"PLM1"

Waikato Regional Council Technical Report 2015/13R

Visual clarity of the Waikato and Waipa Rivers

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online

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As noted earlier, both water clarity and phytoplankton biomass vary throughout the year in the Waikato River (see Figs 3 and 4). Figure 6 shows the monthly-average values of c and c_B at three sites on the river during the past ten years. At Ohakuri, average beam attenuation was highest during the summer, and so too was the contribution from phytoplankton. The *relative* contribution of phytoplankton to beam attenuation (i.e. c_B/c) averaged 54% over the 12 months, with the lowest value (41%) in May, and the highest (69%) in September.

At Narrows, both c and c_B were highest in October, with the ratio c_B/c averaging 53% over the 12 months, and with lowest (31%) and highest (85%) values falling in July and September, respectively. Finally, at Tuakau, c was highest during August-to-November and c_B was lowest during May-to-August, with the ratio c_B/c averaging 35% over the 12 months, and with the lowest value (15%) in August, and the highest (56%) in March.

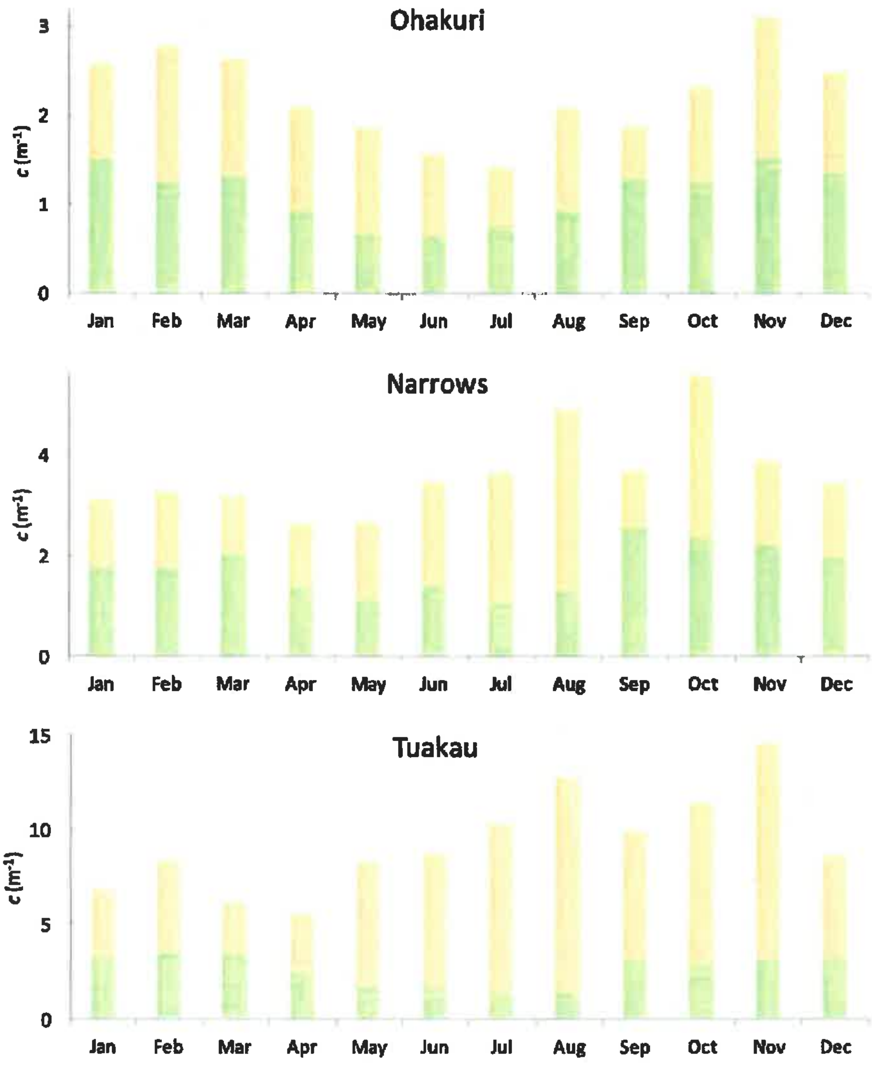

Figure 6: Monthly-average beam attenuation (c) at three sites on the Waikato River, 2005–14, showing the estimated contributions of phytoplankton (c_B, green) and the other constituents (brown).

October 2015

Nutrients and floating algae in the Waikato River

This infosheet provides information on a Technical Leaders Group summary of a number of studies on the relationships between nitrogen, phosphorus and floating algae in the Waikato River system.

It is important to understand how floating algal growth responds to total nitrogen and total phosphorus. As part of the proposed plan change, the following characteristics (or 'attributes') of water will be measured, to check if people's values for the Waikato River are being achieved,

- total nitrogen (TN)
- total phosphorus (TP)
- chlorophyll *a* (monitored to measure floating algae levels in the river)

What's the issue

Floating algae are a natural part of lake and lake-fed river webs. However, they can also affect water clarity, taste, smell and colour. Blooms of certain algal species can result in skin irritations and may be toxic.

Floating algae only become a problem in the main stem of the Waikato River. This is partly due to the dams slowing the river's natural flow.

Information considered and findings

The Technical Leaders Group considered the following information:

- patterns (for example seasonal and location-specific patterns) and trends in chlorophyll *a* and nutrients
- results of two bioassays (tests which measure the effects of a substance on living things), and key findings from further bioassay work
- research on patterns and trends in water quality at the Waikato main stem sites
- a review by a caucusing of experts who interpreted the results of the bioassays.

After considering the information above, the Technical Leaders Group found that:

- Annual median concentrations of chlorophyll *a*, TN and TP generally increase with distance down the Waikato River.
- There appears to be a strong relationship between annual medians of TN, TP and chlorophyll *a*.
- Analysis of relationships between annual median chlorophyll *a* and TP and TN at individual sites over the last 20 years generally shows positive relationships with TP, but weak or negative relationships with TN. So under current conditions in the Waikato River, chlorophyll *a* is mainly responding to TP, not TN.
- Long term trends (since 1990) at sites on the Waikato Rivers show decreasing chlorophyll *a* but increasing TN and therefore a greater ratio of TN to TP at all sites.
- The exotic daphnid zooplankton, which eats floating algae, may have contributed to the pattern of reduced chlorophyll *a*. However, as this species has been in the Waikato River for at least 18 years, it's unlikely it is the key reason for the decreases in chlorophyll *a*.

The Technical Leaders Group also notes the following seasonal patterns of concentrations:

	Winter	Spring	Summer	Autumn
Chlorophyll *a*	lowest		higher	
Dissolved inorganic nitrogen Dissolved reactive phosphorus	higher		lower	

They noted that TN to TP ratios are lowest in summer and autumn and highest in winter, at all sites from Ohakuri downstream to Tuakau. Occasional nitrogen limitation may occur in summer and autumn.

After considering the bioassay studies, the Technical Leaders Group agreed that:

- Neither nitrogen or phosphorus alone promoted growth of floating algae at any site at any time. Floating algae increased most often with addition of both nitrogen and phosphorus.
- The fact that the concentration of chlorophyll *a* in Lake Karapiro increased when nitrogen was added in March, but did not further increase when phosphorus was added, supports evidence that adding nitrogen in summer to autumn could result in increased floating algae growth.

Conclusions

The Technical Leaders Group agreed that the range of information they considered indicates that presently, phosphorus affects the annual median amount of floating algae in the Waikato River more than nitrogen does.

However, at times and in places during summer and autumn (when nitrogen levels in the water are lower due to catchment retention processes, such as in-river uptake by plants) adding nitrogen could increase the amount of floating algae in the river.

This suggests that efforts to control floating algae in the Waikato River should focus most on controlling phosphorus.

However, evidence suggests a secondary focus on nitrogen control is required:

- to help control summer/autumn chlorophyll *a* levels
- as a precautionary approach against increased annual median floating algae abundance, in case there is a reversal in reductions in phosphorus seen in the last decade, for example by extreme climate events that increase erosion processes and deposit more phosphorus-laden sediment into the river system, and as a precautionary approach against nuisance plant effects in downstream estuary and coastal environments.

More information

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PLAN FOR CHANGE

Wai Ora

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Raukawa Charitable Trust
Te Arawa River Iwi Trust
Tūwharetoa Māori Trust Board
Waikato Raupatu River Trust
Waikato Regional Council

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"PLM3"

Prediction of Subsurface Redox Status for Waikato Healthy Rivers - Plan for Change: Waiora He Rautaki Whakapaipai Project

E/S/R

July 2015

PREPARED FOR:	Waikato Regional Council
CLIENT REPORT No:	CSC 15010
PREPARED BY:	Murray Close
REVIEWED BY:	Phil Abraham

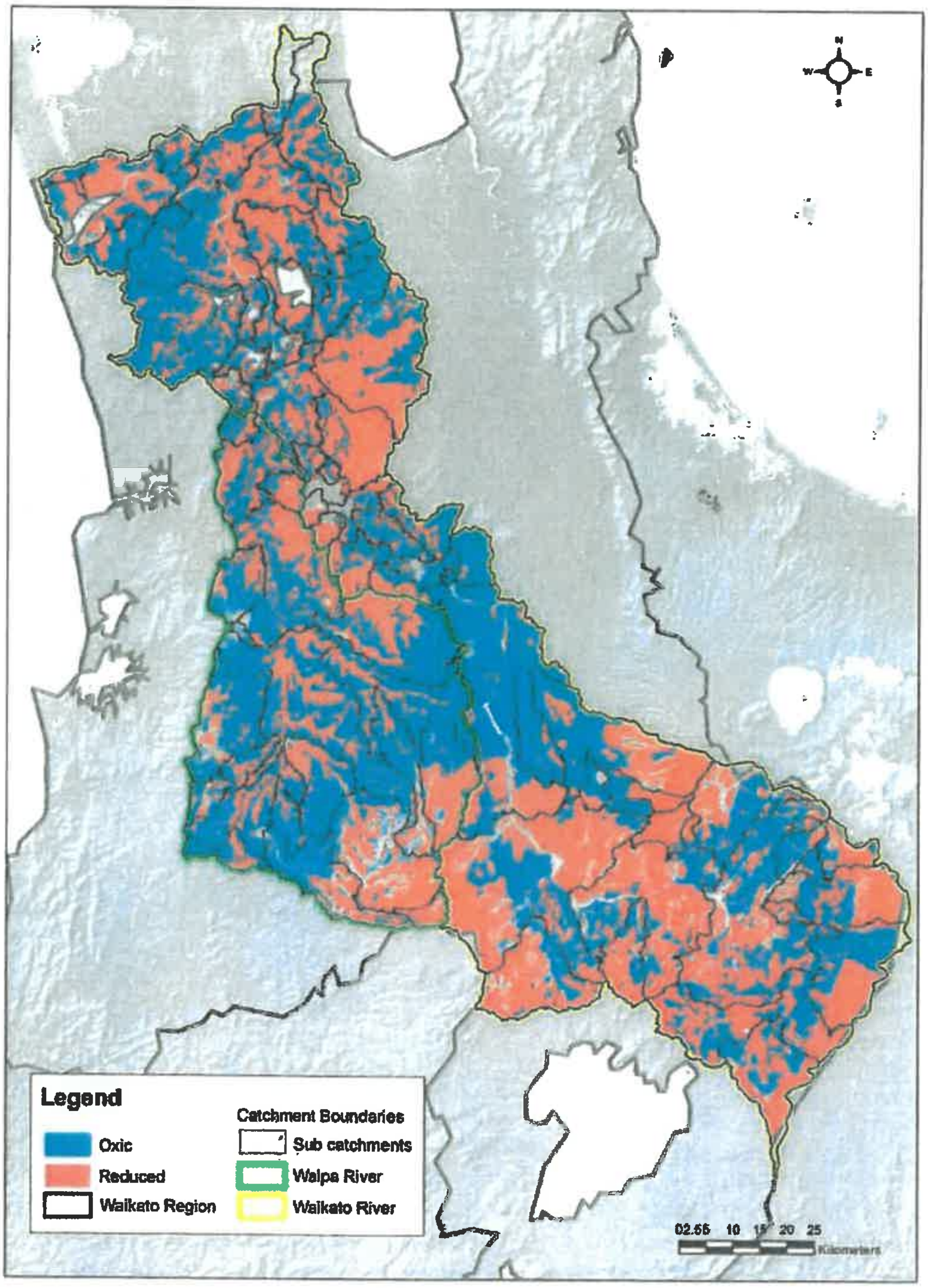


Figure 1: Map of predicted redox status for shallow (<25 m bgl) groundwater overlaid on sub-catchment boundaries for Waikato catchment.

"PLM4"

Healthy Rivers PLAN FOR CHANGE | Wai Ora HE RAUTAKI WHAKAPAIPAI

Draft for discussion purposes

Report No. HR/TLG/2016-2017/4.5

Simulation of the proposed policy mix for the Healthy Rivers Wai Ora process

This report was commissioned by the Technical Leaders Group for the Healthy Rivers Wai Ora Project

The Technical Leaders Group approves the release of this report to Project Partners and the Collaborative Stakeholder Group for the Healthy Rivers Wai Ora Project.

Signed by:

Date: 13 July 2016

steps towards Scenario 1 outcomes across all sites (Section 3.6). The nitrogen load-to-come makes it appreciably more difficult to achieve the 10% step. Concentrations for TN, median nitrate, and 95th percentile nitrate increase at sites where the load-to-come is most pronounced—and hence those downstream that are hydrologically connected also—once the load-to-come is accounted for. This is evident in Table 7 where there is an increase from the "Current state" concentration to the "Current + load-to-come" concentration for each attribute related to nitrogen. Previous research has highlighted the need for substantial afforestation in the Upper Waikato to offset the nitrogen stored in groundwater as a result of past intensification (Doole, 2013; Doole et al., 2015a). In line with this past analysis, this simulation of WRPC1 highlights that reductions in nitrogen in the Upper Waikato are too limited to achieve the target concentrations related to nitrogen loadings at a number of key sites, regardless of the predicted development of iwi land.

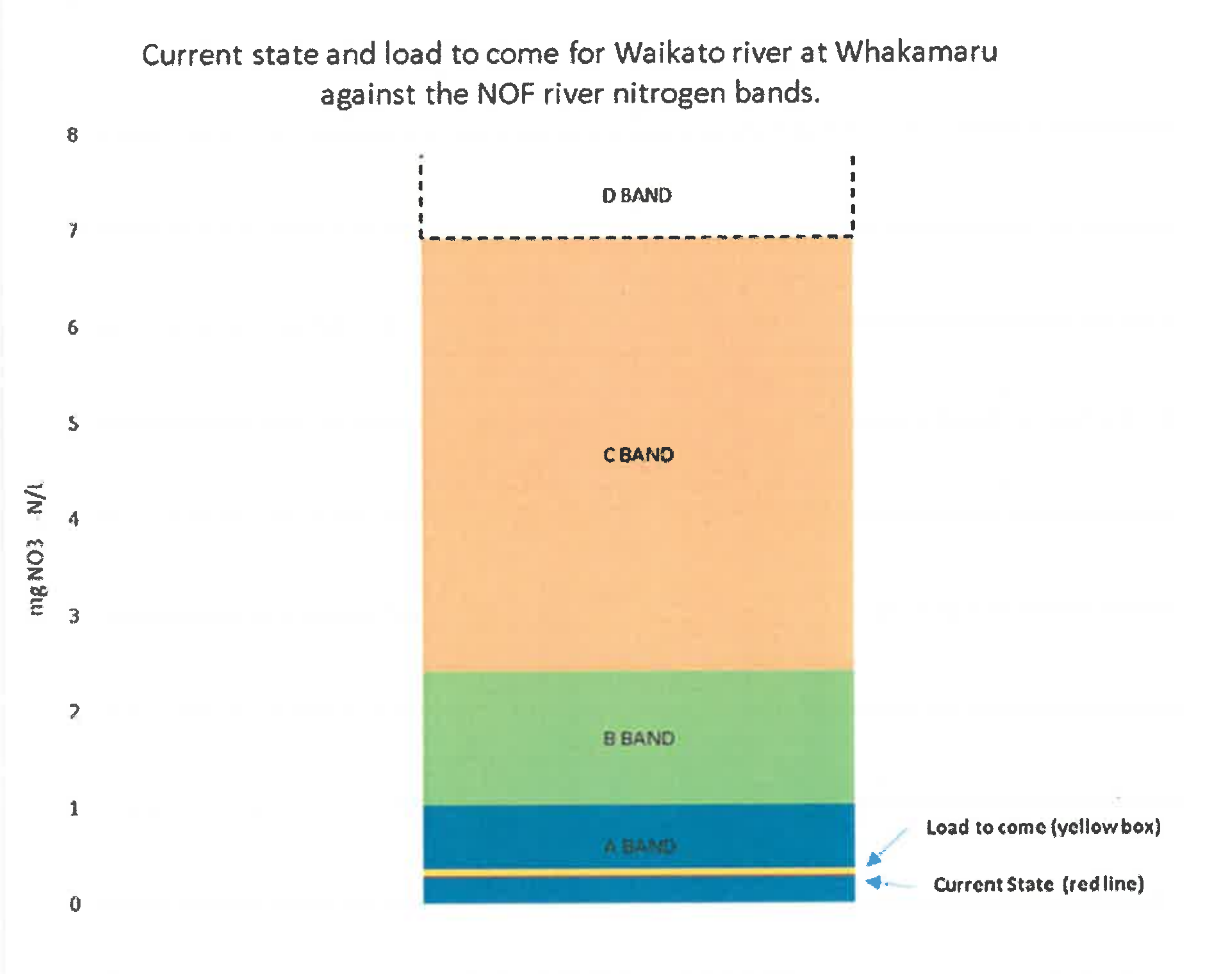
However, there are a number of reasons why the breaches occur, apart from the load-to-come. First, the goals determined for Total Nitrogen in the Upper Waikato FMU are indicative of high water quality ('A' band in the National Objectives framework), which make it easier for breaches to occur in the presence of productive agriculture. Second, improvements towards Scenario 1 are determined from current state and not the future concentration consistent with partial or full expression of the nitrogen load-to-come in surface water over the next decade. Thus, the proposed policy mix must achieve additional mitigation above that required for other attributes, given the need to offset this load-to-come alongside current contaminant loss. Nevertheless, the material implications for ecosystems of these observed breaches are arguably limited. The main implication of Total Nitrogen as a measure of water quality is its contribution to algal growth. Despite breaches being evident for Total Nitrogen in the Upper Waikato FMU (Table 7), targets for both median and maximum chlorophyll-a levels are achieved in all scenarios (Table 5) and many sites for these attributes meet the goals set for them under Scenario 1 too (Table 6). The improvement in median and maximum chlorophyll-a levels in all scenarios reinforces the importance of phosphorus as the key nutrient that currently limits algal growth in the lakes of the Waikato River (Yalden and Elliott, 2015).

Table 7. Concentration data for sites that do not achieve 10% improvements under the proposed policy mix across cases of no, low, medium, and high iwi-land development. Shaded cells denote instances where reported concentrations fail to meet the 10% steps towards Scenario 1 that are the goal of the policy mix.

Attribute	Site[1]	Current	Current + load-to-come	Sc. 1	10% step to Sc. 1	WRPC1 (no)	WRPC1 (low)	WRPC1 (med.)	WRPC1 (high)
TN	EW-1131-107	0.215	0.281	0.16	0.210	0.237	0.241	0.245	0.248
	EW-1131-143	0.336	0.422	0.16	0.318	0.344	0.348	0.352	0.355
	EW-1131-147	0.271	0.354	0.16	0.26	0.291	0.295	0.298	0.301
TP	EW-1131-105	0.011	0.011	0.01	0.011	0.0105	0.0108	0.0111	0.0111
Median nitrate	EW-1202-007	1.210	1.77	1	1.189	1.280	1.280	1.280	1.272
95% nitrate	EW-1202-007	1.555	2.27	1.5	1.55	1.644	1.644	1.644	1.635

[1] Sites are as follows: EW-1131-107 is Waikato River at Ohakuri, EW-1131-143 is Waikato River at Waipapa, EW-1131-147 is Waikato River at Whakamaru, EW-1131-105 is Waikato River at Ohaaki, and EW-1202-007 is Waipapa.

PLM 5



Current state and load to come for Waikato river at Whakamaru against the NOF river nitrogen bands.
8
7
6
5
4
3
2
1
0
mg NO3 - N/l
D BAND
C BAND
B BAND
A BAND
Load to come (yellow box)
Current State (red line)

"PLM6"

Critical pathways overview, Oct 2018.docx

Critical Pathways: Unravelling sub-catchment scale nitrogen delivery to waterways

To be effective and efficient, decision making on land use, land management, and mitigation measures, as well as policy to implement the National Policy Statement - Freshwater Management (NPS-FM), need to be based on a clear understanding of cause-effect relationships between actions on the land and freshwater quality. However, the Land and Water Forum (LAWF) has identified major challenges in defining land use/land management ('sources') that allows community-mandated contaminant limits in a waterway ('receptor') to be met. This is mainly due to insufficient understanding of the different pathways between the sources and the receptor, including their spatial distribution, temporal changes, and their associated lag times and attenuation processes.

The Problems

Present practice is to link activities on the land and water quality outcomes at spatial scales of 100s to 1000s of km^2. However, such large catchments are inevitably heterogeneous in their natural and land use/land management characteristics (Fig. 1). Consequently, it is inherently very difficult to link an observed contaminant flux at the catchment outlet to the many past and present activities within the large catchment that collectively have caused it. The need to focus on the sub-catchment scale (Fig. 2), i.e. the local streams that feed the large rivers that are typically being monitored has therefore recently been emphasised internationally[1-4]. While surface water monitoring data predominantly only exists at the catchment-scale, the development of cost-effective new methods, including real-time nitrate sensors, affords the opportunity to enable finer grained monitoring at the sub-catchment scale (10s of km^2).

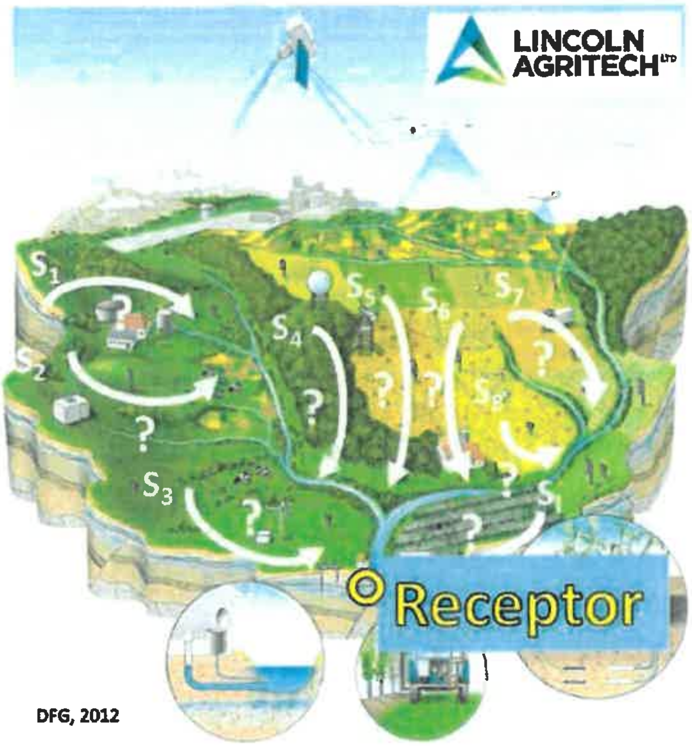


Fig. 1: Schematic illustrating that many diverse sources ($S_1...S_i$), in NZ often estimated by the nutrient budgeting model OVERSEER, collectively make up the source load. If attenuation processes occur along the various transfer pathways, a smaller delivered load arrives at the receptor (stream, river).

Apart from scarce monitoring data, there are several **shortcomings in our scientific understanding and technical capability** that currently prevent us from reliably linking land use/land management and water quality at the sub-catchment scale:

1. **We cannot adequately quantify the dynamic fluxes through shallow lateral pathways** (e.g. surface runoff, interflow, artificial drainage, shallow groundwater; Fig. 3) that are often crucial at the local and intermediate scales (Fig. 2). This applies particularly to undulating to hilly

landscapes, artificially drained land, and wherever low permeability geology restricts deep vertical groundwater recharge. While S-map information is available for the soil zone (approx. top 1m) and QMAP information for the underlying geology, we do not have coherent geospatial data available for the transition zone between soil and rocks (to approx. 20m depth, Fig. 3).

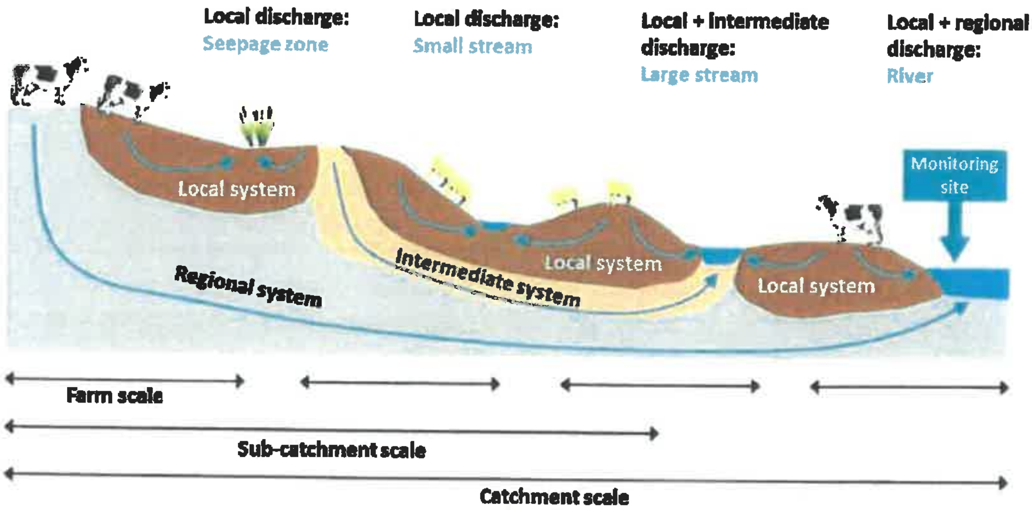


Fig. 2: Illustration of approximate relationships between groundwater flow systems, stream orders and spatial scales. Existing monitoring sites are predominantly located on larger rivers that accrue the contributions from many streams and from regional-scale groundwater discharge.

2. The hydrological and contaminant transfer models commonly used in NZ (e.g. MODFLOW-MT3D suite) focus on scales which represent deeper, regional groundwater systems that discharge into rivers (Fig. 2). The more dynamic **local and intermediate systems that feed at the sub-catchment scale into streams are usually underrepresented**. Accordingly, these models overestimate lag times and cannot describe the dynamic behaviour of many streams (Fig. 3).

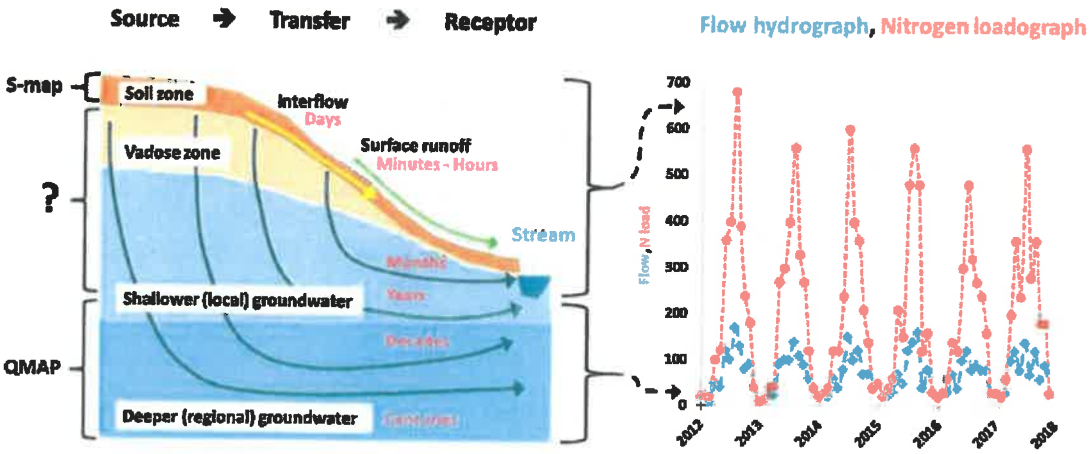


Fig. 3: Schematic illustrating the relationship between transfer pathways and stream responses. The arrows indicate that the nitrogen (N) base load is predominantly provided by the deeper (regional) groundwater, while shallower, shorter, and more dynamic pathways are responsible for the N load peaks typically observed during high-flow periods (particularly in autumn/winter).

3. Several indirect methods to predict the contributions of different pathways to overall discharge from land have been developed. However, currently **we cannot confidently evaluate the utility of these pathway partitioning models in NZ** as we lack the comprehensive datasets required.
4. While significant process understanding on **denitrification** has been gained in recent years, our **understanding of its spatial distribution and cumulative effect on delivered loads remains too uncertain** for defensible quantification and utilisation of this ecosystem service.

How we plan to overcome these shortcomings

We will overcome these shortcomings by introducing an **innovative multi-scale measurement, data analysis and modelling approach** that allows to coherently link transect, sub-catchment and catchment scale hydrogeophysical information. Three key innovations that augment a range of established techniques (e.g. groundwater and stream water analyses, including age-dating) will collectively enable us to unravel and model N transfers at the sub-catchment scale. We will:

1. Introduce a novel geophysical measurement suite to gain information on **structural, hydrological, and chemical characteristics controlling N transport and attenuation**, particularly in the shallow subsurface. In contrast to the point-scale nature of conventional measurements (e.g. soil coring), geophysical data will collectively provide seamless 3D information from transect via sub-catchment to catchment scales. An initial airborne transient electromagnetic survey (http://skytem.com/airborne-geophysics-3/) will provide resistivity/conductivity information that helps identify contrasting sub-catchments (see Fig. 4) in which ground-based surveys with greater resolution in the uppermost 20m of the subsurface will be carried out (http://hgg.au.dk/instruments/ttem/). This work stream benefits greatly from our collaboration with the world-leading HydroGeophysics Group of Aarhus University (http://hgg.au.dk/) and groundwater scientists from the Geological Survey of Denmark and Greenland (GEUS).
2. Innovative **Environmental Data Analytics (EDA)** techniques will be used to integrate structural, hydrological, and chemical information from the 'Big Data' created by the suite of geophysical measurements. These techniques facilitate discovery of relationships that are not generally recognised using conventional statistics. Through a combination of numerical, machine learning, and statistical methods, we will identify continuous **hydrogeophysical units (HGUs),** defined as 3D units within our catchments with similar hydrogeologic and geophysical characteristics.
3. We will use the HGUs identified by EDA together with Lidar to conceptualize and develop a numerical structure for catchment scale flow models. To **simulate the sub-catchment scale flow, transport, and attenuation**, we will nest finer resolution models within the coarser catchment models using information gathered at the sub-catchment scale. The information captured by these models will be scaled up to inform the catchment models (Figs. 3 + 4).

Two intensively farmed catchments with contrasting hydrological and biogeochemical conditions will provide our case study (Fig. 4). The **Waiotapu Stream (Wp)** catchment (approx. 300 km^2) on the North Island's Central Plateau represents a baseflow-dominated upland catchment with large groundwater store in young volcanic deposits. In contrast, the **Piako Stream (Pi)** headwater catchment is a lowland catchment (approx. 100 km^2) in the upper part of the Hauraki Plains with aquifer deposits of lower transmissivity and a high quickflow fraction in the stream hydrograph.

Concurrent with our biophysical research, we will determine **economic implications** of land use and management, mitigation and policy when based on sub-catchment versus catchment scale contaminant fluxes. A **kaupapa Māori-consistent knowledge exchange process** with our iwi partners Ngāti Tahu – Ngāti Whaoa and Ngāti Hauā, combining mātauranga, western contaminant transfer science, and economy, will specifically support the kaitiaki role of iwi making investment decisions around land development and management.

The **research team** comprises members from Lincoln Agritech, Aqualinc Research, Manaaki Whenua Landcare Research, Lincoln University, GNS Science, AgFirst, and Ian Kusabs & Associates. Waikato, Hawkes Bay, and Taranaki Regional Councils and DairyNZ have contributed to programme development and will further support the research by providing cash and/or in-kind contributions.

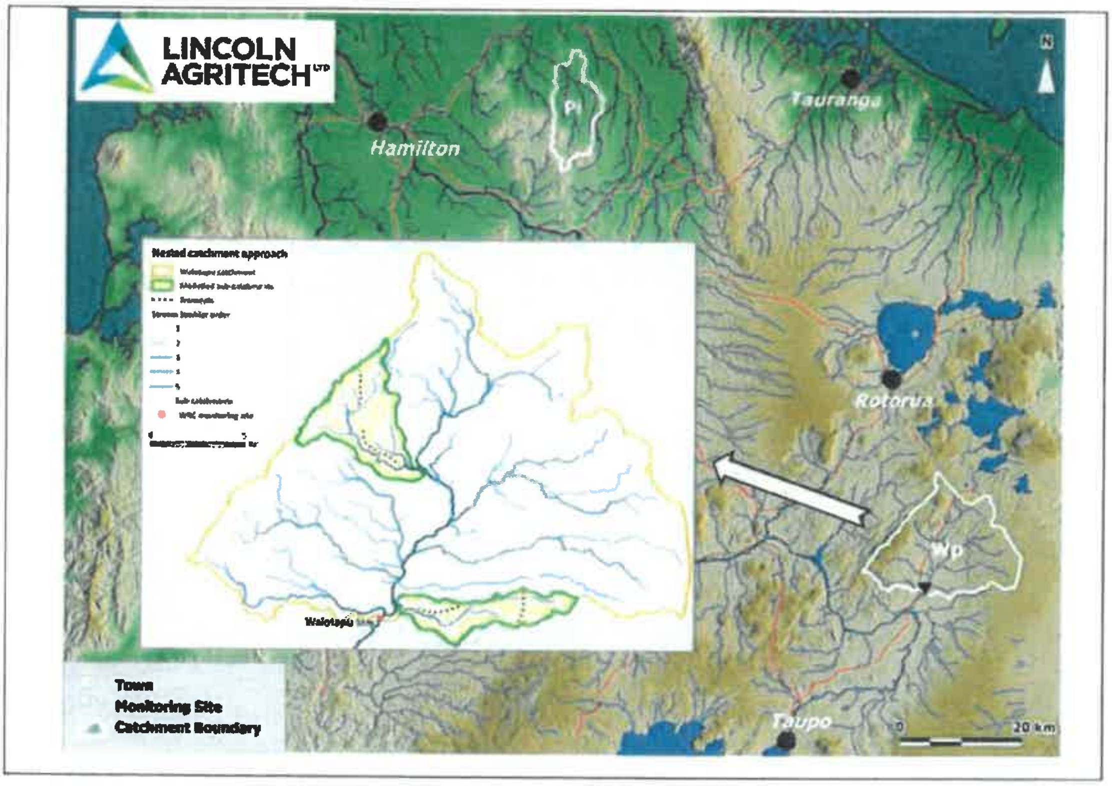


Fig. 4: Map showing the location of the two pilot catchments (Pl, Wp) and schematic illustrating on the example of the Waiotapu Stream catchment (approx. 300 km^2) our nested sampling and modelling approach, stretching from the transect scale via the sub-catchment scale to the catchment scale.

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"PLM7"

Waikato Regional Council Technical Report 2018/30

Trends in river water quality in the Waikato region, 1993-2017

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

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Appendix 1: Trend slopes (% per year) and, in brackets, slope direction probabilities (%) for monthly records of flow-adjusted water quality variables at ten Waikato River sites. Results are shown for 1993–2017 (25-year record) and for 2008–17 (10-year record). Important improvements (see text) are shown in bold; important deteriorations are bold underlined. The names of sites for which a flow index was generated (see section 2.6) are shown in italics. Results for total phosphorus are provisional.

	Temperature	Dissolved oxygen	Conductivity	Turbidity	Visual clarity	Arsenic	Boron	Total nitrogen	Nitrate-N	Ammonia	Total phosphorus	Dissolved reactive P	Chlorophyll *a*	*Escherichia coli*	Enterococci
1993–2017															
Taupo	0.3 (99)	0.0 (87)	0.1 ()99	1.5 (99)	–	1.1 (99)	0.2 (99)	0.5 (92)	–0.4 (99)	0.0 (50)	–1.5 (99)	–0.4 (99)	0.0 (50)	0.9 (91)	0.6 (80)
Ohaaki	–0.2 (99)	0.1 (98)	–0.5 (99)	1.2 (99)	–1.0 (99)	–1.2 (99)	–0.9 (99)	1.1 (99)	0.7 (99)	–6.1 (99)	–1.5 (99)	–1.9 (99)	0.0 (50)	–1.5 (98)	–1.4 (99)
Ohakuri	0.2 (99)	–0.1 (91)	0.0 (74)	0.8 (99)	–0.7 (99)	–0.2 (94)	0.0 (57)	1.4 (99)	1.7 (99)	–2.4 (99)	–0.2 (85)	–0.5 (96)	0.2 (76)	0.7 (83)	0.8 (87)
Whakamaru	0.0 (67)	0.0 (74)	0.0 (66)	0.3 (92)	–0.5 (95)	–0.1 (73)	0.1 (75)	2.0 (99)	2.9 (99)	–0.1 (99)	–0.1 (57)	0.1 (62)	0.9 (94)	3.7 (99)	4.7 (99)
Waipapa	0.1 (91)	–0.1 (99)	0.0 (78)	0.4 (91)	–0.7 (99)	–0.3 (99)	0.0 (67)	1.7 (99)	3.1 (99)	–0.3 (81)	–0.1 (74)	0.8 (99)	–1.2 (99)	–0.7 (77)	0.8 (87)
Narrows	0.1 (80)	–0.1 (99)	0.0 (54)	–0.6 (98)	1.0 (99)	–0.6 (99)	–0.2 (98)	1.5 (99)	3.8 (99)	–0.7 (98)	–0.8 (99)	0.8 (99)	–2.9 (99)	0.9 (80)	2.2 (99)
Horotiu	–0.1 (91)	–0.1 (96)	–0.1 (98)	–0.3 (88)	0.5 (96)	–0.6 (99)	–0.3 (99)	1.1 (99)	3.4 (99)	–4.2 (99)	–1.0 (99)	0.5 (96)	–3.4 (99)	0.3 (71)	–1.7 (98)
Huntly	0.0 (60)	–0.1 (94)	–0.1 (99)	0.4 (86)	0.2 (72)	–1.0 (99)	–0.5 (99)	1.0 (99)	2.3 (99)	–2.9 (99)	–1.6 (99)	–0.7 (99)	–4.0 (99)	–0.1 (54)	–0.1 (53)
Mercer	–0.4 (99)	–0.3 (99)	0.0 (75)	1.6 (99)	–	–1.4 (99)	–0.7 (99)	1.7 (99)	3.3 (99)	0.0 (50)	–1.0 (99)	–0.3 (88)	–3.6 (99)	1.2 (94)	2.3 (99)
Tuakau	–0.4 (99)	–0.3 (99)	0.1 (92)	0.8 (97)	–0.7 (97)	–1.3 (99)	–0.6 (99)	1.5 (99)	3.2 (99)	0.0 (50)	–1.3 (99)	–0.4 (89)	–3.0 (99)	1.5 (94)	1.5 (98)
2008–2017															
Taupo	0.1 (57)	0.2 (88)	0.1 (93)	–0.9 (86)	–	0.9 (99)	0.3 (91)	2.9 (92)	–2.0 (99)	0.0 (50)	0.2 (62)	0.0 (50)	–	1.8 (81)	4.0 (89)
Ohaaki	–0.1 (63)	0.1 (80)	–1.1 (99)	0.7 (83)	3.7 (99)	–3.0 (99)	–1.7 (99)	1.3 (95)	1.0 (72)	–1.3 (99)	–0.3 (67)	0.7 (78)	0.0 (50)	–1.9 (87)	–2.4 (85)
Ohakuri	0.1 (70)	0.2 (87)	–0.8 (99)	0.3 (64)	2.3 (99)	–2.0 (99)	–1.0 (99)	1.0 (84)	1.3 (77)	0.2 (71)	–0.9 (87)	0.4 (65)	1.4 (86)	3.6 (87)	4.3 (92)
Whakamaru	–0.2 (79)	–0.3 (81)	–0.6 (99)	–1.5 (95)	3.4 (99)	–1.9 (99)	–0.9 (99)	–0.2 (55)	2.1 (98)	0.0 (50)	–1.5 (90)	3.3 (99)	0.1 (52)	2.4 (74)	0.3 (55)
Waipapa	–0.2 (82)	0.1 (75)	–0.7 (99)	–1.1 (97)	3.0 (99)	–1.9 (99)	–1.4 (99)	1.4 (97)	2.8 (99)	–2.9 (97)	–1.5 (96)	0.9 (88)	1.7 (87)	3.1 (84)	8.7 (99)
Narrows	0.1 (54)	–0.2 (85)	–0.2 (95)	–1.0 (78)	4.1 (99)	–1.6 (99)	–1.2 (99)	0.6 (86)	1.2 (94)	–0.9 (70)	–1.3 (95)	0.5 (70)	–4.7 (99)	5.1 (99)	6.9 (99)
Horotiu	0.7 (98)	–0.1 (66)	–0.4 (99)	–1.8 (93)	4.1 (99)	–1.3 (99)	–1.3 (99)	0.0 (52)	0.8 (79)	0.1 (52)	–3.5 (99)	–2.4 (99)	–5.0 (99)	–2.1 (76)	–0.4 (53)
Huntly	0.0 (53)	–0.2 (80)	–0.4 (99)	–1.2 (85)	2.3 (99)	–1.4 (99)	–1.0 (96)	0.4 (78)	0.4 (67)	0.4 (86)	–4.0 (99)	–0.1 (53)	–3.0 (91)	2.7 (84)	2.9 (87)
Mercer	–0.3 (79)	–0.1 (77)	–0.6 (99)	–2.5 (99)	–	–1.3 (99)	–1.3 (99)	–0.3 (67)	0.1 (57)	0.0 (50)	–4.8 (99)	–0.2 (56)	–5.5 (99)	1.5 (68)	1.6 (70)
Tuakau	–0.2 (71)	–0.4 (97)	–0.5 (99)	0.0 (51)	1.9 (97)	–1.8 (99)	–1.6 (99)	0.6 (87)	0.8 (86)	0.0 (50)	–3.9 (99)	–0.4 (70)	–3.4 (98)	–0.2 (52)	–0.2 (53)

	Temperature	Dissolved oxygen	Conductivity	Turbidity	Visual clarity	Total nitrogen	Nitrate-N	Ammonia	Total phosphorus	Dissolved reactive P	*Escherichia coli*	Enterococci
Upland tributaries of the Waikato River												
1993–2017												
Kawaunui (48)	0.1 (86)	–0.1 (99)	1.2 (99)	–0.6 (90)	0.4 (94)	3.3 (99)	4.0 (99)	–2.0 (99)	–1.3 (99)	–0.7 (99)	–7.6 (99)	0.3 (63)
Mangaharakeke (43)	0.5 (99)	0.0 (65)	0.6 (99)	0.9 (99)	–0.6 (98)	5.2 (99)	7.3 (99)	–3.9 (99)	–0.2 (82)	0.1 (68)	1.1 (88)	3.1 (99)
Mangakara (49)	0.0 (50)	–0.1 (98)	1.1 (99)	1.2 (99)	0.4 (86)	2.4 (99)	2.8 (99)	–0.6 (99)	–1.1 (99)	–1.0 (99)	–0.2 (60)	1.8 (99)
Mangakino (60)	0.3 (99)	–0.1 (99)	0.7 (99)	2.0 (99)	–1.0 (99)	2.6 (99)	2.8 (99)	0.0 (50)	–0.4 (99)	–0.3 (99)	–	–
Otamakokore (46)	0.1 (90)	0.1 (97)	0.5 (99)	1.2 (99)	–0.5 (98)	1.9 (99)	2.3 (99)	–0.7 (99)	–0.5 (99)	0.2 (96)	0.8 (76)	1.3 (91)
Pueto (52)	0.2 (99)	–0.1 (99)	0.4 (99)	1.6 (99)	0.0 (56)	2.0 (99)	1.8 (99)	–3.9 (99)	–0.7 (99)	–0.2 (96)	0.0 (51)	3.2 (99)
Tahunaatara (44)	0.2 (99)	–0.1 (99)	0.6 (99)	1.5 (99)	–1.0 (99)	2.2 (99)	2.5 (99)	–0.1 (95)	0.0 (58)	–0.2 (94)	1.8 (90)	2.3 (95)
Torepatutahi (51)	0.2 (99)	0.1 (86)	0.6 (99)	0.6 (95)	–	2.9 (99)	3.4 (99)	0.0 (50)	–0.6 (99)	0.0 (50)	–	–
Waiotapu (47)	–0.1 (99)	0.1 (99)	0.5 (99)	0.6 (99)	0.3 (91)	1.5 (99)	2.2 (99)	0.8 (99)	–1.8 (99)	0.0 (50)	1.0 (92)	0.4 (59)
Waiotapu (50)	–0.2 (99)	0.1 (91)	0.4 (99)	1.4 (99)	0.8 (98)	1.1 (99)	1.1 (99)	0.4 (94)	–1.1 (99)	–1.2 (99)	–	–
Waipapa (42)	0.2 (99)	0.0 (67)	1.4 (99)	–0.1 (62)	0.1 (75)	4.6 (99)	5.3 (99)	0.0 (50)	–0.2 (96)	1.3 (99)	0.6 (64)	3.7 (99)
Whirinaki (45)	0.1 (90)	–0.1 (99)	0.4 (99)	0.5 (80)	0.1 (75)	2.1 (99)	2.5 (99)	0.0 (50)	–0.5 (99)	–0.5 (99)	–	–
2008–2017												
Kawaunui (48)	–0.1 (65)	0.3 (95)	0.6 (99)	–0.7 (70)	1.4 (91)	0.7 (98)	0.9 (99)	–6.6 (99)	–5.9 (99)	–4.0 (99)	–9.5 (96)	–0.5 (52)
Mangaharakeke (43)	0.0 (55)	0.0 (53)	0.3 (99)	3.8 (99)	–0.3 (67)	3.2 (99)	3.3 (99)	0.0 (50)	–0.9 (87)	–0.8 (99)	2.5 (90)	10 (99)
Mangakara (49)	–0.4 (82)	0.1 (85)	0.5 (99)	1.3 (82)	2.4 (99)	0.3 (74)	0.6 (93)	5.0 (99)	–3.3 (99)	–0.7 (99)	–2.0 (69)	–3.7 (87)
Mangakino (60)	0.2 (64)	0.1 (70)	0.5 (99)	3.4 (99)	–1.4 (94)	1.9 (99)	2.0 (99)	0.0 (50)	–1.2 (98)	–0.6 (98)	–	–
Otamakokore (46)	–0.3 (95)	–0.5 (92)	–0.4 (99)	0.3 (70)	1.5 (93)	2.4 (99)	2.4 (99)	0.0 (50)	1.7 (99)	–0.1 (67)	–1.2 (67)	–0.5 (54)
Pueto (52)	–0.4 (89)	0.0 (64)	0.2 (99)	3.6 (99)	0.4 (67)	3.2 (99)	2.8 (99)	0.1 (72)	–2.8 (99)	–2.1 (99)	1.4 (60)	7.6 (92)
Tahunaatara (44)	–0.1 (53)	0.0 (53)	0.8 (99)	1.5 (95)	1.1 (91)	2.6 (99)	3.1 (99)	0.0 (50)	0.1 (57)	2.3 (99)	1.3 (57)	3.1 (81)
Torepatutahi (51)	–0.4 (94)	–0.6 (98)	0.3 (93)	1.2 (88)	–	1.6 (99)	1.0 (95)	0.0 (50)	–0.9 (99)	–0.5 (95)	–	–
Waiotapu (47)	–0.1 (77)	0.0 (59)	0.3 (95)	–0.3 (64)	0.8 (87)	0.6 (97)	0.3 (84)	1.2 (99)	–4.7 (99)	1.6 (93)	–0.1 (55)	–1.0 (66)
Waiotapu (50)	–0.5 (92)	–0.6 (99)	–0.1 (74)	1.5 (95)	–	0.7 (99)	0.6 (97)	1.0 (78)	–0.9 (67)	–0.3 (67)	–	–
Waipapa (42)	0.2 (96)	0.0 (50)	1.9 (99)	–6.4 (99)	5.5 (99)	0.7 (93)	1.2 (99)	0.0 (50)	0.5 (68)	–0.4 (80)	–4.8 (96)	–4.6 (85)
Whirinaki (45)	–0.7 (99)	0.2 (93)	0.4 (99)	3.0 (95)	–	1.8 (99)	1.8 (99)	0.0 (50)	–0.8 (99)	–0.7 (99)	–	–

Appendix 2 continued

	Temperature	Dissolved oxygen	Conductivity	Turbidity	Visual clarity	Total nitrogen	Nitrate-N	Ammonia	Total phosphorus	Dissolved reactive P	*Escherichia coli*	Enterococci
Lowland tributaries of the Waikato River 1993–2017												
Awaroa-Otaua (27)	0.2 (98)	−0.3 (99)	0.3 (99)	**2.8 (99)**	**−2.3 (99)**	0.5 (99)	0.8 (99)	−0.1 (59)	0.6 (91)	**−3.2 (99)**		
Awaroa-Rotowar (7)	0.5 (99)	−0.2 (99)	**3.1 (99)**	0.4 (75)	**−1.1 (99)**	**1.6 (99)**	**2.3 (99)**	**1.3 (98)**	**−1.8 (99)**	0.0 (50)	–	–
Karapiro (85)	−0.1 (86)	−0.3 (99)	0.4 (99)	**2.0 (99)**	**−2.2 (99)**	**1.3 (99)**	**1.4 (99)**	−0.4 (78)	**−1.1 (99)**	**−1.2 (99)**	**−3.0 (99)**	−0.2 (57)
Kirikiriroa (90)	0.1 (83)	−0.1 (84)	−0.4 (99)	**−2.0 (99)**	**1.2 (99)**	**−3.2 (99)**	**−1.0 (99)**	**−7.6 (99)**	**−2.9 (99)**	−0.6 (92)	−1.2 (82)	0.6 (72)
Komakorau (6)	0.3 (99)	−0.3 (99)	0.5 (99)	0.8 (99)	0.0 (50)	−0.2 (94)	0.1 (80)	**−2.2 (99)**	−0.9 (99)	**−2.3 (99)**	**−3.1 (97)**	0.3 (59)
Little Waipa (38)	0.1 (89)	0.1 (99)	**1.0 (99)**	**2.8 (99)**	**−2.0 (99)**	**2.4 (99)**	**2.2 (99)**	0.1 (58)	0.2 (90)	0.0 (52)	−1.0 (79)	**2.6 (99)**
Mangakotukutu (87)	0.2 (98)	−0.1 (99)	0.3 (99)	**−1.1 (99)**	**1.3 (99)**	−0.7 (99)	−0.7 (99)	**−2.4 (99)**	**1.1 (99)**	**3.5 (99)**	**2.7 (96)**	0.0 (52)
Mangamingi (40)	0.0 (65)	−0.1 (98)	−0.1 (81)	**3.3 (99)**	**−1.9 (99)**	0.4 (99)	0.7 (99)	0.5 (66)	**−4.2 (99)**	**−4.6 (99)**	**−3.7 (97)**	2.7 (88)
Mangaone (77)	0.4 (99)	0.5 (99)	0.3 (99)	0.3 (79)	−0.3 (82)	**−1.1 (99)**	**−1.3 (99)**	**−4.7 (99)**	**−1.4 (99)**	−0.6 (99)	1.4 (75)	0.5 (70)
Mangaonua (78)	0.2 (95)	0.0 (81)	0.7 (99)	−0.8 (99)	0.4 (90)	0.0 (53)	0.3 (97)	**−1.4 (99)**	**−1.7 (99)**	**−1.8 (99)**	**−1.7 (95)**	**2.5 (97)**
Mangaonua (84)	0.3 (99)	−0.1 (99)	0.3 (99)	−0.7 (98)	0.4 (92)	**−1.1 (99)**	−0.7 (99)	**−11 (99)**	**−4.1 (99)**	**−5.0 (99)**	0.0 (50)	**5.1 (99)**
Mangatangi (30)	0.3 (98)	0.0 (76)	0.0 (55)	**4.4 (99)**	**−4.6 (99)**	−0.9 (99)	**−2.0 (99)**	−0.3 (76)	−0.3 (87)	**−1.2 (99)**	**−4.3 (99)**	**2.2 (97)**
Mangatawhiri (29)	0.0 (69)	−0.3 (99)	0.3 (99)	0.1 (63)	−0.5 (89)	−0.9 (99)	**−2.8 (99)**	0.0 (50)	−0.2 (79)	0.2 (76)	–	–
Mangawara (19)	0.3 (99)	0.2 (99)	0.5 (99)	0.8 (99)	0.0 (53)	−0.3 (91)	−0.3 (90)	−0.4 (94)	−0.3 (92)	0.3 (82)	–	–
Mangawhero (86)	0.3 (99)	0.0 (54)	0.7 (99)	**1.1 (99)**	−0.8 (99)	0.1 (79)	0.3 (88)	**−2.5 (99)**	**−1.0 (99)**	0.7 (94)	–	–
Matahuru (20)	0.4 (99)	−0.2 (99)	0.2 (99)	**1.8 (99)**	−0.6 (89)	−0.9 (99)	**−1.9 (99)**	−0.8 (94)	−0.2 (79)	**−1.0 (99)**	−1.0 (76)	**3.2 (99)**
Ohaeroa (25)	0.1 (84)	−0.2 (99)	0.3 (99)	0.0 (54)	**1.0 (99)**	**1.7 (99)**	**2.0 (99)**	**−2.6 (99)**	**−1.2 (99)**	0.4 (93)	–	–
Opuatia (24)	0.2 (97)	−0.2 (99)	0.6 (99)	**3.3 (99)**	**−3.0 (99)**	**1.1 (99)**	**1.2 (99)**	**−1.9 (99)**	0.4 (86)	**−1.9 (99)**	–	–
Pokaiwhenua (39)	0.1 (76)	0.0 (55)	0.8 (99)	**3.0 (99)**	**−1.6 (99)**	**1.9 (99)**	**1.8 (99)**	−0.4 (95)	**−1.6 (99)**	**−1.8 (99)**	−1.1 (74)	**4.2 (99)**
Waerenga (21)	0.5 (99)	−0.2 (99)	0.3 (99)	**2.2 (99)**	**−1.0 (99)**	0.5 (99)	0.2 (82)	0.2 (79)	0.1 (62)	−0.5 (95)	1.1 (80)	**2.8 (96)**
Waitawhiriwhiri (89)	0.2 (99)	−0.1 (88)	0.1 (84)	−0.1 (63)	0.4 (88)	−0.3 (97)	0.5 (99)	**−1.8 (99)**	**−1.2 (99)**	0.6 (87)	0.4 (60)	2.4 (93)
Whakapipi (26)	0.3 (99)	0.2 (99)	0.9 (99)	−0.8 (99)	0.6 (98)	**1.1 (99)**	**1.2 (99)**	**−2.5 (99)**	**1.1 (99)**	**4.0 (99)**	−2.1 (89)	0.6 (64)
Whakauru (41)	−0.2 (95)	0.0 (87)	0.7 (99)	**5.3 (99)**	**−3.2 (99)**	**8.0 (99)**	**15 (99)**	0.0 (50)	**3.1 (99)**	**2.4 (99)**	–	–
Whangamarino (28)	0.6 (99)	0.3 (84)	0.4 (99)	**−3.2 (99)**	0.8 (98)	**1.7 (99)**	**−4.2 (99)**	−0.3 (61)	−0.5 (96)	**−2.4 (99)**	**5.2 (99)**	**5.1 (99)**
Whangamarino (22)	0.5 (99)	−0.3 (99)	0.3 (99)	**1.7 (99)**	**−1.2 (99)**	**−1.4 (99)**	**−2.1 (99)**	**−1.4 (99)**	0.2 (79)	0.2 (70)	–	–
Whangape (23)	0.0 (50)	0.0 (64)	0.6 (99)	**8.0 (99)**	**−4.5 (99)**	**4.1 (99)**	0.0 (50)	0.0 (50)	**3.0 (99)**	0.0 (50)	–	–

Appendix 2 continued

	Temperature	Dissolved oxygen	Conductivity	Turbidity	Visual clarity	Total nitrogen	Nitrate-N	Ammonia	Total phosphorus	Dissolved reactive P	*Escherichia coli*	Enterococci
Lowland tributaries of the Waikato River 2008–2017												
Awaroa-Otaua (27)	0.3 (71)	**–1.0 (99)**	0.2 (84)	0.0 (51)	**3.8 (99)**	–0.6 (69)	–0.4 (61)	0.6 (59)	**–3.5 (96)**	–0.1 (53)	–	–
Awaroa-Rotowar (7)	0.2 (77)	–0.1 (62)	1.0 (90)	1.0 (65)	–0.3 (53)	**–3.2 (99)**	**–3.7 (99)**	–1.3 (70)	–0.8 (63)	0.0 (50)	**–5.9 (96)**	1.5 (74)
Karapiro (85)	–0.1 (60)	–0.7 (99)	0.3 (81)	–1.0 (76)	1.1 (81)	0.4 (63)	0.6 (70)	1.1 (73)	0.0 (53)	–0.5 (63)	**–13 (99)**	–1.1 (62)
Kirikiriroa (90)	0.3 (88)	0.5 (97)	–0.3 (96)	**–1.7 (99)**	**4.8 (99)**	**–1.6 (99)**	**–1.9 (98)**	0.2 (55)	**–2.2 (99)**	**–2.8 (99)**	–2.5 (68)	–0.3 (51)
Komakorau (6)	0.0 (50)	0.7 (98)	0.1 (64)	0.3 (72)	0.0 (50)	–0.4 (83)	–0.7 (84)	–1.0 (90)	**–2.0 (96)**	0.0 (50)	**–10 (99)**	**–9.1 (99)**
Little Waipa (38)	–0.4 (96)	–0.3 (95)	**1.0 (99)**	**3.6 (99)**	1.3 (88)	**2.6 (99)**	**2.6 (99)**	3.1 (97)	**1.5 (98)**	0.8 (85)	**13 (99)**	5.7 (91)
Mangakotukutu (87)	0.1 (67)	0.0 (55)	0.0 (53)	–0.5 (64)	**3.7 (99)**	–0.6 (86)	–0.8 (84)	–0.7 (71)	**1.7 (97)**	**2.3 (98)**	–12 (93)	–4.1 (80)
Mangamingi (40)	–0.7 (98)	–0.3 (93)	0.1 (57)	**3.3 (99)**	–0.7 (73)	–0.2 (70)	**–1.1 (98)**	**9.4 (99)**	**–5.2 (99)**	**–6.2 (99)**	3.3 (68)	2.6 (73)
Mangaone (77)	0.1 (70)	–0.9 (99)	0.0 (61)	**–4.0 (99)**	**6.7 (99)**	**–2.0 (99)**	**–1.8 (99)**	**–4.0 (99)**	**–3.4 (99)**	0.4 (76)	**–4.5 (95)**	–6.5 (84)
Mangaonua (78)	0.4 (84)	**–1.1 (99)**	0.3 (99)	**–4.8 (99)**	**6.5 (99)**	**–1.9 (99)**	**–2.0 (99)**	**–2.1 (99)**	**–1.3 (87)**	**2.0 (99)**	**–10 (98)**	**–9.7 (98)**
Mangaonua (84)	0.0 (54)	–0.1 (81)	0.7 (99)	**–2.2 (98)**	**3.2 (99)**	**–1.3 (99)**	**–1.0 (96)**	0.0 (50)	**–2.3 (99)**	0.5 (76)	–4.2 (78)	–2.7 (62)
Mangatangi (30)	0.3 (78)	0.2 (86)	–0.1 (68)	1.7 (93)	–2.4 (89)	–0.8 (78)	–0.9 (87)	2.6 (92)	**–2.5 (99)**	**–3.4 (99)**	–	–
Mangatawhiri (29)	–0.1 (58)	0.1 (83)	0.0 (53)	**2.7 (99)**	1.6 (85)	**1.8 (99)**	2.1 (91)	0.0 (50)	**1.7 (95)**	1.9 (94)	–	–
Mangawara (19)	0.7 (89)	**–1.2 (99)**	–0.4 (90)	0.6 (80)	1.3 (92)	–0.9 (93)	**–2.0 (98)**	**1.9 (98)**	**–1.7 (99)**	–0.2 (59)	–	–
Mangawhero (86)	0.4 (84)	0.1 (78)	–0.1 (84)	**–1.2 (97)**	0.2 (63)	–0.5 (91)	–0.8 (83)	0.7 (69)	**–1.6 (99)**	–0.6 (77)	–3.7 (81)	–2.3 (68)
Matahuru (20)	0.4 (79)	–0.7 (99)	0.1 (66)	–0.2 (56)	**5.6 (99)**	–0.7 (83)	**–2.3 (95)**	**4.5 (99)**	**–1.6 (93)**	0.4 (80)	–	–
Ohaeroa (25)	–0.3 (68)	–0.7 (99)	0.3 (99)	1.8 (87)	**2.5 (99)**	**1.4 (99)**	**2.1 (99)**	0.8 (93)	**–2.8 (96)**	0.1 (54)	–	–
Opuatia (24)	0.4 (75)	–0.2 (93)	0.6 (98)	**3.6 (99)**	**–2.4 (95)**	–0.1 (67)	0.0 (54)	2.8 (86)	–1.5 (82)	0.2 (62)	–3.4 (79)	–1.0 (55)
Pokaiwhenua (39)	–0.6 (95)	–0.4 (99)	**1.0 (99)**	**5.8 (99)**	–1.8 (93)	**2.6 (99)**	**2.4 (99)**	**4.0 (99)**	0.8 (84)	0.4 (85)	3.3 (84)	1.7 (66)
Waerenga (21)	0.4 (76)	–0.3 (88)	0.2 (96)	1.7 (94)	0.9 (79)	–0.8 (85)	–0.1 (55)	**3.5 (98)**	–0.8 (76)	–1.3 (71)	–0.1 (54)	**–8.7 (95)**
Waitawhiriwhiri (89)	0.3 (89)	0.2 (85)	–0.2 (75)	–0.3 (62)	**4.6 (99)**	–0.3 (78)	–0.7 (84)	1.0 (82)	**–2.0 (96)**	–1.0 (73)	0.1 (52)	1.4 (56)
Whakapipi (26)	0.4 (94)	0.6 (99)	0.0 (58)	–0.7 (72)	**4.6 (99)**	0.0 (56)	0.6 (70)	0.8 (79)	–1.1 (91)	0.5 (62)	–	–
Whakauru (41)	–0.4 (94)	–0.3 (98)	**1.7 (99)**	**5.7 (99)**	**–2.6 (98)**	**15 (99)**	**22 (99)**	**6.0 (99)**	**5.9 (99)**	**9.4 (99)**	**7.1 (99)**	**7.1 (95)**
Whangamarino (28)	0.5 (88)	0.2 (58)	–0.3 (84)	**–3.2 (99)**	1.6 (93)	0.4 (65)	2.3 (72)	5.6 (90)	**–3.4 (99)**	–0.9 (63)	–	–
Whangamarino (22)	0.3 (77)	–0.9 (99)	–0.1 (71)	2.0 (83)	–0.4 (58)	–0.7 (72)	**–1.8 (85)**	**3.3 (96)**	–0.5 (63)	0.0 (51)	–	–
Whangape (23)	0.0 (50)	**–1.2 (99)**	0.0 (50)	1.0 (74)	0.0 (50)	–0.3 (65)	0.0 (50)	0.0 (50)	–1.2 (85)	0.0 (50)	–	–

	Temperature	Dissolved oxygen	Conductivity	Turbidity	Visual clarity	Total nitrogen	Nitrate-N	Ammonia	Total phosphorus	Dissolved reactive P	Escherichia coli	Enterococci
Waipa River and tributaries												
1993–2017												
Kaniwhaniwha (11)	0.4 (99)	−0.3 (99)	0.2 (99)	0.4 (80)	−0.8 (98)	0.3 (94)	0.1 (73)	−0.5 (95)	−0.3 (78)	0.3 (80)	–	–
Mangaohoi (74)	0.3 (99)	0.0 (62)	−0.1 (94)	−0.5 (94)	1.0 (99)	−1.0 (99)	−1.7 (99)	−1.2 (99)	−0.9 (99)	−0.7 ()99	0.7 (69)	0.4 (64)
Mangaokewa (65)	0.1 (83)	−0.1 (99)	0.5 (99)	0.8 (98)	0.1 (65)	1.3 (99)	1.9 (99)	−5.3 (99)	−1.1 (99)	−0.4 (90)	–	–
Mangapiko (76)	0.1 (82)	0.3 (99)	0.2 (99)	1.2 (99)	−0.4 (84)	−0.4 (96)	−0.8 (99)	−5.4 (99)	−1.3 (99)	−1.6 (99)	–	–
Mangapu (63)	0.0 (67)	−0.2 (99)	0.7 (99)	0.1 (74)	0.1 (59)	0.9 (99)	1.1 (99)	−2.2 (99)	−1.9 (99)	−0.5 (91)	2.7 (92)	1.8 (93)
Mangatutu (73)	0.2 (97)	0.0 (92)	0.4 (99)	0.4 (91)	−0.4 (94)	1.2 (99)	1.3 (99)	−2.0 (99)	−0.7 (98)	−0.4 (90)	−3.9 (99)	−1.6 (94)
Mangauika (13)	0.4 (99)	−0.1 (99)	0.0 (70)	2.7 (99)	0.8 (99)	2.8 (99)	2.9 (99)	0.0 (50)	−0.1 (58)	−2.7 (99)	2.5 (82)	1.2 (76)
Ohote (88)	0.0 (76)	0.3 (95)	−0.2 (99)	0.9 (98)	−1.7 (99)	−0.8 (99)	−1.4 (99)	0.5 (91)	−0.4 (89)	1.7 (99)	1.3 (80)	1.2 (90)
Puniu (75)	0.0 (54)	−0.3 (99)	0.5 (99)	3.6 (99)	−2.7 (99)	1.6 (99)	1.6 (99)	0.7 (99)	0.3 (89)	−0.1 (71)	–	–
Waipa (61)	0.5 (99)	0.0 (50)	0.5 (99)	−0.2 (64)	−0.4 (89)	1.2 (99)	1.7 (99)	0.1 (91)	−1.0 (99)	−1.6 (99)	–	–
Waipa (12)	0.1 (72)	−0.1 (99)	0.4 (99)	0.8 (97)	−1.6 (99)	1.1 (99)	1.2 (99)	−0.6 (88)	−1.2 (99)	−0.6 (99)	0.3 (61)	2.0 (92)
Waipa (2)	0.2 (93)	0.0 (99)	0.3 (99)	−1.7 (99)	1.8 (99)	0.9 (99)	0.7 (99)	−0.2 (61)	−0.7 (99)	−0.5 (99)	−0.3 (64)	–
Waipa (64)	0.1 (94)	−0.1 (99)	0.4 (99)	−1.2 (99)	0.3 (91)	1.4 (99)	1.6 (99)	−1.0 (99)	−2.3 (99)	−1.4 (99)	0.1 (54)	0.4 (65)
Waipa (1)	0.1 (86)	−0.1 (99)	0.3 (99)	2.0 (99)	−0.5 (97)	0.8 (99)	0.8 (99)	0.6 (92)	0.3 (94)	−1.2 (99)	0.6 (57)	–
Waitomo (18)	0.1 (82)	−0.3 (99)	0.2 (99)	0.8 (99)	−0.4 (92)	0.8 (99)	0.6 (99)	−0.8 (97)	−0.1 (64)	−0.1 (65)	−1.6 (81)	0.9 (77)
Waitomo (17)	0.2 (99)	−0.1 (98)	0.3 (99)	0.6 (91)	−0.3 (87)	0.5 (99)	0.7 (99)	−0.5 (99)	−0.2 (74)	0.9 (99)	−1.9 (88)	−0.2 (57)
2008–2017												
Kaniwhaniwha (11)	−0.5 (80)	−0.2 (86)	−0.1 (75)	−1.1 (63)	2.4 (92)	−0.5 (70)	0.6 (75)	2.9 (96)	−2.8 (98)	4.4 (99)	–	–
Mangaohoi (74)	0.5 (96)	0.0 (54)	0.0 (58)	3.9 (99)	0.2 (62)	−1.0 (94)	−3.3 (99)	0.0 (50)	−0.7 (84)	−0.6 (97)	2.6 (76)	−3.0 (63)
Mangaokewa (65)	−0.3 (69)	0.1 (68)	0.4 (95)	1.3 (89)	1.7 (97)	0.3 (79)	0.9 (89)	2.1 (92)	−2.3 (97)	0.0 (52)	–	–
Mangapiko (76)	0.7 (98)	0.3 (90)	0.2 (71)	−2.2 (93)	5.8 (99)	−0.5 (65)	−1.4 (90)	0.0 (51)	−6.0 (99)	−5.9 (99)	–	–
Mangapu (63)	0.1 (63)	0.1 (72)	0.7 (99)	0.1 (59)	1.9 (91)	−2.1 (99)	−1.9 (98)	−4.5 (99)	−6.4 (99)	−4.0 (99)	−3.3 (77)	8.4 (82)
Mangatutu (73)	0.3 (77)	0.1 (75)	−0.3 (88)	0.5 (67)	3.1 (99)	−1.2 (81)	−1.1 (82)	0.0 (50)	−1.8 (98)	1.1 (79)	−6.2 (89)	−2.5 (74)
Mangauika (13)	−0.5 (86)	0.3 (95)	0.0 (64)	2.6 (88)	6.0 (99)	1.3 (86)	0.3 (61)	0.0 (50)	1.4 (82)	0.7 (88)	6.0 (71)	11 (91)
Ohote (88)	0.6 (94)	0.0 (53)	−0.6 (92)	−1.7 (89)	2.1 (90)	−1.1 (93)	−1.0 (92)	−1.4 (86)	1.5 (92)	0.0 (50)	−4.1 (88)	2.1 (72)
Puniu (75)	0.4 (92)	−0.2 (92)	0.2 (70)	2.7 (99)	–	0.5 (71)	−0.2 (53)	1.4 (84)	−0.9 (75)	−0.3 (58)	–	–
Waipa (61)	−0.5 (86)	0.4 (99)	0.0 (60)	2.4 (99)	3.4 (99)	−3.2 (99)	−3.9 (99)	0.0 (50)	−2.6 (99)	2.2 (98)	–	–
Waipa (12)	−0.2 (71)	−0.1 (80)	0.1 (71)	−0.2 (55)	−3.7 (99)	0.8 (84)	0.3 (61)	6.4 (99)	−2.9 (99)	−0.7 (86)	0.4 (55)	−0.8 (52)
Waipa (2)	0.5 (79)	0.1 (99)	0.0 (52)	2.2 (87)	−0.4 (63)	0.8 (87)	−0.5 (76)	−0.7 (60)	0.1 (53)	−0.5 (76)	−1.1 (75)	–
Waipa (64)	0.3 (79)	0.2 (89)	−0.2 (81)	−1.3 (92)	3.2 (99)	−1.1 (94)	−2.0 (97)	0.4 (81)	−5.5 (99)	1.4 (80)	4.5 (74)	2.6 (76)
Waipa (1)	0.2 (78)	0.0 (57)	0.1 (77)	5.9 (99)	0.8 (82)	−0.6 (74)	−2.0 (99)	0.5 (66)	−0.4 (69)	−0.8 (81)	−2.2 (85)	–
Waitomo (18)	0.1 (68)	−0.1 (65)	0.4 (89)	2.1 (97)	−0.6 (60)	0.9 (96)	−0.6 (82)	3.0 (95)	−0.2 (57)	0.1 (57)	5.5 (78)	4.8 (90)
Waitomo (17)	0.2 (82)	0.2 (93)	0.4 (99)	2.7 (99)	0.5 (68)	−0.1 (66)	−0.8 (96)	0.0 (50)	−1.2 (71)	−0.3 (72)	−1.2 (57)	−1.9 (57)

"PLM8"

Hydrology of the Waikato Catchment:

From Chapter 3 of Waters of the Waikato

Edmund Brown

Waikato Regional Council

PLM8

River flow - Tributaries

- 10 major tributaries
- Contribute 135 m^3/s
- Waipa largest 90 m^3/s
- During floods Waipa contributes 65% of flow but catchment is only 20% of area.

"PLM9"

Waikato Regional Council Technical Report 2012/33

Suspended sediment time trends in the Waipa River and Waitomo Stream

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

Executive summary

Waikato Regional Council (WRC) commissioned NIWA to assess the Waipa and Waitomo datasets for evidence of a trend or change in sediment loads that can be related to catchment and bank recovery works.

Since sediment loads are highly dependent on river flows the approach used was to look for temporal change in the relationship between suspended sediment concentration (SSC) and discharge. This involved testing for a time trend in the residuals of a LOWESS fitted relationship between SSC and discharge derived from the full data set. This was carried out over varying time periods to see how time trends have shifted. The significance of each time trend was evaluated using the Student's t-test, testing the hypothesis that the coefficient on the linear relation was significantly different from zero at the 1 % and 5 % significance levels.

The results indicate that statistically significant time trends probably do exist for both the Waipa and Waitomo catchments. However, the Student's-t test assumes normal distribution of data, and therefore, results from significance tests where data is not normally distributed should be treated with caution.

In the Waipa, there was an increase in SSC leading up to 2000 and a decrease in SSC from 2000 through until at least the end of 2010. This indicates that the considerable effort that went into river rehabilitation works in the early 2000's (peaking in 2004/2005) have paid off. The data in the Waipa are slightly biased, as there has been a tendency in recent years for more sampling in the rising stage of events, relative to the falling stage, thereby misrepresenting SSC in recent years. This bias means that the downward trend in SSC is actually stronger than the data would indicate. We recommend that WRC revisit their autosampler operating schedule to improve future monitoring.

In the Waitomo, results are less clear and depend on the period of time selected for trend analysis. SSC was generally decreasing from 1990 through until the end of 1996, reflecting the success of efforts in the 1990's from the Waitomo Landcare Group. From 1997 to the end of 1998 there was an increase in SSC, reflecting the 1998 floods. There was little change from 1999 until 2006, an upward trend from 2006 until 2010 and a decrease from 2010 to 2012. However, there is no overall downward trend in SSC in the Waitomo in the last decade. This does not mean that rehabilitation efforts over the last decade have been ineffective, but may indicate that these efforts are being offset by other drivers increasing SSC within the catchment (such as intensification of landuse).

1 Introduction

1.1 Background

Waikato Regional Council (WRC) commissioned NIWA to assess the Waipa at Otewa dataset for evidence of a trend or change in sediment yields that can be related to catchment and bank recovery works.

While meeting with WRC staff in Hamilton in May, it became apparent that there are also concerns regarding trends in sediment yields in the Waitomo catchment, so an assessment of trends in the Waitomo catchment was added to the scope of this study.

Detecting time trends in suspended sediment yield due to changing sediment supply factors is complicated by hydrological variability. The erratic occurrence of rainstorms and floods can lead to factor-of-ten variability in annual sediment yields (for example in the Waipa at Otewa catchment between 1985 and 2011 the annual specific sediment yield ranged from 36 to 419 t/km^2) with the standard deviation of annual yields being very large in comparison with the mean (with a SD of 92 t/km^2 and a mean of 137 t/km^2 in the Waipa). The upshot is that with only a relatively short monitoring record, there is usually too much hydrologically driven variability to identify a supply related trend simply from annual loads.

A way forward is to remove the flow variability signal by looking for temporal change in the 'rating' relationship between suspended sediment concentration (SSC) and water discharge (Q). This assumes that the rating shifts are driven by changes in sediment supply (or availability).The suspended load in streams during storm runoff events also varies considerably as a result of variations in sediment supply by erosion processes (which tend to be very patchy in space and time); the phase relationship between sediment supply and the water runoff (typically this shows as a clockwise hysteresis in the SSC-Q relation); and entrainment, deposition, and dispersion processes within the flow.

Thus the approach we follow is to look at a time trend in SSC-Q residuals (occurring due to supply effects) but also to check that, if a hysteresis in the SSC-Q relation exists, time trends have not been biased by the sampling schedule (e.g. that not all sampling has been undertaken during rising stages in the first few years and all falling stages in the later years).

In this short report we start by outlining some of the drivers of changes in SSC that may cause a systematic deviation in observed SSC away from the rating. This is followed by a description of the methodology used to examine time trends in SSC. The results of the analysis for the Waipa and Waitomo are then presented, followed by some recommendations.

1.2 Drivers of changes in suspended sediment concentration

Active bank erosion and hillslope erosion are key sources of suspended sediment, and increased rates of erosion may be triggered by events such as floods or landslides or by progressive changes like intensification of landuse. While variation in discharge is incorporated in the SSC rating, large floods may result in elevated SSC even after discharge has receded. In contrast to these factors that increase SSC, SSC may also be systematically lowered as a result of remediation measures, such as bank protection works and riparian and/or hillslope planting. Often, a number of these influences on suspended sediment supply will occur concurrently. For example, intensification of landuse may offset (or be offset by) the benefits of remediation efforts. It is important to understand the history of activities and events in the Waipa and Waitomo in order to provide a context against which to assess time trends in suspended sediment in these catchments.

1.2.1 Waipa

There are a number of events that have occurred in the upper Waipa catchment that could be reflected in the SSC record at the Waipa at Otewa gauge. The most notable is the Tunawaea landslip. This was a block type failure that occurred in August 1991 on the Tunawaea stream just upstream of the confluence with the Waipa River (Jennings et al., 1993). This landslip formed a 70 m high dam which failed on the 22 July 1992 (Jennings et al., 1993; Webby and Jennings, 1994). The volume of sediment generated by this landslip was approximately 9 million m^3 (M. Duffy WRC, pers. comm., 7 May 2012). The grain size distribution of the slip material is unknown, but experience suggests that a substantial portion of the slip material may be fine sediment and susceptible to entrainment by suspension.

The downstream advection of the suspended load portion of the slip material would likely have occurred relatively quickly (within a few years), so we would expect to see a potential increase in the SSC-Q relation in the few years following the dam failure (to say late 1994). In addition to this short-term effect of the Tunawaea slip, the slower diffusion of the bed load portion of the slip material is also having secondary effects. For example, as the bedload component of the Tunawaea slip gradually works its way down the Waipa, the bed becomes locally raised, exacerbating bank and terrace erosion (observed by NIWA staff to be widespread in the upper Waipa). This has been most severe approximately 5-6 km downstream of the Tunawaea confluence where a reach, ~ 800 m long, is bordered on its right bank by a 16 m high terrace of Taupo Pumice (deposited by the Taupo eruption that occurred in 186 AD). In the period since the Tunawaea landslip the aggrading riverbed has allowed floods to undercut these terraces, eroding them back ~ 15-20 m, releasing an estimated 192,000-256,000 m^3 of additional sediment into the Waipa. Again, a substantial portion of this material would have been sufficiently fine to contribute to suspended load, which would have advected fairly rapidly downstream. The remaining bedload portion is now diffusing downstream with the bedload portion of the Tunawaea slip material. These secondary effects of the Tunawaea landslip have potential to contribute to an increase in the SSC-Q relation at least until the bed material slug has moved past the Waipa at Otewa gauge.

Analysis of aerial photographs indicates the presence of further landslips in the upper Waipa, upstream of the Tunawaea confluence. However, the timing and volume of material supplied from these landslips are unknown.

Figure 1-1 shows a hydrograph of the Waipa at Otewa (monitoring station 43481) for the full period over which flow data is available (May 1985 – May 2012). This hydrograph shows the timing of the floods that caused the Tunawaea landslip and landslip dam failure. These floods had peak discharges of 189 m^3/s and 203 m^3/s respectively, which are close to the mean annual flood (171 m^3/s; Table 1-1). The largest flood during this period of record occurred on 29 February 2004 and had a peak discharge of 442 m^3/s. A flood of this magnitude has a recurrence interval of around 50 years (using the non-linear transformation of Gringorten, 1963). Hicks and Basher (2008) showed that events greater than a 10 year recurrence interval tend to leave a sediment supply legacy. It is likely that it was this 2004 event that resulted in most of the Taupo Pumice terrace erosion.

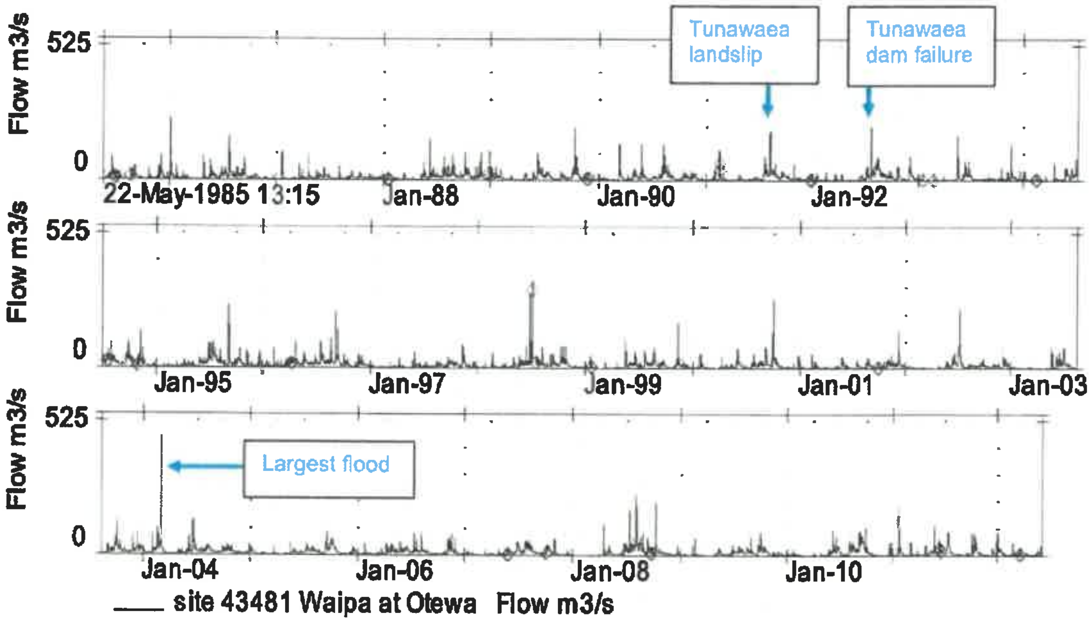

Figure 1-1: Hydrograph of the Waipa at Otewa. The flood events triggering the Tunawaea landslip and the landslip dam failure are identified (Q_{pk}'s of 189 and 203 m^3/s respectively). The largest flood event (Q_{pk} of 442 m^3/s) occurred on 29 February 2004. Note that the flood event in July 1998 is marked with a diamond, indicating that the continuous flow record was interrupted during this flood (leaving a gap in the data record). While the peak discharge recorded during this flood was 325 m^3/s, the flood peak may have been missed.

Offsetting the aforementioned factors which are expected to contribute to increasing suspended sediment loads, in the early 2000's $1 million was spent on riparian restoration work in the Waipa River. This largely involved willow planting on the active floodplain, designed to limit erosion of the Taupo Pumice terraces by floods. The majority of river works in the upper Waipa were completed in 2004/2005.

1.2.2 Waitomo

The Waitomo catchment has the highest specific annual average sediment yield of all the Waikato catchments investigated by Hoyle et al. (2011). This relates to its high mean annual rainfall (and runoff) and dominantly weak, volcaniclastic lithology (tephra, ash etc.).

Historically, suspended sediment in Waitomo Stream has contributed to the build-up of sediment in the Waitomo Caves and has affected the water quality and appearance of the water, some of which is abstracted for rural and town supplies. To reduce sediment loads and improve water quality, WRC helped form a Landcare Group involving the community and a range of national and local agencies, who together have put significant effort into erosion control in this catchment (R. Hill, pers comm., 7 May 2012). Between 1992 and 2002, the group funded more than 60 km of fencing in the catchment (catchment area of ~ 30 km^2) that excludes stock from 625 ha of native bush, 20 km of streams and wetlands and 350 ha of slip-prone land (McKerchar and Hicks, 2003). The group has also facilitated planting of

3 Results and Discussion

3.1 Waipa

Figure 3-1 shows that between 1985 and 2011, specific annual sediment yields for the Waipa at Otewa have ranged from 36 to 419 t/km^2, with a mean of 137 t/km^2 and a standard deviation of 92 t/km^2. 2004 and 2008 had very large specific sediment yields (370 and 419 t/km^2 respectively), and by comparing these results with the annual peak discharge data in Table 1-1 we can see that these years also had large peak discharges (442 and 225 m^3/s respectively, and the 2008 data may have missed the peak as the data record is incomplete). However, fluctuations in discharge do not explain all the variability in sediment yields as 1998 was also a year with a high peak annual discharge (at least 325 m^3/s, as the record gap may have missed the flood peak), and yet the specific annual sediment yield is relatively low at 91 t/km^2. Also, yield depends on flow throughout the year, not just the peak annual discharge.

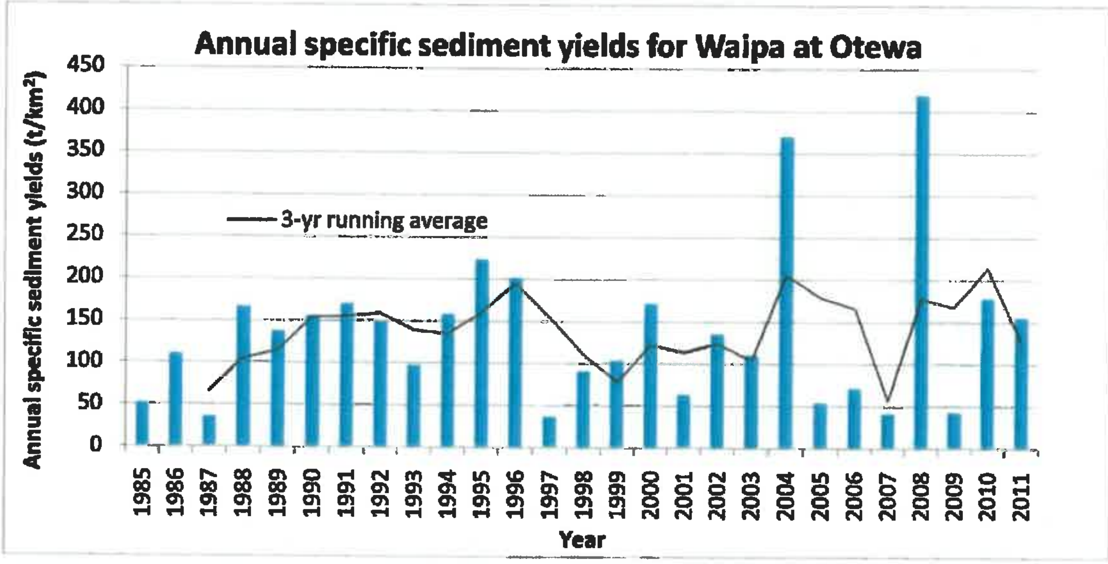

Figure 3-1: Specific annual sediment yields and three year running average yield between 1985 and 2011 for Waipa at Otewa.

Plotting SSC versus Q for each individual auto-sampled event in the Waipa (e.g. Figure 3-2) showed that the Waipa tends to exhibit a clockwise hysteresis (i.e. more sediment is carried on the rising limb relative to the falling limb). These plots also showed that auto-sampling of events early in the sediment monitoring programme (2000- 2007) tended to catch more of the falling limb than the rising limb (missing the start of events and therefore underestimating SSC). In more recent years (2008-2012) auto-sampling has tended to catch more of the rising limb than the falling limb, thereby overestimating SSC. This change in sampling introduces some bias to the time trends, as the residuals of observed SSC/predicted SSC will also be greater over more recent years. WRC may wish to revisit their autosampler operating schedule in the Waipa to improve monitoring of future events. Currently, the auto-samplers are capturing the start of events but are tending to run out of bottles too early. This may be remedied by increasing the time between samples so that both rising and falling stages can be captured without bias.

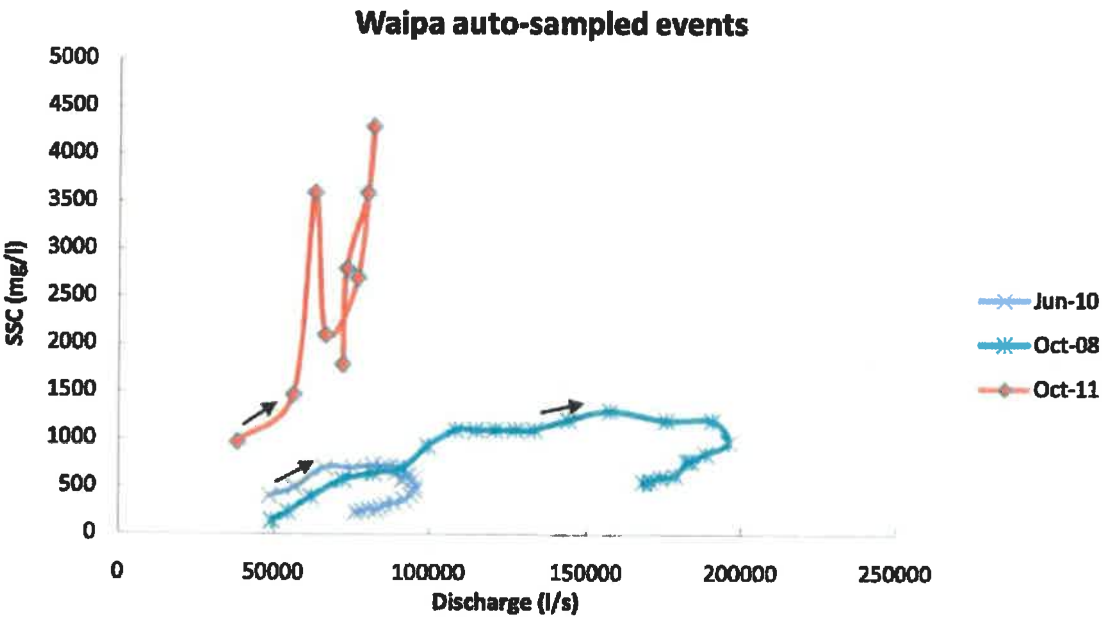

Figure 3-2: SSC versus Q for three individual auto-sampled flood events in the Waipa, showing clockwise hysteresis. Note that the arrows show the order of measurements. For these events there is also a bias towards data being collected on the rising limb (therefore overestimating SSC). This figure also highlights how much SSC can vary for a given discharge.

The results from the time trend tests for the Waipa are presented in Table 3-1, and the plots of residuals over time, from which these results are generated, are presented in Appendix A. Table 3-1 shows that over the full period of data (1990 – 2012) there has been a downward trend in SSC which is statistically significant at the 1 % level (but the data is not normally distributed). There is no significant time trend over the last decade or the preceding decade. Working through the data record in 5-yearly intervals shows that from 1990-1995 and from 1996-2000 there were significant increases in SSC. The upward trend in the first of these periods likely reflects the initial advection of suspended sediment from the Tunawaea slip material. The upward trend in the second period is more likely a reflection of increased bank erosion (and potentially the beginning of the Taupo Pumice terrace erosion), secondary effects of the Tunawaea slug. The trend then changed, with significant decreases in SSC between 2001-2005 and 2006-2010. The first of these periods aligns with the 2000-2004 river works programme, and also covers the 2004 flood, of which there is no apparent signature. The downward trend in the later period is significant despite the bias towards sampling on the rising stage over the last few years of this period. This ten year downward trend is a strong indication of the success of the erosion control efforts in this river. There was no significant trend in 2011, but this may be due to it being too short a period to test for a time trend.

Table 3-1: Summary of time trends results for Waipa at Otewa. Outlining the period of data included in each time trend test, whether the data is normally distributed (based on p value from Kolmogorov-Smirnov and Chi^2 tests), the t-statistic from the two tailed Student's-t test and the significance level of the Student's-t test results.

	from	to	Normal distribution	K-S p	Chi^2 p	t statistic	significant?
Full data period	6/08/1990	1/01/2012	no	<0.01	<0.01	-9.459	Yes at 1%
10 yr periods	2/03/1993	8/12/2002	no	<0.01	<0.01	1.505	No
	21/05/2003	1/01/2012	yes	>0.2	0.518	-1.834	No
5 yr periods	6/08/1990	20/12/1995	yes	>0.2	0.105	2.257	Yes at 5%
	2/04/1996	30/12/2000	no	<0.01	<0.01	3.389	Yes at 1%
	12/02/2001	12/10/2005	no	<0.01	<0.01	-11.970	Yes at 1%
	20/07/2006	1/10/2010	maybe	>0.2	<0.01	-7.952	Yes at 1%
	5/03/2011	1/01/2012	no	<0.05	<0.01	0.008	No

3.2 Waitomo

Figure 3-3 shows that between 1987 and 2011 specific annual sediment yields for Waitomo at Aranui Caves Bridge have ranged from 61 to 461 t/km^2, with a mean of 158 t/km^2 and a standard deviation of 98 t/km^2. The highest annual specific sediment yield in this period occurred in 1998, which was also the year with the second largest peak discharge during this period (Q_{pk} 53 m^3/s;Table 1-2). The year with the largest peak discharge was 2004 (Q_{pk} 90 m^3/s) and yet the specific annual sediment yield for 2004 is relatively low at 165 t/km^2. As in the Waipa, fluctuations in annual peak discharge do not tell the whole story. Sediment yields are accumulated across the full flow record and, therefore, depend on the full flow-duration distribution as well as sediment supply.

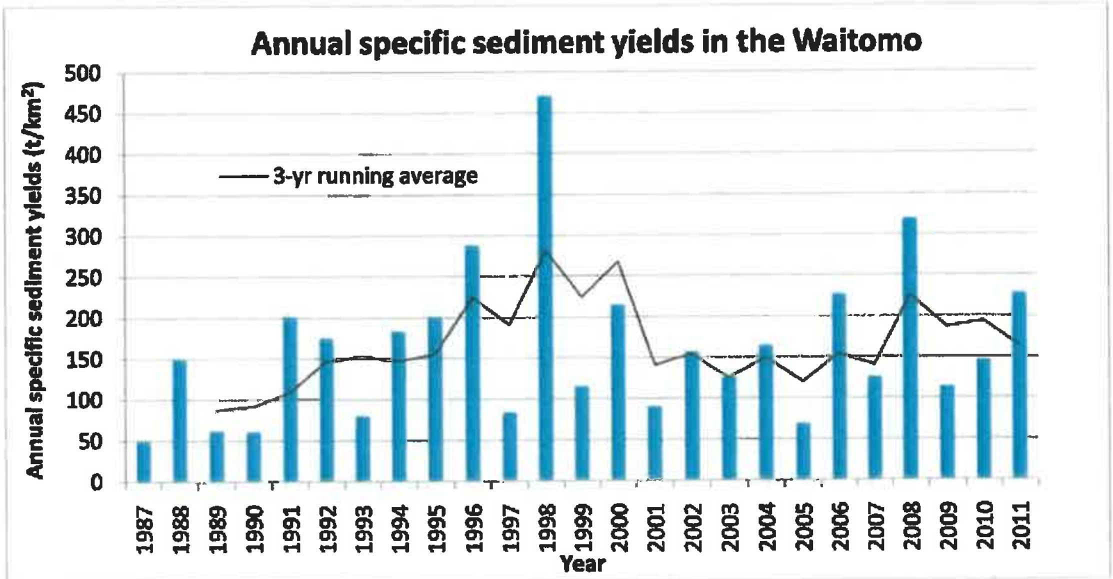

Figure 3-3: Specific annual sediment yields and three year running average yield between 1987 and 2011 for Waitomo at Aranui Caves Bridge.

Plotting SSC versus Q for individual auto-sampled events in the Waitomo (e.g. Figure 3-4) indicates that there is no consisent hysteresis (i.e. the SSC sampled on the rising limb is not consistently greater or less than that on the falling limb). This means that, in terms of looking at time trends, it is less important to consider bias in the sampling schedule for this river.

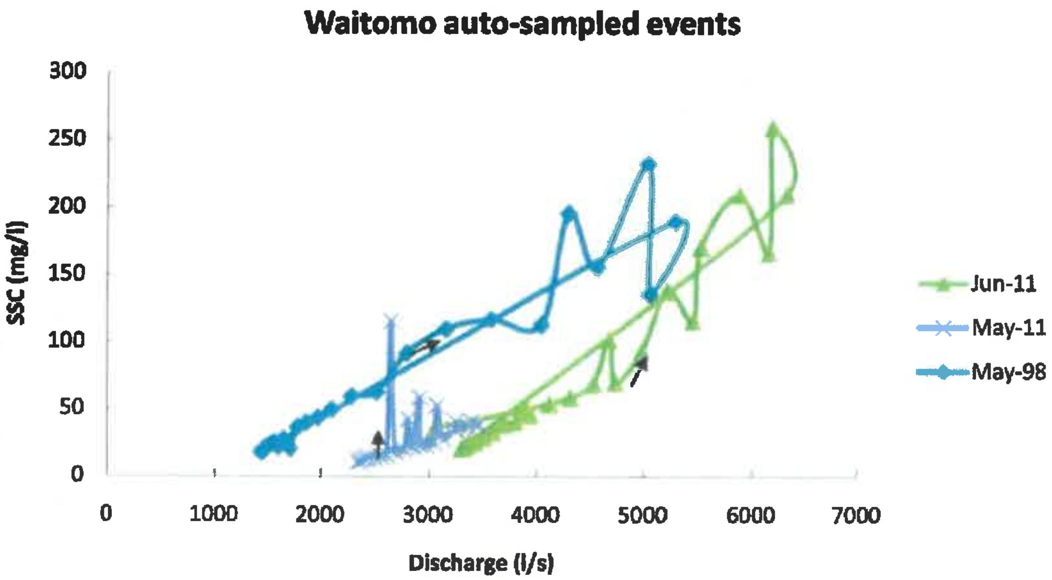

Figure 3-4: SSC versus Q for three individual auto-sampled events in the Waitomo, showing no consistent hysteresis. Note arrows show the order of measurements.

The results from the time trend tests for the Waitomo are presented in Table 3-2, and the plots of residuals over time, from which these results are generated, are presented in Appendix A. Note that there were very few measurements taken from 2001 to 2008. Table 3-2 shows that over the full period of data (1990 – 2012) there is no statistically significant trend in SSC. There is also no significant time trend over the 1992-2002 decade or over the 2003-2012 decade. We know that considerable effort went into catchment erosion control between 1992-2002, but unfortunately the effects of this are not apparent in the decadal time trend analysis. Analysing the data at 5-yearly intervals shows that from 1990-1995 there was a significant decrease in SSC, from 1996-2000 there was no significant trend and from 2001-2004 there were insufficient data to test for a trend (only 3 measurements in 5 years). From 2006-2010, and again from 2011 to March 2012, there were significant increases in SSC.

These results concur with the findings of McKerchar and Hicks (2003), who found that SSC declined by approximately 40 %, for a given flow, between 1990-200. The greatest reduction occurred over 1990-1994, and there was no trend from 1997-2000.

Visual analysis of Waitomo residuals over the full data period (Appendix A) indicated that time trends may be significant over periods different to those discussed above. Analysis of these selected periods showed that from 1990-1996 there was a significant decrease in SSC. There was a significant increase in SSC from 1997-1998, which suggests a response to the 1998 floods, which produced exceptionally large sediment loads. Together, these results indicate that the catchment restoration efforts of the 1990's were effective at reducing

SSC. While the trends are less apparent after 1996, suspended sediment loads from the 1998 floods would likely have been much higher without the Waitomo Landcare programme. Over the following eleven years from 1999 to 2009 there was no significant trend (although very little data were collected for 5 of these years). It is likely that there are insufficient data to pick up any signature of the 2004 event. From 2010- March 2012 there has been a significant decrease in SSC. This decrease in recent years concurs with the anecdotal observations and reduced maintenance work required in the caves.

Table 3-2: Summary of time trend results for Waitomo at Aranui Caves Bridge. Outlining the period of data included in each time trend test, whether the data is normally distributed (based on p value from Kolmogorov-Smirnov and Chi^2 tests), the t-statistic from the two tailed Student's-t test and the significance level of the Student's-t test results.

	from	to	Normal distribution	K-S p	Chi^2 p	t statistic	significant?
Full data period	7/08/1990	4/03/2012	no	<0.05	<0.01	1.204	No
10 yr periods	30/03/1993	10/12/2001	no	<0.05	<0.01	1.461	No
	1/03/2004	4/03/2012	maybe	>0.2	<0.01	-1.500	No
5 yr periods	7/08/1990	12/12/1995	yes	>0.2	0.515	-3.511	Yes at 1%
	11/01/1996	3/10/2000	no	<0.05	<0.01	0.715	No
	10/12/2001	21/06/2004	only three measurements, insufficient data				
	20/07/2006	20/12/2010	maybe	>0.2	<0.01	3.307	Yes at 1%
	29/01/2011	4/03/2012	maybe	>0.2	<0.01	2.728	Yes at 1%
Selected periods	7/08/1990	26/11/1996	yes	>0.2	0.564	-2.749	Yes at 1%
	7/01/1997	8/12/1998	no	<0.15	<0.01	5.364	Yes at 1%
	13/01/1999	19/11/2009	yes	>0.2	0.092	-1.209	No
	28/01/2010	4/03/2012	no	<0.01	<0.01	-5.600	Yes at 1%

4 Conclusions

This study indicates that statistically significant time trends do exist for both the Waipa and Waitomo catchments. Having said this, the Student's-t test assumes normal distribution of data, which is often not the case, and therefore, results from significance tests where data is not normally distributed (Tables 3-1 and 3-2) should be treated with caution.

The keys results for the Waipa are that there was an increase in SSC leading up to 2000 and a decrease in SSC from 2000 through until at least the end of 2010. Relating these results to what we know of catchment drivers of SSC indicates that the considerable effort that went into river rehabilitation works in the early 2000's (peaking in 2004/2005) have paid off. The downward trend in SSC is apparent despite a slight bias towards sampling in the rising stage of events in the Waipa since around 2008, thereby underestimating the SSC reduction in recent years. We recommend that WRC revisit their sampling schedule to try and remove this bias from future monitoring.

The key results from the Waitomo are that SSC was generally decreasing from 1990 through until the end of 1996, reflecting the success of efforts in the 1990's from the Waitomo Landcare group. Results from 1997 onwards vary depending on how time is broken up for analysis. In summary, results indicate that from 1997 to the end of 1998 there was an increase in SSC, reflecting the 1998 floods. There has been little change from 1999 until 2006, and an upward trend in SSC from 2006 until 2010. Results from 2010 to 2012 are somewhat conflicting, with a significant decrease overall, but a significant increase in the last year. Overall, there is no downward trend in SSC in the Waitomo in recent years. However, this does not mean that rehabilitation efforts over the last decade have been unsuccessful. It may be that these efforts are being offset by other drivers increasing SSC within the catchment.

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Draft for discussion purposes

Report No. HR/TLG/2016-2017/4.5a

Regional- and national-level economic impacts of the proposed Waikato Regional Plan Change No. 1—Waikato and Waipa River Catchments

This report was commissioned by the Technical Leaders Group for the Healthy Rivers Wai Ora Project

The Technical Leaders Group approves the release of this report to Project Partners and the Collaborative Stakeholder Group for the Healthy Rivers Wai Ora Project.

Signed by:

Date: 30 August 2016

Regional- and national-level economic impacts of the proposed Waikato Regional Plan Change No. 1—Waikato and Waipa River Catchments

12 August 2016

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1. Introduction

The Healthy Rivers Plan for Change: Waiora He Rautaki Whakapaipai (HRWO) Project (www.waikatoregion.govt.nz/healthyrivers) will establish targets and limits for nutrients (N and P), sediment, and *E. coli* in water bodies across the Waikato and Waipa River catchments. Different targets and limits for these contaminants in waterways within this catchment will have diverse impacts on economic outcomes observed throughout the greater Waikato region. Accordingly, a central contribution of the Technical Leaders Group (TLG) to the HRWO project has been the development and utilisation of an economic model that integrates diverse information such that the size and distribution of abatement costs—across farm, catchment, regional, and national levels—associated with alternative limits and targets is predicted (Doole et al., 2015a, b).

The Collaborative Stakeholder Group (CSG) has proposed a policy to initiate improved water quality across the region, with most actions tied to reducing contaminant loss by the rural sector. The draft Waikato Regional Plan Change No. 1—Waikato and Waipa River Catchments (Proposed) (WRPC1) presented at CSG meeting #27 on 9 May 2016 sets out policies that aim to progressively reduce the concentrations of the four contaminants to meet Freshwater Management Unit (FMU) specific targets and associated values of water clarity and suspended algae (chlorophyll-a). The time frame for meeting these ultimate targets for water-quality improvement is 80 years, whereas the current Plan Change aims to ensure that the actions necessary to make a 10% step towards bridging the gap between the current and target states are implemented over the next decade. The target states that the Plan Change seeks to move towards are a key output of the HRWO process; these define goals of substantial improvement in water quality for swimming, taking food, and healthy biodiversity. This involves an improvement in water quality at all sites in the catchment, even if it is already meeting the minimum acceptable state. For further information on the elements of this aspirational state, see Doole et al. (2015a).

The policy mix contained in WRPC1 involves a number of diverse elements (Ritchie, 2016), given the size of the catchment, diversity of land-use sectors, number of contaminants considered, broad heterogeneity in contaminant loss, diversity of mitigation efficacy and cost, and spatial differences in water-quality limits. An additional consideration is that some gains in water quality brought about by this policy may potentially be offset through a proposed policy that would allow for some future development of iwi land. The complexity of this context emphasises the importance of using predictive modelling to assess the implications of implementing WRPC1. The farm- and catchment-level implications of WRPC1 are set out in the comprehensive study of Doole et al. (2016). However, in contrast to the earlier assessments of Doole et al. (2015a, b), this report does not explore the regional- and national-level implications of the proposed policy mix. This is a deficiency since the regional- and national-level implications of broad-scale policies to reduce the intensification of rural and urban land-use in the Waikato can be significant (Doole et al., 2015a), especially given its size and the importance of this region in terms of agricultural production.

The primary objective of this analysis is to describe the regional- and national-level implications of the policy mix associated with WRPC1 under several different situations. The assumptions used to represent the policy mix are described in Doole et al. (2016). Moreover, that work describes the economic and water-quality implications of these scenarios at the farm- and catchment-level. This report goes a step further, using output from the catchment-level model as an input to an Input-Output (IO) model to identify the regional- and national-level impacts of the WRPC1 policy mix.

Section 2 describes the IO model and the scenarios explored within the model. Section 3 presents model output, with a summary of key findings. Section 4 concludes.

2. Regional economic effects of the proposed policy mix

2.1 Justification of the IO approach

IO models are the most widely-applied method for estimating the regional impacts of environmental policy, both in New Zealand and overseas. Additionally, they are one of the most popular economic methods applied globally (Miller and Blair, 2009), based on their clarity and descriptive capacity. These models study the flow of products, inputs, and sales between households and industries. Their primary advantage is that they describe the complex interdependency between different sectors within an economy, allowing the consideration of numerous flow-on relationships arising from a change in current economic activity. Accordingly, IO models provide a means to estimate the regional impacts of a given policy mechanism, based on the idea that an initial decrease in net revenue entering into a regional economy—for example, in response to a change in milk production arising from reduced dairy-production intensity—will lead to a decline in subsequent spending in other industries within this economy, but the effect of these diminished contributions will dissipate over time due to the leakage of funds from the local economy (e.g. through expenditure outside of the region or through saving) (Mills, 1993). Such models have many benefits; namely, their ability to capture interrelationships between different sectors, low cost, and apparent simplicity, which helps to promote the clarity of their output. Also, the equilibrium structure of IO models is consistent with the steady-state approach employed in the catchment-level model employed throughout the HRWO process (Doole et al., 2015a, b, 2016).

Nevertheless, these frameworks have some limitations, particularly associated with the inclusion of price impacts, budget constraints, and technical change. The application of IO models is based on an explicit assumption that prices remain fixed, consistent with their equilibrium structure. However, an implication of this is that increased competition for scarce factors of production does not flow through to affect prices (Hughes, 2003). Also, the additional output associated with increased input use is assumed constant. These assumptions are highly stylised, but are justified in applied work based on their clarity, ease to deal with during computation, the inherent focus of these models on regional markets, and the complications associated with utilising more-detailed frameworks that do consider price feedbacks and varying returns to scale. Indeed, in relation to the last point, it is common that seeking to include price impacts through extending a model to become a computable general equilibrium framework or spatial decision support system will often lead to a downgrade in the amount of industry-level information that is included (Bess and Ambargis, 2013).

The decision to utilise an IO analysis within the HRWO process is also partially justified by the existence of the Waikato Region Multi-Regional IO Table, which was initially developed for the Waikato Regional Council Economic Futures Model (McDonald, 2010). The extension of a previous framework is more cost-effective than developing a framework from nothing, especially given that the existing framework has been applied previously and extension can take into account practices and principles that were learnt during its prior employment. This decision is also consistent with the time and budget constraints that face many limit-setting processes for water quality improvement in New Zealand, including the HRWO process. The adoption of an IO model has also allowed the seamless integration of the regional economic model with the farm- and catchment-level models, such that the farm-, catchment-, regional-, and national-level implications of alternative limits can be ascertained in an integrated way.

Nevertheless, alternative methods exist that could be used within the HRWO process to explore the regional- and national-level implications of the proposed policy mix. Arguably, the most-valuable alternative would involve the development and application of a Computable General Equilibrium (CGE) model. Key reasons for adopting an IO, rather than a CGE, framework for use in this study are:

1. *Disaggregation*: The IO approach readily produces results that are disaggregated by study regions (in this case, the different FMUs, Waikato region, and New Zealand) and economic sectors (altogether 107 economic sectors or 'industries' are reported in the model, though results are aggregated to 17 key sectors for reporting purposes below). This provides important information on the distribution of economic impacts.
2. *Paucity of data*: Creation of a multi-regional CGE model that reports down to the level of each FMU would necessitate the construction of a Social Accounting Matrix (SAM) for the local area. There is a lack of information pertaining to inter-regional investment flows upon which to complete this task.
3. *Full analysis of 'circular flow of income'*: Although the approach used here is based on the IO format, a concerted attempt is made in this study to take full consideration of the 'circular flow of income' within an economy, much like an analysis based on a Social Accounting Matrix or CGE. Both 'backward' and 'forward' linkages are considered in the IO model applied here. Backward-linkage effects are those experienced by suppliers, or in other words, organisations situated up the supply chain. This includes, for example, the loss in demand for products of fertiliser manufacturers as a result of a reduction in farming intensity. Forward-linkage effects, by contrast, are experienced by those who purchase goods or are situated down the supply chain. This includes, for example, the loss in dairy-product manufacturing necessitated by a fall in the supply of raw milk from farms.
4. *Timeframe and budget*: It has been feasible to couple an IO-based model to the catchment-level model applied in the HRWO process, so as to produce a picture of FMU-, regional-, and national-level economic impacts, while keeping within the timeframe and budget of the project. In contrast, linking the catchment-level framework

to a CGE model would have been a major piece of work well beyond the scope of this project. Indeed, to date, this type of work has not been undertaken within New Zealand for the analysis of water-quality limits.

A broader discussion of available methods for regional- and national-level modelling and why the IO approach was chosen from among them is provided in Doole et al. (2015c).

More information regarding the IO model used in the HRWO process is provided in McDonald (2015).

2.2 Introduction to IO analysis

It is helpful to provide readers, particularly those not familiar with IO analysis, with a brief introduction to the IO framework. (Further information is provided in Miller and Blair (2009).) This introduction is provided below. The remaining sections of the methodology describe the way the different scenarios are incorporated into an IO framework (Section 2.3), including the major assumptions that are applied, and the scenarios explored in the policy mix (Section 2.4).

At the core of any IO analysis is a set of data that measures, for a given year, the flows of money or goods among various sectors or industrial groups within an economy. These flows are recorded in a matrix or 'IO table' by arrays that summarise the purchases made by each industry (its inputs) and the sales of each industry (its outputs) from and to all other industries. By using the information contained within such a matrix, IO practitioners calculate mathematical relationships for the economy in question. These relationships describe the interactions between industries—specifically, the way in which each industry's production requirements depend on the supply of goods and services from other industries. With this information it is possible to calculate, given a proposed alteration to a selected industry (a scenario), all of the necessary changes in production that are likely to occur throughout supporting industries within the wider economy. For example, if one of the changes anticipated for a single FMU were to be a loss in the amount of dairy farming, the IO model would calculate all of the losses in output that would also occur in industries supporting dairy farming (e.g. fertiliser production, fencing contractors, farm-machinery suppliers), as well as the industries that, in turn, support these.

As with all modelling approaches, IO analysis relies on certain assumptions for its operation. Among the most important is the assumption that the input structures of industries (i.e. the mix of commodities or industry outputs used in producing output for a specific industry) are fixed. In the real world, however, these 'technical coefficients' will change over time as a result of new technologies being available, relative price shifts causing substitutions, and the introduction of new industries. For this reason, IO analysis is generally regarded as most suitable for short- to medium-term analysis, where economic systems are unlikely to change greatly from the initial snapshot of data used to generate the base IO tables. This further justifies the selection of this method, given that the catchment-level model applied in the HRWO process also represents a snapshot of reality that is based heavily on current prices, technologies, management practices, and knowledge of biophysical relationships.

2.3 Overview of impacts assessed

The study of economy-wide economic impacts in the modelling commenced with identifying six key categories of likely economic effects associated with the proposed options for water-quality improvement:

Changes to farming systems: backward linkage supply chain impacts. Attribute limits can encourage changes in land-management practices for farms within each FMU. Examples might include removing summer crops and replacing these with supplements and lowering fertiliser use. These measures result in changes to the purchasing patterns of farms, creating flow-on impacts through economic supply-chain linkages.

Changes to farming systems: forward linkage supply chain impacts. The changes in farming practices will also result in reductions to the overall output of farms. With less output (e.g. milk, wool, meat) produced per hectare, the supply to downstream processors (dairy manufacturers, meat processors, textile manufacturers, etc.) will be reduced, ultimately leading to a reduction in sales by these industries.

Conversion between land uses: backward supply chain impacts. In addition to changes in land management, the proposed scenarios will also likely result in changes in land use across the FMUs. This will create additional impacts for industries that would otherwise be involved in supplying goods and services to the existing farms. Businesses that are responsible for providing direct inputs to the forestry sector (e.g. pruning contractors, accountants, etc.) will be positively impacted by conversion of land to forestry. Businesses involved indirectly in forestry supply chains (e.g. firms selling supplies to contractors) will also be positively impacted.

Conversion between land uses: forward linkage supply chain impacts. Similar to the forward-linkage effects resulting from changes in farming systems, the conversion of land from one use to another will result in changes to the supply of key products to downstream processors (for example, more timber to processors, but less raw milk to dairy product manufacturing if dairy land is replaced by forest production or vice versa).

Changes in incomes for land owners. For each of the scenarios evaluated, there will be changes in income for landowners in the form of wages/salaries and profits. This will cause changes in the expenditure patterns of these land owners; hence, creating impacts through the rest of the economy.

Outlays and revenues associated with land conversion. The conversion of land into different uses is associated with a set of discrete capital investments and other economic transfers. For land owners, these can be both outlays (e.g. construction of woolsheds, planting costs) and revenues (e.g. sale of Fonterra shares, sale of dairy herds). The income and expenditure patterns of land owners will have flow-on implications through the district, regional, and national economies.

Changes for wood and paper processing. Baseline FMU wood- and paper-processing input mixes were replaced with better data provided directly by Scion. This ensured that the latest available information on processing methods, unique to each FMU, was appropriately incorporated.

2.4 Scenarios assessed in the regional economic modelling

The modelling investigation is based around the simulation of four primary scenarios:

A. Simulation of the WRPC1 policy mix with *no* development of iwi land.
B. Simulation of the WRPC1 policy mix with *low* development of iwi land.
C. Simulation of the WRPC1 policy mix with *medium* development of iwi land.

D. Simulation of the WRPC1 policy mix with *high* development of iwi land.

These scenarios are hereafter referred to as Sc. A, Sc. B, Sc. C, and Sc. D, respectively. Land use is held constant at its baseline levels in the baseline scenario (Doole et al., 2015a). Rule 2 in the WRPC1 will prevent further development occurring through land-use change. Additionally, farm planning will seek to support business resilience such that the policy should not drive large shifts towards less-intensive enterprises through land-use change.

An exception to this general approach is a focus on the development of iwi land. Development is assumed to occur across two different types of iwi land:

1. Iwi land in the Central North Island. This involves areas of 2,167; 4,333; and 6,500 ha under the low, medium, and high levels of development predicted to occur over the next decade. These levels of development each constitute individual scenarios in the model.
2. Iwi land held under multiple ownership. This involves areas of 900; 1,800; and 2,700 ha under the low, medium, and high levels of development predicted to occur over the next decade. These levels of development each constitute individual scenarios in the model.

The level of development (i.e. no, low, medium, or high) that is simulated *is always the same* on these different types of iwi land. This means that different levels of development between iwi land that is located in the Central North Island or is subject to multiple ownership are not investigated. Development for iwi land is assumed only to occur on land blocks that are above 4 ha in size.

Development of iwi land is assumed to consist of various actions:

- Areas of land use capability (LUC) class 1–4 are assumed to convert from forest to dairy. The new dairy activities that are simulated produce a level of leaching equivalent to the mean dairy farms found in the relevant FMU.
- Areas of LUC class 5–7 are assumed to convert from forest to drystock. The new drystock activities that are simulated produce a level of leaching equivalent to the mean drystock farms found in the relevant FMU.
- Areas of LUC class 8 are assumed to remain in plantation forest.

Areas of iwi land that potentially could be developed were identified using a variety of data sources. The model then determined where it was most profitable to convert existing land within the areas for development set within each scenario, given the implementation of the proposed policy mix.

The way that other elements of WRPC1 were represented in the HRWO catchment-level model is outlined in Doole et al. (2016).

The HRWO economic model involves the successive implementation of the catchment-level model and the IO model, with output feeding from the former into the latter. Standard practice in the assessment of environmental policy involves the comparison of a "without policy" scenario and a "with policy" scenario (Boardman et al., 2011; Pannell, 2015). The catchment-level implications of the "without policy" or "business-as-usual" case are outlined in Doole (2016). Catchment-level output from this application was entered into the IO model to determine the FMU-, regional-, and national-level implications of this scenario. Then, catchment-level output from the application summarised in Doole et al. (2016) was entered into the IO model to determine the FMU-, regional-, and national-level implications of the policy-mix scenarios. The results are reported for the WRPC1 runs below in Tables 1–6 (see Section 3); these are presented relative to the "business-as-usual" baseline.

3. Results and Discussion

The impact of each of the four scenarios (Sc. A–D) is ascertained, relative to the "business-as-usual" baseline described for the catchment in Doole (2016).

The following discussion focuses on information presented across 17 aggregated sectors in the regional and national economy, despite the fact that 107 individual industries are represented in the IO model itself (Doole et al., 2015a; McDonald, 2015).

Tables 1–4 present the changes in Value Added, employment, and international exports across each of the aggregated industries for each FMU, relative to the "business-as-usual" case. Table 5 presents these changes for the Waikato region as a whole, while Table 6 presents the predicted impacts for the national economy.

All employment results are measured by using Modified Employee Counts (MECs). Statistics New Zealand typically reports employment data according to the Employee Count (EC) measure. ECs are a head count of all salary and wage earners for a reference period. This includes most employees, but does not capture all working proprietors—individuals who pay themselves a salary or wage. The modified employment count or MEC measure is based on ECs, but includes an adjustment to incorporate an estimate of the number of working proprietors.

Table 1 presents the changes in Value Added, employment, and international exports for the Lower Waikato FMU across each of the aggregated industries, relative to the "business-as-usual" case. The impacts of WRPC1 are focused mainly on agricultural industries under all scenarios. The most-significant impacts on value added and employment are experienced in the sheep, beef, and arable industries, while lesser effects are felt across the dairy and horticultural sectors. However, the horticultural sector experiences the most-significant decline in international exports, given its high intensity in this FMU.

Table 2 presents the changes in Value Added, employment, and international exports for the Waipa River FMU across each of the aggregated industries, relative to the "business-as-usual" case. The most-significant impacts are experienced in the agricultural sectors again, but this time with dairy production experiencing the largest impacts in terms of value added and employment. There are also some small flow-on impacts experienced throughout the service industries associated with agricultural production, especially dairy-product manufacturing and retail. In particular, dairy-product manufacturing loses only a handful of jobs, but the value of international exports of these products decreases by around 4–10 million dollars (Table 2).

Table 3 presents the changes in Value Added, employment, and international exports for the mid-Waikato (Karapiro to Ngaruawahia) FMU across each of the aggregated industries, relative to the "business-as-usual" case. Employment falls in the horticultural, sheep, beef, arable, and dairy sectors. However, detrimental economic effects predicted for this FMU are mainly concentrated in dairy-product manufacturing and service industries, especially in the wholesale and retail trade sectors. This reflects the location of Hamilton—the main urban area in the Waikato region—within this FMU. Indeed, more than 100 jobs are lost within this FMU within each policy scenario. More than half of these job losses are predicted to occur in the retail, professional, and other-services sectors. The largest loss in value for international exports occurs in the dairy-product manufacturing sector, with around 90% of any decrease across the FMU occurring in this industry.

Table 4 presents the changes in Value Added, employment, and international exports for the Upper Waikato (Karapiro to Taupo Gates) FMU across each of the aggregated industries, relative to the "business-as-usual" case. The WRPC1 is predicted to have significant detrimental impacts on value added and employment in the dairy sector but is predicted to lead to more jobs in forestry and wood and paper manufacturing, relative to the "business-as-usual" setting (Table 4). Indeed, 400, 284, 172, and 40 jobs are predicted to be lost in the dairy sector alone in Scenarios A, B, C, and D, respectively, relative to the "business-as-usual" case (Table 4). Additionally, 35, 25, 15, and 5 million dollars in value added is predicted to be lost in this sector in Scenarios A, B, C, and D, respectively, relative to the "business-as-usual" case. These findings reflect that while the economic impacts of the proposed policy mix are relatively benign at the catchment level (Doole et al., 2016), they are significant in the Upper Waikato FMU when compared to the "business-as-usual" case because of the significant economic benefits associated with broad-scale forestry-to-dairy conversion predicted to occur in the upper catchment in the absence of WRPC1.

Table 5 presents the changes in Value Added, employment, and international exports for the whole of the Waikato Region across each of the aggregated industries, relative to the "business-as-usual" case. This scenario reflects the impact of the proposed policy mix on the FMUs studied within the HRWO process and those other districts within the Waikato but not incorporated within the HRWO (e.g. the Waihou catchment). WRPC1 is predicted to incur a cost of around $100 m annually when there is no iwi land development (Sc. A), with three-quarters of this falling on the dairy industry and around one-fifth coming from the sheep, beef, and arable sector. However, these costs are eroded with the intensification of iwi land, with high development of iwi land leading to a halving of the constituent cost. WRPC1 is also predicted to lead to a loss of around 940 jobs when there is no iwi land development (Sc. A), with around two-thirds of this arising in the dairy industry. Nevertheless, this falls to a loss of around 300 jobs with high iwi-land development. National exports are also predicted to fall as a result of WRPC1, with most impacts being felt in dairy-product manufacturing.

Table 6 presents the changes in Value Added, employment, and international exports for the whole of New Zealand across each of the aggregated industries, relative to the "business-as-usual" case. WRPC1 without iwi-land development is predicted to decrease national value added by around $200 m nationally, with around half of this occurring in the dairy sector. This falls to $150 m, $120 m, and $80 m with low, medium, and high iwi-land development, respectively. High employment losses are observed across all sectors with no iwi-land development, except forestry and wood and paper manufacturing (Table 6). Nearly half of all jobs are lost in the dairy sector, while around one-tenth occurs in the sheep, beef, and arable sectors. Job losses still occur under the iwi-land development scenarios (Sc. B–D), but this intensification helps to offset those losses experienced in Scenario A. Indeed, 427, 805, and 1242 less jobs are lost under the low, medium, and high iwi-land development scenarios given that this intensification leads to greater vitality within the agricultural sectors, especially in the dairy farming and dairy-product manufacturing sectors. The greatest impact of WRPC1 on international exports is again almost exclusively observed within the dairy-product manufacturing sector.

Table 1. Regional economic impacts of the WRPC1 in the Lower Waikato (Ngaruawahia to Port Waikato) FMU, relative to the BAU scenario.

Industry	Value added ($m)				Employment (MECs)				International exports ($m)			
	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D
Horticulture and fruit growing	-2	-2	-2	-2	-21	-21	-21	-21	-1.0	-1.0	-1.0	-1.0
Sheep, beef & grain	-7	-7	-7	-7	-47	-47	-47	-47	-0.3	-0.3	-0.3	-0.3
Dairy farming	-5	-5	-5	-5	-23	-23	-23	-23	0.0	0.0	0.0	0.0
Forestry	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Other primary	0	0	0	0	1	2	2	2	0.0	0.0	0.0	0.0
Agriculture and forestry support	0	0	0	0	0	1	1	2	0.0	0.0	0.0	0.0
Meat and meat product manufacturing	0	0	0	0	-1	-1	0	0	-0.3	-0.2	-0.2	-0.1
Dairy product manufacturing	0	0	0	0	0	0	0	0	-0.3	-0.3	-0.2	-0.1
Wood and paper manufacturing	0	0	0	0	1	0	0	0	0.1	0.0	0.0	0.0
Other manufacturing	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Utilities	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Construction	0	0	0	0	6	6	6	6	0.0	0.0	0.0	0.0
Wholesale and retail trade	0	0	0	0	-2	-2	-2	-1	0.0	0.0	0.0	0.0
Transport	0	0	0	0	-1	-1	0	0	0.0	0.0	0.0	0.0
Professional and administrative services	0	0	0	0	-1	0	0	0	0.0	0.0	0.0	0.0
Local and central government	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Other services	-2	-2	-2	-2	-13	-13	-13	-12	0.0	0.0	0.0	0.0
Total loss relative to baseline	-16.3	-16.2	-16.0	-15.9	-102.0	-99.8	-98.0	-96.0	-1.8	-1.7	-1.6	-1.5

Table 2. Regional economic impacts of the WRPC1 in the Waipa River FMU, reported relative to the BAU scenario.

Industry	Value added ($m)				Employment (MECs)				International exports ($m)			
	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D
Horticulture and fruit growing	0	0	0	0	-3	-3	-3	-3	0.0	0.0	0.0	0.0
Sheep, beef & grain	-4	-3	-3	-3	-38	-21	-21	-19	-0.2	-0.1	-0.1	-0.1
Dairy farming	-6	-6	-6	-6	-49	-46	-46	-44	-0.1	-0.1	-0.1	-0.1
Forestry	0	0	0	0	0	-1	-1	-1	0.0	0.0	0.0	0.0
Other primary	0	0	0	0	1	1	2	2	0.0	0.0	0.0	0.0
Agriculture and forestry support	0	0	0	0	-6	-4	-3	-1	0.0	0.0	0.0	0.0
Meat and meat product manufacturing	0	0	0	0	-3	-2	-2	-1	-1.2	-0.9	-0.6	-0.3
Dairy product manufacturing	-2	-2	-1	-1	-8	-6	-5	-3	-10.5	-8.2	-6.2	-3.8
Wood and paper manufacturing	0	0	0	0	0	0	0	0	0.1	0.0	0.0	0.0
Other manufacturing	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Utilities	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Construction	0	0	0	0	7	7	8	8	0.0	0.0	0.0	0.0
Wholesale and retail trade	0	0	0	0	-5	-5	-4	-4	0.0	0.0	0.0	0.0
Transport	0	0	0	0	-1	-1	-1	0	0.0	0.0	0.0	0.0
Professional and administrative services	0	0	0	0	-1	-1	0	0	0.0	0.0	0.0	0.0
Local and central government	0	0	0	0	-2	-2	-2	-1	0.0	0.0	0.0	0.0
Other services	-2	-2	-2	-1	-17	-15	-14	-13	0.0	0.0	0.0	0.0
Total loss relative to baseline	-15	-14	-13	-12	-126	-97	-91	-79	-12	-9	-7	-4

Table 3. Regional economic impacts of the WRPC1 in the mid-Waikato (Karapiro to Ngaruawahia) FMU, reported relative to the BAU scenario

Industry	Value added ($m)				Employment (MECs)				International exports ($m)			
	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D
Horticulture and fruit growing	0	0	0	0	-21	-21	-21	-21	-0.2	-0.2	-0.2	-0.2
Sheep, beef & grain	-1	-1	-1	-1	-10	-10	-10	-10	0.0	0.0	0.0	0.0
Dairy farming	-1	-1	-1	-1	-2	-3	-4	-9	0.0	0.0	0.0	0.0
Forestry	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Other primary	0	0	0	0	0	0	1	1	0.0	0.0	0.0	0.0
Agriculture and forestry support	0	0	0	0	-1	1	2	4	0.0	0.0	0.0	0.0
Meat and meat product manufacturing	-1	0	0	0	-5	-4	-3	-2	-1.8	-1.4	-1.0	-0.6
Dairy product manufacturing	-6	-5	-3	-2	-21	-16	-12	-7	-27.0	-20.8	-15.0	-8.4
Wood and paper manufacturing	0	0	0	0	1	1	0	0	0.3	0.2	0.1	0.0
Other manufacturing	0	0	0	0	-3	-2	-1	1	0.0	0.0	0.0	0.0
Utilities	0	0	0	0	-1	-1	-1	0	0.0	0.0	0.0	0.0
Construction	0	0	0	0	2	2	3	3	0.0	0.0	0.0	0.0
Wholesale and retail trade	-1	-1	-1	-1	-21	-18	-15	-13	0.0	0.0	0.0	0.0
Transport	0	0	0	0	-4	-3	-2	-1	0.0	0.0	0.0	0.0
Professional and administrative services	-1	0	0	0	-12	-8	-5	-1	0.0	0.0	0.0	0.0
Local and central government	0	0	0	0	-5	-4	-4	-3	0.0	0.0	0.0	0.0
Other services	-5	-4	-4	-3	-60	-53	-48	-42	0.0	0.0	0.0	0.0
Total loss relative to baseline	-16	-13	-11	-8	-162	-139	-119	-100	-29	-22	-16	-9

Table 4. Regional economic impacts of WRPC1 in the Upper Waikato (Karapiro to Taupo Gates) FMU, reported relative to the BAU scenario.

Industry	Value added ($m)				Employment (MECs)				International exports ($m)			
	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D
Horticulture and fruit growing	0	0	0	0	-1	-1	-1	-1	0.0	0.0	0.0	0.0
Sheep, beef & grain	-6	-5	-4	-3	-12	5	28	44	-0.1	0.1	0.3	0.5
Dairy farming	-35	-25	-15	-5	-400	-284	-172	-40	-0.7	-0.5	-0.3	-0.1
Forestry	5	3	1	0	56	38	20	1	1.5	1.0	0.5	0.0
Other primary	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Agriculture and forestry support	0	0	0	0	-7	-4	1	6	0.0	0.0	0.0	0.0
Meat and meat product manufacturing	0	0	0	0	-1	0	0	0	-0.2	-0.2	-0.1	0.0
Dairy product manufacturing	-2	-1	-1	0	-6	-5	-3	-1	-8.6	-6.3	-4.1	-1.5
Wood and paper manufacturing	5	3	2	0	34	23	12	1	10.1	6.9	3.5	0.2
Other manufacturing	0	0	0	0	1	1	1	0	0.0	0.0	0.0	0.0
Utilities	0	0	0	0	1	0	0	0	0.0	0.0	0.0	0.0
Construction	0	0	0	0	4	5	5	5	0.0	0.0	0.0	0.0
Wholesale and retail trade	0	0	0	0	-8	-6	-4	-2	0.0	0.0	0.0	0.0
Transport	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Professional and administrative services	0	0	0	0	1	1	1	0	0.0	0.0	0.0	0.0
Local and central government	0	0	0	0	-1	-1	-1	0	0.0	0.0	0.0	0.0
Other services	-4	-3	-2	-1	-40	-29	-20	-10	0.0	0.0	0.0	0.0
Total loss relative to baseline	-37	-27	-19	-9	-379	-257	-134	4	2	1	0	-1

Table 5. Total economic impacts of the WRPC1 in the Waikato Region, reported relative to the BAU scenario.

Industry	**Value added ($m)**				**Employment (MECs)**				**International exports ($m)**			
	Sc. A	**Sc. B**	**Sc. C**	**Sc. D**	**Sc. A**	**Sc. B**	**Sc. C**	**Sc. D**	**Sc. A**	**Sc. B**	**Sc. C**	**Sc. D**
Horticulture and fruit growing	-3	-3	-3	-3	-46	-46	-46	-45	-1.2	-1.2	-1.2	-1.2
Sheep, beef & grain	-18	-16	-15	-14	-119	-82	-57	-35	-0.7	-0.4	-0.1	0.1
Dairy farming	-56	-44	-33	-20	-563	-423	-292	-139	-0.8	-0.6	-0.4	-0.2
Forestry	5	3	1	0	59	40	20	1	1.5	1.0	0.5	0.0
Other primary	1	1	1	1	6	7	8	10	0.0	0.0	0.0	0.0
Agriculture and forestry support	-1	0	0	1	-18	-9	2	13	0.0	0.0	0.0	0.0
Meat and meat product manufacturing	-2	-2	-1	-1	-19	-14	-9	-4	-7.3	-5.4	-3.6	-1.6
Dairy product manufacturing	-18	-14	-10	-5	-60	-46	-32	-17	-80.4	-60.9	-43.0	-22.1
Wood and paper manufacturing	5	4	2	0	41	28	14	0	10.9	7.4	3.7	0.2
Other manufacturing	0	0	0	0	-4	-2	-1	1	-0.1	-0.1	-0.1	-0.1
Utilities	0	0	0	0	-2	-1	-1	-1	0.0	0.0	0.0	0.0
Construction	1	1	1	1	18	20	21	23	0.0	0.0	0.0	0.0
Wholesale and retail trade	-2	-2	-1	-1	-48	-39	-32	-24	0.0	0.0	0.0	0.0
Transport	-1	-1	0	0	-7	-6	-5	-3	0.0	0.0	0.0	0.0
Professional and administrative services	-1	0	0	0	-14	-10	-5	0	0.0	0.0	0.0	0.0
Local and central government	-1	-1	-1	0	-10	-8	-7	-6	0.0	0.0	0.0	0.0
Other services	-15	-12	-10	-8	-152	-128	-109	-87	0.0	0.0	0.0	0.0
Total loss relative to baseline	-106	-86	-69	-50	-938	-720	-531	-314	-78	-60	-44	-25

Table 6. Total economic impacts of the WRPC1 across New Zealand, reported relative to the BAU scenario.

Industry	Value added ($m)				Employment (MECs)				International exports ($m)			
	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D	Sc. A	Sc. B	Sc. C	Sc. D
Horticulture and fruit growing	-4	-4	-3	-3	-80	-71	-65	-59	-1	-1	-1	-1
Sheep, beef & grain	-24	-20	-18	-16	-196	-141	-98	-56	-1	0	0	0
Dairy farming	-80	-62	-45	-26	-769	-580	-402	-195	-1	-1	0	0
Forestry	7	5	2	0	68	46	23	1	1	1	0	0
Other primary	1	1	1	2	0	4	7	11	0	0	0	0
Agriculture and forestry support	-4	-2	-1	1	-78	-47	-12	25	0	0	0	0
Meat and meat product manufacturing	-4	-3	-2	-1	-37	-28	-19	-9	-11	-8	-5	-2
Dairy product manufacturing	-28	-21	-15	-8	-105	-80	-56	-29	-119	-90	-63	-32
Wood and paper manufacturing	8	5	3	0	69	46	23	0	14	9	5	0
Other manufacturing	-8	-7	-5	-4	-83	-71	-61	-49	-4	-3	-3	-3
Utilities	-2	-2	-2	-1	-5	-4	-3	-3	0	0	0	0
Construction	0	0	1	1	5	10	14	19	0	0	0	0
Wholesale and retail trade	-8	-6	-5	-3	-142	-114	-92	-65	0	0	0	0
Transport	-5	-4	-3	-2	-54	-43	-34	-23	0	0	0	0
Professional and administrative services	-8	-6	-4	-2	-127	-95	-66	-33	0	0	0	0
Local and central government	-3	-3	-2	-2	-36	-30	-25	-19	0	0	0	0
Other services	-33	-27	-22	-16	-311	-256	-210	-156	0	0	0	0
Total loss relative to baseline	-193	-154	-120	-80	-1880	-1453	-1075	-638	-120	-93	-69	-39

4. Conclusions

The draft Waikato Regional Plan Change No. 1—Waikato and Waipa River Catchments (Proposed) (WRPC1) presented at CSG meeting #27 on 9 May 2016 set out policies that aim to progressively reduce concentrations of nitrogen, phosphorus, sediment, and microbes to meet Freshwater Management Unit (FMU) specific targets and associated values of water clarity and suspended algae (chlorophyll-a). The time frame for meeting these ultimate targets for water-quality improvement is 80 years, whereas the current Plan Change aims to ensure that the actions necessary to make a 10% step towards bridging the gap between the current and target states are implemented over the next decade.

The farm- and catchment-level implications of WRPC1 are set out in the comprehensive study of Doole et al. (2016). However, this work did not explore the FMU-, regional-, and national-level implications of the proposed policy mix. The primary objective of this analysis has been to fill this gap using the IO model described in McDonald (2015). This current research is important, given that the economic implications of broad-scale policies to reduce the intensification of rural and urban land-use in the Waikato can be significant (Doole et al., 2015a), especially given its size and the importance of this region in terms of agricultural production. Results are reported relative to the "business-as-usual" scenario described by Doole (2016).

Model output shows that the proposed policy mix will have a significant negative impact on income, employment, and exports within agricultural industries in the Waikato region and those sectors that provide services to them. These impacts are further magnified when connections with industries across the nation are considered. The negative economic outcomes associated with improved water quality are perhaps unsurprising given that in the Waikato region contaminant loss from agriculture is a key cause of water-quality decline (McDowell and Wilcock, 2008), agricultural production is a key source of income and jobs (Doole et al., 2015a), much intensive agriculture is present in the catchment, and there is a distinct lack of profitable mitigation activities across the range of agricultural enterprises and contaminants considered within the HRWO process (Doole, 2015; Doole and Kingwell, 2015). The scale of these losses is also somewhat further exacerbated, given that significant intensification and associated increases in income are predicted to occur in the absence of the WRPC1.

Nevertheless, while this analysis shows that the economic impacts of WRPC1 are likely negative for most primary sectors, the proposed policy mix is predicted to achieve significant improvements in water quality across the catchment (Doole et al., 2016).

Acknowledgements

The primary authors of this report are Garry McDonald and Graeme Doole, who have led the development and application of the primary framework applied in this study. However, this work represents a significant effort invested by many people across many organisations, and we acknowledge their tireless effort in helping us in its development.

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"PLM"

WAIKATO
FEDERATED FARMERS
CHARITABLE SOCIETY INC.

FEDERATED FARMERS OF NEW ZEALAND

Report to Waikato Federated Farmers

Farm Environment Plan Project

Phil Journeaux
AgFirst Waikato

4 November 2016

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1.0 EXECUTIVE SUMMARY

The purpose of this project was to develop Farm Environment Plans (FEP) on several farms throughout the Waikato/Waipa River Catchments in order to:

(i) Undertake an analysis of actual costs of producing and developing a FEP including the Nitrogen Reference Point.

(ii) Assess the cost to the farmer of implementing the farm environment plan actions and any resource consent requirements and the impact on farm profitability.

(iii) Any issues arising with the process of developing the FEP.

(iv) Any wider issues that could be raised in the submission process.

Thirteen farms were visited by AgFirst - three dairy farms, two cropping farms, one lifestyle block, and seven drystock farms, with Fonterra visiting 11 dairy farms. This was done over the period 19 September through to 7 October 2016.

The process essentially involved:

- Development of the Nitrogen Reference Point for the farm
- Development of the FEP to the point where it was accepted by the farmer and consultant
- Review of the FEP by WRC to ensure it met their requirements

Once agreed with the farmer, the FEPs were provided to WRC for them to peruse and see if the FEPs met their requirements. WRC noted a number of omissions in the FEPs and that further refinement of the definitions in Schedule 1 of the proposed plan are required.

The results of the exercise were:

Time taken for the AgFirst Farms

Action	Average time (hours)	Range (hours)
Farm Visit/ Collate data	5.3	2.5 – 9.5
Nitrogen Reference Point	4.75	1.0 – 8.0
Complete FEP	14.7	4.5 – 26.25
Total	**24.75**	**8.0 – 43.75**

Note these times exclude the time taken for the lifestyle block (= 6.5 hours total)

Time taken for the Fonterra Farms

Action	Average time (hours)	Range (hours)
View farm	3.75	3.0 – 5.0
On-farm data collection/collation	3.0	2.0 – 4.0
Develop NRP	1.8	1.5 – 2.0
Complete FEP	5.2	4.5 – 6.0
Total	**13.8**	**11.0 – 17.0**

Costing for the FEP for the AgFirst Farms

Item	Average	Range
LandBase initial subscription	$480	
Farm map	$100 if have electronic map. $500 to develop one.	
Farm Visit	$795	$375 - $1,425
Nitrogen Reference Point	$712	$150 - $1,200
Complete FEP	$2,205	$675 - $3,937
Total*	$4,692	$2,180 - $7,542

*Assumes the farmer does **not** have an electronic map

On-farm costing of actions required: AgFirst Farms

	Total Costing
Farm 1	$12,200 + annual cost of $6,000
Farm 2	$62,800-$67,100
Farm 3	$18,100
Farm 4	$210,000
Farm 5	$113,500
Farm 6	$18,000
Farm 7	$425,432
Farm 8	$0 (change in grazing management only)
Farm 9	$41,000
Farm 10	$9,500
Farm 11	$306,549-$785,687**
Farm 12	$385,500
Farm 13	$1,000

**Range due to issues of interpretation of stock exclusion requirements of Schedule C and Schedule 1

On-farm costing of actions required: Fonterra Farms

	Total Costing
Farm 1	$7,500
Farm 2	$5,000
Farm 3	$88,000
Farm 4	$27,000
Farm 5	$12,000
Farm 6	$67,000
Farm 7	$24,000
Farm 8	$17,000
Farm 9	$56,000
Farm 10	$111,000
Farm 11	$41,000

Note some of the costings on the dairy farms relate to effluent management/storage, which is covered by existing regulations.

Issues identified pertaining to the proposed plan were:

(i) The main issue was around stock exclusion from waterways for drystock farms, and the practicality and cost of fencing, particularly on land >25^0 slope. Currently there is something of a contradiction between Schedule C which requires stock exclusion, and Schedule 1 which allows for alternative mitigations.

(ii) Associated with (i) was the current timeline for stock exclusion, which was felt to be impractical due to the difficulties associated with fencing a lot of hill country, along with the cost involved.

(iii) Identifying permanent versus intermittent/ephemeral waterways.

(iv) Issues around the cultivation of peat land, particularly the need for a 5 metre buffer strip.

(v) Incorporation of mitigation practices that are not in OVERSEER™, and hence difficult to measure.

(vi) Incorporation of cover crops within the Nitrogen Reference Point calculation.

(vii) How lease blocks are to be handled. Potentially they will require separate FEPs and some negotiation between landowners and lessees.

(viii) How to handle future possibilities within an FEP. It is not possible that every eventuality can be covered within an FEP.

(ix) The 5-year rolling average N leaching figure requires a calculation every year, which would then be available for any FEP audit.

(x) If slope is an important issue for the farm and FEP, data needs to be available to allow for accurate mapping.

(xi) Mediation. This is more of an operational issue, but could be a least-cost option if a farmer and consultant cannot agree on a mitigation strategy or some component of the FEP.

2.0 BACKGROUND

The Healthy Rivers Plan Change 1 has recently been notified by the Waikato Regional Council (WRC). A key component of the requirements on farmers will be to have a Farm Environment Plan (FEP) which outlines the issues relating to the discharge of the four contaminants (nitrogen, phosphorus, sediment, microbes) and how the farmer will manage these.

In addition, the FEP will outline actions to prevent stock access to waterways as per conditions of Plan Change 1, as well as indicating the Nitrogen Reference Point for the farm.

3.0 PURPOSE

The purpose of this project was to develop a range of FEPs in order to investigate:

(i) An analysis of actual costs of producing and developing a FEP including the Nitrogen Reference Point. [Excludes any administration/interaction costs with WRC]

(ii) Assess the cost to the farmer of implementing the farm environment plan actions and any resource consent requirements and the impact on farm profitability.

(iii) Any issues arising with the process of developing the FEP.

(iv) Any wider issues that could be raised in the submission process.

Note that while the intent was to have the FEPs as real as possible, they are not binding on the farmers.

4.0 AGFIRST FARMS

4.1 Methodology

Thirteen properties were selected across the Waikato and Waipa River Catchments, via a request from Waikato Federated Farmers for members to volunteer to take part. The farms were:

Table 1: Selected farms

	Description	FMU	Priority catchment
Farm 1	240 ha Dairy	Upper	3
Farm 2	165 ha Dairy	Central	2
Farm 3	197 + 120 ha Dairy farms + 57 ha support block	Upper	1
Farm 4	454 ha Drystock	Waipa	3
Farm 5	443 ha Drystock + arable cropping	Lower	2
Farm 6	107 + 65 ha + 34 ha Arable cropping	Lower	3
Farm 7	1,000 ha Drystock, including intensive finishing	Waipa	2
Farm 8	50 ha Beef + cropping	Waipa	2
Farm 9	124 ha Intensive Drystock	Central	3
Farm 10	202 ha Drystock including grazing dairy heifers (all year)	Upper	3
Farm 11	240 ha Drystock	Lower	1
Farm 12	330 ha Drystock + dairy grazing (all year) + deer	Waipa	2
Farm 13	18 ha Lifestyle block: beef + horses	Central	3

The general process for developing the FEPs was:

(i) Information sheet sent out to the farmer in advance of the meeting

(ii) Consultant views farm/discusses issues with farmer

(iii) Organises an electronic farm map

(iv) Calculates the Nitrogen Reference Point using OVERSEER™

(v) Develops the FEP using AgFirst's "LandBase" software programme

(vi) Discusses the draft FEP with the farmer

(vii) Finalises the FEP

Once the FEPS were completed, they were viewed by WRC staff to gain their view as to how well, or not, the FEPs were sufficient to meet the requirements of the Healthy Rivers Plan Change 1. In a number of instances, the farmer identification detail was removed at the request of the farmer.

4.2 Results

4.2.1 Nitrogen Reference Points

For each farm, the nitrogen leaching level for 2014/15 and 2015/16 was determined using OVERSEER™, with the farmer then choosing which figure to use as the NRP; invariably the higher figure if there was a difference.

These were relatively straightforward to calculate, provided the farmer had good information readily available. Issues arose for a few farms that had little historic (i.e. 2014/15, 2015/16) information available, in which case such information as available was used, with the consultant following the Data Input Standards to determine which defaults within OVERSEER™ were used.

Issues:

(i) Farm 6 had three very geographically distinct blocks, which resulted in three NRPs calculated, one for each block. Given the geographic separation, this farm had three separate FEPs developed – there was no advantage seen in incorporating it all into one FEP.

(ii) Farm 3 had two dairy farms and a support block that while geographically separate, were in relatively close proximity. This enterprise was covered by one FEP, although an NRP was calculated for each separate block.

(iii) Some farms had nutrient budgets calculated on the effective area of the farm. The NRPs calculated were based on the total area of the farm.

Time taken to determine the NRPs varied from 1 (review of existing files) to 8.5 hours, depending on the complexity of the farm system, and the availability of data to enter into OVERSEER™.

Average time across all the farms was 4.75 hours.

4.3 Farm Environment Plans

The first step in developing the FEP was to obtain a farm map in order to record a range of information on it, (e.g. boundaries, internal subdivision, waterways (and fencing thereof), critical source areas, and other pertinent information). The AgFirst LandBase system requires an electronic map, which most of the farmers did not have.

While this was easily remedied, it did add some time and cost to the process. While a hardcopy could suffice, an electronic map is easier to manipulate with regard to drawing in fence lines, waterways, calculating areas, etc.

Given the importance of slope for a number of the FEPs, an attempt was made to map the slope areas within a farm, broken down by <15^0, 16-25^0, and >25^0. The only data available for this was the digital elevation model (DEM) information, which has an 8-metre contour band. It was found that this was too coarse to be very useful, so was abandoned. Good Lidar information is required if slope mapping is to be done with any accuracy.

Prior to the consultant visiting the farm, an information sheet was sent to the farmer detailing the information required to complete the OVERSEER™ analysis, and to input into the LandBase programme.

The time spent on the farm visit varied from 2.5 hours through to 9.5 hours, depending (mainly) on the size of the farm, contour, complexity of the farming system, and the degree to which environmental mitigation work had been carried out previously. Average time was 5.3 hours.

Time taken to complete the FEPs, including liaising back with the farmer and discussing through the options again varied considerably, depending on the issues identified. Excluding the time taken for the NRP and farm visit, but including the mapping component, time taken varied from 4.5 hours through to 26.25 hours, with an average of 14.7 hours. There was a definite time advantage in having an electronic system to develop the FEP.

Table 2: Summary of time taken to develop the FEPs

Action	Average time (hours)	Range (hours)
Nitrogen Reference Point	4.75	1.0 – 8.0
Farm Visit	5.3	2.5 – 9.5
Complete FEP	14.7	4.5 – 26.25
Total	**24.75**	**8.0 – 43.75**

Note these times exclude the time taken for the lifestyle block (= 6.5 hours total)

Average total time to complete the dairy FEPs; 20.5hours
Average total time to complete the arable FEPs; 23.5 hours
Average total time to complete the S&B FEPs; 26.5 hours

4.4 Cost of the FEPs

Assuming a consultancy time cost of $150/hour, the overall cost of the FEPs were:

Table 3: FEP Costs

Item	Average	Range
LandBase initial subscription	$480	
Farm map	$100 if have electronic map. $500 to develop one.	
Nitrogen Reference Point	$712	$150 - $1,200
Farm Visit	$795	$375 - $1,425
Complete FEP	$2,205	$675 - $3,937
Total*	**$4,692**	**$2,180 - $7,542**

*Assumes the farmer does **not** have an electronic map. Also excludes any costing of the lifestyle block.

4.4.1 Costs of completing the actions within the FEPs

Within each FEP, the various actions that the farmer would need to undertake were costed out. Within the time constraint of the project it was not possible to get quotes for these actions, so the costings noted below are based on the consultants and farmer estimates.

Also note that in two of the FEPs the farmer had not agreed with 1 or 2 of the recommendations from the consultant. In the normal course of events these would be discussed through and a solution found. Again given the time constraints on the project, the costings shown include the current consultants' recommendation.

Table 4: Total Costings required to meet FEP Recommendations

	Total Costing
Farm 1	$12,200 + annual cost of $6,000
Farm 2	$130,800 - $135,100
Farm 3	$18,000
Farm 4	$210,000
Farm 5	$113,500
Farm 6	$18,000
Farm 7	$425,432
Farm 8	$0 (change in grazing management only)
Farm 9	$41,000
Farm 10	$9,500
Farm 11	$306,549-$785,687**
Farm 12	$385,500
Farm 13	$1,000

**Range due to issues of interpretation of stock exclusion requirements of Schedule C and Schedule 1

A more detailed breakdown of the individual farm expenditure required is shown in Appendix 1.

5.0 FONTERRA FARMS

5.1 Methodology

Eleven farms were selected, again across the four FMUs. These are outlined below:

Table 5: Selected Dairy Farms

	Description	FMU	Priority Catchment
Dairy farm 1	251 ha: 620 cows calved	Upper	3
Dairy farm 2	195 ha: 430 cows calved	Upper	3
Dairy farm 3	340 ha: 840 cows calved	Upper	2
Dairy farm 4	84 ha: 175 cows calved	Upper	2
Dairy farm 5	115 ha: 300 cows calved	Waipa	2
Dairy farm 6	87 ha: 196 cows calved	Central	3
Dairy farm 7	240 ha: 710 cows calved	Waipa	2
Dairy farm 8	192 ha: 569 cows calved	Lower	1
Dairy farm 9	75 ha: 230 cows calved	Waipa	2
Dairy farm 10	196 ha: 640 cows calved	Lower	1
Dairy farm 11	255 ha: 500 cows calved	Lower	1

The methodology used was very similar:

(i) Sustainability officer views farm/discusses issues with farmer

(ii) Calculates the Nitrogen Reference Point using OVERSEER™

(iii) Develops the FEP

(iv) Discusses the draft FEP with the farmer

(v) Finalises the FEP

Fonterra does have some advantage in that it already has the OVERSEER™ files for all their shareholder farms, plus farm maps, so the process is generally much quicker.

Again once the FEPS were completed, they were viewed by WRC staff to gain their view as to how well, or not, the FEPs were sufficient to meet the requirements of the Healthy Rivers Plan Change 1. All farmer identification detail was removed from the FEPs before being viewed by WRC.

5.2 Time involvement

Average time taken, and the range involved is shown below.

Table 6: Summary of time taken to develop the FEPs for dairy farms

Action	Average time (hours)	Range (hours)
View farm	3.75	3.0 – 5.0
On-farm data collection/collation	3.0	2.0 – 4.0
Develop NRP	1.8	1.5 – 2.0
Produce FEP	5.2	4.5 – 6.0
Total	**13.8**	**11.0 – 17.0**

5.3 Costs of completing the actions within the FEPs

Again within the FEPs there was a range of actions required by the farmers, the cost of which have been estimated by Fonterra staff as indicated below.

Table 7: Total Costings required to meet FEP Recommendations on Dairy Case Study Farms

	Total Costing
Dairy farm 1	$7,500 plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 2	$5,000 plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 3*#	$88,000 plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 4	$27,000 plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 5	$12,000 – $62,000 dependent on pond sealing test, plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 6*	$67,000, plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 7	$24,000, plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 8	$17,000, plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 9	$56,000, plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 10*	$111,000 plus some minor management changes, data recording and maintaining existing improvement actions
Dairy farm 11	$41,000 plus some minor management changes, data recording and maintaining existing improvement actions

*Most of this cost is to meet effluent storage conditions, which is a requirement of existing regulation.

#This farm is also thought to be above the 75th N leaching percentile. Cost of remedying this was not calculated.

The "maintaining existing improvement actions" refers to where a well-managed risk area has been identified and there is an "action" to maintain it; i.e. if it wasn't maintained it would be in non-compliance with the FEP.

6.0 WAIKATO REGIONAL COUNCIL COMMENT

WRC appreciates the initiative of Waikato Federated Farmers in setting up this project as it provides a perfect opportunity to check the implications of the policies in Plan Change 1 when they are put into practice on the ground. The findings of this project can be used to support submissions to refine and improve the policies, and to help in the development of the Implementation Plan.

To support the project WRC drafted a set of standards for each consideration or provision in schedule 1 of the proposed regional plan change 1 (PC1) that are linked to Good Management Practice, and methodologies to ensure that the risks of contaminant discharge are assessed equitably between farms throughout the Waikato and Waipa catchments. The consultants then used those as a guide for their work with the farmers who took part in the project. No specific feedback on those standards is provided in this report and they remain a work-in-progress.

It is important that this work is able to distinguish between the cost of complying with the requirements of Healthy Rivers and other matters, and equally important that it should identify any issues with the wording of PC1 that could lead to uncertainty or confusion.

In some instances on the dairy farms the costs of complying with existing regulation (effluent management) are included but not itemised so it is not clear how much of an impact his has on the overall cost assessment. These are matters that all dairy farmers should have addressed several years ago and are not a cost of PC1.

The project also identified an issue in the wording of Schedule C (stock exclusion) and Schedule 1 (Requirements for Farm Environment Plans) which could be interpreted in two different ways. That resulted in one dry stock farm identifying $479,138 in fencing associated with steep gully fencing to allow sheep grazing while excluding cattle. Schedule One provides for alternative mitigations to be used in these circumstances, but Schedule C does not. Those mitigations would normally involve providing stock water, shade and shelter away from the water body, and in this instance the costs already include a water supply, so depending on the interpretation the costs to this farm could range between $306,549 and $785,687.

It is acknowledged that there is no analysis in the report of the farm systems benefits of such things as soil testing, improved nutrient efficiency, improved stock health and performance as a result of being excluded from contaminated drinking water, or subdivision opportunity arising from the fencing of streams. These matters were not included in the terms of reference of the study, but would in some measure balance the financial impact in some cases.

The project identified a number of matters that provide guidance on both the standards and the process of consistently carrying out Farm Environment Planning as required by Schedule 1. Those matters will be used to further refine the minimum standards where applicable, and to provide training and advice for Farm Environment Planners. Those matters include:

- There needs to be a clearer linkage between the required actions in a farm plan and the farm map so there are no misunderstandings what actions need to be completed and where those actions are required.

- Actions to be completed (as in physical works such as erosion control) require timelines in all cases to ensure a clear understanding to aid the farmer in planning works, and for compliance purposes. This is especially important for fencing for stock exclusion given the compliance dates for the different sub-catchment priority rankings as described in Schedule C of the purposed regional plan.
- Many plans do not have any reference to the sub-catchment they are located in, that is required to ascertain key dates for completion of farm plans and waterway fencing. It should also be used to identify the priority of the risks and therefor the cations to be taken.
- In some cases it is not clear that all of the Schedule 1 provisions have been considered – even if there are no actions required.
- There is inconsistency between identification of wetlands vs springs, and their required actions or mitigations and fencing requirements
- Many farm plans do not give appropriate consideration to animal management and grazing management to protect pasture cover, nor the assessment of appropriate land use and grazing management for specific areas of the farm to maintain or improve the physical and biological condition of the soils and minimise the discharge of contaminants.
- It's not clear that the consultants have considered the farm systems implications of intermittent cropping which may be in different areas over the life of the FEP, either for fodder or for pasture renewal and built this in to the FEP.
- None of the FEPs included actions, timeframes or other measures to ensure that they would remain under the NRP 5 year rolling average.
- It was surprising that none of the plans referred to the management of Olsen P within optimum levels as a cost saving mitigation.

Arising from these points it is clear that further refinement of the interpretations of Schedule 1 will be needed. For example, what are the minimum alternative mitigations expected when it is impractical to fence streams on slopes over 25°?

It is expected that further case studies, including those in the Beef + Lamb NZ LEP project will help to inform this over the next several months. It is also apparent that there are some matters that don't lend themselves to the setting of clear minimum standards, so the skill and judgement of the Farm Environment Planner will remain critical to the quality of the FEPs. Therefore it will be important to provide for ongoing moderation processes to ensure consistency of interpretation of real world situations.

These matters are currently being considered in the Implementation Plan process and we look forward to further work with stakeholders in helping to refine these kinds of details.

Finally the approach of Healthy Rivers in choosing tailored Farm Environment Plans as a key policy tool for getting good practice onto farms recognises the complexity and challenge of defining what is meant by Good Practice in a wide range of farm settings. This relies heavily on the ability of farmers and their consultants to develop practical solutions to problems and make them work.

Our thanks go to those farmers who chose to front-foot the implementation of Healthy Rivers by getting involved in this project and contributing to the further improvement of these policies and their implementation.

7.0 COMMENT

There are several factors to consider as a result of the project.

(i) As noted, the purpose of this project was primarily around developing an FEP, and within that calculating a NRP. It did not involve calculating the cost of reducing N leaching to the 75th percentile. AgFirst Farm 6 had one block which is very probably over the 75th percentile level (given that the actual level is currently unknown). This was a cropping farm, where the block in question had recently come out of pasture. 10-year modelling with OVERSEER™ showed that over this period the N leaching level will drop significantly and hence was not considered an issue.

(ii) Many of the farms have already carried out a range of environmental mitigation strategies, which were not necessarily commented on in the FEP; the FEPs basically concentrated on issues requiring actions into the future.

(iii) Similarly, most of the farmers were not looking at altering their farm system or grazing management, and nor was it felt necessary at this stage.

(iv) In the same vein, the arable farms were operating at Best Practice, and again any mitigations required tended to be minor.

(v) As noted the costs were largely based on estimates, and in a few instances questions could be raised as to whether the mitigations planned include some degree of farmer preference which is above strictly required, or there could be lower-cost alternatives.

(vi) As discussed in the section on NRPs, Farm 3 had several different farms which were geographically separate, but in reasonable proximity. This involved calculating 3 NRPs, but incorporating the whole enterprise in one FEP. Farm 6 also had 3 separate farms, which resulted in 3 separate NRPs and FEPs. Either approach is permissible, depending on the farmers' preference. Time involvement for both approaches was identical.

8.0 ISSUES

The following are a range of issues that arose while developing the FEPs

(i) The main issue was around stock exclusion from waterways for drystock farms, and the practicality and cost of fencing, particularly on land >25^0 slope. This was especially so for grazing beef or deer, and the limited opportunities around alternative grazing such as sheep. It is currently unclear if other alternative mitigations, e.g. silt traps and/or wetlands on lower ground would be acceptable. As noted in the WRC comment, provision of reticulated water (the cost of which was included in several drystock FEPs) along with provision of shade and shelter could well be an alternative to fencing in steep country.

This highlights an issue in regards to meeting the requirements of Schedule C Stock exclusion and Schedule 1 Requirement for a Farm Environment Plan. Schedule C requires exclusion by specified dates with no provision for alternative mitigations whereas Schedule 1 does allow the provision of alternative mitigations where the slope is greater than 25 degrees and stream fencing is impracticable. This is directly reflected in the situation Farm 11 faces; under Schedule C the costs for Farm 11 would be at the higher end shown ($785,687), whereas under Schedule 1 alternatives could be considered.

(ii) As part of (i) was also the proposed time limits on stock exclusion, which under the proposed plan are currently:

- Priority 1 catchments – July 2023
- Priority 2 catchments – July 2026
- Priority 3 catchments – July 2026

A number of the case study farmers did not want time limits included in the FEP around fencing, as they felt these were impractical due to both practicality - there would not be enough time to do the fencing required, as well as meeting the financial cost. Several did not want limits included due to a combination of factors, including practicality and cost; uncertainty around alternatives, information available, and wanting clarification on rules.

(iii) Identifying permanent versus intermittent/ephemeral waterways. The weather over the period of time when carrying out the FEPs was particularly wet, and hence ephemeral waterways were not readily apparent. This potentially could lead to a greater degree of fencing than required.

(iv) The need for a 5-metre buffer strip when cultivating peat, as this will have a significant opportunity cost. The peat cropping farm visited had minimal soil run-off from cultivated areas, even after periods of heavy rain. Direct drilling, which is not classified as "cultivation" is problematic on peat soils. The farmer raised the idea of strip tillage, where only a 150mm strip is cultivated in front of each seed coulter as a possible mitigation, but at this stage strip tillage is included as "cultivation".

(v) Incorporation of mitigation practices that are not in OVERSEER™ - how are these to be handled/how will the benefits be shown?

(vi) OVERSEER™ does not readily incorporate cover-crops in its calculation; it assumes that a fallow period (with attendant run-off/leaching) always follows a crop. For one cropping farm (maize), a cover crop is sown via helicopter prior to harvesting, so no fallow occurs; the trash remains in place and the cover crop grows through it.

(vii) Several of the farms incorporated lease blocks, which for the purposes of the exercise were treated as part of the whole farm. It could be assumed that the responsibility of meeting any regulations lies with the land owner, who presumably would then include any related conditions in the lease agreement. It is probable therefore that a lease block may require its own separate NRP/FEP, which is then incorporated into the wider FEP for the lessee. Conditions of incorporation could vary depending on a range of issues, including the length of the lease, and therefore some guidelines around handling lease arrangements would be useful.

(viii) How to handle future possibilities within an FEP. It is not possible that every eventuality can be covered within an FEP, which needs to be recognised. [For example: when visiting the farm there is no evidence or history of sacrifice paddocks, so consequently is not included in the FEP. A few years later, the farmer uses a sacrifice paddock, for whatever reason]. This issue would also cover annual farm management, and the need to stay within a 5-year rolling average NRP. Many farmers alter farm management in minor ways due to circumstances at the time; it is very difficult to foresee these and incorporate them within the FEP. Which raises the issue of how readily the FEP needs updating relative to changes in management.

(ix) The 5-year rolling average N leaching figure requires a calculation every year, which would then be available for any FEP audit.

(x) If slope is an important issue for the farm and FEP, data needs to be available to allow for accurate mapping.

(xi) Mediation. This is more of an operational issue, but could be an option if a farmer and consultant cannot agree on a mitigation strategy or some component of the FEP, given that (a) the farmer needs to agree with the FEP and similarly, (b) the consultant needs to sign off on the plan. In such instances the option of independent arbitration could be the easiest and least cost method of solving the issue.

9.0 APPENDIX 1. PROPOSED INDIVIDUAL FARM EXPENDITURE REQUIRED: AGFIRST FARMS

	Practice	Cost
Farm 1	Undersow 20 ha/yr to reduce erosion	$6,000/yr
	Re-fence Paddock 12	$400
	Fence duck pond Paddock 9/10	$300
	Fence Paddock 47 to create a wetland	$3,500
	Opus drop test	$1,500
	Lay culvert under Crossing 3	$3,000
	Extend solids storage pad	$3,500
	Total	**$12,200 + annual cost**
Farm 2	Soil test individual paddocks or five LMU blocks every two years	$700 – 5,000
	Fence remaining peat drains	$12,000
	Slope races alongside waterways and upgrade hill races with cut out drains	$30,000
	Fence off and riparian plant blocked Novaflo	$10,000
	Replace blocked culvert and re- fence another culvert	$10,100
	Total	**$62,800-$67,100**
Farm 3*	Installing sump at underpass to direct effluent to the main effluent system	$18,100
	Total	**$18,100**
Farm 4	Stock water reticulation covering 90% of farm	Est $140,000
	Fencing of waterways <25 degrees where a more intensive stocking rate is managed. 2-wire fencing to exclude cattle only. 10km	Est $70,000
	Total	**$210,000**

*Farm 3 also included a cost of $125,000 for installation of a new effluent storage system. This is a requirement of existing regulation.

	Practice	Cost
Farm 5	Planting wetland area by woolshed	under $500
	Resolve cattle yard runoff into drain	Research options with specialist - $3,000. Implement option $10,000
	5-metre buffer zone from drains on crops. Opportunity cost of income forgone	$76,000 lost profit in the downturn. Normal year $100,000 lost profit.
	Total	**$113,500**
Farm 6	Fencing of Stopbank	$18,000
Farm 7	Reticulated water system	$145,000
	Waterway crossings	$190,000
	Fencing waterways. Eight wire post/batten 3,656m	$80,432
	Erosion control and shade planting	$10,000
	Possible plantation forestry (100ha)	No cost estimated at this stage
	Total	**$425,432**
Farm 8	No costs	
Farm 9	Waterway fencing. 4,530m single hot wire	$22,650
	Culverts for waterway crossings (x4)	$13,493
	Ephemeral waterway/seep fencing when water present. Single hot wire.	$1,358
	Planting willow poles for erosion control	$2,000
	Water reticulation system (4 paddocks)	$1,500
	Total	**$41,000**
Farm 10	Completion of fencing programme, 1,500m 2 wire.	$9,500

	Practice	Cost
Farm 11	Waterway fencing, 1,745m 3 hot wires.	$31,549
	Waterway crossings (13)	$100,000
	Reticulated water system	$173,000
	Willow and poplar pole planting for erosion control	$2000
	Potential fencing if cattle need to be kept off steep gully sidings. 21.78km 8 wire post/batten. Most of this land involves broad ridges with steep gullies/sidings.	$479,138
	Total	**$785,687**
Farm 12	9,000 metres of deer fencing flat paddocks along waterways	$180,000
	Reticulate water of remaining 15% of farm	$12,000
	Contouring and subsurface drainage of flat paddocks	$70,000
	Install whisper wires on all deer fences	$10,000
	Metal sites in every paddock for PKE trailer	$10,000
	Crown hill race and install cut out drains	$25,000
	Fill in existing deer wallows connected to waterways and provide artificial wallows	$12,000
	Fence off and plant erosion or erosion prone areas	$35,000
	Riparian plant stream bank erosion	$1,500
	Total	**$355,500**
Farm 13	Fencing and planting of seep	$1,000

10.0 APPENDIX 2. SCHEDULE 1 PROTOCOLS

This describes standards and technical guidance to complete "trial runs" of Farm Environment Plans as prescribed in the Proposed Waikato Regional Plan Change 1 – Schedule 1

This guide describes, for each section of Schedule 1, the provision required, draft standards to be used as a guide for recommending mitigations and actions, and a suggested methodology which includes sources of information.

The appendices provide a reference to the available sources of information, and a reference to the applicable pages of the Visual Soil Assessment Field Guide

Proposed Waikato Regional Plan Schedule 1 requirements

1. Farm Environment Plans should contain as a minimum
    a. Full name, address, and contact details (including email addresses and telephone numbers) of the person responsible for the property or enterprise
    b. Trading name (if applicable, where the owner is a company or other entity)
    c. A list of land parcels which constitute the property or enterprise.
        i. The physical address and ownership of each parcel of land (if different from the person responsible for the property or enterprise) and any relevant farm identifiers such as dairy supply number, Agribase identification number, valuation reference; and
        ii. The legal description of each parcel of land

2. An assessment of the risk of diffuse discharge of sediment, nitrogen, phosphorus and microbial pathogens associated with the farming activities on the property, and the priority of those identified risks, having regard to sub-catchment targets in Table 11-1 and the priority of lakes within the sub-catchment. As a minimum, the risk assessment shall include (where relevant to the particular land use):

(a) A description of where and how stock shall be excluded from water bodies for stock exclusion including:

Provision	Standards / GMPs	Assessment Methodology
(i) the provision of fencing and livestock crossing structures to achieve compliance with Schedule c; and (assume that this provision is only for fences on landscapes up to 25°, as areas above 25° are described below in subsection (ii)) *A water body from which cattle, horses, deer and pigs must be excluded include:* • *Any river that continually contains surface water* • *Any drain that continually contains surface water* • *Any wetland, including a constructed wetland* • *Any lake* *Livestock crossing structure means a lawfully established structure installed to allow livestock to cross a water body*	Fences must be present to a standard to exclude Cattle Deer Pigs Horses (whatever stock classes present on farm) *Modified standard to meet Schedule C requirements.* New fences setback 1 metre on land up to 15° and setback 3 metres on land between 15° and 25° Existing fences can stay in their current position Crossings Stock must not be permitted to enter or pass across the bed of a water body except when using a livestock crossing structure	Measuring the angle of land: Using an inclinometer or smartphone with a suitable app, the angle is measured by standing next to the waterway and sighting the adjacent ridgeline (irrespective of any intervening paddock or property boundaries). Also refer to Waikato Regional Council Best Practice Guidelines for Waterway Crossings
(ii) for areas with a slope exceeding 25° and where stream fencing is impracticable, the provision of alternative mitigation measures.	May include: • Reticulation • Receiving wetland downstream • Land management practices to minimise loss of contaminants such as no grazing in winter, or sheep only for those paddocks • Temporary fencing	Demonstrate that alternative measures effectively minimise the chance of livestock entering the stream, or where this is not practicable demonstrate how any adverse effects of stock access into the waterway will be minimised

(b) A description of setbacks and riparian management, including:

Provision	Standards / GMPs	Assessment Methodology
(i) The management of water body margins including how damage to the bed and margins of water bodies, and the direct input of contaminants will be avoided, and how riparian margin settling and filtering will be provided for; and	That this provision is met in all but severe weather events. No obvious continuous contaminant loss or erosion of the steam banks	Assess site by looking for: • Stream bank erosion • Flattened grass after rain events • Loss of vegetation cover • Soil or other debris deposited from "upstream" Plot all problem areas on a farm plan map with photos? Describe how the direct input of contaminants will be avoided, and how riparian margin settling and filtering will be provided for
(ii) Where practicable the provision of minimum grazing setbacks from water bodies for stock exclusion of 1m for land with a slope of 15° and 3m for land with a slope between 15° and 25°; and	As per a(i) – previous page	
(iii) The provision of minimum cultivation setbacks of 5m. *Cultivation means preparing the land for growing of pasture or crops, and the planting tending and harvesting of that pasture or crop – but excludes:* • *Direct drilling of seed* • *No-tillage practices* • *Re-contouring land* • *Forestry*	No cultivation within 5 metres of a waterway.	Seen as straight forward – NO cultivation within 5 metres of a waterway, irrespective of the location of the riparian fence. Requirement written into the plan as a reminder Plot or shade all applicable no-cultivation areas on the farm plan

(c) A description of the critical source areas from which sediment, nitrogen, phosphorus and microbial pathogens are lost, including:

Provision	Standards / GMPs	Assessment Methodology
(i) the identification of intermittent waterways, overland flow paths and areas prone to flooding and ponding, and an assessment of opportunities to minimise losses from these areas through appropriate stocking policy, stock exclusion and/or measures to detain floodwaters and settle out or otherwise remove sediment, nitrogen, phosphorus and microbial pathogens (e.g. detention bunds, sediment traps, natural and constructed wetlands); and	All active and potential losses through erosion or overland flow are managed to prevent further erosion and minimise sediment loss	Assess for evidence of: • Erosion • Flattened grass after rain events • Loss of vegetation cover • Soil or other debris deposited from "upstream" Plot all problem areas on a farm plan map with photos Possible ranking system so that the most at risk sites are dealt with first. Present options – apply land management planning or land environment planning principles, and/or sediment control principles – refer appendices for further information.
(ii) the identification of actively eroding areas, erosion prone areas, and areas of bare soil and appropriate measures for erosion and sediment control and re-vegetation; and	All active and potential erosion sites are managed to prevent further erosion and minimise sediment loss	Assess for evidence of: • Erosion • Loss of vegetation cover (see Section d methodology) • Areas of slippage or mass movement • Deposition of eroded soil • Areas of slippage or mass movement Plot all problem areas on a farm plan map with photos? Possible ranking system so that the most at risk sites are dealt with first.

		Present options – apply land management planning or land environment planning principles, and/or sediment control principles – refer appendices for further information. Refer to the NZ Soil Conservation Technical Handbook
(iii) an assessment of the risk of diffuse discharge of sediment, nitrogen, phosphorus and microbial pathogens from tracks and races and livestock crossing structures to waterways, and the identification of appropriate measures to minimise these discharges (e.g. cut-off drains, and shaping); and	Avoid or minimise sediment or microbial loss to waterways No obvious discharges to waterways No potential issues of contaminant loss to waterways	Assess for evidence of: • Erosion • Loss of vegetation cover (pasture areas only) • Deposition of eroded soil • Soil or other debris deposited from "upstream" • Proximity of critical source area to waterway, and likelihood of losses during rain events Plot all problem areas on a farm plan map with photos? Possible ranking system so that the most at risk sites are dealt with first. Present options – apply land management planning or land environment planning principles, and/or sediment control principles – refer appendices for further information.
(iv) the identification of areas where effluent concentrates including yards, races, livestock crossing structures, underpasses, stock camps, and feed-out areas, and appropriate measures to minimise the risk of diffuse discharges of contaminants from these areas to groundwater or surface water; and	No actual or potential loss of effluent to waterways Introduce/assess structures or changes to the farm system to ensure minimal build-up of areas of effluent	Assess for evidence of any actual or potential loss of effluent to water: • Examine all areas where effluent is concentrated/captured • Assess proximity to water or overland flow paths or ephemeral waterways and risk of loss during rain events

	Compliance with existing WRC Permitted Activity Rules	Plot all problem areas on a farm plan map with photos? Possible ranking system so that the most at risk sites are dealt with first. Present options – apply land management planning or land environment planning principles, and/or sediment control principles – refer appendices for further information. Refer to industry good management practice guidelines
(v) the identification of other 'hotspots' such as fertiliser, silage, compost, or effluent storage facilities, wash-water facilities, offal or refuse disposal pits, and feeding or stock holding areas, and the appropriate measures to minimise the risk of diffuse discharges of contaminants from these areas to groundwater or surface water.	No diffuse or point loss of contaminants to water Compliance with existing WRC Permitted Activity Rules	Assess for evidence of any actual or potential loss of contaminants to water: • Examine all hot spots • Assess proximity to water or overland flow paths or ephemeral waterways and risk of loss during rain events Plot all problem areas on a farm plan map with photos? Possible ranking system so that the most at risk sites are dealt with first. Present options – apply land management planning or land environment planning principles, and/or sediment control principles – refer appendices for further information. Refer to industry good management practice guidelines

(d) An assessment of appropriate land use and grazing management for specific areas on the farm in order to maintain and improve the physical and biological condition of soils and minimise the diffuse discharge of sediment, nitrogen, phosphorus and microbial pathogens to water bodies, including:

Provision	Standards / GMPs	Assessment Methodology
(i) matching land use to land capability; and	• No erosion • No less than 70% pasture cover in open pasture areas (isolated areas should be treated as a critical source area) • Feed out areas in should be treated as critical source areas • No grazing on permanently wet areas • "Managed" grazing on intermittently wet areas • No grazing in areas of ponding • No widespread areas of pugging or compaction. Poor Condition as described in the Visual Soil Assessment, Volume One, second edition (2009) requires actions to avoid and remedy	Visual Soil Assessment for pasture cover, pugging and compaction: Visual Soil Assessment, Volume One, second edition (2009) • Page 30, Surface Relief • Page 47, Area of Bare Ground See appendices Apply farm systems management principles, or present options by applying land management planning or land environment planning principles – refer appendices for further information. Include in the plan a description of how the physical and biological condition of soils, and how the diffuse discharge of sediment, nitrogen, phosphorus and microbial pathogens to water bodies will be minimised. Refer to industry good management practice guidelines
(ii) identifying areas not suitable for grazing; and		
(iii) stocking policy to maintain soil condition and pasture cover; and		
(iv) the appropriate location and management of winter forage crops; and	See section (f)	

(v) Suitable management practices for strip grazing.	• No erosion • No less than 70% pasture cover in open pasture areas • Feed out areas should be treated as critical source areas • No strip grazing on permanently wet areas • "Managed" grazing on intermittently wet areas • No strip grazing in areas of ponding • No widespread areas of pugging or compaction. Poor Condition as described in the Visual Soil Assessment, Volume One, second edition (2009) requires actions to avoid and remedy	Visual Soil Assessment for pasture cover, pugging and compaction: Visual Soil Assessment, Volume One, second edition (2009) • Page 30, Surface Relief • Page 47, Area of Bare Ground See appendices Apply farm systems management principles, or present options by applying land management planning or land environment planning principles – refer appendices for further information. Refer to industry good management practice guidelines

(e) A description of nutrient management practices including a nutrient budget for the farm enterprise calculated using the model OVERSEER® in accordance with the OVERSEER® use protocols, or using any other model or method approved by the Chief Executive Officer of Waikato Regional Council.

Provision	Standards - Methodology
Overseer Budget completed for the 2014/2015 and 2015/2016 years to ascertain N Reference Overseer Budgets completed to demonstrate a reduction in nitrogen leaching to a level below the 75%ile (where appropriate) Overseer Budgets completed to demonstrate no increase in nitrogen leaching (over a five year rolling average)	See Schedule B of the Proposed Waikato Regional Plan Change 1

(f) A description of cultivation management, including:

Provision	Standards / GMPs	Assessment Methodology
(i) The identification of slopes over 15 ° and how cultivation on them will be avoided; unless contaminant discharges to water bodies from that cultivation can be avoided; and *Cultivation means preparing the land for growing of pasture or crops, and the planting tending and harvesting of that pasture or crop – but excludes:* • *Direct drilling of seed* • *No-tillage practices* • *Re-contouring land* • *Forestry*	Greater emphasis on sites close to a waterway – where overland flows could transport contaminant into the waterway. No actual or potential contaminant losses to waterways from cultivated areas.	Measuring the angle of land: Using an inclinometer or smartphone with a suitable app, the angle is measured by standing at the bottom of the cultivated area and sighting the top of the cultivated area (irrespective of any intervening paddock or property boundaries). Apply farm systems management principles, or present options by applying land management planning or land environment planning principles – refer appendices for further information. Refer to industry good management practice guidelines
(ii) How the adverse effects of cultivation on slopes of less than 15 ° will be mitigated through appropriate erosion and sediment controls for each paddock that will be cultivated including by: (a) assessing where overland flows enters and exits the paddock in rainfall events; and (b) identifying appropriate measures to divert overland flows from entering the cultivated paddock; and	Greater emphasis on sites close to or immediately "upstream" of a waterway – where overland flows could transport contaminant into the waterway. No actual or potential contaminant losses to waterways from cultivated areas.	Methodology as per the description in the provision (opposite) • assessing where overland flows enters and exits the paddock in rainfall events; and • identifying appropriate measures to divert overland flows from entering the cultivated paddock; and • identifying measures to trap sediment leaving the cultivated paddock in overland flows; and

(c) identifying measures to trap sediment leaving the cultivated paddock in overland flows; and (d) maintaining appropriate buffers between cultivated areas and water bodies (minimum 5m setback). (g) A description of collected animal effluent management including how the risks associated with the operation of effluent systems will be managed to minimise contaminant discharges to groundwater or surface water. (h) A description of freshwater irrigation management including how contaminant loss arising from the irrigation system to groundwater or surface water will be minimised.		• maintaining appropriate buffers between cultivated areas and water bodies (minimum 5m setback). • A description of collected animal effluent management including how the risks associated with the operation of effluent systems will be managed to minimise contaminant discharges to groundwater or surface water. • A description of freshwater irrigation management including how contaminant loss arising from the irrigation system to groundwater or surface water will be minimised. Apply farm systems management principles, or present options by applying land management planning or land environment planning principles – refer appendices for further information. Refer to industry good management practice guidelines

3. A spatial risk map(s) at a scale that clearly shows:

    (a) The boundaries of the property; and
    (b) The locations of the main land uses[1] that occur on the property; and
    (c) The locations of existing and future mitigation actions to manage contaminant diffuse discharges; and
    (d) Any relevant internal property boundaries that relate to risks and mitigation actions described in this plan; and
    (e) The location of continually flowing rivers, streams, and drains and permanent lakes, ponds and wetlands; and
    (f) The location of riparian vegetation and fences adjacent to water bodies; and
    (g) The location of critical source areas for contaminants, as identified in 2 (c) above.

Use Landbase® or similar FEP mapping software

Use industry available GIS systems

Plot all risk areas on this map and link to part (4) actions and mitigations (below)

4. A description of the actions that will be undertaken in response to the risks identified in the risk assessment in 2 above (having regard to their relative priority) as well as where the mandatory time-bound actions will be undertaken, and when and to what standard they will be completed.

Expand and complete this table – use reference numbering or similar to link the Risks and actions to the Farm Plan map

Assessment result – RISK	Mitigations - Actions	Timing – Date action is due	Budget
As per WRC resource consent templates As per industry scheme guidelines outlined in Schedule 2 of the Proposed Waikato Regional Plan Change 1			

5. A description of the following:

(a) Actions, timeframes and other measures to ensure that the diffuse discharge of nitrogen from the property or enterprise, as measured by the five-year rolling average annual nitrogen loss as determined by the use of the current version of OVERSEER®, does not increase beyond the property or enterprise's Nitrogen Reference Point, unless other suitable mitigations are specified; or

(b) Where the Nitrogen Reference Point exceeds the 75th percentile nitrogen leaching value, actions, timeframes and other measures to ensure the diffuse discharge of nitrogen is reduced so that it does not exceed the 75th percentile nitrogen leaching value by 1 July 2026, except in the case of Rule 3.11.5.5.

Provision
Overseer Budget completed for the 2014/2015 and 2015/2016 years to ascertain N Reference Overseer Budgets completed to demonstrate a reduction in nitrogen leaching to a level below the 75%ile (where appropriate) Overseer Budgets completed to demonstrate no increase in nitrogen leaching (over a five year rolling average) **Nutrient Budgets completed as per Schedule B of the Proposed Waikato Regional Plan Change 1.**

Assessment result – RISK	Mitigations - Actions	Timing – Date action is due	Budget
As Identified in nutrient budgets and assessment of the farm system			

APPENDICES

Further information

Waikato Regional Council – For Farmers page
http://www.waikatoregion.govt.nz/forfarmers/

Farm Dairy Effluent Design Code of Practice
http://www.dairynz.co.nz/media/2793698/fde-design-standards-and-cop-2015.pdf

Sustainable Milk Plans
http://www.dairynz.co.nz/environment/in-your-region/waikato-environmental-policy/upper-waikato-sustainable-milk-project/

Dairy NZ Guide to Managing Farm Dairy Effluent
http://www.dairynz.co.nz/media/2832537/farmers-guide-to-managing-fde.pdf

Dairy Effluent Storage Calculator
http://www.dairynz.co.nz/environment/effluent/effluent-storage/dairy-effluent-storage-calculator-desc/

Dairy NZ Farm Enviro Walk
http://www.dairynz.co.nz/media/721533/FEW-checklist.pdf

Dairy NZ Riparian Planner Tool
http://www.dairynz.co.nz/environment/waterways/riparian-planner/

Waikato Regional Council Farm MENUs
http://www.farmmenus.org.nz/

Sustainable Dairying Water Accord
http://www.dairynz.co.nz/media/3286407/sustainable-dairying-water-accord-2015.pdf

Supply Fonterra Programme
https://www.fonterra.com/nz/en/sustainability+platform/sustainable+dairying/new+zealand/new+zealand

Pocket guide to determine soil risk for farm dairy effluent application
http://www.dairynz.co.nz/media/757892/fde_soil_risk_pocket_guide.pdf

Industry Agreed Good Management Practices Relating to Water Quality
http://www.ecan.govt.nz/publications/General/Industry_Agreed_GMPs_A5_Version2_Sept2015_FINAL.pdf

Land and Environment Planning Guidelines
http://www.beeflambnz.com/lep

Waikato Regional Council Farmers Guide to Permitted Activities
http://www.waikatoregion.govt.nz/PageFiles/1247/3892_Guide%20to%20permitted%20Activites%20Booklet_2014-WEB.pdf

Land Management on Waikato Dairy Farms
http://www.dairynz.co.nz/environment/land-and-nutrient/land-management-guides/

NZ Deer Farmers Landcare Manual
http://deernz.org/sites/dinz/files/NZ%20Deer%20Farmers%20Landcare%20manual%202012%20for%20web_0.pdf

NZ Landcare Trust Landcare Guide
http://www.landcare.org.nz/Landcare-Guide

Fertiliser Association Code of Practice for Nutrient Management
http://www.fertiliser.org.nz/Site/code_of_practice/default.aspx

Fertiliser Association Code of Practice for Fertiliser Application
http://www.fertiliser.org.nz/Site/code_of_practice/best_management_practices_considerations/fertiliser_application/default.aspx

Irrigation NZ Farm Environment Plan
http://irrigationnz.co.nz/news-resources/irrigation-resources/farm-plans-asm/

Foundation for Arable Research Farm Environment Plans https://www.far.org.nz/research/environment/farm_environment_plans

Overseer Nutrient Budgets
http://overseer.org.nz/

Farmax
http://www.farmax.co.nz/

NZ Pork Farm Environment Plan
http://www.nzpork.co.nz/nzporkservices/environmental-management
and http://www.nzpork.co.nz/images/custom/enviropork_manual.pdf

Horticulture NZ Erosion and Sediment Control Guidelines for Vegetable Production
http://www.hortnz.co.nz/assets/Uploads/Auckland-Waikato-ES-Control-Guidelines-1-1.pdf

Horticulture NZ Code of Practice for Nutrient Management
http://www.hortnz.co.nz/assets/Uploads/Code-of-Practice-for-Nutrient-Management-v-1-0-29-Aug-2014.pdf

NZ GAP
http://www.nzgap.org.nz/

Landcare Research S-Map
http://smap.landcareresearch.co.nz/home

NZ Soil Conservation Technical Handbook
https://www.mfe.govt.nz/sites/default/files/soil-conserv-handbook-jun01.pdf

Plant and Food Research, Trees for the Farm
http://www.poplarandwillow.org.nz/documents/Trees-for-the-Farm-Booklet.pdf

Waikato Regional Council Best Practice Guidelines for Waterway Crossings http://www.waikatoregion.govt.nz/PageFiles/4998/TR0625R.pdf

Visual Soil Assessment
http://www.landcareresearch.co.nz/publications/books/visual-soil-assessment-field-guide/download-field-guide

Spreadmark Code of Practice
http://www.ecan.govt.nz/publications/Plans/hinds-spreadmark-cop.pdf

SURFACE RELIEF

- Observe the surface relief (smoothness) of the paddock at the end of the winter and compare it with the three photographs and criteria given in Plate 24.

Although soils are most susceptible to treading damage (pugging) during wet winter months, observations of surface relief at any time of the year will give useful information on damage caused by past grazing and its likely effects on soil quality.

GOOD CONDITION VS = 2
Surface is relatively smooth and unbroken

MODERATE CONDITION VS = 1
Surface terrain is somewhat broken up and incised by occasional heavy treading events but it is not difficult to walk over

POOR CONDITION VS = 0
Surface is very broken and deeply incised by severe repeated treading. The terrain is difficult to walk across and care must be taken to avoid twisting ankles

PLATE 24 Visual scoring (VS) of surface relief under pasture

Surface relief shows the severity of pugging under stock treading, and can indicate structural damage below the surface. Wet soils can pug severely under intensive grazing by heavy weight animals when the load-bearing capacity of the soil is insufficient to support the weight of the animal. This damages the soil structure and reduces the pores in the soil, which are important for water, nutrient and air movement, and root penetration. Infiltration rates and the movement of water through the soil decreases, increasing runoff, soil erosion, and the risk of flash flooding. Very broken and deeply incised soil as a result of severe pugging can also damage the pasture root system and increase the area of bare ground. It can further induce surface ponding and anaerobic conditions, reducing pasture utilisation and impairing pasture growth as a result of poor shoot growth, fewer tillers and poor plant vigour (see p. 28). In addition, the decay and turnover of organic matter is impaired by the production of methane, alcohol, and aldehydes as described on p. 29.

AREA OF BARE GROUND

- Assess the area of bare ground in winter or early spring. Compare the surface of the ground with the three photographs and criteria given in Plate 44. If there is canopy closure due to good growth, part the pasture with your hands and score at ground level. An assessment of an area of bare ground after a long dry period will show how much pasture has died from lack of moisture.

GOOD CONDITION VS = 2
Pasture covers all or most of the surface area. Surface cover is ≥ 80 %

MODERATE CONDITION VS = 1
Pasture shows significant areas of bare ground and sporadic growth with the ingression of weeds and white clover caused by treading damage. Surface cover is > 40 % and < 80%

POOR CONDITION VS = 0
Large areas of bare ground (≤ 20 % cover) occur because of treading damage and the reduction in density and vigour of the pasture. White clover and less desirable pasture species and weeds may have invaded degraded and bare areas

PLATE 44 Visual scoring (VS) of area of bare ground

In addition to stock camping, disease, insect pests and drought effects, bare ground is formed by the physical churning up of the soil from treading and pugging. This churning causes leaf and stem crushing, reduced tiller density, the uprooting or burial of plants, and root damage, all of which reduce tiller numbers and pasture density, vigour and growth. Weeds and less desirable pasture species can invade the resulting gaps, further reducing pasture production. Like surface relief, the area of bare ground can be a good indicator of below-ground damage.

Bare ground on fields with a slope can increase their susceptibility to water erosion. Good pasture cover on the other hand, and its below-ground root system, returns organic matter to the soil and promotes soil life including earthworm numbers and activity. The physical action of the roots and soil fauna, and the glues they produce promote the development of soil structure, soil aeration and drainage. As a result, infiltration rates and the movement of water through the soil increases, decreasing runoff, soil erosion, and the risk of flash flooding. Pasture cover on sloping ground also reduces soil erosion by intercepting high impact raindrops, and minimising rain-splash and saltation. Moreover, it acts as a sponge, retaining rainwater longer so that it infiltrates into the soil. The root system of good pasture cover further reduces soil erosion by stabilising the soil surface, holding the soil in place during heavy rainfall events. As a result, water quality downstream is improved, with lower sediment loading and lower nutrient and coliform content. The ground surface needs to have at least 70% cover to give good protection; ≤ 30% cover provides poor protection.

Good ground cover (with a high leaf-area index) intercepts and absorbs a large amount of carbon dioxide (CO_2) as it escapes from the soil. The greater photosynthetic uptake of CO_2 increases pasture production and decreases the amount of CO_2 emitted into the atmosphere, thus decreasing the level of greenhouse gas emissions.

BUSINESS DETAILS

Farm name	
Address	
Legal description and farm identifier	
Owner/s	
Phone	
Mobile	
Email	
Manager	
Phone	
Mobile	
Email	
Who is responsible for implementation of this plan?	
Contact information (if different from above)	
Phone	
Mobile	
Email	
Resource consents held in relation to this business (list consent numbers)	

FARM BUSINESS DESCRIPTION

Describe the farm enterprise and the size of the operation (hectares)

Outline the goals and objectives for the business
• • • • • • • • •

Describe the existing farm management policy including:	
Stock types and classes:	
•	•
•	•
•	•
•	•
•	•
•	•
•	•

Numbers wintered:	
•	•
•	•
•	•
•	•
•	•
•	•
•	•

Feed supplement inputs:
• • •

Fertiliser inputs:
• • • • •

Winter management:

Annual and permanent crops grown:	
•	•
•	•
•	•

LAND MANAGEMENT UNITS

Land Management Unit	Description	Strengths	Weaknesses and risks	Uses and Management
1.	•	•	•	•
2.	•	•	•	•
3.	•	•	•	•
4.	•	•	•	•
5.	•	•	•	•
6.	•	•	•	•
7.	•	•	•	•
8.	•	•	•	•

NITROGEN REFERENCE POINT

Overseer calculates nitrogen leaching for the 2014/15 season as ..... kg N/ha/year.
Overseer calculates nitrogen leaching for the 2015/16 season as ..... kg N/ha/year.

FARM MAPS

ENVIRONMENTAL OBJECTIVES & PLANNED PRACTICES

Objective One – Nutrient Management To maximise nutrient use efficiency while minimising nutrient losses to water	
What practices help you achieve objective one?	How can you demonstrate this?

Issue/Risk	Significance (L, M, H)	Response	Timeframe	Who is responsible?

INSERT PHOTOS BELOW RISKS IDENTIFIED with caption underneath referring to the risk

Objective Two – Soil Management To maintain or improve the physical and biological condition of soils in order to minimise the movement of sediment, phosphorus and other contaminants to waterways.	
What practices help you achieve objective one?	**How can you demonstrate this?**

Issue/Risk	Significance (L, M, H)	Response	Timeframe	Who is responsible?

Objective Three – Wetlands and riparian Management To maintain or improve wetlands and water margins to maximise nutrient filtering and enhance biodiversity	
What practices help you achieve objective one?	How can you demonstrate this?

Issue/Risk	Significance (L, M, H)	Response	Timeframe	Who is responsible?

Objective Four – Livestock Management To manage wetlands and water bodies so that stock are excluded from water to avoid damage to the bed and margins of a water body, and to avoid the direct input of nutrients, sediment, and microbial pathogens.	
What practices help you achieve objective one?	How can you demonstrate this?

Issue/Risk	Significance (L, M, H)	Response	Timeframe	Who is responsible?

Objective Five – Offal Pits, Silage Pits and Waste Management To manage the number and location of offal pits, silage pits and waste to minimise risks to human health and soils and water quality.	
What practices help you achieve objective one?	How can you demonstrate this?

Issue/Risk	Significance (L, M, H)	Response	Timeframe	Who is responsible?

Objective Six – Cropping Management To manage the preparation, harvest and grazing of the crop to avoid the movement of sediments and other contaminants to waterways and to avoid or mitigate soil compaction	
What practices help you achieve objective one?	**How can you demonstrate this?**

Issue/Risk	Significance (L, M, H)	Response	Timeframe	Who is responsible?

Objective Seven – Irrigation Management To operate irrigation systems (if applicable) that are capable of applying water efficiently and to implement management practices that ensure actual use of water is monitored and is efficient.	
What practices help you achieve objective one?	**How can you demonstrate this?**

Issue/Risk	Significance (L, M, H)	Response	Timeframe	Who is responsible?

COSTS OF PLANNED PRACTICES

Practice	Description	Total Cost

APPENDICES

Overseer Nutrient Budget for 2014/15

Overseer Nutrient Budget for 2015/16

LandBase Risk Assessment