What are effective design guidelines for protecting small, low-lying New Zealand coastal towns from climate-change induced flooding?

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In Aotearoa New Zealand more than 75% of the population are situated within 10 kilometres of the coast (Hayward, 2008). With global temperatures on the rise, climate change-related hazards are projected to increase in frequency and severity. Additionally, sea levels are expected to rise by 0.3-1.1 meters by the year 2100 (Hernández-Delgado, 2015; NIWA, n.d; O'Donoghue et al., 2021; Oppenheimer et al., 2019; Rouse et al., 2017). Low-lying, small coastal communities face an amplified risk of flooding caused by climate change, due to a lack of infrastructure and limited funding available to local councils, compared to larger cities (James M. Fitton et al., 2021).

At present, larger cities have greater access to mitigation strategies and tools for coping with coastal flooding in the face of climate change (Lamb et al., 2019). Furthermore, little is known about the effectiveness of design guidelines to assist landscape architects to implement appropriate design strategies in small coastal towns. Strategies include design guidelines. Design guidelines refer to recommendations or principles that designers can use to ensure that their designs are effective for their intended purpose (Nijhuis & de Vries, 2019).

Firstly, a narrative literature review was conducted to develop an understanding of what was known and not known about strategies for mitigating climate change induced flooding, as well as determining whether design guidelines for flooding in small coastal towns exist. Secondly, an evaluation of existing guidelines was conducted following Kennedy Evans (2019) *'best practice Landscape Architecture design guideline criteria'* to determine their effectiveness. A set of suggestions to improve existing guidelines were proposed based on the results of the evaluation in conjunction with the narrative literature review.

Māpua, New Zealand was chosen as the case study site for this research as it is highly prone to flooding due to its biophysical characteristics. An inventory and analysis was made of all existing biophysical and land-use characteristics to determine to what extent Māpua met the best practice flooding design guidelines that were proposed. The guidelines were then applied to the site at a regional, masterplan and intermediate scale to demonstrate how the improved design guidelines can be applied to protect a small coastal town. Thus demonstrating what effective guidelines are to protect small, low-lying coastal towns from climate-change induced flooding.

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Chapter 1

Introduction

1.1 Problem Statement

In Aotearoa New Zealand more than 75% of the population are situated within 10 kilometres of the coast (Hayward, 2008). For many low lying, small coastal communities the threat of climate-change induced flooding is amplified in comparison to larger cities due to a lack of infrastructure and reduced funding available to local councils (James M. Fitton et al., 2021). Many communities in Aotearoa are settled on active floodplains, therefore making flooding one of Aotearoa New Zealand's most costly natural hazard (Local Government New Zealand - Te Kāhui Kaunihera ō Aotearoa, 2022). As a result, many New Zealanders will face the impacts of climate change in their lifetime.

Coastal flooding and the hazards associated with climate change induced flooding is now a common occurrence. These events will increase in both frequency and intensity as global temperatures increase, and projected sea levels rise by at least 0.3-1.1m by 2100 (Hernández-Delgado, 2015; NIWA, n.d; O'Donoghue et al., 2021; Oppenheimer et al., 2019; Rouse et al., 2017). As a result, the risk is compounded as increased amounts of water enter these low-lying areas from the upper catchment – water tables elevate and their capacity to hold water decreases (Terry et al., 2021). Therefore, there is growing concern about the effect of climate change-related flooding and the implications it will have on the environment, core infrastructure, and the communities that reside in coastal areas (Doberstein et al., 2019a, 2019b; Francis, 2001a; Hernández-Delgado, 2015).

'Accommodate, protect, retreat, and avoid' are part of a globally recognised strategy to minimise coastal hazards (Doberstein et al., 2019a; Francis, 2001a; Rouse et al., 2017). Green (e.g., living shorelines, wetlands, dune reconstruction) and grey (e.g., storm water and ground water management, stop banks) infrastructure are tools used to implement these strategies (Christchurch City Council, 2021; Doberstein et al., 2019b; Rouse et al., 2017). Traditionally, low-lying coastal towns and cities have relied on hard defensive infrastructure (e.g., levees, sea walls, storm surge barriers) as a means of resisting coastal flooding and increased storm intensity and frequency (Daigneault et al., 2016; Gittman et al., 2015). This is becoming economically unviable due to their lack of adaptability of the changing environment (Chen & Mehrabani, 2019; Morris et al., 2018; Narayan et al., 2016; Reguero et al., 2018; Saraswat et al., 2016). Moreover, there is a growing body of literature that supports the effectiveness of green infrastructure (e.g., wetland restoration, green spaces, swales) to trap sediments, reduce, storm surge, increase flow resistance and contain flood water (Liu et al., 2014; Narayan et al., 2016; Reguero et al., 2018).

Design guidelines are defined as a set of recommendations or principles that can be used by designers to ensure that the implementation of designs are effective for their intended goal (Nijhuis & de Vries, 2019), such as, mitigating climate change-related flooding in small coastal towns. As outlined in Lamb *et al* (2019) there is a large body of literature on strategies and tools for mitigating coastal flooding under climate change in large cities, such as New York, London, Beijing, and Tianjin. However, less is known about how they apply to small coastal towns who have limited resources for their implementation (O'Donoghue et al., 2021). Furthermore, little is known about the effectiveness of design guidelines to assist landscape architects to implement appropriate design strategies in small coastal towns.

1.2 Research Question and Objectives

What are effective design guidelines for protecting small New Zealand coastal towns from climate-change induced flooding?

1.2.1 Research questions

1. Are there existing design guidelines for mitigating the impacts of climate-change induced flooding for small New Zealand coastal towns?
2. Are existing guidelines effective?
3. If no guidelines exist, what are effective guidelines?
4. What are effective design guidelines for protecting small New Zealand coastal towns from climate-change induced flooding?

1.2.2 Research objectives

1. Critically review the theory regarding the causes, impacts and significance of New Zealand small coastal flooding in the context of climate change.
2. Critically review the theory and practice on what is known and not known about design strategies and tools for protecting small coastal New Zealand communities from flooding in the context of climate change.
3. To determine whether there are design guidelines for strategies and tools that protect small coastal communities from flooding with respect to climate change, and if they are effective.

4. To proposed suggestions to existing design guidelines to effectively protect small New Zealand coastal communities.

5. To demonstrate how the guidelines can be applied to protect a small coastal communities in New Zealand.

6. Discuss the limitation of the research and design guidelines.

1.3 Dissertation Structure

An overview of the dissertation structure is outlined in table 1.

An overview of the dissertation structure is outlined in Table 1. This dissertation has been organised into eight chapters. Chapter 1 introduces the research question and objectives. Chapter 2 outlines the method and methodology that this dissertation will follow. Chapter 3 provides an outline of the causes, impacts, and significance of New Zealand small coastal flooding in the context of climate change. Chapter 4 outlines what is known and not known about design strategies and tools for protecting small coastal New Zealand communities from flooding with respect to climate change. Chapter 5 determines whether there are existing design guidelines and strategies to protect small coastal communities from climate change-induced flooding and if they are effective. Chapter 6 proposes suggestions to existing design guidelines to protect small coastal communities. Chapter 7 demonstrates how the design guidelines can be applied to protect a small coastal community in Aotearoa New Zealand. And Chapter 8 discusses the limitations of the research and design guidelines.

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Table 1 Overview of dissertation structure regarding research steps, methods, objectives and chapters

What are effective design guidelines for protecting small, low-lying New Zealand coastal towns from climate-change induced flooding?			
Steps	**Method**	**Objective**	**Chapter**
Critically review the theory regarding the causes, impacts and significance of New Zealand small coastal flooding in the context of climate change.	Narrative literature review.	1	3
Critically review the theory and practice on what is known and not known about design strategies and tools for protecting small coastal New Zealand communities from flooding in the context of climate change.	Narrative literature review.	2	4
To determine whether there are design guidelines for strategies and tools that protect small coastal communities from flooding with respect to climate change, and if they are effective.	Narrative literature review of existing guidelines. Evaluate effectiveness of guidelines with best practice guideline criteria according to Kennedy Evans (2019).	3	5
To proposed suggestions to existing design guidelines to effectively protect small New Zealand coastal communities.	Narrative literature review. Compare results of best practice guidelines with best practice guideline criteria.	4	6
To demonstrate how the guidelines can be applied to protect a small coastal communities in New Zealand.	Case study inventory and analysis of chosen case study site, Māpua.	5	7
Discuss the limitations of the research and design guidelines.	integrate results of the narrative literature review, guideline evaluation and case study inventory and analysis.	6	8

Chapter 2

Method and Methodology

This chapter describes the research methodology and methods used to answer the main research question and related objectives outlined in Chapter 1 (section 1.3; Table 1).

Section 2.1 describes the case study methodology that will be used to approach the study. Section 2.2 describes methods that will be used throughout this study to answer the overarching research question. The table below outlines the steps that will be followed (Table 2).

Table 2: Steps and methods for evaluating effective guidelines to answer the research question

Research Question	Objectives	Methods
What are effective design guidelines for protecting small, low-lying New Zealand coastal towns from climate-change induced flooding?	Critically review the theory regarding the causes, impacts and significance of New Zealand small coastal flooding in the context of climate change	Narrative literature review.
	Critically review the theory and practice on what is known and not known about design strategies and tools for protecting small coastal New Zealand communities from flooding in the context of climate change	Narrative literature review.
	To determine whether there are design guidelines for strategies and tools that protect small coastal communities from flooding with respect to climate change, and if they are effective	Narrative literature review of existing guidelines. Evaluate effectiveness of guidelines with best practice guideline criteria according to Kennedy Evans (2019).
	To proposed suggestions to existing design guidelines to effectively protect small New Zealand coastal communities	Case study inventory and analysis of chosen case study site, Māpua. Develop suggestions based on the results
	To demonstrate how the guidelines can be applied to protect a small coastal communities in New Zealand	Case study inventory and analysis of chosen case study site, Māpua.
	Discuss the limitations of the research and design guidelines	integrate results of the narrative literature review, guideline evaluation and case study inventory and analysis.

2.1 Methodology: Case Study

The case study methodology provides the framework in which the methods in Section 2.2 will work within.

The case study method is a well-established method of study amongst many professions. In accordance with Mark Francis (2001b) a case study is, "*a well-documented and systematic examination of the process, decision making and outcomes of a project that is undertaken for the purpose of informing future practice, policy, theory and/or education*." (p. 9). He notes that although case studies are used amongst other professions, their use within Landscape Architecture is to "*describe and/or evaluate a project or process*" (pp. 9-10).

Robert Stake (1995) in *'The art of case study research'* also notes that) a case study is not a generalisation, rather a specific situation that is well researched. He states, "There is an emphasis on uniqueness" (p. 8), which requires knowledge of other cases from which the case differs, but the main emphasis is on understanding the case study – or site in this instance (Stake, 1995).

2.1.1 Case Study: Māpua, New Zealand

Māpua has been chosen as the case study for this research. It has a population of 2,562 and is located in the Tasman Region on the South Island of Aotearoa New Zealand (Figure 1 &2) (Statistics New Zealand, 2018). Table 3 highlights the important characteristics of Māpua.

Māpua is highly prone to flooding due to its biophysical characteristics. Māpua is uniquely located in a low-lying area at the bottom of the catchment where the Waimea Estuary meets the Tasman Sea. At least 70% of the coastline in the Tasman region is receding. Historically, coastline sediments were deposited from river borne gravels, however, now very little sediment is supplied by rivers to the shoreline (Stewart & Science, 2010). This combined with a high water table; sandy, well-drained soils; coastal inundation and erosion; and minimal infrastructure to mitigate the effects of flooding puts Māpua in an extremely vulnerable position (Verstappen, 2010).

Māpua was subject to storm surge flooding in 2018 from ex-tropical cyclone Fehi as This led to the destruction of core infrastructure (e.g., sea walls, coastal housing, commercial buildings, roads) as well as significant erosion of the coastline (Irwin, 2018; Tasman District Council, 2018). This was considered a benchmark event for sea level rise projections of at least 1 metre by 2100 in the Tasman region (Tasman District Council, 2019).

Table 3: Fact sheet highlighting important characteristics of Māpua

Location	Māpua, Tasman Region, New Zealand
Population	2,562
Size	2.96 km^2
Soil Type	Sandy (RS), Recent (GR), Albic (UE)
Vegetation	Coastal sand dune, wetland, lowland swamp, tussock grassland, exotic pine, riparian, lowland shrub
Biophysical Characteristics	High Water table, sandy-well drained soils, coastal inundation and erosion,

Material Removed due to Copyright Compliance

Figure 1: Map showing the location of Māpua as the top of the South Island at the scale of 1:1,000,000 [adapted] (Land Information New Zealand, n.a.)

Material Removed due to Copyright Compliance

Figure 2: Map showing the location of Māpua at a scale of 1:50,000 [adapted] (Land Information New Zealand, n.a.)

2.2 Methods

2.2.1 Narrative literature review

In this study, a narrative literature review was conducted with the goal to answer objectives one to three. This method was used to identify the causes, impacts and significance of flooding on small New Zealand coastal towns under climate change; what is known and not known about protecting small coastal communities, and whether there are existing design strategies and guidelines for protecting these communities.

The review will be conducted in three steps in accordance to Bart Green *et al* (2006). Step one involves sourcing relevant information from academic literature and or/grey literature regarding (climate-change-related) flooding and related responses, e.g mitigation or adaption strategies and related design responses; existing (design) guidelines for small coastal cities globally and in New Zealand. This step also includes sourcing general information on design guidelines, how to write, analyse and assess them. In step two relevant information will be screened and selected and non-relevant information excluded. The third step involves analysis, synthesis, and discussion of the relevant information (Green et al., 2006).

2.1.1.1 Sourcing Relevant Information

As part of the narrative literature review relevant information was gathered from both scholarly and grey literature. Scholarly literature is sourced from academics in the field that is being researched. This is mostly sourced from peer-reviewed literature from scholarly search engine databases. Grey literature pertains to publicly available information through the form of newsletters, reports, government documents and more. This has not been peer reviewed and often varies in quality (Green et al., 2006; Paez, 2017).

For this review scholarly papers were sourced using the Lincoln University search engine database and Google Scholar. From here peer reviewed literature was obtained from Science Direct; Springer Link; Lincoln University Dissertation, Thesis and PHD database; Landscape Journal; Jstor; Taylor & Francis Online; Wiley Interdisciplinary. Reviews (WireS) and ProQuest. Grey literature was sourced from government websites (e.g, city councils), National Institute of Water and Atmospheric Research (NIWA), the International Panel on Climate Change (IPCC) and some news reports.

2.1.1.2 Literature Screening

Peer reviewed literature was prioritised and if no results were found then grey literature were searched. When searching through databases the earliest year of publication was set to ensure that the literature was up-to date and relevant. The initial screening of literature was relatively broad to grasp an understanding of the topic. Search engine searches pertained to the significance of climate change flooding for New Zealand and coastal areas, mitigation measures for both large metropolitan cities and small towns at both global and local scales. When researching existing design guidelines both local and global examples were used. This is because a large majority of the literature was focused on larger metropolitan cities.

Key words used were 'coastal', 'small towns', 'New Zealand', 'flooding' and 'climate change'. Once this initial search was done, then specific searches were made pertaining to green infrastructure and grey infrastructure, as well as design guidelines and mitigation strategies. Once relevant papers were found, similar papers were found within it by searching through the reference list.

From here the information was filtered in terms of relevance to New Zealand and small coastal towns. This includes mitigation strategies for coastal hazards such as coastal erosion, seawater and floodwater inundation, low lying topography and high-water table. Any information that was not deemed relevant to New Zealand coastal communities was not used. For gathered information to be deemed relevant, the date published needed to be within 5 years of 2022 for both peer-reviewed and grey literature, however if the literature or guideline was deemed important for the study, it was included. This also needed to be within the variables specific to the environmental conditions found in New Zealand, furthermore specific to the flooding variables mentioned above (e.g: coastal erosion, seawater and floodwater inundation, low lying topography and high-water table).

2.1.1.3 Comprehensive Synthesis

The final selection of papers has been determined by the above variables to answer the research objectives one to three. The selected information will then be critically analysed through a comprehensive synthesis followed by a discussion. Through this process relevant literature and guidelines will be gathered.

2.2.2 Best practice evaluation of existing guidelines and development of new guidelines

A design guideline is referred to as a set of recommendations or principles that can be used by designers to ensure the implementation of designs is effective for their intended goal (Nijhuis & de Vries, 2019).

Existing guidelines were found using both peer-reviewed and grey literature through both scholarly and Google search engines. In searching for existing design guidelines, they went through the same rigor as the narrative literature review regarding the three-step process. Peer-reviewed search engines were used first and then grey literature. Seven guidelines (Table 5) were found to be applicable to the overarching research question during the literature review process. These design guidelines were analysed and assessed against Kennedy Evans, '*Best practice Landscape Architecture design guideline criteria'* (2019).

Evans (2019) notes that there are eighteen criteria that determine the effectiveness of design guidelines within the profession of landscape architecture and urban design. These are separated into two attributes: 1) Content attributes individual guides, and 2) Visual attributes whole guideline document. The content attribute consists of the following nine criteria: clear design intent; clear objective; flexible outcomes; design strategies; evidence-based; supporting diagrams and images; direct language; and measurable data. The visual attributes consist of the following nine criteria: structured layout; bullet points/listed; concise guidelines; text hierarchy; simple diagrams; minimal colour diagrams; limited diagrams; explanation/labels and arrows explaining diagram; and keys and legends (Table 4).

Table 4: Kennedy Evans (2019) *'best practice Landscape Architecture design guideline criteria'*

Content Attributes Individual Guidelines	**Visual Attributes Whole Guideline Document**
1. Clear Design Intent	1.Structured format
2. Clear Objectives	2. Bullet points/listed
3. Flexible Outcomes	3. Concise guidelines
4. Design Strategies	4. Text hierarchy
5.Evidence Based	5. Simple Diagrams
6.Supporting Diagrams and Images	6. Minimal colour diagrams
7.Readability	7. Limited diagrams
8.Direct Language	8. Explanations/labels and arrows explaining diagram
9. Measurable Data	9. Keys and legends

Seven guidelines were placed into an excel sheet an allocated a colour as shown in table 4. Seven design guidelines were found whilst researching the literature. Each of these guidelines and reports were found to provide design guidelines that aim to protect coastal communities to some capacity. Each case study or design guideline was placed into a table and allocated a colour as Evan's (2019) does in her research

Following Evans (2019) process of evaluation, a full square is given to the guideline when an attribute is completely fulfilled, a half square is given when an attribute is partially fulfilled, and no square is allocated if the attribute is not fulfilled.

Table 5: Design Guidelines and their allocated colour

1. Guidelines to Prepare India's Coast for Climate Change	
2. Catalogue of Coastal Hazard Adaptation Options	
3. Auckland Design Manual – Water Sensitive Design	
4. Climate Resiliency Design Guidelines	
5. Coastal Hazards and Climate Change – Guidance for Local Government	
6. Coastal Design Guidelines for NSW	

7. Smart Growth for Coastal and Waterfront Communities	

The process of developing suggestions to improve existing design guidelines was based on the results of the '*Best practice Landscape Architecture design guideline criteria'* (Evans, 2019), alongside the narrative literature of what is known about design strategies and tools for protecting small coastal New Zealand communities from flooding in the context of climate change. Firstly, a template is proposed to improved existing visual layouts based on Evans (2019), *'Visual attributes whole guideline document'* criteria. Secondly, a set of new design guidelines are proposed. Table 6 demonstrates the proposed improved design guidelines.

Table 6: New Design guidelines

Strategy	**Intervention type**	**Design guideline**
Protect	Green infrastructure	1. Bioretention systems
		2. Minimise impervious surfaces
		3. Detention and attenuation
		4. Wetlands
		5. Riparian vegetation
		6. Coastal vegetation
		7. Dune restoration
	Grey infrastructure	8. Flood proofing existing infrastructure
		9. Stop banks/bunds
		10. Armouring
Accommodate	Adaptable infrastructure/dwellings	11. Adaptable infrastructure/dwellings (Elevated housing, flood proof housing, amphibious/floating housing)

Retreat	Zoning	12. Zoning (Acquisition, managed retreat, conservation easements etc)
Avoid		

These design guidelines will then be applied to the case study site, Māpua to demonstrate how they can be applied to a small New Zealand coastal town.

2.2.3 Case study methodology: Inventory and analysis

An inventory and analysis will be conducted after proposing suggestions to improve existing design guidelines.

Firstly, a comprehensive abstract/fact sheet, including the significance and impact of the project, is established. Secondly, a full case study inventory will be developed through the collection of both biophysical and land use characteristics that currently determine flooding in Māpua under climate change. This will involve the collection of preliminary maps data and empirical or secondary datasets of visual and spatial information. This will include context, background and history, location and site plans, significance of the project, inventory of all aspects that determine flooding, mitigation, future issues, photographs, user analysis, limitations, and general features and lessons through both desktop and site visit analysis (Deming & Swaffield, 2011; Francis, 2001a).

The inventory includes the following biophysical and land use characteristics, 1) *Projected Sea level rise*, 2) *Soil and soil drainage*, 3) *Ground water levels*, 4) *Coastal inundation and erosion*, 5) *River systems*, 6*) Zoning*, and 7) *Existing green and grey infrastructure.* Thirdly, I will *synthesise* this information through spatial sorting and grouping significant findings. This will be visually represented using graphic techniques (Deming & Swaffield, 2011)

This inventory and analysis will inform to what extent Māpua meets the best practice flood mitigation design guidelines.

Chapter 3

The causes, impacts and significance of New Zealand small coastal flooding in the context of climate change

3.1 New Zealand coastal towns and climate change

In Aotearoa New Zealand more than 75% of the population are situated within 10 kilometres of the coast (Hayward, 2008). Many communities in Aotearoa are settled on active floodplains, therefore making flooding one of Aotearoa New Zealand's most costly natural hazard (Local Government New Zealand - Te Kāhui Kaunihera ō Aotearoa, 2022). As a result, many New Zealanders will face the impacts of climate change in their lifetime.

The impact of climate changes is much larger in ways than what was initially anticipated. The 2021 Intergovernmental Panel on Climate Change (IPCC) sixth assessment report states that climate change is affecting our environment, people's way of life, built infrastructure, infrastructure all over the globe (Pörtner et al., 2022). In the twentieth century, global mean sea level rose by at least 11-16cm and even with immediate reductions in carbon emissions it is expected to rise a further 0.5 meters this century (Kulp & Strauss, 2019).

As global temperatures continue to rise, so will sea level. Climate change is intensifying water systems, bringing more intense rainfall in some regions with others having droughts. Coastal areas will continue to see sea level rise throughout the 21st century, which will contribute to much more frequent and severe coastal flooding especially in low lying areas. Coastal areas that previously had flood events happen every 1 in 100 years, could potentially happen every year by the end of the century (Hsiao et al., 2021; Intergovernmental Panel on Climate Change, 2021).

Under the influence of global warming the magnitude of storm surge and rainfall will rise simultaneously – increasing sea level and seawater evaporation. As a result, there is a risk of flooding events caused by high river discharges and storm surges, which elevate water levels in coastal areas where flooding is mainly caused by sea water overtopping. This is then amplified by rainfall, causing storm surges which slows down drainage and enhances pluvial flooding (Hsiao et al., 2021; Intergovernmental Panel on Climate Change, 2021). As a result, the risk is compounded as increased amounts of water enter these low-lying areas from the upper catchment – water tables elevate and their capacity to hold water decreases (Terry et al., 2021). Therefore, there is growing concern about the effect of climate change-related flooding and the implications it will have on the environment, core infrastructure, and the communities that reside in these coastal areas (Doberstein et al., 2019a, 2019b; Francis, 2001a; Hernández-Delgado, 2015).

3.2 How small coastal towns will be affected by increased flooding

Flooding is the most destructive natural hazard in Aotearoa New Zealand, with at least one flooding event happening every eight months (Local Government New Zealand - Te Kāhui Kaunihera ō Aotearoa, 2022). It is estimated that $160m each year is spent on flood mitigation – a cost that will continue to rise under climate change (Local Government New Zealand - Te Kāhui Kaunihera ō Aotearoa, 2022). Small coastal communities are much more susceptible to climate change-related flooding than larger wealthier cities due to a lack of research, poorer economic conditions and less access to large engineering solutions (Lehmann et al., 2021; Major & Juhola, 2016; O'Donoghue et al., 2021).

As outlined by Statistics New Zealand a small coastal town is defined as a small urban area with a permanent population that does not exceed 10,000 and is greater than 1,000 (Howard, 2015; Statistics New Zealand, 10 February 2021). Currently, there are 100 communities of this size in New Zealand of which 42 are classified as coastal (Howard, 2015). This is based on the National Institute of Water and Atmospheric Research (NIWA) classification of New Zealand's coastal environment, which is defined by beach, coastal and estuary type in regards to exposure, foreshore sediment, water bodies, inland and coastal geography (NIWA, n.d).

With projections in the severity of coastal hazards and the expected growth within coastal settlements, it is vital that they are able to adapt to both current and expected coastal hazards in order to strengthen resilience and reduce risk to climate change (James M. Fitton et al., 2021; Neumann et al., 2015). Though these smaller cities and townships tend to have much larger social capital than larger, their ability to bounce back to normality after extreme natural events will typically be a much longer process (Nakagawa & Shaw, 2004). Flood events that may have little to no impact on larger cities tend to overwhelm smaller communities (Hernández-Delgado, 2015).

Local economies around the world are at risk due to changing environments and increase in storm events and flooding. Many small coastal townships rely on their environment for economic input for their community. The local economy tends to be quite narrow, and in some cases dependent on one industry such as fishing, tourism, leisure and service industries. For much of these small townships (James M. Fitton et al., 2021; Hernández-Delgado, 2015).

3.2.1 Environmental

Inter-tidal ecosystems are natural susceptible to saline intrusion, however other coastal habitats such as sand dunes, grazing marsh and pastures will likely be submerged by prolonged immersion in sea water. This will have impacts on key eco-system services for the community that feed directly back into the local economy (Hoggart et al., 2014).

3.2.2 Economic

Many business may be disrupted for a period of time due to flooding as many of businesses in these areas rely on the ecosystem services provided by the coastal environments. This may include damage to assets and buildings, restricted access to site, as well as damage of raw material. This may have long lasting socio-economic consequences on small communities (Hoggart et al., 2014).

3.2.3 Social Well-being

Flooding not only has an impact on the environment and local economy it can have negative outcomes on human health and social well-being. Impacts include physical health mental health economic well-being (Venkataramanan et al., 2019).

Chapter 4

What we know and don't know about solutions to increased climate-change related flooding

4.1 What is known and not known about existing flood mitigation strategies

'Accommodate, protect, retreat, and avoid' (PARA) are part of a globally recognised strategy to minimise coastal hazards (Doberstein et al., 2019a; Francis, 2001a; Rouse et al., 2017). This framework was outlined in the first International Panel on Climate Change (IPCC) climate change assessment report (1990) by the Coastal Zone Management Subgroup. The purpose of the PARA framework was for coastal adaption to sea level rise. However, it has become a useful tool for flood risk reduction and flood resilience (Doberstein et al., 2019a).

Green (e.g., living shorelines, wetlands, dune reconstruction) and grey (e.g., storm water and ground water management, stop banks) infrastructure are the tools used to implement these strategies (Christchurch City Council, 2021; Doberstein et al., 2019b; Rouse et al., 2017). Green infrastructure, also known as soft defences or nature-based coastal infrastructures are the adoption of more holistic and intuitive approaches for protecting people from flooding. This includes dune reconstruction, living shorelines and coastal wetlands (Narayan et al., 2016; Zhu et al., 2010). Grey infrastructure, also known as hard engineered defences, provide a solid protection between the land and the sea. Grey infrastructure includes, storm surge barriers, detached breakwaters and seawalls (Christchurch City Council, 2021; Zhu et al., 2010).

Traditionally, resistance strategies have been used to minimise flooding in urban areas through hard defences (e.g., levees, sea walls, storm surge barriers) to prevent water from channelling into these areas (Daigneault et al., 2016; Gittman et al., 2015). However, this is becoming less economically viable for government authorities to implement and rely on as they are not 'fail safe' and are unable to adapt to sea level rise, changing ecosystems and increased storm frequency and intensity (Chen & Mehrabani, 2019; Morris et al., 2018; Reguero et al., 2018; Saraswat et al., 2016)

As a result, interest in green infrastructure is growing. Green infrastructure is relatively new in terms of flood mitigation and although there is a growing body of literature that supports the effectiveness of green infrastructure (e.g, wetland restoration, green spaces, swales) to trap sediments, reduce storm surge, increase flow resistance and contain flood water, the application of it has been slow (Daigneault et al., 2016; Liu et al., 2014; Narayan et al., 2016; Reguero et al., 2018).

This is due to a reluctance from decision makers to implement green or green-grey infrastructure because of the lack of understanding of the cost and benefits (Alves et al., 2018; Daigneault et al., 2016; Reguero et al., 2018). Therefore, it is difficult to understand its effectiveness over a long period of time.

4.1.1 Protect

Protective measures are typically proposed in areas where at-risk areas core infrastructure needs protection. As noted, this was traditionally implemented through hard infrastructure (e.g., beach drainage, stop banks, breakwater). However, in more recent times we have seen an increase in soft engineering or green infrastructure (e.g, Shoreline nourishment, dune reconstruction, coastal wetlands, living shorelines) which emulate and/or utilise nature as a protective measure (Christchurch City Council, 2021; Narayan et al., 2016; Zhu et al., 2010)

4.1.2 Accommodate

To accommodate is a course of action that seeks to continue using at-risk land by adapting the infrastructure to raise tolerance to risk. This often involves elevating homes and flood proofing buildings, raising the land, as well as hard infrastructure such as ground and storm water management interventions (Christchurch City Council, 2021; Zhu et al., 2010).

4.1.3 Retreat

Retreating is a coastal hazard strategy that involves removing assets such as housing or commercial zones away from high-risk coastal areas through land acquisitions and leasebacks. This tends to be less favourable as it involves removing people from their homes, however it allows for an increased buffer zone and reduces the need for hard infrastructure. This land can be utilised to create softer edges through conservation easements by implementing green infrastructure such as wetlands, green spaces or recreational areas (Christchurch City Council, 2021; Hino et al., 2017).

4.1.4 Avoid

Avoiding is to ensure that any risk to infrastructure is minimised through land zoning, creating no subdivision areas and ensuring certain activities are not permitted in identified areas (Christchurch City Council, 2021).

4.2 What is known and not known about existing flood mitigation design guidelines

Coastal strategies that are currently implemented for flood risk and flood risk reduction are designed for a much larger scale (James M. Fitton et al., 2021; Lehmann et al., 2021).

There is a lack of literature on how climate change-related flooding effects small coastal communities at both a global and local scale. Small coastal communities do not have the same access to large infrastructure schemes as larger cities, thus putting them in a very unique position (James M. Fitton et al., 2021; O'Donoghue et al., 2021). Although small coastal communities are seemingly disadvantaged to their larger counterparts in regards to economic context. Smaller communities tend to have a stronger sense of community and social capital, therefore it is potentially easier to achieve an aligned consensus on management approaches (James M. Fitton et al., 2021).

Fitton *et al* (2021) notes, there is limited resources available to small towns, therefore their ability to adopt climate adaptation strategies is limited. In '*Challenges to climate change adaptation in coastal small towns: Examples from Ghana, Uruguay, Finland, Denmark, and Alaska* (James M. Fitton et al., 2021), five case studies are chosen. The authors note that although a small number of cases were chosen, there are similarities across them. Furthermore, this highlights the need for a framework to accommodate the niche needs of small coastal communities.

> *"A guideline is 'a principle or criterion guiding or directing action'. Transferred to design this definition suggests that a design guideline gives guidance for design action, meaning that it suggests a specific direction by excluding many other possible, and by implication, less suitable ones."* (van den Brink et al., 2016, p. 221)

As of current there are few to no design guidelines available that provide a framework for landscape architects, planners, and policy makers to protect small New Zealand coastal towns from climate change induced flooding. Current guidelines are catered towards larger metropolitan cities which have their own issues. It is important for small coastal cities to have design guidelines for protecting small coastal towns in New Zealand as they have unique components that differ to larger cities (James M Fitton et al., 2021).

Design guidelines are beneficial as they compress evidence-based literature into an easily accessible format. It provides a framework to work within – a good design guideline will offer solutions that are adaptable, rather than being rigid and static. For landscape architects time is of the essence. When working in an office environment designers will seek out previous projects that had similar issues or components to find solutions. By developing design guidelines it creates a more efficient and effective framework to design within (van den Brink et al., 2016).

4.3 What are best practice design guideline attributes?

As noted in Section *4.1 'What is known and not known about existing flood mitigation strategies',* green and grey infrastructure are largely used in the PARA strategy for protecting towns and cities from coastal hazards. The following attributes have been collected as part of the narrative literature review of existing design guidelines for protecting small New Zealand coastal towns from climate change induced flooding.

4.3.1 Green infrastructure

Rain gardens

Rain gardens are a stormwater management intervention which falls under the 'protect' strategy. They are typically implemented to capture stormwater runoff in urban areas to reduce the impacts of flooding. Rain gardens serve as a sponge for water through a bioretention system into the ground (Malaviya et al., 2019)

Detention and attenuation

Detention basins are depressions of vegetated land which remain empty in dry periods and are able to withstand temporary storage of runoff in periods of heavy rainfall to mitigate flooding (Markou, 2022). Retention basins permanently hold water and are often landscaped to provide aesthetic value to a site. They are designed with additional storage to hold extra water in the event of heavy rainfall (Markou, 2022).

Riparian vegetation

Riparian vegetation (RV) is vegetation which sits along river networks that aids in promoting edge stabilisation for erosion control, water filtration, carbon sequestration and flood protection. At the catchment scale, they provide water flow regulation by reducing the rate of water velocity in the event of heavy rainfall – thus reducing the impact of flooding across the floodplain (Riis et al., 2020).

Coastal vegetation /wetlands

Globally, wetlands are decreasing as humans have, and continue to encroach on coastal areas (van Zelst et al., 2021). Coastal vegetation, such as salt marshes and mangroves are nature-based flood protection measures which reduce wave energy, storm winds, coastal erosion and mitigate flooding (Montgomery et al., 2022; van Loon-Steensma & Vellinga, 2013; Vuik et al., 2016).

Dune restoration

Dunes are large sandy mounds on the coastline which are usually vegetated. They provide a dynamic natural defence which is responsive to the changes that naturally occur in coastal environments and are crucial in providing a natural sand barrier in coastal areas against erosion and flooding (Hanley et al., 2014; Singhvi et al., 2022).

At-source stormwater management

At-source stormwater management includes, living or green roofs and walls, re-vegetation, soil rehabilitation and more. They provide retention and infiltration of stormwater at the source, thus allowing for the re-use of stormwater in a beneficial way (Lewis et al., 2015).

4.3.2 Grey Infrastructure

Flood gates/stop banks

Flood gates, also known as tidal control gates are grey or hard infrastructure flood interventions which are usually implemented downstream near estuaries. They provide a structural barrier in managing flood waters to reduce the impacts of flooding in coastal areas (Yasmin et al., 2022). Similarly, stop banks (also known as flood embankments or levees) are elevated embankments that sit parallel to the river bed to ensure the water does not overtop into the floodplain (Brierley et al., 1997) Both interventions provide temporary relief to flooding, as well as the need for consistent maintenance to ensure that they don't add further flood risk (Yasmin et al., 2022).

Sea walls/flood wall

Sea walls provide a hard structure between the earth in water – providing protection against coastal erosion from wave energy. Sea walls can be constructed into many forms such as concrete walls, rock revetments, gabion baskets and more. They are built in line with the shoreline and are often a preferred protection measure as they tend to require less space than other structures. However, they may need to be built up as sea level continues to rise (Linham & Nicholls, 2010).

Acquisition tools

Land acquisition occurs when at risk-land is purchased by a third-party, or leased back to a previous owner. This typically results in the land being used for coastal erosion to naturally occur as a buffer zone through the softening of edges by implementing wetlands, dunes and other soft infrastructure (Christchurch City Council, 2021).

Zoning

Zoning of land parcels can be used to prohibit or downsizing development on at-risk land, alter the future land-use allowances, as well as increasing development density in areas that are less at risk to coastal hazards (Christchurch City Council, 2021).

Chapter 5

To what extent are existing flood mitigation design guidelines effective?

This chapter will discuss the results from the design guideline analysis and evaluation against Evans (2019) *'Best Practice Design Guideline Criteria'* , which will be used to analyse the effectiveness of existing guidelines that were found as part of the narrative literature review. As noted in the *Method and Methodology* chapter, Kennedy Evans '*Best practice Design Guideline Criteria'* (2019) will be used to analyse the effectiveness of existing guidelines which seek to protect coastal areas from climate change induced flooding.

The results will be summarised in section 5.3.

5.1 To what extent do existing guidelines meet best practice content attributes for effective guidelines?

As noted in the *Method and Methodology* chapter, Kennedy Evans '*Best practice Design Guideline Criteria'* (2019) will be used to analyse the effectiveness of existing guidelines which seek to protect coastal areas from climate change induced flooding.

Table 7 provides a summary on how each design guideline has achieved each of the content attributes criterion. Further rationale on how each guideline has met or hasn't met this will be expanded on below.

Table 7:Summarised results of the content attributes analysed against the design guidelines and design criteria

Content Attributes	Design Guidelines
1. Clear design intent	
2. Clear design objective	
3. Flexible outcomes	
4. Design strategies	
5. Evidence based	

6.	Supporting diagrams and images
7.	Readability
8.	Direct language
9.	Measurable data

5.1.1 Clear design intent

A clear design intent should be stated at the beginning of the document. In doing so it helps inform the reader what the document is about and what it hopes to achieve (Evans, 2019). In reviewing all seven of the design guidelines all of them demonstrated a clear design intent within the first page of the document. Because of this, a full square was given to all the studies.

This was clearly shown in *Catalogue of Coastal Hazard Adaptation Option,* "The guidance document sets out a 10-step decision cycle of structured engagement which aims to increase awareness of the impacts of sea level rise, and lead to the development of community-led adaptation plans that consider the social, cultural, natural and built environments" (Christchurch City Council, 2021, p. 3). This is then followed by the purpose of the report and the approach that it is going to take through the study. This clearly informs the reader of what the document is about and the overall structure of the guidelines.

5.1.2 Clear design objective

Alongside the design intent, the design objectives of the document need to be clear and at the beginning of the document. This is important as it allows the reader to make an informed and quick decision on whether the document is of use to them (Evans, 2019). Based off Evan's (2019) method, a full square was allocated if the design objective was clearly outlined at the beginning of the document. A half square was allocated if there were design objectives at the beginning, however it was unclear what they were wanting to achieve. Five of the seven guidelines demonstrated clear design objectives, with two partially demonstrating it.

This was successfully demonstrated in the *Auckland Design Manual – Water Sensitive Design* (Lewis et al., 2015), which falls under the 'Objectives' header within the design manual/guideline. It clearly states, "The objectives for WSD for stormwater aim to deliver the priorities identified in The Auckland Plan. Relevant priorities in The Auckland Plan are…. Based on these priorities, a set of objectives has been developed for WSD. The objectives listed below are intended to be aspirational at the regional and catchment scale and achievable at the site scale." (Lewis et al., 2015, pp. 28-29). The reader can find the objectives of the document clearly through the use of chapters and headers, whilst clearly stating what the objectives are and its intent.

Another example of this being demonstrated can be found in the *Climate Resiliency Design Guidelines (New York City Department of Environmental Protection, 2020)* which states, "The primary goal of the Guidelines is to incorporate forward-looking climate change data in the design of City capital projects. Codes and standards that regulate the design of facilities already incorporate historic weather data to determine how to design for today's conditions"(New York City Department of Environmental Protection, 2020, p. 5). Although the document states what the overall goal of the guidelines are, they do not go into detail of what that looks like in terms of steps that need to be taken to achieve it.

5.1.3 Flexible outcomes

Flexible outcomes are an important factor in design guidelines as their purpose is to provide A strategy in which a designer can work from to apply to each unique situation (Evans, 2019). Based on Evan's (2019) research, a full square was allocated to documents which had limited restrictions – allowing for looser design direction. Whereas a half square was allocated to documents with restricted outcomes. As a result, all seven design guidelines were allocated a half square.

The Coastal Design Guidelines for NSW (2003) provides a set of objectives for designing natural edges. As part of the objectives for this section it notes, "Setbacks for redevelopment should consider a 100-year planning timeframe to address shoreline retreat and sea-level rise." (Coastal Council of NSW, 2003, p. 59) and "For new developments the foreshore setbacks should be at least 50m wide as a precautionary measure where possible." (p. 59). These guidelines provide a numerical precision on implementing protection and mitigation measures, therefore leaving little room for flexible outcomes.

5.1.4 Design Strategies

Van Den Brink (van den Brink et al., 2016) notes of a successful design guideline that "Each design strategy has its specific design tools and design measures illustrated in a conceptual way, giving future designers freedom to transfer these approaches to their specific cases" (p. 224). For this, a design strategy exists as a catalyst of further thought and expansion beyond the guidelines. Again, this is where flexibility comes into play. Drawing on Evans (2019), a full square was given to guidelines which discuss an overarching design strategy. A half square was allocated to guidelines which have an overarching strategy but didn't discuss it in the document. As a result, six guidelines were given full squares and one was given half a square.

This is clearly shown in the *Catalogue of Coastal Hazard Adaptation Options* document which uses the Protect, Adapt, Retreat and Avoid (PARA) framework as the overarching strategy of the document. This strategy then informs the design intent and objectives of the document.

5.1.5 Evidence Based

For a guideline to be applied there needs to be sufficient evidence to back up what is being promoted. Van Den Brink (2016) notes, "They act as an intermediate step between the mass of research evidence and its application in a complex situation." (p. 222). Based off Evan's (2019) method, a full square is allocated to guidelines which provide a literature review at the beginning of the document and is well referenced, and a half square is allocated to guidelines with little references throughout the document. This resulted in three documents receiving a full square and four receiving a half square.

This is clearly shown the *NYC Climate Resiliency Design Guidelines (New York City Department of Environmental Protection, 2020)* in which it notes that "A facility located in the current 1% annual chance floodplain will face increasing risk and/or depth of flooding during its useful life due to sea level rise" *(p. 24)*. This is accompanied by maps and diagrams showing how to find this information (Figure 3) accompanied by design interventions (flood walls, living shorelines, restored shorelines etc.) to mitigate the impact of flooding.

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Figure 3: Excerpt from the *NYC Climate Resiliency Design Guidelines* (2020) demonstrating evidence-based design guidelines (New York City Department of Environmental Protection, 2020)

Again, this is clearly show in the *Guidelines to Prepare India's Coast for climate Change* (2021) which evaluates the hardness of a mitigation intervention against the methodology and their environmental impact (Figure 4). For example, an offshore reef of 3 to 8 metres in depth has a low environmental impact and is ranked as 'soft'. This is then further discussed in the research with in-text references. This document also provides an in-depth literature review in the beginning of the document to provide contextual information to the issue being discussed. (Black et al., 2021).

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Figure 4: Excerpt from *Guidelines to Prepare India's Coast for climate Change* (2021) demonstrating evidence-based design guidelines (Black et al., 2021)

5.1.6 Supporting diagrams/imagery

Evan's (2019) notes that graphic illustration is vital in ensuring design guidelines are effective. She also notes that the graphic communication and following explanation should emphasise that guidelines are ultimately a framework to work within, and "do not guarantee success" (p. 41) . Based on her research a full square is allocated when documents include graphic communication through diagrams, typologies and imagery with an explanation and a half square was allocated when graphic communication was expressed, however no explanation was included (Evans, 2019). As a result, three guidelines three documents were allocated a full square, and four were allocated a half square.

The *Water Sensitive Design for Stormwater Guideline Document* (2015) clearly demonstrated this in Figure 5. Here they are showing how the water cycle interacts with vegetation along a river corridor through graphic illustrations which is then further accompanied by text underneath to further explain the imagery. The imagery also includes small diagrams within the imagery to aid in explaining what is happening. The page before the imagery also explains why these margins are needed and how they work (Figure 5).

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Figure 5: Supporting diagrams in *Water Sensitive Design for Stormwater Guideline Document* (March 2015) (Lewis et al., 2015)

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Figure 6: Supporting text to diagram in Figure 5 providing further explanation about the diagram above (Lewis et al., 2015)

5.1.7 Readability

For a design guideline to be cohesive and easy to interpret they need to have a structure to them which will guide the reader through the document. Based on Evan's (2019) method a full square is allocated to a guideline if there is a clear structure to the document (e.g., Literature review, methods, results), and a half square is allocated if the document had a structure, however it was difficult for the reader to follow (Evans, 2019). As a result, four of the guidelines were allocated a full square and three were allocated a half square.

One of the guidelines that demonstrated this well is the *Coastal Design Guidelines for NSW (2003).* The document has a clear layout and has separated each chapter according to location of environmental type (e.g., coastal cities, coastal towns, coastal villages, etc). Within each chapter each guideline or intervention is bullet pointed and is consistent across the document. Each sentence is short and concise – providing a much easier to read document. Images were designated to numbered bullet points as well.

5.1.8 Direct language

Direct language is important for ensuring that the reader understands what the document is about and how to use it (Evans, 2019). Based on Evans (2019). method guidelines that were short and concise were given a full square, and guidelines that were longer and more difficult to understand were given a half square. As a result, three guidelines were given a full square, four were given a half square.

Direct language was clearly demonstrated in the *Water Sensitive Design for Stormwater Guideline Document* (Lewis et al., 2015). They provide illustrations with text alongside it that is concise and easily understood by the reader, such as, "Surface water features such as swales and open channels may extend from riparian areas into streetscapes and open space" (Lewis et al., 2015, p. 115) as seen in Figure 5.

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Figure 7: Design guideline from *Water Sensitive Design for Stormwater Guideline* Document (2015) demonstrating how direct language is used (Lewis et al., 2015)

5.1.9 Measurable data

Based on Evans (2019) measurable data is crucial in the application of an effective design guideline. In her research a full square was given if the guideline included measurable data, whilst no square was given if it did not (Evans, 2019). This is because of the topic that she was researching. For this research, although there is a need for accuracy, there is leniency as not all interventions are going to be the same for each location that it is placed on. For this, a full square is allocated if it includes measurable data, and a half square if it included some and no square if none of the data was measurable. As a result, three guidelines were given a full square and four were given a half square.

This is clearly demonstrated in the *Guidelines to Prepare India's Coast for climate change* (2021) which notes, "Reef is built offshore, normally in 3- to 8–m depth" (p. 1121) when speaking to coastal erosion in India. This is measurable data that be placed into a real-world situation.

This was also partly demonstrated in the *Catalogue of Coastal Hazard Adaptation Options (2021), which note,* "Similar to the second method, seepage drains or canals collect subsurface water to prevent the weakening of structure-supporting soil, surface inundation and ponding. Horizontal subsurface drainage (or 'French drains'), use pipes in permeable soils below ground level to divert water and thereby reduce the local groundwater levels." (p. 19). The guidelines are clear and concise; however, they lack measurable data in providing accuracy of this specific guideline.

5.2 To what extent do existing guidelines meet best practice visual attributes for effective guidelines?

The visual attributes which make up the whole design guideline document are just as important as the content attributes as it feeds into the cohesion of the whole document and its readability to the user. Based on Evans (2019) design guideline criteria the visual attributes are made up of the following: 1) Structured layout; 2) Bullet Points/listed; 3) Concise guidelines; 4) Text Hierarchy; 5) Simple Diagrams; 6) Minimal colour diagrams; 7) Limited Diagrams; 8) Explanation/labels and arrows explaining diagram; and 9) Keys and legends (Table 9).

Table 8: Summarised results of the visual attributes analysed against the design guidelines

Visual Attributes	Design Guidelines
Structured layout	
Bullet points/listed	
Concise guidelines	
Text hierarchy	
Easy-to-read diagrams	
Minimal colour diagrams	
Limited diagrams	
Explanations and annotations	
Keys and legends	

5.2.1 Structured layout

Evans (2019) notes that a guideline should be easy to read and distinguishable to the reader. A structured layout ensures that there is a set differentiation between the literature and guidelines. Furthermore, a guideline should be easy to read and distinguishable to the reader. Based on this a full square was allocated for guidelines that were in a structured format outside of the main body of text (Evans, 2019). A half square was awarded when the document was structured, however the guidelines were embedded into the main body of text. One of the guidelines received a full square and six received a half square.

The *Water Sensitive Design for Stormwater Guideline Document (2015)* clearly demonstrated this as seen in Figure 8. There is a clear differentiation between the guideline and the accompanied text. For this – it is easier for the reader to apply these guidelines. In comparison to *The Coastal Design Guidelines for NSW (2003),* which received a half square, although it does have a clear structure as seen in Figure 9 the text is all together and has no text hierarchy in terms of what is literature and what is a guideline.

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Figure 8:The Water Sensitive Design for Stormwater Guideline Document (2015) demonstrating a clear layout between guidelines and accompanied text (Lewis et al., 2015)

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Figure 9: The Coastal Design Guidelines for NSW (2003) demonstrating partial structure to the document (Coastal Council of NSW, 2003)

5.2.2 Bullet points/listed

When visually representing the guidelines, Evans (2019) found that guidelines that were bullet pointed or listed were easier to interpret. This is because it makes the information easier to digest for the reader. Based on this Evans (2019) notes that documents that presented their guidelines in a bullet point should be allocated a full square, with a half square being allocated to guidelines that are just listed. As a result, four guidelines received a full square and three received a half square.

This is clearly shown in *NYC Climate Resiliency Design Guidelines (2020)* as seen in Figure 10 Here they have used bullet points to list each recommendation, or guideline to mitigate flooding. Although this guideline receives a full square for this attribute, it is clear that only listing the guidelines without diagrams or images is not suffice.

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Figure 10: *The NYC Climate Resiliency Design Guidelines (2020)* document demonstrating the guidelines using bullet points (New York City Department of Environmental Protection, 2020)

Similarly, the *Coastal Design Guidelines for NSW (2003)*uses bullet points through a numbering system to outline their guidelines. However, this is then visually portrayed through diagrams on the following page (Figure 11).

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Figure 11: *The Coastal Design Guidelines for NSW (2003)* document using bullet points to outline their guidelines, accompanied by supporting diagrams (Coastal Council of NSW, 2003)

5.2.3 Concise guidelines

Concise guidelines are important as it ensures that the information that the document is presenting to its reader is easy to read and understand. Evans (2019) notes that there are some steps that need to be actioned for guidelines to be considered concise. One of these is that each guideline should be broken down into components using bullet points, lists and short sentences. Based on Evans (2019), a full square was given to guidelines or components of a guideline were one sentence, whilst half a square was given to guidelines that were no longer than two sentences. This resulted in three guidelines receiving a full square, two receiving a half square and two receiving no square at all.

This was conveyed well in the *Water Sensitive Design for Stormwater Guideline Document* (2015). As seen in Figure 12 the guidelines include a short concise sentence underneath to give contextual information about that specific guideline. This was mostly relevant for the whole document, however there were some guidelines which required more in-depth explanations. Although this was the case for part of the document, I felt this was well represented in the whole document with short concise sentences.

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Figure 12: The *Water Sensitive Design for Stormwater Guideline* Document (2015) demonstrating a concise guideline (Lewis et al., 2015)

An example of this not being well represented is the *Guidelines to Prepare India's Coast for climate Change* (2021) document. This is because it is largely text based, as a result the guidelines have become part of the larger body of text making it hard for the reader to search for the guidelines. As seen in Figure 13 it is hard to differentiate between the literature and guidelines, furthermore the guidelines are not short and concise.

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Figure 13: The *Guidelines to Prepare India's Coast for climate Change (Black et al., 2021)*

5.2.4 Text hierarchy

For guidelines to be cohesive and make sense they need to have a text hierarchy – as with any other document would. To help make sense of what is important using bold and italic title and font weights for headings, sub headers and body text. Evans (2019) notes that some design guidelines need to be broken down further and for this, it is important that these documents are using a visual hierarchy for the text so that the guidelines remain clear and concise for the reader (Evans, 2019). Based off her methodology a full square was given to guidelines with clear text hierarchy through headings and subheadings and a half square was given to guidelines that did not display a clear differentiation in text hierarchy. Six of the guidelines received a full square, with only one receiving a half square.

This was well shown in the *Water Sensitive Design for Stormwater Guideline Document* (2015), by using clear headers, subheadings, and distinct body text Figure 14 This guideline also uses varying font weights and variations of a set font to amplify the text hierarchy as part of the design guideline.

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Figure 14: The *Water Sensitive Design for Stormwater Guideline* Document (2015) demonstrating the use of varying font weights and bold font types to highlight text hierarchy (Lewis et al., 2015)

5.2.5 Simple diagrams

Landscape architecture is a largely visual profession, and for that diagrams are a key attribute in the effectiveness of a design guideline. Evans (2019) notes, that these guidelines should be simple and should directly support the text as part of the guideline itself. She notes that this can be shown in a number of ways such as maps, design typologies and illustrated images (Evans, 2019). Based on this a full square is given to guidelines that included simple diagrams which supported the guideline, and a half square was given to guidelines which included diagrams; however, they were difficult to interpret. No square was given if the guidelines did not include diagrams. Based off this, one guideline received a full square, four received a half square and two received no square.

Again, this is clearly shown in *Water Sensitive Design for Stormwater Guideline Document* (2015) document using simply illustrated diagrams and graphics with text alongside the diagram to explain what it is demonstrating. In contrary, this is not clearly shown in the Christchurch City Council *Catalogue of Coastal Hazard Adaptation Options (2021)* as this is a largely text-based set of guidelines with images to illustrate what a guideline looks like once implemented, rather than being diagrammatical Figure 15.

Although this is not a diagram per se in respect to Evans criteria, the images used are supplementing the text to illustrate the guideline itself.

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Figure 15: Excerpt from the Christchurch City Council Catalogue of Coastal Hazard Adaptation Options (2021) document demonstrating how images are used, rather than diagrams (Christchurch City Council, 2021)

5.2.6 Minimal colour diagrams

Alongside the design guidelines needing to visually show diagrams in a simplistic manner, they also need to have a minimal colour. Similarly, to text hierarchy, colours provide a platform to highlight important aspects of a guideline through annotations, arrows and more. It also ensures that there is a sense of cohesiveness throughout the document (Evans, 2019). Based off Evans (2019). method, a full square is allocated to guidelines which used one to three main colours, and a half square was allocated to guidelines which used more than three key colours. The results of this are like, *4.4.5 Simple Diagrams* with one guideline receiving a full square, four receiving a half square and two receiving no square.

Here we see the document *Water Sensitive Design for Stormwater Guideline Document* (2015) showing this clearly by using a minimal colour pallet. The whole document is kept to a neutral colour tone which carries on to the graphics and illustration within the document (Figure 16). The colour pallet consists of neutral greens, blues and white to highlight the necessary part of the guideline.

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Figure 16: Excerpt from the *Water Sensitive Design for Stormwater Guideline Document* (2015) showing minimal use of colour (Lewis et al., 2015)

5.2.7 Limited diagrams

Ensuring that diagrams are reduced to a minimum was an important visual attribute as part of Evans, *Best Practice Design Guideline Criteria* (2019). This means that each guideline should be limited to no more than three to ensure that the presentation of it remained clear and concise. Based on this, guidelines that had less than three diagrams were given a full square, and guidelines with more than three were given no square (Evans, 2019). As a result, two guidelines were given a full square, three were given a half square and two received no square.

This was clearly demonstrated in the *Guidelines to Prepare India's Coast for climate Change (2021)* which provide three diagrams to show how groynes have been implemented in three different locations (Figure 17). Again, the guidelines are showing three ways that headlands have been implemented in three different locations.

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Figure 17: Excerpt from *Guidelines to Prepare India's Coast for climate Change* (2021) demonstrating how groynes have been implemented three different ways (Black et al., 2021)

This is demonstrated poorly in the *Coastal Hazards and Climate Change* (December 2017) which lists guidelines in a graph style, rather than proposing it as a visual document (Figure 18). This makes it much harder for the reader to navigate the document as there isn't a distinction between what is, and what isn't a guideline. For this, it received no squares.

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Figure 18: Excerpt from *Coastal Hazards and Climate Change* (December 2017) showing how the guidelines are visually represented (Ministry for the Environment, December 2017)

5.2.8 Explanations and annotations of diagrams

Evans (2019) notes that, explanations and annotations alongside diagrams are typically short and concise to effectively prompt the reader about what the guideline is represent (Evans, 2019). For this attribute, a full square was given to guidelines which had both annotations and explanations beside each diagram, whilst a half square was given to guidelines that had annotations or explanations - not both (Evans, 2019). As a result, five guidelines received a full square, one received a half square, and one received no square.

This is well demonstrated in the *Coastal Design Guidelines for NSW (2003)* which provides a diagram of how a network of green spaces could be applied to a coastal area (Figure 19). Within the diagram there are numbers correspond to explanations and annotations to further explain the guideline. In contrast to the *Coastal Hazards and Climate Change* (December 2017) which demonstrates this poorly as there are no diagrams to explain a guideline.

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Figure 19: Excerpt from *Coastal Design Guidelines for NSW (2003)* demonstrating annotations and explanation alongside diagrams. (Coastal Council of NSW, 2003)

5.2.9 Keys and legends

Keys and legends are an important visual attribute to design guidelines, particularly with images and diagrams. By providing keys and legends within a guideline it helps the reader understand what the guideline represents (Evans, 2019). Based off Evans (2019) method, a full square was given to a guideline which included keys and legends within the guidelines, whilst a half square was given to guideline that included a key without a legend. No square is allocated if a key and legend was included but deemed beneficial, whilst an N/A was given if no key or legend was included, however it was considered unapplicable to the diagram (Evans, 2019). As a result, two guidelines received a full square and five received no square at all.

This is well demonstrated in the *NYC Climate Resiliency Design Guidelines (2020)* as shown in Figure 20. This document uses a legend to show where the water levels are within the floodplain of New York City which directly relates to the diagram.

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Figure 20: Excerpt from *NYC Climate Resiliency Design Guidelines* (2020) demonstrating the use of keys and legends (New York City Department of Environmental Protection, 2020)

For some of the guidelines which received no square the use of keys and legends was not applicable as they were either largely text based and had no diagrams to add keys and legends to, or they demonstrated the guidelines through illustrations or images.

5.3 Summary

Overall, the seven design guidelines either achieved full or half squares for all of the content attribute criteria. This was clearly highlighted as all guidelines achieved a full square for a clear design intent and design strategies. This was closely followed by the clear design objectives criteria and supporting diagrams and images. However, many of the design guidelines received either half or no square in the visual attributes evaluation. It is clear that many of the guidelines lacked a structured layout, concise structure, easy-to-read diagrams and keys and legends. It is evident that existing design guidelines are not visually inspiring.

Although the design guidelines achieved highly in the content attribute criteria, many of them were not completely applicable to the conditions of a small New Zealand coastal town. They also do not all completely address all design guideline criteria, thus the need for improved guidelines.

Chapter 6

Proposed suggestions to existing design guidelines to effectively protect small New Zealand coastal communities

This chapter will present a series of suggestions to improve existing design guidelines to effectively protect small New Zealand coastal towns from climate change induced flooding. These suggestions will be based on the results of the design guideline evaluation (Chapter 5), and a narrative literature review of existing guidelines. Section 6.1 will propose suggestions to protect small New Zealand coastal towns from climate change induced flooding, with sections 6.1.1 proposing the design guideline visual layout, and section 6.1.2 proposing the design guidelines.

This will then be summarised as part of section 6.2.

6.1 Suggestions for developing effective design guidelines to protect small coastal towns from climate change induced flooding

As demonstrated in Chapter 5, there are currently no design guidelines that are effective in directly address all design guideline criteria as per Evans (2019) '*Best Landscape Architecture design guideline criteria'.* The following sections will provide suggestions for 1) an improved visual layout based on Evans (2019) visual attributes criteria, and 2) Improvements to the existing guidelines based on the evaluation in Chapter 5 and the literature review..

6.1.1 Design guideline visual layout

Based on Evans (2019) 'Best Landscape Architecture design guidelines criteria' for 'visual attributes', an improved visual layout for design guidelines has been proposed (Figure 21). There is a clear structured layout, which is highlighted through the text hierarchy of headings, sub-headings, and body text. Bullet points will be used underneath the guidelines to ensure guidelines are easy to read and concise for the reader. There is space available for diagrams, images, annotations, and keys/legends to visually express the design guidelines.

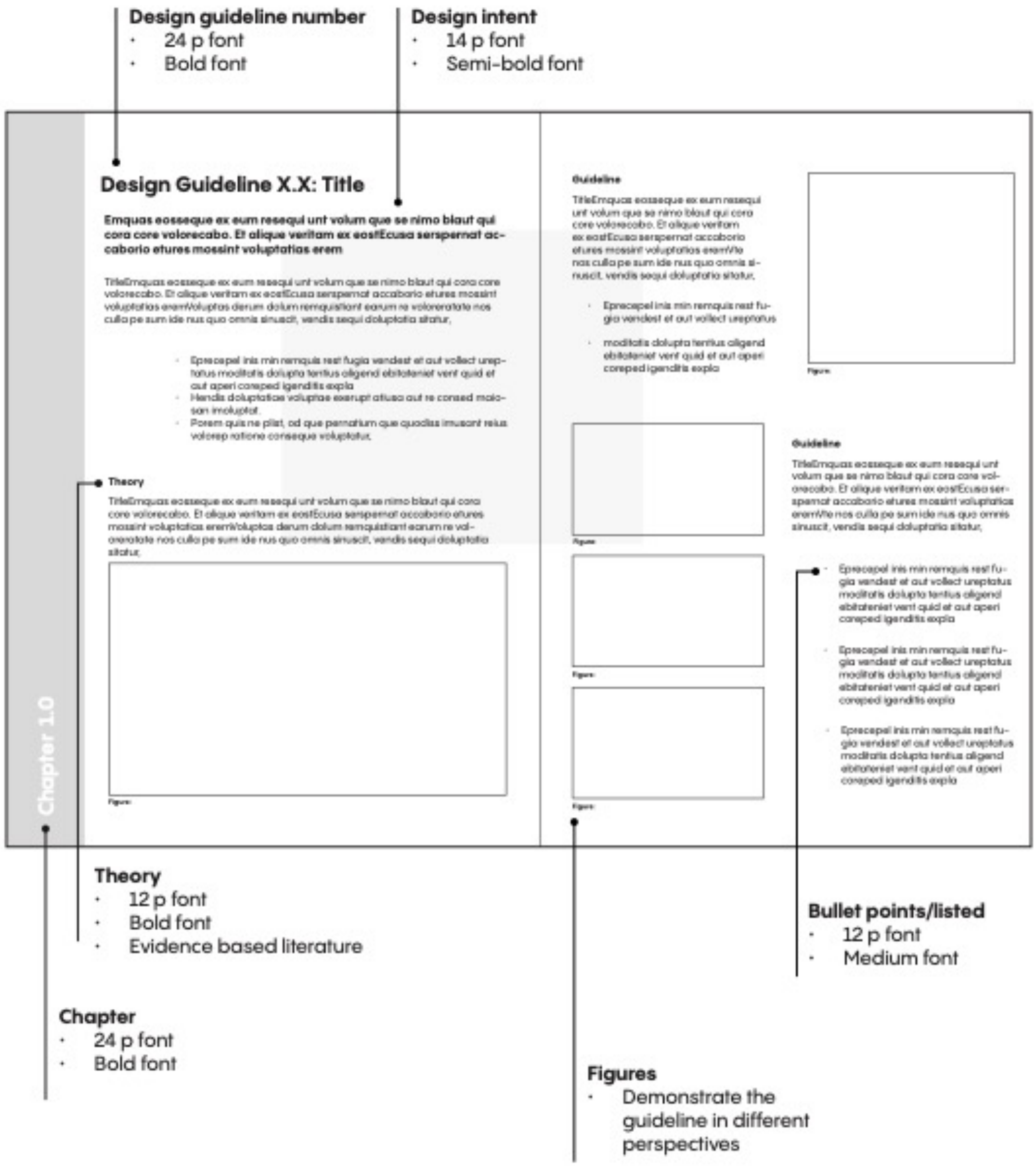

Figure 21 Proposed design guideline visual layout

6.1.2 Best practice flood mitigation guidelines

As per the Methods and Methodology Chapter (*Section 2.2.2 Best practice evaluation of existing guidelines and development of new guidelines)* a set of new design guidelines have been proposed based on the results of the 'Best Landscape Architecture design guideline criteria' evaluation and the narrative literature review (Table 5). This includes, 1) Bioretention systems, 2) Minimise impervious surfaces, 3) Detention and attenuation, 4) Wetlands, 5) Riparian vegetation, 6) Coastal vegetation, 7) Dune restoration, 8) Flood proofing existing infrastructure, 9) Stop banks/bunds, 10) Armouring, 11) Adaptable infrastructure/dwellings and 12) Zoning.

Guideline 1.0: Bioretention Systems

Rain gardens/swales

Design intent:

To capture stormwater runoff in urban areas to reduce surface flooding in periods of heavy rainfall and relieve pressure on the stormwater system (Christchurch City Council, 2021; Lewis et al., 2015; Markou, 2022).

Design guideline

Rain gardens can be used in areas where conventional landscaping would be planting to provide both an aesthetic and functional purpose. Stormwater runoff is filtered through the rain garden through the vegetation on the top layers, which then soaks into the soil. This is then typically piped to a discharge point (Figure 22 & 23) (Auckland Council, 2017).

For proper filtration of stormwater runoff, rain gardens need to have the correct aggregate, clay content, media, and ponding depth, as well as appropriate planting for adequate surface infiltration (Lewis et al., 2015). Planting must be dense to protect the substrate and reduce erosion. (Auckland Council, 2017; Nelson City Council, 2017; Tasman District Council, 2004).

- Enhance the urban ecology of an area.
- Contribute to the aesthetics of a streetscape.
- Incorporating them into existing architectural forms
- Easily incorporated into the existing landform

(Lewis et al., 2015)

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Figure 22 Cross section of a rain garden (Nelson City Council, 2017)

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Figure 23: Image of a rain garden in Christchurch (Julia Atkinson, 2021)

Guideline 2.0: Minimise impervious surfaces

<u>Design Intent:</u>

To limit the use of impervious, or hard surfaces such as roads, buildings and pavements that generate runoff from stormwater (Lewis et al., 2015).

<u>Design guideline</u>

Incorporating more permeable surfaces into urban areas will provide a pressure relief for larger stormwater infrastructure for the catchment. This can be implemented by the following:

- Increased open green space.
- Incorporating pervious and porous pavers, as well as stabilised loose material and living roofs
- Developing planning rules which limit site buildings and hard surfaces.
- Shared driveways

(Lewis et al., 2015)

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Figure 24: Pervious paving (Lewis et al., 2015)

Guideline 3.0: Detention and attenuation

Design Intent:
The design intent it to store surface runoff temporarily during heavy rainfall periods to mitigate flooding in urban areas using detention basins, or to provide permanent water storage with additional capacity for heavy rainfall events through retention basins (Markou, 2022).

Design guideline

Detention/retention basins provide a temporary storage of stormwater for a period of less than 24 hours. Where there are overflow paths nearby, ensure that there is signage to warn people. Detention basins need to pass a 1% AEP event without overtopping and must allow for multi-use function when during dry periods. Because of this, they must be easy to maintain (e.g, mowing) (Figure 25) (Lewis et al., 2015; Tasman District Council, 2004). Similarly, retention basins need to a pass a 1% AEP event, however they must provide appropriate riparian plating around the edge and appropriate vegetation to avoid blockages downstream (Figure 26) (Markou, 2022).

Detention basins typically have a discharge outlet which allows it to pipe out overflow in the case of a large storm event. Typically, these areas remain a low vegetated grass. This is because they are dry for long periods of time, with temporary inundation of water (Lewis et al., 2015).

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Figure 25: Stormwater detention basin (Auckland Council, 2023)

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Figure 26: Stormwater retention basin (Candor3, 2023)

Guideline 4.0: Wetlands

Design Intent

To temporarily hold water during floods and high rainfall and slowly releasing it over a period – providing storm protection and erosion control (Figure 27 and 28) (Christchurch City Council, 2021; Lewis et al., 2015; Tasman District Council, n.a.-b).

Design guideline

Both natural and constructed wetlands can help reduce flooding by temporarily storing and slowly releasing water. Typically, they consist of three zones: the inlet, planted, and high-flow bypass channel. The planted area holds water and reduces pressure on the catchment. Whether a wetland needs a liner depends on the soil and land capabilities (Lewis et al., 2015).

There are three types of constructed wetlands:

- **Surface-flow wetlands:** Designed for water to flow through various pools and wetland for various stormwater treatments.

- **Subsurface flow wetland:** Best suited in areas where sediment is low, to avoid blockages and plant survival.

- **Floating treatment wetland:** Performs similar to raft with hydroponic planting. This wetland treatment is still relatively new.

(Lewis et al., 2015)

Wetlands are generally located at the lower portion of the catchment to drain naturally through high to low elevations (Auckland Council, 2017; Lewis et al., 2015).

- Shallow marsh zones have an average depth of .2m, deep marsh zones have a depth of .5m, and pools should be around 1.5m in depth.

- Length to width ratio should be between 3:1 and 5:1

- Connect wetlands to riparian vegetation

(Auckland Council, 2017; Lewis et al., 2015)

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Figure 27: Awakeri wetland (Auckland Council, n.a.-a)

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Figure 28: Waiatarua Reserve wetlands, located in Remuera, Auckland (Steven Mcnicholl, 2013)

Guideline 5.0: Riparian vegetation

Design Intent:
To promote edge stabilisation for erosion control, water filtration and provide water flow regulation for flood protection(Figure 29 & 30) (Riis et al., 2020).

Design guideline

Riparian margins provide a buffer between the water and the land, by doing so it helps reduce erosion by slowing down runoff through the vegetation. The minimum recommendation for a riparian buffer is at least 10 metres either side of the margin, however to benefit from the buffer a 20 metre strip is recommended (Lewis et al., 2015). Generally, the larger the buffer, the greater the benefits.

- 5 metres: Ongoing maintenance is required to reduce weed infestation. Only recommended if there is no other option
- 10 metres: Indigenous vegetation can continue to grow without the need of constant weed maintenance.
- 20 metres: Indigenous vegetation is self-sustaining

(Lewis et al., 2015)

Riparian buffers reduce the speed of stormwater runoff through the vegetation. The vegetation in combination with the humus layer holds and slowly releases large volumes of water. Riparian margins typically have a dense groundcovers which aid in slowing the velocity of the water. As the buffer is larger in width (e.g., 20 metres and beyond) there are benefits of erosion control through larger shade trees (Lewis et al., 2015).

Figure 29: Riparian vegetation in Horseshoe Lake (Hubert, 2022b)

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Figure 30: Plan view image of a riparian zone (thisNZlife, n.a.)

Guideline 6.0: Coastal vegetation

Design Intent:

The design intent is to reduce wave energy, storm winds, coastal erosion and mitigate flooding through salt marshes and mangroves (Figure 31 & 32) (Montgomery et al., 2022; van Loon-Steensma & Vellinga, 2013; Vuik et al., 2016).

<u>Design guideline</u>

Coastal vegetation functions as a filter strip to flow overland water flow and attenuate stormwater quantities. Coastal vegetation typically consists of saltmarshes and mangroves, with sea grasses and coastal forests offering some protection (Christchurch City Council, 2021; Linham & Nicholls, 2010). By implementing coastal vegetation they can reduce wave energy, storm winds and reduce coastal erosion. They are low maintenance once they are established, however careful selection of planting needs to be considered (Narayan et al., 2016). They provide a nature-based solution coastal flooding as the vegetation is able to adapt to sea level rise and changing conditions in the environment (Christchurch City Council, 2021; Linham & Nicholls, 2010).

Coastal vegetation can hold and slowly release large volumes of water. If it is a mature forest within a coastal wetland environment, it is able to absorb 14 times more water than vegetated grassed areas.

- Low maintenance once they have established
- Can be implemented in areas where there has been managed retreat to be reverted into a softer edge and re-naturalise the landscape

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Figure 31: Salt Marsh (Herber&co, n.a.)

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Figure 32: Mangrove (Hailes, 2010)

Guideline 7.0: Dune restoration

<u>Design Intent:</u>
The design intent is to is to provide a natural defence against erosion and flooding in coastal environments (Hanley et al., 2014; Singhvi et al., 2022).

<u>Design guideline</u>

Dunes offer natural protection against storm surge flooding and are responsive to dynamic weather conditions. They protect the shoreline while also supplying sediment to the beach during periods of high erosion. This provides protection against inundation and erosion from storm surge flooding. Building a fence on the seaward side can promote dune growth, while vegetation can aid in dune stabilization. Sand dunes are made up of three zones: the foredune, back dune, and coastal forests (Figure 33) (Auckland Council, n.a.-b).

Planting is critical in the success of a dune system. Choosing the wrong type of plants can lead to overly dense vegetation and can restrict the dynamic nature of a dune landscape (Auckland Council, n.a.-b)

- Sand binding species need to be planted 0.5m a part.
- Trees and shrubs to be planting 1.0-1.5m a part.
- Larger trees more than 5 m apart.
- The foredune consists of smaller sand binding plants.
- The back dune consists of shrubs and smaller flax vegetation.
- Coastal forest are made up of larger trees.

(Auckland Council, n.a.-b)

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Figure 33: Typical dune vegetation sequence (Auckland Council, n.a.-b)

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Figure 34: Coastal sand dunes (Christchurch City Council, 2017)

Guideline 8.0: Flood proofing existing infrstructure

<u>Design Intent:</u>
To manage flood waters by modifying existing infrastructure (Figure 35 & 36) (Yasmin et al., 2022).

<u>Design guideline</u>

Flood-proofing infrastructure involves modifying existing infrastructure to withstand coastal hazards such as flooding. This can be achieved through upgrading existing assets, such as raising roads in a floodplain, implementing a flood gate by providing a structural barrier to manage floodwaters in river systems, and increasing stormwater retention ponds (Christchurch City Council, 2021).

- Flood gates usually come with two gates, one larger and one smaller, which are designed to allow for unobstructed low flows. This design helps reduce the likelihood of leakage. However, there is a possibility of debris accumulation, so it's advisable to install debris traps both upstream and downstream of the gates (Christchurch City Council, 2003).
- Modifications of existing infrastructure may rely on the availability of the land capacity to expand (e.g., elevating or moving a road, increasing storm water retention basin (Christchurch City Council, 2021).

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Figure 35: Raised streets (Mitchelides, n.a.)

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Figure 36: Moutoa floodgate (Paul Williams, 2921)

Guideline 9.0: Stop banks/bunds

Stop Banks

Design Intent:

To provide an elevated embankment along a riverbed to mitigate flooding (Figure 37 & 38) (Brierley et al., 1997).

Design guideline

Stop banks are designed to prevent the overtopping of flood waters in low-lying areas during a flood event. They typically sit parallel to the river (or seashore). Generally, they are designed to be no less than 4 meters in height, with earth stop banks at 2.5 meters in height to minimize the overtopping of flood waters during a flood event (Bay of Plenty Regional Council, 2014). Typically, they will have a gentler slope on the seaward side and a steeper slope on the land side. This is to reduce the land requirements of a stop bank (Bay of Plenty Regional Council, 2014; Christchurch City Council, 2021).

- Stop banks are typically covered in low grass to facilitate maintenance.
- With continuous exposure to water, stop banks may erode over time.
- Stop banks are effective in mitigating the impact of flood waters, tidal fluctuations, and storm surges by reducing wave energy.
- There needs to be a large enough site for a stop bank to be implemented.
- Ensure that the stop bank does not have adverse effects on neighbouring properties (e.g., blocking existing floodplain drainage).

(Bay of Plenty Regional Council, 2014; Christchurch City Council, 2021)

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Figure 37: Stopbank design (Bay of Plenty Regional Council, 2014)

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Figure 38: Whakatane stop bank (Bay of Plenty Regional Council, 2022)

Guideline 10: Armouring

Design Intent:

Armouring provides a hard structure between the earth in water – providing protection against coastal erosion from wave energy (Figure 39 & 40) (Linham & Nicholls, 2010).

Design guideline

The use of armouring techniques should be used when softening edges is not appropriate. Implementing armouring parallel to the shoreline can be done using rock revetments and sea walls constructed from a variety of materials such as gabion baskets, concrete, and geotextile tubes. When designing the seaward facing structure, it is crucial to consider whether it is smooth or irregular, as this can have a significant impact on erosion. A smoother texture will typically generate more wave energy, whereas irregularity will reduce it (Christchurch City Council, 2021).

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Figure 39: Sea Wall in Tahunanui (Martin de Ruyter, 2019)

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Figure 40: Gabion baskets for coastal protection (Gabion Supply, n.a.)

Guideline 11: Adaptable buildings/dwelling

Elevated Housing

Design Intent:

The design intent of adaptable buildings and dwellings is to create flood-proofed, elevated, and/or floating buildings (Figure 41, 42 & 43) (Neill, 2018).

Design guideline

There are three main adaptable building/dwelling interventions.

- Elevating infrastructure involves constructing buildings above flood water levels using timber or concrete piles. This ensures that the building is protected when water levels fluctuate (Christchurch City Council, 2021; Neill, 2018).
- Wet proofing a house involves designing a structure that remains dry during dry seasons but floods during wet seasons. Flood-resistant materials are used, and water must be able to enter and leave the structure without causing damage (Christchurch City Council, 2021; Neill, 2018). .
- Floating buildings are designed to rise and fall with changing water levels, accommodating the tides of sea-level rise. These buildings adapt to the changing water levels instead of obstructing them (Christchurch City Council, 2021; Neill, 2018).

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Figure 41: Elevated Building (Casey Dunn, 2021)

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Figure 42 Flood Proof Housing (Federal Emergency Management Agency, 2020)

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Figure 43 Floating Building (Dezeen, 2022)

Guideline 12: Zoning (managed retreat)

Design Intent:
To removing assets such as housing or commercial zones away from high-risk coastal areas through land acquisitions and leasebacks (Christchurch City Council, 2021; Hino et al., 2017).

Design guideline

Zoning is a tool that can be used to ensure that development on vulnerable land can either be avoided, or existing assets such as housing or commercial zones are moved from high-risk areas. This can be implemented through prohibiting development in high-risk areas, changing future land use, promoting natural shoreline measures rather than hard infrastructure. This can also be implemented through managed retreat in which land owners surrender their land and are moved to safer areas. This can be done through buyouts, land swaps and leasebacks – in turn, creating room for conservation easements and natural shoreline measures for flood protection (Christchurch City Council, 2021)

6.2 Summary

A set of twelve improved design guidelines have been proposed based on the narrative literature review of existing knowledge on mitigating climate-change induced flooding, in conjunction with the results of the '*best practice Landscape Architecture design guideline criteria'* in Chapter 5. These design guidelines act only as suggestions, rather than the development of a brand new set of design guidelines. These improved guidelines will be now be applied to the chosen case study site in Chapter 7.

Chapter 7

Application of guidelines to case study

This chapter will apply the proposed design guidelines that were developed in Chapter 6. Section 7.1 will evaluate the extent in which Māpua is capable of mitigating flooding in the context of climate change through an inventory and analysis of biophysical and land use characteristics. Section 7.2 will determine what extent Māpua meets the best practice flood mitigation design guideline. And, section 3 will demonstrate the application of the guidelines to protect a small coastal community.

The results will be summarised in section 7.4.

7.1 To what extent is Māpua capable of mitigating flooding in the context of climate change?

This full case study inventory covers the following biophysical and land use characteristics, 1) *Projected sea level rise*, 2) *Soil and soil drainage*, 3) *Ground water levels*, 4) *Coastal inundation and erosion*, 5) *River systems*, 6*) Zoning*, and 7) *Existing green and grey infrastructure.* This full case study inventory will be accompanied by maps, images and diagrams where appropriate. This process has been completed through both desktop and site visit analysis.

7.1.1 Biophysical and land use characteristics currently determining flooding under climate change

Projected sea level rise in the Tasman region

As shown in Table 11 it is predicted that sea level will rise by at least 1 metre by the year 2100 and 2 metres by at least 2150 (Ministry for the Environment, December 2017; Tasman District Council, n.a.-a).

Table 9: Future sea level rise (SLR) projections for the Tasman Region (Tasman District Council, n.a.-a)

SLR (metres)	Year Achieved (approx.)
0.5	2060-2110
1	2100-2200
1.5	2130-2200
2	2150-2200

In 2021 the Tasman District Council prepared a sea level rise map, outlining the coastline of the Tasman Region that will be at risk in the future with sea level rise projections (Figure 44 & 45)

This map outlines the impact that sea level rise will have on low lying areas from .05m to 2m, as well as the impact of a 1% annual exceedance probability (AEP) storm tide under sea level rise projections (Tasman District Council, 2021).

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Figure 44: Map showing present day sea level and flood scenarios in Māpua (Tasman District Council, 2021)

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Figure 45: Map showing 1 metre sea level rise and flood scenarios in Māpua at 2100 (Tasman District Council, 2021)

Mapua is already susceptible to flooding in low-lying areas around the coastal edge. It is evident that this risk will be amplified with sea-level rise, with almost all low-lying areas at risk of the occurrence of a 1% AEP storm tide

Soil and soil draiange

Māpua has three main soil types, Sandy (RS), Recent (gley) (GR) and Albic (UE) (Figure 46) (SoilSMapViewer, 2022). The dominant soils are the *Māpua Sandy Loam* found in low lying coastal areas, and the *Māpua Hill Soil* which is known for being fertile. The Māpua Hill Soils are a large contributor as to why the region is covered in fruit farms and other agricultural crops today (Campbell, 2014). The recent gley soil represents areas that once held native wetlands or estuarine environments. In the case of Māpua, this area has been drained for both residential and agricultural purposes (Campbell, 2018; Maanaaki Whenua Landcare Research, n.a.).

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Figure 46: Map showing varying soil types in Māpua (SoilSMapViewer, 2022)

The Māpua Sandy Loam (yellow) is primarily found on the flat, coastal areas within the township and can also be found throughout Marlborough and Nelson (SoilSMapViewer, 2022). This soil type is imperfectly drained, with slow permeability, resulting in wetness during periods of high rainfall. As a result, much of this soil has been artificially drained for agricultural, residential, and commercial use (Campbell, 2018).

The Māpua Hill soils (green) occur in areas where there are clay or sandy soils. They are primarily found in the North Island, however there is a small pocket of it in the Nelson and Marlborough region. This soil is found in the hilly regions in Mapua and the Tasman region (Campbell, 2018). The recent gley soil (blue) is found in a small area in Māpua. This was once a wetland, which has now been drained (Landcare Research, 2018).

Groundwater levels

Groundwater levels are monitored in the Tasman region every fifteen minutes. The aquifer in Mapua is the *'Deep Moutere Aquifer'* (Figure 47) and has remained at an average of 3.6m to 3.8m from 23 August 2017 to 31 December 2020(Tasman District Council, 2022a)

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Figure 47: Map showing the location of the Deep Moutere Aquifer (Tasman District Council, 2022a)

Ground water levels are particularly high along the coastal areas in the Tasman Region with some areas averaging around 1.3m and 5.75m (Tasman District Council, 2022b). Areas at higher elevations have lower ground water levels as shown in Figure 48.

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Figure 48: Map showing the location and depth of aquifers in the Tasman Region (Tasman District Council, 2022b)

High groundwater levels are often an indicator that there is a higher risk of flooding in that area. As increased rainfall occurs, groundwater levels increase, thus increasing vulnerability to further flooding and inundating the surface (Becker et al., 2022). For coastal areas, this vulnerability is even higher as much of the buildings and infrastructure are likely to be closer to sea level and have lower elevation, posing an even greater risk to communities. As sea levels continue to rise, so does the risk of inundation from groundwater in the event of high rainfall or flooding (Bosserelle et al., 2022).

As shown in Figure 48 this risk is not isolated to Māpua, rather it poses a risk to much of the low lying areas surrounding the Waimea Inlet.

Coastal inundation and erosion

Coastal inundation and erosion are processes that naturally occur. However, under climate change the rate that sea level rise is occurring at is accelerating. Coastal erosion commonly occurs during large coastal storms where the tide redistributes the sand from the shoreline (Zhang et al., 2004). Whereas coastal inundation is the permanent or semi-permanent flooding of coastal land (Gayathri et al., 2017).

As noted in *section 4.5.2.1 Projected Sea level Rise in the Tasman Region*, sea levels will rise in the Tasman region by at least 1 metre by 2100 (Ministry for the Environment, December 2017;

Tasman District Council, n.a.-a). As a result the already low lying land in Māpua will be at an increased risk of coastal inundation and erosion - thus putting people livelihoods at risk. As seen in Figure 45 coastal erosion is more likely to occur around the northern edge where the Tasman sea meets the Waimea Estuary, with coastal accretion occurring on Rabbit Island.

Figure 45 shows that with sea level rise of 1 metre, increased areas of Māpua will be inundated with water in the event of a flood. Almost all of the low lying coastal areas in Māpua which are currently occupied by built residential and commercial infrastructure are at risk in the event of a 1% AEP storm tide. Figure 45 also shows that under 1 metre sea level rise permanent inundation will occur with pockets of land becoming carved out by permanent occupation of water by the mean high water spring (MHWS). Parts of this will occur in areas that were historical wetlands as shown in Figure 49.

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Figure 49: Map showing historical wetlands in the Tasman Region (Landcare Research, 2018)

River systems

Under climate change, extreme weather events are more likely to occur with more intense rainfall resulting in an increased risk of flooding due to river overflow (Archie et al., 2018).

Māpua is a relatively flat coastal township surrounded by the Kahurangi National Park to the West and Mount Richmond Forest Park to the East. There are many rivers and streams which feed directly from the surrounding mountains and hills down to the Tasman Sea and Waimea Estuary (Figure 27).

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Figure 50: Map showing rivers in the Nelson/Tasman Region (Land Information New Zealand, n.a.)

The most impactful river for Māpua is the Waimea River which flows for approximately 10km through the Waimea Plains, through the Waimea Delta Wetland into the Waimea Estuary (Wallace, 2019). The Waimea River cuts through the Waimea Plains which is largely zoned for horticultural and agricultural uses. Because of this, the land has been stripped back to grassland - thus much of the native riparian vegetation along the river has been lost (Hickford, 2012). In the event of heavy rainfall, it is the Waimea River which will feed water down into the Waimea Estuary, thus creating a pinch point of fresh and salt water flooding (inundation) in Māpua (Verstappen, 2010).

Zoning

Māpua's township is largely concentrated in areas close to the coastline that are at high risk of flooding. Much of what dictates Māpua's vulnerability to coastal flooding is the zoning of the township (Figure 51). Most of the flat is zoned residential, commercial or part of the central business district. The wharf – one of Māpua's main attraction points sits within this high risk flood zone. Many residents live along the ‘spit’ and along the coastline. Despite this risk, ‘rural residential - low density’ zoned land is used for subdivisions where there is future risk of flooding (Tasman District Council, 2010).

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Figure 51: Zoning in Māpua township

At a larger scale, the land surrounding Māpua is largely rural, or rural residential where much of the land is primarily used for agriculture and horticulture. The Tasman region is known for its vineyards and orchards. There are opportunities to utilise areas on this land which are unable to grow crops and revert it into conservation land to mitigate flooding.

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Figure 52 Regional Zoning of the Tasman Regio

Existing green and grey infrastructure

Green and grey infrastructure are 'Protect' interventions as part of the *'Protect, Accommodate, Retreat, and Avoid'* (PARA) strategy for mitigating coastal hazards (see section 2.1) (Doberstein et al., 2019b; Rouse et al., 2017; Zhu et al., 2010).

Green infrastructure, also known as nature-based interventions typically mimic what is found in the natural environment. Grey infrastructure are more traditional means of interventions which provide are more solid protection from coastal hazards (Narayan et al., 2016; Zhu et al., 2010). Throughout Māpua there are existing interventions in place to mitigate the impact of flooding. These include riparian vegetation, sea walls, fragmented stop banks and dunes (see sections 4.5…..). At the catchment scale flood/tide gates and stop banks can be found along rivers and streams which lead to the Waimea Inlet (Tasman District Council, 2015).

Riparian vegetation

Riparian vegetation can be found along two of the stream within Māpua. Figures 53 to 56 demonstrate which stream feeds from the hill west of the Māpua wharf, down into the Waimea inlet. This provides some flood mitigation by slowing run-off from heavy rainfall.

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Figure 53: Map showing riparian planting along a stream in Māpua [Adapted] (Land Information New Zealand, n.a.)

Figure 54: Photos of riparian planting along stream in figure x in Māpua (Hubert, 2022b)

Figure 55 shows riparian planting along another stream in Māpua which leads from the large grassed area to the west, down past residential areas through to the Waimea Inlet.

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Figure 55: Map showing Riparian vegetation along a stream in Māpua [adapted] (Land Information New Zealand, n.a.)

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Figure 56: Image showing riparian vegetation around the edges of the Waimea Estuary (Hubert, 2022b)

Coastal vegetation

Coastal vegetation in the Waimea Estuary can be sparsely found around the edges of the coastline within the inlet. As the coastal areas around Māpua provide recreational use, coastal vegetation is sparse in areas where people would walk, boat, or swim. Coastal vegetation can be implemented as a nature-based approach to mitigating the impact of flooding on communities by absorbing wave energy to reduce rates of erosion (Narayan et al., 2016).

As seen in Figure 57 coastal vegetation can be found in some key areas around the edges of Māpua and within the Waimea Inlet.

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Figure 57: Map showing existing areas in Māpua where coastal vegetation is evident [adapted] (Land Information New Zealand, n.a.)

Historically, Māpua was covered in native forests, low lying vegetation, coastal marshlands and riparian ecosystems. From the hills to the sea these ecosystems flourished, making it a favourable place for Māori due to its providing a rich source of mahinga kai (Bray, 2018). Low lying hills were covered in beech, rimu and totara. Coastal bluffs were lined with kowhai, totara, cabbage trees and ngaio. Coastal marshlands and saline estuaries flourished with flax, sedge, ribbonwood and mingimingi. And, river corridors were supported by shrubs, flaxes and toetoe (Hickford, 2012).

Although much of it has been lost, much of the Estuary has surprisingly been spared, with the Waimea Estuary made up of ten major habitat types: Mobile, sand, fine sand, eelgrass, mudflat, high shore flat, sarcpcprnia, pebble and cobble, native rush and sedge, spartina, and subtidal (Hickford, 2012; Robert J Davidson, 1990)

Much of what exists now beyond the Waimea Estuary has been removed and replaced with a mix of both exotic and native species. Rabbit Island is now almost completely covered in pine trees (Figure 58).

Figure 58: Images of pine trees on Rabbit Island (Hubert, 2022b)

Dunes

Dunes can be found in Māpua along the coastline beyond where the sea walls are along the Tasman Sea (Figure 59). These dune provide some protection from coastal erosion for residential infrastructure along the coastline.

Figure 59: Images of fragmented dunes along the coast line in Māpua (Hubert, 2022b)

Rain Gardens

Rain gardens are a Nature Based Solution (NBS) for mitigating storm runoff and flooding in urban spaces. They are often used to capture the 'first flush' of rainfall, acting as a buffer to temporarily hold water (Kasprzyk et al., 2022; Zhang et al., 2020).

It was confirmed during a site visit to the Māpua Wharf that some rain gardens had been implemented as part of the Masterplan redesign of the Māpua Waterfront Park by Canopy Landscape Architects (Figure 60). The location of these can be found in Figure 61.

Figure 60: Images of existing rain gardens in Māpua (Hubert, 2022b)

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Figure 61: Map showing the location of exisiting rain gardens in Māpua [adapted] (Land Information New Zealand, n.a.)

There are opportunities to expand this across all urban areas in Māpua.

Wetlands

Wetlands play an important role in mitigating flooding in coastal zones, as well as supporting shorelines and rivers edge (Ministry for the Environment, 2021). Despite their crucial role in providing flood control and various social, cultural and economic ecosystem service, 90% of wetlands have been lost since European settlement in Aotearoa New Zealand (Clarkson et al., 2013; Ministry for the Environment, December 2017).

There has been a considerable loss of wetlands in the Tasman region as shown in Figure 49 when compared to Figure 62 below.

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Figure 62: Map showing existing wetlands in the Tasman Region (Landcare Research, 2018)

Despite this, the Nelson/Tasman region still boasts six considerable wetlands, of which the Waimea Delta Wetland and Waimea Inlet play a role in flood mitigation for Māpua township. Their locations can be found in Figure 63.

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Figure 63: Location of the Waimea Delta Wetland and Waimea Inlet (Land Information New Zealand, n.a.)

The Waimea Delta Wetland is located at the end of the Waimea River where the fresh water from the river, and the saline water from the Waimea Inlet meet. This is a recent development in 2022, named the ‘Waimea Delta Wetland Enhancement Project’ where paddock land is now being reverted back to its original intent.

For more information on the Waimea Inlet and its flood mitigation functions see sections *4.5.2.8.1 Riparian Vegetation* and *4.5.2.8.2 Coastal Vegetation*

Sea Walls

Sea walls are a hard infrastructure intervention. These have been implemented in Māpua, especially along the coast along the Tasman Sea as this area is vulnerable to high rates of erosion (Figure 64). Because of this, it continuously needs attention.

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Figure 64: Map showing existing areas in Māpua where there are sea walls (Land Information New Zealand, n.a.)

Alongside the large engineered sea walls there are also small fragmented sea walls, as well as man-made concrete sea walls along the edge of Māpua. This is evident through concrete retaining walls around the wharf and water front where there is public access to the coast line (Figure 65).


Figure 65: Images showing smaller engineered sea walls along the coastline of Māpua (Hubert, 2022b)

Flood gates and stop banks

For flooding it is important to not only look at what is happening at the local scale, but also the regional scale as the interventions, or lack of interventions at the catchment scale will have flow on effects at the local scale. As noted in Figure 66 there have been a series of stop banks within the Waimea Estuary. There are approximately thirty of these which are maintained as river assets as part of the stop bank scheme in the Waimea River, of which one is a flood gate (or tide gate) at Pearl Creek in the Waimea (Tasman District Council, 2015)

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Figure 66: Map showing stop banks/bunds within the Waimea Inlet (Land Information New Zealand, n.a.)

Alongside the stop banks found within the inlet, there are a series of undocumented stop banks as part of the Waimea River Park in the Waimea Plains (Figure 67). These were implemented in the 1960's to mitigate the impacts of flooding. As a result, the Waimea River has been artificially straightened and the land upstream has been intensely forested commercially, thus increasing the flow of water and the frequency of flooding within the catchment (Tasman District Council, 2015). The stop banks are approximately 250 to 1150m apart along the length of the park (Tasman District Council, 2015).

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Figure 67: Extent of the Waimea River Park (Tasman District Council, 2015)

7.2 To what extent does Māpua meet best practice flood mitigation design guidelines?

The biophysical and land-use characteristics of Māpua create the perfect situation for coastal erosion and inundation, thus increasing the town's vulnerability to climate change-induced flooding. According to the inventory, sea level rise will greatly impact the main commercial wharf area in Māpua, as well as residential properties surrounding the coastline. As much of Māpua township is primarily low lying, the ground water levels are significantly high. In the event of high rainfall, Māpua poses a greater risk of flooding as ground water levels increase, increasing the risk of flooding and inundation.

The main river system feeding water into the Waimea Inlet is the Waimea river, as much of the land surrounding the river is used for agricultural and horticultural purposes, much of the riparian planting along the river's edge has been lost. As a result, the natural buffer along the edge to slow down water has been removed – increasing Māpua's vulnerability to flooding. Existing green and grey infrastructure interventions are sparse at both a local and regional scale, thus providing opportunities to increase flood protection through improved design guidelines

The proposed guidelines should provide flood mitigation to Māpua at the local scale (e.g, bioretention systems, permeable surfaces, wetlands, adaptable buildings, etc), and regional scale (e.g, Riparian buffers, coastal vegetation, dune restoration, stop banks, etc). Alongside this, there are opportunities to re-zone at-risk housing and commercial areas through various zoning interventions (e.g, managed retreat, conservation easements, land acquisitions, etc).

7.3 How the guidelines can be applied to protect a small coastal community in New Zealand?

This section will apply the improved design guidelines to the chosen case study site, Māpua. The application of the guideline has been implemented based on Mikayla Hubert's (2022a) Major Design project at Lincoln University, *Māpua: Welcoming the Tides – Designing for Dynamic Landscapes* (Appendix A).

7.3.1 Applying the guidelines

Māpua, New Zealand is the chosen case study site for this research. The proposed design guidelines (Chapter 6) will be applied to the site at both a regional and masterplan scale. This is because many of the guideline interventions need to be applied at the catchment scale

Regional Scale

The following design guidelines have been implemented at a regional scale. Wetlands; riparian vegetation; coastal vegetation; dune restoration; stop banks/bunds, and zoning. These are highlighted green in Table 10.

Table 10: Regional scale design guidelines

Strategy	Intervention type	Design guideline
Protect	Green infrastructure	1. Bioretention systems
		2. Minimise impervious surfaces
		3. Wetlands
		4. Detention and attenuation
		5. Riparian vegetation
		6. Coastal vegetation
		7. Dune restoration
	Grey infrastructure	8. Flood proofing existing infrastructure
		9. Stop banks/bunds
		10. Armouring
Accommodate	Adaptable infrastructure/dwellings	11. Adaptable infrastructure/dwellings (Elevated housing, flood proof housing, amphibious/floating housing)

Retreat	Zoning	12. Zoning (Acquisition, managed retreat, conservation easements etc)

Figure 68 demonstrates the key land-use characteristics of the Tasman region before applying the improved design guidelines. Figure 69 shows the application of the design guidelines in the Tasman region, which can also be found in Appendix B and C.

Historic wetlands, highlighted in Figure 49, will be revegetated and returned to their natural state. Riparian margins along the river corridor will be revegetated, especially along the Waimea River that directly feeds water from the mountains into the Waimea Estuary. The application of this guideline is shown in Figure 70. Coastal vegetation within the Waimea estuary will be revegetated as a nature-based response to mitigate the effects of coastal flooding by absorbing wave energy from storm surges (Figure 71).

Dune restoration has been implemented along the coastline nearest to the Tasman Sea, as well as on Rabbit Island along the coastline. Managed retreat of high-risk housing and infrastructure around the coastline will occur. The location where they will be retreated to is shown in Figure 73. The use of zoning will encourage more conservation land and the softening of edges on Rabbit Island. Existing stop banks and bunds will remain along the Waimea River as part of the Waimea River Park.

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Figure 68: Tasman region before applying the design guidelines

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Figure 69: Tasman region after applying the design guidelines

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Figure 70: Riparian buffers before and after applying the design guidelines in the Tasman region

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Figure 71: Coastal vegetation before and after applying the design guidelines in the Tasman region

Masterplan and Intermediate scale

The following design guidelines have been implemented at a Masterplan and intermediate scale , 1) Riparian vegetation, 2) coastal vegetation, 3) wetlands, 4) dunes, 4) stop banks/bunds, 5) flood gates, 6) armouring, and 7) Zoning. The cells which are highlighted green and orange in Table 10 are applied at the Masterplan scale (Figure 73), whereas the cells highlighted in orange were only applied at the intermediate scale (Figure 75).

Table 11: Master plan and intermediate plan design guidelines

Strategy	Intervention type	Design guideline
Protect	Green infrastructure	1. Bioretention systems
		2. Minimise impervious surfaces
		3. Wetlands
		4. Detention and attenuation
		5. Riparian vegetation
		6. Coastal vegetation
		7. Dune restoration
	Grey infrastructure	8. Flood proofing existing infrastructure
		9. Stop banks/bunds
		10. Armouring
Accommodate	Adaptable infrastructure/dwellings	11. Adaptable infrastructure/dwellings (Elevated housing, flood proof housing, amphibious/floating housing)
Retreat	Zoning	12. Zoning (Acquisition, managed retreat, conservation easements etc)

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Figure 72: Master Plan of Māpua before applying the design guidelines

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Figure 73: Master Plan of Māpua after applying the design guidelines

Figure 72 is demonstrating the land-use characteristics of Māpua before applying the best practice flood mitigation design guidelines. Figure 73 is demonstrating how the design guidelines would be applied to Māpua. Historic wetlands as outlined in Figure 49 will be restored. Riparian vegetation will be revegetated along river margins which lead out to the sea. Existing riparian buffers will be extended to at least 10 metres to ensure flood mitigation benefits.

Coastal vegetation within the Waimea Estuary will be revegetated to absorb wave energy and coastal erosion along the coastline. Dune restoration will be implemented where there were previously hard protection measures (sea walls) to soften the shoreline (Figure 74). At-risk land will be converted to conservation land through native planting, wetlands for increased water storage.

Figure 72 and 73 can be found in Appendix D and E.

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Figure 74: Dune restoration in Māpua before and after applying the design guidelines

Figure 75 is demonstrating the land-use characteristics of an urban area in Māpua prior to applying the best practice flood mitigation design guidelines. Figure 76 demonstrates how the best practice flood mitigation design guidelines could be applied to an urban area in Māpua.

Riparian margins will be widened, hard surfaces will be reduced and replaced with permeable surfaces where there is pedestrian access and parking. More rain gardens will be implemented along pathways and in areas where there is large asphalt surfaces. A detention basin will be implemented to provide both increased water storage and stormwater management in urban spaces.

Managed retreat of highly vulnerable areas as highlighted in Figure 69, 72 and 75 will be retreated to higher grounds as demonstrated in Figure 73. This will be reverted to conservation land to soften the edges around the coastline and protect existing housing at low elevation which are set-back from the shoreline. Buildings which remain in these urban areas will be raised to accommodate to sea level rise and flooding in the township.

To scale maps of Figure 75 and 76 can be found in Appendix F and G

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Figure 75: Intermediate plan of an urban area in Māpua before applying the design guidelines

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Figure 76: Intermediate plan of an urban area in Māpua before applying the design guidelines

7.4 Summary

According the inventory and analysis it is clear that Māpua is highly vulnerable to climate change induced flooding. This will only get worse as sea level rise continues to rise and the occurrence of storm events increase over time. The improved design guidelines propose solutions to these vulnerabilities through a mix of green and grey infrastructure interventions, as well as adaptable infrastructure opportunities and zoning.

This provides small New Zealand Coastal towns with the opportunity to implement a variety of interventions and a broad range of scales to effetely mitigate climate change induced flooding.

Chapter 8
Limitations of the research

This chapter will highlight the limitations of the research and research process, including the evaluation process of the design guidelines, development of the new guidelines, application of these guidelines on the case study site, Māpua, and future research for the design guidelines.

8.1 Evaluation Process

Throughout this process it was evident that there were not many design guidelines available to the public that directly related to climate-change-induced flooding. Much of what exists currently is in report form and intended for policy makers and higher government, rather than designers. This made it difficult to determine if something was worthy of being included in the evaluation process. It also made it clear that there is a need to design guidelines for (climate-change) flooding in small coastal New Zealand towns.

The evaluation process also focused only on the elements or attributes of the design guidelines and strategies that were evaluated, rather than the content itself. This criteria was also developed with the aim of developing guidelines for the restoration of eel habitats in mind. Because of this, some of the criteria may not apply to guidelines for mitigating flooding. For example, the attribute 'Flexible Outcomes (Section 5.1.3)' may not be the best indicator as there are specific guidelines that need to be applied at specific scales for intended outcomes. It was also difficult to determine whether the literature was evidence-based, as many of the documents which were analysed were government reports or guidelines and did not include in-text references.

Similarly, measurable data is hard to define in this research as many of the design guidelines for mitigating flooding are larger systems or components, such as coastal vegetation which is implemented over large areas. This is much easier to determine when a guideline is bound to technical details.

8.2 Development of the best practice flood design guidelines

The development of the best practice flood design guidelines was based on a series of suggestions, using the 'best practice Landscape Architecture design guideline criteria' and the narrative literature review process. As these improved guidelines are only suggestions, rather than the development of a completely fleshed out design guideline document, there will be gaps in the research and in the design guidelines. Therefore, it makes it difficult to evaluate the extent to which Māpua meets the best practice flood design guidelines criteria.

8.3 Application of the best practice flood design guidelines to Māpua

The application of the improved design guidelines was implemented through an inventory and analysis process of existing biophysical and land-use characteristics. Then applied to the site at three different scales.

Although the research suggests that the design guidelines will mitigate flooding, it is difficult to determine whether they are effective as they have not been tested in real-time. It is also unclear on how viable the application of these design guidelines is as much of it relies upon local government to implement it which would cost a lot of money.

8.4 Future Research Opportunities

This research could be further developed by establishing an evaluation process for evaluating the effectiveness of guidelines in protecting small coastal towns in New Zealand. Through this evaluation process, a set of improved design guidelines could be developed, rather than just suggestions based on research. The design guidelines could also be much more specific to a particular scale, rather than generic titles such as 'bioretention systems. As this was beyond the scope of my study, I was not able to flesh out each design guideline completely. Therefore, the application of the design guidelines on the case study can be improve with further research in this area of study.

Chapter 9

Conclusion

This dissertation highlights that flooding is one of New Zealand's most costly natural hazards, affecting both people's livelihoods and the environment. With sea levels continuing to rise, the impact of flooding will only worsen. While strategies and guidelines to mitigate coastal flooding and hazards do exist, they are primarily designed for implementation in larger cities rather than small towns.

The evaluation process revealed that existing guidelines or reports do not effectively address all of the criteria outlined in the *'best Landscape Architecture design guideline criteria'* evaluation. This gap in current research underscores the need for effective design guidelines to protect small New Zealand coastal communities from climate change-induced flooding.

Based on the results of the research, a set of suggestions for improving existing design guidelines was developed. An inventory and analysis of a case study site, Māpua, highlighted common vulnerabilities found within small coastal communities in Aotearoa New Zealand. The developed best practice flooding guidelines were then applied to the site to demonstrate how they can effectively protect small New Zealand coastal towns. These improved guidelines demonstrate how interventions can be applied not only at a local scale but also at a regional scale to provide protection at a catchment scale, rather than localised.

This study could be further researched to develop complete design guidelines that fully address all of the criteria outlined in the design guidelines criteria evaluation. Additionally, a more accurate method of evaluating existing guidelines could be developed to better align with the scope of this study

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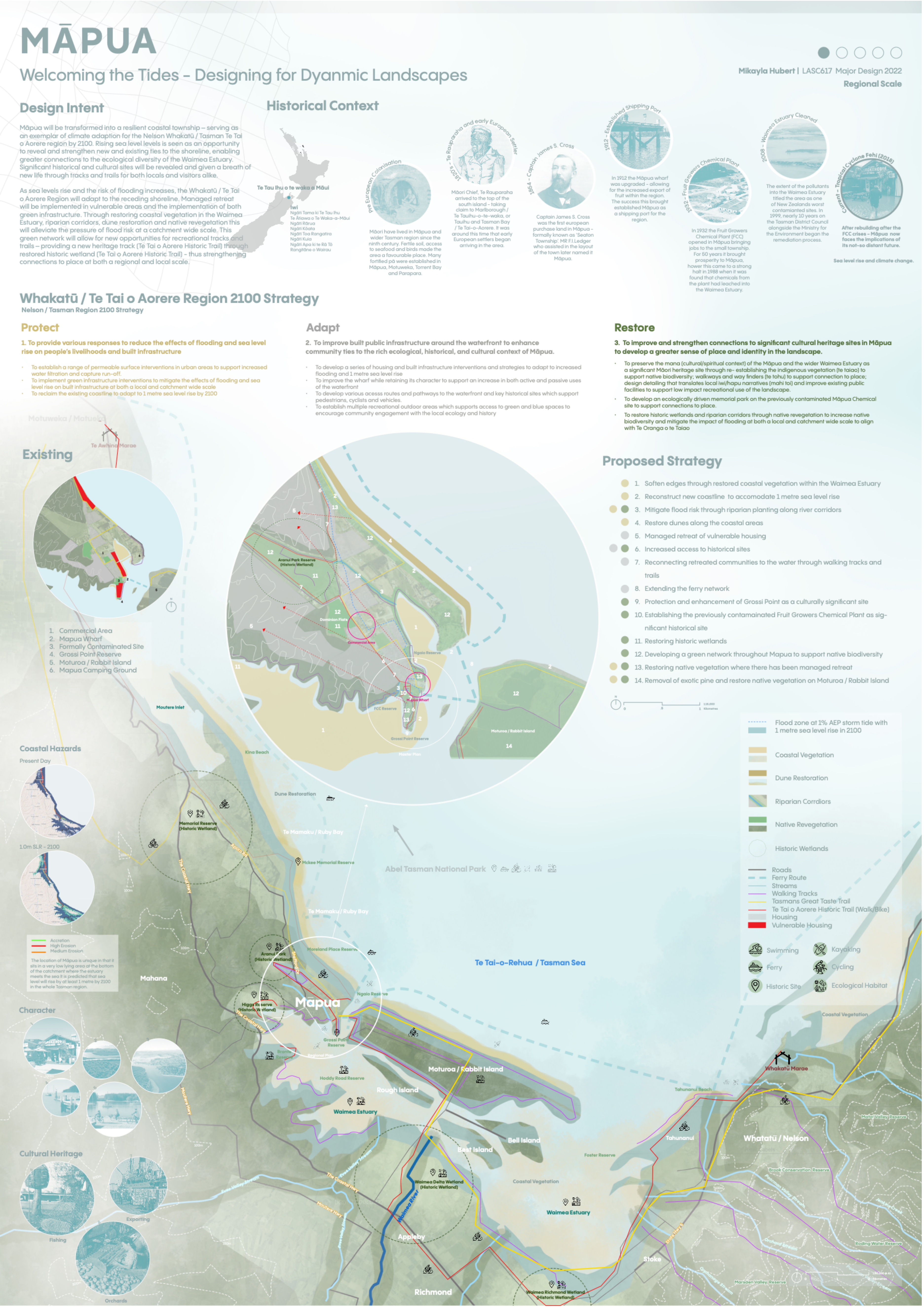
Appendix A

Māpua: Welcoming the Tides – Designing for Dynamic Landscapes



MĀPUA

Welcoming the Tides - Designing for Dyanmic Landscapes

Mikayla Hubert | LASC617 Major Design 2022

Master Plan Scale

Design Intent

The spit of Māpua will serve as a biodiverse coastal landscape and beach where native flora and fauna flourishes and the natural ebs and flow of the sea is embraced. Significant historical and cultural areas will be revealed and given a breath of new life through trails, way finders, sculptural elements and incredible 180° views of the surrounding mountains.

It will be a place where effects of natural hazards are reduced; the rich coastal ecology is bountiful; recreational ties to the shoreline are nourished and a sense of place is grounded in the landscape.

Key Areas

Retreated Shoreline

The retreated shoreline at the most north end of the site welcomes rising sea levels. Homes that were previously there have been retreated to higher ground. Softened edges promotes access to small beaches and a remote island. Walkways along the shoreline accomodate active uses of the space.

Commerical Bay

Commercial bay is a climate resilient shopping and hospitality hub which will accomodate an increase in users over the next 50 years. Raised buildings, increased vegetation, detention basins, rain gardens and open green spaces will act as a mitigator as storm frequency and intensity increases.

Māpua Wharf

The Māpua wharf will be the main point of contact to the sea for both local and visitors from afar. Key features include various lookouts, tidal shelves, multi-use park space, museum, market and jetty. Recreational uses such as swimming, walking, biking, kayaking, paddle boarding and taking the ferry to Rabbit Island. Flood resiliecy will be boasted through raised buildings, coastal vegetation, green spaces, rain gardens and detention basins.

Flood Park

Waterfront park a multi-use space that once host the Fruit Growers Chemical Plant. Bike tracks and walking trails nestle throughout coastal estuaries, native flora and fauna, which now serve as a restorative gesture to the once poisened environment. This area features as a multi-use outdoor area. Resting spots, shade and overhead bridges promotes both active and passive uses of this space.

Grossi Point

Grossi Point is an extremely important site in Mapua. Once a fortified pā and resource for mahinga kai for early māori - it boasts key views of the surrounding mountains, small beachs, native vegetation, tracks and trails, resting spots and an important habitat for the bartailed godwit.

Site Users

The Local

The local is someone who frequently uses the site. They love the water and all the recreational benefits that come with it. They enjoy walking down to their local coffee shop in the early morning before they head off and walk their dog around the coastal boardwalk.

The Family

The family are either a local or tourist. They love all of the family freindly activities in Māpua such as the museum and easy walking tracks around the coastline and in Floodpark. They love that Māpua is embracing Māori history as it is teaching children important history.

The Tourist

The tourist is drawn to Māpua for its rich ecology, biodiversity and various recreational activities. They spend the weekend here learning about Māpua, going shopping, eating at various restaurants and relaxing on the beach. They love using the Te Tai o Aorere Historic Trail to learn more about the history of the region.

The Adventurer

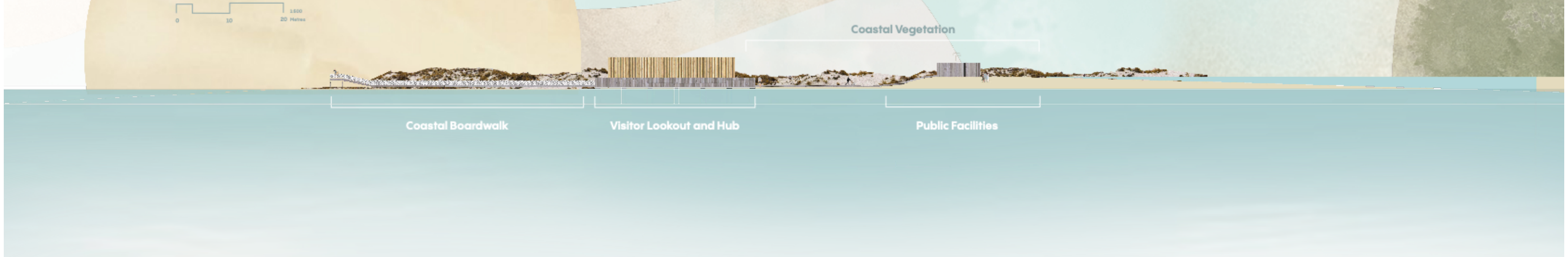
The adventurer comes to Māpua to enjoy the vast array of recreational activities that this small township has to offer. They enjoy mountain biking, walking, running and fishing off the wharf. They often take the ferry across the rabbit island, Māpua Reserve and to Ruby Bay.

The Thinker

The thinker uses Māpua at a living laboratory. They love coming here for the seasonal migation of bartailed godwits, learning about Māori history, looking out to the moutains from viewpoints and admiring the vast array of native flora and fauna.

Section A-A' 1:500

This section is illustrating the waters edge to waters edge at Grossi Point - the end of the spit in Māpua. What was ince a gravel carpark, Grossi Point Reserve has been tranformed - boasting indigenous biodiversity, walkways and recreational areas.



MĀPUA

Welcoming the Tides - Designing for Dyanmic Landscapes

Mikayla Hubert | LASC617 Major Design 2022

Intermediate Scale

Design Intent

As sea levels rise, the main wharf area in Māpua will allow for the tides to come in through the newly retreated and reconstructed shoreline – a natural process that will occur under climate change and 1 metre sea level rise.

What was once an area hardened at the edge, now boasts open green spaces and revegetated edges. Water is encouraged on the site through a series of rain gardens, detention basins and permeable surfaces. Views of the surrounding estuary are uncovered by various view ports around the site. A new ferry route, walking tracks and cycling trails allows for a less car-dependant destination. And, a new museum places Māpua on the map as a key point of outreach on educating visitors on the rich history of the region.

Green Infrastructure

Much of the hard surfaces in Māpua have been replaced with permeable surface interventions to prepare the small coastal township for increased flood and storm events. Green infrastructure has been implemented across the site through coastal vegetation, rain gardens, detentions basins and increased open green space. These interventions serve as practical solution to increased water on site, as well as providing aesthetic value and additional node to the green spine.

Waterfront Trail

The waterfront trail connects people coming off the ferry along the Tasman region to continue their site seeing by foot or by bike along the coastline. The waterfront trail connects people to the existing Tasman Great Taste Trail and the newly implemented te Tai o Aoerere Historic Trail.

Māpua Wharf Realigned

By extending and realigning the wharf with Aranui Road it creates a direct link and entrance for users coming to the site. Alongside this, it allows for an increase of users over an extended period. From here users are invited to catch the Ferry to Moutere Rabbit Island or jump off the jetty to the Ngaio Reserve where the Māpua Camping Grounds once was.

Entrance to Coastal Walkway

Alongside the Wharf, the entrance to the coastal walkway serves as an education point and key access point for people wanting to walk within the flourishing coastal vegetation in the Waimea Estuary.

Protect **Adapt** **Restore**

1. Commercial Area (Raised Buildings)
2. Museum
3. Market
4. Carpark
5. Shared Road (Pedestrian/Bike/Cars)
6. Coastal Track
7. Bike lane
8. Māpua Wharf
9. Access to Water (Ramps)
10. Tidal Shelves
11. Apple Orchard
12. Coastal Vegetation Mounds
13. Public Facilities
14. Detention Basin Garden
15. Ngaio Tree
16. Look Outs
17. Coastal Dune Vegetation
18. Low Lying Coastal Vegetation
19. Open Green Space
20. Native Revegetation
21. Rain Gardens / Swales

+ 0.00 Proposed Spot height
Current Shoreline
Contours
High Tide
Low Tide
1% AEP Flood Event
Exisiting Buildings
New Buildings
Residential Buildings

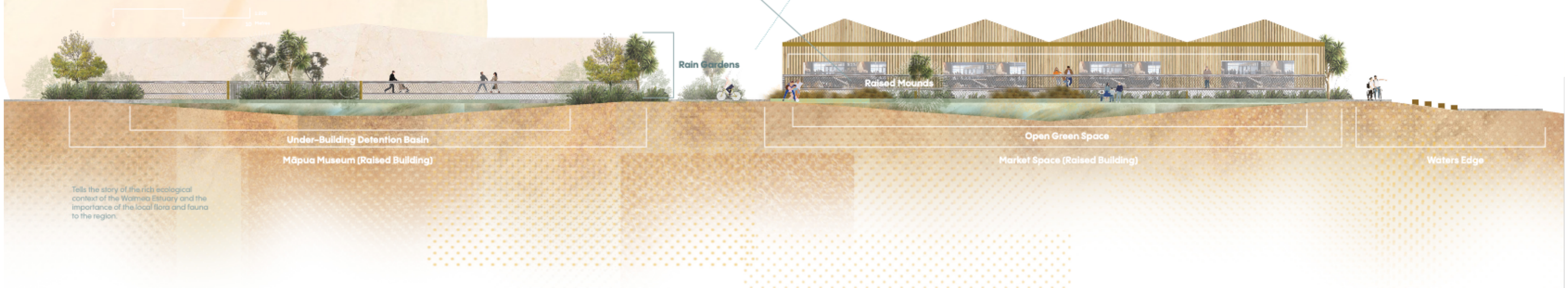
Local Tarakohe Limestone

Repurposed Timber from retreated homes

Section A–A' 1:200

This section is illustrating the cross connection from land to water's edge, whilst showing raised building intervention and future opportunities for water storage in the event of future flooding and storms at 1 metre sea level rise.

Māpua will welcome a new museum – pronouncing its self as a key touch point in educating and reconnecting people with the history of the Nelson Whakatū / Tasman Te Tai o Aorere region. An open-air market by the water front will allow Māpua to re-establish itself as a trading port – grounded in both its European and Māori history.



MĀPUA

Welcoming the Tides – Designing for Dyanmic Landscapes

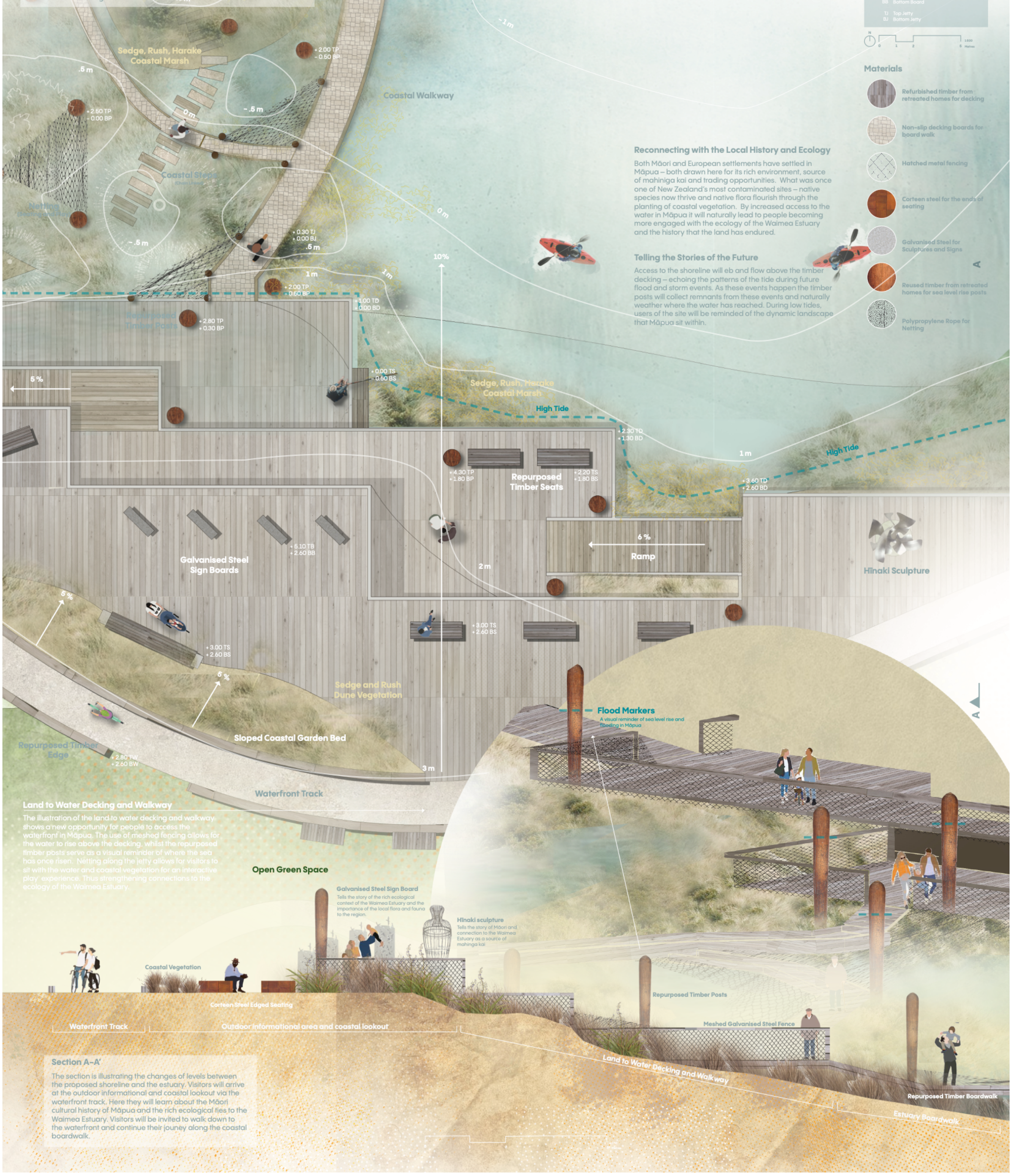
Mikayla Hubert | LASC617 Major Design 2022

Detail Design

Design Intent

The entrance to the coastal walkway will function as one of the key areas for visitors to Māpua to access the Waimea Estuary. The purpose of this area is to educate and connect both locals and visitors to the local history and ecology of Māpua. Access to the site is welcomed via the coastal track by foot or cycling. From here users will have access to 180 views of the Waimea Estuary and a coastal walkway along the reclaimed shoreline. Users will be surrounded by revegetated coastal vegetation that will both protects and nourishes the native ecology of the area.

The tiered timber decking sits within the dense coastal vegetation within the newly reclaimed shoreline. Users are first met with signboards which speak to the local ecology and Māori history of Māpua. As they move down the decking, they are met with repurposed timber posts covered in roped netting. As the tides naturally move up and down, the posts will record where the water has once reached – serving as a visual reminder of rising tides.



Contours (1m / .5m)
Low Tide
High Tide
Cross Falls
+0.00 Proposed Spotheights
TD Top Decking
BD Bottom Decking
TS Top Seat
BS Bottom Seat
TP Top Post
BP Bottom Post
TB Top Board
BB Bottom Board
TJ Top Jetty
BJ Bottom Jetty

Materials

- Refurbished timber from retreated homes for decking
- Non-slip decking boards for board walk
- Hatched metal fencing
- Corteen steel for the ends of seating
- Galvanised Steel for Sculptures and Signs
- Reused timber from retreated homes for sea level rise posts
- Polypropylene Rope for Netting

Reconnecting with the Local History and Ecology

Both Māori and European settlements have settled in Māpua – both drawn here for its rich environment, source of mahinga kai and trading opportunities. What was once one of New Zealand's most contaminated sites – native species now thrive and native flora flourish through the planting of coastal vegetation. By increased access to the water in Māpua it will naturally lead to people becoming more engaged with the ecology of the Waimea Estuary and the history that the land has endured.

Telling the Stories of the Future

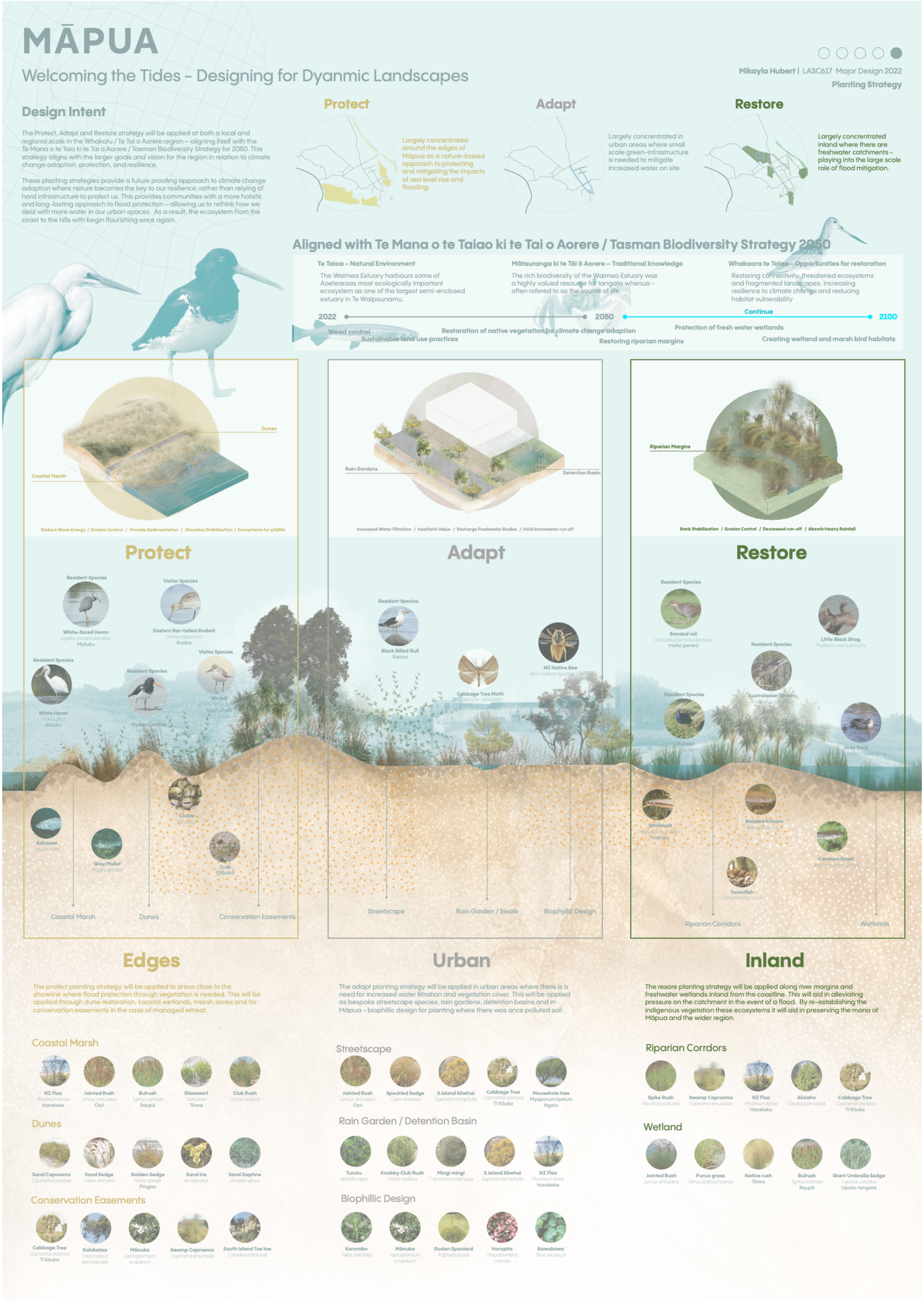
Access to the shoreline will eb and flow above the timber decking – echoing the patterns of the tide during future flood and storm events. As these events happen the timber posts will collect remnants from these events and naturally weather where the water has reached. During low tides, users of the site will be reminded of the dynamic landscape that Māpua sit within.

Land to Water Decking and Walkway

The illustration of the land to water decking and walkway shows a new opportunity for people to access the waterfront in Māpua. The use of meshed fencing allows for the water to rise above the decking, whilst the repurposed timber posts serve as a visual reminder of where the sea has once risen. Netting along the jetty allows for visitors to sit with the water and coastal vegetation for an interactive 'play' experience. Thus strengthening connections to the ecology of the Waimea Estuary.

Section A–A'

The section is illustrating the changes of levels between the proposed shoreline and the estuary. Visitors will arrive at the outdoor informational and coastal lookout via the waterfront track. Here they will learn about the Māori cultural history of Māpua and the rich ecological ties to the Waimea Estuary. Visitors will be invited to walk down to the waterfront and continue their journey along the coastal boardwalk.



MĀPUA
Welcoming the Tides - Designing for Dyanmic Landscapes
Mikayla Hubert | LASC617 Major Design 2022
Planting Strategy
Design Intent
The Protect, Adapt and Restore strategy will be applied at both a local and regional scale in the Whakatu / Te Tai o Aorere region – aligning itself with the Te Mana o te Taio ki te Tai o Aorere / Tasman Biodiversity Strategy for 2050. This strategy aligns with the larger goals and vision for the region in relation to climate change adaption, protection, and resilience.
These planting strategies provide a future proofing approach to climate change adaption where nature becomes the key to our resilience, rather than relying of hard infrastructure to protect us. This provides communities with a more holistic and long-lasting approach to flood protection – allowing us to rethink how we deal with more water in our urban spaces. As a result, the ecosystem from the coast to the hills with begin flourishing once again.
Protect
Largely concentrated around the edges of Māpua as a nature-based approach to protecting and mitigating the impacts of sea level rise and flooding.
Adapt
Largely concrentrated in urban areas where small scale green-infrastructure is needed to mitigate increased water on site.
Restore
Largely concrentrated inland where there are freshwater catchments - playing into the large scale role of flood mitigation.
Aligned with Te Mana o te Taiao ki te Tai o Aorere / Tasman Biodiversity Strategy 2050
Te Taioa – Natural Environment
The Waimea Estuary harbours some of Aoetearoas most ecologically important ecosystem as one of the largest semi-enclosed estuary in Te Waipounamu.
Mātauranga ki te Tāi ō Aorere – Traditional knowledge
The rich biodiversity of the Waimea Estuary was a highly valued resource for tangata whenua - often refered to as the source of life.
Whakaora te Taiao – Opportunities for restoration
Restoring connectivity, threatened ecosystems and fragmented landscapes. Increasing resilience to climate change and reducing habitat vulnerability
2022
2050
Continue
2100
Weed control
Sustainable land use practices
Restoration of native vegetation for climate change adaption
Restoring riparian margins
Protection of fresh water wetlands
Creating wetland and marsh bird habitats
Dunes
Coastal Marsh
Reduce Wave Energy / Erosion Control / Provide Sedimentation / Shoreline Stabilisation / Ecosystems for wildlife
Rain Gardens
Detention Basin
Increased Water Filtration / Aesthetic Value / Recharge Freshwater Bodies / Hold Stormwater run off
Riparian Margins
Bank Stabilisation / Erosion Control / Decreased run-off / Absorb Heavy Rainfall
Protect
Adapt
Restore
Resident Species
White-faced Heron
Matuku
Visitor Species
Eastern Bar-tailed Godwit
Kuaka
White Heron
Kōtuku
Oyster Catcher
Wrybill
Black Billed Gull
Karoro
NZ Native Bee
Cabbage Tree Moth
Banded rail
moho pererū
Little Black Shag
Australasian Bittern
Pukeko
Grey Duck
Kahawai
Grey Mullet
Cockle
Crab
Pāpaka
Whitebait
Banded Kōkopu
Common Smelt
Torentfish
Coastal Marsh
Dunes
Conservation Easements
Streetscape
Rain Garden / Swale
Biophyllic Design
Riparian Corridors
Wetlands
Edges
The protect planting strategy will be applied to areas close to the shoreline where flood protection through vegetation is needed. This will be applied through dune restoration, coastal wetlands, marsh zones and for conservation easements in the case of managed retreat.
Urban
The adapt planting strategy will be applied in urban areas where there is a need for increased water filtration and vegetation cover. This will be applied as bespoke streetscape species, rain gardens, detention basins and in Māpua - biophillic design for planting where there was once polluted soil.
Inland
The resore planting strategy will be applied along river margins and freshwater wetlands inland from the coastline. This will aid in alleviating pressure on the catchment in the event of a flood. By re-establishing the indigenous vegetation these ecosystems it will aid in preserving the mana of Māpua and the wider region.
Coastal Marsh
NZ Flax
Phormium tenax
Harakeke
Jointed Rush
Juncus articulatus
Oioi
Bulrush
Typha orientalis
Raupō
Glasswort
Salicornia
Tōrea
Club Rush
Ficinia nodosa
Dunes
Sand Caprosma
Coprosma acerosa
Sand Sedge
Carex arenaria
Golden Sedge
Ficinia spiralis
Pingao
Sand Iris
Iris arenaria
Sand Daphne
Pimelea villosa
Conservation Easements
Cabbage Tree
Coprosma acerosa
Tī Kōuka
Kahikatea
Dacrycarpus dacrydioides
Mānuka
Leptospermum scoparium
Swamp Caprosma
Coprosma tenuicaulis
South Island Toe toe
Cortaderia Richardii
Streetscape
Jointed Rush
Juncus articulatus
Oioi
Speckled Sedge
Carex testacea
S.island Kōwhai
Sophora microphylla
Cabbage Tree
Coprosma acerosa
Tī Kōuka
Mousehole tree
Myoporum laetum
Ngaio
Rain Garden / Detention Basin
Turutu
dianella nigra
Knobby Club Rush
Ficinia nodosa
Mingi mingi
Coprosma propinqua
S.island Kōwhai
Sophora microphylla
NZ Flax
Phormium tenax
Harakeke
Biophillic Design
Koromiko
hebe salicifolia
Mānuka
Leptospermum scoparium
Goden Spaniard
Aciphylla aurea
Horopito
Pseudowintera colorata
Kawakawa
Piper excelsum
Riparian Corrdors
Spike Rush
Eleocharis palustris
Swamp Caprosma
Coprosma tenuicaulis
NZ Flax
Phormium tenax
Harakeke
Akiraho
Olearia paniculata
Cabbage Tree
Coprosma acerosa
Tī Kōuka
Wetland
Jointed Rush
Juncus articulatus
Purua grass
Genus Bolboschoenus
Native rush
Tōrea
Bulrush
Typha orientalis
Raupō
Giant Umbrella Sedge
Cyperus ustulatus
Upoko tangata

Appendix B

Tasman Region before applying the design guidelines

Material Removed due to Copyright Compliance

Appendix C

Tasman Region after applying the design guidelines

Material Removed due to Copyright Compliance

Appendix D

Masterplan of Māpua before applying the design guidelines

Material Removed due to Copyright Compliance

Appendix E

Masterplan of Māpua after applying the design guidelines

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Appendix F

Intermediate plan of Māpua before applying the design guidelines

Material Removed due to Copyright Compliance

Appendix G

Intermediate plan of Māpua after applying the design guidelines

Material Removed due to Copyright Compliance