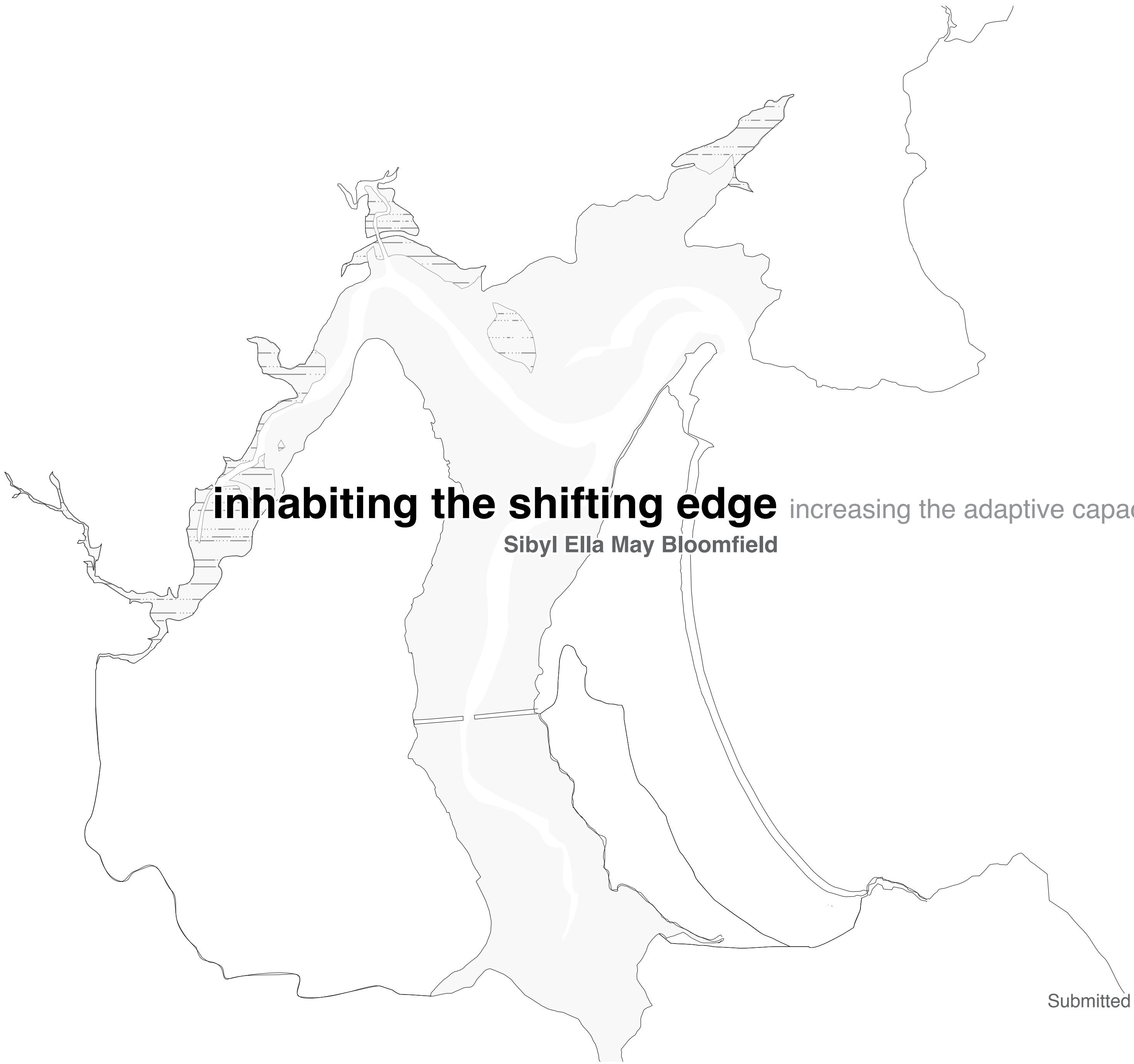

inhabiting the shifting edge

increasing the adaptive capacity of coastal sand spit communities in a changing climate

Sibyl Ella May Bloomfield

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This work is dedicated to Rob, because without his love and support it would not have been completed.

Thank you to Martin for providing guidance, critique and support. To Sophie and Shane for providing some much needed objectivity. To my wonderful family for putting up with me through this process, and to my amazing Nana Shirley for looking after me when I was in Wellington.

This masters thesis uses urban design and landscape architecture to investigate the role of open spaces in increasing the adaptive capacity of New Zealand's sand spit communities in the face of climate related change.

In order to respond to potential climate related change, the design of open spaces should acknowledge the crucial role that natural processes and ecosystems play in protecting coastal environments.

Urban design and landscape architecture have the potential to encourage interaction at the interface of the social and ecological systems within these coastal communities. The design of public open space can encourage more sensitive development patterns and increase the communities' awareness of coastal processes. These spaces can become the focus of social capital building while ensuring the environment has the capacity to absorb potential climate related changes.

This research focuses on three sand spit resort communities on the east coast of New Zealand's North Island. Through a series of design studies, a range of strategies are proposed and tested in response to the potential impacts of climate change and sea level rise. The exclusive and expensive coastal development trend is augmented to provide for all potential beach users. Diversification in both the users, and types of use, in these coastal areas will increase the social capital investment and awareness, further building the adaptive capacity of the spit system.

Abstract	iii
Contents	1
Introduction	2
Defining the Issues	4
Research objectives	10
Methodology	11
The Threats	12
Design studies:	
Map of NZ showing sites	14
Design Studies Introduction	15
Sand spit characteristics	16
Cases:	
Omaha	18
Pauanui	26
Matarangi	34
Precedent Study:	
Awaawaroa Bay Eco-Village	42
Summary of Issues	44
Design Development:	
Design Development Introduction	49
Strategy Development	50
Strategies:	
Scale of the Spit	53
Scale of the Neighbourhood	60
Inundation Testing	66
Scale of the Lot	70
Summary	73
Detailed Design at Omaha:	
Site Analysis	76
Wash-over park	86
Development cluster	92
Inundation Testing	97
Increasing Adaptive Capacity Through Design:	
Design assessment and discussion	99
Principles for increasing adaptive capacity in coastal settlements	103
Glossary of Terms	104
Bibliography	106
Image References	109

Historically human inhabitation has been focused around bodies of water. In New Zealand particularly, access to our coastlines is considered a birthright (Peart). The threat of potential sea level rise is putting increasing pressure on coastal environments. Human intervention into coastal landscapes is having a significant effect on the stability and health of our coastal environments, and their ability to respond to change (Hilton, Macauley & Henderson; McFadgen). The increasing demand for coastal property has seen economic incentives take precedence over the ecological and environmental values, and increasingly coastlines are being overtaken by large-scale developments. The need to develop a resilient and mutually beneficial relationship between these dynamic coastal zones and the human inhabitation is becoming increasingly apparent.

The current models of response to threats to coastal inhabitation are predominantly ‘retreat’ or ‘blockade’ (Beca, Carter, Hollings & Ferner). The Netherlands are the most widely recognized exponents of the ‘blockade response’ with complex systems of dykes and reclamations (Visser). More recently, with the increasingly noticeable effects of climate change and sea level rise, managed ‘retreat responses’ are becoming more common (Beca, Carter, Hollings & Ferner). Moving back to more stable ground and leaving the edge to its own devices neither addresses the history of human inhabitation of the coastal edge nor deals with the vulnerable nature of the coastal system appropriately. The discussion around the occupation of dynamic landscapes needs to move away from one of control and mitigation and toward greater symbiosis.

Climate change is increasing the intensity and frequency of coastal threats and coastal communities need to be better equipped to respond to them. Design-led approaches that acknowledge both human inhabitation and the dynamic nature of the coastal environment are imperative if we are to continue to live the ‘kiwi dream’ of beach holidays in coastal landscapes. The worldwide trend to develop sensitive and ephemeral barrier formations on our coast highlights, in particular, the development style and financial investment that is under threat from climate change and sea level rise.

Open space is critical in providing a buffer between coastal processes and coastal settlements. The recreational and natural amenity these spaces provide adds value to the community while also increasing the flexibility of the natural environment. Most importantly these open spaces, if planned and designed appropriately, can play a crucial role in absorbing coastal threats and increasing the value of the settlements.

This research focuses on the role of public open space in increasing the adaptive capacity of coastal communities. Five approaches for increasing adaptive capacity proposed by Nicholls and Klein (221) form a framework that guides the design outcomes of this project. This framework ensures the designed outcomes increase the adaptive capacity of both the natural and social systems, while acknowledging the significant role the coast plays in New Zealand’s social identity and aiming to maintain the quality of these environments.

A series of design studies of sand spit developments within New Zealand allow the identification of the trends in development and issues arising from them. These sites are representative of New Zealand’s cultural and recreational relationship with the coast. This thesis applies a common format of analysis at three sites to identify key similarities and differences. The ‘multiple design study’ method of analysis of three similar sites on the east coast of New Zealand’s North Island allows a platform for the development of design response testing to be created. Each of the studies investigates the characteristics that make these sites both attractive for coastal development and also vulnerable to the increasing impacts of climate change. This thesis analyses the style of development undertaken, and the responses to the recognised erosion and inundation threats. As well as considering potential new threats that were not accounted for and the impact that the changing climate will have on the existing threats.

Urban design and landscape architecture deal with a complex range of stakeholders, often with opposing views. This makes these disciplines appropriate lenses for addressing the tensions and challenges involved in responding to climate change impacts to coastal settlements. With design as the interface between the conflicting needs of ecological and socioeconomic systems, a more symbiotic relationship between them can be created. This research project proposes designed solutions for integrated coastal development that favours both inhabitation and the conservation of ecological coastal systems equally. This project aims to generate a wider awareness of the vulnerability of each individual component while emphasizing the potential strength of the holistic system if all components are working together.

The intention is to create a model that retro-fits existing coastal developments, enhancing both the social and cultural values of the community, and the ecological and environmental systems that characterize the coast. Generating engagement in, and awareness of, the surrounding environment is critical to understanding and responding appropriately to climate related changes. This thesis focuses on the coastal community of Omaha as a test site. It proposes a number of strategies to address the issues, identified in the design study process, over a range of scales to increase the adaptive capacity of this coastal community. Nicholls and Klein (221) provide an assessment framework and these strategies are tangible approaches to achieving the outcomes identified in the framework. The strategies deal with both the natural and built environment with the intention of creating a community that is both socially and ecologically rich, and resilient to climate related changes. Designed responses that are adaptive to the varying conditions take into account the unique ecological and environmental characteristics of site and develop compatible inhabitation solutions. Designed responses such as these need to become common practice in coastal development to ensure our continuing ability to inhabit the shifting edge.

Defining the Issues

The coast is at the very core of New Zealand identity; covering 18,200km it is the focus of the cultural, economic and social elements that help define who we are as New Zealanders (Brookes; Hayward; Peart). It was also the primary area of settlement focus in both of the colonising waves, as the waterways offered the fastest means of transit. The ability to access the coast is widely considered a democratic right and a significant contributor to wellbeing and quality of life in New Zealand (Peart).

From the end of World War 1, New Zealanders took to the coast and built simple structures from whatever materials were at hand, and often with tenuous rights to even occupy the land (Brookes; Peart). From 1960 onwards, with the appearance of planned coastal subdivisions, these light-weight and simple structures (Figures 1-3) gave way to intensive replications of the urban environment, thus changed the way New Zealanders occupied the coast. At the same time the increasing availability and affordability of cars made travel to the coast more accessible to the urban public.

The second phase began in the 1980s and that simpler life was largely upended with those simple holiday homes evolving into Mc-Mansions. The surge in the property market in the 1990s triggered an increased investment in the coast and particularly in sand spit resort developments. Large holiday homes (Figures 4-9) have become a social status symbol, highlighting over-investment in second homes that are barely inhabited throughout much of the year. These resort-style settlements have become exclusive due to increasingly prohibitive property prices.

THE DEVELOPMENT HARDENED COAST

The hardening of the coastal edge through intensive development has drastically limited the adaptive capacity of the coast, and coastal communities. Climate change and its related impacts continue to increase the tension between the built edge and the sea. Where previously the dunes played the primary mediation role between land and sea, now there are seawalls and large buildings that have little intention of giving. The line that separates land from sea does not really exist beyond the conventions of map drawing (Mathur & Da Cunha). Over time, human interventions on the perceived edge have attempted to define the line more clearly with reclamations, property boundaries, sea walls and even constructed beaches. But the 'line' is not clear. Continuing climate-related change in the coastal environment, such as sea level rise and increasing the frequency of storms, only further blurs the edges.

Increasing investment in the coastal environment, especially financial, has seen the ecological health of the coast take a backseat to maintaining and increasing fiscal value and social status of coastal properties. The issue of wind blown sand accumulating in coastal properties is an example of reverse sensitivity from residents who have little appreciation of the characteristics of coastal proximity. Property owners are becoming focused on protecting the value of their property and are less interested in soft engineering methods of coastal hazard management that have less tangible benefits but provide long term solutions. Hard engineering structures are still popular despite growing acknowledgement of their detrimental effects to the wider coastal area. This is fed by the individuals' need to protect private property from erosion and other threats, and the perceived ineffectiveness of soft engineering approaches. Identification of coastal threats impacting on properties can severely decrease their value and, in some cases, affect their insurability. Some property owners are even going so far as to challenge hazard mapping and sea level-related future inundation levels to protect the value of their investments.

Changing climate and rising sea-levels will see these boundaries disputed further. The natural environment does not work with finite lines and boundaries, and we

Fig. 1-3 Classic simple baches.

Fig. 4-9 The new, larger and more expensive, breed of 'bach'.

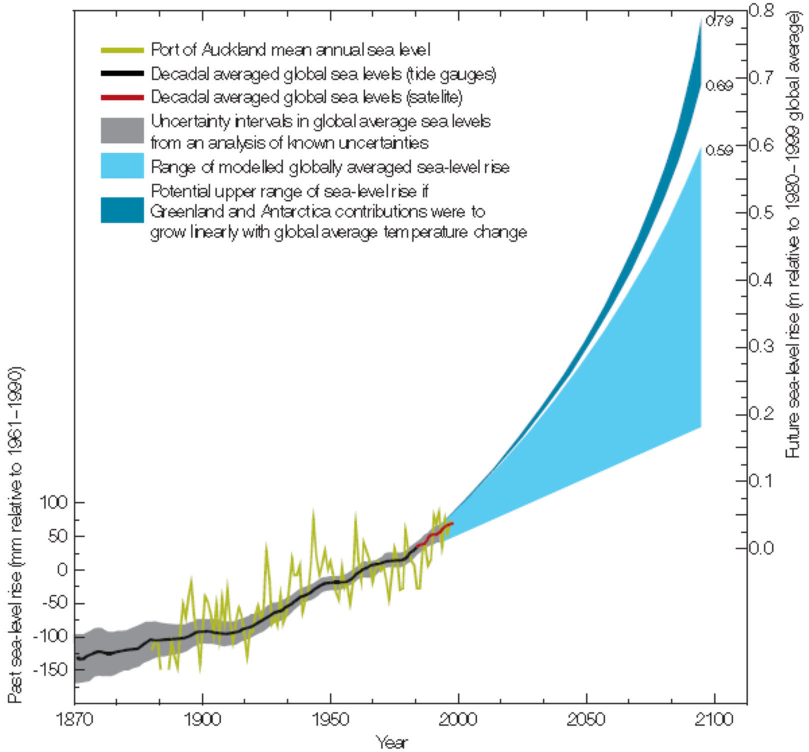


Fig. 10. Sea level rise predictions, Source: NZ Ministry for the Environment.

must begin to accept and integrate this knowledge into our coastal settlements if we wish to lessen the impacts of climate related change and increase our adaptive capacity. A natural disaster is declared when human interests and lives are affected by destructive natural events. These natural events will have an increasing impact, destructive and otherwise, as the global climate warms.

THE IMPACTS OF CLIMATE CHANGE

Climate conditions naturally fluctuate across large time-scales; glacial and interglacial over tens of thousands of years, and El Niño Southern Oscillation (ENSO), or La Niña and El Niño cycling, over 2-3 decades (Wratt & Mullan). Sand-dominated coastlines are characteristic of the current high sea levels that are central to contemporary perspectives of the ecology of coastal systems, but this phenomenon of sandy coasts is entirely ephemeral over geological and evolutionary time-scales (Graham, Dayton & Erlandson). Sea-level rise, increased storm intensity and a warming climate, due to increased C02 levels in the atmosphere, are among some of the accepted indicators of climate change. Coastal landforms and seabed formations that influence locally observed sea levels, relative to the global trend, will provide most variations in actual sea level rise. Uplift and land subsidence, due to tectonic and geomorphological processes, will also affect the extent of relative sea level rise (Nicholls & Klein; Pethwick). Research indicates that while the climate naturally warms and cools over geological timescales there are significant human induced effects evident in the past 50 years (Wratt & Mullan).

Sea Level Rise

Since the last postglacial maximum, approximately 6000 years BP (before present), the sea level fell slightly and then began the rising trend. This rising and falling cycle is part of the climatic fluctuations that happen across a range of time scales. Some short-term variations in sea levels can show rises of as much as 25cm due to La Niña periods seen in the western Pacific (Barnett). Since 1970, water temperatures in the Pacific Ocean have increased at a faster rate than previously increasing concurrent sea level rise due to thermal expansion (Mimura). The current rate of global warming, due to human influences on the environment, is happening at a significantly higher rate (Mimura; Day, Christian & Boesch; King). The increasing rise in sea level will continue to exacerbate existing issues rather than creating new ones, increasing the relevance of learning from historic experiences (Tol & Klein).

There are varying predictions for how much sea level will rise in the future. Nicholls and Klein predict a global sea level rise of 9-96cm between 1990 and 2100, with a mid range of 55cm, assuming no change to emissions (Nicholls and Klein; Klein, Nicholls and Ragoonaden). A rise of between 0.25-0.5m by 2100, which is double the rate of rise for the 20th century, is suggested by Pendleton and Thieler, who also identify other studies suggesting a rise of as much as 1.4m by 2100 (Rahmstorf in Pendleton & Thieler). Barnett identifies that the average sea level has risen 2mm per year for the last 50 years across the Pacific. King believes sea levels have risen 20cm since 1990 due to thermal expansion of oceans and melting land ice. The Intergovernmental Panel on Climate Change (IPCC) predicts an average sea level rise of 0.2m worldwide by 2050, and 0.5m by 2100.

The New Zealand government has adopted the predicted IPCC levels as a guideline for adaptation planning (Figure 10). These predictions also acknowledge the extent of rise could be as much as 0.88m above current levels. Local storm surge levels further increase the predicted rises, ENSO influenced sea levels in the Pacific Ocean, tidal fluctuations, and even the change in pressure associated with storm systems. It is interesting to note that the occurrence of the majority cyclic sea level rising and the cyclone season is concurrent with peak holiday periods during New Zealand’s summer.

Increasing Intensity of Weather Patterns
Coastal environments face a number of threats that will be influenced and increased by changes in our climate. Storms and flooding are the most visible and recognisable threats but the probability of tsunami must be acknowledged. In the case of a localised event, there would only be minutes before the wave impact reaches the shore, while distant events will take longer to travel, and with efficient notification, will allow some time to evacuate threatened areas. Sea level rise will increase these impacts.

In the near future 20 year droughts are expected to recur every 5-10 years in New Zealand, extreme rainfall will double in frequency and with it flooding. While the frequency of tropical cyclones will decrease, their intensity will increase, as will wind strengths (by 10%) with the direction tending more westerly (Bengtsson, Bennett & McKernon). The return period for devastating storm events will shorten, and areas vulnerable to their impacts will find it harder and harder to rebuild in the intervening periods. Human investment in the coastal zone will be impacted upon by these changes through the instability of land, and loss of natural resources, caused by rising sea levels and the greater impact, extending further inland, of storms. Coastal communities will need to become increasingly more resilient to the impacts of climate-related change, to ensure the related threats are mitigated, and the communities' ability to bounce back is increased.

ADAPTATION: HUMAN RESPONSES TO CLIMATE CHANGE

> Adaptation is a long-term process of learning and adjusting, a process which has historically been co-evolutionary between social and environmental systems, and where learning and adjustment has not been sufficient or sufficiently rapid, systems have failed (Barnett 980).

Prehistorically, the use of temporary settlements in changing environments allowed for resource exploitation without a great extent of investment and risk (Nicholson & Cane). Migration has been a human adaptive strategy in the face of changes in the environment due to climate, or catastrophic events that changed the availability of resources or the ability to access them (McLeman & Smit). As the climate settled and the knowledge and technological ability to protect against the advance of the sea developed, investment in the coastal environment has become more prevalent. As confidence in protective structures developed, human responses to changes or instability in the coastal environment began to stabilise, often using hard engineering structures. By limiting the natural responses, the hard engineering protective structures are increasing the tensions between natural process and the made-made environment (Hansom; Klein, Nicholls & Ragoonaden; Charlier & Chaineux; Tol & Klein; Turner, Subak & Adger; Helvarg; Nicholls & Klein).

The importance of inter-system (socioeconomic and ecological) cooperation and support highlights the ability humans have to both anticipate and respond to change (Tol & Klein). We must acknowledge that building in hazardous areas will become increasingly economically prohibitive, and this will ensure that, regardless of their understanding of natural processes, people become aware of the constraints (MacDonald & Thom).

The International Panel on Climate Change
International Panel on Climate Change and Adaptation Intergovernmental Panel on Climate Change (IPCC) was set up to provide the governments of the world with "a clear scientific view of what is happening to the world's climate", and to review and provide recommendations with respect to the science of climate change, the social and economic impact of climate change, and possible response strategies (IPCC). This research led to the development of three basic adaptation strategies:

1. **Protect:** to reduce the risk of an event by decreasing the probability of its occurrence
2. **Accommodate:** to increase society's ability to cope with the effects of the event
3. **Retreat:** to reduce the risk of the event by limiting its potential effects. (IPCC CZMS)

The New Zealand government and others worldwide have adopted these three general adaptation strategies as guiding principles for coastal management. The Resource Management Act (RMA) 2004 and the New Zealand's Coastal Policy Statement (NZCPS) 2010 are New Zealand's coastal management guiding documents. These IPCC principles have been integrated into the NZCPS as: protection of coastal lines; accommodation of coastline hazards; or avoidance of coastal impacts; and managed retreat of coastal settlement. Protection is the most visible response and is therefore most popular with those on the front line. But the direct proximity also blurs the awareness of the downstream impacts created by protecting certain areas with hard structures. The solving of erosion and inundation problems in isolation simply creates further widespread issues. Retreat is a clear directive but seems to ignore the social and cultural issues it creates: issues of loss of property, of economic value, loss of place, and loss of customary cultural use. The IPCC adaptive strategies are very generalised and lack clear definition and direction in their suggestions; while they may produce over arching solutions, at a more local scale the simply generate further problems.

Human needs are most often acknowledged in the short term and this is reflected in coastal policy and management strategies (Tol & Klein; Crance & Draper). Policy and decisions are defined by what society wants and expects from its environment, and this highlights the importance of education and knowledge-sharing (Scott, Holland & Sandifer; McNeil & Hildebrand). Motives of people change rapidly, so human behaviour and the associated socioeconomic changes in the long term are difficult to predict with certainty (Pendleton & Thieler). The economic pressures and short-term social and cultural values are currently having much greater sway in the debate.

> Three barriers to successful integration of structural and behavioural solutions are identified as self-interest, mistrust, and variable perceptions of resource amenities. (Crance & Draper 175).

Proactive Adaptation

Adaptation is defined as being "in response" to change but we need to be prepared to be "responsive" to any eventuality. Adaptation and vulnerability are often discussed with the focus on economic, social and ecological issues as largely separate elements. Vulnerability is typically defined around significant economic losses (Hayward; M. J. Scott). The current focus of adaptive capacity building is human persistence (Barnett), and the huge economic costs (Hayward; M. J. Scott). It is important that ecological systems and processes can continue to function with, and through, human inhabitation to maintain resilience (Barnett; Day, Christian & Boesch; Mercer, Clarke & Bard; MacDonald & Thom; Nicholls & Klein; Klein, Nicholls & Ragoonaden).

> Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks. (Walker, Holling, Carpenter & Kinzig 2)

Social and ecological systems are complex adaptive systems and can exist in different kinds of stable states; a shock or disturbance to any state will trigger a shift into another through a process of readjustment (Walker & Salt).

Adjusting to living with the natural processes in the coastal environs will require a change of attitude, priorities, and of community understanding and awareness if there is to be integrated coastal management, sensitive development and coastal inhabitation in our future (Barnett; Helvarg; MacDonald & Thom; Nicholls & Klein; Turner, Subak & Adger). We exist within a social-ecological system and it is not possible to consider one component without the other. The building of adaptive capacity, as with resilience, allows for the absorption of, and recovery from, changes to lessen vulnerability, when defined both as physical and economic loss. The need for increased diversity and flexibility in settlement patterns and management strategies is a reflection of diversity and flexibility as strengths within the natural environment (Barnett). Acknowledging that changing conditions are the norm will lead to a more dynamic approach to planning for the future (Halpin; Tol & Klein; Turner, Subak & Adger).

Building Adaptive Capacity

The prolonged existence of human settlement in the coastal zone requires greater adaptive capacity and embracing of change. There needs to be a greater understanding of the role that humans can play as part of the holistic system and not as the primary component. In the socio-ecological system adaptability can be defined by “the collective capacity of the human actors in the system to manage resilience.” (Walker, Holling, Carpenter & Kinzig 7). Our way of life is completely integrated into, and reliant on the continuing health and resilience of all inter-related systems both natural and man-made.

Building adaptive capacity within coastal settlements will increase their resilience and create space within the community for the absorption of gradual changes, while also providing a platform for faster recovery in the event of any larger scale disturbances. Nicholls and Klein propose five approaches to proactive adaptation to climate change:

1. Increasing **robustness** of infrastructural designs and long-term investments
2. Increasing **flexibility** of vulnerable managed systems
3. Enhancing **adaptability** of vulnerable natural systems
4. Reversing **maladaptive** trends
5. Improving societal **awareness** and **preparedness**. (Nicholls & Klein 221)

These approaches are tangible; they represent actions and ideals that are accessible and have sufficient definition to form a framework against which a design process and outcomes can be assessed. They deal with both social and environmental issues and cover concepts explored by both IPCC and the Resilience Alliance. Proactive adaptation needs to embrace the concept of redundancy in resilience thinking by providing for change, in both social and physical realms, without being specific about the form that it may take, to build adaptive capacity. Adaptive capacity is about latency and flexibility creating space for responsive adaptation within the socio-ecological system. This is where the link between resilience, or adaptive capacity building, and design needs to be further explored so that resilience can be given an accessible face that engages community interest for reasons other than simple necessity.

The scientific prerogatives of reports dealing with the natural environment often tend to sideline issues of socio-environmental relationships, particularly on the coast. While the ecological research is critically important, the relationships between the natural environment and human settlement need to be better articulated and the high value of ecological resilience needs to be incorporated in the socioeconomic values of community. Our relationship with our environment needs to be symbiotic, and future development needs to value and highlight these inter-relationships and inter-dependencies.

The tensions between the natural coastal processes and human inhabitation are most significant in sand spit settlements. Sand spits are natural intermediary zones between the sea and harbour or river mouth, their size and shape fluctuating in response to the surrounding environmental influences. The time scale for large changes is long and so they often appear stable, but a single storm event can completely alter them. In these circumstances the responsiveness is most critical, as natural systems rebuild over time often taking on different forms. When these dynamic landforms are developed the tolerance for and ability to continually shift and respond is significantly altered.

The indication from surveys undertaken by the Thames Coromandel District Council on beach values was that the public attributed the highest value to natural beaches with intact dunes (Thomson). These are the environments that attract the development initially and when these defining features are lost due to over population and insensitive development, the very identity of the resulting settlements is also lost or significantly altered.

Research Question

What role can Landscape Architecture play in increasing the adaptive capacity of coastal settlements and ensuring the ongoing viability of both social and ecological systems?

Research Objectives

This masters design thesis focuses on the re-development of coastal communities in sensitive coastal environments from a landscape architecture perspective. It proposes that landscape architecture and urban design should play a much greater role in the building of resilience in sensitive coastal environments as a mediator between social and ecological requirements. In New Zealand the current adaptive preference at the government level is managed retreat, as it is the most cost effective method, yet it does not acknowledge the long term social costs that impact on the local communities and wider cultural connections to place. This research project proposes that through the provision of open space networks, that both absorb the dynamic nature of the coastal environment and regenerate the identity and amenity of coastal settlements, the adaptive capacity of the community can be increased. This increased provision of open spaces in coastal settlements strengthens the natural buffer to coastal threats.

OBJECTIVES:

1. To show open space can increase flexibility, responsiveness and adaptive capacity of the natural and built environment.
By testing the effectiveness of changing the traditional heavy pattern of development to release larger areas from the built footprint, and creating more open spaces to allow greater flexibility in the natural coastal systems. These open spaces should have social and ecological functions that will make them the focus for community building and greater public awareness of natural coastal processes. Reducing the extent of the built footprint while providing for the same or even greater population capacity through changes in density and clustering of development areas can strengthen and enhance the sense of community.

2. To show open space in coastal settlements can increase the robustness and ability to recover from significant disturbances to the coastal environment.
By testing how enhancing the protective capacity of the dunes through the regeneration of the natural environment and the implementation of flexible man-made systems that reinforce them, will increase the resilience of the coastal settlement. Greater diversity and flexibility in both the social and ecological system also creates greater robustness and ability to adapt to changes and recover from shocks.

3. To reverse the maladaptive trends in coastal development and create a more responsive and sensitive model of settlement.
Increasing the diversity of the development pattern, through zoning, property and building legislation, allows a wider range of people to buy into these settlements and ensure that they do not continue with the trend toward prohibitively expensive and exclusive resort towns. Addressing the existing maladaptive development trends will shift the focus of coastal settlements back to the coast itself.

4. To increase community and public awareness of and engagement in the natural environment and its processes.
Providing tangible responses to potential threats to human investments in the sand spit which are responsive and sensitive to the natural processes while providing a visible solution. The restructuring of ownership in the coastal environment, and encouraging responsibility for the health of the complete coastal system, are important steps towards changing attitudes toward private land ownership and community engagement. Building social capital, community identity and symbiotic inter-relationships within the socio-ecological system are critical to the resilience of coastal settlement.

The intention is to create a coastal settlement that celebrates the natural processes and surroundings, and provides an environment that encourages both social and ecological capital building.

This thesis focuses on developing and testing a model for increasing the adaptive capacity of sand spit settlements in New Zealand with regard to the threats and impacts of climate change. It is design led.

The literature review process defines the issues both globally and for New Zealand and provides a framework for the assessment of the design process and outcomes. Design studies of three representative sand spit settlements, in the form of a multiple case study process, provide the platform for analysis and testing. The intention for a design outcome means that a case study process is not entirely appropriate, as interventions at all three of the sites is intended. Site analysis at all three sites is identical to ensure that comparisons can be made and corresponding information can be identified as typical.

SITE ANALYSIS COMPONENTS:

- Context analysis
- Geomorphological analysis
- History of development
- Urban and Green space character analysis
- Style of development
- Existing threats
- Impacts of sea level rise
- Resilient and maladaptive attributes

It is predicted that all three sites will be vulnerable to the impacts of climate-related changes, especially sea level rise. The data for sea levels and potential inundation levels is taken from local council information and information available through the New Zealand Ministry for the Environment. Levels are approximate and intended to be indicative only. Detailed data on site-specific sea level variations, and variations in impact of storms at all three of the design study sites is not readily available. A series of inundation levels are calculated for the testing process. They included Significant Wave Heights, El Nino Southern Oscillation influenced rises, IPCC Sea Level Rise predicted rises, storm surge levels and fluctuation due to air pressure.

There is potential for all levels to be exceeded, as the values are averages. Tsunami impacts are discussed in the design study stage but not specifically part of the testing process. The assumption is that lower level waves (2-5m) will respond similarly to levels suggested for storm impacts and larger waves (6-14m) will wipe out all of the settlements.

The development and design of strategies to increase adaptive capacity was achieved through an iterative process of testing at all three sites. Research on existing methods of response to identified threats provided some inspiration and this is then refined in response to typical site conditions. Detailed design at one of the sites (Omaha, NZ) allowed the strategies to be tested and applied in response to more specific site conditions.

The outcome of this research is a series of principles for increasing the adaptive capacity of existing coastal settlements. These principles may also be relevant guidelines for the proposal of new developments.

The issues of erosion (Figures 11 & 12) and coastal inundation (Figures 13 & 14) are constantly plaguing coastal settlements. The threat of tsunami in many coastal areas is known but the long return period for such events means they are often barely acknowledged, although this is changing in the aftermath of the 2004 Indian Ocean Tsunami (Figure 17). The continuing rise in sea levels is increasing the severity of these known threats. In some places erosion has completely undercut houses and made inhabitation of coastal areas inviable. Salt water inundation infiltrates the water table and causes vegetation die off. Damaging storm waves (Figures 15 & 16) have an erosive power that impacts both above and below the water line. Tsunami waves also have significant erosive impact below the waterline. Waves meet hard protection structures and run along their face scouring sand and when they eventually reach softer surfaces the erosive power has increased in intensity and the damage is far reaching.

EROSION

Figure 11. Coastal Erosion at Buffalo Beach, Whitianga, 2001

Figure 12. Severe erosion at Ohiwa Spit, Waikato

COASTAL FLOODING

Figure 13. Coastal Flooding

Figure 14. Coastal Flooding, Omapere Beach, Northland

STORMS

Figure 15. Large Storm waves, Northland

Figure 16. Storm washes through house

TSUNAMI

Figure 17. The Indian Ocean Tsunami engulfs fleeing people, 2004

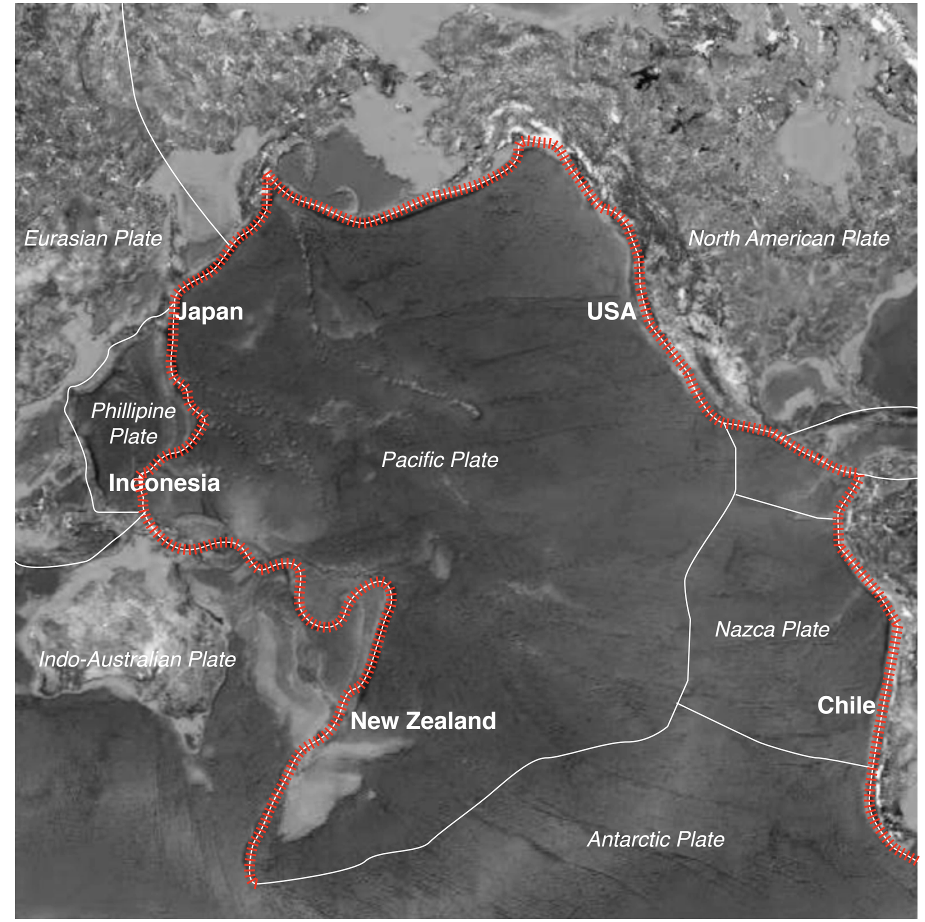


Figure 18. The Pacific Ring of Fire. Earthquakes and volcanic activity along the fault lines create distant and local tsunami threats to the New Zealand coastline.

The base of a wave below the water is a mirror of the wave height above the waterline. In larger storms this can cause huge amounts of sand to be removed due to the erosive power of the waves.

The existing mode of waterfront development has seen houses built well within the dunes and often on top of the flattened foredunes. This makes these properties highly vulnerable to erosion, storm wave damage, inundation and complete destruction from tsunami.

As sea levels rise these impacts will only increase, as the reach of the sea extends further inland.

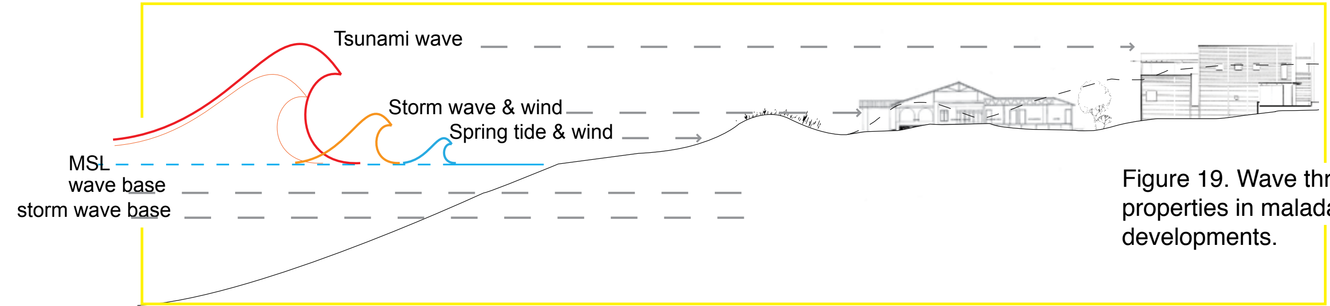


Figure 19. Wave threats to waterfront properties in maladaptive coastal developments.

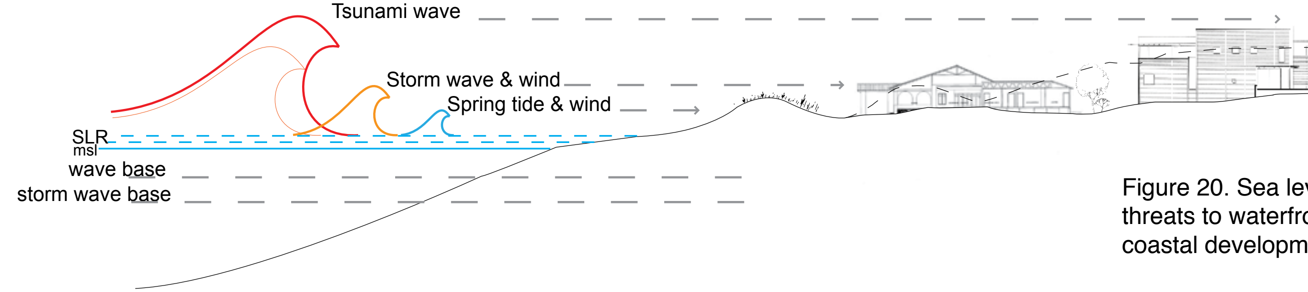


Figure 20. Sea level rise influence on wave threats to waterfront properties in maladaptive coastal developments.

Houses built behind the initial dune line and on higher ground are much less vulnerable to these threats, although tsunami remains a significant threat to all low lying coastal areas. The dunes provide a protective barrier that dissipates the wave energy as it moves inland.

Sea level rise will increase the likelihood of inundation and erosion issues but these properties are still far less vulnerable than those within the foredunes on lower ground.

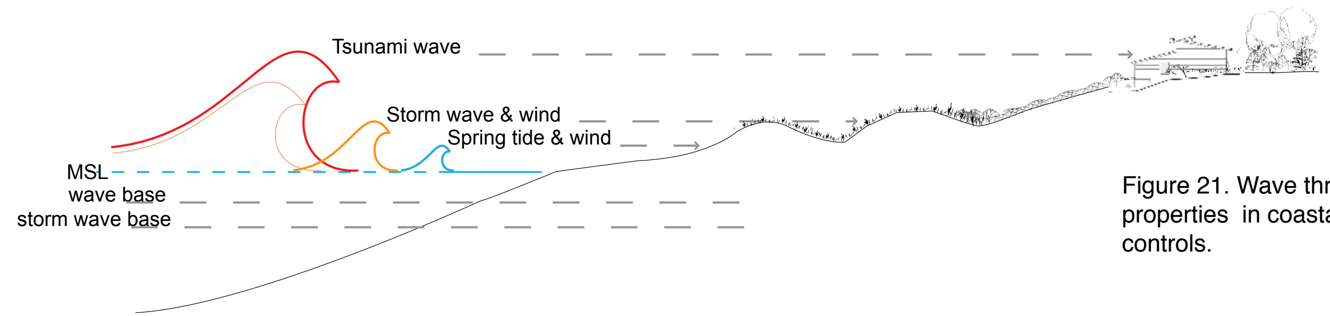


Figure 21. Wave threats to waterfront properties in coastal areas with setback controls.

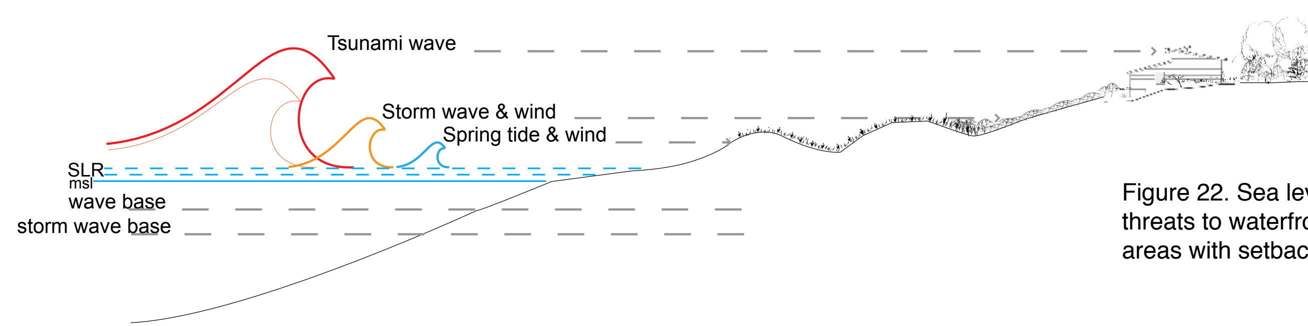


Figure 22. Sea level rise influence on wave threats to waterfront properties in coastal areas with setback controls.

DESIGN STUDY ANALYSIS

Introduction

Sand Spit Characteristics

Design Studies:
- Omaha
- Matarangi
- Pauanui

Precedent Study:
- Awaawaroa Bay Eco-village

Summary of Issues

Figure 23. Context Map adapted from Google Maps 2010

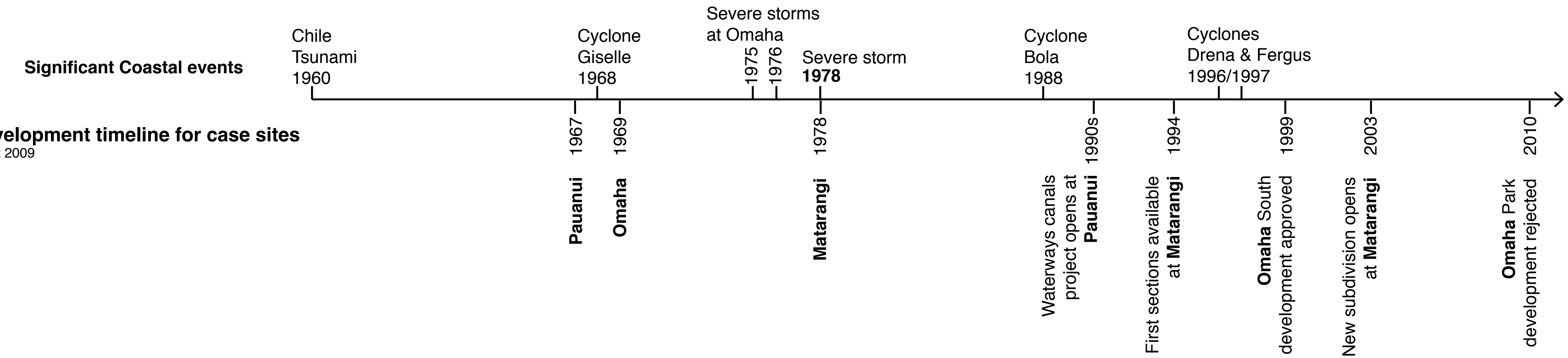


Figure 24. **Development timeline for case sites**
adapted from Peart 2009

The literature review process identified a worldwide trend of developing the sensitive and ephemeral barrier formations on our coast and in particular highlighted the nature of the development style and size of financial investment in these areas that are under threat from climate related change and sea level rise.

These cases are representative of the sand spit holiday resort developments undertaken in New Zealand since the 1960s. Each design study site is a holiday resort located approximately 2 hours from the nearest large city; the population is primarily temporary with a seasonal peak occurring over the Christmas/New Year period. The cases are limited to the highest profile of these coastal resort communities, and those that were most similar in development time line to the pilot case. A common format of analysis was developed through the pilot case study and this was then undertaken at all three case study sites to identify the key similarities and differences.

The case studies investigate the characteristics that make these sites attractive for coastal development and also the characteristics that are vulnerable to the increasing impacts of climate change. This project analyses the style of development undertaken and the responses at the time to the recognised erosion and inundation threats. It also investigates the potential new threats that were not accounted for and the impact that the changing climate will have on those existing threats. All of this information is layered onto foundation analysis of the physical and systems characteristics of the site and wider catchment context.

A pilot study at Omaha generated and structured the format for the case studies there and at 2 other sites: Matarangi and Pauanui. By undertaking a thorough study of Omaha and its surrounding context it was possible to identify issues in relation to development styles and the tensions with increasing threats of climate change-related impacts. The resulting structure for analysis of all 3 sites focused on the nature of these threats and the impacts they would have in each community. This could then form the basis design responses to these threats at Omaha that were then tested at the 2 other sites. The way in which all 3 sites responded helped to develop and fine-tune a design-led response for Omaha that could form the basis for future re-design of coastal settlements, and inform the design of future coastal development in similar environments.

Sand spit Characteristics

Sand spits typically form across the mouths of rivers or shallow harbours. Sediment that is washed down by the waterways and inland by the currents is piled up by the competing forces of river outlets and coastal currents. The coastal currents on the east coast of New Zealand's North Island run northwards causing the sand spits to form with a northern orientation. The formation of the spit pushes the outlet channel to the northern most point. The dunes build towards the sea with new sediments being supplied by the coastal currents and delivered by the tides, then blown ashore by the onshore winds. The silts and sediments running off from the surrounding landscape wash down-stream by the water ways and accumulate behind the dunes, building sand spit slowly inland, low and flat. Because these landforms are actively building and shifting, the dunes never grow to great heights, instead forming rolling, often parallel, rows along the length of the spit. The foredunes are often the highest, though older dunes that have stabilised may be higher due to more active building and sediment supply at an earlier time.

In geological timescales, sand spits are ephemeral landforms. Lying as a protective barrier between sheltered water and open water environments, they are vulnerable to impacts of both river wash-outs and coastal storms. Flooding can cause the river to re-route across the spit in the most direct path to the sea, just as large swells or tsunami can breach the spit from the seaward side through to the harbour.

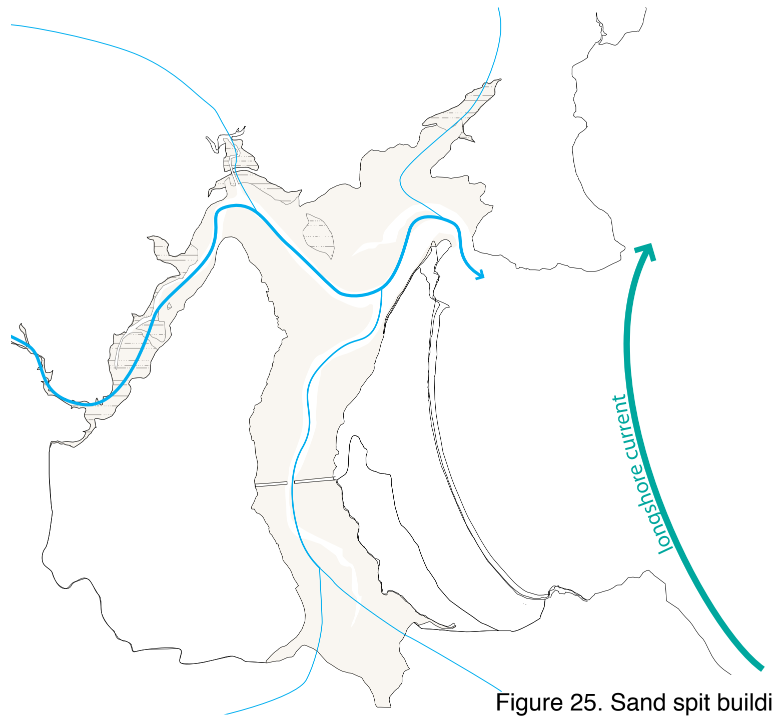


Figure 25. Sand spit building components adapted from Schofield

Omaha spit across the mouth of the Whangateau harbour showing the out flow of the waterways and the direction of the prevailing coastal longshore current.

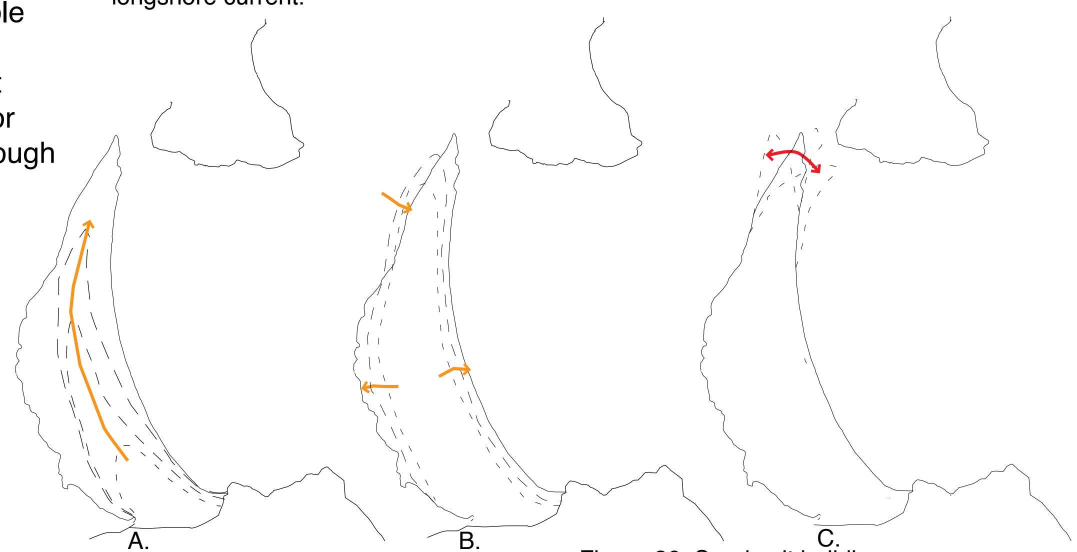


Figure 26. Sand spit building adapted from Schofield

A. The sand spit builds across the mouth of the harbour in the direction of the longshore current.
B. The sand spit collects alluvial material along its inner harbour edge, the dunes and beach build out seaward, while the spit tip typically tends to erode along the harbour edge.
C. The spit tip is the most mobile part, shifting in response to harbour currents, tidal flows and sediment supplies.

R growth & exploitation phase (progradation)
K conservation phase (stabilisation and erosion)
Omega collapse and release phase (significant change)
Alpha reorganization phase (re-stabilisation and progradation)

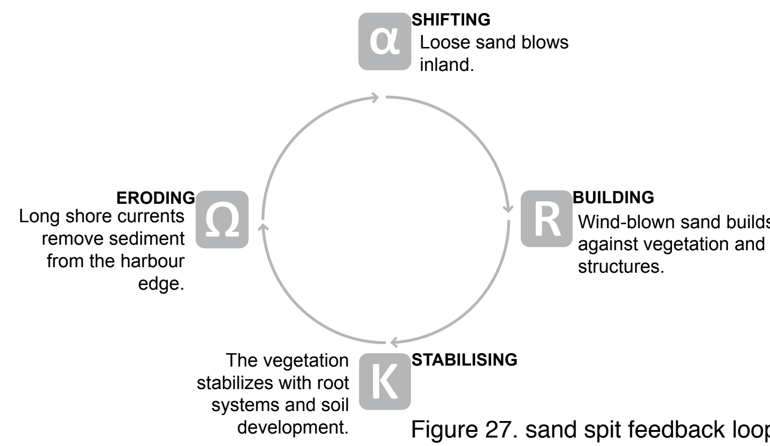


Figure 27. sand spit feedback loop
adapted from the Resilience Alliance adaptive cycle (Walker, Holling, Carpenter & Kinzig)

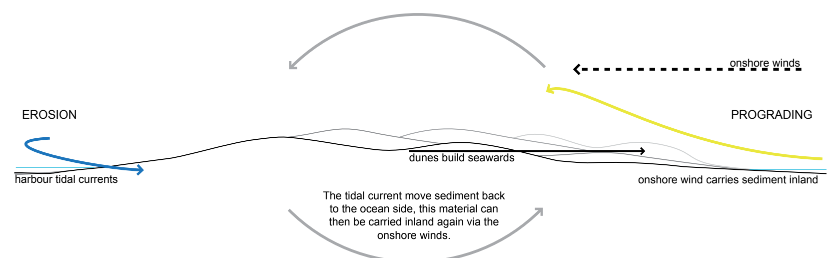


Figure 28. natural sand spit cycle

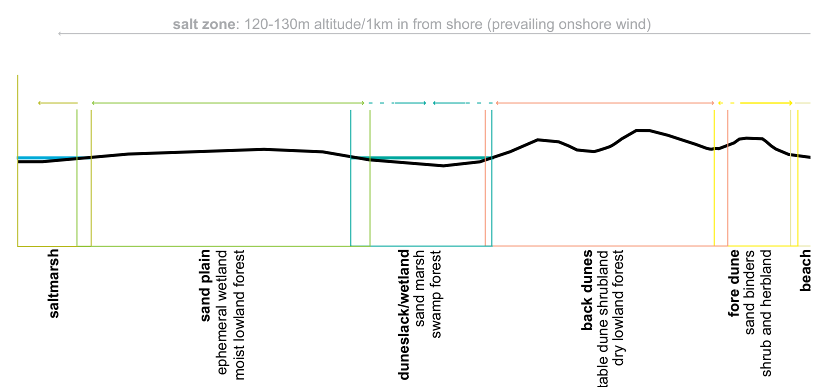


Figure 29. Dune domains
adapted from Gabites

The spit's natural cycle is a continuous loop: building, shifting, stabilising and eroding (Figures 27 & 28). As the dunes migrate inland and the spit builds towards the sea, the vegetation acts to stabilise the loose sands and generate topsoils. This succession moves with the dunes and as blowouts occur and sand is released from the ground cover the process begins again (Gabites). The harbour edge of the spit is prone to erosion as the tidal and long shore currents remove sand and carry it back out into the bay where it is eventually recycled back onto the spit. Sand spit comprises of a succession of dune domains (Figures 29-32); the foredunes are characteristically unstable, exposed to king tides and salty prevailing winds, and have dry, no or very poor soils. The back dunes are more stable, less exposed, and are dry, with a soil layer developing (as soil develops the back dunes become stable). The dune slacks/wetlands are low points where the water table has been exposed. They tend to be wet with peat and biomass developing, raising surface above the water table, where fertile soils develop. These low lying areas are prone to frost where they are sheltered from coastal breezes. Eventually they develop into lowland swamp forest. The inner harbour edge supports salt marsh which develops on tidal mud flats in sheltered waters, helping to filter sediment rich water and providing habitat for spawning fish and wading birds.


Figure 30. Wetlands


Figure 31. Back dunes


Figure 32. Foredunes

CONTEXT ANALYSIS

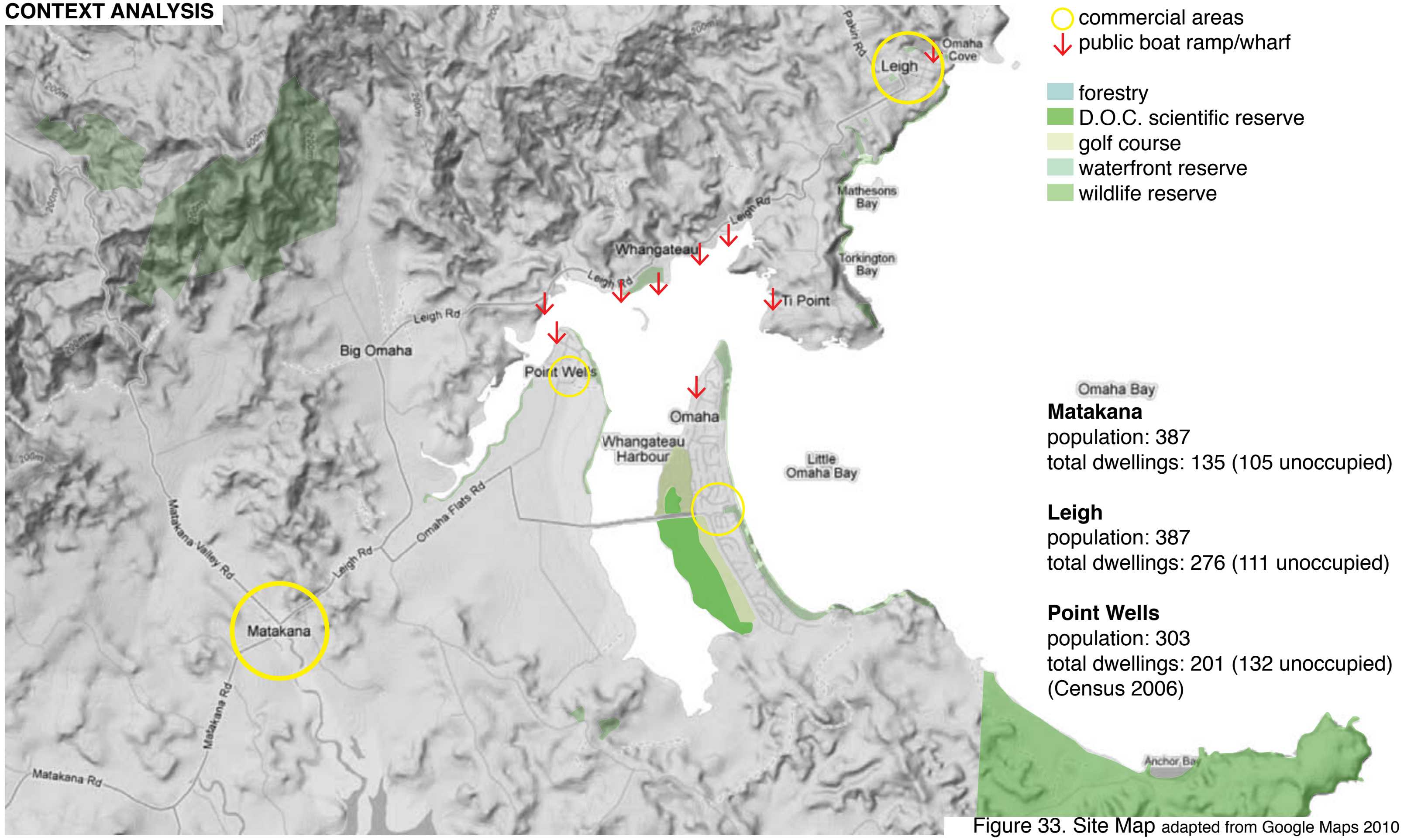
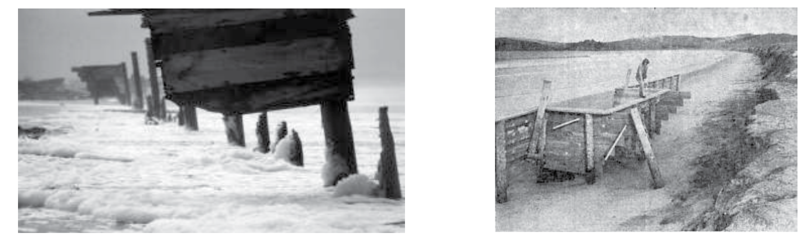


Figure 33. Site Map adapted from Google Maps 2010

Figure 34. **Figure ground of Development PHASES** adapted from Omaha Coastal Compartment Management Plan (Beca Carter Hollings & Fermer)


Figures 35 & 36. Erosion and storm damage to the timber seawall at Omaha

location: 1 hour drive north of Auckland
initial development: 1969
developers: Broadlands Finance

The development of Omaha happened in a series of stages. Original plans included high-rise buildings, shops and a casino. Instead a ‘traditional’ subdivision for 520 houses was built along 1km of the coastline north from the causeway. Erosion was already an issue before development took place; an overseas consultant proposed a timber seawall along the 1km of developed beach, restricting access to a few places, plus sand replenishment. The foredunes were bulldozed to lower them by 3m to increase views of waterfront properties. This development included the planning of the golf course reclamation and the causeway. Three significant storms hit Omaha hard following the completion of the initial subdivision in October 1975, in April 1976, and the largest and most destructive in July 1978, which washed away the timber seawall and waterfront properties (Figures 35 & 36). The July storm was a combination of a high tide and north-easterly winds. The following phase of subdivision extended the original development towards the north of the spit. (The northern-most sections of this extended subdivision have not been made available for purchase although all infrastructure is present), followed by the southern end being granted consents in 1999. The Omaha South development extended the coastal suburb south to the heel of the spit. This latest development also extended the golf course and encouraged the development of a commercial zone for the suburb. These later developers did learn from the mistakes of the initial subdivision and the waterfront properties were set back further in the northern extension, and in the southern development the fore dunes were largely untouched and the setback even more significant although the practice of flattening the back dunes was maintained throughout all development. The Omaha south development still has a large number of undeveloped sections.

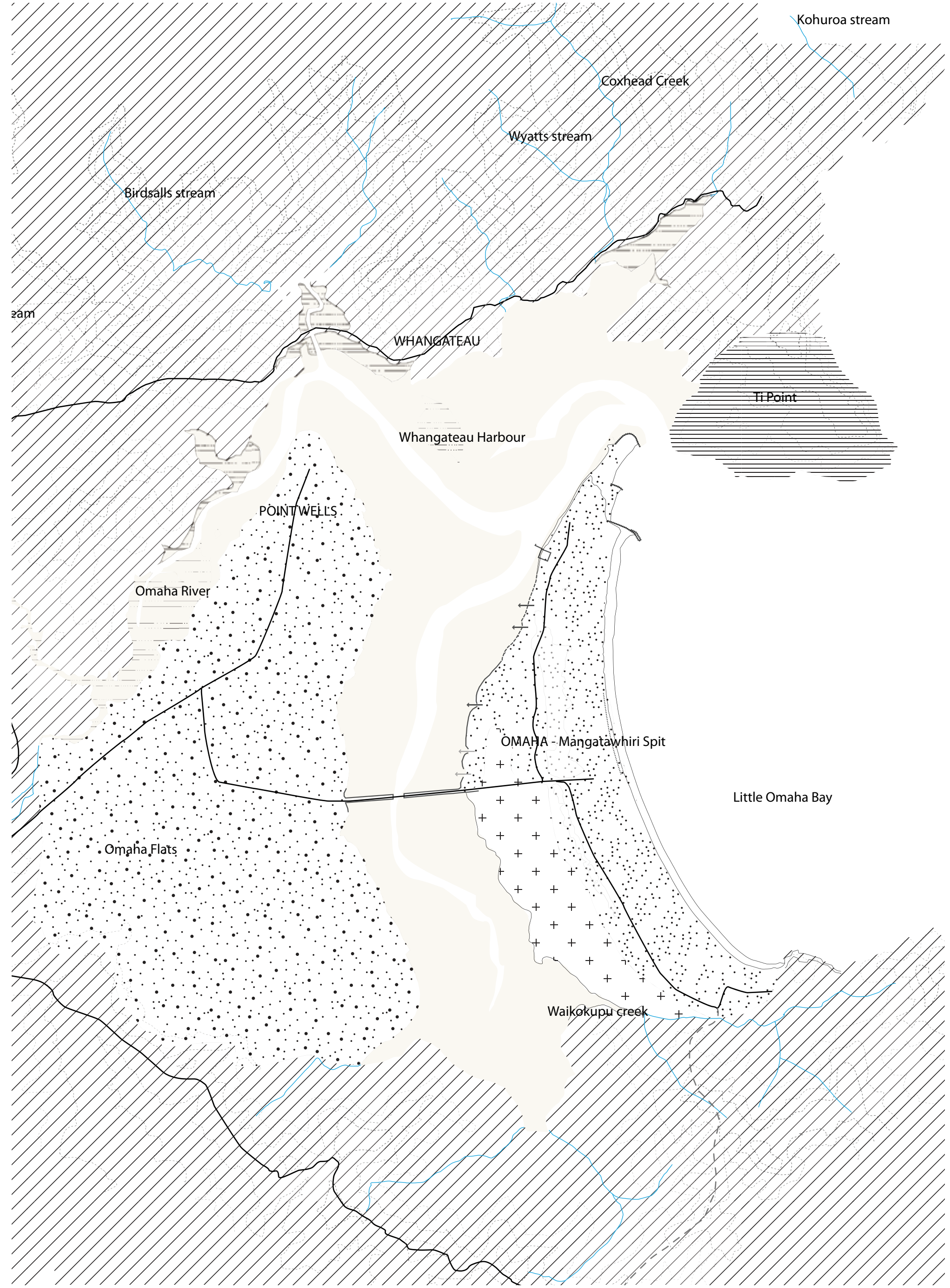


Figure 37. **GEOMORPHOLOGICAL ANALYSIS**
adapted from GNS

Mangatawhiri Spit (Omaha) is made up of both dune sand and alluvial sediments deposited by the waterways feeding into the harbour. The dune sand builds up along the seaward coast and the alluvial material collects along the harbour shore. Point Wells is also sited on an older sand spit formation, composed predominantly of alluvium. The material that forms the surrounding hinterland is harder. Ti Point is a basalt headland that directs the outlet of the harbour in relation to the sand spit tip.

Flood Basalt - Tertiary volcanics

Calcerous Sandstone & Siltstone (Waitemata formation) Tertiary sediments

Alluvium - Late Quartenary sediments

Dune Sand - Late Quartenary sediments

Postglacial Alluvium

Sandbars/mud flats

Mangroves / Saltmarsh

URBAN CHARACTER ANALYSIS

Omaha is accessed via a causeway that meets the spit half way along its inner harbour edge. The most public facilities, including the surf club and, more recently, a small collection of shops, are situated in the centre of the spit directly in line with the causeway. Other than this primary beach access point and commercial centre there is relatively limited public beach access that is of high visibility due to the layout of the waterfront properties and street network.

Roads tend to run parallel to the beachfront with a line of properties, often two deep, between the street and beach. This is also apparent on the inner harbour waterfront (1 & 2). There are very few streets that run directly to the beachfront without being interrupted by private properties.

Waterfront properties tend to have a greater proportion of property covered by building. The inner harbour waterfront properties are most visually prominent from beach/ sea and there is minimal waterfront reserve on harbour edge. The community is based around the recreational facilities provided, primarily the golf club, although there are bowling greens, tennis courts, and a boat ramp and wharf at the northern end. The new commercial area (3) is centralised to provide for the most developed areas of the spit. The southern subdivison is settled most sensitively in the environment, with setbacks and encouraging dune environments, while also increasing the open space links through the developed area. However it has many properties that are not fully developed, and many sections lying empty due to the property market crash.

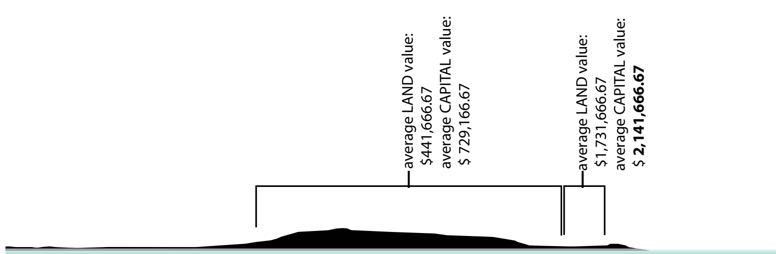
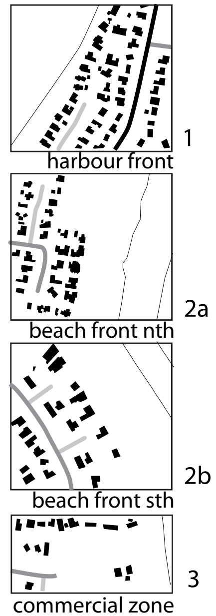
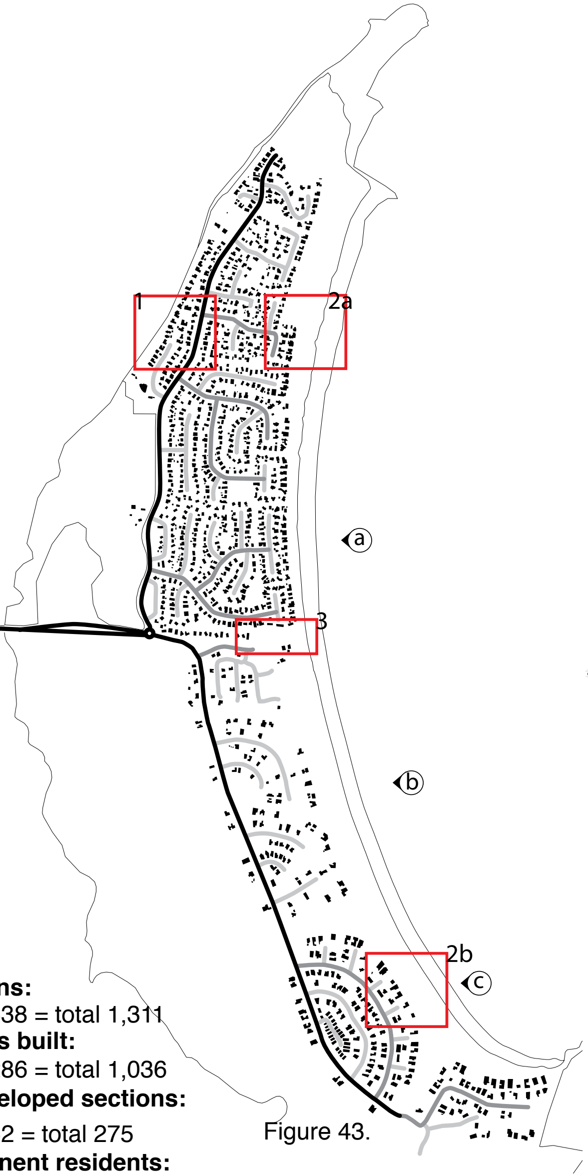


Figure 38.

Figures 39-41.





Number of sections:
North 773, South 538 = total 1,311
Number of houses built:
North 750, South 286 = total 1,036
Number of undeveloped sections:
North 23, South 252 = total 275
Number of permanent residents:
354 (Nov. 2006 census)
Number of peak residents (Christmas/New Year period):
approx 15,000+

Figure 43.

The street pattern creates the underlying structure for residential clusters, though at the northern end the lack of interconnectedness and the higher density of the developed area means this structure is lost. The southern subdivision creates successful clusters with clearer neighbourhood definition. However, the interconnectedness within the cluster area could be further strengthened.

The streets in the original subdivision appear to have been laid out for grandstand views. The modification of the dunes created a single spine in this area rising up from the beach and falling towards the golf course.

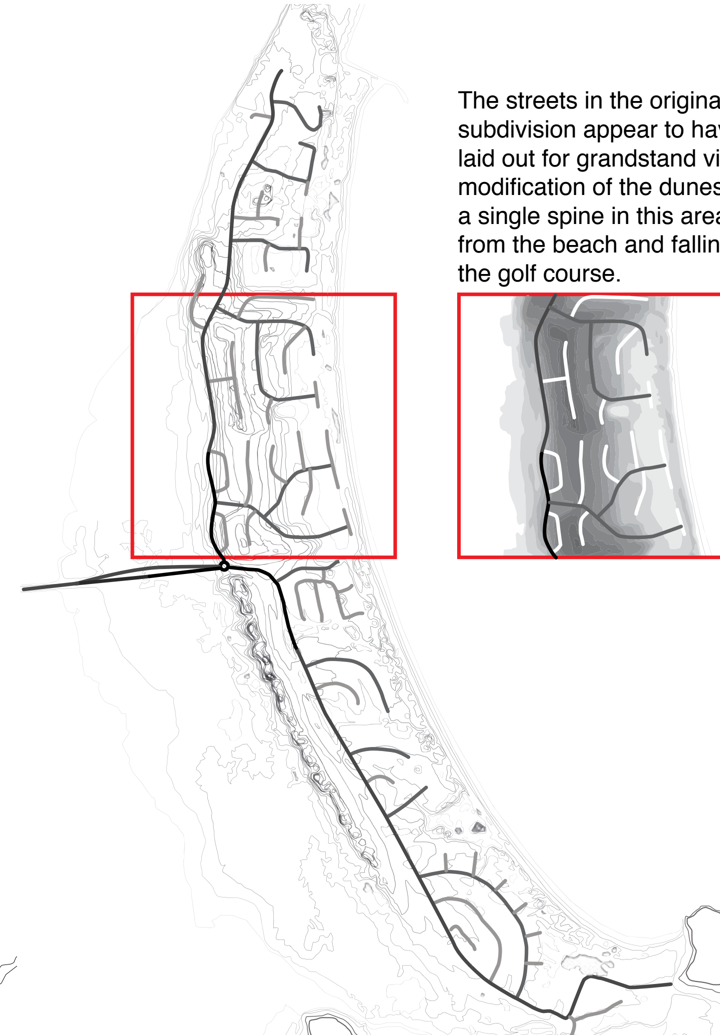


Figure 44.

In the northern subdivision the topography is slightly more varied. The street pattern maximizes beach frontage and, where possible, views. The southern subdivision created largely flat development areas minimising the need for the roads to follow the topography.

Figure 45. Public walkways through residential area at northern end of spit

Figure 46. Public walkways through dunes at southern end of spit

Figure 47. Conservation reserve area, nationally important example of coastal swamp forest succession

Figure 48. Public open spaces in the southern subdivision

Figure 49. Dune environment

GREEN SPACE CHARACTER ANALYSIS

The golf course is an important recreational draw-card for residents. Omaha has a network of small, green space pathways that link through the residential blocks to larger inland open space areas and to the waterfront reserves. These pathways are not clearly defined in most areas, and the fencing of properties adjacent to them further closes them off to the public. There is a network of walkways, through the dunes on the seaward side of the southern subdivision, that connect through the open space areas back to the main street. The open spaces between the southern neighbourhoods correspond to low-lying areas in the dunes.

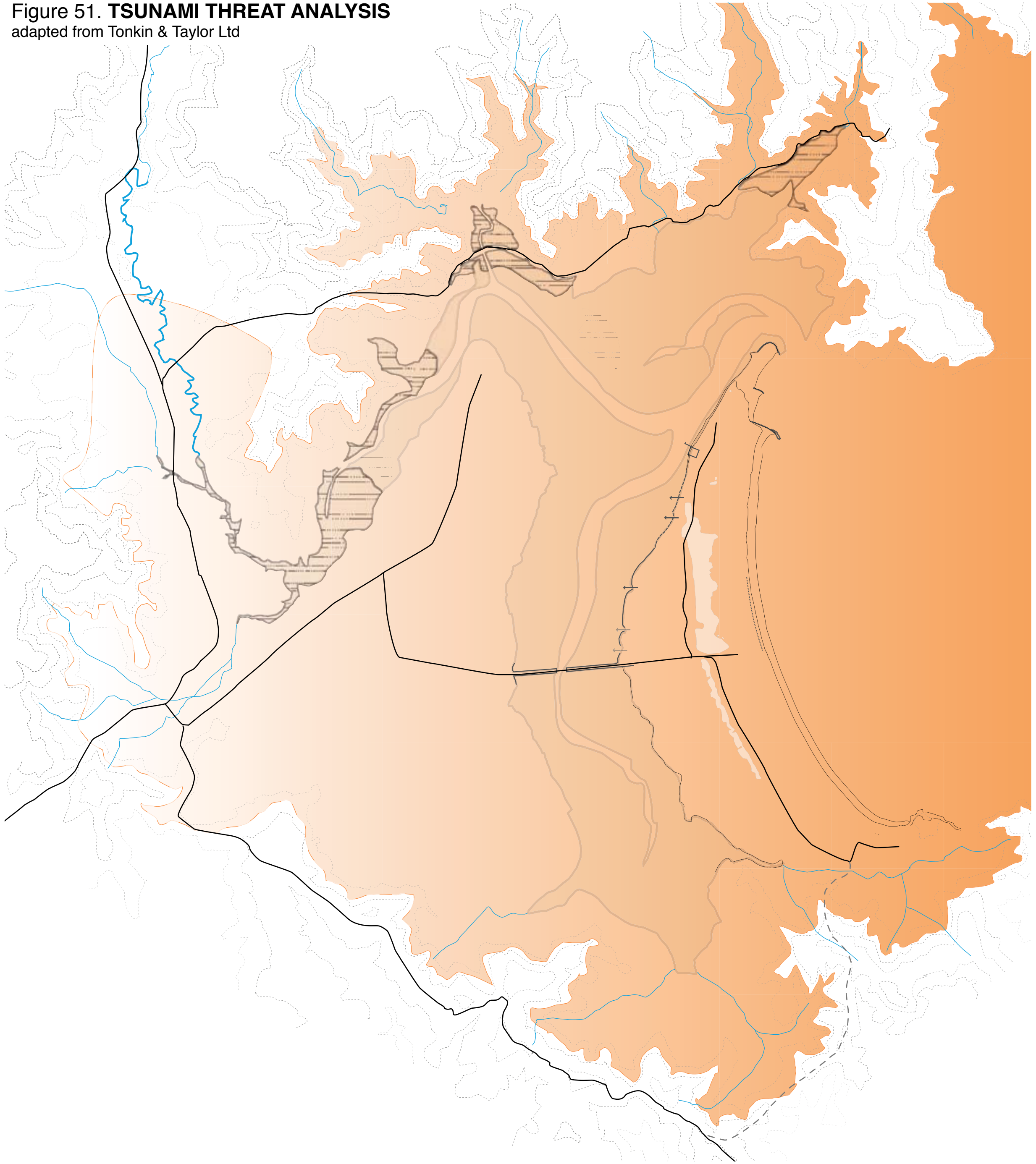
There are large conservation reserve areas on the inner harbour shore containing extensive lowland swamp forest, that is nationally significant, and native wetland and salt marsh ecologies form a scientific reserve. The spit tip is an important nesting habitat for endangered shore birds such as the NZ dotterel.

The foredunes of the northern subdivision have been modified, but lessons learned from early storms that wiped out the initial subdivision mean that they are relatively well formed and 'natural' in appearance. The houses have been constructed to heights that ensure they are not visible from the beach. The later subdivisions of the spit have increased the setbacks of the seaward waterfront properties, although the inner harbour waterfront reserve is much narrower, though no less threatened from erosion or inundation.

The dunes in front of the northern-most properties have been largely left as original and are significantly higher than those along the rest of the beach. Dune and wildlife protection measures are most prolific at the northern end with only board walk access to the beach and large areas of the dunes being fenced off. Private properties still have some pathways through the dunes to the beach though these are strongly discouraged.

Figure 50. Omaha Green Spaces
adapted from Alggi (Auckland Council GIS Viewer)

Figure 51. **TSUNAMI THREAT ANALYSIS**
adapted from Tonkin & Taylor Ltd



The outlying Islands of the Hauraki gulf provide some protection from the larger waves. Omaha is at the northern-most reaches of the gulf and is classified as open coast. Great Barrier and Little Barrier islands lie to east of Omaha and would provide limited protection from distantly generated waves.

A tsunami triggered in Chile has the most direct route to our coast and in Auckland the largest wave on record was 3m above sea level. Indonesia is another source that has generated a 2m wave. Other distant sources have created minimal waves. Locally-triggered tsunami arrive much faster and can be much larger.

The largest record of a locally-triggered wave generated in the Bay of Plenty was 14m high in the Auckland area. The biggest tsunami triggered within the Hauraki Gulf was 2m (ARC).

Tsunami threat zone: 40m above MSL/1km inland

Figure 52. adapted from Google Maps 2010

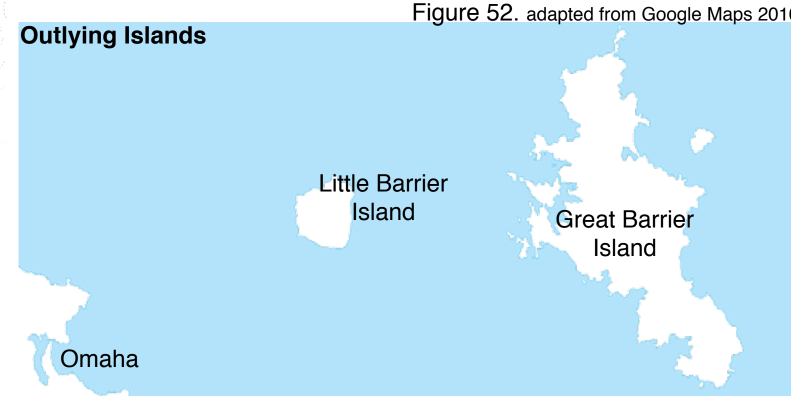
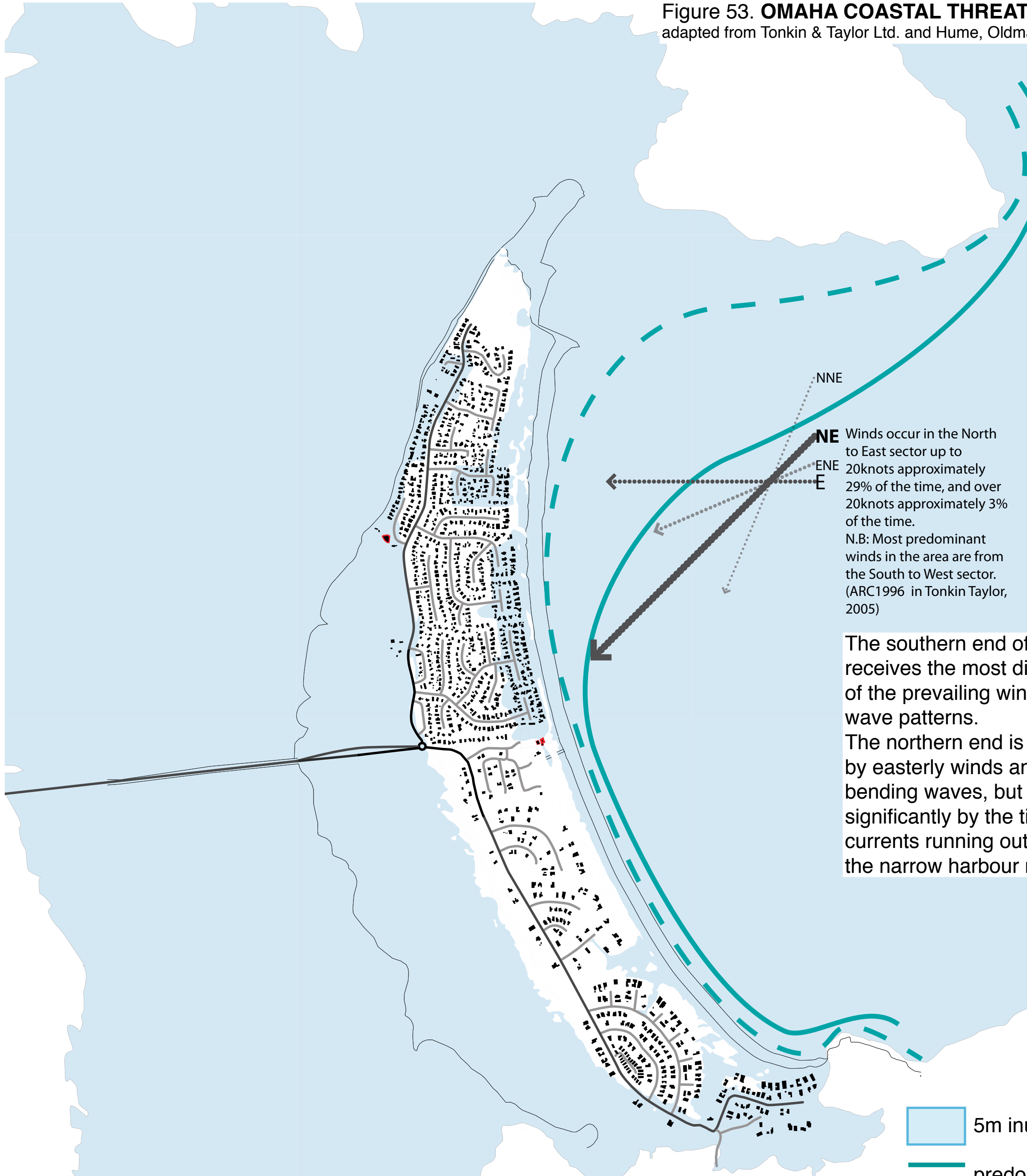


Figure 53. **OMAHA COASTAL THREATS**
adapted from Tonkin & Taylor Ltd. and Hume, Oldman & Black



The southern end of the spit receives the most direct force of the prevailing wind and wave patterns.
The northern end is affected by easterly winds and the bending waves, but most significantly by the tidal currents running out through the narrow harbour mouth.

Figures 54-58. **IMPACTS OF SEA LEVEL RISE**
adapted from MFE

Mean Sea Level = 0.0m

Mean Sea Level = 0.0m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

IPCC SLR 2100 = 0.5m
Storm Surge = 0.9m
ENSO = 0.2
Low pressure = 0.2
Significant Wave Height = 3.5m

IPCC SLR 2050 = 0.2m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2
Significant Wave Height = 3.5m

WORST CASE SCENARIO
IPCC SLR 2100 = 0.88m
Storm Surge = 1.0m
ENSO = 0.25m
Low pressure = 0.3m
Significant Wave Height = 4.0m+

RESILIENT ATTRIBUTES:

1. Maintaining the natural foredunes, in places, as a protective barrier to properties.

2. Golf course sited on low lying land rather than residential development.

3. Central commercial area and community focus of surf club. Highly legible public beach access and parking within in short distance of spit access.

4. Provision of open space in low-lying areas allowings for potential inundation without threatening properties.

5. Conservation of nationally significant ecologies.

6. Clustering of residential development set back from the foredunes and above the low-lying inundation vulnerable areas.

7. Provision of a network of walkways within the dunes to encourage focused access points to beach, thereby protecting delicate dune vegetation.

8. Pedestrian-focused walkway network throughout residential areas.

Figure 59.

Building in sand spit environments is, in itself, a maladaptive practice. The shifting and dynamic nature of these landforms means that any development will compromise their adaptive capacity simply through limiting this responsive shifting.

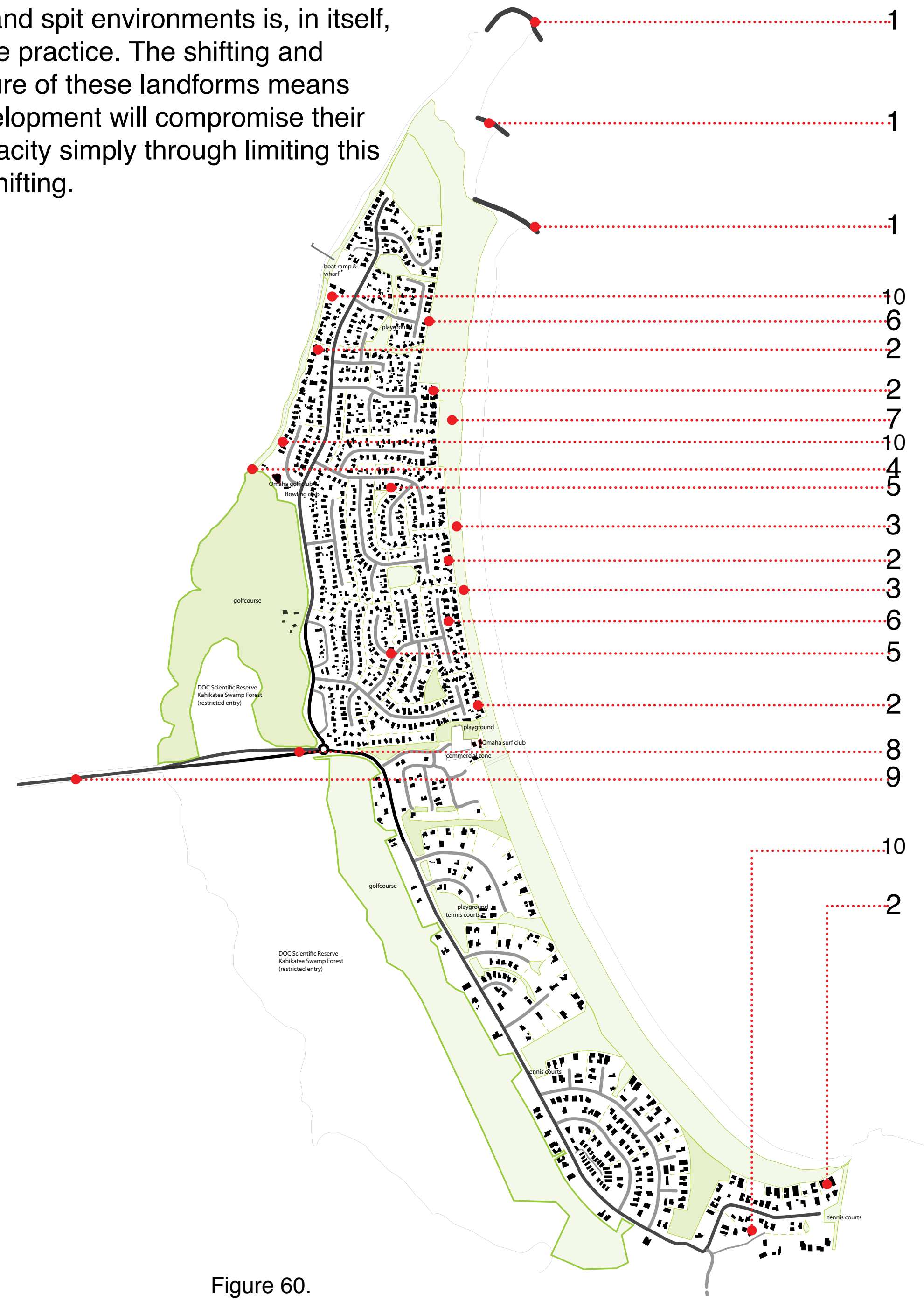


Figure 60.

MALADAPTIVE ATTRIBUTES:

1. Construction of groynes in response to erosion of spit tip, later discovered to be caused by sand mining in the harbour mouth. The groynes lock the spit tip in place.

2. Building too close to the beach, often within the foredunes and potential inundation areas. Harbour beach properties are prone to erosion of the coastal edge.

3. Lowering of the foredunes to increase views also means the protective barrier is compromised.

4. Construction of protective seawalls along the harbour edge, due to erosion caused by the increased tidal currents flowing through the causeway bridge.

5. The street layout is not conducive to connectivity. No clear neighbourhood blocks and lack of legibility makes these residential areas very closed.

6. Streets running parallel to beach front with two-property barriers between street and beach further limiting the access to, and legibility of access to, the beach.

7. Long rows of beach front properties leads to the creation of large numbers of 'private' pathways across dunes to beach, which harms the delicate native vegetation that stabilises the sand.

8. Single access point creates a potential deadlock in the event of necessary evacuation or damage to the access causeway.

9. Causeway across the harbour creates a barrier to the waterflow from the southern catchment area, making it vulnerable to wash out damage.

10. Building houses in low-lying areas areas vulnerable to inundation and flooding.

CONTEXT ANALYSIS

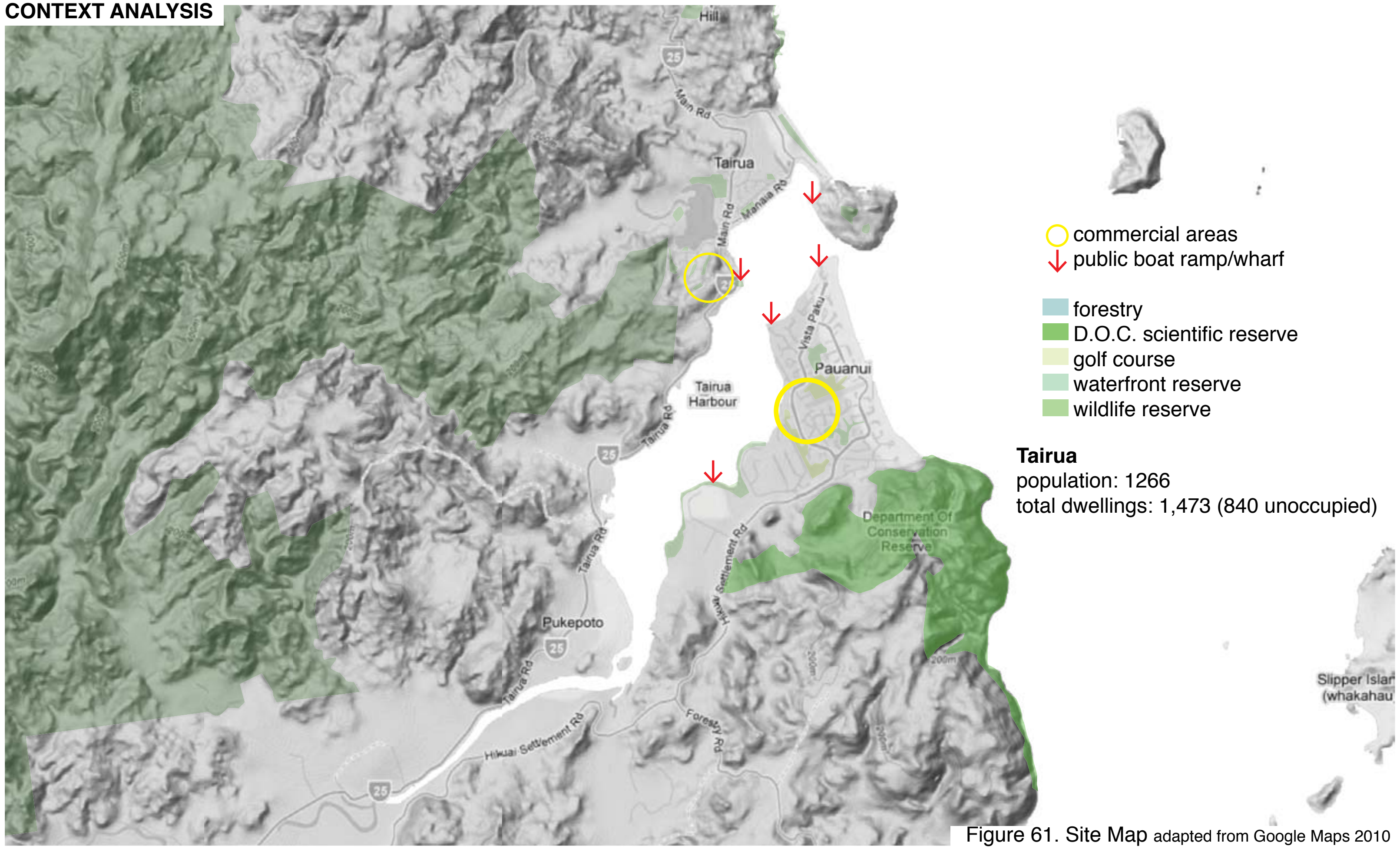


Figure 61. Site Map adapted from Google Maps 2010

Figure 62. **Figure ground of Development PHASES** adapted from Peart (2009)


Figure 63. High tide laps at the eroded face of foredunes at Pauanui.


Figure 64. Flooding of the Lakes golf course adjacent to the Waterways canals development.


Figure 65. Flooded access road, Pauanui.

location: 30min flight, or approximately 2 hour drive from Auckland
initial development: 1967
developers: Hopper Brothers
Pauanui was the first development of its kind, where developers attempted a ‘garden’ subdivision. It is different to the typical/traditional 1960s coastal developments with their ‘grid-like row of sections close to the beach front with minimum supporting infrastructure’ (Peart). The design was done by Frank Easdale, a surveyor, who implemented design controls, provided recreational activities and started the Pauanui Club. The results were more reminiscent of a garden suburb than a coastal village. The first part to be developed was the airstrip across the centre of the spit to provide access. The bulk of the spit was developed at the same time within a network of wide double carriageway streets. The properties stretch to the very outer limits of the development envelope. Further extensions have been made more recently at the heel of the spit with the construction of a canals development. The ‘Waterways canals development’ began in the 1990s and there are still many undeveloped sections.

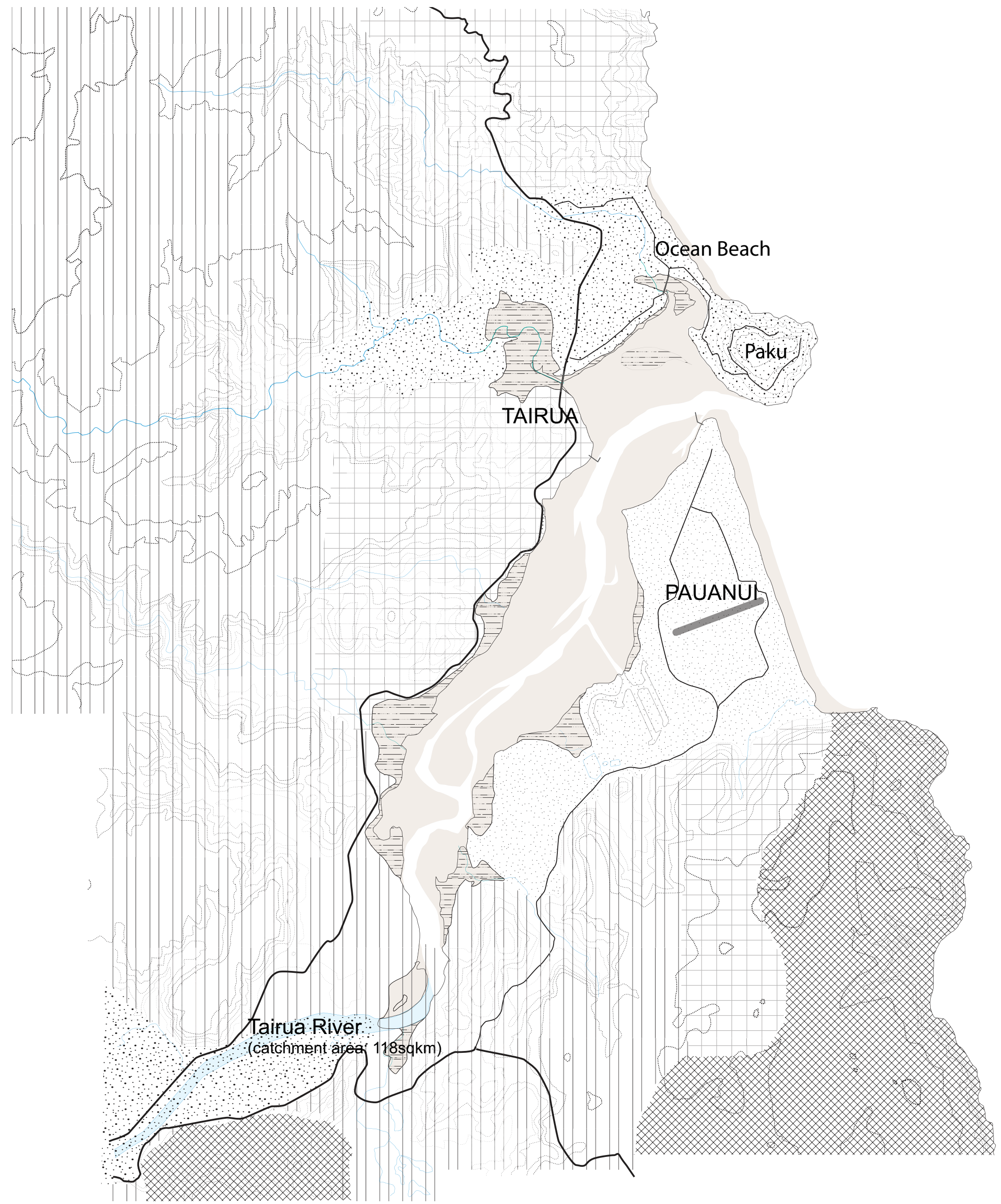


Figure 66. **GEOMORPHOLOGICAL ANALYSIS**
adapted from GNS

Pauanui has formed across the mouth of the Tairua river between the hard material of Paku and the surrounding hinterland. Ocean beach has also formed between Paku and the harder material to the north although the river outlet does not currently cross the sand bar. Pauanui is composed almost entirely of dune sand while Ocean beach is largely composed of alluvial material. Paku directs the river outflow around the tip of Pauanui.

Pumiceous Pyroclastics - Tertiary volcanics

Ryolite of dissected doves and flows
Tertiary volcanics

Andesite of flows - Tertiary volcanics

Alluvium - Late Quartenary sediments

Dune Sand - Late Quartenary sediments

Postglacial Alluvium

Sandbars/mud flats

Mangroves / Saltmarsh

Figure 67.

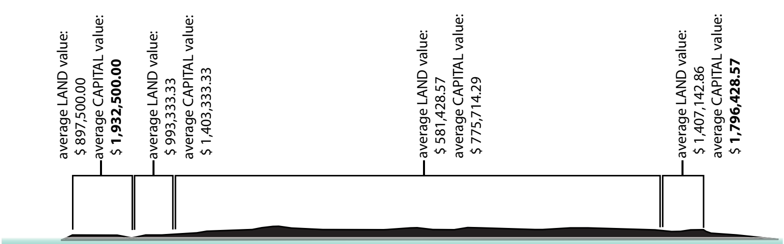


Figure 68.

Figure 69.

URBAN CHARACTER ANALYSIS

Pauanui was planned as a garden suburb, and much of the beach feel of the settlement is lost in the attempts to create a lush manicured green 'garden' settlement. The main access road feeds through the whole spit community in a loop. The spit is accessed from the heel and the dual carriageway roads were designed to be generous and have wide swales and central vegetated medians. This adds to the 'garden' suburb feel but also takes away from the sense of being in the coastal environment.

There is limited public beach access that is of high visibility due to the layout of the waterfront properties and street network. Roads tend to run parallel to the beachfront with a line of properties, often two deep, between the street and beach. This is also apparent on the inner harbour waterfront (1 & 2). There are very few streets that run directly to the beachfront. Waterfront properties tend to have a greater proportion of building coverage. The waterfront properties are most visually prominent from beach/sea and foredunes are understated to the point of being unnoticeable.

The Pauanui surf club is the focus of many beach based activities as is the Pauanui Club, an umbrella for the golf clubs, and other interest clubs and groups. Pauanui also has a shopping centre and large recreational facilities. The commercial area (3) is centralised to provide for the most developed areas of the spit. Through the centre of the Pauanui settlement is the airstrip with adjoining properties allowing for aircraft to be stored 'at home'. The development of the new Waterways canal subdivision on the inner shore at the heel of the spit still has sections that are not developed.

Number of sections: 2,116
Number of houses built: 1,911
Number of undeveloped sections: 205
Number of permanent residents: 699 (population report, Jan 2005)
Number of peak residents (Christmas/New Year period): 11,926 (population report, Jan 2005)

Figure 70.

Figure 71. Modified dunes.

Figure 72. Waterfront reserve and modified dunes.

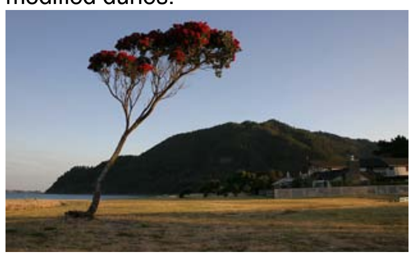


Figure 73. Waterfront reserve.

Figure 74. Pauanui Airstrip.

Figure 75. Stream outlet at southern end of spit

GREEN SPACE CHARACTER ANALYSIS

Pauanui has a network of green space pathways that link through the neighbourhood blocks to larger inland open space areas and to the waterfront reserves. The development was planned for the whole spit from the outset, the development covers the whole area uniformly.

The larger open spaces are situated at the centre of the settlement, pushing the developed area further towards the delicate edge. Golf courses are an important recreational draw-card and there are two separate courses, with the second being developed alongside the Waterways development on the inner harbour heel of the spit. There are extensive recreational facilities provided for the residents of Pauanui including an indoor sports complex.

The foredunes at Pauanui have been highly modified and appear more like a grass berm than natural dune environments. The larger exotic trees that frame the houses visible from the shore, adds to the more developed feel of the beach. The waterfront reserve area provides coastal open space that is flat and highly modified, the seaward-most edge is a dune-like bank with some native sand vegetation. The waterfront reserve area along the harbour shore is even narrower than the seaward area, the calmer waters likely encouraging the closer proximity of waterfront properties to the water.

At the southern end of the spit on the seaward side the outlet of the stream is 'daylighted' into public openspace. Prior to this point it runs between property boundaries and under the road, largely out of public view.

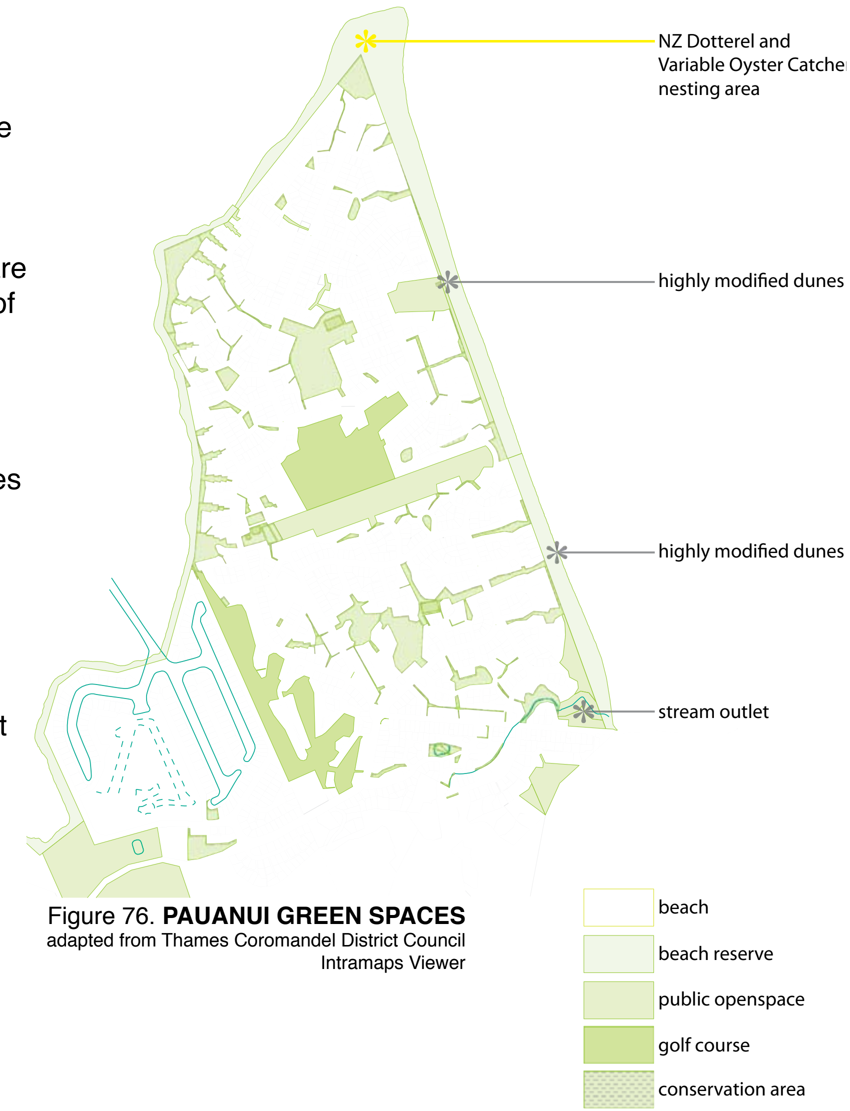
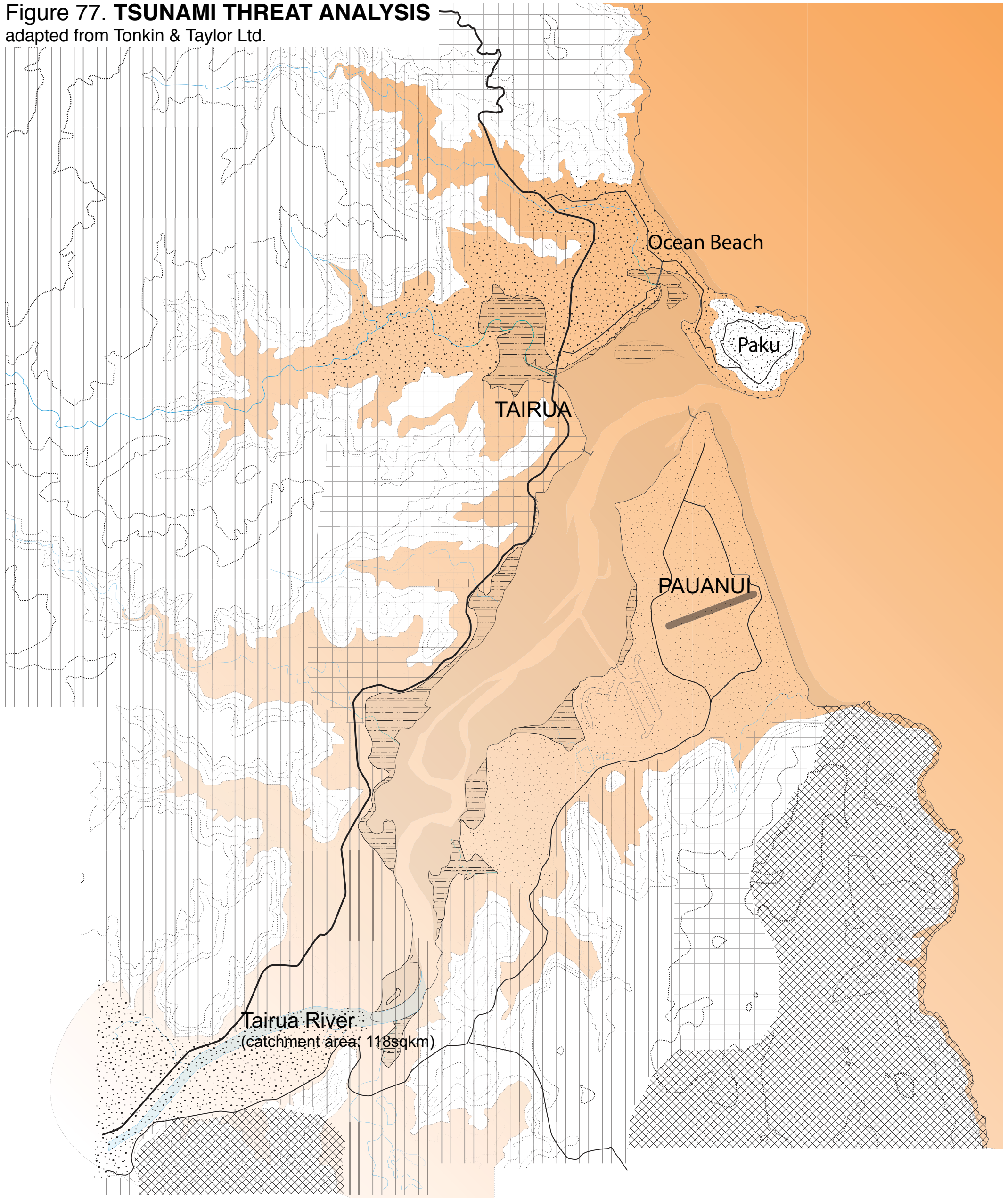


Figure 76. **PAUANUI GREEN SPACES**
adapted from Thames Coromandel District Council Intramaps Viewer

Figure 77. **TSUNAMI THREAT ANALYSIS**
adapted from Tonkin & Taylor Ltd.



Pauanui is at the northern end of the arc of the Bay of Plenty and has few outer-lying islands that would provide protection from tsunami. Slipper Island and Shoe Island may provide some protection from the wave surge. Any wave surge would run up Tairua River and cause damage far further inland due to the 'bore' effect created in narrow waterways.

Tsunami triggered in Chile would have the most direct route to the coast. The Coromandel Peninsula would provide some protection from waves from Indonesia.

The Bay of Plenty has a history of tsunami triggering events, such as landslides below the sea and earthquakes generated by the action of the subduction zone that dissects the bay. Locally triggered tsunami arrive much faster and can be much larger.

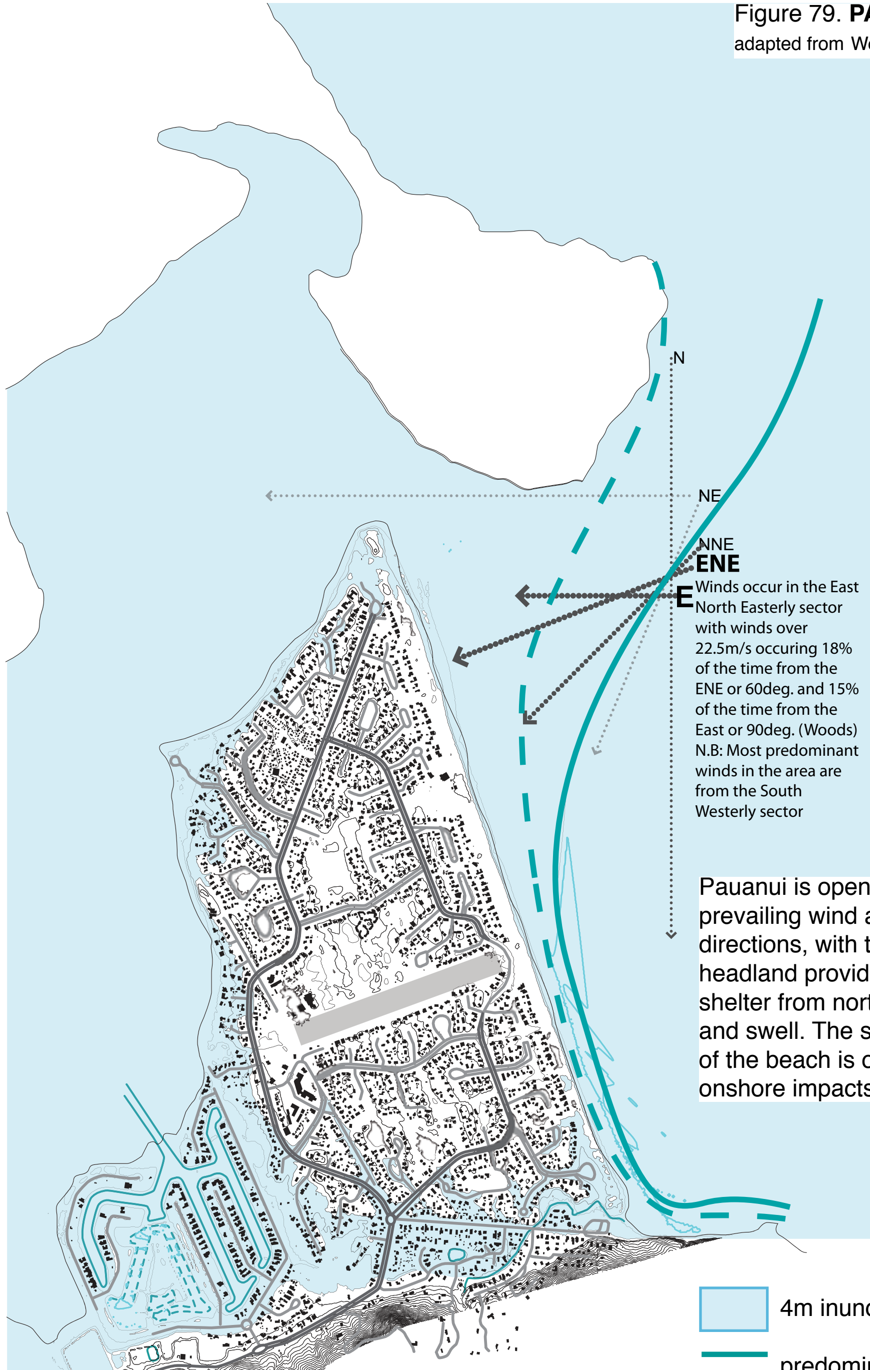
The largest locally-triggered wave on record was generated in the Bay of Plenty, and was 14m high in the Auckland area (ARC), and would have arrived at Pauanui within seconds of the triggering event.

Tsunami threat zone: 40m above MSL/1km inland

Outlying Islands

Figure 78. adapted from Google Maps 2010

Figure 79. **PAUANUI COASTAL THREATS**
adapted from Wood 2010



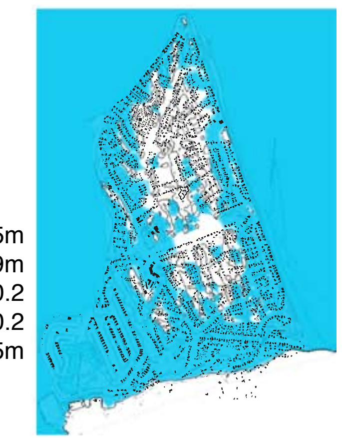
Pauanui is open to the prevailing wind and wave directions, with the northern headland providing some shelter from northly winds and swell. The southern end of the beach is open to all onshore impacts.

Figure 80-84. **IMPACTS OF SEA LEVEL RISE**
adapted from MFE

Mean Sea Level = 0.0m

Mean Sea Level = 0.0m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

IPCC SLR 2100 = 0.5m
Storm Surge = 0.9m
ENSO = 0.2
Low pressure = 0.2
Significant Wave Height = 3.5m



IPCC SLR 2050 = 0.2m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2
Significant Wave Height = 3.5m

WORST CASE SCENARIO
IPCC SLR 2100 = 0.88m
Storm Surge = 1.0m
ENSO = 0.25m
Low pressure = 0.3m
Significant Wave Height = 4.0m+

RESILIENT ATTRIBUTES:

1. Pedestrian-focused network of walkways through the residential area.

2. Large open spaces at the beach front, visible and accessible.

3. Central commercial area and community facilities centralized within development area.

4. Open space and road acess to higher ground from the spit.

5. Access from spit heel.

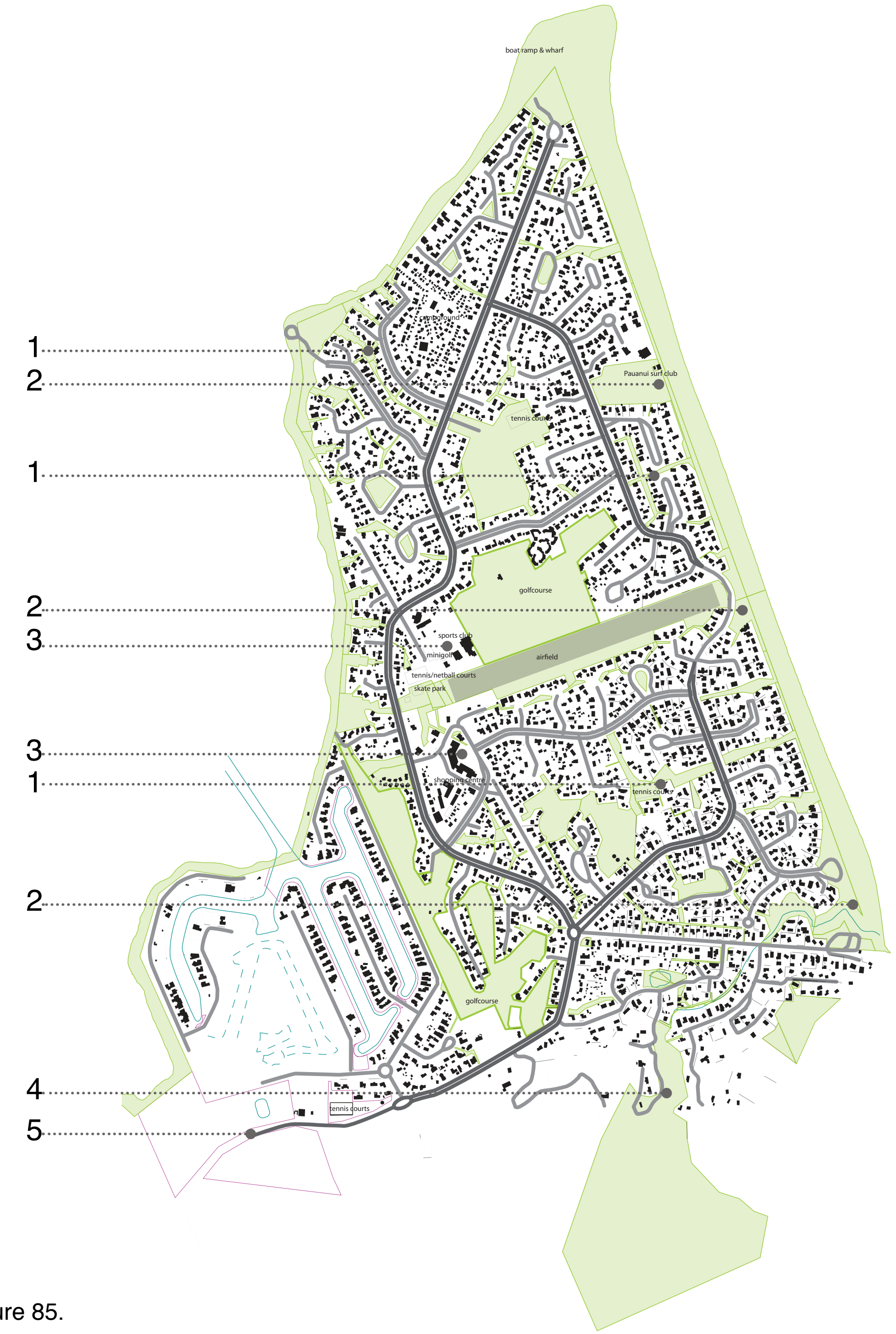


Figure 85.

Building in sand spit environments is, in itself, a maladaptive practice. The shifting and dynamic nature of these landforms means that any development will compromise their adaptive capacity simply through limiting this responsive shifting.

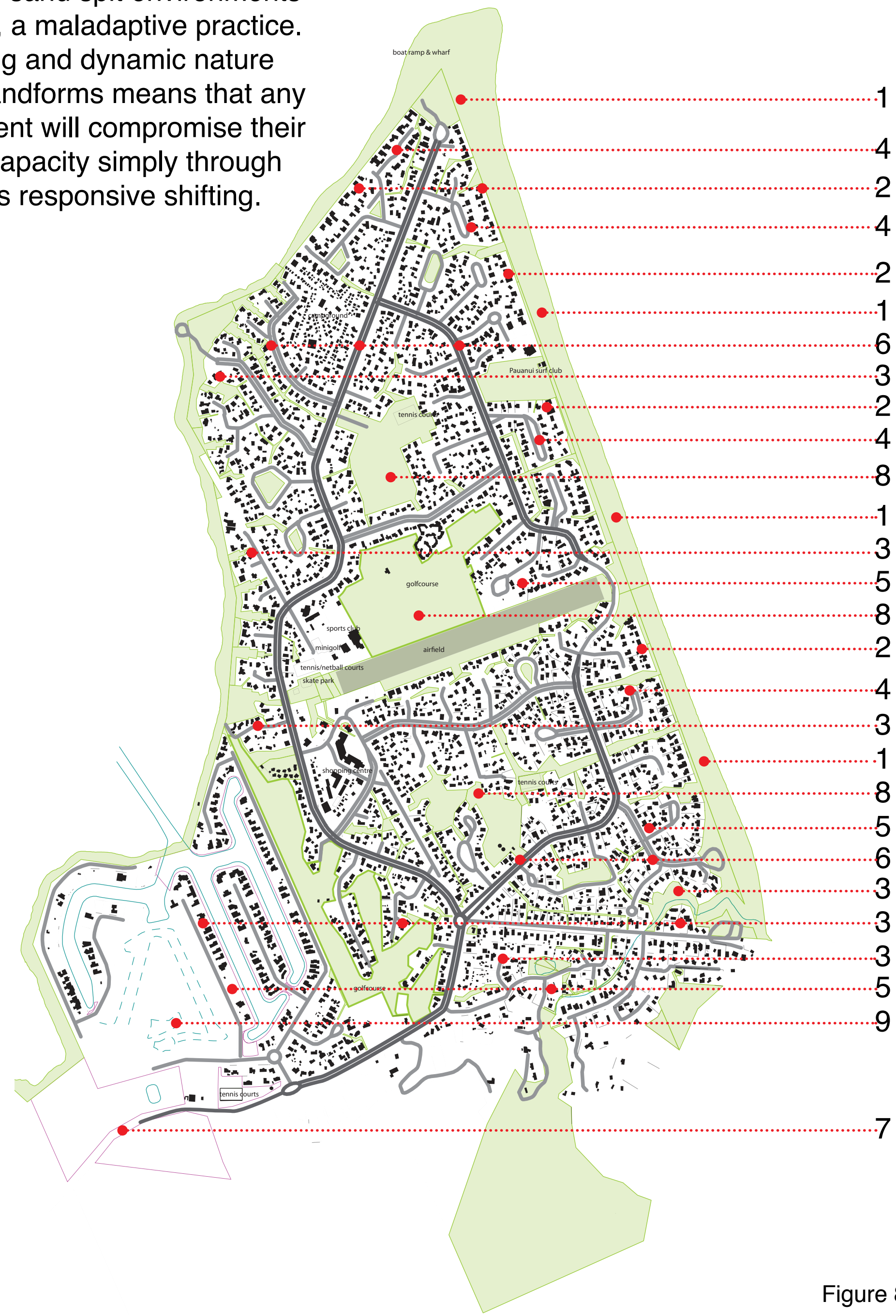


Figure 86.

MALADAPTIVE ATTRIBUTES:

1. Modifiying and lowering the dunes, especially the foredunes. Lowering of the foredunes to increase views also means the protective barrier is compromised.

2. Building too close to the beach, often within the foredunes and potential inundation areas. Harbour beach properties are prone to erosion of the coastal bank.

3. Building houses in low-lying areas vulnerable to inundation and flooding.

4. Streets running parallel to beach front, with a two-property barrier between street and beach, further limits the access to, and legibility of, access to the beach.

5. The street layout is not conducive to connectivity. No clear neighbourhood blocks and lack of legibility makes these residential areas very closed.

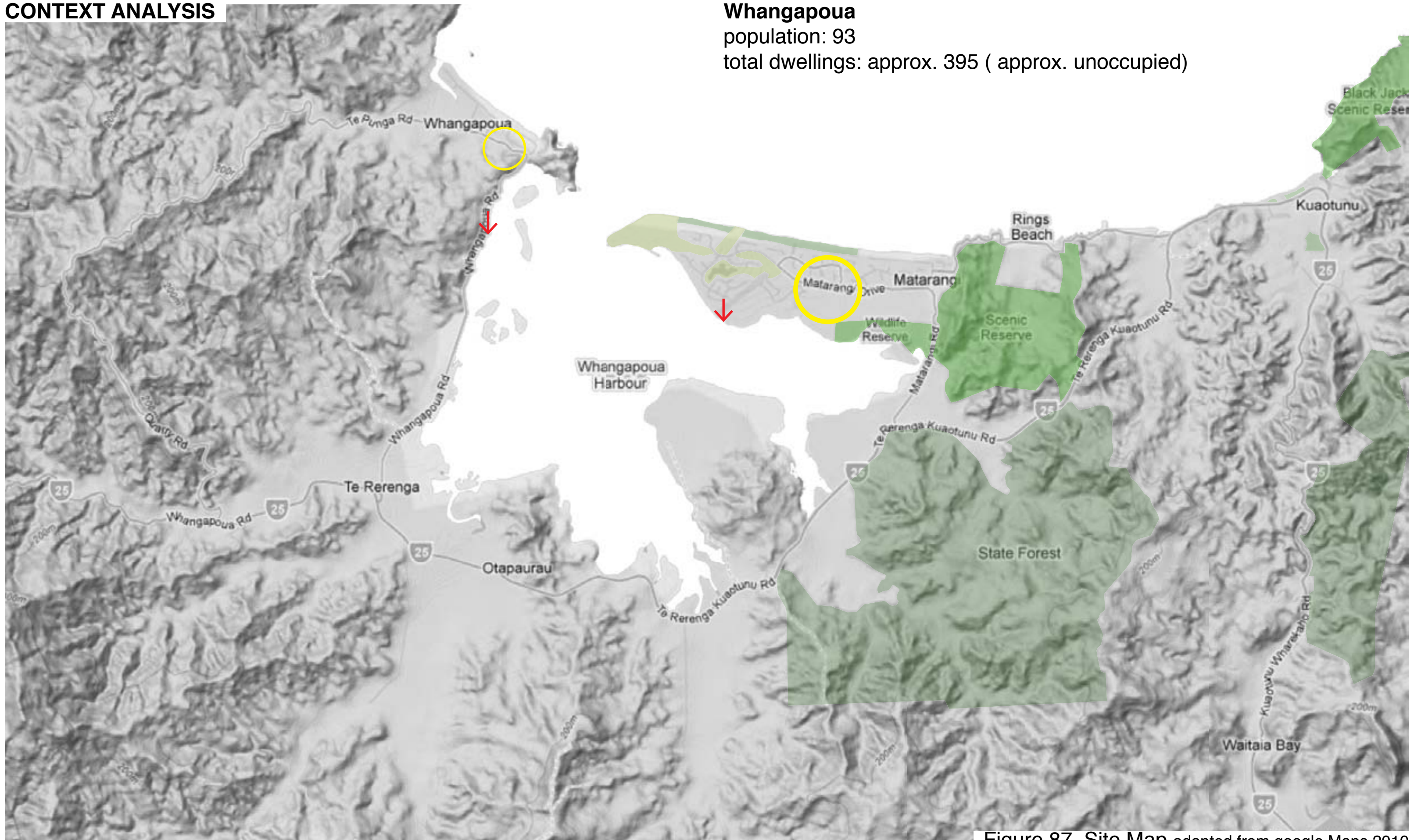
6. Dual carriage way roads increase the hard surface area and therefore stormwater run off.

7. Single access point creates a potential deadlock in the event of necessary evacuation. The access road is prone to severe flooding.

8. Large open spaces at the centre of the spit focus development to the edges, hardening them and making them less flexible.

9. The Waterways canal development is built entirely on lowlying reclaimed land making it highly vulnerable to flooding and land subsidence.

CONTEXT ANALYSIS



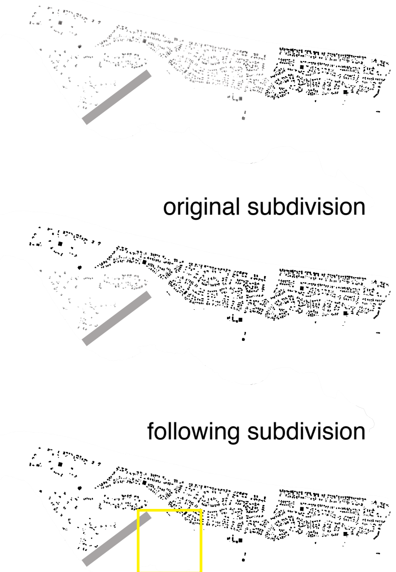
Whangapoua
population: 93
total dwellings: approx. 395 (approx. unoccupied)

Figure 87. Site Map adapted from google Maps 2010

Figure 88. **Figure ground of the Development PHASES**
adapted from Peart 2009

commercial areas
public boat ramp/wharf

forestry
D.O.C. scientific reserve
golf course
waterfront reserve
wildlife reserve



original subdivision

following subdivision

new subdivision started

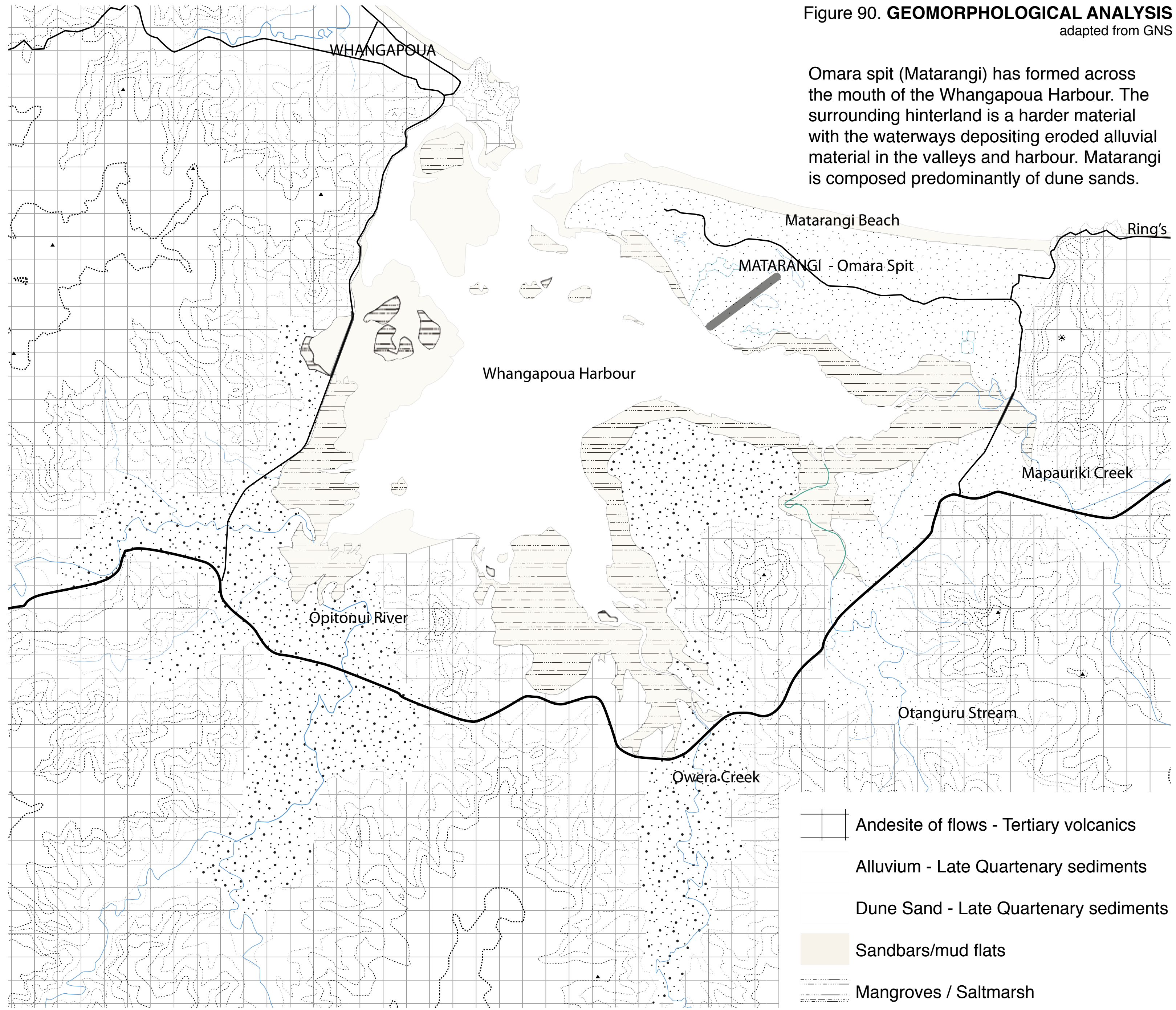
most recent subdivision

Figure 89. Flooding on the main Matarangi access road.

location: 30min flight, or approximately 2 hour drive from Auckland
initial development: 1978
developers: Ken Woodhead & Warrick Keddle
The development of Matarangi sand spit was first proposed in the early 1970s but didn't take off until the mid 1990s with the development of a world-class golf course at the spit tip. Lindsay Gow, a council planner at the time of the initial development proposal, had a vision of clusters of houses set back from the coast leaving large parts of the spit unmodified. New Zealand wasn't ready for this forward thinking strategy and still wanted to build as close as possible to the sea. The original sections were therefore built close to sea, dunes lowered for views and flat sections leaving these properties highly threatened by erosion and inundation. Later waterfront properties toward the spit tip were developed with much larger setbacks. The seaward side of the spit was the first to be developed with new areas of development emerging more recently on the inner harbour side, still with many empty properties. There are fears in the community that the sand spit is already over developed, but the Thames Coromandel District Council believes it can handle much more development. This difference of opinion reached the courts in 2000 when further subdivision of the eco-sensitive wetland area, planned by Matarangi Beach Estates, is being opposed in the environment court by the Matarangi Ratepayers Association.

Figure 90. **GEOMORPHOLOGICAL ANALYSIS**
adapted from GNS

Omara spit (Matarangi) has formed across the mouth of the Whangapoua Harbour. The surrounding hinterland is a harder material with the waterways depositing eroded alluvial material in the valleys and harbour. Matarangi is composed predominantly of dune sands.



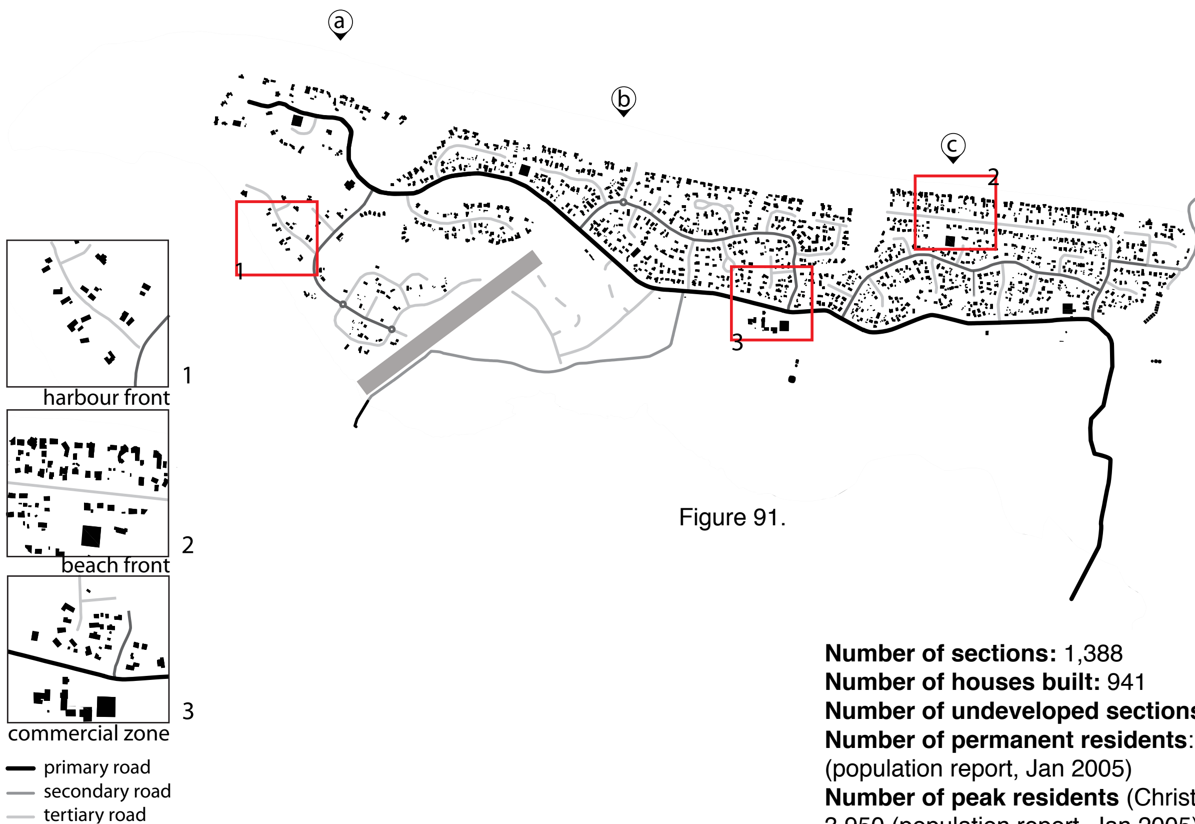


Figure 91.

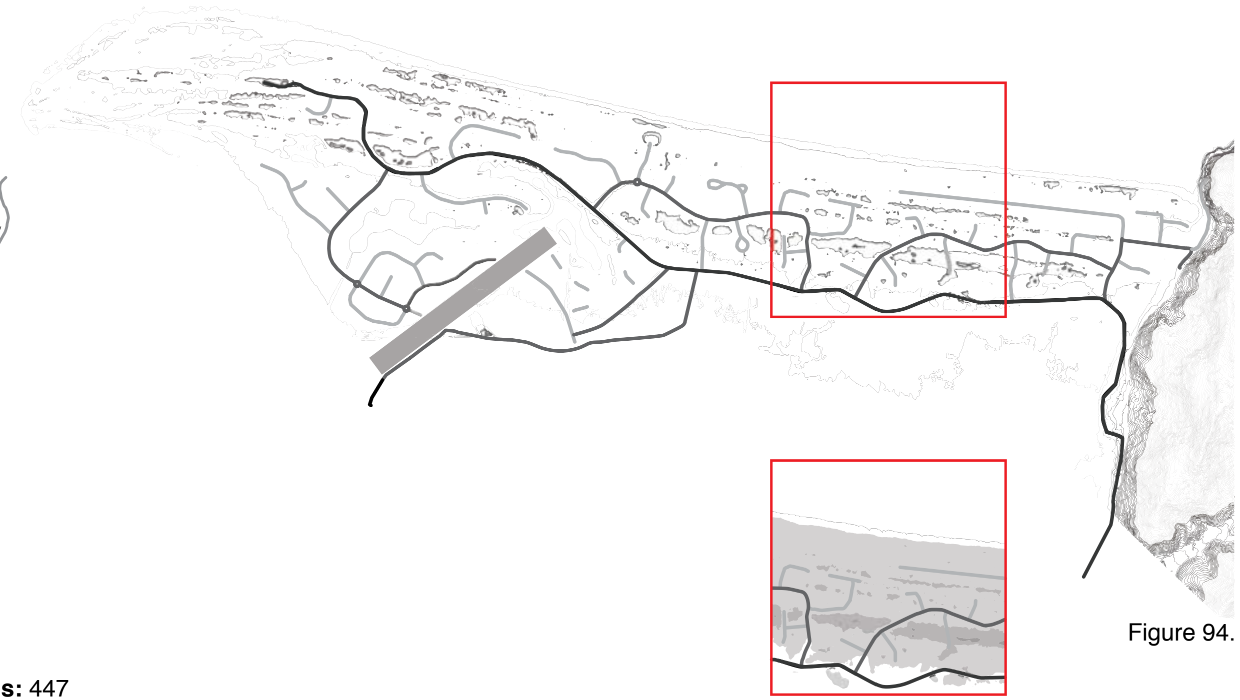


Figure 94.

Number of sections: 1,388
Number of houses built: 941
Number of undeveloped sections: 447
Number of permanent residents: 99
(population report, Jan 2005)
Number of peak residents (Christmas/New Year period):
3,950 (population report, Jan 2005)

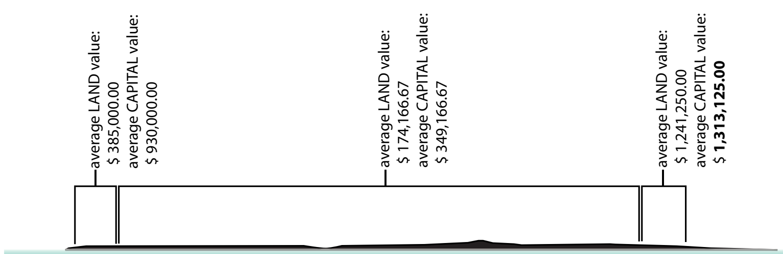


Figure 92.

Figure 93.

URBAN CHARACTER ANALYSIS

Matarangi is accessed from the spit heel, and the main access road feeds through the whole spit community. There is also access along a narrow coastal road linking to beach communities further to the southeast. There is relatively limited public beach access that is of high visibility due to the layout of the waterfront properties and street network. Roads tend to run parallel to the beachfront with a line of properties, often two deep, between the street and beach. This is also apparent on the inner harbour waterfront (1 & 2). There are very few streets that run directly to the beachfront without being interrupted. Waterfront properties tend to have a greater proportion of property covered by building. The waterfront properties are visually prominent from beach/sea and the foredunes are understated to the point of being unnoticeable. The community is based around the recreational facilities provided, primarily the golf club, but also the shopping centres and larger recreational facilities. The commercial area (3) is centralised to provide for the most developed areas of the spit. There is an airstrip with the adjoining properties having direct access allowing for aircraft to be stored 'at home'.

Matarangi has new subdivisions that are not fully developed with many sections lying empty. A further subdivision has been laid out though building is yet to commence on any sections.


Figure 95. Waterfront reserve, highly modified dunes.


Figure 96. Beach access across highly modified dunes.


Figure 97. Low dunes at the spit tip.

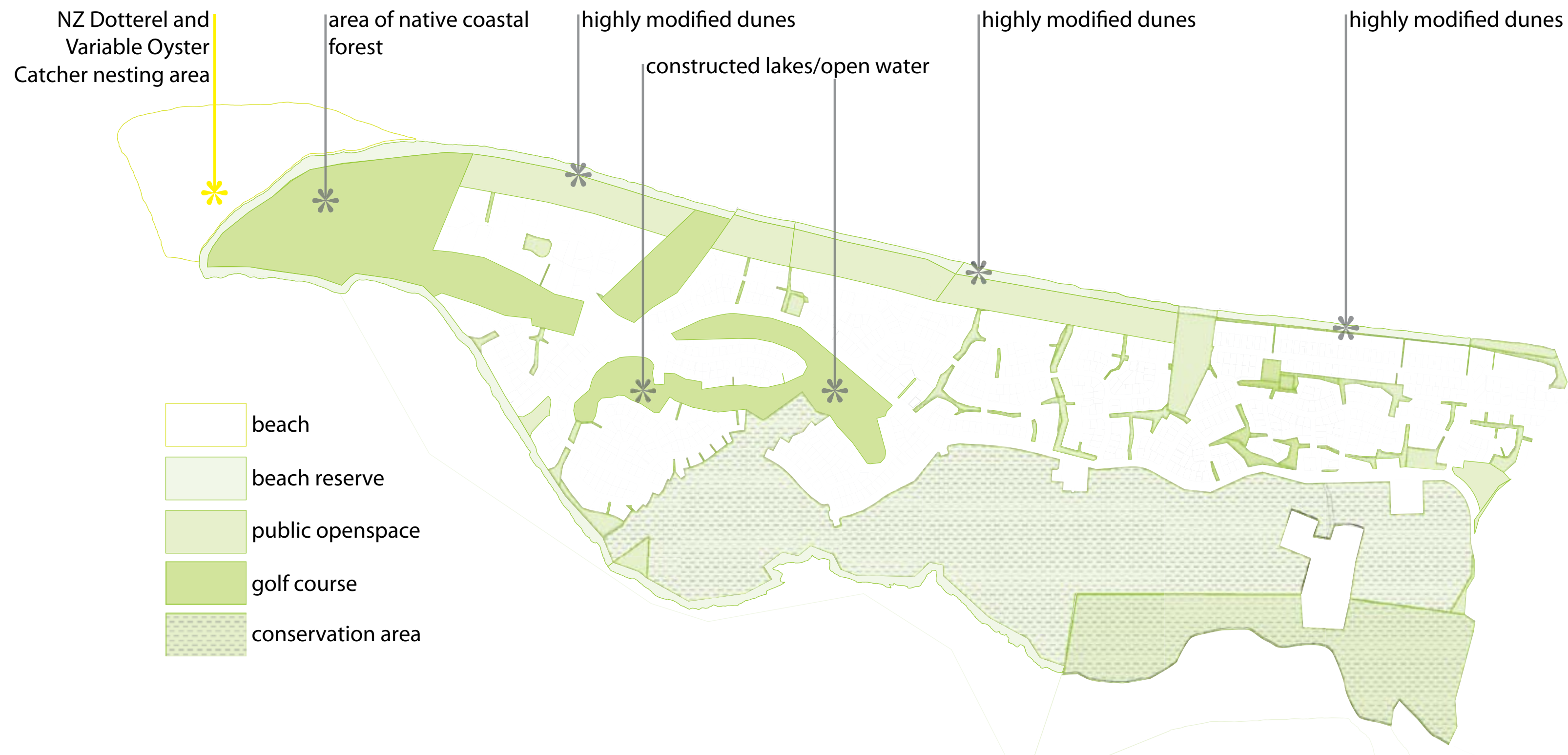


Figure 100. **MATARANGI GREEN SPACES**
adapted from Thames Coromandel District Council Intramaps Viewer


Figure 98. Matarangi airstrip.


Figure 99. Waterfront reserve.

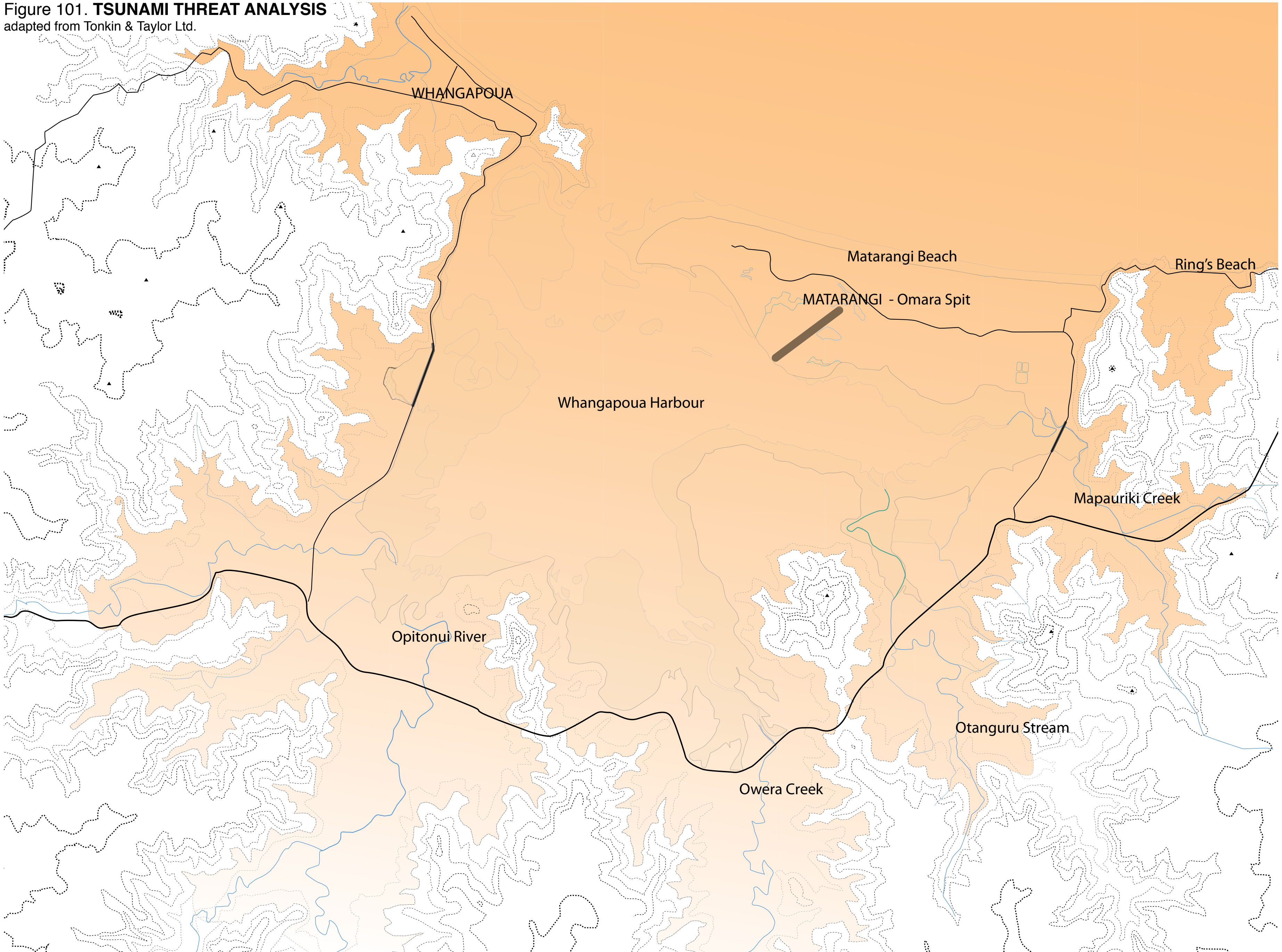
GREEN SPACE CHARACTER ANALYSIS

Matarangi has a network of green space pathways that link through the neighbourhood blocks to larger inland open space areas and to the waterfront reserves. The golf courses are an important recreational draw card for Matarangi. The original golf course was developed as part of the exclusive spit tip subdivision that provided far larger properties and separate recreational opportunities like tennis and bowls facilities for its residents. The course is now a links course, with the extension being developed as part of a new subdivision.

There are large areas of conservation-worthy native wetland and salt marsh ecologies on the inner harbour shore, with only a small part of the southern edge in conservation reserve. The spit tip is an important breeding and nesting habitat for endangered shore birds such as the NZ dotterel and the variable oyster catcher.

The foredunes at Matarangi have been highly modified and appear more like grass berms or gardens than natural dune environments. The larger exotic trees that frame the houses visible from the shore also add to the more developed feel at the beach. The beachfront reserve at Matarangi shows evidence of lessons learned in regards to setbacks of waterfront properties. Although the inner harbour waterfront reserve is much narrower, it is no less threatened by erosion or inundation.

Figure 101. **TSUNAMI THREAT ANALYSIS**
adapted from Tonkin & Taylor Ltd.



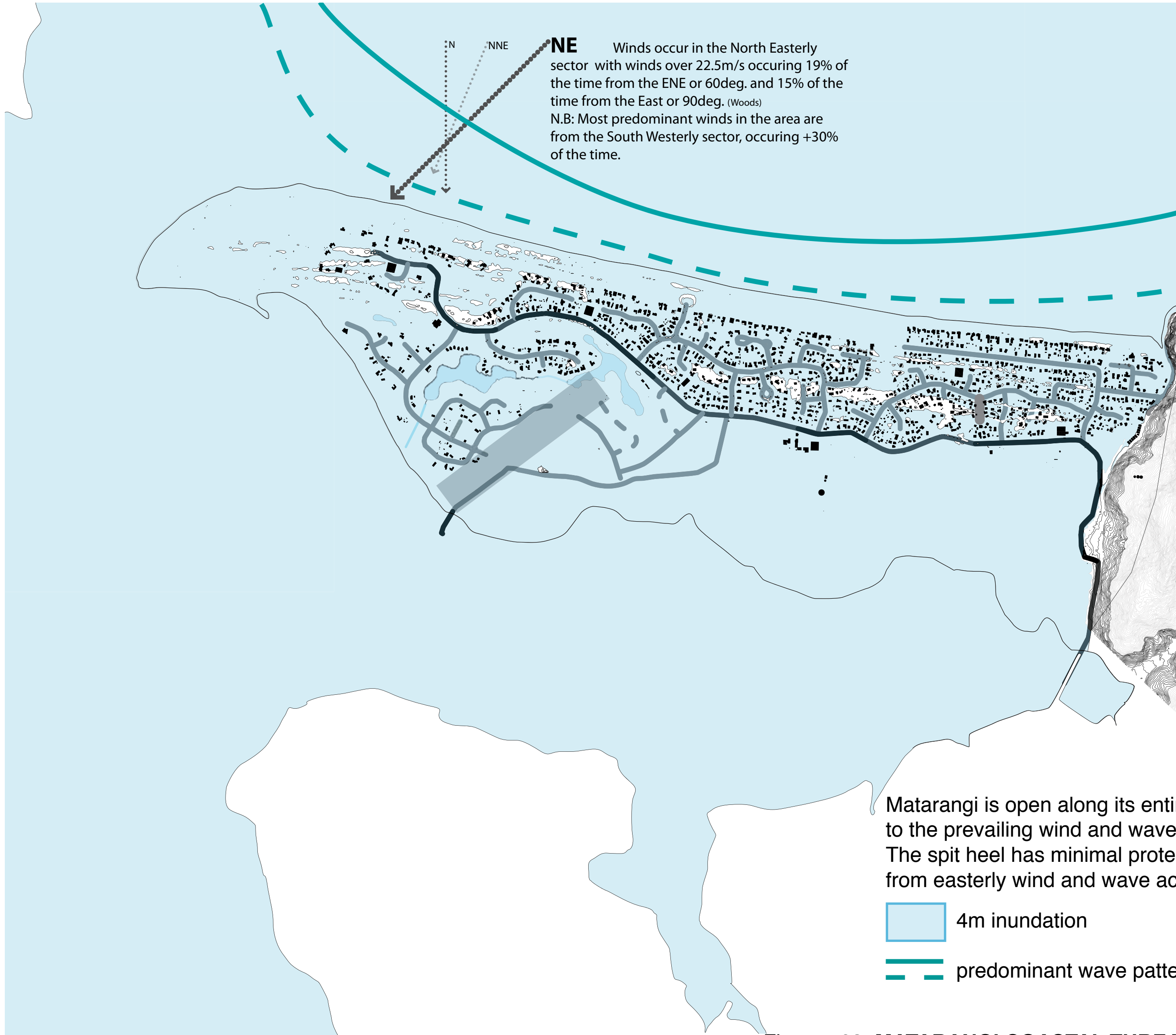
Matarangi is within the Bay of Plenty, well to the northern end of the arc, and is therefore vulnerable to local tsunami threats triggered within the bay. The Bay has a history of tsunami triggering events, such as landslides below the sea and earthquakes generated by the action of the subduction zone that dissects the bay.

Tsunami triggered in Chile would have the most direct route to the coast, and the Coromandel Peninsula would provide some protection from waves from Indonesia. Locally triggered tsunami arrive much faster and can be much larger.

The largest locally-triggered wave recorded was generated in the Bay of Plenty, and was 14m high in the Auckland area (ARC), and would have arrived at Matarangi within seconds of the triggering event.

Tsunami threat zone: 40m above MSL/1km inland

Figure 102. adapted from Google Maps 2010



Matarangi is open along its entire length to the prevailing wind and wave patterns. The spit heel has minimal protection from from easterly wind and wave action.

4m inundation

predominant wave pattern

Figure 103. **MATARANGI COASTAL THREATS**
adapted from Wood 2010

Figures 104-108. **IMPACTS OF SEA LEVEL RISE** adapted from MFE & IPCC

Mean Sea Level = 0.0m

Mean Sea Level = 0.0m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

IPCC SLR 2050 = 0.2m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2
Significant Wave Height = 3.5m

IPCC SLR 2100 = 0.5m
Storm Surge = 0.9m
ENSO = 0.2
Low pressure = 0.2
Significant Wave Height = 3.5m

WORST CASE SCENARIO
IPCC SLR 2100 = 0.88m
Storm Surge = 1.0m
ENSO = 0.25m
Low pressure = 0.3m
Significant Wave Height = 4.0m+

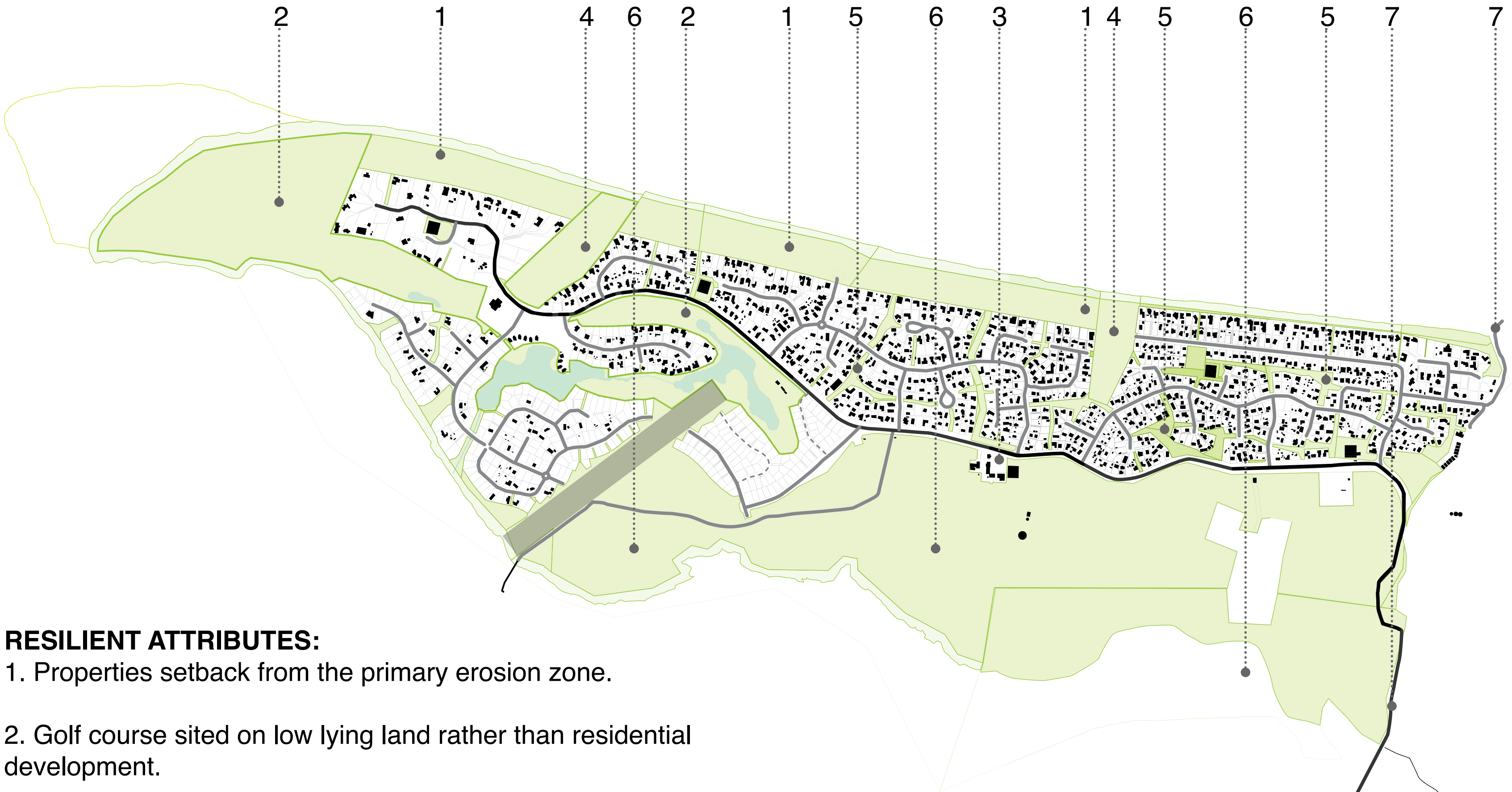


Figure 109.

RESILIENT ATTRIBUTES:
1. Properties setback from the primary erosion zone.

2. Golf course sited on low lying land rather than residential development.

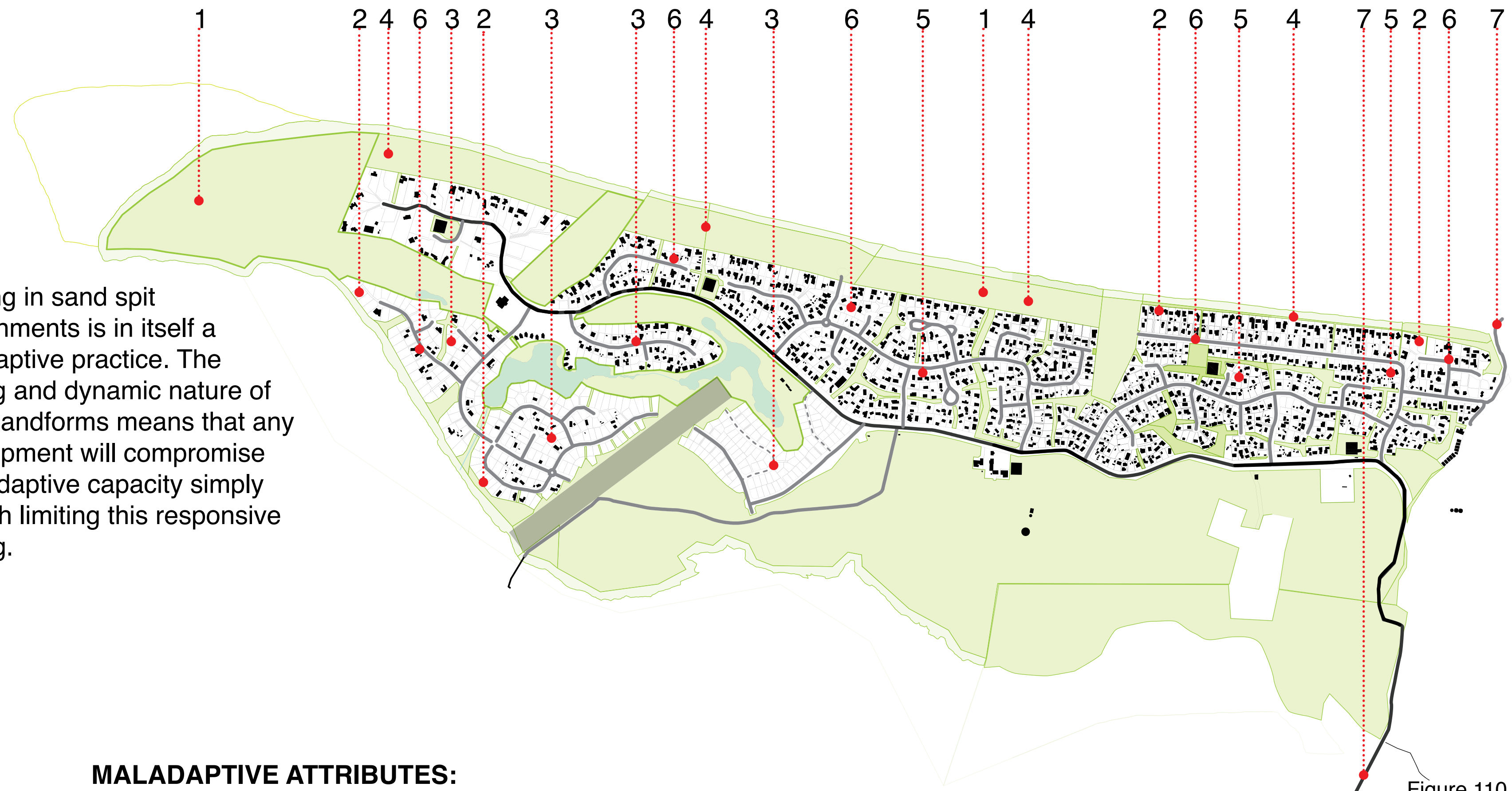
3. Central commercial area and community focus.

4. Provision of open space in dune areas allowing for the potential extension of dune ecologies back from beaches.

5. Provision of a pedestrian-focused green network of walkways throughout residential areas.

6. Non-development of sensitive low-lying wetland and saltmarsh ecosystems.

7. Two points of access to spit from the heel.



Building in sand spit environments is in itself a maladaptive practice. The shifting and dynamic nature of these landforms means that any development will compromise their adaptive capacity simply through limiting this responsive shifting.

Figure 110.

MALADAPTIVE ATTRIBUTES:

1. Modifying the dunes and developing highly managed open spaces, such as golf courses, in sensitive and dynamic areas of the sandspit.

2. Building too close to the beach, often within the foredunes and potential inundation areas. Harbour beach properties are prone to erosion of the coastal bank.

3. Building in low-lying areas, previously sensitive wetland and saltmarsh areas. Construction of houses in low-lying areas areas vulnerable to inundation and flooding.

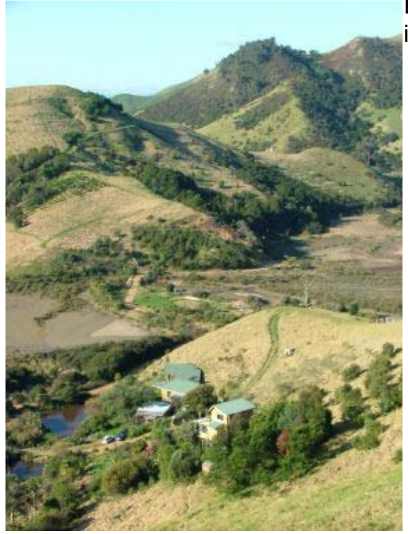
4. Lowering of the foredunes to increase views means the protective barrier is compromised.

5. The street layout is not conducive to connectivity. No clear neighbourhood blocks and lack of legibility makes these residential areas very closed.

6. Streets running parallel to beach front with a two-property barrier between street and beach further limits the access to, and legibility of access to, the beach.

7. Single main access/exit point creates a potential deadlock in the event of necessary evacuation. The secondary access/exit option leads along the exposed coast making it vulnerable to damage in the event of tsunami or severe storms.

Figure 111. Awaawaroa Bay Eco-Village, Waiheke Island, Auckland



Figures 112 & 113. Views of houses in Cluster 3.

Houses are clustered in into three groups to limit the extent of the built area and to maintain the sense of community within the larger landscape.

A community space and facilities are centralised within easy distance from any of the clusters, and provides the focus for the community.

Figure 114. View of Awaawaroa Bay.

The sensitive use of the land within the valley ensures that any run-off into the stream and bay does not contain harmful subtances or large sediment loads.

Alternative models for coastal subdivision do exist in New Zealand, though on a much smaller scale. Awaawaroa Bay Eco-Village was founded in 1994 on Waiheke Island (Figure 111), Auckland, New Zealand, and was developed in a sensitive way to acknowledge and value the landscape it inhabited (Figures 112-114). The 169 hectare property in a coastal valley is owned by fifteen shareholders so is not officially classified as a subdivision. Awaawaroa Bay Ltd. is the company formed by the shareholders. Each shareholder has title to the land and use rights for 999 years to a 1 hectare parcel to build a house and for their own use (Morton). The housing and shareholder parcels are arranged in three clusters to minimise roading needs and there are community facilities and common land to foster the village spirit (Morton). The low impact ethos is applied comprehensively and the village is off the grid, and has alternative waste, water, and composting systems (Morton). Each share has one representative in the company with equal voting rights in the decision making process for the collective (Morton). The company is very conservation and regeneration-focused in its land management processes, but shareholders can lease additional areas of the land from the company for commercial enterprises (Morton).

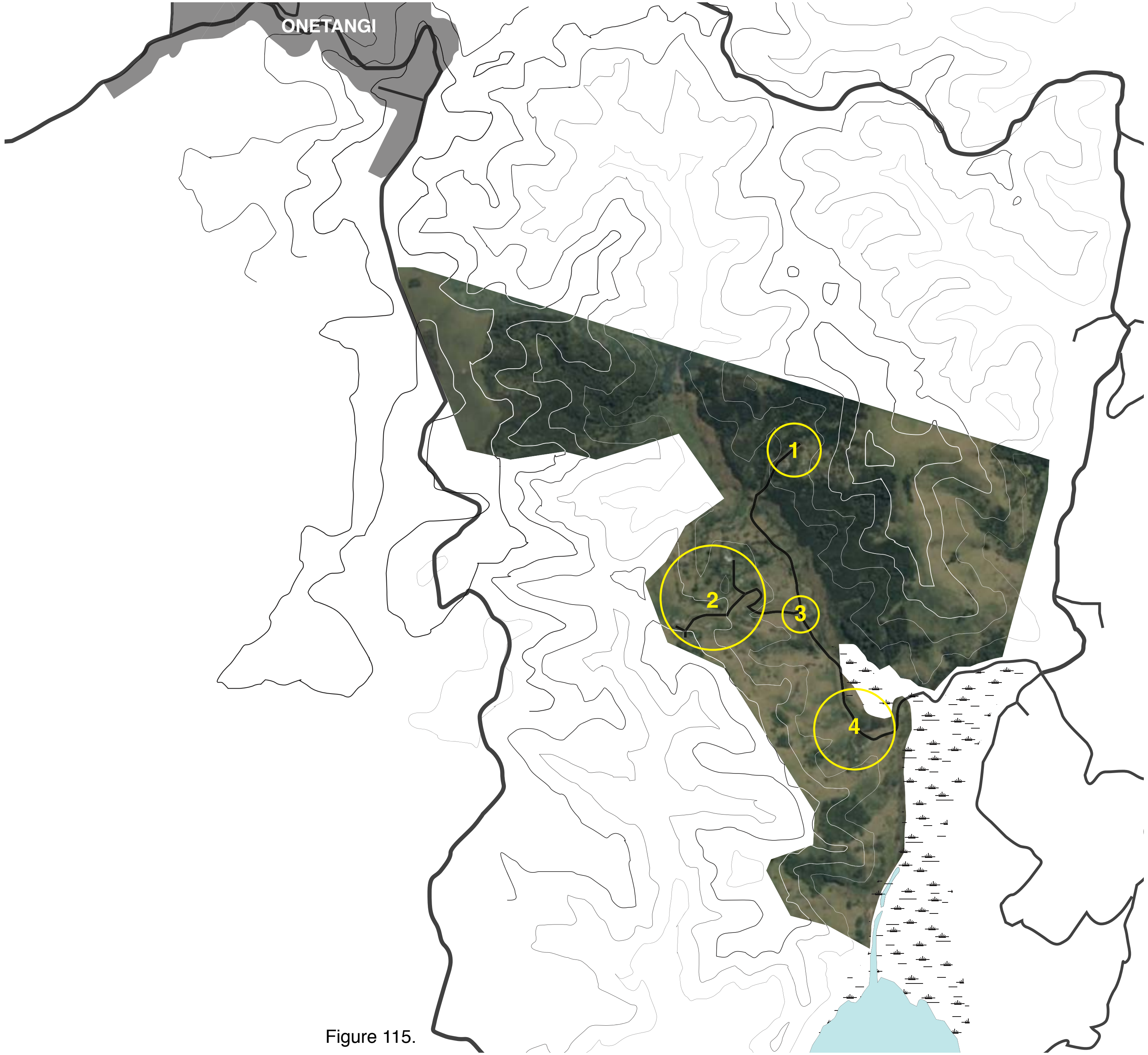


Figure 115.

1. Housing cluster

Figure 116.

2. Housing cluster

Figure 117.

3. Community Buildings.

Figure 118.

4. Housing cluster

Figure 119.

COMPARATIVE STUDY OF DEVELOPMENT STYLES:

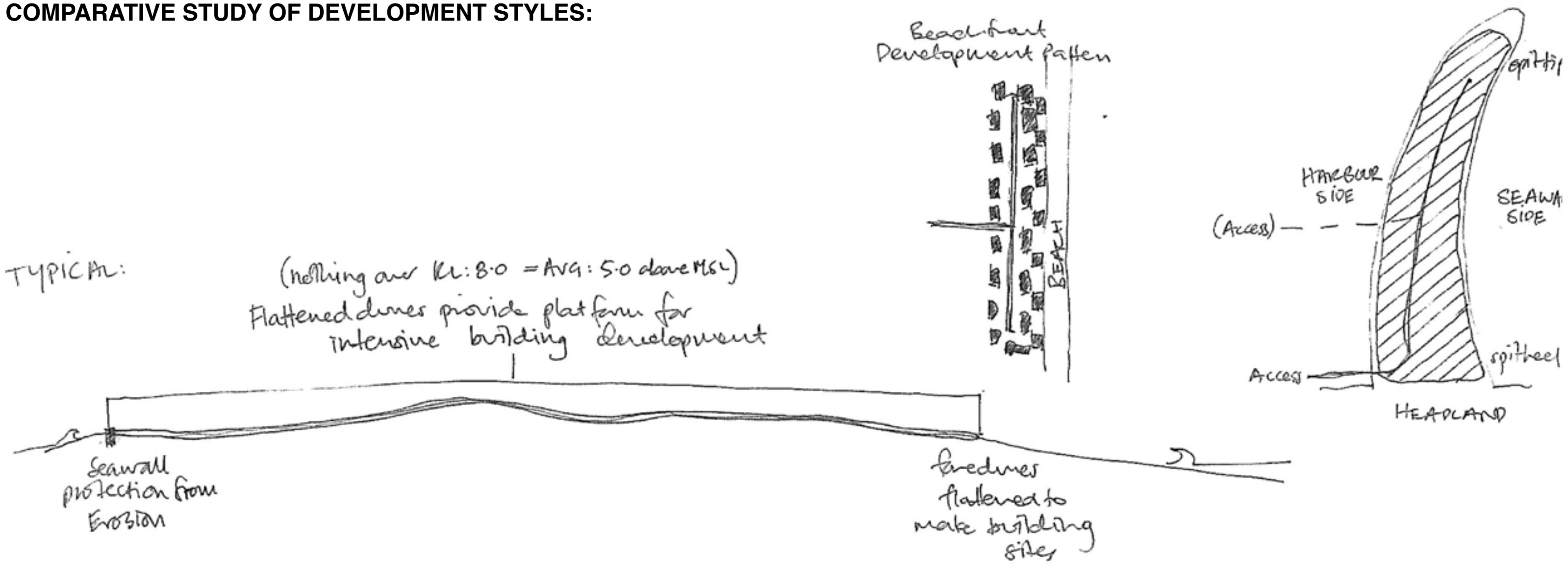


Figure 120. Transectional study of a heavy development model, utilising the extent of the available land area.

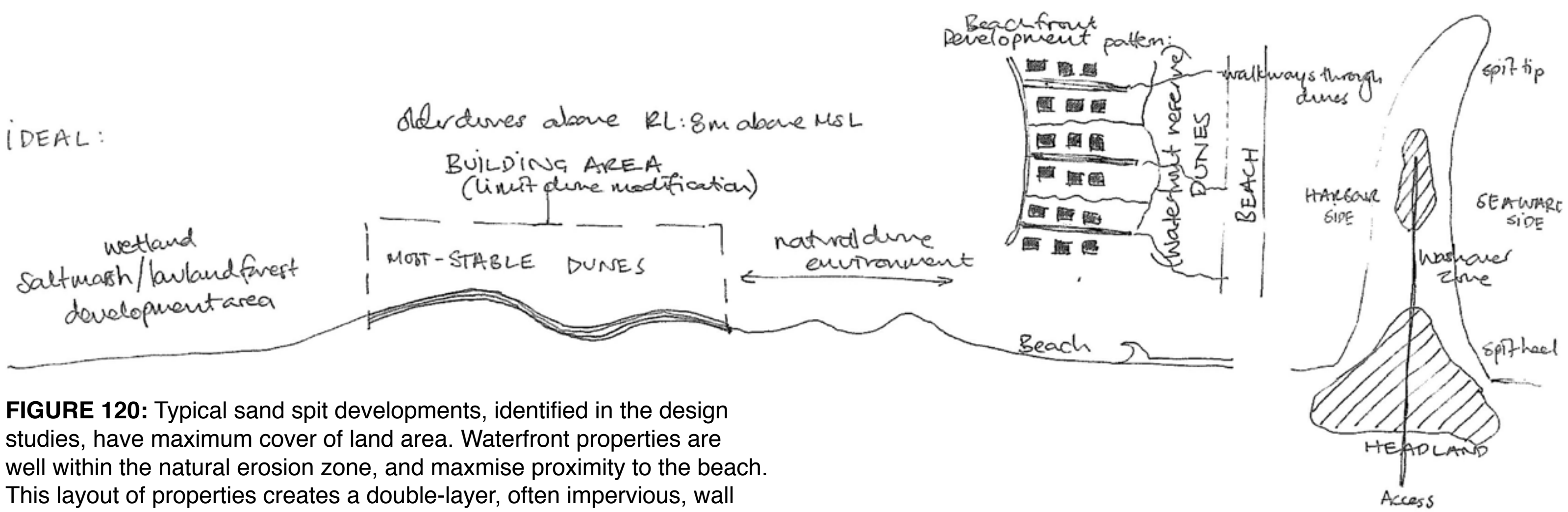


Figure 121. Study of a more ideal development model for a sand spit.

FIGURE 120: Typical sand spit developments, identified in the design studies, have maximum cover of land area. Waterfront properties are well within the natural erosion zone, and maxmise proximity to the beach. This layout of properties creates a double-layer, often impervious, wall along the length of the beach. Access to the beach is limited to those not owning waterfront properties and hence the value of these sections is high. The dwellings constructed on the majority of these sections, especially since the 1990s, fill much of the available land area, often over two or more levels.

These dense rural suburbs typically only have one access point, and it is often vulnerable to flooding or washout.

FIGURE 121: A more sensitive approach to development in these environments would cluster the sections in smaller areas with the largest, most dense area being on or directly adjacent to the solid hinterland at the spit heel. The access would then be through this cluster and the majority of the population would be outide the areas vulnerable to inundation. In this model all streets would run to the beach and properties would be aligned to provide maximum access to all users. Set backs from the dunes would alllow for inundation without significant impacts.

1. Intensity and rigidity of development footprint:
There are many maladaptive trends evident in all of the presented cases. The diminishing flexibility of the sand spit under the developed area is a major issue in the face of climate change and its associated impacts. The developed area is locked down and the acceptable layout is managed to ensure that built up areas are not altered by coastal interferences. This lack of flexibility is further exacerbated by a lack of awareness of, or lack of appreciation for, the natural coastal processes. These cases are a replication of an urban environment on the coast, at odds with the surroundings and, in many ways, at odds with the intentions of a coastal holiday resort. The density of the development over large areas and the necessary roading infrastructure results in greater areas of impervious surfaces. This heavy development model locks down large areas of the spit.

2. Building within the erosion zone:
The delineation of property boundaries and the construction of large dwellings further create a development footprint that is rigid and unresponsive. Property boundaries do not respond to changes in the level of Mean High Water Springs (MHWS), the traditional datum for laying out coastal properties. This results in the cycle of accretion and erosion significantly changing the relationship built structures have with the coastal edge. Omaha and Matarangi both have areas of early development that are set well within the currently accepted coastal hazard area, where erosion is a significant identified threat, and later development is setback further from MHWS. Pauanui has no such changes in setback distances as the whole settlement was laid out at once; this has created an almost uniform edge. Pauanui is also an example of a development that flattened the existing dunes to create desirable building footprints. The waterfront properties have been laid out on the foredunes to gain maximum proximity to the beach, making the properties vulnerable to coastal hazards. This lack of regard for the coastal dune system and its protective role is now recognised as maladaptive.

3. Vulnerable single point of access:
All three cases also have a single point of access that is threatened by inundation and wash out threats. At Omaha the causeway crosses the Whangateau harbour and is vulnerable to washouts and inundation, while Pauanui and Matarangi are accessed from the spit heel but along low-lying land prone to inundation. If these access ways become impassable, isolating the settlements, evacuation options are limited. Matarangi has a second point of access along the coast but in the case of tsunami or severe storm this would also be threatened.

4. Temporary populations:
Seasonal fluctuations in the populations of the coastal holiday resorts create their own problems. Large numbers of temporary residents and visitors flow into these settlements during the summer months often increasing the population by more than five times. These dramatic changes in population over-extend the capacity of waste systems and increase both traffic flows and pedestrian activity within these sensitive environments. During the quiet months of the year the issues of security, property management and maintenance come to the fore. As holiday homes have become larger and more valuable, also increasingly furnished with chattels of significant value, they become vulnerable. The small permanent populations of these coastal settlements are often spread out across the residential area making passive surveillance difficult. Maintenance and property management are also costs that need to be borne by the owners, and if these are not kept up to date then the deterioration of the residential atmosphere can follow.

5. The significant impact of storms:
All three cases were impacted upon by severe storms shortly after their initial conception. Pauanui and Omaha had already begun construction on some properties and these were hit hard by a series of damaging storms. In both cases the popularity of the subdivisions was not significantly

impacted upon, but at Omaha the approach to the development was altered. The foredunes were reinstated in front of the waterfront properties, though at a much lesser scale, and beach nourishment and hard engineering methods were implemented to rebuild the spit. Hard engineering responses, such as seawalls and groynes, were constructed to protect the coast from coastal threats. However, these rigid structures are reducing the flexibility and responsiveness of the coastal environment and simply contribute to locking them down and reducing their flexibility and responsiveness.

6. Maintaining property values:
The majority of properties in the three case sites are second homes and more recently they are also considerable investments. The rateable values of all the properties are well above national averages. This indicates that the demographics of these settlements is becoming increasingly affluent. Where previously the coastal holiday was accessible to all, it is becoming increasingly clear that these settlements are beyond the reach of the majority of New Zealanders.

Erosion and inundation threats to properties threaten their value. The impacts of a soft property market are further exacerbated by inundation reports that identify large areas of waterfront property as potentially vulnerable. These kinds of tensions will only increase, as sea level rise and other related climate changes continue to take effect.

MOVING FORWARD
Attitudes towards coastal development are clear. People are weary of the scarred, seasonally overpopulated, Mc-Mansionville atmosphere prevalent in these case studies, and simply believe that no development is the only way to ensure that this won't be replicated in currently untouched coastal areas. By their very nature sand spits are barrier formations - the first line of defense against coastal threats - and are ephemeral landscapes. The dunes provide a shifting protective barrier for the land beyond and once they have been compromised they are unable to fulfill this role. Development on sand spits hardens these dynamic coastal environments and cause them to become rigid and largely unresponsive to coastal threats, thus making them highly vulnerable. Early developments on sand spits typified by cases 1-3 had little concern for this protective role of the foredunes in particular.

The preservation of these landscapes must become a priority in the future, and existing developments in the coastal environment need to be retrofitted to be more responsive to climate related changes and the demands of an increasing population. Re-design of existing subdivisions to be more responsive and flexible would increase their resilience and longevity. Building new subdivisions on sand spits is not a sustainable practice in the long term.

	ISSUES	OMAHA	PAUANUI	MATARANGI	IMPLICATIONS
Intensity and rigidity of the development footprint	Density of development	approx. 45%	approx. 70%	approx. 46%	Large area developed surfaces and limited flexibility.
	Hardened edges (groynes, seawalls & properties)	approx. 55%	approx. 95%	approx. 60%	Downstream erosion and increased velocity of erosive forces along hard edge.
Building within the erosion zone	Flattened dunes (seaward side)	approx. 1.2km	approx. 4.8km	approx. 6km	Limited protection against onshore threats.
	Dwellings within setback zone	104	184	80	Dwellings threatened by erosion, unstable ground and inundation.
	Dwellings threatened by erosion	123	228	90	Dwellings being undercut and damaged due to ground subsidence.
	Public beach access points	17	16	14	Limited visibility of public access to beach due to overly developed waterfront edge.
Vulnerable single point of access	Single point of access	Causeway	Low-lying road	Low-lying road	Limited options for evacuation, bottleneck potential.
	Vulnerable to flooding, washout, etc.	Washout Flooding	Flooding	Flooding Washout	Prone to damage and flooding closing off the evacuation options for residents in case of emergency. High cost of recurring repairs.
Temporary populations	Seasonal population peaks	low: 354 high: 15,000+	low: 699 high: 11,926	low: 99 high: 3,950	Difficult to maintain property safety, maintenance with limited population in off season. Challenging for commercial businesses with large fluctuations in demand.
Maintaining property values	Buildings in low-lying areas vulnerable to inundation	164	248	91	Properties in vulnerable areas are difficult to insure and information on LIM reports can dissuade buyers.
	Average property values	$1,435,416.64	$1,476,994.02	$864,097.22	Huge financial investment in 2nd homes.

DESIGN DEVELOPMENT

Introduction

Strategy Development

Strategies:
- Scale of the Spit
- Scale of the Neighbourhood
- Scale of the Lot

Summary

The existing adaptive capacity of the three case sites is limited primarily due to the rigid nature of the development footprint.

Reducing the maladaptive trends of development identified in the design study process, and increasing the adaptive capacity of the whole sand spit, are the primary objectives of the design response. The focus is on the development of strategies across three scales to increase the adaptive capacity, and recovery ability, of both the ecological and man-made systems.

Sand spits that form across the mouths of rivers, such as Pauanui, are prone to wash-over when the river levels are increased by flooding. The increased flow levels create the most direct path to the sea, typically through the middle of the sand spit. In areas where this is a relatively regular occurrence, a recognisable low point can be identified.

Sand spits that form across the mouths of harbours, such as Omaha and Matarangi, have a lower risk of wash-over due to the lower flow levels of the waterways from the catchment area. However, in times of significant rain-fall the accumulated flow can create sufficient flow energy to impact upon the harbour edge of the spit; when combined with severe onshore storms, the potential for complete wash-over cannot be ruled out. The series of storms that impacted on Omaha, in the years after development of sections began, washed out the area of the sand spit where the dunes had been lowered, which corresponded with the primary impact-areas of the north-easterly onshore winds and swells.

The initial response to the identified threats and maladaptive trends is to increase the set-back to the development area. The development patterns identified in the case study process, harden the coastal edge through the development of sections parallel to the beach, often two deep within the foredunes. This development style creates a barrier to onshore threats and wears the full force of storm and tsunami impacts. Moving waterfront properties back from the edge, and allowing the foredunes to perform their protective role unimpeded, is a critical first step to increasing the adaptive capacity of these settlements. By removing the houses from the most vulnerable areas the direct tensions are released, and reinstating the natural dune system allows further protection to the development area behind.

This research project proposes that through the provision of open space networks that absorb the coastal dynamic and regenerate the identity and amenity of coastal settlements, the adaptive capacity of the community can be increased. Omaha is the site for the design development process. All strategies are tested at all three of the design study sites in order to assess their wider applicability and to develop a model of relevance beyond the design site.

The removal and reorganisation of a small percentage of properties will allow for the adaptive capacity of the whole sand spit to be increased. If these properties are not released the entire spit is vulnerable to the increasing impacts of climate-related change.

A series of strategies at three scales are proposed to increase the adaptive capacity of the coastal community of Omaha as a test site. The strategies are tangible approaches to reach the outcomes identified in the Nicholls and Klein framework. The development of strategies to increase the adaptive capacity of these sand spits is an iterative process of testing and re-designing. Dealing with both the natural and built environment the intention is to create a community that is both socially and ecologically rich, and resilient to climate related changes. Some strategies focus on certain components of the framework, while others incorporate the majority, together providing a complete tangible response.

stage 1. Single wash-over area in the most vulnerable area where potential freshwater out flow, and seaward onshore impacts correspond, typically in a low-lying area.

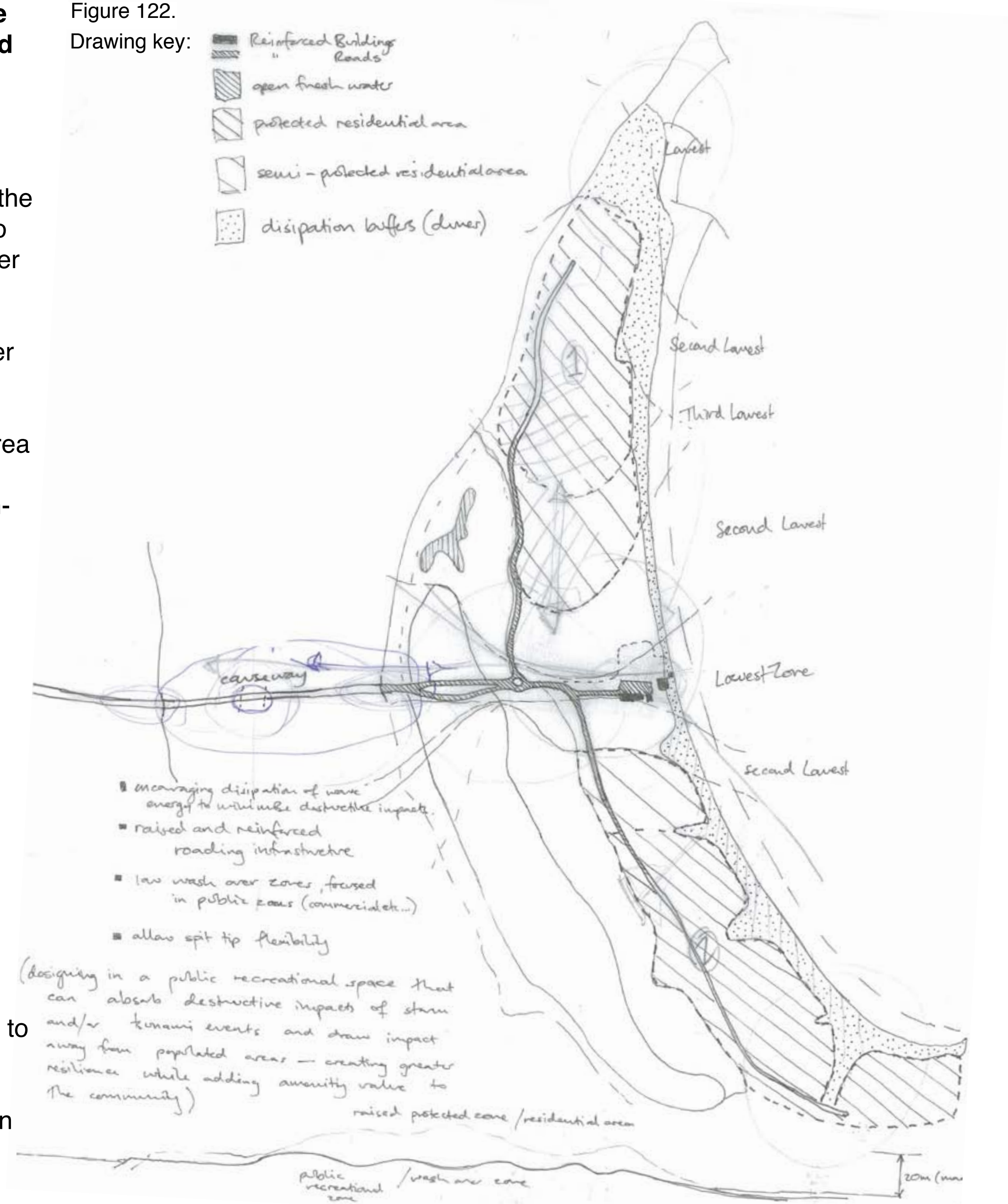
PROS:

- Focuses all potential for wash-over to the area where the highest risk of complete wash-over is, to reduce impact to the developed area. Channeling or directing the wash-over flow allows control of the damaging erosive forces.
- The onshore threats converge at central section of Omaha spit making this the ideal place to force water over the spit thereby focusing the onshore impacts away from other parts.
- The central washover area breaks the development area into two clusters. The washover zone would be low-lying making all development in this area temporary. The wash-over open space has huge potenital to be a connective community amenity, hosting festivals and events.
- Requires the least interruption of the current development footprint.

CONS:

- Would require large scale sea walls to protect the developed areas and direct the water into the washover area.
- The only connection with the mainland is also in the central part of the spit making this access vulnerable in a wash-over event.
- Not currently the lowest lying area so would require signifcant earthworks to create a washover park.
- Reinforcing the roading infrastructre to handle the focused impacts would be prohibitive in cost.
- There are other parts of the spit that are as vulnerable to impacts that are not dealt with in this strategy.
- Doesn't deal with the issues of the hardened coastal edge, and limited flexibility of the development footprint in the rest of the sand spit.

Figure 122.
Drawing key:



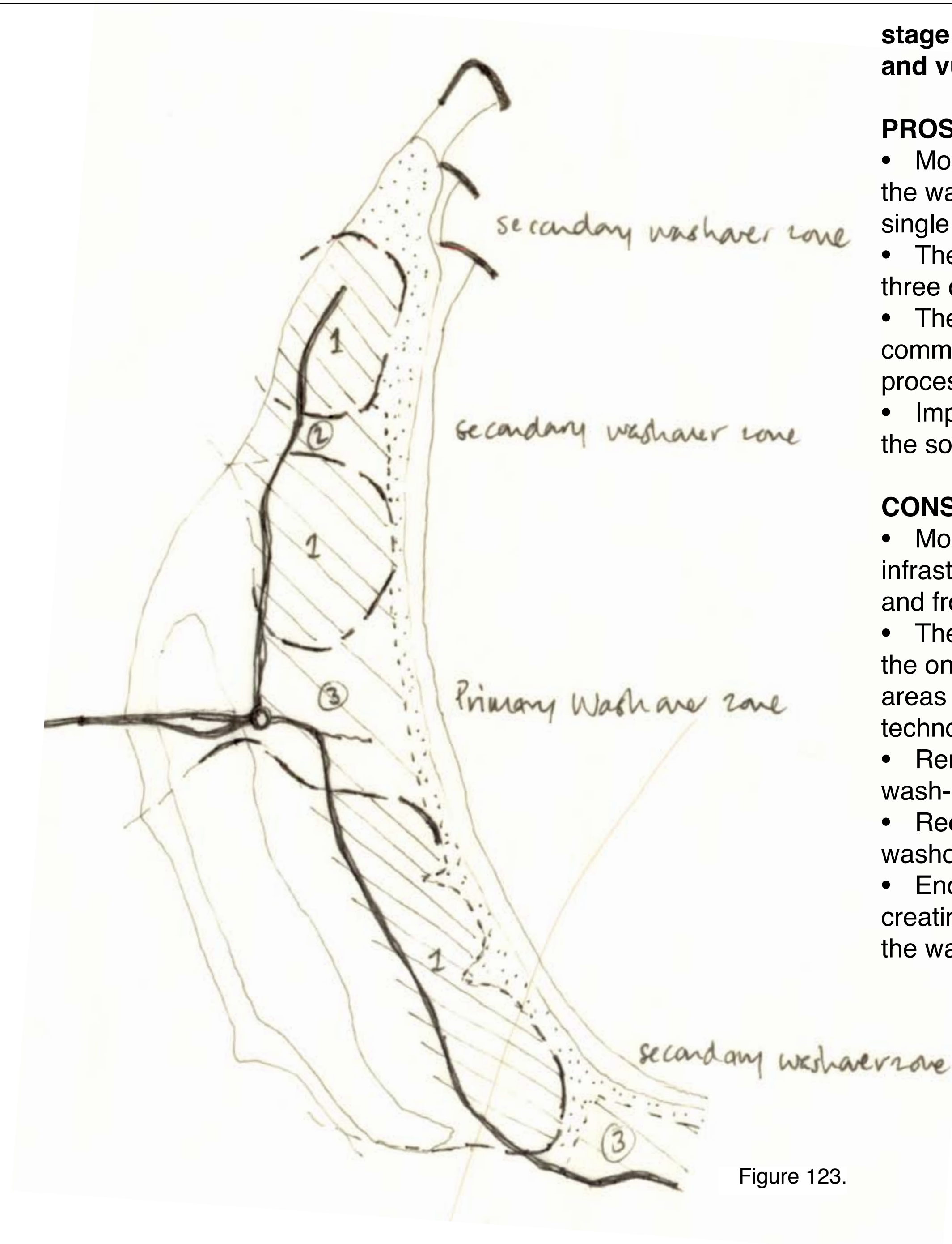


Figure 123.

stage 2. Multiple wash-over areas focused in low-lying and vulnerable areas.

PROS:

- More wash-over areas to spread the impact and lessen the wash-over energy, reducing the onshore threats to a single point of wash-over.
- The development area would be further broken down into three clusters.
- The wash-over parks become the social focus of the community as well as a point of interaction with the coastal process and ecologies.
- Implements the development pattern of clusters, use in the southern subdivision, across the whole spit.

CONS:

- More wash-over areas, means more reinforced roading infrastructure to bridge these areas and maintain access to and from all development areas.
- The development of structures to ensure the forces of the onshore impacts are directing away from development areas into the wash-over zones (take cues from tsunami technology in Japan and Indonesia).
- Removal of large areas to facilitate the creation of large wash-over zones.
- Requires significant earthworks to create a complete washover over area in the centre of the sand spit.
- Encourages all onshore impacts to washover the spit creating issues of erosion on the harbour shoreline when the water washes out of the harbour.

stage 3. Series of wash-over, wash-through and wash-in spaces to absorb the impacts of storms and tsunami while providing public amenity.

PROS:

- Stepping back from the edge and releasing the dunes from development so they can perform their protective role is critical for enhancing the coastal communities adaptive capacity.
- The wash-over, wash-through and wash-in strategies allow the sand spit and settlement to absorb onshore threats without being significantly impacted.
- Provides a range of wash-over spaces that allow the inundation forces to wash-in then out, wash all the way over, and wash-through existing waterways.
- Directing water away from the development clusters is achieved through a tsunami bank system that undulates along the length of the spit providing endo-skeletal support to the natural dune defence system.
- These wash-over spaces then become the social focus of the surrounding community and the access points to the beaches.
- The community interaction and awareness of the natural environment and processes is facilitated and encouraged in these spaces.

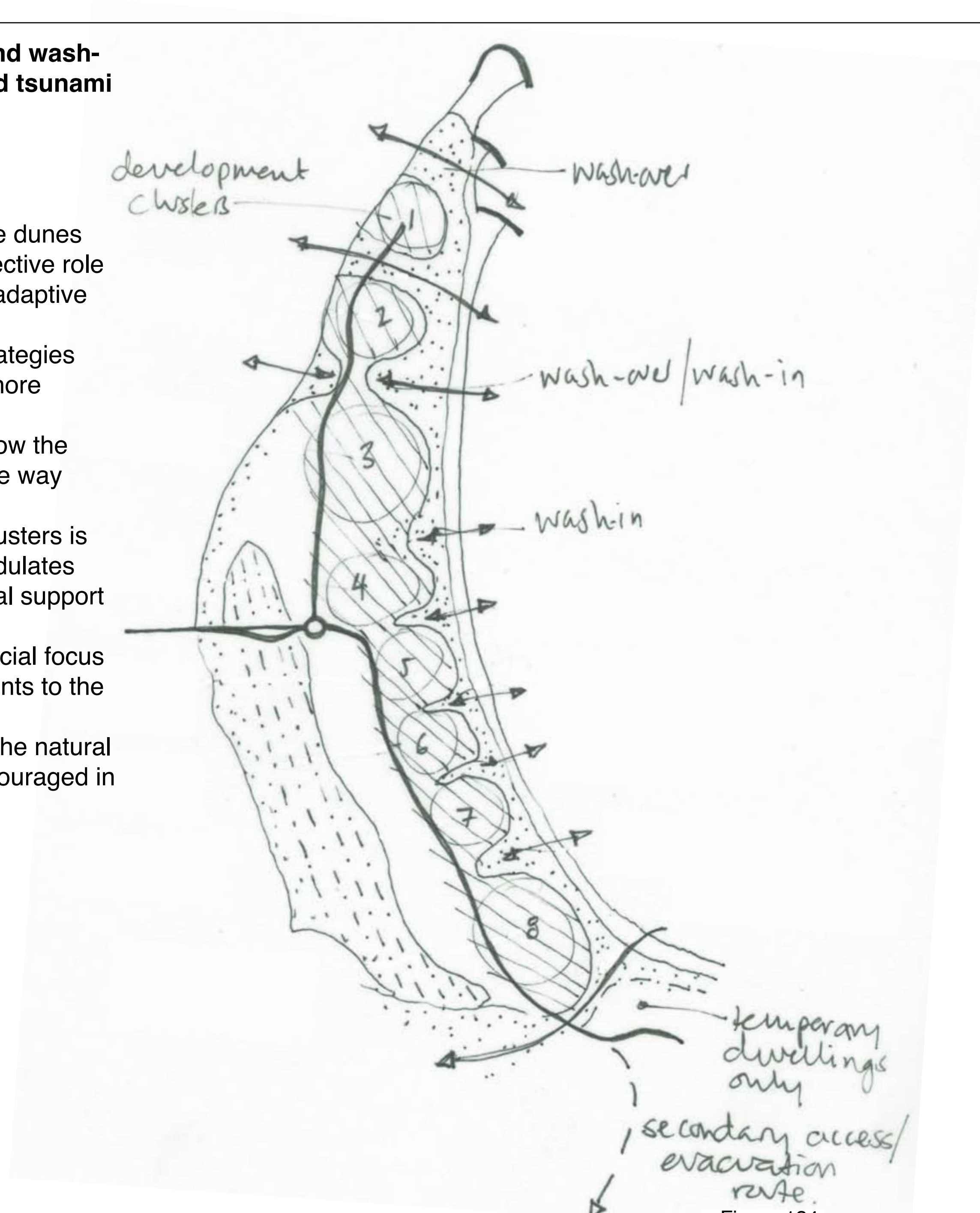


Figure 124.

Hierarchy of open space:
The provision of open spaces, at a range of sizes, that provide for different levels of programme activity and use from large scale natural areas to small scale highly designed areas and private gardens.

For the health of the wider sand spit, the provision of large areas of natural open space is important. It is also important to ensure that smaller scale, socially focused spaces are created within the developed areas to provide a focus for the community. Providing all types of open spaces in the hierarchy ensures that the needs of the natural environment and the community can be met.

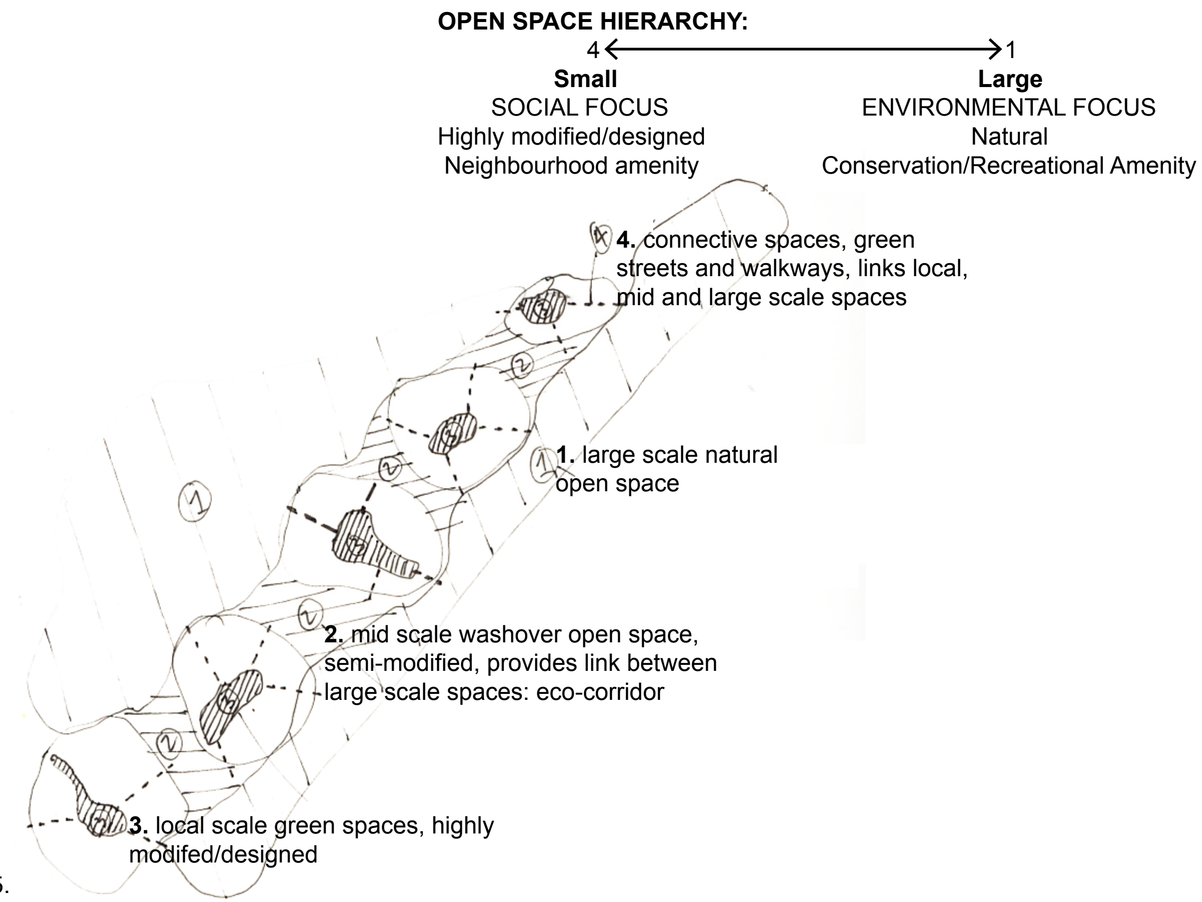


Figure 125.

Reinforcing and regenerating natural environment:
To ensure the protective capacity of the dunes and the health and resilience of the unique sand spit and coastal ecosystems and habitats to ensure the ongoing resilience of the whole spit environment.

Ongoing degradation of New Zealand's coastal dune systems, through clearing, development, sand mining, and the invasion of exotic species, has seen them destabilized and destroyed at an alarming rate. A recent push to restore these ecosystems has been driven by a number of objectives including conservation, natural character preservation, and also the aesthetic and recreational amenity these environments provide (Bergin & Kimberley). The general population is only now becoming aware of the services coastal ecosystems provide in the protection of coastal land. Events such as Hurricane Katrina have made glaringly obvious the role that wetland and salt marsh systems play in dampening the impacts of large storms.

> Coastal plants have evolved physiological, morphological, and reproductive strategies to deal with the impacts of increased and fluctuating water level. (Day, Christian & Boesch 483).

More than simply aesthetic and physical resources they are in fact the first line of defence, especially adapted to absorbing and dissipating coastal threats. The seaward building of sand dunes allows inland dunes to stabilise and support increasingly diverse flora and fauna; the foredunes provide a buffer protecting these inland areas from the sea and storms. It is important for these foredunes to be flexible and responsive to protect the more stable dunes from erosion and destabilisation. In estuary environments the establishment of salt marsh, wetland and mangrove habitats provide protection to inland shores and habitat for spawning fish and wading birds.

Releasing areas from development:
To ensure the success of the natural defence system, existing dwellings sited in areas that compromise the protective capacity of the dune system and are most threatened by coastal impacts will be removed.

The concept of managed retreat has been adopted throughout New Zealand as the primary response to coastal threats (Peart). In the case of this design project the retreat of some properties in endangered areas will be instigated with these dwellings being reinstated within the cluster boundaries. By releasing the dunes in vulnerable areas, and allowing the natural system to regenerate, the wider health and resilience of the spit can be enhanced. The use of the natural dune system as the first line of defence is an important part of ensuring the ongoing viability of settlement in the sand spit environment. Properties are also removed to create wash-over parks that absorb the majority of inundation threats.

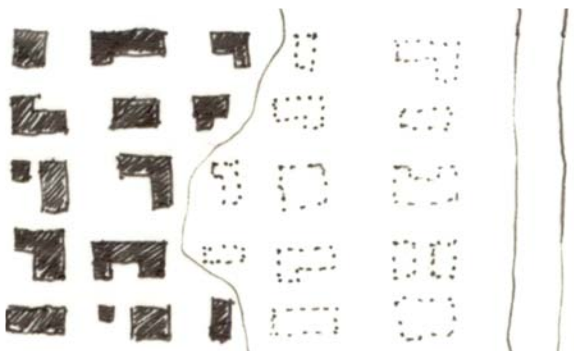


Figure 126. Removing houses from within vulnerable zones and stepping back from the edge will allow the protective dunes greater flexibility.

NATURAL OPEN SPACES

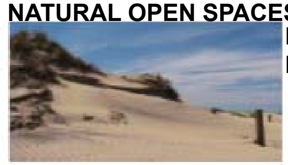


Figure 127. Fore dunes

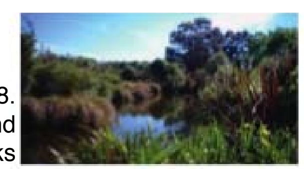


Figure 128. Wetlands and duneslacks

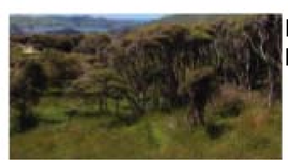


Figure 129. Back dunes

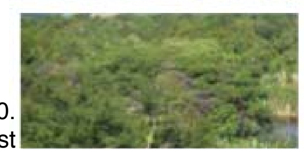


Figure 130. Low land forest

PROPERTIES TO BE REMOVED

- Houses to be removed to release vulnerable areas from development.
- Contours 5m and below
- Contours up to 7m

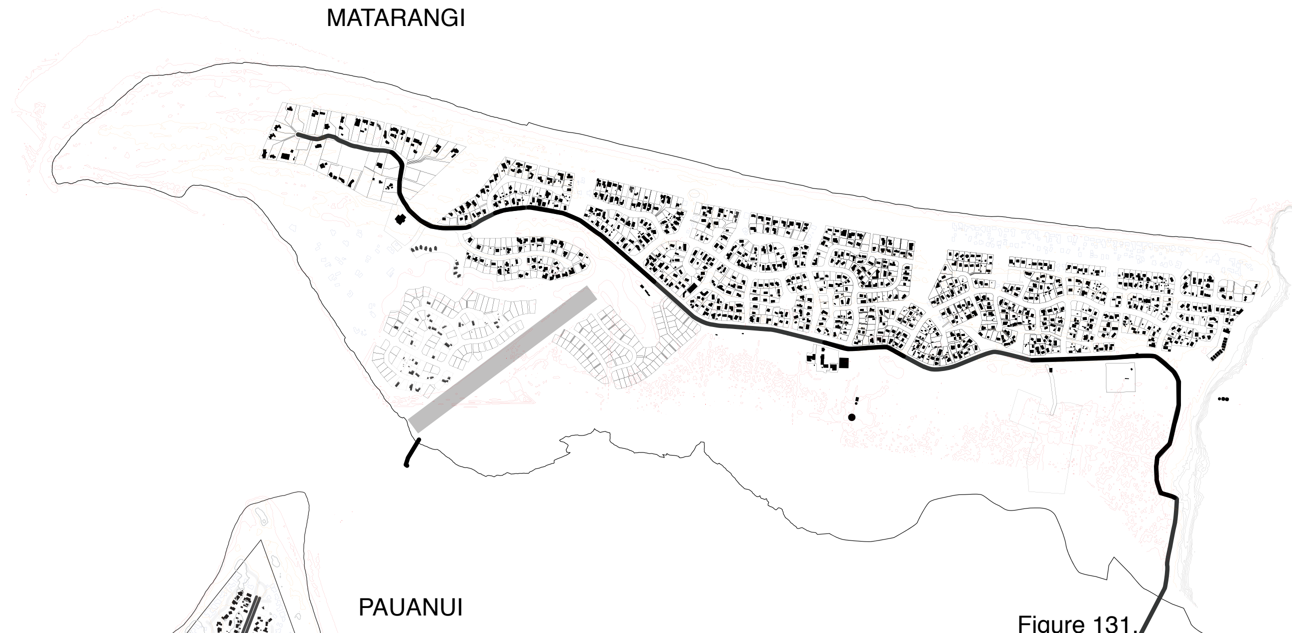


Figure 131.

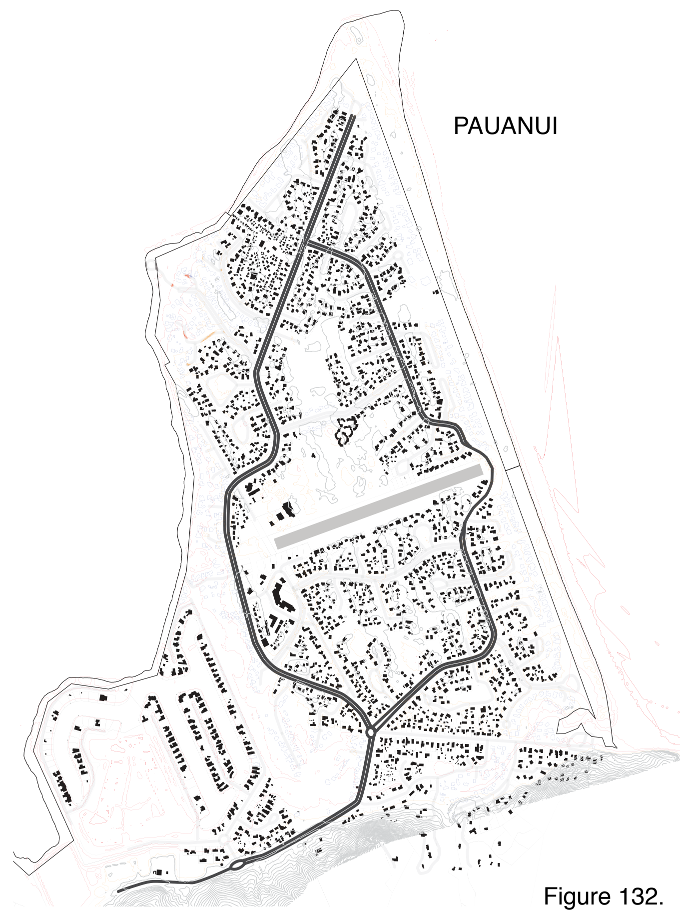


Figure 132.

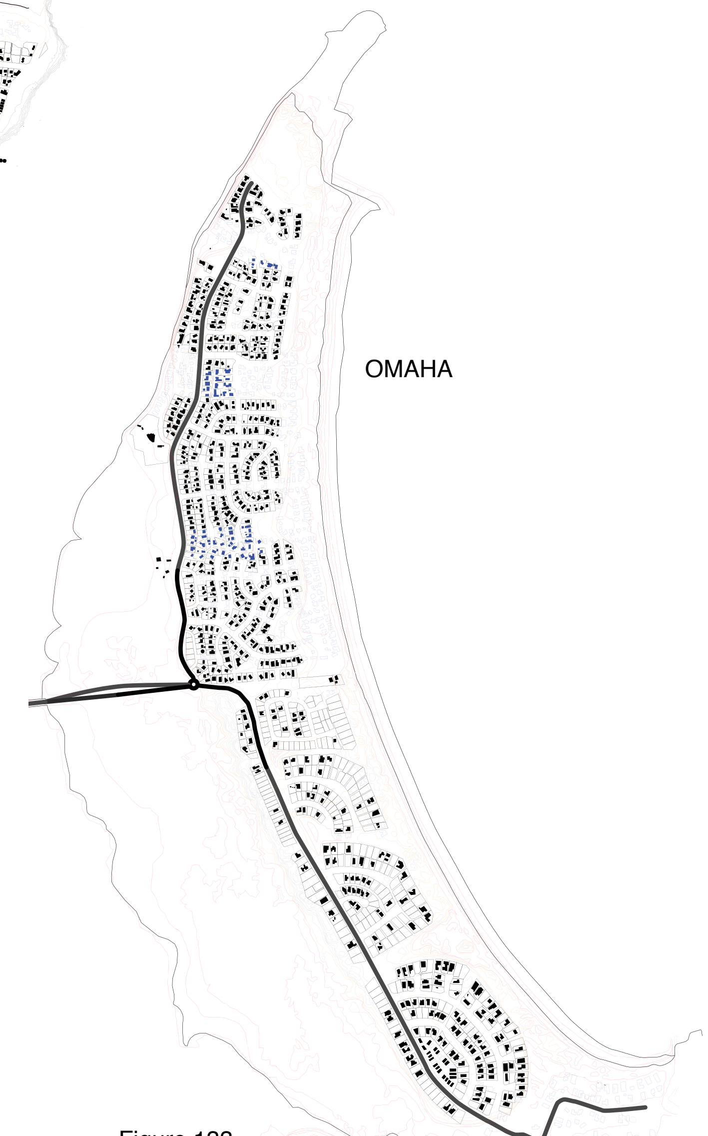


Figure 133.

Tsunami banking:
Installation of constructed inland dune barrier to provide secondary protection of spit community and help build up cluster zones to the minimum level of between 7.0 - 8.0m for built platforms above mean sea level (MSL).

The use of a series of 1m high seawalls to create an endo-skeletal reinforcement of the natural dune system is applied in tandem with extensive planting of the dunes with native sand binding plants and trees. The pile foundations of the built structures, to limit damages to foundations in the event of scouring (Lukkunaprasit & Ruangrassamee), will act as stabilising anchors along the top of the tsunami bank. Rather than a simple 1m hard surface, the seawalls will be constructed in a gabion style along the face with sub-surface reinforcement and anchoring to allow for planting to happen within the bank formation. The tsunami banking structure will consist of an undulating slope along the length of the sand spit to ensure that maximum wave dissipation is achieved. By undulating the tsunami bank, the steepness of the slope with not be constant at any point ensuring the wave will not be able to gather speed along the constructed surface.

Seawalls are the primary method of coastal protection from tsunami in Japan (Matsumoto & Suzuki). Historically extensive coastal forests were used by coastal villages for thousands of years as protection from salt damage, storms and small tsunami. It wasn't until the Chilean Tsunami in 1960 that the construction of seawalls became wide spread (Edward, Terazaki & Yamaguchi). The country's narrow and steep coastal slopes lend themselves to hard structure protection (Edward, Terazaki & Yamaguchi), although issues with accessing the water in ports and on the sandy coasts has also seen breakwaters and natural protection measures, such as planting, implemented. At Nami-ita beach in Funakoshi Bay, Japan, a 4m seawall has been constructed directly beyond the sandy beach, this is further reinforced by a 30m deep strip of densely planted pines followed by another rise of 2m to a coastal highway, beyond which lies the settlement area (Edward, Terazaki & Yamaguchi). These intensive protection measures are common along the most endangered coastlines in Japan.

In Thailand the analysis of damage caused by the 2004 Indian Ocean Tsunami revealed that a simple 1m high seawall could dissipate wave energy and lessen the inland impacts of the wave (Dalrymple & Kriebel). As the wave hits the seawall some of the energy is released skyward in the splash up, and the power of the wave moving inland is reduced (Dalrymple & Kriebel). These observations have yet to be proven beyond doubt but the evidence is clear along beaches in Phuket. In this area where seawalls were constructed to protect against erosion and storm waves, the buildings beyond these low walls were significantly less damaged than those without protected waterfronts (Lukkunaprasit & Ruangrassamee).

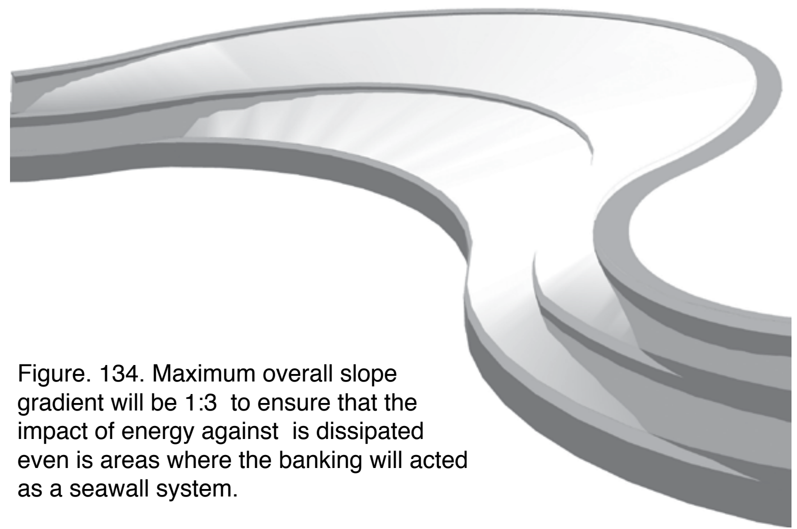


Figure. 134. Maximum overall slope gradient will be 1:3 to ensure that the impact of energy against is dissipated even is areas where the banking will acted as a seawall system.

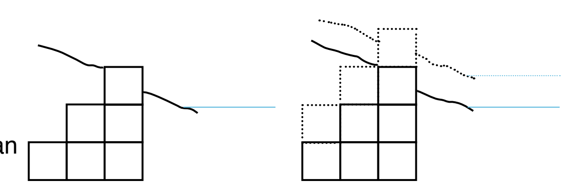


Figure 135. As the mean sea level rises the tsunami banks can also be raised.

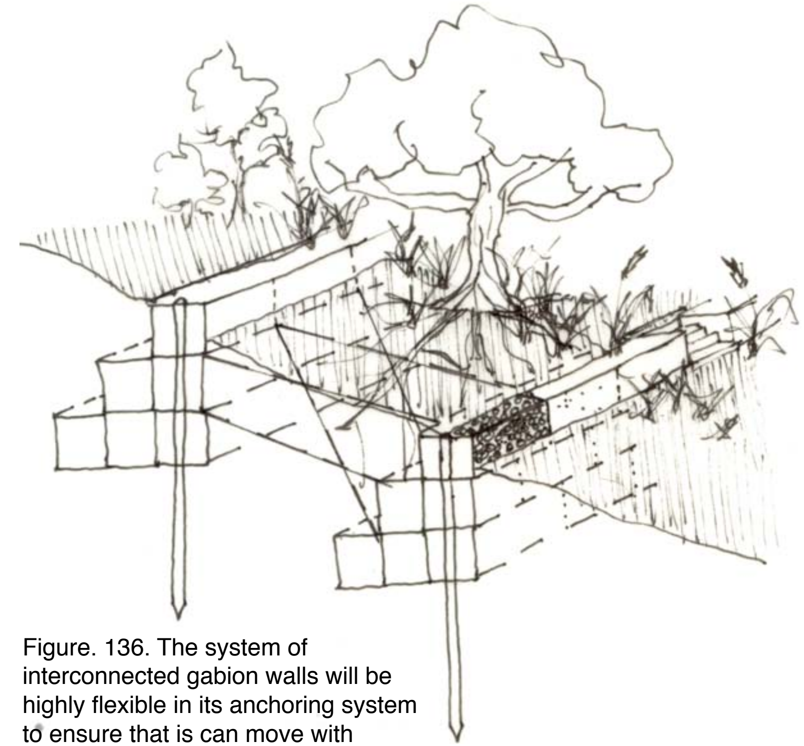


Figure. 136. The system of interconnected gabion walls will be highly flexible in its anchoring system to ensure that is can move with changes in the topographical layout of the dunes and limit the impact of washouts. The vegetation planted with the banking system is crucial in the role of stabilising and building the dunes around the gabion structures. This system acts primarily as an endo-skeletal support to the wider natural dunes system. Providing a platform for recovery and rebuilding as much as a protective barrier to damage.

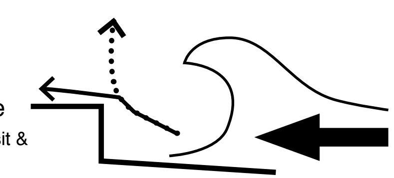


Figure. 137. On impact with the low seawall structure some of the wave energy is dispated vertically, lessening the damaging impact of the horizontal flow. (adapted from Lukkunaprasit & Ruangrassamee)

TSUNAMI BANKING

Tsunami banking (indicated at 2m intervals for clarity).

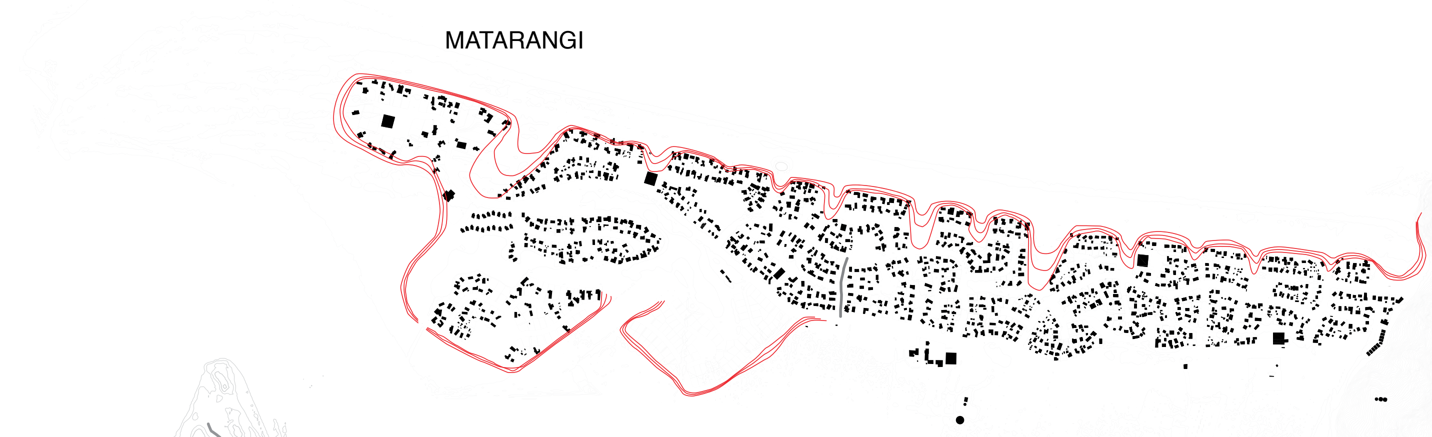


Figure 138.

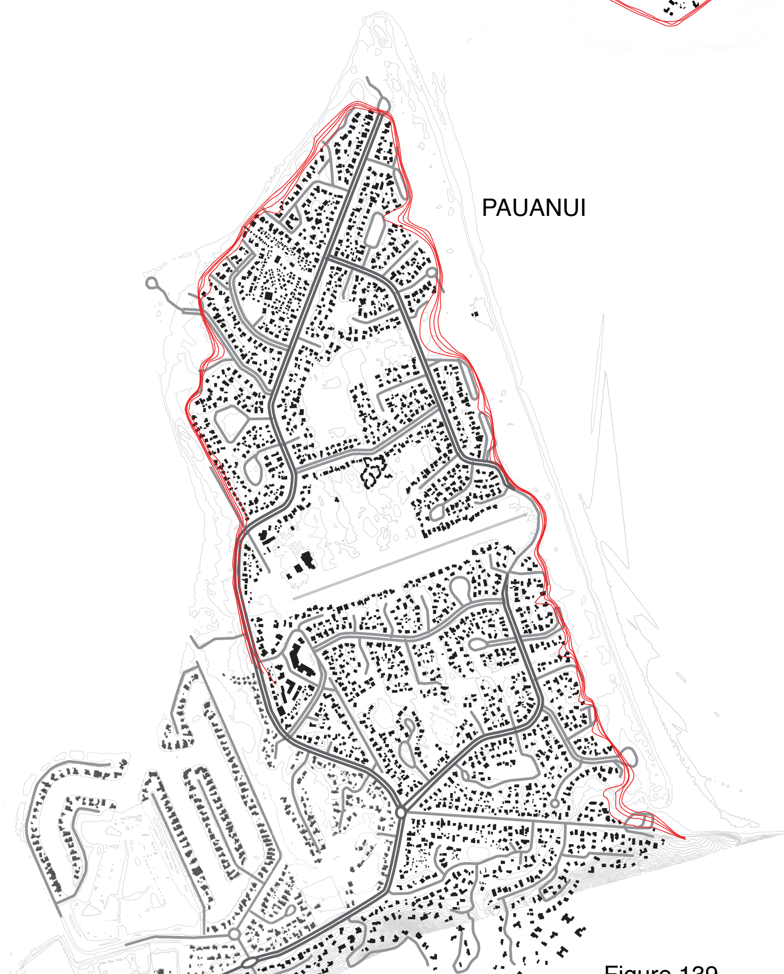


Figure 139.

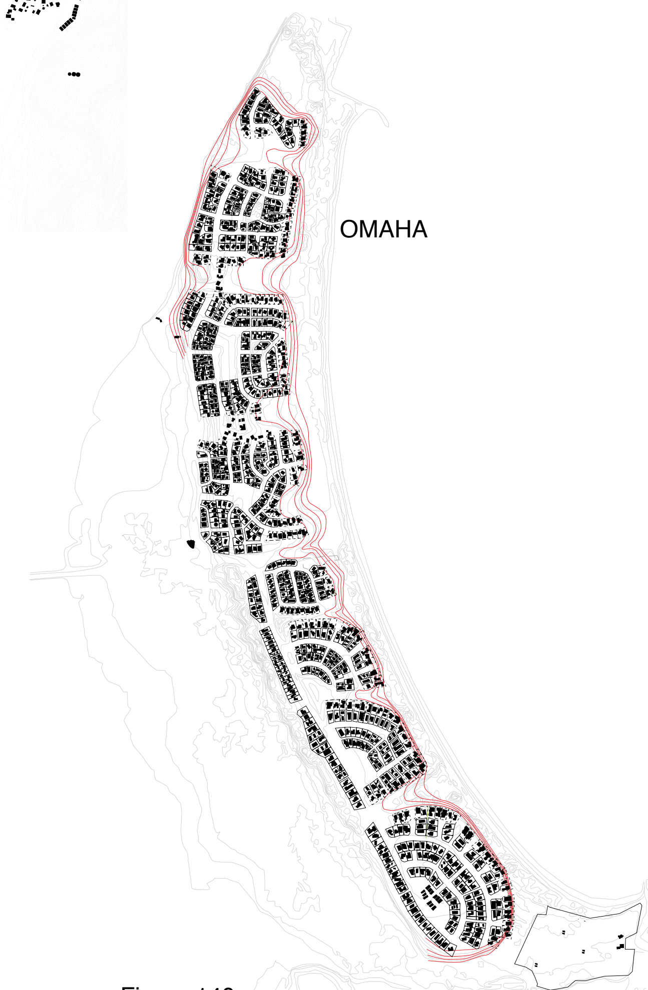


Figure 140.

High-land Walkway:

A walkway along the highest points of land in the spit linking the spit tip to the higher ground of the hinterland at the heel. This walkway is the route for pedestrian evacuation and provides the back bone for the spit-wide network of recreational amenity.

The high-land walkway will ensure the safest route of evacuation by foot, travelling along the highest points of the spit in the most direct route to the high ground of the hinterland. The walkway is connected clearly through each cluster and the wash-over parks. Signage and graphic cues along the route will provide information on the potential hazards, route maps for evacuation and recreational use, and information about the strategies being implemented spit wide to increase the adaptive capacity of the coastal community and natural environment.

Figure 141. Directional paving provides clear visual cues to the evacuation route.

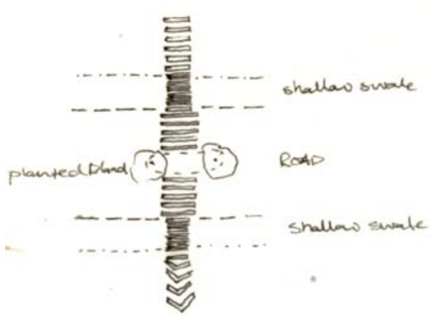


Figure 142. Where the high-land walkway crosses road surfaces the paving acts as standard pedestrian crossing markings.

Interpretive signage and way finding:

Interpretive signage throughout public open spaces provides information on coastal processes, threats, and strong visual cues to create awareness of the routes for pedestrian evacuation if necessary.

The use of directional cues in the paving of the high-land walkway and information signage and plaques throughout the open space network will increase awareness of potential threats and the safest evacuation route. Plaques identifying the level above sea level will be positioned along beach access walkways, as will information signage about the role of the natural environment as a protective barrier and as a unique and specialised ecosystem.

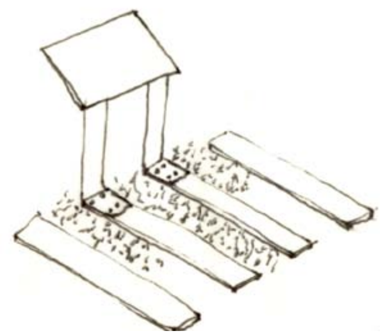


Figure 143. Signage provides information on potential hazards, evacuation route maps and information on the strategies being implemented to create a more adaptive environment

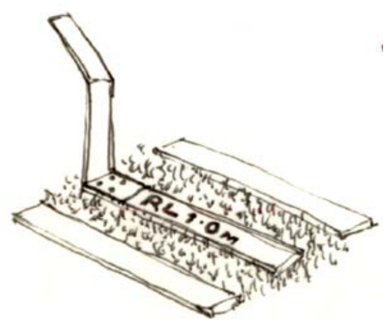


Figure 144. Engraved level markings into the pavers indicate each metre of level change along the path. These are accompanied with signage explaining the graphic and providing further information.

HIGH-LAND WALKWAY

- - - - High-land walkway linking the highest points of the spit enroute to the higher ground of the hinterland.

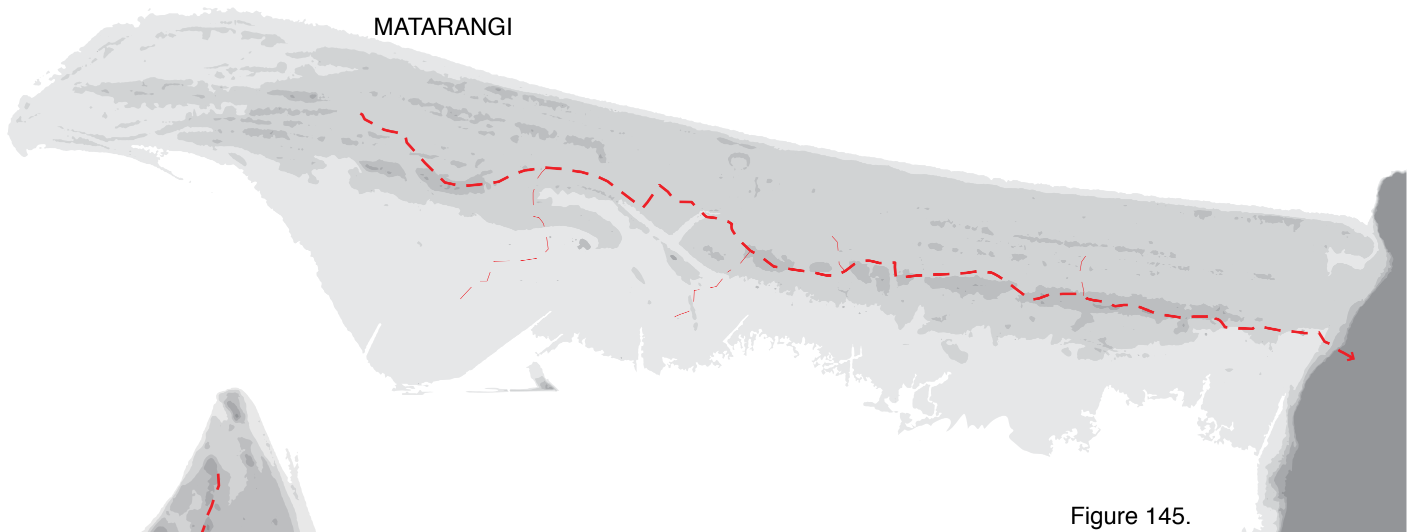


Figure 145.

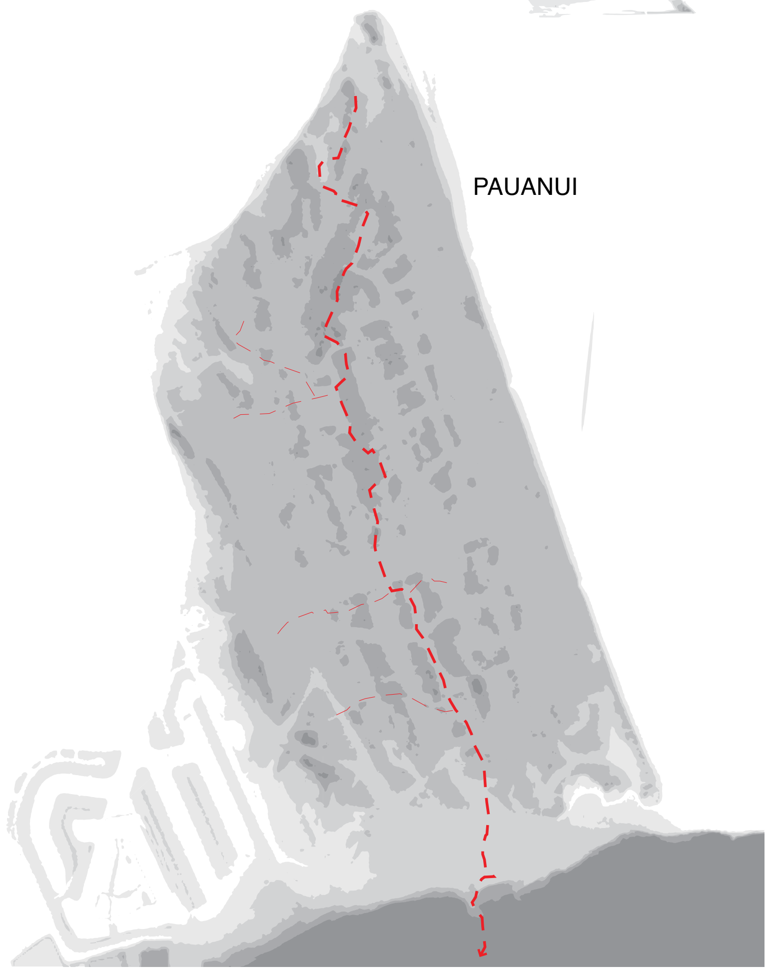


Figure 146.

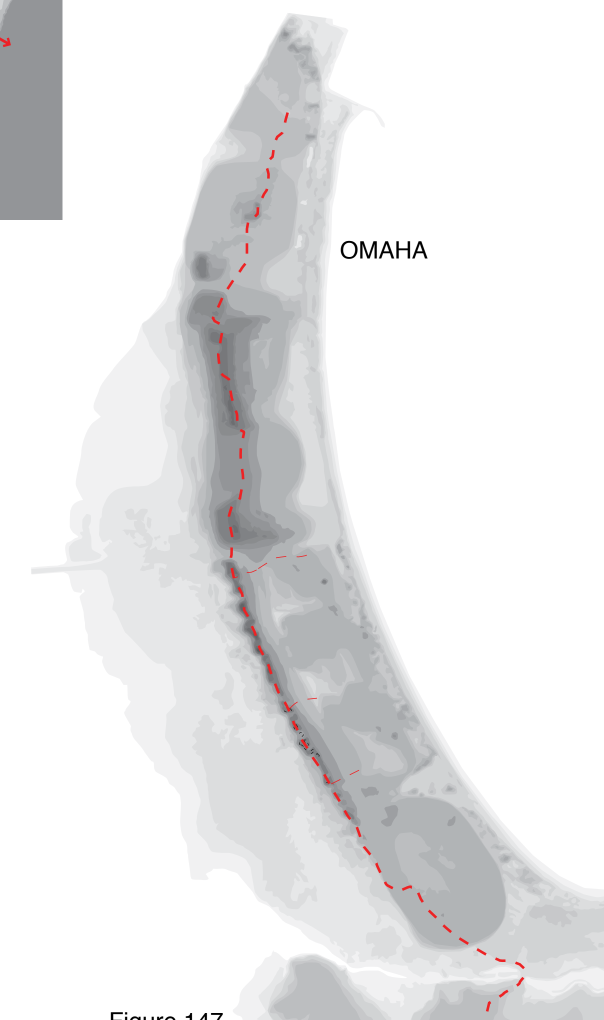


Figure 147.

Wash-over parks:
The creation of open spaces between the residential clusters of development, occupying lower-lying land they absorb inundation related threats and provide for eco-domain migration in response to climate related changes.

The wash-over parks integrate both 'retreat' and 'accommodation' strategies to generate areas able to absorb inundation threats, accommodate eco-domain migrations, and facilitate social program. This increases social capital building and open space recreation opportunities. The wash-over park typologies respond both to their position on the sand spit, and to the topographical and ecological characteristics of their position.

The tsunami banking system works in conjuction with coastal vegetation to provide a protective second line of defence in case of tsunami and severe storm events. The banking within the parks provides this secondary protection while also offering multi-functional outdoor performance, recreation and social spaces, including infrastructure for festival seating/banking and walkways.

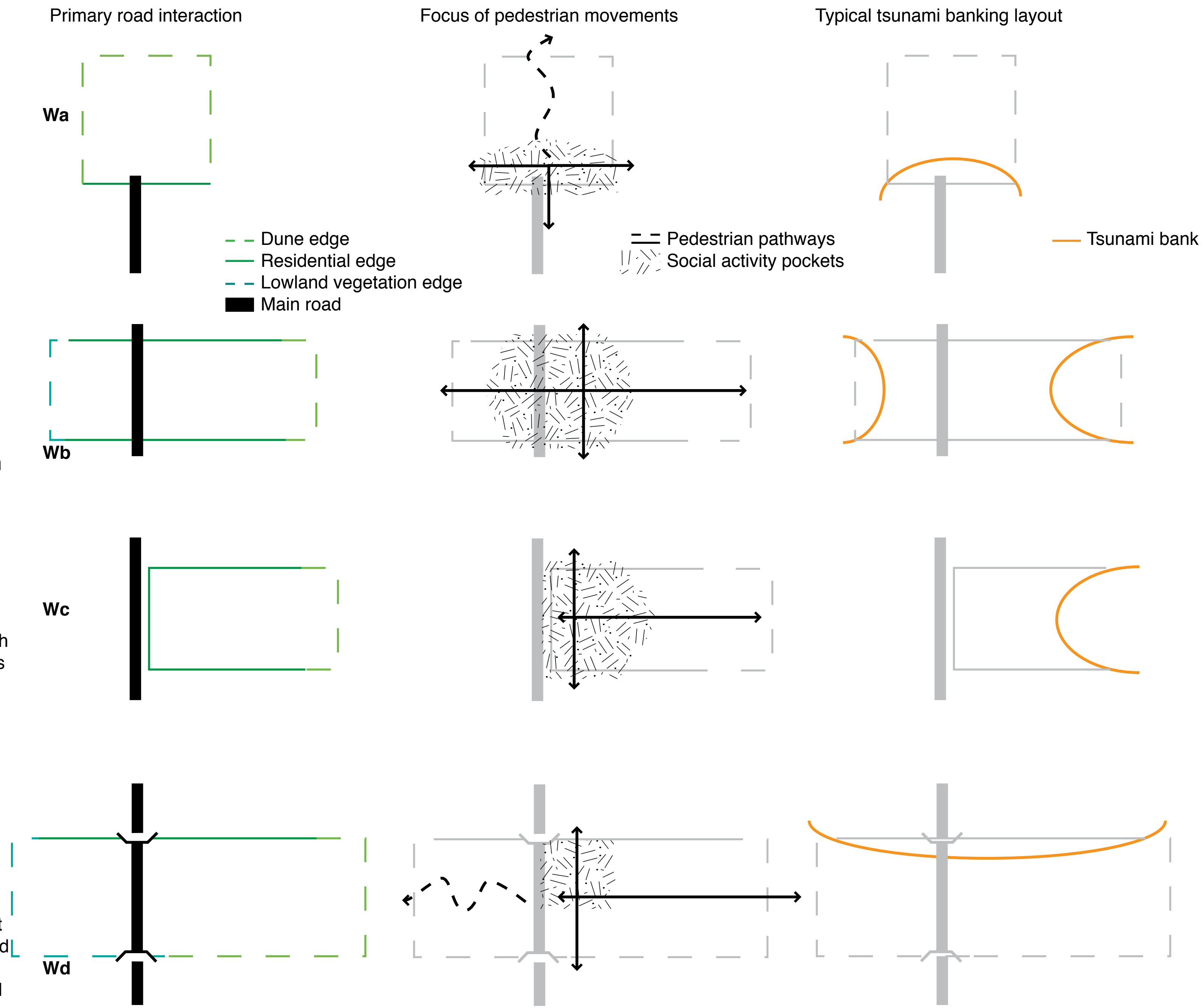
Wa: Spit tip bordered by water and dune environments. Road terminus point. Often adjacent to, or host to, the habitat of native bird species such as the NZ Dotterel and Variable Oyster Catcher. Pedestrian movement is focused away from spit tip towards beaches.

Wb: Typically located towards the spit tip. Crosses spit from beach to beach. Low-xlying with dune ecologies to the seaward side and harbour dune and saltmarsh ecologies at the other. Intersected by a primary distribution road.

Wc: More appropriately considered as a 'wash-in' park to absorb inundation. Low-lying area opening into dune environment, either on the seaward or harbour sides. Terminates at primary distribution road.

Wd: Most likely located at the spit heel in a low-lying area often adjacent to or including a waterway. Open to seaward dunes and dune slacks, and harbour side saltmarsh and wetland areas. Bridged by main distribution proad to ensure access to higher ground. Pedestrian movement focused towards beach to limited traffic through sensitive weltand areas.

Figure 148. **TYPOLOGIES:**



WASH OVER PARK TYPOLOGIES

Figure 149.

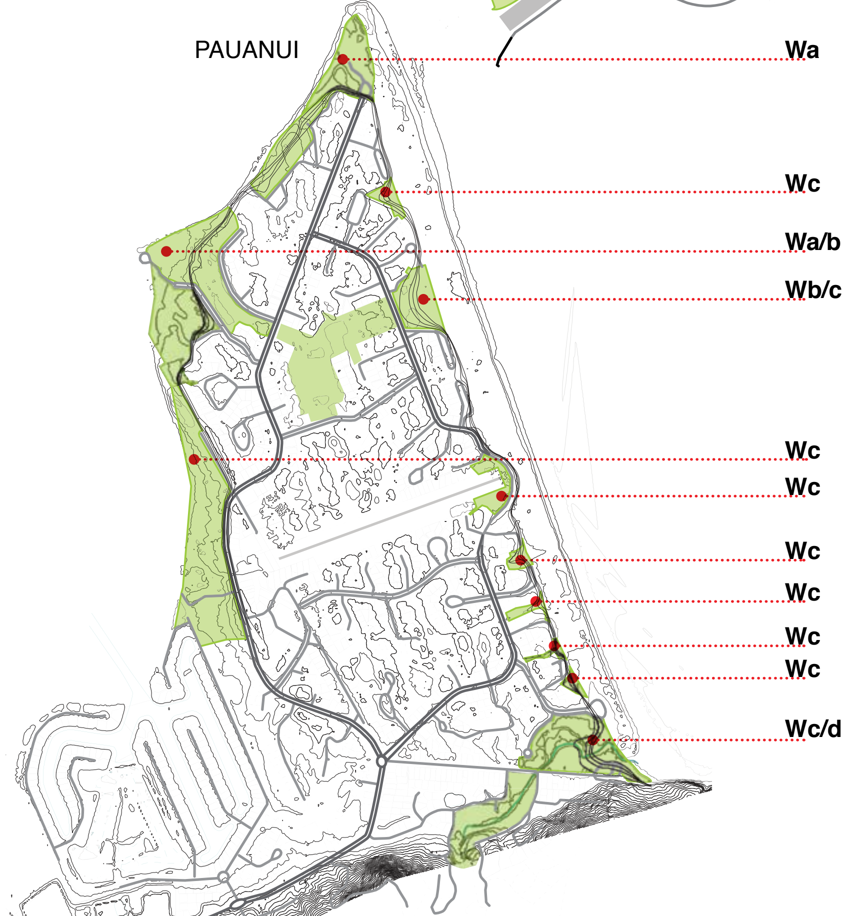


Figure 150.

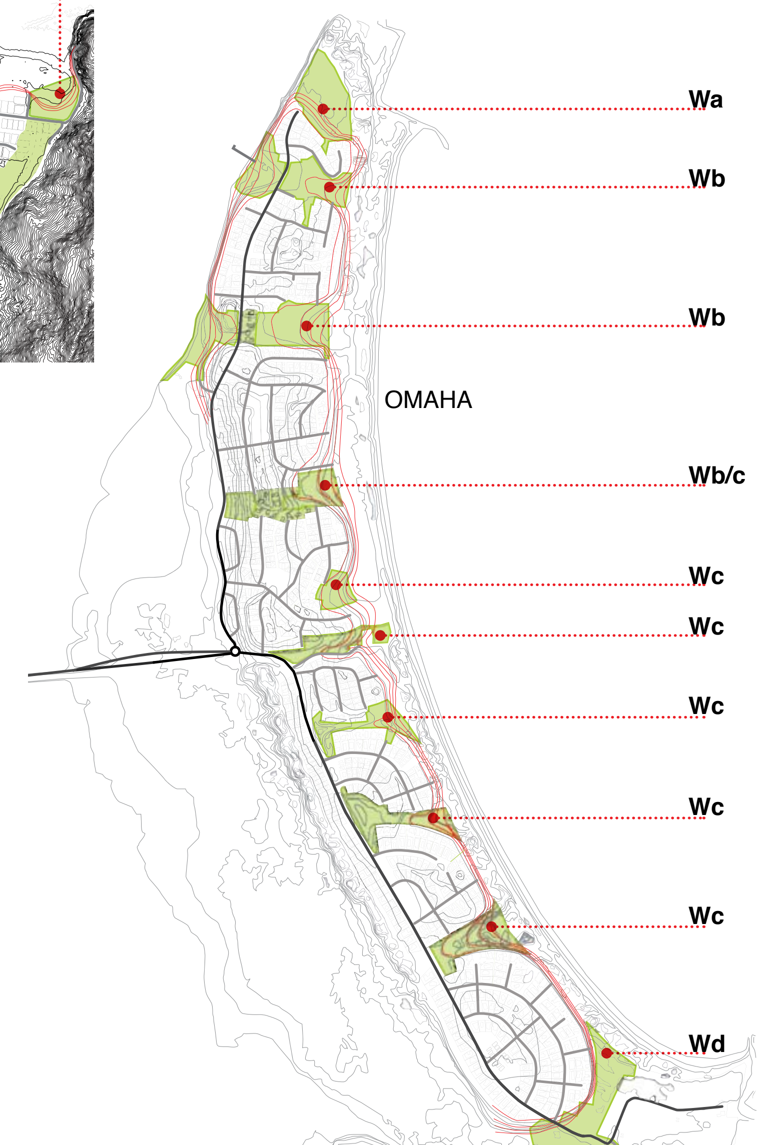


Figure 151.

Development Clusters:
Larger neighbourhood clusters are made up of smaller overlapping clusters. The clusters will be focused around a community facility or amenity and each will have an individual identity within the wider spit community.

The concept of clusters appears at varying scales in urban design discussion. The focus here is on neighbourhood scale clusters and, within these, clusters formed at a block scale. In “A Pattern Language,” Christopher Alexander describes the cluster as the fundamental unit of organization in a neighbourhood. Clusters function best when limited to between 8-12 dwellings, ensuring that social relationships are not strained or diluted by distance or layout (Alexander), and at a larger scale 8-12 blocks. Clusters move away from traditional models of land ownership by making a shared open space the focus of a neighbourhood. This allows for property parcels to be smaller while providing a far greater volume of public open spaces (Blaine & Schear).

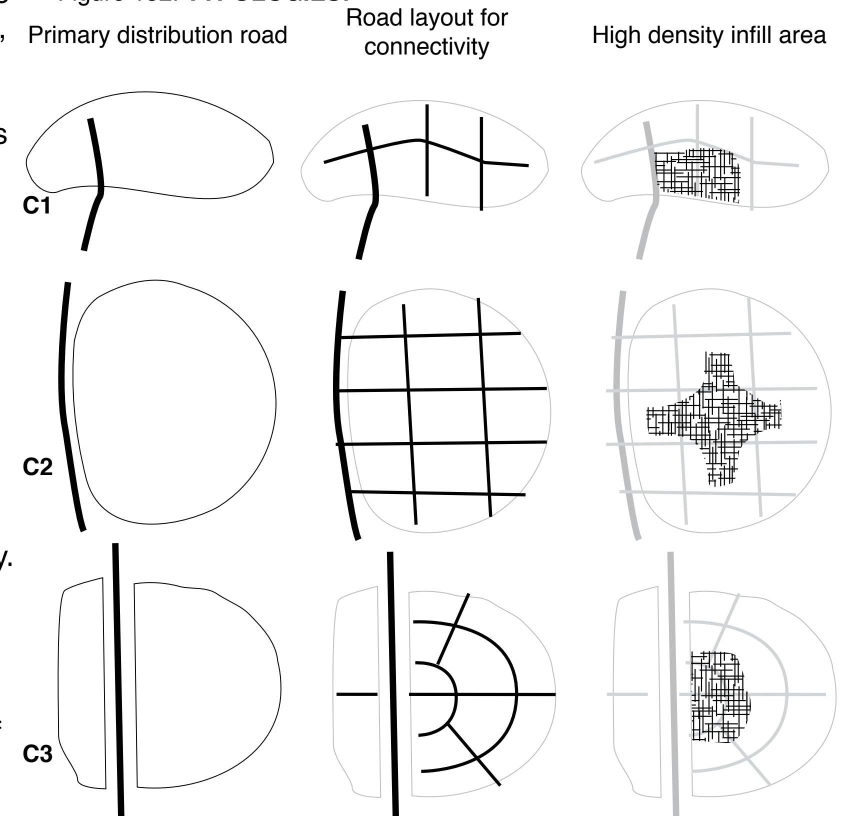
It is important to value the coastal environment and its processes as well as engage with the community beyond the cluster itself. The social and community programmes of the clusters will be focused in the adjacent wash-over parks, encouraging interaction with the wider community and visitors. A network of green streets link through the clusters to the wash-over spaces, providing a clear pedestrian green spaces within the high density areas. The activated areas of the wash-over parks will become ‘extroverted’ nuclei for the community, a shared meeting space to increase social engagement. The programmed areas will be integrated with the natural environment to ensure that the spaces are shared and the the wash-over capacity of the park is not interrupted. Programmatically activated areas of the parks will be adjacent to main thoroughfares, access points and attractions. Alexander calls these spaces ‘activity pockets’ and identifies the need to activate the edges of these spaces as people naturally gravitate towards the edges. People will feel most comfortable in spaces that are not too open and not too enclosed (Alexander).

Some of the advantages of cluster development include the ability to preserve important land qualities and ecosystems, providing a greater sense of community among residents (Blaine & Schear), and reducing the development footprint in sensitive areas. The higher density cluster developments are highly rated as places to live and subsequently maintain high property values (Blaine & Schear). This is an important consideration in coastal environments where the higher occurrence of damaging storms and tsunami can affect property values and insurability. The majority of homes in these sand spit communities are empty for most of the year and property maintenance and management is an expensive and time-consuming consideration. With smaller privately owned parcels, increased allowances for cross-leased/shared ownership arrangements, and greater community engagement, the issue of security and property maintenance for uninhabited homes is reduced significantly.

The edges of the clusters are most vulnerable to potential coastal threats and are therefore less densely developed, and more densely vegetated. Towards the edges of the clusters, the density will become lower and the definition of boundaries will be restricted to limit the impact of the built environment on the adjacent natural open spaces. The lower density edges with no boundary definition help to blur the transition between the open spaces and development areas. Shared management of the properties adjacent to open spaces and of the open spaces themselves ensures that the flexibility of the natural environment is not restricted by private property management.

The cluster typologies all have density rings with the highest density being focused to the core and lessening towards the edges. The road layouts are designed to ensure maximum connectivity and access to adjacent open spaces.

Figure 152. **TYPOLOGIES:**



C1: Small clusters typically located at the terminus of a primary distribution road. Pedestrian green streets link open spaces through cluster encouraging social and community connections.

C2: Large clusters forming most complete density rings. Green streets feed out from the centre and connect with the adjacent open spaces.

C3: Cluster forms around the primary distrbution road. The highest density is adjacent to this road and connected to the surrounding open spaces via pedestrian focused green streets.

CLUSTER TYPOLOGIES

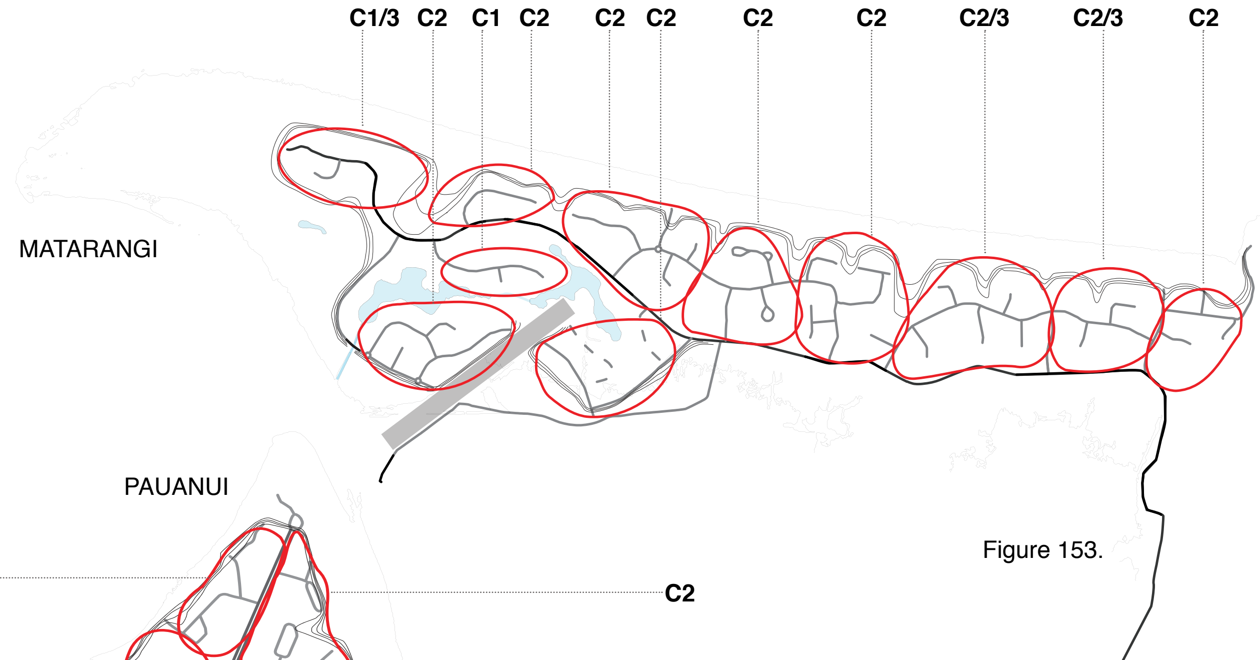


Figure 153.

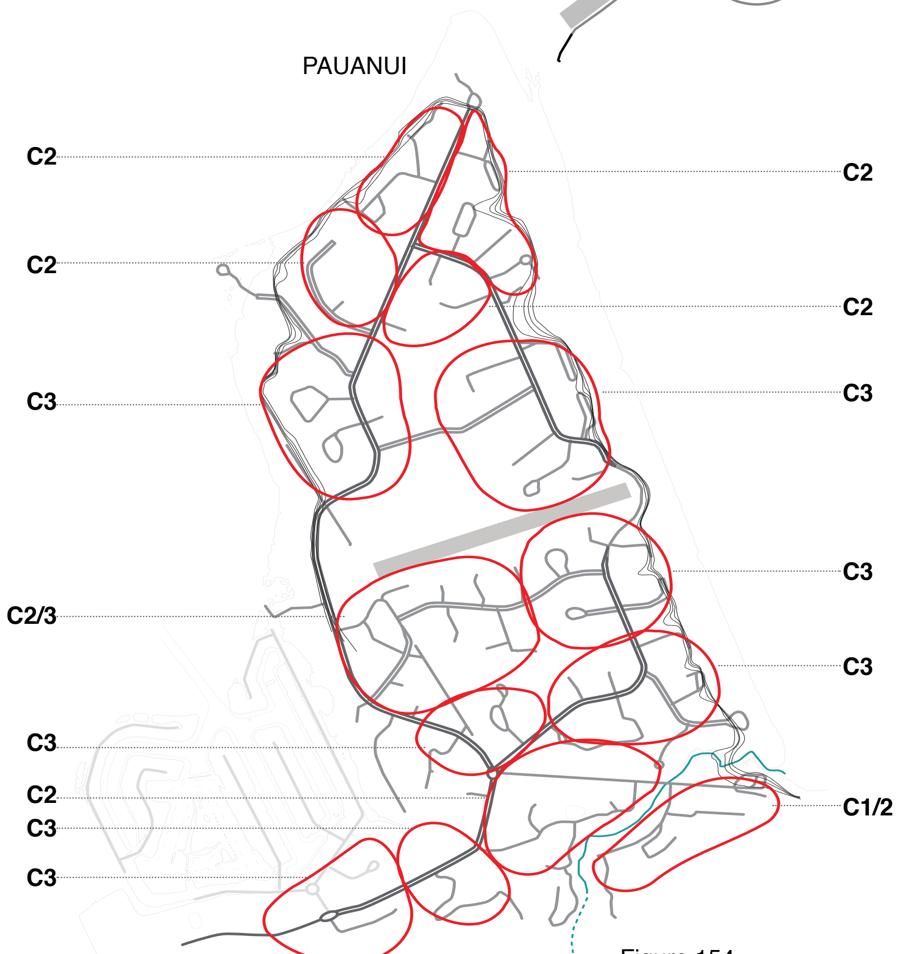


Figure 154.

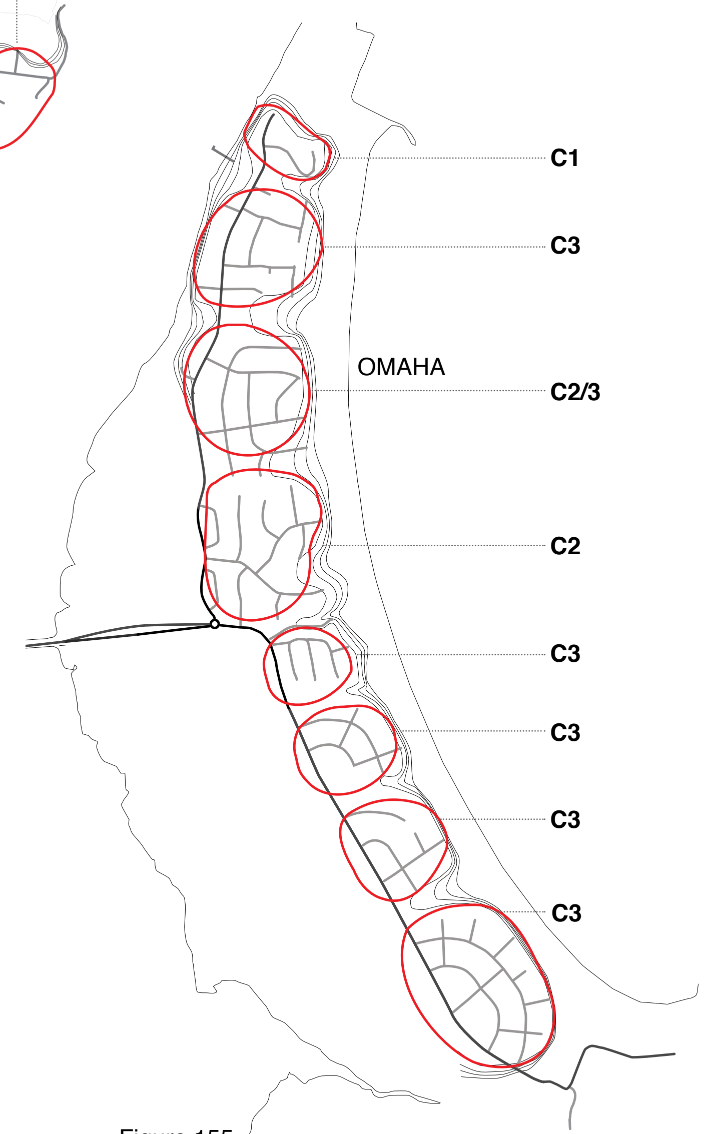


Figure 155.

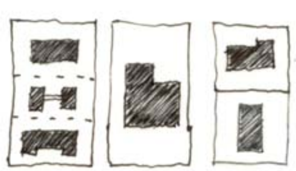
Sub-urban infill:

Re-organisation of property ownership and management systems and minimum parcel sizes will allow for greater density to be accomplished.

Creating clusters of denser development within the centre of neighbourhoods will allow for the release of other areas without exacerbating issues of displacement of those currently situated in vulnerable areas. To ensure that the interface between open space and settlement areas is not abrupt the density will be gradually increased toward the centre of each development cluster. Green street links to the surrounding larger open spaces will provide access to open space in higher density areas. At the centre of each cluster, the minimum parcel size, maximum dwelling numbers, and maximum developed area rules will be adjusted to allow for infill. Changing the zoning regulations within the clusters and allowing the process of infill to happen gradually will help avoid a homogenous and sudden increase in density. Focused infill acts to re-invigorate neighbourhoods and acts as anchors to reinvestment in a community (Felt). The development of vacant or under-utilised properties within the existing built up areas will allow for an increased number of dwellings to become available (Felt). New zoning allows for different kinds of living, creating opportunities for higher density and greater height allowances, without disrupting the existing neighbourhood character. Orientation of new infill dwellings towards the green streets activates these spaces and engages the built edge to shared spaces. Properties will become more affordable within the centre of clusters and shared land arrangements will make the coastal holiday home more achievable for more people (Quigley & Rosenthal).

Figure 156.

Cross lease/shared sections. Dwellings are individually owned and land is shared.



Subdivided sections. Minimum subdivision area adjusted to allow for infill.

Green streets:

Pedestrian orientated connective green spaces that link the wider neighbourhood to a central nucleus and the wider environment.

The development of green streets within the existing street network increases connectivity and creates spaces that favour pedestrian movement while acting as a shared open space for the adjacent properties (Alexander). Green streets and walkways will provide a pedestrian orientated network throughout the sand spit environment linking open spaces through the clusters to the coast. The existing road network will be adapted to accommodate pedestrian focus of community and limit the hard surface area where possible. Where green streets intersect with vehicular roads a central green median and change in materiality will clearly identify the crossing to ensure high visibility of pedestrian movements.

Figure 157 Green streets provide pedestrian only routes between open spaces.

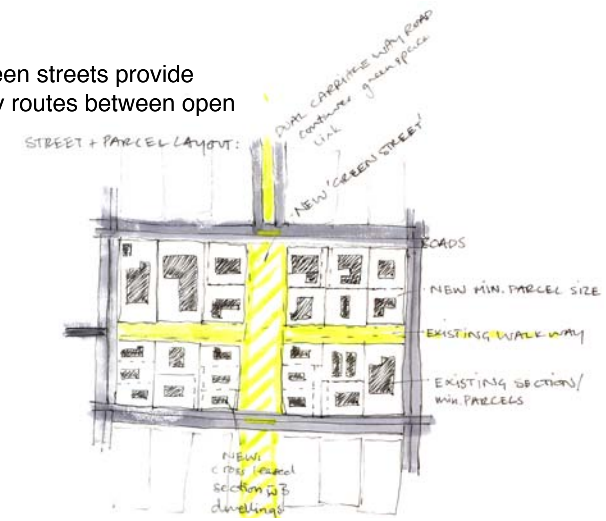


Figure 158. Sectional study of density rings, with graduating building heights.

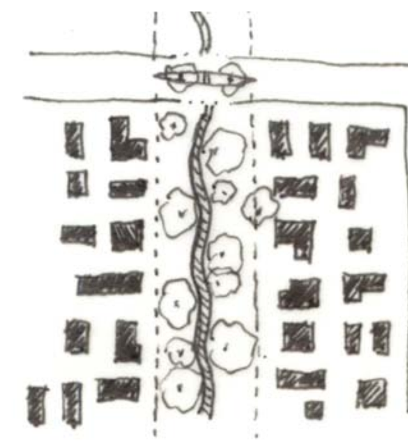


Figure 159. Buildings orientated to face the green streets activate their edges. Adjacency to these green spaces allows for greater density of development.

Figure 160. Minimal boundary definition adjacent to green streets will enhance passive surveillance and neighbourhood awareness.

SUBURBAN INFILL AND GREEN STREETS

- Green streets
- Urban infill opportunities

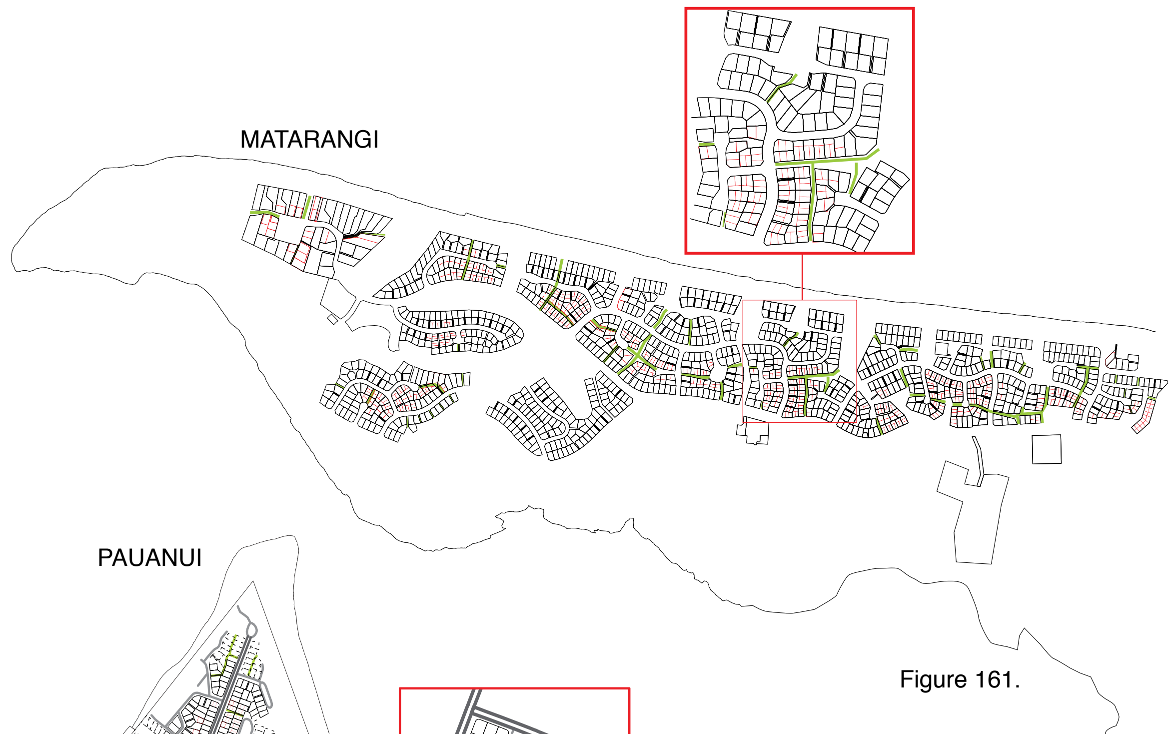


Figure 161.

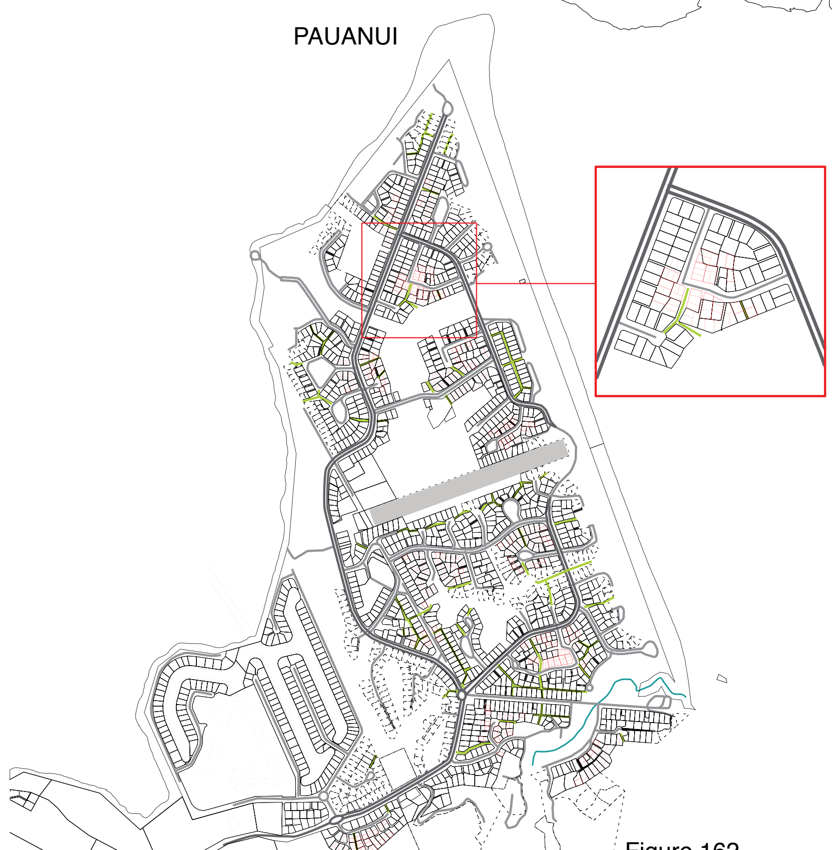


Figure 162.

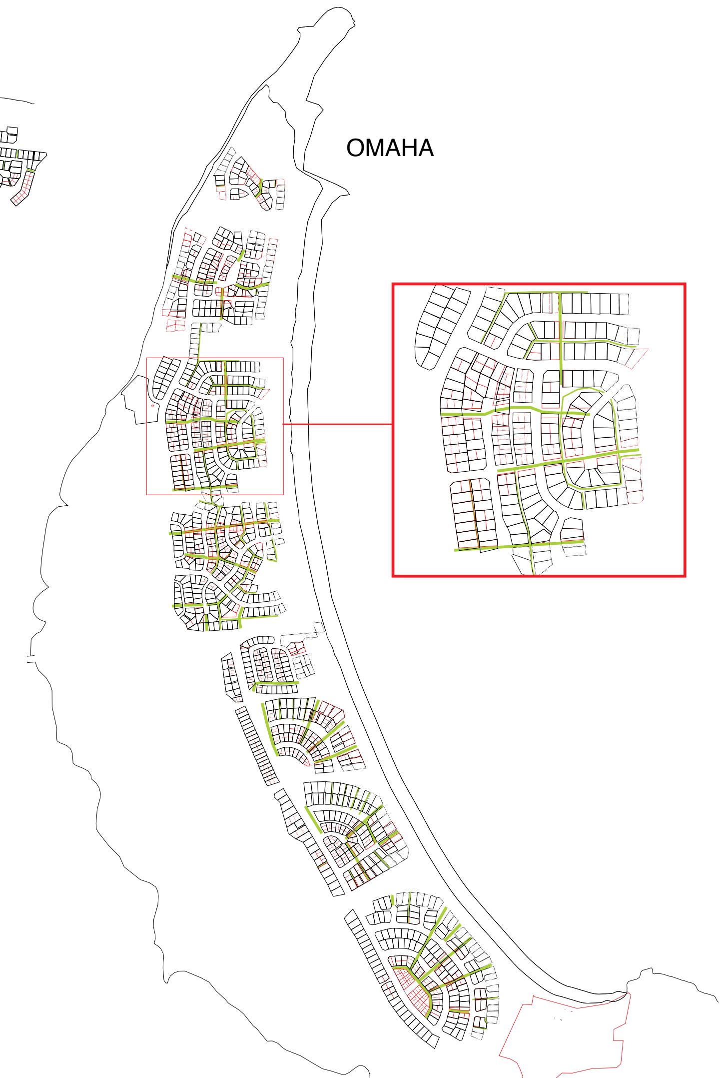


Figure 163.

Figures 164-178. **OMAHA, PAUANUI & MATARANGI:** Impact of inundation threat **BEFORE** the application of the Spit and Neighbourhood scale strategies.

Mean Sea Level = 0.0m

Mean Sea Level = 0.0m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

IPCC SLR 2100 = 0.5m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

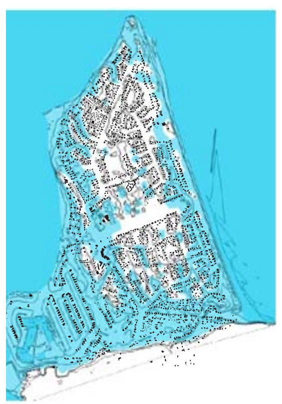
IPCC SLR 2050 = 0.2m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

WORST CASE SCENARIO
IPCC SLR 2100 = 0.88m
Storm Surge = 1.0m
ENSO = 0.25m
Low pressure = 0.3m
Significant Wave Height = 4.0m+





OMAHA

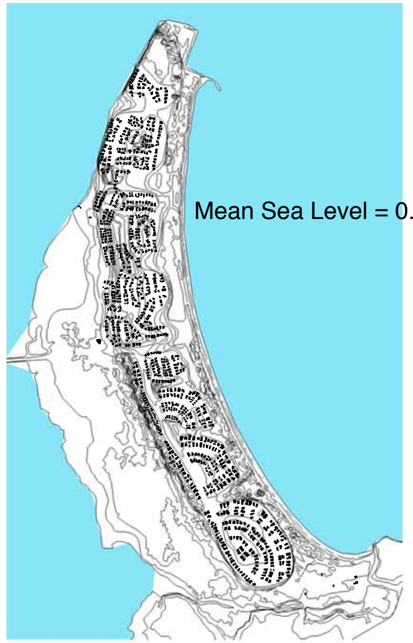




PAUANUI



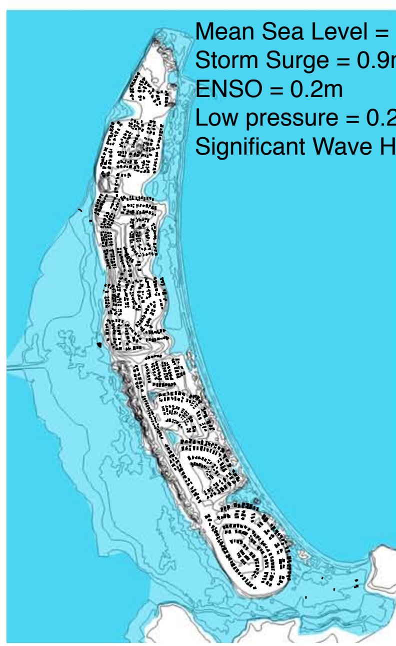


MATARANGI



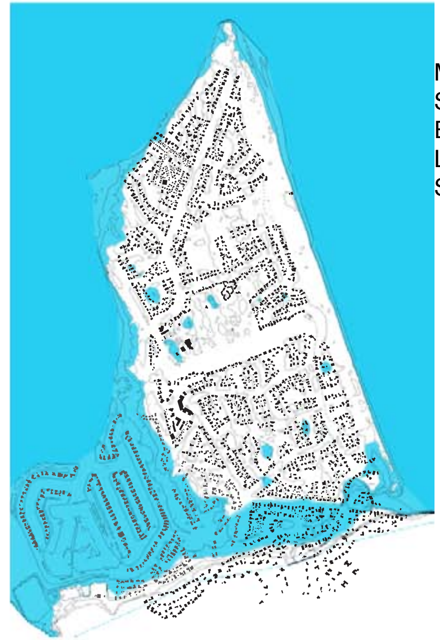
Figures 179-183. **OMAHA:** Impact of inundation threat **AFTER** the application of the Spit and Neighbourhood strategies.

The collaborative application of the strategies at the two larger scales of 'the Spit' and 'the Neighbourhood' can be assessed on the changes made to the inundation impacts identified in the case study analysis process. The construction of the tsunami banking system will raise the level of the develoment area at all three of the case study sites. At Omaha the level is raised to 8m above current MSL. At Pauanui and Matarangi, where the maximum height of the spit overall is little over 8m, the development area level has been raised to 6m above MSL. The inundation level in the worst case scenario for predicted sea-level rise and severe storm conditions is 6.5m+. This level of flooding would have both Pauanui and Matarangi predominately flooded. In this situation the strategies proposed would have limited affect on mitigating the impacts, but would provide a sound foundation to recover and rebuild on.



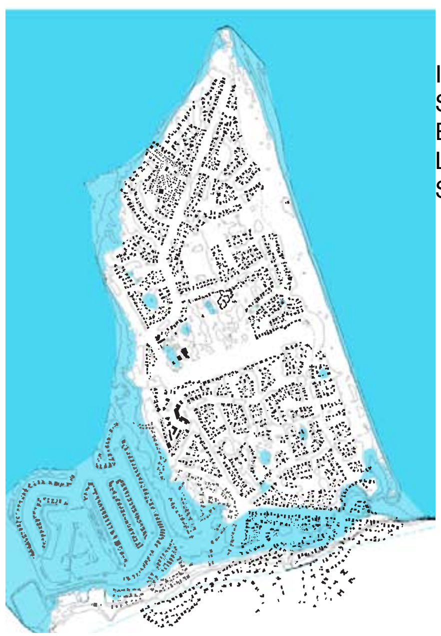
Figures 184-188. **PAUANUI:** Impact of inundation threat **AFTER** the application of the Spit and Neighbourhood strategies.

Mean Sea Level = 0.0m

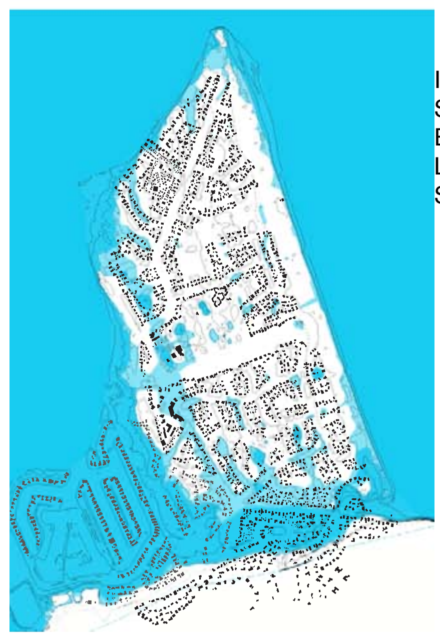


Mean Sea Level = 0.0m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

WORST CASE SCENARIO
IPCC SLR 2100 = 0.88m
Storm Surge = 1.0m
ENSO = 0.25m
Low pressure = 0.3m
Significant Wave Height = 4.0m+

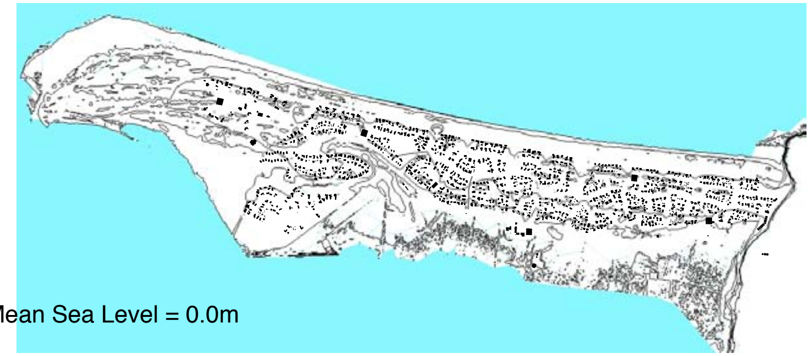


IPCC SLR 2050 = 0.2m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

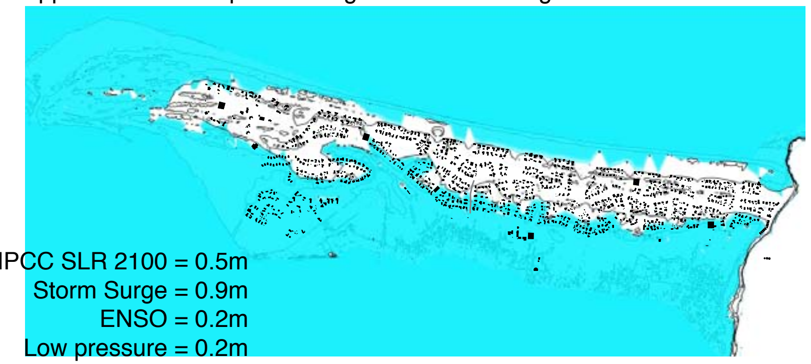


IPCC SLR 2100 = 0.5m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

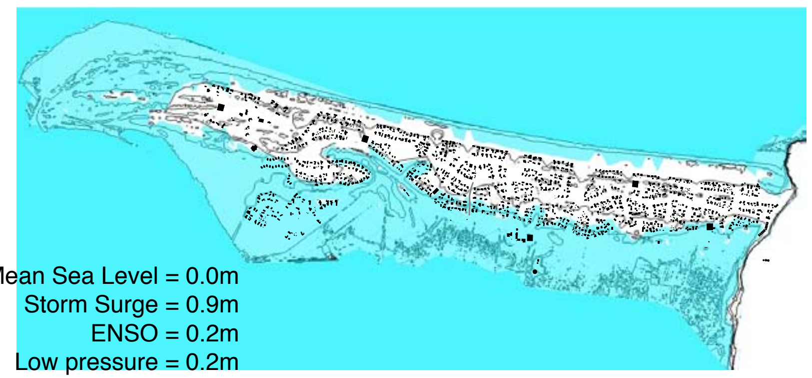
Figures 189-193. **MATARANGI:** Impact of inundation threat **AFTER** the application of the Spit and Neighbourhood strategies.



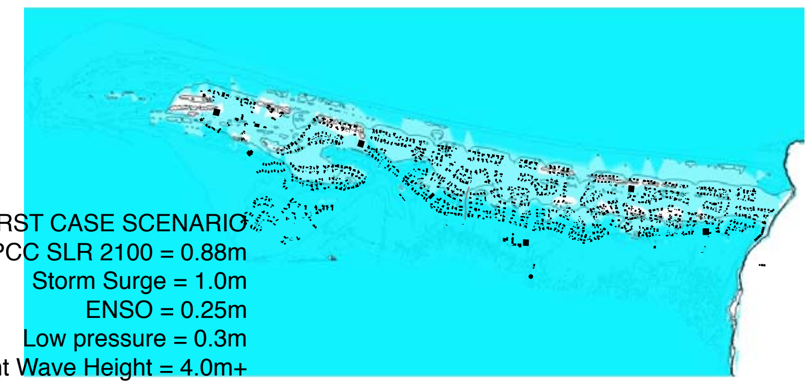
Mean Sea Level = 0.0m



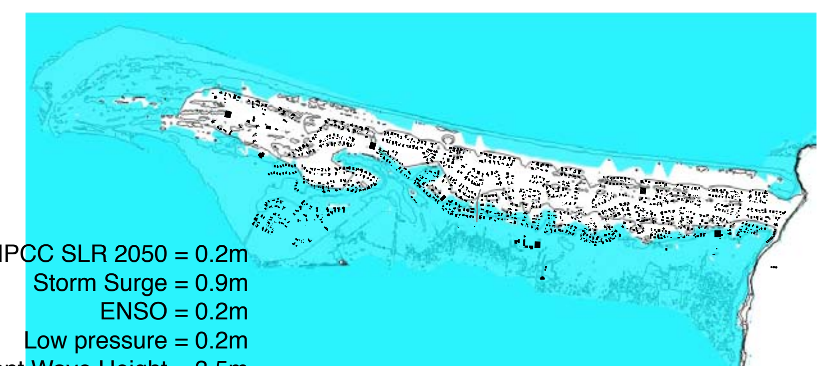
IPCC SLR 2100 = 0.5m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m



Mean Sea Level = 0.0m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m



WORST CASE SCENARIO
IPCC SLR 2100 = 0.88m
Storm Surge = 1.0m
ENSO = 0.25m
Low pressure = 0.3m
Significant Wave Height = 4.0m+



IPCC SLR 2050 = 0.2m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

Graduated building height restrictions:
To maintain views and provide sufficient floor area in central parts of clusters, the max height of built structures will graduate from a single storey at the waterfront front to up to three stories further inland, except where this would interrupt with the visibility of the highest points on the spit.

By graduating the height of built structures away from the adjacent open spaces, issues of over shadowing and visual impacts will be reduced. Buildings should not be visible from the beach to ensure the natural backdrop of the dunes is not interrupted. Further inland high points within the dunes and surrounding hinterland should not be obstructed by built form to ensure visibility of natural landmarks and safe zones in the event of tsunami.

The increased height allowances correspond with the higher density areas, ensuring that visual links to the coastal environment are not lost by the centralised properties. Existing seaward-side waterfront properties have limited sea views due to the dunes.

Figure 194. Graduated building heights moving inland from the coastal fringes.

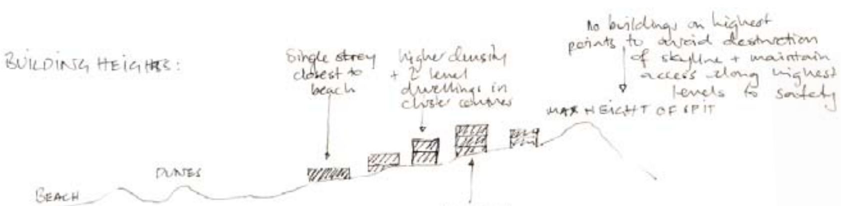
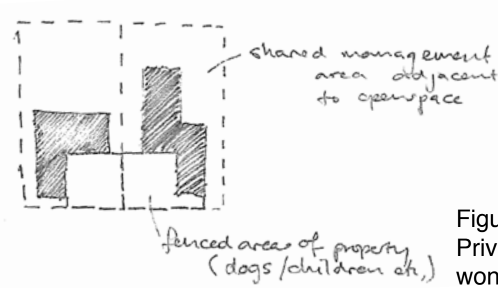


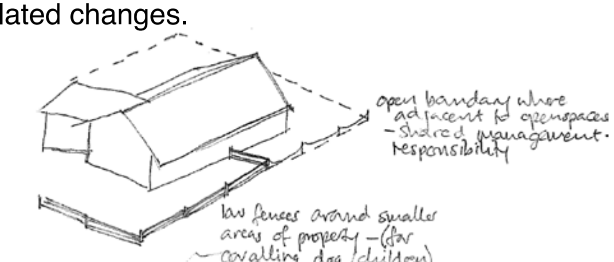
Figure 195. Maximum building height to stay below the height of significant dune height to ensure visual connection with the local environment.

Shared property management:
Introduction of cross-leased sections, with up to three dwellings on shared land, shared management of common green spaces by community. An overlap of larger green space management systems with adjacent properties to ensure the minimum edge effects. Encouragement of openness dwelling facades and of property boundaries to increase the notion of shared space and maximise passive surveillance.

These developments use a shareholder-land ownership structure ensure shared property management and responsibility. This alternative development model was implemented at Awaawaroa Bay, on Waiheke Island, New Zealand, with each shareholder being provided a building site and small allotment of land for personal use, and then the remaining land is collectively managed for both conservation and agricultural purposes (Morton).

This strategy of shareholder ownership allows for several individuals or families to own a property and be able to build a dwelling while sharing the management and maintenance of the land with the other shareholders. This will make owning a holiday home more accessible to lower income families (Hamilton). Towards the edges of the development clusters, the demarcation of property boundaries will be restricted and overlapping management of land will be implemented to ensure that abrupt edges are avoided. This will ensure that built forms will not inhibit any future migration of eco-domains due to climate related changes.





Figures 196 & 197. Minimal boundary definition on public frontages. Private areas can be fenced off to a certain height in areas where it won't interrupt the relationship with the public frontage.

GRADUATED BUILDING HEIGHT RESTRICTIONS

- Single Storey height limit (4m)
- 2 Storey height limit area (7m)
- 3 Storey height limit area (11m)

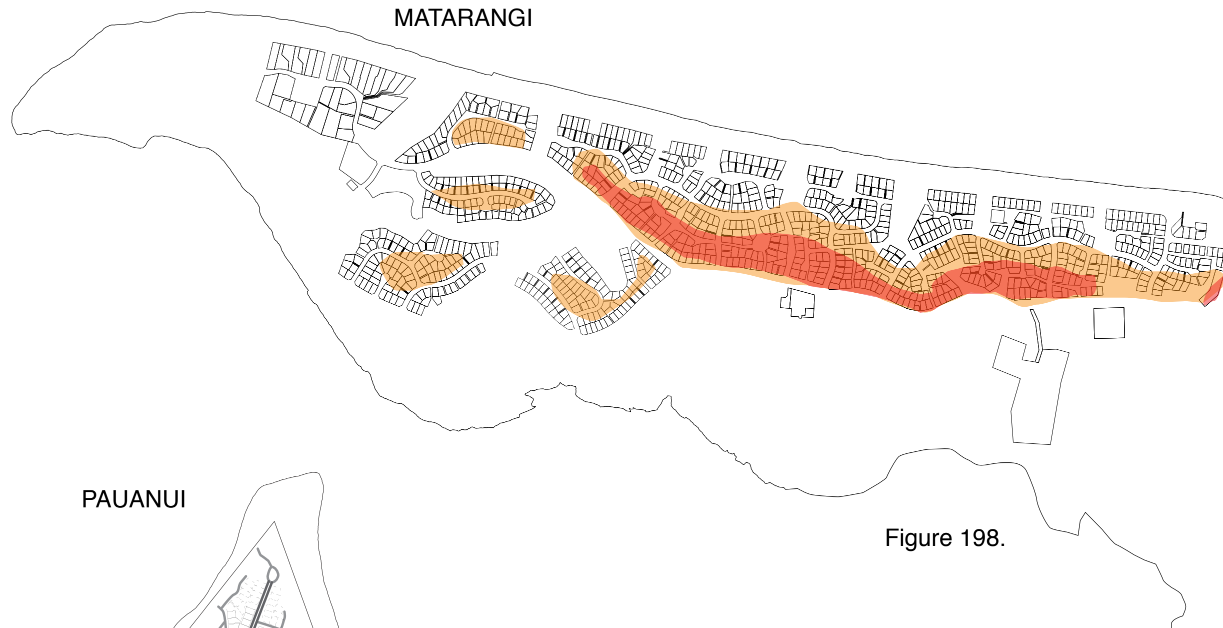


Figure 198.

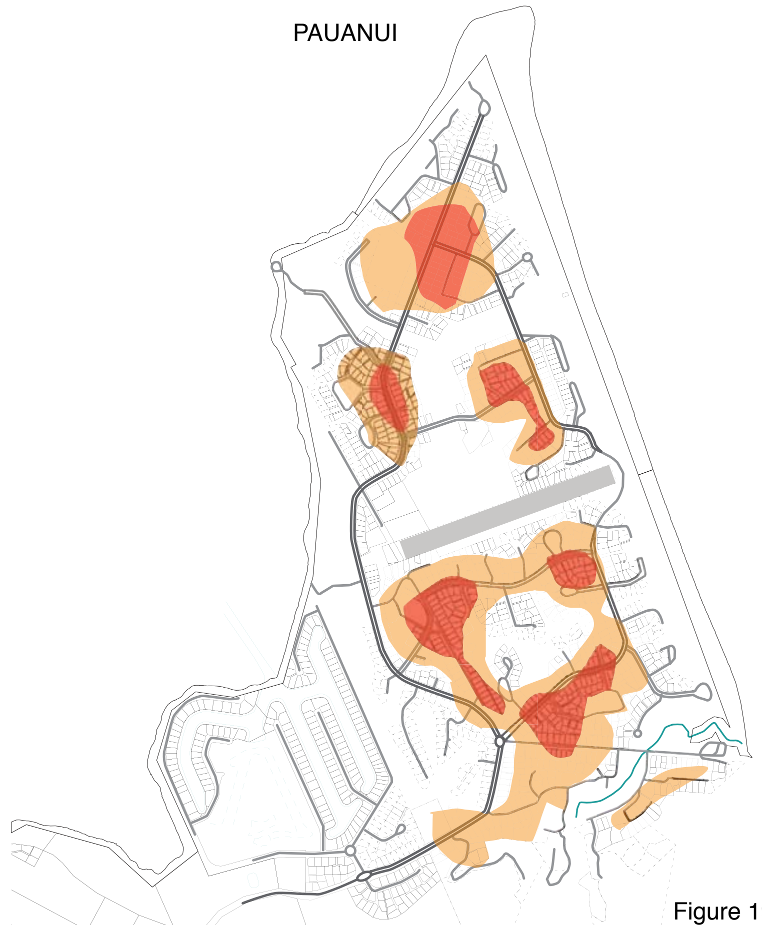


Figure 199.

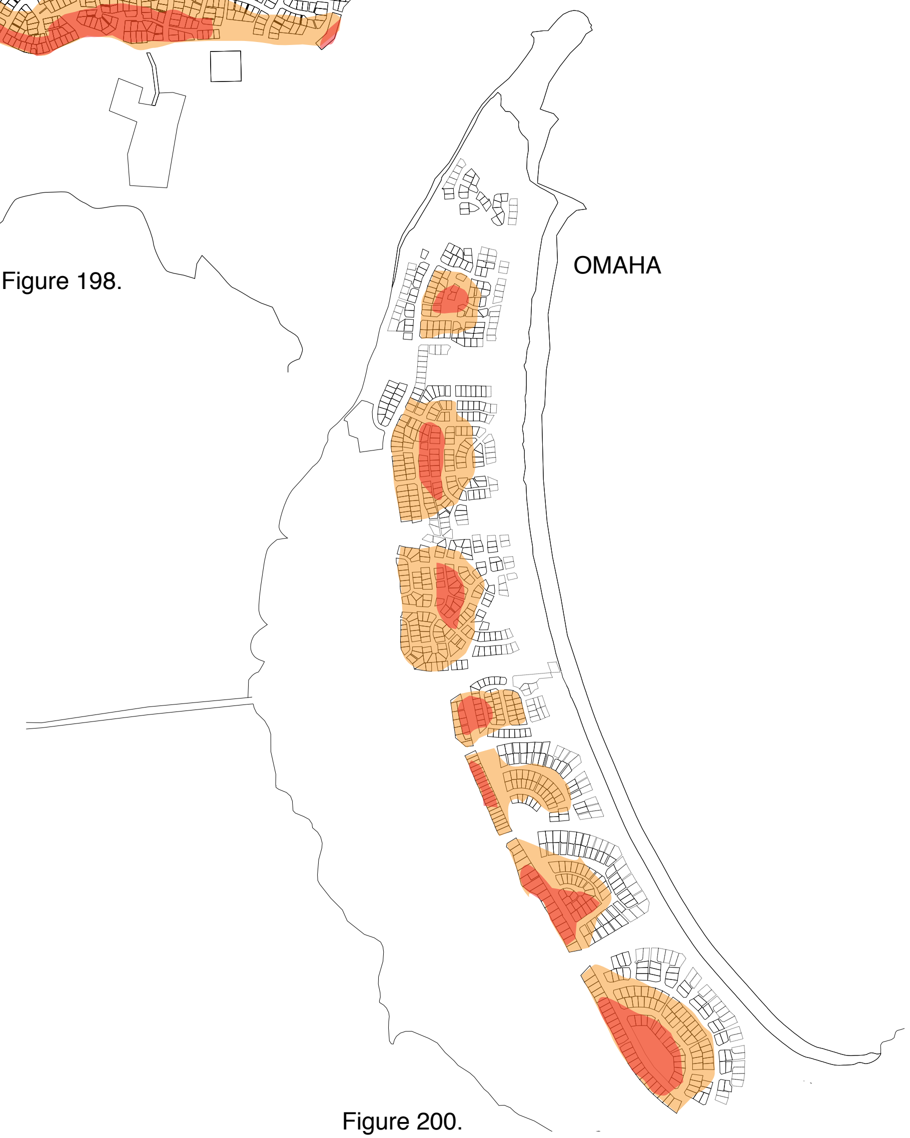


Figure 200.

Limited percentage of built form per section:
To ensure that the ground plane is not too heavily developed. The restrictions of footprint are offset by increased height allowances and provision of community facilities so that large scale socialising can be accommodated.

To maximise the undeveloped land area, and limit hard-surfaces and increased storm water run off, the percentage of built form per parcel will be limited to 30% cover. On larger parcels at the edge of the development clusters this will limit the size of the dwelling, while further toward the centre, as height restrictions are relaxed, the dwellings will be able maintain floor area by building upward.

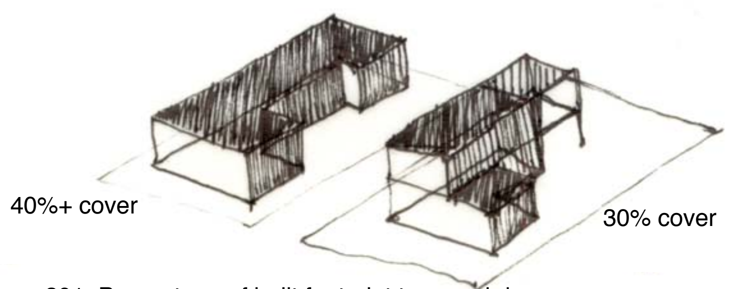


Figure 201. Percentage of built footprint to parcel does not apply to overall size of building in areas where the zoning allows 2 and 3 storey buildings.

Use of sensitive materials:
Buildings will be required to be built of high quality durable materials in a manner that will not create unnecessary visual impact or be too inward focused to feel closed to the street and neighbourhood.

The quality of materials used to construct buildings will be regulated to ensure that degradation due to coastal exposure, or damage from storm or tsunami events is limited. The visual impact of bright colours and reflective materials will be limited to maximise the enjoyment of the natural environment. The building style itself will not be regulated other than the requirement to engage the street or walkway frontage and adhering to height and foundation regulations. Any new building constructed must meet the building quality requirements within 1km of the coastline.

The coastal development of Seaside, Florida, restricts the style of architecture and requires high quality building materials to ensure a certain visual character is maintained (Seaside Florida). While this creates a certain homogeneity, it also ensures a recognisable identity is maintained.

Examples of houses built from visually sensitive materials.

Figure 202.

Figure 203.

Figure 204.

Figure 205.

These strategies have been developed to increase the adaptive capacity of the sand spit and are guided by the Nicholls and Klein framework for proactive adaptation.

1. Increasing **robustness** of infrastructural designs and long-term investments
2. Increasing **flexibility** of vulnerable managed systems
3. Enhancing **adaptability** of vulnerable natural systems
4. Reversing **maladaptive** trends
5. Improving societal **awareness** and **preparedness.** (Nicholls & Klein 221)

Enhancing the natural dune system and allowing it room to shift and respond to climatic conditions is crucial to increasing the adaptive capacity of the sand spit community. Creating awareness of the importance of these environments is also important to ensure support and guardianship from the local community. The enhancement of the natural environment increases the quality of the natural character, and the community's coastal identity.

The clustering of the developed areas limits the built footprint and allows for open space connections across the sand spit. This also allows for overland flow for flood waters and eco-domains if necessary. Greater density within the clustered development is achieved through new property ownership systems and regulations allowing smaller lot sizes and cross-leasing arrangements. The increased density at the centre of the clusters, created through the adapted land zoning and ownership regulations, allows a more diverse range of people to live or own a holiday home. Community engagement and social capital building is encouraged through the creation of activity-rich central amenity spaces, shared green spaces within neighbourhood blocks, and houses that engage with the street.

The visibility and accessibility of the beach is increased and an extensive recreational network throughout the sand spit connects each cluster to the wider environment and to surrounding hinterland. This increased accessibility of the coastal settlement makes it a more welcoming destination for the wider public, ensuring the potential for it to become a seasonal festival host and attracting beach related events.

These strategies work collaboratively to encourage a greater robustness in the natural environment and community.

	KEY FEATURES	ECOLOGICAL BENEFITS	SOCIAL BENEFITS	POTENTIAL LIMITATIONS
Hierarchy of Open space	Provision of open space at a range of scales	Larger spaces are ecologically focused	Smaller spaces and pockets within larger spaces are socially focused	Focus on open space reduces the develop-able area of the spit
Reinforcing and Regenerating the Natural Environment	Enhanced and robust natural environment	Healthy and regenerating ecosystems, increased diversity in flora and fauna	Increased protective capacity of the coastal system, visual and recreational amenity	Requires community and local government buy-in, long-term and continuous process
Releasing Areas from Development	Removing dwellings from vulnerable areas and re-siting them within the cluster areas	Provides greater flexibility for the natural processes, allows expansion of eco-domains	Reduces potential for property damage due to inundation	Displacement of residents, unwillingness to move properties
Tsunami Banking	Large-scale flexibile reinforcing of the natural dune defense system	Supports the natural defense system without limiting the flexiblity or natural character	Protects the development area from potential inundation threats	Large-scale financial undertaking and spit wide construction effort
High-land Walkway	Walkway along the highest points of land	Part of the open space network, acts as an eco-corridor	Highly visible evacuation route, back bone of spit wide recreational network	May have to cross vulnerable low-lying land at spit heel
Interpretive Signage and Way Finding	Clear visual cues and signage to aid navigation and information availability	Increases awareness and appreciation of the natural environment	Provides clear information about the natural environment, potential threats and evacuation routes	Clarity of both the emergency management information and general interest information
Wash-over Parks	Open spaces to absorb coastal threats and provide public amenity	Creates greater flexibility in the natural environment and absorbs and dissipates inundation threats	Provides social and recreational spaces with high value natural and recreational amentity while also absorbing potential coastal threats	Requires the removal of some properties to create space in vulnerable areas

	KEY FEATURES	ECOLOGICAL BENEFITS	SOCIAL BENEFITS	POTENTIAL LIMITATIONS
Development Clusters	Condensing of development area to create more open spaces and higher density neighbourhoods	Reduces the built foot print of the spit and creates more open space	Tighter knit neighbourhoods and higher value open spaces, more diversity in dwellings and residents	Requires reorganisation of existing properties to allow for increased density and the creation of open spaces
Sub-urban Infill	Reorganising of property regulations to allow for increased density	Increasing the density in the centre of the clusters allows lower density at the edges	Higher density areas and clear neighbourhoods foster community engagement	Unwillingness to subdivide current parcels to create higher density areas
Green Streets	Pedestrian focused connective green spaces that link through the cluster to the adjacent open spaces	Creation of eco-corridors linking the open space network across the whole spit	Pedestrian focus and green space creating social spaces within the clusters and links to the wash-over parks	Removal of some dwellings to create the green streets
Graduated Height Restrictions	Graduation of building heights away from the shore	Reduces visual impact	Reduces visual impact of buildings from beach	Limits the potential floor area of waterfront dwellings
Shared Property Management	Blurred edge between public and privaten land management	Reduces potential 'edge effects' and allows flexibility in natural environment	Reduces maintenance of private properties adjacent to public open spaces	Limits the boundary defintions between public and private property adjacent to open spaces
Limited Percentage of Built form per Section	Reduces the built footprint of each property	Reduces hard surfaces and increases flexibility of open spaces	Smaller buildings encourage outdoor living and simpler dwellings	Interrupts the current trend towards large complicated dwellings and large areas of hard surface
Use of Sensitive Materials	Use of visually and ecologically sensitive high quality building materials	Ensures quality, longevity and sensitivity of built environment	Helps to develop the coastal character of the settlement and ensure high qaulity and viaully sensitive buildings	Many existing buildings do not currently adhere to these regulations

DETAIL DESIGN AT OMAHA

Site Analysis

Wash-over Park
- Conceptual Diagram
- Plan and Section
- Programme Analysis
- Detail Elements

Cluster Transect
- Conceptual Diagram
- Plan and Section
- Programme Analysis
- Detail Elements

Inundation Testing

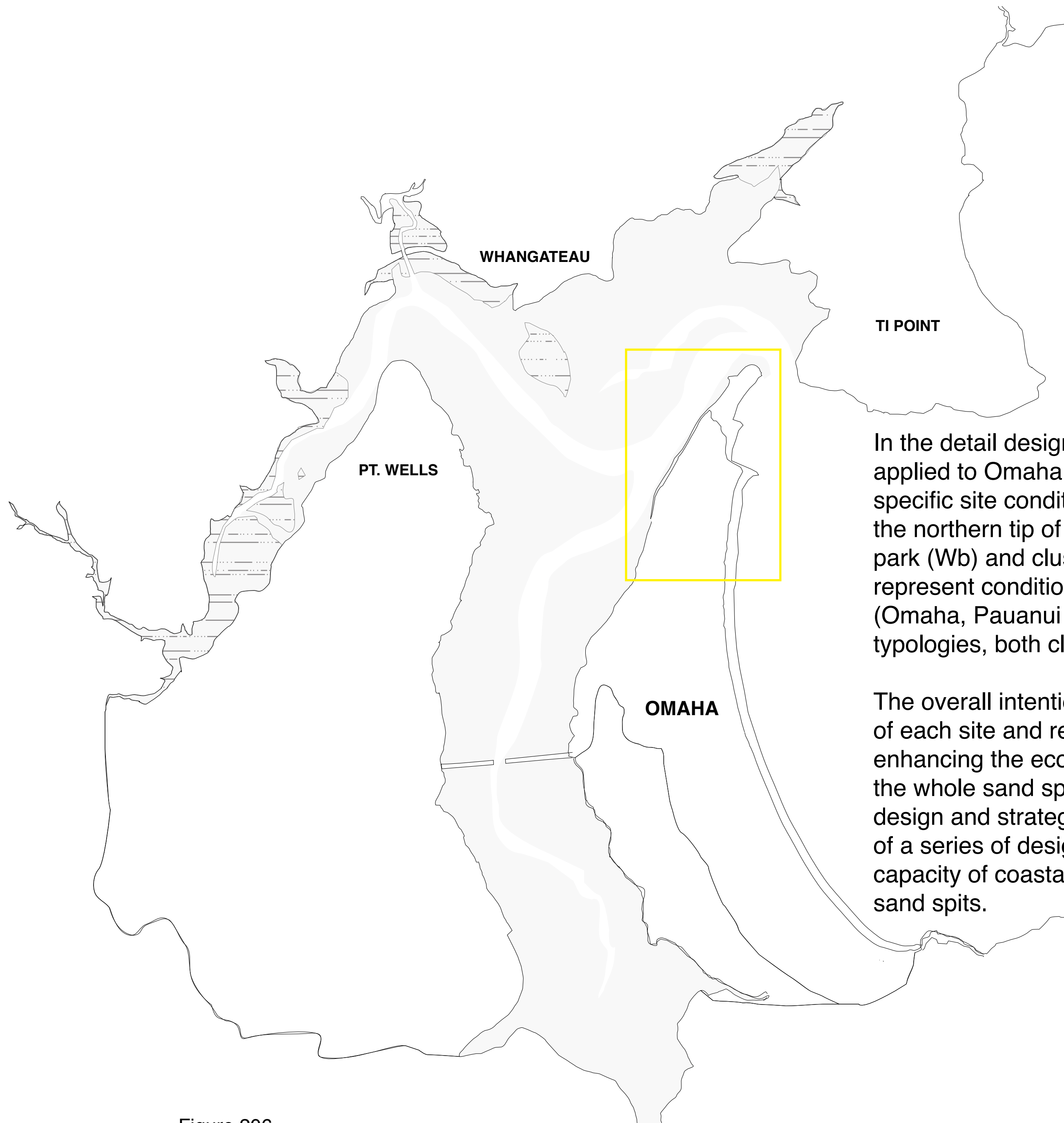


Figure 206.

In the detail design process all of the strategies are applied to Omaha and tested in response to the specific site conditions. The detail design focuses on the northern tip of Omaha, and specifically a wash over park (Wb) and cluster (C3) transect. These two sites represent conditions found in all three of the test sites (Omaha, Pauanui & Matarangi) and characteristics in all typologies, both clusters and wash over parks.

The overall intention is to increase the adaptive capacity of each site and reduce the maladaptive trends while enhancing the ecological, societal and economic value of the whole sand spit community. The assessment of the design and strategies on site facilitates the development of a series of design principles for increasing the adaptive capacity of coastal settlements, and specifically those on sand spits.

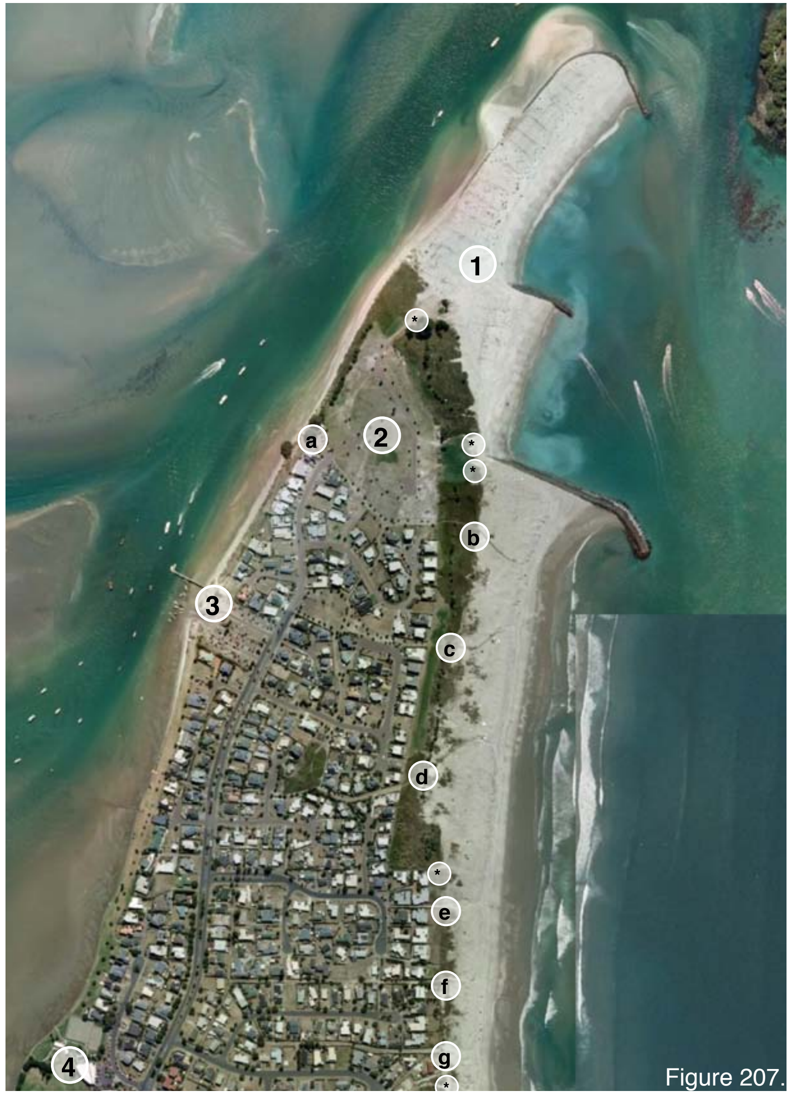


Figure 207.

The northen end of the spit is the most vulnerable to the tidal currents and swells, being the lowest lying and narrowest land. The harbour edge of the spit is highly prone to erosion since the construction of the causeway changed the way the harbour drains.

a-g. Beach Access: council formed beach access including boardwalks across dunes where necessary.

* paths formed by residents and visitors across the dunes without consideration for the delicate ecosystems and vegetation.

ANALYSIS OF EXISTING SITE

1. Dotterel nesting area: one of few remaining nesting areas for these critically endangered native birds.

2. Property land bank: these properties were laid out with the supporting infrastructure in preparation for sale, but were never sold or developed.

3. Boat Ramp and Wharf: the only boat ramp/wharf on the spit, minimal facilities provided.

4. Golf club, bowling club and cafe and tennis courts, the only public recreation facilities in the northern subdivision.

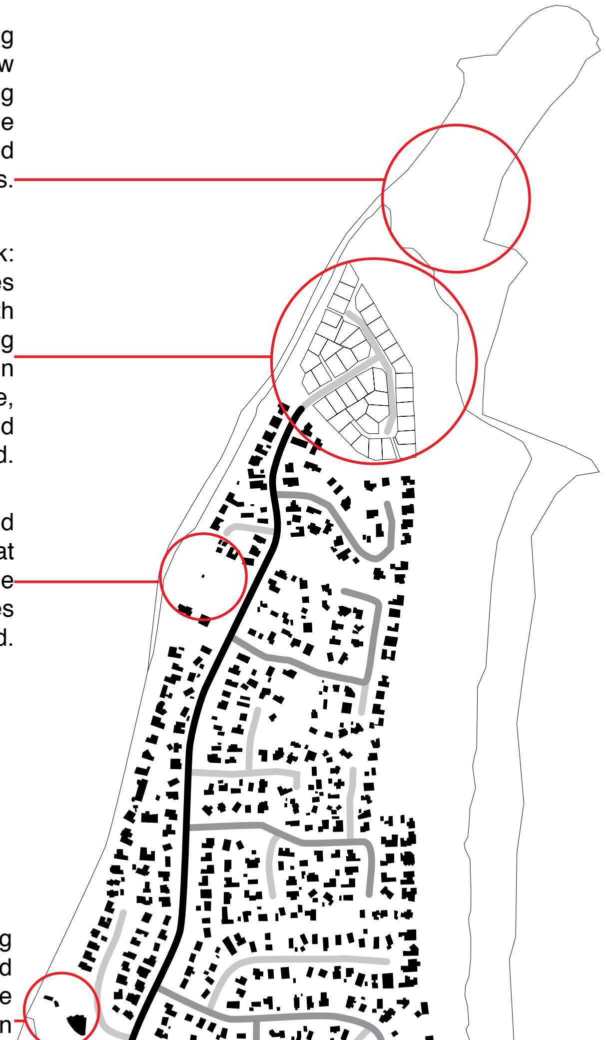


Figure 208.

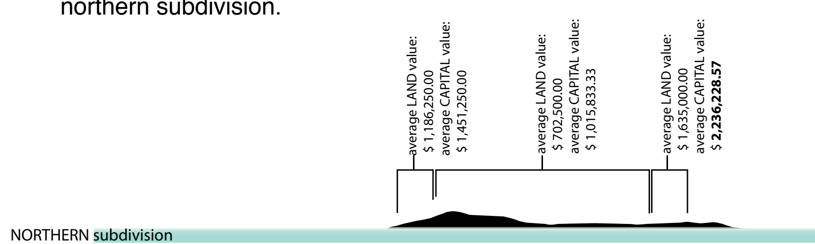
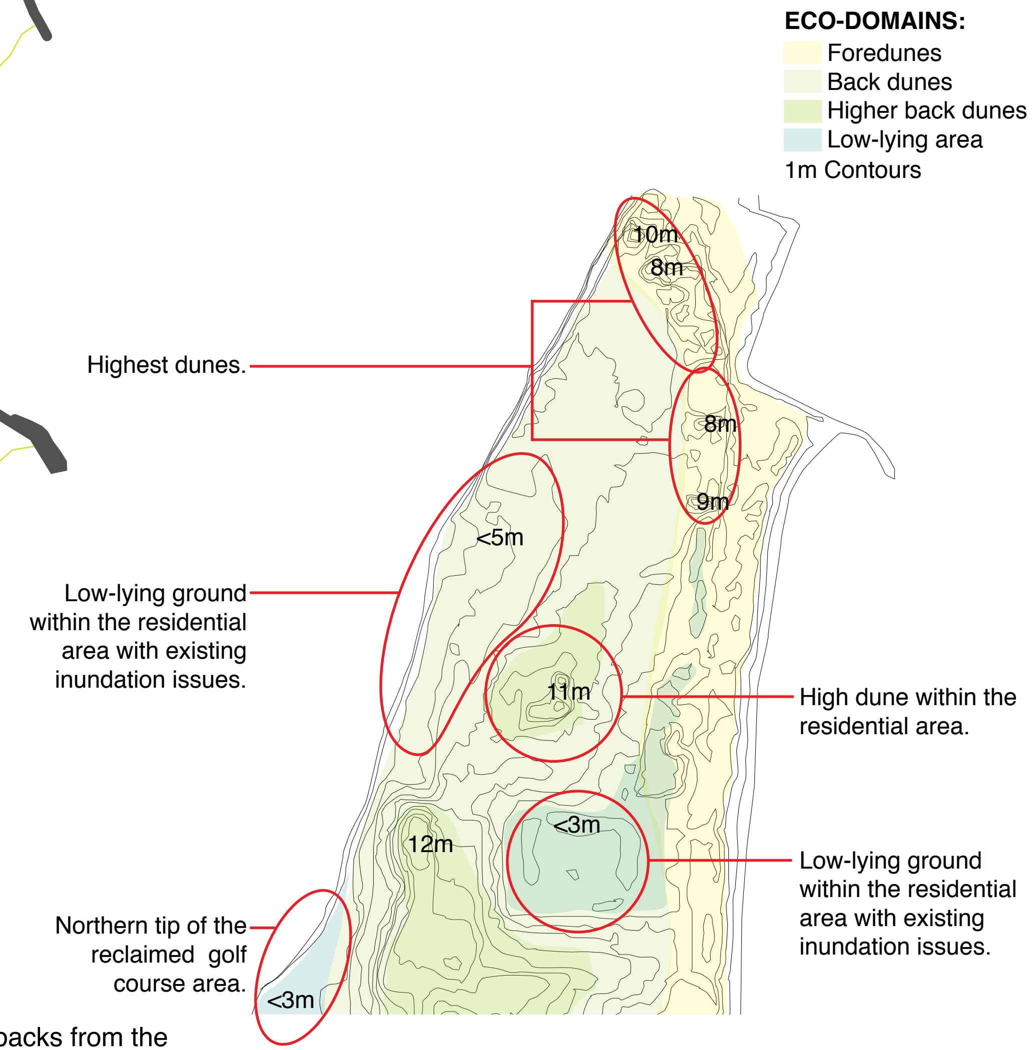


Figure 209.

Figure 210. **EXISTING GREEN SPACE ANALYSIS**

Figure 211. **EXISTING TOPOGRAPHIC ANALYSIS**



The northern end of Omaha has the largest set backs from the seaward edge, but the harbour edge is heavily developed. There are serious erosion issues along the northern-most edge of the development area with a steep drop of over 4 metres from the waterfront properties to the beach. The tidal currents run at their highest velocity along the harbour edge. Sea walls constructed during the reclamation of the golf course land have further exacerbated the erosion of the harbour edge at the north of the spit.

Dwellings

Vulnerable Dwellings

Dwellings to be Removed

EXISTING INUNDATION IMPACT TO RESIDENTIAL AREA:

Scenario 1:
38% of dwellings vulnerable to inundation

Scenario 2:
42% of dwellings vulnerable to inundation

Scenario 3:
54% of dwellings vulnerable to inundation

Scenario 4:
89% of dwellings vulnerable to inundation

The release of the foredunes and the creation of wash-over parks is facilitated by the removal of some dwellings and properties. The new density allowances within the residential clusters provide for the re-siting of all of the displaced dwellings and/or re-housing the residents. The removal of a small percentage of dwellings ensures the protection of the greater proportion of the residential area.

The implementation of the strategies, facilitated by the removal of a small percentage of properties, significantly decreases the number of vulnerable properties on the spit.

Percentage of total dwellings removed: 24%

INUNDATION IMPACT AFTER IMPLEMENTATION OF STRATEGIES:

Scenario 1:
No dwellings vulnerable to inundation

Scenario 2:
1% of dwellings vulnerable to inundation

Scenario 3:
4% of dwellings vulnerable to inundation

Scenario 4:
21% of dwellings vulnerable to inundation

Figures 212-219.

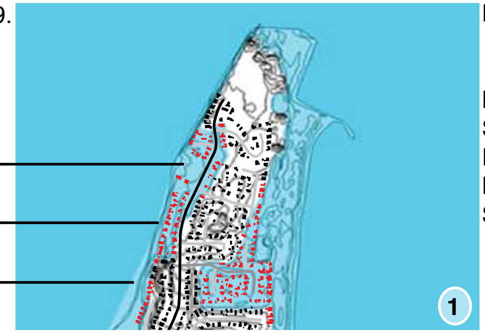
Sections

A

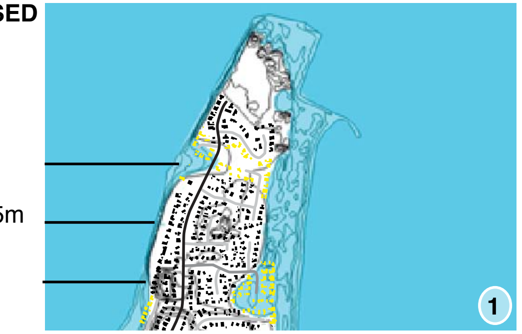
B

C

EXISTING **PROPOSED**



Mean Sea Level = 0.0m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m



IPCC SLR 2050 = 0.2m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2
Significant Wave Height = 3.5m

IPCC SLR 2100 = 0.5m
Storm Surge = 0.9m
ENSO = 0.2
Low pressure = 0.2
Significant Wave Height = 3.5m

WORST CASE SCENARIO
IPCC SLR 2100 = 0.88m
Storm Surge = 1.0m
ENSO = 0.25m
Low pressure = 0.3m
Significant Wave Height = 4.0m+

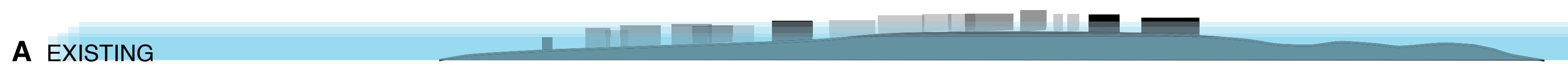


Figure 220. The properties at the northern most end of the spit are vulnerable to potential inundation at all of the suggested potential inundation levels.

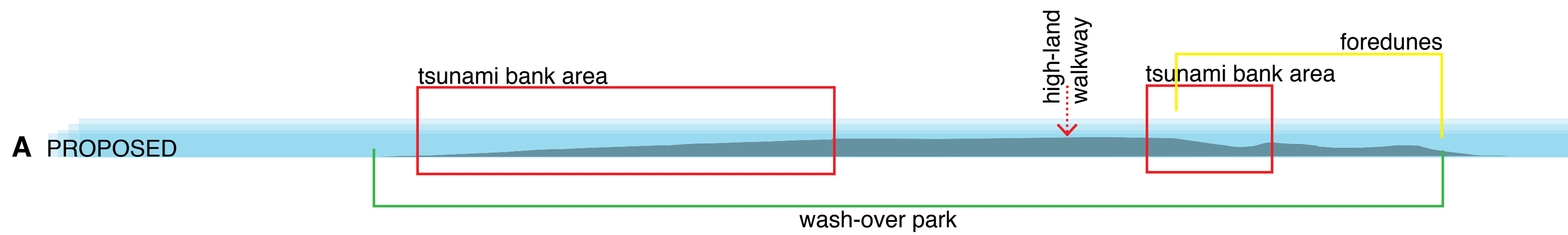


Figure 221. The removal of vulnerable properties to create a wash-over park that will absorb much of the lower levels of potential inundation.

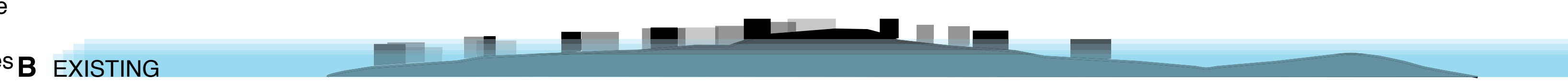


Figure 222. Waterfront properties are particularly vulnerable to inundation and only a small amount of properties are currently above all suggested potential levels.

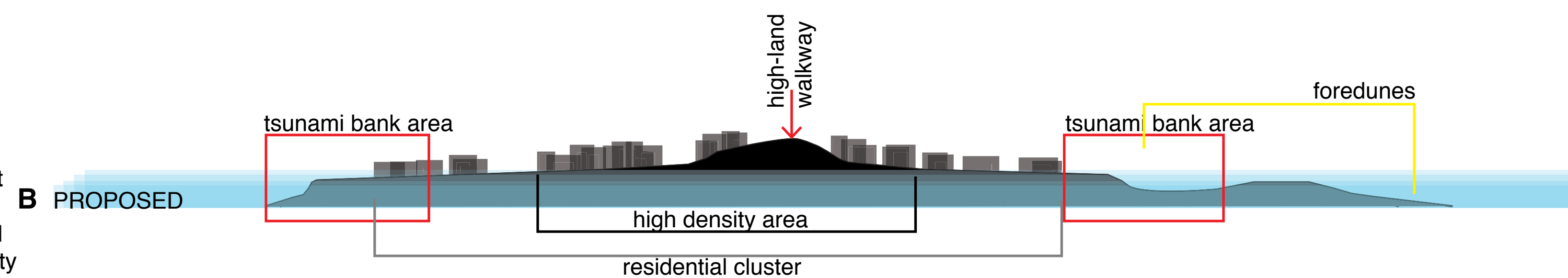


Figure 223. The tsunami banks raise the majority of the residential area above the highest suggested potential inundation level. Waterfront properties have been removed and accommodated within the residential clusters which have increased density allowances in the centre.

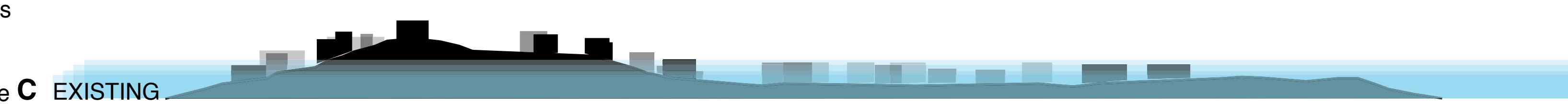


Figure 224. Properties on large areas of low-lying land are vulnerable, especially waterfront properties. A small amount of properties are above all suggested potential inundation levels.

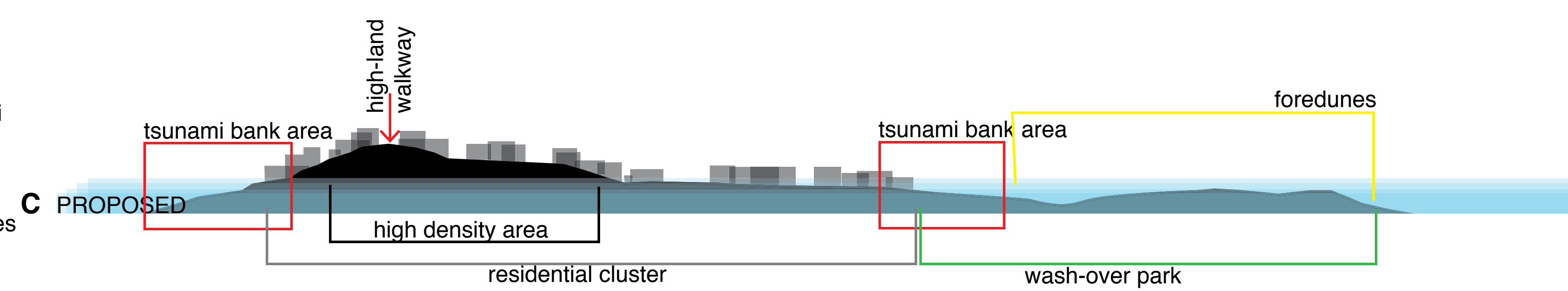


Figure 225. Increasing the level of the residential area with the tsunami banking system and stepping back the waterfront properties reduces the number of vulnerable properties. Higher density allowances towards the centre of the clusters accommodates removed properties.

APPLICATION OF ALL STRATEGIES AT OMAHA NORTH

The spit tip is the most vulnerable point to wash-over from both the harbour and seaward sides. It is most responsive to tidal currents and shifts across the mouth of the harbour outlet over annual and decadal timescales. This shifting is reduced by the groynes.

The wash-over park strategy is applied here to allow inundation to completely wash across the spit, if necessary, and the relationship the built environment has to the park is therefore less direct. The buffer between the wash-over park and the adjacent dwellings is vegetated to slow the water flow and catch any potential debris. The properties on this edge share management with the public open space to ensure the transition from private to public space is not clearly atriculated.

The height of the dwellings allowed in this area is lower than the overall allowance due to the lower-lying land, and more direct proximity to the beach.

A. Wash-over park **Wb** has all the key characteristics common to all three wash-over typologies. Incorporating the complete wash-over capacity of typologies Wa and Wb, with the wash-in capacity of typology Wc.

B. The cluster transect is representative of the central higher-density areas of all the cluster typologies, and shows the cross section across the width of the spit from seaward to harbour coasts.

Tsunami Banks (2m vertical intervals)
Wash over parks
Open spaces
Green streets
Shared management properties
Subdivided properties
Shared ownership properties
Removed buildings
Main road
Highland Walkways

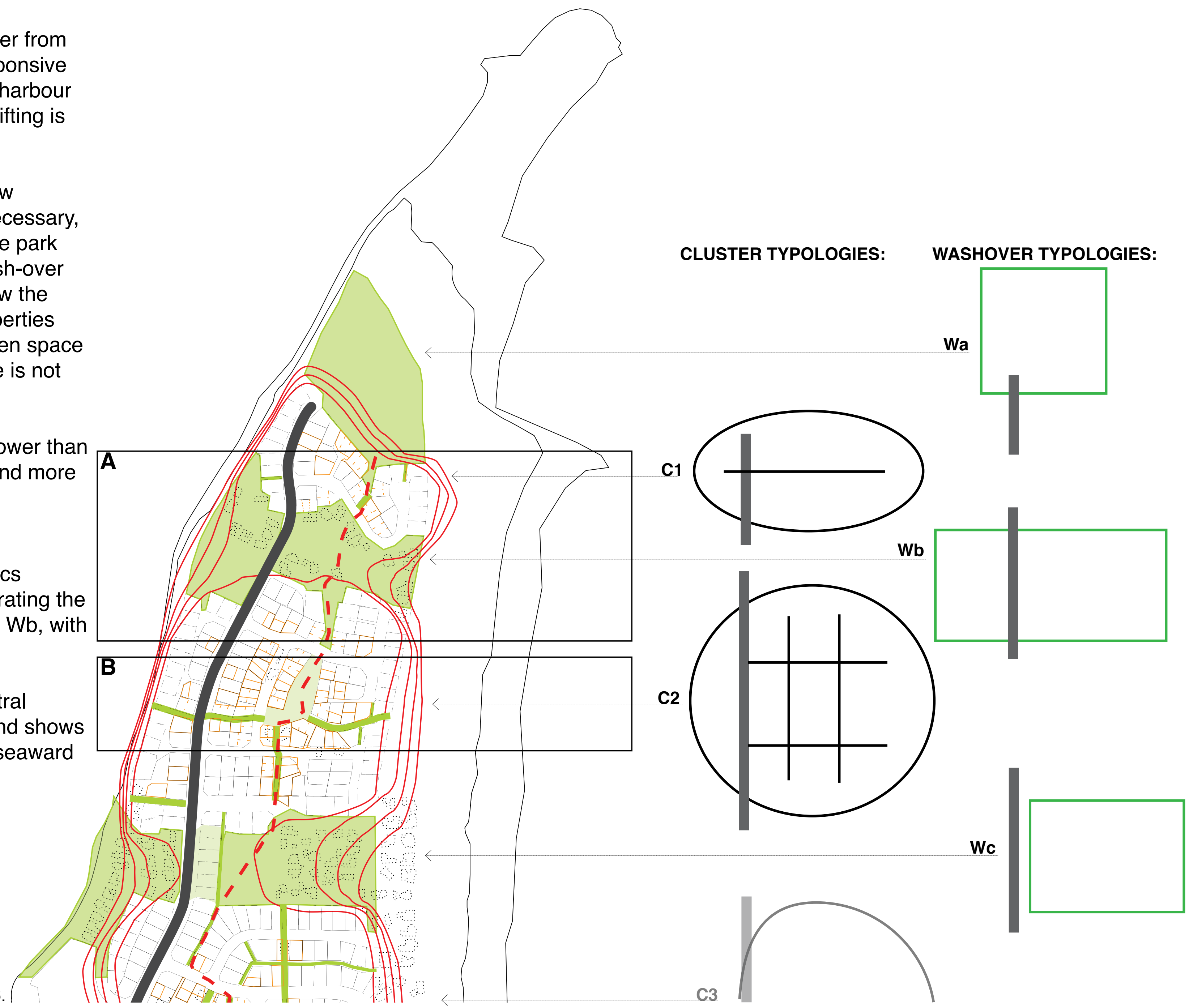
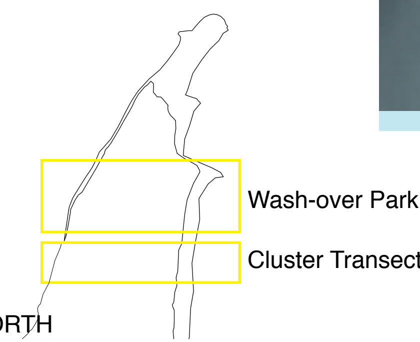


Figure 226.

WASH-OVER SITE EXISTING ANALYSIS

- Existing open spaces
- Waterfront reserve
- Boat ramp/wharf and carparking area
- Wharf
- Beach access board walks
- Inundation up to 5m
- Potential inundation up to 7m

Figure 227.



The residential area is zoned medium density. The foredunes in this area are mostly un-modified, although vegetation is a mix of exotic and native.

Figure 228.

CLUSTER TRANSECT EXISTING ANALYSIS

- Existing open spaces
- Waterfront reserve
- Beach access board walks
- Inundation up to 5m
- Potential inundation up to 5m

A. WASH-OVER PARK:

Figure 229.

N.B: The tsunami banking shown in both plans is predominantly below the ground surface and acts as reinforcement to the natural defences of the spit.

EXISTING:

Open space

Main road

REMOVED:

Dwellings

Properties

AMENDED:

Shared management properties

Green streets

INSERTED:

Wash-over park

Subdivided properties

Shared ownership properties

Highland walkway

Tsunami banking (2m vertical intervals)

The creation of the wash-over park that spans the whole width of the spit, responds to the higher likelihood of complete wash-over in this area, both from the seaward side and also the harbour side. The land is lower-lying here and the boat ramp and adjacent carparking area increase the potential for inundation from the harbour side. Removing dwellings adjacent to this area, properties that are currently at risk of inundation, and the planting of vegetation to protect other properties will limit potential inundation impacts.

The northern residential cluster, although on lower-lying land than the rest of the developed area of the spit, is mostly protected from wash-over. The harbour edge drops 3-5m to the beach due to erosion from tidal currents. The formation of the dunes just north of the wash-over park on the seaward side will protect the most waterfront properties from the direct impact of storm waves. In front of the wash-over park the dunes are lower and vegetation will help slow potential wash-over water flow.

B. CLUSTER TRANSECT:

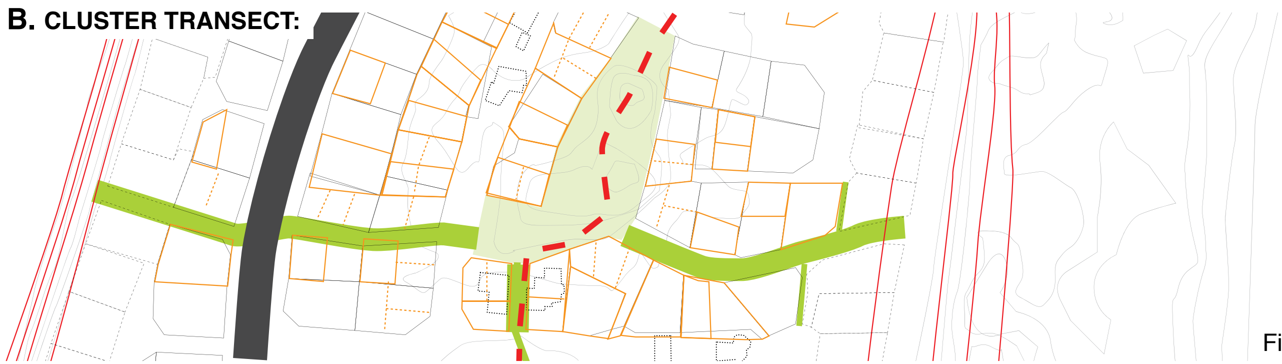


Figure 230.

The cluster transect shows the opportunities for infill, through subdivision and shared property ownership. Increasing the connectivity through the cluster area is achieved through the extention of roads where there are currently dead ends.

The open space is an existing high point and the clustering of the higher density housing opportunities is around this. This high point is connected through the residential cluster by green space walkways to the adjacent open spaces including the waterfront reserves and beaches.

Releasing vulnerable areas from the development foot print of the spit enhances the ability of the natural systems to respond to climate related changes. Removing properties from within the area vulnerable to erosion and inundation and re-siting them within the development area creates greater areas of open space. **Reinforcing and regenerating the natural coastal environment** increases both the natural character of the spit, and the protective capacity of the foredunes. The increase of open space and the **regeneration of the natural processes and ecosystems** allows the spit to absorb changes and threats and adapt in response to climate related changes. A **hierarchy of open spaces** is created to ensure that both natural processes and the social and recreational requirements of the community can be accommodated within the open space network.

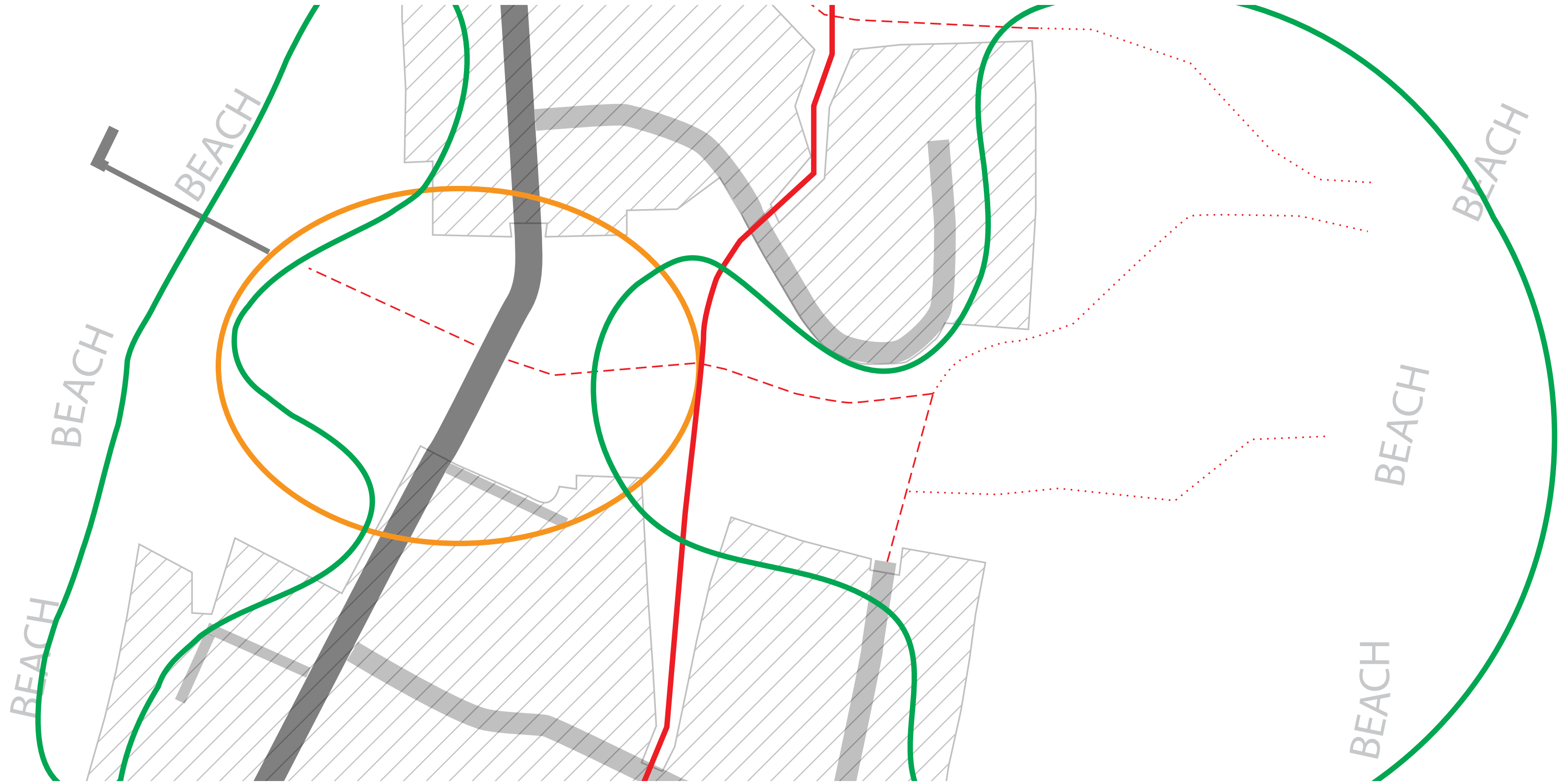
Wash-over parks are created in naturally low-lying areas to absorb inundation threats and provide open spaces for recreational and social amenity. The properties are grouped into **development clusters** to limit the built footprint of the spit and create space for the **wash-over parks**. The increased density allowances, created through a **shared property ownership system**, encourage **sub-urban infill** towards the centre of the clusters. Towards the edges of the clusters the density is reduced with **the percentage of built form per section limited** to reduce hard surface areas. The **management of properties adjacent to public open spaces is shared between the council and the land owner** to ensure the transition between public and private is blurred. By restricting the definition of boundaries, properties are more open and the migration of eco-domains is not impeded.

Figure 231.

Tsunami banking provides an endo-skeletal reinforcement to the natural defense systems of the spit, while also raising the majority of the development footrpint above the suggest potential inundation levels. The tsunami banks are flexible, and largely below the ground surface, and work with the dunes and vegetation to protect against damage caused by inundation. Where the banking breaks the surface it can become the foundation infrastructure for the recreational network that links all the open spaces through the spit and to the beach. A network of **green streets** provides pedestrian focused routes through the **development clusters**, linking the higher density areas in the centre to the adjacent **wash-over parks**, while also providing public green spaces. The back bone of this recreational network is a **high-land walkway** that links the highest points of the spit through to the hinterland and is clearly identifiable as an evacutation route. The use of **interpretive signage and way finding** to provides information on the natural environment, potential threats and evacuation routes. The availablity of this information in a recreational context helps to raise awareness of potential threats and increases the ability of the community to respond appropriately in the case of an emergency.

All of these strategies work concurrently to increase the adaptive capacity of the entire spit. The reinforcing and regeneration of the natural environment is an ongoing process that is started with the release of vulnerable areas from development. After the initial re-siting of removed properties the sub-urban infill also happens over time as demand for properties increases. The smaller parcels and shared ownership opportunities increase the ability of a greater diversity of people to buy-in.

Figure 232. **CONCEPTUAL DIAGRAM**



LEGEND:

- Ecological areas
- Social/programmed areas
- High-land walkway
- Formed pathways
- Beach access boardwalks
- Residential area
- Main road

WASH-OVER PARK DESIGN

Figure 233.

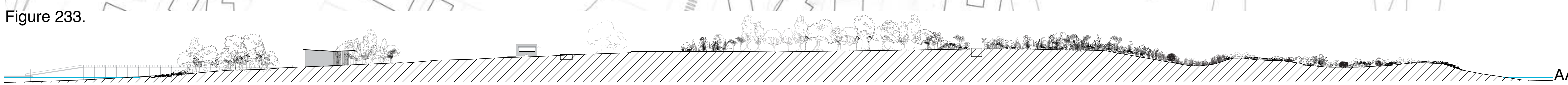


Figure 234.

LEGEND OF DESIGN ELEMENTS:
1. High-land walkway
2. Tsunami bank walkway
3. Tsunami bank step
4. Power for temporary food facilities
5. Shared road space
6. Boat ramp/wharf facilities
7. Boardwalk beach access
8. Playground

i. Informative signage provides guidance and information on the coastal processes. Maps of the recreational network and facilities will be accompanied by evacuation route maps and information on potential threats.

WASH-OVER PARK PROGRAMME ANALYSIS

Figure 235.

EDGES:

Property boundaries adjacent to the wash-over park are defined only by vegetation.

PROGRAMME:

a. Boat ramp, wharf, carparking, toilets and changing rooms. These are mostly existing facilities that have been extended and integrated further into the wider park space.

b. During summer the temporary food stalls provide vibrance to the area. Picnic and playground equipment, as well as open areas for recreational activities, are the social focuses for the communty. Proximity to the boat ramp is enhanced, and the park is a base for recreational activities.

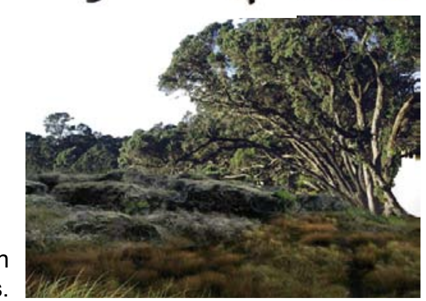
c. Childrens play equipment, seating.

d. Open area for informal recreational and leisure activities.

e. Formed pathways are part of the recreational network of the wider spit.

VEGETATION:

f. Open mid canopy to maintain visual connections across park.



Low coastal vegetation mixed with larger shade trees.

DESIGN ELEMENTS

1. HIGH-LAND WALKWAY:

The high-land walkway is the primary evacuation route for tsunami and provides the backbone to the recreational network throughout the sand spit settlement. In-paving text with supporting signage provides information on the walkways height above sea level, with graphic pavers appearing at every 1m of elevation change. This information works in collaboration with directional paving to generate awareness of the walkways roll in case of an evacuation, while also providing information and visual interest for recreational users. The sleeper-style pavers implements the visual association with the pedestrian crossing to encourage a pedestrian focus and ensure visibility when intersecting with roads.

Figure 236.

2. TSUNAMI BANK WALKWAY:

Where the tsunami bank structure is visible above the ground surface it can become the foundation for the walkway network providing access to the beach and linking open spaces throughout the sand spit settlement. Stairs are provided in areas where the ground levels change significantly due to the tsunami banks, this also provides seating opportunities. People are encouraged to use the provided boardwalks and picnic areas to allow for the dune vegetation to establish and regenerate.

Figure 237.

Figure 238.

3. TSUNAMI BANK STEP:

In most places the tsunami banking will be below the ground surface, but where it is above ground the gabion structure will be evident. Each gabion layer is a metre deep requiring stairs where it is greater than 150mm above the ground surface. The inland edge of the gabion will typically be level with the top of the bank with the seaward edge falling away. In areas where the gabion step is not planted it will act as a terrace step, in some places providing an edge for seating with intermittent stairs, and in others a single step down or up.

Figure 239.

4. POWER FOR TEMPORARY FOOD FACILITIES:

In the wash-over areas all facilities will be temporary to limit damage to commercial and community infrastructure. To provide for the large numbers of visitors in the peak seasons, provision for food carts/stalls and vendors to trade, power and water will be made available in certain areas of the open space network. These services will be available via bollards within the space and accessible to those with pre-arranged permits to occupy the space. Public BBQ facilities and picnic table seating will be available near by to create an outdoor plaza environment during the peak season.

5. SHARED ROAD SPACE:

In areas where the wash-over zone crosses the road there is an extended shared surface that will blur the edges between pedestrian dominated spaces and the road. Strips of concrete extend across the entire space filled between with surfaces ranging from grass and sa to gravel and tarseal. The strips will run approximately parallel to the predicted water flow to ensure that any scouring will not adversely disrupt them.

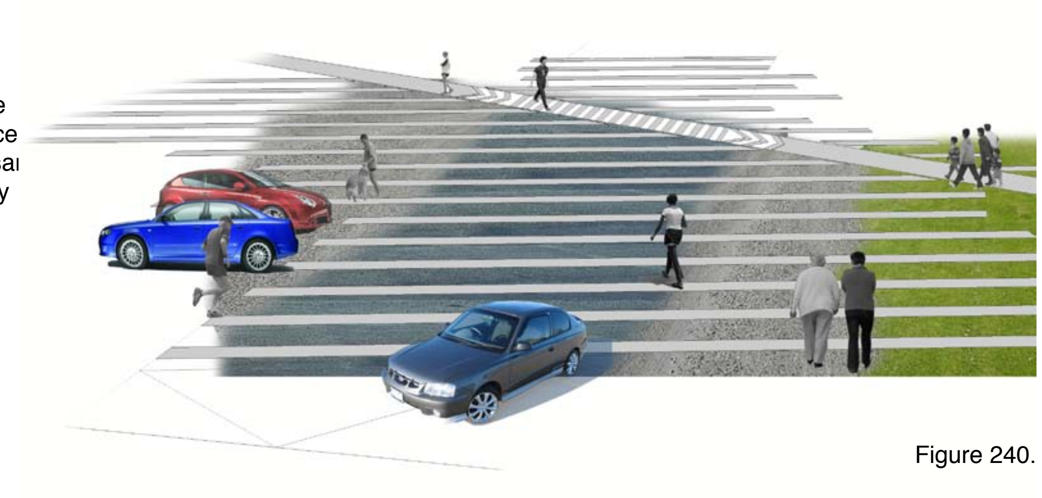


Figure 240.

6. BOAT RAMP/WHARF FACILITIES:

The boat ramp and wharf areas will typically be located within the wash-over parks that extend from seaward beach to harbour beach. The shared road surface will be integrated into the boat ramp structure. Simple facilities for water, toilets and changing are provided where they can be used by a wide range of visitors. Harbour edge vegetation will be encouraged and protected by the provision of clear walkways and vehicle appropriate surfaces.

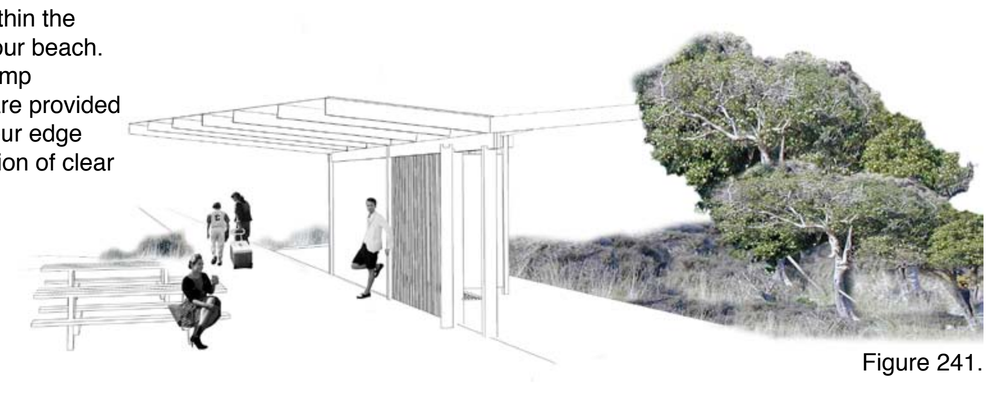


Figure 241.

Figure 242. **CONCEPTUAL DIAGRAM**

LEGEND:

- Ecological areas
- Social/programmed areas
- High-land walkway
- Formed pathways
- Beach access boardwalks
- Green streets
- Residential area
- Main road

CLUSTER TRANSECT DESIGN

Figure 243.

TYPOLOGY: **C3** Cluster transect

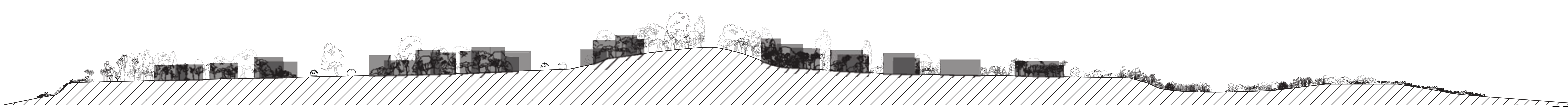


Figure 244.

LEGEND OF DESIGN ELEMENTS:
7. Boardwalk beach access
8. Playground
9. High-land walkway crosses road
10. Green street
11. Green street crosses main road

CLUSTER TRANSECT PROGRAMME ANALYSIS

Figure 245.

EDGES:
Property boundaries adjacent to the wash-over park are defined only by vegetation.

a. Childrens play equipment, seating.

bcd. Formed pathways are part of the recreational network of the wider spit.

VEGETATION:

b. Open mid canopy to maintain visual connections across park.

cd. Low coastal vegetation mixed with larger shade trees.

DESIGN ELEMENTS

7. BOARDWALK BEACH ACCESS:

Beach access is focused to a series of boardwalks to ensure that the dunes vegetation is not disturbed across the bulk of the dune environment. These boardwalks will connect to the coastal open spaces and wider recreational network. The structures of the boardwalks will encourage the build up of sand and establishment of more sensitive dune vegetation. The beach-most end will be a flexible linkage of timber sleepers that move with the buildup or erosion of sand on the fore dune face.

Figure 246.

9. HIGH-LAND WALKWAY CROSSES ROAD:

The paving pattern of the high-land walkway is designed to create a visual link with the pedestrian crossing motif. This ensures that when the walkway intersects with roads it maintains its prominence and pedestrian focus. Rumble strips on the road surface leading up to the crossing will slow cars and generate greater awareness of the crossing.

n.b. housing shown indicates potential form of infill

Figure 247.

10. GREEN STREET:

Pedestrian-focused streets linking through the clusters from the central nuclei to the coastal open spaces. These streets are public green spaces that blend out from the adjacent properties allowing for higher density development along the fringes. Boundary definition along these frontages is not encouraged and houses are orientated and open towards the public edge. The green streets create eco-corridors for the migration of vegetation in response to climatic changes and the extension of natural habitats into the cluster areas.

n.b. housing shown indicates potential form of infill

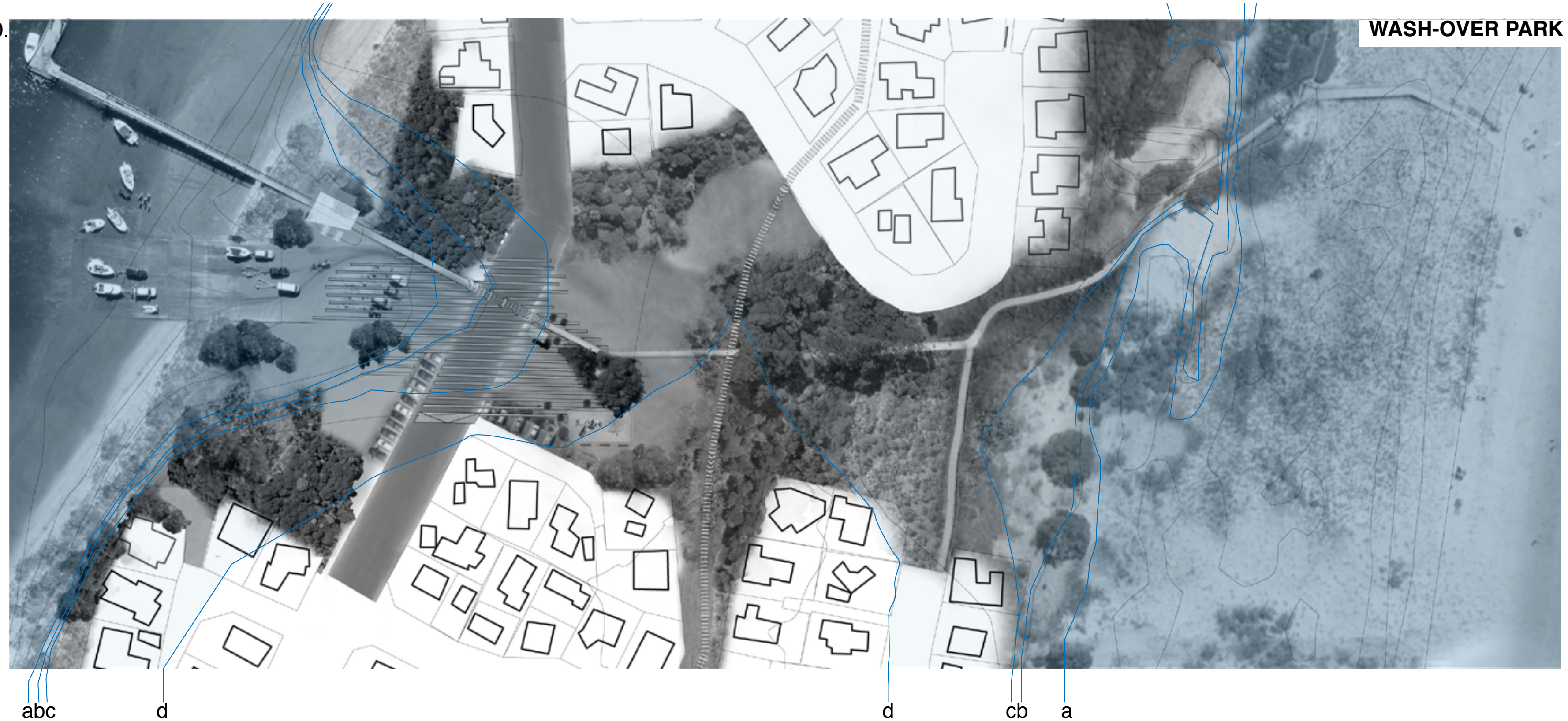
Figure 248.

11. GREEN STREET: ROAD CROSSING

Where the green streets intersect with vehicle roads there is a vegetated traffic island and swale bridges that continue the pedestrian focus across the road surface. In the case of evacuation the green streets will provide the most direct route from the shore line to the high-land walkway. The link will be clearly sign posted and directional paving will appear at key intersections to provide visual cues to the evacuation route.

Figure 249.

Figure 250.



Layering the levels of potential inundation over the detail design sites shows the extent of impacts. The wash-over park area is sited at the northern end of Omaha where the natural ground level is below RL7.0m. The northern most development cluster and edge of the wash-over park are completely flooded in the worst case scenario.

In all but the worst case scenario the tsunami banking and wash-over parks mitigate the inundation threats to the main development areas.

POTENTIAL INUNDATION LEVELS:

a. Mean Sea Level = 0.0m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2m
Significant Wave Height = 3.5m

b. IPCC SLR 2050 = 0.2m
Storm Surge = 0.9m
ENSO = 0.2m
Low pressure = 0.2
Significant Wave Height = 3.5m

c. IPCC SLR 2100 = 0.5m
Storm Surge = 0.9m
ENSO = 0.2
Low pressure = 0.2
Significant Wave Height = 3.5m

d. WORST CASE SCENARIO
IPCC SLR 2100 = 0.88m
Storm Surge = 1.0m
ENSO = 0.25m
Low pressure = 0.3m
Significant Wave Height = 4.0m+

Figure 251.

INCREASING ADAPTIVE CAPACITY THROUGH DESIGN

Design assessment and discussion

Principles for increasing adaptive capacity in coastal settlements

The design study analysis process identified some key issues with coastal development on sand spits in New Zealand. The most obvious, but least discussed, is that all of the cases were planned during a relatively stable or prograding period, and as the cycle has moved into an erosion period, the early development areas in particular have come under threat.

The heavy development model implemented in the late 1960s and early 1970s locked down large areas of the sand spit creating a large and unresponsive footprint. Waterfront properties built on the foredunes, flattening them for better views and building footprints, are now well within the red zone during the erosion part of the coastal cycle.

At Omaha in particular the construction of the causeway for access to the new development created a deep channel and erosive force that continues to threaten the harbour side properties. The construction of a seawall to protect the golf course reclamation, and earlier sand mining in the harbour mouth, has further exacerbated this issue.

The effective transference of an urban neighbourhood to these 'rural' coastal environments has meant there is limited flexibility in the development footprint for shifts brought on by climate change. The lack of awareness or appreciation for the coastal processes, when these settlements were first conceived, has grown as the development areas have grown and intensified.

There are now issues of reverse sensitivity threatening the coastal environment that first attracted the developers. With the development trend heading towards larger and more expensive second homes, the over investment in the dynamic coastal environment is creating a call for more visible protective structures.

Although hard engineering structures are now recognised as inappropriate measures to combat erosion issues, there is still demand for tangible and instant protection measures. The government-led shift towards soft engineering methods is being supported where homes are not in the direct firing line. However, where they are under serious threat, the tendency has been to protect them at all costs.

Seasonal pulses in the population mean that for large parts of the year these coastal settlements are empty. When combined with increasingly exclusive and inward looking properties, this can make it difficult to develop strong social and community investment in the surrounding environment. Issues of security for unoccupied properties are also a concern, as are property maintenance and management.

The issues identified in the design study analysis directed the development of the strategies for increasing the adaptive capacity of sand spit communities. All three cases showed that the waterfront areas needed to be released from the development footprint, and the natural dune system regenerated and reinforced.

Enhancing the natural dune system, through reinstating the foredunes and re-vegetating, increases their stability and provides the primary line of defence. The implementation of an endo-skeletal reinforcement to the natural defences, takes the form of tsunami banking, that works below the ground surface and behind the dunes themselves to create a second line of defence. It further provides a foundation for rebuilding after significant damage. The development of a high-land walkway provides an evacuation route, and also forms the back bone to the spit wide pedestrian focused recreational network.

The network of walkways links open spaces of all scales, in particular the wash-over parks that form the social focus for the adjacent cluster neighbourhoods. The clustered development areas create focus areas of built fabric with density rings to provide flexibility on the outer edges and increased capacity towards the centre. They also allow larger areas of open space and greater flexibility in the natural environment.

The zoning and land ownership regulations are reorganised within the clusters to encourage greater diversity in the population and greater flexibility around the built footprint. The clusters have centralised nuclei of open space amenity to facilitate the higher density, and this is linked to the surrounding open spaces via pedestrian focused green streets. Built form within the cluster is graduated in height towards the centre, while ensuring that prominent landforms and natural features are not overshadowed.

The relationship of buildings to the streets and green streets will be open and engaging, this encourages community interaction and passive surveillance. Buildings will be required to be constructed of robust but visually sensitive materials to create a physical environment appropriate to coastal living.

The Nicholls and Klein approaches to increasing adaptive capacity were adopted as the framework for developing strategies in response to the issues identified in the case study process.

1. Increasing **robustness** of infrastructural designs and long-term investments
2. Increasing **flexibility** of vulnerable managed systems
3. Enhancing **adaptability** of vulnerable natural systems
4. Reversing **maladaptive** trends
5. Improving societal **awareness** and **preparedness**. (Nicholls & Klein 221)

The relationship between socio-economic and ecological systems on the coast is fraught with misunderstandings and one-sided arguments. Design, and in particular landscape architecture, plays a critical role as the interface between ecological needs and socio-economic needs and wants. With design as the interface the relationship can be symbiotic. The strategies developed in response to the issues identified in the design studies, provide a platform for finer-grained design moves that will interface the natural environment values with those of the settlement community.

The open space hierarchy shows that the provision of interlinking open spaces at a range of scales can serve both ecological and social requirements.

Robustness of social capital, economic value and long term investments can be developed through the creation of high value social spaces that encourage community interaction and social capital building. Building and maintaining a strong sense of place and community identity relies on strong public spaces and high value natural character that the community is closely engaged with. Community engagement in, and responsibility for, the interlinked ecological systems that characterise the sand spit community is important, particularly in settlements where the majority of the population is temporary. Social capital drives economic and social investment and leads the way for robust infrastructural designs that support and enhance the natural environment. It also supports the social and built fabric. Increasing the robustness of the sand spit and settlement, and building social capital, is achieved through encouragement of greater interaction and engagement in the natural environment and processes.

The creation of wash-over parks, to absorb potential threats and changes, also provides high value public open spaces that encourage greater social engagement and community building. It also adds value to the social and economic investment. Changing attitudes towards the coastal processes can be achieved by making these processes accessible, so that the community can work with and reinforce the natural environment, while creating greater awareness of the potential threats.

The hard engineering techniques employed to protect the development footprint have made the settlement more vulnerable. Soft engineering techniques, while more

OPEN SPACE HIERARCHY:

4 ⟵	⟶ 1
Small	**Large**
SOCIAL FOCUS	ENVIRONMENTAL FOCUS
Highly modified/designed	Natural
Neighbourhood amenity	Conservation/Recreational Amenity

appropriate, don't provide a visible enough response in some cases. In areas where significant damage has been done to the protective dune system, soft engineering may simply not be enough. The development of the tsunami banking system as an endo-skeletal foundation to reinforce the sand spit and provide a footprint for development clusters ensures that tangible protective measures are made while not interrupting the natural defensive system. In this way, natural and man-made environments can work together to ensure the ongoing viability of the settlement, without sacrificing the flexibility and responsiveness of the sand spit.

Flexibility in the man-made environment, as well as in the natural systems, is critical in increasing adaptive capacity. Space must be made for changes, both ecologically and socially driven, to ensure the continued viability of coastal sand spit settlements. Releasing the foredunes from the development footprint allows this system to function in its protective and adaptive capacity. The foredunes are the front line of defence, absorbing coastal threats and protecting the land behind from the bulk of the impact.

Flexibility must also be achieved in ownership and management responsibilities, to allow for greater diversity in both the social and ecological systems. Encouraging shared responsibility and ownership creates space for change in both the ecological and built fabrics, providing greater flexibility in all elements of the physical environment and socio-economic and ecological systems. This space allows them to absorb changes in the environment. Stepping back from edge, and releasing the coastal dunes from the development footprint allows them to perform their protective roles and shift in response to coastal and climate changes.

Density rings in the development cluster allows greater density to be achieved in the centre to accommodate the increasing demand and greater diversity in population and dwelling typologies, while the decreasing density towards the edges ensure flexibility where the built and natural fabrics overlap. Changing attitudes towards property ownership and boundary definition will allow for greater flexibility within the development footprint for the migration of eco-domains in response to climate related changes.

Adaptation is a response to change, and adaptive capacity is the space that is made to allow for changes. Space is not just a physical phenomenon; it can be created through social awareness to accommodate changes without being adversely disruptive.

Creating space or tolerance is part of building robustness and increasing flexibility. A strong foundation, built from robust social and ecological capital, and supported by robust infrastructural designs, provides a framework within which change can happen without disrupting the sense of place or social character. Building an external shell and protecting the contents from change only creates a precarious utopia that will eventually be completely lost without any foundation for rebuilding.

Adaptive capacity is about absorbing and responding to changes. Adapting allows gradual change and growth of the entire socio-ecological system concurrently. Enhancing the natural systems through regeneration, conservation programs, and public awareness of the value of natural processes and eco-system services, is an integral part of increasing their adaptive capacity.

Identifying and reversing **maladaptive** trends in development, land management, infrastructural designs and societal attitudes is recognised worldwide. However the process of changing habits and short-term-goal driven attitudes is complicated. The importance of creating an attractive package is obvious. Society is more likely to buy into wholesale changes if the changes are wrapped attractively in 'added value' and 'increased surety'.

Awareness builds **preparedness**, and the strength of infrastructural and social systems is critical in response to potential threats that will be exacerbated by climate change. The natural environment has been responding and changing for millennia. The impact of coastal threats affects the social and built fabric most severely. If coastal settlements are to increase their adaptive capacity then awareness of, and preparedness for, potential threats is critical.

Having information about coastal processes and potential threats available to the public in a recreational context, means that the information can be absorbed voluntarily, and awareness is developed through exploring the recreational network and public open spaces. When information is readily available and evacuation routes form the backbone to the recreational network, they are instantly recognisable when necessary. It is important that the recreational environment plays a part in building public awareness of the natural processes at work, as well as the potential threats, by understanding the role the natural environment plays in protecting the settlement.

This thesis proposes and tests design-led solutions to climate-related issues that impact upon coastal settlements. The strategies developed work together to enhance the existing resilient attributes and reduce or reverse the maladaptive trends.

As with all large-scale re-design projects there is significant cost in the construction of new and re-designed infrastructure such as the tsunami banking system, as well as the relocation of the dwellings currently situated within the fore dune systems.

In the design study settlements, where the majority of residents are temporary, these costs may be great, yet the value added by the implementation of these strategies would likely outweigh the initial costs over a short time. The regeneration and re-zoning strategies grow with the settlement over time, the clusters developing high density due to infill and the dune systems gaining strength from increases flexibility and conservation support.

The awareness of the local community, and of visitors, feeds from the design and construction of the active pockets within the wash-over parks, and linked open spaces, while the social capital is developed through the encouragement of greater social interaction and engagement in the surrounding environment.

The implementation of all proposed strategies at Omaha would regenerate not only the natural sand spit environment, but also re-brand the settlement and encourage a more diverse range of users. Currently considered the playground of the financially-able or an upmarket suburb of Auckland, creating a high value open space network, with a range of recreational opportunities at Omaha, and increasing the accessibility of the beach will encourage more visitors and support property values. The greater density within the clusters created by new zoning and ownership concepts, will allow people from more diverse financial abilities to buy into the neighbourhood, and open up the opportunities for more communal and inclusive living practices.

The tsunami banking system is a proposition for endo-skeletal foundations for the sand spit settlements. It is based on the performance of low seawalls in tsunami events throughout the Pacific, as well as hard engineering systems developed in Japan to protect coastal settlements from tsunami. The system requires further research and testing that is beyond the scope of this project. However, in theory, it provides an internal structure to support the natural defence systems and helps provide a building platform for the development clusters above the potential inundation levels. The implementation of such a structure would be a huge undertaking but once complete would cause little visual interruption unlike the hard engineering structure currently employed.

Adaptive capacity is achieved through creating open space. Open space allows flexibility, which in turn, ensures a robust coastal system. Design is a medium for generating space which can both mediate, and encourage symbiosis between, the wants and needs of the community and the ecological imperatives of the natural environment. Successfully designed open spaces within our coastal environment can perform environmental services and social ones, creating and supporting the interaction of natural and man-made systems to ensure the ongoing resilience of the coastal settlement.

1. Step back from the edge to allow the natural protective systems to absorb the threats.
Ensuring the flexibility of the natural environment is critical in maintaining and building adaptive capacity. Design helps to mediate this need against those of the settlement.

2. Enhance and support the natural coastal systems and processes.
The community needs to be engaged in the enhancement and support of the natural systems and processes to ensure their continued investment in their health.

4. Ensure flexibility within the built environment to allow for eco-domain migrations.
Making space for change requires awareness and flexibility. Through the design of interpretive signage and flexible infrastructure communities can achieve awareness in the community and flexibility in the built environment.

5. Cluster development areas to create greater areas of open space to absorb the threats.
Limiting the built footprint and creating a range of open spaces, from highly natural through to highly programmed, allows for the absorbtion of potential coastal threats and increased public amenity.

6. Encourage connectivity and social interaction to ensure social capital building and investment.
The role of public open space as the centre of the community engagement ensures that recreational and social amenity brings together clustered neighbourhoods. Ensuring building have open relationships with public spaces and connectivity within clusters and across the whole community is critical in maintaining social interactions.

7. Build diversity in socio-economic systems, in ecological systems, and in zoning densities.
Making the coastal settlement available to a wider range of people is important in avoiding exclusivity. A range of property sizes and values ensures more people have access to the area, while creating a strong and visible recreational network that attracts visitors from outside the community. Diversity in ecological systems is enhanced with planting and allowing for complete sucessions of ecodomains throughout the spit. Public awareness of the critical importance of conserving and protecting delicate ecosystems is imperative.

8. Activate open spaces to encourage social engagement and interaction with the natural environment and processes, and greater awareness of threats.
Provide a range of open spaces with focuses from natural through to highly programmed. The focus on enhancement of natural systems and processes must be mediated by the provision of socially focused activity pockets within the recreational and open space network.

9. Avoid protective exo-skeletal systems, instead reinforce internally by building robustness in the social and ecological systems supported by endo-skeletal structures where necessary.
Armouring the settlement with hard engineering responses to coastal threats is maladaptive. Building robustness must be achieved in social and ecological systems. This can be reinforced with flexible protective infrastructure than does not interrupt or adversely affect the role of the ecological systems both locally and in the surrounding area.

ENSO: El Nino Southern Occilation is an irregular periodic climate pattern that occurs in the Pacific, most typically at an average of 5 year intervals.

El Nino (the boy) which brings warmer weather and higher air pressure to the western Pacific, and
La Nina (the girl) which brings cooler weather and low air pressure.
Southern Occilation: Refers to the movement of surface air pressure from the eastern to western Pacific influencing tradewinds, weather patterns, and sea levels.

IPCC: Intergovernmental Panel on Climate Change is the leading scientific body for the assessment of climate change. Set up in 1988 to review and assess current available research on climate change and liase with governments. It has 194 member governments and released its first report in 1990.

LIM Report: Land Information Memoradum Reports are available on all sections and provide all available information held by the council on the property. Includes information on known and potential hazards.

Low (Barometric) Pressure: Low air pressure systems have higher sea levels, with every 1 hector Pascal drop in pressure representing a concurrent 10 millimeter rise in sea level. Low pressure systems are typified by unstable weather patterns.

MHWS: Mean High Water Springs is the mean level of high tide. Does not take into account spring, and king tide levels.

MSL: Mean Sea Level is the average sea level, taking into account seasonal fluctuations and tidal changes.

Significant Wave Height: Is the average height of 1 in 3 of the largest waves when measured from trough to crest. Does not indicate highest wave possible.

SLR: Sea Level Rise is the predicted rise of average sea level.

"Wash-in": Open space in low lying coastal areas where wave impacts can be absorbed and dissipated, without completely washing over the whole spit width.

"Wash-over": Open spaces in low lying areas where the water can wash right over the width of the spit without causing significant damage to the surrounding areas.

"Wash-through": Open spaces in low lying areas, where water ways or wetland areas already exist, that allow for water to wash through without causing significant damage to the surrounding areas.

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