Re-Emerging Wetlands:
Shaping Multifunctional Landscapes Through Integrated
Flood Management Strategy

By Yota Kojima

figure 1. Te Horo Beach shingle dunes

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Throughout this document are full-page images, taken over the course of my research, of Te Horo and the Kapiti Coast.

They range from pictures taken on site-visits, just passing through and from around nearby. They capture the moments in the landscape that made me want to know more about it, how it works, how it all comes together and how it all came together. It also made me think about how its all going to change.

All photographs were taken by myself.

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ABSTRACT

The Kapiti Coast is a unique cultural landscape, and while agriculturally-dominated, there are remnants of ecologically significant habitat along the coast that need to be protected.

Moving forward, there are two major impacts that impose large-scale and influential change on landscape process and biodiversity: climate change and urban development.

This compounded with current conflicts between the agricultural industry and natural water resources produces a slow release of complex issues that affect a wide range of land-uses and ecologies and negatively impact the growth and resilience of the Kapiti Coast.

Moving toward planning the future of our rural landscapes, there is a need to shift toward a more multifunctional and resilient model that not only takes into considerations our movements and actions on the landscape, but also changes that occur within the landscape itself; climate change poses to accelerate these changes and exacerbate existing problems.

Figure vii. Flowers bloom along foredunes

Figure 1. Coastal erosion of foredune

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INTRODUCTION

1.1 Problem

1.2 Research Question

1.3 Site Location

1.4 Scope of Research

1.5 Methodologies

1.6 Intention and Objectives

1.7 Thesis Structure

THE PROBLEM

Opportunity for change

The current flood management plan for the Peka-Peka to Otaki (PP2O) expressway extension calls for 'hydraulic neutrality'; which means that post-development run off peak flows are not to exceed pre-development flows for specific rainfall events, in this case, referring to a 1% Annual Exceedance Probability (AEP) or 1 in 100-year rainfall event (van Lierop, Aurecon New Zealand Ltd).

This thesis argues that this kind of approach to flood management is no longer appropriate due to the impacts of climate change on the frequency and intensity of rainfall events. Research on climate change (NIWA, 2016) states that the west coast of both the North Island and South Island are likely to experience increased frequency and intensity of rainfall events, while the east coast is likely to see a decrease in rainfall. As climate change accelerates due to global warming, what we refer to today as a 1% AEP rainfall event could become a 2% AEP (1 in 50-year) rainfall event within the next couple decades, making today's hydraulic neutrality obsolete, well within the lifetime of the new expressway.

However, there is an equal opportunity to develop a better integrated, and multifunctional flood management plan that aims to accomplish more than just 'neutrality'; rather seeking to generate a framework for future landscapes that are not only resilient to flood hazard but that also contribute to building stronger communities, habitats networks and ecologies.

This thesis will explore and develop adaptive strategies that can be used to integrate land-use, landscape processes and biodiversity initiatives to form a multifunctional flood management plan for the Mangaone Stream.

figure 1.2. Wellington Northern Corridor

CLIMATE
CHANGE

FLOOD
HAZARD

**COASTAL
LANDSCAPE**

Adaptive
Strategies

MULTIFUNCTIONAL
LANDSCAPE

figure 1.3. Research question

RESEARCH QUESTION

Can 1% AEP flood hazard mapping be used as a design tool to produce adaptive resilience strategies for flood management in coastal agricultural landscapes?

Adaptive resilience is resilience through adaptation to change. It differs from the tendency to try and prevent the change. Instead it welcomes the changes by adapting to a different set of conditions and processes. In the context of this thesis, adaptive resilience is used to indicate that it is fruitless to resist climate change and urban development in rural landscapes; that instead the most resilient method is to anticipate change, the rate of change, and the impacts of change, and then in response to develop adaptive strategies.

This thesis is largely driven by the need to address flood management in coastal landscapes, especially in agriculturally-dominated coastal landscapes. The coastal landscape is susceptible to impacts driven by both climate change and human processes, including settlement patterns, road infrastructure, culverts, and effluent runoff.

figure 1.4. New Zealand waterways

SITE LOCATION

Mangaone Stream, Te Horo

The Kapiti Coast is on the west coast of the lower North Island.

The site of the thesis is located on the Mangaone floodplain, beyond the foothills of the Tararua Ranges. The area of study is based around the small settlements of Te Horo and Te Horo Beach and along the Mangaone Stream. The design-research will be focused around the restoration of the Mangaone Stream as catalyst for the implementation of adaptive strategies for climate change and continued urban growth demands.

figure 1.5. Kapiti Coast waterways, building footprints & roads

SCOPE OF RESEARCH

Water management and flood hazard

This thesis will explore the impacts of climate change, urban development and agricultural processes on the landscape; focusing on water resource management, conservation of marine ecologies and flood hazard management. In the context of hydrological process, there are two primary climate change impacts that need to be addressed, increased precipitation and sea-level rise (NIWA, 2016). The main focus of this study is to develop adaptive strategies for addressing the increased flood hazard risk due to climate change.

The Kapiti Coast is a cultural landscape, that is expecting an increase in residential development interest along with upgrades to the Wellington northern corridor along State Highway One (SH1). This kind of urban interest puts additional development pressure on the coastal landscape, water resources and capacity to support biodiversity. This thesis aims to produce adaptive strategies that will protect and help manage our water resources, agricultural identity and facilitate future urban growth, in the face of climate change impacts and increasing need to address flood hazard risk.

Due to limitations on time and disciplinary knowledge, I have not sufficiently explored how residential developments could also address climate change impacts. I do however acknowledge that the way in which we settle the coastal landscape will also have to adapt to climate change impacts.

Figure 1.6 Te Horo town center

METHODOLOGY

Two ways of design

In order to tackle the sheer scale and scope of the landscape, I made the decision to organise the impacts of climate change and urban development through two methodological processes:

Design at varying scales: Feedback loop

1. This methodology analyses the tangible landscape, what is there now and how it currently works together. The landscape was primarily explored at two scales; large-scale and transect. More specific exploration of the small-scale environment was achieved with the help of literature-based research, site-visits and design iterations, which are elaborated in the final section of this document.

The Feedback Loop was instrumental in understanding the existing processes and focusing on the landscape itself, by isolating the analysis from the plethora of changes, impacts and externalities that were imposed on the Kapiti Coast and the transect.

Design for change: Phasing of strategies

2. This methodology is entirely focused on the process of change, and the subsequent changes that occur; change begets change. The literature review will present key readings, ideas and insight that will inform the full extents of the impacts and externalities of climate change and human impacts.

This process was instrumental in the phasing of the adaptive strategies; according to the rate of change in the landscape.

By separating the design-research into two methodologies, I was able to focus on the relationship between the impacts and the landscape processes; and the impacts and the change that it imposed, respectively.

Figure 1.7. Wild wood sorrel grows amongst fallen pine needles

Design at varying scales: Feedback Loop

The first methodology explores the cultural landscape through a three-tiers of investigation and research; with large-scale analysis of the landscape; an intermediate, design-focused transect; and a research-driven investigation of the small-scale which explores the functionality of specific landscapes through change impacts.

This methodology generates a dialogue between the three scales, each producing its own set of research and analysis parameters, creating a feedback loop of impacts and externalities that is used to test design iterations, concepts and ideas.

Through research of the cultural landscape at varying scales, I found that there is a 'feedback loop' of impacts and externalities that involve a unique range of landscape systems and landscape typologies.

figure 1.8. Three tiers of landscape investigation, each scale produces a different range of parameters for design

Design for change:

Phasing of Strategies

The second methodology explores the cultural landscape through the lens of impacts and externalities, in the context of change. Whether it be from existing landscape processes, or emerging changes, this approach aims to develop strategies to build resilience to future changes.

This methodology maps how the landscape may develop over time and react to climate change, forecasting where and how future externalities may occur in order to generate adaptive strategies.

figure 1.9 Using externalities and impacts to estimate change

Phasing of strategies according to the rate of change

"Landscapes are the expression of the interaction between the natural environment and man's activities who tries to make his environment more suitable for his living and needs. Both the natural conditions and man's needs change in time and are controlled by different but highly interactive factors" (Antrop, 1998).

The cultural landscape is a shared space between the landscape processes, human ecologies and natural ecologies. Landscape processes will continue without natural and human ecologies; and natural ecologies will continue to exist without human ecologies. However for human ecologies to exist, both a functional natural ecosystem and stable and predictable landscape processes must align according to the needs and requirements of the human population. In order to have flourishing human settlements, there must be a stable and fruitful landscape, and healthy natural ecologies that provide food and resources to support the growth of a town and support productive human processes and agricultural and urban development.

This thesis explores the impacts and subsequent externalities of change in the cultural landscape; focusing on large-scale impacts that produce a myriad of externalities, the most of which only affect a small, but nonetheless consequential, matrix of ecologies and land-uses. Over time, these small changes can reproduce and develop into a collective, large-scale problem of which its foundations are so complex and with so many small-scale variables, that it becomes very difficult to pin-point the cause(s) and develop adaptive strategies.

Therefore it is crucial that the change is anticipated and that adaptive strategies are formed at an early stage, to insure the continuous productivity and resilience of our cultural landscapes to future changes or crisis.

The phasing is a kind-of timeline of the 'change' of the adaptive strategies. The phasing of the adaptive strategies are based on milestones or markers of change impacts and externalities; for example, dissolved oxygen-levels in water dropping below habitable range due to eutrophication; shifts in low percentage AEP flood events; salinisation of freshwater ecologies; or an actual 1-in-100 year rainfall event. The adaptive strategies are developed over time, parallel in time with such climate change milestones.

The phasing is an important approach to processing how things change over time and that each change should be treated also as an formidable event on its own; these stages will represent the rate of climate change versus pace of development of the adaptive strategies. The idea is to develop the cultural landscape in line with the adaptive strategies at a pace that is faster than that of the climate change impacts; when salinisation markers become present, there will already have established an alternative habitat; when the frequency of rainfall events increase, there will be inundation and retention pools available. In this way, small changes in the landscape, whether it be to processes or entire ecologies themselves, are treated as events that could lead to significant disruption to the way we live.

INTENTION & OUTCOMES

Adaptive Strategies

This thesis aims to produce adaptive strategies that each focus on a different set of problems concerned with flood hazard management; conservation of habitat networks and biodiversity; and integration of urban infrastructure with landscape processes.

1. **Flood Hazard Management**
 - a. Sea-level rise, groundwater ponding
 - b. Increased rainfall, stream overflow flooding
2. **Conservation of habitat networks and biodiversity**
 - a. Sea-level rise, salinisation of coastal habitat
 - b. Agricultural run-off, eutrophication of water resources and stream turbidity
3. **Integration of urban infrastructure**
 - a. Roads that cross water: bridges and culverts
 - b. Setting up a framework for future residential development (riparian and coastal)

figure 1.10 Te Horo Beach, Mangaone Stream mouth

figure 1.11. Pukemanu Drain

figure 2. Seagulls fight over fish carcass, Te Horo Beach

2

LITERATURE REVIEW

2.0 Overview and Structure

2.1 Review One

- a. Climate Change Impacts
- b. Human Impacts

2.2 Review Two

- a. Ecological Land-use Complementation
- b. Multifunctional Landscapes

2.3 Review Three

- a. Habitat Networks and Biodiversity
 - b. Road Ecology
-

LITERATURE REVIEW

Overview and Structure

The literature review will outline and explain key concepts and areas of research that have not only better informed the design, but also serves as a foundation to explore how future changes may develop.

It is important to understand that some of the climate change impacts that this thesis aims to address are yet to exist in this particular cultural landscape, making the literature a key part of understanding how these changes may affect the operation of large-scale systems and the functionality of the small-scale ecologies. Therefore, this literature review may be treated as a case study review, that has formed a framework for how the adaptive strategies may be structured.

The literature is composed of case studies of how similar impacts have affected similar typologies or land-use. The literature forms a basis for certain design moves to be made based on how others have dealt with similar impacts. The strength in the research literature is that they provide a potential outcome scenarios based on different methods of dealing with a specific impact or change in the landscape. The design-research is the process of developing adaptive strategies in two ways; in response to existing conflicts in the landscape; and in response to change in the landscape.

The literature review is structured in three parts according to closely associated research topic, so that there is a clear connection between the adaptive strategies and the change that has informed them. The timeline may be used to understand the particular order that each impact and adaptive strategy was conceptualised.

RESEARCH TIMELINE

figure 2.1 chronological flow chart of key literature

Climate Change Impacts

Increased Rainfall & Sea-level Rise

Shifts in Biodiversity and Habitat

The primary driver of this thesis is to investigate the impacts of climate change and develop strategies to adapt to an evolving landscape and anticipate future conditions so that we can plan the development of a more resilient urban landscape and agricultural systems.

The key climate change impacts that have been identified for the Kapiti Coast and in particular affect the transect, are increased rainfall and sea-level rise (NIWA). Climate change also has a significant impact on biodiversity and habitat, which will be explored in part 3 of the literature review.

The sum of these two climate change impacts result in a progressively increasing frequency and intensity of high rainfall events, making extreme rainfall event much more likely in the process; within the century, what we refer to as 1-in-100-year flood events could be as common as 1-in-40-year floods (NIWA).

Additionally, sea-level rise will put an increasing pressure on the coastal groundwater level, resulting in the salinisation of freshwater ecologies and a frequency in lowland ponding and even permanent states of inundation during periods of high rainfall.

Key literature:

Ian Smith, Clive McAlpine. 2014. Estimating future changes in flood risk: Case study of the Brisbane River, Australia.

Keywords:

Climate change, flood mitigation, flood retention, overflow-flooding, biodiversity adaptation, biodiversity resilience, landscape connectivity, ecological landscape dynamics.

To understand the implications and magnitude of climate change on the cultural landscape of the Kapiti Coast, I explored ideas presented in two key readings;

1. Response to flood mitigation in waterways via upstream water retention device.
2. An overview of climate change impacts on biodiversity and habitat networks.

The research that was gathered based on climate change impacts on flood hazard and biodiversity is combined with specific rainfall projections and flood hazard risk in the Kapiti Coast region (NIWA, LAWA) to produce a refined image of the landscape systems that will be affected and the externalities that it is likely to produce. This study also highlights the need to address adaptative strategies for the conservation and management of biodiversity in the cultural landscape.

Findings towards adaptive strategies:

Flood risk due to river overflow is mitigated with the construction of a dam upstream of the floodplain. This study highlights that the dam acts as a temporary flood attenuation device, reducing the frequency of flood in an area that was historically plagued by floods during high rainfall events.

Adaptive strategies should aim to integrate systems for the conservation and management of biodiversity and habitat networks.

Human Impacts

Agricultural Processes & Urban Development

The impact that human settlements and agricultural processes have on the coastal landscape should by now be reasonably evident. A significant portion of developing adaptive strategies is to anticipate the function of the cultural landscape in the future; as a small locality in a rural landscape, there will not necessarily be a significant spike in local population or industry, making an urban development-focused adaptive strategy redundant. However, there are many lessons that can be learnt from the error or success of other urban settlements and how they have integrated or degraded the natural landscape, including habitat networks and biodiversity.

Agricultural processes make up a significant part of total human impact on the coastal landscape. Externalities of agricultural processes are major contributors to the pollution of our waterways and loss of biodiversity.

One of the basic dynamic principles of landscape ecology is the continuous interaction between structure and functioning of the landscape (Forman and Godron, 1986); understanding the affects and impact of human processes and requirements for growth on the natural landscape and existing landscape processes is the first step to an integrated and multifunctional landscape.

Key literature:

Caitlin M. Crain, et al. 2009. *Understanding and Managing Human Threats to the Coastal Marine Environment*.

Keywords:

Conservation interest, cumulative effect of multiple threats, ecosystem-based management threat management, altered salinity, eutrophication and hypoxia

Crain et al suggest that in order to assess the impact of human processes on the coastal landscape, four questions must be considered:

1. What are the human threats to the coastal landscape and what are their impacts?
2. How are these threats distributed and which are of greatest concern?
3. What is the cumulative impact from multiple human threats occurring simultaneously in coastal landscape habitats?
4. How can coastal ecosystems be best managed in light of human threats?

In applying this criterion to the Kapiti Coast and the transect, the most prominent human threat is the construction of the Peka-Peka to Otaki Expressway and Te Horo Over bridge; the ongoing construction will not only affect habitats and species, but negatively impact waterways such as the Mangaone Stream, contributing to pre-existing threats such as agricultural run-off, hypoxia and rising stream-bed due to increased turbidity from construction run-off. Despite the plethora of problems caused by the construction of the expressway, there is a lack of development into improving the health of the stream. The construction advises instead to aim for 'neutrality', where the post-construction conditions are no better or worse than the pre-construction conditions.

Findings towards adaptive strategies:

In response, this thesis suggests an approach that will improve the post-construction conditions by revolving the adaptive strategies around the restoration of the Mangaone Stream and adjacent landscapes.

Reflection and Findings

Development of strategies toward building a multifunctional landscape

Key findings and strategies in response to climate change impacts and human impacts:

1. Develop climate change resilience in the conservation and management of biodiversity and habitat networks
2. Mitigate stream overflow and flood hazard with upstream water retention devices.
3. Restoration of the Mangaone Stream and riparian landscape

At this stage of the design development I was seeking literature that supported the idea of integrating the management and mitigation of flood hazard with stream restoration and biodiversity conservation in the context of climate change and urban development.

Part 2 of the literature review explores how these findings and strategies could be further developed using ecological land-use complementation, with the aim of creating multifunctional landscapes.

figure 2.2 Iron-oxidising bacterial deposits in the sand at Te Kowhai Stream estuary

Ecological Land-use Complementation Adaptive Strategies in the Overlap of Landscape Typologies

Land-use distribution within the cultural landscape (fig 1.9) showed that there was a concentration of multiple land-uses at the overlap of landscape typologies. Unsurprisingly, the climate change impacts and human impacts—that were further explored in Part 1 of the literature review—were also clustered at the overlap of landscape typologies (fig 1.12).

Successful application of Ecological Land-use Complementation (ELC) at the overlap of landscapes typologies could assist in addressing the existing conflicts between urban, agricultural and natural landscape systems. Furthermore, the successful application of ELC should aim to achieve the strategies produced at the conclusion of Part 1; the restoration of the Mangaone Stream, flood mitigation devices and integration of a resilient biodiversity and habitat network.

Further discussed in the next chapter, ELC is a key design principle in producing multifunctional landscapes through flood management strategy.

Key literature:

Johan Colding. 2006 . 'Ecological land-use complementation' for building resilience in urban ecosystems.

Keywords:

Multifunctional landscapes, land-use, biodiversity management, climate change resilience, ecological process, landscape dynamics

Ecological Land-use Complementation (ELC) is a landscape-integration approach to creating multifunctional landscapes, which suggests that by clustering certain land-uses together, they could synergistically interact to support a far greater network of ecologies and design objectives. Colding notices the work of Dunning et al. (1992) and the four types of ecological processes when describing species range, habitat networks and biodiversity; in particular drawing on the processes of landscape (patch) complementation and supplementation.

For example, landscape complementation occurs when a species that requires two or more resources finds them in two or more habitat patches in close proximity; landscape supplementation occurs when an ideal habitat area is not large enough to support an entire species population, however by aligning with surrounding substitutable habitats, is able to provide enough resources to generate a sustainable habitat network.

While Colding suggests that ELC has a high potential for application in urban ecosystems, he does point out that there are also equal opportunities for ELC to be applied in emerging urban areas, suburban areas and throughout agricultural landscapes, i.e. Te Horo/Kapiti Coast. He continues to indicate that ELC could be used to promote a more robust cultural landscape by intertwining the needs and requirements of urban processes with natural systems, developing interdependency, whereby the success of both systems is necessary for the function of the other.

On the application of ELC in urban/suburban areas he states,

"the likelihood of many species occurring in domestic gardens is dependent on the surrounding local habitat rather than the garden habitat alone."

Suggesting that for suitable designed habitats to become successfully integrated into the existing landscape and an existing habitat network, two fundamental steps need to be considered.

1. That the designed habitat reflects the surrounding species range, and is established to function in conjunction with the existing habitat network in either a complementary or supplementary manner,
2. And that the largest possible habitat patch is maintained (in terms of area) to maximize a higher species diversity and occurrence, which affects the success of habitat diversity within the scope landscape of the transect.

Findings towards adaptive strategies:

Applying ELC principles to the transect provides a consistent framework to what land-use can be clustered together and configured in a way that produces a better network for the development of suitable habitats and biodiversity. While Colding's suggestions revolve around finding space for the conservation of biodiversity and habitat networks, could similar principles be applied to make room for flood mitigation strategies along the transect?

Multifunctional landscapes

Finding synergy between strategies to achieve more than just adaptation

When describing the aims and objectives of multifunctional landscapes Lovell states:

“The first objective is to improve landscape performance by developing designs that integrate multiple functions in the landscape... The goal in designing a multifunctional landscape is to consider ecological, production, and cultural functions within the same site; aiming for multiple targeted performance standards.”

In a nutshell, to design a multifunctional landscape is to develop a synergy between multiple functions within the same landscape, to produce something that is greater and more successful than the sum each of the individual components.

For the transect, this means developing a design that aims to integrate multiple landscape functions; such as, conservation of biodiversity; integration of habitat networks; flood mitigation and retention, in order to achieve the restoration of the Mangaone Stream. Furthermore, the restoration process should aim to achieve more than just improved water quality and riparian buffers, provoking the question of what else could the Mangaone Stream accomplish?

This chapter will explore the analysis, evaluation and development models used to produce the adaptive strategies and highlight the theoretical underpinnings for producing multifunctional landscapes, that further advance the objectives of the adaptive strategies.

Key literature:

Sarah Taylor Lovell, Douglas M Johnston. 2009. Creating Multifunctional Landscapes: how can the field of landscape ecology inform the design of the landscape?

Keywords:

Design with nature, representation models, process models, evaluation models, change models, potential landscape transformations, impact models, decision models, externalities

In developing a multifunctional landscape in the transect, the first thing to consider the impact of change. As opposed to the development model that is suggested by Lovell, this thesis comprises of creating a multifunctional landscape within a changing climate and flood hazard. Time in this case, is not a vehicle for the progression of the design, but a ticking time-bomb of devastating flood hazard (1% AEP flood) and major infrastructural development (PP2O expressway).

Therefore, there is an obligation to address the function of time and change as a component of the multifunctional landscape. The problem being that the construction of the PP2O expressway is only concerned with achieving 'neutrality' and in the same vain considers flood hazard as a static event. This kind of approach is not only irresponsible, but contradicts the principles of ELC, multifunctional landscapes and the adaptive strategies. This conflict of interests is further investigated in the final chapter 'Road Ecology' of the literature review.

The development of the adaptive strategies combines the component of time and change with the six stages of landscape inquiry. Originally developed by Steinitz (2002), process models and change models to track the transition and rate of change; representation models to analyse the existing landscape and impact models to analyse the future landscape. An externalities model is used to map the secondary effects of the change and impact models; and representation and process models are used to produce the phasing of landscape transformation models.

Findings towards adaptive strategies:

Based on Lovell's multi-scale ecosystem approach, the adaptive strategies should follow three stages in integrating the program of time and change in creating a multifunctional landscape.

1. The first step to integrating change is to identify the cause or impact; climate change casts a wide and complex range of impacts, small and large, in this case focusing on flood impacts. The large-scale mapping presented in Section 1 of this document (fig. 1.11 and 1.15) show these impacts.
2. The next stage is to record the how these changes occur, noting milestones and markers that indicate substantial changes in the landscape. Following this process is an important step in determining the rate of change for each impact. Changes such as sea-level rise will occur gradually, but definitely; urban development will occur in relatively short but intensive stages; and flood events that could happen at any time with devastating impact. The transition of time in the landscape is a key methodology, briefly explored on pages 40-43.
3. The final stage is to understand that while the cause of change may not be flexible, the severity of the impacts is relative to the resilience and preparedness of the landscape and land-use. By anticipating change and the impact of change, the adaptive strategies will aim to produce a more desirable outcome.

Land-use configurations

- a urban center pushes habitat patches to the outskirts
- b habitat patches dispersed throughout urban area, but as a result become isolated
- c natural corridor is formed, although creating an urban barrier in the process
- d natural corridor is formed, urban area becomes permeable.

figure 2.3 Examples of ecological land-use complementation (a) and (c)

- e natural corridors form at the urban edge, although still isolated from each other
- f proximity to green space enhances urban patches but isolated habitats generate low biodiversity
- g large habitat patch is generated, however urban barrier effect still remains
- h largest habitat patch is formed without urban barrier effect, green space effects maintained

Reflection and Findings

Developing adaptive strategies with uncertain and unpredictable variables

While the cause of change cannot be substantially modified, the degree of impact is relative to the resilience of the affected landscape. Developing the resilience of the transect and the Mangaone Stream at a rate that is ahead of the projected rate of climate change and stages of urban development is manageable due to the foreseeability of future changes. However, building resilience to flood events is much more difficult due to the unpredictability of the frequency and intensity of extreme rainfall events.

The most appropriate strategy is to therefore develop the adaptive strategies in line with predictable human and climate change impacts while gradually implementing a framework that builds resilience to flood hazards, in particular to stream overflow and mitigating lowland ponding.

The objective is not necessarily to be prepared for 'the big one', but rather to be more prepared than 'the last one'. Resilience to flood hazard is not a static condition, but rather a continuous adjustment of the resilience threshold for landscape change that must be integrated into a productive and multifunctional landscape.

Part 3 of the literature review will explore the ecological aspect of the adaptive strategies, giving insight to the considerations made for the conservation and restoration of biodiversity and habitat networks within the changing landscape. The final chapter of this section will address the impacts of transportation infrastructure in the context of biodiversity and habitat networks, investigating externalities such as road area effects, habitat fragmentation, and habitat loss.

figure 2.5 Residential development along parabolic dunes

Habitat Networks and Biodiversity

Integrating habitat networks and ecological processes into the urban and agricultural landscapes

The impact of climate change on biodiversity and habitat networks was a consideration from the beginning of this thesis. It was addressed that there is a need to integrate the conservation of habitat networks and adaptive biodiversity initiatives with the climate change adaptation strategies.

Here lies a unique opportunity to align the outcomes of a habitat network and biodiversity initiatives with flood hazard management (see image below). In this example, sea-level rise, flood hazard, effluent run-off and conservation of biodiversity can all addressed through the function of a wetland, establishing a habitat network while simultaneously mitigating other impacts.

Integrating habitat networks and biodiversity into the restoration of the Mangaone Stream through mitigation of external threats.

Key literature:

Nicole E. Heller, Erika S. Zavaleta. 2008. *Biodiversity management in the face of climate change: A review of 22 years of recommendations.*

Keywords:

Biodiversity management, climate change resilience, adaptation strategies, conservation, habitat networks, landscape connectivity

This paper is a review of the published literature specifically addressed at biodiversity management and adaptation in the face of climate change between 1986-2008. Heller criticises that in the past, strategies for biodiversity adaptation to climate change have been largely composed of 'general principle' guidelines that lack the specificity needed for implementation. Instead, biodiversity strategies should relate to specific, cause-and-effect models that pin-point a specific impact to a specific outcome; accordingly, adaptive strategies should have:

1. More specific, operational examples of adaptation principles that are consistent with unavoidable uncertainty about the future
2. Greater integration of social science into an endeavor that, although dominated by ecology, increasingly recommends extension beyond reserves and into human-occupied landscapes.

For example, the most frequently cited strategies fell under the general principle category, that provided a strong framework but lacked the specificity to a particular cause or impact, targeted biome(s) and geographical range:

1. Increase connectivity – planted corridors, remove barriers, locate reserves in close proximity
2. Integrate climate change into planning objectives – maintenance routines, community exercises, harvest schedules and agricultural limitations
3. Mitigate external threats – fragmentation, pollution, salinisation, habitat loss

Other less frequently cited recommendations included more detailed guidelines that proposed similar outcomes but provided 'actionable' specificity on how the adaptive strategy would function and in response to what problem:

1. **Create large ecological reserves that are connected through smaller reserves** that are distributed throughout the landscape that act as stepping stones between major habitat patches.
2. **Actively shift from resistance of climate change to resilience.** Heller states that while resistance to change can be expensive and uncertain of success to what end; "resilience on the other hand, explicitly focuses on increasing the flexibility and ability of systems to adapt and self-organize in response to change."
3. **Re-assess conservation objectives to address process rather than patterns.** In response to climate change, biodiversity conservation must focus on the process of change rather than the consequences of change; treating the change as a constantly evolving impact rather than a one-off event.

Road Ecology

Understanding the impact of transportation infrastructure on fragmentation and habitat loss

"A road can be a source of water when it runs off the road, a sink for water when it accumulates on the surface, a barrier for water when it holds back the flow on a slope, or a conduit for the flow of water when it runs down ruts in the roadway." (Forman et al, 2003)

The construction of the PP2O expressway puts the spotlight on the impact of roadways to the regional landscape. While the hydrology guidelines aim for 'neutrality'(AEE 2013), this does not have to be the case. The PP2O expressway could be a major opportunity for positive, lasting change and step in the right direction with better integration of road infrastructure with local hydrology, landscape ecologies and the cultural landscape.

Rather than condemn the use of cars and the negative impact of roads on habitat networks, Forman et al. (2003) assert that both cars and roads are a key benefits to the function of a productive city. Instead they suggest that road infrastructure should be developed to better integrate with both ecological processes, habitat networks and species range.

However, it is necessary to understand the complex relationship that roads have with their adjacent environments and how the local ecologies and species respond.

This chapter will summarise the relationship between road infrastructure, flood management, habitat networks and biodiversity; the impacts and externalities of roads ecology and its integration with the development of the adaptive strategies.

Key literature:

Niko Balkenhol and Lisette P. Waits. 2009. Molecular road ecology: exploring the potential of genetics for investigating transportation impacts on wildlife.

Keywords:

Road ecology, molecular ecology, landscape genetics, habitat fragmentation, road barrier, genetic diversity, gene flow

The fundamental requirement of integration of systems is to have a common function on which the relationship can build on; such as with integrating flood management and wetland habitats, the common functions are water flow and water retention. These characteristics can be found in the natural landscape as streams and wetlands, therefore a common relationship is formed between two systems. To better integrate the function of road infrastructure, with habitat networks and adaptive strategies, first we must grasp a more specific understanding of how roads contribute to habitat loss, road barrier effects and habitat fragmentation.

Habitat loss is the first condition of road infrastructure. Any development of the natural landscape results in immediate, temporary habitat loss. The degree of habitat loss is dependent on several factors; width of road, width of buffer, speed limit; base resilience of pre-existing habitat network, vulnerability of species, species diversity and so on.

Road barrier effects refer to the general impact of road infrastructure on habitat fragmentation and habitat loss, although the 'barrier effect' of roads can occur for different reasons according to species, season or migratory behaviour. In some cases, roads can enhance habitats for certain species, in particular small mammals and invertebrate, whereby the road barrier effect drives away predators and by default creating an ideal habitat despite being adjacent to a road. Furthermore, if the road buffer zone complements or supplements the species ideal habitat, road infrastructure can be utilised as movement corridors that are safe from predators.

Referring to the construction process of modern roads, Balkenhol notes that the road effect on habitat loss is often exaggerated, and that much of the initial habitat loss occurs during the excavation and soil compaction period, attributing the noise and pollution during the construction phase of the road to have a much larger impact than the use of the road itself.

However, for the majority of species, the road barrier effect leads to disruption of movement corridors, loss of habitat and road area effects such as noise and lighting, resulting in habitat fragmentation and increased road mortality. As explored in Part 2 with ELC landscape patches, road infrastructure can be just as harmful as a concentrated urban area without complementary or supplementary capacities. It is noted that wider roads with large volumes of high-speed traffic are more likely to have a strong adverse effect on a wider species population, as opposed to smaller, less-travelled roads.

In observing road-kill studies over a wide-range of species, Balkenhol suggests that landscapes with a higher quality habitat experience higher rates of road-kill due to species crossing the road more frequently due to the abundance of resources and shelter. However, Alexander et al. (2005) support the case that road-related mortalities have a traffic threshold; to which species will not attempt to cross, effectively bringing down road-kill rates.

In large roads such as the PP2O expressway, perhaps there is an opportunity to make available an alternative under-bridge or expanded culvert to facilitate the movement of a wider range of species.

3

REVIEW

Reflection and Findings

Implementing adaptive strategies toward generating multifunctionality

The complexity and dynamics of habitat networks and biodiversity extend far beyond the scope of this thesis, although with each parcel of information that gives insight into species range, landscape dynamics and genetic diversity, the adaptive strategies seem to grow richer in multifunctional capacity. Despite the fact, the intention of this thesis is to develop adaptive (flood management) strategies that produce a multifunctional landscape through integration of land-use and mitigation of external threats. Such threats include, habitat fragmentation, habitat loss and local species extinction, but are not the primary scope of this design-research.

The first part of the literature review explored climate change impacts and human impacts, in the context of habitat networks and biodiversity. Due to the nature of habitat and biodiversity literature, the impact study is forced to move to the smaller scale; biodiversity strategies should relate to specific, cause-and-effect models that pin-point a specific impact to a specific outcome. By focusing the body of research to a smaller and more specific impact, a more specific outcome is produced.

Moving forward, adaptive strategies should aim to fulfil objectives that are in the interest of conservation of habitat networks and adaptive biodiversity initiatives, so long as they can be integrated into the function of adaptive flood management strategy and contribute to multifunctionality in the landscape.

figure 2.6 Undergrowth of Pine forest

figure 2.7 Kapiti Island in the distance

figure 3. Geese fly over Pharazyn Reserve

3

DESIGN RESEARCH

Design statement

3.0 Overview

3.1 Site Analysis

- a. Landscape Typologies
- b. Land-use
- c. Transect

3.2 Preliminary Design

- a. Impacts and Externalities
- b. Adaptive Strategy Development

3.3 Developed Design

- a. Adaptive Strategies
-

Design Statement

The intention of this thesis is not to develop an idea into a detailed, small-scale space. It is to develop a comprehensive and detailed set of adaptive strategies that address the increase of flood hazard risk in the landscape and agricultural community of Te Horo, particularly around the Managone Stream.

From the beginning, I had no intent to make haste to develop small-scale spaces. Instead I took my time to analyse, design and research the Kapiti Coast based on findings and mapping at the large-scale. At this scale, I was able to map the landscape and survey the dune morphology, soil series, wetlands and dune lakes, streams and rivers, roads, building footprints and flood extents.

The outcome of this in-depth, large-scale analysis was that I began to understand the scale of the landscape processes and the extent to which they affect the landscape.

OVERVIEW

Design-Research Process

1. Landscape Typologies
 - Natural landscape
 - Agricultural landscape
 - Urban landscape
 - Site photo gallery
2. Land-use
 - Human landscape
 - Natural landscape
 - Flood extents
 - Partial to flood
3. Transect
 - Mangaone Stream
 - 1 in 100-year flood
 - Overflow and ponding
 - Increased rainfall
 - Sea-level rise
 - Existing externalities
 - Future externalities
4. Impacts and externalities
 - Change at varying scales
 - Flowchart of externalities
5. Adaptive strategy development
 - From foredunes to headwaters
6. Developed Design
 - Wetland Reservoir Park
 - Overflow Reserve Park
 - Drain Confluence Wetlands
 - Embankment Walkway

Landscape Typologies

The cultural landscape of the Kapiti Coast is broadly determined by a mosaic of three primary landscape typologies; the *natural landscape*, the *agricultural landscape* and the *urban landscape*. Mapping these typologies would become instrumental in the analysis at the large scale, and lead to identifying consequent sub-typologies; natural-urban; agricultural-urban; and natural-agricultural landscapes.

The natural landscape that is explored in this study refers to what remains of the landscape that despite human settlement or human processes, is able to maintain significant ecologies or the capacity to support ecologies. A key characteristic of the natural landscape is to have the capacity to support life and contribute to the ecosystem function.

The agricultural landscape is a natural landscape that has been developed to support human processes and growth, such as the conversion of wetlands to pasture. The agricultural landscape will often rely on a healthy ecosystem and climate in order to operate, with any change to these conditions, such as flood, having an adverse effect on the operation of the landscape. However, the operation of the agricultural landscape may have adverse long-term effects on the natural landscape and functioning ecologies.

The urban landscape is a natural or agricultural landscape that has been further developed to support or facilitate human settlement and habitation. It can vary in intensity as a single built residential structure to suburban development, a rural town center to an urban city center.

The extent of these landscape typologies is defined by the point of interaction with a dissimilar landscape typology. There are three types of interactions; coexistence, conflict and integration. In places of conflict, there can be resolution; where there is integration, there can be improvement; where there is coexistence, there can be symbiosis.

This thesis aims to explore the design opportunities that exist at these points of interaction to determine a multi-functional framework that supports urban growth and agricultural functionality in a natural/ecological system.

- streams
- wetlands and rivers
- dunes

TE KOWHAI STREAM

MANGAONE STREAM

OTAKI RIVER

PEKAPEKA TO OTAKI

MACKAYS TO PEKAPEKA

WAIKANAE RIVER

0 0.25 0.5 1.5 2.5 7.33 Kilometers

NATURAL LANDSCAPE

LAND-USE TYPOLOGIES

foredune and coastline

stream and rivers

wetland and dune lakes

coastal hinterland

parabolic dunes

forest and ranges

The natural landscape may be translated as the ecological landscape, broadly it encompasses any landscape that has the capacity to support life and develop functioning ecologies that can contribute to the existing ecosystem.

Water is a fundamental component of the natural landscape; as clean water is necessary to support functioning ecologies. The land-use typologies indicate the remnants of our natural ecosystem.

The map on the right shows how other land-uses have dominated the landscape, resulting in the fragmentation of significant ecologies and habitat loss. Rivers and streams are the only connections between the Tararua Ranges and the coastline.

Kapiti Coast Natural Landscape

modification of natural landscape

- no significant modification
- retained natural features

AGRICULTURAL LANDSCAPE

LAND-USE TYPOLOGIES

The agricultural landscape is the dominant landscape typology on the Kapiti Coast, the extents are only limited by nature reserves, roads and subdivisions. Even then, many households are also located agricultural land, indicating that agriculture and urban land-use can be complementary as well as supplementary.

It is also noted that the complete absence of agricultural land-use is only observed in nature reserves or in concentrated urban areas. This gives an indication on the spectrum of compatibility of the landscape typologies; how much is too much, and how much is just right?

▲ figure 3.5 Agricultural land-use

► figure 3.6 Agricultural land-coverage

Kapiti Coast Agricultural Landscape

intensity of agricultural processes

- intensive pasture and crops
- extensive pasture and crops

URBAN LANDSCAPE

LAND-USE TYPOLOGIES

coastal subdivisions

transportation infrastructure

regional town centers

rural subdivisions

rural town centers

medium density housing

The urban landscape is our contribution to the cultural landscape, but more specifically where we live. Coastal and rural subdivisions express the lesser density urban landscape, the other end of the spectrum being medium-density housing and regional town centers. Rural town centers and transportation infrastructure (hereafter: roads) are temporary spaces that we occupy over the course of a day, they are a supplementary land-use.

Despite this, roads are the backbone of human settlement and are a fundamental component in the urban landscape. Road upgrade projects such as the PP2O are make priceless contributions to the growth of urban population. However, there is always a better way to do something well.

Kapiti Coast Urban Landscape

degree of built infrastructure

- road & highway
- 40-50% site coverage
- 30-15% site coverage
- <15% site coverage

PHOTO GALLERY

a.

b.

c.

d.

e.

f.

g.

h.

i.

In the photo gallery are pictures that I took while on site-visits or just passing through on the way out of the city. They highlight the dysfunctional relationship between the the impacts of each landscape typology, such as the increasing turbidity of the Mangaone Stream, or ways in which wide-scale ponding could affect communities.

PHOTO GALLERY

j.

k.

l.

m.

n.

o.

a.	Clear stream water near State Highway 1	j.	Increasingly turbid water at another drain confluence
b.	Bridge across Mangaone Stream	k.	Turbid effluent enters Mangaone Stream at another drain confluence
c.	Indication of water pollution near drain confluence	l.	Overgrowth indicates eutrophication in Mangaone Stream
d.	Te Hapua wetland reserve, Peka-Peka	m.	Light coastal scrub along foredunes, Te Horo
e.	Small grassed embankment, Te Horo	n.	Coastal grasses along foredunes, Te Horo
f.	Planted buffer around pasture, Peka-Peka	o.	Tetragonia implexicoma grows under pines in the dune slacks, Te Horo Beach
g.	Raised house at Te Horo Beach		
h.	Ponding at Te Horo Beach		
i.	Ponding in lowland pasture		

LANDSCAPE TYPOLOGIES & LAND-USE

Land-use in the cultural landscape can be reimagined to work together, as a Venn diagram illustrating what land-use belong in similar landscape typologies, the Venn diagram indicates that many land-uses occur in the overlap of landscape typologies, as many land-uses require resources from more than one landscape typology.

At the center of this diagram are roads and streams; these land-uses at one point or another, interacted with all landscape typologies and other land-uses. This diagram illustrates the (large-scale) relationship between the Mangaone Stream and Te Horo Beach Road, and how they interact with the other land-uses.

▲ figure 3.9 Land-use typologies, overlapping landscape typologies

► figure 3.10 Cultural landscape land-use

General land-use is indicated as:

- transporation infrastructure
- urban landscape
- urban-natural
- agricultural-urban
- agricultural landscape
- natural landscape

HUMAN LANDSCAPE

The human landscape is characterised by how we have settled the landscape and indicates the relationship between dwellings, roads and property divisions lines that define the urban landscape.

Within the transect, we see concentration of dwellings at Te Horo town center and at Te Horo Beach, with several groups of rural subdivisions along the Mangaone Stream.

figure 3.11 Property lines, building footprints, road centerlines

NATURAL LANDSCAPE

The natural landscape is defined in three geographical typologies, raised foredunes and parabolic dunes; coastal flats and floodplain; and streams, rivers and wetlands.

The agricultural landscape tends to dominate the floodplain and coastal flats, however as explored on the next page, make them susceptible to groundwater ponding and overflow flooding. Notice the extent of lowland/floodplain between the Managaone Stream and the Otaki River.

figure 3.12 Foredunes, parabolic dunes, streams, rivers, wetlands

FLOOD EXTENTS

This map indicates the extent of saline intrusion (+2.0m SLR) along the coast with an overlay of the 1% AEP flood extents indicated on the KCDC web portal (fig. 3.13). Flooding is prominent in coastal lowland, floodplains and along stream, rivers and wetlands.

figure 3.13 1% AEP flood extents (KCDC)

PARTIAL TO FLOOD

An analysis of soil series along the Kapiti Coast indicate three main types; coastal and alluvial sand (yellow), former wetlands and forest (blue); and pre-Pleistocene era soil (brown).

The soil that is coloured in blues indicate soils that are partial to surface flood and are likely to pond in increasing frequency as groundwater rises. This analysis indicates a historical wetland corridor between Te Horo Beach and Waikanae Beach, and the predominance of flood-prone soils within the transect along the Mangaone Stream.

figure 3.14 Soil series, Kapiti Coast (Landcare Research)

PLOTTING EXTERNALITIES WITH LAND-USE

The impacts of climate change are plotted in blue text, and the externalities are plotted in black text. This diagram illustrates that the climate change and human development externalities in the cultural landscape occur at the overlap of landscape typologies, indicating that these landscapes are the most susceptible to change.

The design-research is based around the integration of these overlapping landscape typologies, and to build a multifunctional landscape out of the existing land-use and potential externalities.

▲ Figure 3.15 Impacts and externalities of climate change

► Figure. 3.16 1 in 100-year flood extents between Otaki River and Waikanae River.

FLOOD IN THE LANDSCAPE

From the large-scale analysis, it is hard to pin the externalities to specific landscape typologies or even to ascertain specific land-uses. So unlike the specificity of externalities plotted in the diagram on the facing page, there is a limit to how much design and research can be accomplished. The difference between these two approaches is the result of the two methodologies for understanding the complexity of impact and externalities.

Te Horo Beach
shingle dunes

This is a detailed topographic map of a coastal area. The map features contour lines indicating elevation, with a prominent ridge of dunes running diagonally from the top right towards the bottom right. A thick black line, likely representing a road or a boundary, runs horizontally across the middle of the map. Several drains are marked with dashed lines and labeled: 'Powles drain' is located in the upper middle; 'Pukemanu drain' is in the lower middle; and 'Sages drain' is in the lower right. A specific area of dunes is highlighted with a grey rectangular box and labeled 'Parabolic dunes'. The bottom left corner shows a 'coastal subdivision' with various rectangular plots. The overall terrain is rugged and hilly, typical of a coastal dune environment.

Parabolic dunes

Powles drain

Te Horo Beach
coastal subdivision

Pukemanu drain

Sages drain

Figure. 3.17 0.5m contours along transect

• MANGAONE STREAM •

Transect

Mangaone Stream

The most significant stakeholder in the transect is the Mangaone Stream. The Mangaone Stream plays a large part in the processes of the landscape; agricultural drains discharge into the stream; its floodplain irrigates the pasture and hydrates wetlands; it runs passed both Te Horo and Te Horo Beach. The restoration of the Mangaone Stream is a large part of this thesis and is the catalyst in implementing and developing the adaptive strategies for a more productive, multifunctional and resilient cultural landscape.

The angle of the perspective was instrumental in developing strategies that took into consideration the entirety of the stream, from headwaters to estuary, rather than focusing on individual areas at a time. This put a focus on the holistic development of adaptive strategies in the transect; for example, the impact of a previous design phase, could be calculated into the design of the following move. Regrettably, this made the design-research process very slow.

At this stage in the design process, I moved to apply the externalities to the transect. The landscape of the transect is a pin-cushion for the externalities, many existing at the edge of two or more land-uses. The transect is the focus site of this design-research.

In a 1 in 100-year flood

Mangaone Stream

The flood extents from this perspective look very different and are more reflective of the flooding process. The darker blue indicates overflow water from the stream.

1. Rainwater rushes down from the Tararua ranges and immediately the Mangaone Stream overflows and surface water runs freely over the floodplain.
2. The overflow water is then funnelled under State Highway One resulting in subsequent overflow on the other side.
3. Overflow flood affects residential homes and properties, including pasture.
4. Irrigation drains act as conduits for flood water resulting in wide-scale ponding in lowland pasture.
5. Overflow water continues to rush downstream, flooding coastal homes and inundating roadways.

FLOOD EXTENTS: OVERFLOW AND PONDING

How does elevation affect flood extents?

There are two types of flood in the transect, overflow flood and ponding.

Each type is explained as below:

Overflow ponding (<5.5m) is due to the displacement of water into either flat elevation land or poor draining soil. This type of ponding will typically subside in less than a week but can be prolonged due to oversaturated soil, depending on the duration of the rainfall event and frequency of rain in that period.

Groundwater ponding (0m-5.5m) is due to a combination of low elevation land and high water table, and can last up to several weeks. This type of ponding primarily affects coastal dairy farmers and will become more common/frequent with sea-level rise induced groundwater rise.

INCREASED RAINFALL

Surface flooding

Increased rainfall and high rainfall events put pressure on streams and riparian systems, resulting in greater surface run-off and the widening of stream corridors. Effective management of surface water and riparian corridors will become increasingly crucial over time.

Externalities:

- Widening and deepening of stream corridors
- New overflow/stream corridors
- Flash floods become more common
- Breakout flooding more common

figure 3.21 Increased rainfall

SEA-LEVEL RISE

Groundwater-table rises

Sea-level rise puts pressure on ground water, driving the water-table upwards. This results in the expansion of wetlands due to groundwater recharge and the ponding of coastal lowlands during frequent rainfall events.

Externalities:

- Groundwater-table rise
- Emerging wetlands
- Lowland ponding
- Emerging water bodies as flood conduits

EXISTING EXTERNALITIES

Externalities explored here are the current conflicts in the landscape, largely between agricultural process and stream health.

figure 3.23 Mapping externalities in the landscape (transect)

figure 3.24 Mapping externalities with flood extents (transect)

Impacts and Externalities

Change at varying scales

There are two different ways to look at impacts and externalities; through different scales and over time. The diagram on the facing page illustrates the range of specificity when it comes to referring to certain impacts, across different scales. The flow chart on the next two pages (page. 104-105) illustrates how certain impacts produce externalities.

General impacts affect multiple biota in multiple landscape typologies. They are explored through large-scale analysis, and produce central impacts that require additional specificity to apply the impact to a particular biota and land-use. Impacts within this range become key drivers to specific design moves aimed at resolving specific local impacts.

Local impacts are specific externalities that are often derived from a range of general impacts, central impacts and are particular to specific landscapes or land-uses.

However, externalities within this range are beyond the scope of design. The externalities presented in this thesis are those that provide insight into landscape dynamics that are influential to the development of the adaptive strategies, such as linking local species extinction to hypoxia and salinisation of marine habitat.

GENERAL IMPACTS

CENTRAL IMPACTS

LOCAL IMPACTS

figure 3. 25 Specificity of impacts according to scale.

figure 3.26 Flow chart of impacts and externalities

Adaptive Strategy development

From Foredunes to Headwaters

This section will cover the development of adaptive strategies through a range of pertinent and influential studies on the impacts and externalities in the transect. The design-research begins with looking at threats to the coast which is largely driven by initial interest in the impacts of sea level rise, concluding with impacts of stream overflow and flooding.

1. Foredune erosion and coastal subdivisions
2. Eutrophication of estuaries and saline intrusion into freshwater ecologies
3. Lack of accessibility between stream habitats and wetland reserves
4. Habitat and biodiversity meets flood management in complementary landscape
5. Flood management meets agricultural processes in supplementary landscape
6. Full impacts of climate change on flood hazard

figure 3.27 Adaptive Strategies

THREATS TO THE COAST

Foredune erosion and coastal subdivisions

Beachfront subdivisions encroach on foredunes and coastal habitable landscapes. Hard-settlements interfere with the stability of foredunes, compromising its ability to adapt and contributes to an acceleration of erosion and foredune depletion. Sea-level rise also threatens the stability of foredunes and is the primary natural cause of erosion and foredune depletion.

The combined impact of sea-level rise and beachfront development undermine the sustainability of foredune systems which play an fundamental role in maintaining inland coastal ecosystems, such as back-dune marshland; wetlands; and dune lakes.

Conclusion:

The pertinent issue is the disparity of timescale between dune migration, sea-level rise and residential development; where dune migration and formation occur over thousands of years; sea-level rise over hundreds of years; whereas residential development can proliferate within a decade. Therefore, there is a responsibility in urban development to consider the timescale of the existing landscape and its adaptability to not only climate change, but also the manner in which coastal landscapes are developed and settled.

COASTAL BIOTA

Eutrophication of estuaries and saline intrusion into freshwater ecologies

Agricultural runoff runs into drains that deposit into streams. The effluent then collects at stream estuaries, reducing water quality and promoting algal blooms that lead to hypoxic conditions. This is particularly prevalent with smaller streams located within an intensive agricultural landscape.

Sea-level rise and saline intrusion will result in a gradual increase in the salinity concentration of brackish marine habitats and threatens to infiltrate freshwater habitats. Salt can prove fatal to many freshwater fauna and flora, and can interfere with migration, breeding and spawning cycles.

Conclusion:

The combined impact of saline intrusion and eutrophication-induced hypoxia of marine habitat results in a decreased level of dissolved oxygen in water, and poses a fatal threat to freshwater species.

These species will have nowhere to migrate, as the agriculturally-dominated coastal landscape lacks accessible freshwater wetland reserves.

HABITAT FRAGMENTATION

Lack of accessibility between stream habitats and wetland reserves.

Mapping of the soil series indicated that there was once a 'belt' that was comprised of wetlands and dense wetland vegetation, including native giants such as kahikatea and totara. These soils (gley, organic) have poor drainage and have a high capacity to absorb water making them much more prone to ponding. The map shows that major drains are located in these lowland flood-prone soils and are the most susceptible to flood hazard.

Conclusion:

Reconnecting the large wetland reserves with smaller streams and dune lakes could open up the possibility for potential for wetland restoration and wetland floodwater retention. Farmers would however have to forfeit their land to the development of wetlands.

WETLAND RESERVES + FLOODWATER RETENTION

Habitat and biodiversity meets flood management in a complementary landscape

The idea came to integrate the flood management and biodiversity initiatives by creating wetland reserves that would take the role of flood water retention pools in such an event. This would form a large central wetland habitat that would also mitigate the impact of overflow flood in a high volume rainfall event.

The largest reserve would be located to the east of SH1 and would be constructed alongside the construction of the PP2O expressway. The secondary overflow wetlands are located in parts of the landscape that are above the groundwater ponding threshold, and are affected primarily by overflow surface water from the stream. These retention wetlands will require a different approach to the lowland flood management strategies they respond to a different type of flooding.

Conclusion:

The central wetland habitat will be supplemented with smaller, temporary habitats along the stream, creating a network of habitats along the Mangaone Stream (explored on next page).

EFFLUENT FILTRATION + FLOODWATER RETENTION

Flood management meets agricultural processes in a supplementary landscape

The existing drain confluences discharge effluent into the stream during the majority of the year, and take on the role as floodwater conduits in high rainfall events. Due to the lack of water management and flood control at these drain confluences, floodwater backflows up the drains and leads to wide-scale ponding.

Conclusion:

A flood control measure with an integrated effluent filtration strategy would prevent backflow during flood events and filter out effluent and reduce water turbidity would be an appropriate strategy at these confluences. This would eventual phase into a restored landscape where the stream water is clear and healthy enough to support life, creating a network of supplementary habitat.

THE COMBINED IMPACT OF SEA-LEVEL RISE AND HIGH RAINFALL

Surface water and ground water meet

The combined impact of groundwater rise and increased surface water flow is that there will simply be more water in the landscape. There is a very pertinent need to address the value of efficient and resilient flood management strategies along the Kapiti Coast and similar coastal landscapes.

The two impacts would put pressure on supplementary wetlands at drain confluences, instead creating choke points with a high risk of overflow. Then the solution is to widen the stream corridor itself with a riparian embankment that would serve as both water retention and community walkway. By allowing the community to become better acquainted with the fluctuation in water-level of the stream, the better prepared they can in the case of a flood crisis.

Figure. 3.33 Surface water and ground water meet

Consider the accumulative impact of externalities on future landscape

- Breakout flooding finds emerging water bodies as conduits/flood extenders
- Flash floods into saturated lowlands can cause wide-scale ponding
- Storm events spread eutrophic/polluted water into vulnerable ecologies.
- Floodwater damage to transportation and residential infrastructure

Design Iterations - Wetland reservoir park

Early concepts explored the idea of a wetland reservoir that would have a secondary purpose as a flood water retention pool. The reservoir would regulate the volume of water further downstream mitigating overflow flood. Retained floodwater can then be used to support alternative agriculture practices and better incorporate hydrological systems into the transect.

Figure. 3.34 Conceptual sketch of adaptive strategies along Mangaoene Stream

Design Iterations - Overflow reserves & walkway embankments

Supplementary to the wetland reservoir park will be a series of smaller wetlands at drain confluences that filter effluent, can retain floodwater and will eventually regenerate the capacity to support ecologies. Along the stream and around the overflow reserves are embankments with additional community walkways along the spine. Integrating community recreation frameworks into flood management.

Figure. 3.35 Conceptual sketch of drain wetlands along Mangaone Stream

Figure. 3.36 Transect perspective with adaptive strategies outlined

1% AEP FLOOD EXTENTS

Figure. 3.37 Transect perspective with adaptive strategies outlined (flood overlay)

DEVELOPED DESIGN -
ADAPTIVE STRATEGIES OVERVIEW

Adaptive strategy according to externalities
and land-use

ADAPTIVE STRATEGY	<p>Wetland Reservoir Park</p> <p>This is a long-term adaptive strategy that aims to make room for water and welcomes inundation just like a wetland would at the end of a long, dry summer. The intention is not to prevent inundation, but to integrate it into the development of the PP2O expressway (see: road ecology, page 60-61). The wetland reservoir park will function as a inhabitable wetland over the years and a floodwater basin in times of high rainfall.</p> <p>The park also includes the overflow reserve park located downstream, acts as a secondary inundation zone in rainfall events, but is utilised as a rugby field during the year.</p>
	<p>ROAD BARRIER</p> <p>HABITAT LOSS</p> <p>HABITAT FRAGMENTATION</p> <p>WATERLOGGED/ UNPRODUCTIVE LAND</p> <p>EMERGING URBAN ECOLOGY</p> <p>FLOODS AND PONDING</p> <p>FLOODS SEVER ROAD CONNECTIONS</p>
LAND-USE	<p>TRANSPORTATION INFRASTRUCTURE</p> <p>AGRICULTURAL IRRIGATION AND DRAINS</p> <p>INTENSIVE GRAZING PASTURE</p> <p>WETLANDS AND DUNE LAKES</p> <p>STREAMS AND RIVERS</p> <p>COASTAL HINTERLAND</p> <p>RURAL TOWN CENTERS</p>

Drain Wetlands

The phasing of this adaptive strategy is an important demonstration of how the phasing process functions and develops according to the increasing risk of extreme flood versus the time that the landscape takes to heal.

The outcome of the drain wetlands is have a terraced wetlands that filter effluent and mitigate backflow ponding during flood events. Each phase of this strategy marks a milestone in the regeneration of the stream water quality and its capacity to support life.

EUTROPHICATION
 POLLUTION AND HYPOXIA
 LOSS OF BIODIVERSITY
 PUGGING / UNPRODUCTIVE LAND
 FLOODS AND PONDING
 FLOODS SEVER ROAD CONNECTIONS

TRANSPORTATION INFRASTRUCTURE
 AGRICULTURAL IRRIGATION AND DRAINS
 INTENSIVE GRAZING PASTURE
 EXTENSIVE GRAZING PASTURE
 STREAMS AND RIVERS
 RURAL 'QUATER ACRE' SUBDIVISIONS

Walkway Embankment

Running adjacent to the Mangaone Stream and Te Horo Beach Road is the Walkway Embankment.

This embankment is a key design strategy for increasing the capacity for the stream to widen during rainfall events and flood events. The embankment serves as a community walkway around the transect landscape, while in place to reduce ponding extents.

ROAD BARRIER
 HABITAT FRAGMENTATION
 WATERLOGGED/ UNPRODUCTIVE LAND
 LOSS OF BIODIVERSITY
 FLOODS AND PONDING
 FLOODS SEVER ROAD CONNECTIONS

TRANSPORTATION INFRASTRUCTURE
 AGRICULTURAL IRRIGATION AND DRAINS
 STREAMS AND RIVERS
 COASTLINE AND FOREDUNES
 COASTAL SUBDIVISIONS
 RURAL 'QUATER ACRE' SUBDIVISIONS

Wetland Reservoir Park

SECTION PERSPECTIVE

Instead of constructing a culvert at the stream under the expressway, this strategy uses a bridge with a continuous source of water below. The bridge itself creates cool shaded wetland habitats which are ideal breeding/spawning environments.

The illustration depicts how the water reservoir is integrated with the new expressway, and that marine habitats can be formed in the gaps, reducing the habitat loss caused by road infrastructure.

Figure. 3.38 Section perspective of Wetland Reservoir Park

LOOKING SOUTH FROM THE OVERBRIDGE

SHADED MARINE HABITAT

SHADED WETLAND GRASSES

EMBANKMENT

PASTURE

TE HORO OVERBRIDGE

WETLAND RESERVOIR

TOWN CENTER

SPILLWAY BUFFER

GREEN HOUSES

FLOOD MONITORING STATION

PASTURE

EMBANKMENT WALKWAY

SPILLWAY CORRIDOR

Flood management and habitat networks

AERIAL PERSPECTIVE

Although flooding may have high and low periods throughout the year, the increase in rainfall over the Tararua Ranges would widen stream corridors and begin to inundate the wetland reservoir and drain wetlands. Meanwhile, the riparian and spillway buffers attempt to regenerate biodiversity and habitat network.

Figure. 3.39 Aerial perspective of Wetland Reservoir Park

BRIDGES OVER CULVERTS

Regeneration of habitatable landscapes

Bridges provide a great opportunity to create a marine habitat as they offer shade and relief from the sun, especially in the absence of shade from appropriate riparian planting initiatives.

While culverts may be logistically easier, opting for a bridge and allowing the stream to widen and change naturally reduces the risk of a breakout flood due to the funnelling effect that culverts have during flood events.

Figure. 3.40 Existing Te Horo bridge over Mangaone Stream

Figure. 3.41 Proposed Te Horo overbridge and expressway bridge.

Figure. 3.42 Overflow reserve used as a rugby field and recreation walkway

Figure. 3.43 Overflow reserve inundated with floodwater, but keeps embankment dry

A RUGBY FIELD IN A SPILLWAY

Recreational flood management strategies

It is important that the flood management strategies are integrated with a wide range of land-use, and recreation and wellbeing are no exception. The Overflow Reserve is a full 5 hectare natural reserve made to function as a community park space and a spillway reservoir to the Wetland Reservoir.

The Embankment Walkway joins the walkway around the Reserve Park connecting to the stream (see next page).

The embankment walkway around the Overflow Reserve works in the same way as the stream corridor

TE HORO OVERBRIDGE

WETLAND RESERVOIR

spillway directs water to reserve

stream widens during high flow

Maintain waterflow through Mangaone Stream

AERIAL PERSPECTIVE

The function of the spillway and Overflow Reserve is to regulate the flowrate of the Mangaone Stream as not to have a detrimental impact on regenerating ecologies.

High velocity flow can uproot vegetation and disrupt breeding cycles, which would only hinder the development of a habitat.

Figure. 3.44 Aerial perspective of Wetland Reservoir Park during flood event

Flood Mitigation and Biodiversity Restoration

Phasing of drain wetlands

▲ Figure. 3.45 Phased sections of drain wetland development

► Figure. 3.46 Aerial perspective drain wetlands and embankment walkway

Flood Mitigation and Nature walkway

Phasing of Mangaone Embankment

▲ Figure. 3.47 Phased sections of embankment walkway development

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figure 4. A flock of birds fly over dunes

4

CONCLUSION & BIBLIOGRAPHY

This section will conclude with a summary and discuss application and relevance of this thesis.

4.1 Conclusion

4.2 Reflection

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CONCLUSION

Summary

The developed design of this thesis is not what I would refer to as particularly detailed and resolved small-scale spaces, but are nonetheless complex and highly resolved adaptive strategies for climate change and future development.

The transect landscape is an archetype of the coastal landscape, especially along the lower west coast of the North Island. Streams and rivers along the lower west coast of the North Island face similar problems to the Mangaone Stream; conflict between agricultural processes and the impact on natural ecologies is far from being resolved.

All the same, the design strategies show that adaptation to climate change can be accomplished by simply understanding the idiosyncrasies of the landscape and working with it to find places where conflicts can be resolved, not necessarily through high-funded projects, but through small, phased amendments to the fragmented landscape that develop positively with gradual changes in the cultural landscape.

REFLECTION

Summary

It is my intention that this thesis could be a valuable source of research and collection of studies in the field of flood management in coastal landscapes, in particular agricultural processes and habitat networks and biodiversity.

This thesis explores an issue that will become increasingly pertinent as we become more susceptible to climate change impacts. It considers a wide range of variables to change, and considers design responses to each.

It is my hope that this thesis may be of use others that choose to research design in the coastal agricultural landscape.

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END

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