Sustainable Ecological Systems and Urban Development in New Zealand: a Wetlands Case Study

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Philosophy
in
Ecology

at Massey University,
New Zealand.

Karen Thelma Palmer

2013

Abstract

The destiny of urban wetlands lies largely in the hands of the urban planners. The results of this study suggest that planners are underestimating the importance of the urban wetland with irreversible consequences. The ecological integrity of natural systems like wetlands is inevitably compromised when they occur in urban environments. The Resource Management Act 1991 altered the approach to urban development from being entirely anthropocentric to one of consideration of the environment in which such developments were planned. Supposedly, adherence to the Act has resulted in a more focused approach to environmental outcomes in district and regional plans. However, this research into the effects of urban development on urban wetland riparian areas identifies a lack of appreciation of their structure and function.

Eight palustrine wetlands were assessed for health and riparian function. They comprised two non-urban wetlands that provided the best-available ecological data on wetland health and six urban wetlands. Ecological indicators and urbanisation data were incorporated into a multi-metric model (named the Urban Wetland Health Index) to evaluate the biological health of urban wetlands.

A key finding of this research is that the urban wetlands have poor ecological health and functioning indicated by excessive nutrients and algal blooms. Other key findings included the inadequate structure and function of the wetland riparian areas; the loss of riparian habitat associated with a lack of indigenous vegetation; the minimal cultural values given to the urban wetlands; and the negative impacts of urban imperviousness and inadequate stormwater infrastructure on wetland health. Notably, older residential areas that had poor stormwater connections to appropriate drainage also had the least healthy urban wetlands. The role of stormwater runoff in compromising the health of the urban wetlands was not addressed in the 2010 Kapiti Coast District Plan Review documents regarding Landscape and Biodiversity. These documents guide the development of the ‘second generation’ district plan.

The Urban Wetland Health Index was found to be robust and reliable with this research. It was designed to address a gap in the tools available to planners, ecologists and other professionals seeking to assess the impacts of urban development on urban wetland ecosystem health. This Index is an important tool for use by councils in reviewing their district plans and undertaking plan changes. The incorporation of ecosystem services science into their policies and plans, and the understanding of the value of urban wetland ecosystem services, is needed to foster urban sustainability.

Acknowledgements

My thanks go to my supervisors, Dr Michael Joy, Associate Professor John Holland and Associate Professor Christine Cheyne. They have been forever patient and encouraging with their 'second career' student. Also to the Massey Ecology Group technical staff, Paul Barrett and Tracy Harris, who made sure that I had appropriate laboratory materials and equipment.

Special thanks go to the people who allowed me access to their wetlands – Lorraine and Ian Jensen at Te Hapua; Bruce Benseman and staff at Nga Manu Nature Sanctuary; David Blair and Wendy Huston of the Sevenoaks Midlands Gardens Retirement Village Trust and the Ferndale Trust administrator and staff. Emily Thomson, Kapiti Coast District Council (KCDC) helped me with maps and documents and Brian Phillips, a neighbour of Tower Lake No 1, Chris Horne, Wellington Botanical Society, Rob Cross, Biodiversity Officer KCDC and Jonathan Smith, Owner of Ngarara Farm, Waikanae, were generous with their time and information.

Many others have contributed to the work-in-progress, not the least my family Penny and Mark, John and Jenny, and Mark and Megan, who have been required to listen and read my efforts, and even accompany me on sampling trips. My Wednesday tramping group have withstood my highs and lows as we walked the Wellington hills. My close friends have lent an ear to my frustrations and shared my excitement. My thanks to them all.

Table of Contents

Title page

Abstract i

Acknowledgements ii

Table of Contents iii

Tables vii

Figures viii

Abbreviations used in text ix

Chapter 1 Introduction

1.1 Introduction 1

1.2 Problem Statement 2

1.3 Aim and Objectives 2

1.4 Contribution to Knowledge 3

1.5 Limitations to research 3

1.6 Research Approach 3

1.7 Format of Thesis 4

Chapter 2 Urban Development Processes in New Zealand

2.1 Introduction 7

2.2 Land–use Transformation 7

2.3 History of Urban Development 8

2.4 Urbanisation and the Environment 8

2.5 Urban Development in New Zealand 9

2.6 Indigenous Biodiversity versus Urban Development 10

2.7 The Resource Management Act 11

2.8 Role of Central Government and the RMA 12

2.8.1 Ministry for the Environment 12

2.8.2 Department of Conservation 13

2.8.3 The Parliamentary Commissioner for the Environment 14

2.9 RMA and Urban Development 15

2.9.1 Regional Council Responsibilities 15

2.10 The Local Government Act 2002 16

2.11 District Councils and District Plans 17

2.12 Resource Consents 17

2.13 Managing the Impacts of Development 18

2.14 Urban Design, Standards and New Developments 19

2.15 Conclusion 20

Chapter 3 Ecosystem Modification Associated with Urbanisation

3.1 Introduction 23
3.2 Intact Ecosystems 23
3.3 International Studies of Impacts of Urbanisation on Ecosystems 24
3.4 Global Ecosystem Awareness 26
3.5 Global Response 27
3.6 Global Failure 29
3.7 The Impact of Urban Development on Ecosystems 30
3.8 Landscape Fragmentation 31
3.9 The New Zealand's Ecosystem Experience 1250-1800 32
3.10 Ecosystem Modification and Urbanisation post 1800 33
3.11 Planned Colonies and Unplanned Results 35
3.12 New Zealand's Environmental Legislation post 1840 36
3.13 Grasslands, Forests and Conflicts 1920-1960 39
3.14 The Conservation Movement – from 1960 41
3.15 The Urban–Rural Gradient 43
3.16 Valuation of Ecosystems 45
3.17 Urban Ecosystems 49
3.18 Landscape Mosaics – Culture, Restoration and Recovery 50
3.19 Conclusion 51

Chapter 4 Wetland Riparian area Ecosystems

4.1 Introduction 53
4.2 New Zealand Wetlands Defined 53
4.2.1 Wetland Classification 54
4.2.2 Wetland Functions 55
4.3 Ecological Metrics for Wetland Condition 56
4.3.1 Wetland Riparian Areas 57
4.4 Wetlands and Urbanisation 60
4.5 Urban Wetland Sustainability 61
4.6 Hydrological Compromise 62
4.7 Infrastructure and Species Loss/Extinction 63
4.8 Wetland Riparian Areas Defined 63
4.9 Wetland Riparian Functions 65
4.9.1 Urban Wetland Riparian areas 66
4.9.2 Connectivity 67
4.10 Riparian area Value 68
4.11 The Kapiti Coast Case Study 69
4.11.1 Regional Geomorphology 69
4.11.2 Kapiti Coast History 72
4.11.3 Regional Ecology 73

4.11.4 Social and Cultural Values 74
4.12 Conclusion 75

Chapter 5 Research Design and Methods
5.1 Introduction 77
5.2 A Wetland Case Study – Loss of Wetland Ecosystems 78
5.3 Choosing Study Sites 80
Site Descriptions: 81
5.4 A New Assessment Index – Filling the Gap 87
5.5 Ecological Assessment Methods 89
5.6 Metrics Measuring Urban Wetland Condition 92
Metric 1: Hydrology 92
Metric 2: Physicochemical Parameters 94
Metric 3: Riparian Ecosystem Intactness and Habitat 98
Metric 4: Native Avifauna 98
Metric 5: Ecological, Cultural and Social Values 99
Metric 6:Urban Development and Infrastructure Impacts 99
Metric 7: Stormwater and Imperviousness 102
5.7 Data Analysis 103
5.8 Macroinvertebrate Indicators: Use of WMCI and QWMCI 104
5.9 The Proposed Urban Wetland Health Index 104

Chapter 6 Research Results
6.1 Introduction 105
6.2 Results of Urban Wetland Assessment 105
Metric 1: Hydrology 105
Metric 2: Physicochemical Parameters 107
Metric 3: Riparian Ecosystem Intactness and Habitat 110
Metric 4: Native Fauna Abundance 114
Metric 5: Ecological, Cultural and Social Values 115
Metric 6: Urban Development and Infrastructure Impacts 117
Metric 7: Stormwater Impacts and Imperviousness 118
6.3 Proposed Urban wetland Health Index 120
6.4 Data Analysis 127
6.5 Macroinvertebrates and the South Island WMCI and QWMCI 128
6.6 Conclusion 129

Chapter 7 Discussion of Results
7.1 Introduction 131

7.2 Urban Wetland Health Index 131

7.2.1 Wetlands and Regulatory Controls 133

7.2.2 Wetland Ecological Assessment 134

Metric 1: Catchment, Wetland and Riparian Hydrology 135

Metric 2: Physicochemical parameters 138

Metric 3: Riparian Ecosystem Intactness and Habitat 139

Metric 4: Native Avifauna 142

Metric 5: Ecological, Cultural and Social Values 142

Metric 6: Urban Development and Infrastructure Impacts 143

Metric 7: Stormwater Impacts and Imperviousness 144

7.7 Urban Wetland Health Index Assessments 145

7.8 Kapiti Coast Plan Review 2010 and the RMA 146

7.9 Conclusion 147

Chapter 8 Conclusions and Recommendations

8.1 Introduction 149

8.2 The Rhetoric and the Reality 149

8.3 Key Recommendations of this Research 150

8..1 Urban Wetland Health and Regulatory Controls 150

8.3.2 Wetland Health and Riparian Function 151

8.3.3 Wetland Riparian Function and the UWH Index 151

8.3.4 Urbanisation Impacts 153

8.4 Sustainable New Zealand Ecosystems and Urban Development 154

8.5 Future Directions 155

8.6 Limitations to this research 155

8.7 Sustainable Urban Wetland Health – Whose Responsibility is it? 156

Bibliography 163

Appendices 191

1. Background Information About the Study Sites 191
2. Protocols for Sampling Aquatic Macroinvertebrates 196
3. Worksheet for Assessment of Wetlands and Riparian areas 198
4. Riparian Vegetation Composition of study wetlands 207
5. Avifauna List and Distribution 210
6. Kapiti Coast Urban Wetland Aquatic Macroinvertebrate Assembly 211
7. Spreadsheet of Urban Wetland Health Index Results 213
8. Wetland riparian areas defined . 215

Tables

4.1	A wetland classification system	55
4.2	Impacts of urbanisation on wetland hydrology	62
4.3	Impacts of urbanisation on wetland ecology	63
4.4	Impacts of urban development on riparian area	68
4.5	Value of riparian area	69
5.1	UWH Index components and their scores	91
5.2	Resource consents for urban development Kapiti Coast	100
5.3	Indicative ISC% imperviousness Kapiti Coast	102
5.4	Indication of soil porosity on Kapiti Coast	102
5.5	Connective Impervious Areas (CIA%) of Kapiti Coast	103
6.1	Catchment, wetland and riparian hydrology scores	107
6.2	Physicochemical data	108
6.3	Physicochemical scores	109
6.4	Riparian ecosystem intactness and habitat	114
6.5	Avifauna distribution	115
6.6	Ecological, Cultural, and Social values	116
6.7	Urban development and infrastructure impacts within the riparian zones	118
6.8	ISC% calculation	119
6.9	Urban stormwater impact on wetland water and riparian areas	119
6.10	Proposed Urban Wetland Health Index results for Kapiti Coast	120
6.11	False Discovery Rates	123
6.12	Independent parameters for NMDS	128
7.1	Relationship between catchment hydrology scores and CIA% and ISC%	135
8.1	Central and local government oversight of urban wetlands	157
8.2	Ecological needs for Kapiti Coast urban wetlands	160

Figures

1.	Lake, Wetland, Estuary, Lagoon or Natural Body of standing Water	59
2.	Map 1: The Great Swamp Kapiti Coast 1840 and 1993	71
3.	Development of Tower Lakes 1982	78
4.	Lake Ngarara development 2010	78
5.	Map 2: Study sites on Kapiti Coast (Google Earth .jpg)	79
6.	Te Hapua Wetlands, Shoveler Lagoon (Google Earth .jpg)	81
7.	Nga Manu top pond (Google Earth .jpg)	81
8.	Te Hapua Wetlands, Shoveler Lagoon west end.	82
9.	Nga Manu Nature Reserve top pond	82
10.	Waimeha Lagoon (Google Earth .jpg)	83
11.	Lake Ngarara (Google Earth .jpg)	83
12.	Waimeha Lagoon western end	84
13.	Lake Ngarara north end	84
14.	Tower Lake No 1 (Google Earth .jpg)	85
15.	Midlands Gardens north pond (Google earth .jpg)	85
16.	Tower Lake No 1	86
17.	Midlands Gardens top pond	86
18.	Lake Kotuku (Google Earth .jpg)	87
19.	Lake Kotuku stormwater collection pond	88
20.	Ferndale stormwater collection pond outlet	88
21.	Algal bloom, Lake Kotuku, May 2010	110
22.	Swan nest, Tower Lake No 1	110
23.	Vegetated swale, Ferndale	113
24.	Midlands Gardens riparian lawn	113
25.	Spearman Rank-order Correlations	122
26	Cluster Dendrogram of metric components	124
27	Five-Clusters Dendrogram	125
28	NMDS of scoring parameters	126
29	NMDS of non-scoring parameters	127
30	Relative positions of the wetlands catchments imperviousness.	135

Abbreviations used in the text

BP	Before present time
CIA	Connected Impervious Areas
CMS	Conservation Management Strategy
CRC	Canterbury Regional Council
CSD	Commission for Sustainable Development
DOC	Department of Conservation
EDS	Environment Defence Society
EERNZ	Ecological Economics Research New Zealand
EMAP (US)	Environment Monitoring Assessment Program - Wetlands
EPA	Environment Protection Authority
EPT	Ephemoptera, Plecoptera, Tricoptera
ERE	Environment Result Expected
ERMA	Environment Risk Management Authority
GIS	Geographic Information System
GPS	Geographic Positioning System
GWRC	Greater Wellington Regional Council
ha	hectare
HERCULES	High Ecological Resolution Classification for Urban Landscapes and Environmental Systems
HGM	Hydrogeomorphic Classification Method
IPCC	Intergovernmental Panel on Climate Change
ISC	Impervious Surface Cover
IUCN	International Union for Conservation of Nature and Natural Resources
KCDC	Kapiti Coast District Council
LGA	Local Government Act
LINZ	Land Information New Zealand
LIUDD	Low Impact Urban Design and Development
LUC	Land Use Capability
MA	Millennium Ecosystem Assessment
MCI	Macroinvertebrate Community Index
MED	Ministry of Economic Development
MfE	Ministry for the Environment
MUL	Metropolitan Urban Limit
NES	National Environmental Standard
NGO	Non-Governmental Organisations
NIWA	National Institute for Water and Atmospheric Research
NPS	National Policy Statement
NPSFM	National Policy Statement for Freshwater Management

NWI (US)	US Fish and Wildlife Service’s National Wetlands Inventory Program
NZBS	New Zealand Biodiversity Strategy
NZS	Standards New Zealand
PCE	Parliamentary Commissioner for the Environment
QP	Quality Planning
QV	Quotable Value (of property)
REC	River Environment Classification
RMA	Resource Management Act
RMC	Riparian Management Classification
RPS	Regional Policy Statement
SOE	State Owned Enterprise
TAG	Technical Advisory Group
TEV	Total economic Value
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Changer
UWHI	Urban Wetland Health Index
USDA	U.S. Department of Agriculture
Vol	Volume
WCC	Wellington City Council
WCED	World Commission on Environment and Development
WET	Wetland Evaluation Technique
WMCI	Wetland Macroinvertebrate Community Index
WMO	World Meteorological Organisation
WWF	World Wildlife Fund

Chapter 1 Introduction

1.1 Introduction

Wetland ecological systems are considered among the most threatened of environmental resources. The term ‘ecology’ was first coined by Ernst Haeckel in 1866 to describe a branch of biology concerned with inter-relationships between loosely organised communities that are now defined as ecological systems or ecosystems (Stauffer 1957). These ecosystems are complex physical and biological environments in continuous states of flux and adaptation to stressors. Plants, animals and microorganisms interact with one another collaboratively and competitively to produce and decompose biomass, sequester carbon, enable the transport of minerals from water and sediment to organisms, transfer water to the atmosphere and provide food, fibre and building materials for humans (Alberti 2005).

Although humans are an integral part of ecosystems, throughout history they have attempted to exert control over the world’s ecosystems with changes in land use, resource consumption, modification of energy flow, disruption of hydrological cycling, altered nutrient cycling and habitat destruction (Alberti *et al.* 2003; Alcamo & Bennett 2003; McDonnell & Pickett 1993). The continuing severe changes to landscape ecological structures have led to significant losses of global biodiversity. This has been amply demonstrated by the deforestation of the Amazon rainforests for human settlement and land development that has resulted in an enormous loss of the flora and fauna of the region (Laurance *et al*. 2002).

The lack of recognition of ecosystems as an essential part of human life reflects a longstanding belief that they were always there and always would be (Alcamo & Bennett 2011). The negative effects of the assumption that wetlands would not disappear are now apparent throughout the world as landscapes are irreversibly transformed often as a result of urban development and its infrastructure needs. The ‘natural’ world is diminishing. Kimberling *et al*. (2007, p 59) suggested that until “we measure the biological responses from human actions, we cannot accurately predict their consequences, or their associated risks, for human society”.

In 1998, Costanza *et al.* warned of the loss of ecosystems through lack of protection as a result of failure to value them. The value of ecosystems, as represented by their services, has proved difficult to calculate as it requires a multidisciplinary approach that may include economists, conservationists, land owners, businesses and lawyers together with local, regional and national authorities. One example of the lack of appreciation of the benefits of ecosystems can be found in the world’s wetlands where the economic value of their benefits is usually excluded from decision-making formulae (Manuel 2003).

Ecosystems are under pressure as a result of growing world populations. In New Zealand, the population nearly doubled between 1961 and 2012 (Statistics NZ 2012). In most regions there has been ongoing modification or destruction of the ecosystems, particularly wetlands, for agriculture and greenfield urban development as the population grows. Successive central governments together with regional councils and territorial authorities have identified this problem but ecosystem modification continues (Sullivan *et al.* 2009).

Although the sustainable management of natural resources is presented as the cornerstone of the Resource Management Act (RMA) 1991 and its amendments, the interpretation and implementation of the principles of the Act have varied across the country (MfE 2011c). Section 30 requires regional and local environmental management agencies to achieve integrated management of the natural and physical resources of a region. This is implemented by applying conditions to resource consents for any ecosystem modification (MfE 2011c).

1.2 Problem Statement

Urbanisation severely affects freshwater ecosystems and as a result of these being located in the lowest lying areas of the landscape, any changes upstream in surrounding land use are reflected in the health of streams, degradation of riparian areas, loss of water quality and loss of ecological functioning in wetlands. In particular, the potential for the effects of urban development to overwhelm a wetland's riparian system with nutrient and sediment excess and changes to hydrology is given limited credence. These effects on the management of urban streams and wetlands have been the subject of many studies (Ehrenfeld 2008; Verhoeven *et al*. 2006; Houlahan *et al.* 2006; Groffman *et al*. 2003). However, in New Zealand there is no published ecological assessment index for urban wetland health. The incorporation of ecosystem services science into local government policies and plans, and the understanding of the value of urban wetland ecosystem services, is needed to foster urban sustainability. The development of an urban wetland health index fills the gap in this process.

1.3 Aim and Objectives

The aim of this research is to assess the ecology and cultural values of urban wetlands, the effects of urban planning (past and present) and development, on the sustainability of urban wetland ecosystems and evaluate the impact on them. This information will then form the basis for an assessment index of urban wetland health designed to provide a consistent, objective measure for comparison in space and time. The objectives are to:

1. Review urban development processes in NZ.
2. Review ecosystem modification literature.
3. Develop a model to assess the effects of urban development on the health of urban wetlands.
4. Undertake case study research into the health of urban wetlands to test the rigour of the model.
5. Provide recommendations to assist local government urban planners to develop and maintain sustainable urban wetlands.

1.4 Contribution to knowledge

Sustainable natural ecosystems rely on maximising the resilience to landscape changes, great and small. Although this study focuses on the functions of existing urban wetlands, there is a need to ensure that all wetlands are sustainable resilient in the face of landscape changes. The introduction of an Urban Wetland Health Index will provide a means of assessing and monitoring wetland ecological condition.

1.5 Limitations of Research

The major limitations to defining the impact of development on urban wetlands will be the quality of the data from local authority records and its availability. Resource consent conditions for any subdivision development and details of their monitoring and evaluation are public documents recorded and filed by district councils for future reference but if not available, this would be a serious limitation.

1.6 Research Approach

This thesis examines the impacts of urbanisation on the structure and functions of urban wetlands. Although globally the major changes in land use are for agriculture, the greatest impacts are associated with population density and the needs for safe food and clean water (Ehrenfeld 2004). Sustainable landscapes and their management are not a priority for many countries.

New Zealand's urban developments have occurred only over the last 170 or 180 years. The legislative response to sustainable management of ecosystems associated with these developments is through national, regional and local level policies and plans informed by international concepts and treaties. Despite assurances from territorial authorities and the Environment Court that urban development follows the spirit of, and criteria associated with, the Resource Management Act, Wheen (2004, p 274) noted, "The underlying value preference in New Zealand favours development and the management of environmental impact. Without either very clear and uncompromising ecological bottom lines, or a transition to a greener value paradigm, this bias will continue to manifest itself in environmental decision-making".

The Kapiti Coast District, on the lower south-west coast of the North Island, was chosen as a case study for an investigation of the health of urban wetlands in an urban area with widespread and varied ecosystem modification and destruction. During the first half of the twentieth century its urban development was a slow process of quiet conversion from rural properties and later holiday baches to permanent dwellings. Then during the 1960s, improved access by road and rail from the nearby capital city of Wellington resulted in a doubling of the population in Paraparaumu and Waikanae from 6320 in 1961 to 11,630 in 1971, doubling again to 25,710 in 1991 and again to over 46,000 by 2010 (KCDC 2010).

The effect of this population growth on the landscape has been profound with loss of natural contour, forest and wetland areas. The entire urban area of the Kapiti Coast has been developed on floodplains and sand dunes. Some of the subdivisions have small wetland ponds on the sites of previous swamps or wetlands excavated to the water table. Several areas of bush and swamp have been formally protected from development, and some survive on private farmland with or without formal protection. This study of the ecological health of urban wetlands is located in this region. The research encompasses two strands, first, assessment of the health of the selected urban wetlands and their riparian areas and, second, analysis of the impacts of urban changes on the riparian areas. The wetlands selected for study comprise two non-urban wetlands providing best available near natural data, and six urban wetlands of different origins, namely remnant swamps, excavations to the water table and constructed stormwater collection ponds.

The measurable indicators from the two strands of enquiry form the basis of a new Urban Wetland Health Index that has been developed as part of this study. This new Index utilises a scoring system that is largely derived from known wetland and riparian data sets (Suren *et al.* 2010; Clarkson *et al*. 2004; Quinn, 2003). The statistical evaluation of the data collected uses the Spearman rank-order correlations to avoid bias and p-values are corrected for false positives using false discovery rate to identify the significant correlations between the metrics used and the Index.

1.7 Format of Thesis

Following this introductory chapter, Chapter two discusses urban development in New Zealand and the statutory framework governing such processes. Particular attention is given to the RMA 1991 and the Local Government Act (LGA) 2002, which provide the statutory and policy framework for regional councils and territorial authorities within which they undertake urban planning and development, mitigation, restoration and enhancement.

Chapter three presents a review of the literature regarding New Zealand's environmental history and response to urban development. The impacts of global urbanisation on ecological, economic, social and cultural developments are discussed together with their application to the New Zealand situation of landscape destruction and urban-rural ecological gradients. New Zealand legislative response to sustainable management of ecosystems is reviewed.

Chapter four introduces urban wetlands as examples of ecosystems where ecological functions and values have been modified by urban development. It provides a background description of the characteristics of the Kapiti Coast, the district selected for this study of its urban wetlands that includes history, geomorphology, ecology and cultural values.

The case study of the impact of the Kapiti Coast District Council's district plan on urban wetlands is described in Chapter five. A multi-metric Urban Wetland Health Index developed from the ecological investigation of the urban wetlands and data from Kapiti Coast District

Council planning documents is introduced and its scoring system discussed. The selected study wetlands are described and the on-site ecological assessment are described. These ecological assessments included biodiversity observations and sample collection for aquatic macroinvertebrates and riparian flora identification. Resource consent and urban development information pertaining to the study sites were obtained from the Kapiti Coast District Council (KCDC), Greater Wellington Regional Council (GWRC) and other relevant bodies including the Department of Conservation (DOC).

The results of the research are presented in Chapter six with the details of the scoring and analysis of each metric and its parameters. The Urban Wetland Health Index (UWHI) provides a summary of these results. Chapter seven focuses on the evaluation and interpretation of the UWH Index results for their ecological and political importance. The significant correlations of the indicator metrics with wetland health together with other data sourced in this research is likely to be of use in future urban planning in the second-generation district plans. The conclusions and recommendations from the study are presented in Chapter eight.

Chapter 2 Urban Development Processes in New Zealand

2.1 Introduction

The purpose of this chapter is to provide a background to this study of urban wetlands and the institutional processes that have been influential in their present management. It outlines the history of urban development in New Zealand, its characteristics and the processes through which it occurs in order to highlight the impact on ecosystems and in particular wetlands. From the first planned migration of British colonists to New Zealand in 1839-1840 and the commencement of urban development, laws protecting the environment were enacted. A plethora of environmental laws developed over 140 years of settlement were rationalised between 1986 and 1990 culminating in the RMA 1991.

The RMA 1991 and the LOCAL GOVERNMENT AMENDMENT ACT 2013 provide the current framework for urban planning and development and protection of the environment. National Environmental Standards and Regulations and National Policy Statements developed from the RMA provide guidance for its implementation by regional councils and territorial authorities. Other central government agencies also provide advice for urban development and environmental management.

The balance between urban development and sustainable ecosystem management through the institutional agencies is highlighted. The strategies used in regional and district councils' second-generation plans are intended to give greater emphasis to the expected environmental effects of land use changes. Although the RMA allows for "avoiding, remedying or mitigating any adverse effects of activities on the environment" (RMA, Section (2c)), the resulting ecotones seldom replicate the original ecosystem. The seven essential design qualities of the Low Impact Urban Design and Development protocol (context, character, choice, connections, creativity, custodianship and collaboration) (NZUDP (MfE 2005) may provide a pathway to economic environmental management as discussed at the end of the chapter.

2.2 Land-use Transformation

Competition for land use throughout the world has shaped the future of human history for thousands of years. Access to water has been the major factor determining historic land use **(**Cadenasso *et al.* 2008). Since the nineteenth century, the competition for land has focused on ownership and speculation, rather than the usability of a finite resource, in the hope that it might render personal wealth above and below ground.

Human activities have changed the environment by altering land use, land cover and shape, interfering with the composition of atmospheric gases and the hydrological cycle, and modifying biological resources (Flannery 2010). The initial land use transformation was for agriculture with its attendant deforestation, but urbanisation, technology and industries now provide greater impacts to the global environment since 80% live in urban areas **(**Vitousek & Mooney 1997).

2.3 History of Urban Development

Urban development has been occurring for thousands of years with humans congregating in settlement groups to provide security from wild animals and other humans. The development of sophisticated trading systems followed with the formation of towns where many of the occupants no longer grew crops or herded animals. Within these towns, rules of habitation and rules for war were developed, and religious beliefs were encouraged both at a personal level and as a method of crowd control. Distinct cultures emerged reflecting the strengths, habits and spiritual systems of the people and as settlements grew and coalesced they assumed power over land and food sources (Wright 2004, p 69).

Early settlements and villages were associated with accessible water in river valleys and it was to defend this from others seeking to have some of the spoils that began many early skirmishes (Wright 2004, p 68-73). The trading of goods was common but water was not easily tradeable. As trade grew, towns, and later cities, became established in coastal areas near river mouths giving them power over the river estuaries, along the river banks (Wright 2004, p 48 & p 78) and access to coastal waters.

With population growth the governance of the large towns became more defined. Centres for government, business and religion developed leading to the building of public works, monuments and art works. This pattern of development occurred independently in five locations between 3,500BC and 1,200BC in Mesopotamia, Egypt, Indus River Valley, upper Yellow River and Mesoamerica. By 3,500BC, Uruk, the largest city[1] in Mesopotamia, had a population around 50,000. Wright (2004) argued that by about 750 BC, powerful rulers usurped the people's power to control their resources, their trade and their freedoms (Wright 2004, p 69-72 & p 145). Their subjects were required to go to war for the 'greater good' of the rulers. The rewards were safety and prosperity for the most powerful cities. Steel (2009) noted that the same pattern has continued over succeeding centuries with disastrous results for many people, and now involves entire countries.

2.4 Urbanisation and the Environment

Urban growth is seldom an orderly process and is characterised by tensions between the conservation of the landscape and expanding settlement. Marked increases in the world's population over the last century (Alberti 2005; McDonnell *et al.* 1997) are associated with urban centres extending into rural areas and 'waste lands' to accommodate the more than 60% of the total world population in towns and cities (McDonnell 2007; Meurk & Swaffield 2000). Where no

---

[1] 'City' is ill defined. It may (1) be created by charter and have a cathedral; (2) be defined by a municipal corporation; (3) be an urban centre with complex business and governance structures; (4) have a large population (Oxford Complete Wordfinder 1994). In NZ a city must have a population of not less than 50,000, be urban and be a major centre of activity (Local Government Act 2002).

'suitable' land for habitation is readily available, deforestation is common, wetlands are drained and in-filled, harbours and coastal areas reclaimed and sand dunes flattened.

In a study of the effects of urbanisation on the wetlands of Portland, Oregon, Kentula *et al.* (2004) found that 60% of the wetlands had hydrological modifications. An assessment of the ecologic condition of wetlands (including on-site impacts, off-site stressors, hydrology and vegetation, buffers and landscape use) showed only 11% of the wetlands were rated 'good', with 46% rated fair and 43% poor.

Urban centres are characteristically densely populated, highly modified areas surrounded by less densely populated suburbs and decreasing landscape modifications (Kentula *et al.* 2004; McDonnell *et al.* 1997). There are large concentrations of energy use, water, food, materials, pollution and waste matter within the urban areas. The lifestyles of urban inhabitants are directly responsible for the land cover changes that are dominated by large impervious surfaces and artificial structures, poor air quality and a warmer microclimate (see, for example, Hahs & McDonnell 2006).

By contrast, the less densely populated rural areas have lower concentrations of energy use, materials, water and human waste. It is these differences in the effects on the landscape that ultimately disrupt and may destroy intact ecosystems (Alberti 2005). A further differential from the New Zealand rural landscape arises from ruminant animals depositing nitrogenous excreta on the land and methane to the atmosphere. By comparison, industrial emissions within New Zealand urban centres are minimal on a world scale.

2.5 Urban Development in New Zealand

New Zealand is the last settled landmass in the world comprising a series of uninhabited islands and isolated in the southern Pacific Ocean until the thirteenth century. From about 1250AD, Polynesian voyagers (Maori) settled in small coastal villages (Smith 2008, p 368) and relied on a hunter-gatherer lifestyle. The natural landscape had had neither previous contact with humans nor any experience of land mammals or fast-growing plants from continental lands. Maori land ownership was communal with leadership and organisation within the pa (villages). Trading developed with neighbouring friendly iwi (tribes) but there were skirmishes with tribes competing for land and resources. Urbanisation, as recognised today, with high-density buildings, infrastructure and governance did not develop.

Contact between Maori and Europeans (explorers, whalers and sealers) began in the 1790s. In 1814, missionaries settled in North Auckland and traders soon established agricultural and horticultural trade with Sydney, Australia. When British settlers arrived in the 1840s-1850s, the landscape had already been modified by fire, pests and deforestation (Park 2003, p 184). Planned settlements post 1840 followed the usual British town plans of the time with the first towns being built around harbours and rivers (King 2003, p 168). Forests were milled and burnt, and waterways used for transport and waste disposal.

As roads and railways were constructed, the towns developed commercial centres and with rapid population growth some towns had exceeded 20,000 people by 1874 (King 2003, p 208). Twenty years later, in 1896, 25% of New Zealand's population was living in four main centres (Auckland, Wellington, Christchurch and Dunedin). The 1911 census showed that urban populations had exceeded rural populations and by 1926, 50% were living in cities. In the 2006 census, 80% of the population lived in urban areas. According to Statistics NZ (2011) the total New Zealand population had reached 4.4 million people by 2011 with 1.41 million in Auckland, 430,000 in Wellington, 389,900 in Christchurch and 117,700 in Dunedin (Statistics NZ 2011).

For some towns on flat land, for example, Christchurch, the original British town plans with their symmetrical road plans seemed appropriate particularly when wetlands could be drained to create further flat land. However, such plans fitted less well in towns and cities with hills and little flat land such as Wellington and Dunedin. Land transformation from forest and wetland to townscapes moved quickly. The development ethos of a new nation allowed little space for consideration of the ecological harm that was occurring.

2.6 Indigenous Biodiversity versus Urban Development

During the 1860s and 1870s there was a large influx of exotic flora and fauna from Britain for farming, food, and recreational hunting. The harm to the indigenous biodiversity remained unrecognised for some decades (King 2003, p 192). There was a strong desire for early settlers to have a 'comfortable' landscape and the phrases 'little England' and 'home' were commonly used when remembering their origins. Historically, urban expansion was not controlled by local councils, provincial councils or, later, by central government. Today, land use changes continue as the population increases and urban developments continue to expand into greenfields. (Brooking & Pawson 2011, Ch 11; CRC 2006; PCE 2001; Kilvington 1998).

New Zealand has had a long history of faunal extinctions with the loss of more than 30% of native birds and reptiles since human arrival. It is now also being described as "one of the world's weediest countries" (Landcare Research 2009). Many species of introduced plants and animals provide immediate threats to native biodiversity (DOC 2009). Global concerns for the loss of biodiversity and the consequent risks to humans were initially discussed at the 1971 United Nations Conference on the Human Environment in Stockholm, Sweden. This conference concluded with the 1972 Stockholm Declaration that highlighted the need for integrated resource management and sustainable development, and developed the precautionary principle for future developments affecting the environment (UNEP 1972).

During the 1980s rationalisation of the environmental laws in New Zealand was undertaken. Between 1985 and 1987, the first environmental reforms commenced with the separation of environmental protection and management functions from resource development. The latter became the responsibility of state owned enterprises (SOE) and included Crown owned land, forestry and energy resources (Furuseth & Cocklin 1995). Environmental protection was divided between DOC, responsible for the implementation of the Conservation Act 1987, the National

Parks Act 1980 and the Reserves Act 1977; the Parliamentary Commissioner for the Environment (PCE) appointed under the Environment Act 1986 as an independent officer of Parliament monitoring environmental issues and policies (Young 2007); and the Ministry for the Environment (MfE) responsible for policy development and management of the Environment Act 1986.

In 1989, the structure of local government reform resulted in widespread amalgamation of local authorities (Furuseth & Cocklin 1995). Twelve regional councils and one unitary council[2] **(**EDS 2008) were formed with the loss of regional organisations including catchment boards, rabbit boards and drainage boards (Bush 1995, p 117-119). Three further unitary councils were identified following a review in 1992 (PCE 1992).

The RMA 1991 was the culmination of the rationalisation of environmental law in New Zealand. It provided a means of using and developing physical and natural resources or protecting them. Its key focus was the sustainable management of these resources while ensuring that people and communities were enabled to provide for their social, economic and cultural wellbeing (MfE 2003; RMA 1991), and it provided for the participation of local communities through consultation in environmental decision-making.

2.7 The Resource Management Act

Section 5(1) of the RMA states that the purpose of the Act is to "promote the sustainable management of natural and physical resources". Sustainable management is defined as

> managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing, and for their health and safety while: sustaining the potential of natural and physical resources (not minerals) to meet the reasonably foreseeable needs of future generations; and safeguarding the life-supporting capacity of air, water, soil and ecosystems; and avoiding, remedying or mitigating any adverse effects of activities on the environment (RMA 1991).

The Act defines natural and physical resources as including "land, water, air, soil, minerals and energy, all forms of plants and animals (whether native to New Zealand or introduced), and all structures" (RMA 1991). The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 adopted Conference Agenda 21. This emphasised the importance of connecting developments in economic growth, social equity and protection of the environment, and of promoting broad public participation in decision-making for achieving sustainable development (MfE 2003).

The RMA focus on sustainable and integrated management of natural resources seeks to establish a balance between the protection of the environment and its development. This does

[2] Unitary authorities have smaller catchments than regional councils but carry out the combined role of regional council and a territorial authority. The first formed was the Gisborne District Council (EDS 2008). In 1992 three more were formed, Marlborough, Nelson and Tasman (PCE 1992). Auckland Council is the first unitary council for a large urban area created in 2010. It is expected that further unitary councils will be formed in the near future as a result of amendments to the LGA in late 2012.

not prevent development but does provide a mechanism for conditions of resource consent applications to include that a development may not proceed if there are adverse environmental effects or if these cannot be avoided, remedied or mitigated (King 2003, p 446).

Section 6 of the Act provides specifically for the protection of wetlands and their margins from inappropriate subdivisions.

6. Matters of national importance.

> In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall recognise and provide for the following matters of national importance:
> (a) the preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and development: (RMA 1991)

The implementation of the RMA is through a devolved hierarchy of responsibility from central government through regional councils to territorial authorities. Central government is responsible for providing National Policy Statements (NPS) on sustainable use of resources and National Environmental Standards (NES). The NPSs gazetted to date are the NZ Coastal Policy Statement 2010, the Electricity Transmission NPS 2008, the Renewable Electricity Generation NPS 2011 and the Freshwater Management NPS 2011. There are a number of NPS that have been considered and waiting adoption such as the Proposed Indigenous Biodiversity NPS (EDS 2011; MfE 2010).

2.8 Role of Central Government and the RMA

The Environment Act 1986, Conservation Act 1987 and RMA 1991 outline the role of the central agencies (MfE, EPA, and DOC) that have key responsibilities for environmental management and planning along with the independent officer of Parliament, the PCE. Their roles are briefly discussed below.

2.8.1 Ministry for the Environment

The Ministry for the Environment (MfE) was established under the Environment Act 1986 as the main advisor to the government on the environment and associated laws and policies. It has a mandate to manage natural and physical resources while taking into account the sustainability of the resources, their intrinsic ecological values and the future needs of society.

The MfE is required to provide a state of the environment report every five years that includes current information on water, air and other natural resources. The first report was *State of New Zealand Environment 1997*. However, the second report was not published until ten years later as the *State of the Environment 2007* (MfE 2007). No reason was given for the delay. A subsequent *State of the Environment* report was due to be released in 2012 and every five years thereafter. In 2011, a discussion paper to the Minister for the Environment proposed that the *State of the Environment* report be the responsibility of the Parliamentary Commissioner for the Environment thereby providing an independent report to Parliament (PCE 2011;

Both the 1997 and 2007 Reports give recognition, in a small paragraph, to wetlands as important ecosystems that have the most threatened habitats and ecosystems. They also remain under-represented as legally protected areas either public or private. A large proportion of them are on private land (MfE 2007, p 367-368). The 2007 Report commended the six wetlands that had reached Ramsar[3] (2007) status and also provided a summary of the ecosystems including wetlands that had registered covenants over them from the Queen Elizabeth II National Trust. In 2007, the 302 wetlands registered occupied 9,000 hectares.

During the 2000s there was increasing concern about delays and costs associated with planning processes under the RMA (MfE 2010). Amendments were made to the RMA in 2009 that were intended to streamline and simplify planning processes. These were the outcome of what is referred to as Phase 1 of the RMA reform. A second phase was underway at the time of writing. As well, in March 2012 the government announced an eight-point plan of local government reforms (Smith 2012; Cheyne 2012). The intention of both these reform processes is to consolidate the planning process.

An Environment Protection Authority (EPA) was established on 1 July 2011 with responsibilities for national-level resource consents and regulatory functions including processing proposals involving lands of national significance where it will make independent decisions about such proposals. Other responsibilities include decisions about Water Conservation Orders, National Policy Statements and the Climate Change Response Act 2002. The outcomes of the decisions made by the EPA will impact on policies, plans and resource consents at local government level.

2.8.2 Department of Conservation

The Department of Conservation was established by the Conservation Act 1987. Its functions are outlined in Section 6 of the Act. The country is divided into conservancies for sub-national conservation management. Each conservancy is required to prepare a Conservation Management Strategy (CMS) for the region every 10 years. A Conservation Board monitors the implementation of the CMS and reviews it every 10 years. The CMS provides a guideline for day-to-day management of a conservancy and priorities that are to be set for future management (DOC 2013).

Although DOC has little direct role in urban areas, it has a legislative role approving easements over a variety of features as well as oversight responsibilities under the Reserves Act for urban reserves and biodiversity in general. According to van Roon & Knight (2004, p 20), DOC’s relationship with regional councils is one of strong advocacy for the protection of ecosystems that are threatened and vulnerable such as dunes, wetlands, swamp forests and lowland forest remnants that are not part of the conservation estate. Protected Area status may be given to an

[3] The convention on Wetlands of International Importance, especially waterfowl Habitat was signed at Ramsar, Iran, 1971. Wetlands with Ramsar status meet international standards of habitat and care. In New Zealand the Department of Conservation acts as the Government agent for their annual reviews (see Chapter 4).

area to ensure that control, management, development and preservation of the area is appropriate under the Conservation, Reserves and Wildlife Acts (DOC 2010). Such areas in the Wellington region include Kapiti and Taputeranga Marine Reserves, the salt marshes at Pauatahanui Nature Reserve and Waikanae Oxbow Reserve. There is also a scheme for private land with significant bush areas to be registered as 'protected private land' by agreement with DOC and that is then registered on the title of the land. This mechanism has been used in some peri-urban properties on the Kapiti Coast.

The Wellington Hawkes Bay Conservancy manages 381,725 ha. The Conservancy is divided into Chatham Island Area, Hawkes Bay Area, Kapiti Wellington Area, Manawatu Rangitikei Area and Wairarapa Area (DOC 2013). Twelve percent of the conservancy is public conservation land mainly within five Forest Parks (Tararua, Rimutaka, Aorangi, Ruahine, Kaweka). It also administers hundreds of smaller reserves including a Ramsar wetland at the Manawatu Estuary and Lake Wairarapa. It has no direct responsibility for ecosystems on private land but has the power to purchase land that is at risk from urban development such as the Whareroa Farm, Paekakariki (Palmer 2008).

The first generation Wellington Conservancy CMS adopted in 1996 was reviewed in accordance with the statutory requirements of the Conservation Act but the completion and public notification expected in 2010 were delayed by the amalgamation of the Wellington and Hawkes Bay Conservancies (DOC 2013). This sort of delay, which is not uncommon, means that in many areas conservation management strategies that are currently in place are ones first prepared in the early 1990s and therefore likely to be out of date.

2.8.3 The Parliamentary Commissioner for the Environment

The Parliamentary Commissioner for the Environment (PCE) is an independent officer of Parliament giving advice on the laws, regulations, processes and agencies associated with managing and protecting natural resources. The PCE comments and reports on broad environmental issues. The PCE does, however, have the power to initiate its own investigations and to respond to citizen concern. One such investigation in 2002, *Boggy Patch or Ecological Heritage? Valuing wetlands in Tasman* (PCE 2002) was a response to concerns about wetland management in the Tasman District where agricultural production and economic values and local government practices were in direct conflict with the proposed Tasman Resource Management Plan associated with significant natural areas (PCE 2002).

The establishment of the PCE role was a direct consequence of the requirements of the Environment Act 1986. According to Young (2007, p 148), its inception reflected the failure of the population at large and Parliament in particular, to undertake the responsibility for dealing with long-term issues. In a review of the first 20 years of the PCE role, Young (2007) observed, "Many of the general public have never heard of the PCE and are unfamiliar with its reports. But from the views of the special sample selected, there is no question that its work is vital to a democratic and sustainable New Zealand" (Young 2007, p 148).

2.9 RMA and Urban Development

This section on the RMA outlines the statutory and other plans for protecting ecosystems including wetlands and landscapes within an urban environment. One of the outcomes of the RMA has been the liberalisation of the consent notification procedures with the repeal of the Town and Country Planning Act 1977. The RMA reduced the number of consent proposals that needed to be publicly notified, relying instead on robust planning consent procedures. Curran (2004) argued that non-notification served the interests of developers provided they had sought and obtained written agreement from those to likely be impacted by the proposed development (Curran 2004).

Matters of national importance are reflected in the New Zealand Coastal Policy Statement (NZCPS) and Regional Policy Statements (RPS). Regional schedules, published as part of the RPS, list regional landscapes and natural features such as wetlands, bush and heritage sites that must be recognised and protected when consideration is given to resource consent applications for land change. Section 57 identifies matters of national importance that must be considered and provided for including:

> (a) The preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and development; (b) The protection of outstanding natural features and landscapes from inappropriate subdivision, use, and development; and (c) The protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna.

The implementation of National Policy Statements such as the NPS Freshwater Management (NPSFM) 2011, is the responsibility of regional councils and territorial authorities. The latter are responsible for any land use issues that affect freshwater management, including impacts of urban development. Objective 2 of the NPSFM states, ‘it is the values rather than the wetland itself that Objective 2 seeks to protect’. However, it goes on to state, ‘the rarity of wetlands does not necessarily make all wetlands significant’, a definition ‘determined according to regional community preferences’ (NPSFM 2011, p 12). Further clauses and objectives in this NPS refer to water quality and quantity in all water bodies. Objective B4 states that “the significant value of wetlands is relevant for both water quality and water quantity”, this to be accomplished by a ‘limits-based water management regime’ and resource consenting (see section 2.11). These limitations of the NPSFM together with the principles of the RMA 1991 and amendments being primarily focused on natural resources may not extend to the urban landscape and its wetlands.

2.9.1 Regional Councils’ Responsibilities

The implementation of Section 5 of the RMA is vested in regional councils and territorial authorities. Regional councils are required to produce a Regional Policy Statement (RPS) defining their approach to sustainable management of environments of their region as part of their responsibilities under the RMA, and then to review it every 10 years. The RPS identifies the major resource management issues and presents them as objectives to be achieved within the life of the policy. The responsibilities for implementation of the methods for achieving these objectives are shared with territorial authorities (regional, district and city councils) that must produce Regional and District Plans containing policies, objectives and rules associated with resource management. Monitoring is undertaken by both regional and district councils.

The implementation of the Act has not proceeded smoothly in many instances. Monitoring, even when national standards had been set such as for water quality, has been variable and sometimes absent (Staples 2008). The overriding requirement for sustainability of ecosystems, nationally and regionally, has led to situations where bidders for land use change, rural and urban, are in conflict with groups and individuals concerned about the effects of these changes on ecosystems and landscapes. Second-generation regional and district plans, at present being drafted, are required to include Environmental Results Expected (EREs) derived from the combined effects of objectives, policies, rules and other methods in the regional and district plans (see Section 2.12).

An example of the difficulties encountered by regional councils can be seen with the preparation of Greater Wellington Regional Council's (GWRC) operative Regional Policy Statement (RPS) (GWRC 2010). The GWRC has responsibility for regional environmental management policies in the south of the North Island including the Kapiti Coast, the location of this study. The review of the previous RPS 1995 was commenced in 2008, two years later than scheduled (GWRC 2008). Public consultation was undertaken with a series of meetings and website interactions. Of the 144 submissions by individuals, groups and organisations, fourteen hundred submission points were made on the draft (GWRC 2009). The new RPS incorporated points from those submissions but was not published until 2010. In the meantime the previous RPS was operative for fourteen years. The continuing relevance of those policies was questioned by interest groups, particularly in reference to subdivision and landscape management, transport infrastructure and biodiversity protection.

2.10 The Local Government Act 2002

The purpose of the Local Government Act (LGA) 2002 is "to provide for democratic and effective local government that recognises the diversity of New Zealand communities". Section 14(h) of the Act promotes the taking of a sustainable development approach to local government by local authorities by providing for (i) "the social, economic, environmental and cultural wellbeing of communities; (ii) the need to maintain and enhance the quality of the environment; and (iii) the reasonably foreseen needs of future generations".

Each local authority is required to publish a Long Term Plan (LTP) that sets out the council's planned activities and sources of revenue for expenditure. The LOCAL GOVERNMENT AMENDMENT ACT 2013 requires local authorities to consult the public on their draft Long Term Plans (LTP) (Section 93, LOCAL GOVERNMENT AMENDMENT ACT 2013).

2.11 District Councils and District Plans

The district plan identifies the significant resource management issues of the district and the requirements for their sustainable management. Monitoring of the methods for achieving sustainable management is a shared activity with the regional council. Although the district plan has a ten-year lifespan, the original plan is rarely intact at the end of that time with multiple plan changes occurring to match current needs. These include infrastructural needs as well as land use changes. The original plan together with any plan changes normally had community input through a submission process before adoption by the territorial authority. Section 75 (1) of the RMA states that district plans must express objectives for the district and the policies and rules to implement those objectives. As well, district plans must have regard for the objectives of NPSs and the relevant RPS.

The original district plans were based on rules and regulations and had a lifespan of ten years although many exceeded this with multiple amendments. According to McRae at the NZPI Annual Conference 2003, 'First generation plans were born of ignorance of the subtlety of meaning within the Resource Management Act ...... Decades of consistent regime [Town and Country Planning Act], which led to physical changes in the environment' did not prepare councillors for the 'new emphasis on bush and landscape protection' (McRae 2003).

The second-generation district plans, now being developed, are more issues-focused and formatted to enable greater understanding of the RMA requirements. They endeavour to provide clarity to the relationship between the RMA requirement for sustainable management of natural and physical resources and the economic concept of 'sustainable development' that relies on connections between economic, environment and social performance to ensure no harm to the environment (McRae 2003).

2.12 Resource Consents

Land use changes are within the jurisdiction of territorial authorities and must be assessed against the district plan. Where an activity such as a subdivision or land use change is not permitted in the district plan, resource consent is required. In accordance with the RMA 1991, resource consent conditions associated with urban development are required to take into account all aspects of environmental disruption. For example, an increase in impervious surfaces in urban areas may lead to excess stormwater run-off contributing to significant changes to the hydrology of an area. Urban development may also destroy the equilibrium of ecosystems by disturbance of landscape-patch relationships. In wetlands this can include changes to the natural water flow, to avian flight paths, fish paths and the introduction of exotic plants.

Section 108 of the RMA 1991 allows for conditions to be placed on resource consents to ensure that the effects on the environment are managed sustainably (MfE 2009). For example, such conditions are usually standards or restrictions on an activity and are enforceable. The conditions may be reviewed should an adverse effect (such as discharge to a stream) occurs or is ongoing (as in subdivisions where the planting of exotic trees may be restricted or low-build housing mandatory).

The National-led government, elected in 2008, embarked on sweeping reforms of the RMA and LGA designed to foster economic growth through facilitating development (LGA 2011). In September 2010, the Environment Minister, Hon Dr Nick Smith released the RMA Phase 2 Reforms Discussion Paper. The principal focus of the reforms is a complete revision of sections 6 and 7 of the RMA. A technical advisory group was formed in 2010 to identify any requirements for urban planning and infrastructure reforms that would improve the economic performance and competitiveness of cities and ensure efficient, effective and integrated planning systems (MfE 2012). An independent review of Sections 6 and 7 has addressed the 'contemporary values and priorities' of current and emerging resource management issues including natural hazard risks that will now need to be considered by councils when granting resource consents (MfE 2012).

The Resource Management Reform Bill (2012) gives greater weight to economic values than to the environment. A submission from the Environmental Defence Society (EDS) notes that, 'the proposed changes [to the RMA] …. emphasise economic development, including a specific requirement to identify and assess the effects of economic growth and employment. This places undue weight on economic values at the expense of the environment' (EDS 2013). The ultimate effect on urban wetland management via the district plans and resource consents cannot be predicted.

2.13 Managing the Impacts of Development

Section 5 (2c) of the RMA provides for avoiding, remedying or mitigating any adverse effects on the environment. According to Peart (2007), 'Mitigation on its own inevitably leads to degradation' as the cumulative effects of mitigation on the landscape are not being recognised, and that, 'the ultimate result of mitigation efforts can simply be to extend the time period within which a given level of environmental degradation occurs' (Peart 2007).

The economic valuation of ecosystem services is underestimated in most development projects. Costanza *et al.* (1998**)** noted that extent of the loss of ecosystem services is seldom economically valued as there are no indicators as to their market values. Daly (1998, p 21) commented, 'If we are to avoid uneconomic growth we must be sure that the value of the natural capital services sacrificed as a result of human expansion is not greater than the value of the services gained for the expanded manmade capital'.

A survey of local authorities in 2007 by the MfE found that more than 99% of resource consents applications were approved although there is little data on the number or nature of mitigation conditions including the fate of any wetlands affected (MfE 2007a). District plans presently being prepared will require that EREs must be documented in a resource consent application and this includes any proposed mitigation. Prior to this there had been no formal framework for ecosystem relocation and monitoring (Norton 2009).

Norton (2009) suggested six principles for biodiversity mitigation in New Zealand, namely:

- avoidance of the impacts of the development at the present site before mitigation is considered
- guarantees that the mitigating action will occur
- recognition that some ecosystems cannot be replaced and therefore mitigation is inappropriate
- protection of an existing site or part thereof is always considered
- detailed ecological values are obtained ensuring that there is equivalency in the offset site
- acknowledgement of the uncertainty of the desired outcome.

2.14 Urban Design, Standards and New Developments

The publication of the New Zealand Urban Design Protocol by the Ministry for the Environment in 2005 was part of an attempt to ensure that urban design is given greater priority in urban development. In particular the Protocol recognised the importance of natural landscapes and ecosystems. It identifies seven essential design qualities, namely context, character, choice, creativity, custodianship and collaboration (NZ Urban Design Protocol 2005, p 4). It is particularly focused on the interaction between towns and cities and the natural environment stressing the importance of landscape and environment in economic success as well as health and culture.

The New Zealand Urban Design Protocol endorsed the philosophy of the Low Impact Urban Design and Development (LIUDD) research programme initiated by Landcare Research (Manaaki Whenua) in 2003. The LIUDD research programme was a six-year research programme that was trialled by district and regional councils to improve their 'social, cultural, economic and ecological aspirations' as mandated by the RMA and the LGA (Heslop & Hunter 2008). The LIUDD research programme had three general principles. The first principle was 'that human activity should respect and operate within natural cycles' (van Roon & Knight 2004, p 92) thereby minimising adverse effects on the catchment, streams and wetlands. The second principle was the optimisation of any site for development within the urban area, taking into account topography, any design and build problems, any development history and current and future infrastructural capacity. The third principle included the integration of water management from water supply to the consequences of imperviousness, stormwater piping, sewage and wastewater management (Dixon & Heslop 2008).

This latter principle is particularly important in New Zealand where there are significant impacts on waterways and wetlands associated with stormwater and wastewater from urban development (Eason *et al.* 2004). The common practice of clearing vegetation and compacting land leads to the impermeable surfaces responsible for the rapid stormwater runoff.

Many local authorities have now embraced the principles of LIUDD for new urban developments. Urban refurbishment of older inadequate infrastructure also occurs but appears to be mainly in response to functional failures rather than planned programmes. Eason *et al.* (2004) noted, however, that there is continuing discharge of sediment and contaminants into most coastal and inland waterways. Alsager (2012) reported on the contamination of Wellington Streams after rainfall events, the high metallic content arising from roof runoff and paved surfaces. Although local authorities are not required to embrace the principles of LIUDD (Eason *et al.* 2004), they are required to promote sustainable management of natural and physical resources under the RMA and LGA (Heslop & Hunter 2008). The incorporation of the LIUDD principles into the policies of the second-generation district plans would further reduce the impacts of urban development on the environment (Puddephatt & Heslop 2008).

In 2005, the Kapiti Coast District Council published a document outlining *Subdivision and Development Principles and Requirements* which was incorporated into the operative District Plan (KCDC 2005). The principles have been implemented on the Kapiti Coast at the Ferndale subdivision in Waikanae (see Figure 4). (Ferndale is one of the wetland sites studied in this research. A description of it can be found in Ch. 5, and Appendix 1). Feeney (2009) noted that some territorial authorities and their councils have been less than enthusiastic, citing difficulties with persuading property developers, builders and plumbers.

In 2010 Standards New Zealand adopted many of the LIUDD concepts in its revision of NZS 4404:2010 Land Development and subdivision infrastructure. This provides local authorities, developers and advisors with criteria for their development projects. The standard is applicable to greenfield developments, infill developments and brownfield redevelopments (NZS 2010).

2.15 Conclusion

This chapter on urban development processes in New Zealand began by tracing the history of urbanisation over the last 10,000 years. The transition of early civilisations from rural subsistence economies to large scale urban societies was the beginning of an inevitable tension developing between the use of land as a food source and its use for high density settlements dependent on the land. Latterly, this tension has extended to become a new tension between the conservation of the land, its naturalness and landscapes, and the development of the highly modified ecosystems associated with urban areas.

The global movement to protect the environment that began in 1987 with the Brundtland Report (WCED 1987) influenced New Zealand's resource management law reform processes in the late 1980s and shaped the Resource Management Act 1991. Its focus is on sustaining the potential of natural and physical resources for the future and safeguarding the life-supporting capacity of air, water, soil and ecosystems. This was a dramatic and often unpopular change of emphasis toward protecting natural resources.

Its implementation has, however, often been the focus of criticism especially in relation to its ability to guide appropriate urban development related to land use change within and near urban centres. In particular, the shortcomings of the RMA for protecting, restoring and enhancing urban wetlands are rarely acknowledged although the Freshwater National Policy Statement 2011 introduced limitations to modifying freshwater ecosystems, particularly with regard to the pollution and neglect of streams and natural wetlands. The purpose of this research is to investigate the extent to which the statutory planning framework ensures the sustainability of wetlands, particularly those in urban areas and then to explore mechanisms for achieving sustainability where it does not occur.

Although legislation in New Zealand has sought to balance the protection of the natural environment with urban development, the anthropocentric view is little changed from that in 1840 which viewed empty land as waste land and therefore available for development. Chapter three presents a literature review focused on the ecosystem modifications that occur with urbanisation.

Chapter 3 Ecosystem Modification Associated with Urbanisation

3.1 Introduction

The aim of this chapter is to review literature regarding New Zealand's environmental history and responses to urban development. Although much of the country's environmental history has been specific to the unique characteristics of New Zealand, global events over the last 75 years have influenced the local legislative approach to the effects that urban development has had on natural resources. Ecosystem modification has been widespread and often ruinous in many countries. This global awareness of the acuity of the problem has, however, not yet led to a global solution and the modification continues.

In the 1960s the public awareness of the need to protect the environment and its ecosystems from the government's 'think big' projects led to the 'reshaping of planning and environmental processes' in the form of the RMA (1991) as discussed in the previous chapter. While local government was being required to publish annual plans to account for their expenditure and consult with the electorate, central government was being forced to consider environmental issues in light of the destruction wrought by its projects. Miller (2011, p 19) comments, 'It is the clear inconsistencies between the environmental intentions of the RMA and the move to less regulation that lie at the heart of the RMA, which helps to explain the difficulties with its implementation'.

Following an outline of the international view of ecosystem modification associated with urbanisation, this chapter outlines the New Zealand experience over the last 170 years of settlement. The chapter then continues with a discussion of the complex relationships between land-use planning and the environment and the difficulties in valuing ecosystems. In the market-led twenty-first century, this has placed many ecosystems, such as wetlands, under threat of destruction for economic reasons. The far-reaching ecological effects of urbanisation can be seen in the urban-rural gradient studies providing a picture of both overt and hidden damage to ecological communities. The chapter closes with a short summary of urban ecosystems.

3.2 Intact Ecosystems

Article 2 of the Convention on Biological Diversity (CBD), adopted by the United Nations in 1992 defined an ecosystem as 'a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting 'as a functional unit' (CBD 1992, Article 2**)**. Hruby (2011) defined intact wetland ecosystems[4] 'as wetlands not degraded by human stressors i.e.

[4]Intact wetland ecosystems are defined as wetlands not degraded by human stressors i.e. an ecosystem in which the composition, structure, function, and ecological processes are within their historic range of variability i.e. native species are dominant; invasive species are absent, or if present have minimal cover; little human caused alteration of native vegetation, or vegetation has recovered from disturbance; little or no human-caused alterations to wetland topography or soils; key ecological processes are intact; no human caused changes to hydrology or nutrients/sediments, or the wetland has recovered from any changes; expected diversity of species and functional groups present (Hruby 2011).

an ecosystem in which the composition, structure, function, and ecological processes are within their historic range of variability' (Washington State Department of Ecology 2011).

Natural ecosystems provide the large variety of goods and services that sustain life, and support biodiversity, social wellbeing, economic independence and cultural values (Alcamo & Bennett 2003). The relationship between humans and nature has occurred throughout human history though it has varied from allowing ecosystem sustainability with little human input to complete human domination of the ecosystem processes and emergence of the 'urban ecosystem' (Andersson 2006; Alberti *et al*. 2003). However, as Andersson (2006) points out there is no such thing as a self-sufficient sustainable city as cities are always dependent on their hinterland. He strongly recommends a new focus on urban landscapes from ecological, social and economic aspects to increase the resilience of urban ecosystems and consequently the access to essential ecosystems (Andersson 2006).

Natural ecosystems are continuously in a state of flux as they adapt to climate, seasonal hydrology and geochemical changes. They have boundaries within which strong interactions between parameters are more important than the size and shape of the ecosystem (Hobbs 2002). Corridors for mobile fauna, plants, water and nutrients develop at the weakest part of the boundaries. It is these that determine the biodiversity and potential sustainability of landscape patches[5].

Disturbances include the loss of land cover and the ensuing impacts on hydrology. Where there is landscape disturbance from fire, drought, storms, animal and human activity (including urban development) the distribution of patches and their ecosystems changes (Cadenasso *et al.* 2008; Williams *et al.* 2005a; Hobbs 2002). It is widely accepted that where more than 60 percent of the land cover is removed connectivity between patches is disrupted, the remaining fragments are isolated, and the survival of species within them threatened (Walker *et al*. 2006). Meurk & Swaffield (2000) point out that these impacts are likely to result in the loss of any functions that the affected species may have performed.

Ecosystem modifications can have as many variations as there are ecosystems and the impacts range from mild to severe or fatal and from very gradual to sudden. The survival of all organisms depends on their ability to adapt to the continuous ecosystem modifications of which they are a fundamental part. For example, changes in hydrology are associated with increased run-off from adjacent bare land, reduced nutrient cycling, and the development of "edge effects" (Alcamo & Bennett, 2003). This latter effect facilitates invasions of weeds, such as *Clematis*

[5]Patches are elements 'of spatial heterogeneity' within boundaries. 'Patchiness focuses on the spatial matrix of ecological processes, and emphasises the flux of materials and organisms within and between parts of the landscape'. 'Patches may comprise different ecosystems, different land uses or different community types, successional stages or alternative states within a particular ecosystem'. (Hobbs 2002).

vitalba at local bush edges in New Zealand (Holland *et al.* 2010), and feral predators such as possums[6] (Head 2005).

3.3 International Studies of Impacts of Urbanisation on Ecosystems

The Millennium Ecosystem Assessment (MA) Project 2003 focused on the role of human decision-makers in determining any interventions to ecosystems. It defined direct and indirect drivers (Alcamo & Bennett 2003). Direct drivers had measurable effects on ecosystems – physical, chemical and biological. Indirect drivers included economic, cultural, demographic, scientific, technological and socio-political influences that were difficult to measure but crucial to the complex interactions within an ecosystem.

Human-induced changes may render ecosystems incapable of performing their natural functions. In particular, land transformation that modifies the structure and functioning of ecosystems is the major catalyst to altered interactions within the carbon, hydrological and nitrogen cycles (Vitousek & Mooney 1998). Urban development is a pernicious form of ecosystem modification. Although land may be denuded, forests milled and wetlands drained, the small scale of these individual activities is such that it is the damage from cumulative effects on the environment that is finally recognised such as the contamination of the Tamaki Estuary, New Zealand, reported by Abrahim & Parker (2002).

Delayed recognition of indirect or distant effects defers mitigation or remediation, sometimes for years. Economic and population growth increase pressure for development that occurs without adequate consideration for the ecosystem. As noted in chapter two, the New Zealand RMA attempts to guide development in New Zealand at the same time as providing for sustainable management but as Wheen (2004, p 273) discusses, the complex and bureaucratic, politically ideological processes of local authorities and the lack of significant redress in most situations where damage has been done, leads to continuing bad ecological practice.

Human domination of ‘natural’ ecosystems is most marked in the urban areas where human activities, including land use changes and infrastructure development, impact on the biophysical processes associated with the geomorphology of an area or the natural disturbance regimes of wetlands (Cadenasso *et al.* 2008; Alberti *et al.* 2003). The impacts from urban development are also found more remotely in the catchment supporting an urban area where forests may be milled for agricultural land or where waste management requires landfills (Antrop 2003). Chen & Jim (2008) noted that ‘urban forests are integral parts of urban ecosystems’ providing benefits to humans directly as from their timber and indirectly including green landscapes and warm climate. McDonnell *et al.* (1997) examined the ecological processes occurring along a gradient from New York city to rural areas 140km distant and found that although forests at the urban

[6] The Common Brushtail Possum (*Trichosurus vulpecula*) was imported from Australia in 1837 for the fur trade. They have spread over the entire country destroying forests and attacking bird nests for eggs and chicks. They infect cattle with tuberculosis. Possums are nocturnal marsupials. There are an estimated 70 million in New Zealand. The average density in North Island is four per hectare and they have a home range of approximately 1.5ha. (Te Ara 2009).

end of the gradient had poorer functional ecology such as poor leaf litter quality, the increased heat from the city increased decomposition rates and denitrification rates.

Other investigators have shown evidence of urban homogenisation of species (Ignatieva *et al.* 2011). Muller & Werner (2010) reviewed the literature regarding the situation in cities where the existing plant species were being replaced by a small number of widespread aggressive species. They then highlighted the role that the Convention on Biological Diversity might play in redeeming this situation. In New Zealand, McAlpine & Wotton (2009) noted that the 'consequences of biodiversity changes on ecosystem functioning is becoming increasingly critical' and that 'human activity is having a profound – and largely negative - influence on natural ecosystems in a myriad of ways, many of which have the potential to degrade the goods and services that humans depend on'.

McKinney (2006) drew attention to the homogeneity of urban development (design, buildings, gardens and infrastructure) across the world providing environments for 'urban-adaptable' species to spread at the expense of indigenous species, often 'garden escapees'. Clergeau *et al*. (2006) examined urban homogenisation effects on avifauna in Europe and concluded that species numbers were reduced with few dominant birds and that the bird communities were simplified. Williams *et al*. (2005) investigating the effects of the urban-rural gradient on the grasslands of Victoria, Australia, noted that the loss of local grass species was closely associated with urban landscape changes and disturbance regimes.

In a study of the urban patterns in the Puget Sound Region, Alberti (2005) showed that the amount of impervious surfaces and the pattern of urban development and roads were closely correlated with ecological conditions that included the density and diversity of both avian and aquatic invertebrates. Urban sprawl was associated with loss of landscape patches and loss of species. Within in New Zealand a similar pattern has been emerging although the suburban sprawl may be constrained by topography, for example, in Wellington where the steep hill suburbs have difficult infrastructural requirements for transport and stormwater management.

Stormwater management is an inevitable problem in urban development. Stormwater runoff is particularly destructive on steep slopes as rapid flow destabilises the clay banks and their vegetation causing landslips and blocked drains. A study by Goonetilleke *et al*. (2005**)** on the Gold Coast, Queensland, concluded that while street surfaces were the most important source of pollutants and the cause of increased run-off, the contribution from detached houses with gardens should not be underestimated and was significantly greater than that from multi-storey units.

The Baltimore Ecosystem Study, a long term study of the physical, biological and social drivers (urban ecology) of three principal watersheds over five counties, showed that the piping of stormwater together with the loss of urban riparian areas led to an increase in nitrate concentrations and particulate matter in urban streams and coastal waters (Cadenasso 2008).

The study focused on land cover in urban areas, both dwellings and vegetation, as a means of ascertaining the effectiveness of nitrate retention. It recognised the reduced infiltration of urban soils and that lowered water tables caused urban riparian areas to dry out, change vegetation composition and be unable to process stormwater.

3.4 Growing Ecosystem Awareness

When humans began harnessing natural resources for their benefit, the impacts of small populations on ecosystem modifications were limited. However, following the last ice age about 12,000 years ago, small groups of people knowledgeable about their environment and with limited technology were able to make cumulative changes to their surroundings (Simmons, 1993). Cultivation of crops on fertile floodplains became established and then at about 8,000 BC domestication of animals occurred (Spodek 2000, p 53).

According to Wright (2004), the first documented towns were Uruk and Ur in Sumer, Mesopotamia. Population numbers increased only slowly over time but the requirement for agricultural land grew, forests were milled and farms expanded (Wright, 2004, p 78). Wright argues that the development of hierarchical community structures led to land being overgrazed, over-ploughed and over-cropped to provide excess wealth for the community leaders. Unusable bare soil was exposed to the sun and baked hard. Deforestation was followed by flash floods that swept soil downstream. Irrigation of the parched land produced salinisation. By 4,000 BC, when crop failure had become critical the towns had disappeared (Wright 2004, p 79). The Sumerians were dependent on a single ecosystem, vulnerable to natural events such as floods and droughts. The role of the modifications to the environment by humans had not been recognised. Now, 4,000 years later, this land remains a desert and salinated (Wright 2004, p 79). Urbanisation failed because ecosystem services were not understood and so the ecosystem was destroyed.

Similarly, failure to understand ecosystem functions occurred in other regions including Iceland where in the ninth century, the Vikings removed the trees from the land to develop pasture for their cattle (McGovern et al, 1988). The Norse colonists misjudged the nature of the soils that were volcanic and not clay as in Scandinavia with the result that pastoral farming became impossible for much of Iceland when the denuded soils blew away leaving the land eroded and unable to sustain pasture (Diamond 2005, p 204 & p 273).

3.5 Global Response

It was not ecosystem modification *per se*, however, that stirred public awareness to recognise that ecosystems were failing. Instead, it was an outcome of ecosystem modification, the loss of birdsong. In 1962, Rachel Carson published *Silent Spring* highlighting the effects of pesticides on the environment (Carson 1962). The impact was startling. Established practices for managing pest plants and animals were condemned and 'modern' technology questioned. Environmentalists, such as Barry Commoner, the American politico-environmentalist, who had long attempted to alter practices in the environment were energised and developed political impact (Ivanova 2007, p 340: Hazlett 2004, Commoner 1971).

In 1968, Sweden proposed to the United Nations General Assembly that a UN conference be convened in 1972 to identify environmental problems and increase global awareness of the need for international cooperation to address them (Ivanova 2007, p 341). The United Nations Conference on the Human Environment was held in Stockholm in 1972 with the motto "Only One Earth". It agreed on a Declaration containing twenty-six principles relating to the environment and development, and on an Action Plan of 109 recommendations. Principle 2 referred to the safeguarding of natural resources including water. Principle 21 provided for States to have responsibility for activities within their jurisdiction that could cause damage to the environment beyond their borders.

The result was the establishment of either ministries or national agencies for environmental monitoring, and the creation of the United Nations Environment Programme (UNEP) (Engfeldt 2002; UNEP 1972). In 1972 the New Zealand Cabinet established the position of Minister for the Environment and created the New Zealand Commission for the Environment. In the same year, the Water Resources Council was created to have responsibility for water quality and pollution control. The functions of the Council were later largely devolved to Regional Water Boards with a focus on streams and rivers rather than wetlands (Te Ara 2011).

However, another view of the world's future was expressed in 1968 by the Club of Rome, a global think tank that comprised 85 businessmen and scientists, whose focus was less on the environment *per se* and more about the plight that humanity faced with ever decreasing resources to support it. In 1972 the Club of Rome published *Limits to Growth* (Meadows *et al*. 1972). Its purpose was to investigate five major trends identified by the think tank that were of global concern, namely increasing industrialisation, rapid population growth, malnutrition, depletion of non-renewable resources and the deteriorating environment. The report concluded that if the rate of change seen in 1972 continued, the limits to growth of the world would be reached within 100 years. It predicted that unless the exponential growth they observed was stopped, mankind would self-destruct from pollution or starvation. There was criticism worldwide of the modelling used to reach these conclusions (Beckerman 1972).

In 1974, Mesarovic & Pestel published *Mankind at the Turning Point*: *The Second Report of the Club of Rome* that sought to correct the mathematical analysis in the widely criticised report of 1972. It noted that there were many environmental factors within human control and that these needed to be identified so that action could be taken to avoid environmental and economic disaster. The environmental factors included energy use (especially dependence on oil), pollution, water shortages and famine. One scenario offered was for international cooperation and interdependence to manage the world's economy. Both Club of Rome reports were widely debated at the time and have been followed by many reports on the global economics but none have had the impact of the original *Limits to Growth.* In May 2012, the Club of Rome published a 40th year update – *2052: A Report to The Club of Rome Commemorating the 40th Anniversary of The Limits to Growth* that focused on the likely outcome of the next 40 years unless strategies were in place to increase human response to global environmental disaster (Randers 2012)[7].

The impetus from the 1972 Stockholm Conference dwindled over the following decade. This led to the United Nations General Assembly establishing an independent Commission to examine environmental sustainability. The Norwegian Prime Minister Gro Harem Brundtland was appointed Chair of the World Commission on Environment and Development (WCED) that published its conclusions in *Our Common Future,* also known as the Brundtland Report. The theme throughout the document was of the need to have sustainable development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED 1987, Ch. 2(1): Clause1). It also argued that 'sustainable development must not endanger the natural systems that support life on Earth: the atmosphere, the waters, the soils, and the living beings' (WCED 1987).

The WCED definition of sustainable development was widely debated and many compromises and rewording efforts undertaken until in 1991 the United Nations General Assembly endorsed the wording that sustainability was 'improving the quality of human life while living within the carrying capacity[8] of supporting ecosystems' (IUCN/UNEP/WWF 1991). In 1992, the United Nations Conference on Environment and Development took place in Rio de Janeiro, Brazil. Known as the 'Earth Summit', it was attended by 172 governments and many NGOs. Three major documents were agreed to - the Rio Declaration, Agenda 21, and the Statement of Forest Principles as well as two global conventions (one on biological diversity and one on climate change). The Rio Declaration focused on responsibility, liability, the polluter pays principle and the precautionary principle; Agenda 21 focused on integrating the environment into development at all levels from national to individual; and the Statement of Forest Principles reflected a global consensus on forest preservation (UNCED 1982).

3.6 Global Failure

Following the Rio Conference, the Commission for Sustainable Development (CSD) was established to ensure effective follow-up of the issues (Engfeldt 2002). Implementation of the agreements and conventions proceeded only very slowly with the gaps between rich and poor

[7] *2052- A Report to the Club of Rome*: While the process of adapting humanity to the planet's limitations has started, the human response could be too slow. - The current dominant global economies, particularly the United States, will stagnate. Brazil, Russia, India, South Africa and ten leading emerging economies (referred to as 'BRISE' in the Report) will progress. - But there will still be 3 billion poor in 2052. - China will be a success story, because of its ability to act. - Global population will peak in 2042, because of falling fertility in urban areas - Global GDP will grow much slower than expected, because of slower productivity growth in mature economies. - CO_2 concentrations in the atmosphere will continue to grow and cause +2°C in 2052; temperatures will reach +2.8°C in 2080, which may well trigger self-reinforcing climate change (Randers 2012).

[8] Carrying Capacity is defined as the number of individuals who can be supported in a given area within natural resource limits and without degrading the natural social, cultural and economic environment for present and future generations (Hardin, 1968).

nations widening, resource use vastly increasing and environmental considerations lagging behind targets.

A decade following the Rio Earth Conference, the World Summit on Sustainable Development, known as ‘Earth Summit 2002’, was held in Johannesburg. It was attended by most nations but the United States of America refused to send a delegation (Vidal 2002). The Johannesburg Declaration on Sustainable Development agreed in Declaration 19 to focus on ‘world conditions that pose a threat to the sustainable development of people’ including malnutrition; natural disasters; armed conflict; terrorism and diseases. Eight Millennium Development goals were agreed of which only the seventh was ‘to ensure environmental sustainability’. There was no reference to ecological matters and no agreement on how to ensure water management for all populations (McMichael *et al*. 2003).

In 1988 UNEP and the World Meteorological Organisation (WMO) were asked by the United Nations to establish the Intergovernmental Panel on Climate Change (IPCC) to provide governments with a clear scientific view of what was happening with the world’s climate (IPCC, 2009). Its first report in 1990 contained scientific evidence that was used as a basis for the UN Framework Convention on Climate Change (UNFCCC) treaty on reducing global warming and its consequences. Since that time, there have been three more reports – 1995, 2001 and 2007.

However, there are, and have been, many detractors from the reality of global warming and climate change, particularly because of the implications any solutions or compromises might have on large industry polluters and the burgeoning industrialisation of ‘third world’ countries. Political solutions have had little effect to date in controlling pollution.

3.7 The Impact of Urban Development on Ecosystems

Responsibility for the environment and its ecosystems has been highlighted in multilateral environmental agreements but economic growth has been given greater priority (Alberti 2005). Wheen (2002, p 269) argued that as populations expand and life-supporting resources diminish, the rhetoric increases but little occurs that make a difference to the environment. National and local authorities have largely failed to accept their responsibility for the environment in the face of political pressure for economic progress.

Antrop (2006) questioned whether landscape sustainability was a realistic goal when human factors such as changing lifestyles and economic realities could determine profound changes to the environment as demonstrated clearly in ever-changing landscapes. Although industrial agriculture has transformed land to a greater degree than urban development, urbanisation has caused the greatest irreversible loss of natural landscapes replacing them with new and often less acceptable ones. Andersson (2006, p 34), however, highlighted the importance of the positive role that urban green areas play for urban inhabitants. He stated, ‘there is no such thing as a sustainable city’, and that cities have always been ‘dependent on their hinterland for food and other ecosystem goods and services’, a theme echoed from Grimm *et al.* (2000).

In New Zealand, reports from the PCE in 2001 and again in 2003 draw attention to the patterns of development of the suburbs affecting landscape, landform, biodiversity and ecosystem function (PCE 2001, 2003). Shepherd & Ortolano (1996) developed a strategic environmental assessment (SEA) for evaluating the plans and policies of local authorities to promote sustainability principles. They recognised that definitions of sustainable development were ‘inconsistent and debatable in the literature’ and therefore they used the WCED (1987) definition for their environmental assessment of urban development. Hasse & Lanthrop (2003) observed that the most destructive of the impacts appeared to be the acquisition of land at the periphery of existing urban areas and/or the subdivision of peri-urban rural land into ever-smaller plots together with the attendant infrastructure.

Ecosystems such as forests and wetlands that become embedded within new urban boundaries are isolated from their normal ecological corridors. This pattern of urban development and landscape fragmentation is found worldwide (Miller & Boulton 2005; Alberti *et al.* 2003). Infrastructure, such as railways and roads, that bisects intact landscapes also isolates established patches and provides barriers to natural corridors, physically and ecologically (Alberti 2005; Forman & Alexander 1998). The ecological barriers include changes to drainage, loss of land cover, road pollutants and the loss of original flora and fauna followed by the invasion of exotic species tolerant of the new conditions.

The solutions to such ecological isolation are often difficult within the planning framework of urban developments. However, in 2010, Goddard *et al.* reviewed the possibility of managing or restoring corridors to ecosystem patches in an urban landscape such as Dunedin City. They proposed that recognising contiguous residential gardens as patches would foster corridors for flora and fauna to the periphery of the city.

3.8 Landscape Fragmentation

The problems associated with patch isolations and landscape fragmentation are found in all developed countries. In 1985, the German Federal Government declared its intention to preserve un-fragmented spaces as a principle of regional planning. However, in 2007, Jaeger *et al.* reported that a 1998 German Study Commission on the Protection of Humans and the Environment had found that urban sprawl had led to the loss of landscape in the four administrative regions of Baden-Wurttemberg studied. Urban development and its transport infrastructure needs were identified as the major influences in landscape fragmentation, with the effective patch size being reduced by 43% between 1930 and 2004. The reduction in patch size was from 22.92 km^2 to 13.01 km^2 when municipal roads were considered. Excluding municipal roads the loss was from 31.6 km^2 to 19.58km^2 (Jaegar *et al.* 2007). These reductions in patch size were seen as a major cause of biodiversity loss and sustainable land use throughout the study area.

Within the urban areas, Jaeger *et al.* (2007) found that municipal roads commonly caused patch isolation as a result of urban planners prioritising residents' ease of access over ecological concerns. Patch isolation was also seen as occurring when roads traversed forests or covered long distances across landscapes. Although German Federal intentions to preserve un-fragmented spaces were stated 15 years earlier, the study concluded that the policies had neither been endorsed nor implemented by regional authorities, and landscape fragmentation had continued (Jaeger *et al*. 2007).

In the USA, the Heinz Center identified seven indicators of landscape fragmentation for their State of the Nation's Ecosystems Project (Heinz Center 2008). Each state was required to report on these although initial reporting was incomplete. From 2008 regular reports from throughout the USA were published. The Heinz Center's concern for the environment is that the loss of landscape connectivity, as demonstrated by loss of habitat, isolation of remnants and the lengthwise creation of edges to remnant areas, continues despite laws and recommendations from the U.S. Federal government and state governments. Data gathered from each state by 2008 showed that the construction of new houses increased between 1990 and 2000 with the conversion of peri-urban and rural land to low-density housing. Over 1 million housing units were built on land with a pre-existing density of one housing unit per 1-2 acres (0.41 – 0.81 ha), and 2 million housing units were built on land with a pre-existing density of one housing unit per 2-10 acres (0.81 – 4.05 ha) (Heinz Center 2008).

The expansion of road networks associated with peri-urban expansion was also a concern of the USA as deforestation and forest fragmentation had altered the structure and functional connectivity of landscapes causing loss of species, changes of species and changes of landform (Kupfer 2004). Patch sizes and shape were affected, isolation of patches occurred, and roads changed the dynamics of the vegetation through which they passed due to changes to water flow, sediment yield, chemical environments and vegetation abundance of exotic species. Some sites left to re-establish after deforestation or closure of perforating roads developed second growth forest but species composition differed from the original (Bellemare *et al.* 2002).

Remnant patches, however, tended to shrink in size until they could no longer sustain re-growth and disappeared (Foster & Motzkin 2003). The lack of hard data about the effects of forest fragmentation on habitat loss, disruption of ecological processes and the ongoing environmental effects remote in time and space, had, according to Goodale & Aber (2001), frequently led to intuitive management of forests in the face of urbanisation and its infrastructure needs. Benitez-Malvido & Martinez-Ramos (2003) reported that after 19 years of fragmentation in the Amazon Forest, that the 'life-form composition and structure' in regenerating forest fragments within cattle ranches north of Manaus, was a threat to the future of rainforest species diversity. Barlow *et al*. (2006) studied the response of the understorey birds to forest fragmentation associated with logging at six sites in Amazonia and found that the diversity of the avifauna was greatly decreased in the forest fragments compared to the undisturbed forest. Other authors have shown the presence of edge effects in the Amazonian forests and the altered forest structure (Tabarelli *et al*. 2004; Laurance *et al*. 2002, 2001).

3.9 The New Zealand Ecosystem Modification Experience 1250 –1800

Natural ecosystem modifications have occurred in New Zealand for millions of years. Ice ages, severe weather events, erosion, earthquakes and volcanic activity have altered the country's landform (Campbell & Landis 2001). New Zealand's isolation for over 85 million years from any other landmass led to high-level endemism in the fauna and flora (Gibbs 2006, p 19). Gradual ecological changes occurred with the opportunistic arrivals of birdlife and seed by wind and ocean currents over time. However, from approximately 1250AD, human settlement changed the ecology dramatically with pest animals, alien plants and human habitation (Diamond 1989, p 3). Ongoing environmental changes, including long term climate change, have been reflected in the composition of the bush in the South Island and lower half of the North Island with the gradual replacement of broad-leaf-podocarp forest by beech (*Nothofagus sp)* forest (Gibbs 2006, p 77). There is evidence of forest fires over the last 3000 years throughout New Zealand probably arising from lightning strikes (McFadgen 1997) although the majority of fires that occurred more recently have been associated with human activity.

As discussed in Chapter 2, the first humans to arrive were from Polynesia in about 1250-1300 AD. Holdaway (1996) records that their influence on the environment was marked by the decline and extinction of an estimated 30 species of birds by 1800 AD and Smith (2008) noted their involvement in the decimation of the seal population in the North Island**.** The Polynesians (later called Maori[9]) brought the kiore or Polynesian rat (*Rattus exulans*) that added to the devastation of the birdlife (McGlone 1989). The kuri or Polynesian dog (*Canus lupus familiaris*) would have been a predator of ground-living birds although kuri were mainly used for meat and skins. The moa (*Dinornis sp*), large browsing birds, were hunted to extinction by about 1600AD (Gibbs 2006, p 142).

As a consequence of the human fires, bracken fern (*Pteridium esculentum*) and grassland (McFadgen 2007, p 45) replaced the forest. The dry fertile coastal areas were the first to be burnt. These areas were also the sites of settlements where middens[10] containing large numbers of moa and other avian bones have been located. The settlements were often transitory and had little effect on the landscape. Elsdon Best (1942) wrote about the cycle of burning bracken fern every three to five years to ensure stronger fern roots and then reforestation that followed when not burnt. Best (1942, p 33) noted a Maori cautionary tale: 'When brushwood is set fire and the fire does not confine itself to the place where it was kindled, no, the whole countryside takes fire'. The burning cycle occurred mainly along the

[9] Maori: name given to indigenous New Zealanders. The original meaning of the word is lost but may mean ordinary or normal i.e. usual inhabitant.

[10] Midden: an archaeological site, usually a cooking or storage pit, containing shells, bones or other evidence of food**.**

eastern side of both the North and South Islands, during the period 1400-1600AD. By 1800AD the dune forests had been permanently replaced by bracken and scrub and Maori settlements had moved inland (McFadgen 2007, p 130). The permanent Maori pa (villages) were constructed in an orderly manner following the customs and rules of their society, but the degree of urbanisation was minimal. The success of a pa was measured by the communal garden and hunter-gatherer model that remained until the nineteenth century.

3.10 Ecosystem Modification and Urbanisation in New Zealand post 1800

Large tracts of land were already deforested by the time Captain James Cook arrived in 1769. There was cultivation of taro (*Colocasia esculenta*) in the north of the country and kumara (*Ipomoea batatas*) on cleared patches of the lowlands as far south as Banks Peninsula (McFadgen 2007, p 111). The introduction of the potato (*Solanum tuberosum*) and pigs (*Sus domestica* and *S. scrofa*) saw changes in horticultural practices (Smith 2008**),** but the most destructive effect came from the accidental introduction of the European rats from ships (*Rattus rattus* and *R. norvegicus*). These proved very successful feral animals with an appetite for native fauna especially birds.

According to Smith (2008), the first Europeans to live in New Zealand were eleven sealers left behind in 1792 in Dusky Sound. They had little impact on their terrestrial environment although they built several houses and a boat. The remnants of their habitation have largely been erased by the recovery of the bush and the action of wet, acid soils. By 1802 pelagic whalers were obtaining food and water from coastal Maori settlements in Northland. Wigglesworth (1981) noted that Maori had readily embraced capitalism in the early nineteenth century. They successfully traded with Australia and Britain in N.Z. flax, timber, sealskins and whale oil. In return for exports, New Zealand received grain (wheat), animals (sheep and cattle), guns, ship iron and potatoes. The introduction of the firearms in the 1820s had a devastating effect on both coastal and bush wildlife, and ultimately was a factor in tribal and civil wars.

Permanent settlement by missionaries and traders began in Northland in 1814. Initially Pakeha[11] settlements were very small but there were great changes in the botanical landscape. Land was cleared for gardens and houses. Small farms were established for the cattle, pigs and sheep, swamps and wetlands were drained to provide fertile land and maize was cultivated as an export crop (McAloon 2002). European plants and invertebrates arrived in New Zealand through the 1830s and 1840s. The plants rapidly became garden escapees and weeds, and together with the introduced birds and a plethora of deciduous trees changed the biological and environmental patterns. The landscape in towns was also rapidly altered with the building of houses and trading posts (Park 2003, p 237).

---

[11] Pakeha is the term that was given to the pale skinned European settlers by Maori. It has become widely used throughout New Zealand (Te Ara Encyclopaedia of NZ 2011). It has no official status as an ethnic group or term but does appear as an option on the Census form.

3.11 Planned Colonisation and Unplanned Results

Planned colonisation of New Zealand occurred between 1839 and 1842 when William Wakefield's New Zealand Company responded to lobbying from prominent whaling and shipping entrepreneurs (King 2003, p 172). William Wakefield and his brother, Edwin Gibbon Wakefield, touted New Zealand as a fertile flat country and Charles Heaphy spoke of the summer climate lasting eight months (McAloon 2002). The settlers were ill prepared for the bush, swamps and hill country that they encountered on arrival (Park 2003, p 74). Town plans drawn up in London bore no relationship to the topography of the settlements. The New Zealand Company 'bought' land for settlement from Maori with little regard for prior ownership. The 1843 Waste Lands Doctrine[12] brought the settlers into conflict with Governor William Fitzroy who was concerned to ensure the rights of both Maori and Europeans (King 2003, p 196). He was ignored and replaced in 1845 by Governor George Grey who pursued the Waste Lands Doctrine to acquire land. Bush was removed, swamps drained and towns developed (Park 2003, p 47; McAloon 2002).

In rural areas, bush was burnt or milled for farming and European grasses and forbs planted changing the lowland and hill country landscapes. As the bush retreated to inaccessible hill country, the native birds went with it (Park 2003, p 173). The eastern sides of both islands were denuded by fire with an estimated seven million hectares of bush remaining after early deforestation being replaced by tussock grasslands and weeds (Anderson 2002; Holland *et al.* 2002). In the Canterbury and Otago high country of the South Island, the tall tussock that was unpalatable to the animals was burnt to allow soft native grasses to regrow. However, after burning a grazing, the slow regeneration of the tussock on the poor quality land allowed the spread of even more unpalatable native plants - *Aciphylla sp* (speargrass), *Discaria toumatou* (matagouri, wild Irishman), *Celmisia spectabilis (*mountain daisy), *Bulbinella hookeri* (Maori onion), *Kunzea ericoides* (kanuka) and *Poa cita* (silver tussock) (Peat & Patrick 1999, p 123; Dawson 1988, p 147). It also allowed the much later introduction of weeds such as *Hieracium*. In the centre of the North Island, fires and degradation of the tussock grasslands eventually made sheep farming uneconomic and regeneration to kanuka, manuka (*Leptospermum scoparium*) and beech (*Nothofagus sp*.) slowly occurred in the absence of fire (van Roon & Knight 2004, p 212).

However, the spread of pastoral farming on the lowlands throughout the country became a major factor in the country's economy. By 1861,158,000 acres (63,940 ha) of mixed tussock and grass pastures was being farmed. This expanded to 3.5 million acres (1.42m ha) by 1881 and 16.5 million acres (6.68 m ha) by 1925. Any native ecosystems were erased (Holland *et al.* 2002**),** land was fenced, wetlands drained and commercial crops made an appearance as early as 1865 (Brooking & Pawson 2011, p 26). Intensive farming practices were adopted but the deforested land sustained such management for only a few years. The soils of the deforested

[12] Waste Lands Doctrine: a doctrine developed by various European thinkers in the seventeenth and eighteenth centuries when the usual custom was that only cultivation gave rights to land. Therefore, any land not cultivated could be taken by the Crown to be turned to profit (McGlone 2003).

land were thin, acidic and impoverished of essential minerals in many parts of the country (Brooking & Pawson 2011, p 69; King 2003, p 435).

In many areas weeds and pest animals became an issue, especially rabbits that had been imported from 1838 to 1860, and had quickly adapted to the open lands (Druett 1983, p 150). Much of the Otago high country land became barren and was abandoned. The first Rabbit Nuisance Act[13] was passed in 1867 allowing rabbiters employed by Rabbit Boards to use ferrets, cats, weasels, poisons (cyanide) and dogs to control the rabbits but little was achieved and they remain a pest today together with the ferrets, stoats, cats and weasels that were also introduced as control agents (Brooking & Pawson 2011, p 82; Holland *et al.* 2002).

The Otago gold rush of 1861 increased the dispersal of the population to the interior of the South Island but the environment was decimated by the activities of the gold dredges. The rivers were turned into shingle banks with the river channelled through them and the topsoil was washed away with the tailings. A few people became very wealthy as public natural resources, such as river water, were converted into sources for private income, and riparian rights repealed to enable this (Hearn 2002, p 84).

The 1870s were an economic boom time for South Island sheep farmers with exports of wool to Britain and then, with the advent of refrigeration in 1882, the export of meat, butter and cheese. Dairy farming had had small beginnings but soon grew to occupy the fertile drained wetlands of the Waikato and Taranaki provinces (Brooking & Pawson 2011, p 37). However, the country experienced a long depression from 1885-1900 when produce export and land prices fell to low levels. Manufacturing developed to become an export-led economy from the 1890s (Hunter 2010).

Urban areas rapidly developed through the second half of the nineteenth century. Coastal shipping, roads and railways, that eventually extended from Kawakawa to Wellington in the North Island and Picton to Bluff in the South Island, ensured that towns were well provisioned (Te Ara 2006, p 71). Natural ecosystems suffered major disruptions in accessible areas. The environmental hallmarks of the late nineteenth century and the early twentieth century were deforestation for the timber industry, milling of kahikatea (*Dacrycarpus dacrydioides*) for butter boxes, drainage of wetlands for fertile farm soils, coal mining (open cast and deep mining) for fuel, farming of marginal lands, high country erosion and desertification (Mather 1982) and unplanned insensitive urban extension.

3.12 New Zealand Environmental Legislation post 1840

The first document outlining any environmental considerations for New Zealand was the Treaty of Waitangi in 1840. Although it is not a piece of legislation, it is the founding document for New Zealand and its principles have been incorporated into legislation. The Treaty of Waitangi is an

[13] Subsequent Rabbit Nuisance Amendment Acts were passed in 1881, 1882, 1892 and 1947. In 1989 rabbit control became the responsibility of regional councils (Te Ara Encyclopaedia of NZ 2011)

agreement between the British Crown and Iwi and comprises three Articles of agreement. It was signed in both English and Maori (Orange 2012). The Crown's interpretation of Article Two resulted in its acquisition of most of the South Island and much of the North Island by 1850. Orange (1990, p 64) has commented that most Maori did not understand that their land ownership rights had been removed until 1870 when the British administration withdrew from the country leaving its administration to New Zealand Government.

Park (2003, p 331 & p 311) argued that although Article Two mentioned forests and fisheries, it was not environmental concerns but ownership that became the focus of Maori resistance to land sales (Harrop 1937, p 403). According to King (2003) the relationship of Maori to natural environments was one of habitat and food supply and the care of the land was garnered around these needs. Land ownership issues erupted in the North Island into a brutal civil war in the 1860s (King 2003, p 187; Flannery 1994, p 336). The 'rebels' were punished under the New Zealand Settlements Act 1863 with confiscation of two million hectares of Maori lands (Stokes 2002). The Native Land Court established in 1862 and the Native Lands Act 1862 was designed to allow Maori to have ownership of land if their rights to the land in 1840 could be ascertained.

The first legislation to protect freshwater resources was a response to problems in the Central Otago goldfields (Natlib 2012). The Gold Fields Act 1858 provided the statutory regime for the regulation of gold mining ensuring the rights of the Crown in respect of gold mines and gold fields. There was an assumption that the Crown owned or controlled resources including minerals in New Zealand as in England. Gold mining rights allowed private mining to occur on public land, but as Hearn (2002, p 84) noted, the authorities ignored the pollution of the streams and waterways as a result of gold mining even when the freehold owners complained or took court action to prevent it. No concern was expressed about the environmental consequences of dredging the rivers where water quality was degraded and piles of tailings were, and some still are, unusable and even heritage sites (ODT 2010). On the West Coast, forests were cleared to enable access to streams containing gold (Park 2003, p 296).

In 1886, a government enquiry was held into goldfield land ownership and sludge disposal. The eventual outcome was the Mines Act 1904 which defined discharge standards from mining. The Rivers Commission 1900-01 determined the usage of the watercourses declaring many of them sludge channels and then paid compensation to the landowners who were affected. As Hearn (2002, pp 84-99) commented, the governments of the day justified these actions because the profits from gold mining were very much greater than the perceived costs of remediation of the waterways.

Coal mining, underground and open cast, began in the 1830s in Otago and then spread north to the West Coast and by 1914 to the Waikato. It was controlled initially by the Lands Act 1877 and then the Coal Mines Act 1908 which allowed mining 'in the most approved manner' but recommended that the mining do as 'little injury as possible on the land surface'. However, as

Hearn (2002, p 85) noted, governments failed to act and allowed the miners to clear the bush around the mining towns and to dump hills of waste rock and coal dust near the houses.

The other important industry of the nineteenth century was the removal of native forests for timber (Section 3.11). There was no recognition that timber was a finite resource (Park 2003, p 270). Sawmills were established throughout the country. The bush was clear-felled for farming and later for townships. Fire was used to clear the land, often out of control. The New Zealand Forests Act 1874 created the first state forests and provided milling regulations for native timbers. A Conservator of State Forests was appointed. Forest reserves were identified and the State Forests Act 1886 was passed providing penalties for destruction or damage to the forests (Swale 2000). However, in the 1890s the Act was repealed and until 1919 large areas of the forestland were given for settlements (Wynn 2002, p 100).

The conservation of ecosystems continued to have a chequered course through the late 19th and most of the 20th centuries. In 1874, following a trip to the South Island, Prime Minister Julius Vogel argued that the intrinsic values of the country should be preserved (Park 2003, p 305). However, his efforts at forest preservation did not find favour with parliamentary colleagues and no action was taken (Young 2004, p 82). The introduction of rabbits and mustelids (Park 2003, p 191) saw bird population numbers plummet. In 1891, following pressure on the government from Scenic Reserves and Conservation Societies in the main cities, Resolution Island was established as a sanctuary. It was followed by the Land Act 1892 that provided for scenic reserves to be identified (Young 2004, p 84). By 1900, Secretary Island, Little Barrier Island and Kapiti Island had all become sanctuaries.

In 1864 some protection was given to native ducks by the Animal Protection Act 1864 but it was not until 1873 that other native birds were gradually added as amendments to the Act (Young 2004, p128). The Native Plants Protection Act 1934 prohibited the removal of native plants from Crown land. Most native birds were eventually granted absolute protection under the Wildlife Act in 1953 (Te Ara 2009; Wheen 2002, p 263; Star & Lockhead 2002, p 123).

National Parks were first established in 1894 following the gift from Te Heuheu Tikino IV in 1887 of the three volcanoes in the Tongariro National Park – Tongariro, Ngauruhoe and Ruapehu. This was followed by Egmont National Park in 1900. Park (2003, p 318) ascribes the creation of these National Parks to tourism and scenery and not conservation. During the first decade of the twentieth century environmental legislation had an emphasis on scenic and recreational activities in the countryside, water quality and protection of areas of beauty. As well as protection of national parks and reserves, protection was also given to forest remnants in or about cities including the inner Town Belts in Wellington and Dunedin, the Waitakere Ranges in

Auckland and Riccarton Bush in Christchurch (Park 2003, p 318). By 1907, 1.21m ha of land had been reserved in National Parks, and 6.88m ha in state forests[14].

The Scenery Preservation Act 1903 included protection for forests and tourism but not for ecological or conservation reasons although the politician, Harry Ell, raised the issue twenty times between 1901 and 1903 (NZH on line, 2007). In 1904 a Scenery Preservation Commission was appointed. The Swamp Drainage Act 1915 gave the Crown permission to drain swamps on all lands, public and private, for their purposes. Initially this was to be at Waihi and Kaitaia but was used throughout the country (Park 2003, p 156). It was repealed in 1947.

3.13 Grasslands, Forests and Conflicts 1920-1960

Following two World Wars and the Great Depression of the 1930s, the protection and conservation of natural resources was a secondary consideration to economic, health or safety concerns. However, deforestation of the hill country for farming continued and a ‘grasslands revolution’ gained momentum (Pawson 2008). In 1922, the Wellington daily newspaper the *Evening Post* commented on the politics of increasing grasslands, ‘Are there not already enough object lessons of the consummate stupidity of the policy of growing one blade of grass where two trees grew before?’ (cited in Brooking & Pawson 2011, p 209). The grasslands were enhanced in 1949 with the advent of aerial topdressing of superphosphate using adapted surplus World War 2 military planes (Maber 2012).

Productivity associated with increased stock units was a feature during the 1930-1950s period when over three million tons of superphosphate was applied to farmland (Hopkins & Wilkins 2006). Sheep numbers reached a peak of thirty million by 1949 and increased to seventy million by 1972 before declining again (Brooking *et al.* 2002). By 2002, 39% (100,000km^2) of arable land was in grass according to *Environment New Zealand 2007* (MfE 2007b, Ch. 9).

Gorse (*Ulex europaeus*), introduced in the 1860s as a hedge plant, became a major pest as it spread throughout deforested farmlands and hill country. The herbicide 2,4,5-T, a defoliant developed by the American military during WW2, was introduced post war to control gorse and other woody plants including manuka. It was banned in 1988 (MfE 2011d). Currie (1959) reported trials of aerial spraying of gorse in the Raglan hill country. The concept was that the gorse would be contained until it was dense enough to burn and then once burnt could be over-sown with pasture mix and top-dressed. The practice was widely followed, and ‘out-of-control’ fires burnt many hectares of land including native shrubland and swamp. Other herbicides including DDT were also developed and widely used to control weeds.

---

[14] In 2009, the fourteen National Parks occupied 3.09 million ha. Other types of protected areas had also been created including Conservation Parks, Nature Reserves, Scientific Reserves, Historic Reserves, Scenic Reserves and Marine Reserves. Smaller special areas such as sanctuaries, wildlife refuges and wilderness areas have restricted public access. There are also three World Heritage[14] sites and six Ramsar wetland sites (Te Ara, 2009).

Many farmers had herds of goats for gorse control but the goats were mainly interested in young gorse rather than the mature plant. Sheep would also eat young gorse but not adult plants. Guthrie-Smith in *Tutira: the Story of a sheep station* described the need to have goats and cattle for gorse, blackberry and bracken fern control on relatively poor land (Guthrie-Smith 1953). Radcliffe (1984) reported on a two-year trial of goats alone and a goat/sheep mix for gorse control on the hills of North Canterbury. He found that a high goat stock rate (35/ha) was the most effective control. Many goats became feral causing damage to bush and land.

In the 1930s, the success of pastoral farming was allayed in some regions, particularly the east coast of the North Island, by severe soil loss due to heavy rain. Soil conservation was encouraged but not the replanting of the deforested hills (Cumberland 1944). The Soil Conservation and Rivers Control Act 1941 enabled the establishment of catchment authorities whose role was to develop catchment and farm plans for soil, flood and vegetation management (Cumberland 1981). The resistance of farmers to reforesting their vulnerable land continued until the 1950s and continues in some regions (Page *et al.* 2008).

The drainage of swamps and marshes for forestry was enabled by the Land Drainage Act 1910 (Young 2004, p 111). Forestry gained momentum from 1925 onwards with the establishment of the Monterey pine (*Pinus radiata*) in the central North Island in response to a predicted shortage of milled native timber for housing. The estimation of the time to maturity of native timber was very long with beech taking 80-120 years, kauri 135-150 years and the podocarps having slow growth and poor regeneration (Roche 2002).

The Forests Act 1921 established the State Forest Service (renamed New Zealand Forest Service after WW2). Its Director, Leon Ellis, spearheaded the planting of 300,000 acres (121,400 ha) over ten years of *P. radiata*. In 1939 the next Director of Forests, Alex Entician, began lobbying for pulp and papermaking but it was not endorsed by the Government until 1949 when the timber from the Kaingaroa State Forests was sold to the Tasman Pulp and Paper Ltd (Roche 2002). This led to the development of the ‘boom towns’ of Kawerau and Tokoroa.

The Forests Act was amended in 1949 and in 1952 the Waipoua Kauri Forest was made a sanctuary under the Act thus preventing further milling of kauri (Young 2004, p 148). The debate about the use of native timbers for pulping did not die, however, as the milling of some private beech forests on the West Coast continued. The presence of indigenous biodiversity in plantation forests was reviewed by Norton (1998) who found that many indigenous plants and animals coexisted with the pines. Some depended on the buffering effect of the trees and others used the connectivity of patches to advantage.

In 1981 the threat of logging rimu and miro in the coastal swamp forests at the edges of Okarito Lagoon was averted following vigorous campaigning by conservation groups. This joined similar campaigns for the West Coast beech forests in 1975, Pureora forest in 1978, Whirinaki Forest in 1984 and the Cook River forests in 1987. However, many other rainforests continued to be milled until a moratorium in 1981 (Young 2004, p 187).

Urban development continued alongside the agricultural and forestry industries. Although there had been two failed attempts at establishing state housing for workers and jobless people (1905 and 1921), it was the first Labour Government in 1935 which was successful when it built wooden houses for people to rent at 25% of their earnings. The collapse of the previous efforts was said to be because the construction costs and rents were too high. In 1939, 5,000 state houses were built with 400 different designs and then after WW2 10,000/year until 1950. The housing was concentrated in suburbs, initially independent dwellings but in the 1950s new housing was built in higher density apartments (Housing NZ 2013).

The economy was slow to recover following the Great Depression of the 1930s but WW2 was economically beneficial as it stimulated demand for New Zealand food needed by Great Britain, especially meat, as well as wool and other commodities (Reserve Bank 2007). Public works projects including new roads and bridges were built, the population grew and houses were built. The country became more reliant on road transport. The environment began to be important again. Possum control with biodegradable 1080 (sodium fluoroacetate) commenced in 1954. The bait initially had ground-based distribution but as the areas to be covered were large, aerial drops were introduced (Isern 2004, p 236). There was opposition from hunters and environmentalists as it was poisonous to all mammals including dogs. Concerns about waterways contamination were not upheld by any scientific investigations (Eason *et al*. 2011; Suren 2006). With possum control, bird populations and trees recovered in treated areas (Urlich & Brady 2005) and the incidence of bovine tuberculosis declined (Porphyre *et al.* 2007).

The major environmental legislation in the 1950s was the Wildlife Act 1953 which provided protection for most species of wildlife native or introduced. Game birds (e.g. ducks, Canada geese, pheasants) and animals (e.g. thar, chamois, white tail deer) were given a lower level of protection although harvesting them could require a permit. Native birds, bats, reptiles and frog species were absolutely protected.

3.14 The Conservation Movement – from 1960

A fundamental change in environmental thinking occurred in the 1960s with the threat to the naturalness of Lake Manapouri from hydroelectric development. The battle was bitter with the government determined to proceed and then obtaining the water rights for the Crown. In 1969 an environmental-impact report was finally published and in 1972 a change of government determined that the lake levels had to be maintained at normal levels. The Manapouri-Te Anau Development Act was amended in 1981 to provide for ‘Guardians for the Lakes’ to be involved in the relationship between the developers and conservation (Mark 2000).

The ‘Save Manapouri’ campaign resulted in increased public awareness of the environment and conservation. The Nature Conservation Council operated from 1962 to 1990 to oversee the

Manapouri Power scheme (Te Ara 2009). Environmental impact assessments became mandatory for all government projects. Nevertheless, some decisions on developments continued the apparent bias to economic development over environmental conservation.

A second campaign 'Save the Whales', that was launched in 1971 also changed government policy culminating in the Marine Reserves Act 1971 and the Marine Mammals Protection Act 1978 (Bess 2010). A third campaign to save the West Coast beech forest resulted in the formation of the Native Forest Action Council that, together with the Friends of the Earth, negotiated a compromise solution to milling native beech. The emphasis was on natural, intrinsic and scientific values of the forests (Tilling 1992).

Amendments to the Town and Country Planning Act 1953 were made in 1973 to protect the coastal and lakeshore areas, recognising 'that coastal land was matter of national importance but not fixed quantity' and that there should be 'retention in sufficient quantity of the native coastal flora and fauna in its natural state as well as the unique and the typical coastal scenery' (Waikato Regional Council 2013). Unfortunately, these amendments were not achieved (Hilton 1992) and the Act was repealed in 1991. The Clean Air Act 1972 addressed air pollution from industry and household fires by control of emissions but had minimal air quality measures (Furuseth & Cocklin 1995). It was repealed in 1991 because of the RMA.

Hydroelectric power facilities continued to be built with considerable destruction of the landscape (MacFarlane 2009). In 1982 the Clyde dam was built on a site selected by politicians and not geologists, the valley was flooded, orchards and the town of Cromwell destroyed. Once again the government assumed the water rights with the Clutha Development (Clyde Dam Empowering) Act 1982. The scheme was widely criticised and, although the government lost a series of court cases regarding the allocation of water resources and breached important constitutional conventions, the dam went ahead (Memon 1989).

The enactment of the RMA (1991) with its focus on sustainable management introduced a theme that was incorporated into other natural resources acts such as the Fisheries Act 1996 according to Wheen (2004, p 273). Sustainable management was also introduced for all indigenous forests, private and Crown owned, by the Forests Act 1993 (Young 2004, p 227). But the notion of sustainable management has proved an anathema to many individuals. According to Young (2004, p 228), neither all fishermen nor all forest owners complied with the sustainable management regulations imposed on them and this situation remains a continuing issue for Crown negotiations (Straker *et al.* 2002). Disputes over land use, water use and riparian rights may be considered by the Environment Court. However, attempts to ensure that there is no preference for environment over development leaves many people dissatisfied with the outcome. There is a feeling that those with financial resources always do best for themselves and seldom for the environment (Wheen 2004, p 273).

The New Zealand Biodiversity Strategy (NZBS) was launched in 2000 nearly a decade after the Convention on Biological Diversity was published. The four goals of the strategy are to:

> enhance community and individual understanding about biodiversity, and inform, motivate and support widespread and coordinated community action to conserve and sustainably use biodiversity;
>
> actively protect iwi and hapu interests in indigenous biodiversity, and build and strengthen partnership between government agencies and iwi and hapu in conserving and sustainably using indigenous biodiversity;
>
> maintain and restore a full range of remaining natural habitats and ecosystems to a healthy functioning state, enhance critically scarce habitats, and sustain the more modified ecosystems in production and urban environments;
>
> maintain the genetic resources of introduced species that are important for economic, biological or cultural reasons by conserving their genetic diversity (NZBS 2000).

It has a framework of ten themes to support implementation by DOC and other government agencies (MfE 2000) and its themes are expected to be incorporated into second-generation district plans (Miller 2011, p 82).

In 2007, the Minister of Conservation abandoned a proposed NPS on Indigenous Biodiversity and replaced it with a Statement of National Priorities in the NZ Biodiversity Strategy that included biodiversity on private as well as public land. These ‘national priorities were intended to protect

1. Indigenous vegetation associated with land environments
2. Indigenous vegetation associated with sand dune and wetlands: ecosystems that have become uncommon due to human activity
3. Indigenous vegetation associated with ‘originally rare’ terrestrial ecosystems
4. Habitats of acutely and threatened indigenous species’. (MfE 2007a).

The response from territorial authorities has been variable but all have included biodiversity within their planning documents. Freeman & Buck (2003) developed a strategy for ecological mapping for urban areas using Dunedin City as an example of the mechanism for ensuring that the urban biodiversity was addressed in policy and planning for a city. Their research focused on current habitats, both indigenous and exotic, and the mapping of these in detail. As expected the overwhelming flora was exotic in the residential gardens but differed in species from the peripheral farmland. There was very little indigenous flora but native birds had adapted to the urban environment (Freeman & Buck 2003). Other New Zealand cities have also developed policies for management of biodiversity including Wellington City Council’s ‘Biodiversity Action Plan 2007’ document that includes the streams, estuaries and wetland areas within the city precinct (WCC 2007).

Section 31 of the RMA 1991 requires that

> Every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:
>
> (a) ....

> (b) the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of—
>
> (i) ....
>
> (ii) ....
>
> (iii) the maintenance of indigenous biological diversity.

and the proposed Regional Policy Statement objectives (3 & 16) and policies (22, 23, 46 & 61) provide direction for the local authority to maintain biodiversity (KCDC 2010c, p 9).

The Kapiti Coast District (KCDC) 2010 Plan Review Discussion documents have focused on the council's obligations under the RMA 1991 including restoration and maintenance of biodiversity. The biodiversity discussion paper comments that there are no environmental indicators or environmental performance standards to ensure the national priorities are included in district council plans and that the lack of monitoring of biodiversity outcomes 'remains a serious problem for local government agencies trying to formulate RMA plans' (KCDC 2010c, p 8).

3.15 The Urban - Rural Gradient

New Zealand's environment history, as outlined above, focused on the ways in which the impacts of environmental damage associated with urban development and deforestation had on the legislation of the country. While the legislation, rules and regulations may be effective in altering 'current practice', the ecological effects of urban development extend widely beyond urban boundaries into the hinterland and waterways and are cumulative and long term. Wetlands associated with urban expansion are particularly vulnerable to the effects of pollution, patch disturbances and invasion of exotic plants, as their integrity remains largely invisible to most of the population. Although the research into the ecological urban-rural gradient is limited in New Zealand, there is a growing focus on it in the international literature.

In Australia, McDonnell & Hahs (2008**)** used urban-rural gradient studies to analyse the ecological outcomes of urbanisation. They identified four major characteristics of urban-rural gradients, namely new land cover, altered chemical and physical environments, new assemblages of organisms and altered disturbance regimes. They recommended the development of specific measures for ecological patterns within urbanisation. Their index included variables such as species richness, land cover and the population density per urban area. They reviewed studies published between 1990 and 2007 of peer-reviewed journals. The results confirmed the emphasis on the distribution of flora and fauna (Williams *et al.* 2005a, 2005b**)**, nutrient recycling (Walsh *et al.* 2005), pollution (Goonetilleke *et al.* 2005; McDonnell *et al.*1997**)**, water quality (Holland *et al.*1995) and landscape structure (Hahs & McDonnell 2006; Kentula *et al.* 2004**)**. The finding of all these studies was that there is an urban-rural gradient affecting natural ecosystems, that it is complex and may not be strictly linear (Alberti 2005; van de Ree & McCarthy 2005; Williams *et al.* 2005).

Kowarik (2011) discussed the importance of cities for biodiversity conservation. He noted that where urbanisation was occurring, forest specialist species or those species incapable of flight were more commonly found in suburban and rural areas, while mobile species predominated within the urban core. He concluded,

> urban areas cannot substitute the functioning of natural ecosystems as habitats for a broad array of species, including .... species that are highly sensitive to fragmentation. However, there is an increasing body of evidence that individual urban habitat types .... can add a significant contribution to biodiversity conservation.
> (Kowarik 2011, p 1979).

Williams *et al.* (2005a**)** studied the fragmentation of grasslands associated with increasing urbanisation around Melbourne, Australia, over a 15-year period (1985-2000). In the study area of 188,000ha they found 23% of the grasslands area had been destroyed by development and 21% degraded to 'non-native grassland'. The number of patches had declined and the distance between patches had increased. Grassland patches within 20km of the city centre or 1200m of a major road were most likely to be destroyed. The rate of destruction declined at a relatively constant rate with distance from the central business district. Ownership of the patches appeared to be significant with those owned privately or by the government, and near major roads or near Melbourne city more likely to be destroyed. The protection given for areas of 'biological significance' was variable and often ignored.

Another study by Williams *et al.* (2005b) of the species composition of native temperate grassland fragments along an urban-rural gradient in western Victoria, Australia, showed that between 1979 and 1990, there was a higher local extinction rate of species in urban landscapes (37%) than in peri-urban landscapes (27%) or rural landscapes (20%). The rural sites were more than 93 km from Melbourne CBD, peri-urban sites 16-75km and urban sites 10-16km. Further analysis of the species composition indicated that those species that had survived within the urban environment had particular attributes which rendered them less sensitive to urbanisation such as heavy seeds (not airborne).

In an investigation of a transect 140 X 20km from New York through red oak forests to Lichfield County, McDonnell *et al.* (1997**)** showed that there was an overall pattern of a non-linear reduction in human population density, traffic volumes and the area of built up land with increased distance from the urban core. However, the percentage of forested land and sizes of forest patches increased with distance in a linear manner, urban air temperatures were 2º-3^{0}C greater than rural ones, urban air quality was poorer and soil metals (lead, copper, nickel) within the forests had higher concentrations nearer the urban core. Although the leaf litter layer in the forests was deeper with distance from the core, its decomposition was slower possibly associated with lower temperatures affecting earthworm activity.

The harmful nature of urban sprawl into the hinterland studied in USA cities, has only recently been recognised, probably because it is usually slow, often decades, allowing many adaptive systems to develop between humans and ecosystems during that time (Alberti *et al*. 2003)**.** The adaptation of an urban ecosystem may initially appear to be successful with mixed composition ecosystems. However, with intensification of urban development, the introduction of exotic species within an ecosystem generally leads to the loss of the endemic species, a process heightened by the reduction and loss of natural disturbance regimes especially in wetland areas (Alberti *et al.* 2003). Patz *et al.* (2004) have drawn attention to the increasing level of human disease occurring with urbanisation ranging from this increased contact with wildlife (e.g. bears in Canadian towns), water- borne diseases (e.g. schistosomiasis in Egypt) and mosquito-borne diseases (e.g. dengue fever in the Pacific Islands). Pollution, water management, waste mismanagement, vector ecology and urban microclimates are some of the issues that have conspired to spread disease in poor countries.

There is a small New Zealand literature about the use of specific urban-rural gradient indicators around the cities and towns. Crisp *et al*. (1998) showed an increase in coleoptera numbers in peri-urban native vegetation compared to urban areas. Clarkson *et al*. (2007) found that indigenous land cover in urban areas was 80 percent less than in peri-urban areas and had lower biodiversity. They noted that some remnant areas of indigenous biodiversity needed protection urgently including some rivers and freshwater water bodies and recommended that there be a national programme to increase the biodiversity of the cities. Another New Zealand urban-rural gradient issue is point source water pollution particularly from sewage treatment plant overflow into streams or rivers, and leachate from landfills affecting soils and groundwater (MfE 2007a; Harding 2005).

In 2012, the PCE report on *Water Quality in New Zealand: Understanding the science* addressed the three main pollutants in New Zealand – pathogens, sediment and nutrients, from rural, industrial and urban sources (PCE 2012). The report drew attention to the need for local government to address the problem of freshwater contamination in their policies and plans as a matter of some urgency. The PCE reported President of Federated Farmers, Bruce Wills (2011) saying that, 'If we've got a dirty river let's understand why it's dirty and what science can tell us about fixing it...'(PCE 2012, p 5). Unfortunately, as North *et al.* (2003) noted, the environmental effects of pollutants may not be recognised for some time and at some distance. Harding *et al*. (2005) found contamination of freshwater downstream of source with heavy metals including cadmium, zinc and mercury, led to altered behaviour, impaired physiology and increased susceptibility to disease among invertebrate larvae and crustacea. Russell (1993) described the process as the 'ecology of the subtle'.

3.16 Valuation of Ecosystems

The economic valuation of ecosystems encompasses their ecological, physical, cultural, aesthetic, conservation and recreational functions as well as the values derived from their existence and services to humankind according to Costanza *et al.* (1998**).** For many ecosystems there is also a scarcity value as urbanisation increases with its attendant acquisition of land for dwellings and industries – forests milled, wetlands drained, rivers channelised and coastal dunes destroyed (Pearce 2001; Mitsch & Gosselink 2000). The actual value of ecosystems, as represented by their services, has proved difficult to calculate as it requires a multidisciplinary approach that may include economists, conservationists, users, land owners, businesses, lawyers and local, regional and national authorities (Liu *et al*. 2010). Another confounding factor is the recognition that the income derived from many of the ecosystem services never enters the market.

In 2002, a senior environmental adviser to the World Bank, Robert Goodland, when asked 'how valuable is an ecosystem?' and 'Valuable to whom?' suggested that economic valuation should (a) determine the total benefits that an ecosystem provides; (b) determine the net benefits of an intervention in an ecosystem; and (c) understand how the different costs and benefits are to be distributed (Goodland 2002). He also emphasised that, because knowing the value of natural ecosystem services is only of use if they are to be retained, identifying potential financing for conservation is essential. The comparison of the net benefits that a group would receive without conservation with those that the group would receive with conservation is likely to influence any decision-making regarding ecosystem values.

The value of a wetland ecosystem in the Tasman District, Nelson, New Zealand, was the subject of a report by the PCE (2002). The response to the potential loss of the Tasman wetlands was an insistence that the Tasman District Council should identify the values of the wetlands, undertake an extensive investigation into their sustainability, their extent and significance as a resource. The PCE further noted that wetlands were not just patches of land for alternative land uses and could not be evaluated simply in economic terms, but had 'ecosystem and recreational values to society' (PCE 2000, p iv). However, the PCE also acknowledged that a wetland, if drained, had an economic value that would not be realised and that further funding was required from national or local government for the protection of the wetlands.

New Zealand literature on ecosystem services has had a heavy focus on agriculture, conventional and organic. Sandhu *et al.* (2008), investigating the value of ecosystem services to 29 arable farms on the Canterbury Plains, asserted, 'that conventional New Zealand arable farming practices can severely reduce the financial contribution of some of these services in agriculture whereas organic agricultural practices enhance their economic value'. In 2010, Sandhu *et al*. described the value that ecosystem services (biological control, pollination, nutrient cycling and soil formation) and ecotechnologies would have for small-scale farmers.

MacLeod *et al*. (2008) in a study of bird ecology and management in New Zealand's agricultural landscape, expressed concern about New Zealand's agro-ecosystems and its avifauna, noting that little concern was paid to the removal of natural habitats for endemic species in favour of production land bereft of bush. They suggested that there needed to be a new focus in addition to the major efforts used for the preservation of critically endangered birds in favour of an integrated approach to the habitat and ecological requirements of endemic species within agro-ecosystems (MacLeod *et al.* 2008).

In 2004, Ecological Economics Research New Zealand (EERNZ)[15] was established at Massey University to carry out research using methods of ecological economics and in particular to measure the value of ecosystem services (EERNZ 2010). The integration of socio-economics and ecological economics underlies their programme of environmental valuation and their research results are promoted to regional councils and governments departments (EERNZ 2012).

The impact of change on an ecosystem service may be able to be estimated by the change in economic value when there is loss or change of function. An example highlighted by the Millennium Ecosystem Assessment (MA) project, is the change in the value of the benefits from a forest after deforestation causing changes in hydrology leading to a change in the availability of water for irrigation and a change in the production of irrigation-dependent produce and thence a change in household income (Alcamo & Bennett 2003). However, most of the ecosystem functions thus their values are not identified (Pearce 2001).

The MA project on Economic Costs and Benefits of Ecosystem Conversion (2005) compared the total economic value (TEV) of sustainable ecosystems that were converted to alternative unsustainable management (Alcamo & Bennett 2003). This showed that the economic value of conversion to agriculture or urban areas did not usually favour the change of land use. Examples cited by the MA included the conversion of a mangrove system in Thailand to aquaculture (shrimps) where the TEV was reduced from a possible $36,000/ha to $200/ha; an extensive drainage of Canadian freshwater marshes for agriculture reduced the TEV from $5,800/ha to $2,400/ha; and that a conversion of tropical forest to small scale agriculture or plantations in Cameroon reduced the TEV from $3,400/ha to $2,000/ha.

There are many methods for estimating ecosystem values depending on the services and (Randers 2012)[16] benefits that are derived from the ecosystem. These may be categorised into direct use values derived from marketable commodities e.g. wood from forests for building; indirect use values associated with an ecosystem's natural function e.g. flood protection by wetlands; option values related to preserving an environment for possible future use e.g. biological diversity and with urban wetlands a non-use or existence value (Brander *et al*. 2006; Pearce 2001).

---

[15] The Ecological Economics Research New Zealand is now known as the New Zealand Centre for Ecological Economics (NZCEE).

[16] While the process of adapting humanity to the planet's limitations has started, the human response could be too slow. - The current dominant global economies, particularly the United States, will stagnate. Brazil, Russia, India, South Africa and ten leading emerging economies (referred to as 'BRISE' in the Report) will progress. - But there will still be 3 billion poor in 2052. - China will be a success story, because of its ability to act. - Global population will peak in 2042, because of falling fertility in urban areas - Global GDP will grow much slower than expected, because of slower productivity growth in mature economies. - CO2 concentrations in the atmosphere will continue to grow and cause +2°C in 2052; temperatures will reach +2.8°C in 2080, which may well trigger self-reinforcing climate change (Randers 2012).

Lambert (2003), Cho (2008) and Ramachandra *et al.* (2005) have discussed in detail the role of wetland ecosystem TEVs in market failure. They all noted that if ecosystem functions of potential economic value were to be traded outside markets or if their actual value was not realised, then it would not be acknowledged in TEV calculations. The valuation of ecosystems such as wetlands will always vary according to the possible alternative uses of the area and the wants and/or needs of people to have short-term returns on any enterprise rather than a long-term view of benefits of an intact ecosystem (Lambert 2003). The lack of promotion of the values of urban wetland functions is also evident in local government plans (for example KCDC 1999) where only those established natural wetlands with documented ecological (biodiversity and cultural) values are identified.

3.17 Urban Ecosystems

Human interactions with ecosystems have accelerated over the last 300 years to the present situation where more than 40% of global primary production is used by the more than 60% of humans who live within urban areas (Vitousek & Mooney 1998). Cities are dynamic ecosystems subject to continuous change (Alberti *et al.* 2003). The threats cities impose on urban and non-urban ecosystems arise from their tendency to (a) disrupt other functioning ecosystems (local and global) with infrastructure development, hydrological interference and waste disposal; (b) ignore the biotic or biodiversity elements of ecosystems; (c) pay little attention to the ecological landscape; and (d) fail to consider any cultural values that may be important (Ehrenfeld 2000; Vitousek & Mooney 1998).

Although the expansion of impervious surfaces in towns and cities is obvious, most people pay little attention to their environmental impacts. According to Miller & Boulton (2005) ignorance and disinterest, even in the face of education and publicity, have meant that environmental values for most of the population are confined to parks and public gardens (Kilvington *et al*. 1998). Urban streams suffer particularly poorly in this situation with inadequate riparian areas, channelisation, dams and ponds created for visual effect. Suren (2000) has noted that in New Zealand where natural riparian areas remain, the biological integrity of the stream is higher than if deforested. Where the riparian replacement is with exotic trees that have only autumn leaf fall, unlike the evergreen trees with leaf fall all year, the macroinvertebrate assemblages vary considerably from the natural fauna.

Alberti's 2005 study of urban ecological impacts on Chicago urban forests (mixture of diverse species including white ash, mulberry, green ash, Norway maple, elm) showed that there were positive ecological effects from the forests' influence on the microclimate, a reduction of atmospheric pollutants and provision of a local carbon store. They also contributed to community recreational and aesthetic values and sense of wellbeing (Alberti 2005). Ecologically the diversity of species was an advantage in the face of disease or pest invasion such as the gypsy moth (Nowak *et al,* 2010). Distortions of natural disturbance regimes were a major threat to the health of these urban forests. The sharp boundaries imposed on them within the landscape encouraged weeds and predators. Lack of connectivity between ecosystem patches remained a deterrent to biodiversity in both wetlands and forests.

A study in Puget Sound by Alberti *et al.* (2003) found that ecosystem functions were best served in suburban areas with 'single family residences', where the land cover was less disturbed and fragmented, and impervious surfaces had less effect on ecological conditions. However, Southerland (2004) warned that suburban (dispersal[17]) development could result in adverse effects on air, water and land through the cumulative effects of small impacts. These impacts included transport infrastructure, landform changes such as levees, and poor water quality from runoff from impervious surfaces. He also commented that suburban development would adversely affect terrestrial habitats in wetland, stream, lake and coastal ecosystems. Ladson (2005) drew attention to the role of urban impervious surfaces in stream degradation.

Wright *et al.* (2007) surveyed upland streams near Sydney over a six-year period using macroinvertebrate indicators. They found that streams draining the urban catchments and their impervious areas had marked ecological impairment with poor water quality, altered water chemistry, loss of pollution sensitive macroinvertebrates and invasion of pest species. The urban waterways were mildly alkaline and the upland streams were acidic.

As discussed in Chapter 2, the reduction of imperviousness is a major theme in Low Impact Urban Design and Development that has been adopted by New Zealand Standards in NZS4404. This is an attempt to preserve natural ecosystems, or provide systems that do not destroy them, while allowing urban growth (Eason *et al.* 2004). LIUDD is also included in the guidelines for the second-generation district plans now being compiled by New Zealand territorial authorities for the next decade (Quality Planning 2009).

3.18 Landscape Mosaics – Culture, Restoration and Recovery

Urbanisation has determined that many landscapes have changed irreparably, structurally and functionally, and that fragmentation of natural ecosystems occurs rapidly. This does not allow adaptation to the new situation, thus leaving isolated patches. Ignatieva *et al*. (2011) have drawn attention to the focus of many urban restoration schemes where the goal is to have geomorphic stability rather than recovery of intact ecosystems, patches and corridors. Such goals aim to protect property and infrastructure and do not prevent threats such as stormwater rapidly flowing across impervious surfaces carrying nitrates and particulate matter into urban streams, wetlands and coastal waters (Cadenasso *et al.* 2008).

The recovery of degraded land requires particular attention to hillside land cover, stream bank and wetland riparian areas with sufficient width and vegetative cover, and the disbursement of stormwater across surfaces able to reduce its flow rate. The development of a system to

[17] Dispersal development has four characteristics: (1) the population is dispersed in low density development; (2) houses are separated from shops and workplaces; (3) the network of roads is marked by large blocks and poor access; (4) there is lack of well-defined activity centres (Southerland 2004).

classify urban land cover, HERCULES (High Ecological Resolution Classification for Urban Landscapes and Environmental Systems), has allowed more detailed about urban ecological functions to be recognised (Cadenasso *et al.* 2008).

Attention to landscape structure is important in recognising the cultural values that arise as a result of the long-standing relationships that humans have with the ecosystems (Antrop 2007). Cultural values are non-material values that extend to the wise use of resources, sacred sites, medicinal values, traditions and respect for the ecological functions of the ecosystem. Within New Zealand these values have developed over the last 800 years of occupation and extend across our multicultural society. Unfortunately, urbanisation has imposed economic values on land and the strength of the cultural values has declined (Stephenson 2007). In Nova Scotia, Manuel (2003) surveyed 82 households in the neighbourhoods of small urban wetlands. She found that the values given to the wetlands were mainly for passive aesthetics and recreation. Furthermore, 93% reported seeing wildlife of interest and 69% valued the 'naturalness' of having a nearby wetland.

3.19 Conclusion

Urbanisation and ecosystem modification are processes that have been underway for 8000 years. They only became major environmental issues in the western world in the late 19th and early 20th centuries as a result of environmental public health concerns. Global population increases together with decimation of the environment and loss of natural resources associated with that conflict changed people's view of the permanency of the world's environment and its resources. This led to 50 years of global environmental conferences, declarations and agreements that have made positive differences to the living conditions of millions of people but have had variable success environmentally. The complex relationships that exist between humans, ecosystems and economies have made ecosystem sustainability difficult to achieve globally and within New Zealand. The anthropocentric view of the value of ecosystems is embedded in the laws, customs and cultures of most societies.

New Zealand's environmental history over the last 800 years has been one of great ecosystem modification, though only over the last 175 years has this been associated with urbanisation. Maori, who arrived in New Zealand about 800 years ago, were hunter-gatherer people who moderated landscapes and ecosystems with pests, fire, tree felling and extinctions. The British colonists post 1840 paid even less respect to the environment with many of their activities as they tried to farm the land. Many of their descendants, however, developed empathy for the natural landscape and when this was increasingly threatened in the 1960s, a conservation movement emerged. This led to changes in the legislation for managing environmental issues. Despite this, tensions between politicians, developers and community environmentalists remain under the RMA 1991.

The conclusion from this literature review is that there are still many environmental issues to be addressed at all levels of government and society in New Zealand. There is a need to find a balance between economically secure lifestyles such as that found in urban developments and the maintenance of intact environmental ecosystems (Alcamo & Bennett 2005). The literature is clear that value of ecosystems is the value that communities put on them. Unfortunately many of the services, such as flood protection, remain unrecognised by most people and therefore are not valued until the ecosystem is destroyed. In the next chapter the functions and futures of wetland ecosystems are presented together with background information on the Kapiti Coast, the district for this case study.

The following case study into the sustainability of urban wetland ecosystems in the Kapiti Coast District highlights the tensions between economic development and environmental sustainability. Resource consents, a vehicle for the implementation of the RMA, have not protected the ecological health of the study wetlands nor their riparian areas, regarded as having aesthetic and recreational qualities by their neighbourhoods. Yet their restoration and maintenance is disregarded in the Kapiti Coast District Council Operative District Plan 1999 and documents guiding the current district plan review, as will be discussed in chapter six.

Chapter 4: Wetland Riparian area Ecosystems

4.1 Introduction

Wetland riparian areas are ecosystems that have been significantly modified by urban development in New Zealand. Although wetlands have been extensively reported on, the roles of their riparian areas have had limited attention (USEPA 2008). It has been estimated that 6% of the earth's land surface area is still occupied by natural wetlands (Erwin, 2009), representing approximately 530 million hectares of which approximately 30% are bogs, 26% fens, 20% swamps and 15% floodplains (Hook 1993). A Ramsar Report on Wetlands (1996) estimated that 50% of the world's wetlands were lost during the 20th century (Stone 1996).

According to Ausseil *et al*. (2007) the wetland area in New Zealand has been reduced over the last 200 years from an estimated one million ha to 100,000 ha with most of the reduction occurring during the first half of the 20th century. In 1997, MfE commented that, 'of the several thousand wetlands that remain, seventy are of international importance but many have been degraded by drainage and pollution' (MfE 1997). In the Wellington region, wetlands once covered 103,000 ha (12.7% of the regional area) but by 1993 this had been reduced to 13,300 ha (13% of the original wetland area and 1.6% of the regional area**)** and further reduced to 12,150 ha by 2010 (Tidswell *et al.* 2010). Figure 1 shows the decline in wetlands on the Kapiti Coast near Wellington between 1840 (Carkeek 1966) and 1993 (Fuller 1993).

The first part of this chapter deals with the classification of New Zealand wetlands and discusses their ecological functions and values, the impact of urban developments affecting their functions and the use of ecological indicators. The second part addresses the role and functions of wetland riparian areas in both natural wetlands and urban sites. The chapter concludes with background information about the Kapiti Coast where this study of the urban wetland riparian areas was undertaken.

4.2 New Zealand Wetlands Definition

The New Zealand Wetlands Management Policy 1986 defined wetlands as

> permanently and intermittently wet land, shallow water and land-water margins. Wetlands may be fresh, brackish or saline, and are characterised in their natural state by plants or animals that are adapted to living in wet conditions (DOC 1987).

This New Zealand definition is similar to that adopted by the International Union for the Conservation of Nature and Natural Resources (IUCN) for Wetlands of International Importance and now known as the Ramsar Convention. Under this Convention, the New Zealand government is responsible for protecting the 'economic, cultural, scientific and recreational value' of wetlands, a responsibility delegated in New Zealand to the Department of Conservation. The strict IUCN criteria for the value of wetlands have been met at only seven sites within New Zealand although in 1996 DOC identified 73 wetland areas that complied with the criteria for international importance. The lack of IUCN-approved wetlands in New Zealand,

and particularly palustrine ones, may reflect either public disinterest or ignorance (Deans & Preece 2007; PCE 2002) or lack of government leadership.

There is no New Zealand definition for urban wetlands. Tiner (2000) in his review of the urban wetlands on Staten Island, New York defined palustrine, urban wetlands as 'wetlands [that] are predominantly vegetated marshes and swamps, but also include freshwater ponds with or without macroscopic plant life'.

Sutula *et al.* (2008) produced a Technical Report for the Los Angeles Regional Water Quality Control Board that defined freshwater urban wetlands as 'wetlands predominantly vegetated marshes and swamps, but also include freshwater ponds with or without macroscopic plant life'. They mapped the status of 40 freshwater urban wetlands that 'were highly modified from historical reference, with a large percentage type converted to forms atypical in the landscape'. Their definition of urban wetlands included basins:

> Basins are freshwater depressional wetlands that consist of habitat types known colloquially as ponds, pools, wet meadows, treatment wetlands, or wetland detention basin. Isolated basins occur in topographic depressions, either natural or manmade, in the landscape. Dominant water sources can include runoff from adjacent uplands, point source discharges, precipitation, and groundwater discharge. The direction of flow is normally from the surrounding uplands toward the center of the depression.

In New Zealand, a method of rapid mapping and prioritisation of wetland sites in the Manawatu - Whanganui Region was developed by Ausseil *et al.* (2007**)** and subsequently was adopted by DOC to complete a nationally consistent inventory of New Zealand's natural wetlands. A further assessment of the ecological state (wetland condition) of 7,000 wetlands greater than 0.5ha, reported by Ausseil *et al*. (2010), show that more than 60% had a wetland condition score of less than 0.5 indicating moderate to severe degradation and biodiversity loss.

The information from the 2011 National Wetland Inventory has been made available to regional councils and territorial authorities for restoration and conservation purposes. A National Wetland Centre, established in the Waikato region by the National Wetland Trust in 1999, has been developed as a centre for reference and encouragement for the restoration of wetland landscapes. Scientific background information for landowners, and restoration and management strategies for regional councils and other institutions is now widely available in written form and on websites from Landcare Research (2010) and regional councils including Greater Wellington Regional Council (GWRC 2003).

4.2.1 Wetland Classification

Wetlands are classified according to their hydrosystems, topographical and biogeochemical profiles and vegetation structure and composition (see Table 4.1 below) (Johnson & Gerbeaux 2004, p15). Individual natural wetlands are classified with reference to their characteristics such as water tables, landforms (geology), the forms they create or contain (e.g. domes) and the vegetation structure and composition.

The riparian areas around wetlands are a continuum of zones reflecting different degrees of flooding. Palustrine[18] wetlands are the most common of New Zealand wetlands (Thompson 2012; Ogle 1991**).** They are distinct from riverine, estuarine or lacustrine wetlands, forming in sites where there is poor drainage such as old inactive riverbeds, low lying depressions and dune swales. They are fed by rainfall, groundwater and surface water and are the wetlands most commonly affected by urban development.

4.2.2 Wetland functions

According to the USEPA, wetlands have been regarded as the most important ecosystems in the world, their dynamic environments providing many services and economic, cultural, scientific and recreational opportunities (Wratten *et al*. 2013; McInnes 2013; USEPA 2012). The degradation of wetlands and riparian areas negatively affects these services (Myers *et al*. 2013).

Table 4.1. A wetland classification system

I.HYDROSYSTEM (Based on broad hydrological and landform setting, salinity, temperature) Estuarine; Riverine; Lacustrine; Palustrine
II. WETLAND CLASS (Based on substrate, water regime, nutrients, pH) Bog; Fen; Swamp; Marsh; Ephemeral wetland[19]
III. STRUCTURAL CLASS Structure of the vegetation (e.g. forest, rushland, herbfield) Or Predominant ground surface (e.g. rocky, mudflat)
IV. COMPOSITION OF VEGETATION One or more dominant plants (e.g. manuka, wire rush)

Adapted from Johnson & Gerbeaux 2004, p15.

2013; Lougheed *et al.* 2008; Hogan & Walbridge 2007). However, not all wetlands perform all functions or at the same levels. Variations in wetlands' functions depend on their size, geographic location, climate and relationship with their water source (Middleton 2012; Novitski *et al.* 1994).

The most important factor in the survival of a wetland and its functions is its hydrology Thompson 2012; Richardson & Vepraskas 2001). Interference with this from water source to wetland leads to degradation and loss of functions. The philosophy of 'Integrated Whole-Catchment Management' is being encouraged in New Zealand by Landcare Research and

[18] NZ palustrine wetlands categories:
Fen – wetland on peat, groundwater fed, water table at surface, sedges, ferns and tussock.
Marsh - fed by groundwater or surface water, good drainage, rushes and grasses.
Swamp – nutrient rich, groundwater or run-off fed, water high, flax, rushes and forest.
Seepage – flow of groundwater down slope, moss, cushion plants (Johnson & Gerbeaux 2004, p30).

[19] Ephemeral wetlands are wetlands occurring in surface depressions that have a marked seasonal water level alteration between wet and dry seasons, and a turf and sward vegetation that is species rich and distinctive (Johnson & Rogers 2003).

NIWA to acknowledge this continuum and its vulnerability from all sources (Campbell 2010; Quinn *et al.* 2009; Dodd *et al*. 2008). Significant interference results from deforestation leaving bare land, conversion of bush to pasture or urban development, altered stream or river flows with dams, infrastructure development and high imperviousness (PCE 2013). Where these scenarios are present, the surface water run-off may be so rapid that the fast rate of flow results in flash flooding of the wetland or may even cause channelisation and bypass it. Natural wetlands are adapted to gentle pulse flooding but excess water leads to dysfunction and compromised services (Innis *et al.* 2000).

Euliss *et al.* (2008) suggest that integrated wetland management plans that have a 'process-based perspective' to wetland services would provide improved future ecological sustainability to natural wetlands. Their concern is to acknowledge that in highly modified landscapes, wetland management should consider the dynamic processes required for wetland services as important as social, economic and political imperatives. Although New Zealand protocols for monitoring wetland health/condition have been developed by Clarkson *et al.* (2004), environmental management systems for ensuring that sustainable economic and ecological systems can co-exist are not well developed according to Valentine *et al*. (2007).

4.3 Ecological Metrics for Wetland Condition

Measurable metrics of change in wetland condition encompassing biological surveys, palaeolimnology, historical data and predictive modelling have been reported (Adamus & Bartlett 2008; Niemi *et al.* 2004)**.** Such metrics are based on wetland characteristics including soils, vegetation and water properties. The complex nature of wetlands ecosystems has meant that assessment methods for these functions have not met with universal agreement. Sutula *et al.* (2007, p 157) point out that rapid assessment processes have a range of issues and choices that may involve 'accuracy, precision, robustness, ease of use and cost'**.**

By 2010 over 40 ecological methods of assessing wetland functions had been devised: Fennessy *et al.* (2007) focused on the effectiveness of rapid assessment methods using hydrology, soils and biotic communities as ecological indicators; Liu *et al*. (2006) used TOPSIS methodology[20] for prioritising wetland rehabilitation potential; Brooks *et al.* (2004) assessed wetland condition using Synoptic land-cover maps; Clarkson *et al.* (2004) developed five ecological indicators (hydrology, physicochemical, ecosystem intactness, browsing, native plant dominance) for monitoring wetland condition; and Thiesing (2001**)** evaluated wetland assessment techniques with the clear conclusion that no single technique could evaluate all wetland functions.

Assessment methods were first developed by the US Army Corps Engineers in 1983 (Adamus *et al.* 1987) and included two techniques, namely the Wetland Evaluation Technique (WET) that evaluates functions and values in terms of effectiveness, social significance and habitat

[20] TOPSIS = Technique for Order Preference by Similarity to Ideal Solution, a multi-criteria decision method to assist in assessing wetland condition and priority for rehabilitation using 16 possible indicators including naturalness, buffer size, habitat for fauna (Liu *et al*. 2006)

suitability (Adamus 1983), and the Environmental Monitoring Assessment Program–Wetlands (EMAP)[21] that identifies indicators of the wetland condition (Spencer *et al.* 1993; Novitski 1994; Cowardin 1979**).** These were followed by the development of the Hydrogeomorphic Classification Method (HGM) that compares the characteristics of a specific wetland with a regional reference group of wetlands (Thiesing 2001; Brinson 1993). HGM was adopted by the USA Corps of Engineers as their preferred method of assessment of wetland condition, and has been used in combination with EMAP (Whigham *et al*. 2007). These early techniques were difficult to apply, involved qualitative results and had poor predictive values. They also ignored landscape, riparian and wetland system-level functions.

More recently, assessment has included watershed and biodiversity issues. Lopez & Fennessy (2002) tested the Floristic Quality Assessment Index (FQAI) using plant species richness as an indicator of wetland disturbance such as human land use. They concluded the method was useful for monitoring provided new landscape disturbances did not occur (as in 'human-induced landscape changes'). Miller & Wardrop (2005) also used the FQAI as a measure for habitat quality but determined that it was excessively influenced by species richness where non-native plants were ignored for their contribution to habitat quality. They subsequently adjusted the FQAI to reduce the sensitivity to species richness. Tiner (2005) used the digitally enhanced U.S. Fish and Wildlife Service's National Wetlands Inventory Program (NWI) to assess the historically accumulated loss of wetland functions in the Nanticoke River watershed of Maryland and Delaware States, USA, and thereby provide a basis for conservation.

Indices of Biological Integrity (IBI) have been developed to objectively assess water quality. These multi-metric indices provide a quantitative value for a wetland's condition. Reiss (2005) used a combination of scored metrics including tolerant indicator species, exotic species, FQAI and wetland status species to develop the 'Florida Wetland Condition Index for depressional forested wetlands' (FWCI) which was then correlated with the Landscape Development Intensity index of the 100m buffer to the wetlands. Hargiss *et al*. (2007) developed the Index of Plant Community Integrity (IPCI) to evaluate the condition of wetland plant communities in seasonal wetlands of Dakota based on their disturbance levels. The disturbances included climatic events such as drought as well as human induced ones including crops.

The Australian and New Zealand approaches to assessment have been to use reference wetland sites and functional indicators. In a review of 16 assessment methods, Fennessy *et al.* (2004) focused on four indicators that were common to the majority of methods – hydrology, soils/substrate, vegetation and landscape setting. In New Zealand, Clarkson *et al.* (2004) in the *Handbook for Monitoring Wetland Condition* described five ecological indicators for monitoring estuarine and palustrine wetlands. These indicators, which include standard information about hydrological integrity, physical and chemical parameters and ecosystem intactness, are scored numerically and take into account any modifications or pressure on functions and the canopy

[21] EMAP (Environmental Monitoring Assessment Program) includes assessment of soil stability, width of fringing vegetation, height and diversity of fringe vegetation, % cover of aquatic vegetation, water turbidity, conductivity & algal bloom frequency (Spencer *et al*. 1993).

cover of the wetland. The resulting wetland condition score is valid currently and is a basis for future comparisons of function.

The large number of people and time taken to undertake the above assessments together with the limited availability of data, has led to the development of methods using digital and remote sensing techniques (Ausseil *et al*. 2011; Ozesmi & Bauer 2002). However, the data available from remote sensing is not necessarily up-to-date as it relies on the last time that satellite data was obtained. Nevertheless, rapid assessment protocols have also been developed partially in response to the Clean Water Act (USA) that requires that all waters of the USA must be assessed every two years (Wardrop *et al*. 2007; Ausseil *et al* 2007; Brooks *et al*. 2004).

Ashraf *et al*. (2010) addressed the problems associated with the access, scale and distribution of wetlands in New Zealand using high-resolution imaging with 'appropriate spectral characteristics'. Although these digital techniques are now widely applied worldwide to assess landscape and wetland conditions, and any progress in restoration, small urban wetlands have not been studied. Wetlands as small as 0.5 hectares in the conservation areas of New Zealand have been able to be identified with digital methods (Ausseil *et al*. 2011).

Wardrop *et al*. (2007) noted that there needed to be three levels of landscape assessment, namely (a) landscape assessment using digital and Geographic Information System (GIS) data, (b) rapid assessment refining the landscape assessment by adding visual indicators of human effects on the wetland and (c) intensive assessment, the most costly, where there is data collection and a complete evaluation. They further suggest that In the USA setting of biennial assessments, these multi-level assessments are the most appropriate for economic and ecological decision-making.

Ecosystem intactness has proved the most difficult indicator to measure. Though the composition of communities of flora and fauna, including aquatic macroinvertebrates, is well accepted in river and stream evaluations and regularly reported on, the use of aquatic macroinvertebrates as assessment criteria for wetland condition is poorly documented (Davis *et al*., 2006). In 2010, New Zealand's Department of Conservation undertook an investigation into the characteristics of aquatic invertebrates in lowland wetlands throughout the country (Suren *et al.* 2010). This was followed by the publication of *South Island Wetland Macroinvertebrate Community Index score* (WMCI) (Suren & Sorrell 2010). The WMCI differs markedly from the NZ stream MCI, an indication of the different tolerance values of the common invertebrates of wetlands and different species.

4.3.1 Wetland Riparian Areas

Despite the plethora of wetland ecological assessment methods mentioned above, there have been no specific indicators for wetland riparian health. An analysis of the Canadian riparian forest management defines 'wetland riparian buffer zones' as those areas surrounded by protected areas of forest[22] (O'Carroll 2012) (Appendix 8). The County of Santa Cruz (2012) Riparian Corridor and Wetlands Protection ordinance prohibits development within riparian corridors defined as 'Lands extending 100 feet (30.48m) (measured horizontally) from the high watermark of a lake, wetland, estuary, lagoon or natural body of standing water' (Figure 1). The USEPA (2005) defined riparian areas as

> A vegetated ecosystem along a water body through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent water body. These systems encompass wetlands, uplands, or some combination of these two landforms.
> The definitions for riparian areas can vary. For example, a definition of riparian areas might be based on geographic region (arid or humid climates) or on distance from a stream channel rather than on site characteristics. Even those riparian areas that fall outside wetland boundaries provide many of the same important water quality functions that wetlands provide.
> In many cases, the area of concern might include an upland buffer adjacent to sensitive wetlands or riparian areas that protects them from excessive Nonpoint Source Pollution (NPS) impacts or pretreats inflowing surface waters (USEPA 2005).

Many of the wetland indicators cover both the wetland edges and peri-wetland margins including the riparian vegetation composition. Wetland riparian areas have not been recognised for their independent functions but rather defined as 'buffer zones' that have the sole purpose of protecting water sources to ensure water quality free from pollutants (Verhoeven *et al.* 2006). How this might be achieved is often poorly considered with random planting, walkways, cycleways and mown grass occurring in the buffer (Groffman *et al*. 2003). Natural wetlands' riparian areas, however, provide functions that not only improve water quality but also maintain the undisturbed integrity of the wetland. These functions are further discussed in Section 4.2.2.

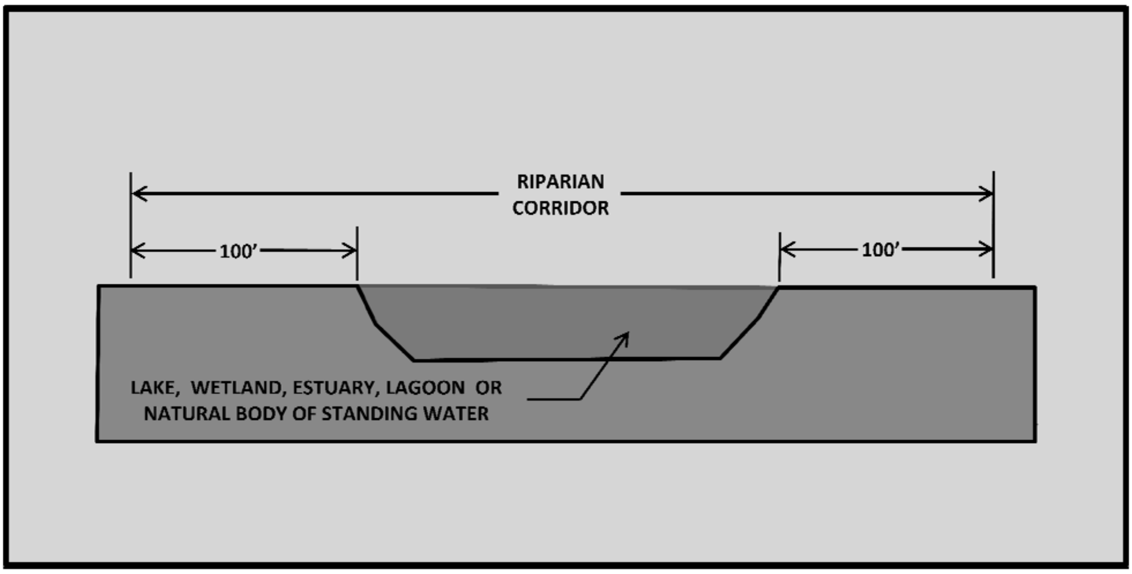


Figure 1. Lake, Wetland, Estuary, Lagoon, or Natural Body of Standing Water.
from County of Santa Cruz, California, USA 2012 (see Appendix 8).

[22] Riparian forest buffer zones apply on all sides of waterbodies. A waterbody is a mass of water, e.g. streams, lakes and wetlands (O'Carroll 2012).

4.4 Wetlands and Urbanisation

Most of the wetland loss in New Zealand has been associated with land use changes in the rural sector, which accelerated from 1900 onwards, the greatest loss being in the first 50 years. However, van Roon & Knight (2004) reported that a Ministry for the Environment (MfE) survey of wetlands nationally showed that there was continuing loss of wetlands including the loss of 263,000ha (12,000ha/yr) between 1954 and 1976. Following agricultural intensifying, urban development was the next major land use change. The only major New Zealand city partly built on wetlands is Christchurch[23], but most of the cities and larger urban areas contain some wetland reclamation including Auckland, Napier, Hutt City, Kapiti Coast and Palmerston North.

Urban development in wetland areas is generally associated with lack of understanding of the role of the wetlands and their riparian areas, drainage of wetlands, lack of respect for the land and lack of awareness of the cultural and spiritual values associated with the wetlands (Ramsar Convention 2009; Brown & Vivas 2005; Mitsch 2000). Such clashes occur worldwide and are part of a far larger problem of ‘saving the planet’ (Orr 2003). In a study of 164 listed wetlands affected by urban development in Portland, Oregon, Holland *et al.* (1995) found that between 1982 and 1992, more than 60% of the urban wetlands had been lost by wetland drainage, compaction and reclamation.

Manuel (2003) noted in a survey of cultural perceptions of urban wetlands in Canada that, ‘small remnant wetlands were often too small, isolated, polluted, monotonous or inconspicuous to fit into wetland protection and management frameworks designed for mainly rural and wild environments’ (Manuel 2003, p 921). Nevertheless, she further concluded from her survey that although the ‘supporters of these [remnant wetland] sites are very small in number compared to the larger constituency of a municipality or developer interests’ there was a ‘cultural basis for successfully integrating small wetlands into urban developments’. Ehrenfeld (2000, p 253) suggested that, ‘the fact they are there, in an urban context, lends them significance’.

Urban wetlands include original wetlands found within urban boundaries as well as those developed during urban development (Ehrenfeld 2000). They differ from natural wetlands with altered natural hydrology, the presence of invasive plant species and high levels of site disturbance from people (Sutula *et al*. 2008; Ravit *et al.* 2008). The physical boundaries developed around a wetland interfere with surface water flow and stormwater drainage into the wetland (Fisher & Acreman 2004). Where a subdivision develops a water feature either in a swamp area or at the water table level, the hydrology is affected and pollutants introduced to the wetland. Infrequently a zone is developed around the wetland pond with native and/or exotic plants but more usually the peri-wetland land is mown grass. Many urban areas are now introducing constructed wetlands to deal with sewage and stormwater that are landscaped but their capacity to manage the pollutants nitrogen (N) and phosphorus (P) is variable (Rutherford *et al*. 2009), and eutrophication is a common symptom (see Figure 23).

[23] Christchurch city was partially destroyed by earthquakes in 2010 with the loss of 187 lives. Many areas suffered severe liquefaction and loss of residential and commercial buildings.

Patten (2006, p 17) identified the potential conflicts between the interests and values of the public and urban policy makers on the one hand and the ecological science community on the other: 'establishing desired wetland and riparian conditions following public input may conflict with scientific information on historic or natural variability of the ecosystems of interests'. Well-informed communities and developers understand the relationships between clean water and riparian habitats. However, many communities are not mobilised to retain or restore wetlands and their riparian areas (Ehrenfeld 2000). Patten (2006) has suggested that adaptive management processes[24] might resolve any conflicts to the benefit of the wetlands. His view is that individuals, communities and planners contribute to an agreed solution where clean water and riparian habitat coexist with recreational needs within the urban setting. In the Santa Cruz County, USA, definitions of wetland riparian corridors have been established as part of that County's ordinance affecting urban development (Appendix 8).

4.5 Urban Wetland Sustainability

The ecological sustainability of wetlands in the presence of urban development is a compromise between the modification of the landscape to satisfy community and business needs and the wise use of the geology and hydrology required to maintain the wetland services and functions. The disturbance regimes required for healthy ecological cycles are frequently abhorrent to a society requiring aesthetic environments at all times. Peri-urban wetlands have often been exploited for their products (Boyer & Polasky 2004) and, where towns have expanded, have been seen as useless areas that can be drained or filled to provide fertile land for horticulture and flat land for residential development (Hook 1993; Williams 1991).

The economic sustainability of an area that is being subdivided for housing usually means that functional riparian areas are either obliterated or so diminished that they cannot perform their function. Hogan & Walbridge (2009) showed that urban developments in Fairfax County, Virginia, USA, had a more 'dramatic' impact on riparian ecosystem structure and function than agriculture activity. While the concentrations of phosphorus and nitrogen increased in the riparian native vegetation with agricultural production, there was greater distortion of nutrient loading in the urban environment with excess phosphorus providing ideal conditions for prolific exotic weed invasion. They further noted that the pulses of sediment originating from excavations within a catchment altered the riparian soil balance especially for soil iron, further encouraging exotic weed growth.

Hanson *et al.* (2005) studied the potential for improving biodiversity in constructed wetlands in the presence of nutrient retention. They found that 'shallow depth, large surface area and high shoreline complexity' attracted a high biodiversity including birds, aquatic macroinvertebrates and macrophytes. They also noted that while the shallow wetland accommodated a high

---

[24] Adaptive management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions are monitored. It recognises the importance of natural variability in contributing to ecological resilience and productivity. It is learning and acting while doing. (Stankey et al. 2005).

nutrient load, a smaller deeper wetland pond had more efficient retention of phosphorus. Their recommendation to urban planners and designers was to evaluate the needs of the projected development.

4.6 Hydrological Compromise

Mitsch and Gosselink (2000) commented that hydrology was the vital component of wetlands as it was responsible for the development of the hydric soils and therefore determined the composition of the biotic communities. Urban development inevitably interferes with the hydrological cycle in a number of ways (Table 4.2), including the abstraction of water from surface and groundwater stores, reduced infiltration surfaces arising from the development of impervious surfaces and consequent increased stormwater run-off (May 2007, p 80; Patten 2006; Ehrenfeld 2000).

Where these factors are persistent and sufficiently severe a ‘hydrologic drought’ may occur (Groffman *et al.* 2003). The normal functions of wetlands are affected by lowered water tables, altered soil structure and chemistry, changed vegetation composition and reduced nutrient and pollutant removal**.** The supply and quality of potable water needed for urban requirements becomes compromised even with rainwater collection and rationing. The hydrology of the wetlands is ultimately a function of catchment health. Water provided to a wetland by a stream, or as groundwater, will fluctuate according to rainfall conditions and the amount of upstream storage available. Increases in stormwater flow from deforested land or ‘flash’ run-off from impervious urban surfaces consequent on land changes to the catchment may degrade or destroy a downstream wetland (Campbell 2010; Laudon *et al.* 2007).

Goonetilleke *et al*. (2005) undertook a water quality research project on the Gold Coast, Australia, that showed that the common management processes of dealing with urban stormwater quality by allowing the sediment to settle were ineffective as suspended solids were not correlated with total P (TP), total N (TN) or total organic carbon (TOC). They showed that TP and TN were in the dissolved form, bio-available and a major cause of pollution.

Table 4.2. Impacts of urbanisation on wetland hydrology

Decreased surface storage causes increased run-off from impervious surfaces
Increased erosion of streams leading to increased sediment load to wetlands
Decreased water quality including increased water turbidity, increased nutrients, pollutants and metals
Higher peak stream flow for each storm event
Less time between rainfall, run-off and increased stream flow
Increased flood recurrence frequency, More flash floods
Less groundwater recharge
Greater wetland water level fluctuations
Changes to wetland ecotones reduces habitat availability

Adapted from Ehrenfeld (2000, p 253)

Mayer *et al*. (2005) found that as the variability of stormwater flow patterns and rates across a riparian area affected nitrogen removal, groundwater provided more efficient denitrification as it regulated the interaction of nitrates with soil denitrifiers. This latter function, acknowledged as very important in the agricultural industry to manage fertiliser nitrate runoff, is also important in urban environments where stormwater carries pollutants from urban impervious areas (Rutherford *et al*. 2009). Where the fluctuating water table is saturated and waterlogged in riparian areas, the soil profile can be altered to such an extent that the denitrification process cannot proceed (Groffman *et al*. 2005).

4.7 Infrastructure and Species Loss/Extinction

The invasion of wetlands by exotic plants and weeds and the replacement of native plants by dryland species are indicative of the vulnerability of the wetland riparian vegetation to infrastructure development. Drainage of palustrine wetlands, once the preserve of agricultural activity, is now commonplace in urban development with the consequent loss of both the wetland and the riparian vegetation. Riparian edges to waterways become compacted. Levees built along riverbanks reduce or obliterate flood disturbances. Along major roads there is increased waste and toxic matter disposal into roadside wetlands (May 2007, p 83; Ehrenfeld 2000). Changed habitats and the noise from vehicles affect the fauna in a wetland, especially the birds (Forman & Alexander 1998). Table 4.3 summarises some of the disregarded effects of urbanisation on wetland ecology.

Table 4.3. Impact of urbanisation on wetland ecology

Invasion of exotic species including weedy species
Depauperate species pool
Changes to soil and sediment from trash and other pollutants
Remnant habitats of natural vegetation often without landscape corridors or context
Wetland edges compacted by trampling, development etc
Fauna with small habitat ranges favoured
Loss of relationship with upland fluctuating water sources and flood frequency

Adapted from Ehrenfeld (2000, p 253)

4.8 Wetland Riparian Areas Defined

Riparian areas or 'buffer zones' have been defined as interfaces or three -dimensional ecotones of interaction between terrestrial and aquatic systems (Quinn 2003**;** Ilhardt *et al.* 2000; Naiman & Decamps 1997**)** and as such they can be indicators of environmental damage to the linked ecosystems. Johnston *et al*. (2009) noted that the term riparian is now used for the areas around or along the edges of waterbodies including rivers, streams and wetland ponds[25]. Their

[25] The word 'riparian' arose for the Latin 'riparius' meaning bank of a stream. Ilhardt *et al*. defined it as 'the area of land and water forming a transition from aquatic to terrestrial ecosystems along streams, lakes and open water wetlands' (Ilhardt *et al*. 2000). Santa Cruz County, USA, define riparian corridors as 'Lands

outer boundaries are not at defined distances from the water edge but vary according to their functional limitations within their geology and landscape. Their function and structure varies with the type and site of the wetland, and topography, although a constant feature is that vegetation is tolerant of high soil moisture. Where vegetation outside the zone contributes organic material to the zone, it may also be considered part of the riparian area (O'Carroll 2012; Naiman & Decamps 1997).

The composition of the riparian area plants and animals reflects the dynamic nature of the wetland system, varying with the seasonal and climatic changes (Johnson & Rogers 2003; Ogle 1991). The wet-dry cycles of ephemeral wetlands are not necessarily annual and the dry or wet periods may last several years. They are disturbance-adapted and often highly specialised within their environments. These disturbances include flooding, drought and erosion.

According to Naiman and Decamps (1997) riparian plants can be classified into four categories of functional adaptations, namely:

(a) 'invaders' that produce wind or waterborne seeds e.g. mercer grass (*Paspalum distichum*) produces waterborne seeds and raupo (*Typha orientalis*) windborne seeds . Also grey willow.

(b) 'endurers' that regrow from damaged stems or roots e.g. grey willow (*Salix cinerea*), crack willow (*S. fragilis*) and cabbage trees (*Cordyline australis*)

(c) 'resisters' that can resists floods or fire e.g. New Zealand flax (*Phormium tenax*) and toetoe (*Austroderia toetoe*)

(d) 'avoiders' that lack adaptations and do not survive when the disturbances such as flooding occur frequently. Many annual weeds and pasture grasses are in this group (Naiman & Decamps 1997, p 624).

The dominance of any one of these categories can be the direct result of the stressors and disturbances applied to a wetland's riparian area. However, there have been alternative hypotheses (Tilman 1982; Grime 2001,1979) about the interactions of plants with their landscapes, including competition for light, water and limiting nutrients. Tilman (1999) showed that greater diversity was associated with decreased invasions by exotic species. This competitiveness between exotic species and native species is pertinent to the increasing fragmentation of the urban landscape. Destruction of all or part of urban wetland riparian areas leads to compromised patch size, loss of connectivity and a species richness with a different biodiversity (Goddard *et al*. 2010).

A riparian area adjacent to part or all of a wetland is regarded as part of the wetland system whereas that adjacent to a stream or river has a more distinct set of functions **(**Naiman & Decamps 1997)**.** Pollock *et al.* (1998) noted the distinction between riparian wetlands vulnerable to river and stream hydrological events and the palustrine wetland riparian areas that were independent of any particular stream event but relied on ground and surface water. Wetland

---

extending 100 feet (measured horizontally) from the high watermark of a lake, wetland, estuary, lagoon or natural body of standing water '(Santa Cruz County 2012). (Figure 1).

riparian areas are biologically rich, provide essential horizontal connectivity at the water-land interface (Innis *et al.* 2000) and habitats for fauna.

There have been many debates about the appropriate breadth of wetland riparian areas, ranging from 3m to over 100m or more, depending on the desired functions (Allen & Walker, 2000). The Greater Wellington Regional Council recommends a riparian area of at least three metres (GWRC 2013). According to Mander *et al*. (2005) the effective removal of suspended solids from surface water requires a width of more than 5m to retain 60% of the material. The meta-analysis used by Mayer *et al.* (2007) showed that riparian area widths greater than 50m were more effective in removing nitrogen than a width of less than 25m. McElfish *et al*. (2008) noted that while nutrients and sediment would be removed in less than 9m, more pollutants were removed more consistently with riparian areas of 9m–31m.

Semlitsch and Jensen (2001) suggested that the criteria that applied to such zones were from the anthropocentric viewpoint of protecting an asset, particularly the reservoir of water. They proposed the rescinding of the names ‘buffer zone’ and ‘riparian area’ in favour of ‘core habitat’ to restore the focus to the ecology of such critical areas. This would be achieved by dividing the unmeasured area into three zones: an ‘aquatic buffer’, a semi-aquatic core habitat and a ‘terrestrial zone. This change of focus to the functions of the riparian areas rather than the nominal size was seen as essential in the maintenance of biodiversity.

Studies of pristine natural wetland sites have shown that they have dynamic and productive communities within diverse patches, each varying their response to the degree and frequency of disturbances (Grime 2001; Pollock *et al.* 1998). However, the construction and/or restoration of wetland riparian areas in urban settings may interfere with natural disturbance regimes and is frequently related to the excavation of sites with unnatural and steep bank slopes. A five-year New Zealand study of the stabilising characteristics and effectiveness of twelve indigenous woody species on slopes and stream banks has relevance to this type of development and restoration (Marden *et al.* 2005). Although the article does not specify the angle of the slopes studied, they are referred to as ‘steep and unstable’.

4.9 Wetland Riparian Functions

Wetland riparian areas provide a set of functions that generally maintain the water quality of wetland ponds, provide breeding grounds for native fish and a habitat for fauna including insects, birds, reptiles and amphibians. The maintenance of high quality water and associated health of a wetland relies on the ability of the riparian vegetation and soils to filter contaminants, breakdown of organic toxins and pollutants from surface water and to provide suitable conditions for denitrification and nutrient uptake (Innis *et al.* 2000). Riparian vegetation also assists with the control of flooding and sediment deposition. Unlike stream riparian areas, that bind the edge of the stream with their roots, natural wetland edges are less distinct, their blurred boundaries covered by algae and water tolerant reeds, grasses and shrubs.

The degree to which riparian functions can occur depends on the site of the wetland. Palustrine wetlands are not directly affected by stream and river overflows but do receive surface water from surrounding land and urban areas that may be sufficient to cause flooding particularly in the presence of persistent heavy rain prior to entering streams and rivers (Mander *et al.* 2005). Surface water also carries sediment and pollutants that are not dispersed or processed if the riparian areas are dysfunctional.

The riparian soils provide filtration for particles and are enhanced by a roughened surface providing a greater area for absorption, and ground cover that delays run-off. Land use and topography adjacent to the wetland are major factors in determining the rate of water flow through a riparian area. If the flow rate is too great there is insufficient time for the soil and plants to absorb the water and remove its pollutants (Mander *et al.* 2005). Phillips (1989) noted that because sub-soil water flows more slowly than surface water, denitrification and nutrient uptake would be more efficient.

There is little information on the extent, density and composition of riparian vegetation that is needed to maintain urban wetland health. One measureable indicator of wetland health is the number and diversity of aquatic macroinvertebrates in a wetland. Olson *et al.* (1995**)** found that wetland vegetation had a major impact on macroinvertebrate assemblages, with increased invertebrate densities and diversity. Suren *et al.* (2008) investigated natural fens and swamps of the West Coast of the South Island, New Zealand, and found that a relatively species-poor invertebrate community was present at all sites regardless of the size of the pools within the wetlands. However, the impact of riparian vegetation on the macroinvertebrate assembly was not investigated. According to Parkyn (2004), native vegetation is likely to be the most effective vegetation for conserving native fauna.

Denitrification is most efficient in hypoxic situations. As discussed above, the amount and width of vegetation on a steep slope may be critical to any effective denitrification (Castelle *et al.* 1994**).** The removal of phosphorus by riparian areas depends mainly on soil adsorption and plant uptake of dissolved phosphorus. However, where there are peatlands, the phosphorus is sequestered into the peat by microbial activity. But, McElfish (2008) noted that in conditions of low water flow, riparian areas might release nitrogen and phosphorus into water leading to macrophyte and algal exuberance and eutrophication.

4.9.1 Urban Wetland Riparian areas

The ecology (structure and function) of landscape patterns is made more complex where there has been rural development prior to interference from urbanisation (Hobbs 2002). Especially vulnerable are stream and bush corridors within a landscape that are believed to be essential for the movement of animals and birds and the maintenance of water flows. As early as 1984, Swift warned that 70% of stream and wetland riparian woodlands in the USA had already been cleared for alternative land uses, including urbanisation, to the detriment of habitat and water quality (Swift 1984).

Wetland riparian area functions have been investigated largely in agricultural situations where there is the problem of increased nutrient run-off from farm animals and fertiliser and where flooding becomes an issue when wetland riparian areas abut streams. However, urban wetlands face different issues including the flow dynamics of surface water that can be rapid and acute and frequently contains non-biodegradable pollutant chemicals, and high levels of nutrients and sediment (Harrison *et al*. 2011; USEPA 2008; Hogan & Walbridge 2007).

The necessary width for a functional riparian area has been widely debated. Bingham *et al* (1980) suggested a 1:1 ratio of a long grass buffer to polluted surface area would successfully filter 90% of pollutants. The US Fish and Wildlife Service (1980) concluded that a buffer of 3m - 107m was needed depending on the species to be protected. Groffman *et al*. (1990) showed that a forested buffer of 32m reduced background commercial noise to acceptable levels. Ghaffarzadh *et al.* (1992) showed that 85% of sediment could be removed by grass vegetated filter strips that were 18m wide on slopes of 7-10 degrees.

Castelle *et al.* (1994) listed seven functions that should determine the width of a riparian area, namely, sediment removal and erosion control; excess nutrient and metal removal; moderation of stormwater run-off; water temperature control; habitat diversity; species distribution and diversity; reduction of human impact. They concluded that wetland riparian areas less than 5 - 10m would not protect water quality and that under most circumstances 15-30m was necessary but site specific decisions need to be considered.

Semlitsch and Jensen (2001) proposed a zone of up to 300m as necessary for habitat in some regions. This width would currently be economically untenable in most situations where urban land values were considered. Houlahan *et al*. (2006) suggest that land use, urban or agricultural, within 250-400m of the wetland has significant effects on the vegetation composition. Hogan and Walbridge (2009) note the tendency for urban surface water runoff to favour P (phosphorous) rather than N (nitrogen) enhances the likelihood of invasive species in a riparian area. KCDC has not set any riparian requirements but negotiates the width during resource consent procedures and with consideration to the natural ecological situation of the wetland (Cross 2011, pers. comm.).

4.9.2 Connectivity

The ecological functioning of a riparian area are dependent on its semi-aquatic fauna and plants and their connectivity with other ecological zones. Hobbs (2000) noted that isolated urban wetland habitats were more susceptible to urban impacts and particularly the loss of ecosystem integrity. May *et a*l. (2007) identified four parameters of riparian integrity - adequate lateral width, longitudinal riparian corridor connectivity, ‘quality vegetation’, and unfragmented landscape.

In many urban situations the landscape changes are so severe that the natural corridors that may have been present have disappeared. The passages for fauna then depend on the roadside and private garden growth to link the isolated wetlands. This may result in slower migration and different flora and fauna composition. The spread of exotic flora may be enhanced by modified water table levels, as indigenous flora is adapted to the normal hydrological conditions of an area.

4.10 Riparian Area Value

The economic, ecological and cultural sustainability of the urban wetlands both influence, and are influenced by, riparian area management. Tables 4.4 and 4.5 summarise the value that the riparian area structure and functions are to a wetland and the consequences of changes to the riparian area associated with urbanisation. Various authors have considered the value of the wetland riparian area structure and function to the associated wetland with the clear outcome that in urban areas it has a function as a buffer zone for pollutant removal and, therefore, for water quality (Groffman 2003).

Given the value of the riparian functions, it is concerning to see so many wetlands, natural and constructed, with mown grass frontages to residences. As previously documented in this chapter (see Section 4.4), damage to all or most urban wetland riparian functions occurs with urban development. It is apparent that only if there is a human need for wetland functions will there be regard and care for the riparian area (Mayer 2007; USEPA 2005). Further assessment of these effects is reported in Chapter 6.

Table 4.4. Impacts of wetland and riparian area destruction during urban development.

- Hydrological changes: imperviousness causes lowered water tables and altered water flows in and out of the wetland; hydric soils become aerobic; pollutants and sediment impact wetland health; altered plant communities with increased dryland plants.

- Biogeochemical functions: changes in water quality from stormwater and wastewater discharges including altered clarity, acidity, nitrogen and phosphorus content and oxygenation cause excessive growth of high nutrient vegetation species, and decline in smaller sensitive species.

- Loss of ecosystem intactness and integrity: destruction of patch and landscape with altered riparian vegetation composition; loss of native vegetation and invasion of exotic plants; altered macroinvertebrate community composition associated with water pollution; loss of semi-aquatic and terrestrial fauna with loss or alteration of habitat and change in flora.

- Riparian habitat loss: direct damage and/or subtle damage from catchment developments; landform changes; land cover changes; altered fauna with loss of food sources and loss of nesting sites.

Table 4.5. Value of intact riparian area structure and function to a wetland

• Flood tolerant species provide control for overland surface run-off.
• Sediment and pollutants are filtered by entrapment of sediment
• Nitrate sink from dissolved organic matter is modified by plant uptake
• Denitrification occurs in anoxic, carbon-rich, nitrate-containing soils
• Key landscape parameters maintain ecological patches and corridors for plant and animal movements.
• Riparian areas provide vegetation for food, shelter and nesting (e.g. insects, birds, reptiles, mammals)

Sources: Rutherford *et al.* 2009; Mayer *et al.* 2007; Groffman *et al*. 2003; Naiman & Decamps 1997.

4.11 The Kapiti Coast Case Study

The Kapiti Coast is a coastal plain lying east of the Tararua Ranges between Paekakariki (40°58' E; 174°57'S) and Otaki (40°45'E; 174°57'S) (see Map 2). It is traversed by many streams and several rivers. The urban areas of the case study lie on the Waikanae River, Wharemauku Stream and Mazengarb Stream floodplains. There are coastal wetlands and flaxlands to the north of the region and a swamp forest to the east. The climate for the area is moderate to mild. Summers are warm with summer daytime maximum temperatures of 19^0C – 25^0C and winter maximum temperatures 10^0C – 14^0C. The average annual sunshine hours are 2050 hrs (KCDC 2005). Though the average annual rainfall is 1040-1100 mm, El Nino weather cycles have been associated with particularly dry periods and low water levels interspersed with heavy rainfall and flooding.

4.11.1 Regional Geomorphology

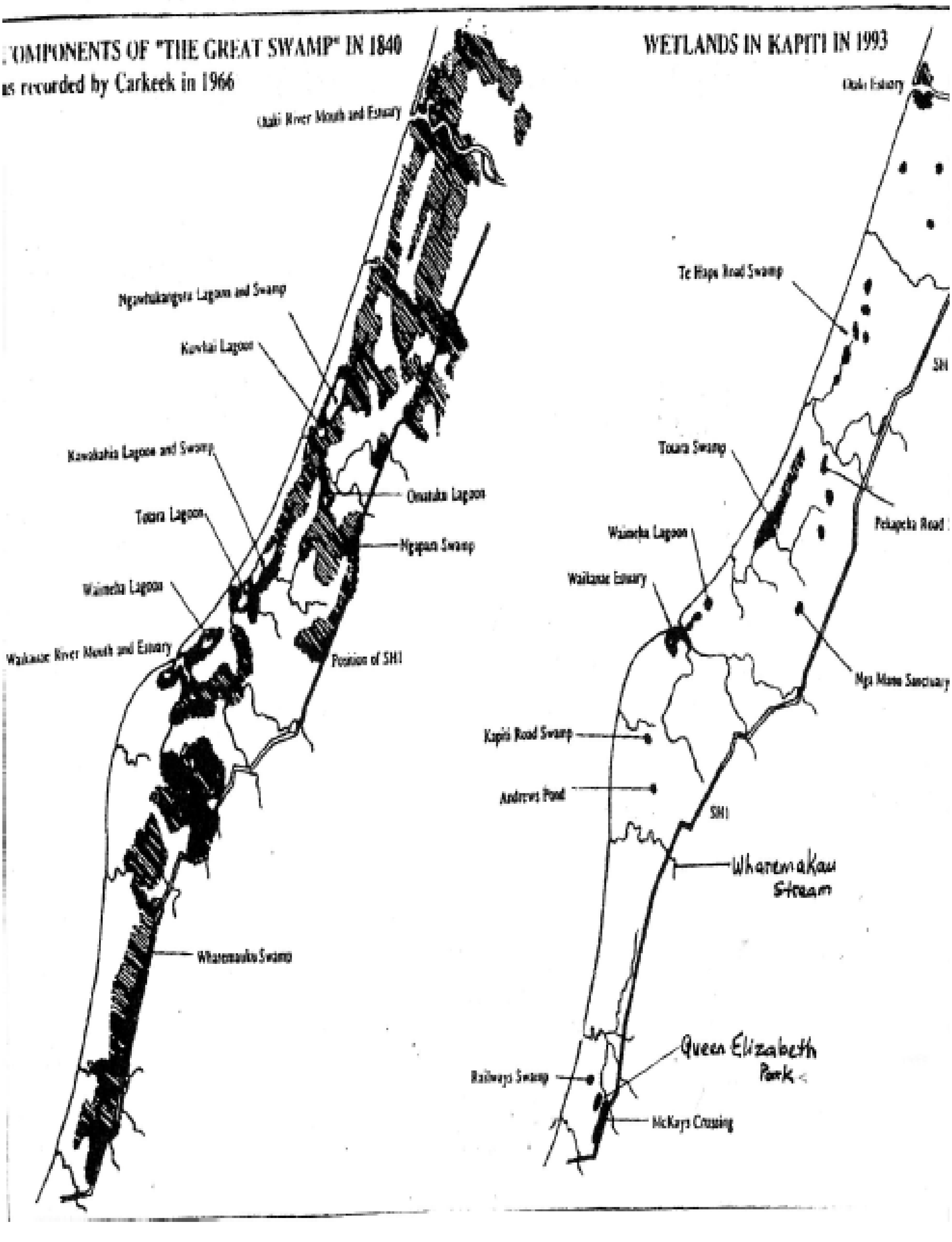
The Waikanae River, that traverses the district, arises in the foothills of the Tararua Ranges and has a catchment of 149km^2. The Tararua Ranges, which reach a height of 1,559m, are composed of hard greywacke and argillite deposited in the Triassic period (190-240 million yrs BP) (Heron *et al.* 1998**;** Fleming 1971). Severe erosion, faulting and frost occurred in the Tararua Ranges during the Waimea penultimate glaciation about 750,000 years BP. The rivers on the western slopes deposited thick layers of gravel in the valleys and foothills. The penultimate interglacial period from 120,000 to 70,000 years BP was associated with sea level rises of up to six metres above present and consequent erosion of the foothills leaving remnant cliffs that are still visible. Following this, further glaciation saw sea levels drop again and erosion debris flowed down the rivers to form alluvial fans and flood plains. The silt blew back on to the hills as loess. The last glacial period finished about 12,000 years ago and was followed by an inter-glacial period which so far peaked about 6000 years ago with a sea level rise of approximately two metres above present level (McFadgen 1997).

The Kapiti Coast dunelands date from the Holocene period over 6000 years ago. They extend north parallel with the coastline from Paekakariki to Foxton (Manawatu River) (McFadgen 2007, p 45**;** Stevens 1988, p 178-189) and 10km eastward to Hemi Matenga (514m) and the foothills of the Tararua Ranges. The dunes developed in response to the prevailing northwest winds and ocean currents that carried sand and silt from northern rivers. They overlie the alluvial gravel and sandstone derived from the Tararua Ranges (Adkin 1951).

The oldest dunes on the Kapiti Coast are the Foxton dunes. West of these are the Taupo dunes, which contain pumice from the Taupo eruption of 1900 years ago. Other dune sequences include the Motuiti dunes (1000 years old), the Old Waiterere dunes (450-100 years old) and the Younger Waiterere dunes (150 years to present). The natural processes of dune building continues throughout the region **(**McFadgen 1997) but destruction associated with human activities between the 1950s and1990s has seen 81% of the dunes lost for urban development or planted with marram grass and pine forests (Hilton *et al*. 2000).

The inter-dune wetlands of the Great Swamp (Carkeek 1966) initially sustained coastal forests and reed/tussock swamps (see Figure 2 below). They extended from Paekakariki in the south to Manawatu River in the North, about 100km. The present landform has wetlands and lagoons between the consolidated rolling dunes that were formed when sea levels receded trapping water behind the foredunes. Organic deposits in the residual swamps formed the Paraparaumu Peat that underlies the present seaward dunes. The forests were destroyed by waves of human habitation from the 14th century with fire and felling, but particularly over the last 150 years with milling and drainage for farming and urban development. A few remnant swamps and lagoons remain. The land that has been developed has topsoil on a peat base, or consolidated sandy topsoil (Boffa Miskell 2001).

The Waikanae River floodplain provides the gravels beneath the inland dunes that support shallow aquifers. However, groundwater levels are declining possibly as a result of abstraction by private bores for town water and agriculture (Phraetos 2002**).** Seasonality of groundwater levels has been observed at the Nga Manu swamp forest, with the lowest levels in the summer (Benseman 2009, pers. comm.**).** This has been monitored by GWRC that also monitors the deep groundwater at the Te Hapua Swamp, Te Horo. A suggestion of tidal effects on groundwater levels especially near the Waikanae River estuary has not been verified **(**Law 2008).



From Carkeek (1966) and Fuller (1993).

Figure 2. The Great Swamp, Kapiti Coast 1840 and the remnant wetlands in 1993.

Note: By 2013, the natural wetlands had contracted further with the loss of Andrews Pond, Paraparaumu. The water table at the Te Hapua flaxlands and swamp has also been lowered by adjacent farm drainage. Totara Swamp is part of the Kawakahia Swamp in Waikanae, a regional ecological feature, that is under threat from the development of an expressway through the neighbouring farmland.

4.11.2 Kapiti Coast History

The dune wetlands on the Kapiti Coast, such as those at Queen Elizabeth Park, Paekakariki, Te Hakari Wetland at Kuku Beach and Te Harakeke Wetland at Waikanae are examples of the wetlands that once extended along the west coast of the lower North Island. When Europeans arrived in the 1840s, most of the dune forests had already been cleared or burnt by the incumbent Maori tribes. Kumara (*Ipomoea batatas*) gardens were present on the lower hill slopes, but cultivated gardens on the flats developed only with the introduction of potatoes and wheat in the early 19th century. The first documented permanently settled iwi were the Muapoko. However, in the 1820s they were dispossessed of their land, initially by Te Ati Awa and then by Ngati Toa from Taranaki. At the same time, contact with whalers and sealers on neighbouring Kapiti Island resulted in intermarriage and ultimately coastal settlement by Europeans (Pakeha) from 1839 (GWRC 2007).

With the first wave of settlers arriving from Wellington to the Waikanae coast, land purchases north of the Waikanae River commenced. Negotiations were undertaken with Maori leaders but were fraught with difficulties. Nevertheless, trading in flax and timber commenced and relationships with Te Rauparaha[26] were established. Land trading issues were taken to the Native Land Court and prominent Maori leader, Wiremu Parata, given the responsibility of overseeing the purchase process. He retained over 8000 acres for the use of his iwi. Parata township was developed north of the Waikanae River but after his death the name reverted to Waikanae. He is remembered in the name of the Wi Parata Reserve, Waikanae (MacLean & MacLean 1988).

In 1906 W.H. Field became the largest landowner in the Waikanae area. He was a conservationist, active in preservation of the remnant lowland swamp forests and active in exploring the Tararua Mountains. In 1958 the Smith family bought the Ngarara Farm from the Field Estate. Much of the original holding had been sold for urban development (Smith 2009, pers. comm.). Moss Smith, the owner and also a conservationist, sold a 15ha block of land containing swamp forest to Peter McKenzie for the Nga Manu Nature Reserve in 1975. A swamp forest has also been preserved in neighbouring Jack's Bush (Horne 2009, pers. comm.). Residual wetlands and swamps of the Kapiti Coast are identified in Figure 2.

Urbanisation has progressed north and east of Waikanae township (Figure 4). In 2007, the Ferndale Riding School sold 14ha of its compacted duneland to the Ferndale Trust for a low impact urban development (KCDC 2007). This was opened for occupation in April 2009. West of the Nga Manu Nature Reserve, a 300ha area for development known as the Waikanae North

[26] Te Rauparaha was a prominent rangitira (leader) of the Ngati Toa tribe. He used Kapiti Island as his base for intertribal and anti-British wars. His followers spread to the Kapiti Coast where villages were set up and some intermarriage with the pakeha whalers took place. His sorties extended to the lower part of the South Island. He signed the Treaty of Waitangi and developed trade with the pakeha settlers in flax and timber. However, his belligerent behaviour eventually led to his capture by the British Army and exile to Auckland. He remained there until a year before his death in 1848 when he was allowed to return to Otaki.

Development Zone was notified as a District Plan Change in March 2009, designed to have eco hamlets and low urban design build. The Ngarara Farm had resource consent to establish eleven eco villages over the next 30 years but this has been compromised by the anticipated expressway from Paraparaumu to Peka Peka that traverses the farm (KCDC 2009).

South of the Waikanae River, the settlements of Paraparaumu and Otaihanga were established in the 1850s. They were pivotal stops for the Wellington-Whanganui mail service and the Ferry Inn was built for accommodation at the mouth of the Waikanae River. The clearance of the land enabled sheep farms to flourish. The settlements were slow to grow though there was a regular coach service along the beachfront (Maclean & Maclean 1988). The Wellington-Manawatu Rail line was opened in 1866 with stations at Paraparaumu, Otaihanga and Waikanae. A winding inland road link from Wellington was established over the Paekakariki Hill in 1865. The opening of Centennial Coastal Highway in 1940 provided an alternative route to the Kapiti Coast ensuring that many more people went to the area, though initially it was for weekend camping, baches[27] and beach-houses (Paekakariki Rail & Heritage Museum 2008).

Permanent settlement was gradual with minimal reticulation – septic tanks for wastewater; water tanks for rainwater or bores for groundwater. Streams were culverted, swamps drained and dunes flattened. The population increased markedly from the late 1970s together with infrastructure including a wastewater treatment station and public facilities. The coastal settlements that began in the 1860s grew into two towns.

4.11.3 Regional Ecology

Esler (1978) in his *Botany of the Manawatu,* suggests that swamp forests across the lowlands and floodplains in the north of the Kapiti Coast were once dominated by kahikatea and pukatea, and that the dunes forests were largely composed of mahoe, tawa and titoki. The dunes were bound by spinifex (*Spinifex serceus*) and pingao (*Desmoschoenus spiralis*). Further south remnants of the original inter-dune swamps and dune forests (totara and kahikatea stumps) are present at Paekakariki, Waikanae and Te Hapua. The remaining dunes are now largely covered with exotic grasses, marram grass (*Ammophila arenaria*), lupin (*Lupinus arboreus*) and weeds (Robertson & Stevens 2007). Sand tolerant plants such as ice plants (*Carpobrotus edulis*) were introduced where any topsoil had formed to reduce or prevent the wind blown loss of sand from the foredunes. Binding of the sand became an important issue with urbanisation as house building was permitted on the dunes. Details of the present flora in the Kapiti Region can be found in Appendix 4.

A number of ecological surveys of the dunes and inter-dune wetlands have been conducted for GWRC, KCDC, DOC and private developers. They include lists for all the wetland sites **(**Wildlands 2003), trip reports and botanical lists from botanists and the Wellington Botanical Society (Ravine 1992**;** Ogle 1991; Mitcalfe & Horne 2008); and a by a consultant hired by

---

[27] A bach is a small dwelling also known as a crib, hut, or whare, usually with few rooms and limited toilet facilities, usually found at the beach or riverside (The New Zealand Dictionary 1994).

KCDC (Harlen 1993). Other surveys were completed as part of the Key Native Ecosystem Programme (Phraetos 2002); for resource consents for abstraction of water from the Waikanae River (Porter 2003); for restoration of the wetlands by Wellington Regional Council (Wildlands 2002); risk assessment and monitoring on the Kapiti Coast (Robertson & Stevens 2007); preparation for resource consent to develop a new subdivision (SKM & Maypole 2008) and hydrological assessments of ten wetlands in the Wellington region (Thompson 2012). There were no ecological surveys of the dune lands at the new housing subdivision of Ferndale. These studies have largely confirmed the considerable biodiversity history of the Kapiti Coast. Many of them have presented information on the vulnerability of the present ecology in the face of the urban development that has occurred and continues.

The effects of infrastructure development on the ecology of the Kapiti Coast are clearly visible at the Queen Elizabeth Park, Paekakariki, following the recent construction of a state highway flyover and railway embankment that have divided a palustrine wetland into two areas. The eastern wetland area has semi-permanent water with extensive raupo (*Typha orientalis*) growth; the western wetland area is an ephemeral wetland with large numbers of exotic weeds. A culvert pipe beneath the rail embankment connects the two parts. This distortion of the wetland has followed the profound changes that occurred during the 1942 USA Marines' occupation with the construction of a military camp requiring the drainage of the swamps and compaction of the ground. It is likely that many wetland species were lost from the area. However, documentation from that period is fragmentary at best. More recent losses have been documented and include the rare native grass, *Amphibromus fluitans* that disappeared between 1990 (Ogle 1991) and 2006 (Wellington Botanical Society field visit 2006).

The risk of drought affecting the wetlands of the Kapiti Coast depends on the El Nina cycle weather pattern and therefore the amount of rain received by the area. In March-April, 2010, GWRC records at the Te Hapua Shoveler Lagoon showed that groundwater levels at a bore depth of 5m had dropped by 130mm and that the wetland water levels had dropped by 200mm during those months (GWRC 2010). They were replenished by winter rainfall in the catchment. According to Boffa Miskell (2008) the average seasonal variation in natural wetland water levels across the Kapiti Coast can be as great as 1.5m, although the largest percentage of this likely to be associated with abstraction for urban use rather than evapo-transpiration. The consequences of these changes in hydrology can be severe for the flora and fauna of the wetlands.

4.11.4 Ecological, Cultural and Social Significance

Maori intermittently occupied the Waikanae dune area from the 14th century. Marine shell middens are poorly represented in the local dunes but some have been recorded just south of the Waikanae River at the Kenakena Pa site (McFadgen 1997). They contained loosely scattered shells, mainly pipi (*Clebidonax deltoides*), with a few fish bones. Moa (*Dinornis sp.*) bones were not found in the Waikanae dune middens but have been found in middens to the north and south of Waikanae suggesting that moa were probably hunted near Waikanae as well. Archaeological evidence indicates that early Maori settlements were in well-forested sand dune areas where there were excellent food resources in the forest, lagoons, swamps and the sea (McFadgen 1997; Adkin 1948**)**.

The Waikanae estuary was the site of three Ngati Awa pa and a centre of N.Z.flax (*Phormium tenax*) trade. The estuary was also the site of inter-tribal warfare in 1839 that was followed by the decline of Te Rauparaha as a powerful leader. The area is regarded as tapu[28] by the Ngati Awa tribe. The swamps of the Waimeha River (now Waimeha Lagoon) may have provided fresh water mussels as well as eels. Kai moana[29] is still available along the beaches but with the leisure invasion of the beaches and pollution of the streams and rivers, is now less abundant.

The more recent development of the Kotuku Park subdivision Stage 2 at Kenakena (1987 - 2010) took into account the Maori Cemetery within that area and it was given Reserve status in 1992. In 1991, the graves of early settlers Weber (d.1899), H.A.Field (d.1899), Tom Wilson (d.1878) and James Erskine (d.1872) were identified near the Waikanae River and local historians requested that KCDC mark them appropriately.

4.12 Conclusion

Wetlands are complex ecosystems that through history have provided humans with many life-dependent services including food, fibre and clean water. Other major functions including flood protection, sediment control, pollution management, stormwater management and aesthetic and recreational roles have been used to varying degrees by civilisations. Some wetlands have been incorporated into urban developments and many constructed within subdivisions. All wetlands, however, perform their functions only if they are healthy, and that is reliant on the presence of water and of complex systems to ensure that water quality is maintained.

Wetland border (riparian) zones are an integral part of a wetland health providing buffering from other land uses by filtering sediment and delaying movement of pollutants into the wetland allowing denitrification to occur (USEPA 2008). These essential functions are, however, frequently compromised by urban development where aesthetics and accessibility to water mean more than ecological health, catchment hydrology is disrupted by barriers to water flow and habitats are destroyed (Tables 4.2 & 4.3). Also destroyed with most urban development are the corridors between ecological patches, which allow the movement of flora and fauna across a landscape. Palustrine wetlands rely on rainfall and groundwater and are particularly affected by this type of isolation when surrounded by infrastructure and buildings.

While ecologically important natural wetlands have a special status in environmental decision-making, urban wetlands do not usually appear in New Zealand district or regional plans unless

[28] Wahi Tapu may be translated as a sacred site. It is usually associated with a burial site or place where a death occurred. In most cases there is a ceremonial lifting of the tapu when grieving has been completed but some sites have permanent tapu (The New Zealand Dictionary 1994).

[29] Kai moana: Maori for seafood (shellfish and fish).

they are for stormwater collection. Guidelines for subdivision developers make scant reference to them beyond determining whether they have ecological values and therefore require a buffer zone. However, the Christchurch City Council has been able to ensure that there is no urban encroachment on to the Travis Wetland, one of only 2% of palustrine freshwater wetlands remaining in Christchurch, by forming a Nature Heritage Park to protect it. It is included in the Christchurch City Council plan.

The characteristics of the Kapiti Coast, identified in the latter part of this chapter, provide a background to this investigation into the ecological health of its urban wetlands. The ecological indicators used in the study are related directly to the complex functions and structure of a ‘healthy’ urban wetland and its riparian area as described above. Many indicators of wetland health have been promoted over time but none have specifically examined the role that the urban wetland riparian area has in maintaining wetland condition. The methodology for examining the impacts of urban developments on the functions and structures of the selected wetlands is described in the next chapter.

Chapter 5 Research Design and Methods

5.1 Introduction

Case study research was undertaken to investigate the relationships between the ecology and role of urban wetlands and their riparian areas, the aesthetic needs of urban development and the land-use planning of a subdivision. The purpose of this chapter is to describe the case study selection and the methods of data collection and analysis. The impacts of urban development on the functions of wetlands are seldom measured in New Zealand, yet overseas literature is emphatic that the health of wetlands is compromised by inadequate and ineffective riparian areas around the wetlands (Hogan & Walbridge 2007; Alberti 2005; Ehrenfeld 2000, p 253). Although there are assessment tools for natural wetlands (Clarkson *et al*. 2004), the lack of any ecological assessment of urban wetlands in New Zealand has exposed a gap in the understanding of the role of wetlands in urban sustainability.

For many years urban subdivisions have either enveloped an existing wetland remnant or have constructed one as an amenity feature but most have had very little aftercare. The Kapiti Coast urban area has a plethora of such wetlands but their ecological health is unknown and few are monitored by Kapiti Coast District Council. The wetlands studied came from different origins and were spread geographically across the Kapiti District. The fieldwork incorporated physical, geochemical and biological assessments and was followed by laboratory identification of flora and fauna. As well as the desk-top analysis of hydrological and resource consent data, the fieldwork was undertaken at the case study sites in May 2010 and November 2010, with at least three visits to each site.

Given that there is no index of urban wetland health in New Zealand, a multi-metric index was developed in this study to assess the effect of urban development on urban wetland health. A handbook of wetland condition for non-urban wetlands (Clarkson *et al*. 2004) is available but is not focused on the urban environment. Many district plans have guidelines for the management of constructed stormwater collection ponds and regional councils have plans for constructed wetland management by their owners that recommend regular inspection and repair of banks and spillways. A maintenance plan for constructed wetlands is required for resource consent in all regions. No formal regimes for monitoring other urban wetlands by local authorities have been developed.

This new Index attempts to fill this gap in recognising the importance of wetland health in established and new urban developments by presenting the current urban wetland riparian condition and the potential for improvement. Correlations between ecological metrics with wetland riparian function were investigated to see how the different metrics behaved. The Index uses scoring methods derived from published guidelines by Rowe *et al.* (2008), Clarkson *et al.* (2004), Snelder *et al.* (2004), Quinn (2003) and other published work documented below, but adapted to the particular conditions of the palustrine, interdune, urban wetlands.

5.2 A Wetland Case Study – Loss of Wetland Ecosystems

Rapid urban development on the Kapiti Coast since the 1960s has resulted in the loss of sand dunes and wetland ecosystems with the removal of the sand to in-fill wetlands and dune swale depressions for flat residential development (Figures 3 & 4 below). However, some subdivisions have small remnant or created wetlands but the ecology of neither the wetland nor the riparian areas surrounding them appears to have been given any particular attention.

Figure 3. In-fill of depression to form Langdale Road between Tower Lakes No 1 (right) & No 2 (left) 1982. (Photo: B. Phillips)

Figure 4. Urban development by flattening dunes at Lake Ngarara, 2010. (Photo: K. Palmer)

Section 108 of the Resource Management Act 1991 requires that,

> resource consents applied to any site encompass economic, ecological, cultural and social values (fair, reasonable and lawful) and must relate to avoiding, remedying or mitigating any adverse environmental effects associated with the activity.

The presence and quality of a sustainable wetland riparian ecosystem (as defined in Section 4.8 and Appendix 8) in urban areas is one measure of ecosystem protection that local authorities, therefore, have responsibility for as well as for the management and monitoring of the urbanisation process (as discussed in Ch. 2).

For this study, data were collected from two principal sources: (1) an ecological assessment of the wetland and riparian areas at the selected wetlands and (2) a document analysis of policies and plans relevant to resource consent conditions applied to each wetland's riparian areas and to the imperviousness of the urban development.

The locations of the study sites (Figure 4) comprised two non-urban wetlands (Te Hapua and Nga Manu) and the six urban wetlands studied (Ferndale, Waimeha Lagoon, Lake Ngarara, Lake Kotuku, Tower Lake and Midlands Gardens). Details of these wetland sites are presented in Section 5.3 and Appendix 1.

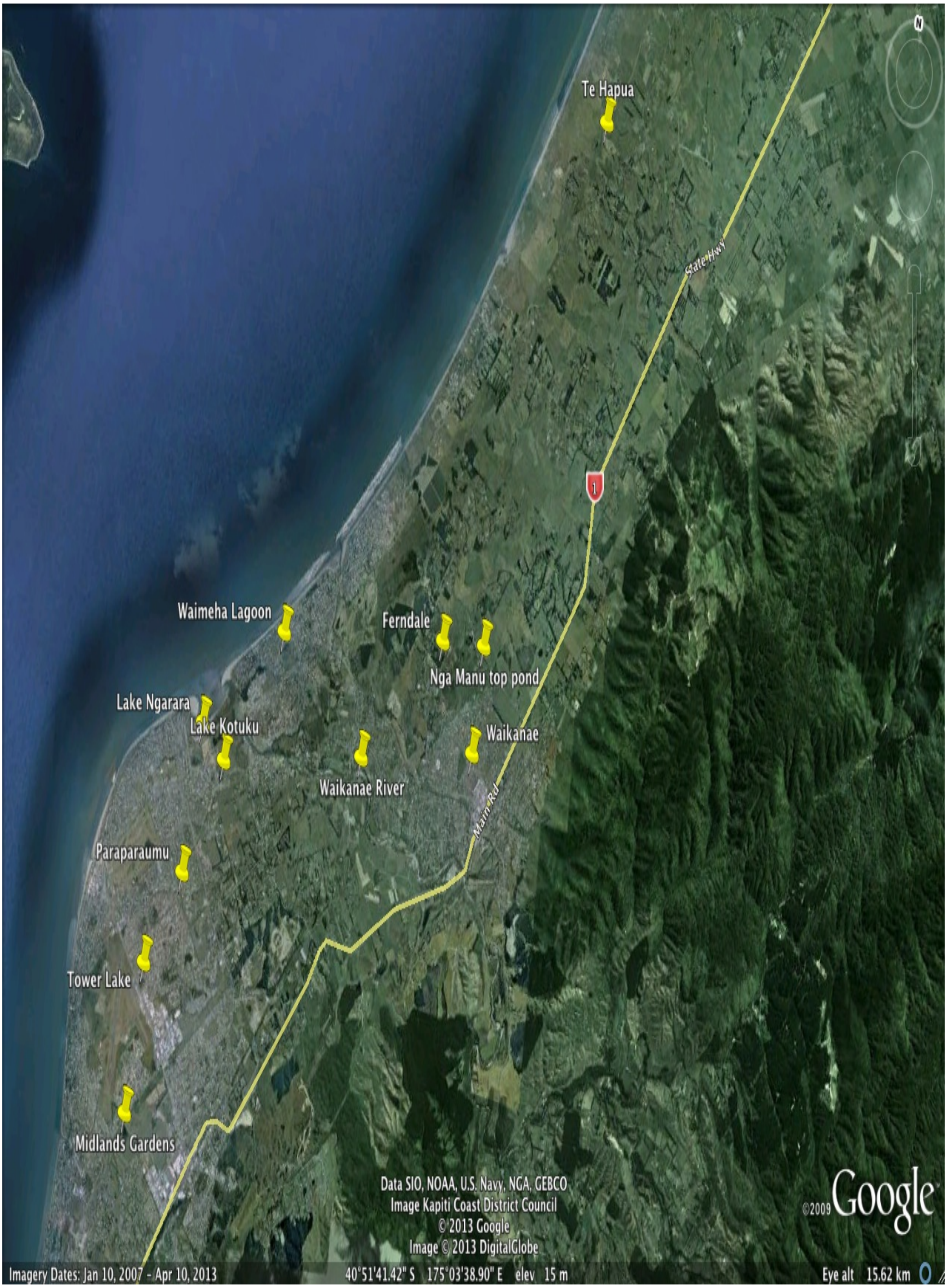


Figure 5. Google Earth image of the location of the case study wetlands – Te Hapua, Ferndale, Waimeha Lagoon, Lake Ngarara, Lake Kotuku, Tower Lake No 1 and Midlands Gardens. Also named are the townships of Paraparaumu and Waikanae and the Waikanae River.

5.3 Choosing Study Sites

Eight sites were selected for the case study, all of which were interdune, palustrine wetlands with permanent still water (Map 2: Figure 5). Two non-urban wetlands served as ecologically 'best available' sites in the same interdune geomorphic domain as the urban sites. They were chosen to represent wetlands with some natural character against which comparisons could be made to identify the effects of urban development. The other six wetlands were all in urban areas. The two non-urban wetlands (Te Hapua Wetland Lagoons and Nga Manu Nature Reserve Top Pond) had had minimal human activity for approximately 15-20 years although their catchments included agricultural land. Data from South Island lowland natural wetlands assessments by Suren & Sorrell (2010) and Suren *et al.* (2010) were also used for comparison with the urban data found in this study.

All urban wetland sites were within the urban areas of Waikanae and Paraparaumu and had housing within 40m of the water edge. 'Urban wetland' refers to those wetlands in close proximity to housing either because they are incorporated within the urban development or they are constructed in association with the urban development. The sites on private properties were accessed with landowner permission, the others were on Reserves and public land.

The urban wetland sites comprised two remnant wetlands (Waimeha Lagoon and Lake Ngarara); two sites excavated to the water table in dryland reclaimed areas (Tower Lake No 1 and Midlands Gardens Lakes); and two constructed wetlands for stormwater management (Lake Kotuku and Ferndale). These sites were selected for their different geomorphological origins. They were also of varying size[30]. It was important to have a spread of sites of different origins across the Kapiti Coast District to obtain data about their ecological health in different urban development areas with different histories. The responsibilities for the care of urban wetlands, new and old, are unclear and not defined but the operative KCDC District Plan 1999, Objective C1-11.1, Policy 5 states that the council will 'ensure that the effects of subdivision, land use and development activities do not alter the water table of wetlands and lakes to a significant extent'.

The following descriptions of the study wetlands use information derived from the landowners, personal observation, consultant reports to Kapiti Coast District Council and Greater Wellington Regional Council (GWRC) and other published work (GWRC 2010; Enright *et al*. 2006; Wildlands 2003). The consultant reports were from developers, ecologists, botanists, part of submissions to the Environment Court and resource consent applications. There were also GWRC biodiversity and water quality reports and State of the Environment reports. To complete the site profiles, a Google aerial photo (2007) and a site photo taken in 2010-2011 accompanies each site description (see Figures 6 to 13 below). (Further detailed descriptions of the study wetlands may be found in Appendix 1).

[30] Wetland sizes (***Duguid et al, 2005***): very large >10km^2 (1000ha); large > 1km^2 (100ha); medium >0.5km^2 (50ha); small > 0.1km^2 (10ha); very small <0.1km$^{2.}$ (<10ha)

Site Descriptions:

5.3.1 Non-urban Wetlands (Google Earth .jpg, images at 10 Jan 2007)

Figure 6. Te Hapua Wetland Lagoons: Shoveler Lagoon.
Note: *Azolla rubra* in wetland.

Figure 7. Nga Manu Top Pond in swamp forest.
Note: Longfin eel feeding station on north side of pond area

(a) Te Hapua Wetland Lagoons: Shoveler Lagoon (~0.3 ha)

Map ref: 604162.442 2685082.222. (Figure 6 & 8)

Te Hapua Wetland Lagoons comprise several wetland ponds within extensive flaxlands. The wetlands are partially protected by a QE11 Covenant[31] and are listed by Greater Wellington Regional Council as sites of Regional Ecological Importance. Shoveler Lagoon is one of these interdune wetlands on private land. It was deepened about twenty years ago to a maximum depth of 5m. It is dependent on groundwater and rainwater to maintain water levels that have considerable seasonal variation in water depth. Greater Wellington Regional Council has a monitoring station at Shoveler Lagoon that includes a bore to a depth of 60m to obtain information about the deep aquifer water levels and fluctuations. GWRC also measures daily rainfall and groundwater levels (GWRC 2010). A hydrological assessment was undertaken for GWRC by Thompson (2012). A comprehensive vegetation report was compiled by Enright *et al*. (2006) for the landowners.

Figure 8. West end of Te Hapua Shoveler Lagoon with a large stand of *Baumea sp.* (Photo: K. Palmer 2010)

Figure 9. Nga Manu Nature Reserve top pond swamp forest and outlet at southwest corner of pond (Photo: K. Palmer 2010)

(b) Nga Manu Nature Reserve Top Pond, Waikanae (~0.3 ha)

Map ref: 6036158.909 2683464.503. (Figure 7 & 9)

The Nga Manu 'Top Pond' is centred in a remnant of coastal lowland swamp forest and lies in swales between consolidated sand dunes. It is within the Nga Manu Nature Reserve, which is registered as an area of Regional Ecological Significance (KCDC 2003). The wetland has a depth of more than 5m in its centre and is sustained by groundwater emanating from the Ngarara Stream and its tributaries. Water flows west from the 'Top Pond' via a small stream and flaxland to a larger main pond. The swamp forest has 300-400 year old kahikatea (*Dacrycarpus dacrydioides*), and is home to longfin eels (*Anguilla dieffenbachia*) and brown mudfish (*Neochanna apoda*) (Nga Manu Trust 2009).

[31] QEII National Trust was established 1977 to encourage and promote long term protection of natural and cultural feature. Most covenants are on private land. The covenant is entered on the LIM report to ensure values are protected forever.

5.3.2 Urban Remnant Wetlands (Google Earth .jpg, images at 10 Jan 2007)

Figure 10. Waimeha Lagoon.
Note: boardwalk through wetlands at south-eastern end.

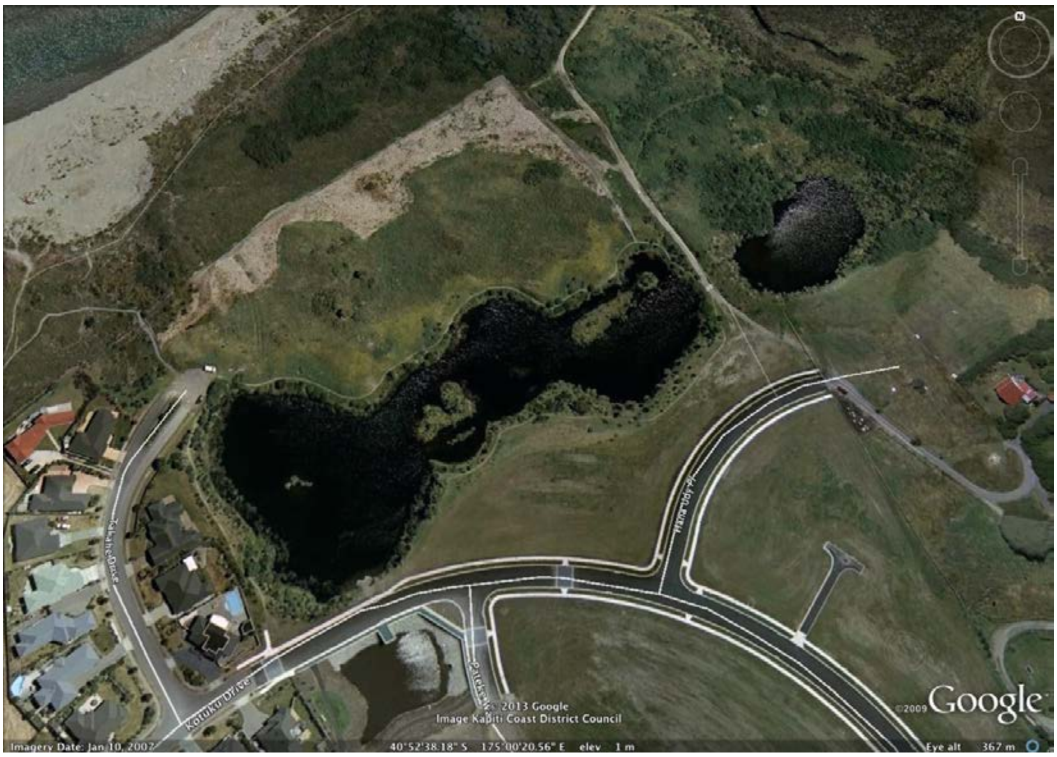


Figure 11. Lake Ngarara.
Note: boardwalk and path across southern end dividing the wetland. New subdivision on east and west sides were not yet constructed in 2007.

(a) Waimeha Lagoon, Waikanae (5.32 ha)

Map ref: 6035800.414 2680173.144. (Figures 10 & 12)

The Waimeha Lagoon and the adjacent Waimanu Lagoons are remnants of the Waimeha River, a division of the Waikanae River until 1896. The Waimeha River remnant, the Waimeha Stream, was diverted through the Waikanae North foredunes in 1921. Waimeha Lagoon was developed from the ensuing swamp (MacLean & MacLean 1988). A narrow piped channel connects the saltwater Waimanu Lagoon with the freshwater Waimeha Lagoon. The Waimeha Lagoon is administered by KCDC for the Department of Conservation (DOC) and is a site of Regional Ecological Importance (KCDC 2003). Since the 1970s, there has been on-going restoration of the wetland riparian area with flaxes, toetoe, sedges and reeds (Figure 10). A boardwalk crosses the wetland area at the southern end of the lagoon and there is a bird watching hide at the north-eastern end (Wildlands 2003). At the north end, several small stormwater drains enter the lagoon.

Figure 12. View of western shore of Waimeha Lagoon. (Photo: K. Palmer 2010).

Figure 13. Northern corner in Lake Ngarara with reed beds. (Photo: K. Palmer 2010).

(b) Lake Ngarara, Kotuku Park, Paraparaumu (~4 ha)

Map ref: 6032710.884 2678877.038. (Figure 11 & 13)

Lake Ngarara is an interdune wetland at the eastern end of the Waikanae Estuary Scientific Reserve and forms the western boundary for the Kotuku Park subdivision. It is a remnant freshwater lagoon. It is mainly groundwater and rainwater fed and but also receives overflow stormwater from a detention pond and Lake Kotuku further east. It has a variable depth from 5m at the western edge to 600mm at the eastern side. There is a seasonal water level variation of 500mm according to Boffa Miskell (2004). The Kotuku Park subdivision has proceeded in stages since 1988 with the continual destruction of sand dunes to ensure flat land for housing (Figure 4) and at a level above 100yr flood hazard level. Lake Ngarara has a reed bed (Figure 13) at the northern end. There is also a small culvert bridge at the north end separating the main body of water from a smaller pond area that is overgrown with blackberry and scrub. Patches of riparian native flora have been planted around part of the lake margin interspaced with mown grass.

5.3.3 Urban Reclaimed Dryland Sites Excavated to the Water Table

(Google Earth .jpg, images at 10 Jan 2007).

Figure 14. Tower Lake No 1 on the corner of Langdale Avenue and Kapiti Road.

Figure 15. Midlands Gardens Top Pond at east end of the Paraparaumu Airport runway.

(a) Tower Lake No 1, Langdale Avenue, Paraparaumu (0.57ha)

Map ref: 6034294.017 2679104.327. (Figure 14 & 16)

The three Tower Lakes were formed in the mid-1980s as part of a subdivision from Kapiti Road along Langdale Avenue, Paraparaumu. They were excavated in a dune swale to the water table depth (Figure 3). The associated consolidated sand dunes were flattened for housing. The three lakes connect via a culvert beneath Langdale Avenue. Any overflow reaching the third and largest lake discharges via drains and culverts to ponds and wet areas between Campbell Road and Langdale Avenue. The drains extend to the amenity lake at Summerset Retirement Village and then the water drains into the Mazengarb Stream.

Tower Lake No 1 is reliant on rainwater and, since 1994, also on water from a 60m deep bore. The flow from the bore is 50,000 litres per hour and it runs for 4-5 hours most days in the summer and less often in the winter to maintain water levels at the culvert outlet level (B. Phillips 2010, pers. com). The lake is bordered on the north and east by private properties, the south and west sides being owned by KCDC. In 1991 it was proposed that Tower Lake No 1 be a stormwater storage pond but this was not implemented. Although it was once considered as a local Ecological Site of Importance, it has now been withdrawn from that list (KCDC 2003**).** Since 1994 the wetland has been used as a public area for feeding ducks from a small constructed peninsula. A black swan nests there annually (Figure 22).

Figure 16. The south-western corner of Tower Lake No 1. (Photo: K. Palmer 2011).

Figure 17. Midlands Gardens north pond central island. (Photo: K. Palmer 2011).

(b) Midlands Gardens Retirement Village North Lake, Paraparaumu (~0.3 ha)

Map ref: 6038856.220 2678010.916. (Figure 15 & 17)

Midlands Gardens Retirement Village North Lake is at the east end of the Paraparaumu Airport. It is part of a privately owned six-lakes complex developed in a sandy scrub area of the floodplain of the Wharemauku Stream and an adjacent tributary. Sand dunes were flattened in the 1970s prior to airport development. The lake was deepened about ten years ago below the water table and the fill used to form an island in the middle. A levee along the west pond boundary separates the lake from the streambed of a tributary of the Wharemauku Stream.

The lake depends mainly on groundwater and rainwater but a small amount of stormwater from the village flows into it (Kapiti Retirement Trust 2010). The riparian area has patches of flaxes, toetoe, *Carex sp.*, rushes and reeds as well as willows and exotic trees around it with large lawn areas between patches.

5.3.4 Constructed Stormwater Collection Wetland Ponds

(Google Earth .jpg, image at 10 Jan 2007).

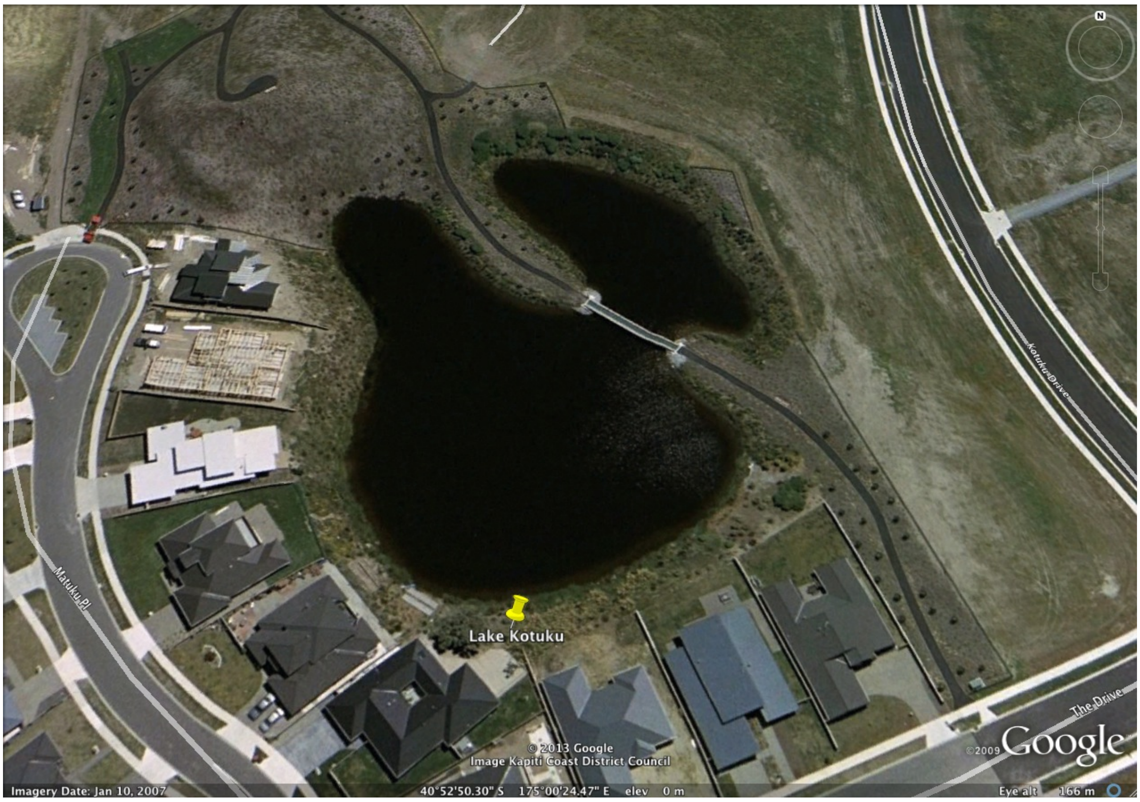


Figure 18. Lake Kotuku with bridge dividing the wetland pond in two.

(a) Lake Kotuku, Paraparaumu (0.4 ha)

Map ref: 6034274.404 2679071.561. (Figure 18 & 19)

This constructed stormwater collection pond for the Kotuku Park subdivision, Paraparaumu, was formed in 1991. It was designed to receive water from the adjacent floodable rural land of the Mazengarb Stream catchment and some stormwater runoff from the neighbouring residential area. It is a sandy basin with the lake floor near the water table. Apart from floodwater and stormwater inputs it is also aquifer-fed. It has a capacity of 7600m^3 and a depth of 1.4m. The stormwater is filtered and subjected to sunlight before it is flows west through a culvert to a detention pond and thence into Lake Ngarara. The concept is that the water will be filtered of toxins and sediment before it reaches the wetlands and salt marshes of the Waikanae Estuary Scientific Reserve (Boffa Miskell 1999). Neighbouring properties extend to the water's edge. The lake is monitored by KCDC for water quality. Its tendency to eutrophication and large algal blooms (Figure 21) in warm weather have been noted (Cross 2010, pers. comm.).

Figure 19. Lake Kotuku stormwater collection pond south arm from adjacent constructed sand dune. (Photo: K. Palmer 2010).

Figure 20. Ferndale stormwater collection pond outlet with an overgrowth of *Lemna minor*. (Photo: K. Palmer 2010)

(b) Ferndale subdivision, Ngarara Road, Waikanae (small)

Map ref: 6035912.031 2682702 602. (Figure 20).

(Note: no aerial images of Ferndale Pond wetland available as Google imagery is dated 10 Jan 2007 which was before Ferndale was constructed).

Ferndale subdivision is a residential development of 15ha on two consolidated sand dunes in a north-south orientation with swales between them. There is no natural wetland area. However, a constructed stormwater collection pond has been developed at the water table in a boggy paddock. A small stream enters the pond from the east. The pond discharges westward via a small stream to a swale soak-pit. The catchment areas for stormwater are small with limited impervious surfaces – no more than 40% of any property. There are filters for stormwater at the roadside (Connell Wagner 2007). The swale detention areas are vegetated with grasses and sedges. All the stormwater discharges are required to meet the standard of the Greater Wellington Regional Freshwater Plan and the Greater Wellington Regional Discharges to Land Plan (GWRC, 1999).

5.4 A New Assessment Index – filling the gap

An Urban Wetland Health Index (UHWI) (Table 5.1) is proposed for assessment of the condition and function of urban wetlands. A survey of all New Zealand district plans has revealed that no district councils had specifically identified the management of urban wetlands or their riparian areas in their current district plans (apart from Wellington City Council's management plan for Waitangi Park, an estuarine wetland, and Travis Wetland, a palustrine wetland, in Christchurch City's Council's management plan).

The lack of an instrument to evaluate urban wetland health appears to be a reflection of the low status they hold in urban planning. There were no references to urban wetland riparian areas or buffer zones, in district plans although these are pivotal for the protection of urban wetlands and essential for the sustainability of their functions and structures (Phillips 1989).

The proposed UWHI is a multi-metric index. Each metric comprises four or five parameters. These parameters are specific to the urban wetland situation, some are modelled on published sources (Papas 2007; Liu et al. 2006; Fennessy *et al*. 2004; Clarkson *et al.* 2004), each has a robust literature behind it determining its validity. They also reflect the general district where the study was undertaken. For example, the Kapiti Coast urban district is built on sand dunes and floodplains and hence the metrics assessed for the urban catchment reflect this (Table 5.1 below). The metrics are predicated on a 'damage profile' such that the non-urban wetland scores reflect that they are the least damaged, best available wetlands for comparisons. Where precise measurements of quality, such as wetland water pH or conductivity, are used these have been compared with appropriate biological indicators or references such as the wetland invertebrate index developed by Suren *et al*. (2010).

The urban wetlands were not subjected to the natural disturbance regimes of the riverine and lacustrine wetlands, fire damage or animal browsing described by Clarkson *et al*. (2004). They were, however, affected by human activities associated with urban development including stormwater runoff. Urban wetlands also commonly have riparian areas of limited structure and function. The metrics for assessing urban wetland health were, therefore, specifically associated with urbanisation effects or adapted from those applied to natural wetlands. The indicators for urban wetland ecological, cultural and social values were derived from consideration of what might be expected of a natural wetland in the same domain. The scoring of the impacts of urban development on the wetland and its riparian area were based on historical information in the local authority documents and other reference works.

5.5 Ecological Assessment Methods

The UWHI assesses the multiple parameters of wetland condition including the hydrology of the catchment, wetland and riparian area, physicochemical factors, macroinvertebrates, riparian ecosystem intactness and habitat, bird counts within 25m of the wetland water's edge, and the direct impacts of urban development and infrastructure on the wetlands. These particular metrics were chosen following a literature search of wetland studies in New Zealand and abroad e.g. Ausseill *et al*. 2011; Papas (2007); Alberti (2005); Clarkson *et al.* (2004); Ehrenfeld (2000) and some stream studies e.g. Rowe *et al*. (2008, 2004); Quinn (2003). The parameters were designed to provide information on the impact of a particular stressor on the may have such e.g. artificial barriers to water flow affecting hydrology of wetlands. The choice of the metric parameters was made with regard to wetland and riparian ecosystem functions (Jacobs *et al*. 2010).

The scores from the assessed seven metrics and their parameters were tabulated and totalled. The potential performance attained was expressed as a percentage (Fennessy *et al.* 2007). Table 5.1 lists the five condition options that describe the metrics for the Urban Wetland Health Index, with '5' being the best ecological option. These options are indicative of the stress that applied to the parameters. Section 5.6 details their use, and details are also found in Appendix 3, 'Worksheets'. The sum of the scores of all the metrics is the Urban Wetland Health Index for an individual wetland (Table 6.14). Table 6.14 also indicates the overall Kapiti Coast District Urban Wetland Health Index from the averages of the metrics of the six urban wetlands.

Field visits were made up to five times during April-May 2010 and again in November 2010 to all wetlands to obtain samples for aquatic invertebrates (Appendix 2), for physicochemical data from the wetland water, evaluation of flora and fauna and to monitor any changes during those month and between seasons. However, for hydrological assessments, historical and continuous data were sourced from both direct observations, previous studies and records provided by the GWRC, KCDC and private developers seeking resource consents or conservation covenants that provided relevant information on water fluctuations and flows, nutrients and water quality. Fieldwork sheets (Appendix 3) were completed on all visits to each wetland. The seasonal visits gave a perspective on the species of aquatic invertebrates present in autumn and spring respectively. Date, time, GPS location, altitude and plot numbers were recorded and each site was photographed at the first visit.

Table 5.1 The proposed Urban Wetland Health Index metrics. The best ecological option scores = 5. **(**See section 5.6 and Appendix 3 for details).

SCORE	5	4	3	2	1
Hydrology (Metric 1)					
Catchment land cover	Native forest/ Swamp	Native scrub planted	Forest - exotic	Horticulture/ agriculture	Urban development
Artificial barriers to flow in catchment	None	Parks, reserves	Urban development	Stormwater drains	Infrastructure
Catchment affected by urban land use %	0-20%	20-40%	40-60%	60-80%	>80%
Wetland type	Interdune forest / swamp	Remnant wetland	Excavated swamp	Excavated dryland	Constructed stormwater collection
Artificial barriers to flow	None	Stopbanks	Urban development	Stormwater drains	Infrastructure
%dryland plants	No dryland plants	<25% dryland spp.	25-50% dryland spp.	50-75% dryland spp.	75-100% dryland spp.
Riparian land slope	0-5º	5-10º	10-15º	15-20º	>20º
Riparian area width	>15m	10-15m	5-10m	3-5m	<3m
Physicochemical parameters (Metric 2)					
Water clarity	>90cm	70-90cm	55-89cm	35-54cm	<35cm
% algal bloom cover	No eutrophicat-ion	Infrequent algal blooms	25-50% algal blooms	50-75% algal blooms	>75% algal blooms
% cover high nutrient plants	None	<25%	25-50%	50-75%	>75%
Riparian ecosystem intactness (Metric 3)					
Loss of original riparian area	No loss	<25% loss	25-50% loss	50-75% loss	>75% loss
Topographical evidence of riparian loss	Original riparian area >20 yrs	Excavated swamp or wetland riparian	Planted riparian area	Urban development in zone	Zone destroyed by infrastructure
Riparian vegetation integrity	No direct human contact 15-20yr.Mature native trees or tussock	Minimal human activity. Native canopy	Moderate human influences. Native or exotic canopy	Extensive human activity. Minimal canopy	Managed vegetation / no canopy
Riparian area land use	Native forest, swamp, tussock,	Exotic forest/ planted native	Residential	Agricultural/ horticultural	Commercial, Infrastructure
Riparian area status	Conservation	Reserve/ recreation	Walkway/ cycleway	Private residence	Roadway/ stopbanks
Native vegetation cover abundance	100% native	>75% native	50-75% native	25-50% native	<25% native or >75% exotic or bare ground
Dominant vegetation	Native forest, swamp tussock	Flax, toetoe, high shrub	Scrub native or exotic, planted zone	Willows, weeds, gardens	Grasses, bare ground

SCORE	5	4	3	2	1
Percentage native avifauna (Metric 4)					
Native avifauna	>75% native birds	50-75% native	25-50% native	10-25% native	<10% native birds
Cultural values (Metric 5)					
Cultural, social and ecological values	National & regional ecological values	Wildlife values	Cultural importance	Recreational values	Aesthetic values
Urban impacts on riparian area					
Urban developments within riparian area	No urban development in riparian area	Reserve/ recreation park to water edge	Residential development in area	Playground areas, private gardens	Commercial development in area.
Urban infrastructure within area	No infrastructure	Cycle tracks, walkways	Sheds, piers, fences	Car parks, access ways, footpaths	Roads, bridges, water reticulation, gas, sewer
Stormwater impacts on wetland (Metric 7)					
Impact of stormwater runoff	No runoff.	Stormwater piped via filter.	Stormwater piped - no filter	Open drain from road.	No stormwater collection drainage.
Imperviousness %CIA	CIA >70% connected	CIA 60-70% connected	. CIA 50-60% connected	CIA 40-50% connected	CIA <40% connected

Sources included: Jacobs *et al.* 2010; Suren *et al.* 2010; Rowe *et al.* 2008; Papas 2007; Rowe *et al.* 2005, Clarkson *et al.* 2004; Snelder *et al.* 2004; Quinn 2003.

5.6 Metrics Measuring Urban Wetland Health

Details of each metric are discussed below and are accompanied by examples of the scoring (Table 5.1) applied to one of its parameters. The scores applied to all metric parameters are given in Table 5.1. These scores represent the presence of the dominant ecological condition at each site. Some of the data that was collected for the proposed Urban Wetland Health Index was later discarded for a mix of reasons discussed in Sections 5.8 and 6.4. For example, in the study by Suren & Sorrell (2010) of 40 natural lowland wetlands across New Zealand, water temperature, pH and conductivity were analysed but the same parameters were not scored for the Kapiti Coast UWHI.

Metric 1: Hydrology of Catchment, Wetland and Riparian Systems

Catchment Hydrology

The catchment data was derived from the GWRC and KCDC records of previous consent applications for changes in land or water use, letters of complaint and dissent, records of commissioner hearings and Environment Court decisions, maps and photographs. Landforms were identified from geological maps of the area (McFadgen 2007; Stevens 1988; Adkins 1947). Each parameter was scored for the physical attributes of the Kapiti District e.g. land cover adapted from the River Environment Classification (REC) (Snelder & Biggs 2004). They also reflected the urban nature of the catchment (Papas 2007; Alberti 2005). The catchment landform was determined by their sites on the floodplains and previous sand dunes with the rural sites differing in land use from the urban sites. For all sites the baserock was greywacke from the erosion of the Tararua Ranges and its foothills over-layered with alluvium, sand and in the rural sites peat.

Clarkson *et al*. (2004) suggested that continuous measurement of water levels was a suitable measure of the hydrologic state of a wetland and its catchment if practicable. As this was not practicable for this study, the hydrologic parameters affecting the hydrology were measured, namely, catchment land cover (Papas 2007; Reiss 2006), the presence of artificial barriers including to surface water flow including drains and infrastructure (Liu *et al*. 2006) and the percentage of the catchment hydrology affected by urban land use (Papas 2007). They were scored according to the parameter that had the greatest effect on, or caused the greatest stress to, the hydrology e.g.

Artificial barriers in catchment	None	Parks, reserves	Urban development residential	Stormwater drains	Infrastructure include roads
Score	5	4	3	2	1
Examples:	Nga Manu	Waimeha	Tower Lake	Lake Kotuku	-

Wetland hydrology

Wetland functions were assessed on site. Palustrine wetlands form in landscape depressions where water levels depend on rainwater, surface water and groundwater. Ground water levels have been monitored by Greater Wellington Regional Council (GWRC) at Te Hapua Shoveler Lagoon since 2009 (GWRC 2009). There were some water level recordings on the Koromiko Stream abutting Nga Manu Reserve last century but none at the Top Pond. No long-term records were available for water tables at the other Waikanae or Paraparaumu wetlands. Details of flood frequency and drought at the wetlands were also unavailable. The limited available data were therefore not scored.

Artificial barriers to groundwater and surface water flow are a common outcome of urban development associated with palustrine wetlands. The drainage of stormwater into these wetlands has impacts on the wetland function with the likelihood that it contains non-biodegradeable pollutants from roads and gardens (Goonetilleke *et al*. 2005; Alberti 2005). Stopbanks and dams impede surface water runoff from the surrounding landscape that in turn may affect the recharge of the wetland. Disturbance regimes required for ecosystem function in natural wetlands are a major casualty of the changed land use associated with urban development (Alberti 2005).

Changes in the water table, as evidenced by dryland plant invasion, were scored using the Clarkson guidelines for dryland plant invasion (Clarkson *et al.* 2004). The presence of these invasive plants represents drying of the wetland over time. The common dryland species noted in those guidelines included mahoe (*Melicytus ramiflorus*), *Hebe sp.*, kanuka (*Kunzea ericoides*), gorse (*Ulex europaeus*), broom (*Cytisus scoparius*), hawksbeard, introduced grasses and white clover. This parameter is based on the percentage of dominance of the invasive plants as measure of water table change (Jacobs *et al*. 2010) e.g.

%dryland plants as measure of water table change	No dryland plants	<25% dryland spp.	25-50% dryland spp.	50-75% dryland spp.	75-100% dryland spp.
Score	5	4	3	2	1
Examples:	Te Hapua	Midlands	-	Tower	-

Riparian Hydrology

The riparian areas assessed were defined as those areas adjacent to and surrounding the wetlands up to a width of 15-20m with vegetation adapted to damp conditions (O'Carroll 2004; Figure 1; Appendix 8). This width was selected following a review of the literature regarding average widths of urban wetland riparian areas (USEPA 2005; Semlistch & Brodie 2003) (also Ch. 4). Although the required width depends on the riparian function that is needed, Semlitsch & Jensen (2001) have considered that the ecological use of the riparian area should decide the width with respect to the needs of the fauna inhabiting it. However, for this study the width and slope were measured as the two parameters relating to the hydrology of the riparian area (Parkyn *et al.* 2000).

The effectiveness of nutrient and sediment capture relies on the rate of water flow across the riparian area of a palustrine wetland and this in turn is determined by the width and slope of the area. Impediments to flow across the area such as that caused by riparian vegetation allows for pollutant and nutrient capture and enables denitrification (Mayer *et al.* 2007; Phillips 1989). However, a high rate of flow from steep narrow slopes, does not allow effective riparian functions to occur. The slope for each riparian area was measured using a clinometer e.g.

Riparian land slope	0-5º	5-10º	10-15º	15-20º	>20º
Score	5	4	3	2	1
Examples:	Te Hapua	Ngarara	Midlands	-	Lake Kotuku

Metric 2 Physicochemical Parameters

The physicochemical assessments were made for wetland water but not riparian soil. There was compacted sand surrounding all the wetlands. The wetland pond water measurements included water temperature, water conductivity, water clarity, pH and percentage of high nutrient plants. A Cyberscan pH and conductivity meter was used for recording acidity and conductivity.

Conductivity was measured in micro-Siemens (µS/cm) and is an indicator of the concentration of electrolytes in the water (Heyda 2006). According to the United States Environmental Protection Agency (USEPA) (2012) most wetland pond water will have conductivity ranging from 150-500µS/cm. However, the conductivity of polluted stormwater and rural wetlands waters may exceed 1000µS/cm and of water with industrial pollution may exceed 10,000µS/cm

(USEPA 2012). Suren & Sorrell (2010) found that conductivity across 40 natural wetlands in New Zealand ranged from 20µS/cm to 3810µS/cm with an average of 167.7µS/cm. The National median conductivity for drinking (potable) water in New Zealand in 2008, was 204µS/cm (MfE 2008). This parameter was discarded from Metric 2 following results documented in Chapter 6, Section 6.2.

Wetland water pH was measured at least three times per wetland in April-May and then same again in November 2010. Wetland water pH (acidity and alkalinity) is an important influence on the composition of aquatic macroinvertebrate communities (Suren & Sorrell 2010; Nicolet *et al.* 2004) and pond vegetation, such as *Azolla rubra,* which is found in mildly acidic water (Johnson & Brooke 2009). Ockland (1990) noted that water with a low pH also had low concentrations of free calcium and therefore did not support snail communities. Wurts (2003) described the daily pH cycle, its dependence on CO_2 and its relationship with ammonia production from decaying biomass. The pH of pond water is highest (most alkaline) in the evening as a consequence of the loss of CO_2 during daylight hours. He noted that the evening alkalinity may reach a pH of 9.0. The accumulation of CO_2 during the night may, however, lower the pH below 7.0 by sunrise.

The 'normal' range for wetland pond water varies with the study cited but according to the USEPA (2010) and the Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines for water quality, normal pH is 6.5-8.0. The GWRC (2013) water quality chemical analysis of the Te Marua Water Treatment Plant, Wellington, NZ, cited a maximum acceptable standard for Drinking Water Standards New Zealand of pH of 7-8.5. Suren & Sorrell (2010) in their study of 40 natural New Zealand lowland wetlands, recorded pH levels ranging from 3.9 – 8.9 with an average of 5.9. In view of the large variations of a possible normal pH value for this parameter and thus the difficulty developing a range of scores, it was discarded from Metric 2.

Water temperatures were recorded at each visit to the wetlands. No twenty four hour temperature recordings were taken. Due to the inconsistent results associated with changing weather patterns and time of day variability, they were discarded from this Metric.

Water clarity was measured with a water clarity tube (black disc) (Clarkson *et al.* 2004). This measure is an indication of the sediment and algae in the water column e.g.

Water clarity (cm)	>90cm	70-90cm	55-89cm	35-54cm	<35cm
Score	5	4	3	2	1
Examples:	-	Nga Manu	Ngarara	Tower	Ferndale

The presence of high-nutrient species and the changes in the vegetation composition from slow growing short plants to tall growing species such as *Typha orientalis*, are an indication of increased levels of nitrogen and phosphate in the water and soil (Clarkson *et al.* 2004; Lopez &

Fennessy 2002). According to Clarkson *et al*. (2004), nitrogen and phosphorus may change the nutrient limitation of a wetland such that plant species composition may change to a mixture of species of plants (exotic and native) adapted to the increased fertility. Increased nutrient levels can, therefore, be inferred from evidence of this increase in biomass.

The percentage cover of the pondweeds and other macrophytes and the presence of algal blooms were recorded and scored as proposed by Clarkson *et al.* (2004) i.e. the total percentage cover of the wetland pond. When evidence of algal bloom was present during a visit, photographs were taken (Figure 21) and samples sent to Te Papa Tongarewa and Landcare botanists for identification. If a plant was unknown in the field, it was placed in sample jars or sealed plastic bag for later identification by botanists. e.g.

% cover high nutrient plants	None	<25%	25-50%	50-75%	>75%
Score	5	4	3	2	1
Examples:	-	Ngarara	-	Kotuku	-

Metric 3 Riparian Ecosystem Intactness and Habitat

The riparian area was defined as that area surrounding the wetland pond as shown in Figure 1 (O'Carroll 2012). For this study the assessments of the riparian ecosystems were limited to the nominal width of 20m from the water edge as discussed in Chapter 4, Section 4.2. The parameters assessed for riparian ecosystem intactness may be regarded as an indication of the loss of naturalness (Ausseill *et al.* 2011). They included loss of riparian area and loss of original topography, vegetation integrity (human activity effects), predominant riparian land use, riparian area status, native vegetation abundance and dominant vegetation.

Loss of Original Riparian Area

This was assessed from direct observation and previous aerial photos as the percentage of loss of the original riparian area from land use during the last 20 years. The topographical evidence was separately scored (below).

Topographical Evidence of Riparian Loss

The topographical changes to the wetland riparian areas over time were was estimated from historical maps and photos, aerial photos (KCDC 2010), site photos, site visits and descriptions of the topographical landform and biota from written histories (McFadgen 2007 & 1997; Maclean & MacLean 1988; Stevens 1988) and discussions with Kapiti residents past and present (see Figures 2,3 & 4) e.g.

Topographical evidence of riparian loss	Original riparian area >20yrs	Excavated swamp or wetland riparian	Planted riparian area	Urban development in zone	Zone destroyed by infrastructure
Score	5	4	3	2	1
Examples	Nga Manu	Midlands	Kotuku	Tower	

Riparian Vegetation Integrity

This is a measure of the human impact on the riparian integrity. The presence of a native canopy with a native understorey or intact swamp flora is regarded as the ideal indication of naturalness (Rowe *et al.* 2004). The contribution of the exotic vegetation to the wetland ecosystem is not evaluated in this component. Some authors, such as Reiss (2005), have included it in their wetland quality indices but Miller & Wardrop (2005) did not do so. e.g.

Riparian vegetation integrity	No direct human impacts >15-20yrs. Mature native trees or tussock	Minimal human activity. Native canopy.	Moderate human influences. Native or exotic canopy	Extensive human activity. Minimal canopy	Urban structures. No canopy Mown
Score	5	4	3	2	1
Examples:	Te Hapua	Waimeha	Ferndale	Midlands	Tower Lake

Riparian Area Land Use

The predominant urban land use for the study sites was residential. However, Suren *et al*. (2010) showed that land use within 1km of wetlands was positively correlated with the water quality of the wetland. The only commercial activity within 1km of the urban Kapiti Coast wetlands was the Paraparaumu Airport control tower about 100m from Tower Lake No 1. All the urban wetlands had roadways closer than 1km radius. e.g.

Riparian area land use within 1km	Native forest, swamp, tussock, sedges	exotic forest, planted native trees or swamp plants	Residential & roadside houses & gardens	Agricultural, horticultural	Commercial, Infrastructure
Score	5	4	3	2	1
Examples:	Nga Manu	Waimeha	-	Te Hapua	Tower

Riparian Area Status

This parameter scores the ecological status of the riparian area and is closely linked to the cultural significance of the wetland. Conservation land and Reserve land around a wetland provide the best outcome for the establishment of a well functioning riparian area and thence the water quality of the wetland. These categories of land status are legislated for and provide protection for the wetland. While the use of the riparian area for walkways and cycleways or for residential gardens may be acceptable to the local population, the level of protection for the wetland water quality from the riparian area may be poor (Innis *et al*. 2000).

Riparian Area Native Vegetation Cover

To assess the vegetation composition of the riparian slopes a vertical transect line was placed from water edge to 20m. An area 1m each side of the transect line at 5m intervals provided information about the composition of the vegetation and of the transition from wetland to dryland plants (Dickinson & Mark 1994). The riparian vegetation composition and structure were analysed using the Atkinson System for naming and mapping vegetation (Atkinson 1985) but were not scored for the UWHI. A plant species list including native and exotic species was compiled (Appendix 4). The percentage of native vegetation at each wetland site was assessed visually providing an indication of the total percentage of native vegetation cover in the riparian area. **T**ussocks were included in the best mix scoring 5.

Dominant vegetation

The displacement of the dominant native plants from a riparian area by exotic invader plants may indicate that changes to the structure and function of the wetland have occurred including increased available nutrients (Clarkson *et al*. 2004) or hydrology and soil properties (Ehrenfeld 2008). Ultimately, exotic invasion will cause adjustments to the original fauna with loss of the fauna dependent on the particular conditions offered by the original ecosystem (Barker & Wilson 2004). The loss of native vegetation may be an indication of early homogenisation of biota occurring, a syndrome found in many urban communities (Lougheed *et al.* 2008). Ehrenfeld (2008) noted that ‘there is little relationship between size [of the wetland] and invasion [of exotics] among smaller sites (<100ha), suggesting that even small parcels within urban landscapes may have few non-native species in the flora’.

The mix of native and exotic vegetation in gardens and on road sides varied with the site of the wetland. The only wetland with completely dominant exotic vegetation was Tower Lake. This parameter identifies the extent of exotic vegetation (or lack of native vegetation) in urban wetland riparian areas e.g.

Riparian native vegetation abundance	Native forest, swamp tussocks, sedges	Flax, toetoe, high shrub, native + some exotic	Planted native or exotic, scrub	Willows, weeds, gardens	Grasses. Bare ground
Score	5	4	3	2	1
Examples:	Te Hapua	Waimeha	Ferndale	Tower	-

Metric 4 Percentage of Native Avifauna

The diversity of avifauna within and around a riparian area is an indicator of riparian habitat biodiversity and function. This includes the presence of aquatic birds using the riparian area for shelter and breeding. Native bird species richness in urban Australia (Munyenyembe *et al.* 1989) and North America (Sears & Anderson 1991) were positively correlated with the species diversity and volume of native flora (McKinney 2002). Daniels & Kirkpatrick (2006) studied avifauna in Hobart gardens and concluded that diversity in gardens (exotic and native flora) would maximise native bird richness

Bird species diversity and abundance data were collected during standard 10-minute counts of birds seen within a 25m range (Peters 2005). In urban wetland environments with adequate riparian vegetation as well as suitable vegetation among neighbouring residences, the presence of tuis, silver eyes, welcome swallows and paradise shelducks would be expected.

Other fauna recorded included any terrestrial insects including bees, butterflies and midges, amphibians and reptiles seen at each site. This metric was reported as the percentage of native birds seen at each wetland (see Table 6.5 and Appendix 5).

% native bird spp. (Metric 4)	>75% native	50-75%	25-50%	10-25%	<10%
Score	5	4	3	2	1
Examples:	-	Waimeha	Midland	Kotuku	-

Metric 5 Ecological, Cultural and Social Values

The parameters of this metric were: national or regional ecological recognition; local ecological recognition; cultural significance; recreational value and aesthetic values. The recognition of ecological worthiness/value nationally or regionally is marked by the protection given by statute i.e. The Conservation Act 1987, the Reserves Act 1977, and also the Regional Plan. Covenants included the QE11 covenant on private land registered with Land Information New Zealand (LINZ). Other parameters were sourced from KCDC documentation, DOC inventory of significant indigenous flora and fauna, the Regional Plan and other published work including a review by Manuel (2003). The scoring is focused on community ecological values with higher scoring given to them than to recreational and aesthetic values (Table 6.6) e.g.

Cultural, social and ecological values (Metric 5)	National & regional ecological values	Wildlife values	Cultural significance	Recreational values	Aesthetic values
Score	5	4	3	2	1

Metric 6 Urban developments and infrastructure impacts

The focus of this part of the investigation was confined to landform and land use changes such as infrastructure development, stormwater drainage, wetland and pond development, housing density and any special conditions applying to the sites including flooding potential and wetland and riparian health. Where available, the records of the monitoring requirements for each wetland were noted. The resource consent data could not be measured for the Urban Wetland Health Index because it was incomplete in the KCDC documents. However, the impacts of urban development were scored.

Resource consents

Territorial authorities are responsible for imposing conditions on resource consents applied to the development of a site and their subsequent monitoring. It was assumed that all the urban development associated with the study sites would have been consented by the Kapiti Coast District Council (KCDC), or its predecessors (the Hutt County Council and the Horowhenua County Council), as required by the RMA 1991, or its predecessor, the Town and Country Planning Act 1977. However, the records available for older wetland developments do not provide those details. The available records of resource consents for the urban development since 1995 were noted, but this potential parameter could not be measured for the UWHI because of this lack of information about the resource consents and/or their monitoring. The available information is summarised in Table 5.2.

Table 5.2 Resource consents for urban development at the Kapiti Coast subdivisions containing urban wetlands indicating the paucity of information (from KCDC records 1978 to 2010).

Te Hapua flaxlands, Shoveler Lagoon, Jensen property	No records of any resource consent conditions associated with this site. Water quality is monitored by GWRC.
Nga Manu Nature Reserve	1978 Horowhenua County Council planning consent for the construction of the information centre; 1981 whole site planning consent was granted by Horowhenua County Council; 2008 KCDC consented to the construction of a fish ladder from the Koromiko Stream to the lower pond. Water quality of outflow stream monitored by GWRC.
Waimeha Lagoon	No resource consent information available. Was originally surrounded by seaside baches and a camping ground. Water quality monitored by KCDC.
Midlands Gardens Retirement Village	Bare land purchased 15 years ago by Kapiti Retirement Trust from farmland owner; 2000 Ponds dredged; No information on resource consent conditions; 2007 Midlands Gardens Retirement Village opened.
Tower Lake	Formed in early 1980s as part of Langdale Avenue/Campbell St. subdivision; 1991 Recommended for stormwater storage area; 1994 buildings required to have concrete slab floors over compacted sand; 2010 request for resource consent to build a house over the water declined.
Lakes Kotuku and Ngarara	1988 consent to commence Stage 1 of 19 lots on Manly St; 1989 Stage 2 consented for Manly St. north to Maori cemetery; 1992 consents to deepen Lake Ngarara and commence Stage 3 of 19 lots on flattened dunelands; 1994 consent to form Lake Kotuku for stormwater collection; 1998 consent for Stage 5; 2002 Environment Court appeal by KCDC lost; 2003 stage 6 development of detention pond between Lakes; 2004 consent for Stage 8; 2007 required to build up land for 1:100yr flood protection. Monitoring of wetland water quality is done by KCDC.
Ferndale subdivision	2007 Plan Change 67 to District Plan to allow subdivision consented with conditions including KCDC control over low impact measures for roads and public areas, rainwater attenuation devices, use of eco-sourced vegetation to enhance Nga Manu ecological area; 2007 consent for stormwater design with maintenance and monitoring by KCDC; 2009 consent to change names of 4 roads at Ferndale. KCDC monitoring water quality.

Infrastructure impacts

The impacts of Infrastructure on the urban wetland riparian areas include the presence of roads, bridges, walkways, cycle tracks, children's play areas, ducting for gas and sewage, water reticulation and commercial activities. These impacts add to the stress of the urban development with interference to the quality of the habitat and the intactness of the associated wetland ecosystem.

Impacts of urban development on riparian area

This parameter assessed the impacts of urban developments on the integrity of the wetland riparian area. The assessments of the impacts took into account the quantity and quality of the compromises to riparian function and structure. The stressors included the use of the riparian area for recreation and the development of residential and/or commercial activities within the zone including access ways to private properties and viewing points. The impacts were both subtle and overt.

Urban developments & infrastructure within zone	Reserve area. No infrastructure	Recreation park, cycling, walkways	Residential, play areas, access ways	Commercial in zone. Car parks.	Infrastructure including roads, bridge, reticulation
Score	5	4	3	2	1
Examples:	Te Hapua	Midlands	Kotuku	-	Tower

Metric 7 Stormwater and imperviousness

Stormwater runoff is closely associated with housing density and imperviousness. Although these are not measured for individual wetlands they are very important contributors to the impacts of stormwater drainage at each site.

Stormwater impact

Stormwater impact was assessed for the Index by direct observation of drainage into a wetland or riparian area as well as an assumption that where lawns were closely mown to the water edge, there would be significant run-off depending on the slope (Deletic 2005). The non-urban wetlands had no urban stormwater input, being replenished by groundwater and rainfall. The constructed stormwater management ponds were fed by rainfall, stormwater drains and overflow drains. This metric parameter focused on appropriate stormwater runoff to drainage although the impact of the stormwater will also be reflected by the macroinvertebrate and riparian vegetation composition of a wetland e.g.

Stormwater runoff & %CIA connected	No runoff. CIA >70%	stormwater piped via filter. CIA 60-70% connected	stormwater piped no filter. CIA 50-60% connected	open drain from road. CIA 40-50% connected	Older established area. CIA <40% connected
Score	5	4	3	2	1
Examples:	Te Hapua	Ferndale	Lake Kotuku	-	Tower

Imperviousness

Imperviousness can be measured either by the percentage of Impervious Surface Connectivity (%ISC) or the percentage of Connected Impervious Areas (%CIA). The Kapiti Coast District Council has not in the past routinely calculated imperviousness for new subdivisions. Lu (2006) used %ISC (Impervious Surface Connectivity) and land use classification to estimate the imperviousness of urban areas in Indianapolis. This relied on digital imagery estimations of housing densities per km^2 to give an approximate %ISC (Table 5.3). For the estimation of a catchment ISC% land use intensity, the present housing densities in Waikanae and Paraparaumu were calculated using the most recent Google Earth 2007 imagery.

Table 5.3 Indicative percent Imperviousness (ISC%) associated with land use and population density on Kapiti Coast.

Residential land use	Population density	%ISC
Low intensity	<500 /km^2	< 30%
Medium intensity	500-1500/ km^2	>20% - <50%
High intensity	1500-2000/ km^2	>40%
Very High	>2000/ km^2	>50%
Commercial, industrial & transport	<10/ km^2	>60%

Source: Lu (2006) *Remote Sensing of the Environment.* 102:146.

Although the operational KCDC District Plan 1999 did not define imperviousness, guidelines for preparedness for flood level peak flows via stormwater drains using Isohyets are provided in KCDC District Plan 1999, Appendix 1. These Isohyet Guidelines and Charts are used to define Connected Impervious Areas (CIA) i.e. 'the % residential zone that is impervious and directly connected via formal drainage systems to the receiving waterway' (KCDC 2010). To calculate the CIA, consideration is given to the soils of an area that are divided into categories from A to D depending on their porosity (Table 5.4).

Table 5.4. Indication of potential soil porosity on the Kapiti Coast (KCDC 2010)

Soil category	Runoff potential	Soil type
A	Low runoff potential = high infiltration rate	Deep, drained sands & gravels
B	Moderate infiltration rates	Moderately deep well drained soils, inland compacted sand & valley loams
C	Low infiltration rate –water movement impeded	Soil moderate to fine texture, greywacke & loess-based soils
D	High runoff potential, low infiltration rates	Clay-based soils and peat bogs

Source: *Auckland Regional Council Technical Publications* 108, (1999)

The soils for the Kapiti Coast are mainly categories B and C. Generalised land use classifications and soil water storage potential during peak flows from rainfall provide the basis for a CIA value. The Imperviousness as measured by the %CIA was scored according to the percentage connected to appropriate stormwater drainage (Table 5.5) as a parameter of this metric.

Table 5.5 Connected Impervious Areas (CIA) of Kapiti Coast residential areas in 2010.

Rural/open space	60-70%	50-60%	40-50%	<40%
5	4	3	2	1

Category	%CIA	Wetlands in these sites	Score
Residential A: Older lots, 0.0800ha average	38%	Tower Lake,	1
Residential B: Newer lots, 0.0600ha average	55%	Lakes Ngarara & Kotuku, Ferndale,	3
Residential C: Retirement villages	65%	Midlands Gardens,	4
Road designation	36%		1
Industrial	72%		5
Paraparaumu Town Centre	50%		3
Open space/ rural	Rural	Te Hapua & Nga Manu, Waimeha	5

Source: KCDC 2010

5.7 Data analysis

Data analyses for the multi-metric Urban Wetland Health Index were done by looking at individual metrics, their parameters and their relationship to each other:

- The UWH Index metric scores were the average of the recorded parameter scores at each wetland i.e. each parameter was scored out of a possible 5. These scores were added and the sum divided by the number of parameters for that metric to give the metric score. The metric scores were then changed to percentages of the possible score for that metric and this was used for the UWHI of that wetland (Table 6.10).
- Aquatic macroinvertebrates were identified and counted for each site. The MCI was calculated**.** The WMCI and QWMCI were calculated according to the formula published by Suren *et al.* (2010). (Note: Following analysis of the results obtained of this potential metric, the QWMCI was withdrawn as Metric as the results were invalid for North Island wetlands). (See Section 5.8).
- Spearman Rank-order Correlation coefficients were applied to determine relationships between parameters (Figure 25). p-values were corrected for false positives (Type 1 errors) using the false discovery rate (FDR) (Table 6.11). Instead of controlling the chance of any false positives, FDR controls the expected *proportion* of false positives when multiple statistical tests are used with the same data set (Benjamini & Hochberg 1995). A FDR threshold is determined from the observed p-value distribution .
- Cluster dendrograms were constructed for the metric parameters indicating the relationships between the metric parameters (Figures 26 & 27).
- Non-Metric Multidimensional Scaling (NMDS) ordination (Figures 28 & 29) and an NMS Scree plot for stress (Figure 30) were used to show relationships between parameters and the Stress value. NMDS is regarded as the best ordination method for community data (Clapham 2011). The computer package used was PC-Ord.

5.8 Macroinvertebrate indicators: Use of WMCI and QWMCI

The quality of the Kapiti Coast wetlands water was investigated using aquatic macroinvertebrate assemblages as an indicator of wetland health. Aquatic macroinvertebrates were collected from three widely separated locations at each wetland pond (Suren *et al.* 2008; Cheal *et al.* 1993) both in April and November 2010. The method used was as detailed in Protocol C2 - soft bottomed semi-quantitative and Protocol P3 for analysis (Suren *et al.* 2010; Stark *et al.* 2001) (Appendix 2). The South Island Wetland Macroinvertebrate Community Index (WMCI) and the Quantitative WMCI (QWMCI) were then calculated according to the formulae outlined by Suren *et al.* (2010) in *Development of a South Island Wetland Macroinvertebrate Community Index Score.* Though these parameters pertained to non-urban wetlands of the West Coast of the South Island, they were used in this study to gauge the quality of the wetlands (wetland health) as no other wetland-specific MCI scoring was available in New Zealand (Suren *et al.* 2010).

Suren *et al.* (2010) noted that the WMCI relied on the presence of taxa at a site and not their abundance, whereas the QWMCI measured the abundance of tolerant taxa and therefore provided a more accurate picture of wetland health. The WMCI is the average score of all the taxa found at a site and is rarely less than 90. A low QWMCI is associated with wetland communities where taxa have MCI tolerance values (TVs) of less than five such as *Potamopyrgus*, Daphniidae, and *Gyraulus* (Suren *et al.* 2010**).**

However, as further discussed in Chapter 6, the QWMCI has been now been found to be unsuitable for North Island wetlands (Suren *et al*. 2010) as the taxa assemblages differ from the South Island wetlands. The Taranaki Regional Council Policy and Planning Committee (2010) noted that all the wetlands in the North Island scored only fair or poor because of these differences. Data analysis (Section 6.4) confirmed the inadequacy of this potential metric. Therefore, as this metric is no longer pertinent as a measure of water quality in this study, it has been discarded from the proposed UWHI Table 5.1. The macroinvertebrate assembly data is available in Appendix 6.

5.9 The Proposed Urban Wetland Health Index

The proposed Urban Wetland Health Index is a multi-metric assessment process developed to fill a gap in wetland assessment processes that are inadequate for the urban environment where little attention is afforded to water quality or the needs of urban riparian areas and patch connectivity. It is designed to assist with the assessment and monitoring of established urban wetlands as well as to inform planners about the needs for sustainable wetlands in new subdivisions. It is a summary of the results of all the above assessments using a scoring system that embraces both ecological and urban planning indicators. The Index can be expanded to incorporate other relevant metrics of urban development.

Chapter 6 Research Results

6.1 Introduction

The results from application of the multi-metric Urban Wetland Health Index (UWHI) described in chapter five, are presented here. The UWHI identifies the ecological condition attained by each wetland as well as the wetland's response to urban developments and its influence on the culture associated with the wetland. It also allows for comparison with other wetlands and, therefore, presents a target for improvement of wetland health by identifying the poorest scoring indicators (metrics). The relationships between the parameters and the metrics that make up the UWHI are discussed.

The value of riparian structure and function in ensuring the ecological health of urban wetlands is frequently unrecognised, or, is in direct conflict with the popular aesthetic appearance of grassy banks and the monetary value for the potential loss of land area for urban development. However, lack of available information in the Kapiti Coast District Council records prevented a comprehensive assessment of the impacts of these developments on the riparian areas. Records pertaining to resource consent conditions for the urban developments issued before 1989, when the Kapiti Coast District Council was established, were unavailable. Some may be archived in other previous Councils' records such as Hutt County Council and Horowhenua County Council, or possibly have been misfiled in Kapiti Coast District Council's own archives.

6.2 Results of the Urban Wetland Assessments

The methods used to assess the ecological condition of the urban wetlands have been described in Table 5.1. Details of the scores for the UWHI are presented in Appendix 7. The results for each Index Metric are discussed here in the same order as described in chapter five.

Metric 1 Hydrology of Catchment, Wetland and Riparian Area

The parameters for this metric were catchment hydrology, wetland hydrology and riparian hydrology. They provide the basis for the survival and quality of palustrine wetlands with the maintenance of the water levels needed for the wetland and its riparian ecosystems.

Catchment hydrology

The catchment hydrology metric parameters scored were catchment land use (residential), land cover and artificial barriers to surface water flow in the catchment (Table 6.1). The evaluation of the catchment geomorphology and hydrology showed that there were considerable changes to the catchment land cover and land use associated with urban development. Of the two non-urban wetland catchments, the Te Hapua Shoveler Lagoon's score reflected the influence of its largely agricultural catchment, whereas the Nga Manu swamp forest catchment scored the possible total. Both catchments were on the floodplain of the many streams that flow from the foothills of the Tararua Range and Hemi Matenga and which contribute to the groundwater and springs beneath the wetlands. The Te Hapua Shoveler wetland is a recharge wetland with groundwater derived from the Mangaone Stream and possibly from the Puruka Drain from the north (Thompson 2012). The Nga Manu 400 year old swamp forest has groundwater from the Ngarara Stream floodplain (Tidswell 2009).

The six urban catchment areas are on the floodplains of the Waikanae River, the Waimeha Stream, the Ngarara Stream, the Mazengarb Stream and the Wharemauku Stream. Their lower scores for catchment hydrology are associated with the urban and infrastructure developments across the floodplains resulting in disruption to flow patterns for both groundwater and surface water and the consequent compromised vegetation integrity. The present population density of 63.2 persons/km^2 (Census 2013, NZ Statistics) is projected to increase thus providing further stress to the hydrological system.

The base rock for all the catchments was compacted sand up to 6000 years old (McFadgen 1997). Some of the older swamp areas in the Te Hapua and Nga Manu catchments have peat beneath sand. Records suggest that there was also peat beneath Tower Lake No 1 but it was removed before sand dunes were used to fill the land depression in 1982. River gravel, present across the Waikanae floodplain, allows groundwater to filter down to aquifers but only Tower Lake No 1 uses the aquifer water (by pump) to maintain its water level. The presence of artificial barriers in the catchments was difficult to assess because the disruption to the original landform meant that changes to the subsoil flow have almost certainly occurred over time. However, this parameter was scored for the presence or absence of parks and reserves, stormwater drains, urban developments and infrastructure (roads, railways) across the catchment.

Wetland hydrology

The wetland hydrology parameters were wetland type, artificial barriers to water flow outlet and evidence of changes to water table (Table 6.1). The evaluation of the wetlands' hydrology indicated that there were impacts from urban development particularly at Tower Lake No 1 where housing abuts the lake (Figure 14). The hydrological function of the remnant wetlands was also affected though to a lesser degree. Although the base rock for all sites is compacted sand, both at Te Hapua Shoveler Lagoon and Nga Manu have peat at a depth of 1.5m. All sites are at low altitudes from 3m - 15m above sea level.

The percentage of dryland species within the wetland can be used as an indication of changes to the water table (Papas 2007; Clarkson *et al.* 2004). No site had more than 25% of its wetland with dryland plants. The non-urban sites had very few dryland species within the wetlands. Waimeha Lagoon and Lake Ngarara both had some shoreline shrubs including *Hebe sp.* and manuka (*Leptospermum scoparium*). Tower Lake No 1 (Figure 14) had willows around its edges extending well into the water around its south and west sides, garden plants, weeds (including blackberry), garden escapees (canna lilies) on the east side, and a house above the water edge on the north bank.

Riparian hydrology

The parameters for riparian hydrology assessment were riparian land slope and riparian area width (Table 6.1). Te Hapua Shoveler Lagoon, Nga Manu swamp forest and Waimeha Lagoon were the only sites where the riparian area was greater than 20m for any or most of their shorelines. At all sites the substrate was compacted sand.

The riparian land slope, measured by clinometer, ranged from 2^0 at Te Hapua and Waimeha Lagoon to 15^0 at Midlands Gardens north pond and 20^0 at the west end of Lake Kotuku. The soil was stable on the steeper slopes apart from the west end of Lake Kotuku where erosion was occurring. Midlands Gardens riparian area width varied from 5 - 10m with some steep banks of mown grass and several areas of native plants and a mix of introduced trees and shrubs. Tower Lake No 1 riparian area of 3-7m was mainly closely mown grass or private gardens. Lake Kotuku had steep banks with 10-12m of native planted riparian areas and private properties with roughly mown grass and weeds also on steep banks. Lake Ngarara on its eastern and southern sides had areas 10-12m long of grass followed by similar sized areas of native plants. Land drainage was an issue at Tower Lake No 1 riparian area on the closely mown grass and muddy 'peninsula' into the wetland. Ferndale wetland run-off was via a drain to soak pits in compacted sand dunes. All other riparian areas were well drained.

Table 6.1. Hydrology (catchment-wetland-riparian).

Hydrology Metric 1 Max score each parameter = 5	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Catchment land cover (urban)	2	5	1	1	1	1	1	1
Artificial flow barriers	5	5	4	3	4	4	2	1
% urban land use effects	5	5	3	1	1	1	1	1
Wetland type	5	5	4	4	2	2	1	1
Artificial barriers to wetland outflow	5	5	3	4	2	4	2	2
% dryland plants	5	5	4	3	2	4	4	4
Riparian land slope	5	4	5	4	4	3	1	4
Riparian area width	5	5	4	3	2	3	3	2
Total score (catchment + wetland + riparian = 40)	37	39	28	23	18	22	15	16
UWHI (Max 100)	93	98	70	58	45	55	38	40

Metric 2 Physicochemical parameters

This data collected over two seasons included water temperature, pH, conductivity and water clarity. Only water clarity was scored. Water temperature readings were taken with each wetland visit, but not continuously over 24 hour periods and therefore, as they did not inform about the temperature variations that indicate any stress that might have affected the aquatic inhabitants, were discarded. The pH measurements ranged from 6.7 at both Te Hapua Shoveler Lagoon and Nga Manu top pond to 8.0 in Lake Kotuku and 8.1 in Lake Ngarara. There was no seasonal difference in pH seen in any wetland (Table 6.2). These results were also regarded as insufficiently discriminatory and were discarded from this metric.

Alkalinity of the urban wetlands (pH >7.4) may be an indicator of excess nutrients, probably phosphates and nitrates, from stormwater runoff (Clarkson *et al.* 2004; Bressler & Paul 2002). At Lake Kotuku the pH of 8.0 was associated with algal bloom (Figure 21). The slight acidity of Te Hapua Shoveler Lagoon and Nga Manu Top Pond reflects relatively undisturbed wetlands containing some decaying plant material. They both had *Azolla rubra* floating on them, an indication of the slight acidity and relatively low phosphates in the water (Brownsey & Perrie 2013).

Table 6.2 Physicochemical data (averages from two seasons)

Physicochemical non-scoring data	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
pH (actual reading)	6.7	6.7	7.4	8.1	8.0	7.7	8.0	7.4
Conductivity (µS/cm)	358	180	512	339	473	213	570	450
Clarity (cm)	67	80	60	75	43	75	41	15
Altitude (m asl)	3.3	13.4	11	8	6	11	15	14
ISC%	0	0	25	30	40	25	20	15

Note: pH 7.2 = neutral; pH <7.0 = acidic; pH >7.4 = alkaline.
Conductivity pond water = 150-550µS/cm (USEPA 2012)

Conductivity ranged from 180 µS/cm (Nga Manu) to 570µS/cm (Lake Kotuku) which is within the accepted range of conductivity for pond water of 150-550µS/cm (USEPA 2012). There was no consistent pattern of change with seasons, but a general trend upwards followed the spring rains. The mobilization of minerals via groundwater and surface water with the increased flow and volumes of winter rainwater is likely to have been responsible for this. Nga Manu remained unaffected. As these results (non-urban and urban) were within the ‘normal’ range they were discarded from this UWHI metric.

Water clarity varied from 90cm (Nga Manu) to 20cm (Ferndale) with some consistency over both seasons and was scored for the UWHI. Ferndale has a small catchment. It suffered from a lack of rainwater during the dry autumn of 2010. This resulted in a low water table level and increased suspended sediment in the remaining water. In the spring, the clarity of the water improved only slightly from 20cm to 30cm in spite of the winter rains. This is likely to be associated with the input from a small drain arising in a residential subdivision to the east of Ferndale, and the lack of road runoff from lack of rain

The scores for the percentage of cover associated with increased nutrient levels is highest for clear, low nutrient-containing water. Thus a low score is the worst scenario indicative of a high level of nutrients in the wetland water (Table 6.3). Lake Kotuku had large autumn algal blooms (Figure 21) and high nutrient species including raupo (*Typha orientalis*) and pondweeds. There was a small areas of *Lemna minor* at the Nga Manu top pond and raupo at its east end. Waimeha Lagoon water had reduced clarity as well as excess aquatic weed growth with *Lemna minor* and large areas of raupo at the north end of the lagoon.

High nutrient flora in water bodies may be attributed to excess nitrogen and/or phosphorus from a variety of sources. These include pollution from urban surface water runoff, agricultural runoff or derived from vegetation decay within the wetland (Bressler & Paul 2002). In this study the measurements for N or P were not undertaken. Thompson (2012) found that Te Hapua wetlands had raised Total Nitrogen and Total Phosphorus during his assessment but attributed most of this to plant decay together with the recent removal of willows from the flaxlands with the consequent disturbance of the sediment causing nutrient release. He also noted the effects of bird droppings in wetlands.

The presence of healthy stands of raupo, as at Waimeha Lagoon, Lake Kotuku and Nga Manu, are likely to be because of high nutrient concentrations or high groundwater flow rates (Thompson 2012). This latter may also be contributing to a raupo stand at the east end of Nga Manu top pond. Tidswell (2009) investigated 31 bores on the Kapiti Coast to determine the nitrate levels of groundwater in the area. She found that groundwater with elevated nitrogen concentrations was present north of Te Hapua wetlands but suspected that migration southward to the wetlands would occur unless measures were put in place to change this. The likely source of the nitrate was horticulture and agriculture occurring on the Kapiti coast north of the Otaki River and in southern Horowhenua. Trend analysis from 1996 to 2008, reported by Tidswell (2009), indicates a reduction in groundwater nitrates in those areas.

Table 6.3. Physicochemical parameters

Physicochemical parameters Metric 2	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Clarity (cm)	3	4	3	4	2	4	2	1
NO algal bloom = 5	4	5	4	3	3	4	2	4
% cover high nutrient plants	5	4	3	4	4	4	2	4
Total score (Max 15)	12	13	10	11	9	12	8	9
UWHI (Max 100)	80	87	68	73	60	80	53	60

The Lake Kotuku autumn algal bloom species were identified by Landcare Research and Te Papa Tongarewa botanists as the algae *Rhizoclonium* and *Hyalotheca* and the common diatom epiphyte *Cocconeis sp.* (Lehnebach 2010, Te Papa, pers. comm.) and reported to the Biodiversity Officer, KCDC.

Although the water in Lake Kotuku drains via an outlet pipe into a collection wetland pond en route to Lake Ngarara when water levels are high enough, Lake Ngarara did not have evidence of the same rise in pollutant levels suggesting that either the connecting collection pond provided an essential trap for delaying their dispersal or that the water levels in Lake Kotuku seldom reached the required level for drainage to occur.

Figure 21. Algal Bloom, Lake Kotuku, May 2010.
(Photo: K. Palmer 2010)

Figure 22. Swan nest Tower Lake No 1. May 2010.
(Photo: K. Palmer 2010)

Metric 3 Riparian Ecosystem Intactness

This metric assessed those aspects of riparian function that impacted on urban wetland health including changes wrought by urban development over the last several decades of rapid urbanisation. Included in this assessment (Table 6.4) were loss of original riparian area and topographical evidence of this, land use within 1km of the wetlands, effect of human activity on the vegetation integrity, the naturalness or nativeness of the vegetation, and the status afforded by the community to the wetland area.

Loss of Riparian Area and Topographical Evidence of Change

The percentage of loss of riparian area was assessed as a percentage of loss of the original area as judged from the topographical changes. The dominant riparian topographical change occurred in the urban area whereas the reference wetland sites, Te Hapua Shoveler Lagoon and Nga Manu top pond, had minimal change over the last 20 years. Te Hapua Shoveler Lagoon has been adequately fenced off from sheep and beef cattle. Nga Manu top pond had not been modified apart from an access for viewing and eel feeding at the north-eastern edge. Waimeha Lagoon, originally a swamp, was last deepened in 1982 and had had restorative riparian and wetland planting since then. At the south end, reconstructed dunes separate it from the saline Waimanu Lagoon. During the latter half of the 20th century, the surrounding dunes were flattened for baches, now permanent housing.

The estimated loss of original riparian area from KCDC historical WW2 aerial photos and Google 2007 photos was less than 25% at Te Hapua Shoveler Lagoon and a similar percentage at Nga Manu (Figures 6 & 8). Waimeha Lagoon lost 25-50% of its riparian area over a half a century but this has been largely restored. Lake Ngarara has lost 50-75% of the riparian area to urban development (Figure 4). The other sites that had had no 'original' riparian areas, because they were developed from excavated dunes, were scored at >75% loss of original dune vegetation e.g. Tower Lake (Figure 3).

Riparian Vegetation Integrity

Biotic evidence of changed riparian function was least at Te Hapua Shoveler Lagoon and Nga Manu where there was augmented original riparian vegetation. Nga Manu forest had an understorey of ferns, seedlings and some reeds at the water margins but few weeds within the forest although there were blackberry and other weeds at the outer margins over 20m away. Te Hapua is part of a significant wetland complex with flaxland, tussock and reeds (Thompson 2012). The riparian vegetation integrity i.e. the interference from human based activities, was assessed as minimal.

At the Waimeha Lagoon, the riparian area had some weeds where it was less than 20m from the water edge and riparian plants were intermittent but the loss of original vegetation and the ingress of weeds; e vegetation integrity was maintained for most of the riparian area. The access point at the south edge wetland board walk had a mix of introduced grasses and weeds together with reeds, tussocks and shrubs. Near the bird-watching hide at the north end there was mown grass. The small native trees interspersed with the flax and toetoe included cabbage trees (*Cordyline australis*) and *Coprosma sp*. The assessment of the overall integrity of the riparian vegetation suggested that there was evidence of moderate human interference in the wetland area but less around the lagoon area.

Assessment of riparian integrity for the other urban wetland areas showed a picture of some efforts to improve riparian function (Ferndale and Lake Kotuku plantings) but for most sites it was aesthetic considerations that influenced the riparian planting. At Lake Ngarara and Midlands, patches of native plants included shrubs, flaxes and tall herbs but in more than 50% of their riparian areas mown grass extended to the water’s edge. Lake Kotuku and Ferndale had low canopies with young native trees and shrubs but between the shrubs the weeds (including clover, dandelion and grass) were sprayed. There were no mosses or ferns on their banks. Any dune plants documented by Harlen (1993) at Lake Ngarara had disappeared with the dunes. The grassed area of Tower Lake No 1 had several willows sufficiently safe for a black swan to nest in (Figure 15).

Riparian Area Land Use

The riparian land use at Te Hapua was mainly swamp plants although In some small areas there were exotic plants (weeds), The main flora were tussocks, reeds and small shrubs for most of the riparian area. At the margins of the riparian area, and outside the fenced area, pasture grasses and forbs occur and are grazed by cattle. Nga Manu swamp forest riparian areas were mainly native trees with some exotic invaders at the outer rim including blackberry and grasses. Access to the wetland area is confined to a small area on the north side.

However, the predominant riparian land use around the urban wetlands was residential development. Waimeha Lagoon riparian area surrounds the pond area with reeds, tussocks, small shrubs and raupo, and is itself surrounded by mown grass and a small children's play area. The residential area is outside the riparian area and grass area and has minimal effect on it. There is access to the southern wetland via a boardwalk but there is no access to the pond except at the hide at the north end. Although this is an urban wetland it is the least affected of the study sites by residential developments.

At Tower Lake the riparian land use was residential development. On the north side and to the east there are private dwellings to the water edge with gardens and from one property a pier into the water. The riparian area is adjacent to roadways (Kapiti Road and Langdale Avenue) on the south and west sides and close to Paraparaumu Airport. It has one large planted pohutukawa (*Metrosideros excelsa*), several large willows (Figure 22), a few toetoe and flax bushes but mainly mown grass, exotic trees, shrubs, scrub, blackberry and garden plants.

The riparian areas of Lakes Kotuku and Ngarara have been subject to urban development since 1992. Lake Kotuku is surrounded by residential development. It has native plants, now three to five years old, covering approximately 60% of the riparian areas not in private ownership. The private properties have a mixture of garden plants and grass on steep slopes. A walkway bridge spans the pond area. There is no access to the pond water (Figure 18), but at the top of the western sand hill there is a viewing platform (Figure 19) and west of the sand hill is road access and a children's play area.

The Lake Ngarara riparian area is a mix of mown grass, planted shrubs (native and exotic) and flattened sand dunes with remnants of dune plants (Figure 3). These riparian enhancements are surrounded by residential development and roadways. At the south end of the pond is an iris bed and pond weeds surrounding a culvert entrance from Lake Kotuku. At the northern end there is culvert-causeway dividing a small area of water to the north from the main pond area. It is almost covered with blackberry and other weeds. The south side of this causeway has a reed bed (Figure 11). At several of the shallower pond areas are pondweeds extending from the shores for several metres. A walkway was established around the pond area but this has been destroyed on the west side by the new urban development there.

Ferndale has native plantings in the stormwater collection swales (Figure 23) as well as around the pond area and in the developing wetland. There is access to the pond riparian area via the car park and a children's play area, and at its outlet. There are walkways around the whole area. The residential developments are not close to the wetland area. Midlands Gardens riparian areas have some areas of planted native and exotic plants but large areas of steep closely mown lawn (Figures 13 & 17). There is a walkway above the pond area on the stopbank between the pond area and a tributary of the Wharemauku Stream. The residential area is not close to the pond area. It is above the riparian area on the northern and eastern sides.

Riparian Area Status

Te Hapua and Waimeha Lagoon riparian areas have a status as conservation sites and Nga Manu as a Reserve. These three sites have large areas of natural native vegetation. Te Hapua swamp was augmented by N.Z. flax planting 18-20 years ago. Nga Manu had a mix of sedges and reeds at water level and then trees as the land sloped up the dunes. Swamp plants were reaching maturity to a width of over 20m around Waimeha Lagoon, covering more then 75% of the riparian area with only small gaps near the bird watching hide and the southern wetland area.

The scores in Table 6.4 showed that those wetland ponds within established areas of urban development (Lake Ngarara, Tower Lake and Midlands Gardens) had disturbed riparian ecosystems. There was a lack of vegetation and particularly native vegetation in those sites. Waimeha Lagoon is surrounded by a reserve and recreational area allowing for the riparian area to develop including the restored wetland at the south end.

% Native Vegetation Cover and Dominant Vegetation Assessment

The native vegetation abundance was low at most urban sites (Table 6.4). Clarkson *et al*. (2007) noted the 'severe depletion of indigenous biodiversity in New Zealand' with the invasion of exotic species and changes in land cover particularly within 20km of cities. Other researchers have commented on the homogenisation of flora in urban areas including urban wetlands (Lougheed *et al*. 2008) and the dilemma between retaining naturalness while agricultural and urban developments alter the landscape (Walker *et al*. 2006).

Riparian vegetation composition at most study sites was mixed native and exotic, scrub, grasses and trees. Te Hapua was dominated by N.Z. flax (*Phormium tenax*) interspersed with tussocks (*Austroderia toetoe*) and associated with sedges (*Baumea articulata*) at the water's edge. Nga Manu was mainly swamp forest but had areas of sedges (*Carex sp, Austroderia toetoe* and *Typha orientalis*). Waimeha Lagoon was also dominated by N.Z. flax and tussocks but had large areas of *T. orientalis* around the water edge.

Figure 23. Native vegetation in swale at Ferndale (Photo: K. Palmer, 2010)

Figure 24. Midlands Gardens riparian lawns (Photo: K. Palmer, 2010)

Lake Ngarara, Tower Lake and Midlands Gardens riparian areas were classified as urban grassland with exotic grasses forming the dominant vegetation. Lake Kotuku and Ferndale wetland pond were classified as shrubland because their planted riparian areas were immature. (Details of the plants identified are in Appendix 4).

Table 6.4. Riparian ecosystem intactness and habitat

Riparian ecosystem intactness Metric 3	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Loss original riparian area	4	4	3	2	1	1	1	1
Topographical change	5	5	4	2	2	3	3	3
Riparian vegetation integrity	5	5	4	1	1	1	2	2
Riparian land use	5	5	5	3	3	3	4	4
Riparian area status	5	5	4	3	2	2	2	3
Native vegetation % cover	4	4	4	2	1	2	3	3
Dominant vegetation	5	5	4	3	2	3	3	3
Total score (35)	33	33	28	16	12	16	18	19
UWHI (Max 100)	95	95	80	44	33	44	50	53

Metric 3 Native Avifauna Abundance

As an indicator of riparian habit and ecosystem intactness, bird counts provide insights into the availability of food and shelter in the riparian area. For this metric, all avifauna were counted according to the method outlined in chapter five, and then sorted into native and introduced avifauna. The native group included naturalised birds such as the welcome swallow. The avifauna were reported as either terrestrial or aquatic, and native or introduced (Table 6.5) and scored for the Index as percent native fauna of total at each wetland. The aquatic birds were within 25m of the study site water edge. As expected there were more taxa and more of each taxa in the spring than the autumn. Only observed birds were counted. The duck-shooting season was avoided.

The total number of native birds, both terrestrial and aquatic, at each wetland was smaller than expected. As previously commented, the riparian habitats of the study urban wetland riparian areas (Metric 3, Ch 6) lack sufficient food sources and shelter and are too small for the required territories of most terrestrial native birds. Although a total of 160 aquatic birds were counted, the small numbers counted at most sites was due to the small sizes of the wetlands, the majority of which were less than one hectare in area. Lake Ngarara (4ha) and Waimeha Lagoon (5.3ha) had greater numbers of aquatic birds with eleven taxa at Lake Ngarara and eight taxa at Waimeha Lagoon. Notably, however, mallard ducks have spread to all the ponds and appeared in larger numbers at Lake Ngarara and Tower Lake No 1. There is a duck feeding area for families at the latter wetland pond.

Table 6.5. Avifauna taxa distribution across the Kapiti Coast District wetlands

Distribution of aquatic and terrestrial avifauna taxa Metric 3	Terrestrial	Aquatic	Distribution of native and introduced taxa	Native	Introduced	% native avifauna – UWHI
Te Hapua	4	5	Te Hapua	4	5	45
Nga Manu	4	4	Nga Manu	4	4	50
Waimeha Lagoon	4	5	Waimeha lagoon	5	4	56
Lake Ngarara	2	8	Lake Ngarara	6	4	60
Tower Lake	5	5	Tower Lake	4	6	40
Midlands Gardens	3	4	Midlands Gardens	2	5	29
Lake Kotuku	3	2	Lake Kotuku	2	3	40
Ferndale	4	2	Ferndale	3	3	50

While the most common aquatic native birds were paradise shelducks (24) and pukeko (19), the commonest introduced aquatic birds were the mallard duck (129), black swan (28) and Canada geese (20). There were small numbers of native terrestrial birds - tui (5), fantails (2), harrier hawk (1), silver eye (1) and welcome swallows (21). The other terrestrial birds were all introduced originally from Europe the commonest of which were sparrows (39). (Details of the species identified are documented in Appendix 5).

Other Wetland Fauna

Apart from the non-biting midges and damselflies, there were only very small numbers of other insects observed and these included bumblebees, monarch butterflies, mosquitoes, white butterflies and dragonflies. It was apparent that the vegetation in the riparian areas was not favoured by most visible insects. The larvae of non-biting midges were found on examination of the wetland samples for macroinvertebrates. No reptiles or amphibians were seen but samples from two sites had large numbers of frog's eggs and tadpoles (Tower Lake, and Lake Ngarara). No mammals or feral animals were seen at the study sites, and there was no evidence of grazing or possum damage in the riparian areas including the non-urban areas.

Metric 5 Ecological, cultural and social values

The values assessed for this metric were national (Statutory status) and regional ecological values, wildlife values, cultural importance, recreational values and aesthetic values (Table 6.6). The focus for scoring was on the ecological and cultural importance to the local community as represented by its district and regional councils. There is a clear divide in statutory status afforded to the Te Hapua flaxlands, Nga Manu Nature Reserve and Waimeha Lagoon that have several protection schemes applied to them. The other five wetlands have no national or local statutory protection or covenants apart from Ferndale that has private covenants. These five urban wetlands appear to have ill-defined amenity values within their neighbourhoods but lack sufficient importance to ensure their sustainability. A statutory status for a site under the Conservation Act 1987 or the Reserves Act 1977 provides for protection for the flora and fauna of the site. Permits may be required to enter such protected areas and damage to the area, its plants and animals, is punishable according to the statute ranging from fines to jail.

Table 6.6 Ecological, cultural and social values of the urban wetland sites

Ecological, cultural and social values Metric 5		Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Ecological importance national and regional	Reserves Act	5	5	-	-	-	-	-	-
(5)	Conservation Act - DOC	5	-	5	-	-	-	-	-
	Regional Plan	5	5	5	-	-	-	-	-
	Historic Places trust	-	-	-	-	-	-	-	-
	QE11 Covenant	5	5	5	-	-	-	-	-
	Private covenants	-	5	-	-	-	-	-	5
Wildlife values	Wildlife Refuge	4	4	4	4	4	-	-	-
(4)	Rare/endangered species	4	4	4	-	-	-	-	-
	Park/Reserve	-	4	4	-	-	-	-	-
Cultural importance	Archaeological site	-	-	-	-	-	-	-	-
(3)	Maori burial site/uru pa	-	-	-	-	-	-	3	-
Recreation values	Bird watching	2	2	2	-	-	-	-	-
(2)	Picnicking	-	2	-	-	-	-	-	-
	Walking, cycling	-	2	2	2	-	-	-	-
	Bird/eel feeding	-	2	2	-	2	-	-	-
Aesthetic values	Scenic views & vistas	1	1	-	-	-	1	1	-
(1)	Open space qualities	1	1	1	1	-	1	-	-
	Landscape design	-	-	-	1	-	1	1	1
	Unique physical features	-	1	-	-	-	-	-	-
SCORE (Max 60)		32	43	34	8	6	3	5	6
UWH Index score (%)		53	72	57	14	10	5	9	10

Bird watching, walking/cycling and duck feeding were the most common activities occurring at five of the wetlands. There appeared to be no recreational activities at Midland Gardens, Lake Kotuku or Ferndale. Te Hapua, Nga Manu and Waimeha Lagoon offer scenic, open space qualities and wildlife refuges. There is longfin eel feeding at Nga Manu. The residents of Tower Lake No 1 did not use the lake except to feed the waterfowl but believe it has aesthetic appeal (Phillips 2011, pers. comm., Neighbour to Tower Lake). The other wetlands have limited appeal as places of interest apart from the waterfowl residing there. Only Nga Manu swamp forest is considered to have unique physical features. Lakes Kotuku and Ferndale collection pond have been landscape designed within recent subdivisions.

There were no sites of national ecological importance. Nga Manu swamp forest, Te Hapua flaxlands and Waimeha Lagoon are classed as sites of regional ecological importance as they have locally rare or endangered species of birds, plants or fish. The other five urban wetlands sites have minimal or no cultural significance.

Lake Ngarara, although adjacent to the Waikanae Estuary Reserve, has medium density urban developments around the western side of the lake with gate access only to the Reserve. It may have been a site for mahinga kai in the 19th century. No sites of archaeological importance have been identified by KCDC or interested persons, at any of the wetlands, although there is a uru pa (Maori burial site) preserved near Lake Kotuku. Archaeologists have also located the graves of early settlers and the remains of the Kenakena Pa near Lake Ngarara and the adjacent Waikanae River. These have not been protected.

Metric 6 Urban Development and Infrastructure Impacts

The impacts of urban development on wetland and riparian function form part of the resource consent protocols for subdivisions. However, historically this did not apply and some of the urban wetlands in the Kapiti Coast District have ecological impacts on these waterbodies. This metric assesses these impacts from urban development and infrastructure supporting it.

Urban Planning Processes and Resource Consents

Data available regarding resource consents (Table 5.2) could not be scored as there was difficulty finding the conditions of resource consent for some of the sites within the KCDC records (Table 5.2). Some information regarding urban planning was sourced from other documents, such as regional histories (Appendix 1). Detailed information about consents for stormwater runoff and/or infrastructure impacts on wetlands and riparian areas was minimal for some sites. There was little comment on formal monitoring procedures in the documents provided by KCDC. It is evident from informal discussions with owners and KCDC staff that there is or has been, some monitoring of wetland water quality by KCDC at Ferndale, Waimeha Lagoon, Lake Kotuku and Lake Ngarara and possibly Tower Lake No 1, although details were scant. Water levels are monitored by GWRC at Te Hapua Shoveler Lagoon (GWRC 2010) but not at the other sites (Allen 2010; Tidswell 2009).

Impacts of Urban Development on Riparian area

Urban development within wetland riparian areas is a direct threat to the ecology and health of the urban wetlands. Tower Lake No 1 has residential development on 50% of its riparian area (Table 6.7) including a house, gardens, sheds and a pier into the pond area. Less impact is present at the new subdivisions around Lakes Ngarara and Kotuku and Ferndale where residences are at the outer margins of the riparian area although closely mown grass reaches to the water's edge at Lake Ngarara. The recent development of the last stage of the Kotuku Park development was accompanied by loss of the riparian ecology as the western riparian sand dunes were flattened in 2010 for residential purposes (Figure 3).

Infrastructure Impacts

These impacts on the riparian areas are the less obvious outcomes of urban development, namely the recreational and transport needs of the population. The infrastructure impacts within the riparian areas were mainly walking and cycling tracks with roads at the outer edge of the zones. The southwest corner of Tower Lake is at the intersection of Kapiti Road and Langdale

Avenue and the southeast edge of Lake Ngarara is close to Kotuku Drive. In both cases there is a sealed footpath between the mown grass and the road. At Lake Ngarara, Lake Kotuku and Ferndale there are pedestrian bridges crossing part of the pond and swamp areas. There was no evidence of gas or sewage ducts in the riparian areas. At Tower Lake there was freshwater reticulation from a deep bore.

Table 6.7 Urban development and infrastructure impacts within riparian area

Impacts of urban developments &/or infrastructure on habitats and ecosystems. Metric 6	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Reserve area. no infrastructure	5	5	5	4	4	5	4	4
Recreation park to water edge. Children's play areas. Cycle & walkways	5	4	4	4	3	3	3	3
Residential in riparian area. Sheds, piers, garages. Close mown grass.	5	5	4	3	1	3	4	4
Commercial development. Access ways. Car parks.	5	5	5	5	5	5	5	4
Infrastructure includes roads, bridges, reticulation	5	5	4	3	2	4	1	2
Total score (25)	25	24	23	19	15	20	17	17
UWHI (100)	100	96	94	76	60	75	68	68

Metric 7 Stormwater and imperviousness

For this metric the main observable impact was the wetland response to a high nutrient environment (Table 6.9). There is some stormwater runoff at all the urban sites due to inadequate protection from surface water. At the Waimeha Lagoon there was an overgrowth of algae, *Azolla rubra* and *Lemna minor* extending several metres into the lagoon near the mouth of a very small stormwater drain from one house entering the lagoon at the north end. This was closely associated with 10-15m of raupo (*Typha orientalis*) growth around the eastern shores of the lagoon. In the autumn of 2010, Lake Kotuku had a large area of algal bloom extending more than two metres into the lake (Figure 21) and at the western end, a stand of more than two metres of raupo (Figure 18). There were excessive growths of pondweeds as well as *Isolepsis prolifer* and the clubrush, *Schoenoplectus validus*, along the shores. Such a high nutrient vegetation profile is consistent with stormwater pollution, a likely cause as Lake Kotuku is a stormwater collection pond in the Mazengarb Drain catchment.

Ferndale, also a stormwater collection wetland, is fed by filtered road runoff but as there were very few houses erected in the subdivision by the last assessment visit in November 2010, the level of pollution appeared to be very low as was expected. The Ferndale stormwater is directed from roadside gravel drains to vegetated swales and thence to the Ferndale pond. The Ferndale residents' covenant limits the impervious area on any site to less than 40% of the section area including the house and drive.

Imperviousness

The %CIA (Connected Impervious Areas) results for imperviousness were incorporated in the scores for stormwater and imperviousness. Although the areas were generalised rather than specific to a wetland (Table 5.5), they provided a more complete picture of one of the causes for the continuing issue of stormwater runoff (Table 6.9).

The %ISC (Impervious Surfaces Connected) (Table 6.8) for the urban wetland sites were not scored for the UWHI as they were calculated from population density (Lu 2006) as adjudged for the Google photos 2007 and including new-build since then (Table 5.3). Such calculations must at best be approximate but are in line with the CIA%.

Table 6.8. %ISC calculations for study sites

ISC%	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midland	Kotuku	Ferndale
	0	0	25	30	40	25	20	15

Table 6.9. Urban stormwater impact on wetland water and riparian areas

Urban stormwater runoff and %CIA. Score = 5 is least impacted Metric 7	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midland	Kotuku	Ferndale
Stormwater runoff	5	5	4	3	3	3	3	4
Riparian slope	5	4	5	4	4	3	1	4
% CIA	5	5	5	3	1	4	3	3
% cover high nutrient plants	4	4	3	4	4	4	2	4
Total score (Max 20)	19	18	17	14	12	14	9	15
UWHI (Max 100)	95	90	85	70	60	70	45	75

6.3 The Proposed Urban Wetland Health Index

The results in Table 6.10 reflect the decline of wetland riparian health from the best available non-urban wetlands to the urbanised Tower Lake No 1 and the stormwater collection ponds (Lake Kotuku and Ferndale). These results are a compilation of the metric parameters that describe the metric. The data derived from the parameters has been analysed to ensure their robustness. Some parameters (e.g. pH and conductivity) have thus been discarded from their Metric. As previously discussed, Metric 3 (QWMCI) has been discarded from the proposed Urban wetland Health Index as it was not a sufficiently sensitive metric for North Island wetlands to be included.

The UWHI results for the individual wetlands are in columns 1-8. Columns 9-10 indicate the Kapiti Coast District performance firstly for all wetlands and then for the urban wetlands only. The influence of the Waimeha Lagoon on the results for the urban wetlands is evident from the scores in the last column. The aggregated scores indicate that there is considerable potential for improvement with deficits in most metrics. The impacts of being an urban wetland with inadequate water quality and riparian structure and function appears to be, at least in part, responsible for the lack of native birds and the limited numbers of macroinvertebrates in the wetlands. (Appendix 7 spreadsheet provides details of the UWHI scores).

The data analysis (Section 6.4) has validated the role of the seven metrics listed in the UWHI as being appropriate assessment tools for wetland health across the Kapiti Coast urban wetlands. The lack of a metric for assessment of the macroinvertebrate assemblage can be regarded as a reflection of poor environmental quality, particularly hydrology. In this study, the protocol followed was derived from the 'Soft-bottomed Stream Protocol' where there was running water and macroinvertebrate communities had broad tolerance values. In the urban wetland situation where hydrology is compromised and water is still, the small numbers of macroinvertebrates had low TVs, indicating greater tolerance to polluted water. They could not be assessed in any discriminatory way across the wetlands.

Table 6.10. The UWHI for the Kapiti Coast

The metric scores for the seven wetlands assessed for the proposed Urban Wetland Health Index.	Metric	Te Hapua	Nga Manu	Waimeha Lagoon	Lake Ngarara	Tower Lake	Midlands Gardens	Lake Kotuku	Ferndale	**ALL wetlands average**	**URBAN wetlands average**	**Urban wetlands minus Waimeha**
Hydrology	1	93	98	70	58	45	55	38	40	**57**	**44**	**39**
Physicochemical	2	80	87	68	73	60	80	53	60	**70**	**64**	**65**
Riparian ecosystem intactness	3	95	95	80	44	33	44	50	53	**62**	**51**	**45**
Percentage native birds	4	45	50	56	60	40	29	40	50	**46**	**46**	**44**
Cultural/ ecological values	5	53	72	57	14	10	5	9	10	**29**	**18**	**10**
Urban development and Infrastructure impacts	6	100	96	94	76	60	75	68	68	**80**	**73**	**69**
Stormwater & %CIA impacts	7	95	95	85	70	60	70	45	75	**74**	**68**	**624**
Maximum score 700		571	596	512	382	318	358	310	344	**418**	**374**	**336**
% possible performance		82	85	73	55	45	51	44	49	**60**	**53**	**48**

6.4 Data Analysis

The development and usefulness of an Urban Wetland Health Index, requires that the metrics and parameters are appropriate for an Index, are measureable and repeatable. The assessment system for the UWHI was tested at the wetlands with simple 1-5 scoring system for the best ecological status for each parameter. The robustness of the data and the relationship between metrics, and between metrics and physical measures was assessed by Spearman Rank-order Correlations, Cluster dendrograms, Non-metric Multidimensional Scaling (NMDS) ordination, NMS ordination plots and NMS Scree plot for stress.

Spearman Rank-order Correlations

Although the UWHI is a sum of seven metric scores, these metrics are only as valid as the relationships of their component parameters. To establish these relationships and their significance as measures of wetland health, Spearman Rank-order Correlations were applied (Figure 25). The application of False Discovery Rates (FDR) to the Spearman Rank-order Correlations showed that a probability level of 0.02 or less was significant at $p = 0.05$ There were 26 significant correlations (Table 6.11). The parameters not meeting this probability level were ‘commercial development within a riparian area’ and ‘QWMCI’.

The relationship between the metrics is shown in the correlation matrix (Figure 25). The only negative relationships (in red) were for QWMCI with topographical change, vegetation integrity, riparian land use, % native vegetation, dominant vegetation, residential development in the riparian area, commercial developments in riparian area, mown lawns and culture. These parameters all have important roles in maintaining good water quality described in Chapter 5. These negative relationships and the low significance levels of the QWMCI found in the Spearman Rank-order Correlations suggest that the QWMCI is not a suitable measure of condition in these wetlands. No recent (2013) data relating to its usefulness in the North Island, nor a North Island model, has been forthcoming (Suren *et al.* 2010). In view of these findings, the South Island QWMCI was discarded from the Urban Wetland Health Index.

	Catchlandcover	catchbarriers	urbanlanduse	wetlandtype	wetbarriers	dryplants	riparianslope	ripwidth	waterclarity	algalbloom	nutrientplants	QWMCI	riparealoss	topochange	vegeintegrity	riplanduse	ripstatus	nativevege	dominantvege	nativebirds	urbandev	residential	commercial	infrastructure	reservearea	stormwaterruno	mownlawns	culture
Catchlandcover	1.00																											
catchbarriers	0.77	1.00																										
urbanlanduse	0.86	0.81	1.00																									
wetlandtype	0.77	0.86	0.85	1.00																								
wetbarriers	0.78	0.78	0.73	0.89	1.00																							
dryplants	0.80	0.53	0.80	0.50	0.64	1.00																						
riparianslope	0.35	0.47	0.66	0.65	0.36	0.25	1.00																					
ripwidth	0.78	0.75	0.90	0.84	0.83	0.79	0.44	1.00																				
waterclarity	0.36	0.54	0.32	0.66	0.80	0.22	0.02	0.58	1.00																			
algalbloom	0.64	0.57	0.69	0.55	0.62	0.70	0.43	0.54	0.36	1.00																		
nutrientplants	0.63	0.49	0.33	0.50	0.58	0.26	0.15	0.18	0.44	0.63	1.00																	
QWMCI	0.33	0.26	0.00	0.26	0.39	0.00	0.07	-0.13	0.26	0.34	0.87	1.00																
riparealoss	0.80	0.74	0.93	0.94	0.82	0.65	0.70	0.90	0.50	0.58	0.37	0.07	1.00															
topochange	0.78	0.62	0.90	0.58	0.61	0.95	0.44	0.84	0.19	0.74	0.18	-0.13	0.74	1.00														
vegeintegrity	0.78	0.62	0.90	0.58	0.61	0.95	0.44	0.84	0.19	0.74	0.18	-0.13	0.74	1.00	1.00													
riplanduse	0.78	0.62	0.90	0.58	0.61	0.95	0.44	0.84	0.19	0.74	0.18	-0.13	0.74	1.00	1.00	1.00												
ripstatus	0.78	0.57	0.90	0.81	0.70	0.71	0.76	0.78	0.29	0.70	0.41	0.13	0.93	0.78	0.78	0.78	1.00											
nativevege	0.65	0.42	0.86	0.53	0.47	0.85	0.53	0.80	0.08	0.60	0.00	-0.33	0.76	0.93	0.93	0.93	0.83	1.00										
dominantvege	0.80	0.63	0.93	0.76	0.77	0.90	0.53	0.93	0.40	0.70	0.25	-0.07	0.90	0.93	0.93	0.93	0.90	0.93	1.00									
nativebirds	0.13	0.29	0.39	0.63	0.29	-0.17	0.76	0.31	0.29	0.11	0.13	0.00	0.61	0.02	0.02	0.02	0.54	0.21	0.27	1.00								
urbandev	0.76	0.57	0.64	0.82	0.83	0.49	0.44	0.68	0.50	0.30	0.52	0.44	0.80	0.43	0.43	0.43	0.73	0.41	0.65	0.42	1.00							
residential	0.78	0.39	0.81	0.48	0.51	0.93	0.36	0.76	0.04	0.58	0.16	-0.13	0.71	0.92	0.92	0.92	0.80	0.94	0.90	0.01	0.53	1.00						
commercial	0.22	0.60	0.29	0.51	0.43	0.00	0.00	0.51	0.60	-0.18	-0.09	-0.22	0.35	0.09	0.09	0.09	0.00	0.00	0.18	0.26	0.29	-0.09	1.00					
infrastructure	0.76	0.84	0.76	0.87	0.96	0.65	0.46	0.78	0.74	0.76	0.64	0.45	0.78	0.65	0.65	0.65	0.70	0.48	0.75	0.28	0.71	0.48	0.34	1.00				
reservearea	0.74	0.76	0.59	0.58	0.82	0.73	0.06	0.64	0.58	0.66	0.58	0.45	0.48	0.64	0.64	0.64	0.41	0.35	0.60	-0.23	0.52	0.47	0.29	0.86	1.00			
tormwaterrunoff	0.86	0.89	0.81	0.85	0.81	0.62	0.31	0.86	0.55	0.38	0.39	0.15	0.80	0.64	0.64	0.64	0.60	0.50	0.71	0.23	0.75	0.56	0.67	0.76	0.72	1.00		
mownlawns	0.65	0.20	0.64	0.30	0.30	0.78	0.17	0.64	-0.10	0.23	-0.07	-0.33	0.56	0.74	0.74	0.74	0.61	0.82	0.73	-0.05	0.46	0.92	0.00	0.20	0.23	0.50	1.00	
culture	0.65	0.74	0.86	0.86	0.56	0.40	0.74	0.77	0.31	0.34	0.17	-0.13	0.89	0.58	0.58	0.58	0.77	0.63	0.70	0.72	0.61	0.51	0.51	0.55	0.23	0.76	0.46	1.00

Figure 25. Spearman Rank-order Correlations were applied to the parameters of the metrics for the Urban Wetland Health Index. The negative correlations are highlighted in red and the positive correlations >0.7 are in green. Note: the QWMCI negative correlations highlighted in red.

Key to abbreviations in Tables 6.13, 6.14 & 6.15: catchlandcover = catchment land cover; catchbarriers = catchment barriers to flow; urbanlanduse = % urban land use in catchment; wetland type = wetland type; wetbarrier = barriers to wetland outlet flow; dryplants = % dryland plants; riparianslope = riparian slope; ripwidth = riparian area width; waterclarity = water clarity; algalbloom = algal bloom; nutrientplants = % nutrient plant cover; QWMCI = QWMCI; ripealoss = % original riparian area lost; topochange = evidence of topographical change; vegeintegrity = vegetation integrity associated with human activity; riplanduse = urban land use in riparian area; ripstatus = riparian cultural status; nativevege = %native vegetation cover; dominantvege = type of dominant vegetation; nativebirds = % native birds; urbandeve = urban development within riparian area; residential = % residential within riparian; commercial = % commercial development within riparian; infrastructure = % infrastructure in riparian; reservarea = no infrastructure within riparian area; stormwaterruno = stormwater runoff; mownlawns = mown lawns in riparian area; culture = cultural importance of wetland.

Table 6.11. False Discovery Rate results for Spearman Correlation of metrics with the total score. Samples with a probability level of 0.02023768 or less are significant at p = 0.05.

Descriptor	r statistic	N	Probability	FDR P-value
Dominant vegetation	0.932227	28	0.000000	0.000000
Riparian area loss	0.932227	28	0.000000	0.000000
Riparian width	0.901853	28	0.000000	0.000000
Riparian status	0.901853	28	0.000000	0.000000
Wetland barriers	0.889499	28	0.000000	0.000000
Wetland type	0.878310	28	0.000000	0.000000
Infrastructure within riparian area	0.872872	28	0.000000	0.000000
Urban land use	0.866025	28	0.000000	0.000000
Riparian land use	0.778312	28	0.000001	0.000003
Topographical riparian change	0.778312	28	0.000001	0.000003
Vegetation integrity	0.778312	28	0.000001	0.000003
Native vegetation %	0.765958	28	0.000002	0.000005
Catchment land cover	0.763763	28	0.000002	0.000005
Dry plants %	0.740674	28	0.000007	0.000012
Algal bloom	0.740674	28	0.000007	0.000012
Urban development in riparian area	0.728561	28	0.000011	0.000019
Residential development riparian	0.716541	28	0.000018	0.000030
Culture, ecology & social	0.704187	28	0.000029	0.000045
Stormwater runoff	0.701068	28	0.000032	0.000048
Catchment barriers to flow	0.675164	28	0.000081	0.000113
Water clarity	0.642416	28	0.000228	0.000304
Reserve area riparian	0.619780	28	0.000436	0.000555
Riparian slope	0.561890	28	0.001861	0.002265
Mown lawns	0.494166	28	0.007521	0.008775
Native birds %	0.457104	28	0.014467	0.016203
Nutrient plants %	0.436436	28	0.020238	0.021794
Commercial development riparian	0.247436	28	0.204276	0.211842
QWMCI	0.125988	28	0.522936	0.522936

Cluster Dendrograms

The relationships between the parameters of the metrics were further illustrated using hierarchical cluster analysis to form dendrograms (Figure 26). At the first level the two most similar clusters i.e. those with the least dissimilarity, are fused (e.g. ‘urban development in riparian area’ and ‘stormwater runoff’). The distances at the second level, e.g. ‘riparian topographical change’ fusing with the level 1 fusion of ‘riparian width’ and ‘dominant vegetation’, indicates greater dissimilarity. As the levels of fusion increase the dissimilarities are greater finally tending toward a single cluster (Burns & Burns 2008). The final cluster for this dendrogram has the parameters relating to land use and land cover at the greatest height (>15) when relating to all other clusters i.e. they have the least relationship or greatest dissimilarity to the other clusters.

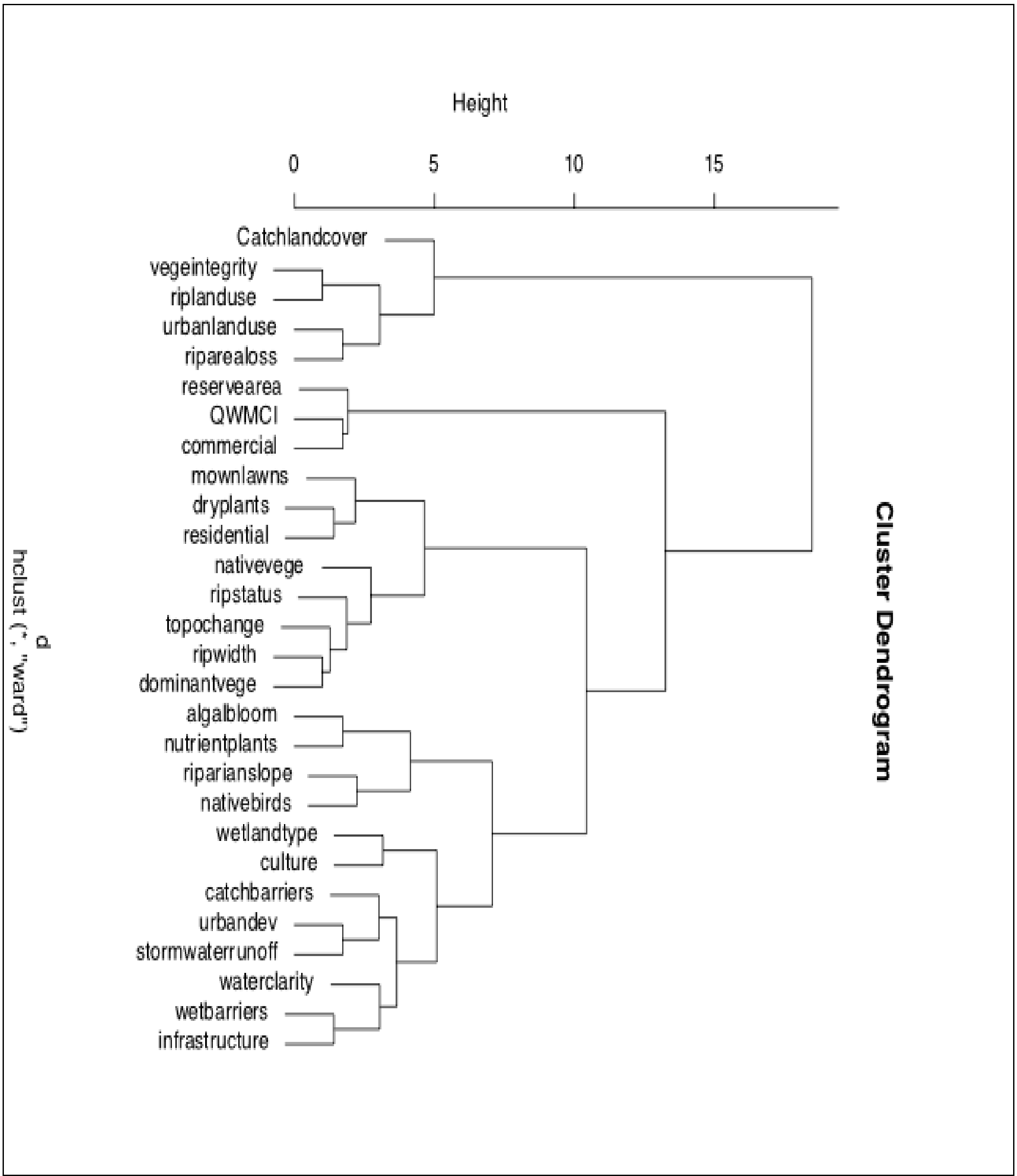


Figure 26. Cluster Dendrogram indicating the relationships between the metric parameters.

Clusters of parameters can be aggregated at any level of dissimilarity as measured by the table of heights. The five clusters groups in Figure 27 do not match the UWHI metrics but rather show the similarities between the parameters to fusion level 6.

Note: 'QWMCI' and 'commercial urban development' are clustered together at level 1 in a small cluster and have a great dissimilarity (>height of 10) with other clusters.

.

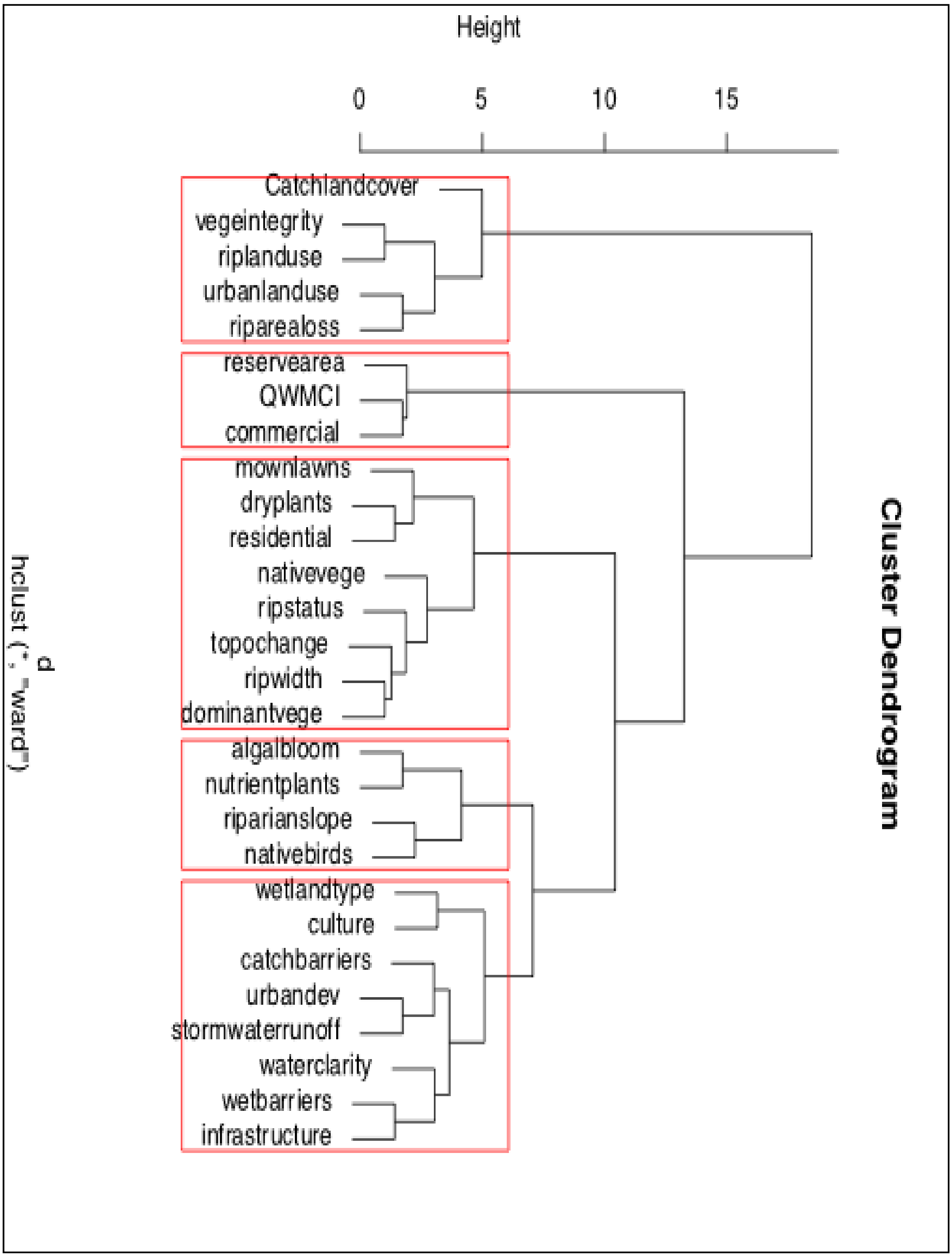


Figure 27. Cluster Dendrogram indicating five clusters with the least dissimilarities

Non-metric Multidimensional Scaling (NMDS)

Non-metric Multidimensional Scaling (NMDS) is regarded as the best ordination method for community data. It is based on rank-order distances between samples (Legendre & Birks 2012).

.

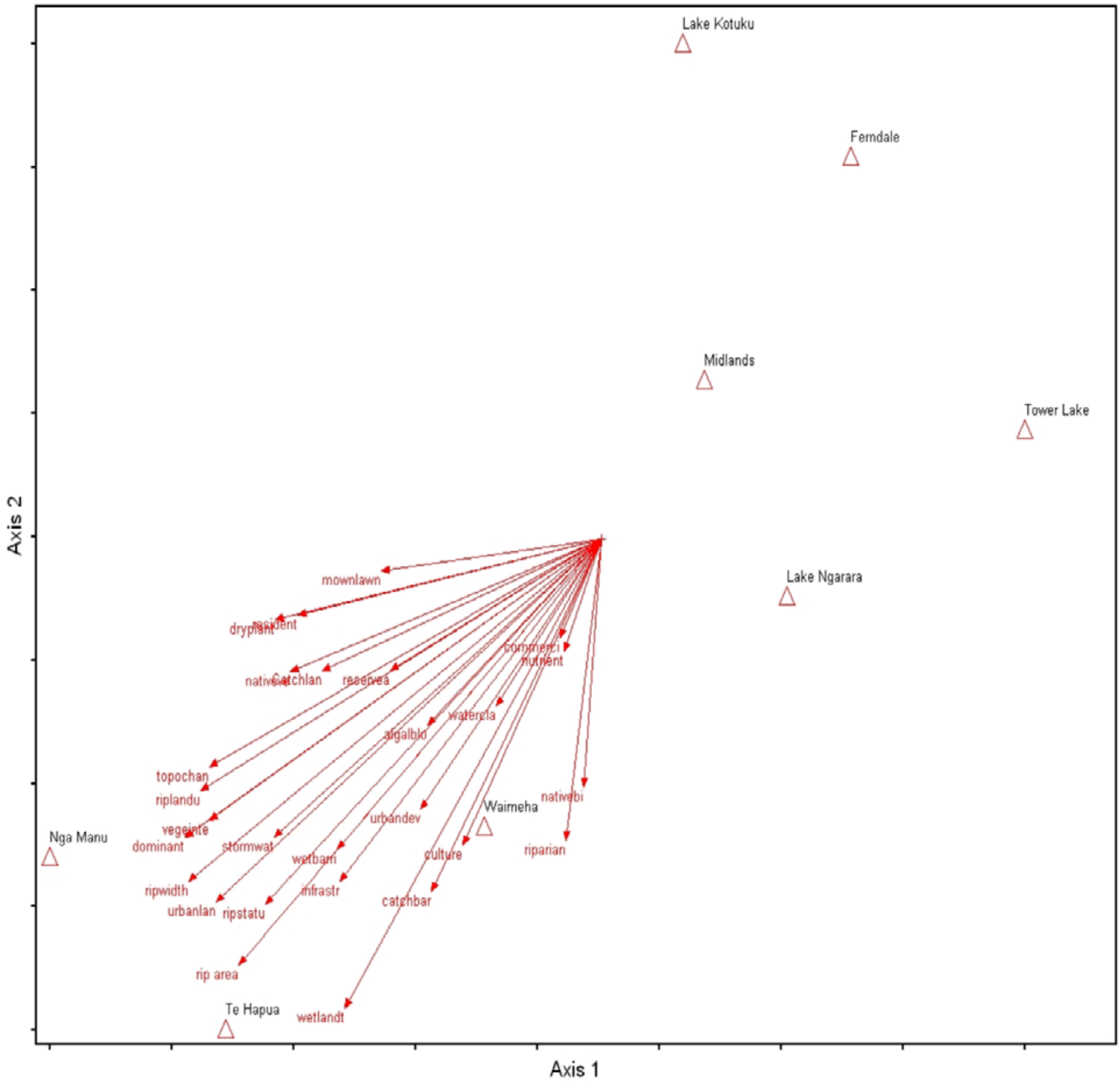


Figure 28. Non-metric Multidimensional Scaling ordination plot for the scored parameters of the proposed UWHI. The plot shows the relationships of the scored metric parameters with the eight wetlands

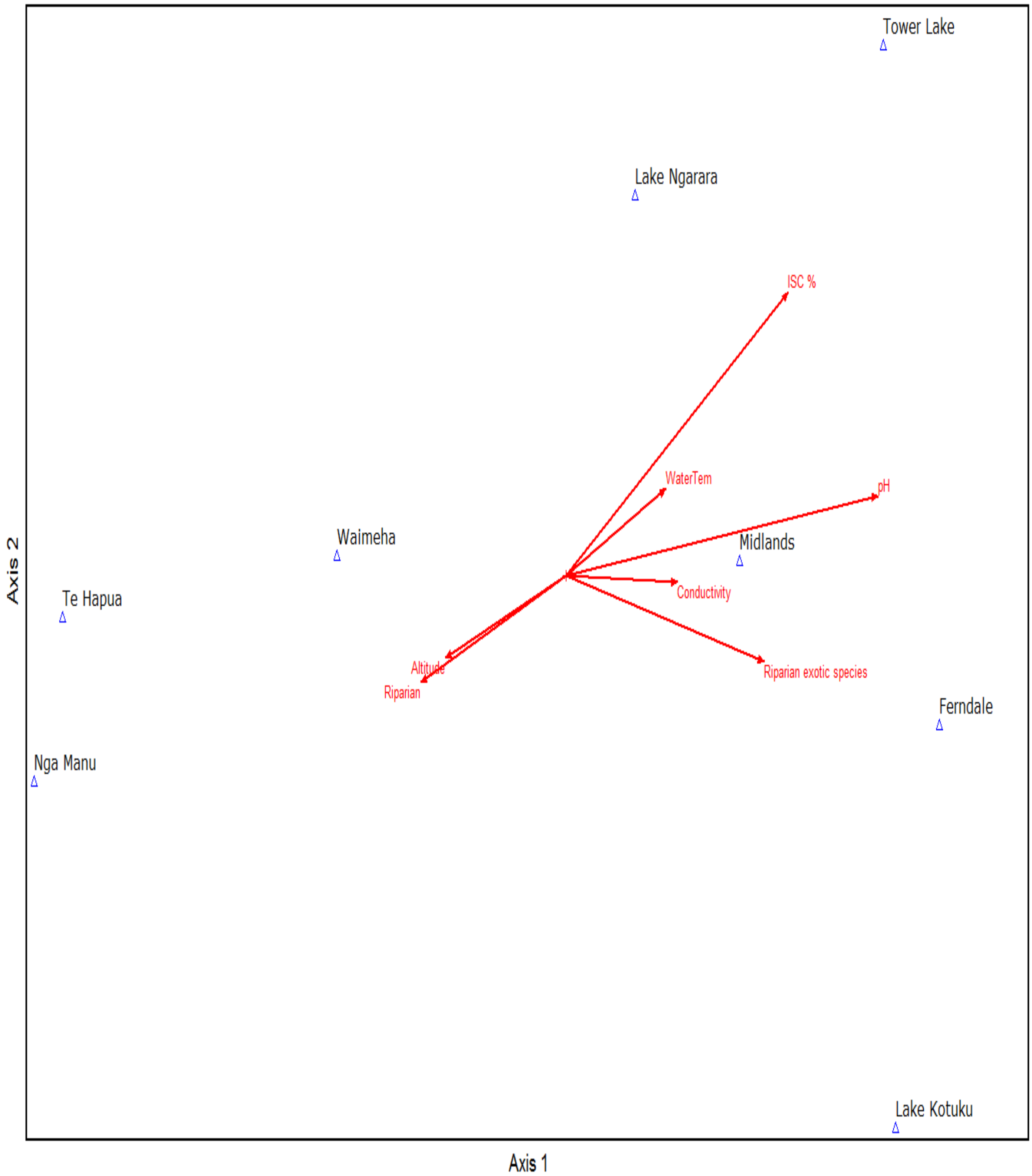


Figure 29. Non-metric Multidimensional Scaling ordination plot for independent metric parameters (Table 6.12) .

The NMDS ordination scree plot had a stress level of 8.35 which was the lowest after 250 randomised ordinations

The two NMDS plot diagrams indicate that the independent (Figure 29) metric parameters i.e. those not included within the proposed UHWI, had negative or low positive correlations with the parameters in Figure 28.

Table 6.12. Independent parameters for NMDS

Non-scoring parameter for NMDS (Figure 29).	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Water temperature ^{0}C	12	15	14	16	16	29	24	15
pH	6.7	6.7	7.4	8.1	8.0	7.7	8.0	7.4
Conductivity (µS/cm)	358	150	512	339	473	213	570	450
Altitude (m asl)	3.3	13.4	11	8	6	11	15	14
ISC%	0	0	25	30	40	25	20	15
No. species native flora	10	24	14	14	6	14	12	11
No. species exotic flora	4	5	4	5	8	13	13	7

6.5 Macroinvertebrates and the South Island WMCI and QWMCI

This potential metric was discarded from the UWHI as the parameters could not be validated. Although macroinvertebrate diversity and abundance data are used in many wetland health assessments, and in all stream health assessments, there was inadequate data to do so for this study (Appendix 6). The preponderance of molluscs, oligochaetes and tanypodia in the samples is reflected in many studies on wetland sediments. Carew *et al.* (2007) investigated the role of chironomids in determining urban pollution in Melbourne wetland sediments and concluded that some species may be able to be used as markers of specific pollutants.

The Wetland Macroinvertebrate Community Index (WMCI) and the Quantitative WMCI (QWMC) were calculated as per the method of Suren *et al.* 2010) using the small number of taxa collected. The QWMCI values ranged from 2.6 to 5.9 which, according to the criteria established by Suren *et al.* (2010), indicates poor to fair health. However, **t**he South Island QWMCI has not been validated in the North Island as a water quality measure. North Island taxa assemblies differ markedly from the South Island assemblies. The Taranaki Regional Council Policy and Planning Committee (2010) drew attention to the results of all the North Island wetlands where the QWMCI was only fair or poor and rejected its use.

Macroinvertebrate data is available in Appendix 6.

6.6 Conclusion

The evaluation of urban wetland health is ideally associated with measuring the ecological performance of the urban wetland and comparing it with the ecological performance of unaltered ‘reference’ wetlands (Ehrenfeld 2000). In this study, there were not any unaltered ‘reference‘ sites within the Kapiti Coast District. However, rural natural wetlands were available in the north of the district. These were on the same coastal domain. Their human interference had been minimal for 15- 20 years and the riparian areas surrounding these wetland ponds were largely populated with native flora. Although not the perfect choice for ‘reference’, (Ehrenfeld 2000) they were the best available for providing comparisons with the parameters used to assess wetland health. The Urban Wetland Health Index derived from the study (Table 6.10) confirms this view.

Riparian structure and function have been shown to be both essential for water quality in streams and to reflect changes associated with urbanisation. Although there are structural differences in riparian areas for wetlands, they serve the same purpose in protecting the wetland ponds from sediment and pollutants and providing habitat for fauna. Also they ensure the integrity of the wetland water (Groffman et al. 2003). The use of the term 'riparian' for wetland pond margins has become widespread over the last decade (O'Carroll 2004) and is used in this study to identify the area surrounding the wetland that contains flora that are adapted to damp and wet environments. The limits of riparian area width are difficult to define with variations from 3m to 200m to be found in the literature (USEPA 2005; Semlistch & Jensen 2001). A 20m width was used for each wetland for comparison of the ecological changes to the Kapiti Coast wetlands. This was a representative choice as the reference rural wetlands had wider margins and several urban wetlands had narrower area compromised by development.

The Urban Wetland Health Index is based on evaluation of the ecological functions of a wetland and the effects of urban development on their structures and functions. The metrics and their parameters provided qualitative and qualitative assessments. The relationships between the parameters were examined using the Spearman Rank-order correlations, Cluster Dendrograms, Non-metric Multidimensional ordination and a MNS Scree plot. NMDS ordination with independent parameters validated the data used in the UWHI (Figures 25-30).

The Urban Wetland Health Index developed in this study can ideally be used by local authorities and planners as a tool to monitor established urban wetlands as well as those planned in the future. By using the simple scoring system (Table 5.1), the deficit between good quality wetlands and those of poor quality is clear, thus providing an indication of requirements for improved quality. This is further discussed in the next chapter together with discussion on the responsibilities of local authorities for the management of waterbodies in their areas as required by the RMA 1991, Section 30.

Chapter 7 Discussion of Results

7.1 Introduction

In this chapter, the results of the research documented in chapter six are discussed and where relevant related to other studies. Section 30 of the RMA 1991 requires environmental management agencies (regional councils and territorial authorities) to achieve integrated management of the natural and physical resources of the region. To date, urban development in New Zealand and elsewhere, has paid little attention to the ecological requirements of an urban wetland (Alberti 2008). The plans and policies for urban wetlands from regional councils and territorial authorities have varied throughout the New Zealand. However, most new 2013 District Plans have acknowledged the requirement for the Environment Results Expected (ERE) as part of the resource consent procedure. Healthy ecological functioning of wetlands is essential in supporting the resilience of an urban area (Pickett *et al*. 2103; Alberti 2008).

The urban wetland sites in this study were all within 20km of one other in the same geographic domain (Figure 5) but had differing origins and variable responses to the impacts of urban development on their ecological health. The Urban Wetland Health Index (UWHI) investigated their responses to urban development. The two non-urban wetlands, also investigated, were the best-available reference wetlands providing a basis for comparing the ecological responses to urban development. The UWHI data analysis confirmed that the ecological health of five of the urban wetlands was compromised and this was consistent across the parameters assessed. Waimeha Lagoon, the sixth urban wetland, straddled the results between urban and rural wetlands, probably associated with its history and the limited effects from its surrounding low density residential developments (Appendix 1).

The potential for improved ecological conditions in line with the RMA and LGA requirements are discussed later in this chapter, as are the Kapiti Coast District Plan Review, 2010, discussion documents. These documents outline possible improvements in long term planning in line with Objective 13 of the Greater Wellington Regional Council Regional Policy Statement, 2009-2019. The use of the Urban Wetland Health index would be a positive adjunct to the KCDC deliberations and subsequently for incorporation in the monitoring of the health of urban wetlands.

7.2 Using the Urban Wetland Health Index

The Urban Wetland Health Index was developed to fill a gap in New Zealand wetland assessments and monitoring, namely assessments for the urban wetlands ponds and riparian areas. This gap exists in the Kapiti Coast District Council (KCDC) District Plan 1999 and its 2010 Review documents. A search of other published operative district plans throughout New Zealand gave a similar result. Whangerei District Plan 2010 had a monitoring strategy for the riparian strips on esplanades but not wetlands. The former Auckland City Plan 2011 had monitoring of stormwater collection pond water quality as a requirement, as did the Waikato District Plan 2010. Environment Waikato Regional Council 2010 had a policy of developing riparian margins for protection of water bodies including natural wetlands but no mention of urban wetlands. Hawkes Bay Regional Council has plans for an esplanade riparian reserve of 20m but not in the cities and no mention of urban wetlands.

Wellington City Council monitored the Waitangi Park stormwater estuarine wetland and the Botanic Gardens duck pond and GWRC monitors the water quality of a small selection of non-urban wetlands. Dunedin City Council Plan 2010 did not mention urban wetlands or their management and may not have any such wetlands. Any policies and plans of the Christchurch City Council (CCC) are currently associated with remediation of the Avon and Heathcote Rivers following the 2009-2010 earthquakes.

However, prior to this event its Council's Plans had references to wetland restoration and planting of riparian areas at natural wetland sites. It was also involved in the restoration of the Travis Wetland which is suburban and the installation of swale filters for the runoff from Tumara Park wetland area on the periphery of the city. In 2011, the Christchurch City Council published its 'Waterways and Wetlands Philosophy Document' for the future management of its streams and wetlands. All the details are not available on the website, but the general introduction does not appear to cover the situation where the wetland is a new and integral part of a subdivision (ccc.govt.nz/ 2011). These guidelines have not been reviewed since 2011.

All the territorial authorities referred to above had plans for restoration of waterways that focused on streams and in many areas also included degraded natural or rural wetlands. Many district plans alluded to wetland ponds being privately owned and indicated that the owners would monitor their own wetland ponds (GWRC 2007). There was no consistency in the above district plans regarding ongoing management of wetlands in urban subdivisions. The responsibility for these was not identified apart from responses by some territorial authorities when they receive complaints (Cross 2012, KCDC, pers. comm.).

The situation highlighted by the UWHI for the Kapiti Coast urban wetlands is a statement of their present health. All of these urban wetlands have not had monitoring regularly and there appears to be no line of responsibility over time for these waterbodies and their riparian areas. This is not an isolated problem as discussed in earlier chapters (e.g. Manuel 2003). The restricted implementation of the RMA requirements by KCDC to only ecologically important wetlands has done the urban wetlands a disservice. The way forward using the UWHI as a means of assessment may lie with the following initiatives or similar.

The local authority could trial the use of private contractors to ensure the ongoing health of the wetland ponds and riparian areas modelled on an Auckland Motorway Alliance (AMA) solution. In 2006, the AMA contracted Wetland Solutions Environmental Consultancy & Land Development Experts to undertake regular monitoring of the stormwater ponds associated with the motorway development and thereby to assist AMA with compliance with their resource management obligations. As listed on their website (www.wetland.co.nz), 'Wetland Solutions' are required to 'report on asset health and function, maintenance and budgeting; weed control; rubbish and litter removal; plant supply and planting' (Wetland Solutions 2006).

The involvement of the community in monitoring local wetland ponds has been promoted by the New Zealand Landcare Trust since 2011 with the development of the WETMAK Kit (Wetlands Monitoring and Assessment Kit). This an online resource (www.landcare.org.nz/wetmak) and is specifically aimed at community groups. The kit has useful information about restoration goals and monitoring of wetland health. The UWHI could be an important part of this activity. Local authority endorsement of such a kit and the UWHI assessment tool could assist with the improvement of the health of the urban wetlands (Landcare Trust 2011).

7.3 Wetlands and Regulatory Controls

The effects of urban development on the wetland riparian functions were assessed for the Urban Wetland Health Index to ascertain the extent of the territorial authority's (KCDC) response to implementation of the RMA 1991 and amendments 2012 (Ch. 2). Urban development must also comply with the requirements of the Local Government Amendment Act 2012 that requires councils to take a sustainable development approach. The operative KCDC District Plan 1999, Objectives C1-11.1, Policy 5 states that the council will 'ensure that the effects of subdivision, land use and development activities do not alter the water table of significant wetlands and lakes to a significant extent'.

Those wetlands not regarded as significant by the local authority (Metric 5, Ch 5) together with urban wetlands appear to be excluded from this policy, although Objective C1-11.1, Policy 8 states that the Council will 'encourage planting of locally sourced indigenous species adjacent to water bodies and other areas that will restore linkages and ecological corridors' (KCDC 2010). Policy objectives, particularly those relating to the impacts of infrastructure, stormwater and urban development on and in riparian areas, are implemented through the resource consent procedures (Ch. 2). They also provided the background for the assessments used in the UWHI (Tables 5.1 & 6.10; Appendices 3 & 7) outlined in the previous chapters. These will be further discussed in Section 7.4, Metric 7, of this chapter.

The issue of urban 'green spaces' has been addressed by most territorial authorities in their district and regional plans. Such plans include restoration and ongoing protective management of green town belts, parks and reserves and berms. However, while these general management plans apply to public areas and areas of ecological significance, they do not directly affect the urban wetlands in subdivisions. Resource consents that allow the construction of these wetlands do not appear to have ongoing management plans for their health. However, New Zealand councils may be interested to take note of the announcement of the Mayor of London in April 2013 that planners and designers need to integrate water within urban planning (Illman 2013). The UK Landscape Institute is focused on an 'integrated approach to land use and the benefits of a green infrastructure can create a multifunctional landscape'. Their view is that water features within a city will ‘enhance the microclimate and reduce heat’. The desire is to have water sensitive cities.

7.4 Wetland Ecological Assessment

The Urban Wetland Health Index scores provided the data to compare the ecological performances of the eight study sites (Table 6.10). Ehrenfeldt (2000) suggested that it was not appropriate for ‘urban sites to be directly compared with non-urban sites’ for their structure and function. Her example of urban environments in New Jersey, USA, with dense populations and industrial precincts, differs considerably from the situation on the Kapiti Coast where the 46,000 people have a low rise, non-industrial, urban environment. It was therefore appropriate to use nearby non-urban wetlands as comparative wetlands for this study.

The parameters of the metrics used in the UWHI were adapted from previously published assessments of New Zealand streams, wetland monitoring information and other sources documented in chapter 5, providing validation for the indicator selection made. Spearman Rank-order Correlations analysis of the indicators using FDR p-values showed significant positive correlations between 26 ecological parameters (Figure 25). The possible reasons for lack of significant correlations between the other two parameters tested, QWMCI and ‘commercial use of the riparian area’, are outlined below. All parameters were also analysed using Cluster Dendrograms and NMDS ordination and NMS ordination scree plot for stress (Ch. 6, Section 6.3).

The QWMCI assessment returned invalid results for the Kapiti Coast wetlands and has been withdrawn as a measure of wetland health (Suren *et al.* 2010). Although it is valid for the South Island wetland health, it is not valid for the North Island wetlands where the taxa assemblies are markedly different. In the South Island study the QWMCI had positive correlations with land use within a 1km buffer zone and native vegetation but negative correlations with agriculture, exotic vegetation, urban development, pH and conductivity (Suren *et al*. 2010). The assertion that the pollution leading to the low tolerance values of the wetland aquatic macroinvertebrates can come from any source including agriculture, forestry and urban, is also true for North Island wetlands.

In this study, more than 64% of macroinvertebrate taxa retrieved from each wetland, both urban and rural, had low tolerance values i.e. TVs = or <5. The macroinvertebrates were dominated by the mud snail, *Potamopyrgus antipodarum* which has a TV=3. In 2011, Suren *et al.* assessed the use of diatoms and macroinvertebrates in landscape-based indices as measures of wetland condition but concluded that neither communities assemblies were useful in determining wetland health. They did note, however, that nutrient concentrations had an influence on aquatic macroinvertebrates (Suren *et al.* 2011). The lack of a role for macroinvertebrates as indicators for wetland health is in contrast to their importance in the assessment of stream health where the MCI is an important guide to stream health (Winterbourn *et al*. 2000).

Metric 1. Hydrology

The hydrology of a wetland ecosystem is critical to its ecological functioning. Where there is a dysfunction in one of the hydrological parameters such as lack of sufficient rainfall, that will affect the groundwater, wetlands and streams that are dependent upon it. Mitsch & Gosselink (2000) noted, 'hydrology is probably the single most important determinant of the establishment and maintenance of specific types of wetlands and wetland processes'.

Catchment Hydrology

In this study, the Indices used for catchment, wetland and riparian hydrology, showed that there were clear differences between the hydrological performances of the non-urban wetlands and the urban wetlands (Table 6.1). The Waimeha Lagoon, a remnant swamp (Figure 10), which had the least compromised urban wetland and riparian hydrology, was associated with a larger, less urbanised site and well developed vegetated riparian area for most of its water edge. The poor catchment hydrology result for Lake Ngarara, another remnant swamp (Figure 11), was associated with considerable urban development of the catchment during the last two decades altering surface water flow as streets and houses continue to be constructed and dunes flattened around its perimeter.

In an urban catchment, land use disturbances that arise from increased impervious surfaces and alteration of water flows both above and below ground have wide implications for the hydrology (Hogan & Walbridge 2009). Increased impervious areas lead to rapid and increased surface water runoff to a wetland (Ehrenfeld 2000). Whether or not excess water affects the wetland is likely to be dependent on the size and functions a riparian area's vegetation and its resilience to high water flows. The negative effects of a high water flow from a catchment include a reduction in groundwater if runoff is too rapid for it to be absorbed into the ground (Ch. 4). Campbell (2010) has advocated the use of integrated catchment management principles to reduce such adverse effects. Whether this approach can be adopted across the urban areas of the Kapiti Coast is uncertain until the issues of imperviousness and stormwater runoff are dealt with.

As discussed in chapter four, there are moderate to high proportions of imperviousness across the Kapiti Coast catchments. The assessment of the Impervious Surface Connectivity (ISC%) and the Connected Impervious Areas (CIA%) data indicated that the greatest imperviousness occurs in the established residential areas (Tables 5.3 & 5.5). As these areas, on compacted sand-alluvium, have only moderate to low infiltration rates (Table 5.4) the stormwater runoff with its sediment and pollutants drains into the nearest wetland or stream.

The non-urban wetlands had less hydrological disturbance from changes in landform, land use, land cover and artificial barriers than the urban wetlands and were not subjected to stormwater drainage effects. The relationship between the hydrology of wetlands and their predicted response to stormwater from heavy rainfall events (CIA%) is shown in Table 7.1.

Waimeha Lagoon is in an older established area with low population density giving it a poor CIA% rating for stormwater drainage but with low density population in its catchment also has a low ISC%. By contrast Tower Lake No 1, also in an older area with a low CIA% rating for stormwater, has a medium-high ISC% as it is a more densely populated area. Ferndale subdivision is probably a sinecure here as it is a new subdivision with new drainage and only a few houses.

Table 7.1 Relationships between hydrology, CIA% and ISC%
(see Tables 6.1, 5.3 & 5.5 for details)

	Hydrology Metric 1	CIA %	ISC %
Te Hapua Shoveler	93	0	<30
Nga Manu	98	0	<30
Waimeha Lagoon	70	38	<30
Lake Ngarara	58	55	20-50
Tower Lake	45	38	20-50
Midlands Gardens	55	65	20-50
Lake Kotuku	38	55	20-50
Ferndale	40	55	<30

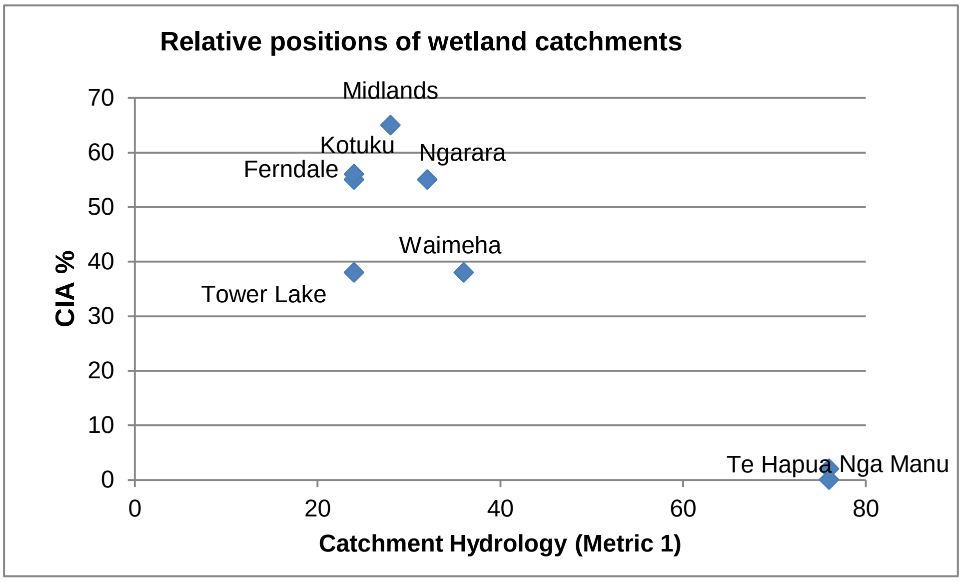


Figure 30. Relative positions of the wetlands catchments imperviousness.

Wetland Hydrology

As a wetland's hydrology is driven by catchment hydrology it is vulnerable to any changes in volume or direction of water flow from the catchment. In an urban setting this is a common problem during and after urban development where barriers to flow include dams and weirs, drainage pipes, bores, bridges or excavations. Roadside gutters and blocked drains in developed residential areas also alter water flow dynamics. The ensuing negative effects are discussed in chapter four.

Wetland water levels are dependent on both surface water and groundwater and therefore any impediment to inflow of water threatens the existence of the wetland flora and fauna. Natural wetland cycles where plants and fauna are adapted to pulses of dry and wet periods are not replicated in urban isolated wetlands where the erratic pulses of rainfall and rapid surface runoff present a more violent all-or-nothing scenario (Karim *et al*. 2012). Of the wetland sites assessed in this study, only Tower Lake No 1 has a positive plan to maintain its water table levels, as it received 40,000 litres of deep groundwater daily. During the summer of 2010-2011, drought conditions on the Kapiti Coast affected Midlands Gardens North Pond and Ferndale pond with very low groundwater levels. At Lake Kotuku the low water levels were associated with algal blooms and eutrophication (Figure 21).

Riparian Hydrology

Riparian hydrology is dependent on the adequacy of both wetland and catchment hydrology, as well as its ability to absorb surface water runoff. As previously discussed in chapter four, the slope and width of a riparian area, its soil permeability and its vegetation composition are the major determinants of water absorption.

However, as discussed in chapter four, debate continues in the literature about the extent of riparian area width with factors affecting this ranging from habitat concerns to the financial concerns of developers needing land. Recommendations from a wide selection of researchers are for a riparian area width of more than 20m and a slope of less than 10º (McElfish *et al.* 2008; Mayer *et al.* 2007; Mander *et al.* 2005; Allen & Walker 2000). The riparian slopes at two sites (Midlands Gardens and Lake Kotuku) were greater than 15^0, which might indicate that their ability to absorb the surface water or to collect sediment from runoff was greatly reduced. The Lake Kotuku banks showed signs of erosion due to runoff in heavy rain episodes and lack of sufficient mature vegetation. Of the other study sites, only Nga Manu Top Pond riparian area was wider than 20m with a slope of 5º. Five of the six urban wetland riparian areas measured were less than the 20m wide.

Urban wetlands as part of residential subdivisions are frequently constructed for amenity purposes or for stormwater collection (Boyer & Polasky 2004). In Perth, WA, their value to a community is demonstrated in the increased value of properties within 1.5km (Tapsuwan *et al*. 2008). The KCDC District Plan Review Biodiversity Discussion Document 2011 states that KCDC will ‘analyze the effects of resource consents, permitted activities and plan changes, and the effectiveness of the conditions imposed on resource consents intended to protect or enhance biodiversity’ but no particular attention is paid to urban wetlands and their riparian areas (KCDC 2010a, p 113) although they could be an integral part of the proposed biodiversity corridors. In future their width and slope in new subdivisions, which have profound influences on sediment trapping as described in chapter four, will continue to be negotiated by KCDC (Cross 2012, KCDC, pers. comm.).

Because the vegetation composition and structure of a riparian area determines the effectiveness of the removal of sediments, closely mown grass on riparian areas, as at Lake Ngarara, Tower Lake and Midlands Gardens, is unlikely to provide efficient sediment removal. However, Naiman & Decamps (1997) promoted combinations of tall grasslands and forest/bush as giving optimal conditions. Adamus (2007) suggested that grassy and herbaceous vegetation would be the most effective combination.

Cole *et al.* (1997) found that the length and height of buffer grass controlled sediment runoff, but it did not significantly affect nutrient runoff. However, Moss *et al.* (2006) showed that nutrient runoff using grass buffers of multiple heights (25, 38 & 51mm) reduced N and P runoff such that only 2% N and 6% P from that applied as fertiliser was lost in runoff. While they agreed that this was still unsatisfactory, the result was significantly better than previous methods of grass control of pollutants.

There is no clear answer to the vegetation mix, native or exotic, tall grass or bush, but a complete covering of the bare ground with robust vegetation is essential. The urban wetlands apart from Waimeha Lagoon did not meet this criterion. The value of a riparian habitat to fauna is dependent on riparian hydrology being able to support the vegetation.

Metric 2 Physicochemical parameters

As discussed in the previous chapter and confirmed in the NMDS ordination of the Independent parameters - conductivity, pH and temperature, for this study were not sufficiently consistent to be included in this metric. This inconsistency was also found by Suren and Sorell (2010) in their study of 40 New Zealand wetlands where there was considerable variation in pH levels as well as with conductivity and temperature measurements. They suggested that the type of wetland, its latitude and its ecological situation contributed to this. The Kapiti Coast wetlands were all floodplain, palustrine wetlands of varying ages and method of formation, and within varying areas of population density. As the study wetlands were of similar latitudes, extending from 40^0 54’ S (Midlands Gardens) to 40^0 48’ S (Te Hapua), this is an unlikely reason for any variations.

A significant relationship for water clarity with wetland barriers to inflow and riparian urban infrastructure was confirmed by both Spearman rank-order correlation and the Cluster Dendrogram. Water clarity is a measure of the dynamics of the water movements into wetlands with the sediment derived from surface water, streams and bank erosion following rainfall. The water clarity in this study were measured at approximately one metre from the water’s edge.

The presence of high nutrient plants and algal blooms was positively correlated with loss of riparian area, vegetation integrity and riparian land use as well as effects of infrastructure within and around the riparian area. The Cluster Dendrogram also aligned them with riparian slope and percentage of native birds. Thompson (2012) noted that the groundwater at Te Hapua had high nutrient levels and drew attention to the contribution of birds to the nutrient load of wetlands. Waimeha Lagoon and Lake Ngarara have significant populations of ducks and also have stands of raupo and visible pondweeds. Tower Lake has large areas of pondweeds and a population of ducks and pukeko.

Wetlands have been regarded as sinks for nitrates and are widely used as such for rural runoff (Rutherford *et al*. 2009). Harrison *et al*. (2011) reviewed riparian denitrification across a range of urban alluvial wetlands in Baltimore, USA. They found that denitrification rates did not differ with wetland types and that the rates of denitrification occurred year-round. Their conclusion was that urban wetlands of all types had the potential to reduce the amount of nitrate in urban landscapes and should be considered for this function. This concept has been used widely with the development of constructed wetlands for wastewater management from rural and industrial sources. Lee *et al*. (2009) reviewed this ‘low-energy ‘green’ technique’ suggesting that it could be significant in the removal of more than 50% of urban nitrogen derived from stormwater, sewage, industrial and landfill leachate sources.

The Kapiti Coast urban wetlands in this study have not primarily been constructed for denitrification purposes but for amenity. Lake Kotuku was originally constructed to provide a sink for stormwater and as an overflow for flood water from the Mazengarb drain. It’s primary purpose was to reduced solids and pollutants from reaching Lake Ngarara but denitrification occurs as well. Ferndale constructed pond is fed from vegetated swales and filtered stormwater drains to reduced solids and pollutants. All urban wetlands will undertake some denitrification processes if they receive stormwater though this has not been measured in New Zealand.

Mayer *et al*. (2006) undertook meta-analysis of nitrogen removal by wetland riparian ‘buffers’ and found a wide variation of removal with the width of the riparian area. Riparian areas of >50m were more effective than those of <25m or less but the nature of the vegetation (herbaceous or forest) had less effect on the efficiency of the removal. The denitrification process was more closely related to the amount of vegetation and the sub-surface water flow rate. The Kapiti Coast urban wetlands riparian areas, excluding Waimeha Lagoon, have narrow riparian areas and limited vegetation suggesting that they would not be effective areas for nitrogen removal from stormwater. According to Verhoeven *et al*. (2006), this situation may lead to losses of wetland biodiversity.

Metric 3 Riparian Ecosystem Intactness and Habitat

Riparian habitat features and functions are among the most sensitive indicators of the effects of urban development (Alberti 2005). The association of riparian ecosystem intactness with riparian habitat reflected their co-dependencies.

As discussed in chapter four, all the wetlands investigated have had their terrestrial and aquatic flora and faunal habitats altered by land use changes over the last two centuries, both with agricultural and urban development. These include major landform changes with the removal of dunes, their vegetation and fauna, to fill landscape depressions. This widespread landform change has resulted in the Kapiti Coast urban area being re-contoured and habitats lost.

Waimeha Lagoon has some original swamp vegetation, but sand dune vegetation (grasses and small shrubs) was removed from the dune lakes (Lakes Ngarara and Kotuku) before urban development following advice from a landscape consultant to KCDC. He noted that 'the area was found to contain a few plant forms of particular interest', while the bulk of the vegetation was dominated by sedges and rushes surrounded by pastoral grassland (Harlen 1993).

Quality riparian habitats are required for wetland ecosystems to flourish. Natural wetland riparian habitats are part of the landscape patterns that maintain ecological connectivity for flora and fauna (Grose 2010). The presence of exotic plants in the riparian vegetation may have several consequences including the effects of weeds that invade and prevent riparian shrubs and trees from growing (e.g. *Tradescantia fluminensis*). If there is a seasonal leaf fall from deciduous riparian trees into the wetlands, the New Zealand macroinvertebrate communities are unable to process the leaves as the only invertebrate shredders, stoneflies (Perlidae), are usually found in fast moving streams (Suren & Sorrell 2010). The breakdown of exotic leaves by abrasion in moving water occurs, but in still water they may lie for a long time slowly decaying and adding to potential eutrophication. Gasith & Resh (1999) noted that 'the sudden and greater nutrient load placed into soil microsystems and wetlands by deciduous trees can lead to a great alteration in water quality, and be a problem to other living things within those systems'.

In the Northern Hemisphere, the autumn leaf fall is followed by a winter season when cold or icy weather breaks down cell walls allowing invertebrates and microbial communities to access the leaf tissue in the spring (Merritt & Cummins 2008). The most common of these invertebrates are the amphipods, Coleoptera, molluscs and oligchaetes (Maltby 2009). However, there is lack of evidence that invertebrate shredders play a significant role in affecting decomposition compared to the microbes (Euliss *et al.* 1999; Higgins & Merritt 1999).

In this study, there were minimal established, ecologically functioning, urban wetland riparian habitats apart from the Waimeha Lagoon. Terrestrial fauna, including birds and insects, rely on adequate space and food sources in the riparian areas as well as ecological corridors to allow connection with other habitats (Karim *et al*. 2011). However, the integrity of such a system in an urban setting system may be difficult to achieve. The highest riparian integrity was seen at Nga Manu top pond where there is an almost continuous swamp forest riparian area, but ecological corridors were limited there also by peripheral farmland and may be further limited by planned residential developments at North Waikanae and a future expressway. Angold *et al*. (2006) warned of the limits to altering established urban biodiversity too rapidly and suggested that while mammals and birds may use ecological corridors for dispersal, this was not the case in their study of urban habitats in Birmingham.

Riparian Vegetation

The use of residential gardens as ecological corridors is promoted in many towns and cities world wide including Dunedin. The measure of success for most studies has been the wide expansion of the bird population (Goddard *et al.* 2009). The major debate in the literature is what to grow in an urban or suburban garden that is sensible for a garden and will make a difference. Grose (2010) discussed the possible outcomes of placing exotic trees and bushes in urban and suburban areas, the value of lone trees as corridors for birds and the nutrient load that seasonal leaf fall can have on soil and wetlands. The restoration of a wetland riparian area to enable it to support bird and insect life successfully required informed input from the local community.

The special characteristics of riparian flora are their ability to withstand periods of wet soil as the adjacent wetland water levels fluctuate. There is debate about the quality of the vegetation appropriate to restore a site. Parkyn *et al.* (2000) in their report to the Auckland Regional Council recommended the use of indigenous vegetation as it had greater potential than exotic vegetation to establish a 'self-sustaining community'. They also noted that native vegetation for riparian management was associated with increased and diverse terrestrial biodiversity. Grose (2010) noted that the removal and successful replanting of trees depends on the selective soil micro-organisms that travel with the tree.

A survey of the riparian vegetation in the Murrumbigee River, ACT, by Johnston *et al.* (2009) strongly advocated the reduction in riparian exotic vegetation, the protection of remnant indigenous vegetation and the re-vegetation of riparian areas with indigenous species to maintain and promote riparian health. They noted that where there had been destruction of the riparian trees, weeds thrived with the lack of shade from them. Houlahan *et al.* (2006) have asked whether riparian vegetation composition should be native ecologically appropriate plants and what proportion of exotic flora is acceptable?

This research could never provide an answer to these questions. However, the measures of vegetation integrity for this study were based on the expectation that native plants were more appropriate to the region and its wetlands (Ch. 4). The parameters 'native vegetation abundance' in the riparian area and 'dominant vegetation ' acknowledged the presence of non-native vegetation. However, Kourtev *et al*. (2002) were able to show that exotic species altered the soil microbial community structure and function of soil such that they provided a threat to native biodiversity. Where there is sufficient leaf drop from exotic trees, such as pine, oak and silver birch, the ground may become matted, acidic and prevent the growrth of any understorey.

Mace *et al*. (2011) have questioned the relationship of biodiversity to ecosystem services noting the multifactorial nature of it. Goddard et al. (2009) noted that urban areas with garden and exotic vegetation provided a real threat to native diversity. The European settlement of the Kapiti Coast over 150 years ago is synonymous with the introduction of exotic plants, trees, flowers and forbs, ensuring that they now form part of the wider landscape. Have the ecosystem services declined with the changes in biodiversity? It is certain that over the last 150 years, both the biodiversity on the Kapiti Coast and the ecosystem services provided by the original landscape have been diluted or largely destroyed. The new order of restoration of some water bodies and some bush areas and the education of the population is a small effort to address an impossible goal.

However, Bullock *et al*. (2011) warn that although 'ecological restoration is becoming regarded as a major strategy for increasing the provision of ecosystem services as well as reversing biodiversity losses. ....restoration projects can be effective in enhancing both, but conflicts can arise, especially if single services are targeted in isolation. Furthermore, recovery of biodiversity and services can be slow and incomplete'. Mace *et al*. (2011) have also commented on the confusion related to the management of ecosystem and the treatment of biodiversity. They observed that in some cases biodiversity and ecosystem services are regarded as being co-dependent – manage one and the other will be retained. Other views have included that biodiversity is an ecosystem service.

Metric 4 Native Avifauna

It is apparent from this study that native avifauna population is very low in the Kapiti Coast urban wetland riparian areas (Table 6.5). The UWHI used the percentage of native birds at each wetland as a marker of their abundance (Metric 4, Ch 5). There are likely to be many underlying urban-based reasons for the lack of terrestrial native avifauna including the small sizes of riparian areas, limited food and shelter or insufficient vegetation corridors for the birds. By contrast, the non-urban swamp forest at Nga Manu Nature Reserve has a resident population of terrestrial native birds as well as predator control (cat traps).

Metric 5 Ecological, Cultural and Social Values

The ecological, cultural and social values were strongly correlated with hydrology, urban land use, riparian ecosystems intactness, the presence of native birds, and stormwater management (Figure 25). Although these values, present at Te Hapua, Nga Manu and Waimeha Lagoon, have been recognised by the wider community with covenants and statutory recognition (Table 6.6). However, there were poor correlations with vegetation integrity and native vegetation within the riparian areas. Factors including the lack of native vegetation in the urban wetlands and the inaccessibility of the flaxlands at Te Hapua Shoveler Lagoon may be some of the reasons for this lack of appreciation as to their ecological and cultural importance.

Aesthetics and recreational pursuits are more likely to satisfy urban dwellers than native bush and birds (Manuel 2003; Meurk & Swaffield 1998). However, residents value the 'wildlife' values of the wetlands with duck feeding and bird watching (Manuel 2003). Sims & Thompson-Fawcett (2002, p 252) noted 'at present the cultural landscape is under increasing pressure from development resulting in the destruction of the physical landscape but also defilement of associated values'. They concluded on p 267, 'while the physical landscapes and their guardians may change, the cultural associations remain'.

The KCDC District Plan Landscape Review (KCDC 2010c) did not define cultural values but did identify landscapes, character and heritage as important values to the Kapiti Coast population. It acknowledged that as a result of 'cumulative adverse effects (from developments) there is a loss of the district's landscape and character values' (KCDC 2010c, p 6). It also noted 'with the exception of historic buildings, the subdivision of land is not required in the (current) District Plan to take account of heritage places and their surroundings' (KCDC 2010c, p 8). These negative views of the district's cultural values are to be reviewed for the second-generation district plan.

The cultural values of the several iwi on the Kapiti Coast district have not been a feature of this research or of the district plans. According to MfE (2010a) the development of *A Cultural Health Index for Freshwater and Terrestrial Values* will incorporate the Maori values of mauri, mahinga kai and kaitiakitanga into freshwater management within the RMA 1991. Harmsworth (2002) developed the *Maori Environmental Monitoring Sheet: Maori Indicators- Wetland Monitoring Sheet* that assesses the taonga and mauri of a wetland to assist with the water-people interface of wetland management. The urban wetlands of this study were outside areas of iwi concern although the Kenakena Pa was near Lake Ngarara and the mouth of the Waikanae River. For expansion of the cultural assessment metric in the UWHI, Maori metrics can be added as necessary (see Harmsworth 2002).

Metric 6 Urban Planning Processes

The conclusion from the results in chapter six is that urban planning, past and present, has not served the studied urban wetlands well. Sensitivity to ecological processes is not a feature of the older residential developments on the Kapiti Coast that have large impervious areas and inadequate stormwater drainage. The Connected Impervious Areas (CIA%) assessments indicate that newer residential and industrial areas have better stormwater drainage. However, road run-off drainage is poorly collected and often flows directly into wetlands. If urban planning for new subdivisions or resource consents is given for urban wetlands, their ecological health should be included in the plans and conditions of consent. This includes attention to the riparian areas, which this study found to be in poor condition with various mixes of inadequate vegetation, steep slopes and inadequate widths.

As discussed in chapter two, the Local Government Amendment Act 2013 requires territorial authorities to 'maintain and enhance the quality of the environment'. The mechanism for this is the resource consent process where environmental concerns must be considered within the conditions of the consent and then monitored. This includes changes to land use, removal of vegetation and biodiversity, any increase in imperviousness and the infrastructure needs of urban developments, all of which impact on the environment. The destruction of wetlands for residential purposes has been an obvious casualty of a less than careful urban development programme over time.

The documentation available from KCDC regarding the planning and resource consent procedures that applied to the wetlands studied in this research was incomplete. There were some records from sites that were developed before the enactment of RMA 1991 and subject only to the developers, owners and builders ideas. The previous building regulations, such as that applied to Nga Manu Nature Reserve Information Centre, were the basis for planning consent from the Horowhenua County Council although there were no comments on land use. Some sites had no recorded information regarding land use such as the Jensen property (Te Hapua Shoveler Lagoon) but building regulations in 1994 required concrete floors for residences near Tower Lake No 1. A summary of the information available regarding resource consents is provided in Table 5.2.

There was also difficulty in locating information about the monitoring criteria and practices that were put in place in the consent procedures that were granted. There has been oversight of various indicators, such as water quality, occurring at some sites by KCDC and GWRC officers and/or ecologists from private developers (Metric 6, Ch 6). The KCDC Plan Review 2010 states an intention to 'analyze the effects of resource consents, permitted activities and plan changes, and the effectiveness of the conditions imposed on resource consents intended to protect or enhance biodiversity'. Should this be included in the final plan it could improve the health of the urban wetlands. The requirements of the RMA 1991, Local Government Amendment Act 2013 and NZ Standards for the LIUDD principles for 'new build' are endorsed in the KCDC District Plan: Plans and Policies, 1999 (KCDC 2010).

Residential and Infrastructure Impacts

Ehrenfeld (2000, p 253) commented, 'wetlands in urban regions may take on human related values*'.* This is evident on the Kapiti Coast where the price of a view and access to the water's edge is the loss of the riparian vegetation and its functions. The consequences are that the inflow of stormwater and other pollutants increases, the inflow of stream water decreases due to piping or deviation, and there is enrichment of the water where high nutrient species dominate (Allen, 2010). Infrastructures development, including walkways, cycleways, roadways and footpaths disrupt riparian vegetation leaving bare areas that are susceptible to erosion into the wetland. Also disrupted are the habitat of the riparian fauna, avifauna and insects.

The UWHI results indicate that the studied urban wetlands suffer from some of these impacts including car parks at Lake Ngarara and Ferndale, viewing points at Midlands Gardens and Lake Kotuku. (Table 6.7). Residential developments to the water's edge were confined to Tower Lake and parts of Lake Ngarara. The effects of urban development on the hydrology of the wetlands and riparian areas is seen in compromised ecosystems such as at Tower Lake. Spearman Rank-order correlations showed a significant relationship between residential developments and vegetation integrity, the latter describing the human impacts on riparian vegetation. Tower Lake, Lake Ngarara and Midlands Gardens were the worst affected. The Cluster Dendrogram, Cluster 3, indicates a very close relationship between residential development and ecosystem effects, and Cluster one shows a similar relationship between vegetation integrity and urban land use.

Metric 7 Stormwater Impacts and Imperviousness

Urban wetlands are prone to increased accumulation of pollutants and sediments as discussed in chapter three. Not only is the wetland water quality compromised but also the wetland riparian areas are affected by excess concentrations of pollutants. The ability of urban stormwater controls to ensure that no pollutants enter the wetlands depends in turn on the infrastructure that is in place to carry the water to a collection site for decontamination. In its District Plan Review 2010, KCDC announced an intention to adopt NZS4404:2010 for engineering requirements to manage stormwater, although the intention is that most stormwater will be managed 'before pipes' under the Low Impact Urban Design and Development umbrella.

As discussed in chapter four, Goonetilleke *et al.* (2005) concluded from their Queensland study that high-density housing would offer the best outcome for stormwater pollution for the smallest footprint. Such planning solutions do not fit with the operative district plan for the Kapiti Coast, which, although permitting a certain amount of residential in-fill, has height restrictions; is in favour of low-medium density housing; and plans for greenfield developments in the near future at North Waikanae (KCDC 2010b). However, there are recommendations for reducing the imperviousness of the residences with guidelines for in-fill (KCDC 2010b).

Because the Kapiti Coast residential areas grew somewhat haphazardly until the last six decades, it was common to have bungalow low-density housing with high imperviousness. The land is largely compacted sand allowing surface runoff to be mediated to a small extent only by filtration to groundwater through the sand. Therefore, the urban wetland areas, including the constructed stormwater collection ponds, receive road and property run-off and show evidence of increased nutrient in their algal and aquatic vegetation growth, high conductivity and low water clarity. It is the intention of KCDC as discussed in the District Plan Review Infrastructure and Biodiversity Documents 2010, to integrate stormwater drainage with other values (i.e. environmental, ecological, cultural, landscape and recreational) in accordance with NZS4404: 2010 (KCDC 2011).

The operative KCDC District Plan has already addressed some of these issues with the endorsement of the LIUDD principles in its amended policies and building consents procedures. These principles include low impact housing, sustainable stormwater management, water saving and energy efficiency. New subdivisions are required to be compatible with natural ecologically intact water systems as agreed in Kapiti Coast District Plan Change 75, 2010. An example of compliance with the KCDC pamphlet, *Best Practice Building Code for Developers*, is the recent subdivision at Ferndale, which has 62 residences over an $800m^2$ area and complies with the other requirements of low imperviousness and water saving.

7.5 UWHI Assessments of Urban Wetland Health

Ecological systems are modified or destroyed during urban development. The protection of the urban wetland ecosystems is essential for the resilience of the urban environment. The UWHI provides a tool for assessing the health of a wetland. The key findings of the case study research undertaken here were:

- There was a need for a multi-metric index for assessment of urban wetland health.
- There were significant correlations for all parameters measured apart from the 'commercial use of the riparian area' and 'QWMCI'. These two parameters were discarded from the UWHI.
- Catchment-wetland-riparian hydrology was compromised in the urban wetlands (55%).
- Water quality measures i.e. water clarity and high nutrient species together with the independent parameters pH, conductivity and water temperature, indicated that the urban wetlands had a moderate (35%) decline in water quality.
- The aquatic macroinvertebrate assemblages were dominated by the mollusc, *Potamopyrgus* sp., tanypods and *Daphnia sp.*
- The percentage of native birds seen in each wetland was small but related closely to the size of the riparian area.
- Residential development, infrastructure development, imperviousness and stormwater runoff affected the structure and function of the wetland and its riparian area leading to high - nutrient species in all wetlands.

7.6 Kapiti District Plan Review 2010 and the RMA

The operative Kapiti Coast District Plan for the Kapiti Coast that was completed in 1999 underwent many amendments until 2009. A review of the district plan was commenced in 2010 with the expectation that it would be completed by October 2012 and then, following consultation on the draft plan, published in March 2013 (Ch. 2). Review discussion documents regarding all the KCDC functions and responsibilities were available during 2010 and 2011. Of particular interest to this study are the 'Urban Form and Transport', 'Infrastructure and Essential Systems', 'Landscape, Character and Heritage' and 'Biodiversity' documents (KCDC 2010a).

Analysis of the District Plan Review documents has attempted to future-proof the new District Plan through outlining new ideas and possible improvements to encourage community discussion. The protection of the landscape and its biodiversity were prominent themes. There were also subtle changes from the operative district plan in emphasis. For example, the operative district plan states, in Section C1.2, that 'Ecosystems and ecological processes are not [to be] adversely affected by surrounding activities'. The 'Urban Form and Transport ' discussion document page 9 states in that 'Undeveloped land may have a variety of flora and fauna, landforms and waterways as part a functioning ecosystem that could be disturbed by urban development' (KCDC 2010c, p 9).

The Review discussion documents also drew attention to Section 17 of the RMA where councils are required to avoid, remedy or mitigate adverse effects on the environment. The Biodiversity discussion document sees mitigation or offsetting as a current problem for Kapiti District to be corrected (KCDC 2010c, p 12). Section C1.2 of the current operational District Plan requires that 'ecosystems and ecological processes are not to be adversely affected by surrounding activities' [due to residential development]. The implication is that this has not been observed adequately, a view that this study endorses. The UWHI clearly showed that there is pollution of urban wetlands, limited function of riparian areas with a lack of native vegetation and very poor water quality within the wetland ponds.

The RMA principles, as interpreted by the current operational District Plan or the Review discussion documents, do not apparently extend to the urban wetlands and their riparian areas. The requirements for protection and monitoring of biodiversity and landscape have nonspecific indicators for environmental reporting such as 'regular surveying of all ecological sites, and an assessment of whether rules and incentives for their protection and management are having the desired effect' (KCDC 2010, p 12). When the new draft District Plan is completed, the EREs will need to be more specific to ensure change. There may also be changes in emphases with the new Local Government Act introduced into Parliament on May 2012.

7.7 Conclusion

This study shows that the implementing of the KCDC 1999 District Plan policies and plans or any subsequent amendments, did not extend to the established urban wetlands and their riparian areas. The data analysis of the parameters for the UWHI indicated that the Metrics were appropriate for assessing wetland health and that the QWMCI and WMCI were not appropriate measures for the North Island wetlands' water quality (Suren *et al.* 2010).

The loss of riparian areas or the lack of suitable vegetation on them appears to be major factors in the nutrient load that the urban wetlands carry. This consequence of the lack of riparian control of sediment and pollutants from surrounding urban areas determines their physicochemical quality and therefore their use as a habitat for macroinvertebrates and other fauna. It is uncertain how this can be easily remedied and how restoration of the urban wetlands and their riparian areas can occur without some leadership from the District Council.

The present position of KCDC is that small ecosystems suffer large edge effects and are not a priority for investment (KCDC 2010c). If urban wetlands are not sufficiently important ecosystems to be given 'ecological importance' status, then they are also unimportant economically and no investment is made in their ecological wellbeing. Although this view would seem to be in conflict with the requirements for care of natural resources in the RMA 1991 and RMA Amendments 2009, it common to many jurisdictions. Blackwell & Pilgrim (2011) drew attention to the benefits of small wetlands which are often regarded as too difficult to manage ignoring their potential role in the delivery of ecosystem services (water quality, water regulation and biodiversity). The UWHI can be used as a tool for benchmarking the state of urban wetlands and monitoring them. The above UWHI results provide an indication of this potential for the Kapiti Coast urban wetlands. The urban catchment hydrology will be improved when the KCDC planned stormwater management improvements have occurred. Both good quality groundwater and a reduction in surface water runoff could be the best outcomes. The UWHI metrics are able to serve as a useful guide to other developments that will ensure functionally healthy wetlands.

Adequate and appropriate vegetation composition for the urban wetlands could be one neighbourhood project that, supported by the District Council, would have an early influence on wetland health. This initiative, together with improved vegetation corridors in residential gardens and streets, would be a medium term community project similar to that seen along some stream corridors in New Zealand. The next chapter will present the conclusions derived from this research and my recommendations for future management of the urban wetland riparian areas.

Chapter 8 Conclusions and Recommendations

8.1 Introduction

As set out in chapter one, the aim of this research was to determine what impact urban development had on the ecological function of wetlands in New Zealand. Section 30 of the RMA 1991 requires that environmental agencies provide integrated management of natural and physical resources, and Section 14(h) of the Local Government Amendment Act 2013 promotes the maintenance and enhancement of environmental quality. These requirements were tested using a case study to investigate whether, on the Kapiti Coast, there was satisfactory urban wetland riparian function at all urban wetlands, that the urban wetland water quality reflected the riparian function and that this was monitored effectively.

The key outcome of the research was the development of a multi-metric assessment tool, the Urban Wetland Health Index, for evaluating the sustainability of the urban wetland and riparian ecology. This showed that although the Kapiti Coast District Plan 1999 complied with the requirements of the RMA, LGA, the Statement of National Priorities in the New Zealand Biodiversity Strategy and the Proposed National Policy Statement on Indigenous Biodiversity 2012 according to their documents, the urban wetlands studied were in poor ecological condition. This suggests that the problem for urban wetlands health is with the implementation of the legislation and plans by the Kapiti Coast District Council.

This concluding chapter highlights the key findings and recommendations derived from this study of the eight wetlands on the Kapiti Coast. In particular, it recommends to the local authorities the need to understand ecosystem services including the role of riparian area and the need to value urban wetland ecosystem services; the need to provide protection and undertake restoration/enhancement of urban wetlands through plan provisions, consent procedures and the use non-regulatory tools; and to use the Urban Wetland Health Index as a measure for the monitoring of, and accountability for, the urban wetland health of Kapiti wetlands.

8.2 The rhetoric and the reality

The contribution of local government to urban wetland sustainability should be measureable and of good quality. Regional and district plans incorporate the principles of the RMA and provide the mechanisms for their implementation within the plans. However, this study has shown that urban wetlands on the Kapiti Coast are not well cared for (Ch. 6 & 7). The deficits ranged from lack of effective riparian areas to abnormal biochemical markers from stormwater pollutants and urban development.

The search through the KCDC records for the resource consents conditions issued for the establishment of the wetland ponds in subdivisions, together with the details of the monitoring and evaluation of their quality was fruitless for most of the study wetlands as outlined in chapter five (Table 5.2). Each region and district has the facilities to keep the detailed files of these resource consents. The files should be explicit and the information available to the public.

Without this evidence of responsibility and accountability for the on-going health of the urban wetlands, the deterioration seen on the Kapiti Coast with poor water quality and eutrophication will continue.

8.3 Key Recommendations of this Research

The key recommendations of this research are

- There is a need to develop riparian areas, with suitable qualities and processes, including appropriate vegetation .
- A change of approach to wetland management from the selective ‘significant’ areas to a broader ‘green framework’ is needed.
- Improved stormwater management is needed and should include the development of more effective riparian areas.
- Imperviousness across the whole urban area requires active management and limits set in within the resource consents.
- A greater level of monitoring of the wetlands by the local authority is needed to maintain and/or improve urban wetland health.
- Restoration of the failing urban wetlands is needed and an action plan involving the community implemented as soon as feasible.
- The Urban Wetland Health Index is a tool that can provide support for these changes and should be used by the local authorities when assessing urban wetlands.
- The addition of the Environment Results Expected (ERE) to resource consents will assist the health of future urban wetlands. The ERE should be seen as a regulatory control for wetland and riparian area damage (MacKay 2013, pers. com.).

8.3.1 Urban Wetland Health and Regulatory Controls

The KCDC District Plan Review Biodiversity Document 2010 suggests that urban wetland riparian areas are not valuable habitats for biodiversity as they suffer edge effects (KCDC 2010a, p 7). However, there is also a suggestion that for new subdivisions, ‘site setback provisions for development’’ in the District Plan could be amended so that in the development of an area zoned ‘Natural Area’, there could be larger than the standard setbacks for ‘all zones’ (KCDC 2010a, p 15). It is difficult to know just what this entails for resource consents or what developers would be prepared to agree to. Recent literature on the role of the urban garden as a habitat and as well as a part of ecological corridor suggests that a simple design approach would be to ensure that such gardens are required in urban planning (Ignatieva *et al.* 2011; Goddard *et al.* 2009).

There is a significant body of research about palustrine wetlands and their vegetation but, until recently little attention has been given by researchers to the special nature of the urban wetland riparian area (McElfish *et al.* 2008). Kapiti Coast District Council’s planning and policies for urban development also fails to address the need for healthy urban wetlands and their riparian areas. Their ecological status may not be deemed ‘Significant’ by the local authorities (Boffa

Miskell 2011) but they form a very important role within the resilience of the urban environment as detailed in chapter four and endorsed by the Ramsar Convention 2012, Draft Resolution X1.11: *Principles for the planning and management of urban and peri-urban wetlands.* Principle 10 of the draft resolution recognises the importance of the wetland ecosystem services and further recognises that 'access to urban green space can make a positive contribution to people's physical and mental well- being'. Objective 13 states 'the wise use of wetlands should be considered as a key parameter within sustainable human settlements'.

As discussed in chapter seven, the operative Kapiti Coast District Council District Plan, Objectives C1-11.1, Policy 5 provides assurances that the effects of urban subdivisions on 'significant' wetlands will be monitored and Policy 8 encourages restoration of 'water bodies' but both ignore the urban wetland's needs for comprehensive evaluation as an integral part of sustainable urban development. The monitoring and accountability provided by the second-generation district plans' Environment Result Expected (ERE) protocols for subdivision resource consents will be critical for the future health of urban wetlands.

It is of concern that although the health of the new urban wetland riparian areas may be addressed by the new EREs there appears to be no indication that the present situation will be amended. This is a very narrow view of the RMA 1991, the Statement of National Priorities in the New Zealand Biodiversity Strategy 2007 and the Proposed National Policy Statement of Indigenous Biodiversity 2012. The NZBS priorities appear to be being applied by KCDC only to 'ecologically significant' areas. The KCDC Biodiversity discussion documents for the KCDC District Plan Review 2010 give little hope that there will be any changes with the comment that 'creating thin strips of vegetation along roadsides, or a pond bordered by native plants in a residential subdivision does not create a valuable habitat and may result in the destruction of the native wildlife it attracts ' (KCDC 2010c, p 12). No evidence for this statement is offered in the document.

The correlation of the UWHI with stormwater drainage impacts indicated that for the urban wetlands the probability of stormwater having a significant effect on the wetland health was high. In an urban setting this is mainly the effect of contaminants from surrounding streets and gardens, usually with increased phosphates and nitrates but also non-biodegradable oils, metals, and other debris (Moores *et al.* 2010). Section 15 of the RMA restricts the discharge of contaminants into water. This together with the Local Government Amendment Act 2013 requirements for territorial authorities to provide adequate functioning stormwater drainage must be reflected in the implementation of district plans. Although these requirements are noted in the KCDC District Plan Review, there is one strategy for managing the pollutants that is missing. The Kapiti Coast urban wetlands require a functioning riparian area for each of them. As discussed in chapter seven, these zones provide conditions for filtration and sediment collection. A closely mown grassy bank is inadequate for the task.

The UWHI results from this study lead to the strong recommendation to KCDC urban planners to endorse the recommendations for the district's urban wetlands, both those established and those proposed in new subdivisions. Urban planners need to provide a framework for established residential areas with urban wetlands, as well as new subdivisions, to have appropriate management of these urban wetlands. Restoration of riparian areas and wetland health is entirely suitable for community input with expert advice and leadership from the District Council for the need to use an holistic measure like the UWHI.

8.3.2 Wetland Health and Riparian Function

In this study, the UWHI identified significant correlations for riparian habitat with wetland hydrology as well as with catchment hydrology illustrating the important relationship between riparian function and wetland health. However, it was not possible to tell which indicator was dominant i.e. was polluted groundwater responsible for the wetland health decline or the failure of an inadequately functioning riparian area to filter stormwater or both? In an urban environment both will contribute with many factors such as soil porosity, imperviousness, stormwater runoff and failure of the riparian area to adequately filter pollutants among the most likely.

Physicochemical assessments of the case study urban wetlands' water indicate that the urban wetlands in this study are mildly alkaline and have high nutrient levels. These results are associated with a poor riparian condition assessment of less than 50% of the non-urban wetlands. (Waimeha Lagoon, with its functioning riparian area, is an outlier with an assessment of 80%) (Table 6.3). This inadequate riparian function, including habitat, is associated with urban development where competing interests between people and environment have resulted in compromises between access, aesthetic pleasure and ecosystem requirements (Ch. 4).

The conclusion derived from these results is that wetland health, while clearly a complex issue, could be improved by more active management of stormwater and pollution associated with upgrading the wetland riparian areas with eco-sourced native vegetation. The system of isolated patches of wetland riparian vegetation among impervious lawns means that riparian functions are inadequate for the management of surface water runoff. The percent Impervious Surface Cover (%ISC) and percent Connected Impervious Areas (%CIA) values on the Kapiti Coast (Tables 5.3 & 5.5) confirm that a reduction in the total imperviousness of the district would decrease the volume of stormwater runoff. Such a reduction is highly recommended for inclusion in the second-generation district plan.

8.3.3 Wetland Riparian Functions and the UWHI

The UWHI identified the correlations associated with riparian function, namely catchment, wetland and riparian hydrology, riparian habitat and ecosystem intactness, and abundance of native vegetation, as significant indicators of the structure and functions of the Kapiti Coast urban wetlands riparian areas. Correlations with the other ecological indicators including the terrestrial native avifauna, biogeochemistry and QWMCI (Suren *et al.* 2010), did not reach statistical significance but did provide insight into the wetlands' riparian functions. The UWHI also identified urban development within the riparian areas and stormwater management as having significant impacts on wetland riparian functions.

Urban palustrine wetlands have requirements that differ from stream wetland riparian areas. The processes operating in urban wetlands have different spatial and temporal requirements of its vegetation, and management of denitrification and flood events. Wetland riparian function is maximised by width, slope, vegetation and porous soils allowing slow flow across a riparian area before the water reaches the wetland. In this study, the riparian area widths (<20m) were inadequate to reduce inflow of pollutants; the slopes (>15º) were too steep to temper water flow rates; and the lack of appropriate vegetation did not provide time for denitrification (Groffman 2012).

The riparian habitats were also found to be of poor quality. Introduced aquatic avifauna is best adapted to urban environments including breeding within them. The lack of terrestrial native birds within the habitats can be ascribed to lack of suitable riparian vegetation and food trees, patch isolation with lack of corridor trees in private dwellings, and human impacts such as possums, cats, noise and movement.

The UWHI confirmed that urban developments within or affecting the riparian areas up to 20m have considerable adverse effects on riparian function. Apart from the two collection ponds, stormwater had free entry to the wetlands from drains and surface flow from road and residential properties. Evidence of high nutrient wetland vegetation was found in all the urban wetlands and eutrophication was present in two. The structure of the riparian areas was disrupted by cycleways and walkways at most urban sites and by residential construction at Lake Ngarara and Tower Lake No 1.

Although the UWHI score for Kapiti Coast urban wetland health was only 52% of attainable health (Figure 26), there is potential for an improved performance in the future. The wetland functions that poorly performed were identified by the Index thus allowing improvements to be focused on them. The UWHI should be part of the Kapiti Coast District annual 'score card' for environmental performance. This would mean that they would be monitored by Environmental Results Expected in the second-generation district plan.

8.3.4 Urbanisation Impacts

The vulnerability of urban wetlands to urban development was exposed in this study. The overall conclusion from the UWHI is that while the health of the urban wetland riparian areas is multi-factorial, the overriding common factor was the compromised hydrology of the wetlands. All the urban wetlands had urban catchments where the groundwater was from the rivers and streams that flowed across the floodplains and had been polluted by stormwater and drainage from the 46,000 people living in the area.

The natural filters for sediment and pollutants removal have been lost over time by landform changes, vegetation destruction and urban development. It is no surprise that wetland water quality is poor. Parkyn (2004) suggests that indigenous vegetation gives the best outcome for riparian function as it is highly adaptable to wetland conditions. The results of the assessment of indigenous vegetation cover in the riparian areas in this study showed that there were less than 20% native plants in the same urban wetlands as poor riparian habitat and poor ecosystem intactness. These were significant correlations.

8.4 Sustainable New Zealand Ecosystems and Urban Development

This study was a snapshot of the plight of urban wetland systems in New Zealand. Even after two decades of implementing the RMA 1991 and then the Local Government Amendment Act 2013 with their focus on sustainable management and sustainable development, there are many areas within the urban environment that are ecologically stressed including the urban wetland. The many mechanisms for protection of the environment identified in chapter three have been challenged by every restriction that could be imposed on them.

Land for urban development in New Zealand is a limited commodity with the country's mountainous terrain and dependence on agriculture. Wetlands have been expendable in the desire to establish flat areas for towns and cities. Small urban wetlands have been established in many towns and cities as amenity areas but they have not been well tended. Blackwell & Pilgrim (2011) suggest that ''small-scale wetlands have been largely overlooked because they are considered problematic to manage' and they 'fall outside the remit for wetland inventories'. The UWHI shows that on the Kapiti Coast they are indeed failing ecosystems.

At the present time district plan reviews are being undertaken throughout the New Zealand. The new plans will provide guidance in urban development focusing on the Low Impact Urban Design and Development model of low-rise housing and wastewater management. On the Kapiti Coast there are imperatives for reducing imperviousness and stormwater runoff and reducing the spread of subdivisions into rural areas. Community consultations will have influenced the direction that the forthcoming KCDC District Plan will take.

However, the plan may not address urban wetland ecological sustainability. One measure that will be incorporated within the plan is the ERE where likely environmental outcomes to a proposed development will be explicit and linked to monitoring of a project. The UWHI should be part of this assessment. Second-generation district plans have a format designed to make their intentions clear to users and the public and ensure that the intent of the RMA and its subsequent amendments are implemented. These will include clarity surrounding the resource consent conditions that are granted to developers when ecological sustainability is at risk.

8.5 Future directions

This research has left some unanswered ecological questions including:

(a) should a minimum riparian width be established for urban wetland riparian areas in new subdivisions, taking in to account the nature of the soils and appropriate vegetation e.g. 20m or more, the realities of the economics of property development and the purpose of the wetland pond? Access to the water edge is dependent on the purpose of the wetland pond area. Waimeha Lagoon has no convenient access to water but has a bird hide at the north end and a boardwalk through the riparian swamp at the south end. It has an intact functioning riparian area. However, Midlands Gardens pond and Tower Lake No 1 have minimal functioning riparian areas and considerable accessibility via grassed banks. The stormwater wetlands, Lake Kotuku and Ferndale, have newly planted riparian areas and limited accessibility via bridges.

(b) is native riparian vegetation essential because it has a different role from exotic vegetation or is it just desirable? The leaf fall from exotic deciduous trees near streams is seasonal and affects the function and structure of the stream. If exotic trees abut a wetland, does this alter the wetland function? Is there a preferred vegetation composition for intact urban wetland riparian function and habitat? Are weeds a satisfactory option for the riparian area? Parkyn *et al.* (2000) concluded that indigenous vegetation had a greater potential than exotic vegetation to establish a self sustaining community. In their report to the Auckland Regional Council Environmental Research, they recommended native vegetation for riparian management to sustain long term native terrestrial biodiversity.

The development of the UWHI has provided a template for assessment of the important functions that comprise urban wetland health. It also provides a baseline and measurable target goals way for realising the potential for improvement in the urban wetland health through its scoring system. It could be used by planners when developing EREs for the second-generation district plan where there is a need for science to inform planning and policy if the RMA definition of sustainable development is to be implemented.

Urban development continues in New Zealand and throughout the world with more than half the world’s population now urban (as at 2010). The global population is expected to reach nine billion by the end of this century with over five million in New Zealand. Urban areas have spread across New Zealand’s most productive land. Sustainable development is now arguably more critical than ever before. Attention to the small things such as standards for urban development and sustainable wetland functions will be a measure of their intentions.

8.6 Limitations to this research

The Urban Water Quality Index combines a series of factors to provide a useful starting point for monitoring urban water bodies. In its current form the index generates a measure of the difference between a given site and the ideal of an intact native ecosystem. The metrics used in this work to measure ‘ecosystem health’ score highly for those sites that approach an intact ecosystem and therefore the index could be used to assess the level of modification of an urban site. The current form of the index attributes lower scores to constructed wetlands. Any broader application of the index is likely to need some further development, refinement and testing of the methodology.

8.7 Sustainable Urban Wetland Health – Whose Responsibility is it?

Central and local government oversight for the ecological health of urban wetlands is documented in Tables 8.1 & 8.2 together with a summary of the current situation and the deficiencies in the management of urban wetlands on the Kapiti Coast identified by this research. Tables 8.1 & 8.2 also recommend strategies for improved ecological management to be included in the second-generation regional and district plans. Each entry has a reference to the chapter and section of the thesis that discusses the topic.

Table 8.1. Central and local government (KCDC) oversight in the health of urban wetlands, problems identified in this research and recommendations for future ecological management.

Regulatory institutions	Current situation re urban wetlands	Problems identified	Recommendations from this study
Parliamentary Commissioner for the Environment (PCE) provides independent reports to Parliament on environmental investigations (Section 2.8.3, Ch. 2)	2002: report on Tasman wetlands as significant ecosystems to be preserved in face of subdivision. 2012: Report on water quality in NZ does not include urban wetlands specifically.	Can only advise and make recommendations that need to be implemented by local and central government	Further independent review of implementation of Land and Water Forum - limits–setting process and outcomes with reference to wetlands
Department of Conservation (DOC) manages public conservation land, has responsibilities under the Reserves Act and Wildlife Act and for Ramsar wetland reporting (Section 2.8.2, Ch 2)	In the case study district has oversight of sites including Whareroa Farm Park, Te Hapua flaxlands, Tararua Forest Park, Waimeha Lagoon. Has no role in urban areas but DOC policies are reflected in the RPS and district plans where appropriate.	Underfunded leading to omissions and limited activities in conservation.	Continue close relationship with regional and district councils for issues of common concern. DOC needs to actively participate in statutory process and advocate conservation values.
Ministry for the Environment (MfE) advises Government, monitors RMA activity and produced a five yearly *State of the Environment* (SOE) report until 2007 when it was discontinued. (Section 2.8.1, Ch 2).	Many reports acknowledge the place of wetlands in sustainable management of natural resources, but not role of urban wetlands as part of urban resilience.	Any input into urban wetlands is via support for the volunteers that are restoring ecosystems. MfE may, on application, fund and supply plants and equipment for planting where volunteers are active in restoring wetlands and streams.	Continue ecosystem restoration support and include urban wetlands as well as streams. Reinstate SOE reporting as a matter of urgency.
Environmental Protection Authority (EPA) manages MED & ERMA. Processes national level consents and proposals under RMA. Monitors NES and NPS (Section 2.8.1, Ch 2)	Does not have a role for urban wetlands unless they are part of a nationally important change of land use. The NES and Freshwater NPS are incorporated in the RPS and District plans.	Monitoring of the NES and NPS yet to be defined for their impact on local government plans. Possible role in urban subdivision resource consents in some areas.	EPA should maintain a close relationship with the MfE especially with regard to wetland development or loss in urban subdivisions.

Statutory tools	Current situation	Problems identified	Recommendations
Resource Management Act 1991 (RMA) purpose statement: to promote sustainable management of natural and physical resources… Includes all land, water, soils, minerals and energy, all forms of plants and animals… (Section 2.7,Ch 2)	Sustainable management concept is ambiguous and needs to be replaced by an un-ambiguous concept such as sustainable level. Confusion between 'sustainable development' and 'sustainable management'. Compliance with RMA requirements is within district and regional plans.	Variable interpretations of the sustainability especially with changes of land use and infrastructure. Although some activities have NES, resource consents vary with the territorial authority' interpretation. Mitigation strategies are usually unsatisfactory for wetlands.	Need an independent body to monitor outcomes of district and regional plans (e.g. Conservation Boards monitor Conservation Management Strategy. Mitigations involving wetlands should be rare events. Where alternative wetlands are devised adequate monitoring MUST be long term and appropriate. Loss of landscape for subdivision should not be permitted.
Local Government Act (LGA) 2002, Section 14(h) requires that local government to maintain and enhance the quality of the environment. LGA requires local government to produce an LTP that after consultation with population that should reflect cultural and environmental wellbeing (Section 2.10, Ch 2)	Consultation for LTP to develop objectives for district plan. Ramsar Convention not acknowledged. Inadequate focus on environmental sustainability.	Consultation process has not commented on urban wetlands as they were not in documents for discussion.	Ramsar Conference 2012 focused on urban wetlands as important items in the well being of a community. Local government should reconsider their stance on their management.
National Policy Statements (NPS) and **National Environmental Statements (NES)**. (RMA Section 5) are legally binding statements defining the national approach to major resource management issues presented as objectives for development and implementation in the regional and district plans.	Failure to adopt/publish proposed NPS for indigenous Biodiversity (NPSIB) 2012	.	NES and NPS incorporated into all local government future plans. Proposed NPS for Indigenous Biodiversity needs to be adopted as a matter of urgency.
National Biodiversity Strategy 2007 and **Proposed National Policy Statement on Indigenous Biodiversity NPS 2012 (NPSIB)** provide a framework for active conserving and managing NZ biodiversity to be implemented by regional and district councils (Section 2.9, Ch 2)	Applied by KCDC only to significant ecological areas in district plan BUT NPSIB Policy 6 endorses maintenance of biodiversity outside identified areas of significance. KCDC urban development is associated with removal of vegetation and sand dunes.	Gaps in biodiversity requirements. Minimal involvement with urban wetlands habitat or ecosystems by NZ district councils. Proposed NPSIB should be adopted	NPSIB Policy 6 should apply to new and old subdivisions. Landscape and landform preservation required in future. KCDC district plan review should endorse NPSIB Policy 6 to include urban wetland health.

Statutory tools	Current situation	Problems identified	Recommendations
NPS Freshwater Management 2011 (NPSFM) is a framework for RPS and its implementation in regional and district plans. RPS Obj. C1, Policy C1 promotes Integrated management of catchment to sea with particular attention to land use issues. NPSFM requires healthy ecosystem functioning to support diversity of indigenous species sustainably (Section 2.9, Ch 2)	Urban wetlands not considered by GWRC. KCDC 'Bores Strategy' for Kapiti Coast. GWRC and KCDC proposal for Maungakotukutuku Stream dam consented for future water needs of Kapiti Coast.	Poorly functioning urban wetland & riparian ecosystems. KCDC appears disinterested. Eutrophication and stormwater runoff is a common problem for urban wetland health. KCDC urban wetland biodiversity is of poor quality (QWMCI <5), few avifauna taxa and poor riparian vegetation composition. Hydrology of urban wetlands may be affected by KCDC 'Bores Strategy'.	Urban Wetland Health Index (UWHI) assessments applied to urban wetland ecosystems give guidance to approach for restoration and management. UWHI also focuses on total catchment hydrology and thence urban wetland and riparian health.
<u>Local Government:</u> **Regional Councils:** Greater Wellington Regional Council (GWRC) Second-generation Plan and EREs will have less emphasis on rules and more on methods for management of policies. Plans should be hierarchical – must do- should do- might do- low priority. (Section 2.9.1, Ch 2)	Regional Environment Results Expected (EREs) being developed for guidance of second-generation regional and district plans.	GWRC Regional Plan to be implemented in 2013. Significant wetlands are included in the Plan but urban developments and therefore urban wetlands are not a regional council's prime responsibilities.	Urban wetlands should be included in the RPS to ensure that the health of the urban wetland is attended to by the local authorities as part of the requirement to ensure community wellbeing.
Regional Policy Statements (RPS) reflect the NPS. (Section 2.9.1, Ch 2)	GWRC RPS response to wetlands & ecosystems (Obj. 13), & urban design (Obj. 27, Policy 38)	Urban wetlands not identified or included in RPS as their management is with the district council.	2013 RPS Review of regional transport, water, parks & reserves, possums control, infrastructure. Urban wetlands may be part of a Reserve within a subdivision and therefore be included in the Plan.
District Council: Second-generation Kapiti Coast District Plan and EREs. 2010 Review documents for consultation included Biodiversity; Landscape, Character & Heritage; Urban Form & Transport; Infrastructure & Essential Services. (Section 2.10, Ch 2)	District plan review endorses LIUDD EREs associated with resource consents being developed. . provision for protection of landscapes and vegetation.	Urban wetlands not identified in review documents. They were not identified in the 2010 District Plan apart from being discussed in resource consent hearings for sub-divisions (land use change). No monitoring plans proposed.	Urban wetlands should be included in ecological, biodiversity and cultural management and monitoring. Also protected from external influences such as stormwater. This would be part of EREs.

Table 8.2. Environmental planning and management priorities for urban wetlands incorporated in statutory plans.

Good Practice[32]	Current KCDC situation	Problem identified	Recommendations
<u>Biophysical:</u> **Urban wetlands Water quality** (Section 6.2, Ch 6)	No listed requirements in KCDC Plan 2010 beyond conditions of resource consent where they existed (many unknown). GWRC and KCDC monitor water at Waimeha Lagoon. (Also at rural Te Hapua).	Water quality: poor QWMCI at all sites, high nutrient plants, pH>7.4, low clarity and high conductivity. Algal blooms.	Use Urban Wetland Health Index (UWHI) assessments routinely to monitor functioning of urban wetlands Development and restoration of riparian areas.
Urban wetlands: urban riparian ecosystems. Acknowledgement of role of riparian area (Section 6.2, M 7, Ch 6)	Urban riparian ecosystems not identified in 2010 KCDC plan review despite being in proposed NPSIB Policy 6 .	Riparian vegetation ecosystems of urban wetlands are of poor quality and not functional for water quality – slope, width, minimal vegetation, mown lawns. 2010 KCDC plan review indicates that the urban wetlands are not important and have no potential as habitats	UWHI assessments to guide restoration of riparian areas.
<u>Ecological:</u> **Urban wetland functions: a. Riparian hydrology.** Adequate hydrology – rainfall and groundwater, disturbance regimes, clean surface runoff. (Section 6.2, M 3. Ch 6)	Rainfall 1030mm pa. Groundwater fluctuates with rain but disturbance regimes stopped with urbanisation. Water quality poor Urban development causes sediment increase, barriers to groundwater and increased surface water flow. Stormwater excess.	Urban wetland zones too narrow, inadequately vegetated and some too steep for water absorption. Pollutants enter wetland ponds. Eutrophication Stormwater runoff Altered nutrient load.	Use UWHI assessments to monitor stormwater runoff and to guide restoration.

[32] Good practice is evolving and reference should be made to relevant professional associations, in particular the NZ Ecological Society.

Good Practice	Current KCDC situation	Problem identified	Recommendations
Urban wetland functions: **b. Riparian ecology** Riparian hydrology intact, ecosystem intactness, suitable terrestrial and aquatic habitats, dominant native vegetation composition and integrity, minimal infrastructure impact, minimal human domination. (Section 6.2, M 8, Ch 6).	Altered topography. Poor attention to riparian ecosystems. Variable amounts of native vegetation. Landscape fragmentation. Lawns and exotic plants. Excess stormwater runoff. Poor habitat for terrestrial fauna and pollution of aquatic zone. Human domination of flora almost complete.	Patch fragmentation and landscape destruction. Exotic riparian vegetation composition and appropriateness for urban wetlands. Inadequate zone width and slopes.	Use UWHI to monitor riparian re-vegetation and restoration and to inform policy and planning. Promote the use of urban gardens as ecological corridors in urban planning design (Section 7.4.2)
Urban wetland functions: **c. Cultural Values** Good quality wetlands with thriving fauna. Aesthetic environment Protected open spaces. Recreational values (Section 6.2, M11, Ch 6).	Poor quality wetland ponds. Low number of aquatic macroinvertebrates with low TVs. Community input low (apart from Waimeha Lagoon). Low recreational values.	Poor quality wetland water & riparian areas. Polluted ecosystems. People 'unfriendly' sites.	Use UWHI assessments to provide baseline for restoration. Establish community-council enterprise and communication to restore riparian and wetland health and develop local culture.
Urban wetland functions: **d. Urban Developments and Resource Consents**. Regionally – land use consents, discharge consents, water permits, coastal permits. District – Local land use, subdivisions. EREs required for all. Biodiversity monitoring 2nd generation plans. (Section 6.2, M12. Ch 6)	Standard procedure for applications with larger land changes heard by Commissioners. Permitted activities being extended with consensus of community. Time-span for application of complaints to be shortened.	Resource consents difficult to trace in KCDC records. KCDC are considering AEE (Assessments of Effects on Environment) in District Plan Review.	Urban wetland development via resource consent procedures to be monitored by council when development completed and not just by complaint procedure.

Good Practice	Current KCDC situation	Problem identified	Recommendations
Urban wetland function: **e. Stormwater Impacts on Riparian area.** Limited imperviousness in all areas. Low incline, well vegetated with native flora, stormwater piped to collection ponds via filters to remove pollutants & sediment. (Section 6.2, M14, Ch 6).	Polluted water, with high nutrient vegetation. High degree of Imperviousness. Poor connectivity with stormwater drainage system for older residential areas leading to high surface water runoff. Ferndale collection via filters.	%ISC & CIA values very poor. Assoc with lawns, gardens, steep pond banks. %ISC & CIA show >50% are impervious. Runoff from lawns is considerable. Lake Kotuku has steep banks & stormwater pipe flowing through to holding pond. Midlands Gardens has steep banks.	Reduce impervious surfaces. LIUDD in all new developments. Upgrade stormwater collection systems throughout district. Subdivisions use filtration as at Ferndale.
Monitoring: RMA, LGA, NPS, NES RPS & Regional Plans District Plans KCDC stormwater drains visited every 4 weeks. KCDC Annual Report 2011-2012 Parks & Reserves.	Records available from GWRC but not in detail from KCDC. KCDC intention in Plan Review 2010 to require developers to monitor water quality in 'their' subdivisions as part of consent.	Most urban wetland water quality not monitored by KCDC.	Utilise UWHI to generate baseline date and monitor change.
Reporting: Second generation RMA plans regional and district. EREs State of Environment -. annually GWRC MfE reporting	GWRC Annual reports on website. KCDC reports not routinely on website – only summary documents.	KCDC monitoring not reported in detail.	UWHI assessment and follow up. KCDC monitoring of urban wetlands data should be publicly available on a website

Bibliography

Aber, J., & Pavri, F. (2012). Wetland Environments: a Global Perspective. Blackwell, USA.

Adamus, P.R. (1983). *FHWA Assessment method v.2 of method for wetland functional assessment.* Washington D.C. U.S. Department of Transportation, Federal Highway Administration Report no: FHWA-IP-82-24.

Adamus, P.R. & Bartlett, C. (2008). *Wetlands of Crater Lake National Park: An assessment of their Ecological Condition.* Oregon State University. www.people.oregonstate.edu/

Adamus, P.R., Clairain, E.J., Smith, R.D. & Young, R.E. (1987). *Wetland Evaluation Technique (WET), v.2 of Methodology* Vicksburg, Miss., U.S. Army Corps of Engineers, Waterways Experiment Station, Operational Draft Technical Report. 206.

Adkin, G.L. (1951). Geology of the Paekakariki Area of the Coastal Lowland of Western Wellington. *Transactions and Proceedings of the Royal Society of New Zealand* 1868-1961. 79: 157-179. www.rsnz.natlib.govt.nz/volume/rsnz

Adkin, G.L. (1947). *Horowhenua*. Department of Internal Affairs, Wellington.

Alberti, M (2008), Advances in urban ecology: Integrating humans and ecological processes in urban ecosystems. e-Book. Springer. http://www.springer.com/life+sciences/ecology/

Alberti, M. (2005). The Effects of Urban Patterns on Ecosystem Function. *International Regional Science Review*. 28(2): 168-192.

Alberti, M., Marzluff, J.M., Shulenberger, E., Bradley, G., Ryan, C. & Zumbrunnen, C. (2003). Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems. *Bioscience* 53(12): 1169-1179.

Alcamo, J. & Bennett, E.M. (2011). 'Millennium Ecosystem Assessment. (MA). Current State and Trends: Cultural and Amenity Services', in Alcamo, J. & E.M. Bennett (eds) *Ecosystems and Human Well-being,* World Resources Institute, Washington DC.

Alcamo , J. & Bennett, E.M. (2005). 'Millennium Ecosystem Assessment (MA). Economic Costs and Benefits of Ecosystem Conversion', in Alcamo, J. & E.M. Bennett (eds) *Ecosystems and Human Well-being: Biodiversity Synthesis*. World Resources Institute, Washington, DC.

Alcamo, J. & Bennett, E.M. (2003). 'Ecosystems and Human Well-being: a Framework for Assessment', in Alcamo, J. & E.M. Bennett (eds). *Millennium Ecosystem Assessment*. Island Press, Washington, DC. www.energysndenvironment.undp.org/undp/index.cfm

Allen, C. (2010). Hydrological Characteristics of the Te Hapua Wetland Complex: The Potential Influence of Groundwater Level, Bore Abstraction and Climate Change on Wetland Surface Water Levels. MSc Thesis. Victoria University of Wellington.

Allen, W.J. (2001). Working for environmental management: the role of information sharing and collaborative learning. PhD thesis. Massey University.

Allen, M. & Walker, C. (2000). *Water Notes: Advisory notes for Land Managers on River and Wetland Restoration*. Water and River Commission, Waterways WA Program. Western Australia.

Allen, R.B. & Beadle, S.M. (2002). Ecology and Restoration of Te Harakeke Wetland, Waikanae. Wildlands Consultants Contract Report 490 for Wellington Regional Council, Wellington.

Andersen, J. & Hanssen, O. (2005). Riparian beetles, a unique, but vulnerable element in the Fennoscandia. *Biodiversity and Conservation*. 14(14): 3497-3524.

Anderson, A. (2002). A fragile plenty: Pre-European Maori and the New Zealand environment. In E. Pawson & T. Brooking (eds), Ch 2, *Environmental Histories of New Zealand.* Oxford University Press, Melbourne.

Andersson, E. (2006). Urban landscapes and sustainable cities. *Ecology and Society* 11(1): 34.

Angold, P.G., Sadler, J.P., Hill, M.O., Pullin, A., Rushton, S., Austin, K., Small, E., Wood, B., Wadsworth, R., Sanderson, R. & Thompson, K. (2005). Biodiversity in urban habitat patches. *Science of the Total Environment*. 360(2006): 196-204.

Antrop, M. (2006). Sustainable landscapes: contradiction, fiction or utopia? *Landscape and Urban Planning.* 75:187-197.

Antrop, M. (2005). Why landscapes of the past are important for the future. *Landscape and Urban planning* 70: 21-34.

Ashraf, S., Brabyn, L., Hicks, B.J. & Collier, K. (2010). Satellite remote sensing for mapping vegetation in New Zealand freshwater environments: a review. *New Zealand Geographer* 66:33-43.

Ausseil, A.E., Chadderton, W.L., Gerbeaux, P, Theo Stephens, R.T. & Leathwick, J.R. (2011). Applying systematic conservation planning principles to palustrine and inland saline wetlands of New Zealand. *Freshwater Biology*. 56:142-161.

Ausseil, A.E. (2007). Rapid Mapping and Prioritisation of Wetland Sites in the Manawatu – Wanganui Region, New Zealand. *Environmental Management* 39: 316-325.

Ausseil, A.E., Chadderton, W.L., Gerbeaux, P., Stephens, R.T. & Leathwick, J.R. (2011). Applying systematic conservation planning principles to palustrine and inland saline wetlands of New Zealand. *Freshwater Biology*. *Special Issue: Freshwater Conservation Planning.* 56(1): 142-161.

Atkinson, I.A.E (1985). Derivation of vegetation mapping units for an ecological survey of Tongariro National Park, North Island, New Zealand. *New Zealand Journal of Botany* 23: 361-378.

Australian Water Resources. (2005). *A baseline assessment of water resources for the National Water Initiative. Level 2 assessment. River and wetland health theme. Assessment of river and wetland health: a framework for comparative assessment of the ecological condition of Australian Rivers and Wetlands.* Australian National water Commission.

Australian New Zealand Environment and Conservation Council (ANZECC) (2002). *Guidelines for water quality*. Ministry for the Environment, Wellington. http://www.mfe.govt.nz/publications/water

Barker, J.D. & Wilson, S.C. (2004). Using ecological restoration to constrain biological invasion *Journal of Applied Ecology*. 41:1058-1064.

Barbier, E.B. (2013). Valuing ecosystem services for coastal wetland protection and restoration: progress and challenges. *Resources* 2:213-230.

Barlow , J., Peres, C.A., Henriques, L.M.P., Stouffer, P.C. & Wunderle, J.M. (2006). The response of the understorey birds to forest fragmentation, logging and wildfires: an Amazonian synthesis. *Biological Conservation*. 128: 182-192.

Beckerman, W. (1972). Economists, scientists and environmental catastrophe. *Oxford Economic Papers. New Series*. 24(3): 327-344.

Beier, P & Noss, R.F. (1998). Do Habitat Corridors Provide Connectivity. *Conservation Biology* 12(6): 1241-1252.

Bellemare, J., Motzkin, G & Foster, D.R. (2002). Legacies of the agricultural past in the forested present: an assessment of the historical land use effects on rich mesic forests. *J. Biogeographica* 29(10-11): 1401-1420.

Benitez-Malvido, J. & Martinez-Ramos, M. (2003). Impact of forest fragmentation on understory plant species richness in Amazonia. *Conservation Biology*. 19(2): 389-400.

Benjamini, Y. & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society*, Series B 57: 289-300.

Bess, R. (2010). Maintaining a balance between resource utilisation and protection of the marine environment in New Zealand. *Marine Policy*. 34(3): 690-698.

Best, E. (1942). *Forest Lore of the Maori*. Polynesian Society. Wellington.

Bingham, S.C., Westerman, P.W. & Overcash, M.R. (1980). Effects of grass buffer zone length in reducing the pollution from the land application areas. *Transactions of American Society of Agriculture and Biological Engineers*. 23: 330-342.

Blackwell, S.A. & Pilgrim, E.S. (2011). Ecosystem services delivered by small-scale wetlands. *Hydrological Sciences Journal.* 56(8): 1467-1484.

Boffa Miskell. (2011). Wetlands of the Wellington Region: a desktop delineation and assessment of significance. Report W10140-007 prepared for Greater Wellington Regional Council by S. Fuller.

Boffa Miskell. (2008). Ngarara Ecological Assessment. Report to SKM & Maypole Environmental Ltd. Christchurch.

Boffa Miskell. (2004). Kotuku Subdivision Information brochure for Prospective Purchasers. www.kotukuparks.co.nz

Boffa Miskell. (1999). Second thoughts transform Kotuku Park subdivision. Brochure for Information for Prospective Purchasers. www.kotukuparks.co.nz/about.php

Boyer,T. & Polasky, S. (2004). Valuing urban wetlands: a review of non-market valuation studies. *Wetlands.* 24(4): 744-755.

Brander, L.M., Florax, R.J.G.M. & Vermaat, J.E. (2006). The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature. *Environmental and Resource Economics*. 33(2): 223-250.

Bressler, D.W. & Paul, M.J. (2002). *Effects of Eutrophication on wetland ecosystems*. Tetra Tech, Inc. http//:n-steps.tetratech-fix.com

Bridgham, S.D. & Lambert, G.A. (2009). In Section 2, Maltby, E. & Barker, T. (eds). *The Wetlands Handbook.* J. Wiley & Sons. Technology and Engineering. pp 338-339

Brinson, M.M. (1993). A Hydrogeomorphic Classification for Wetlands. Wetlands Research

Program Technical Report WRP-DE-4, U.S. Army Corps of Engineers, Waterways Experiment Station. USA.

Brinson, M. M. & Malvarez, A.I. (2002). Temperate freshwater wetlands: types, status and threats. *Environmental Conservation*, 29: 115-133.

Brinson, M.M. & Reinhardt, R. (1996). The role of reference wetlands in functional assessment and mitigation. *Ecological Applications* 6(1): 69-76.

Brooking, T. & Pawson, E. (2011). Conclusion, in Brooking, T. & E. Pawson (eds), *Seeds of Empire: The Environmental Transformation of New Zealand*. Ch 11. L.B.Tauris, London.

Brooks, R.P., Wardrop, D.H. & Bishop, J.A. (2004). Assessing Wetland Condition on a Watershed Basis in the Mid-Atlantic Region Using Synoptic Land-Cover Maps. *Environmental Monitoring and Assessment*. 94(1-3): 9-22.

Brooks, R.P., Wardrop, D.H., Cole, C.A. & Campbell, D.A. (2005). Are we purveyors of Wetland homogeneity? A model of degradation and restoration to improve wetland mitigation performance. *Ecological Engineering* 24: 331-340.

Brown, M.T. & Vivas, M.B. (2005). Landscape development intensity index*. Environmental Monitoring and Assessment* 101: 289-309.

Brownsey, P.J. & Perrie, L.R. (2013). *Azolla rubra* revisited. New Zealand Botanical Society Newsletter. 111: 6-7.

Bullock, J.M., Aronson, A.C., Pywell, R.F. & Rey-Benayas, J.M. (2011). Restoration of ecosystem services and biodiversity: conflict and opportunities. *Trends in Ecology and Evolution*. 26(10): 541-549.

Burchell, R., Lowenstein, G., Dolphin, W., Galley, C., Downs, A., Seskin, S., Gray Still, K. & Moore,T. (2002). *Costs of Sprawl 2000*. Washington (DC): National Academy Press.

Burns, B. & Burns, R. (2008). Cluster Analysis. Chapter 23 in: *Business Research Methods and Statistics using SPSS*. Sage Publications Ltd.

Bush, G. (1995). *Local government and politics in New Zealand*. Second Edition. Auckland University Press.

Cadenasso, M.L., Pickett, S.T.A., Groffman, P.M., Band, L.E., Brush, G.S., Galvin, M.F., Grove, J.M., Hagar, G., Marshall, V., McGrath, B.P., O'Neill-Dune, J.P.M., Stack, W.P. & Troy, A.R. (2008). Exchanges across Land-Water-Scape Boundaries in Urban Systems. *Annals New York Academy of Science*. 1134: 213-232.

Cadenasso, M.L., Pickett, S.T.A. & Schwarz, K. (2007). Spatial heterogeneity in urban ecosystems: reconceptualising land cover and a framework for classification. *Front. Ecol. Environ.* 5: 80-88.

Campbell, D. (2010). 'Hydrology', In Peters, M. & B. Clarkson (eds), *Wetland Restoration: a Handbook for New Zealand Freshwater Systems*. Manaaki Whenua Press. Lincoln.

Carew, M.E., Pettigrove, V., Cox, R.L. & Hoffmann, A.A. (2007). The response of Chironomidae to sediment pollution and other environmental characteristics in urban wetlands. *Freshwater Biology.* 52(12): 2444-2462.

Carkeek, W. (1966). *The Kapiti Coast*. A.W. & A.H. Reed, Wellington.

Carpenter, S.R. & Kitchell, J. (1996). *The Trophic Cascade in Lakes*: *Cambridge Studies in Ecology*. Cambridge University Press, Cambridge, New York.

Carson, R. (1962). *The Silent Spring*. Hamilton Hamish, London, UK.

Castelle, A.J., Johnson, A.W. & Conolly, C. (1994). Wetland and Stream Buffer Size Requirements – A Review. *Journal Environmental Quality.* 23: 878-882.

Cheal, F., Davis, J.A., Growns, J.E., Bradley, J.S. & Whittles, F.H. (1993). The influence of sampling method on the classification of wetland macroinvertebrate communities. *Hydrobiologia.* 257: 47-56.

Chen, W.Y. & Jim, C.Y. (2008). Assessment and valuation of the ecosystem services provided by urban forests. p53-83 in Carriero, M., Sung, Y.C. & Wu, J. (eds) *Ecology, planning and management of urban forests*. International Perspectives. Springer.

Cheyne, C.M. (2012). Better local government reform proposals: Improving or diminishing local government. *Policy Quarterly.* 8(2): 37-40.

Clapham, M.E. (2011). Ordination methods and the evaluation of Ediacaran communities. Ch. 1 in Laflamme, M., Schiffbauer, J.D. & Dornbos, S.Q. (eds), *Quantifying the evolution of early life: Numerical approaches to evaluation of fossils and ancient ecosystems*. Springer. NATURE. (Google eBook).

Clark, K. (1971). *Civilisation.* BBC Corporation, London, England.

Clarke, I. (2009). Resource act revamp is really just tinkering. *Dominion Post*, Wellington. August 26, 2009. www.stuff.co.nz/dominion-post/comment/

Clarkson, B.D, Wehi, P.M. & Brabyn, L.K. (2007). A spatial analysis of indigenous cover patterns and implications for ecological restoration in urban centres, New Zealand. *Urban Ecosystems.* 10(4): 441.

Clarkson, B.R., Sorrell, B.K., Reeves, P.N., Champion, P.D., Partridge, T.R. & Clarkson, B.D. (2004). *Handbook for Monitoring Wetland Condition*. Coordinated Monitoring of New Zealand Wetlands. A Ministry for the Environment Sustainable Management Fund Project (5105).

Cole, D. (2002). The assessment of herbaceous plant cover in wetlands as an indicator of function. *Ecological Indicators.* 2: 287-293.

Cole, J.T., Baird, J.H., Basta, N.T., Hunhnke, R.L., Storm, D.E., Johnson, G.V., Payton, M.E., Smolen, M.D., Martin, D.L. & Cole, J.C. (1997). Influence of buffers on pesticide and nutrient runoff from bermudagrass turf. *Journal of Environmental Quality*. 26(6): 1589-1598.

Commoner, B. (1971). *The Closing Circle: Nature, Man and Technology*. Alfred A. Knoff. New York.

Connell Wagner Ltd. (2007). Earthworks Management Plan, 'Ferndale' Subdivision, Ferndale Trust. Paraparaumu.

Conservation Act. (1987). NZ Government. www.legislation.govt.nz/act/public/1987

Convention on Biological Diversity. (CBD). (1992). UNEP. http://www.cbd.int/convention/convention

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P. & van den Belt, M. (1998). The value of ecosystem services: putting the issues in perspective. *Ecological Economics.* 25: 67-72.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Robert, V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature.* 387(66300): 253-260.

Costanza, R. & Daly, H.E. (1992). Natural capital and sustainable development. *Conservation Biology.* 6: 37-46.

Cowardin, L.M., Carter, V., Golet, F.C. & La Roe, E.T. (1979). Classification of wetland and deepwater habitats of the United States, U.S. Fish and Wildlife Service Biological Services Program. FBS/OBS – 79/31, US Government Printing Office, Washington, DC.

CRC (Canterbury Regional Council). (2006). Application by Pegasus Town Limited for land use consent and other permits to the Canterbury Regional Council. www.ecan.govt.nz/news-and-notices/norices/hearingdecisions/

Crisp, P., Dickinson, P. & Gibbs, G.W. (1998). Does native invertebrate diversity reflect native plant diversity? A case study from New Zealand and implications for conservation. *Biological Conservation.* 83:209.

Curran, S.E. (2004). Sustainable Development v Sustainable Management; The Interface between the Local Government Act and the Resource Management Act. New Zealand *Journal of Environmental Law*. 8: 267-294.

Daniels, G.D. & Kirkpatrick, J.B. (2006). Does variation in garden characteristics influence the conservation of birds in suburbia? *Biological Conservation.* 133: 326-335.

Daly, H.E. (1998**).** The return of Lauderdale's paradox. *Ecol. Econ.* 25, 21–23.

Davis, J., Horwitz, P., Norris, R., Chessman, B., McGuire, M. & Sommer, B. (2005). Are river bioassessment methods using macroinvertebrates applicable to wetlands? *Hydrobiologia.* 572: 115-128.

Dawson, J. & Lucas, R. (2004). *Nature Guide to the New Zealand Forest*. Random House, New Zealand.

Dawson, J. (1988). *Forest Vines to Snow Tussocks*. Victoria University Press, Wellington.

Deans, N. & Preece, J. (2007). Assessing Wetland Significance. Proceedings of NZFWSS and ASL Meeting, Queenstown, New Zealand. December 2007.

Delectic, A. (2005). Sediment transport in urban runoff over grassed areas. *Journal of Hydrology*. 301:108-122.

Department of Building and Housing. (2011). Building Consent Statistics: a Summary of New Zealand Data. NZ Government, Wellington.

Department of Conservation (DOC). (2013). Wellington Hawkes Bay Conservancy Board: by region. http://www.doc.govt.nz

Department of Conservation (DOC). (2010). Statutory framework for management of public conservation land. http://www.doc.govt.nz/publications/about-doc/role/policies

Department of Conservation (DOC). (1987). New Zealand wetlands management policy. http://www.doc.govt.nz/publications/conservation/

Diamond, J. (2005). *Collapse: How societies choose to fail or survive.* Penguin Books, Australia.

Diamond, J. (1989). New Zealand as an archipelago: an international perspective, in Towns, D.R., Daughtery, C.H & Atkinson, I.A.E. *Ecological restoration of New Zealand's islands*. Conservation Sciences Publication No. 2. Department of Conservation, Wellington.

Dickinson, K.J. & Mark, A.F. (1994). Forest-wetland vegetation patterns associated with a Holocene dune-slack sequence. Haast Ecological District, South-western New Zealand. *Journal of Biogeography* 21: 259-281.

Dodd, M.B., Quinn, J.M., Thorbold, B.S., Parminter, T.G. & Wedderburn, M.E. (2008). Improving the economic and environmental performance of a New Zealand hill country farm catchment: 3. Short-term outcomes of land use change. *New Zealand Journal of Agricultural Research* 51(2): 155-169.

Duguid, A., Barneston, J., Clifford, B., Pavey, C., Albrecht, D., Risler, J. & McNellie, M. (2005). Wetlands of the Arid Northern Territory. A report to the Australian Government Department of the Environment and Heritage. NT Project ID: 98017.

Eason, C., Miller, A., Ogilvie, S & Fairweather, A. (2011). An updated review of the toxicology and ecotoxicology of sodium fluoroacetate (1080) in relation to its use as a pest control tool in New Zealand. *N.Z Journal of Ecology.* 35(1): 1-20.

Eason, C., Pandey, S., Feeney, C., van Roon, M. & Dixon, J. (2004). Low Impact Design and Development: Making it Mainstream. Conference proceedings of the New Zealand Society for Sustainability: Engineering and Science at the First International Conference on Sustainability, Engineering and Science. Auckland.

Ecological Economics Research New Zealand (EERNZ). (2011). Massey University. http://www.massey.ac.nz/massey/research/centres-research/eernz/

Ecological Economics Research New Zealand EERNZ. (2010). Integrated Assessment of Sustainable Pathways for Wellington and Auckland, New Zealand, briefing paper.

Ehrenfeld, J.G. (2008). Exotic invasive species in urban wetlands: environmental correlates and implications for wetland management. *Journal of Applied Ecology* 45(40: 1160-1169.

Ehrenfeld, J.G. (2004). The expression of multiple functions in urban forested wetlands. *Wetlands* 24(4): 719-733

Ehrenfeld, J.G. (2000). Evaluating wetlands within an urban context. *Ecological Engineering* 15: 253-265.

Engfeldt, L (2002). Chronicle Essay: The Road from Stockholm to Johannesburg. Online Edition. http://www.un.org/Pubs/chronicle/2002/issue3/0302p14_essay.html

Enright, P., John, O. & Jensen, I. (2001). Vascular plants on the properties of 182 Te Hapua Road, Te Horo. Report prepared for land owner.

Environment Court of New Zealand. (2008). http://www.justice.govt.nz/environment/

Environmental Defence Society (EDS). (2013). Environmental Defence Society's Submission on Resource Management Reform Bill. EDS Newsletter 13 February 2013. http://www.eds.org.nz

Environmental Defence Society (EDS). (2011). Resource Management Act. www.rmaguide.org.nz/rma/statutorybodies

Erwin, K.L. (2009). Wetlands and global climate change: the role of wetland restoration in a changing world. *Wetlands Ecology and Management.* 17: 71-84.

Esler, A.E. (1978). *Botany of the Manawatu District, New Zealand.* Government Printer, Wellington.

Euliss, N.H., Smith, L.M., Wilcox, D.A. & Browne, B.A. (2008). Linking ecosystem processes with wetland management goals: Charting a course for a sustainable future. *Wetlands* 28(3): 553-562.

Euliss, N.D., Wrubleski, D.A., & Mushet, D.M. (1999). Wetlands on the prairie pothole region: invertebrate species composition, ecology, and management. in (eds) Batzer, D.P., Rader, R.B. & Wissinger, S.A. Invertebrates in freshwater wetlands of North America: ecology and management. Wiley. New York. p 471-514.

European Commission (2008). *Balancing urban expansion with biodiversity conservation*. European Commission, Environment DG, The Hague, The Netherlands.

Faulkner, S. (2004). Urbanization impacts on the structure and function of forested wetlands. *Urban Ecosystems* 7: 89-106.

Feeney C. (2009). If we adopt LIUDD, what will we measure to tell us how well it worked? A summary report for Manaaki Whenua Landcare Research and the University of Auckland. http://www.landcareresearch.co.nz/research/built/liudd/

Fennesy, M.S., Jacobs, A.D. & Kentula, M.E. (2007). An evaluation of rapid methods for assessing the ecological condition of wetlands. *Wetlands* 27(3): 543-560.

Fennesy, M.S., Jacobs, A.D. & Kentula, M.E. (2004). *Review of rapid methods for assessing wetland condition*. EPA/620/ R-04/009, U.S. Environmental Protection Agency, Washington, D.C.

Fisher, J. & Acreman, M.C. (2004). Wetland nutrient removal: a review of the evidence. *Hydrology and Earth System Sciences*, 8(4); 673-685.

Fleming, C.A. (1971). The Contribution of C14 Dates to the Quaternary geology of the ‘Golden Coast’, Western Wellington, in *Tuatara* 19(2): 61-74.

Forman, R.T.T. & Alexander, L.E. (1998). Roads and their major ecological effects. *Annual Review of Ecological Systems*. 29: 207-31.

Foster, D.R. & Motzkin, G. (2003). Interpreting and conserving the open-land habitats of New England: insights into landscape history. *Forest Ecology and Management.* 185: 127-150.

Froude, V. (1997). Biodiversity protection provisions. Council implementation of the biodiversity protection provisions in the Resource Management Act. Pacific Ecologic Resource Management Associate, Wellington. *Planning Quarterly* September 1997.

Furuseth, O. & Cocklin, C. (1995). Regional perspectives on Resource Policy: Implementing sustainable management in New Zealand. *Journal of Environmental Planning and Management* 8(2): 181-200.

Furuseth, O. & Cocklin, C. (1985). An institutional framework for sustainable Resource Management: The New Zealand model. *Natural Resources Journal* 35: 243-273.

Ghaffarzadeh, M., Robinson, C.A. & Cruse, R.M. (1992). Vegetative filter strip effects on sediment deposition from overland flow. In Agronomy Abstracts, ASA. Madison, USA.

Gibbs, G. (2006). *Ghosts of Gondwana, a History of Life in New Zealand*. Craig Potton Publishing, Nelson.

Goddard, M.A., Dougill, A.J. & Benton, T.G. (2009). Scaling up from gardens: biodiversity conservation in urban environments. *Tree* 1175:1-9.

Goodale, C.L. & Aber, J.D. (2001). The long-term effects of land-use history on nitrogen cycling in northern hardwood forests. *Ecological Applications* 11(1): 253-267.

Goodland. (2002). Sustainability: Human, Social and Environmental. World Bank, Washington, D.C. In *Encyclopaedia of Global Environmental Change*. John Wiley & Sons, Ltd.

Goonetilleke, A., Thomas, E., Ginn, S. & Gilbert, D. (2005). Understanding the role of land use in urban stormwater quality management. *Journal of Environmental Management* 74: 31-42.

Greater Wellington Regional Council (GWRC). (2013). Chemical analysis – Te Marua. http://www.gw.govt.nz/Chemical-analysis-Te-Marua.

Greater Wellington Regional Council (GWRC). (2013). How to design a good pond. http://www.gw.govt.nz/our-services/

Greater Wellington Regional Council (GWRC). (2010). Te Hapua at Shoveler Lagoon. http://www.gw.govt.nz/te-hapua-at-shoveller-lagoon/

Greater Wellington Regional Council (GWRC). (2008). Draft Regional Policy Statement for the Wellington Region 2008. Wellington. www.gw.govt.nz/assets/importedfiles/

Greater Wellington Regional Council (GWRC). (2003). *A beginner's guide to wetland restoration*. Greater Wellington Regional Council, Wellington. http://www.gw.govt.nz/our-services/

Grime, J.P. (2001) *Plant Strategies, Vegetation Processes, and Ecosystem Properties.* John Wiley & Sons, New York.

Grime, J.P. (1979). Plant strategies and vegetation processes. John Wiley, Chichester.

Grimm, N.B., Faeth, S.H., Golubiewshi, N.E., Redman, C.L., Wu, J., Bai, J.M. & Briggs, J.M. (2008). Global Change and the Ecology of Cities. *Science* 3139(5864): 756-760.

Grimm, N.B., Grove, J.M., Pickett, S.T.A. & Redman, C.l. (2000). Integrated approaches to longterm studies of urban ecological systems. *BioScience* 50(7): 571-584.

Groffman, P. (2012). *Landscape and regional scale studies of denitrification*, in Proceedings of Eco Summit 2012 (in Press). Ohio.

Groffman, P.M, Bain,D.J., Band, L.E., Belt, K.T., Brush, G.S., Grove, J.M., Pouyat, R.V., Yesilonis, I.C. & Zipperer, W.C. (2003). Down by the Riverside: urban riparian ecology. *Frontiers Ecology Environments* 1(6): 315-321.

Groffman, P.M, Gold, A.J., Husband, T.P., Simmons, R.C. & Eddlemam, W.R. (1990). *An investigation into multiple uses of vegetated buffer strips.* NBP-90-44. Dept. Nat. Res. Sci., University of Rhode Island, Kingston, Rhode Island.

Grose, M. (2010). Small decisions in suburban open spaces: Ecological perspectives from a hotspot of global diversity concerning knowledge flows between disciplinary territories. *Landcare Research* 35(1): 47-62.

Grundy, K.J. & Gleeson, B.J. (1996) Sustainable management and the market. *Land Use Policy* 13(3): 197-211.

Hahs, A.K. & McDonnell, M.J. (2006). Selecting independent measures to quantify Melbourne's urban-rural gradient. *Landscape and Urban Planning* 78: 435-448.

Hansard Debates. (2009). A Parliamentary Debate on the Second reading of the Resource Management Amendment Bill 657: 6133.

Hanson, L., Bronmark, C., Nilsson, P.A. & Abjornsson, K. (2005). Conflicting demands on wetland ecosystem services: nutrient retention, biodiversity or both? *Freshwater Biology.* 50: 705-714.

Harding, J.S. (2005). Impacts of metals and mining on stream communities, in T.A. Moore, A. Black, J.A. Centeno, J.S. Harding, D.A. Trumm (eds), *Metal Contaminants in New Zealand.* Resolutionz Press, Christchurch.

Hardin, G. (1968). The Tragedy of the Commons. *Science*. 162: 1243-1248.

Hargiss, C.L.M., DeKeyaser, E.S., Kirby, D.R. & Ell, M.J. (2007). Regional assessment of wetland plant communities using the index of plant community integrity. *Ecological Indicators* 8: 303-307.

Harlen, C. (1993**).** *Preliminary Plant Survey of remnant consolidated dune lakes*. Conservation Marketing and Consultancy. Prepared for Kotuku Parks Ltd, Wellington**.**

Harmsworth, G. (2002). Maori Indicators - Wetland Monitoring Form. In *Handbook for Monitoring Wetland Condition* (eds) Clarkson, B. *et al.* Ministry for the Environment,

Harrison, M.D., Groffman, P.M., Mayer, P.M., Kaushai, S.S. & Newcomer, T.A. (2011). Denitrification in alluvial wetlands in an urban landscape. *Journal of Environmental Quality.* 40(2): 634-646.

Hasse, J.E. & Lathrop, R.G. (2003). Land resource indicators of urban sprawl. *Applied Geography* 23:159-175.

Hazlett, M. (2004). Woman vs Man: gender and popular ecology in early reactions to ‘Silent Spring’. *Environmental History* 9(4): 701-729.

Hearn, T. (2002). Mining the quarry, in E. Pawson & T. Brooking (eds), Ch.6, *Environmental Histories of New Zealand*. Oxford University Press, Melbourne.

Heinz Center (The John Heinz Center for Science, Economics and the Environment). (2008). The State of the Nation’s ecosystems: Measuring land, water and living resources of the United States of America. Cambridge University Press, New York. www.heinzstr.org/ecosystems/report.html

Helgen, J. (2002). *Methods for evaluating wetland condition: developing an invertebrate IBI for wetlands.* USEPA.

Heron, D., van Dissen, R. & Sawa, M. (1998). Late Quaternary movement on the Ohariu Fault, Tongue Point to Mackays Crossing, North Island, New Zealand. *New Zealand Journal of Geology & Geophysics* 41: 419-439.

Heslop, V. & Hunter, P. (2008). The capacity to change with Local Government to strengthen policy. www.landcareresearch.co.nz/research/research

Heyda, M. (2006). A Practical Guide to Conductivity Measurement. http://www.mbhes.com/conductivity_measurement.htm

Higgins, M.J. & Merritt, R.W. (1999). Temporary wood-land ponds in Michigan: invertebrate seasonal patterns and trophic relationships. In Batzer, D.P., Rader, R.B. & Wissinger, S.A. (eds). Invertebrates in Freshwater Wetlands of North America. *Ecology and Management*. pp 279-297. John Wiley and Sons, New York.

Hill, G. (2008). The Effectiveness of the Auckland Metropolitan Urban Limit – Ring-fencing Urban Development. Environmental Defence Society Conference, Auckland.

Hilton, M., Macauley, U. & Henderson, R. (2000). *Inventory of New Zealand's active dunelands.* Science for Conservation 157. Department of Conservation, Wellington.

Hilton, M. (1992). Coastal policies need not entail conflict. *Planning Quarterly* No 106. AGM Publishing. Auckland.

Hobbs, R.J. (2002). 'The ecological context: a landscape perspective', in Perrow, M.J. & A.J. Davy (eds), *Handbook of Ecological Restoration.* Cambridge University Press, Cambridge.

Hogan, D.M. & Walbridge, M.R. (2009). Recent land cover History and nutrient retention in riparian wetlands. *Environmental Management* 44: 62-72.

Hogan, D. & Walbridge, M. (2007). Urbanization and Nutrient Retention in Freshwater Riparian Wetlands. *Ecological Applications*. 17(4): 11442-1155.

Holdaway, R. (1996). Arrival of Rats in New Zealand. *Nature.* 384 :225-226.

Holland, C., Honea, J., Gwin, S. & Kentula, M.E. (1995). Wetland Degradation and Loss in the Rapidly Urbanizing Area of Portland, Oregon. *Wetlands* 15(4); 336-345.

Holland, P., O'Connor, K. & Wearing, A. (2002). Remaking the Grasslands of the Open Country. In E. Pawson & T. Brooking (eds), Ch 5, *Environmental Histories of New Zealand* Oxford University Press, Melbourne.

Hook, D.D. (1993). Wetlands: History, Current Status and Future. *Environmental Toxicology and Chemistry* 12: 2157-2166

Houlahan, J.E., Keddy, P.A., Makkay, K. & Scott Findlay, C. (2006). The effects of adjacent land use on wetland species richness and community composition *Wetlands.* 26(1): 79-96.

Housing New Zealand. (2013) History of state housing. On line: www.hnzc.cco.nz/about-us

Hruby, T. (2011). *Wetlands*. Washington State Department of Ecology. Olympia, Washington.

Ignatieva, M., Stewart, G.H. & Meurk, C. (2011). Planning and design of ecological networks in urban areas. *Landscape Ecological Engineering*. 7:17–25.

Ilhardt, B.L., Verry, E.S. & Palik, B.J. (2000). Defining riparian areas, in Verry, E.S., Hornbeck, S.W. & C.A. Dolloff (eds), *Riparian Management in Forests of the Continental Eastern United States.* Lewis, New York.

Illman, S. (2013). Water sensitive design: integrating water with urban planning. *The Guardian.* http://www.theguardian.com/sustainable-business/

Innis, S.A., Naiman, R.J. & Elliott, S.R. (2000). Indicators and assessment methods for measuring the ecological integrity of semi-aquatic terrestrial environments. *Hydrobiologia* 422/423: 111-113.

Intergovernmental Panel for Climate Change (IPCC). (2009). www.ipcc.ch/organization/organization_history.htm

International Union for Conservation of Nature/United Nations Employment Programme/World Wildlife Fund (IUCN/UNEP/WWF). (1991). *Caring for the Earth: A Strategy for sustainable Living*. Gland, Switzerland.

International Union for Conservation of Nature/World Bank (IUCN/Worldbank). (2005). *How*

Much Is an Ecosystem worth? Assessing the Economic Value of Conservation. www.wds.worldbank.org/servlet/WDS_IBANK_Servlet

Ivanova, M. (2007). Designing the United Nations programme: a story of compromise and confrontation. *International Environmental Agreements: Politics, Law and Economics* 7(4): 337-361.

Jacobs, A.D., Kentula, M E. & Herlihy, A.T. (2010). Developing an index of wetland condition from ecological data: An example using HGM functional variables from the Nanticoke watershed, USA. *Ecological Indicators*. 10:703-712.

Jaegar, J.A.G., Raumer, H.S., Schwarz-von Esswein, H., Muller, M. & Schmidt-Luttmann, M. (2007). Time Series of Landscape Fragmentation Caused by Transportation Infrastructure and Urban Development: a case Study from Baden-Wurttemberg, Germany. *Ecology and Society*, 12(1): 22.

Johannesburg Declaration on Sustainable Development (2002). The World Summit on Sustainable Development. UN Documents: Gathering a Body of Global Agreements. www.un-documents.net/jburgdec.htm

Johnson, P. & Brooke, P. (2009). *Wetland Plants in New Zealand*. Manaaki Whenua Press, Lincoln, Canterbury.

Johnson, P. & Gerbeaux, P. (2004) *Wetland Types in New Zealand*. Department of Conservation. Wellington.

Johnson, P. & Rogers, G. (2003). Ephemeral wetlands and their turfs in New Zealand. *Science for Conservation* 203, Department of Conservation, Wellington.

Johnston, L., Skinner, S., Ishiyama, L. & Sharp, S. (2009). Survey of vegetation and habitat in key riparian areas: Murrumbidgee River, ACT. Technical Report 22. Conservation, Planning and Research, Department of Territory and Municipal Services. Canberra.

Kapiti Coast District Council (KCDC). (2010). Kapiti Coast District Plan. www.kapiticoast.govt.nz/documents

Kapiti Coast District Council KCDC. (2010a). Isohyet based calculation of design peakflows. Isohyet Guidelines and Charts. Appendix 1, Kapiti Coast District Plan. www.kapiticoast.govt.nz/documents

Kapiti Coast District Council KCDC. (2010b). Medium Density Housing Guide, Best Practice, a design guide for developers, planners, architects and others. URBANISMPLUS Ltd, Newmarket, Auckland.

Kapiti Coast District Council (KCDC). (2010c). Kapiti Coast District Plan Review: Discussion Documents: Urban Form and Transport; Infrastructure and Essential Systems; Landscape, Character and Heritage; Biodiversity. www.kapiticoast.govt.nz/documents

Kapiti Coast District Council (KCDC). (2005). *Subdivision and Development Principles and Requirements.* Kapiti Coast District Plan.

Kapiti Coast District Council (KCDC). (2003). District Plan Heritage Register. www.kapiticoast.govt.nz.

Karim, F., Kinsey-Henderson, A., Wallace, J., Arthington, A.H. & Pearson, R.G. (2011).

Modelling wetland connectivity during overbank flooding in a tropical floodplain in North Queensland, Australia. *Hydrological Processes.* 26(18): 2710-2723. Wiley On-line Library.

Kentula, M.E., Gwin, S.E. & Pierson, S.M. (2004). Tracking changes in wetlands with urbanization: Sixteen Years of Experience in Portland, Oregon. *Wetlands* 24 (4): 734-73.

Kerr, G.N. & Sharp, B.M. (2003). Community Mitigation Preferences: A Choice Modelling Study of Auckland Streams. Research Report No 256, Agribusiness and Economics Research Unit, Canterbury.

Kilvington, M., Rosier, J., Wilkinson, R. & Freeman, C. (1998). Urban restoration: social opportunities and constraints. In Proceedings of Symposium on Restoring Health and Wealth of Ecosystems. Christchurch 1998.

Kimberling, D.N., M.A. Hawke, and J.R. Karr. (1999). A new approach to assessing ecological health: Using the Index of Biological Integrity at Hanford. In Proceedings of The First Annual Health of the Hanford Site Conference: Current Challenges, 59-68. Richland, WA: University of Washington

King, M. (2003). *The Penguin History of New Zealand*. Penguin Books (NZ) Ltd. Auckland.

Kourtev, P.S., Ehrenfeld, J.G. & Haggblom, M. (2002). Exotic plants alter the microbial community structure and function in the soil. *Ecology.* 83(11): 3152-3166.

Kowarik, I. (2011). Novel urban ecosystems, biodiversity and conservation. *Environmental Pollution* 159: 1974-1983

Kupfer, J. (2004). Fragmentation: Landscape Pattern and Quantification, in *Identifying the Biodiversity Needs related to Forest Fragmentation*. Ch 4. NCSSF Research Project A7, National Council for Science and the Environment. Washington D.C.

Ladson, A.R., Walsh, C.J. & Fletcher, T.D. (2005). Improving Stream Health in Urban Areas by Reducing Runoff Frequency from Impervious Surfaces. In: 29th Hydrology and Water Resources Symposium: Water Capital, 20-23 February 2005, Rydges Lakeside, Canberra. Engineers Australia.

Landcare Trust. (2011). Wetlands Monitoring and Assessment Kit (WETMAK). http://www.landcare.org.nz/wetmak

Landcare Research. (2010). *Wetland Restoration: A handbook for New Zealand freshwater systems*. Manaaki Whenua Press.

Laudon, H., Sjöblom, V., Buffam, I., Seibert, J. & Mörth, M. (2007). The role of catchment scale and landscape characteristics for runoff generation of boreal streams. *Journal of Hydrology* 344:198-209.

Laurance, W. F., Lovejoy, T.E., Vasconcelos, H.L., Bruna, E.M., Didham, R.K., Stouffer, P.C., Gascon, C., Bierregaard, R.O., Laurance, S.G. & Sampiao, E. (2002). Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conservation Biology* 16:605-618.

Laurance, W.F., Cochrane, M.A., Bergen, S., Fearnside, P.N., Delamonica, P., Barber,C., D'Angelo, S. & Fernandes, T. (2001). The future of the Brazilian Amazon. *Science.* 291(5503): 438-439.

Legendre, P. and H. J. B. Birks. 2012. From classical to canonical ordination. Chapter 8, pp. 201-248 in: *Tracking Environmental Change using Lake Sediments, Volume 5: Data handling and numerical techniques.* In (eds). H. J. B. Birks, A. F. Lotter, S. Juggins and J. P. Smol. Springer, Dordrecht, The Netherlands.

Law, R.A. (2008) The hydrological viability of Te Hakairi wetland, Waikanae. Thesis submitted for MSc in Physical Geography, Victoria University. Wellington.

Lee, C., Fletcher, T.D. & Sun, G. (2009). Nitrogen removal in constructed wetland systems. *Engineering in Life Sciences*. 9(1): 11-22.

Liu, C., Frazier, P., Kumar, L. & MacGregor, C. (2006). Catchment-wide wetland assessment and prioritization using the multi-Criteria Decision-Making Method TOPSIS. *Environmental Management*. 38(2): 316-326.

Local Government Act 2002 Amendment Act 2012 http://www.legislation.govt.nz/act/

Local Government NZ (2011). Enhanced Policy agility – proposed reform of Resource Management Act. Local Government. New Zealand Regional Sector group. December 2011. New Zealand Government. Wellington

Local Government Act (LGA) (2002). New Zealand Government. www.legislation.govt.nz/pdf

Lopez, R.D. & Fennessy, M.S. (2002). Testing the floristic quality assessment index as an indicator of wetland condition. *Ecological Applications* 12(2): 487-497.

Loreau, M., Downing, A., Emmerson, M., Gonzalez, A., Hughes, J. Inchausti, J., Joshi, J.,Norberg, J. & Sala, O. (2002). New perspectives on ecosystem stability.....: a new look at the relationship between diversity and stability. Part 3, Ch. 4 in Loreau, M., Naeem, S. & Inchausti, P. (eds). *Ecosystem Functioning Synthesis and Perspectives*. Oxford University Press Inc. New York.

Lougheed, V.L., McIntosh, M.D., Parker, C.A. & Stevenson, R.J. (2008). Wetland degradation leads to homogenization of the biota at local and landscape scales. *Freshwater Biology* 53: 2402-2413.

Lu, D. (2006). Use of impervious surfaces in land-use classification. *Remote Sensing of the Environment.* 102(1-2): 146-160

Lunde, K,B, & Resh, V.H. (2012). Development and validation of a macroinvertebrate index of biotic integrity (IBI) for assessing urban impacts to Northern California freshwater wetlands. *Environmental Monitoring and Assessment*. 184:3653-3674.

Maber, J. (2012). Topdressing – origins of aerial topdressing. Te Ara Encyclopaedia of New Zealand. www.TeAra.govt.nz/en/topdressing

McAloon, J. (2002). 'Resource Frontiers, Environment, and Settler Capitalism 1769-1860', In E. Pawson & T. Brooking (eds), in Ch 4, *Environmental Histories of New Zealand.* Oxford University Press, Australia.

McAlpine, K.G. & Wotton, D.M. (2009). Conservation and the delivery of ecosystem services. Science for the Environment No 295. Department of Conservation. Wellington.

McCrae, F. (2003). *Second Generation District Plans*. Paper presented to the NZPI Annual Conference.

McDonnell, M.J. & Hahs, A.K. (2008). The use of gradient analysis studies in advancing our understanding of the ecology of urbanizing landscape: current status and future directions. *Landscape Ecology* 23: 1143-1155

McDonnell, M.J. (2007). Restoring and managing biodiversity in an urbanizing world filled with tensions. *Ecological Management & Restoration.* 8: 2.

McDonnell, M.J., Pickett, S.T.A., Groffman, P., Bohlen, P., Pouyat, R.V., Zipperer, W.C., Parmelee, R.W., Carriero, M.M. & Medley, K. (1997). Ecosystem processes along an urban-to-rural gradient. *Urban Ecosystems.* 1: 21-36.

McDonnell, M.J. & Pickett, S.T.A. (1993). The Application of the Ecological Gradient Paradigm to the Study of Urban Effects. in McDonnell, M.J. & S.T.A. Pickett (eds), *Humans as Parameters of Ecosystems: The Ecology of Subtle Human Effects and Populated Areas*. Springer-Verlag, New York.

McElfish, J.M., Kihslinger, R.L. & Nichols, S.S. (2008). *Planners Guide to Wetland Buffers for Local Governments.* Environmental Law Institute, Washington, D.C.

McFadgen, B. (2007). *Hostile Shores: Catastrophic Events in Prehistoric New Zealand and their Impact on Maori Coastal Communities*. Auckland University Press, Auckland.

McFadgen, B. (1997). *Archaeology of the Wellington Conservancy: Kapiti-Horowhenua*. A *prehistoric and palaeoenvironmental study*. Department of Conservation, Wellington.

MacFarlane, D.F. (2009). Observations and predictions of the behaviour of large, slow-moving landslides of schist, Clyde Dam Reservoir, New Zealand. *Engineering Ecology* 109(1-2): 5-15.

McGlone, M.S. (1989). The Polynesian Settlement of New Zealand in Relation to Environmental and Biotic Changes. *New Zealand Journal of Ecology* 12: 115-129.

McGovern, T.H., Bigelow, G., Amorosi, T. & Russell, D. (1988). Northern Islands, human error and environmental degradation: a view of social and ecological change in the Medieval North Atlantic. *Human Ecology* 16(5): 225-270.

McInnes, R.J. (2013). Recognizing ecosystem services from wetlands of international importance: an example for Sussex, UK. *Wetlands* (2013) 1-17.

McKinney, M.L. (2002). Urbanization, biodiversity and conservation. *BioScience.* 52(10): 883-890

MacLean, C. & MacLean, J. (1988*). Waikanae Past and Present*. The Whitcombe Press. New Zealand.

MacLeod, C.L., Blackwell, G., Moller, H., Innes, J. & Powlesland, R. (2008). The Forgotten 60%: bird ecology and management in New Zealand's agricultural landscape. *New Zealand Journal of Ecology* 32(2): 240-255.

McLintock, A.H. (2009). Nature Conservation from: An Ecyclopaedia of New Zealand. www.TeAra.govt.nz/1966/nature-conservation

McNeill, J.K. (2008). The Public Value of Regional Government: how New Zealand's regional councils manage the environment. PhD Thesis Massey University, Palmerston North.

Mace, G.M., Norris, K. & Fitter, A.H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology and Evolution*. 27(1): 19-26.

Maltby, L., Forrow, D.,M., Boxall, A.B.A., Calow, P. & Betton, C.I. (2009). The effects of motorway runoff on freshwater ecosystems: Field study. *Environment and Toxicology and Chemistry* (Impact Factor 2:62) 14(6): 1079 – 1092.

Mander, O., Hayakawa, Y. & Kuusemets, V. (2005). Purification processes, ecologic functions, planning and design of riparian buffer zones in agricultural watersheds. *Ecological Engineering* 24(5): 421-432.

Manuel, P.M. (2003). Cultural perceptions of small urban wetlands: Cases from the Halifax Regional Municipality, Nova Scotia, Canada. *Wetlands* 23 (4): 921-940.

Marden, M., Rowan, D. & Phillips, C. (2005). Stabilising characteristics of New Zealand indigenous riparian colonising plants. *Plant and Soil* 278:95-105.

Mark, A.F. (2000). Integrating conservation with hydro-electric development of Lakes Manapouri and Te Anau, New Zealand: an exercise in complexity. *Complexity International*. www.complexity.org.au/Vol08/mark01/

Mark, A.F. & Johnson, P.N. (1985). Ecologically derived guidelines for managing two New Zealand lakes. *Environmental Management* 9(4): 355-364.

Mather, A.S. (1982). The desertification of Central Otago. *Environmental Conservation* 9(3): 209-213.

May, C. (2007). Biophysical impacts of urbanization on aquatic ecosystems, in E. Shaver, R. Horner, J. Skupien, C. May & G. Ridley (eds), *Fundamentals of Urban Runoff Management*. North American Lake Management Society (NALMS). Second Edition.

Mayer, P.M., Reynolds, S.K., McCutcheon, M.D. & Cranfield, T.J. (2007). Meta-Analysis of nitrogen removal in riparian buffers. *Journal of Environmental Quality* 39(4): 1172-1189.

Meadows, D.H., Meadows, D.I., Randers, J. & Behrens, W.W. (1972). *Limits to Growth*. A Report for The Club of Rome' project on the predicament for mankind. Universe Books. New York.

Memon, P.A. (1989). Decision making for multiple utilization of water resources in New Zealand. *Environmental Management*. 13(5): 553-562.

Merritt, R.W. & Cummins, K.W. (eds). *An Introduction to the Aquatic Insects of North America*. Third Edition. Kendall Publishing Company, Dubuque, Iowa.

Mesarovic, M. & Pestel, E. (1974). *Mankind at the Turning Point.* A Second Report for The Club of Rome. E.P. Dutton & Co. New York.

Meurk, C.D. & Swaffield, S. (2000). Integrated landscapes and farming systems. Convention On Biological Diversity CBD) Report. Ministry for Agriculture and Forestry (MAF).

Meurk, C.D. & Swaffield, S. (1998). *Prospects for a New Zealand–Aotearoa cultural landscape*. Conference on Ecological Restoration in New Zealand. Lincoln University.

Middleton, B. (2012). *Global damage and the function and distribution of wetlands.* Middleton, B. (eds). EBSCO Publishing, Massachusetts.

Miller, C. (2011). *Implementing sustainability: the New Zealand experience*. Routledge, Oxford.

Miller, L. (2013). Ecology of urban freshwater wetlands, in Paul, S. (eds). WET e-Book: *Workbook for managing urban wetlands in Australia*. http://www.sopa.nsw.gov.au/

Miller, S.J. & Wardrop, D.H. (2006). Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. *Ecological Indicators* 6:313-326.

Miller, W. & Boulton, A.J. (2005). Managing and rehabilitating ecosystem processes in regional urban streams. *Hydrobiologica* 552: 121-133.

Ministry for Agriculture and Forestry (MAF). (2008). Brief descriptions of land use capability classes in New Zealand (pertaining to Gisborne/East Coast). http://www.maf.govt.nz/forestry/east-coast-forestry/lic.htm

Ministry for Agriculture and Forestry (MAF). (2000). *Brief description of land use capability in New Zealand*. http://www.maf.govt.nz/forestry/east-coast-forestry/luc.htm

Ministry for the Environment (MfE). (2013). Resource Management Amendments 2013. http://www.mfe.govt.nz.

Ministry for the Environment (MfE). (2011a). An iwi perspective on freshwater and its management. In *Environmental Stewardship for a prosperous New Zealand*. Ministry for the Environment, Wellington.

Ministry for the Environment (MfE). (2011b). *Environmental Reporting: a Discussion Document*. Ministry for the Environment, Wellington.

Ministry for the Environment (MfE). (2011c). Resource Management Act: Survey of local authorities 2010/2011. Ministry for the Environment, Wellington.

Ministry for the Environment (MfE). (2011d). The Organochlorines Programme – Dioxins. http://www.mfe.govt.nz/issues/hazardous/contaminated/dioxins.html.

Ministry for the Environment (MfE). (2010). *Urban design*. http://www.mfe.govt.nz/publications/rma/

Ministry for the Environment (MfE). (2009). An Everyday Guide to the Resource Management Act Series 2.1: apply for resource consent. www.mfe.govt.nz

Ministry for the Environment (MfE). (2008a). *Making a submission on a proposed plan or plan change*. www.mfe.govt.nz/publications/rma/everyday/

Ministry for the Environment (MfE). (2008b). Your Guide to the Environment Court. www.mfe.govt.nz/publications/rma/everyday/

Ministry for the Environment (MfE). (2007a). Protecting Our Places: Introducing the national priorities protecting rare and threatened native biodiversity on private land. www.biodiversity.govt.nz/pdfs/

Ministry for the Environment (MfE). (2007b). *Environment New Zealand 2007*. www.mfe.govt/publications/ser/

Ministry for the Environment (MfE). (2005). *New Zealand Urban Design Protocol* .N.Z. Government, Wellington.

Ministry for the Environment (MfE). (2003). *Urban sustainability in New Zealand: an information resource for urban practitioners*. Hargreaves, R. & K. Davies (eds). Ministry for the Environment, Wellington.

Ministry of Forests and Range, British Columbia (MFR). (2008). Defining adaptive management. Retrieved from www.for.gov.bc.ca/hfp/amhome/Admin/index.htm

Mitsch, W.J. & Gosselink, J.G. (2000). The value of wetlands: importance of scale and landscape setting. *Ecological Economics* 35: 25-33.

Moser, M; Prentice, C. & Frazier, S. (1996). *A global overview of wetland loss and degradation*. www.ramsar.org/about/about-wetland_loss.htm

Moss, J.Q., Bell, G.E., Kizer, M.A., Payton, M.E., Zhang, H. & Martin, D. (2006). Reducing nutrient runoff from golf course fairways using grass buffers of multiple heights, Crop Science 46:72-80.

Munyenyembe, F.J., Harris, J., Hone,J. & Nix, H. (1989). Determinants of bird populations in an urban area. *Australian Journal of Ecology*. 14:549-557.

Myers, S.C., Clarkson, B.R., Reeves, P.N. & Clarkson, B.D. (2013). Wetland management in New Zealand: Are current approaches and policies sustaining wetland ecosystems in agricultural landscapes? *Ecological engineering.* 56:107-120.

Naiman, R.J. & Decamps, H. (1997). The Ecology of Interfaces: Riparian areas. *Annual Review of Ecology and Systematics.* 28: 621-658.

Nathan, S. (2009). Environmental activism, 1996-1987 – Conservation – a history. Te Ara Encyclopaedia of New Zealand. www.TeAra.govt.nz

National Policy Statement for indigenous Biodiversity (Proposed), (NPSIB). (2010). www.mfe.govt.nz/biodiversity

National Library. (2012). *The Gold Fields Act 1858*. www.paperspast.natlib.govt.nz

Nelson, S.M. & Andersen, D.C (1994). An assessment of riparian environmental quality by using butterflies and disturbance susceptibility score. *The Southwestern Naturalist*. 39(2): 137-142.

New Zealand Wetlands Management Policy. (1986). Department of Conservation. Wellington.

New Zealand Biodiversity Strategy. (2000). Ministry for the Environment. Wellington.

New Zealand Standards (NZS). (2010). Land development and subdivision infrastructure NZS4404: 2010. www.nzstandards.co.nz/services/publications

Nga Manu Trust (2009). Nga Manu Nature Reserve Newsletter no 7. Wellington.

Nicolet, P., Biggs, J.B., Fox, G., Hodson, M.J., Reynolds, C., Whitfield, P. & Williams, P. (2004). The wetland plant and macroinvertebrate assemblages of temporary ponds in England and Wales*. Biological Conservation*. 120: 261-278.

Niemi, G.J. & McDonald, M.E. (2004). Application of ecological indicators. *Annual Review of Ecology, Evolution and Systematics*. 35: 89-111

National Institute for Water and Atmosphere (NIWA). (2005). http://www.niwa.co.nz

Norton, D.A. (2009) Biodiversity Offsets: Two New Zealand case studies and an assessment framework. *Environmental Management* 43:698-706

Novitzki, R.F., Smith, R.D. & Fretwell, J.D. (1994). *Restoration, creation and recovery of wetlands: wetland functions, values and assessment*. United States Geological Survey Water Supply Paper 2425. National Water Summary on Wetland Resources. U.S. Geological Survey.

Novitski, R.P. (1994) EMAP-Wetlands-A program for assessing wetland condition, in Mitsch,W.J., (eds) *Global wetlands-Old World and New*. New York, Elsevier Science.

Nowak, D.J., Hoehn, R.E., Crane, D.E., Stevens, J.C. & Fisher, C.L. (2010). Assessing urban forest effects and values: Chicago's Urban Forest. Resource Bulletin. NRS-37 Newtown Square, PA: Department of Agriculture, Forest Service, Northern Research Station. USA

O'Carroll. A. (2004). Where land and water meet, in Gysbers, J.D. (eds) *An Assessment of Canada's Riparian Forest Management*. Global Forest Watch, Edmonton.

Ockland, J. (1990). The effects of acidic water on freshwater snails: results of a study of 1000 lakes and streams. *Environmental Pollution.* 78:127-130.

OECD/IUCN. (1996). Guidelines for aid agencies for improved conservation and sustainable use of tropical and sub-tropical wetlands. OECD, Paris.

Ogden J., Basher, L. & McGlone, M. (1998). Fire, forest regeneration and links with early human habitation: evidence from New Zealand. *Annals of Botany* 81: 687-696.

Ogle, C. (1991). When is dryland wetland? *Forest and Bird* 22(3): 46-49.

Olsen, E. (1987). Towards a new society. in *The Oxford History of New Zealand,* Ch.10. Oxford University Press. Auckland.

Olson, E.J., Engstrom, E.S., Doeringsfeld, M.R. & Bellig, R. (1995). Abundance and distribution of macroinvertebrates in relation to macrophyte communities in a prairie marsh, Swan Lake, Minnesota. *Journal of Freshwater Ecology* 10: 325-335.

Orr, D. (2003). *Four challenges of sustainability*. School of Natural Resources –The University of Vermont: Spring Seminar Series 2003 – Ecological Economics. www.ratical.org/co-globalize/

Ozesmi, S.L. & Bauer, M.E. (2002).Satellite remote sensing of wetlands. *Wetlands Ecology and Management.* 10(5): 381-402.

Page, M., Trustrum, N. & Gomez, B. (2008). Implications of a century of anthropogenic erosion for future land use in the Gisborne-East Coast region of New Zealand. *New Zealand Geographer* 56(2): 13-24.

Palmer, K.T. (2008). An evaluation of the ecology and riparian management of the south branch of the Whareroa Stream, Paekakariki. MApplSc Thesis. Massey University, Palmerston North.

Papas, P. (2007). *Index of Wetland Condition: Review of wetland assessment methods*. Department of Sustainability and Environment, Victorian Government, Melbourne.

Park, G. (2003). *Nga Uruora: ecology and history in a New Zealand landscape*. Victoria University Press, Wellington.

Parkyn, S. (2004). *Review of riparian buffer zone effectiveness*. MAF Technical Paper No. 2004/05. New Zealand Ministry of Agriculture and Forestry. Wellington.

Parkyn, S., Shaw,W. & Eades, P. (2000). Review of information on riparian buffer widths necessary to support sustainable vegetation and meet aquatic function. Report to Auckland Regional Council Environmental Research. NIWA, Hamilton.

Parkinson, B. & Horne, D. (2007). *Insects of New Zealand.* New Holland Publishers NZ Ltd. Auckland.

Parliamentary Counsel Office (2010) Functions of Department of Conservation. www.legislation.govt.nz/act/public/1987/

Parliamentary Commissioner for the Environment (PCE). (2012). *Water quality in New Zealand :*

Understanding the science. Office of the Parliamentary Commissioner to the Environment to Parliament. Wellington.

Parliamentary Commissioner for the Environment (PCE). (2003). *Superb or suburb: International case studies in management of icon landscapes*. Office of the New Zealand Parliament. Parliamentary Commissioner for the Environment. Wellington. www.pce.govt.nz/reports/allreports/

Parliamentary Commissioner for the Environment (PCE). (2002). *Boggy patch or ecological heritage? Valuing wetlands in Tasman*. Office of the New Zealand Parliament. Parliamentary Commissioner for the Environment, Wellington.

Parliamentary Commissioner for the Environment (PCE). (2001). *Managing change in Paradise. sustainable development in peri-urban areas.* Parliamentary Commissioner for the Environment. Wellington.

Parliamentary Commissioner for the Environment (PCE). (1992). *Local government environmental management: a study of models and outcomes*. www.pce.parliament.nz

Patten, D. (2006). Restoration of wetland and riparian systems: The role of science, adaptive management, history and values. *Journal of Contemporary Water Research & Education* 134: 9-28.

Patz, J.A., Daszak, P., Tabor, C.A., Aguirre, A.A., Pearl, M. (2004). Unhealthy landscapes: policy recommendations pertaining to land use change and disease emergence. *Environmental Health Perspectives* 112: 1092-1098.

Paul, S. (eds). (2013). 'Workbook for managing urban wetlands in Australia'. 1st edition. (Sydney Olympic Park Authority), eBook available through http://www.sopa.nsw.gov.au/education/WETeBook/

Pearce, D.W. (2001) The economic value of forest ecosystems. *Ecosystem Health* 7(4): 284-296.

Peat, N. & Patrick, B. (1999). A question of ethics. In *Wild Central*. University of Otago, Dunedin.

Peart, R. (2007) Landscape-level biodiversity protection under New Zealand's Resource Management Act 1991. Paper presented to *The Biodiversity Extinction Crisis: An Australasian and Pacific response* session at Australasian Conservation Biology Conference, Sydney.

Peng, Y. & Zhu, G. (2006). Biological nitrogen removal with nitrification and denitrification via nitrite pathway. *Applied Microbiology and Biotechnology*. Springer-Verlag on-line.

Peters, G.M. (2005). Making management recommendations from annual bird point count data. USDA Forest Service Gen. Tech. Rep. PSW-191.

Phillips J.D. (1989). An evaluation of the factors determining the effectiveness of water quality buffer zones. *Journal of Hydrology* 107: 133-146.

Phraetos Limited (2002) Te Harakeke Wetland, Kapiti Coast: Hydrological study. Final Report for Wellington Regional Council.

Pickett, S.T.A., Cadenasso, M.L. & McGrath, B. (2013). (eds). Future City. In Linking Theory and Practice for Sustainable Cities. Vol 3. Springer e-Book.

Pollock, M.M., Naiman, R.J. & Hanley, T.A. (1998). Plant species richness in riparian wetlands –

a test of biodiversity theory. *Ecology* 79(1): 94-105.

Porphyre, T., McKenzie, J. & Stevenson, M. (2007). A descriptive analysis of bovine tuberculosis in intensively controlled cattle farms in New Zealand. *Veterinary Resources* 38: 465-479.

Porter, S. (2003). *Waikanae River Ecological Report*. Opus International Consultants report for Kapiti Coast District Council. New Zealand.

Quality Planning (New Zealand). (2009). Plan development: Structuring and organising regional and district plans. www.planning.org.nz/

Quality Planning. (2008). Conditions of resource consent. www.planning.org.nz

Quality Planning. (2006a). Private Plan Changes. www.planning.org.nz/

Quality Planning. (2006b). Structure planning. Ministry for the Environment, Wellington. www.planning.org.nz/

Quality Planning. (2004). Investment certainty, environmental compliance costs and the RMA – perceptions and reality. www.planning.org.nz/

Quinn, J.M. (2003). Riparian management classification for Canterbury streams. Report prepared for Environment Canterbury. NIWA Client Report: HAM2003-064.

Quinn, J.M., Croker, G.F., Smith, B.J. & Bellingham, M.A. (2009). Integrated catchment management effects on flow, habitat, instream vegetation and macroinvertebrates in Waikato, New Zealand, hill-country streams. *New Zealand Journal of Marine and Freshwater Research* 43(3): 775-802.

Quinn, J.M., Suren, A.M. & Meurk, C.D. (2001). Riparian management classification for Canterbury streams. Hamilton, NIWA Client Report MFE01229/1

Ramsar Convention on Wetlands: Wetlands and Biological Diversity. (1996). Paper prepared on Biological Diversity, Buenos Aires, Argentina. Document UNEP/CBD/COP/3/Inf.21.

Randers, J. (2012). *2052: A global forecast for the next forty years.* Club of Rome. Chelsea Green Publishing Company, Vermont, USA.

Randerson, A. (2007). The Beginnings of the Resource Management Act. in *Beyond the RMA: An in depth exploration of the Resource Management Act 1991*: Ch 6. Conference Proceedings, May 2007, Auckland. Environmental Defence Society.

Ravine, D.A. (1992**).** Survey Report for Protected Natural Areas Programme*. New Zealand Protected Natural Areas Programme No 19*. Department of Conservation, Wellington.

Ravit, B., Obropta, C. & Kallin, P. (2008). A baseline characterization approach to wetland enhancement in an urban watershed. *Urban Habitats* 5(1): 126-138.

Reiss, K.C. (2006). Florida Wetland Condition Index for depressional forested wetlands. *Ecological Indicators* 6: 337-352.

Richardson, J.L. & Vepraskas, M.J. (2001). *Wetland soils: genesis, hydrology, landscapes and classification.* Boca Raton, London.

Resource Management Act (RMA). (1991). New Zealand Legislation, New Zealand Government. www.legislation.govt.nz/act/public/1991/

Roberson, E. (2002). *Economy vs. the Environment: Fact or Fiction*. Native Plant Conservation Campaign, California Native Plant Society, Center for Biological Diversity, Sacramento, California.

Robertson, B. & Stevens, L. (2007). Kapiti, Southwest, South Coasts and Wellington Harbour: Risk Assessment and Monitoring Recommendations. Prepared for Wellington Regional Council.

Rowe, D.K., Parkyn, S., Quinn, J., Collier, K., Joy, M.K., Maxted, J. & Moore, S. (2008). A rapid method to score stream reaches based on the overall performance of their main ecological function. *Environmental Management* 43:1287-1300.

Rowe, D.K Quinn, J.F., Collier, K., Hatton, C., Joy, M.K., Maxted, J., Moore, S.J., & Parkyn, S. (2005). Ecological valuation: a method for scoring the ecological performance of perennial Auckland streams, Rep. No. HAM2004- 073. NIWA, Hamilton.

Russell, E.W.B. (1997). *People and the land through time: Linking ecology and history*. New Haven. Yale University Press.

Russell, E.W.B (1993). Discovery of the Subtle, in McDonnell, M.J. & S.T.A. Pickett, (eds), *Humans as parameters of ecosystems: The Ecology of Subtle Human Effects and Populated Areas*, Springer-Verlag, New York.

Russell McVeagh (2005). Legal mechanisms to control future subdivision. Appendix 3. In R. Peart (eds), *Landscape Planning Guide for Peri-urban and Rural Areas*. Environmental Defence Society. Auckland.

Rutherford, J.C., Schroer, D. & Timpany, G. (2009). How much runoff do riparian wetlands affect? *New Zealand Journal of Marine and Freshwater Research* 43(5): 1079-1094

Sandhu, H.S., Wratten, S.D. & Cullen, R. (2010). The role of supporting ecosystem services in conventional and organic arable farmland. *Ecological Complexity* 7:302-310.

Sandhu, H.S., Wratten, S.D.. Cullen, R. & Case, B. (2007). The future of farming : the value of ecosystem services in conventional and organic arable land. An experimental approach. *Ecological Economics* 64: 835-848.

Santa Cruz Country. (2012). *Riparian Corridors and Required Setbacks*. County of Santa Cruz, California. www.co.santa-cruz.ca.us

Schrader,B. (2005). *We call it home – A history of State Housing in New Zealand*. Raupo Publishing (NZ) Ltd. Wellington.

Sears, A.R. & Anderson, S.H. (1991). Correlation between birds and vegetation in Cheyenne, Wyoming. Pages 75–80, in Adam LW, & K.L. Leedy (eds). *Wildlife Conservation in Metropolitan Environments*. Columbia (MD): National Institute for Urban Wildlife.

Semlitch, R.D. & Bodie, J.R. (2003). Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology*. 17(5): 1219.

Semlitsch, R.D. & Jensen, J.B. (2001). Core Habitat, Not Buffer Zone. *National Wetlands Newsletter* 23(4): 5-11

Shepherd, A & Ortolano, L. (1996). Strategic environmental assessment for sustainable urban development. *Environmental Impact Assessment Review: Managing Urban Sustainability* 16(4-6): 321-335.

Sherratt, S. & Sherratt, A. (1993). The growth of the Mediterranean economy in the first millennium BC. *World Archaeology* 24(3): 361-374.

Simmons, I.G. (1993). Human Societies and Environmental Change: The Long View, in R. Johnston (eds), *The Challenge for Geography*. Blackwell, Oxford.

Sims, M. & Thompson-Fawcett, M. (2002). Planning for the cultural landscape, in M. Kawharu (eds), *Whenua: Managing Our Resources*. Reed Books, NZ.

SKM & Maypole Environment Ltd (2008). Ngarara: Sharing the Spirit of Beach and Countryside. Ngarara-PC 80. www.ngarara.com

Smith, B.J. (2003). NIWA Quick Guide to MCI EPT.

Smith, I. (2008). Maori, Pakeha and Kiwi: Peoples, cultures and sequence in New Zealand archaeology. www.epress.anu.edu.au/terra_australis/ta29/pdf/ch23.pdf

Snelder, T., Biggs, B. & Weatherhead, M. (2004). *New Zealand River Environment Classification User Guide.* NIWA and Ministry for the Environment, Wellington.

Snelder, T. & Biggs, B. (2002). Multiscale River Environment Classification for Water Resources Management. *Journal of the American Water Resources Association* 38(5):1225-1239.

Spencer, C., Robertson, A. & Curtis, A. (1993). Environmental Monitoring Assessment Program (EMAP). *Journal of Environmental Management.* 54(2): 143-156.

Spodek, H. (2000). *The World's History, Vol 1: to 1500BCE*. Prentice Hall, Upper Saddle River, New Jersey.

Stankey, G.H., Clark, R.N. & Bormann, T. (2005). Adaptive management of natural resources: theory, concepts and management institutions. Department of Agriculture. General Technical Report PNW-GTR-654. Portland, Oregon.

Staples, A. (2008). Conflict in Paradise – Where do we want to go? A Local Government Perspective – Rural Subdivision, in *Proceedings of Environmental Defence Society Conference*. Auckland.

Star, P. & Lochhead, L. (2002). Children of the burnt bush: New Zealanders and indigenous remnant. In E. Pawson & T. Brooking (eds), Ch 8, *Environmental Histories of New Zealand*. Oxford University Press, Melbourne.

Stark, J.D., Boothroyd, I.K.G., Harding, J.S., Maxted, J.R. & Scarsbrook, M.R. (2001). *Protocols for sampling macroinvertebrates in wadeable streams*. Prepared for the Ministry for the Environment: Sustainable Management Fund Project No 5103.

Statistics NZ (2008). New Zealand: An Urban/rural Profile. www.stats.govt.nz/urban-rural-profiles/defining-urban-rural-nz

Statistics New Zealand (2006). New Zealand: an urban/rural profile www.stats.govt.nz/urban-rural-profiles/

Stauffer, R.C. (1957). Haeckel, Darwin and Ecology. *The Quarterly Review of Biology* 31(2): 138-144.

Stein, E.D., Brinson, M., Kleindl, R.W. & Hauer, R. (2009). Wetland assessment debate. *Wetland Science and Practice*. 26(4): 20-24.

Steel, C. (2009). City, Sitopia. *Ecologist* 39(5): 19-211.

Stephenson, J. (2007). The cultural values model: an integrated approach to values in landscapes*. Landscape and Urban Planning* 84: 127-139.

Stevens, G.R. (1988*). Rugged Landscape; The geology of Central New Zealand, including Wellington, Wairarapa, Manawatu and the Marlborough Sounds*. A.H. & A.W. Reed, Wellington.

Stokes, E. (2002). Contesting resources: Maori, Pakeha, and a Tenurial Revolution. In E. Pawson & T. Brooking (eds), Ch 3, *Environmental Histories of New Zealand*. Oxford University Press, Melbourne.

Stone, D. (1996). Wetlands and biological diversity. Paper prepared by Ramsar Convention Bureau for distribution to delegates to the Third Meeting of the Conference of Parties to the Convention on Biological Diversity, Buenos Aires, Argentina. October 1996.

Straker, G., Kerr, S. & Hendry, J. (2002). A regulatory history of New Zealand's quota management system. MOTU: Economic and Public Policy Research. www.motu.org.nz

Stromberg, J.C., Beauchamp, V.B., Dixon, M.D., Lite, S.J. & Paradzick, C. (2007). Importance of low-flow and high-flow characteristics to restoration of riparian vegetation along rivers in the arid south-western United States. *Freshwater Biology*. 52: 651-679.

Suren, A.M. (2000). Effects of urbanization, in *New Zealand Stream Invertebrates: Ecology and Implications for Management*. Collier, K.J. & M.J. Winterbourn, (eds). New Zealand Limnological Society, Hamilton. 260-288.

Suren, A.M., Kilroy, C., Lambert, P., Wech, J. & Sorrell, B. (2011). Are landscape-based wetland condition indices reflected by invertebrate and diatom communities? *Wetlands Ecological Management.* 19: 73-88.

Suren, A. & Sorrell, B. (2010). Aquatic invertebrate communities of lowland wetlands in New Zealand. *Science for Conservation 305*.

Suren, A., Stark, J., Wech, J. & Lambert, P. (2010). Development of a South Island Wetland Macroinvertebrate Community Index Score. NIWA Client Report: CHC2010-080.

Suren, A., Lambert, P., Image, K. & Sorrell, B.K. (2008). Variation in wetland invertebrate communities in lowland acidic fens and swamps. *Freshwater Biology* 53(4): 727-744.

Sutula, M., Brown, J., Fetscher, E., Mattson, M., Madon, S., Santolo, G., Byron, E. & Stransky, C. (2008). *Habitat value and treatment effectiveness of freshwater urban wetlands*. Technical Report 559. Los Angeles Regional Water Quality Control Board for the Assessment of Effectiveness of Treatment Wetlands for Stormwater BMPs and Compatibility with Wildlife Beneficial Uses. Agreement No 04-090-554-0.

Sutula, M.A., Sutula, E.D., Stein, J.H., Collins, A.E. & Fetscher, R.C. (2006). Practical Guide for the development of a wetland assessment method: the Californian experience. *Journal of the American Water Resources Association* 42(1): 157-175.

Swaffield, S. (2008). Sustaining the Country: Ideals, opportunities and imperatives for future Rural landscapes, in *Proceedings of Environmental Defence Society Conference*, *June 2008*, Auckland.

Swift, B.L. (1984). Status of Riparian Ecosystems in the United States. *Water Resources Bulletin*, Paper No 84007, American Water Resources Association 20 (2): 223-228.

Tabarelli, M., Cardosa da Silva, J.M. & Gascon, C. (2004). Forest fragmentation, synergisms and the impoverishment of neotropical forests. *Biodiversity and Conservation*. 13: 1419-1425.

Tapsuwan, S., Ingram, G. & Brennan, D. (2009). Capitalized amenity value of urban wetlands: a hedonic property price approach to urban wetlands in Perth. Australian Journal of Agriculture and Resource Economics. 53(4):537-545.

Taranaki Regional Council. (2010). Agenda for the meeting of the Policy and Planning Committee of the Taranaki Regional Council to be held in the Taranaki Regional Council Chambers on Thursday 2 September 2010: Item 5: Update on Wetland Macroinvertebrate Community Index. Document: 792612. New Plymouth.

Te Ara: The Encyclopaedia of New Zealand. (2011). Wellington. www.TeAra.govt.nz/

Technical Advisory Group (TAG). (2009). Report of the Minister for the Environment's Technical Advisory Group. Ministry for the Environment. Wellington.

Tellis, W. (1997). Application of a Case Study Methodology. *The Qualitative Report*, 3(3). On-line: www.nova.edu/sss/QR

The Reserve Bank. (2007). The Reserve Bank and New Zealand's Economic History. NZ Government, Wellington. www.rbnz.govt.nz/publications

Thiesing, M. (2001). *An Evaluation of wetland assessment techniques and their applications to decision making*. In Proceedings of Workshop 4, 2nd International Conference on Wetlands and Development, Dakar, Senegal.1998, in Finlayson, C.M., Davidson, N.C. & N.J. Stevenson (eds).US Environment Protection Agency. New York.

Thompson, K. (2012). *Hydrological assessments of ten wetlands in the Wellington region and recommendations for sustainable management: a holistic approach*. Te Hapua wetlands. Prepared for the Greater Wellington Regional Council, Wellington.

Thompson, R.M. & Townsend, C.R. (2000). New Zealand stream invertebrates communities: an international perspective. In Ch.2. in Collier, K.J. and Winterbourn, M.J. (eds), New Zealand stream invertebrates: ecology. and implications for management. New Zealand Limnologi al Society, Christchurch.

2.2Tilling, A.J. (1992). Indigenous forest management in New Zealand: From interventionist to monetarist policies and the special case of the South Island's West Coast. *N.Z. Forestry* 35: 8-13.

Tidswell, S., Annear, L., & Lee, E. (2010). *Annual groundwater monitoring report for the Wellington region, 2009/10.* Greater Wellington Regional Council, Report GW/EMI-G-10/162.

Tilman, D. (1999). The ecological consequences of changes in biodiversity: a search for general principles. The Robert H. MacArthur Award Lecture. Ecology 80:1455-1474.

Tilman, D. (1982). Resource competition and community structure. Princeton University Press. Princeton, New Jersey.

Tiner, R. (2005). Assessing cumulative loss of wetland functions in the Nanticoke River watershed using enhanced National Wetlands Inventory data. *Wetlands* 25(2): 405-419.

Tiner, R. (2000). *Valuable Vanishing Urban Wetlands*. Staten Island Wetlands, New York.

Turner, B.L. & Meyer, W.B. (1993). Environmental Change: The Human Factor, in McDonnell, M.J. & T.A. Pickett, (eds). *Humans as Parameters of Ecosystems: The Ecology of Subtle Human Effects and Populated Areas*. Ch 4. Springer-Verlag, New York.

United Nations Conference on Environment and Development (UNCED). (1992). Rio de Janeiro.

United Nations Environment Programme (UNEP). (1972). www.unep.org/Documents.Multilingual/

United Nations Framework Convention on Climate Change (UNFCCC). (2011). www.unfccc.int/documentation/items/2643.php

Urban Services (1998). Water Resources Act 1998 ACT: Design Standards for Urban Infrastructure www.tams.act.gov.au/data/assets/pdf

United States Environmental Protection Agency (USEPA). (2012). *Water: Monitoring and Assessment: Water quality conditions.* http://www.epa.gov/water/

United States Environmental Protection Agency (USEPA). (2010). Memorandum of Agreement between The Department of the Army and The Environmental Protection Agency. http://www.epa.gov/lawsregs/water/

United States Environmental Protection Agency (USEPA). (2008). *Polluted runoff (Nonpoint source pollution): Management measures for wetlands.* http://www.epa.gov/owow/nps/MMG/Chapter7/

United States Environmental Protection Agency. (2002). Methods for evaluating wetland condition: vegetation-based indicators for nutrients.

United States Environmental Protection Agency. (2002). Methods for evaluating wetland condition: using vegetation to assess environmental conditions of wetlands. http://www.epa.gov/waterscience/criteria/wetlands/

United States Environmental Protection Agency. (2002). Nitrification. Document prepared by AWWA with assistance from Economic and Engineering Services, Inc. Washington DC. http://www.epa.gov/safewater/disinfection/tcr/regulation_revisions.html

Urlich, S.C. & Brady, P.J. (2005). Benefits of aerial 1080 possum control to tree fuchsia in the Tararua Range, Wellington. *New Zealand Journal of Ecology* 29(2): 299-309.

Valentine, I., Hurley, E., Reid, J. & Allen, W. (2007). Principles and processes for affecting change in environmental management in New Zealand. *Journal of Environmental Management.* 62(3): 311-318.

van de Ree, R. & McCarthy, M.A. (2005). Inferring persistence of indigenous mammals in response to urbanisation. *Animal Conservation* 8: 309-319

van Roon, M. & Knight, S. (2004). *Ecological Context of Development: New Zealand Perspectives*. Oxford University Press, Auckland.

van Roon, M. & van Roon, H. (2005). Low impact Urban Design and Development Principles for Assessment of Planning, Policy and Development Outcomes. Working paper 051 for the Centre for Urban Ecosystem Sustainability, University of Auckland, Auckland.

Verhoeven, J.T.A., Arheimer, B., Yin, C. & Hefting, M.M. (2006). Regional and global concerns over wetlands and water quality. *Trends in Ecology and Evolution* 21(2): 96-103

Vidal, J. (2002) Ten years on-slow progress on sustainable development. *The Lancet.* 360 (9335): 737

Vitousek, P.M. & Mooney, H.A. (1998). Human Domination of Earth's Ecosystems. *Science*

277(5325): 494-499

Waikato Regional Council. (2013). *The Evolution of 'Natural Character' into New Zealand Planning Law and Policy: The early 1970s – a time for Reform:1.2.3 Enactment of 'Natural Character' into the Town and Country Planning Act 1953*. Hamilton. www.waikatoregion.govt.nz/Environment

Walker, S., Price, R., Rutledge, D. Stephens, R.T.T. & Lee, W.G. (2006). Recent loss of indigenous cover in New Zealand. *New Zealand Journal of Ecology* 30(2): 169-177.

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M. & Morgan, R.P. (2005). *Journal of the North American Benthological Society*, 24(3): 706-723.

Wardrop, D.H., Kentula, M.E., Stevens, D.L., Jensen, S.F. & Brooks, R.P. (2007). Assessment of wetland condition: an example from the upper Juniata watershed in Pennsylvania, USA. *Wetlands*. 27(3): 416-431.

Watts, L.F.& Hawke, R.M. (2003). The effects of urbanisation on hydrologic response: a study of two coastal catchments. *Journal of Hydrology (NZ*) 42(2): 125-143.

Wellington City Council (WCC). (2008). Council Decision on Proposed District Plan Change 61. November 2008. www.wcc.govt.nz

Wellington City Council. (2007). Biodiversity Action Plan, Wellington. www.wcc.govt.nz/

Wellington City Council WCC. (2006). Draft Northern Reserves Management Plan. Wellington. www.wcc.govt.nz

Wheen, N. (2004). A History of New Zealand Environmental Law, in E. Pawson & T. Brooking (eds), Ch 17, *Environmental Histories of New Zealand.* Oxford. University Press, Australia.

Whigham, D.F., Jacobs, A.D., Weller, D.E., Jordan, T.E. Kentula, M.E., Jensen, S.F. & Stevens, D.F. (2007). Combining HGM and EMAP procedures to assess wetlands at the watershed scale – status of flats and non-tidal riverine wetlands in the Nantichoke River watershed, Delaware and Maryland (USA). *Wetlands* 27(3): 462-478.

Wigglesworth, R.P. (1981). The New Zealand Timber and Flax Trade 1769-1840. PhD Thesis, Massey University, Palmerston North.

Willems, H.P.L., Rotelli, M.D., Berry, D.F., Smith, E.P., Reneau, R.B. & Mostaghimi, S.(1997). Nitrate removal in riparian soils: Effects of flow rate, temperature, nitrate concentration and soil depth. *Water Resources* 31(4): 841-849.

Wildlands Consultants (2003). Kapiti Coast District Council, 2002-2003 Ecological Sites Survey. Contract Report No 662.

Williams, N.S.G., McDonnell, M.J. & Seager, E.J. (2005a). Factors influencing the loss of an endangered ecosystem in an urbanising landscape: a case study of native grasslands from Melbourne, Australia. *Landscape and Urban Planning* 71: 35-49

Williams, S.G., Morgan, J.W., McDonnell, M.J. & McCarthy M.A. (2005b). Plant traits and local extinctions in natural grasslands along an urban-rural gradient. *Journal of Ecology* 93:1203-1213.

Wilson, R. (1982). *From Manapouri to Aramoana: The Battle for New Zealand's environment.* Earthworks Press, Auckland.

WCED (World Commission on Environment and Development) (1987) *Our Common Future:*

The Report of the World Commission on Environment and Development. Towards Sustainable Development. Report of United Nations Commission chaired by Gro Harlem Brundtland. Oxford University Press, Oxford.

Winterbourn, M.J., Gregson, K.L.D. & Dolphin, C.H. (2000). Guide to the Aquatic Insects of New Zealand. *Bulletin of the Entomological of New Zealand*.

World Bank, The Nature Conservancy & IUCN-The World Conservation Union. (2004). How much is an Ecosystem Worth? Assessing the Economic Value of Conservation. The World Bank, Washington DC.

Wratten, S., Sandhu, H., Cullen, R. & Costanza, R. (2013). *Ecosystem Services in Agriculture and Urban Landscapes.* John Wiley and Sons Ltd, West Sussex, UK.

Wright, I. A., Davies, P., Wilks, D., Findlay, S., & Taylor, M. P. (2007). Aquatic macroinvertebrates in urban waterways: comparing ecosystem health in natural reference and urban streams, In *Proceedings of the 5th Australian Stream Management Conference. Australian rivers: making a difference* (eds) Wilson,A.L., Dehaan, R.L., Watts, R.J., Page,K.J., Bowmer, K.H., and Curtis. A. pp. 467–472. (Charles Sturt University: Thurgoona, NSW).

Wright, R. (2004) A *Short History of progress*. House of Anasi Press Inc, Toronto, Canada.

Wurts, W.A. (2003). Daily pH cycle and ammonia toxicity. *World Aquaculture*. 34(2): 20-21.

Wynn, G. (2002) Destruction under the guise of improvement?: The Forest 1840-1920 in E. Pawson & T. Brooking (eds), Ch 7, *Environmental Histories of New Zealand.* Oxford University Press, Melbourne.

Yin, R.K. (2009) *Case Study Research: Design and Methods*. 4th Edition. California.

Young, D. (2007) *Keeper of the Long View: Sustainability and the PCE*. Office of Parliamentary Commissioner for the Environment.

APPENDIX 1

Background information about the study sites

This appendix provides further background details for the eight wetlands presented in chapter five, including information on the flora and fauna found in previous studies.

Te Hapua Shoveler Lagoon (~0.3ha)

Map ref: 604162.442 2685082.222

Te Hapua Wetland Lagoons comprise several ponds within extensive flaxlands. The wetlands are partially protected by a QE 2 Covenant and are listed by the Wellington Regional Council as sites of Regional Ecological Importance. Shoveler Lagoon is one of these interdune ponds on private land. It was deepened about 20 years ago to maximum depths of 3-5m. It is dependent on groundwater and rainwater to maintain water levels that have considerable seasonal variation in water depth. The Wellington Regional Council has a monitoring station at Shoveler Lagoon that includes a bore to a depth of 60m to obtain information about the deep aquifer water levels and fluctuations. It also measures rainfall and groundwater levels (GWRC, 2010).

In a review of the ecological significance of the Te Hapua Lagoons (Enright *et al.* 2001), it was reported that the lagoons and their surrounding flaxlands provided a habitat for spotless crake (*Porzana tabuensis*), Australasian bittern (*Botaurus poiciloptilus*), Shoveler ducks (*Anas rhynchotis*), mallard and grey ducks, pukeko (*Porphyrio porphyrio*) and paradise shelducks (*Tadorna variegata*). They contained plants that were uncommon in the Wellington region including *Ranunculus macrocarpus* (swamp buttercup), *Carex dipsacea, Potentilla anserinioides* (silverweed)*, Gratiola sexdenta, Baumea articulata* (jointed twig rush) and *Schoeneplectus validus* (kapungawha or lake clubrush).

Nga Manu Nature Reserve Top Pond, Waikanae (~0.3ha)

Map ref: 6036158.909 2683464.503

The Nga Manu Nature Reserve was purchased by Peter McKenzie in 1974 from the neighbouring Ngarara Farm. In 1987 it was vested in the Nga Manu Trust which continues to administer it. The Nga Manu 'Top Pond' is centred in a remnant of coastal lowland swamp forest and lies in swales between consolidated sand dunes. It has a depth of more than 3m in its centre. It is within the Nga Manu Nature Reserve is registered as area of Regional Ecological Significance (KCDC 2003). It is sustained by groundwater emanating from the Ngarara Stream and its tributaries. Among the swamp forest trees are 300-400 year old kahikatea (*Dacrycarpus dacrydioides*), pukatea (*Laurelia novae-zealandiae*), swamp maire (*Syzygium maire*)*,* rimu (*Dacrydium cupressinum*) and tree ferns. The swampy areas support flax, toetoe, reeds, raupo and *Carex spp*. (Nga Manu Trust, 2009).

Long fin eels (*Anguilla dieffenbachia*) and brown mudfish (*Neochanna apoda*) have been found in or near this pond. Both fish are endemic threatened species (Nga Manu Trust 2009). A large variety of native birds including kereru (*Hemiphaga novaeseelandiae*), kaka (*Nestor meridionalis*), kakariki (*Cyanoramphus novaezelandiae*), ruru (*Ninox novaeseelandiae*), bellbirds (*Anthornis melanura*), tui (*Proethemadera novaeseelandiae),* pukeko and paradise shelducks use the sanctuary for breeding or as a passage to and from Kapiti Island and the Tararua Range (Nga Manu Trust 2009). Town birds also use the trees for food and breeding.

Waimeha Lagoon, Waikanae (5.32ha)

Map ref: 6035800.414 2680173.144

The Waimeha Lagoon and the adjacent Waimanu Lagoons are remnants of the Waimeha River which originally divided from the Waikanae River as it entered the floodplain. While the Waikanae River continued southwest across the floodplain, the Waimeha River flowed northwest to the coast where it was contained by foredunes up to 10m high. It then turned south to re-enter the Waikanae River near its estuary. By the 1890s the river had disappeared to be replaced by the Waimeha Stream that originated from the river terraces near the present Waikanae Village (MacLean & MacLean 1988). The Waimeha River was shown on maps from 1872 but had disappeared by 1896**.**

In the 1920s a channel was cut through the foredunes for the exit of the Ngarara Stream from the north and the Waimeha Stream from the south. In the 1970s, lagoons were developed in the swamps east of the dunes. At the south end of the swamp, the Waimanu Lagoons were opened to the Waikanae River estuary and are saline. The northern Waimeha Lagoon was dredged in 1981 and contains freshwater. A narrow piped channel connects the lagoons. Since the 1970s, there has been on-going restoration of the wetland riparian area with flaxes, toetoe, sedges and reeds. Small trees and shrubs are also present including karamu (*Coprosma robusta*), raupo and reeds (KCDC, 2003). A boardwalk crosses the wetland area at the southern end of the lagoon and there is a bird watching hide at the north-eastern end. Australasian bittern (*B. poiciloptilus*) and Royal spoonbills (*Platalea regia*) have been reported as well as mallard and shoveler ducks **(**Wildlands, 2003). At the north end, several small stormwater drains enter the lagoon.

Lake Ngarara, Kotuku Park, Paraparaumu (~4ha)

Map ref: 6032710.884 2678877.038

Lake Ngarara is an interdune wetland at the eastern end of the Waikanae Estuary Scientific Reserve and forms the western boundary for the Kotuku Park subdivision. It is a remnant freshwater lagoon. It is mainly groundwater and rainwater fed and but also receives overflow stormwater from a detention pond and Lake Kotuku further east. It has a variable depth from 5m at the western edge to 600mm at the eastern side. There is a seasonal water level variation of 500mm (Boffa Miskell 2004). The Kotuku Park subdivision has proceeded in stages since 1988 with the continual destruction of sand dunes to ensure flat land for housing and at a level above 100yr flood hazard level. Lake Ngarara has small culvert bridge at the northern corner separating the main body of water from a smaller pond that is overgrown with blackberry and scrub.

In 2004, Boffa Miskell Ltd recommended that there should be dense riparian planting to ensure maximum removal of pollutants (Boffa Miskell, 2004). However, only patches of riparian flora have been planted around the lake margin interspaced with mown grass. These include flaxes, toetoe, reeds and sedges, with some shrubs and small trees such as ngaio (*Myoporum laetum*), kowhai (*Sophora microphylla*), karamu, cabbage trees (*Cordyline australis*) and hebes. Algal blooms have occurred during hot summers (O'Brien 2010, pers. comm.). The lake is used by a variety of waterfowl, native and introduced.

Tower Lake No 1, Langdale Avenue, Paraparaumu (0.57ha)

Map ref: 6034294.017 2679104.327

The Tower Lakes were formed in the mid-1980s as part of a subdivision from Kapiti Road along Langdale Avenue, Paraparaumu. They were developed in a swale at water table level between consolidated sand dunes that were flattened for housing. Their names reflected the presence of the airport control tower directly across Kapiti Road from them. The three lakes connect via culverts beneath Langdale Avenue. Any overflow reaching the third and largest lake discharges via drains and culverts to ponds and wet areas between Campbell Road and Langdale Avenue. The drains extend to the amenity lake at Summerset Retirement Village and then the water drains into the Mazengarb Stream.

Tower Lakes No 2 and No 3 are owned by the properties that border them. An absentee landlord owns Tower Lake No 1. The land beneath the Tower Lake No 1 has a QV of $145,000 and is for sale. The lake is bounded on 2 sides by private properties, the other 2 sides are owned by KCDC. In 2011 resource consent was sought to build a small residence out over the water. Although Tower Lake was once considered as a local Ecological Site of Importance, that classification has now been withdrawn from that list (KCDC, 2003**).** The resource consent was denied.

Tower Lake No 1 is reliant on rainwater and, since 1994, also on water from a 60m deep bore. The flow from the bore is 50,000 litres per hour and it runs for 4-5 hours most days in the summer and less often in the winter to maintain water levels at the culvert outlet level (Phillips 2010, pers. comm.). In 1991 it was proposed that Tower No 1 be a stormwater storage pond but this was not implemented. The pond hosts variety of waterfowl including mallard ducks, pukeko, paradise shelducks and black swans. Small, unidentified fish have been found in the lake. The riparian area has been planted for several decades with willows and a few toetoes, flaxes and a pohutukawa at the southern end. The private gardens at the north and eastern sides include willows, raupo and canna lilies at the pond edge. There have been no reports of algal blooms but neighbours believe that pondweeds are spreading (Phillips 2010, pers. comm.). Mown grass extends to the water edge on KCDC area. Since 1994 the pond has been used as a public area for feeding ducks from a small constructed peninsula.

Midlands Gardens Retirement Village North Lake, Paraparaumu (~0.3ha)

Map ref: 6038856.220 2678010.916

Midland Gardens Retirement Village North Lake is at the east end of the Paraparaumu Airport. It is part of a privately owned six-lake complex developed in a sandy scrub area of the floodplain of the Wharemauku Stream and an adjacent tributary. The lake was deepened below the water table and the fill used to form an island in the middle. A levee separates the lake from the streambed of a tributary of the Wharemauku Stream. The riparian area has patches of flaxes, toetoe, *Carex sp.*, rushes and reeds as well as willows and exotic trees around it with large lawn areas between patches. Most of the lake is accessible via a perimeter path along mown grassy banks. The central island has blackberry, willows, *Carex s*p, toetoe and kowhai. The lake depends mainly on groundwater and rainwater but a small amount of stormwater from the village flows into it. Water plants include Mercer grass (*Paspalum paspalodes*), pondweed (*Potamogeton spp*) and *Myriophyllum aquaticum*. Waterfowl including mallard ducks, Canada geese, and pukeko use the lake (Kapiti Retirement Trust, 2010).

Lake Kotuku, Paraparaumu (0.4ha)

Map ref: 6034274.404 2679071.561

This constructed stormwater collection pond for the Kotuku Park subdivision, Paraparaumu, was formed in 1991. It was designed to receive water from the adjacent floodable rural land of the Mazengarb Stream catchment and some stormwater runoff from the neighbouring residential area. It is a sandy basin with the lake floor near the water table. Apart from floodwater and stormwater inputs it is also aquifer fed. It has a capacity of 7600m^3 and a depth of 1.4m. The stormwater is filtered and subjected to sunlight before it is flows west through a culvert to a detention pond and thence into Lake Ngarara. The intention is that the water will be filtered of toxins and sediment before it reaches the wetlands and salt marshes of the Waikanae Scientific Reserve (Boffa Miskell, 1999). Neighbouring properties extend to the water's edge but the lake is monitored by KCDC.

The riparian areas have been planted with native trees by developers of Kotuku Park Limited . As pond water levels are dependent on stormwater, rainfall and evapo-transpiration the lake has had a tendency to eutrophication and large algal blooms in warm weather have been noted. Swathes of lake clubrush (*Schoenoplectus validus*), raupo and *Isolepis* are found at the water edge (KCDC, 1998**)**.

Ferndale subdivision, Ngarara Road, Waikanae (small)[33]

Map ref: 6035912.031 2682702 602

[33] Wetland sizes (***Duguid et al, 2005***): very large =10km^2 (1000ha); large = 1km^2 (100ha); medium = 0.5km^2 (50ha); small = 0.1km^2 (10ha); very small <0.1$km^{2.}$ (<10ha)

Ferndale subdivision is a residential development of 15ha on two consolidated sand dunes in a north-south orientation with swales between them. Building of residences has been slow due to economic downturn and the cost of the houses. There is no natural wetland area but a constructed stormwater collection pond has been developed at the water table in a boggy paddock. A small stream enters the pond from the east. The pond discharges westward via a small stream to a swale soak pit.

The catchment areas for stormwater are small with limited impervious surfaces – no more than 40% of any property. There are filters for stormwater at the roadside. These filters are rock lined over filter fabric to ensure that no sediment flows into the stormwater collection pipes (Connell Wagner, 2007). The swales' detention areas are vegetated with grasses and sedges. Each property in the subdivision also has a soak pit. All the stormwater discharges are required to meet the standard of the Regional Freshwater Plan and the Greater Wellington Regional Discharges to Land Plan. A planted riparian area surrounds the pond area. There is a small levee around the pond between it and a boggy paddock to the north. The water levels are determined by the weather and stormwater flow. Waterfowl including mallard ducks, paradise shelducks and Canada geese have been seen (Ferndale Trust, pers. comm. 2009).

APPENDIX 2

Protocol for sampling aquatic macroinvertebrates.

This Protocol was followed during the investigation of the ecology of the urban wetlands. As discussed in chapter 5 this Protocol is designed for soft-bottomed streams but there are no protocols yet developed for wetlands. Suren & Sorrell (2010), in their study of wetlands on the South Island west coast, found that it was a satisfactory ecological study in a wetland.

Protocol C2: Soft-bottomed, Semi-quantitative.

(Stark, J. D.; Boothroyd, I. K. G; Harding, J. S.; Maxted, J. R.; Scarsbrook, M. R. 2001: Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for Ministry for the Environment. Sustainable Management Fund Project No. 5103, 57p).

Requirements:

1.Waders (chest)
2. D-net (0.5 mm mesh)
3. White tray or bucket
4. Sieve or sieve bucket (0.5 mm mesh)
5. Plastic screw-top sample containers (600-1000 ml volume)
6. Fine tweezers
7. Preservative
8. Labels and waterproof marker pen (or pencil).

1. Ensure that the sampling net and bucket are clean.

2. Sample a unit effort (0.3 m^2) of woody debris, bank margins, or aquatic macrophytes using the following procedures. Avoid dredging the net along the bottom in mud or sand, and avoid leaves and algae if possible. Avoid hard (stony) substrates (or sample them separately using Protocol C1).

Woody Debris – Select submerged and partially decayed woody debris (50-250 mm diameter preferred). Place over the mouth of the bucket or sieve bucket. Pour water over the substrate while brushing the substrate gently by hand to remove organisms. Larger pieces may be sampled in situ by brushing the log while holding the net directly behind it. Each 1-metre section of woody debris has a sample area of about 0.3 m^2.

Bank Margins – Locate an area of bank with good structure and aggressively jab the net into the bank for a distance of 1-metre to dislodge organisms, followed by 2-3 cleaning sweeps to collect organisms in the water column. Each sample unit is about 0.3 m^2.

Macrophytes – Sweep the net through macrophyte beds for a distance of 1-metre to dislodge organisms, followed by 2-3 cleaning sweeps to collect organisms in the water column. Each sample unit is about 0.3 m^2.

3. Repeat Step 2 at 10 locations while moving progressively upstream. Remove sample material to a bucket or sieve bucket after each collection to avoid clogging the net. Select substrates to be sampled in proportion to their prevalence along a 50 - 100 m reach of stream. Record the reach length and the proportion of the sample taken from each substrate type (e.g., 50% wood, 25% banks, 25% macrophytes). After the 10th unit effort, wash or pick all animals off the net. The bucket or sieve bucket should now contain one entire sample comprising material dislodged from 3 m2 of substrate.

4. Fill the bucket with water and rinse and remove any unwanted large debris items (e.g., sticks, leaves) that may not fit into the sample container or will absorb and diminish the effectiveness of the preservative.

5. Transfer the sample to the sample container via a 0.5 mm sieve if a sieve bucket is not used. Two containers may be needed; each container should be no more than 2/3 full with sample material. Inspect the sieve or sieve bucket and return any macroinvertebrates to the sample container. (Tweezers may be useful here).

6. Add preservative. Aim for a preservative concentration in the sample container of 70-80% (i.e., allowing for the water already present). Be generous with preservative for samples containing plant material (leaves, fine detritus, algae, moss, and macrophytes).

7. Place a sticky label on the side of the sample container and record the site code/name, date, and replicate number (if applicable) using a permanent marker. Write on the label when it is dry and do not rely on a label on the pottle lid! Place a waterproof label inside the container. Screw the lid on tightly.

8. Note the sample type (e.g., D-net), collector's name and preservative used on the field data sheet.

9. Record notes on the field data sheet describing the proportion of habitat units sampled (e.g., 4/5/1, woody debris/bank margins/macrophytes). Also describe on the field sheet the condition of the substrates sampled (woody debris diameter range, type of wood, %cover, periphyton, macrophytes species, bank structure, etc.).

APPENDIX 3

URBAN WETLAND HEALTH INDEX ASSESSMENT WORKSHEET

Note: Data collection Charts 1- 4 are at end of assessment worksheet.

Date:	Time:
Wetland name:	Plot number:
GPS: S	E
Altitude:	Annual rainfall (mm/yr):

Catchment area (km^2):	
Catchment landform:	Dominant base rock:

HYDROLOGY

Catchment Hydrology					
Catchment land cover	Native forest/ Swamp	Native scrub planted	Forest - exotic	Horticulture/ agriculture	Urban development
	5	4	3	2	1
Artificial barriers to flow in catchment	None	Parks, reserves	Urban development	Stormwater drains	Infrastructur e
	5	4	3	2	1
% catchment affected by urban land use	0-20%	20-40%	40-60%	60-80%	>80%
	5	4	3	2	1

Wetland Hydrology					
Wetland type	Interdune forest / swamp	Remnant wetland	Excavated swamp	Excavated dryland	Constructed stormwater collection
	5	4	3	2	1
Artificial barriers to inflow	None	Stopbanks	Urban development	Stormwater drains	Infrastructure
	5	3	2	1	0
% dryland plant invasion	No dryland plants	<25% dryland spp.	25-50% dryland spp.	50-75% dryland spp.	75-100% dryland spp.
	5	4	3	2	1

Riparian Hydrology					
Riparian land slope	0-5º	5-10º	10-15º	15-20º	>20º
	5	4	3	2	1
Riparian area width from water edge	>15m	10-15m	5-10m	3-5m	<3m
	5	4	3	2	1

Physicochemical parameters

Water temperature ^{0}C:	pH:
Conductivity (µS/cm):	

Water clarity	>90cm	70-90cm	55-89cm	35-54cm	<35cm
	5	4	3	2	1
% algal bloom cover	No eutrophic-cation	Infrequent algal blooms	25-50% algal blooms	50-75% algal blooms	>75% algal blooms
	5	4	3	2	1
% cover high nutrient plants	None	<25%	25-50%	50-75%	>75%
	5	4	3	2	1

Riparian Ecosystem Intactness and Habitat

Loss of original riparian area	No loss	<25% loss	25-50% loss	50-75% loss	>75% loss
	5	4	3	2	1
Topographical evidence of riparian loss	Original riparian area >20 yrs	Excavated swamp or wetland riparian	Planted riparian area	Urban development in area	Area destroyed by infrastructure
	5	4	3	2	1
Riparian vegetation integrity	No direct human contact 15-20yr.Mature native trees or tussock	Minimal human activity. Native canopy	Moderate human influences. Native or exotic canopy	Extensive human activity. Minimal canopy	Managed vegetation. no canopy. Grass.
	5	4	3	2	1
Riparian area land use	Native forest, swamp, tussock,	Exotic forest/ planted native	Residential	Agricultural/ horticultural	Commercial, Infrastructure
	5	4	3	2	1
Riparian area status	Conservation	Reserve/ recreation	Walkway/ cycleway	Private residence	Roadway/ stopbanks
	5	4	3	2	1

Native vegetation cover abundance	100% native	>75% native	50-75% native	25-50% native	<25% native or >75% exotic or bare ground
	5	4	3	2	1
Dominant vegetation	Native forest, swamp tussock	Flax, toetoe, high shrub	Scrub native or exotic, planted area	Willows, weeds, gardens, lawns	Grasses, bare ground
	5	4	3	2	1

See Chart 3 for method of assessing Riparian Vegetation Composition using Atkinson System (after Atkinson 1995).

Ten minute Bird Count

Complete chart 1 for bird count and other terrestrial fauna.

Total bird count					
% Native avifauna	>75% native birds	50-75% native	25-50% native	10-25% native	<10% native birds
	5	4	3	2	1

Aquatic Macroinvertebrates abundance and diversity

Use Protocol C-2 - soft-bottom semi-quantitative for sampling at three widely separate sites at each wetland and Protocol P3 for analysis (Stark *et al.* 2001).

Complete Chart 2 with details of the macroinvertebrates and other fauna found.

Ecological, Cultural and Social Values

Cultural, social and ecological values	National & regional ecological values	Wildlife values	Cultural importance	Recreational values	Aesthetic values
	5	4	3	2	1

For details of parameter scores, see chart 4.

Urban impacts on riparian area

Urban developments within riparian area	>20m Reserve area.	Recreation park to wetland area.	Residential in riparian area	Commercial in riparian area.	Structures within riparian area
	5	4	3	2	1
Infrastructure impacts	No infrastructure	Cycle tracks, walkways	play areas, access ways	Car parks.	Infrastructure - roads, bridge, reticulation
	5	4	3	2	1
Impact of stormwater runoff	No runoff.	Stormwater piped via filter.	Stormwater piped - no filter.	Open drain from road.	No stormwater collection drainage.
	5	4	3	2	1
Imperviousness = %CIA - % connected to stormwater drains	Rural / open space or >70% connected	Retirement villages. 60-70% connected	Newer subdivisions. 50-60% connected	Older subdivisions. 40-50% connected	<40% connected
	5	4	3	2	1

Chart 1 – 10 minute bird count.

Names of birds seen within 25m radius	Total Number	Native	introduced

Insects within plot	Number	Lizards, amphibians, fish	Number

Chart 2 – Aquatic Macroinvertebrates.

Reference: Winterbourn *et a*l. (2000). *A Guide to Aquatic Insects of New Zealand*.

Date sample collected:

TAXA	Number	Comments
SNAILS: *Physa*		
Potamopyrgus		
Other MOLLUSCS		
MAYFLIES: *Deleatidium*		
Austroclima		
Zephlebia		
Coloburiscus		
DOBSON FLIES: *Archichauliodes*		
DAMSEL FLIES: *Xanthocnemis*		
Austrolestes		
CADDIS FLIES: *Aoteapsyche*		
Hydrobiosis		
Pycnocentrodes		
Psilochorema		
Hydrobiosella		
Olinga		
BLACK FLIES: *Austrosimulium*		
MOSQUITOES: *Northodixa*		
Culex		
STONEFLIES:		

Sternoperla		
Zelandoperla		
Acroperla		
Austroperla		
CRANE FLIES: *Aphrophila*		
Eriopterini		
Hexatomini		
HYDROPHILIDAE		
CHIRONOMIDS *Chironomus*		
Polypedilum		
TANYPOD *Tanytarsus*		
WORMS: Annelids		
Flatworms		
Leeches		
CRUSTACEA: Amphipods		
HEMIPTERA		
SIgara		
Anisops		
Microvelia		
DYTISCID Beetles		
Elmidae		

Chart 3 – Riparian Vegetation Composition

Vegetation unit (forest, scrub, etc)	
Structural name (dominant growth form)	

Compositional name: Species cover >20% Species cover 1-20% = most abundant <1% = type of ground surface	
Canopy height variation (use hyphen - for similar height; use / for dissimilar height)	
Species names: NATIVES	EXOTICS Comment: deciduous trees, monocultures,

Chart 4 – Ecological, Cultural and Social Values.

Circle the relevant score(s)

Ecological, cultural and social values	Parameters	Score
Ecological importance – national and regional	Reserves Act	5
	Conservation Act - DOC	5
	Regional Plan- significant ecological site	5
	Historic Places trust	5
	QE11 Covenant	5
	Private covenants	5
Wildlife values	Wildlife Refuge	4
	Rare/endangered species	4
	Regional or District Park or Reserve	4
Cultural importance	Archaeological site	3
	Maori burial site/uru pa	3
Recreation values	Bird watching	2
	Picnicking	2
	Walking, cycling	2
	Bird or eel feeding	2
Aesthetic values	Scenic views & vistas	1
	Open space qualities	1
	Landscape design	1
	Unique physical features	1

APPENDIX 4

Riparian Vegetation Composition for the study wetlands

The vegetation composition at each site was compiled from vertical transepts across the riparian area, as described in chapter five, and identifying all plants within one metre of the line. They were then subdivided into native species and exotic ones.

SITE	Te Hapua	Nga Manu	Waimeha
GPS: Easting/Northing	604162.442	6036158.909	6035800.414
	2685082.222	2683464.503	2680173.144
Altitude asl	3.2m asl	75m asl	9.5m asl
Vegetation Unit	Flaxland	Shrubland	Tussockland
Structural Unit	Flax	Kanuka	*Austroderia*
Composition name	Flax	Kanuka	Toetoe
Canopy height variation	2m Flax	15m Kanuka-4m Tree fern	3m Toetoe - 1.5m *Typha*
Species - Native	*Phormium tenax*	*Phormium tenax*	*Austroderia toetoe*
	Cyperus eragostis	*Melicytus ramiflorus*	*Typha orientalis*
		Dodonaea viscosa (akeake)	*Phormium tenax*
	Cortaderia toetoe	*Muehlenbeckia australis*	*Cordyline australis*
	Cyathodes fasciculata	*Cyathodes fasciculata*	*Lemna minor*
	Typha orientalis	*Isolepis prolifer*	*Azolla rubra*
	Viola lyalli	*Pseudopanax arboreus*	*Isolepis prolifer*
	Azolla rubra	*Myrsine australis*	*Carex spp*
	Baumea articulata	*Kunzea ericoides*	*Apium prostratum*
	Carex spp	*Coprosma robusta*	
	Isolepsis prolifer	*Teucridium parvifolium*	
		Cyperus eragostis	
		Austroderia toetoe	
		Dicksonia squarrosa (wheki)	
		Pteridium esculatum	
		Geniostoma rupestre	
		Asplenium longifolium	
		Asplenium bulbiferum	
		Rubus squarrosus	
		Carpodetus serrata	
		Ripogonum scandens	
		Polystichium vestitum	
		Lemna minor (duckweed)	
Species - Introduced	*Agrostis stolonifera*	*Solanum nigrum*	*Ranunculus repens*
	Holcus lanatus	*Rubus fruticosus*	*Polygonum persicaria*
	Galium palustre	Grasses	lawn grasses
		Digitalis purpurea	*Calystegia sp*

SITE	Lake Ngarara	Tower Lake	Midlands
GPS: Easting/Northing	6032710.884	6034294.017	6038856.22
	2678877.038	2679104.327	2678010.916
Altitude asl	7m asl	7m asl	8m asl
Vegetation Unit	Sedgeland - PLANTED	Grassland	Sedgeland - PLANTED
Structural Unit	Sedge	lawn grass	Sedge
Composition name Species >20%	Cyperus-Phormium	grass	Carex sp
Canopy height variation	sedge 160cm- flax 100cm		
Species - Native	*Cyperus ustulatus*	willow trees 10m	*Carex* 1.2m
	Hebe spp		
	Phormium tenax	*Metrosideros excelsa*	*Carex spp*
	Typha orientalis	*Lemna minor*	*Isolepis prolifer*
	Lemna minor	*Phormium tenax*	*Juncus gregiflorus*
	Apium prostatum	*Isolepis prolifer*	*Cotula coropifolia*
	Austroderia toetoe	*Austroderia toetoe*	
	Isolepis prolifer	algae	*Coprosma intertexta*
	Schoenoplectus validus		*Austroderia toetoe*
	Myoporum laetum		*Cyperus eragostis*
			Epilobium komaroviranum
			Utricularia australis
Introduced	*Ranunculus repens*	*Salix babylonica*	*Rumex obtusifolius*
	Calystegia sp	*lawn grasses*	*Calystegia sp*
	Polygonum persicaria	*Rubus fructosus*	*Epilobium ciliatum*
	Pasture grasses	*Canna lilies*	*Rumex acetosella*
	Rumex obtusifolius		
			Ranunculus repens
			Agrostis stolonifera
			Solanum nigrum
			Prunus sp.
			Myosotis discolor
			Lagarosiphon major

SITE	Lake Kotuku	Ferndale
GPS: Easting/Northing	6034274.404	6035912.031
	267907.561	2682702.602
Altitude asl	12m asl	16m asl
Vegetation Unit	Sedgeland - PLANTED	Flaxland - PLANTED
Structural Unit	sedges	Flaxes
Composition name	Isolepis prolifer	flaxes 50%
(species >20%)		
Canopy height variation	toetoe 1m *Carex* 70cm	Flax 1.5m
Species - Native	*Austroderia toetoe*	*Phormium tenax*
	Phormium tenax	*Griselinia littoralis*
	Cordyline australis	*Cordyline australis*
	Isolepis prolifer	*Cotula coronopifolia*
	Carex spp	*Isolepis prolifer*
	Schoenoplectus validus	*Carex spp*
	Typha. orientalis	*Juncus articulatus*
	Griselinia littoralis	*Lemna minor*
	Potamogeton cheesmanii	
	Lemna minor	
	Apium prostatum	
	algal mass	
	Cyperus eragostis	
	Myoporum laetum	
Species - Introduced	*Myosotis discolor*	*Rumex obtusifolius*
	Rumex obtusifolius	*Ranunculus repens*
	Ranunculus repens	*Phytolacca octandra*
	Calystegia sp	*Agrostis stolonifera*
	Rumex acetosella	*Solanum nigrum*
	Galium aparine	
	Lotus sp.	
	Brassica rapa	
	Anagallis arvensis	
	Plantago major	

Sources: Johnson & Brooke 2009; Dawson & Lucas 2004.

APPENDIX 5

Avifauna List and distribution

Avifauna taxa numbers were seen during 10-minute counts at each site. Following identification, the species were sorted into native and exotic, and aquatic and terrestrial.

Native bird taxa numbers		Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Teal	*Anas chloritis*	1							
Pukeko	*Porphyrio porphyrio*	2	2	2	5	3	1	1	
Australasian hawk	*Circus approximans*	1							
Shag	*Stictocarbo punctatus*				2				
Red-billed gull	*Larus novaehollandiae*				4				
Black back gull	*L. dominicanus*				3	1			
Paradise shelduck	*Tadoma variegata*		2	2	6		2		10
Tui	*Prosthermadera novaeseelandiae*		2	2					1
Royal spoonbill	*Platalea regia*			1					
Fantail	*Rhipidura fulginosa*		2						
Welcome swallows	*Hirundo neoxena*	2		3	8	1		3	4
Silver eye	*Zosterops lateralis*					1			

Introduced bird taxa numbers		Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Canada geese	*Branta Canadensis*	5			7	2	4		
White geese	*Branta sp*	2							
Mallard ducks	*Cairina moschata*	6	7	6	20	24	4	7	2
Starlings	*Stumus vulgaris*	3					2	2	
House Sparrows	*Passer domestica*	4	4	6	6	8	2	6	
Black swan	*Cygnus atratus*		1	8	4	1			
Blackbird	*Turdus merula*		1	2		2	2		1
Thrush	*T. philomelos*					1			
Chaffinch	*Fringilla coelebs*								1

Avifauna taxa distribution

	Terrestrial	Aquatic		Native	Introduced
Te Hapua	4	5	Te Hapua	4	5
Nga Manu	4	4	Nga Manu	4	4
Waimeha	5	4	Waimeha	5	4
Lake Ngarara	2	8	Lake Ngarara	6	4
Tower Lake	5	5	Tower Lake	4	6
Midlands	3	4	Midlands	2	5
Lake Kotuku	3	2	Lake Kotuku	2	3
Ferndale	4	2	Ferndale	3	3

APPENDIX 6

Kapiti Coast Urban Wetland Aquatic Macroinvertebrate Assembly

The aquatic macroinvertebrate taxa in the Kapiti Coast urban wetlands, May & November 2010, were identified from the *Guide to the Aquatic Insects of New Zealand* , Winterbourn *et al.* (2000) as discussed in chapter five.

Numbers of aquatic macroinvertebrates in Kapiti Coast Wetlands, May 2010.

Taxa	Sites >>>> April/May 2010 * = EPT species	WMCI TV	Te Hapua	Nga Manu	Waimeha	Lake Ngarara	Tower Lake	Midlands	Lake Kotuku	Ferndale
Acarina	*Acarina*	9								
Amphipoda	*Paracalliope*	5		44	52	5			8	3
Cladocerans	*Daphnia magna*	3	3		14					
Diptera	*Austrosimulium austrolens*	6								
Diptera	*Chironomus*	4	8		1	2			1	1
Diptera, Culicidae	*Culex*	4								
Diptera,	*Tanypodinae*	8	2	1				11		
Ephemoptera	*Deleatidium spp.*	9*				2				
Hemiptera	*Sigara*	4				1			1	
Hemiptera	*Anisops wakefieldi*	5	2	15		4	4	3	12	4
Hemiptera	*Microvelia macgregori*	6		7	6		2	1	1	
Hirudinea	*Hirudinea sp*	4	3					1		
Hygraula	*Hygraula*	5								
Isopoda	*Isopodae*	6								
Mollusca	*Potamopyrgus*	3	158				3	11	4	
Mollusca	*Gyraulus*	2		2						
Nematoda	*Nematoda*	7								
Odonata,	*Xanthocnemis zealandia*	6	5		2	20		11	15	
Odonata,	*Austrolestes colensonis*	5				5		1		
Ostracoda	*Ostracoda*	5								
Oligochaete	*Oligichaeta*	4								
Plecoptera	*Hydrobiosis parembripennis*	9*	1							
Trichoptera	*Aoteapsyche spp.*	*								
Trichoptera	*Paroxyethira spp.*	5								
Number of Taxa			8	5	5	7	3	7	7	3
Number Individuals	Total: 464		183	69	75	39	9	39	42	8
MCI			90	92	84	100	94	92	90	92

Aquatic macroinvertebrates numbers in Kapiti Coast Wetlands. November 2010

Taxa	Nov 2010 * EPT species	WMCI TV	Te Hapue	Nga Manu	Waimeha	Ngarara	Tower	Midland	Kotuku	Ferndale
Acarina	*Acarina*	9		12		4	10	8	1	
Amphipoda	*Paracalliope*	5								
Cladocerans	*Daphnia magna*	3	3	40		270	119	20	155	14
Diptera	*Austrosimulium austrolens*	6		5		5	4			
Diptera	*Chironomus*	4		3			24	3	24	8
Diptera, Culicidae	*Culex*	4								1
Diptera,	*Tanypodinae*	8		268	4	67	35			
Ephemoptera	*Deleatidium spp.*	9*								
Hemiptera	*Sigara*	4		1			2			1
Hemiptera	*Anisops wakefieldi*	5	2			127	50	89	29	58
Hemiptera	*Microvelia macgregori*	6		11	2	14	12	5	3	17
Hirudinea	*Hirudinea sp*	4					1			4
Hygraula	*Hygraula*	5						1		
Isopoda	*Isopodae*	6		11	130	7	4		12	
Mollusca	*Potamopyrgus*	3		218				3	16	
Mollusca	*Gyraulus*	2			7	27	45	1		
Nematoda	*Nematoda*	7							1	
Odonata,	*Xanthocnemis zealandia*	6	2	2		10		1		
Odonata,	*Austrolestes colensonis*	5				4		2		
Ostracoda	*Ostracoda*	5							7	65
Oligochaete	*Oligichaeta*	4		2	1		90	40	35	
Plecoptera	*Hydrobiosis parembripennis*	9*								1
Trichoptera	*Aoteapsyche spp.*	*				1				
Trichoptera	*Paroxyethira spp.*	5	2	5	1			16	2	4
Number of Taxa			4	12	6	11	12	12	11	10
Number Individuals	Total: 2385		9	590	151	547	408	201	296	183
MCI			85	87.6	61	95	82	82	68	72

Sources: Winterbourn, Gregson & Dolphin

Seasonal distribution of aquatic macroinvertebrates across all wetlands.

Aquatic macro-Invertebrate distribution	Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Autumn taxa	8	5	5	7	3	7	7	3
Individuals	183	69	75	39	9	39	42	8
Spring taxa	4	12	6	11	12	12	11	10
Individuals	7	590	151	547	408	201	296	183
Total different taxa	9	15	9	15	13	14	14	10
Total Individuals	190	659	226	586	417	240	338	191

APPENDIX 7

Spreadsheet of Assessment worksheet results.
For scoring see Assessment worksheet (Appendix 3 and Table 5.1).

UWHI scores		Te Hapua	Nga Manu	Waimeha	Ngarara	Tower	Midlands	Kotuku	Ferndale
Hydrology (Metric 1)									
Catchment:	Catchment land cover	2	5	1	1	1	1	1	1
	Artificial barriers to flow across catchment	5	5	4	3	4	4	2	1
	% catchment affected by urban land use	5	5	3	1	1	1	1	1
Wetland:	Wetland type	5	5	4	4	2	2	1	1
	Artificial barriers to inflow	5	5	3	4	2	4	2	2
	% dryland plant invasion	5	5	4	3	2	4	4	4
Riparian area:	Riparian land slope	5	4	5	4	4	3	1	4
	Riparian area width	5	5	4	3	2	3	3	2
Physicochemical parameters (Metric 2)	Water clarity	3	4	3	4	2	4	2	1
	% algal bloom cover	4	5	4	3	3	4	2	4
	% cover high nutrient plants	5	4	3	4	4	4	2	4
Riparian ecosystem intactness (Metric 3)	% loss of original riparian area	4	4	3	2	1	1	1	1
	Topographical evidence of loss	5	5	4	2	2	3	3	3
	Riparian vegetation integrity	5	5	4	1	1	1	2	2
	Riparian area land use	5	5	5	3	3	3	4	4
	Riparian area status	5	5	4	3	2	2	2	3
	% Native vegetation cover	4	4	4	2	1	2	3	3
	Dominant vegetation	5	5	4	3	2	3	3	3
% native avifauna (Metric 4)	Total bird taxa count (actual)	9	8	9	10	10	7	5	6
	Native bird taxa count (actual)	4	4	5	6	4	2	2	3
	% native birds	45	50	56	60	40	29	40	50
Cultural, social & ecological values (M5)	National & regional ecological value	20	20	15	0	0	0	0	5
	Wildlife values	8	12	12	4	4	0	0	0
	Cultural importance	0	0	0	0	0	0	3	0
	Recreational values	2	8	6	2	2	0	0	0
	Aesthetic values	2	3	1	2	0	2	1	1

Urban impacts on riparian area (Metric 6)	Urban developments in riparian area	5	5	4	3	1	3	4	4
	Infrastructure impacts	5	5	4	3	2	4	1	2
(Metric 7)	Impact of stormwater runoff	5	5	4	3	3	3	3	4
	Imperviousness - %CIA	5	5	5	3	1	4	3	3

APPENDIX 8

O'Carroll, A. 2004. Where Land and Waters Meet: An Assessment of Canada's Riparian Forest Management Standards (J.D. Gysbers (ed). Edmonton, Alberta: Global Forest Watch Canada. 66 pp.

This report analyses the existing regimes for the management and protection of forests found along the banks of streams, lakes, and wetlands across Canada.
The report discloses a vast array of differing standards and policy instruments for the conservation and management of Canada's riparian forests.

p5: Wetlands
All wetlands in the Northwest Territories receive a 60-metre riparian reserve zone.
All wetlands in Manitoba receive a 100-metre riparian management zone.
The majority of small wetlands (less than 1 hectare in area) found throughout British Columbia receive no protection for their riparian forests. Some very large wetlands (greater than 1,000 hectares in area) in British Columbia do not receive protection for their upland forests.
Saskatchewan does not have an instrument that specifically requires or recommends the protection of riparian forests along the shorelines of wetlands.
In New Brunswick, all wetlands greater than 1 hectare receive a minimum 30-metre management zone.

Key Definitions Employed
Riparian forest buffer zones apply on all sides of waterbodies. Throughout this report, the width of riparian buffer zones is given for only one side of the waterbody and, unless otherwise noted, this width applies to all sides of the waterbody.

Waterbody: a mass of water, e.g. streams, lakes and wetlands.
Riparian Forest: forest adjacent to a waterbody that directly affects, or is affected by, the aquatic environment.
Basal Area: the area of the cross section at breast height of a single tree, a group of trees, or all of the trees in a stand. Basal area is a way to measure how much of a site is occupied by trees.
Buffer Zone: a corridor of forest adjacent to a waterbody that is subject to forest management restrictions designed to protect the ecological functioning of the riparian forest. A buffer zone may be composed of a reserve zone, a management zone, or a combination of both.
Reserve Zone: an area of forest adjacent to a waterbody that is reserved from active forest development wherein logging and road building is strictly prohibited by law or explicitly recommended against in policy, to protect the ecological functioning of the riparian forest. Exceptions to the general rule prohibiting active forest development must be limited in scope.
Management Zone: an area of forest adjacent to a waterbody wherein forest development practices are permissible but limited in law or policy with an objective of protecting the ecological functioning of the riparian forest.

Riparian Corridors and Required Setbacks

County of Santa Cruz, California, USA 2012
www.co.santa-cruz.ca.us

This document is intended to explain where development and structures are allowed to be constructed adjacent to riparian corridors. Any proposed development (such as grading, land clearing, building and tree or shrub removal) within areas designated for protection through the Riparian Corridor and Wetlands Protection ordinance requires a Riparian Exception application.

The Riparian Corridor and Wetlands Protection ordinance prohibits development in the following areas unless exempted by the ordinance or through a riparian exception:

- riparian corridors
- areas within the urban and rural services lines within a buffer zone as measured from the top of an arroyo.

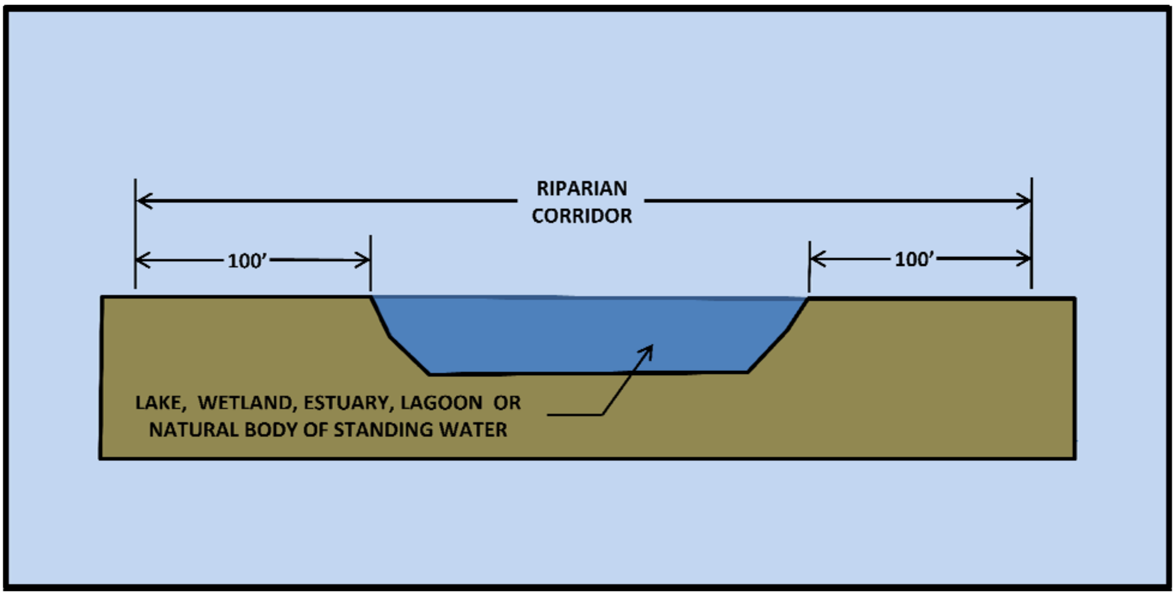
Riparian corridor

The County of Santa Cruz's Riparian Ordinance defines the following a Riparian Corridor:

4) Lands extending 100 feet (measured horizontally) from the high watermark of a lake, wetland, estuary, lagoon or natural body of standing water;

Lake, Wetland, Estuary, Lagoon, or Natural Body of Standing Water

The riparian corridor extends 100' from the high water mark.



Lake, Wetland, Estuary, Lagoon, or Natural Body of Standing Water.

The riparian corridor extends 100’ from the high water mark or out to the edge of riparian woodland.