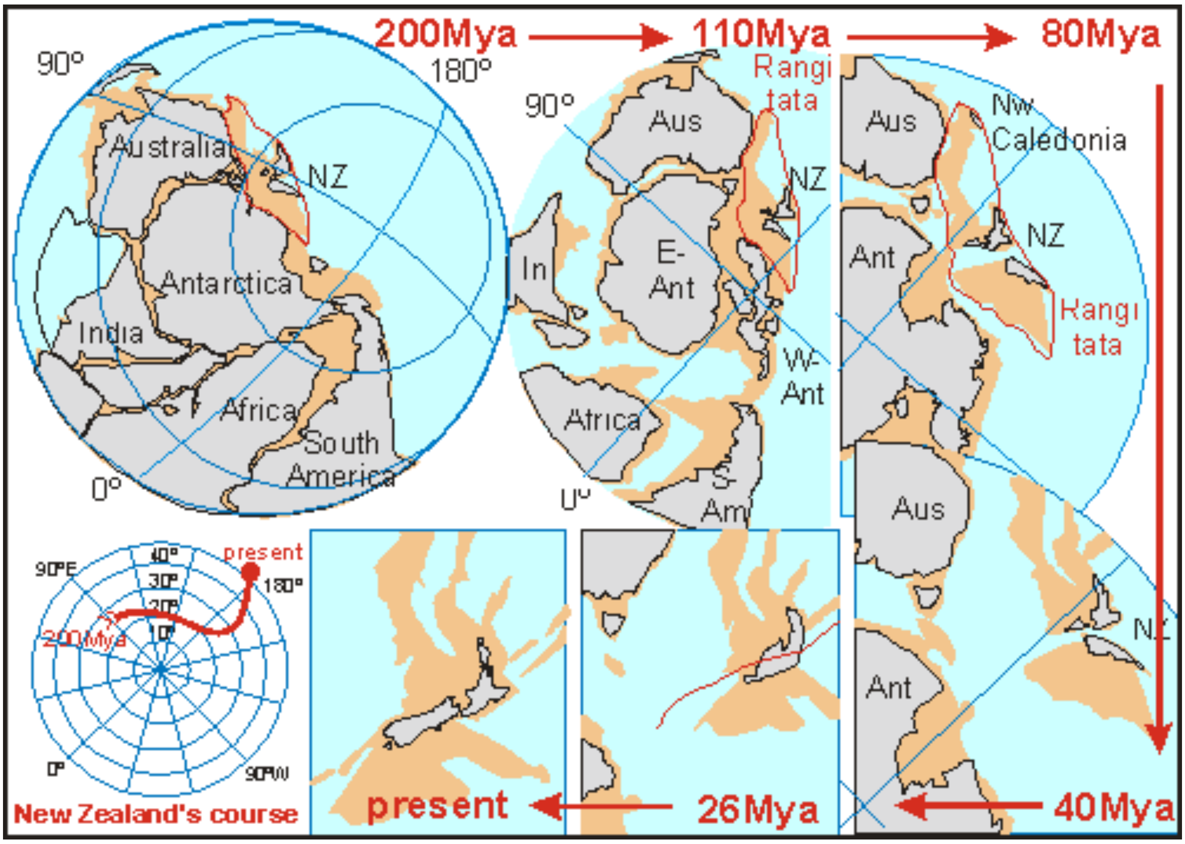


FIGURE 4: Sketch maps showing the journey of Zealandia from Gondwanaland to its present position. Note that Zealandia includes both dry land in grey and the surrounding continental shelf in brown (Source: Images for Gondwana, Google).

6. As layer upon layer of sediment built up on the seafloor, the bottom layers became increasingly compacted and solidified to form the metasandstone composed predominantly of quartz, feldspar, chert, and volcanic rock fragments along with the minerals epidote and biotite, etc. (Moore 1981), which collectively, give the light grey colour to greywacke (Fig.3).

7. About 83 Ma, Zealandia separated from Australia and Antarctica via sea-floor spreading, leaving behind two major gaps, which became the Tasman Sea and Southern Ocean. It took about 30 Ma for the Tasman Sea to reach its present width (Graham 2008).

8. Some 55-40 Ma, plate tectonic forces associated with a plate boundary through Zealandia, resulted in the uplift of the sedimentary rocks of Zealandia (Graham 2008), including the Waipapa Group basement rocks of the B.O.I.

9. From about 26-20 Ma, there was a further period of intense tectonic activity associated with a shift in plate boundary movements between the Pacific and Australian Plates resulting in localised NW trending and subordinate NE trending faults, cross joints and fractures, forming zones of weakness in the hard to very hard basement rocks (Graham 2008; Edbrooke & Brook 2009).

10. It is likely that a major NW trending, sub-horizontal syncline, the axis of which extends roughly through the centre of Urupukapuka, Waewaetorea and Okahu Islands (Moore 1981), formed during the periods of intense tectonic activity between 55 and 20Ma.

11. By 20-17Ma, the Pacific-Australia plate boundary had propagated through the Northland region to lie somewhere to the NE, resulting in the extinction of many volcanoes such as those around Kerikeri, previously associated with plate movements and crustal ruptures (Isaac 1996).

12. From 16-11 Ma, regional uplift and gentle W tilting, together with normal block faulting, continued to raise much of Northland above sea-level, as the plate boundary where the Australian and Pacific Plates collide, drifted further E (Edbrooke & Brook 2009).

13. The last 10 Ma were characterized by relative tectonic stability with deep weathering of the greywacke into erodible clays. There are now no known active faults in the area and the Quaternary geology is consistent with a period of relative stability (Edbrooke & Brook 2009).

14. The Quaternary Period includes both the Pleistocene Epoch (2.588-0.0117 Ma) and the Holocene Epoch (last 11,700 years), the former spanning the worlds recent period of repeated glacial-interglacial cycles and the latter, the relatively warm Present Interglacial in which humanity currently lives.

15. Well-preserved Pleistocene coastal landforms between Whangarei and Parengarenga Harbours indicate that the Northland east coast, including the B.O.I., has been tectonically stable with no local uplift or downdrop over at least the last 125,000 years (125ka). The Far North has the least seismic activity of any area in New Zealand (Isaac 1996; Edbrooke & Brook 2009).

4.2 Coastal Evolution

16. The seacoast is the unique boundary in Nature where the forces of the sea, land and atmosphere meet. As the land at the site has been relatively tectonically stable during the Quaternary Period, the proximate cause of coastal evolution has been sea-driven erosion processes associated with major global climatic cycles specifically affecting the rise and fall of the sea.

17. During the Pleistocene Epoch, the initial length of the glacial-interglacial cycles between 2.588 and about 0.9Ma was 41ka up to the Mid-Pleistocene Transition (MPT). Following the MPT at about 0.9Ma, the cycle length suddenly increased from 41ka to about 100ka. This would suggest some 50 global climate cycles have occurred over the last 2.6Ma.

18. The B.O.I. is a drowned river valley with tributaries, resulting in many small embayments, islands and estuaries (Morley & Hayward 1999). At the site, the present diverse coastlines and landforms have been sculptured from the basement rocks by the sea during the multiple Interglacial highstands of the sea (Fig.5) during the Pleistocene Epoch, particularly since the MPT.

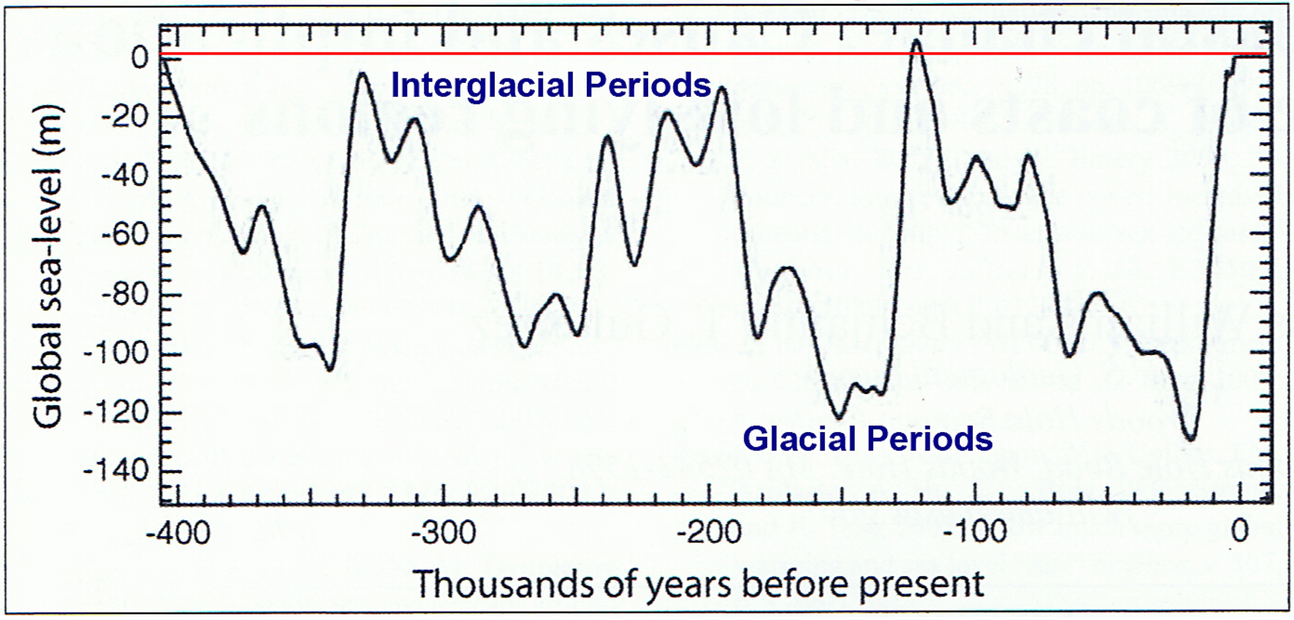


FIGURE 5: Global sea-level trends over the last 400ka in response to major climatic cycles. For the last 4 cycles shown, global sea-level fluctuations have ranged from about 85 to 130m between Interglacial and Glacial Periods (Source: Huybrechts 2002).

19. At the start of this evolutionary erosion process about 2.6Ma, there would have been one continuous unbroken island at the site, extending NW out past Te Nunuhe (Whale) Rock. The islands (Fig.1) as we know them today would not have existed.

20. During the Pleistocene Epoch, erosion processes associated with the successive Interglacial highstands of sea-level were largely responsible for splitting the original island at the site into Okahu, Waewaetorea and Urupukapuka Islands and the smaller islands such as Whanga-apau (Fig.1).

21. During the highstands, coastal erosion processes focused on structural weaknesses such as dormant faults, fractures and joints that formed during the period of intense tectonic activity some 26-16Ma, resulting in the formation of the extensive bold seacliffs evidenced today, that truncate the contour of the land (Fig.6).

22. The present orientation of Okahu, Waewaetorea and Urupukapuka Islands (Fig.1), suggests that they are fault bounded by dominant NW trending faults, paralleling the NW axis of the ancient synclinal structure.

23. The NE trending Okahu, Waewaetorea and Albert Channels that separate the islands from each other and the mainland, suggest the presence of subordinate NE trending faults that have weakened the basement rock allowing breaches by the sea.

FIGURE 6: Photo looking SE toward Te Rawhiti at bold seacliffs cut by the sea during the Pleistocene Epoch, truncating the coastal ridges along the exposed open coast of Urupukapuka Island.

24. On a relatively small scale, a network of fractures and joints associated with both sets of faults delineate the many localised canyons, tunnels, caves, and blowholes incised by the sea into the seacliffs during the interglacial high-stands of sea-level (Fig.7).

25. The original hard to very hard greywacke exposed surfaces have been further weakened by sub-aerial processes to form relatively soft, deep yellow and red clays (Fig.8).

FIGURE 7: Photo of a blowhole on Waewaetorea Island (*top*) where the sea has cut the 80-100m long Orarua tunnel (Fig.1) through the greywacke along an extinct fault under an ancient pa site, and; photo looking NE through a canyon (*bottom*) about 100m N of the blowhole (Fig.1), that formed from a collapsed tunnel through the coastal ridge.

FIGURE 8: Photo taken by Dean Wright looking W at deep surface weathering of greywacke bedrock at Red Head, Okahu Island, to form erodible clays. The seacave at the base is being cut along an ancient fracture in the massive bedrock.

4.3 The Last and Present Interglacial

26. At the climax of the Last Interglacial about 125ka (Kopp *et al.* 2009), sea-level in tectonically stable parts of New Zealand such as Northland, was 2-3m higher than today's level (Gibb 1986; Isaac 1996; Edbrooke & Brook 2009). Figure 9 shows the full Last Interglacial-Glacial-Present Interglacial cycle.

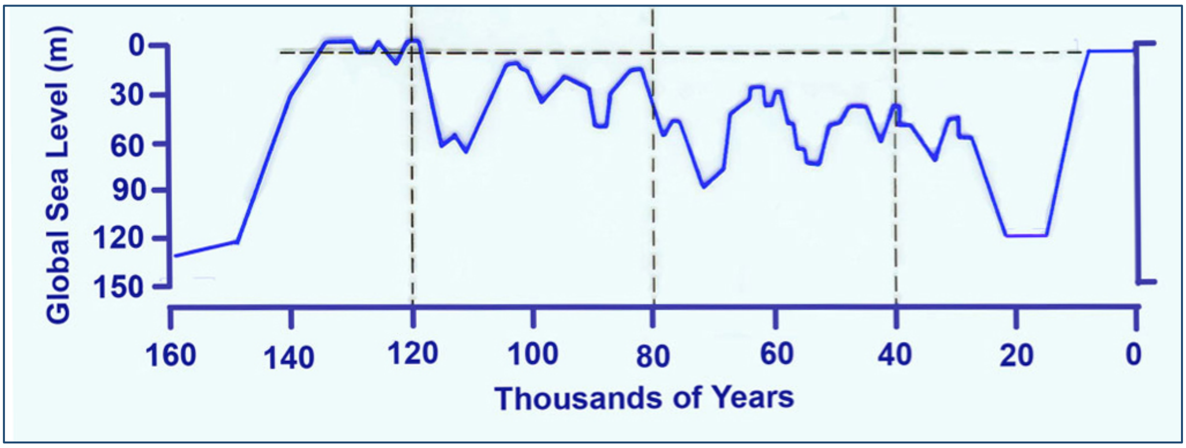


FIGURE 9: Global sea-level trends during the Last Interglacial-Glacial-Present Interglacial cycle over approximately the last 140ka that affected coastlines worldwide including the B.O.I. (Source: Murray-Wallace 2007).

27. Around 125ka, shoreline features were formed which are preserved in the E B.O.I. on Waewaetorea, Urupukapuka, Poroporo, Moturua, and Motuarohia Islands. Figure 10 shows a well-preserved Last Interglacial shore platform 2-3m above the present-day platform on the N shore of Poroporo Island.

FIGURE 10: Photo taken at low tide, looking S of a remnant 125ka wave-cut shore platform 2-3m above the present-day platform on the sheltered N facing greywacke seacliffs of Poroporo Island.

28. On the N part of Waewaetorea Island there is a tombolo of beach sand and gravel connecting the main island to its N headland. On the E flank of the tombolo there is a 2-3m high gravel beach ridge above and adjacent to the present-day forming feature deposited by the sea about 125ka (Fig.11).

29. On the SW Point of Waewaetorea Island there is a remnant shore-platform about 2-3m above the present-day shore platform also interpreted here to have been cut by the sea during the Last Interglacial highstand of sea-level (Fig.11).

30. The 125ka shoreline features provide an important analogue to evaluate the effects of forecast rises in sea-level over the next 1-2 centuries on different coastal environments, in response to increased global warming from an Enhanced Greenhouse Effect.

FIGURE 11: Photos taken looking looking NNW, of a 2-3m high 125ka beach ridge (top) above the present day gravel ridge at Station OP-18 on Waewaetorea Island, and; looking NE to a 2-3m high 125ka wave-cut shore platform (bottom) above the present-day platform on the sheltered SW greywacke seacliffs of Waewaetorea Island.

31. Following the Last Interglacial climax, global sea-level fell some 130m (Fig.9), before reaching the Last Glacial climax about 22-18ka. At the climax, the shoreline in the BOI area was at the outer limit of the continental shelf near the 130m-depth contour (Fig.12).

FIGURE 12: Bathymetric Chart with the approximate position of the Last Glacial 18ka shoreline lying about 14 nautical miles offshore from Waitangi. The red arrow shows the approximate extent of the zone swept by successive regressions and transgressions of the sea about every 100ka (Chart source Eade 1970).

32. In response to the onset of global warming of 4-5°C, sea-level then rose on average at 12mm/year, between 18ka and 7.5ka, a global event described as the Postglacial Marine Transgression (PMT). During this time, the coastlines retreated everywhere around New Zealand (Gibb 1979; 2012).

33. Within the B.O.I., the PMT cut an erosional surface on the continental shelf between the 18ka and present-day shorelines (Fig.12) as it progressively drowned the river valley and its tributaries. Recent sub-bottom boomer surveys and cores have mapped the erosional surface on the seafloor as a prominent reflector of mostly shell-lag sediment overlain by postglacial mud (NIWA 2010).

34. The PMT culminated at the present sea-level about 7.5ka around New Zealand (Gibb 2012). Over the last 7.5ka, sea-level fluctuations on the order of a few decimeters have occurred (Gibb 1986; Church et al. 2008). The latter part of the PMT and the period of relative global sea-level stability during the Holocene Epoch (11.7ka) are known as the Present Interglacial.

35. During the Holocene Epoch, coastal landforms have formed at the site including relatively narrow coastal plains flanking Okahu and Waewaetorea Passages, and Entico Bay, along with all the Sand and Gravel beaches and wave-cut shore platforms fringing the seacliffs (Fig.13).

FIGURE 13: Photo looking SW from Urupukapuka Island, of a shore platform cut by the sea around Whanga-apau Islands over the last 7.5ka. The sail training ship, "*Spirit of New Zealand*" is in the background.

36. At the NW end of Entico Bay (Fig.1), a small but rare tidal estuary also formed which has become a haven for small fish. Because of its very sheltered position in the corner of the bay the entrance is never blocked by sediment transport.

4.4 Nearshore Seabed

37. Within the B.O.I., bottom substrates range from hard greywacke and basalt rock through to unconsolidated shell hash or rhodolith gravels and clean Shelly Sand, to soft Muds inshore and Fine Sandy Mud further offshore. The wide range of habitats has contributed to a relatively high diversity of marine life including some 551 Mollusc species (Morley & Hayward 1999).

38. Recent multibeam mapping of the seabed around the site, has revealed predominately soft sediments on the relatively sheltered SW side of the Islands compared to a predominantly rocky seabed on the relatively exposed N and NE side of the Islands (Kerr 2010a; NIWA 2010). There is no Mud in the predominantly Shelly Sand soft sediments (Vince Kerr & Andrew Swales, *pers. comm*., Aug. 2012).

39. Figure 14 (top) shows that NW and NE of the site; the seabed is composed predominantly of high-relief shore-connected reefs that extend out to depths of some 20-30m. Further seaward, generally low-relief offshore reefs separated by areas of Shelly Sand occur.

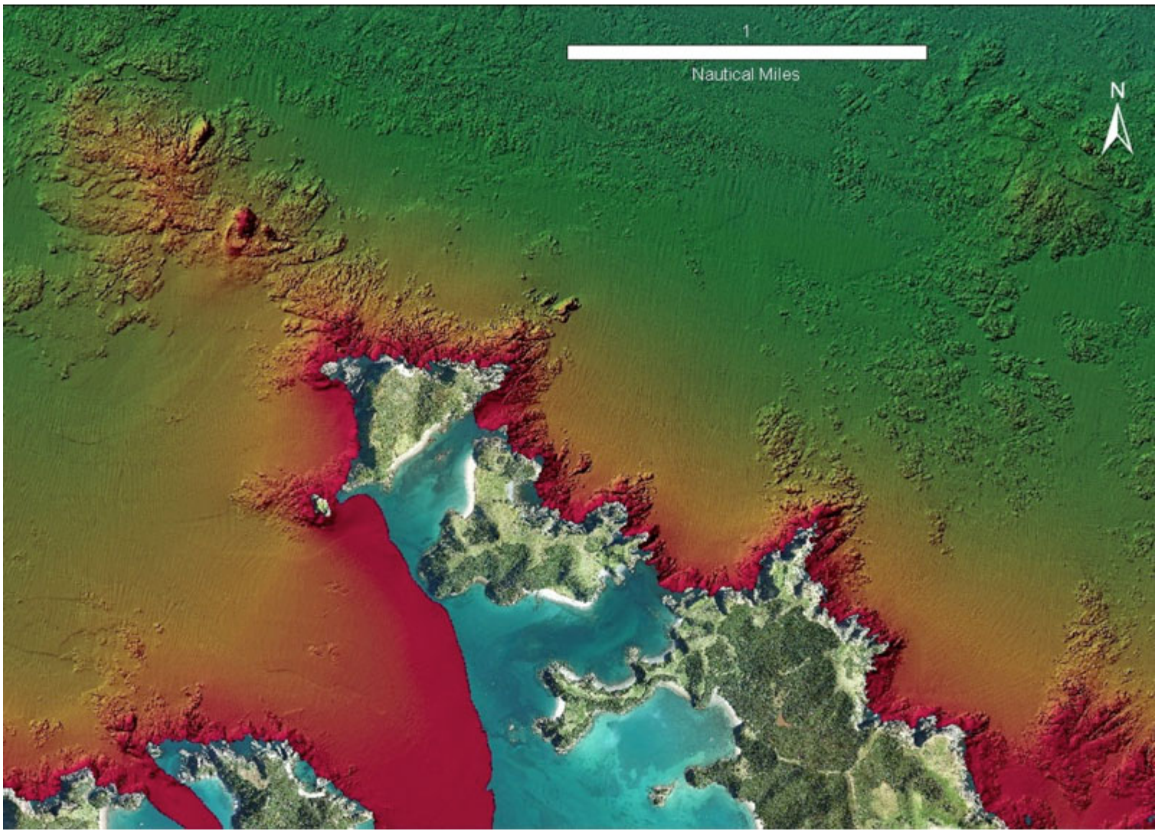
40. Figure 14 (bottom) shows that the shore-connected reefs are dissected by numerous crevices and canyons along ancient NW and NE trending faults and fractures similar to, and often coterminous with, those exposed on the coast such as the blowhole and canyon (Fig. 7) on the SE corner of Waewaetorea Island, which extend below sea-level.

41. In both Waewaetorea and Okahu Passages, the seabed is composed of patches of Gravels, Medium to Coarse Shelly Sand, Shelly Gravel, Rhodolith Gravel, Boulders and exposed greywacke reefs. The shell hash content of the coarse sediments is some 50-80% (NIWA 2010).

42. Within Entico Bay, recent Laboratory analyses reveal the seabed to be composed dominantly of Fine Shelly Sand with significant portions of Medium and Very Fine Shelly Sand (Matheson *et al.* 2010).

43. The fine sediments and sheltered nature of Entico Bay have allowed the growth of some 13ha of seagrass meadow (Fig. 15). Although aerial surveys reveal the area has fluctuated since the 1950s (John Booth, *pers. comm.* Aug 2012), there has been a small increase in extent since 1961 (Matheson *et al.* 2010).

44. Seagrass is a well-recognized provider of food and habitat for an abundance of marine organisms such as crustaceans and fish, and an important nursery for juvenile fish such as Snapper, Parore, Trevally, etc. (Matheson *et al.* 2010). In July 2012, we observed that the seagrass extended to maximum depths of 5.7mMSL.



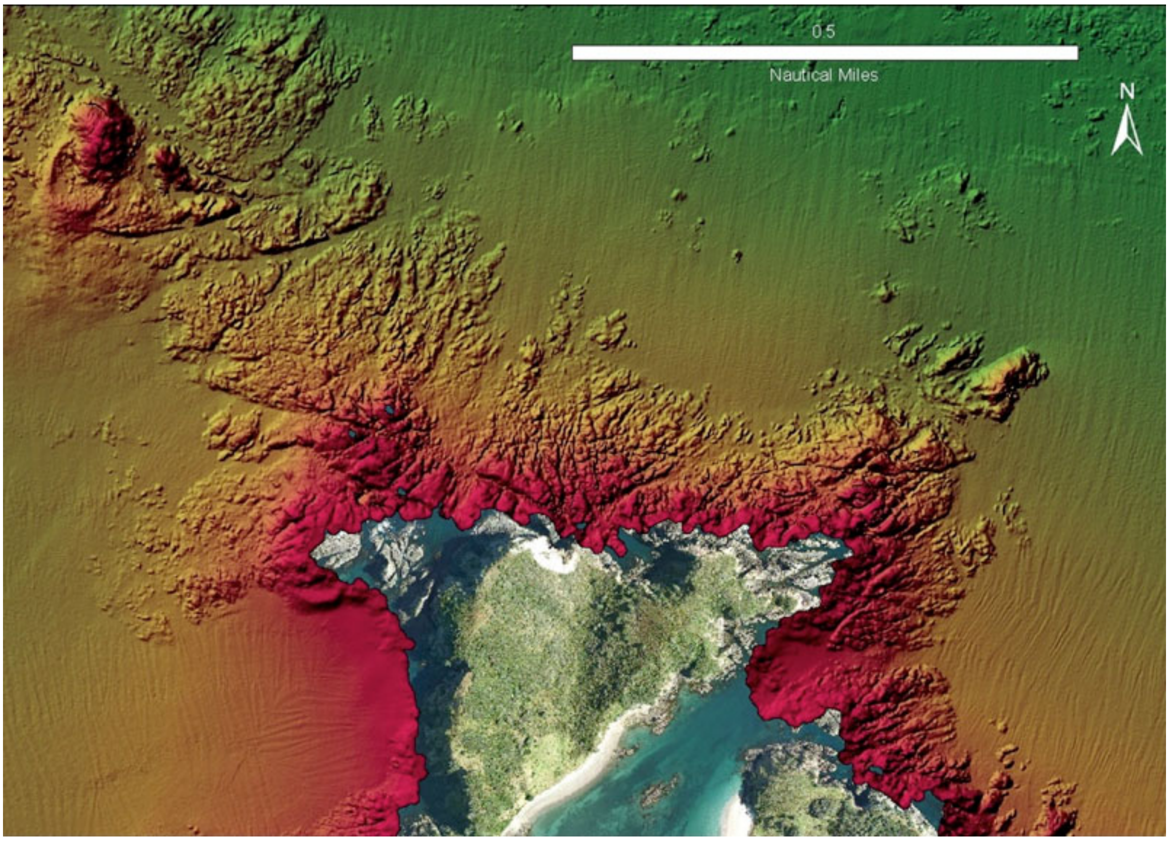


FIGURE 14: (*Top*) - Digital Terrain Model (DTM) of the seabed of the site derived by NIWA from the Oceans Survey 20/20 multibeam survey of the B.O.I.in 2009. (*Bottom*) - DTM of the seabed around Okahu Island as far as Whale Rock to the NW showing relief of shore-connected reefs (Source: NIWA 2010).

FIGURE 15: Photo taken at low tide looking SW of a dense seagrass meadow in Entico Bay growing in Fine Shelly Sand.

45. The dominant supply source area of the Fine Shelly Sand to the beach at the head of Entico Bay is the nearshore seabed out to about 10m water depths. The erosion trend of this beach suggests that the dense seagrass meadow may be inhibiting mass transport of Fine Shelly Sand to the shore by wave action.

46. At depths greater than 50m beyond the site, the seabed is composed of Fine Sandy Mud with the percent of Fine Sand increasing with depth. The shelf sediments have a carbonate content of 30-50% (NIWA 2010).

47. The dissected shore-connected and offshore reefs, Gravel and Shelly Sand sediments of the nearshore seabed, form a diverse range of interconnected habitats at the site for a wide range of marine flora and fauna.

4.5 Beaches

48. Physical properties of the beaches are listed in Table 2-A (Appendix A), for 20 Stations sampled from 15 beaches at the site (Fig.2), plus whether each beach was observed to be either retreating from erosion, advancing from accretion, or in a state of dynamic equilibrium.

49. Table 2-A shows that the beaches are mostly mixtures of Sand and Gravel, with dominant size classes ranging from Fine Shelly Sand (0.125-0.25mm diam.) to greywacke Cobbles (64-256mm diam.)(Fig 16).

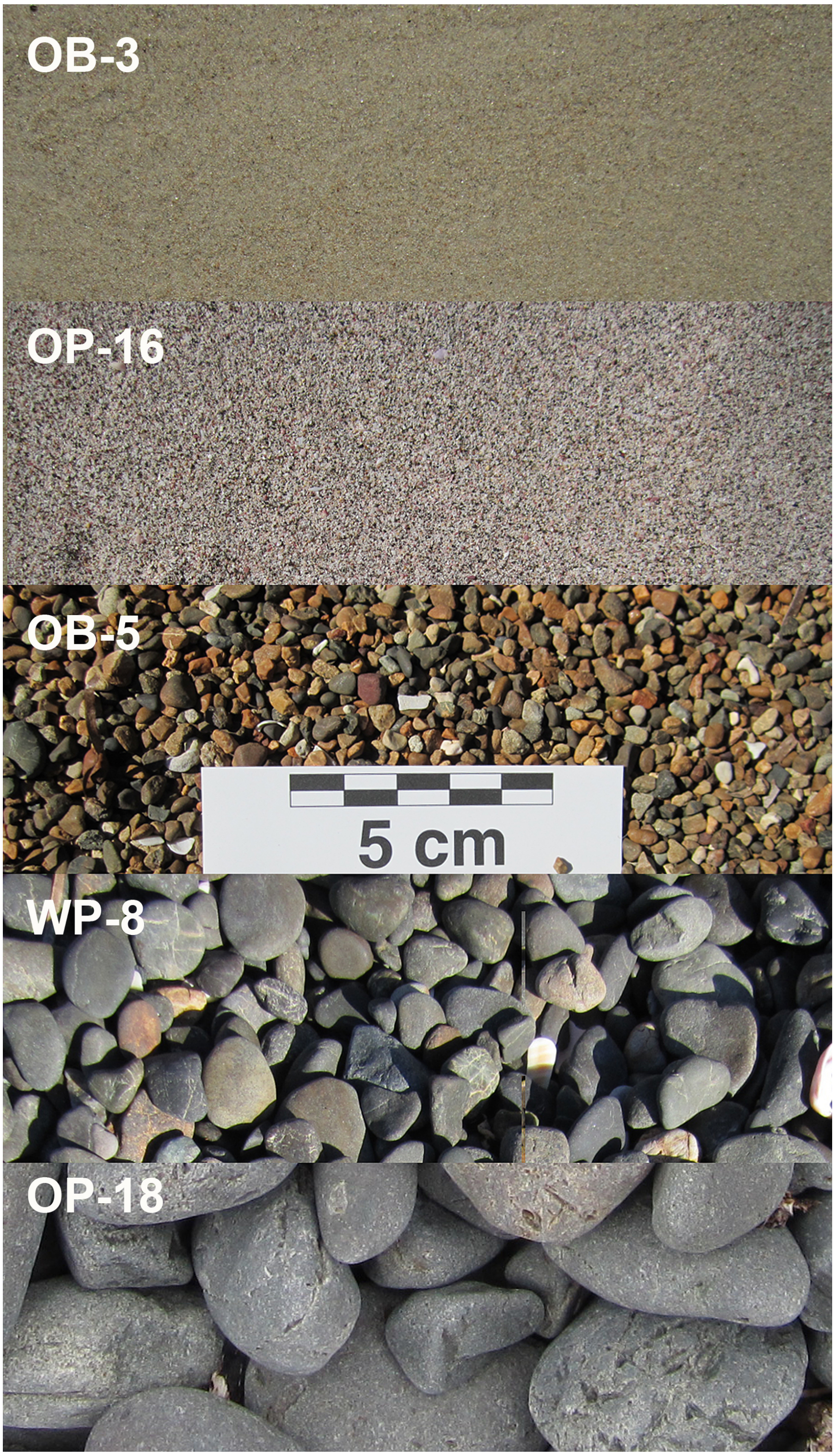


FIGURE 16: Photos of beach sediment grain sizes. Top to bottom; Fine Shelly Sand in Entico Bay; Medium Shelly Sand in Okahu Passage; weathered greywacke and chert Pebbles in Entico Bay; greywacke and chert Pebbles in Waewaetorea Passage, and greywacke Cobbles on the NE facing coast of Waewaetorea Island.

50. The dominant supply sources for the Sand beaches are firstly, the nearshore seabed SW of the site which supplies whole and broken shells to form the Shelly Sand, and secondly, the adjacent eroding seacliffs, shore-platforms and nearshore reefs that supply greywacke-derived Sand and Gravel.

51. Because of the relative erosion resistance of the hard to very hard greywacke, supply rates of gravel from these sources are proportionately extremely low. It is possible that some of the Gravel beaches include reworked gravels deposited 125ka ago.

52. Shell material is transported to the beaches by mass transport driven by long low swells from the N-NE sector that have been refracted almost 360 degrees into Entico Bay and both Okahu and Waewaetorea Passages to approach the shore from SW.

53. Once ashore, greywacke-derived sediments are mostly driven alongshore by breaking waves until trapped in the pocket beaches (Fig.17), a process known as longshore transport, during which time the gravels are rounded by abrasion.

FIGURE 17: Photo looking SW of a small Pebble pocket beach in Waewaetorea Passage at Station WP-12. The adjacent wave-cut shore platform that has supplied some of the gravel over the last 7.5ka lies in the background. The ridge crest marks maximum storm-wave runup.

54. In general, grain sizes are related to relative exposure to wave energy with the finest sediment occurring in the most sheltered areas such as Entico Bay (Fig.18), and the coarsest sediment in the more exposed areas such as the NE coast of Waewaetorea Island (Fig.10) and Passage (WP-9) (Table 2-A, Appendix A).

FIGURE 18: Photo looking NW into Entico Bay showing the Fine Shelly Sand beach overlain by rafts of locally derived Pebbles. Note the patchy seagrass meadow seaward of the beach.

55. The most beautiful, most widely used beach by the boating public is located on the sheltered E shore of Okahu Passage (Fig.19). The beach, which is backed by an incipient foredune, is composed dominantly of Medium Shelly Sand with rafts of well-rounded greywacke and chert Pebbles with whole dead shell along the lower profile where it is ground up by wave action.

56. Of the 20 Stations in Table 2-A (Appendix A), 8 reveal a dominant trend of shoreline retreat from erosion with the remaining 12 exhibiting a state of dynamic equilibrium. None of the beaches observed were advancing from accretion, indicating that sediment supply rates do not exceed erosion rates at the site.

FIGURE 19: Photo looking N of a Medium Shelly Sand beach in Okahu Passage (OP-16 & OP-17).

57. There are many interacting factors that cause beach erosion but the most common causes are; a diminished sediment supply from both the adjacent seabed and rocky shores, sea-level rise, and increased wave activity (Gibb 1979).

58. Compounding this effect, excessive wake from launches and tourist vessels, particularly in Okahu and Waewaetorea Passages, were observed to be enhancing erosion, particularly of the sandy beaches where sand is lost offshore.

59. The beaches in dynamic equilibrium are mostly composed of Gravel or mixtures of Sand and Gravel thereof. The rounded to well rounded Gravels are very hard and resistant to erosion forces such as wave abrasion, being driven mostly upslope during wave attack (see Fig. 17).

4.6 Sediment Accumulation Rates

60. During postglacial times sediment accumulation rates (SAR's) within the inner B.O.I. averaged about 23,000±9,200 t/year (tonnes per year). During the last 100 years, there has been an order of magnitude increase to 509,000±210,000 t/year (NIWA 2010).

61. The significant increase in SAR's over the past century is due to increased catchment erosion following large-scale deforestation during early Maori and

European occupation. The main B.O.I. inlet catchments responsible are the Waikare, Kawakawa, Waitangi, Kerikeri and Te Puna (NIWA 2010).

62. Sediment transport modeling shows that the bulk of sediments under both mean flow and flood conditions, settle close to their respective sources in sheltered bays and inlets such as the Kawakawa and Waitangi. Most sediment is discharged during synoptic storm events (NIWA 2010).

63. The single largest sediment sink is Te Rawhiti Inlet where some 30% of annual sediment deposition in the B.O.I. takes place. The major source is thought to be suspended Muds from the Waitangi and Kawakawa Rivers and Waikare Inlet, bypassing Tapeka Point E into Te Rawhiti Inlet during strong W winds coupled with ebb tide currents (NIWA 2010).

64. Within the B.O.I. inlets, SAR's of mostly Muds have ranged from about 1-5mm/year, with rates of 3.2mm/year in Te Rawhiti Inlet (NIWA 2010). In Kerikeri Inlet, we have measured differential rates up to 10-20mm/year since Hereward Pickmere first surveyed the Inlet in the 1940s.

65. The lack of Muds in the seabed sediments of the site indicates that the suspended sediments from terrestrial sources, do not reach the site. If they did, then Mud would be found in the Entico Bay sediments, an area of weak currents dominated by Fine Shelly Sand.

66. NW and W of Okahu Island, surveys show some 0-5m of Shelly Sand overlies greywacke bedrock of which postglacial deposits of Shelly Sand are 1-2m thick (NIWA 2010), indicating extremely low sedimentation rates over the last 7.5ka of the order of 0.1-0.3mm/year (millimetres per year) from predominantly broken shell.

67. The present-day width of the beaches plus adjacent coastal plains is of the order of 20-60m suggesting extremely low net accretion rates of 4-8mm/ year over the last 7.5ka. The fringing shore-platforms are of the order of 5-20m wide suggesting net back cutting rates into the hard greywacke seacliffs of about 0.7-3mm/year.

68. In the context of erosion-accretion rates around the 18,000km-long coastlines of New Zealand (Gibb 1978), which are usually of the order of metres per year, the extremely low rates of beach accretion and seabed deposition make the site relatively stable but vulnerable to a widespread reversal to erosion from forces such as increasing sea-levels coupled with a reduction in supply of dead shell.

5 PHYSICAL OCEANOGRAPHY

69. North of New Zealand, warm subtropical water within the Tasman Front travels from Australia to North Cape where most passes along E Northland as the East Auckland Current, spawning giant eddies that slowly stir waters to depths of 2km (Carter 2001).

70. Figure 20 shows the directions of flow of the dominant ocean currents affecting the B.O.I. Offshore, the East Auckland Current sets SE along the coast reaching maximum velocities in knots (kn) of 1.0-1.5 kn (UKHO 2004). Where it meets the Brett Peninsula, part of the SE flow is deflected NW as a counter current toward the Cavalli Islands.

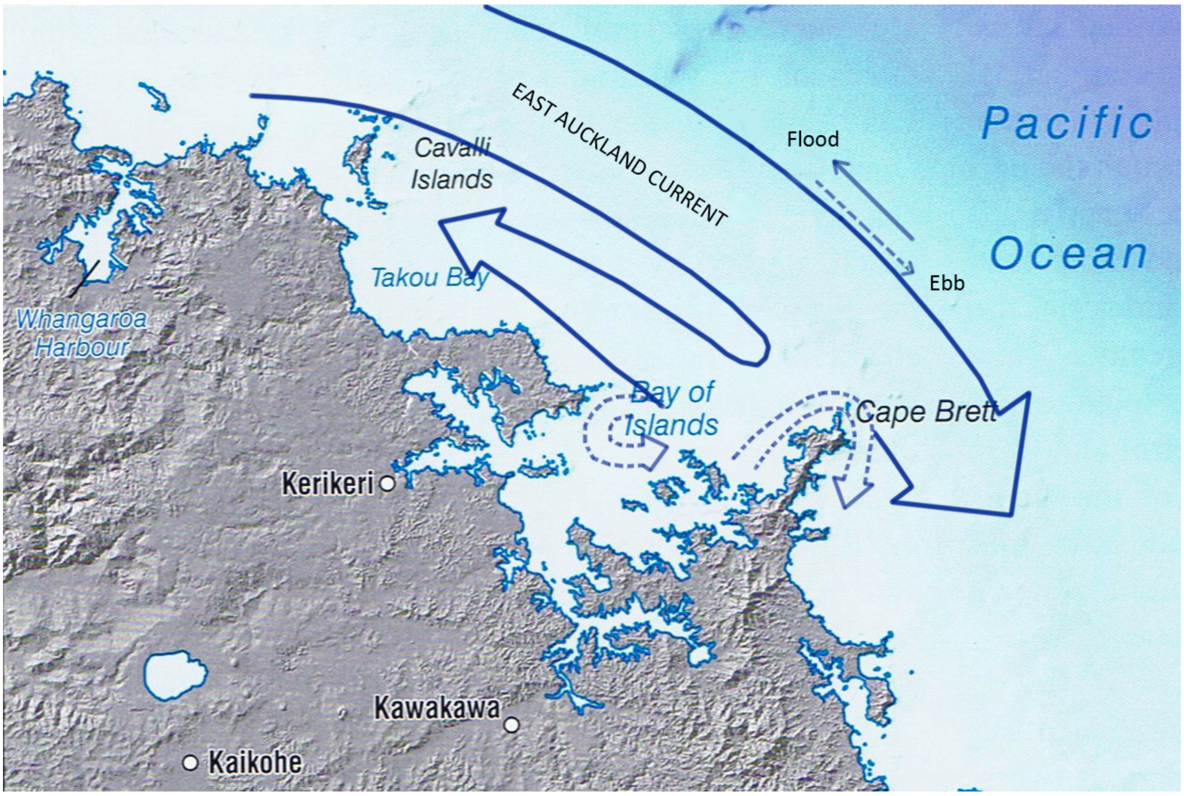


FIGURE 20: Shaded topographic relief model of the B.O.I. area between Whangaroa and Whangaruru Harbours showing the inferred pattern of ocean surface currents and ebb & flood tide flow (Base map adapted from Edbrooke & Brook 2009, fig.3a).

71. Drift card measurements by Booth (1974) over a 20-month period from 1970-1971, suggested that the NW flowing current induces an anticlockwise movement of at least surface water within the B.O.I., the flow spilling S around Cape Brett (Fig.20).

72. As the rising tide sets NW and the falling tide SE outside the B.O.I. (Fig.20), the tide may either enhance or reduce velocities of the East Auckland Current. During Spring tides, both ebb and flood tide flows may reach 0.5 and 0.6 kn, respectively, in this area (RNZN 1993).

73. Between 2008 and 2012, we recorded maximum summer sea-surface temperatures (SST) of 22±1.0°C in February and minimum winter SST's of 14±1.0°C in July, at the site.

74. Booth (1974), recorded maximum mean SST's of 14.8° C and 23.1° C for July and February 1970-1971, respectively, noting an annual range of 6.5°C near Waewaetorea Island.

75. No direct measurements of the tides and currents are available for the site. Notwithstanding, based on tide stations elsewhere in the B.O.I., Neap tide ranges are likely to be of the order of 1.2-1.4m and Spring tide ranges, 1.8-2.1m. There are 2 springs and 2 neaps per lunar month (LINZ 2010).

76. Within the B.O.I. tides produce the strongest currents assisted at times by surface wind driven currents especially during SW and NE gales, the prevailing wind directions in Northland. The weakest current influence within the B.O.I. is from the East Auckland Current (NIWA 2010).

77. In 1990-1991,the RNZN recorded maximum tidal velocities in the throat of Albert Channel of 0.4-0.5kn (0.21-0.26m/sec) and 0.3-0.6kn (0.15-0.31m/sec) during spring flood and ebb tides respectively, with the tide flooding SSE and ebbing NNW (LINZ 2007).

78. In the centre of Te Rawhiti Inlet, very low maximum ebb and spring tide velocities of 0.1kn were recorded (LINZ 2007), which partly explains the relatively high rates of settlement of Muds in this area.

79. In both Okahu and Waewaetorea Passages, the rising tide floods SW and the falling tide ebbs NE. Although they dominate current flow, tidal velocities are not known but appear to be generally weaker than those recorded in Albert Channel.

80. Within Entico Bay, tidal currents appear to be very weak to non-existent and surface wind driven currents appear to dominate. Notwithstanding, the pattern and strength of tidal currents around the site must contribute to the lack of Muds and relatively clean Shelly Sand and reefs.

81. In general, the nearshore bottom tidal currents at the site appear to be below the threshold required to transport Sand and Gravel on the seabed. Medium to Fine Sand requires a critical bottom current velocity of about 0.2m/sec (O.4kn) and Pebbles about 1.0m/sec (2.0kn) (Hjulstrom 1939).

82. Salinity is close, if not equal to the standard ocean water strength of 35 ppt (parts per thousand). In January 2010, NIWA (2010) recorded a value of 35.4 ppt, which compares favourably with values of 35.1 ppt in Spring and 35.2 ppt in Summer 2009, recorded by Matheson et al. (2010).

83. In 1970-1971, Booth, recorded salinities near Waewaetorea Island of 35.525ppt in May 1971 and 35.279ppt in June 1971. Closer inshore, freshwater runoff resulted in a freshwater surface layer forming, reducing salinities to about 27ppt at Slains Castle and Brampton Reef (Booth 1974).

84. At the site, water clarity is consistently exceptional for the E B.O.I. (Fig.21). In July 2012, we observed the seabed at the SW entrance to Okahu Passage down to a maximum depth of 12.5m. In February 1971, Booth (1974) recorded a maximum secchi disc visibility value of 15.5m compared to a value of 12.5m in June 1971.

FIGURE 21: Vertical aerial photo taken in 2009 at mid to low tide, showing the clarity of water in Okahu Channel with visibility down to about 10m. Note the tombolo flanked by Sand (W) and Gravel (E) beaches, on the N end of Waewaetorea Island (Source: OS 20/20 NIWA 2010).

85. The lack of Mud in the bottom sediments at the site coupled with relatively high year-round salinity and water clarity values indicates that suspended sediment derived from the mainland catchments of Waikare, Kawakawa, Waitangi, Kerikeri, and Te Puna does not appear to reach and be deposited at the site making it unique in the context of the B.O.I.

86. The most likely explanation for this is that the pattern of ocean and tidal currents around the site keeps it permanently free of suspended mud reaching and being deposited in this area. Mud from nearby catchments appears to be trapped and deposited mostly in the B.O.I. inlets like Te Rawhiti.

87. No direct measurements of the B.O.I. wave climate are available for the site. Notwithstanding, storm wave runup (SWRU) can be estimated from either flotsam lines or the height of the vegetation line above High Water on both the relatively sheltered beaches and exposed seacliffs.

88. On the open-exposed coasts, maximum SWRU elevations of the order of 6-8m are likely to occur during severe NE wave storms compared to maximum runup elevations of 1-1.5m on the relatively sheltered shores.

89. It is during severe wave storms that maximum beach erosion occurs, forming an erosion scarp in the vegetated bank above the beach. Unless the beach is resilient enough to recover following the storm, a long-term trend of shoreline retreat enhanced by rising sea-level results, such as in Entico Bay.

90. In tectonically stable Pounawea Inlet, Otago Region, Gehrels *et al.* (2008) determined a very slow rising sea-level at 0.3± 0.3mm/yr from AD 1500-1900, increasing to 2.8± 0.5mm/yr during the 20th century. Globally, sea-level has risen about 185mm at 1.7±0.2mm/year from 1900-2009, with satellite altimetry data indicating acceleration to 3.2±0.4mm/year since 1993 (Church & White 2011).

91. Even though a rise of 0.185m is relatively small it would still contribute to an erosion trend in areas of extremely low accretion rates such as those at the site as the beach profile adjusts landward.

92. Salinity values coupled with exceptional water clarity and lack of Muds in bottom sediments, suggest the site is directly influenced by subtropical oceanic water from the East Auckland Current for most, if not all the year.

PART III - MARINE RESERVE DETERMINATION

6 PROTECTION OF ATTRIBUTES

93. In terms of the Marine Reserves Act 1971 (quotes italicized), this study has revealed that the physical attributes of the "*Foreshore, Sea, and Seabed*" of the site, more than satisfy the statutory requirements of the Act, justifying their lasting protection in the national interest, as a Marine Reserve.

94. The predominantly greywacke basement rocks of the site are "*typical*", or representative, of the B.O.I. and most of Northland's E coast. Within the greywacke, the outcrops of rare white marble at Te Hoanga Point and red-brown mudstone at Okahu Island containing lumps of pink limestone and coral are "*unique*".

95. The two remnant Last Interglacial shorelines on Waewaetorea Island are of local, national, and international scientific importance and are "*unique…natural features*", as analogues for climate change effects in the context of New Zealand and SW Pacific.

96. The diversity of coastal landforms comprising the “*Foreshore*” of the site, make it “*typical’* of the entire B.O.I. and Northland coasts, with many “*beautiful*” and “*unique*”…natural features”, such as canyons, sea-caves, arches, stacks, the unique Waewaetorea blowhole, clean white sand beaches, bold seacliffs, and fringing wave-cut shore platforms.

97. Because of its clarity, regular flushing by the tides, exposure to both open-coast and sheltered wave climates, and being beyond the effects of terrestrial sedimentation whilst so close to the mainland (3-5km), the “*Sea*” at the site is; “*unique, ... beautiful, ... of such distinctive quality*.” As a significant habitat of marine life this element alone warrants protection.

98. The relative exposure of the site to relatively heavy seas on the open-exposed NE facing coasts compared to relatively small wind waves on the sheltered SW facing coasts, over such small distances, is a “*unique*” feature contributing to the diverse range of habitats.

99. The small, rare estuary at the NW end of Entico Bay is another “unique” coastal landform. This feature appears to be permanently open to tidal flows and is the only estuary frequently flushed by the tides found on any of the islands of the E B.O.I.

100. The 13ha seagrass meadow in Entico Bay is “*unique*,” as it is one of the few seagrass beds in the B.O.I. that is not being destroyed by terrestrial pollution and Mud deposition. It is an important nursery for marine life and appears to be growing in area.

101. SW of the site, the seabed is composed of mobile Shelly Sand out to about 25m depths, on which the Sand beaches depend for their long-term stability. The soft, shell rich sediments provide a “*typical*” shore-connected marine habitat, which also requires recognition and protection.

102. Underwater canyons, caves and crevices often coterminous with similar features on the foreshore, dissect shore-connected greywacke reefs around the site creating “*unique*” habitats for marine life.

103. These natural landforms both above and below present sea-level all contribute to a significant range of interconnected marine habitats, that clearly warrant protection under the Act, as physical components of a Marine Reserve.

6.1 Design of Proposed Marine Reserve

104. For practical navigation reasons, sea areas to be protected as Marine Reserves are delineated by boundaries on RNZN Charts. For the reserve to be effectively managed, the public must be able to identify boundaries from both the sea and coast so that they know whether they are in or out of a Marine Reserve.

105. For this study, the strategies and guidelines of Kerr (2010b) were adopted for the design of the proposed Marine Reserve, along with site-specific practical navigation criteria.

106. Following consultation with Vince Kerr (*pers.comm*. Aug.2012), the initial design was modified to principally allow for a greater buffer of Shelly Sand around shore-connected reefs and full inclusion of the diverse range of coastal-marine habitats.

107. The design accommodates the physical attributes identified in this study with special reference to the diverse coastal-marine habitats and clarity of the sea. Marine life was not considered as although important, is beyond the scope of this study.

108. The design includes 5 potential boundary lines (Fig. 22), with measurements listed in Tables 1 & 2 for the site. The proposed sea area for protection is 835ha, equating to 2.06% of the B.O.I. (Vince Kerr, *pers. comm.* Aug. 2012). In the context of the B.O.I., we regard this as an absolute minimum.

TABLE 1: Potential Marine Reserve boundary lines (1-5) plotted on Navy Chart BOI 4; Scale 1:25,000, Oct 2003 (Fig.22). All measurements scaled directly from BOI 4. Lengths in sea miles (M); Compass bearings both clockwise and anticlockwise along Lines given in both True and Magnetic degrees where 19^0 has been subtracted from True bearings to correct for Magnetic Variation up to the year 2012.

LINE	LOCALITY	LENGTH (M)	BEARINGS	
			True °	Magnetic °
1	Paradise Bay North	0.62	254/074	235/055
2	Motukiekie-Urupukapuka Channel	1.60	313/133	294/114
3	Red Head-Whale Rock	1.20	035/215	016/196
4	50m depth contour	1.70	110/290	091/271
5	Te Hoanga Point	0.70	032/212	013/19

TABLE 2: Longitude and Latitude positions of all change points of the 5 boundary lines listed in Table 1, including start and finish points, for the potential Marine Reserve (Fig.20). All positions were scaled from BOI 4 at 1:25,000 Scales and are reliable to 2 decimal places of a minute.

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LINES	LOCALITY	LAT. S	LONG. E
Start	Paradise Bay Beach N	35° 13.00’	174° 13.76’
1/2	Motukiekie Channel	35° 13.17’	174° 13.04’
2/3	Motungarara Island W	35° 12.30’	174° 11.625’
3/4	Okahu Island N	35° 11.08’	174° 12.46’
4/5	Urupukapuka Island N	35° 11.67’	174° 14.40’
Finish	Te Hoanga Point	35° 12.26’	174° 13.96’

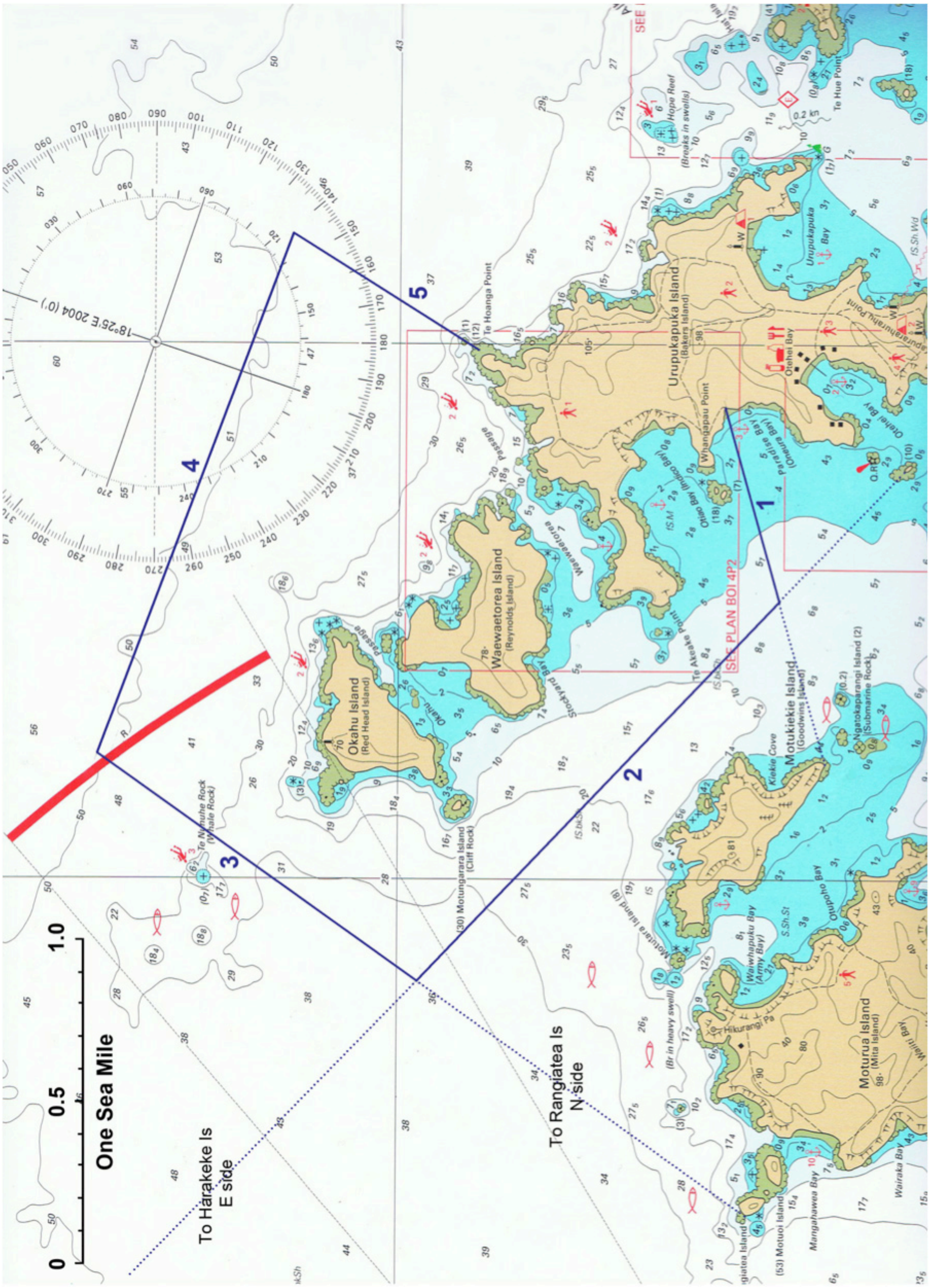

FIGURE 22: Chart showing potential Marine Reserve boundary lines (1-5) around the site, marked by the solid blue line. The vector lines and red band by Line 3 represent the limits of the Fraser Rock Light at Tapeka Point which flashes White and Red every 6 seconds (Source RNZN 2003).

109. Line 1 (Fig.23), is a transit bearing 254^0 True (Table 1), from the easily recognizable NW end of the white sand strip of Paradise Bay beach, to intersect the SE tip of Motukiekie Island (Fig.23).

FIGURE 23: Photo looking SW at the N end of Paradise Bay beach along a potential Marine Reserve boundary (Line 1), marked by the intersect of the foreground figure with the yacht "*Sea Hawk*" mid-ground, and the SE tip of Motukiekie Island just visible in the background.

110. Line 2 (Fig.22), is a transit bearing 313^0 True (Table 1), between a 10m-high rock in Poroporo Channel and the seaward edge of Harakeke Island off Cape Wiwiki, both easily recognizable landmarks from the sea.

111. Line 1 intersects Line 2 about 0.62M (Table 1) from Paradise Bay beach, extending 1.6M NW to the start of Line 3, capturing a representative section of the Shelly Sand habitats, the relatively sheltered shore-connected reefs W of Motungarara Island and Te Akeake Point, the SW entrances to Okahu and Waewaetorea Channels, and the seagrass meadow in Entico Bay (Fig. 22).

112. Line 3 (Fig.22), extends NNE for 1.2M along a bearing of 035°True (Table 1), from the N side of Rangiatea Island to intersect the 50m-depth contour NE of Whale Rock (Fig.22), capturing the inshore section of the relatively exposed shore-connected Whale Rock reef plus gravel and dissected reef habitats around the rocky shores of Okahu Island.

FIGURE 24: Photos of Te Hoanga Point (Line 5), a natural, easily recognizable potential Marine Reserve boundary marker, viewed from the land (top) looking NE, and the sea (bottom) looking SE towards Te Rawhiti.

113. Line 4 (Fig.22), extends along a bearing of 110°True (Table 1), ESE along the approximate 50m-depth contour for 1.7M, capturing a representative section of shell hash beds and both the dissected shore-connected and deep reef habitats offshore from the relatively exposed NE facing coasts of Okahu, Waewaetorea, and Urupukapuka Islands.

114. Line 5 extends along a bearing of 032°True (Table 1), to intersect Line 4 0.7M NE of Te Hoanga Point (Fig.22), which is a prominent landmark easily visible from both sea and land (Fig.24).

115. Both Lines 4 & 5 capture the NE approaches to Waewaetorea and Okahu Passages, an area containing a wide range of marine habitats, ranging from dissected shore-connected and offshore reefs to areas of Shelly Sand.

116. Navigation beacons can easily be erected on land to mark the Te Hoanga Point (Line 5) and Paradise Bay (Line 1) boundaries (Fig.22). Where Line 2 intersects Lines 1 and 3 on the SW side of the site, permanent secured and marked navigation buoys should mark the change points (Table 2).

117. Where Line 4 intersects Lines 3 and 5, it would not be cost-effective to mark the points of intersection with buoys owing to greater risk of loss during storms and 50m water depths. Use of a depth finder plus visuals and compass bearings are probably the most practical navigation techniques to determine the seaward limits of a Marine Reserve in this exposed area.

7 FURTHER WORK

118. To establish a Marine Reserve under the Marine Reserves Act 1971, it is essential for any Applicant to provide robust scientific evidence on the geology, physical oceanography, and marine biology of a candidate site.

119. In this study, reasonably comprehensive scientific evidence is provided on the geology and physical oceanography of the candidate site that is based on the combination of field observations (2008-2012) and study of relevant literature. This evidence has been peer reviewed to ensure the facts are correct and that nothing has been overlooked.

120. Further work is required on the attributes of marine life living in the wide range of habitats described in this study. Especially so as both past and present scientific research has identified the presence of *"typical, unique and outstanding"* marine flora and fauna within the study area that warrant protection (e.g.Andrew Swales, NIWA, pers. comm. Aug 2012; Morley & Hayward 1999).

121. The preparation of robust scientific evidence on the marine life of the site will, along with this report, provide a compelling case to protect this outstanding site in the B.O.I. as a Marine Reserve. The additional evidence on marine life is

likely to lead to a review of the Marine Reserve design presented here and a possible increase in the proposed area above 2.06% of the sea area of the B.O.I..

8 CONCLUSIONS

122. In terms of the Act, this study finds that the physical attributes of the "*Sea, Foreshore and Seabed*", both collectively and individually; justify protection of this outstanding site as a Marine Reserve… "*for the purpose of preserving them in their natural state as the habitat of marine life for scientific study*".

123. From the many easily accessible vantage points on both Urupukapuka and Waewaetorea Islands, the "*outstanding"* seascapes in all directions are "*beautiful"* and at various times, simply breathtaking (see inside cover).

124. The diverse range of beaches and coastal landforms within such a relatively small area (835ha) is *"unique*" for both Northland and the B.O.I. The remnant Last Interglacial shorelines are of local, national and international scientific importance as analogues for the effects of climate change this century and beyond.

125. The clarity of the sea, warm summer water, good anchorages and easy access by both young and old make snorkeling and discovery of marine life at the site a joy. In both Okahu and Waewaetorea Passages, novice divers can safely reach a diverse range of marine habitats from sheltered beaches and safe anchorages.

126. Protecting this outstanding site as a Marine Reserve is in the *"national interest*" as it will create a baseline type area within the B.O.I. for scientific study, to monitor the changing state of the wider coastal-marine environment against a recovering, representative site.

127. Based on the outstanding performance of both Goat Island and the Poor Knights Islands Marine Reserves further S, a Marine Reserve established at this site will create new tourism opportunities within the B.O.I., helping to sustain and grow the Northland economy.

128. The sea area of the B.O.I. is 40,518 ha and the area of the proposed Marine Reserve is 835 ha, making it 2.06% of the B.O.I. In the context of the B.O.I., where there are currently no Marine Reserves, an area of little more than 2% proposed in this study, is regarded here as an absolute minimum.

129. Further work is required to provide robust scientific evidence on the attributes of the marine life of this outstanding site, which may lead to a review of the design of the proposed Marine Reserve presented here, possibly increasing its area to greater than 2.06% of the B.O.I.

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APPENDIX A

Table 1-A: Standard sediment grain sizes.

Table 2-A: Beach sediment properties at site.

TABLE 1-A: Standardised grain and rock size classes used in this study and by NZ marine geoscientists (e.g. Cullen 1966; Cullen & Gibb 1965), including nomenclature developed by Wentworth (1922). Where there are mixtures of size classes, the dominant class is given last e.g. Pbl.V.c.S. - Very coarse Sand is dominant and Pebbles subsidiary. Table adapted from Cullen and Gibb (1965), Folk *et al.* (1970), and Gibb (1977).

	MILLIMETRES	MICRONS	PHI	WENTWORTH SIZE CLASS AND ABBREVIATIONS			
	mm	µ	Ø				
	4096		-12.00	Boulder (-8 to -12Ø)	(Bldr.)		
	256		-8.00				
				Cobble (-6 to -8Ø)	(Cbl.)	GRAVEL	(G.)
	64		-6.00				
				Pebble (-2 to -6Ø)	(Pbl.)		
	4.00		-2.00				
				Granule	(Gran.)		
	2.00		-1.00				
				Very coarse Sand	(V.c.S.)		
	1.00	1000	0.0				
				Coarse Sand	(C.S.)		
1/2	0.50	500	1.00				
				Medium Sand	(Med.S.)	SAND	(S.)
1/4	0.25	250	2.00				
				Fine Sand	(F.S.)		
1/8	0.125	125	3.00				
				Very fine Sand	(V.f.S.)		
1/16	0.063	63	4.00				
				Coarse Silt	(C.Si.)		
1/32	0.031	31	5.00				
				Medium Silt	(Med.Si.)		
				Fine Silt	(F.Si.)	MUD	(M.)
				Very Fine Silt	(V.f.Si.)		
1/256	0.004	3.9	8.00				
				Clay	(Cy.)		

TABLE 2: Beach sediment properties at 20 Stations within Otiao Bay (OB-1 to OB-6), Waewaetorea (Otawake) Passage (WP-7 to WP-15), and Okahu Passage (OP-16 to OP-20) and general observations about long-term beach trends. Place names, where given, are from the "Pickmere Atlas of Northland's East Coast" (Watkins1974). Sediment properties were identified in the field using charts in the 2005 Field Wallet of the Geological Society of NZ plus a tape measure and digital camera. Positions were fixed by Garmin GPSmap 60Cx. Field work by Dr JG & Mrs AR Gibb, 15-16 March and 9 April 2012. Table 1 was used to describe the range of sediment size classes. Where there are mixtures of size classes, the geological convention was adopted where the dominant class is given last and the subsidiary class (>20%) first. e.g. Pbl.Med.Sh.S. (Medium Shelly Sand dominant with subsidiary Pebbles).

STATION	SAMPLING		POSITION		WENTWORTH	NOTES
	Date	NZDT	Latitude. S	Longitude. E	Size Class	
OB-1	15/03/12	1425	35^0 12.961'	174^0 13.689'	Pbl.F.Sh.S.	Fine Sand grading down profile slope to rounded to subangular Pebbles. Trend retreat. Entico Bay
OB-2	15/03/12	1445	35^0 12.887'	174^0 13.684'	Pbl.F.Sh.S.	Fine Sand grading down profile slope to rounded to subangular Pebbles. Trend retreat. Entico Bay
OB-3	15/03/12	1450	35^0 12.841'	174^0 13.658'	Pbl.F.Sh.S.	Pebbles layered over Fine Sand at about LWM. Trend retreat. Entico Bay
OB-4	15/03/12	1500	35^0 12.800'	174^0 13.610'	Pbl.F.Sh.S.	Rounded to angular Pebbles layered over profile at LWM. Dead shell at HWM. Trend retreat. Entico Bay
OB-5	15/03/12	1522	35^0 12.809'	174^0 13.523'	Pbl.	Well sorted subrounded to subangular Pebbles with minor Shell fragments. Trend retreat. Whangatokai Beach.
OB-6	15/03/12	1535	35^0 12.770'	174^0 13.455'	Pbl.V.c.Sh.S.	Pebbles become finer on lower profile. Trend retreat. Whangatokai Beach.
WP-7	15/03/12	1630	35^0 12.852'	174^0 13.085'	Med.Sh.S.	Pocket beach of Medium Shelly Sand. Trend dynamic equilibrium.
WP-8	15/03/12	1655	35^0 12.785'	174^0 13.297'	C.Sh.S.Pbl.	Dominantly Pebble beach with pockets of Coarse Shelly Sand. Trend dynamic equilibrium.
WP-9	15/03/12	1720	35^0 12.709'	174^0 13.414'	Cbl.	Steep Cobble beach with storm berm c.2.5m above average berm crest. Trend dynamic equilibrium.
WP-10	15/03/12	1730	35^0 12.679'	174^0 13.467'	C.Sh.S.	Coarse Shelly Sand beach. Trend dynamic equilibrium.
WP-11	15/03/12	1745	35^0 12.603'	174^0 13.484'	Pbl.Med.Sh.S.	Mixed Sand and Gravel beach. Trend dynamic equiplibrium.
WP-12	15/03/12	1800	35^0 12.452'	174^0 13.279'	Pbl.	Pebble pocket beach in dynamic equilibrium.
WP-13	15/03/12	1810	35^0 12.463'	174^0 13.213'	Pbl.Med.c.Sh.S.	Mixed Sand and Gravel beach in dynamic equilibrium.
WP-14	15/03/12	1825	35^0 12.532'	174^0 13.057'	Pbl.Med.Sh.S.	Mixed Sand and Gravel beach retreating from erosion. Otawake Beach.
WP-15	15/03/12	1836	35^0 12.489'	174^0 13.810'	Pbl.	Subangular Pebble beach in dynamic equilibrium. 'Stockyard Bay'.
OP-16	16/03/12	0955	35^0 12.311'	174^0 12.751'	V.c.Med.Sh.S.	Sediment grades down-profile from Medium to Very Coarse Shelly Sand. Shore-parallel megaripples increasing seaward from 0.3m to 0.8m width at closure depth which is c.1.0m below MSL. Trend retreat.
OP-17	16/03/12	1005	35^0 12.217'	174^0 12.759'	Pbl.Med.Sh.S.	Medium Shelly Sand overlies layers of broken Shell and well rounded Pebbles. The Medium Sand is transported by W-SW winds to form an incipient foredune naturally stabilised by Spinifex. Trend dynamic equilibrium.
OP-18	16/03/12	1035	35^0 12.246'	174^0 12.895'	Cbl.	Rounded to subrounded Cobble high enery beach backed by Last Interglacial Cobble Beach ridge c.2.5m above present-day berm crest. Trend dynamic equilibrium.
OP-19	16/03/12	1105	35^0 12.111'	174^0 12.604'	Sh.Pbl.	Low energy Shelly Pebbly beach in dynamic equilibrium.
OP-20	16/03/12	1115	35^0 12.138'	174^0 12.573'	V.c.Sh.S.Sh.Pbl.	Backshore of Very coarse Shelly Sand tranported by strong S-SE winds to form an incipient foredune grading seaward to a Shelly Pebbly foreshore. Trend dynamic equilibrium.

ADDENDUM

Physical attributes of NE coast of Motukiekie Island and seabed, including revised potential Marine Reserve boundaries, from investigations carried out by Coastal Management Consultancy Limited in April 2013 for Fish Forever, Bay of Island Maritime Park Incorporated Society.

FURTHER WORK APRIL 2013

Jeremy G Gibb Ph.D.

1. INTRODUCTION

1. At the request of members of the Fish Forever Working Group, CMCL have completed further work on the project since completion of the main report in October 2012. The purpose of this Addendum to CMCL Consultancy Report CR 2012/2 is to report on findings thus far.

2. GEOLOGY

2. The basement rocks of Motukiekie Island consist predominantly of massive Sandstone (greywacke), with subsidiary interbedded green and red Chert, belonging to the Waipapa Group of rocks, laid down when New Zealand was part of Gondwanaland during the Triassic to Late Jurassic Periods, around 251-145 Ma (million years ago).

3. The original horizontal beds of sediments have been deformed by powerful tectonic forces around 55-40 Ma and 26-20 Ma, resulting in localized NW trending and subordinate NE trending faults, cross joints and fractures, forming zones of weakness in the hard to very hard basement rocks.

4. For the area, the last 10 Ma have been characterized by relative tectonic stability with deep weathering of the greywacke into erodible clays. Geological evidence indicates that the Northland east coast, including the BOI, has been tectonically stable with no coseismic uplift or downdrop over at least the last 125,000 years (125ka).

2.1 Coastal Evolution

5. There are a diverse range of coastal landforms along the NE coast of Motukiekie Island ranging from Sand and Gravel pocket beaches such as Pink Beach and Kiekie Cove, to wave-cut shore platforms, stacks, small canyons, sea caves, bold seacliffs and intertidal reefs.

6. The coastal landforms have been sculptured from the basement rocks during multiple Interglacial highstands of the sea during the Pleistocene Epoch over the last 2.588 Ma, during which time the Last Interglacial sea-level maximum about 125ka and the Present Interglacial sea-level maximum over the last 7.5ka have had the greatest erosional impact.

7. Remnant shoreline features that formed during the Last Interglacial climax at 125ka are preserved today on Waewaetorea, Urupukapuka, Poroporo, Moturoa, Motuarohia, and Motukiekie Islands in the Eastern BOI. Seaward of these features, landforms formed during the Present Interglacial climax of 7.5ka duration may also be observed.

8. New 125ka landforms identified in this Addendum are shown in Figure 1a (Kiekie Cove) and Figure 2a (Whanga-apau Point). The difference in height between the 125ka and 7.5ka wave-cut shore platforms clearly indicates that sea-level in Northland was some 2.5-3m higher than present about 125ka in response to a global average surface temperature some 2^0 higher than present.

Figure 10a: Photo taken at low tide looking N, of a remnant wave-cut shore platform about 3m above the present-day platform on the N point of Kiekie Cove, Motukiekie Island.

2.2 Seabed Composition

9. Sediment textures (Table 1a) coupled with multi-beam backscatter analyses of the 2009 NIWA BOI Oceans Survey 20/20 by Vince Kerr, reveal seabed composition ranging from bedrock reef to both coarse and fine sediments, often with high percentages of broken shell.

10. The multi-beam backscatter images reveal that the boundaries between both discrete seabed sediment facies and reefs are generally abrupt and well defined. Reef is shown as irregular, very light grey texture and colour; Pebbles and Shell hash as smooth, light grey; Medium Shelly Sand as smooth, dark grey, and: Muddy Very fine Sand as smooth, very dark grey.

11. Reef is either shore-connected or offshore outcrops on the seabed as structures of generally low relief. Pebbles are likely derived in-situ from erosion of the reefs by wave action, mostly during lower sea-levels than today in response to Pleistocene Glacial-Interglacial global sea-level fluctuations.

12. Medium Shelly Sand likely overlies and post-dates the coarse sediments and has probably been derived from their progressive breakdown since the culmination of the Postglacial Marine Transgression about 7.5ka and relative stabilization of sea-level.

Figure 11a: Photos taken at low tide looking E, of a remnant wave-cut shore platform about 2.6±0.1m above the present-day platform on Whanga-apau Point, Urupukapuka Island

Table 1a: Physical sediment properties of 4 representative Stations from the seafloor of the proposed Marine Reserve site. Sediment properties were identified in Feb. 2013 by the author from charts in the 2005 Field Wallet of the Geol. Soc. of NZ. Standardised sediment size classes and abbreviations adopted are from Table 1-A, Appendix A. For mixtures of size classes, the geoscience convention was adopted where the dominant class is given last and the subsidiary class (>20%) first. e.g. M.V.F.S. (Very Fine Sand dominant with subsidiary Mud).

STATION	SAMPLED	WAYPOINT	LAT. S	LONG. E	DEPTH	WENTWORTH		NOTE
	2013				(m)	SIZE	CLASS	
B-30	12 Feb	635	35^0 12.504'	174^0 11.844'	30.77	Med. C.	Pbl.	Poorly sorted rounded to subangular Medium to Coarse Pebbles with minor amounts of whole and broken Shell and Very Fine Sand. Pebbles 5-30mm long, brown stained quartz, sandstone, argillite and red chert, locally derived from reefs and seacliffs of the Triassic to Late Jurassic Waipapa Group of rocks.
B-40	12 Feb	636	35^0 12.428’	174^0 11.916'	30.52	Med. Sh	S.	Well-sorted grey/brown Medium Shelly Sand. Shell fragments 0.25-0.5mm diam. Locally derived from Waipapa Group bedrock outcrops and modern shell beds during the Late Holocene sea-level stillstand near todays sea-level
B-60	12 Feb	638	35^0 12.096'	174^0 11.748'	35.59	Pbl.	Sh.	Moderately sorted rounded to subrounded Medium Pebbles with about 60% shell fragments and 40% greywacke Pebbles, 2-15mm diam. Sediments active and locally supplied from Waipapa Group bedrock outcrops and modern shell beds during the Late Holocene sea-level stillstand.
B-200	12 Feb	637	35^0 11.418'	174^0 13.824'	55.93	M.	V.f.S.	Very well sorted Very Fine Sand with subsidiary Mud composed of about 60% V.f.S. and 40% M.

13. Muddy Very Fine Sand in depths exceeding 50m is likely to also be derived from in-situ breakdown of the nearshore coarser sediments, as there is no firm evidence of a mechanism to transport fine terrigenous sediment to this unique site.

14. The persistent water clarity to depths up to 15m and lack of Muds in the channels and nearshore sediments of the site strongly indicates that the seabed sediments within the Waewaetorea Marine Reserve candidate site are marine in origin.

3. REVISION OF MARINE RESERVE DESIGN

15. At its 28 March 2013 meeting, the Fish Forever Working Group decided to extend the potential Marine Reserve boundary lines in Fig.22, to include a significant part of the NE facing coast of Motukiekie Island and channel to the NE.

16. As a consequence, fieldwork was undertaken on 2 April 2013 over Easter by Dean Wright on “Arethusa”, and by the author on “Sea Hawk”, to determine practical shore-based sites on Motukiekie Island to establish marker beacons for the extended potential marine reserve boundaries. In addition, CMCL recorded the physical attributes of the seacoast.

17. The revised design is shown in Figure 4a with measurements and waypoint positions recorded in Tables 2a & 3a. Also shown on Figure 4a are 4 representative sediment stations (B30 etc.), sampled by Dr. Roger Grace and Vince Kerr in February 2013. Table 3a presents physical properties of these seafloor sediments, determined by CMCL.

18. In Figure 4a, new boundary Line 1a is an extension of original Line 1 from Waypoint (b) along the same transit bearing of 2540 True, to intersect with the SE tip of Motukiekie Island (see Fig.23). No marker beacons are necessary as the landform is a natural marker clearly visible from the sea.

19. New boundary line 3a (Fig. 4a) extends diagonally from Waypoint (c) along a transit bearing of 1610 True to intersect the N facing slopes of Motukiekie Island. The area selected is a moderate grassed slope where erected beacons would be easily visible from the sea and is located slightly W of the existing solar panels on the ridge crest (Fig.3a).

Figure 12a: Photo looking S of a potential site on the N facing coast of Motukiekie Island to establish boundary markers for a Marine Reserve.

Table2a: Potential Marine Reserve boundary lines (1-5) (Fig.22), plotted on Navy Chart BOI 4; Scale 1:25,000, Oct 2003, extended to include new boundary lines (1a & 3a)(Fig. 1a). All measurements scaled directly from BOI 4. Lengths in sea miles (M); Compass bearings both clockwise and anticlockwise along Lines given in both True and Magnetic degrees where 19^0 has been subtracted from True bearings to correct for Magnetic Variation up to the year 2012.

LINE	LOCALITY	LENGTH (M)	BEARINGS	
			True °	Magnetic °
1	Paradise Bay North	0.62	254/074	235/055
2	Motukiekie-Urupukapuka Channel	1.60	313/133	294/114
3	Red Head-Whale Rock	1.20	035/215	016/196
4	50m depth contour	1.70	110/290	091/271
5	Te Hoanga Point	0.70	032/212	013/193
1a	Line 1 to Motukiekie Point Is SE	0.52	254/074	235/055
3a	Line 3a to Motukiekie Is N	0.90	341/161	322/142

Table 3a: Longitude and Latitude positions of all change points (waypoints), of the 7 boundary lines listed in Table 1, for the potential Marine Reserve (Fig. 1a). All positions were scaled from BOI 4 at 1:25,000 Scales and are reliable to 2 decimal places of a minute.

WAYPOINTS	LOCALITY	LAT. S	LONG. E
a	Paradise Bay Beach N	35° 13.00’	174° 13.76’
b	Motukiekie Channel	35° 13.17’	174° 13.04’
c	Motungarara Island W	35° 12.30’	174° 11.625’
d	Okahu Island N	35° 11.08’	174° 12.46’
e	Urupukapuka Island N	35° 11.67’	174° 14.40’
f	Te Hoanga Point	35° 12.26’	174° 13.96’
g	Motukiekie Island SE	35^0 13.13’	174^0 12.44’
h	Motukiekie Island N	35^0 12.92’	174^0 11.97’

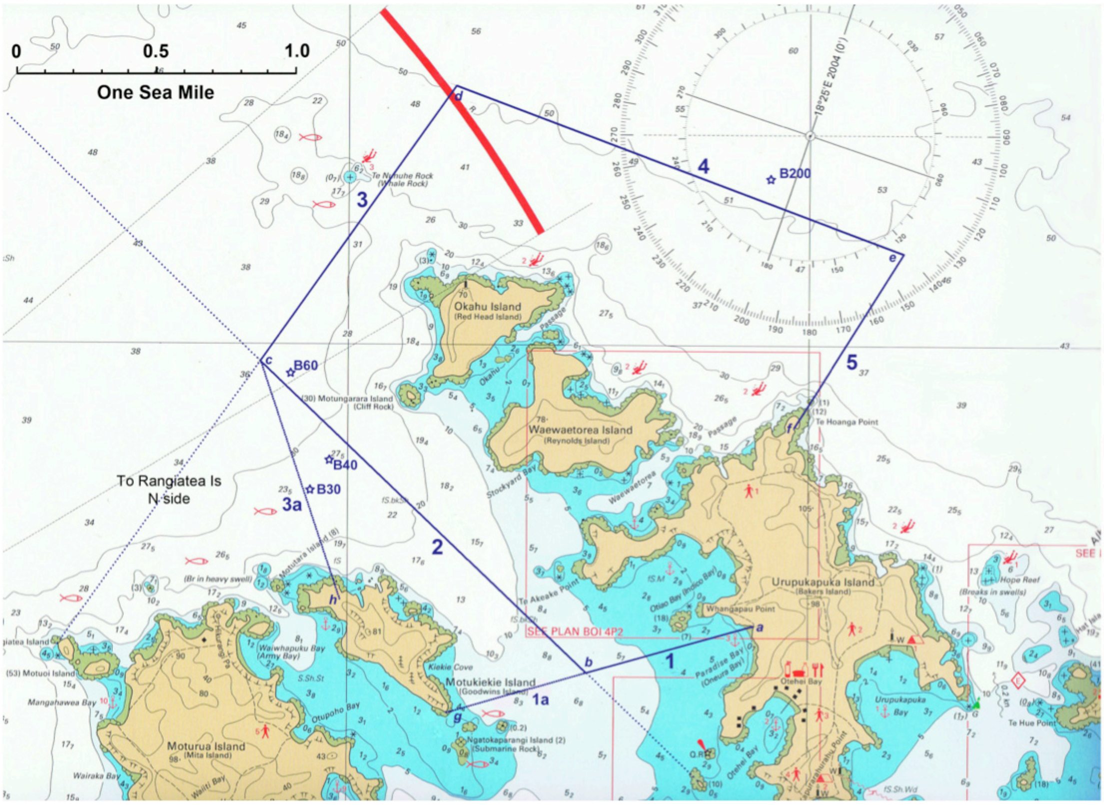

Figure 4a: Chart showing revised potential Marine Reserve boundary lines (1-5 etc.) to include the NE coast of Motukiekie Island and location of 4 sediment sampling Stations (B30, B200, etc.)