ARARIRA / LII CATCHMENT: HYDROLOGY, ECOLOGY AND WATER QUALITY

In Support of :

The Department of Conservation/Fonterra Living Water Partnership

Report Number: 1414458_7410-003-R-Rev2

NOVEMBER 2015

PROJECT LIMITATIONS

Your attention is drawn to the document, "Report Limitations", as attached. The statements presented in that document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks to which this report relates which are associated with this project. The document is not intended to exclude or otherwise limit the obligations necessarily imposed by law on Golder Associates (NZ) Limited, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

ACKNOWLEDGEMENTS

In completing this project and preparing this report Golder Associates (NZ) Limited (Golder) and our project partners Instream Consulting Limited and Sanders Consulting Ltd would like to thank the following individuals and organisations for their support and guidance:

- The Living Water Partnership and particularly: Robin Smith (DOC) and Nicola Toki (Fonterra).
- The local scientific community whose research, finding and experience forms the bases of current understanding of Te Waihora / Lake Ellesmere and its tributaries. Thank you for sharing your extensive knowledge with us. This report has benefited significantly from comments made by John Harding (UOC), Daniel Clarke (ECan) Shirley Haywood (Dairy NZ) and Philippe Gerbeaux (DOC).
- The various stackholder organisations and groups who are interested in and passionate about,Te Waihora/Lake Ellesmere and its tributaries.
- The Lincoln and wider Te Waihora / Lake Ellesmere community.

Department of Conservation
Te Papa Atawhai

Fonterra

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Executive Summary

Living Water is a joint partnership between the Department of Conservation (DOC) and Fonterra Co-operative Group Limited (Fonterra). Through working with local iwi, communities, dairy farmers, and other stakeholders, the Living Water partnership aims to improve water quality and biodiversity in a number of sensitive catchments. The Ararira / LII River catchment is one of five Living Water project areas throughout New Zealand.

The Ararira / LII River is a spring-fed tributary of Te Waihora / Lake Ellesmere and its headwaters are in the small town of Lincoln. The Ararira / LII River is highly modified and is primarily managed for drainage. However, there is growing interest in improving the catchment's ecological state, and a desire for the river to be managed for values in addition to drainage, including cultural values, water quality, ecology and recreation.

The scope of this report is to describe the hydrology, water quality and ecology of the Ararira / LII River catchment, to identify environmental enhancement opportunities, and to provide monitoring recommendations.

Table 1 highlights the key findings, the identified knowledge gaps and suggested sampling recommendations for filling the knowledge gaps. Continuation of ECan's water quality and flow monitoring at Pannetts Road and general groundwater level monitoring is important for providing good state of the environment data for the catchment. Future restoration projects should include targeted, localised, before and after monitoring to ensure the costs, benefits and implications of any restoration activities are understood and documented. Synergies should be developed between stakeholder groups to ensure effective catchment monitoring through minimising the cost while maximising the benefit from any monitoring. A monitoring strategy for the entire Te Waihora / Lake Ellesmere catchment is currently being developed. We suggest that the Living Water project partners co-ordinate with the Te Waihora / Lake Ellesmere monitoring reference group, to ensure monitoring within the Ararira / LII catchment is consistent with and complementary to the wider catchment monitoring strategy.

Where possible, enhancement and restoration activities should be designed holistically and ideally benefit hydrology (through improved flood protection), water quality (initial focus on sediment, *E. coli* and phosphorus) and ecology (particularly native riparian plants and animals and valued biota). Greatest benefit is expected from activities which protect and enhance existing values (e.g., Yarrs Flat & Lagoon) and are focused on habitat restoration and recreation. When considering enhancement and restoration activities maintenance and longer term implications must be fully considered. Development of a strategic plan and goals for the catchment would help ensure that local enhancement and restoration activities fit within a holistic catchment wide vision. Development of a restoration strategy is seen as a priority within the Ararira / LII Catchment, although this can occur simultaneously with commencement of restoration activities by landowners.

It is recommended that restoration activities initially focus on: spring heads, enhanced waterway maintenance (particularly less weed cutting and dredging), identification and addressing 'water quality hotspots' (particularly sediment) and enhancing Yarrs Lagoon and Yarrs Flat.

Table 1: Ararira / LII River catchment key summary points.

Findings	Gaps and Uncertainties	Gap-Filling Recommendations
<u>Hydrology</u> ■ The flow regime is dominated by baseflow from springs ■ Springs throughout catchment (not just upper reaches) ■ Lake affects river as far upstream as Pannetts Rd recorder site (4 km from mouth) ■ Drainage and flooding are key issues ■ Uncertain effects of proposed CPW irrigation scheme and Variation 1 changes. Modelling for Variation 1 suggests average flow, median flow and annual catchment yield in the Ararira / LII River at Pannetts Road will all increase by at least 30% from current while low flows are expected to decrease slightly. ■ Low gradient / topography and groundwater levels has an overriding effect on drainage (more so than channel size and aquatic weeds).	<u>Hydrology</u> ■ Springs – location and condition (current data old and patchy) ■ Relationship between drain flow and neighbouring local shallow groundwater levels i.e., how effective are the drains at lowering neighbouring water levels. ■ CPW – actual effects are unknown. ■ Relative hydrological benefits (flow, velocity, maintenance costs etc.) of different waterway management options.	<u>Hydrology</u> ■ Springs survey – including location & condition (biodiversity & cultural value). ■ Improve understanding of relative benefits of different waterway management options, preferably by doing trials.

<u>Water Quality</u>
■ Nitrate concentrations – relatively high for Canterbury lowland streams, and increasing.
■ Dissolved Reactive Phosphorus – elevated, but typical for Canterbury lowland streams.
■ *E. coli* – elevated, especially poor in some tributaries.
■ Turbidity – above average for spring-fed lowland streams.
■ Metals – lead, copper and zinc – generally low, although slightly elevated in certain locations following rainfall.
■ Spatial trends:
  ▪ Nitrate declines downstream (dilution / uptake).
  ▪ DRP increases downstream (runoff / drain inputs)
  ▪ Large variation amongst tributaries ('water quality hotspots'). For example, Lincoln Main Drain had very high nitrate and *E. coli* concentrations during April 2015 (low flow) survey and very high turbidity and nitrate during July 2015 (high flow) survey.
	<u>Water Quality</u>
	■ Understanding where key pollution hot spots are and potential causes.
	■ Continuous dissolved oxygen and temperature data to quantify macrophyte effects and potential for fish kills.
	■ Continuous turbidity data to better understand the turbidity flow relationship and to assist in identifying potential turbidity / TSS / sediment sources i.e., is most of the sediment derived from infrequent flood events or normal flow conditions.
	■ Before / after monitoring in relation to restoration activities.
		<u>Water Quality</u>
		■ Targeted water quality monitoring to identify key pollution hot spots
		  ▪ E.g., Turbidity at multiple tributary locations (particularly the Lincoln Main Drain) after rain events.
		■ Install continuous dissolved oxygen and turbidity monitoring probes at Pannetts Road and potentially temporarily at other locations.
		  ▪ ECan have indicated they may be able to loan probes

<u>Ecology</u>
■ Habitat: Poor overall, due to high fine sediment cover, lack of habitat diversity (pools, runs, riffles), lack of riparian trees and shrubs (shade, cover, organic matter inputs).
  ▪ Generally most of the drains are well fenced and – associated erosion not considered a big issue. Care is required during drain maintenance to minimise downstream sediment movement during maintenance and to minimise risk of erosion following maintenance.
■ Plants: Mainstem and tributaries are macrophyte-dominated, with macrophyte cover often at excessive levels. Due to lack of shade, dominance of fine sediments, stable flow, and adequate nutrient concentrations.
  ▪ Periphyton (algae) less common (mainly due to fine substrate)
■ Invertebrates – Very limited data suggests fauna is typical of degraded lowland rivers (very few pollution-sensitive mayfly, stonefly and caddisfly species).
  ▪ Koura and kākahi present, but very limited data
■ Fish – Very limited data.
  ▪ Longfin eel, trout, inanga, smelt, lamprey (old record), bullies, mudfish (possibly present, but no records)
  ▪ Longfin eel – one of the larger populations amongst the lake's tributaries
■ Birds – Particularly important around mouth / Yarrs Flat
  ▪ Important species include Bittern and Marsh Crake
■ Riparian and Wetland Plants – Patchy data.
  ▪ Swamp nettle a notable species (e.g., Yarrs Lagoon)
	<u>Ecology</u>
	■ Lacking basic ecological survey data for:
	  ▪ Native riparian plants and animals
	  ▪ Birds
	  ▪ Aquatic macroinvertebrates
	  ▪ Aquatic mega invertebrates – kākahi and koura
	  ▪ Fish
		<u>Ecology</u>
		■ Baseline surveys to better understand current ecological state. Particularly important for (highest priority indicated by *):
		  ▪ Riparian invertebrates* and lizards*
		  ▪ Birds
		  ▪ Aquatic macroinvertebrates*
		  ▪ Aquatic mega invertebrates – kākahi and koura
		  ▪ Fish*

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GLOSSARY AND ABBREVIATIONS

7d MALF	7 day mean annual low flow
amsl	above mean sea level
CPW	Central Plains Water
DOC	Department of Conservation
DRP	Dissolved reactive phosphorus
E.coli	*Escherichia coli*
ECan	Environment Canterbury or the Canterbury Regional Council CRC
FMP	Farm Management Plan
EPT	Ephemeroptera, Plecoptera, and Trichoptera (It is the number of species in the sample in the generally more environmentally sensitive orders)
FSANZ	Food Standards Australia New Zealand
Golder	Golder Associates (NZ) Limited
ha	hectare
Inanga	One of five whitebait species found in New Zealand, but in most rivers they comprise the majority of the whitebait catch.
Kākahi	Freshwater mussel.
Kanakana	Lamprey an eel-like fish that has a sucker mouth with horny teeth and a rasping tongue.
km	kilometre
Kōura	Freshwater and salt-water species of crayfish although in this case we are referring to only freshwater crayfish.
Kowaro	Canterbury mudfish.
LWRP	Land and Water Regional Plan
LINZ	Land Information New Zealand
L/s	litre per second
M	Million
m	metre
m^3	cubic metre
mahinga kai	The customary gathering of food and natural materials and the places where those resources are gathered
mana	Integrity, status, prestige, power
MAR	Managed Aquifer Recharge
mm	millimetre
MSc	Masters of Science (degree)
NPS-FM	National Policy Standard - Freshwater Management
NZFFD	New Zealand Freshwater Fish Database
RL	Reduced level
RMA	Resource Management Act
RPS	Regional Policy Statement
SDC	Selwyn District Council
taonga	Valued resources, treasures and possessions, both tangible and intangible.
TSA	Targeted stream augmentation
TSS	Total suspended solids
tuna	Eel of various species, including the long-finned eel and short-finned eel
waipuna	Spring of water
UOC	University of Canterbury

1.0 INTRODUCTION

Living Water is a joint partnership between the Department of Conservation (DOC) and Fonterra Co-operative Group Limited (Fonterra). Through working with local iwi, communities, dairy farmers, and other stakeholders, the Living Water Partnership aims to improve water quality and biodiversity in a number of sensitive catchments throughout New Zealand. The Ararira / LII River catchment is one of five Living Water focus areas, with the other four being Awarua-Waituna Lagoon in Southland, Tikapa Moana / Firth of Thames near Thames, the Waikato peat lakes, and the Kaipara Harbour, north of Auckland.

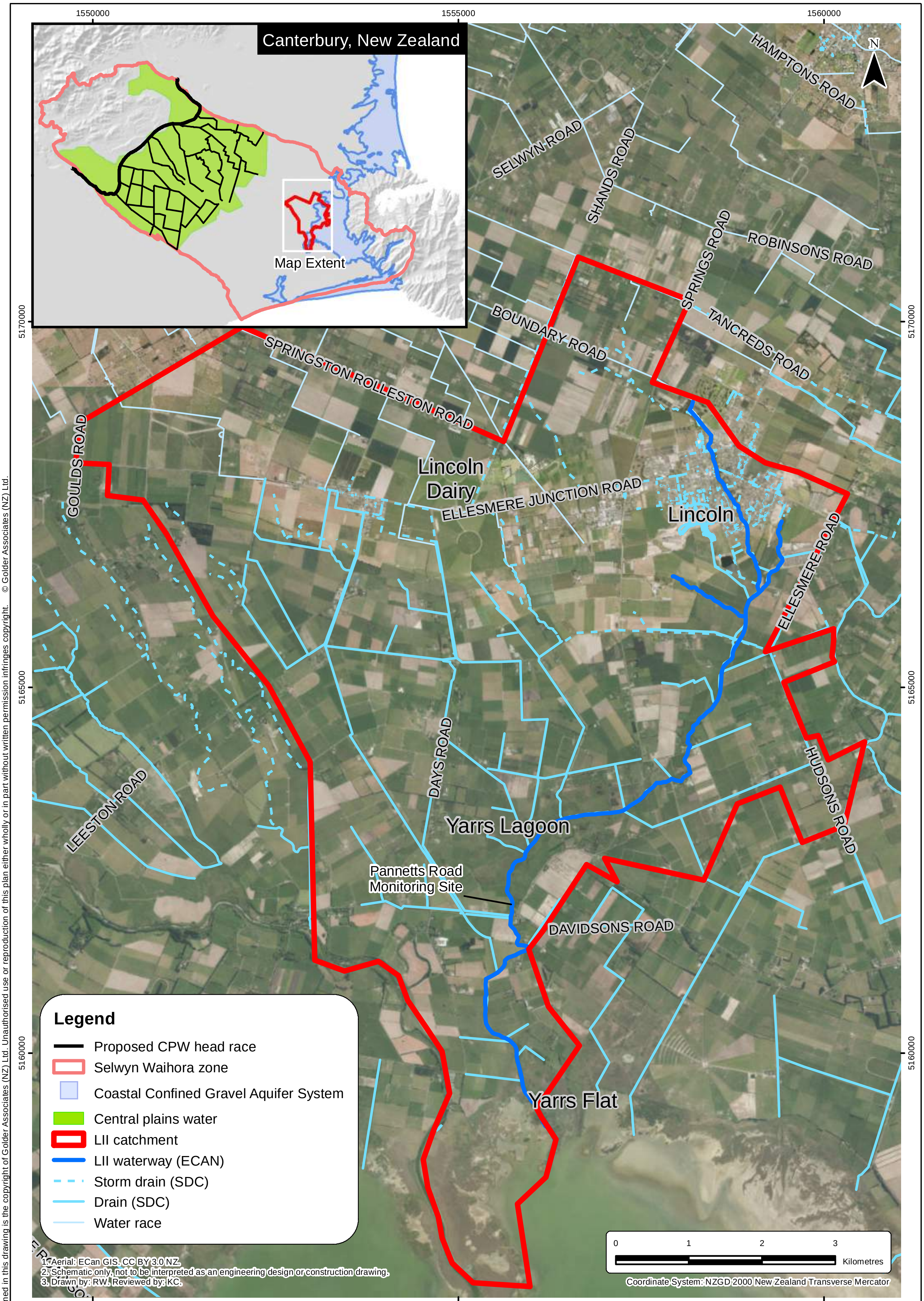
The Ararira / LII River is a spring-fed tributary of Te Waihora / Lake Ellesmere and its headwaters are in the small town of Lincoln (Figure 1). Although the Te Waihora / Lake Ellesmere catchment is highly modified by agricultural and some urban land use, the lake and its tributaries support diverse fish and bird communities of regional and national significance. There are a number of agencies and community groups interested in improving water quality and biodiversity of Te Waihora / Lake Ellesmere and its tributaries. These agencies and organisations include central, regional and local government as well as Whakaora Te Waihora, the Waihora Ellesmere Trust, Te Ara Kākāriki Greenway Canterbury Trust, and the Living Water Partnership. This report is of relevance to all the above organisations, but it has been prepared specifically for the Living Water Partnership.

The scope of this report is to describe the hydrology, water quality and ecology of the Ararira / LII River catchment, to identify environmental enhancement opportunities, and to provide monitoring recommendations. A comprehensive desktop review of existing information was supplemented with habitat data collected during a "stream walk survey" conducted at representative mainstem and tributary locations in autumn 2015 (Figure 2). Water quality samples were also collected from ten sites at a mixture of mainstem and tributary locations in 2015 under both low flow and high flow conditions (Figure 2). No dedicated ecological sampling was undertaken for this report.

This report is separated into two parts and nine sections. Part one follows this introduction section and describes the current state of the Ararira / LII River catchment. Part one contains five sections which commence with a catchment overview (Section 2.0), followed by sections on hydrology (Section 3.0), Water Quality (Section 4.0) and Ecology (Section 5.0). Part one concludes with a summary of key values and issues (Section 6.0). Part two is focused on enhancement opportunities and commences with a section on waterway enhancement (Section 7.0). Monitoring recommendations are provide in Section 8.0 and concluding remarks are provided in Section 9.0. A reference list is provided at the back of this report.

This report has been written for an audience that includes readers without a science background. This means that the report focuses on key take-home messages, and tries to avoid unnecessary scientific detail or background explanations as much as possible. However, the report still contains significant scientific interpretation. It is envisaged that this report will form the basis of a community hand-out which will highlight the key messages. The appendices for this report are presented in a separate Appendix Report[1]. Readers who wish to delve deeper into the background technical information or the collected data are referred to the Appendix Report which contains the Stream Walk and water quality survey results and various supporting data maps.

[1] Golder 2015a, Appendices: LII / Ararira Catchment Hydrology, Ecology and Water Quality. Appendix document containing collected data which supports this main summary report.



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TITLE ARARIRA / LII RIVER LOCATION MAP

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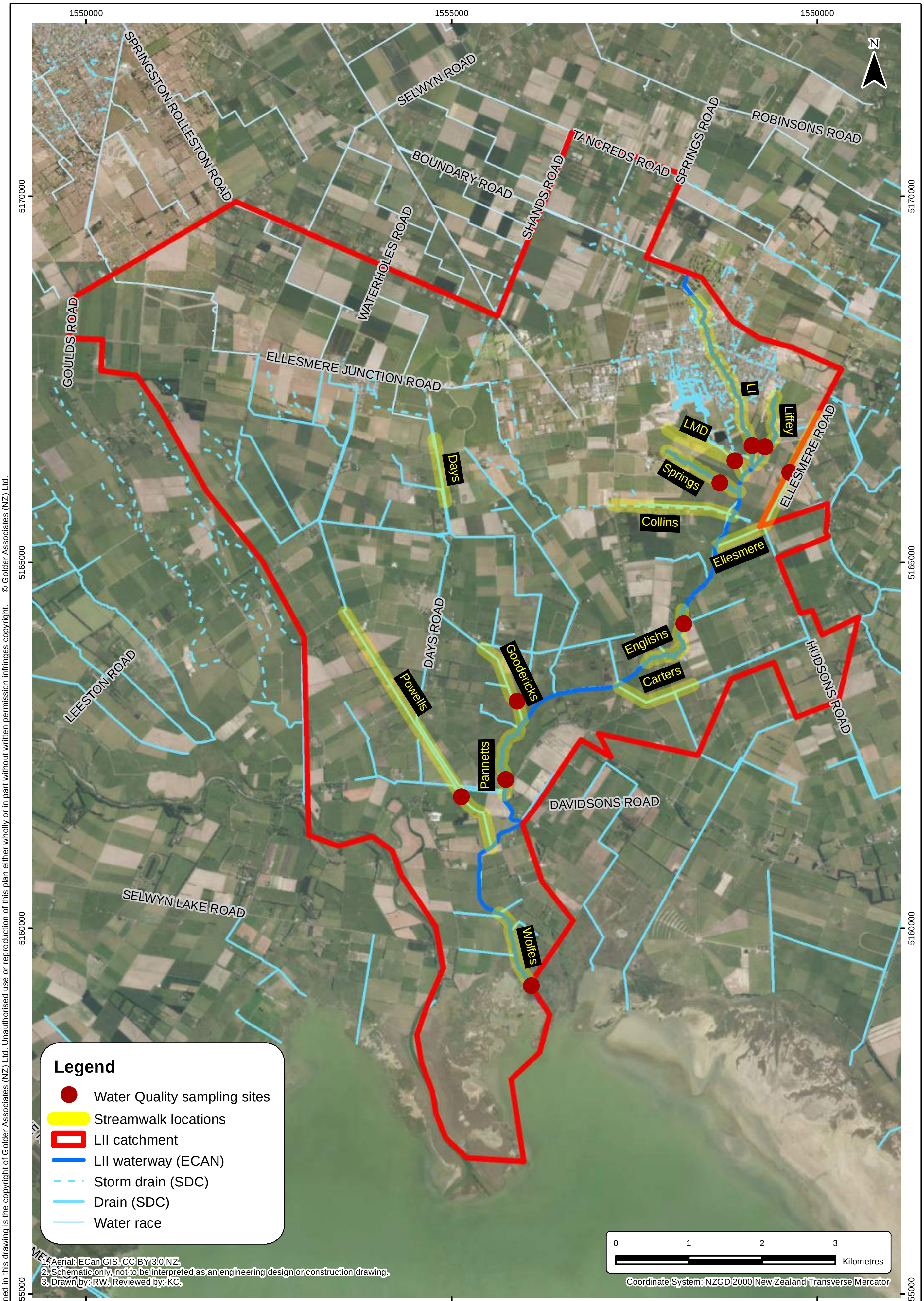

1. Aerial: ECan GIS. CC BY 3.0 NZ.
2. Schematic only, not to be interpreted as an engineering design or construction drawing.
3. Drawn by: RW. Reviewed by: KC.

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ARARIRA / LII RIVER STREAMWALK & WATER QUAILTY SITES

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PART

ONE

CURRENT STATE

Includes

2.0 CATCHMENT OVERVIEW

The Ararira / LII River catchment is situated on the north side of Te Waihora / Lake Ellesmere with its headwaters within Lincoln township (Figure 2). The Ararira / LII River catchment covers approximately 6,300 hectares (ha). The following paragraphs provide a broad description of the Ararira / LII River catchment as it looks now and historically. We have included the historic state as it is useful to know the historical context when considering goals for environmental restoration and enhancement.

Te Waihora / Lake Ellesmere

Te Waihora / Lake Ellesmere is the largest lake in Canterbury, although technically it is not a bona fide lake but a coastal lagoon that is intermittently open to the sea. Te Waihora / Lake Ellesmere is of national and international importance for its wetland habitat and support of migratory birds, and a tribal taonga[2] representing a major mahinga kai[3] and an important source of mana[4] for local Maori.

Prior to Polynesian settlement of the Canterbury plains about 1000 years ago, the area surrounding Te Waihora / Lake Ellesmere was a mosaic of swampland and large podocarp forests comprising of tōtara, kahikatea and mataī. During Polynesian settlement these forests were cleared by fire to encourage bracken growth and to create open hunting areas. Following deforestation, the burned areas were colonised by harakeke / flax, raupō and sedge vegetation (*Carex*) in wetland habitats, with tussock grassland and shrubland in drier areas (Williams 2005). Most of the remaining native shrub and grassland vegetation was cleared and drained following European settlement about 150 years ago, to make the land more suitable for agriculture and towns. Over the last 150 years this land improvement has continued such that currently <0.5 % of the plains support native, remnant vegetation (Williams 2005).

Te Waihora / Lake Ellesmere has a very diverse history and over the last few thousand years has been a bay, an estuary, a coastal lagoon and a lake. Approximately 700 years ago the Waimakariri River veered south from its current course and is known to have flowed out through what is now Te Waihora / Lake Ellesmere (Singleton 2014). Similarly, the Rakaia River to the south is likely to, at some point in its history, have had a more northerly course and flowed out through what is now Te Waihora / Lake Ellesmere. Both rivers (particularly the Waimakariri) still influence the lake in that they leak water through their river beds to assist in recharging the groundwater system that in turn supports the numerous spring-fed creeks including the Ararira / LII River that flow into Te Waihora / Lake Ellesmere.

Beginning in Maori times and continuing through to the present day, the water level in Te Waihora / Lake Ellesmere has been artificially regulated by cutting a channel to the sea several times a year. Since 1901 the lake has been opened between one and seven times a year, with an average of 3.7 openings a year, each lasting on average approximately three weeks. ECan currently manage lake levels with the goal of keeping them between 0.3 and 1.8 m above mean sea level, which corresponds to an average lake depth of approximately 2 m.

The original extent of Te Waihora / Lake Ellesmere was considerably larger than its current approximate 20,000 ha extent. Prior to controlled opening of the lake it is expected that during floods Te Waihora / Lake Ellesmere expanded to cover approximately 30,000 ha with lake depths up to 4-5 m and would have inundated much of the Ararira / LII River catchment.

Major land use changes

European settlers developed lowland areas by draining the land for farming using a network of open channels, with drain construction starting around the 1850s[5]. The land drainage activities within the catchment were assisted by the practice of regularly opening the lake to the ocean to manage water levels in the area. The natural conditions of the area, in terms of flat topography, poorly draining soils, the high water table and the influence of Te Waihora / Lake Ellesmere, make drainage a challenge.

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[2] Taonga means valued resources, treasures and possessions, both tangible and intangible.

[3] Mahinga kai means, the customary gathering of food and natural materials and the places where those resources are gathered.

[4] Mana means Integrity, status, prestige, power.

[5] Singleton 2014, Chapter 8 pages 59-63, provides a good description of typical drainage activities that occurred through the 1860's.

Land use within the Ararira / LII River catchment has changed significantly with initial deforestation, subsistence farming, extensive land drainage and more recently a move to increasingly intensive farming including irrigation development (initially flood but now predominantly spray, particularly centre pivots).

Aerial photos are available for most of the Ararira / LII River catchment from 1973 and at approximately 10 yearly intervals since which provides a visual overview of changing landuse throughout the catchment (Appendix D). Current land use in the Ararira / LII River catchment is dominated by intensive farming (Figure 3). The Lincoln area is currently experiencing a high growth rate with large residential subdivisions expanding the urban limits and increased subdivision of surrounding larger properties into smaller lifestyle blocks. This, coupled with changing rural land use and particularly conversion of farms to dairying, is resulting in rapid and anticipated ongoing change within the catchment.

Public land reserves within the catchment include Yarrs Lagoon (managed by Selwyn District Council (SDC)), Yarrs Flat (managed by the DOC), Liffey Springs and the LI Reserve within Lincoln township.

Ararira / LII River and tributaries

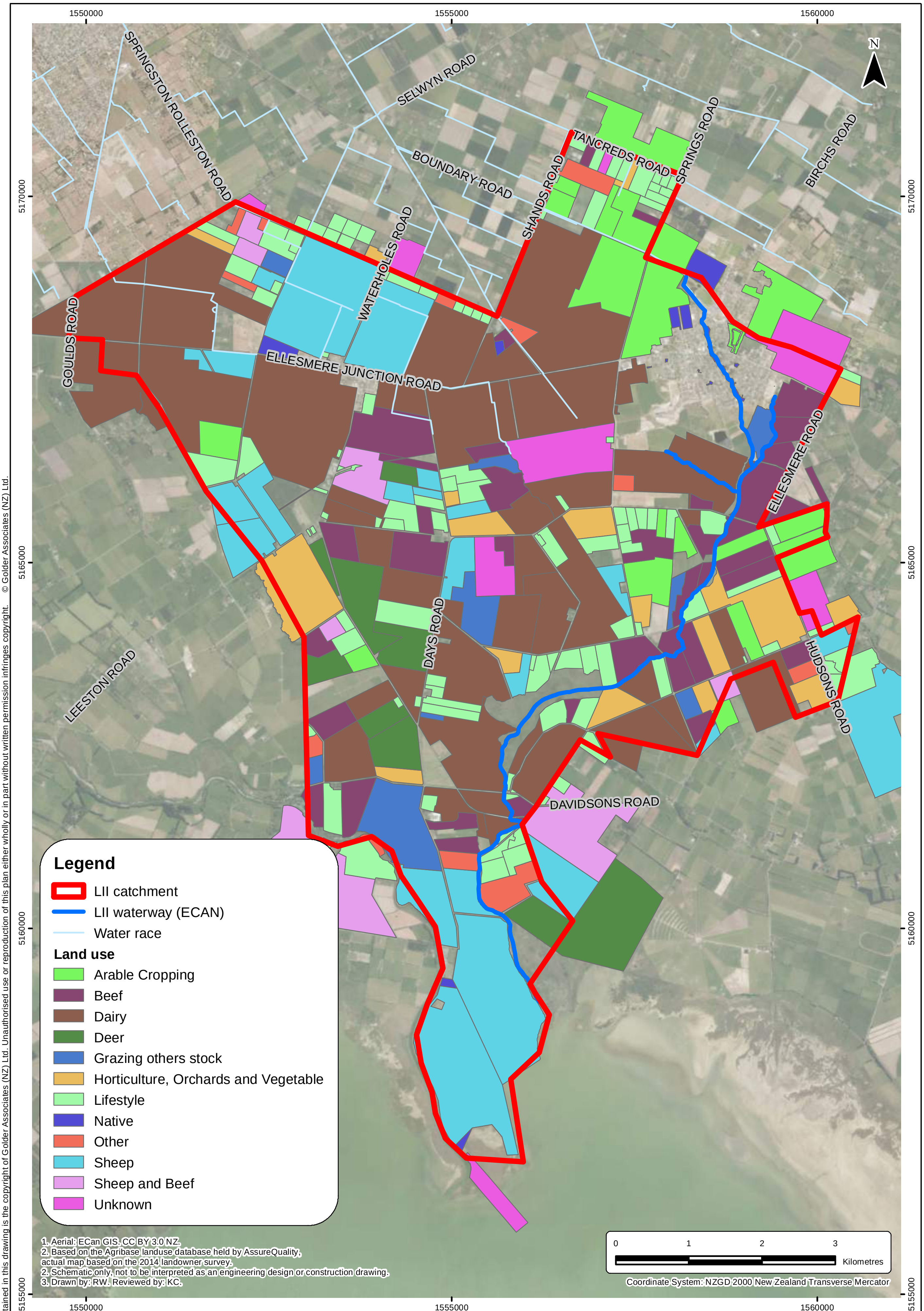
The LI and LII rivers are named from early land survey points, with the "L" standing for Lincoln. The LI Creek is approximately 3 km long and starts as a group of springs just north of Lincoln, then crosses Edward Street (the main street) before flowing through new subdivisions and joining another tributary known locally as the Liffey (Figure 2). The Liffey also arises from springs, which are adjacent to the new Liffey Springs subdivision. From the confluence of the LI and Liffey, the river is known as the LII or Ararira (we use both names here). Springs Creek is the only other named tributary[6], which joins the LII about 500 m downstream of the LI and Liffey confluence. The Ararira / LII River is approximately 11 km long from the confluence of the LI and Liffey creeks to its mouth into Te Waihora / Lake Ellesmere (Figure 2). In addition to these named waterways, the Ararira / LII River catchment includes an extensive drainage network of over 75 km of "classified" drains – meaning drains that are rated and managed by SDC – and many more "unclassified" drains that are under the responsibility of individual landowners.

The threat of flooding remains a key issue for landowners in the catchment, particularly those living close to the lake. The LII Drainage Committee is funded by SDC through rates and is responsible for maintaining the flood carrying capacity of the drainage network[7]. This maintenance work primarily involves mechanical removal of nuisance aquatic plants (or "weeds") and sediment from the large drainage network annually, although maintenance work has previously included dredging of the mainstem of the Ararira / LII River as well as weed cutting activities.

As discussed in the following sections, the Ararira / LII River is highly modified and is primarily managed for drainage. However, there is growing interest in improving the catchment's ecological state, and a desire for the river to be managed for values in addition to drainage, including cultural values, water quality, ecology and recreation.

[6] As shown on the LINZ 1:50000 / Topo50 topographic map of New Zealand.

[7] The LII Drainage Committee is responsible for maintaining the flood carrying capacity of the "classified" drains only.



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TITLE ARARIRA / LII RIVER CATCHMENT LAND USE MAP

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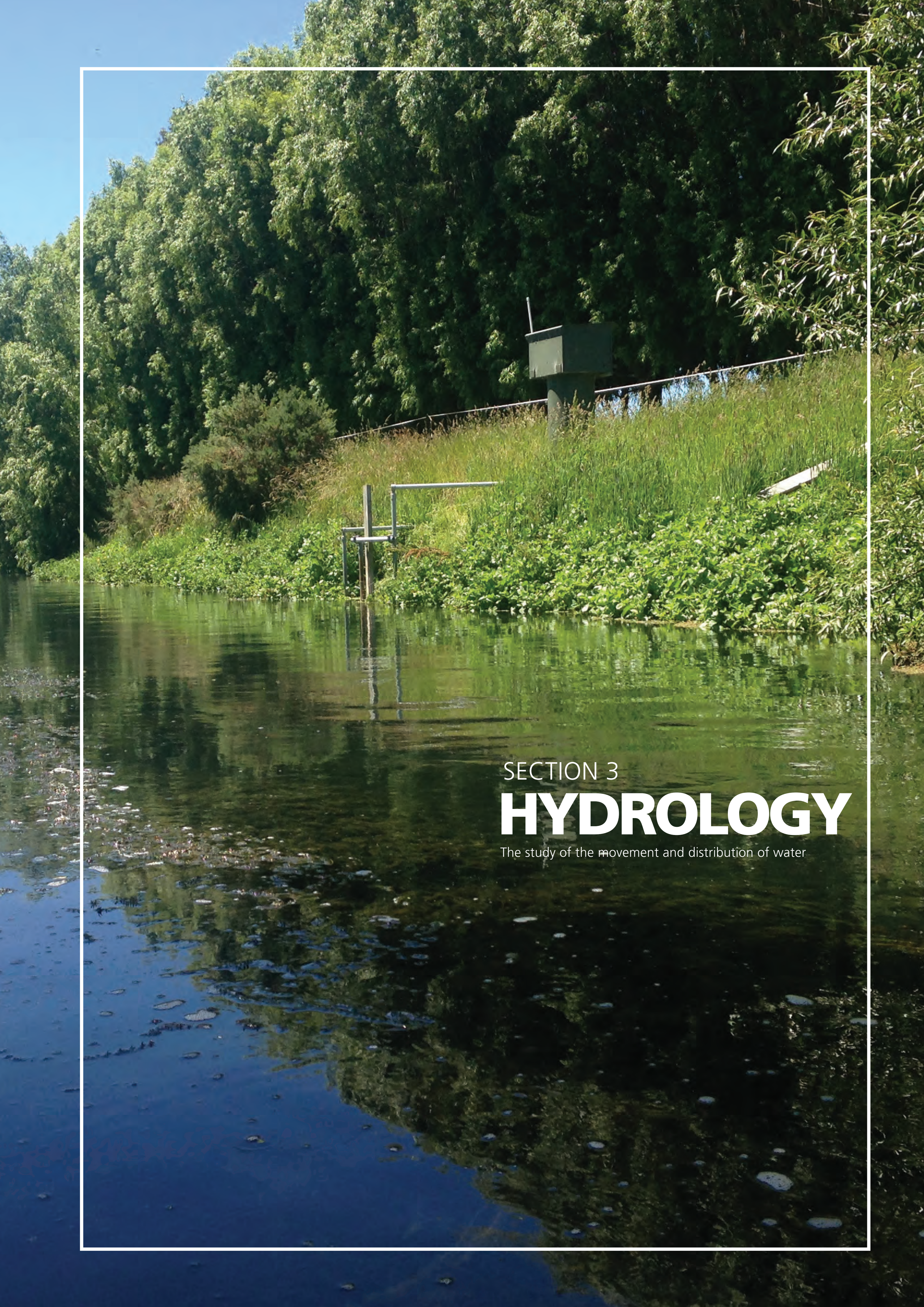


SECTION 3

HYDROLOGY

The study of the movement and distribution of water

3.0 HYDROLOGY

The hydrology of the Ararira / LII River catchment is well understood and is based on an extensive set of records from within the catchment. The Ararira / LII River is a major contributor of flow to Te Waihora / Lake Ellesmere and has the highest low flow[8] and mean flow contributions and only the Selwyn River contributes a higher annual volume to the lake. The hydrology of the Ararira / LII River catchment is dominated by the influence of groundwater and Te Waihora / Lake Ellesmere. Control of the lake's level and land drainage works throughout the catchment have significantly altered the area's hydrology. Prior to these alterations groundwater level was high throughout the catchment and wetlands extended from the lake to the outskirts of Lincoln. Most of the indigenous hydrology of a large wetland has been removed by a drainage network to support agricultural development. Current hydrology is dominated by low velocity channelized flow along mostly straight, homogeneous drains and channels (Figure 4).

Figure 4: Typical Ararira / LII River waterways: Springs Creek (left); Lincoln Main Drain (centre) and Ararira / LII below Englishs Road (right), note rectangular cross section and low velocities.

3.1 Available Hydrology Data and Records

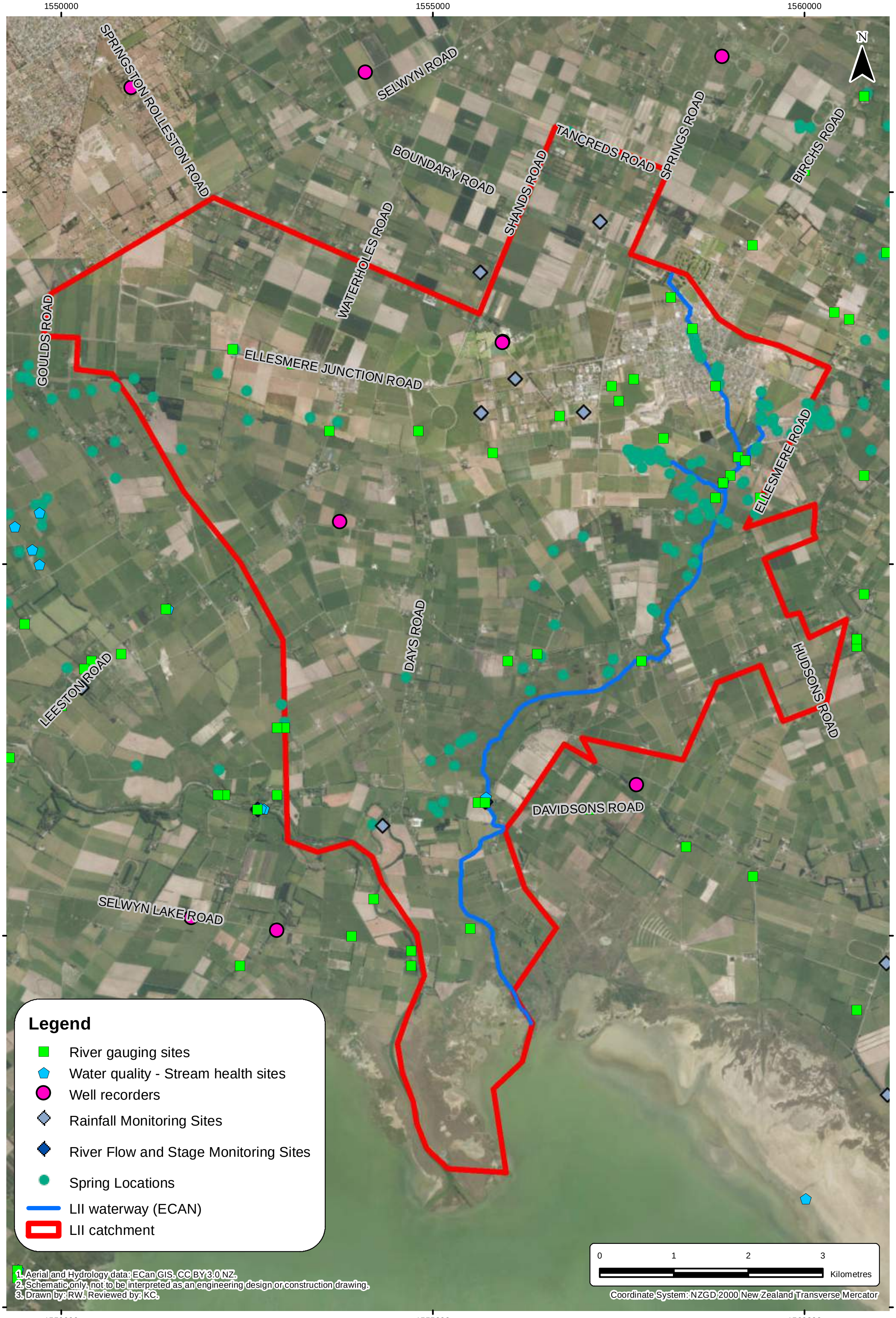
There is an extensive set of hydrological records available for the Ararira / LII River catchment, including:

- Long climatic records from Lincoln with rainfall records back to 1881 and climate records starting in 1928.
- Continuous flow[9] data for the Ararira / LII River at the Pannetts Road bridge since November 2008 plus various flow gaugings at other locations in the catchment.
- Water level data for Te Waihora / Lake Ellesmere which dates back to the late 1940s.
- Groundwater level data from two monitoring bores both of which have records that date back to 1980.
- Information on the numerous wells and bores drilled in the catchment and the numerous aquifer tests that have been undertaken is available. The location of many springs has been mapped although some of this information is old and there is limited information on spring flow rates.
- Information on water consents is available and water use data is becoming more available.

Figure 5 shows the location of many of the above records.

[8] Low flow as represented by 7d MALF.

[9] The flow data is based on continuous water level monitoring and maintenance of a rating curve.



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TITLE ARARIRA / LII RIVER
KEY HYDROLOGICAL FEATURES

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3.2 Climate

Based on climate data from Lincoln since 1928 the Ararira / LII River catchment receives on average approximately 650 mm of rainfall annually (Figure 6). Rainfall varies from year to year with 1988 being the driest on record with just over 310 mm and 1936 the wettest with almost 1,050 mm. Average monthly rainfall is fairly constant at approximately 50 mm although extreme rainfall months (both high and low rainfall) can occur throughout the year (Figure 6).

Annual Penman potential evapo-transpiration has averaged approximately 870 mm ranging from a low of just over 720 mm in 1951 to a high of just over 1,000 mm in both 1998 and 2003 (Figure 6). Penman potential evapo-transpiration is highly seasonal averaging over 100 mm / month during the summer months of November to February but falling to less than 20 mm / month during the winter months of June and July.

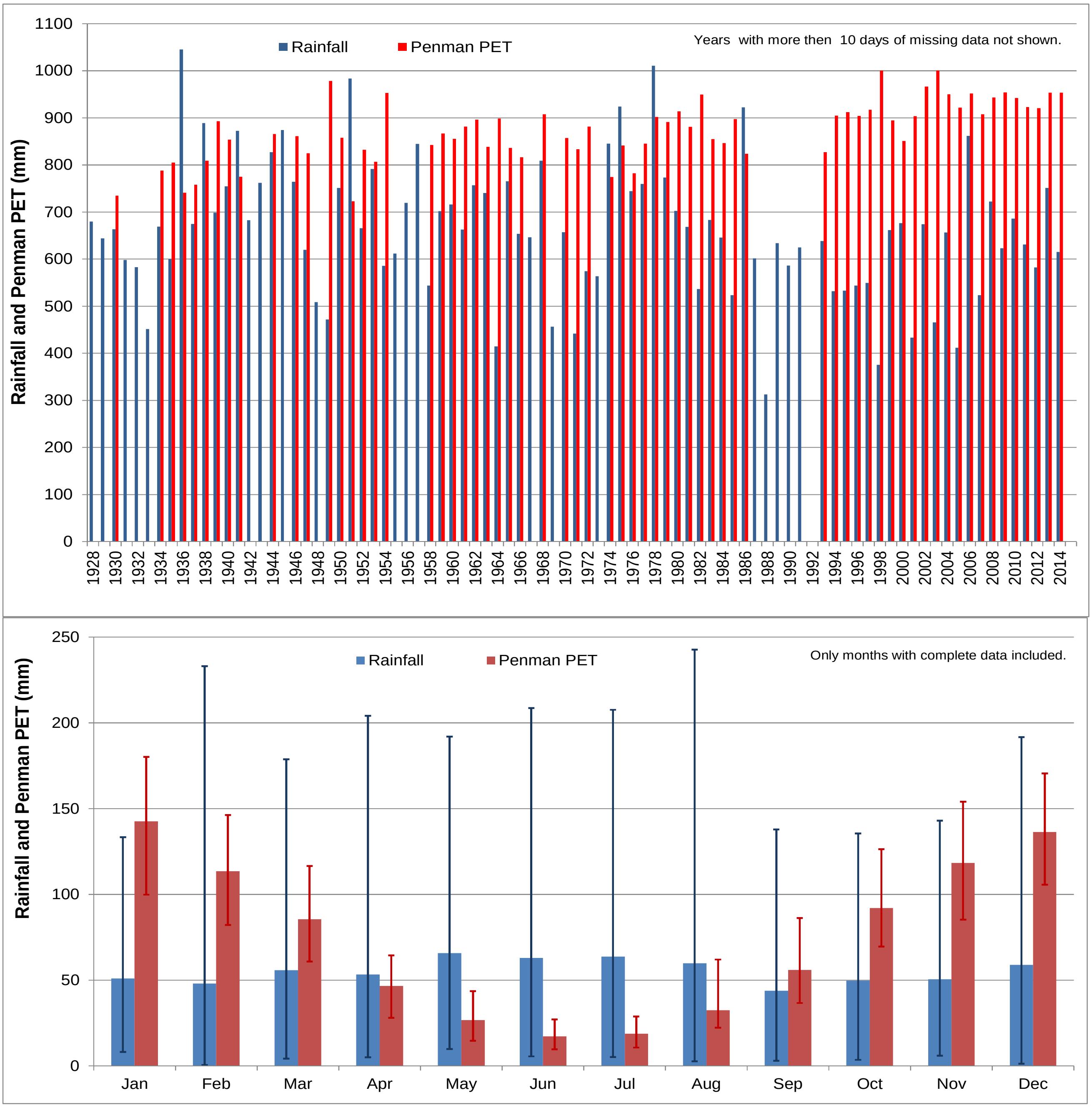


Figure 6: Rainfall and potential evapo-transpiration at Lincoln.

3.3 Soils

The soils of the catchment have been well mapped[10] and are predominantly heavy with a high water holding capacity. Peat soils and areas of poor drainage are common in the lower parts of the catchment. Small rainfall events will mostly infiltrate, but more substantial rainfall events produce runoff which flows to the catchment's waterways.

3.4 Groundwater

Groundwater dominates the hydrology of the Ararira / LII area and the wider Te Waihora / Lake Ellesmere catchment. The groundwater resources that underlie the Canterbury Plains and particularly those within the Te Waihora / Lake Ellesmere catchment have been extensively studied. They have been summarized in various catchment reviews (Taylor 1996, Brown 2001, Hughey and Taylor 2009, Williams 2010) and have been subject to extensive scrutiny during numerous consent processes (i.e. the large Raikaia-Selwyn and Selwyn-Waimakariri Groundwater Zone hearings and the hearing for Central Plains Water). Lake symposia organised by the Waihora Ellesmere Trust (WET) and held biannually since 2007 have discussed groundwater at length. More recently the Selywn-Waihora Zone Committee undertook an extensive scientific review and consultative process which culminated in Variation 1 to the Canterbury Land and Water Regional Plan.

The Canterbury Plains consist of a series of large coalescing fluvio-glacial fans built by the large alpine rivers. The gravels range in thickness from over 300 m to greater than 600 m (Williams 2009). Near the coast the gravel-dominated fluvial deposits are inter-fingered with finer grained marine and coastal deposits of silts and clays which restrict water movement and act as aquitards separating the porous gravel based aquifers (Figure 7). Most of the Ararira / LII catchment is underlain by the coastal confined aquifer system although the confining layers thin and peter out towards the west of the catchment.

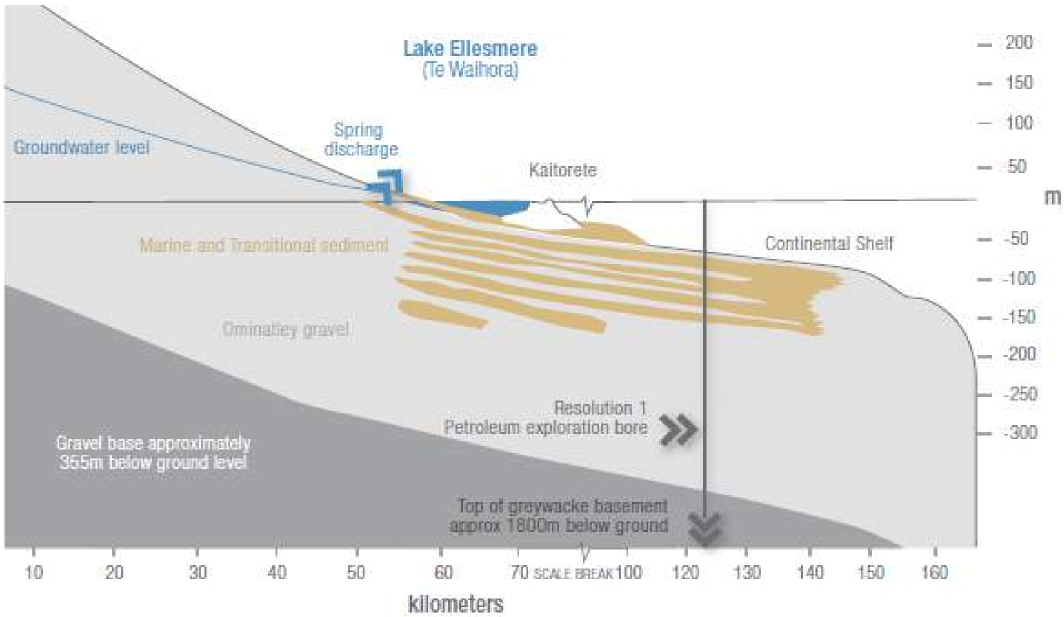


Figure 7: Geological cross-section showing the schematic relationships between strata, spring discharge, Te Waihora / Lake Ellesmere and Kaitorete barrier.

(from Hughey and Taylor 2009 but based on Ettema 2005).

Flow in the catchment waterways is strongly related to groundwater levels (Horell 2001, Williams et al 2006) and groundwater discharges via spring (waipuna) are the dominant source of flow in the Ararira / LII waterways. The area contributing groundwater to the Ararira / LII waterways is considerably larger than the

[10] A soil map for the catchment is shown in Appendix D.

surface water catchment which contributes runoff. The source of the spring water is generally from artesian, gravelly aquifers which are fed from both land surface infiltration from areas north and west of Lincoln and flow losses from various up-gradient waterways including the Waimakariri and Selwyn rivers (Earl 1998). Use of groundwater within the catchment is extensive with the catchment essentially pin-cushioned with bores[11]. Groundwater is considered over-allocated in the Te Waihora / Lake Ellesmere catchment (Clark 2014), causing a decline in spring and waterway baseflow in the Ararira / LII River. A declining trend in some of the groundwater level data supports this. Springs in the upper part of the catchment can cease flowing during times when dry weather combines with groundwater abstractions, resulting in upper catchment waterways running dry.

3.5 Surface Water

Within the catchment, the surface hydrology reflects a highly altered state with significant agricultural impacts. The extensive drainage network maintained by the SDC, LII Drainage Committee, and private landowners serves to lower the groundwater table and convey water via mostly straight, homogeneous channels that were constructed for development purposes (few waterways within the Ararira / LII River catchment have natural alignments or characteristics). The main stem of the Ararira / LII River widens as it approaches the lake, but it too has been straightened, improved, and maintained for drainage purposes. Due to the natural flat topography of the land, many waterways have low flow velocities, resulting in very limited bed movement or scour. As a result silty sediment, which occurs naturally in the catchment[12] but is aggravated by development, accumulates in the waterways until mechanically removed. Terrestrial and aquatic plants grow near / in the waterways and rapidly colonise areas of deposited sediment until removed by weed cutting activities. Pockets of wetlands similar to the indigenous condition of the catchment are still present as at some spring locations e.g., Yarrs Lagoon, and at the river mouth. Recent stormwater management features near Lincoln township have included development of wetlands to manage flow discharges and filter out contaminants (Figure 8).

Figure 8: Constructed wetlands near Lincoln township.

ECan maintains a flow monitoring site on the Ararira / LII River at the Pannetts Road bridge which has recorded flow since November 2008. Water level data from the Pannetts Road bridge recorder indicates that water levels fluctuate over an approximately 1.5 m range and are highly influenced by weed growth in the channel. The record also shows periodic abrupt changes in water levels (decreases), consistently in January / February which are due to mechanical weeding of the river at or downstream of Pannetts Road (Figure 9).

[11] A map of bores, aquifer tests and groundwater abstraction consent within the Ararira / LII River catchment is contained in Appendix D.

[12] The underlying geology of the catchment is dominated by alluvial (i.e. clay bound gravel deposits) and wetland (i.e. peat) deposits. A geological map for the catchment is contained in Appendix D.

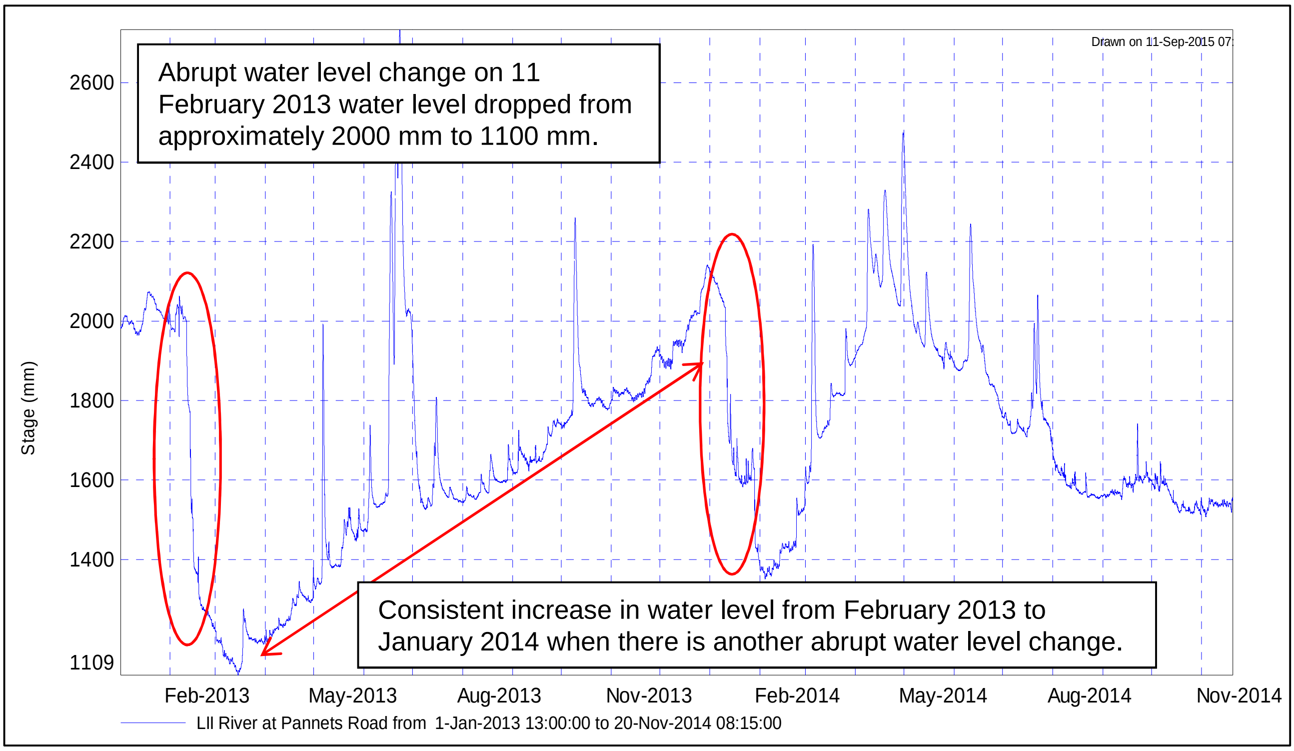


Figure 9: Ararira / LII River at Pannetts Road water level record showing weed influence on record.

Te Waihora / Lake Ellesmere has a subtle influence on water levels in Ararira / LII River at Pannetts Road. When lake levels are high backwater effects extend up the Ararira / LII River to at least Pannetts Road (Figure 10). Relatively rapid lowering of the backwater effects occurs during lake opening. Wind has a significant effect on water levels within Te Waihora / Lake Ellesmere. These effects extend all-be-it subtly up the Ararira / LII River to at least Pannetts Road.

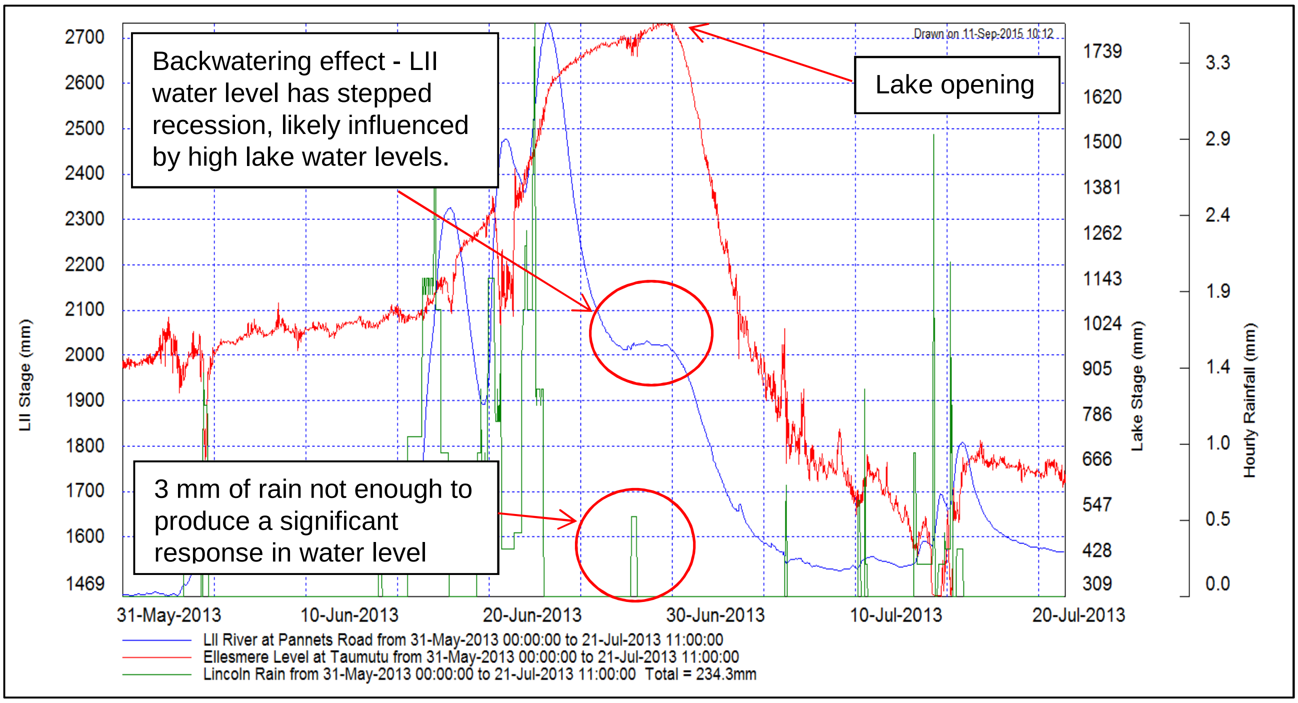


Figure 10: High lake level influence at Pannetts Road.

Analysis of the flow data from the Pannetts Road recorder indicated the following flow statistics (Table 2).

Table 2: Flow statistics for the Ararira / LII River at Pannetts Road (12 Nov 2008 to 20 Nov 2014).

Data	Flow (m^3/s)							
	Minimum	Maximum	Mean	Standard Deviation	Lower Quartile	Median	Upper Quartile	7DMALF[1]
Instantaneous	0.97	10.6	2.30	0.78	1.80	2.24	2.64	N/A
7 Day average	1.09	7.65	2.30	0.70	1.83	2.28	2.69	1.31

Notes: [1] 7DMALF is 7 day mean annual low flow and is the 7 day annual low flow averaged over the dataset based on hydrological years 1 July to following 30 June.

ECan has completed spot gaugings of flow at four locations on the Ararira / LII River. These gaugings show that flow contributions are greater in the upper part of the catchment (due to a higher concentration of springs), though flow in the main stem of the river continues to increase all the way to Te Waihora / Lake Ellesmere (Figure 11).

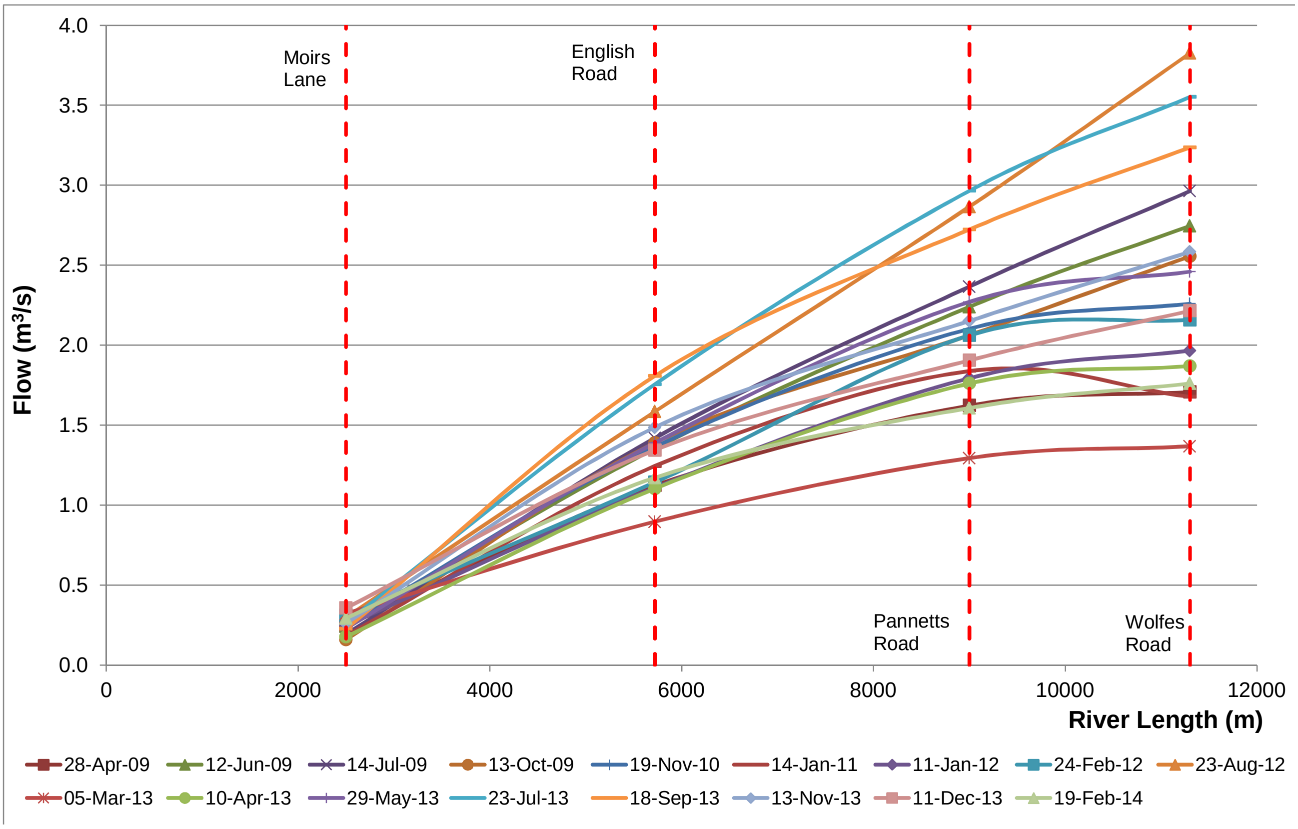


Figure 11: Flow changes down the Ararira / LII River.

3.6 Flooding and Drainage

Flooding in the lower parts of the catchment, particularly around Yarrs Lagoon is common and is caused predominantly by high groundwater levels and saturated soils rather than excessive runoff of catchment rainfall. Flooding can be particularly widespread when water levels in Te Waihora / Lake Ellesmere are high as this causes a backwater effect which can extend for several kilometres up the Ararira / LII River. An extensive network of drains extends across the catchment to control and lower groundwater levels, without which most of the catchment would revert back to a swampy wetland. High groundwater levels and the flat topography of the Ararira / LII River catchment makes efficient land drainage both necessary and a challenge, requiring regular waterway maintenance by the SDC and LII Drainage Committee. Maintenance of the drainage network to remove sediment and weed is an important requirement to preserve land drainage.

The LII Drainage Committee maintains 75.3 km of rated drains within the Ararira / LII River catchment. The LII Drainage Committee oversee assets which have an estimated replacement value of almost $8 million. A maintenance budget of approximately $43,000 is funded through a targeted rate on approximately 4,750 ha within a total service area of approximately 6,690 ha (SDC 2012 and 2015). The LII Drainage Committee holds resource consents CRC000818.1 and CRC000819 which relate to operation of a weed cutting machine. Land drainage activities are controlled through rules 5.75 to 5.80 of the Land and Water Regional Plan. In November 2011 SDC lodged a resource consent application (CRC120988) in relation to their land drainage activities. The application is currently on hold pending discussions with stakeholder and further investigations. Water level within the various Ararira / LII waterways is highly influenced by weed growth. The effectiveness of the weed cutter at lowering water levels can be seen in the water level data from Pannetts Road recorder (Figure 9) with weed cutting activities in January 2013 and 2014 resulting in water level drops of approximately 900 mm and approximately 800 mm respectively.

Low lying sections of the catchment particularly around Yarrs Lagoon are difficult to drain due to a combination of high groundwater levels, a lack of gradient to drive drainage to Te Waihora / Lake Ellesmere and backwater effects from the lake. Soils in the area are often waterlogged which limits production and prevents intensive farming. Any future increases in groundwater level due to sea level rise, higher lake levels and / or increased up-gradient groundwater recharge will only compound the situation and make some low lying areas very difficult to farm. It is expected that managed retreat from some areas allowing them to revert to their natural wetland state will be the best long term management option.

3.7 Water Use and Management

Use of both surface water and groundwater is extensive throughout the catchment and both resources are considered either fully or over allocated. Figure 12 highlights the active water related resource consents in the area.

As part of Variation 1 to the proposed Land and Water Regional Plan, ECan recently completed detailed modelling and technical reports to better understand the current and future[13] conditions of the hydrology in the Te Waihora / Lake Ellesmere catchment. The Variation 1 process has involved considerable community input via the Selwyn-Waihora Zone Committee. Some of the key results from the hydrology reports for the Ararira / LII River at the Pannetts Road bridge recorder site are shown in the table below. While flows in the Ararira / LII River are currently showing a declining trend due to groundwater over-allocation, the addition of the Central Plains Water (CPW) irrigation scheme (Figure 1) is expected to add flows to the Ararira / LII River due to increased infiltration associated with the increase in irrigated area. Additional measures such as Managed Aquifer Recharge (MAR), Targeted stream augmentation (TSA), and reduction in abstractions are proposed under Variation 1 to bring flow and water quality values closer to the natural state. The expectation is that the combined effect of CPW and the measures in Variation 1 will increase median flow, average flow and the average annual volume in the Ararira / LII River at Pannets Road by approximately 30 % from current conditions, although low flows are expected to be slightly lower. Current and expected future flow statistics for the Ararira / LII River at Pannetts Road are provided in Table 3.

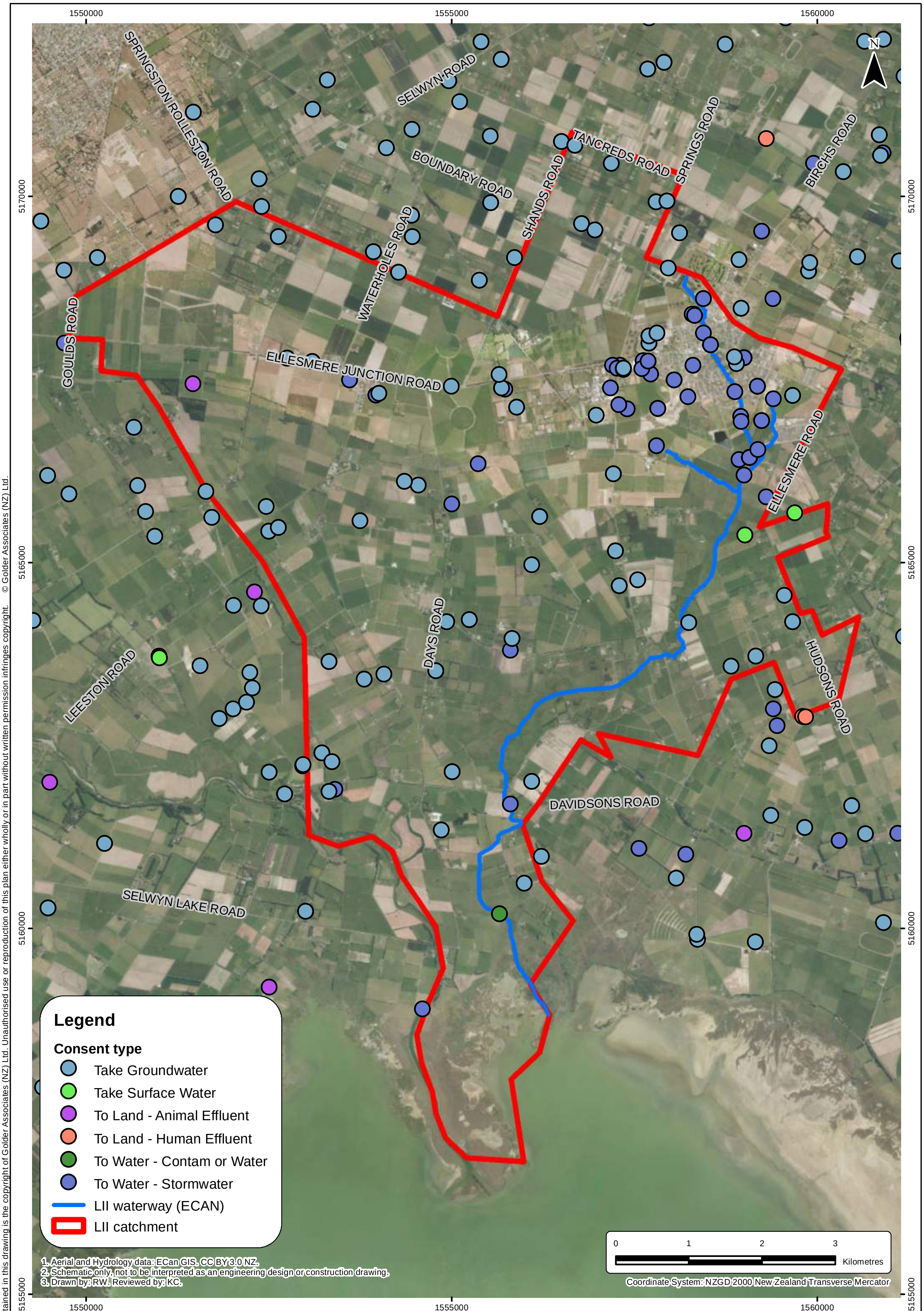
[13] Future conditions consider both increased irrigation and land use intensification associated with CPW and proposed regulatory changes and mitigation option included such things as stream augmentation and managed aquifer recharge.

Table 3: Predicted flow statistics for the Ararira / LII River at Pannetts Road 1984 - 2010.

Scenario	Ararira / LII River at the Pannetts Road bridge flow recorder site				
	Low Flow (7d MALF)	Mean Flow	Annual Volume	Median Flow	Flow Permanence
	L/s	L/s	Million m³	L/s	%
Current state based on past flow recordings and gaugings	1544	2011	63.4	1966	100
Conditions expected if all abstractions are ceased	2230	2959	93.4	2709	100
Future conditions if current land use continues	1050	2307	72.8	2171	99.8
Effects from CPW irrigation scheme	1371	2645	83.4	2506	100
Zone Committee Solutions Package: Effects from CPW irrigation scheme, MAR, TSA, and a reduction in abstractions	1447	2710	85.5	2559	100

Notes: The predicted flow statistics above were derived from an extensive modelling process which included a number of assumptions and approximations. When interpreting the values emphasis should be placed on the relative difference between the scenarios rather than the specific values. The reader is referred to Clark 2014 for a full explanation of the modelling process and the predicted flow statistics.

Waterway and catchment management decisions within the Ararira / LII River catchment are currently made using predominantly anecdotal information and traditional practices with minimal scientific input. There are no catchment management plans or hydraulic models of the waterways. The effects of lake levels, sediment, weeds, maintenance, and riparian management practices have not been scientifically established in the Ararira / LII River catchment. Similarly there is some uncertainty over what the actual future effects of CPW and the implications of Variation 1 will be.



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TITLE ARARIRA / LII RIVER - WATER CONSENTS

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SECTION 4

WATER QUALITY

4.0 WATER QUALITY

4.1 Background and Policy Framework

Water quality can broadly be defined as "*the suitability of water composition for supporting a range of water values, including habitat for aquatic life and human uses including recreation* (Davies-Colley 2013)". River water quality is affected by both point-source pollution (e.g., wastewater discharges) and diffuse pollution from land use. Improved wastewater treatment over the last 30 years means that point-source pollution is now relatively uncommon (Davies-Colley 2013). Diffuse pollution is now the primary water quality issue, and increasing urbanisation and agricultural intensification is placing greater pressure on water quality.

Both agricultural and urban land uses can have negative effects on water quality, although their effect on water quality differs in intensity and extent. While urban land use typically has a more negative effect on water quality than agricultural land use, urban land use covers less than 1 % of New Zealand's land area, compared to pasture covering around 40 %. This means that agricultural land use currently has the greatest impact on water quality in New Zealand (Davies-Colley 2013). Different forms of farming can, however, have varying impacts on the receiving surface water environments. For example, McDowell & Wilcock (2008) studying the difference in contaminant loads from land uses under different livestock, found that sediment and P yields are typically higher from deer farming than from sheep, mixed or dairy farms. In contrast, N losses were greatest from dairying catchments, when compared with other farming types (deer, mixed, sheep).

Key contaminants of concern in agricultural waterways include nutrients (particularly phosphorus), sediment, and faecal matter sourced from overland flow paths, bank erosion, and stock access. Nitrate nitrogen is also an important nutrient, and its primary source in agricultural streams is from nitrate-enriched groundwater from leaching under cattle urine patches. Lack of shading can also be associated with high water temperatures and depleted oxygen concentrations, due to high oxygen demand from excessive growths of aquatic plants and algae. In addition to elevated nutrients, fine sediment, faecal material, high temperatures and low dissolved oxygen concentrations, urban waterways can also have toxic metals and hydrocarbons from roads, roofs and other impermeable surfaces.

Water quality directly influences both the ecology present within the waterbody and use of the waterbody. However, water quality can also indirectly effect the hydrology of the waterbody in that water quality influences plant growth in, and adjacent to, the waterbody and sedimentation both of which can affect water levels within and the flow carrying capacity of the waterbody.

There are numerous water quality guidelines that are currently in use in New Zealand, which have been derived to protect instream values and the recreational use of waterways:

- The National Policy Statement for Freshwater Management (NPS-FM) (2014) defines compulsory national values for parameters relating to ecosystem health (periphyton, nitrate, ammonia and dissolved oxygen concentrations), and human health (secondary contact recreation) (*E. coli* counts).
- The Canterbury Land and Water Regional Plan (LWRP), as described by the NPS, also defines limits for additional chemical parameters (dissolved oxygen saturation and temperature) related to ecological health indicators. Variation 1 to the LWRP contains policies and rules specific to the Selwyn Te Waihora sub-region which covers the Ararira / LII River catchment.
- ANZECC (2000) guidelines are a key resource for managing water quality and protecting aquatic ecosystems in Australia and New Zealand. They are the most substantial set of national water quality guidelines in New Zealand.
- Ministry of Agriculture and Fisheries (1993) turbidity trigger value for recreational and aesthetic values.

In addition to these national and regional regulatory guidelines, Stevenson et al. (2010) provides a regional assessment of Canterbury Rivers which shows typical concentrations for various chemical parameters across different river types in the region.

The key documents that apply to each water quality parameter are summarised in Table 4.

Table 4: Water Quality parameters and relevant guidelines.

Water quality parameter		Relevant documents and guidelines	Limits
Dissolved oxygen		National Policy Statement for Freshwater Management	5 g/m^3 (National bottom line [as 7-day mean min.])
		LWRP (Spring-fed – Plains waterway type)	70 %
Temperature		LWRP (Spring-fed – Plains waterway type)	20 °C (maximum)
Nutrients	Nitrate	National Policy Statement for Freshwater Management	6.9 g/m^3 (National bottom line [as annual median])
	Dissolved reactive phosphorus (DRP)	Regional assessment of Canterbury Rivers by Stevenson et al. (2010)	'Enriched' = >0.009 g/m^3 'Excessive' = >0.03 g/m^3
	Ammonia	National Policy Statement for Freshwater Management	1.3 g/m^3 (National bottom line [as annual median])
E. coli		National Policy Statement for Freshwater Management	1000 *E. coli* /100 mL (National bottom line [as annual median])
Turbidity		Ministry of Agriculture and Fisheries turbidity trigger value for recreational and aesthetic values (MAF 1993)	2 NTU
		ANZECC (2000) – Lowland rivers	5.6 NTU
Heavy metals		ANZECC (2000)	Copper: 1.4 mg/m^3; Lead: 3.4 mg/m^3; Zinc: 8 mg/m^3 (95 % level of protection values)

The Ararira / LII River catchment includes a mix of urban and rural land use, so the following water quality summary includes water quality parameters that can be affected by both rural and urban land use. As part of this study water quality samples were collected from ten sites within the Ararira / LII River catchment at a mixture of mainstem and tributary locations in 2015 under both low flow and high flow conditions (Figure 2).

4.1.1 Available water quality reports and data

Numerous reports contain information on the water quality of the Ararira / LII River catchment and the wider Te Waihora / Lake Ellesmere catchment, including:

- Franklin (2010): MSc thesis that studied the spatial patterning of water quality in stream networks on the Canterbury Plains. Multiple sites were sampled throughout the Ararira / LII River catchment on a single occasion in autumn 2009.
- Stevenson et al. (2010): Report prepared by ECan to provide an overview of the state and trends in water quality in Canterbury waterways. The analysis was based on long-term data for different river types in Canterbury.
- Serriere et al. (2012): Study investigating the water quality from three Lake Ellesmere tributaries: LII, Halswell and Kaituna rivers. Water quality was assessed during baseflow and following rainfall at numerous sites throughout the Ararira / LII River catchment in 2012.
- Hanson (2014): A report focused on groundwater quality prepared by ECan to support the limit setting process in Selwyn Waihora catchment. A simple spreadsheet model was used to predict the effects of different land use scenarios on water quality within the Te Waihora / Lake Ellesmere catchment.

- Hayward (2014): Report prepared for the LII Living Water Programme, which summarises water quality data from Pannetts Road bridge (from 1994 to present), and from three other sites sampled between April 2013 and May 2014 (Moirs Lane, Englishs Road and Wolfes Road). Data sourced from ECan.
- Kelly (2014): Report focused on surface water quality and ecology prepared by ECan to support the limit setting process in Selwyn Waihora catchment. Discusses the potential consequences of different land use scenarios on water quality and environmental / ecological values in lowland streams in the Te Waihora / Lake Ellesmere catchment.
- Various unpublished water quality data sets from Ararira / LII River catchment the most extensive of which is ECan's water quality data from the Ararira / LII River at Pannetts Road.

4.2 Temperature and Dissolved Oxygen

Both temperature and dissolved oxygen fluctuate diurnally (daily) and can be adversely affected by urban and agricultural land use. Lack of shading is a major cause of elevated temperatures and reduced dissolved oxygen concentrations, with the effects being greatest in smaller waterways during summer months. While some aquatic species, such as longfin eels, are relatively tolerant of higher temperatures and low dissolved oxygen, other species, such as mayflies and brown trout, are relatively sensitive.

Temperature

Average water temperatures are cool (around 13 °C) and average dissolved oxygen levels are high (around 85 – 90 %) at the ECan's long-term monitoring site at Pannetts Road (Hayward 2014). Instantaneous temperature readings (taken at 15 minute intervals) from this site between June 2009 to March 2010 and between June 2012 to January 2013 show that temperatures remained below the freshwater outcome of 20 °C for spring-fed plains rivers in the Canterbury L and and Water Regional Plan (LWRP) (ECan unpublished data).

Dissolved oxygen (DO)

While dissolved oxygen saturation readings are typically above the freshwater outcome of 70 % for spring-fed plains rivers in the LWRP, approximately 12 % of readings fell below this value (ECan unpublished data).

The spot measurements of dissolved oxygen concentration and saturation from this study show (see Table C1) that numerous sites had low dissolved oxygen, with the lowest concentrations and saturations being generally recorded from tributaries with the highest macrophyte cover.

Comparison between sites for temperature and dissolved oxygen

Dissolved oxygen saturation readings from Ellesmere, Powells, Goodericks, Springs and Pannetts during the dry sampling round were all below the freshwater outcome of 70 % for spring-fed plains rivers in the LWRP. Saturation values recorded during the wet sampling round were much higher, except for Goodericks which was still below the 70 % threshold. Temperature values recorded from all sites on both sampling occasions were below the LWRP freshwater outcome of 20 °C.

Temperature and dissolved oxygen data from ECan are based on spot measurements (similar to this study), so they will underestimate the daily extremes in both water quality parameters. Based on observations elsewhere in the region, high macrophyte cover throughout the catchment likely drives dissolved oxygen concentrations down to very low levels during summer, which could result in fish kills.

Low dissolved oxygen levels could have contributed to the deaths of two large longfin eels observed during a site visit in December 2014, but without any continuous monitoring data, one can only speculate. It is assumed that temperature and dissolved oxygen extremes are greatest in smaller tributaries, which are less buffered by flow, but data is lacking to confirm this.

Continuous monitoring of dissolved oxygen and temperature in the mainstem and tributaries would help improve our understanding of water quality impacts in the Ararira / LII River catchment.

4.3 Nutrients

Plant nutrient availability (particularly nitrogen and phosphorus) is a major factor controlling aquatic plant and algal growth in streams and rivers. High concentrations of these nutrients in water bodies can cause excessive aquatic plant growth, and can be toxic to fish. In turn, excessive plant growth can lead to blooms of algae and nuisance weeds that can influence the physico-chemical character of a river by altering the acidity (pH) and / or dissolved oxygen levels. Such algal blooms can have detrimental effects on fish and other aquatic animals, reduce the recreational and aesthetic value of water bodies, alter flow and drainage patterns and block water intakes and pumping systems.

Nutrients (both N and P) can be categorised into particulate (suspended) and dissolved forms, as well as organic and inorganic forms. The bioavailability of nutrients depends on its chemical form:

- Organic particulate nutrients: these include living and dead organic matter such as bacterial, plant, and animal tissue. These forms of nutrients need to be converted to inorganic forms before being bioavailable for plant growth (i.e., via microbial breakdown and mineralisation).

- Inorganic particulate nutrients: include minerals and nutrients adsorbed (attracted to the surface) to suspended inorganic sediment particles. Phosphates are readily transported to waterways in this form in overland runoff.

- Dissolved organic nutrients: these include numerous types of biological molecules, such as proteins, containing N and P. These forms are not immediately bioavailable (need to be mineralised), although they do form part of total nutrient concentrations.

- Dissolved inorganic nutrients: these are the most bioavailable forms of nutrients and are, therefore, the more important with respect to controlling excessive plant and periphyton growth in streams. Dissolved inorganic P is known as dissolved reactive phosphorus (DRP). Phosphates readily bind to soil and sediment particles and can enter streams bound to sediment particles from overland flow pathways. Dissolved inorganic nitrogen (DIN) is comprised of a combination of oxidised nitrogen species (nitrate and nitrite), ammonia and dissolved N gas. In well-oxygenated waters, however, nitrate is the main component of DIN present. In contrast to P, nitrate does not bind to soils or particles in the water and is readily transported through overland or subsurface (leaching) flows. Due to its conservative nature, any excess nitrate present that is not used by plants will move downward through the soil to groundwater.

Nitrate

Nitrate-nitrogen is the most common form of soluble inorganic nitrogen in Canterbury waterways, and its primary source in agricultural streams is from nitrate-enriched groundwater that has been derived from leaching under cattle urine patches.

Water quality samples collected as part of this study[14] show that nutrient concentrations from many tributary and mainstem sites were high, with two of the 10 sites sampled exceeding the national bottom line[15] for nitrate toxicity of 6.9 mg NO_3-N/L (Figure 13). On both sampling occasions, all 10 sites were above the median value recorded for spring-fed plains waterways in Canterbury (1.8 g/m^3) (Stevenson et al. 2010). The highest concentrations were recorded from Lincoln Main Drain on both sampling occasions; this tributary has previously been shown to have high nitrate concentrations (Franklin 2010). Nitrate was the main form of nitrogen present at all 10 sites, and this finding corroborates with previous studies that show nitrate comprises the majority of DIN in waterways of the Canterbury Plains (Stevenson et al. 2010; Serriere et al. 2012).

In terms of spatial differences, nitrate concentrations recorded from tributaries were more variable than those recorded from the mainstem sites during both sampling events. There was no apparent longitudinal difference in concentrations down the catchment. This is in contrast with the findings of Serriere et al. (2012)

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[14] Further information on the water quality sampling programme and associated complete results undertaken as part of this study can be seen in the appendix report.

[15] The National Policy Statement for Freshwater Management 2014 (NPS-FM) provides a national objectives framework for freshwater management. Appendix 2 of the NPS-FM sets national bottom lines or minimum acceptable states for various parameters including Periphyton, Nitrate, Ammonia, Dissolved Oxygen and E. coli in rivers.

and Hayward (2014), who found that nitrate concentrations generally decreased with increasing distance downstream on the Ararira / LII River. It should be noted, however, that the limited sampling (only two sampling events) that occurred in this study reduces the ability to detect trends, as water quality can vary considerably over time at a given location.

As previously mentioned, nitrate concentrations displayed significant variation between tributaries; this also being observed by Serriere et al. (2012). Similar to our findings, that same study also found that nitrate concentrations were generally lower following rainfall, especially in the upper catchment near Springs Creek and the confluence of the LI Creek and Liffey Stream.

In terms of temporal differences, Hayward (2014) reported that there is a long-term trend (1994 onwards) of increasing nitrate concentrations in the Ararira / LII River mainstem. Nitrate contamination of surface waters generally occurs via runoff, leaching through groundwater or from fertilizer and / or effluent applications, wastewater discharges and livestock intrusion. In the case of the Ararira / LII River catchment, it is likely that the principal source of the nitrate is nitrate-rich groundwater sourced from up-gradient areas of the Plains (Hayward 2014). This report states that interventions aimed at reducing nitrate concentrations in the Ararira / LII River mainstem, and thereby reducing inputs to Te Waihora / Lake Ellesmere, would need to “consider options (such as wetland creations or enhancements) at the headwaters”.

DRP

Dissolved reactive phosphorus (DRP) is the form of phosphorus dissolved in water, which is most readily available for plant and algae growth. The main sources of phosphates are raw and treated wastewater, animal manure, phosphate fertilizers and breakdown of phosphate rock and soil components. Unlike nitrates, however, phosphorus generally binds to soil and does not readily leach into groundwater (Stevenson et al. 2010). Notwithstanding this fact, certain soil types have increased vulnerabilities to leach phosphorus (Webb et al. 2010). Therefore, while overland flow is recognized as the main discharge pathway of phosphorus to receiving waters, groundwater should also be considered (at least as a partial contributor). Phosphorus concentrations in surface waters usually display a strong positive relationship with total suspended solids (TSS) concentrations, as phosphorus adsorbs or “sticks” to sediment particles.

Dissolved reactive phosphorus (DRP) concentrations measured as part of this study were generally quite high, with eight out of the 10 sites exceeding the ‘enriched’ concentration limit for DRP on either sampling occasion – this limit is based on a regional assessment of Canterbury rivers by Stevenson et al. (2010) (Figure 13). In general, higher concentrations were recorded during the wet sampling round, especially in certain tributaries. Only a single site, however, exceeded the ‘excessive’ limit proposed by the same study (Powells during the wet sampling event). The concentrations recorded during this study were comparable to those reported in earlier studies of the Ararira / LII River catchment (Serriere et al. 2012; Hayward 2014), and from spring-fed Plain rivers in Canterbury (Stevenson et al. 2010).

In terms of spatial differences within the catchment, DRP concentrations increased with increasing distance downstream along the mainstem, which suggests that concentrations reflected the accumulation of inputs from the adjacent land and from the numerous tributaries that enter the mainstem along its length (Figure 13). This was also observed by both Serriere et al. (2012) and Hayward (2014). DRP concentrations displayed significant differences between tributaries, especially during the wet sampling round. Serriere et al. (2012) also observed that DRP concentrations increased following rainfall, with the rainfall-mediated increase varying in magnitude between mainstem and tributaries, and between individual tributaries. A similar trend was generally observed in this study. These findings suggest that there are localised areas within the catchment that are key sources or ‘hotspots’ of DRP runoff.

In terms of long-term DRP trends, Hayward (2014) showed that DRP concentrations have been declining in the Ararira / LII River mainstem since 1994.

Ammonia

Ammoniacal-nitrogen (ammonia-N) is the common reduced form of soluble nitrogen and is usually derived from animal urine, breakdown of urea and animal proteins, industrial processes, or reduced nitrogen under anoxic conditions (Stevenson et al. 2010).

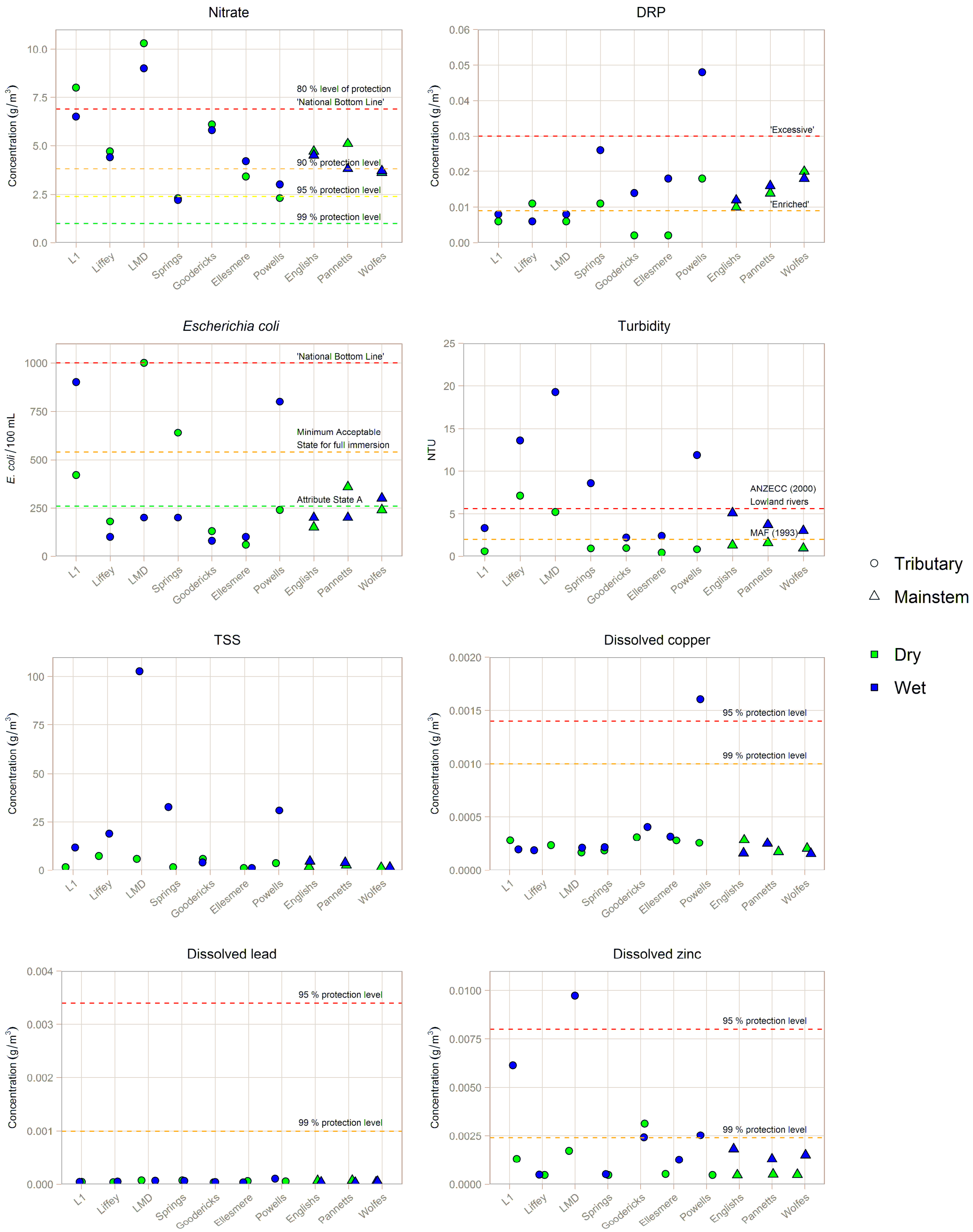

Figure 13: Selected water quality results from the 'dry' and 'wet' sampling events Ararira / LII River catchment 2015.

The nitrate and *E. coli* guidelines are based on the NPS-FM (2014), the DRP guidelines are based on a regional assessment of Canterbury rivers by Stevenson et al. (2010), and the dissolved metal guidelines are based on ANZECC (2000) aquatic ecosystem trigger values.

Of the 10 sites sampled during this study the only site to record relatively higher ammonia-N concentrations was Pannetts during the dry sampling round. However, the concentrations recorded from this site on that occasion (0.04 g/m^3) were low and below the ANZECC (2000) 99 % level of protection for aquatic species (0.32 g/m^3 at pH 8). All sites recorded concentrations comparable to those recorded from other spring-fed Plains rivers in Canterbury (Stevenson et al. 2010).

Ammonia concentrations recorded from the upper Ararira / LII River have improved considerably since the early 2000s, when the discharge of sewage from Lincoln township ceased (Hayward et al. 2014).

4.4 *Escherichia coli*, Turbidity and Suspended Solids

Escherichia coli (E. coli), turbidity and total suspended solids (TSS) are the key indicators which influence use of a water body. *E. coli* is important for health reasons while turbidity and TSS are important for clarity/amenity reasons. Turbidity and TSS also have a significant role in both phosphorus concentrations (i.e. DRP discussed above) and ecological communities (through smothering, filtering of light etc.)

Escherichia coli (E. coli)

E. coli are the bacteria commonly used as an indicator of pathogens associated with faecal contamination of water bodies. In New Zealand, the primary sources of faecal contamination are human and livestock waste (e.g., cattle, sheep, deer, etc.); however, dense bird populations can also be a significant source (e.g., waterfowl). In spring-fed plains streams, such as the Ararira / LII River, contamination from agricultural activities, including direct access by stock and diffuse runoff from pasture, are considered to be the primary contributors (Stevenson et al. 2010). The presence of faecal contamination can affect the value of water resources for human uses such as potable supply, contact recreation and stock-water supply.

Of the 10 sites sampled during this study the highest *E. coli* counts were recorded from the closely located upper catchment tributaries: Lincoln Main Drain and the LI Creek (Figure 13). The *E. coli* count from Lincoln Main Drain during the dry sampling event was at the national bottom line of 1,000 cfu / 100 mL, set out by the NPS, which sets the minimum acceptable risk for secondary contact recreation (Figure 13). In contrast, the highest *E. coli* count from the LI Creek was recorded during the wet sampling event. Springs Creek (during the dry sampling event) and Powells (during the wet sampling event) also recorded high *E. coli* counts. Earlier data (sampled in 2006 – 2007) from Springs Creek reveals that this tributary is prone to high *E. coli* counts, with levels generally increasing in a downstream direction along this waterway (Markham-Short 2012). While it is likely that the source of high *E. coli* counts from these sites is a combination of runoff from agricultural (e.g., effluent spray runoff, runoff from farm tracks / races / yards, etc.) and urban sources (e.g., wastewater and sewerage infrastructure, especially for the LMD and LI Creek), further work is required to pinpoint the sources.

There was no apparent longitudinal difference in *E. coli* counts down the mainstem of the Ararira / LII River. Long-term data available for *E. coli* counts from Pannetts Road show that there has been little change in median concentrations since 2007; however, the 95^{th} percentile values have been steadily decreasing since 2011 – 2012 (Hayward 2014).

Turbidity and suspended solids

Turbidity and total suspended solids (TSS) concentration are two related indicators of water clarity and sediment input to streams. Along with *E. coli*, turbidity is a major attribute that determines the recreational value of rivers and streams. Turbidity is a measure of water clarity and is determined by the quantity of organic and inorganic matter suspended in the water column. High turbidity can affect the ecological, amenity and recreational values of a waterway. Furthermore, the deposition of suspended particles can also lead to subsequent detrimental impacts on aquatic biota (Jones et al. 2012). Recent research in agricultural streams in Canterbury has shown that fine sediment deposition is the primary determinant influencing benthic invertebrate communities (Burdon et al. 2013).

In general, the majority of sites sampled during the dry sampling round had low turbidity and TSS concentrations that are typical of spring-fed plains rivers in Canterbury (Stevenson et al. 2010). However, turbidity and TSS concentrations recorded during the wet sampling event were higher at most sites, especially the tributaries (Figure 13). Four of the seven tributary sites exceeded the ANZECC (2000) trigger value for turbidity for lowland rivers during the wet sampling event. In addition, all ten sites exceeded the Ministry of Agriculture and Fisheries (MAF 1993) turbidity trigger value for recreational and aesthetic values during the wet sampling round.

There are no national guidelines for TSS concentrations in surface waters, although adverse effects on benthic invertebrates can occur at TSS concentrations above 5 g/m^3 (Reid & Quinn 2011). TSS concentrations recorded from five out of the seven tributary sites during the wet sampling round were greater than this guideline value. The highest TSS concentration was recorded from LMD during the wet sampling event (103 g/m^3).

Similar to this study, Serriere et al. (2012) observed a similar marked increase in turbidity in this area of the catchment following rainfall (between the confluence of the LI Creek and Liffey Stream downstream to the confluence of Springs Creek with the mainstem), with turbidity decreasing in a downstream direction from this point. The current data from this study, combined with the findings of Serriere et al. (2012) and EOS Ecology (2014), suggest that suspended sediment inputs to the mainstem are principally sourced from tributaries in this general area (Figure 14).

Once again, there was no apparent spatial difference for either TSS or turbidity longitudinally down the catchment. In terms of temporal changes, data collected from numerous sites on Liffey Stream between 2000 and 2003 show that this stream was less turbid during that period (average turbidity of 3.3 NTU) (Markham-Short 2012). Long-term data from the mainstem at Pannetts Road show that turbidity values and TSS concentrations have increased over the last eight years, and that both are strongly associated with flow (Hayward 2014). This same study also noted that the average turbidity from 2009 – 2014 did not comply with the recreational and aesthetic guideline value of 2 NTU.

Figure 14: Tributaries can be major sources of sediment, especially during rainfall events.

4.5 Heavy Metals

Dissolved heavy metals (copper, lead and zinc) in surface waters are predominantly sourced from urban runoff (e.g., industrial sources and vehicle traffic (Suren & Elliot 2004)), although certain agrichemicals can contain varying amounts of copper (e.g., copper fungicides / bactericides, footbaths in dairy yards, etc.), as can palm kernel extract).

The only site to record a dissolved copper concentration above the laboratory detection limit was Powells during the wet sampling round (Figure 13). This site exceeded the ANZECC (2000) 95 % level of protection for aquatic species on this occasion. Further monitoring is required however, to determine the source of this elevated copper concentration.

Dissolved zinc concentrations recorded from most sites during both sampling events were below the ANZECC (2000) 99 % level of protection for aquatic species. However, concentrations recorded from LMD and the LI Creek during the wet sampling round exceeded the 99 % protection level, with LMD also exceeding the 95 % protection level. These findings are in good agreement with previous monitoring that has shown that zinc concentrations recorded following rainfall in the LI Creek and LMD are usually higher than concentrations recorded from Liffey Stream and the Ararira / LII River (downstream of the confluence point of LMD) (EOS Ecology 2014). This same study also shows that concentrations recorded from these two former sites regularly exceed the ANZECC (2000) 95 % trigger value during significant rainfall events. Combined, these results suggest that rainfall-mediated runoff from urban areas is the primary source of zinc in these waterways.

Dissolved lead concentrations recorded from all sites on both sampling occasions were low, and were all below the ANZECC (2000) 99 % level of protection for aquatic species.

SECTION 5

ECOLOGY

The study of the relationship between organisms and their environment

5.0 ECOLOGY

The ecology of the Ararira / LII River catchment reflects its highly modified nature. The original widespread wetland ecological system has been replaced by an ecosystem dominated by intensive farmland. The remaining indigenous ecosystem values are confined to small areas within the catchment. These are associated with a few protected springs, some areas of riparian vegetation adjacent to the catchments waterways, the Yarrs Flat area where the Ararira / LII River flows into Te Waihora / Lake Ellesmere, and reserve areas such as Yarrs Lagoon and adjoining wet farmland where a lack of cultivation and pasture development has resulted in the retention of some indigenous vegetation.

5.1 Terrestrial and Wetland Vegetation

The Land Environment New Zealand (LENZ) environment classification system provides a basis for describing the environments present within the Ararira / LII River catchment. LENZ uses a range of geologic, climate, soil and geographic (e.g., aspect, elevation) data to cluster land areas with the same or similar attributes into environmental categories (Leathwick et al. 2002, Leathwick et al. 2003). The system has a four tier output ranging from 20 level 1 broad scale environments (useful for national analyse) to 500 level 4 fine scale environments (useful for regional and local analyses). The majority of the Ararira / LII River catchment is classified as two level 4 environment types (N1.1a or N1.2c) within the common Eastern South Island Plains (level 1 environment)[16].

LandCare Research and DOC conduct reviews of the threat levels of each level 4 environment using the LENZ level 4 environments, the Land Cover Database (LCBD) and areas of legally protected land (e.g., DOC estate, QE II covenants). A five-tier threat classification is used which provides a measure of both the environmental change that is occurring and the level of protection. Other than a small area on the lake margin the entire Ararira / LII River catchment has the highest threat classification of 'acutely threatened' with less than 10 % of the indigenous cover left. Any remaining areas of indigenous vegetation within the Ararira / LII River catchment are of high value due to their rarity[17].

Currently much of the Ararira / LII River catchment consists of agricultural land (refer to Section 2.0). There are, however, a number of reserves within the catchment that contain areas of significant vegetation. These include Yarrs Lagoon (Ta-rēre-kau-tuku) reserve (76.9 ha) and Yarrs Flat wildfire reserve (286 ha) in the lower catchment (Figure 2), and to a lesser extent Liffey Domain (2.9 ha) and Mahoe reserve (<1 ha) in the upper catchment. These two latter mentioned reserves have been created, whereas Yarrs Lagoon and Yarrs Flat are both remnants of a widespread wetland swamp that existed prior to human settlement (Parker & Grove 2013).

Despite Yarrs Lagoon comprising mainly of exotic willows, it does provide habitat for a range of native plants, with many of these being abundant in the willow understorey (Parker & Grove 2013). In particular, the area supports populations of nationally threatened swamp nettle (Figure 15), locally rare mānuka and twig-rush (Parker & Grove 2013). Yarrs Lagoon is considered one of the largest contiguous freshwater wetland habitats remaining within the area of the former central plains swamp (Parker & Grove 2013).

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[16] The LENZ level 1 and level 4 maps for the catchment are shown in Appendix D.

[17] The LENZ threatened environment classification map for the Ararira / LII River catchment is shown in Appendix D.

Figure 15: Swamp nettle in Yarrs Lagoon.

The vegetation of Te Waihora / Lake Ellesmere, including around the mouth of the Ararira / LII River has been described and mapped in surveys in 1983 and 2007 (Grove 2013). Like Yarrs Lagoon, the lake edge continues to support important native vegetation, despite extensive and ongoing effects of invasion by exotic plants and other adverse effects. For example, Te Waihora / Lake Ellesmere supports more than 80 % of Canterbury's coastal saltmarsh, and the lake shore vegetation, including the area around the mouth of the Ararira / LII River, is of regional and national significance. Yarrs Flat, which is part of a large tract of flat estuarine-margin land around Te Waihora / Lake Ellesmere known as Greenpark Sands, also harbors populations of significant vegetation such as native musk, as well as swamp nettle and fennel-leaved pondweed (Butt 2015). This area provides important habitat for many migrant and native wading birds such as Australasian bittern, white heron and banded dotterel. Threats to the ecological value of these wetlands include further weed encroachment, waterway maintenance effects (e.g., spraying and removal of native vegetation during maintenance activities), declining water quality and stock-associated damage (Parker & Grove 2013; Butt 2015).

Other native plants that have been recorded from these wetlands, as well as from the wider catchment include raupō, sedges, common spikerush, harakeke / flax, cabbage trees, swamp kiokio, pig fern, prickly shield fern, bracken and pohuehue (Jensen 2013).

Numerous exotic weed species are also common in the catchment (Jensen 2013). One of the most notable weed species is grey willow, as this species has greatly increased its distribution along the lake margins since the early 1980s (Jensen 2013). Other weed species of particular concern in the catchment include yellow flag iris, canary reed grass, Chilean rhubarb, montbretia, everlasting pea, and floating sweetgrass (Jensen 2013; Parker & Grove 2013; Butt 2015).

Because of the highly-modified state of Canterbury vegetation, both the large remnants of native vegetation and the scattered individuals and small patches along waterways are all valuable, not only for their own sake, but as sources of seeds for natural and assisted regeneration, and (probably) as habitat for native invertebrates, lizards and birds.

5.2 Aquatic and Riparian Vegetation

5.2.1 Aquatic plant communities

Aquatic plants, or "macrophytes", are a dominant feature in many waterways in the Ararira / LII River catchment. In many of the mainstem and tributary survey reaches, macrophytes (both emergent and submerged forms) cover more than 70 % of the stream bed. This high biomass is driven by the fact that habitat conditions in most waterways are very suitable for macrophyte growth, with sufficient light (due to minimal shading), abundant nutrients in the water column and sediment, and soft substrate for root establishment. In addition, as the waterways are predominantly spring-fed and low gradient, there is little opportunity for flood flows to scour or displace macrophytes. Once established in a waterway, macrophytes themselves can act as sediment traps, thereby, increasing sediment deposition in the growing season. High macrophyte biomass in a waterway (in the range of 40 – 60 % streambed coverage) can also lead to large diurnal (daily) changes in pH and dissolved oxygen concentrations, which can adversely affect aquatic biota (Matheson et al. 2012).

Macrophyte communities in the mainstem are generally dominated by submerged species, as most reaches are too deep for emergent macrophyte growth, apart from the banksides. The most common species recorded in the mainstem during the stream walk surveys were exotic Canadian pondweed and curly-leaf pondweed and native water milfoil. Patches of native charophytes were often intermixed within these submerged macrophytes. There were a few localised areas of other native macrophyte species, such as fennel-leaf pondweed, particularly in the lower reaches of the mainstem by Te Waihora / Lake Ellesmere. Fennel-leaf pondweed is one of several species being considered for macrophyte restoration as part of the Whakaora Te Waihora programme. Emergent macrophytes are generally more abundant in the smaller tributary waterways, particularly in the least shaded reaches. Many tributaries have large sections that often become covered by emergent macrophytes. The two main emergent species present are monkey musk and watercress (Figure 16).

Periphyton (algae that attaches to stream beds and other surfaces) biomass can become high in some waterways, particularly in the unshaded sections of the channelized tributaries (Figure 16). Long filamentous algae were the most commonly observed algal group during the stream walk. However, as is the case with other Te Waihora / Lake Ellesmere tributaries, macrophytes are more visually dominant than periphyton in most waterways (Kelly 2014). The toxic cyanobacterium *Phormidium* was also observed at a single site from the upper Liffey Stream during the surveys. *Phormidium* is found in a number of Canterbury lowland rivers; it is highly toxic to dogs and may also be harmful to humans.

5.2.2 Riparian plant communities

The riparian zone is defined as the interface between terrestrial and aquatic ecosystems, where direct interaction between land and water occur. These interactions include waterway shading by terrestrial plants, inundation of the banks at normal high flows, input of wood and litter, provision of in-stream habitat as cover, and use of the banks for spawning by stream biota (Harding et al. 2009). The benefits of a well-managed riparian zone are numerous, but some of the main functions include (from Collier et al. 1995):

- Provides shading to reduce excessive macrophyte growth, and also to reduce stream water temperature.
- Helps to filter runoff to reduce sediment (and associated nutrients) and other particulate loads to receiving waterways.
- Riparian vegetation can take up nutrients from shallow groundwater.
- Provides inputs of prey items for invertebrates and fish.
- Provides woody debris, which enhances in-stream habitat heterogeneity.
- Improves bank stability, and roots help to prevent bank erosion and undercutting.
- Spawning habitat for native fish, such as inanga.
- Provides habitat for terrestrial fauna.

Woody riparian vegetation was generally quite limited along most mainstem and tributaries reaches, reflecting the predominantly agricultural land use. In many of the reaches surveyed during the stream walk, fencing was within 3 m of the waterway. The majority of riparian margins, especially for waterways flowing through agricultural land, comprise mainly of exotic rank grasses (tall fescue, creeping bent, amongst others), dock, willow weed, with the occasional patch of gorse, and blackberry (Figure 16). Tributaries that flow alongside roads have a grassy buffer strip as part of the roadside reserve, which contain little if any woody vegetation. The most common trees within the riparian margins include willows (mainly crack and grey), gums, poplars, elder, alder and ornamentals (oak, sycamore and silver birch).

Nevertheless, many regionally rare native species (i.e., uncommon on the Canterbury Plains) have been observed in the Ararira / LII River catchment from a very limited number of surveys. Some species include [*Jason Butt observations (comms 2/10)*]:

- Orange nut sedge near Pannetts Road.
- Square sedge near Englishs Road and surrounding drains, as well as Yarrs Lagoon.
- Bog rush [couple of hectares] near Pannetts Road.
- Grass-leaved rush near Pannetts Road.
- Choisy in Yarrs Lagoon.
- Swamp nettle is quite common along drains and the mainstem.
- White violet and Haaka, (New Zealand native violet) in Yarrs Lagoon. These are uncommon on the Plains.
- *Isolepis distigmatosa* in Yarrs lagoon.
- Waoriki in Yarrs lagoon.
- Teasel Sedge in Yarrs Flat.
- Blinks in Yarrs Flat.

5.2.3 Management of macrophytes

As discussed in Section 3.0, macrophytes are periodically removed from the mainstem and tributaries to ensure channel conveyance is maintained at a level that minimises the risk of flooding to the surrounding land. The removal of macrophytes from waterways is carried out using a variety of methods including:

- Weed rake (rake-type excavator attachment).
- Standard excavator bucket.
- Weed-cutting boat.

These operations can have a major impact on fish and aquatic invertebrates present in these waterways (Hudson & Harding 2004; Greer 2014). In addition to direct mortality from the operations (i.e., crushing, abrasion, or physical removal from the channel and stranding), the loss of habitat and increased sedimentation can have longer lasting adverse effects on the aquatic biota of these waterways. Currently, periodic macrophyte clearance is regarded as the most effective approach to maintain channel capacity. However, preventative actions to reduce macrophyte growth such as riparian planting could help to reduce the reliance on these responsive approaches (i.e., macrophyte removal). In doing so, long term maintenance costs associated with macrophyte removal would be reduced, whilst both the in-stream and terrestrial habitat would be simultaneously enhanced. Weed clearance and opportunities for alternative approaches are discussed further later in the enhancement section of this report.

Emergent macrophytes were abundant in many tributary reaches

High filamentous algal cover

Typical bank-side vegetation of many tributaries

Native plants are mainly associated with riparian plantings

Figure 16: Selected photographs from the Stream Walk surveys.

5.3 Aquatic Habitat

5.3.1 Survey method

As part of this project, ten individual tributaries and three sites on the mainstem of the Ararira / LII River were surveyed using the ECan Stream Walk Assessment Specification (Golder 2014) (Figure 2). These 13 sites (and 79 associated reaches therein) were selected to provide a representation of the range of tributary and mainstem conditions present within the catchment. Further information on this methodology, as well as the data collected can be found in Appendix B.

5.3.2 Mainstem

The Ararira / LII River mainstem consists mainly of run[18] habitat with a soft-bottomed substrate dominated by silt and sand (Figure 17). Exposed stony substrate is virtually absent from the mainstem, apart from a few isolated sections near Englishs Road in the middle reaches, and around a number of road bridges (e.g., Pannetts Road Bridge) (Figure 17). The Ararira / LII River channel has low sinuosity (i.e., meanders) along most of its length, with many reaches having been historically straightened and channelized (e.g., through Yarrs Lagoon). These activities, as well as macrophyte removal operations, have resulted in it being predominantly channelized with a rectangular cross section.

The banks are mainly moderate (31 – 60 °) to steep (61 – 80 °), but are generally relatively stable with limited active bank erosion being observed during the surveys (Figure 17). Fencing generally prevents stock access to the mainstem, apart from a few isolated areas (Figure 17). Aquatic habitat variability is uniformly low throughout much of the mainstem, as in-stream structures such as woody debris and varying habitat types (e.g., riffle[19], run, pool sequences) are all but absent. Apart from areas of bare soft sediment, which provides poor quality habitat for most aquatic biota, macrophytes and some undercut banks and overhanging vegetation provide the main habitat and refuge for aquatic invertebrates and fish. Channel shading is low (generally <15 – 20 %) throughout much of the mainstem.

5.3.3 Tributaries

Many of the Ararira / LII River tributaries are straightened, channelized, soft-bottomed waterways. These waterways generally have steep-sided banks, and consist mainly of run habitat with occasional stagnant areas resulting from abundant emergent macrophyte (aquatic plant) growth (Figure 16). There are, however, a few larger tributaries in the upper catchment that have a more natural, sinuous channel form (at least in certain sections). These include the LI Creek, Liffey Stream and Springs Creek. Stony substrate is rare in most tributaries, and is restricted to the mid to upper reaches of Powells Road Drain, Goodericks Drain, Liffey Stream, and the LI Creek. Springs occur in many tributaries, especially those in the upper catchment (e.g., Springs Creek).

Tributaries, like the mainstem, are subject to periodic channel maintenance and macrophyte clearance (Figure 18) that result in extensive channel downcutting, over-steepening of the banks and reduced bank stability. Stream bank slumping, which is likely to be primarily attributable to such activities, was observed in many of these waterways during the stream walk survey (Figure 18). In addition, bed substrate is often removed from the beds of many of these tributaries as part of maintenance activities (Figure 18).

Most tributaries that flow through farmland are fenced to prevent stock from accessing the waterway; however, there are a number of exceptions. One example in particular was the lower reaches of Carters Road Drain, which shows obvious signs of stock damage (pugging) (Figure 19). Numerous springs that emerge close to waterways are also unfenced (Figure 19). Many tributaries have culverts or bridges, but the majority of these structures do not appear to impede fish passage. Overall habitat quality in the tributaries is broadly similar to that found in the mainstem, with macrophytes providing the main habitat type for aquatic biota. Some tributaries do, however, have greater shading from riparian vegetation, compared with the mainstem. These tributaries include Carters Road Drain, Collins Road Drain, Days Road Drain, Ellesmere Road Drain and Goodericks Road Drain.

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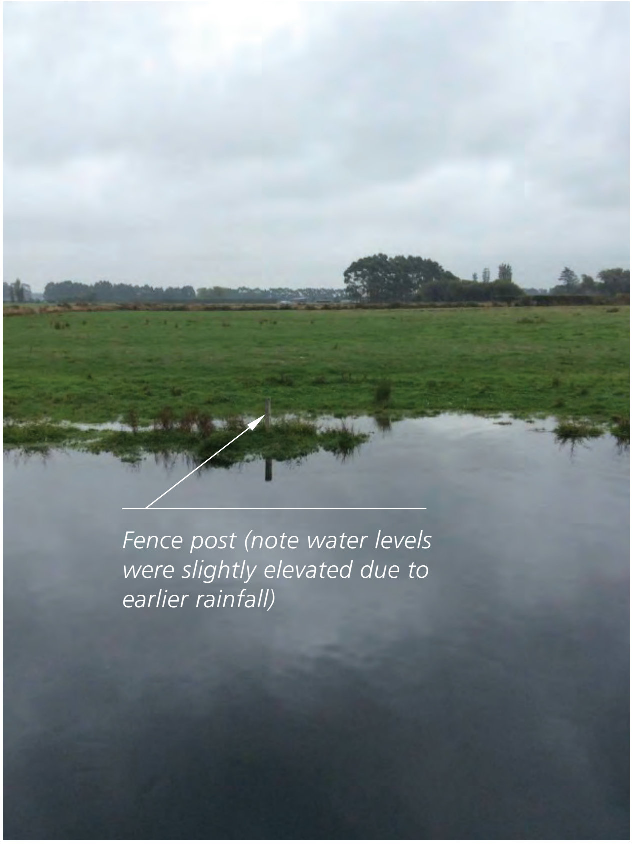
[18] Run habitat: slow-moderate depth and water velocity, uniform-slightly variable current, surface unbroken, smooth-rippled (Harding et al. 2009).

[19] Riffle habitat: shallow depth, moderate to fast water velocity, with mixed currents, surface rippled but unbroken (Harding et al. 2009).

Typical run habitat, which is the dominant flow habitat type for the catchment

Exposed gravel substrate like this is rare in the catchment

Bank slumping and erosion on the mainstem



Fencing too close to the water's edge

Figure 17: Selected photographs from the Stream Walk surveys.

Typical tributary habitat

Drain condition immediately following drain maintenance

Stream bank slumping observed during the surveys

Bed (and bank material) substrate removed during drain clearing

Figure 18: Selected photographs from the Stream Walk surveys.

Well-fenced and planted riparian margin

Complete lack of fencing and obvious stock damage

Stock damage surrounding a spring source

Lack of fencing on ephemeral waterways

Figure 19: Selected photographs from the Stream Walk surveys.

5.4 Aquatic and Riparian Animals

5.4.1 Aquatic invertebrates

Aquatic invertebrate data is quite limited from the Ararira / LII River catchment. The only aquatic invertebrate data available at the time of writing this report was data collected in 1980 and 1981 from three sites on the mainstem between Englishs and Wolfes roads (Rutledge 1981), and in 2013 and 2014 from four sites in the upper catchment (EOS Ecology 2013; 2014). Unfortunately, there appears to be a dearth of biological data from most tributaries and large sections of the mainstem. In addition, no information exists on the ecological status of the numerous springs in the catchment. These spring habitats are likely to be 'biodiversity hotspots', as studies have shown that springs often contain a high number of species, many of which are rare "phreatic" species that are adapted to living in sub-surface groundwater environments (Gray 2005; Golder 2013). Common taxa of groundwater invertebrate communities in New Zealand include: mites, amphipods, isopods, Syncarida, molluscs, oligochaetes, flat worms and copepods (Golder 2013).

The earlier data collected in 1980 and 1981 from immediately downstream of Englishs Road bridge, Pannetts Road bridge and opposite Wolfes Road show that the invertebrate communities at these locations were dominated by pollution-tolerant invertebrates such as amphipods, snails and chironomids (Rutledge 1981). Sensitive, 'cleanwater' EPT[20] taxa were recorded in low abundances from all three sites. Interestingly, the common mayfly *Deleatidium* was not recorded (Rutledge 1981).

The data collected in 2013 and 2014 from these four sites on the LI, Liffey Stream and the LII River in the upper catchment show that the invertebrate communities are generally in 'poor' ecological health[21]. Similar to the earlier study by Rutledge (1981), the communities of each of the four sites were dominated by pollution-tolerant invertebrates such as amphipods, snails, dipteran larvae and seed shrimps. Sensitive EPT taxa were practically absent from all four sites. Such invertebrate community types are typical of lowland Canterbury streams whose habitat has been degraded by inputs of sediment and nutrients (Greenwood et al. 2011; Burdon et al*.* 2013). In addition, the invertebrate communities at each of these four sites also declined in health between 2013 and 2014 (EOS Ecology 2013; 2014). Fine sediment inputs, excessive nutrient inputs, lack of in-stream and riparian habitat heterogeneity (i.e., uniform, featureless channels), and channel maintenance activities are the primary factors limiting the macroinvertebrate communities of the Ararira / LII River catchment.

Kōura / freshwater crayfish have an "At Risk-Declining" threat status (Grainger et al. 2014) and are present in the Ararira / LII River catchment (Figure 20). There have been numerous sightings of kōura from Liffey Stream (Nick Hobbs, Liffey Springs development, pers. comm.). In addition, a recent survey of the same waterway for kōura by staff from the University of Canterbury recorded a single individual. It is worth mentioning that a post-graduate student from the University of Canterbury intends to sample koura using a diverse array of methods from Liffey Stream as part of their MSc research on kōura ecology. Other areas of the Ararira / LII River catchment where koura have been observed include the lower mainstem near Wolfes Road (Tipa & Associates 2013) and the upper mainstem (Murray Tyson, LII Drainage Committee waterway maintenance operator, pers. comm.). There is also a single record of kōura in the NZFFD[22] for the mainstem near Englishs Road. During the recent stream walk habitat survey, kōura burrows were recorded from upper Springs Creek; however, no individuals were observed. A review of NZFFD data has shown kōura to be quite rare in Te Waihora / Lake Ellesmere lowland streams (Golder 2012). This is corroborated by a recent study carried out by Whakaora Te Waihora staff who found that kōura were quite rare in many of Te Waihora / Lake Ellesmere streams (Te Rūnanga o Ngāi Tahu 2014, http://ngaitahu.iwi.nz/our_stories/concern-wai-koura/ (accessed 10 May 2015).

[20] Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) comprise the group of more pollution-sensitive invertebrates known as EPT taxa.

[21] This assessment is based on the Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) scores, which provide an indication of the 'ecological health' of the invertebrate community with respect to organic enrichment.

[22] New Zealand Freshwater Fish Database, accessed on 18 May 2015.

Figure 20: A koura observed from Liffey Stream.

Prior to the large-scale land use change that occurred in the catchment, kōura would likely have been much more widely distributed. Kōura require habitat that contains plenty of cover and shade (e.g., woody debris, undercut or earthen banks, cobbles etc.) which provides shelter from terrestrial and aquatic predators, and from cannibalism. Threats to kōura populations are quite similar to those for invertebrate communities in general and include predation from introduced predators (i.e., trout), habitat degradation and declining water quality. Kōura are often referred to as 'ecosystem engineers' because their activity helps to mobilise fine sediment from streambeds and help keep some substrate surfaces free of fine sediment.

Kōura is regarded as a delicacy by Māori, and they are still occasionally harvested as food. In addition to customary fishing, recreational (non-commercial) fishers can also currently take 50 kōura per person per day under the Fisheries (Amateur Fishing) Regulations 1986.

Another iconic, mega-invertebrate present in the Ararira / LII River catchment is kākahi / freshwater mussel. Kākahi is a valuable mahinga kai resource for many Māori; however, they are not as popular or as important as they once were in the past. This is due mainly to the taste of kākahi, as well as the perception that kākahi may be unhealthy to consume as they have the potential to accumulate pollutants, heavy metals and toxins (Phillips et al. 2007). A recent toxicological report of kākahi collected from Harts Creek showed that the wai kākahi[23] was only just below the FSANZ[24] regulatory limit for lead (Stewart et al. 2014).

A recent targeted survey for kākahi in the lower reaches of the Ararira / LII River found that they were "in abundance" in the lower mainstem towards the mouth (Sophie Allen, ecologist contracted to Whakaora te Waihora, pers. comm.). A limited number of empty kākahi shells have also previously been observed from other areas of the mainstem (Murray Tyson, LII Drainage Committee waterway maintenance operator, pers. comm.). Kākahi are an extremely long-lived species, so it is possible that the population present in the Ararira / LII River catchment is an aging population that is not actively recruiting, as has been noted for many freshwater mussel populations elsewhere (Österling et al. 2010). Kākahi populations, particularly juveniles, are in decline in New Zealand and worldwide. The current conservation status of this invertebrate species in New Zealand is 'At Risk–Declining' (Grainger et al. 2014). This decline has been attributed to the widespread habitat degradation of its habitat, as well as changes in the populations of its host fish (originally kōaro), on which its life cycle depends (McDowall 2002).

The endemic[25] freshwater shrimp, characteristic of many lowland streams in New Zealand, has not previously been observed in the Ararira / LII River catchment, despite being recorded in nearby Harts and Taumutu creeks (Carpenter 1976; NEMO[26]). The low gradient and high macrophyte cover of the waterways in the lower Ararira / LII River catchment would appear to provide suitable habitat for this species. Carpenter's study is, however, quite dated and more recent data or a future survey is required to truly know the current status of this species in the Ararira / LII River catchment.

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[23] Wai kākahi: the juice of the kākahi after it has been cooked in a hot spring (Te Rangi Hiroa 1921).

[24] Food Standards Australia New Zealand – FSANZ develops food standards for food available in Australia and NZ.

[25] Endemic: only known from this certain place or region.

[26] NIWA Environmental Monitoring and Observations (NEMO) database. This database combines data from a wide range of sources and survey methods, which include the NZ Freshwater Fish database, the Aquatic Plants Database, Invertebrates, diatoms and some regional council data sets. Accessed on 18 May 2015.

5.4.2 Fish

Overview

The Ararira / LII River catchment has a reasonably diverse fish fauna, with nine species having recently been recorded[27] (Figure 21; Table 5). These fish include native species such as longfin eel, shortfin eel, inanga, common smelt, pātiki / black flounder, upland bully, as well as introduced species such as brown trout, rudd, and goldfish. Rudd and goldfish are both considered pest species in New Zealand because once they invade a waterway they are extremely difficult to remove, and can easily spread throughout an entire catchment causing severe adverse effects on the pre-existing ecological values. For this reason, regulatory bodies are constantly battling to prevent their spread or to eradicate them from freshwater habitats.

In addition to these nine species, common bully and torrentfish were recorded during earlier surveys in 1986, and a single kanakana / lamprey record exists from the LI Creek from the 1920s. While common bully is quite likely to be still present in the Ararira / LII River catchment, as it is the most abundant species recorded from the lake itself (Jellyman 2012), the current status of both torrentfish and lamprey within the catchment remains unknown. These species have rarely been recorded from the Te Waihora / Lake Ellesmere (NZFFD). Both of these species require specific habitat for certain periods of their life history (McQueen 2013) that is quite uncommon in most waterways in the Ararira / LII River catchment. Considering both of these points, it is likely that both are reasonably uncommon (if at all present) in the Ararira / LII River catchment.

Table 5: Fish species recorded from the Ararira / LII River catchment.

Fish species [1]	**Conservation status [2]**	**Diadromous [3] (Y / N)**	**Migration type [4]**
Longfin eel	At Risk–Declining	Y	Catadromous
Shortfin eel	Not threatened	Y	Catadromous
Inanga	At Risk–Declining	Y	Amphidromous
Common smelt	Not threatened	Y	Facultatively amphidromous; readily land-locks in lakes
Black flounder	Not threatened	Y	Catadromous
Upland bully	Not threatened	N	NA
Common bully	Not threatened	Y	Facultatively amphidromous; readily forms non-diadromous populations
Torrentfish	At Risk–Declining	Y	Amphidromous
Lamprey	Threatened–Nationally Vulnerable	Y	Anadromous
Brown trout	Introduced and naturalised	Y	Mainly non-diadromous, but can be anadromous
Rudd	Introduced and naturalised	N	NA
Goldfish	Introduced and naturalised	N	NA

Note: [1] Data sourced from NZFFD records. [2] Conservation status follows Goodman et al. (2014). [3] Diadromous: migrate between freshwaters and the sea as part of their life cycle. [4] Amphidromous: migration of larval fish to sea soon after hatching, followed by early feeding and growth at sea, and then a migration of small post-larval fish from sea back into fresh water where sexual maturation and reproduction occur; Anadromous: most feeding and growth are at sea prior to migration of fully grown, adult fish into fresh water to reproduce; Catadromous: most feeding and growth are in fresh water prior to migration of fully grown, adult fish to sea to reproduce (McDowall 1997).

[27] Data sourced from the NZFFD, Jellyman & Graynoth (2010), Golder unpublished data, general observations during the current habitat surveys.

Figure 21: Recent fish relocation from a tributary waterway near Lincoln township.

First impressions of tributary waterways such as these on the top left may suggest that they have very limited ecological value. However, a recent fish relocation operation in February 2015 from a 70-m section of waterway turned up a total of 145 fish: 33 of which were eels (top right), 57 were inanga (bottom left), and the remainder were bullies (bottom right).

Interestingly, a single large salmonid believed to be a Chinook salmon was observed in the mainstem of the Ararira / LII River upstream of Pannetts Road during the current stream walk habitat surveys. Although rare, salmon are known to enter the lake and migrate up some of the tributaries when the lake is opened (Tony Hawker, Fish & Game, pers. comm.). However, further investigation would be required to confirm this species' presence in the catchment.

Tuna / eels

The Ararira / LII River catchment provides important habitat for tuna / eels, especially for longfins. Jellyman & Graynoth (2010) investigated the importance of tributary streams of Te Waihora / Lake Ellesmere in maintaining populations of longfin eels in Te Waihora / Lake Ellesmere, and found that the LII mainstem had the second highest catch rate of longfin eels of the four larger Te Waihora / Lake Ellesmere tributaries (Halswell, Harts Creek, Selwyn and LII). LII tributaries (e.g., Lincoln Main Drain) are also known to harbour large numbers of both tuna / eel species (Golder 2015, unpublished data). Jellyman and Graynoth (2010) revealed that juvenile longfins (<200 mm long) comprised a relatively small proportion of longfin eels recorded from a number of tributary streams of Te Waihora / Lake Ellesmere. While this is probably due to poor regional recruitment, the authors highlight that juvenile eels, especially longfins, require fast-flowing riffles and that such habitat is generally lacking from many of the Te Waihora / Lake Ellesmere tributaries. The provision of stable, fast-flowing riffles in less flood-prone areas of the Ararira / LII River catchment is an enhancement option that should be considered for this species. Additionally, the capacity of a given waterway to harbour larger tuna / eels is predominantly determined by the availability of suitable habitat and refuge in the form of undercut banks, overhanging vegetation, woody debris and macrophyte beds (Graynoth et al. 2008). Although tuna / eel populations in Te Waihora / Lake Ellesmere tributaries are overall considered to be in a healthy state (Jellyman & Graynoth 2010), the addition of further cover and refugia in the Ararira / LII River and its tributaries would likely lead to increased abundances of tuna / eels and would likely benefit many other aquatic biota. Good tuna / eel habitat was uncommon during the recent stream walk surveys.

Figure 22: An inquisitive longfin eel in the Ararira / LII River.

The commercial eel fishery in Te Waihora / Lake Ellesmere was historically the single largest eel fishery in New Zealand. However, concerns over declining catches led to increased regulation in the form of reduced quotas to protect shortfin eel populations, as longfins are not commercially harvested (Jellyman 2012). This reduced quota seems to be having a beneficial impact, as recent catch data and commercial fishers' opinions show that catches are noticeably better in recent years (Rennie & Lomax 2013). Commercial fyke netting for eels is prohibited in Te Waihora / Lake Ellesmere tributaries under the Fisheries Act, to protect spawning runs of brown trout.

Tuna / eel are an extremely important taonga species for Māori, as historically they were very abundant and easily caught using a wide range of customary methods. In recent times customary fishing has usually been carried out using modern fyke nets. With respect to Te Waihora / Lake Ellesmere, customary and recreational eel fishing is generally restricted to the larger tributaries such as the lower Selwyn and Halswell rivers (Booker & Graynoth 2008). Little information, however, exists on the importance of the Ararira / LII River catchment for such activities.

Kanakana / lamprey

Kanakana / lamprey are an important taonga species for Māori, who used to construct intricate weirs (utu piharau) to catch them. Although once prolific in New Zealand, lamprey are now believed to be less common; notwithstanding that they are a data-deficient species, simply because they are such a hard species to observe (James 2008). This lack of knowledge on the species' biology and distribution throughout New Zealand is one of the main reasons why lamprey are currently classified as 'Threatened–Nationally Vulnerable' (Goodman et al. 2014). For example, it was only in late 2013 that the very first lamprey spawning site in New Zealand was recorded (from Banks Peninsula). While there is one historical record of lamprey from the LI Creek almost a century ago, targeted surveys for the species would help to determine if they are indeed still present in the Ararira / LII River catchment.

Kowaro / Canterbury mudfish

Another 'unknown' fish species for the Ararira / LII River catchment is the endemic kowaro / Canterbury mudfish. This species is one of New Zealand's most threatened fish – classified as 'Threatened–Nationally Critical' (Goodman et al. 2014) – due to the extensive destruction of its habitat that has occurred across the Canterbury Plains (McDowall 2000). Predation by trout and eels combine to further reduce its available habitat. Kowaro is a very range-restricted species found only in Canterbury, with a total habitat area estimated to be about 24 ha (O'Brien & Dunn 2012). Kowaro usually occur in isolation from other fish species in spring-fed waterways (many of which are ephemeral) flowing through wetland areas. Kowaro survive periodic dry periods by aestivating under logs, amongst roots and within vegetation. Kowaro can also be found in man-made habitats such as farm ponds, scour holes, underneath road culverts and stockwater races. While the majority of records for kowaro are from the upper Selwyn River catchment, especially from the Hororata and upper Waianiwaniwa rivers, it is possible that this species is present in spring-associated habitats in the Ararira / LII River catchment. Targeted surveys for this species to map their distribution within the catchment would greatly aid in formulating a practical management plan to protect any surviving populations.

Inanga

Inanga are one of five whitebait species found in New Zealand, but in most rivers they comprise the majority of the whitebait catch. When the lake is open during the whitebait season (August to November), inanga form the basis of the whitebait fishery at the lake opening and at the mouths of the Irwell, Selwyn and Halswell rivers (Jellyman 2012). The biomass of the whitebait catch in these areas is unknown (Rennie & Lomax 2013).

Inanga are usually amphidromous, meaning that they are born in freshwater / estuaries then drift into the ocean as larvae before migrating back into freshwater to grow into adults and spawn. Adult inanga spawn gregariously in the tidally-influenced riparian vegetation in the lower reaches of rivers, where after a period of about 2 – 4 weeks, the developed eggs hatch after being re-inundated by high, usually tidally-influenced water levels (Taylor 2002). Spawning activity in most rivers is usually highest in late summer or autumn, especially during new moon periods. There are, however, a number of locations where inanga have formed non-migratory (landlocked) populations (e.g., five lakes in Northland (McQueen 2013)). In the Northland lakes at least, it is believed that inanga spawn amongst emergent macrophyte beds. In the case of Te Waihora / Lake Ellesmere, it is highly likely that both diadromous and non-diadromous populations of inanga are present. This is evidenced by the fact that inanga spawning has previously been recorded from Waikekewai Creek near Taumutu, months before the lake was ever opened to the sea (Taylor 1996). There have also been observations of what look like spawning aggregations at the mouth of the Selwyn River and in Harts Creek; although no eggs have been found at either location (Mike Hickford, University of Canterbury, pers. comm.). The likelihood of inanga populations in the lake being solely sustained in the long term by diadromous inanga populations seems less plausible, as historical and current lake opening periods are unlikely to have fully aligned with critical migratory periods for outgoing larvae and returning whitebait.

Brown trout

Brown trout are found throughout much of the Te Waihora / Lake Ellesmere catchment, although adult trout are mainly restricted to the larger tributaries including the Selwyn River, Harts Creeks, Halswell River and the

LII River. Unsurprisingly, national angling surveys carried out between Fish & Game and NIWA show that angling effort (angler days) is also highest in these waterways, especially the Selwyn River (Unwin 2009). This study also highlights that there has been a general decline in angling effort in most of the Te Waihora / Lake Ellesmere tributaries over the last two decades. Angling effort in the LII has dropped from a high of 2130 angler days in 1994 – 1995 to 600 days in 2007 – 2008. In a survey of anglers' perceptions of the state of lowland trout fisheries (Jellyman et al. 2003), the concerns of Canterbury anglers (including the Te Waihora / Lake Ellesmere catchment) were generally related to declining water quality and low flows affecting fishery values. The study noted this decline is likely a function of many cumulative factors (e.g., including increasing angling pressure and reduced angler access), as opposed to a single overriding factor.

Brown trout abundances have been in decline in the Te Waihora / Lake Ellesmere catchment since the 1940s (Millichamp 2009). This decline can be split into two separate phases: the decline which took place immediately after the Wahine Storm (in 1968), and the more gradual decline which has taken place over the last 20 – 30 years. This decline has been most pronounced from the historically world-renowned Selwyn River. This decline has received plenty of attention, although the underlying reasons are less well understood. Many of the suggested reasons for the decline are common pressures affecting trout populations elsewhere, and include declining quality and quantity of available spawning and juvenile habitat. Others factors involved are more specific to Lake Ellesmere: declining habitat quality in the lake via eutrophication and loss of macrophyte beds; mortality from commercial fishing (i.e., bycatch); and changes to the frequency and timing of lake openings affecting migrations. For the Selwyn River in particular, lower flows have also prevented adult access to the spawning grounds in the headwaters (historically a major spawning area). It is most likely that this well-documented decline in trout numbers in the Te Waihora / Lake Ellesmere catchment, including the Ararira / LII River catchment, is due to a combination of these factors (and perhaps even more), as opposed to one overriding determinant.

Brown trout spawning was recorded from the Ararira / LII River catchment during a survey in 1980, but a more recent survey in 2005 suggested that trout spawning had declined (Taylor & Good 2006). Specifically, the quality of spawning habitat in the LI Creek (through Lincoln township) and Powells Road drain, the two areas known to have trout spawning, have declined substantially over the last few decades. Similarly, historic observations suggest trout spawning in the mainstem of the Ararira / LII River at the Englishs Road and Pannetts Road bridges (M. Rutledge, DOC, pers. comm. 2015); however, the stream walk surveys indicated that both locations were covered in soft sediment and were not suitable for trout spawning.

Trout need clean, relatively silt-free gravels to excavate and lay their eggs in nests (redds). However, the few isolated areas of this suitable spawning habitat have severely degraded over time, likely due to increased sedimentation and reduced flows (Taylor & Good 2006). The recent stream walk surveys showed that trout spawning habitat is extremely limited within the catchment, and in all likelihood, further declines in trout spawning can be expected if spawning habitat is not improved in the few remaining hard-bottomed reaches. Fine sediment removal from these habitats, especially in the LI Creek, should be given consideration (e.g., using the Sand Wand™ or similar technique [Gray 2013]). In the case of Powells Road drain, reducing the biomass of emergent macrophytes via riparian planting in the mid-reaches would likely go a long way in helping restore trout spawning in this waterway, as the current gravel substrate does not contain a prohibitively high amount of silt / sand.

5.4.3 Riparian invertebrates and lizards

Although not observed during the recent stream walk surveys, common skink, McCann's skink, spotted skink and Canterbury gecko are all likely to be present within the riparian zones of waterways within the Ararira / LII River catchment (Simon Chapman, Golder Associates herpetologist, pers. comm.). Skinks generally prefer a mixture of habitat types, including dense vegetation and cover for refuge from predators, whilst also requiring nearby open areas for foraging and basking. Skinks often prefer to live along edge habitat. In contrast, the Canterbury gecko, whilst still preferring refuge-rich habitat (e.g., wood clusters), is nocturnal and so does not require nearby open areas for basking. While no data exists for these species from the Ararira / LII River catchment, recent monitoring data from Kaitorete Spit suggests that the spotted skink has declined to almost undetectable levels (Hughey 2013).

Both geckos and skinks / kārara show a distinct preference for fruit-bearing shrubs and vine trees. Therefore, planting divaricating shrubs such as *Coprosma* spp. or *Muehlenbeckia* spp., as well as sedges, toetoe and flaxes would provide additional habitat for these species. All introduced mammals (cats, mustelids, hedgehogs, and in particular rodents) and some birds such as magpies and starling predate on lizards / kārara. Therefore, controlling these pest species would be beneficial for lizards / kārara populations.

Similar to aquatic invertebrates, data on terrestrial invertebrates is also very scarce from the overall catchment, not just riparian areas. At the time of writing this report, the only known data available included a study of ground beetle diversity from a single salt marsh site near Wolfes Road (Emberson et al. 2011), and also data from a BioBlitz that was carried out in Liffey Domain in 2009 (Rowland et al. 2009). The study by Emberson et al (2011) showed that the site near Wolfes Road had moderate beetle species richness (relative to the 26 other sites investigated in the Selwyn District). Results from the 2009 BioBlitz revealed that this event recorded more species than the other six previous BioBlitz events held in New Zealand (Rowland et al. 2009). A high proportion (84 %) of the terrestrial insects and spiders recorded were endemic[28] species. Some of the most notable finds during this event included a native flatworm species that had not been recorded in over a hundred years, and a Banks Peninsula endemic spider usually found in forested areas, not fragmented landscapes (Rowland et al. 2009). Despite the relatively high species count, this study considered the native biodiversity within Lincoln to be generally poor, and that increasing native plantings should be considered to increase native biodiversity.

The adults of aquatic insects (e.g., caddisflies) prefer well-developed riparian zones as they provide a supply of food, sites for resting, mating and completion of egg development, and protection from predators (Smith & Collier 2002). Additionally, riparian zones provide ecological corridors that enable greater dispersal in adult aquatic insects. Furthermore, odonate adults (dragonflies and damselflies) use the narrow riparian zone as a territory for hunting. Planting riparian zones with native vegetation with a mixture of vegetative layers (e.g., shrubs and trees for canopy) would greatly benefit these and many other aquatic and terrestrial species (e.g., Lepidoptera (moths and butterflies), Coleoptera (beetles) etc.).

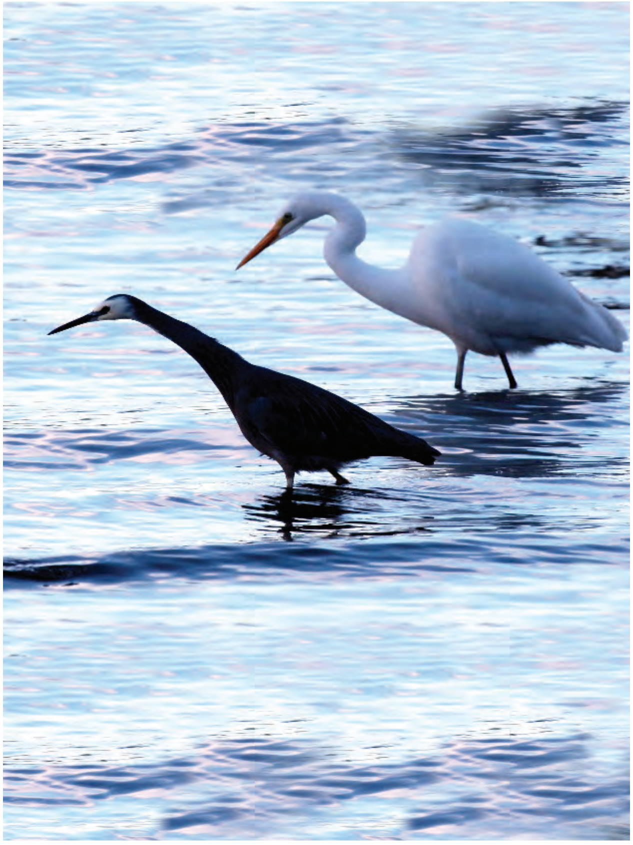
5.4.4 Birds

The Ararira / LII River and associated tributaries, wetlands and surrounding farmland (e.g., wet pastures) form a part of a larger network of aquatic and wetland habitats that includes the internationally-significant bird habitats of Te Waihora / Lake Ellesmere and the Avon-Heathcote Estuary. This habitat network supports a high diversity and abundance of birds, with more than 160 species recorded, and 80 species regularly recorded (Hughey & O'Donnell 2009). Although the birdlife of Te Waihora / Lake Ellesmere is well-known, little formal information has been recorded about birds for inflowing streams such as the LII, although many of the numerous species seen at Te Waihora / Lake Ellesmere also use habitats within the Ararira / LII River catchment. These include not only birds commonly associated with wetland habitats (e.g., the native paradise shelduck, Australasian shoveler, black swan, grey teal, pukeko, black and little shag, pied stilt, kingfisher, and the introduced mallard and Canada goose), but also birds of farmland such as the native fantail, silvereye, Australasian harrier, and introduced species such as little owl, skylark, starlings, and various finches.

In addition to these fairly widespread and sometimes abundant species, the Ararira / LII River provides suitable habitat for much more secretive and rarer species, including, notably, breeding habitat for the nationally-endangered Australasian bittern and the relict marsh crake in raupo beds in the lower reaches of the river (Langlands 2014) (Figure 23).

[28] Endemic species are species only recorded from that specific geographic area.

Bittern in flight



Pair of Herons fishing

Marsh crake in raupo

Mute swan

Figure 23: Birds of the Ararira / LII River catchment

6.0 SUMMARY OF KEY VALUES AND ISSUES

6.1 Hydrology

The hydrology of the catchment is well understood and is dominated by the influence of groundwater and Te Waihora / Lake Ellesmere. The indigenous hydrology of a wetland has been removed by a drainage network to support agricultural development. The Ararira / LII River is highly modified and is primarily managed for drainage. Natural conditions of the area, in terms of flat topography, poorly draining soils, the high water table and the influence of Te Waihora / Lake Ellesmere, make drainage a challenge. The threat of flooding remains a key issue for landowners in the catchment, particularly those living close to the lake.

Increased irrigation up-gradient of the Ararira / LII River catchment namely CPW, is expected to increase groundwater levels and spring flows within the Ararira / LII River catchment (Weir 2008, Scott et al 2014). CPW, coupled with preferred management options developed by the Selywn-Waihora Zone Committee, is projected to increase median flow, average flow and the average annual volume in the Ararira / LII River at Pannetts Road by greater than 30 %. When considering future water management and potential restoration projects the impact of these significant hydrological changes need to be carefully considered.

6.2 Water Quality

The available water quality data shows that nutrient concentrations, in particular nitrate-N and DRP, are quite high in many areas. Nitrate concentrations are higher in the upper catchment near the source of springs, while DRP concentrations increase in a downstream direction. *E. coli* counts, turbidity and TSS concentrations are also quite high, especially in certain tributaries. It is apparent from the available data that there are likely to be a number of ‘water quality hotspots’ throughout the catchment that are key contributors of certain contaminants. However, further monitoring is required to pinpoint the exact source(s). Long-term data (from 1994 onwards) available from the mainstem at Pannetts Rd show that DRP concentrations have been declining, while nitrate and TSS concentrations and turbidity have been increasing. Long-term data on physico-chemical parameters that can majorly influence aquatic invertebrate and fish distributions, such as temperature and dissolved oxygen concentration and saturation, is not available from the catchment.

6.3 Stream Walk Observations

6.3.1 General overview

The majority of habitat present in the tributaries and mainstem that were surveyed was slow-moving run habitat, with a soft-bottomed (silt and sand) substrate. Despite periodic macrophyte removal, macrophyte cover is generally high in most waterways, with emergent forms dominating in the narrower tributaries and submerged forms dominating in the wider and deeper mainstem. The lack of channel shading due to poor riparian cover, the high fine sediment cover, the high nutrient concentrations and the lack of high velocity flushing flows provides habitat that is well suited to high macrophyte biomass. Exotic species dominate the macrophyte communities, with native macrophytes having a very restricted and patchy distribution. Suitable fish habitat, in terms of refuge and suitable spawning habitat, is lacking from many of the reaches surveyed during this study. Riparian plant cover, especially tall woody vegetation, is quite rare along most waterways.

Ephemeral waterways on farmland generally lack fencing, and show obvious signs of stock damage. These waterways are likely to be key contributors to sediment and nutrient runoff during high rainfall events. These ‘water quality hotspots’ should be mapped (or at least considered) to ensure they are managed effectively.

Springs are common in many tributaries, especially those in the upper catchment (e.g., Springs Creek). Numerous springs were observed in farmland adjacent to the waterways, many of which lacked adequate protection and as a result had degraded physical habitat. It seems highly likely that there are further undocumented springs present throughout the catchment that would greatly benefit from adequate protection.

6.3.2 Key observations

A summary of the current state of habitat present in each waterway or reach surveyed is presented in Table 6. A description of the stream walk methodology, as well as the data collected can be found in Appendix B.

Table 6: Stream Walk summary of reaches surveyed.

REACH	REPRESENTATIVE PHOTOGRAPH	DESCRIPTION
Englishs (mainstem)		***Current state:*** ■ *Run habitat. Generally quite deep (>1.5 m water depth), with average wetted width ranging from 8 – 10.4 m.* ■ *Predominantly soft-bottomed; however, localised patches of gravel / pebble areas present that are heavily embedded with fine sediment.* ■ *Bank vegetation dominated by rank grasses; little tall woody riparian vegetation.* ■ *Channel shading low.* ■ *Mostly moderate-angled stable banks that are partially fenced. Six erosion / slumping hotspots observed.* ■ *High cover of submerged macrophytes (70 – 90 %) – dominated by Elodea, Potamogeton and Myriophyllum.* ■ *Springs observed in reach 2.* ***Potential enhancement options:*** ■ *Riparian planting for channel shading, habitat, biodiversity value, and bank stabilisation.*
Wolfes (mainstem)		***Current state:*** ■ *Run habitat. Average water depth approx.1.0 m, with a wetted width ranging from 11 – 15 m.* ■ *Soft-bottomed.* ■ *Bank vegetation comprised of a mix of native and exotic vegetation, with willow trees, sedges and rushes providing overhead cover near bank margins.* ■ *Channel shading low in reaches 1 and 2 (5 – 10 %), but higher in reaches 3 and 4 (20 – 25 %).* ■ *Riparian cover high, especially along true left bank (TLB).* ■ *Generally moderate to steep-angled stable banks that are unfenced. No active erosion / slumping observed.* ■ *High cover of submerged macrophytes (45 – 75 %) – dominated by Elodea, Potamogeton and charophytes.* ***Potential enhancement options:*** ■ *Tall riparian vegetation on TRB for channel shading and biodiversity value.*
Liffey (tributary)		***Current state:*** ■ *Run habitat. Water depth increases downstream, (0.3 m to 1.2m). Wetted width increases downstream (2 m to 6 m).* ■ *Soft-bottomed, except reach 6 with larger gravel / pebble substrate (this reach modified, Liffey Springs development).* ■ *Bank vegetation dominated by exotic grasses / herbs in lower reaches, and exotic trees in mid to upper reaches. Banks recontoured and recently planted in reach 6.* ■ *Riparian cover high in reaches 3, 4 and 6, low elsewhere.* ■ *Channel shading high in reaches 3 and 4, low elsewhere.* ■ *Banks angles generally moderate to steep, and generally unfenced. Seven areas of active erosion / slumping observed.* ■ *Macrophyte cover generally high throughout.* ■ *Two springs observed in reaches 5 and 6.* ***Potential enhancement options:*** ■ *Bank recontouring and riparian planting to stabilise banks, enhance biodiversity and provide stream shade.*
Springs (tributary)		***Current state:*** ■ *Straightened channel dominated by run habitat. Average water depth 0.4 – 0.7 m. Average wetted width 2.0 – 3.0 m.* ■ *Soft-bottomed, except for localised patch of larger substrate at man-made weir near irrigation in-take structure at reach 3.* ■ *Bank vegetation mainly exotic grasses with occasional exotic shrub / tree, reach 4 had greater cover of exotic trees.* ■ *Banks steep (except reach 4) – and fenced throughout all reaches. Three areas of active erosion / slumping observed.* ■ *Channel shading low (≤15 %); highest in uppermost reach.* ■ *High macrophyte cover (35 – 90 %), comprised of a mixture of emergent and submerged forms.* ■ *Numerous springs observed in reaches 3 and 4.* ***Potential enhancement options:*** ■ *Bank recontouring and riparian planting to stabilise banks and provide shading; addition of boulders or snags to increase hydraulic variation.*
Pannetts (mainstem)		***Current state:*** ■ *Run habitat. Average water depth generally >1.0 m, with average wetted widths ranging from 13 – 15 m.* ■ *Predominantly soft-bottomed, with small patch of gravel substrate near road bridge.* ■ *Bank vegetation dominated by rank grasses; very little tall woody riparian vegetation.* ■ *Channel shading very low downstream of Yarrs Lagoon.* ■ *Swamp nettle observed on true right bank (TRB) within the downstream edge of Yarrs Lagoon.* ■ *Low to steep-angled stable banks that are fenced. One erosion / slumping hotspot observed.* ■ *High cover of submerged macrophytes (80 – 90 %) – dominated by Elodea, Potamogeton and Myriophyllum.* ***Potential enhancement options:*** ■ *Riparian planting for channel shading, habitat, and biodiversity value.biodiversity value, and bank stabilisation.*
LI (tributary)		***Current state:*** *Predominantly run habitat although riffle areas present in reach 8. Water depth generally shallow (average 0.1–0.5 m), with an average wetted width ranging from 2 – 6 m.* ■ *Soft-bottomed, except for reaches 5, 7, 8, 10 and 11 where gravel / pebble substrate was present. These areas of larger substrate were heavily embedded with fine sediment.* ■ *Bank vegetation generally dominated by exotic trees, mixed understorey vegetation and exotic (or no) groundcover.* ■ *Riparian cover and channel shading generally high.* ■ *Banks angles vary considerably between reaches. Four areas of active erosion / slumping observed.* ■ *Submerged macrophyte cover generally low throughout; emergent macrophyte cover high in reaches 2, 4 and 5.* ■ *Numerous springs observed in reaches 4 and 6.* ***Potential enhancement options:*** ■ *Sediment removal from riffle areas, and riparian planting to stabilise banks (and enhance biodiversity) where needed.*
LMD (tributary)		***Current state:*** ■ *Straightened channel dominated by run habitat. Average water depth ranged from 0.5 – 1.0 m. Average wetted width varied from 1.6 – 2.3 m.* ■ *Soft-bottomed, except for localised patch of larger substrate at confluence of channel from Te Whāriki development.* ■ *Bank vegetation dominated by exotic grasses; no woody riparian vegetation present. Channel shading very low.* ■ *Banks are steep, which are fenced throughout. Multiple areas of active erosion / slumping observed.* ■ *Numerous large eels and inanga observed.* ■ *High macrophyte cover (65 – 80 %), comprised of a mixture of emergent and submerged forms – dominant species include Erythranthe, Nasturtium and Elodea.* ***Potential enhancement options:*** ■ *Bank recontouring and riparian planting to stabilise banks and provide shading; addition of boulders or snags to increase hydraulic variation.*
Collins (tributary)		***Current state:*** ■ *Straightened channel dominated by run habitat. Average water depth 0.2 – 0.7 m. Average wetted width 0.6 – 3.0 m. Upper reaches ephemeral (i.e., from reach 4 upstream).* ■ *Soft-bottomed, except for small patch of gravel in reach 3.* ■ *Variable bank vegetation, dominated by exotic grasses, with occasional exotic shrubs / trees. Reach 2 had higher cover.* ■ *Riparian cover and shading highest on TLB in reaches 2 and 4. Riparian cover and shading low in remaining reaches.* ■ *Banks angles generally steep to vertical, and fenced through farmland. Two areas of active erosion / slumping observed.* ■ *High macrophyte cover (50–75 %) in reaches 1 and 3, low in remaining reaches (≤5 %).* ■ *Numerous springs observed in reach 1.* ***Potential enhancement options:*** ■ *Bank recontouring and riparian planting to stabilise banks and provide shading; addition of boulders or snags to increase hydraulic variation.*

Table 6: Stream Walk summary of reaches surveyed. (Continued)

REACH	REPRESENTATIVE PHOTOGRAPH	DESCRIPTION
Ellesmere (tributary)		***Current state:*** ■ *Straightened channel dominated by run habitat. Average water depth 0.4 – 1.5 m. Average wetted width 1.5 – 2.7 m.* ■ *Soft-bottomed.* ■ *Variable bank vegetation. Mainly native sedges, rank grasses and exotic shrubs / trees. Native riparian planting on TLB at reach 9.* ■ *Banks mainly moderate to steep and partially fenced through farmland. Two areas of active erosion / slumping observed.* ■ *Channel shading generally low, except for reach 5 (85 %).* ■ *Riparian cover generally highest in lower reaches, and along TRB of reaches 5 and 6 and TLB of reach 9.* ■ *High macrophyte cover throughout, except reach 5 (15 %).* ■ *High filamentous algal cover in reaches 6 and 7 (40 – 70 %).* ■ *Spring observed between reaches 3 and 4.* ***Potential enhancement options:*** ■ *Riparian planting to stabilise banks and provide shading; addition of boulders or snags to increase hydraulic variation.*
Carters (tributary)		***Current state:*** ■ *Straightened channel dominated by run habitat. Average water depth 0.5 – 0.6 m. Average wetted width 2.4 – 4.2 m.* ■ *Soft-bottomed.* ■ *Bank vegetation generally dominated by exotic grasses (and occasional exotic shrub) on TLB and exotic trees on TRB.* ■ *Banks moderate to steep and unfenced. Erosion / slumping and stock damage observed along TLB of reach 1.* ■ *Channel shading moderate to high: 60 – 80 % in reaches 1 and 2; and 25 – 30 % in reaches 3 and 4.* ■ *Riparian cover high on TRB and low on TLB throughout.* ■ *Macrophyte cover relatively low throughout (≤20 %).* ***Potential enhancement options:*** ■ *Fencing to prevent stock access to waterway, and riparian planting to stabilise banks; addition of boulders or snags to increase hydraulic variation.*
Powells (tributary)		***Current state:*** ■ *Straightened channel dominated by run habitat. Average water depth 0.2 – 0.9 m. Average wetted width 1.5 – 4.0 m.* ■ *Soft-bottomed reaches 1-3, hard-bottomed reaches 4–11. Gravel/pebble substrate not heavily embedded with fines.* ■ *Variable bank vegetation, mainly exotic grasses, shrubs and trees. Native riparian planting was present on the TRB downstream of the intersection of Days and Powells roads.* ■ *Banks low to steep and fenced through farmland. Three areas of active erosion / slumping observed.* ■ *Channel shading low in most reaches, apart from reach 2, 5 and 11 which were moderately shaded (25 – 30 %).* ■ *Riparian cover variable between reaches.* ■ *Macrophyte cover very high throughout (≥80%). Submerged forms dominant lower three reaches, while emergent forms dominant upstream.* ■ *High filamentous algal cover in reaches 1 and 3 (70 – 75 %).* ■ *Numerous springs observed in reaches 2, 3 and 6.* ***Potential enhancement options:*** ■ *Bank recontouring and riparian planting to provide shade, expose hard-bottomed substrates in mid to upper reaches, addition of boulders or snags to increase hydraulic variation.*
Days (tributary)		***Current state:*** ■ *Straightened channel dominated by run habitat. Average water depth 0.1 – 0.3 m. Average wetted width 1.0 – 1.5 m.* ■ *Soft-bottomed.* ■ *Bank vegetation dominated by exotic grasses and exotic shrubs/ trees, except native riparian planting at reach 3.* ■ *Banks moderate to steep and fenced along TLB (through farmland). No active erosion / slumping observed.* ■ *Channel shading moderate to high, except reach 3 (15%).* ■ *Riparian cover highest on TLB (70 – 95 %), and low on TRB except for reach 2.* ■ *High filamentous algal cover in reaches 1 and 5 (30 – 40 %).* ■ *High macrophyte cover, except reaches 2 and 5 (5 – 15 %).* ***Potential enhancement options:*** ■ *Riparian planting to provide shading; addition of boulders or snags to increase hydraulic variation.*
Goodericks (tributary)		***Current state:*** ■ *Straightened channel dominated by run habitat. Average water depth 0.3 – 1.0 m. Average wetted width 1.4 – 5.0 m.* ■ *Soft-bottomed reaches 1-3, hard-bottomed reaches 4–7. Gravel/pebble substrate not heavily embedded with fines.* ■ *Bank vegetation in reaches 1-2 mainly exotic grasses, herbs and shrubs on TRB and exotic trees on TLB. Other reaches mainly exotic grasses on TRB, exotic shrubs / tree on TLB.* ■ *Banks low to steep and mainly fenced through farmland. No active erosion / slumping observed.* ■ *Channel shading low, apart from reach 3 (35 % shaded).* ■ *Riparian cover high on TLB of reaches 1 – 5, otherwise low.* ■ *High filamentous algal cover in reaches 1 and 6 (35 – 60 %).* ■ *Macrophyte cover very high throughout all reaches (≥80 %). Emergent forms generally dominant.* ■ *Numerous springs observed in reaches 3 and 6.* ***Potential enhancement options:*** ■ *Bank recontouring and riparian planting to provide shade and expose hard-bottomed substrates in upper reaches; addition of boulders or snags to increase hydraulic variation.*

Table 6: Stream Walk summary of reaches surveyed.

6.4 Aquatic and Riparian Flora and Fauna

Although the catchment is predominantly agricultural land, there are a number of reserves within the catchment that contain areas of significant native vegetation. These include Yarrs Lagoon (Ta-rēre-kau-tuku) reserve and Yarrs Flat wildlife reserve in the lower catchment and to a lesser extent Liffey Domain and Mahoe reserve in the upper catchment. Notable species recorded from Yarrs Lagoon include the nationally threatened swamp nettle, as well as the locally rare mānuka and twig-rush. While these areas harbour significant vegetation, in particular Yarrs Lagoon and Yarrs Flat, they also likely support native invertebrates, lizards and birds (e.g., marsh crake). These areas are, however, susceptible to further weed encroachment, waterway maintenance effects, declining water quality and stock damage.

In terms of aquatic and terrestrial animals, there is a general lack of data available from the catchment. The limited data that does exist, however, shows that the aquatic invertebrate communities are generally in poor ecological health, and are typical of lowland waterways whose habitat has been degraded by inputs of sediment and nutrients. Although there have been observations (mainly casual) of mega-invertebrates (such as koura and kakahi), there is insufficient data available to determine their current status in the catchment. Data is similarly limited for the fish, bird and terrestrial invertebrate communities present within the catchment, especially for some of the more notable species (e.g., tuna, lamprey, bittern etc.).

PART

TWO

ENHANCEMENT

Includes

7.0 WATERWAY RESTORATION

7.1 Why Bother?

The Ararira / LII River and its tributaries are highly modified, with minimal native riparian vegetation, the channels are often choked with aquatic weeds, and management is focussed on land drainage. Given these facts, the cynic may well ask, "Why bother attempting to restore this waterway at all?" The answer to this question is that there are *many* good reasons for restoring the Ararira / LII, as summarised by the following bullet points.

- **The Ararira / LII River is degraded.** Vegetation clearance, urban and agricultural development, waterway straightening and regular mechanical weed clearance all contribute to the catchment's currently degraded water quality and ecology. The river is a major tributary of Te Waihora / Lake Ellesmere, and it carries with it a high nutrient load to the lake. While the river supports some valued biota (e.g., a large population of longfin eels relative to other lake tributaries), degraded habitat and water quality limit many other ecological values (e.g., habitat for trout spawning, juvenile eels, lizards and birds).

- **Restoration efforts do make a difference.** Each restoration activity will affect the environment differently, with some activities having a wider range of benefits than others. However, every carefully considered restoration effort does have a beneficial ecological outcome at the local scale and contributes to an overall improvement at the catchment scale. For example, planting native trees and shrubs along the mainstem of the Ararira / LII River may provide less shade than a similar planting on a narrow tributary, but the native planting will still increase local plant biodiversity, and will provide habitat for birds, lizards and terrestrial invertebrates.

- **Prevention is more effective than the cure.** Many restoration actions both improve the current environmental state and help prevent it from degrading again. For example, fencing off and planting stream margins help stabilise banks (reducing bank erosion) and shade the stream, reducing aquatic plant cover and the costs associated with regular mechanical weed clearance. While the restoration effort will entail an initial cost outlay, these short term costs are often outweighed by the long term financial and environmental benefits.

- **Regulatory compliance.** National and regional environmental legislation, such as the NPS-FM and LWRP, require councils and landowners to comply with new water quality limits and environmental outcomes in the near future. Council and landowner activities that reduce their impact on freshwaters (e.g., fencing, riparian planting, stock management and waterway design to reduce soil erosion) will both help restore the ecological health of the waterway, but also increase the likelihood of complying with new environmental limits.

- **Early adopters will be rewarded.** Initiatives such as the Living Water Partnership have some funds to assist landowners with restoration efforts, but such funding will not always be available. Over time, there is an expectation that all landowners will take the necessary actions to comply with environmental limits. In addition to financial benefits, early adopters of environmental initiatives are often seen as industry leaders, and they carry considerable pride in their efforts and achievements.

7.2 Guiding Principles

Waterways in the Ararira / LII River catchment are currently managed for land drainage, but waterway restoration is a primary focus of the Ararira / LII Living Water programme. In this report we use the definition of waterway restoration of Parkyn et al. (2010) as *"actions taken to return freshwater ecosystems towards their natural condition"*. This definition indicates that catchment restoration requires *actions*, but it also acknowledges that restoration success does not necessarily require a return to pre-human conditions, rather some level of acceptable improvement towards the natural condition. This definition seems appropriate for the Ararira / LII River catchment, given the constraints of an existing drainage network.

A review of recent literature on waterway restoration reveals a number of common principles (Jähnig et al 2011; Pander & Geist 2013; Palmer et al 2014), as summarised in the following paragraphs. Following these high-level principles in the Ararira / LII River catchment will increase the likelihood of successful waterway restoration.

- **Set clear and realistic goals.** It is important to be realistic about what a given restoration activity can achieve on its own and in combination with other activities. For example, riparian plantings improve riparian plant biodiversity and also help improve aquatic ecosystem health by providing shade and cover. However, the benefits to aquatic ecosystems will be limited by upstream activities that affect water quality and habitat quality. Similarly, improving habitat for fish and invertebrates will only be effective at increasing fish and invertebrate diversity if there are no migratory barriers present.
- **Choose environmental indicators and monitor their change over time.** Despite the amount of effort and cost involved, surprisingly few restoration projects assess improvements over time. Common indicators include measures of biodiversity, water quality, and habitat quality. Biodiversity indicators typically include a mixture of measures of ecosystem health (e.g., abundance of pollution-sensitive species, or number of species present), as well as the presence and abundance of valued species (e.g., threatened species and species with particular cultural or recreational value). It is important to collect data prior to restoration, so that you can measure environmental change against a baseline.
- **Protect what is already there.** It is generally far more complex and costly to re-create natural ecosystems than it is to simply protect them. Protection of native riparian plant communities may be as simple as fencing them off from intensive grazing and removing nuisance weed species.
- **Focus on headwaters.** Restoring habitat and water quality in small headwater streams provides both local and downstream ecosystem benefits. Smaller streams are also more strongly influenced by local land use and habitat factors, so stand to benefit the most from local improvements. Springs are typically hotspots for biodiversity and have substantial cultural significance, so restoration of spring-fed headwaters can have far-ranging benefits.
- **Improve land and waterway management.** This principle acknowledges that the degree of restoration success will be greatly improved if pollution sources are identified and dealt to. For urban catchments, this typically involves detaining and treating stormwater before it enters waterways, and for rural catchments, it involves a variety of land management practices to reduce the loss of contaminants to groundwater and surface waters (e.g., nutrient budgeting and managing stocking rates according to soil type). Enhanced waterway management includes consideration of alternatives to activities such as weed cutting or artificial bank stabilisation that can have negative environmental effects.
- **Work with others.** Working with other environmental groups, government agencies and iwi greatly increases the capacity of an individual restoration project, while potentially also contributing to broader restoration goals. Restoration initiatives and groups currently involved with the Te Waihora / Lake Ellesmere catchment include Whakaora Te Waihora (a joint programme between Environment Canterbury (ECan) and Ngāi Tahu), the Waihora Ellesmere Trust, Te Ara Kakariki, and the University of Canterbury waterway rehabilitation experiment, called CAREX. Community engagement is also very important because local ownership of a restoration initiative greatly increases its chance of success.
- **Be prepared to try bold initiatives.** Landowners are often apprehensive about committing to restoration activities on their own property, despite many examples in the literature of all sorts of successful restoration activities yielding positive results. It is therefore important to identify potential “early adopters” who are prepared to make the first moves and provide the local example for others to follow. If a restoration activity is new to an area, then it is also important to be realistic about the likelihood of success and, be clear about what the restoration will achieve (i.e., what the goals are).

7.3 Restoration Focus for the Ararira / LII River Catchment

Key ecological restoration goals for the Ararira / LII River Living Water programme currently include:

- Restoration of the Ararira / LII River mouth to its former natural state as a mixed wetland, shrubland, and forest ecosystem.
- The Ararira / LII River, tributaries and associated drain network from Lincoln township to Te Waihora / Lake Ellesmere, has had some form of restoration through riparian planting and improved drain management.
- The Ararira / LII River supports a healthy tuna (eel) population.

Based on our review of the current state of the catchment, we believe restoration in the catchment should also include the following goals:

- Restoration and protection of springs, due to their cultural and ecological significance, and the ecosystem value of protecting headwater sites.
- Protection and enhancement of existing remnant wetland and indigenous vegetation, with a focus on Yarrs Lagoon and Yarrs Flat.

Restoration can be considered both in terms of the types of values that are being restored (e.g., water quality and threatened species) and the locations or habitats where the restoration should occur (e.g., springs and wetlands). Table 7 below summarises the types of values in need of restoration in the Ararira / LII River catchment, given the current state of hydrology, water quality and ecology. The subsequent sections describe the locations and habitats where restoration would be most beneficial, building on the broad restoration goals outlined in the bullet points above.

Table 7: Values Targeted for Restoration.

Value	Details
Hydrology	■ Maintain or improve current level of flood protection. In some low lying areas which are particularly vulnerable to flooding consideration should be given to the option of managed retreat i.e., relocation of infrastructure, forgoing active drainage maintenance works and allowing the area to revert to its natural wetland state.
Water Quality	■ Suspended and deposited fine sediment, faecal contamination, and phosphorus are the water quality parameters most likely to respond positively to improved land management and riparian enhancement. Reduced levels of these contaminants would benefit sensitive aquatic invertebrates and fish. ■ Nitrate concentrations are less likely to improve, due to the primary groundwater source, but wetland treatment at spring sources could help reduce concentrations.
Ecology	■ Increased diversity of native riparian plants can be achieved in part with plantings (assuming appropriate species selection and ongoing care). Plantings may also increase diversity of riparian animals. ■ Valued aquatic biota, including: ▪ Longfin eel (tuna), inanga, and lamprey (conservation and cultural value) ▪ Brown trout (recreational fishery value) ▪ Koura and kākahi (conservation and cultural value)

Landuse, hydrology, water quality and ecology are interrelated and when considering restoration activities it is important that a holistic approach is adopted and that all potential effects of the proposed restoration activities are fully considered.

7.3.1 Springs

Goal: Locate, protect and restore spring habitats.

Rationale: Springs are ‘biodiversity hotspots’ and are culturally significant, plus restoring spring habitat is consistent with the restoration principle of focussing on headwater areas. Springs are generally poorly protected in the catchment and have degraded physical habitat.

Activities: Review available information regarding spring location from landowners, ECan and from aerial imagery. This will likely require some fieldwork to verify the location and condition of springs. Restoration activities may include fencing, plantings, and physical improvements (e.g., silt removal). Explore the feasibility of formally protecting spring habitats with local landowners.

Indicators: Key habitat indicators include measures of bank erosion, streambed particle size, water depth and width, shading and habitat variability. Relevant water quality indicators would include turbidity/clarity, temperature, dissolved oxygen, nutrients, and faecal indicator bacteria. Nitrate concentrations are unlikely to change much with local restoration efforts, due to the influence of upwelling groundwater with high nitrate concentrations. Ecological indicators may include stream invertebrate community health and diversity (e.g., QMCI scores, presence of specialist groundwater species), and abundance and population structure of kākahi and koura.

7.3.2 Wetland restoration

Goal: Improve ecological condition of existing wetlands and increase overall wetland extent. Improve and encourage public access to view and appreciate wetland ecosystems.

Rationale: Wetlands are threatened ecosystems nationally and regionally, and provide important habitat for native plants and animals. Yarrs Lagoon and Yarrs Flat are the two largest wetlands in the Ararira / LII River catchment and they should be the focus of restoration efforts. Improved local awareness of the ecological value of these wetlands could benefit the wider catchment. There is also merit in restoring other wetland habitat where conditions permit, such as on poorly drained farmland prone to pugging, as it would increase the overall extent of wetland habitat and may help improve downstream water quality.

Activities: For Yarrs Lagoon and Yarrs Flat, work with iwi and relevant government agencies, interest groups and stakeholders to develop a restoration plan to improve wetland condition and raise public profile. Key activities are likely to include weed management, native plantings and fencing. Yarrs Lagoon in particular could benefit from improved public profile and this could be achieved through a publicity campaign (e.g., through local schools), and providing improved access to walkers and recreational boaters (e.g., addition of walking tracks and a boat landing). Wetland restoration at other sites would require discussion with landowners to identify candidate sites (e.g., wet land that may be prone to pugging), and development of site-specific restoration plans.

Indicators: Key indicators of wetland condition include the presence and abundance of weed species, the abundance and diversity of native plant species, and the presence and extent of threatened or regionally rare plant species. Total wetland extent can be measured on an area basis, along with measures of wetland condition. Public access and engagement can be measured in a variety of ways, including visitor counts and perception surveys.

7.3.3 Enhanced waterway management

Goal: Improve aquatic habitat, biodiversity, and cultural value of waterways whilst maintaining or improving current levels of flood protection.

Rationale: Much of the Ararira / LII River catchment is managed primarily for drainage, but other values are present and could be enhanced. Activities such as weed cutting and dredging impact on aquatic habitat, invertebrates and fish. Alternative management options, such as planting riparian grasses, shrubs and trees, can increase stream shading and reduce the need for mechanical or chemical weed clearance. The effectiveness of riparian plants at providing shade will depend on the width of the stream, the height and density of riparian plants, and also the dominant aquatic weeds present (some species are more shade-tolerant than others). Sediment is a significant issue within the watercourses of the Ararira / LII River catchment in that it provides a source of nutrients to aquatic plants, is detrimental to aquatic ecosystems and clogs the waterways reducing the flow carrying capacity.

Activities: Trial the effectiveness of riparian plantings at providing adequate shade to reduce aquatic plant cover and the need for weed cutting and dredging. Plantings should focus on Ararira / LII River tributaries, which are relatively narrow and would therefore be more easily shaded than the mainstem. Access to the waterway should be maintained for weed cutting machinery, at least until it is established that enough shading is being provided to keep the channel sufficiently clear of nuisance plant growth. In areas prone to bank erosion, trial re-grading over-steepened banks and riparian planting to improve bank stability. Identify key sediment sources in the catchment and develop site specific tailored solutions. Trial the removal of soft sediment from the streambed. Such trials should target areas where the soft sediment is underlain by a cobble bottom and where upstream sediment sources have been identified and addressed.

Indicators: Key ecological indicators of success include stream shade, streambed coverage with aquatic plants, waterway hydrology (depth and flood carrying capacity), and frequency of weed cutting and dredging, and relevant indices of invertebrate and fish community health. Measures of cultural health are beyond the scope of this report.

7.3.4 Other restoration activities

A variety of restoration activities could be undertaken to improve habitat quality and biodiversity at a local scale. General habitat restoration activities include riparian planting, enhanced channel profiles (battering banks and providing a narrower low flow channel), targeted removal of fine sediment, and instream habitat creation (e.g., creation of riffles for juvenile longfin eel habitat). Such activities can all potentially benefit ecosystem health. In addition, threatened or at risk animal species such as koura and kākahi could be re-introduced to restored and protected habitats. Sites for re-introduction would need to be evaluated in consultation with DOC, iwi, landowners and relevant stakeholders. The relative benefits of a given restoration activity will largely be driven by the site. However, measureable improvements in ecosystem health (e.g., increased abundance of juvenile longfin eels) will be more achievable at smaller tributary sites, which are less influenced by activities upstream of the restoration site.

7.4 Catchment Management

In addition to restoration there is a need to ensure that management of landuse and development activities throughout the catchment is as effective as possible. Initiatives such as:

- the development and implementation of effective farm environment plans,
- appropriate sediment controls for earthworks,
- protection and where possible enhancement of existing biodiversity values, and
- encouragement of increased community use and appreciation of the general catchment

need to occur in tandem with restoration initiatives in order to achieve overall catchment gains.

7.5 How and Where to Start?

Given Fonterra's involvement in the Living Water initiative, Fonterra dairy farms are a logical place to start with restoration efforts. Public land, such as Yarrs Lagoon and Yarrs Flat reserves, are also obvious places to commence restoration work, because they are in public ownership and there is no burden on an individual landowner. However, given the highly modified nature of the catchment, waterway restoration could realistically commence wherever there is a willing landowner. The key is in getting interest, refining a restoration strategy, and commencing work with the early adopters.

Based on discussions with landowners, stakeholders and councils to date as part of this project, there is interest within the catchment to get involved in restoration activities. The next two steps – refining a strategy and commencing work with early adopters – can occur simultaneously.

The stream walks undertaken as part of this study identified enhancement opportunities in every reach studied (see Section 6.3.2). However, the stream walks only covered a small portion of the total catchment and many other opportunities for restoration likely exist. Some additional planning is therefore needed to ensure restoration efforts target the right locations and are co-ordinated in a logical fashion. We suggest that refinement of a restoration strategy should take into account the guiding principles and focus areas outlined in the previous sections, and it should involve the following steps:

- Identify and pursue restoration opportunities on Fonterra farms.
- Pursue restoration opportunities in Yarrs Lagoon and Yarrs Flat.
  - Living Water has already undertaken some restoration plantings and it is working with local schools to raise public awareness in the Yarrs Flat area. There is also interest in ongoing weed removal in Yarrs Lagoon.
- Work with the LII drainage committee to identify additional opportunities in the catchment.
- Prepare a restoration strategy that includes a range of restoration activities throughout the catchment and is supported by a monitoring programme to evaluate progress.
  - We consider that it is premature to present a restoration strategy in this report, because discussions first need to be had with Fonterra farmers and other landowners to determine what is feasible.
- Present the draft restoration strategy to catchment landowners, iwi, councils, and stakeholders for feedback, then refine and implement the strategy following feedback.

The following photographs and figures highlight potential restoration opportunities.

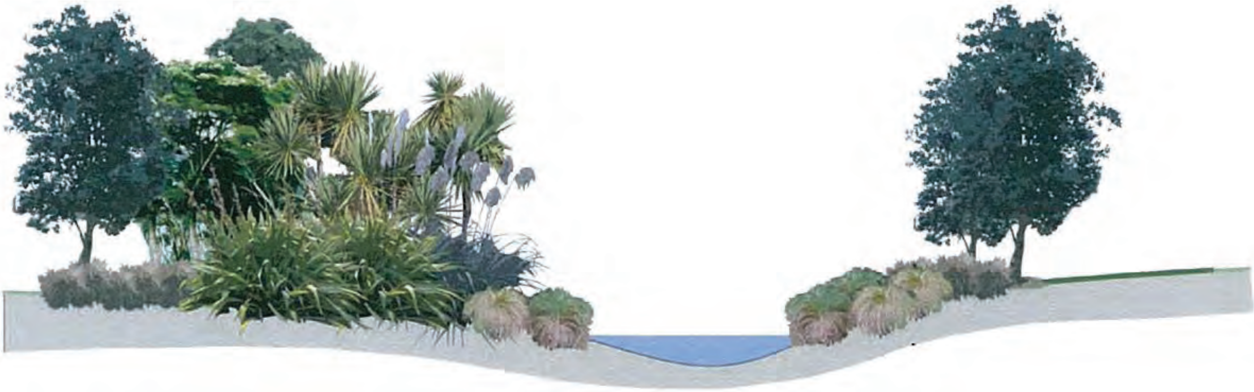
A bird's eye view of Yarrs Lagoon. This area contains significant wetland vegetation and should be a focal point for restoration efforts in the catchment.

Tributary waterways such as these would greatly benefit from riparian shading to reduce macrophyte growth.

Photograph from Liffey Stream showing a spring source in the centre of the channel (bubbling up). Springs should be protected across the catchment.

The benefits of shading provided by riparian vegetation: reduced macrophyte growth and reduced channel maintenance requirements.

Inputs of sediment can lead to very high sediment cover on the streambed, which reduces habitat quality for aquatic invertebrates and fish. This can have subsequent detrimental effects on terrestrial animals that live in or near the riparian margin (e.g., birds feed on the adult stages of aquatic insects).



A schematic showing an example of two different layout options for riparian plantings. Such plantings provide a range of benefits; however, their influence on channel shading is likely to be highest in narrower tributary waterways.

Photograph from the mainstem downstream of Pannetts Rd Bridge showing well-established riparian plantings on the true left bank. Such plantings improve bank stability, provide refuge, foraging and nesting habitat for a diverse range of terrestrial animals, and also provide overhanging cover for aquatic animals that is largely absent from riparian margins in the catchment.

An example of a restored ditch in the Silverstream catchment a similar spring-fed tributary of Te Waihora / Lake Ellesmere. The riparian plantings were undertaken 12 months prior to the taking of this photograph.

8.0 MONITORING RECOMMENDATIONS

The primary purpose of monitoring restoration is to track changes – and hopefully improvements – in key indicators over time. As noted in the previous section, it is important to have clear restoration goals that can be monitored, rather than haphazardly collecting data that may or may not prove useful in time. One of the challenges for this project is a lack of baseline ecological data for much of the Ararira / LII River catchment, as it is difficult to evaluate the effectiveness of restoration actions without an adequate baseline. Our monitoring recommendations therefore assume that some baseline data collection will occur. Monitoring recommendations will likely need to be revisited once further baseline data has been collected and we have a more complete picture of the current state of the catchment. In turn, it is assumed that monitoring results from this catchment will help inform future management actions both within the catchment and throughout the wider Living Water programme.

A further challenge to both monitoring and restoration efforts is the future changes that are expected due to increased irrigation and land use intensification up-gradient from the Ararira / LII River catchment. In particular, it is uncertain what the influence will be of CPW on future groundwater levels, groundwater quality and spring flows within the Ararira / LII River catchment. Construction of CPW is well underway and while model predictions provided an indication of potential future changes there still remains uncertainty over what the actual changes will be and how long they will take to fully manifest.

The following bullet points cover attributes we believe the Ararira/LII Living Water monitoring programme should include. For more information about monitoring the ecological success of stream restoration, refer to the Restoration Indicator Toolkit, by Parkyn et al. (2010), or see the Handbook for Monitoring Wetland Condition, by Clarkson et al (2004).

- **Adequate baseline data.** For some indicators (e.g., native plant diversity), this may simply require a one-off survey prior to restoration activities, while other indicators (e.g., water quality) may require several rounds of sampling to characterise seasonal changes. There is sufficient baseline water quality, flow and groundwater level data to characterise flows, groundwater levels and general water quality in the catchment, but additional data would be necessary to assess local impacts of restoration on hydrology and water quality. Continuous dissolved oxygen and temperature data are lacking, and there is currently inadequate baseline data for invertebrates, fish, and riparian plants and animals (invertebrates, lizards and birds) throughout the catchment.

- **Appropriate monitoring sites.** Individual restoration activities may have only localised effects, at least at the start of a catchment restoration project. It is therefore important that monitoring sites are located to detect anticipated environmental improvements at the right scale. In rivers, this typically involves sampling a short distance upstream and downstream of the restoration activity, both before and after restoration. Monitoring sites can also be located to detect catchment-scale changes (e.g., ECan's Pannetts Road water quality monitoring site).

- **Relevant indicators.** As noted in the restoration section, common restoration indicators include measures of biodiversity, water quality, and habitat quality. Indicators should include parameters of direct relevance to the restoration goal at a given site (e.g., juvenile longfin eel abundance), as well as supporting environmental data that is indirectly relevant (e.g., cover and substrate composition).

- **Collaboration.** Monitoring should be co-ordinated with other agencies, interest groups, iwi and stakeholders, to make the best use of available resources. Monitoring that requires specialist technical knowledge and experience (e.g., collection of water quality samples for laboratory analysis) should be left to relevant experts, but many other types of monitoring can be undertaken by community groups with some expert guidance (e.g., monitoring koura or water clarity). Community involvement in a monitoring programme increases the chances of success, both in terms of the resources available for monitoring, and also in terms of overall community engagement and pride.

- **Realistic scope.** Any monitoring programme needs to be realistic about what can be achieved within budget constraints. Scoping out the monitoring programme entails consideration of the number of parameters being collected, monitoring frequency, number of sites, how many months or years it will take to detect changes, and the associated costs. Monitoring scope in the Ararira / LII River catchment, will depend both on the financial commitment of the Living Water partners and the degree of collaboration achieved with other groups.
- **Catchment overview and documenting change.** Tools such as GIS mapping, aerial photos and remote sensing provide methods for assessing and storing data at a catchment level. While monitoring of individual restoration activities requires a local focus there is also a need to monitor and document wider and often more subtle changes at a catchment level (i.e., changing vegetation patterns such as the removal of tall vegetation due to increased use of large centre pivot irrigators, increased areas of protection (reserves, QE2 trust covenants etc., areas covered by farm management plans etc.) within the catchment.

Table 8 below provides a summary of suggested restoration goals and associated indicators for the Ararira / LII River catchment. We have assumed that ECan will continue to monitor water quality and flows at the Pannetts Road site, which will provide useful information on the catchment-scale effects of changing land use, flows, and restoration activities. Short term collection of continuous turbidity data at Pannetts Road would allow a better understanding of the turbidity flow relationship to assist in identifying potential turbidity / TSS / sediment sources. Such information would determine if most of the sediment is derived from infrequent high flow and high turbidity events or whether mid-low flow and mid-low turbidity events dominate total sediment movement. Baseline data collection and monitoring of specific restoration activities will need to be co-ordinated with the agencies, interest groups, iwi, and stakeholders that have an interest in restoration in the catchment.

An integrated monitoring strategy is currently being prepared for the entire Te Waihora / Lake Ellesmere catchment by a reference group that includes Ngai Tahu, ECan, Fish and Game, and DOC. The aim of the draft strategy (dated August 2015) is to: *"…integrate the disparate aims for the lake and the range of management interventions so as to produce an integrated monitoring strategy that will lead to ongoing integrated reporting on the state of the lake and its environs, that is scientifically robust, fit-for-purpose, supported by the community and is cost-effective."* The draft strategy includes a wide range of monitoring areas, including water quality and quantity, vegetation, wildlife, and fish. However, at the time of writing this report, the strategy still required further details concerning what data would be collected, when, and by whom. We suggest that as the Ararira / LII restoration strategy is developed, the Living Water project partners co-ordinate with the Te Waihora / Lake Ellesmere monitoring reference group, to ensure monitoring within the Ararira / LII catchment is consistent with and complementary to the wider catchment monitoring strategy.

Table 8: Suggested restoration goals and monitoring activities for the Ararira / LII River catchment.

Restoration Goal	Indicators	Adequate Baseline Data?	Monitoring Frequency
Spring habitat restoration	Habitat: measures of bank erosion and other critical source areas, streambed particle size, water depth and width, bank cover, shading and instream habitat variability.	No	Annual
	Water quality: turbidity and / or clarity, temperature, dissolved oxygen, nutrients, and faecal indicator bacteria.	No	Monthly to quarterly
	Ecology: Aquatic invertebrate community health, abundance and population structure of kākahi and koura.	No	Annual
Wetland restoration	Hydrology: water level (depth to groundwater or surface water depth)	No	Continuous (preferably) or monthly (minimum)
	Habitat: measures of bank erosion and bed particle size.	No	Annual
	Water quality: if part of the wetland restoration goal is to improve downstream water quality, then monitor as per the spring habitat restoration goal.	No	Monthly to quarterly
	Ecology: Presence and abundance of weed species, the abundance and diversity of native plant, bird, and terrestrial animal (lizards and invertebrates) species, the presence and extent of threatened or regionally rare plant species, mapping wetland extent.	No	Annual
Enhanced waterway management	Hydrology: water level, flow, flooding risk and maintenance requirements.	No	Continuous (preferably) or monthly (minimum) for water level and flow. Hydraulic modelling to assess flood risk. Maintenance assessed through annual expenditure.
	Habitat: riparian shade, sedimentation.	No	Quarterly initially, then annual
	Water quality: turbidity / clarity, dissolved oxygen, temperature.	No	Continuous (preferably) or monthly (minimum) for turbidity / clarity. Continuous for temperature and dissolved oxygen.
	Ecology: species composition and cover of native and exotic aquatic plants, frequency of weed cutting and dredging, macroinvertebrate community health, abundance of koura, kākahi, native fish abundance and diversity, juvenile longfin eel abundance, brown trout spawning activity.	No	Annual

9.0 CONCLUDING REMARKS

The Ararira / LII River is highly modified and is primarily managed for drainage. However, there is growing interest in improving the catchment's ecological state, and a desire for the river to be managed for values in addition to drainage, including cultural values, water quality, ecology and recreation. The threat of flooding remains a key issue for landowners in the catchment, particularly those living close to the lake.

Increased irrigation up-gradient of the Ararira / LII River catchment namely CPW is expected to increase groundwater levels and spring flows within the Ararira / LII River catchment. When considering future water management in the catchment and potential restoration projects the impact of these expected future hydrological changes need to be carefully considered.

Continuation of ECan's water quality and flow monitoring at Pannetts Road and general groundwater level monitoring is important for providing good state of the environment data for the catchment. Future restoration projects should include targeted, localised, before and after monitoring to ensure the costs, benefits and implications of any restoration activities are understood and documented. Synergies should be developed between stakeholder groups to ensure effective catchment monitoring through minimising the cost while maximising the benefit from any monitoring.

Before undertaking restoration activities the following steps should be undertaken:

- **FIRST:** Ensure the goals of each restoration activity are clearly defined and that they have measurable targets.
- **ALSO:** Implementation of different management practices need to be carefully considered and informed by good science and engineering, and relevant experience.
- **ALSO:** Co-ordinate any restoration actions with other interested agencies, including CAREX, TRONT, ECan, Lincoln University, Lincoln Dairy Farm, WtW etc.
- **ALSO:** Work with relevant agencies to address land management issues, such as sediment and faecal sources ("fix the leaky plumbing").
- **PRIOR:** Undertake local background / baseline surveys to document current conditions so that any future changes / improvements can be assessed.
- **THEN:** Commence a variety of restoration activities, with the primary goal being to measure improved ecological outcomes for key indicators for each activity (the indicators may vary depending on the nature of the restoration activity).

Where possible enhancement and restoration activities should be designed to be holistic and ideally benefit hydrology (through improved flood protection), water quality (initial focus on sediment, E. coli and phosphorus) and ecology (particularly native riparian plants and animals and valued biota). Greatest benefit is expected from activities which: protect and enhance existing values (e.g., Yarrs Flat & Lagoon), are focused on habitat restoration and creation. When considering enhancement and restoration activities maintenance and longer term implications must be fully considered. Development of a strategic plan and goals for the catchment would help ensure that local enhancement and restoration activities fit within a holistic catchment wide vision.

It is recommended that restoration activities initially focus on: spring heads, enhanced waterway maintenance (particularly less weed cutting and dredging), identification and addressing water quality hotspots (particularly sediment) and enhancing Yarrs Lagoon and Yarrs Flat.

10.0 REFERENCES

ANZECC 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

Booker DJ, Graynoth E 2008. Instream habitat and flow requirements for Birdlings Brook, the Halswell River, and the Lee River. Report prepared by NIWA for Environment Canterbury. Environment Canterbury Report No. U08/51.

Brown L 2001. Canterbury. Pp.441-459 In: Groundwaters of New Zealand, M Rosen and P White (eds) New Zealand Hydrological Society Inc, Wellington.

Burdon F, McIntosh A, Harding J 2013. Habitat loss drives threshold response of benthic invertebrate communities to deposited sediment in agricultural streams. Ecological Applications 23: 1036–1047.

Butt J 2015. Rapid Ecological Assessment of the Yarrs Flat/LII Area. Report prepared for Fonterra/Department of Conservation Living Water Partnership. Wai-Ora Forest Landscapes Ltd. 23 p.

Carpenter A 1982. Habitat and distribution of the freshwater shrimp *Paratya curvirostris* (Decapoda: Atyidae) in North Canterbury. Mauri Ora 10: 85–98.

Clark D 2014. Technical report to support water quality and water quantity limit setting process in Selwyn Waihora catchment. Predicting consequences of future scenarios. Surface water quantity. Environment Canterbury Report No R14/8. Environment Canterbury, Christchurch, New Zealand. 41p.

Clarkson BR, Sorrell BK, Reeves PN, Champion PD, Partridge TR, Clarkson BD 2004. Handbook for monitoring wetland condition. Wellington, New Zealand: Ministry for the Environment. 73 p.

Clausen B, Horrell G 2007. Estimation of daily flows in Lake Ellesmere tributaries (1 April 1991 – 31 December 2006). Environment Canterbury Report No U07/85. Environment Canterbury, Christchurch, New Zealand. 80p.

Collier KJ, Cooper AB, Davies-Colley RJ, Rutherford JC, Smith CM, Williamson RB 1995. Managing riparian zones: a contribution to protecting New Zealand's rivers and streams. Volume 2: Guidelines. Department of Conservation, Wellington, New Zealand.

Davies-Colley RJ 2013. River water quality in New Zealand: an introduction and overview. In: Dymond JR ed. Ecosystem Services in New Zealand – Conditions and Trends. Manaaki Whenua Press. Lincoln, New Zealand. pp. 432–447.

Earl P 1998. Pilot Study of the Springs of the Halswell – LII Catchment. Environment Canterbury Report No U98/9. Environment Canterbury, Christchurch, New Zealand. 32p.

Emberson R, Syrett P, Bowie M 2011. Preliminary biodiversity assessment of potential Significant Natural Areas in Selwyn District, using ground beetles and other beetles collected in pitfall traps as indicator groups. Lincoln University Wildlife Management Report No. 31. 17 p.

EOS Ecology 2013. Lincoln Integrated Stormwater Management Plan: Pre-development Waterway Monitoring. EOS Ecology, Christchurch, New Zealand. 23 p.

EOS Ecology 2014. Lincoln Integrated Stormwater Management Plan: Waterway Monitoring (Year 2). EOS Ecology, Christchurch, New Zealand. 40 p.

Ettema M 2005. Statement of evidence of Marcus Ettema. Lynton evidence presented at Environment Court.

Franklin HM 2010. Understanding variation in water quality using a riverscape perspective. Unpublished MSc thesis. University of Canterbury. 147 p.

Golder 2012. Te Waihora / Lake Ellesmere: a review of critical lake opening periods, habitats and locations for fish in the Te Waihora / Lake Ellesmere catchment. Prepared for the Canterbury Regional Council. Report no. 0978110119. 29 p.

Golder 2013. Te Waihora / Lake Ellesmere: functional significance and sensitivity of groundwater fauna. Prepared for the Canterbury Regional Council. Report no. 0978110119_006. 12 p.

Golder 2014. Guide to Stream Walk Assessment. Report prepared by Golder Associates (NZ) Limited for Canterbury Regional Council. 39 pages.

Goodman JM, Dunn NR, Ravenscroft PJ, Allibone RM, Boubee JAT, David BO, Griffiths M, Ling N, Hitchmough RA, Rolfe JR 2014. Conservation status of New Zealand freshwater fish, 2013. New Zealand Threat Classification Series 7. Department of Conservation, Wellington. 16 p.

Grainger N, Collier K, Hitchmough R, Harding J, Smith B, Sutherland D 2014. Conservation status of New Zealand freshwater invertebrates, 2013. New Zealand Threat Classification Series 8. Department of Conservation, Wellington. 32 p.

Gray D. 2005. Braided river ecology: distribution, benthic ecology, and the role in the landscape. Unpublished MSc thesis. University of Canterbury. 222 p.

Gray DP 2013. Fine sediment removal from streams: environmental effects, protocols and a proposed rule. Environment Canterbury technical report No. R13/95. 73 p.

Graynoth E, Francis RICC, Jellyman DJ 2008. Factors influencing juvenile eel (*Anguilla* spp.) survival in lowland New Zealand streams. New Zealand Journal of Marine and Freshwater Research 42: 153–172.

Greenwood MJ, Harding JS, Niyogi D, McIntosh A 2011. Improving the effectiveness of riparian management for aquatic invertebrates in a degraded agricultural landscape: stream size and land-use legacies. Journal of Applied Ecology 49: 213–222.

Greer M 2014. Memorandum regarding drain clearing best management practices. Prepared for the Canterbury Regional Council. 19 p.

Grove P 2013. Vegetation. In Hughey K, Johnston K, Lomax A, Taylor K eds. Te Waihora / Lake Ellesmere: State of the lake 2013. Technical report No. 1. Waihora Ellesmere Trust, Christchurch. Pp. 19–22.

Hanson C 2014. Technical report to support water quality and water quantity limit setting process in Selwyn Waihora catchment. Predicting consequences of future scenarios. Groundwater quality. Environment Canterbury Report No R14/11. Environment Canterbury, Christchurch, New Zealand. 30p.

Harding J, Clapcott J, Quinn J, Hayes J, Joy M, Storey R, Grieg H, Hay J, James T, Beech M, Ozane R, Meredith A, Boothroyd I 2009. Stream Habitat Assessment Protocols for wadeable rivers and streams in New Zealand. University of Canterbury, Christchurch. 133 p.

Hayward S 2014. Ararira / LII River water quality: summary of the current state of knowledge and recommendations for a monitoring survey. Report prepared by DairyNZ. 18 p.

Hudson HR; Harding JS 2004. Drainage management in New Zealand: A review of existing activities and alternative management practices. Science for Conservation 235. 39 p.

Hughey KFD, O'Donnell CFJ 2009. Birdlife of the lake. In Hughey KFD, Taylor KJW eds. Te Waihora / Lake Ellesmere: status of the lake and future management. Lincoln University, New Zealand. Pp. 57–75.

Hughey KFD 2013. Wildlife. In Hughey K, Johnston K, Lomax A, Taylor K eds. Te Waihora / Lake Ellesmere: State of the lake 2013. Technical report No. 1. Waihora Ellesmere Trust, Christchurch. Pp. 23–24.

Hughey KFD, Taylor KJW (eds) 2009. Te Waihora/Lake Ellesmere: State of the Lake and Future Management. EOS Ecology, Christchurch. 150pp.

James A 2008. Ecology of the New Zealand lamprey (*Geotria australis*) – a literature review. Department of Conservation, Whanganui: 28 p.

Jähnig SC, Lorenz AW, Hering D, Antons C, Sundermann A, Jedicke E, Haase P 2011. River restoration success: a question of perception. Ecological Applications 21: 2007–2015.

James A 2008 Ecology of the New Zealand Lamprey (Geotria australis): A literature review. Report prepared for the Department of Conservation, Wanganui Conservancy, Wanganui, New Zealand.

Jellyman D 2012. Fish recruitment into Te Waihora / Lake Ellesmere. A consideration of the requirements of key species. NIWA report prepared for Environment Canterbury. 74 p.

Jellyman D, Graynoth E. 2010. The importance of tributary streams of Te Waihora / Lake Ellesmere in maintaining populations of longfin eels. NIWA report prepared for Environment Canterbury. 65 p.

Jellyman D, Unwin MJ, James GD 2003. Anglers' perceptions of the status of New Zealand lowland rivers and their trout fisheries. NIWA technical report 122. 61 p.

Jensen C 2013. Weed surveillance and priorities for control in the LII catchment. Report prepared for ECan. 34 p.

Jones JI, Murphy JF, Collins AL, Sear DA, Naden PS, Armitage PD 2012. The impact of fine sediment on macro-invertebrates. River Research and Applications 28: 1055–1071 p.

Kelly DW 2014. Technical report to support water quality and water quantity limit setting process in Selwyn-Waihora catchment. Predicting consequences of future scenarios: surface water quality and ecology in lowland streams. Environment Canterbury technical report No. R14/13. 32 p.

Longlands P 2014. A report on the LII and suggested habitat enhancements for birdlife. Report prepared for the Department of Conservation, Christchurch, New Zealand.

Leathwick J, Morgan F, Wilson G, Rutledge D, McLeod M, Johnston K 2002. Land environments of New Zealand: technical guide. Wellington: Ministry for the Environment, Manaaki Whenua Landcare Research 237 p.

Leathwick J, Wilson G, Rutledge D, Wardle P, Morgan F, Johnston K, McLeod M, Kirkpatrick R 2003. Land Environments of New Zealand. Auckland: David Bateman Ltd. 184 p.

MAF (Ministry of Agriculture and Fisheries) 1993. Towards sustainable agriculture: freshwater quality in New Zealand and the influence of agriculture. Ministry of Agriculture and Fisheries Policy Technical Paper 93/10.

Markham-Short R 2012. Compilation of Lincoln University water quality monitoring data for Lake Ellesmere/Te Waihora catchment: 1993– 2011. Summer scholarship report prepared by the Waterways Centre for Freshwater Management. WCFM Report 2012-001. 64 p.

Matheson, F., Quinn, J. and Hickey, C. (2012). Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: discussion document. Phases 1 and 2 final report. Prepared for the Ministry of Science and Innovation Environlink Fund. NIWA Client Report No. HAM2012-081.

McDowall RM 1997. The evolution of diadromy in fishes (revisited) and its place in phylogenetic analysis. Reviews in Fish Biology and Fisheries 7: 443–462 p.

McDowall RM 2000. The Reed field guide to New Zealand freshwater fishes. Reed, Auckland. 223 p.

McDowall RM 2002. Decline of the kakahi – identifying cause and effect. Water and Atmosphere 0(4): 8–9.

McDowell RW, Wilcock RJ 2008. Water quality and the effects of different pastoral animals. New Zealand Veterinary Journal 56: 289–296 p.

McGlone, M.S., 1983: Polynesian deforestation of New Zealand: a preliminary synthesis. Archaeology in Oceania 18, 11-25 p.

McQueen S. 2013. A photographic guide to freshwater fishes of New Zealand. New Holland Publishers. 143 p.

Milichamp R 2009. Brown trout fishery. In Hughey KFD, Taylor KJW eds. Te Waihora / Lake Ellesmere: status of the lake and future management. Lincoln University, New Zealand. Pp. 49–56.

O'Brien, L.K.; Dunn, N.R. 2012: Canterbury mudfish sub-population assessment database. Ichthyo-niche and Department of Conservation, Dunsandel and Christchurch, New Zealand.

Österling, M. E., Arvidsson, B. L. and Greenberg, L. A. (2010), Habitat degradation and the decline of the threatened mussel *Margaritifera margaritifera*: influence of turbidity and sedimentation on the mussel and its host. Journal of Applied Ecology 47: 759–768.

Palmer MA, Hondula KL, Koch BJ 2014. Ecological restoration of streams and rivers: shifting strategies and shifting goals. Annual Review of Ecology, Evolution and Systematics 45: 247–269 p.

Pander J, Geist J 2013. Ecological indicators for stream restoration success. Ecological Indicators 30:106–118.

Parker M, Grove P. 2013. Tā-rere-kau-tuku (Yarrs Lagoon): Wetland Condition, Threats and Significance Assessment. Jan-Feb 2013. ECan unpublished report. 9 p.

Parkyn S, Collier K, Clapcott J, David B, Davies-Colley RJ, Matheson F, Quinn J, Shaw W, Storey R 2010. The restoration indicator toolkit. NIWA, Hamilton, New Zealand. 134 p.

Phillips N, Parkyn S, Kusabs I, Roper D. 2007. Taonga and mahinga kai species of the Te Arawa lakes: a review of current knowledge – kakahi. NIWA report prepared for Te Arawa Lakes Trust. 19 p.

Reid D, Quinn J 2011. Preliminary information for developing sediment guidelines for streams of the West Coast, New Zealand. Prepared for West Coast Regional Council. NIWA Client Report HAM2011-012.

Rennie H, Lomax A 2013. Fish. In Hughey K, Johnston K, Lomax A, Taylor K eds. Te Waihora / Lake Ellesmere: State of the lake 2013. Technical report No 1. Waihora Ellesmere Trust, Christchurch. Pp. 25–26.

Rowland S, Bowie M, Sullivan J 2009. The past, present and future of biodiversity in Lincoln, Canterbury, New Zealand: the results of Lincoln's BioBlitz 2009. 45 p.

Rutledge M 1981. Distribution and trophic relationships of the phytomacrofauna in three Canterbury rivers. Unpublished BSc thesis University of Canterbury. 49 p.

Scott D, Weir J. Technical Report to support water quality and water quantity limit setting process in Selwyn Waihora Catchment. Predicting consequences of future scenarios: Groundwater Quantity. Environment Canterbury Report No R14/16. Environment Canterbury, Christchurch, New Zealand.

SDC 2009. Selwyn District Council Fiver Water Strategy August 2009 - The Future for: Community Water Supplies, Wastewater, Waterraces, Land Drainage and Stormwater. Prepared by Selwyn District Council, Rolloston. Dated 26 August 2009. Available from https://www.selwyn.govt.nz/my-property/water-utilities.

SDC 2012. Selwyn District Council 5Waters Activity Plan Part 3 – Te Waihora – Stormwater, Water Races, Land Drainage. Prepared by Selwyn District Council, Rolloston. Dated January 2012.

SDC 2015. Selwyn District Council 5Waters Activity Management Plan - Volume 5 Land Drainage. Prepared by Selwyn District Council, Rolloston. Dated January 2015 Available from https://www.selwyn.govt.nz/my-property/water-utilities.

Serriere A, Bechu T, Verdier T 2012. Water quality in the Halswell, Kaituna and LII rivers 2012. Report prepared as part of a Fish & Game internship. 50 p.

Singleton G 2014. Ellesmere the Jewel in the Canterbury Crown. Selwyn District Council, Rolleston.

Smith B, Collier K 2002. Living on the edge: putting the heat on adult aquatic insects. Water & Atmosphere 10(3).

Stevenson M, Wilks T, Hayward S 2010. An overview of the state and trends in water quality of Canterbury's rivers and streams. Environment Canterbury Report R10-117. 80 p.

Stewart M, Olsen G, Hickey C, Home M, Tipa G, Williams E. 2014. Whakaora Te Waihora: contaminants in Mahinga Kai. NIWA presentation, November 2014.

Suren A, Elliot S 2004. Impacts of urbanisation on streams. In Harding J, Mosley P, Pearson C, Sorrell B eds. Freshwaters in New Zealand. New Zealand Hydrological Society Inc. and the New Zealand Limnological Society Inc. Christchurch, New Zealand.

Taylor KJW 1996. The natural resources of Lake Ellesmere (Te Waihora) and its catchment. Canterbury Regional Council. 322 p.

Taylor M, Good M 2006. Brown trout spawning in the Lake Ellesmere (Te Waihora) tributaries, and some surrounding catchments. Report prepared by Aquatic Ecology Limited for Environment Canterbury. Report No. 31. 129 p.

Taylor MJ 2002. The National Inanga Spawning Database: Trends and implications for spawning site management. Department of Conservation, Wellington. Science for Conservation 188: 37 p.

Te Rangi Hiroa 1921. Art. 48 – Maori Food-supplies of Lake Rotorua, with Methods of obtaining them, and Usages and Customs appertaining thereto. Transactions and Proceedings of the New Zealand Institute 53: 433–451.

Te Rünanga o Ngäi Tahu and Department of Conservation Te Papa Atawhai 2005. Te Waihora Joint Management Plan Mahere Tukutahi o Te Waihora. Report dated 10 December 2005.

Tipa & Associates (2013). Cultural values, flow & water management issues for the Waikirikiri / Selwyn – Te Waihora catchments. Using data collected by the Taumutu / Tuahuriri COMAR Team & Horomaka COMAR Team. 196 p.

Unwin M 2009. Angler usage of lake and river fisheries managed by Fish & Game New Zealand: results from the 2007/08 National Angling Survey. NIWA report prepared for Fish & Game New Zealand. 110 p.

Webb T, Hewitt A, Lilburne L, McLeod M, Close M 2010. Mapping of vulnerability of nitrate and phosphorus leaching, microbial bypass flow, and soil runoff potential for two areas of Canterbury. Report prepared by Landcare Research and Environmental Science & Research for Canterbury Regional Council. Report R10/125.

Weir, J 2008: Evidence presented at Environment Canterbury hearing on consents applied for by Central Plains Water.

Williams K 2005. Native plant communities of the Canterbury Plains. Department of Conservation report, Christchurch, New Zealand

Williams, HR 2009: Groundwater and the living lake, pp 9-19, in Hughey, KED and KJW Taylor (eds.) 2009: Te Waihora / Lake Ellesmere: State of the lake and future management; EOS Ecology, Christchurch, 150 p.

Williams HR 2010: Groundwater resources in the Te Waihora / Lake Ellesmere catchment: management issues and options; Environment Canterbury Report No. R10/05, 71 p.

Williams H, Aitchison-Earl P 2006 Relationships between groundwater pressures and lowland stream flows in the Lake Ellesmere area. Environment Canterbury Report No U06/31. Environment Canterbury, Christchurch, New Zealand. 21p.

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