Healthy Rivers Plan Change Technical Support for Horticulture New Zealand's Submission

Horticulture New Zealand

Values and Current Allocation of Responsibility for Contaminant Discharges

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Executive Summary

The Proposed Healthy Rivers Plan Change has been developed to give effect to the Vision and Strategy for the Waikato River and the National Policy Statement for Freshwater Management 2014 (NPS FM). It requires regional councils to formulate freshwater objectives that give effect to the objectives of the NPS FM and describe the condition that Waikato regional communities want for fresh water in the future. The NPS FM process included identifying freshwater management units (FMU) and the values for each, and then choosing relevant water quality attributes and attribute states that can be monitored over time.

The values and water quality attributes wereprepared by the Collaborative Stakeholder Group (CSG) and consist of Mana Atua (intrinsic values) and Mana Tangata (use values) of the water. The attributes that the plan focuses on are the following water quality indicators: nitrogen, phosphorus, chlorophyll, sediment and *E.coli.*

The objective of this report is to provide technical support for amendments to the Proposed Waikato Regional Plan Change 1 – Waikato and Waipa River Catchments (Dated 3 December 2016) (WRC, 2016) (‘PC1’) that would achieve the Mana Atua and the Mana Tangata values of the Plan in pragmatic and equitable manner.

Modelling limitations

The water quality models developed for the Healthy Rivers process include numerous limitations including limitations in the underlying contaminant yield and landuse datasets. Our report does not seek to review the validity of the modelling undertaken for the Healthy Rivers process.

We have used some of the model inputs and outputs to discuss the assumed relative contribution of diffuse discharges from the primary sector and discussed some of the limitations of the modelling.

In our view it is vital that decision makers are aware of the limitations of the water quality modelling used to inform policy development.

Horticulture land use and values

Section 3 of this report summarises the impact of horticultural landuse in the catchment on the attributes identified by the CSG, and the corresponding effect that this has on values identified in PC1.

In total, horticultural land occupies 0.6% of the total area of the Waikato River catchment, and accounts for 2.5% of the Total Nitrogen (TN) loads and 0.9% of the Total Phosphorous (TP) load in the overall catchment. The contribution of horticulture land to sediment loads predicted from each sub-catchment is also very low. The sediment concentrations in the Lower Waikato are influenced by the inflow of the Waipa River at Ngaruawahia, the Whangape Lake Catchment, the Opuatia catchment, and the Whangamarino River. There is also a marked increase in chlorophyll *a* concentration between Huntly-Tainui and Tuakau, which is in response to the inflows from the hypertrophic riverine lakes; Lake Whangape and Lake Waikare.

There is a decreasing water clarity trend throughout the Waikato catchment which generally reflects the increasing concentrations of other constituents that influence it, including nitrogen, phosphorous, sediment and chlorophyll *a*. Environmental mitigation programs on horticultural properties are very focused on ways to reduce firstly sediment and phosphorus discharges closely followed by nitrogen discharges. Furthermore the majority of the horticultural property in the Waikato is in the Lower Waikato catchment, meaning the impact of phosphorus runoff and nitrogen leaching from horticultural enterprises covers a small proportion of the overall Waikato catchment. Horticulture also has a minimal impact on E.coli loads in the overall Waikato River catchment and contributes less E.coli yields compared with dairy, sheep and beef and urban land use.

Horticulture may have higher nitrogen (N) leaching values but a very small N load overall when compared by land area to dairy. Policy 3 g states that ‘*the degree of reduction in diffuse discharges of nitrogen, phosphorus, sediment and microbial pathogens is proportionate to the amount of current discharge (those discharging more are expected to make greater reductions), and the scale of water quality improvement required in the sub-catchment*

PC1 outlines that changing landuse to commercial vegetable production is a non-complying activity. However Horticulture New Zealand thinks it should be provided for as a restricted discretionary consent for new commercial vegetable production where it can be demonstrated there is an overall reduction across all four contaminants considered in PC1. The assessment of an application for new commercial vegetable production should allow recognition for any reductions in bacterial contamination as a result of the conversion of land. And in some cases, if it can be demonstrated that the land use change results in a similar or lesser effect on core values protected by the Vision and Strategy; an increase in discharges of nitrogen should be provided for.

Leaching rate assumptions in water quality modelling

Nitrogen is one of the four contaminants that are a focus of this plan. All four contaminants affect the values. The introduction of a nitrogen reference point places an inequitable emphasis on one contaminant. It is the view of Horticulture New Zealand that a balanced approach needs to be taken to contaminant reductions across all the 4 contaminants.

Nitrogen mitigation and the influence of Variation 6

Discharges of nutrients can be estimated to increase without sufficient irrigation to raise crop yields; however surface water takes for crop irrigation are likely to be reduced to phase-out overallocation in the catchment. This is due to past decisions regarding the management of water quantity (e.g. Variation 6 and the Watercare application). This will remove a key mitigation for commercial vegetable growers seeking to reduce discharges using efficient irrigation unless alternative sources of water can be found.

Offset mitigation

The Whangape Lake Catchment, the Opuatia catchment, and Lake Waikare are hypertrophic riverine lakes and discharge sediment and phytoplankton into the Lower Waikato catchment. These sub-catchments have the potential to impact on the ability of the downstream community to achieve targets for contaminant reduction or restoration of values to achieve The Vision and Strategy for the Waikato River.

PC1 provides for offset to be used for point source discharges. The discharge from Lake Waikare into the Whangamarino wetland is a consented point source and therefore this policy could apply to mitigating the impact of the flood protection scheme on the water quality discharged from Lake Waikare.

Horticulture New Zealand seeks an offset measure for horticulture in an alternative location or locations to the non-point source discharge, for the purpose of ensuring positive effects on the environment to lessen any residual adverse effects of the discharge(s) that will or may result from allowing the activity

Farm Management Plans

Horticulture New Zealand seeks amendments to the Farm Management Plan Schedule1; part of Horticulture New Zealand's issue with the current plan is the lack of focus on managing losses from cultivation practices across broader rural land than that occupied by the vegetable sector. Horticulture New Zealand considers that a range of practices could be mandated across cultivated land.

In the Mangaone catchment Horticulture makes up 2% of the landuse, bare earth makes up 5% of the land within the catchment. Our estimate is the horticultural landuse makes up approximately 30% of the bare earth within the catchment, which means that 70% of the bare earth is within other landuses

Managing the effect of soil erosion from cultivated land, will require measures are implemented on all landuses, including horticultural land.

Sub-catchment allocation

The Horticulture New Zealand submission proposes a change to Objective 3 to add the *achievement of the contaminant load reduction targets specified for each subcatchment in Table 3.11.*

We requested catchment loads that were associated with the 10 year water quality targets from Waikato University, at the time of submission these loads have not been made available, however we know these loads were developed as part of the Healthy Rivers modelling, and could be supplied along-side the water quality concentration targets.

We have attempted to calculate loads for TN, Nitrate, TP and E.coli, for those sites where it was possible, the calculations we have undertaken include a number of assumptions. These loads should be updated with the modelled loads. It was not possible to calculate a catchment load for Chl a from the data available.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to review available technical reports undertaken by third parties for the Proposed Waikato Regional Plan Change 1 – Waikato and Waipa River Catchments and assess the information in support of a submission on behalf of Horticulture New Zealand on the plan change in accordance with the scope of services set out in the contract between Jacobs and Horticulture New Zealand (‘the Client’). That scope of services, as described in the Jacobs proposal dated 16 December 2016, was developed with the Client.

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1. Introduction

The objective of this assessment is to provide technical support for amendments to the Proposed Waikato Regional Plan Change 1 – Waikato and Waipa River Catchments (Dated 3 December 2016) (WRC, 2016) (‘PC1’) that would achieve the Mana Atua and the Mana Tangata values of the Plan in pragmatic and equitable manner.

The analysis draws on existing published science for testing the proposed case studies and these results are discussed in the context of the Healthy Rivers water quality modelling results. Wherever possible we have utilised the Healthy Rivers data sets to test scenarios using the Healthy Rivers water quality modelling methodology.

Section 2 of this report summarises the values identified in the Healthy Rivers Plan and Section 3 discusses the impact of horticultural landuse in the catchment on these values. The discussion covers all the values, and considers the link between water use and water quality and focuses on the following water quality indicators: nitrogen, phosphorus, chlorophyll, sediment and *E.coli*.

Section 4 discusses the PC1 allocation of responsibility for contaminant discharges, and provides four cases studies to provide focus for the relief sought by the Horticultural New Zealand submission. The case studies include:

- Leaching assumptions focused on horticulture and dairy leaching
- Nitrogen mitigation and focused on the influence of Variation 6 and the Watercare abstraction
- Offset mitigation and the potential for offset to be used for the flood protection scheme point source discharges and Horticultural diffuse discharges
- Farm Management Plans and in particular managing sediment form cultivated land.

Section 4.5 includes a sub-catchment load table. Horticulture New Zealand’s submission includes seeking the ability for people to manage diffuse discharges on a sub-catchment scale.

2. Summary of values and targets

The Vision and Strategy for the Waikato River is the primary direction setting document for the Waikato and Waipa Rivers, and regional and district plans must give effect to the Vision and Strategy. PC1 gives effect to the Vision and Strategy, whereas the current Regional Plan objectives do not currently fulfil the Vision and Strategy. Furthermore, the National Policy Statement for Freshwater Management 2014 (NPS FM) requires regional councils to formulate freshwater objectives that give effect to the objectives of the NPS FM and describe the condition that Waikato regional communities want for fresh water in the future. The NPS FM process included identifying freshwater management units (FMU) and the values for each, and then choosing relevant water quality attributes and attribute states that can be monitored over time.

The values to be enforced by PC1 were prepared and supported by the Collaborative Stakeholder Group (CSG). The final list of values and uses were finalised on 9-10 August 2015 and consist of the following:

- Mana Atua is the **intrinsic** values of water including mauri (the principle of life force), wairua (the principle of spiritual dimension), and mana (the principle of prestige, authority of the water and its ecosystems in their natural state).
- Mana Tangata refers to the **use** values of water from its use for economic, social, spiritual and cultural purposes.
- Together these represent Te Mana o te Wai. Te Mana o te Wai represents the relationship between the health and mauri of the water and the health and mauri of the environment which is integral to the social, cultural, economic and environmental well-being of communities (MfE, 2014).

Mana Atua in PC1 is made up of 3 key values and Mana Tangata is made up of 10 key values, which can be further grouped under cultural and social use values, and economic use values (see Table 2-1 below).

Table 2-1 : Key values listed in the Proposed Plan.

Values	Description
Mana Atua Values	
History	Each River Iwi has their own unique and intergenerational relationship with the rivers.
Ecosystem Health	The Waikato and Waipa catchments support resilient freshwater ecosystems and healthy freshwater populations of indigenous plants and animals.
Natural Form and Character	Retain the integrity of the rivers within the landscape and its aesthetic features and natural qualities for people to enjoy.
Mana Tangata Values	
Wai tapu (sacred waters)	Area of water body set aside for spiritual activities that support spiritual, cultural and physical wellbeing.
Geothermal	A valued resource that is naturally gifted to sustain certain activities (meeting spiritual and physical needs).
Mahinga kai and fishing	The ability to access the Waikato and Waipa and their tributaries to gather sufficient quantities of kai (food) that is safe to eat and meets the social and spiritual needs of their stakeholders.
Human health for recreation	The rivers are a place to swim and undertake recreation activities in an environment that poses minimal risk to health.
Transport and tauranga waka	All communities can use the rivers to pilot their vehicles and waka and navigate to their destinations.
Primary production	The rivers support regionally and nationally significant primary production in the catchment (agricultural, horticultural, forestry). These industries contribute to the economic, social and cultural wellbeing of people and communities, and are the major component of wealth creation within the region. These industries and associated primary production also support other industries and communities within rural and urban

Values	Description
	settings.
Water supply	The rivers provide for community water supply, municipal supply, drinkable water supply and health.
Commercial, municipal and industrial use	The rivers provide economic opportunities to people, businesses and industries e.g. tourism; assimilative capacity for discharges, wastewater disposal, flood and stormwater.
Electricity generation	The river provides for reliable, renewable hydro and geothermal energy sources and thermal generation, securing national self-reliance and resilience.
Mitigating flood hazards	Flood management systems protect land used and inhabited by people.

From the above values that were developed, three core values were identified: **human health for recreation, ecosystem health,** and **mahinga kai**. For each value, the expert panel of the Technical Leaders Group (TLG) reviewed attributes contained in the NPS-FM National Objectives Framework (NOF) and assessed how they might be applied to the Waikato-Waipa catchment. The panel also provided advice on other attributes deemed relevant to the measurement of the three values in FMUs in the catchment (i.e. if they were within scope and related to the four contaminants) (WRC, 2016a). This process is outlined in more detail in Scarsbrook (2016). The agreed attributes are based on the NOF for nitrate, ammonia and *E. coli*; on the NOF for phytoplankton (chlorophyll *a*), total nitrogen and total phosphorus for lakes except that they are also to be applied to the main stem of the Waikato River (in recognition of the hydro-lakes); and on a proposed clarity attribute developed by the TLG to address sediment with input from the CSG to define appropriate bands (WRC, 2016).

The impact that relevant water quality attributes have on the three core values are outlined in the table below (Table 2-2). This is based upon the information outlined in the NPS FM (Appendix 2 – Attribute tables). A summary is outlined in the points below:

- Human Health for Recreation is measured against concentrations of *E. coli* (in lakes, rivers, and lake-fed rivers), chlorophyll *a* (lakes and lake fed rivers) and planktonic cyanobacteria (lakes only), and levels of clarity (lakes, rivers, and lake-fed rivers). Visual clarity is measured as the horizontal sighting range of a black disc under base flow conditions. The key contributors to visual clarity are considered to be yellow substance, phytoplankton (floating algae) and fine sediment.
- Ecosystem Health is measured against trophic state indicators such as concentrations of chlorophyll *a* (lakes and lake-fed rivers) and planktonic cyanobacteria (lakes only), TP and TN concentrations (lakes and lake-fed rivers), and nitrate-N and ammoniacal N (as toxicants in rivers and lake-fed rivers).
- Mahinga kai is measured against concentrations of *E. coli* (in lakes, rivers, and lake-fed rivers) and chlorophyll *a* (lakes and lake-fed rivers) and planktonic cyanobacteria (lakes only).

Table 2-2 : The chosen water quality attributes and the corresponding effect that each have on the three core values identified in PC1.

Values	Description	Total Nitrogen[1], Nitrate[2], Ammonia[2]	Total Phosphorus[1]	Clarity[3]	*E. coli*[3]	Chlorophyll *a*[1] Planktonic cyanobacteria[4]
Human health for recreation ('Swimmability')	The rivers are a place to swim and undertake recreation activities in an environment that poses minimal risk to health.	**Not directly used to measure the state of this value.** However, elevated nutrients and increased residence time can lead to excessive algal and/or plant growth may limit visibility.	**Not directly used to measure the state of this value.** However, elevated nutrients and increased residence time can lead to excessive algal and/or plant growth may limit visibility.	Reductions in water clarity which may limit visibility resulting in injury. Water clarity influences people's choice of where to swim, but does not directly affect human health (Scarsbrook, 2016).	Pathogens such as E. coli are harmful to human health. People can be exposed to a risk of infection from contact with water during activities and with occasional immersion and some ingestion of water (such as wading and boating). (MfE, 2014).	Planktonic cyanobacteria - Potential health risks (eg, respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with fresh water) (MfE, 2014).
Ecosystem Health	The Waikato and Waipa catchments support resilient freshwater ecosystems and healthy freshwater populations of indigenous plants and animals.	Trophic state - Ecological communities may become degraded due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as the loss of oxygen in bottom waters of deep lakes (MfE, 2014). Toxicity – Nitrate and ammonia may impact on growth of multiple species and approach acute impact level (i.e. risk of death) for sensitive species at higher concentrations (MfE, 2014).	Trophic state - Ecological communities may become degraded due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as the loss of oxygen in bottom waters of deep lakes (MfE, 2014).	**Not directly used to measure the state of this value.** Affects ecosystem health either through deposition and smothering of biota or through the clarity reductions altering the success of visual feeders such as birds and fish (Hughes, 2015; Yalden & Elliot, 2015).	**Not directly used to measure the state of this value.**	Trophic state - Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat (MfE, 2014).
Mahinga kai	The ability to access the Waikato and Waipa and their tributaries to gather sufficient quantities of kai (food) that is safe to eat and meets the social and spiritual needs of their stakeholders.	**Not directly used to measure the state of this value.** Ecological communities may become degraded due to elevated nutrients and increased residence time leading to excessive algal and/or plant growth, as well as the loss of oxygen in bottom waters of deep lakes (MfE, 2014).	**Not directly used to measure the state of this value.** Ecological communities may become degraded due to elevated nutrients and increased residence time leading to excessive algal and/or plant growth, as well as the loss of oxygen in bottom	**Not directly used to measure the state of this value.** Affects ecosystem health either through deposition and smothering of biota or through the clarity reductions altering the success of visual feeders such as birds and	Pathogens such as E. coli are harmful to human health	Planktonic cyanobacteria - Potential health risks (eg, respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with fresh water) (MfE, 2014).

Values	**Description**	**Total Nitrogen[1], Nitrate[2], Ammonia[2]**	**Total Phosphorus[1]**	**Clarity[3]**	***E. coli*[3]**	**Chlorophyll *a*[1] Planktonic cyanobacteria[4]**
			waters of deep lakes (MfE, 2014).	fish (Hughes, 2015; Yalden & Elliot, 2015).		

Notes:

1. TN, TP and chlorophyll *a* (phytoplankton) attributes apply to lakes but also over the entire length of the main stem of the Waikato River from Taupo Gates to Port Waikato. This recognises that the Waikato River is lake-fed, the eight hydro-dam affected reaches function as lakes and phytoplankton growth occurs along the entire river.
2. Nitrate and ammonia attributes apply to rivers, and lake-fed rivers.
3. Water clarity and *E. coli* attributes apply to lakes, rivers, and lake-fed rivers.
4. Planktonic cyanobacteria attribute applies to lakes only.

3. Horticulture land use and value attributes

The three core values, **human health for recreation**, **ecosystem health**, and **mahinga kai**, have associated water quality attributes that directly or indirectly measure their corresponding effects. This section will discuss these water quality attributes including their current measured status in the Waikato River, the short and long term water quality targets set in PC1, and the modelled yield contributions of horticultural land use to these attributes at a subcatchment scale throughout the Waikato River catchment.

In the following subsections each water quality attribute is discussed in greater detail at the subcatchment scale (linked to monitoring sites) and in relation to horticultural land use. Figure 3.1 on the following page shows the location of the monitoring sites associated with each subcatchment along the Waikato River, from the source at Lake Taupo to the mouth at Port Waikato.

Sites appear in order from upstream to downstream as follows: Ohaaki, Ohakuri, Whakamaru, Waipapa, Narrows, Horotiu Br, Huntly-Tainui Br, Mercer Br, Tuakau Br, and Port Waikato. Port Waikato does not have measured water quality data or water quality targets listed in PC1.

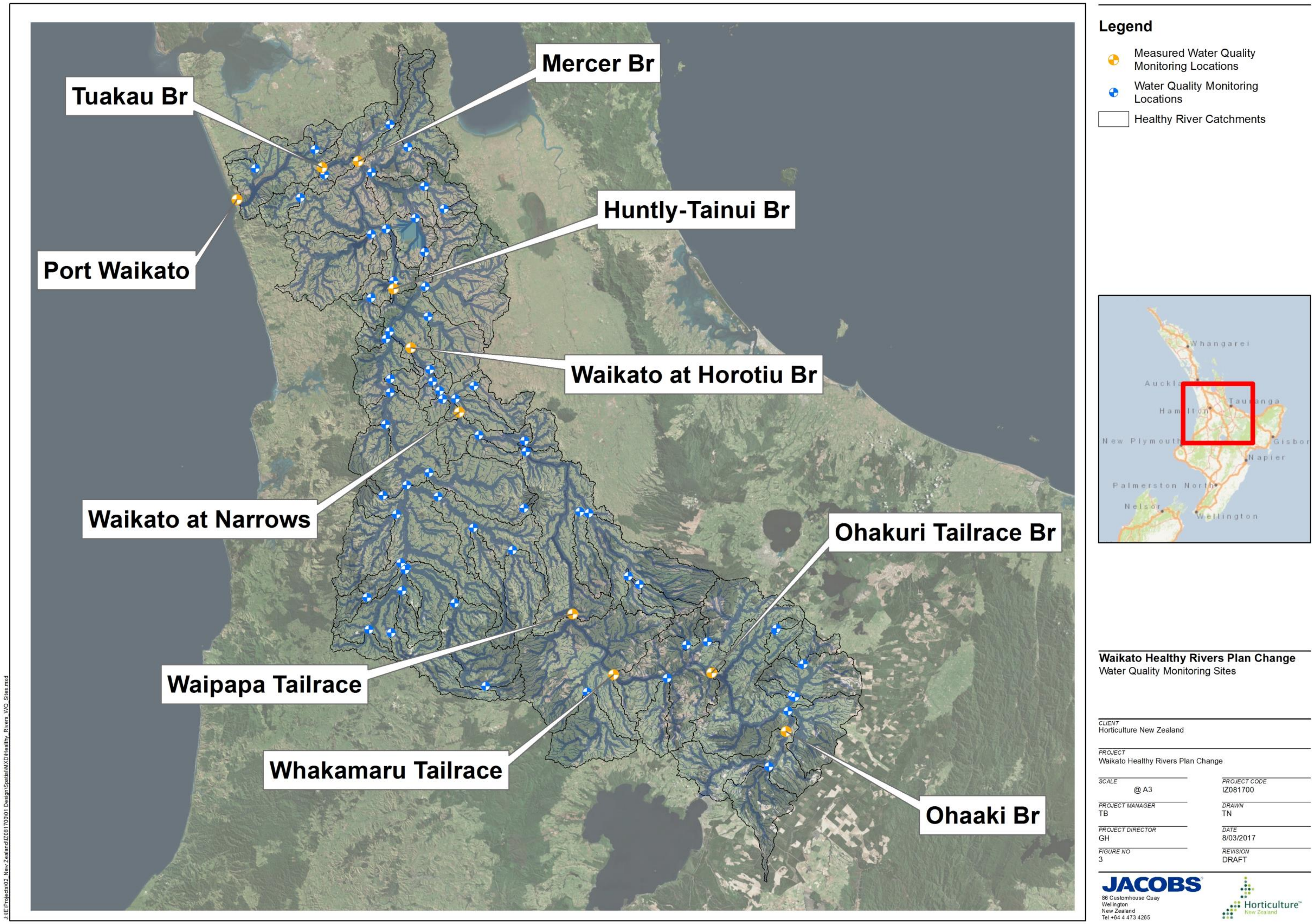

Figure 3.1: Water quality monitoring sites.

3.1 Nitrogen

Total nitrogen (TN) is a measure of the state of ecosystem health, and can in-directly impact on the state of the water body for human health for recreation in respect to the influence of nitrogen on chlorophyll *a* and the impact of chlorophyll *a* on clarity.

In the nutrient modelling undertaken for the Healthy Rivers process, horticulture had the highest nitrogen leaching value compared to all other land uses (see the table in Section 4.1 on pg. 22 of this report).

PC1 provides water quality targets at the subcatchment scale for the short term (10 years) and long term (80 years), the short term target being 10% of the long term target. These targets have been based on the measured median values at those sites, with the aim to improve water quality within the 10 and 80 year timeframes. These targets are listed alongside the median measured TN values (2010 to 2014) for Waikato River monitoring sites in Table 3-1 (listed upstream to downstream) and graphed in Figure 3.2 on the following page.

Median TN concentrations in the upper catchments measured at Waikato at Ohaaki with a median value of 0.134 mg/L increase almost five fold to 0.595 mg/L at Waikato at Tuakau Bridge.

Table 3-1: 2010 – 2014 median measured TN values for each Waikato River monitoring site and associated short and long term water quality targets from PC1.

HRWO sub-catchment monitoring sites	TN median measured values (mg/L)	WQ targets (mg/L)	
		Short Term	Long Term
Waikato at Ohaaki	0.134	0.134	0.134
Waikato at Ohakuri	0.211	0.206	0.160
Waikato at Whakamaru	0.271	0.260	0.160
Waikato at Waipapa	0.336	0.318	0.160
Waikato at Narrows	0.41	0.404	0.350
Waikato at Horotiu Br	0.441	0.432	0.350
Waikato at Huntly-Tainui Br	0.585	0.562	0.350
Waikato at Mercer Br	0.662	0.631	0.350
Waikato at Tuakau Br	0.595	0.571	0.350

These values are graphed and displayed in Figure 3.2 along the approximate location of other major waterbodies draining to the Waikato River in relation to monitored water quality sites; the hydro lakes and the Waipa River.

Median TN concentrations steadily increase from Ohakuri to Horotiu, followed by a marked increase between Horotiu and Huntly-Tainui Br, which is also where the Waikato and Waipa Rivers meet, increasing still between Huntley-Tainui and Mercer, which is also where the Whangamarino Wetland discharges to the Waikato River, and a decrease in concentrations between Mercer and Tuakau Br. Overall, the median concentrations measured from Ohaaki increase three fold by Horotiu, and almost five fold by Mercer Br.

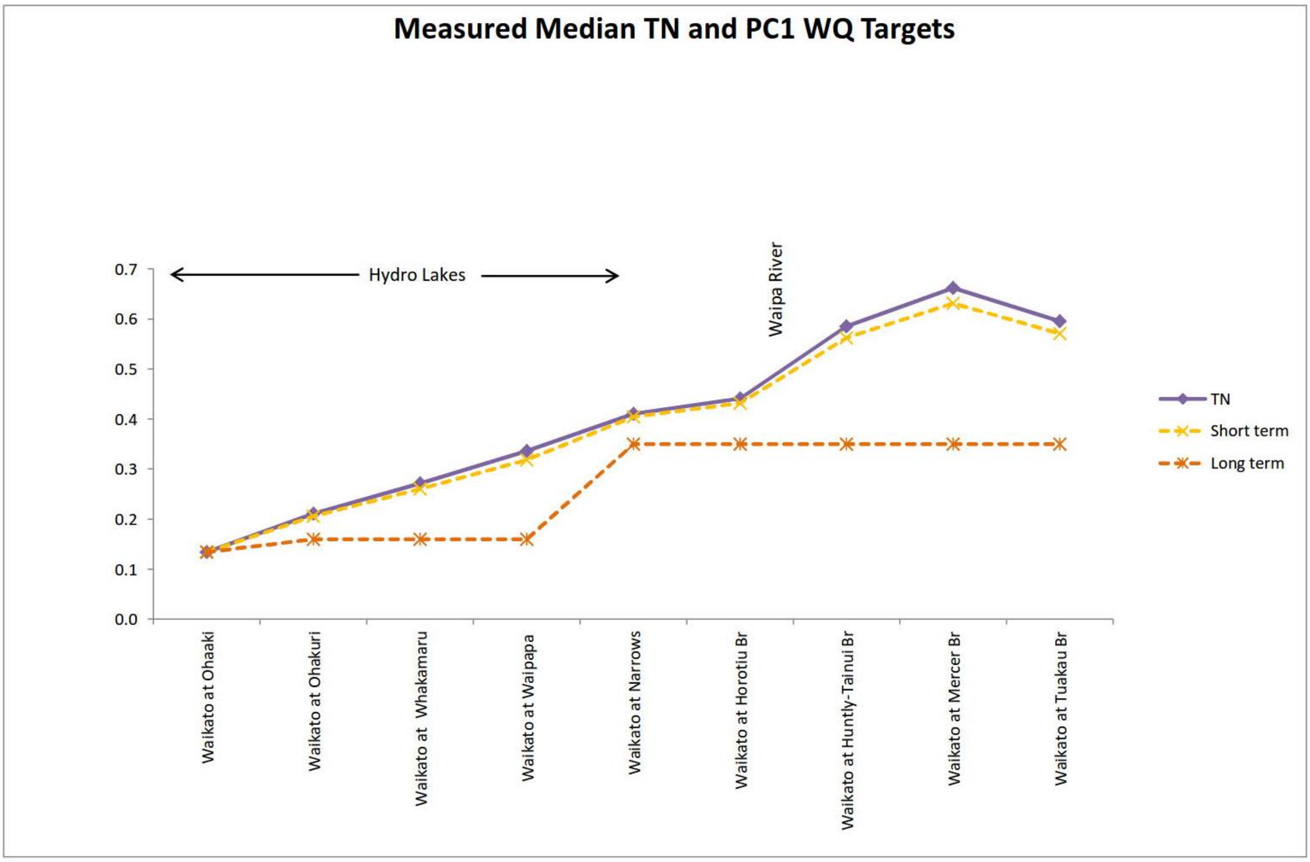

Figure 3.2: Graph of Total nitrogen measured median values (2010-2014) and associated short term and long term water quality targets from PC1.

Based on data provided by NIWA, in total, horticultural land occupies 0.6% of the total area of the Waikato River catchment, and accounts for 2.6% of the TN loads in the overall Waikato River catchment. Figure 3.3 on the following page illustrates the percentage contribution of TN loads from horticulture per subcatchment. Pie charts illustrating the proportion of horticulture N loads in each subcatchment compared to other land use types are provided in Appendix B and C.

The majority of the horticultural property in the Waikato is in the lower catchment of the Waikato River, meaning the impact of nitrogen leaching from horticultural enterprises covers a small proportion of the overall Waikato River catchment.

Figure 3.3 illustrates the percentage of the nitrogen load attributed to horticulture used in the NIWA water quality modelling. (Semadeni-Davies, September 2015). Note the NIWA modelling simplified the landuse assumptions compared with landuse layer supplied to Jacobs by NIWA. In some catchments no horticulture was assumed in the nutrient modelling, where the landuse layer indicates horticulture is present.

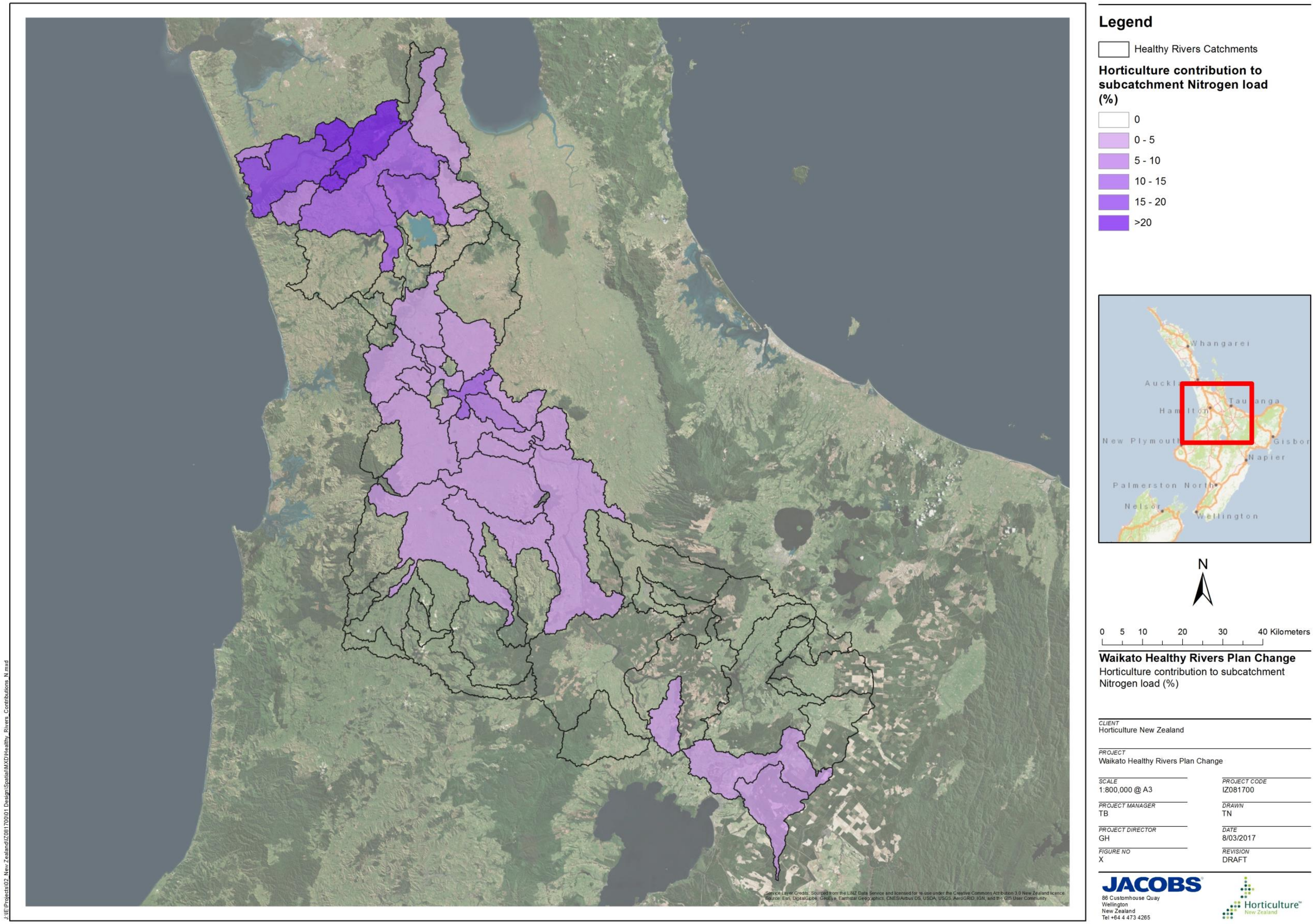

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Figure 3.3: Contribution of unattenuated nitrogen loads from horticulture land use on a subcatchment scale.

3.2 Phosphorous

Like nitrogen, phosphorous (P) is used to measure the state of the ecosystem health and can in-directly impact on the state of the water body for human health for recreation in respect to the influence of phosphorus on phytoplankton biomass and therefore chlorophyll *a* concentrations, and the impact of chlorophyll *a* on clarity.

PC1 short term (10 years) and long term (80 years) water quality targets for each subcatchment scale are based on the measured median values at those sites. These targets are listed alongside the median measured total phosphorous (TP) values for Waikato River monitoring sites from 2010 to 2014 in Table 3-2 and graphed in Figure 3.4.

Measured median TP concentrations in the upper catchments at Waikato at Ohaaki, with a median value of 0.010 mg/L, increase over fivefold to 0.053 mg/L at Tuakau Bridge. This increase is of the same magnitude as we observed for TN.

Table 3-2: 2010 – 2014 median measured TP values for each Waikato River monitoring site and associated short and long term water quality targets from PC1.

HRWO sub-catchment	Median measured values 2010-2014 (mg/L)	WQ targets - Median TP (mg/L)	
	TP	Short Term	Long Term
Waikato at Ohaaki	0.010	0.010	0.010
Waikato at Ohakuri	0.017	0.017	0.017
Waikato at Whakamaru	0.020	0.020	0.020
Waikato at Waipapa	0.025	0.025	0.020
Waikato at Narrows	0.028	0.028	0.020
Waikato at Horotiu Br	0.036	0.034	0.020
Waikato at Huntly-Tainui Br	0.045	0.043	0.020
Waikato at Mercer Br	0.052	0.049	0.020
Waikato at Tuakau Br	0.053	0.050	0.020

These values are graphed and displayed in Figure 3.4 with the approximate location of other major waterbodies draining to the Waikato River in relation to monitored water quality sites; the hydro lakes and the Waipa River.

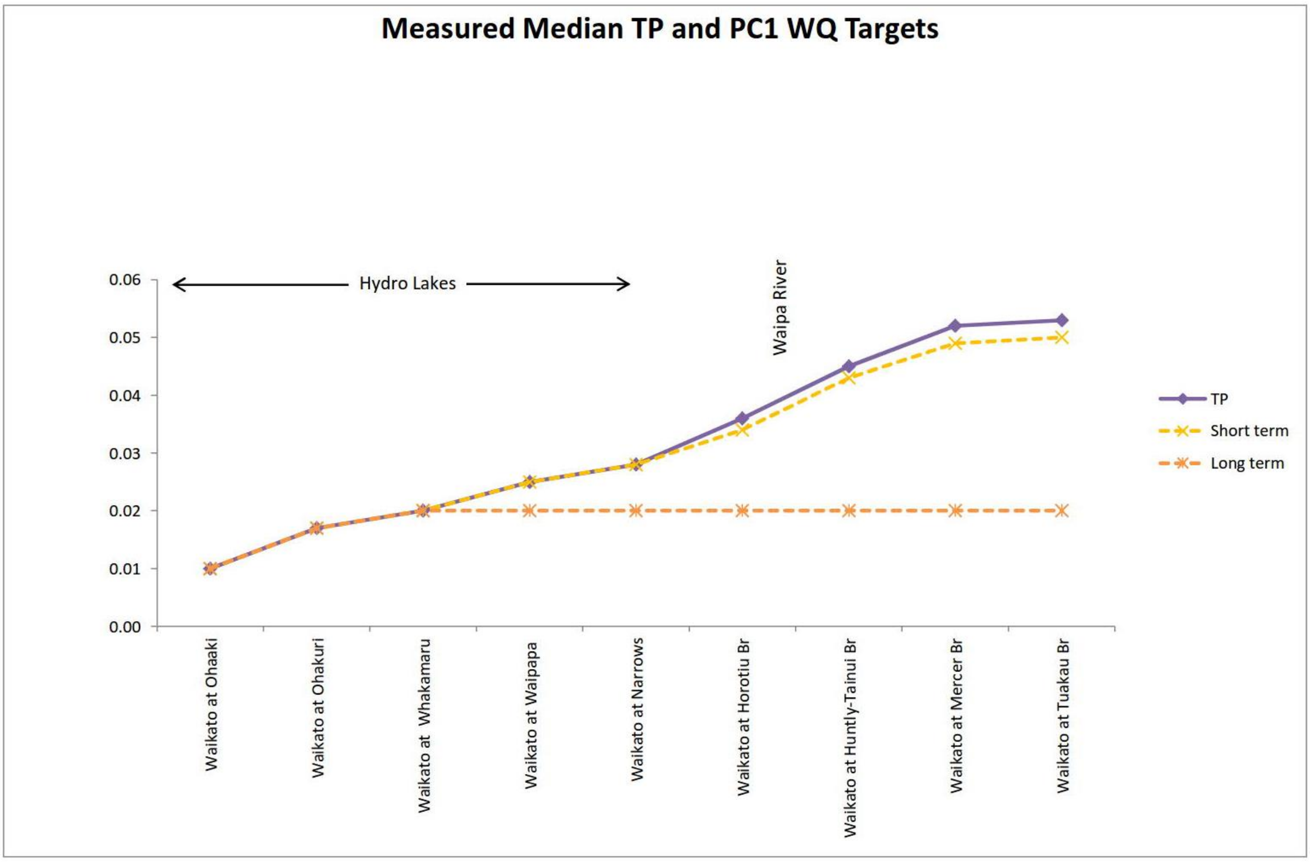


Figure 3.4: Graph of TP measured median values (2010-2014) and associated short term and long term water quality targets from PC1.

TP median concentrations steadily increase from Ohaaki to Narrows, continuing at an increasing rate between Narrows and Mercer, between which the Waikato and Waipa Rivers meet and the Whangamarino Wetland discharges to the Waikato River. There is a slight increase in concentration between Mercer and Tuakau Br. No concentrations are listed for sites below the Tuakau Br. Overall, the median concentrations measured from Ohaaki increase almost fivefold by Tuakau Br.

Horticultural land occupies 0.6% of the total area of the Waikato River catchment, and accounts for 0.9% of the TP load in the overall catchment, as modelled by NIWA. Figure 3.5 below illustrates the percentage contribution of TP loads from horticulture per subcatchment. Pie charts illustrating the proportion of horticulture TP loads in each subcatchment compared to other land use types are provided in Appendix B and C.

The majority of the horticultural property in the Waikato is in the lower catchment of the Waikato River, meaning the impact of phosphorous leaching from horticultural enterprises covers a small proportion of the overall Waikato catchment, similar to what is observed for nitrogen.

Figure 3.4 illustrates the percentage of the phosphorus load attributed to horticulture used in the NIWA water quality modelling. (Semadeni-Davies, September 2015). Note the NIWA modelling simplified the landuse assumptions compared with landuse layer supplied to Jacobs by NIWA. In some catchments no horticulture was assumed in the nutrient modelling, where the landuse layer indicates horticulture is present.

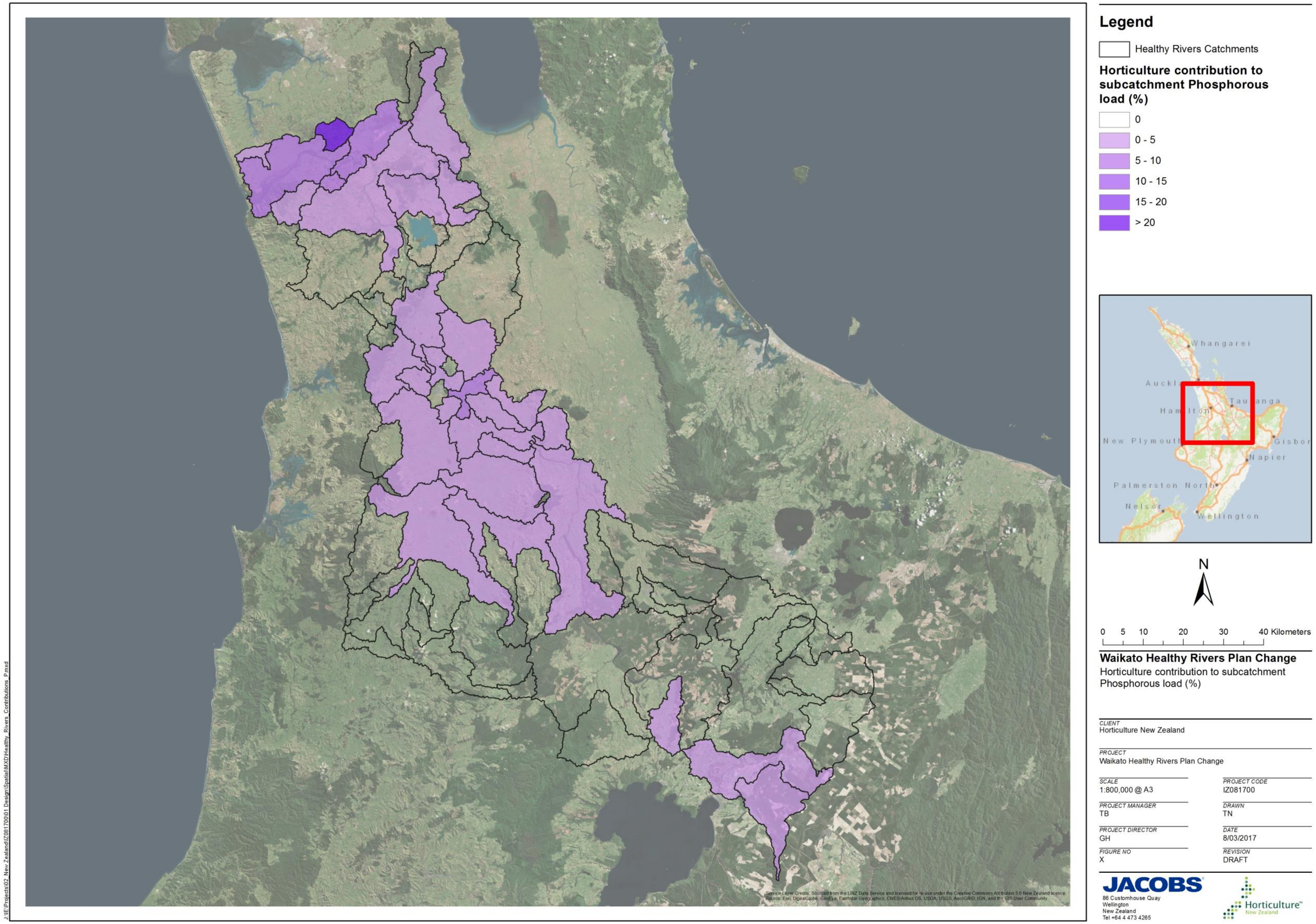


Figure 3.5 : Contribution of unattenuated phosphorus loads from horticulture land use on a subcatchment scale.

3.3 Sediment

Fine sediments like silts and clays are key light attenuating constituents that contribute to the impact on water clarity.

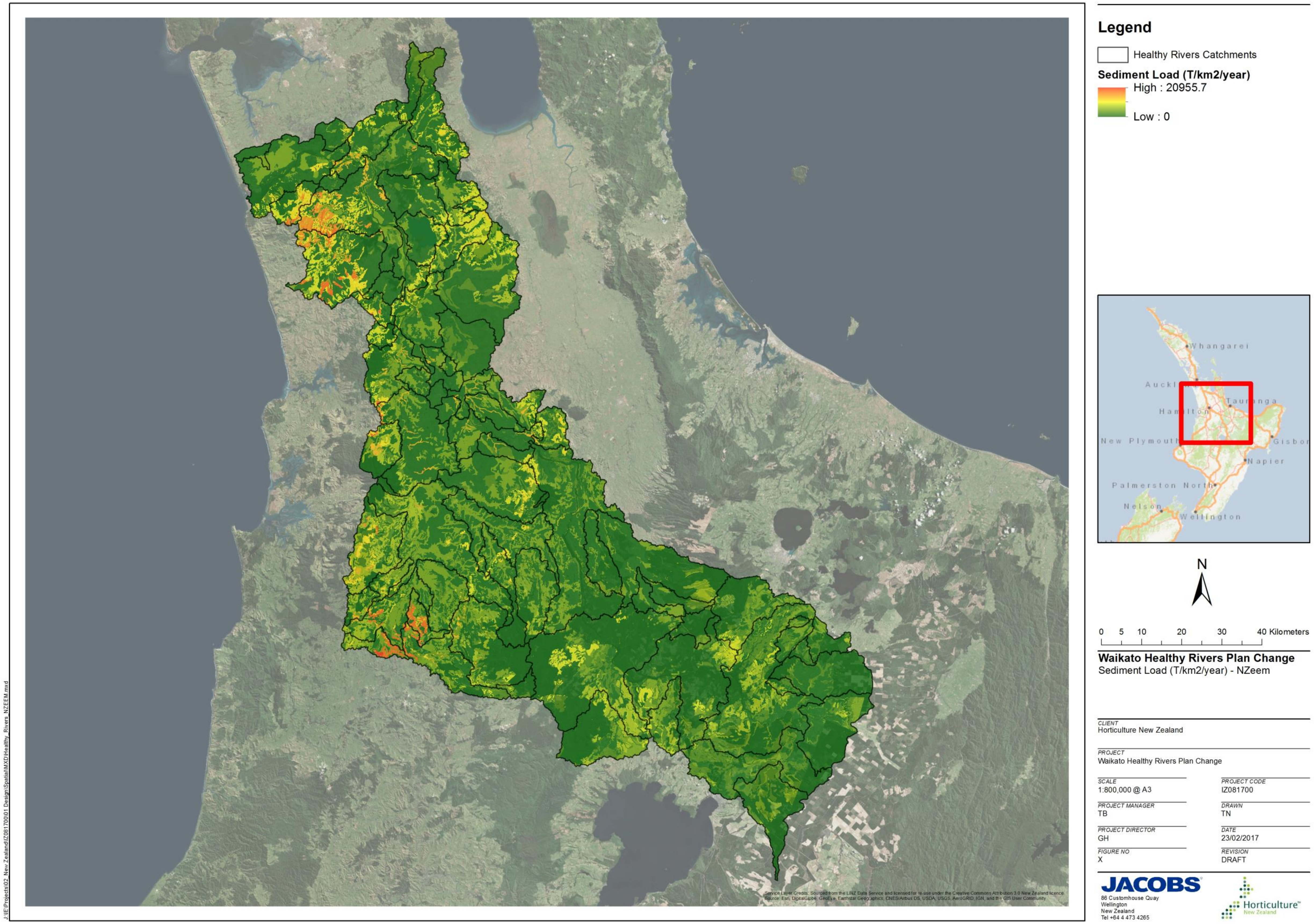
NIWA (Hughes, 2015) modelled annual sediment loads separately for each subcatchment using the New Zealand Empirical Erosion Model (NZEEM), for the purposes of representing annual average sediment loads lost from the land for PC1.

The NZEEM uses annual rainfall, land cover and erosion terrain (rock, soil, slope erosion process) to inform the prediction of sediment yield. The NZEEM does not differ between pasture and bare earth and therefore does not account for the sediment generated from bare earth associated with horticulture and arable farming. Figure 3.6 displays the subcatchments and sediment yield across the greater catchment in tonnes per square kilometre per year.

The majority of horticultural land is located downstream of Mercer. The sediment concentrations in the Lower Waikato are influenced by the inflow of the Waipa River at Ngaruawahia. In addition between Rangiriri and Mercer, there are three significant tributaries that contribute high sediment loads. These are the Whangape Lake Catchment and Opuatia to the west, and the Whangamarino River to the east. Figure 3.7 maps the sediment yield in these areas, Figure 3.9 illustrates the relatively high sediment yield in the catchments that drain to Lake Waikare and Lake Whangape.

The contribution of horticulture land to sediment loads predicted from each sub-catchment is very low, as illustrated in Figure 3.8. Note the NIWA modelling simplified the landuse assumptions compared with landuse layer supplied to Jacobs by NIWA for nutrient modelling. When calculating the sediment load attributable to horticultural land Jacobs used the supplied landuse layer.

Pie charts illustrating the proportion of horticulture land contributing to sediment loads in each subcatchment compared to other land use types are provided in Appendix B and C.



Service Layer Credits: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 3.0 New Zealand licence
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 3.6 NZEEM sediment yield tonnes/km2/year

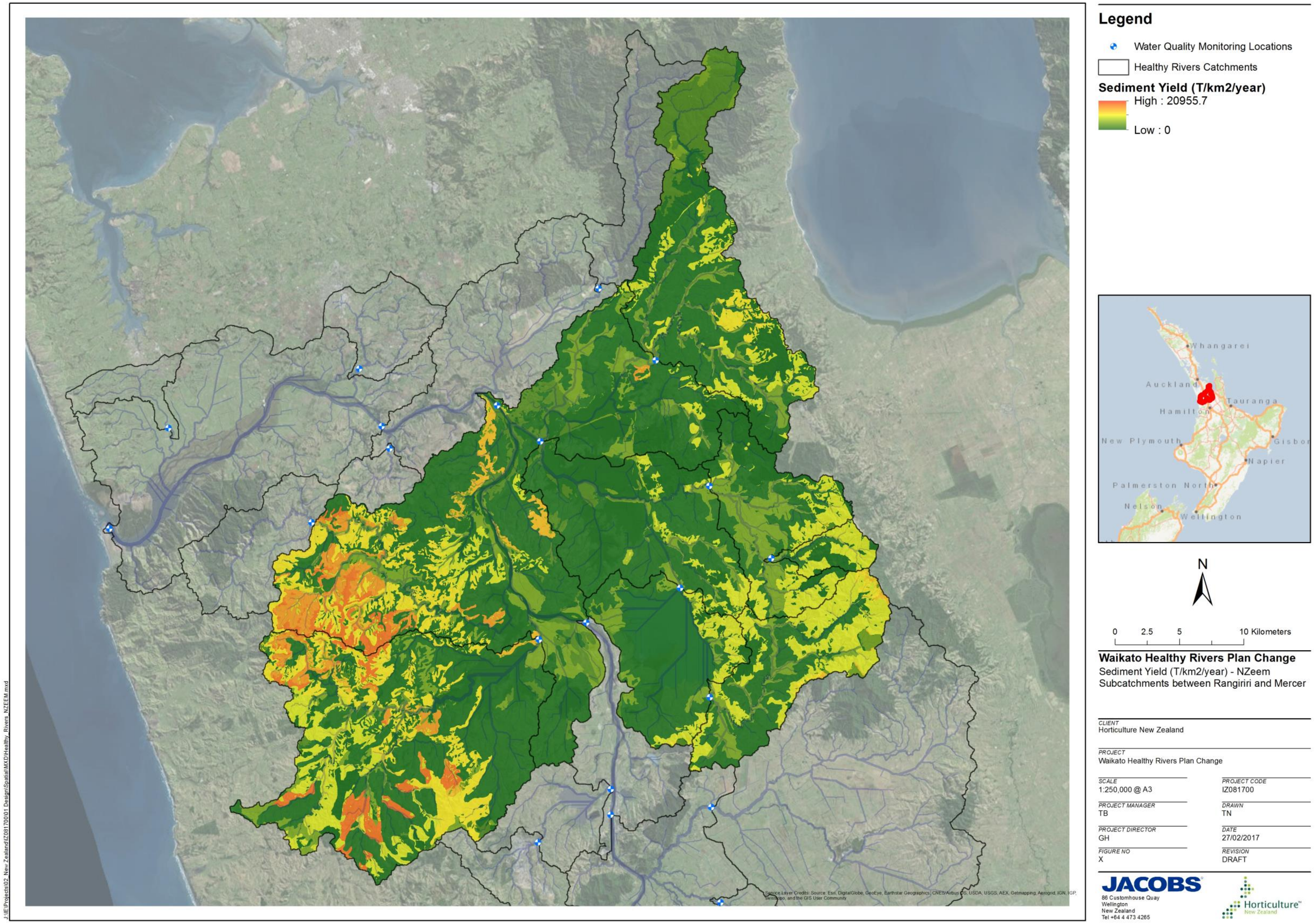
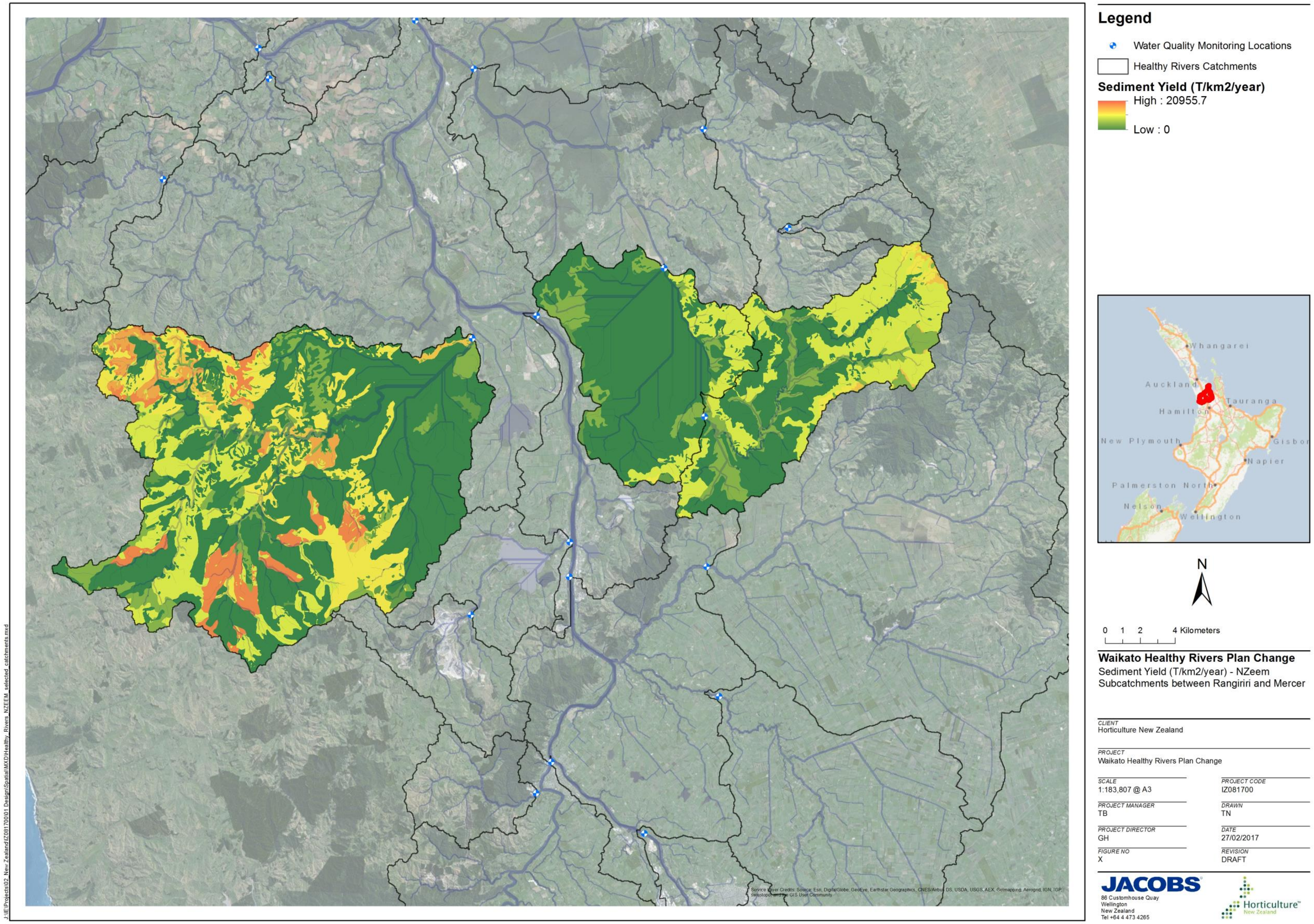


Figure 3.7 NZEEM sediment yield Tonnes/km2/year for the sub- catchments between Rangiriri and Mercer.



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Waikato Healthy Rivers Plan Change
Sediment Yield (T/km2/year) - NZeem
Subcatchments between Rangiriri and Mercer

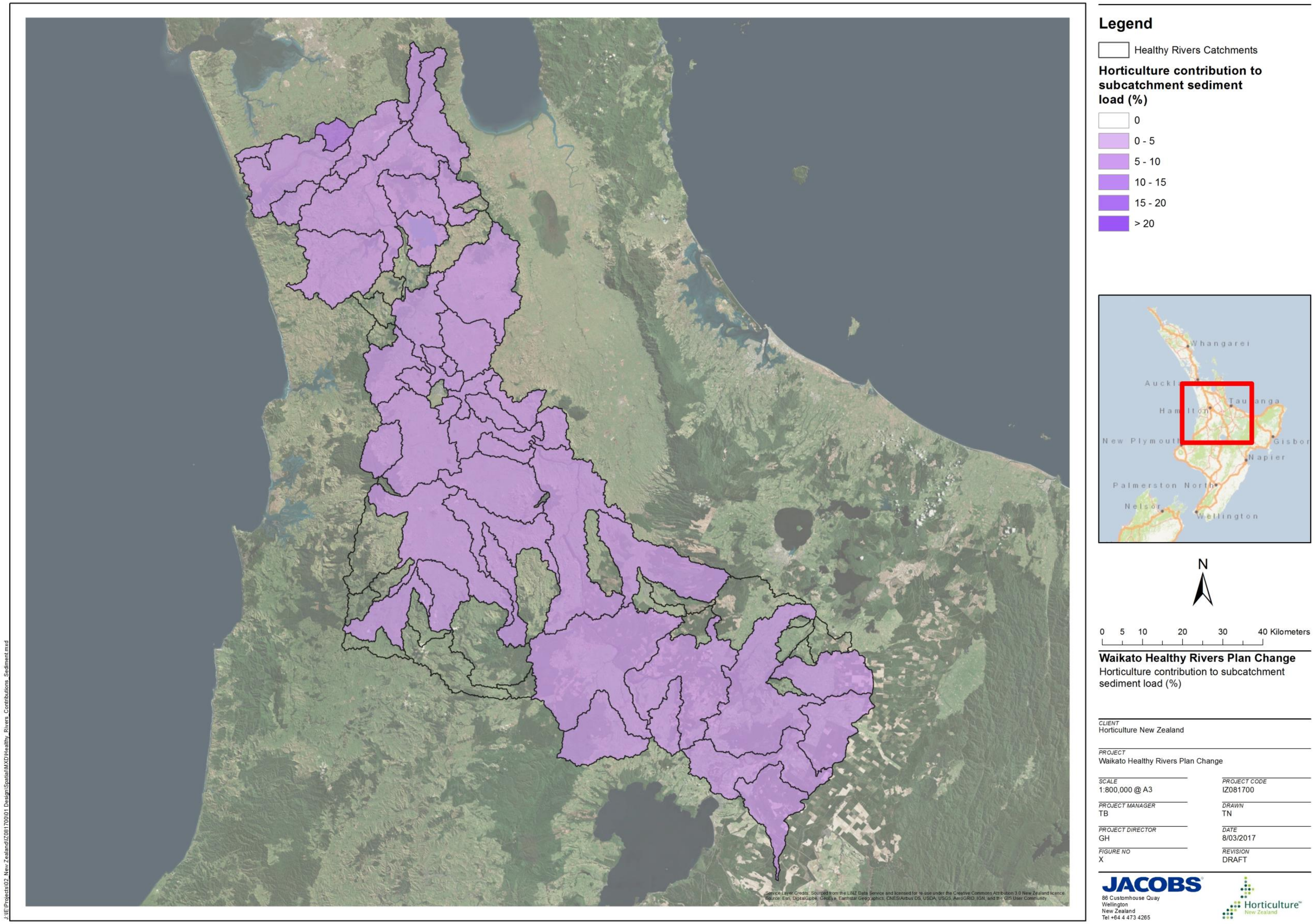
CLIENT
Horticulture New Zealand

PROJECT
Waikato Healthy Rivers Plan Change

SCALE 1:183,807 @ A3	PROJECT CODE IZ081700
PROJECT MANAGER TB	DRAWN TN
PROJECT DIRECTOR GH	DATE 27/02/2017
FIGURE NO X	REVISION DRAFT

86 Customhouse Quay
Wellington
New Zealand
Tel +64 4 473 4265

Figure 3.8 NZEEM sediment yield Tonnes/km2/year for the Lake Whangape and Lake Waikare catchments



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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 3.9 : Contribution of sediment loads from horticulture land use on a subcatchment scale.

3.4 Chlorophyll *a*

Phytoplankton (floating/planktonic algae) is a natural part of river and lake food webs, providing energy to the food chain and cycling nutrients. Chlorophyll *a* (chl-a) is a component of phytoplankton cells and therefore increases in phytoplankton biomass production causes an increase in chl-a concentrations. Phytoplankton also contributes to the degradation of water clarity (by increases in chl-a concentrations), taste and smell, and alters water colour, and blooms of certain algal species can cause skin irritation and may be toxic.

Phytoplankton only becomes problematic in the main stem of the Waikato, and are monitored there as chl-a. The Waipa is too turbid and lacks the residence time for phytoplankton to develop. Phytoplankton biomass in the Waikato main stem is influenced by a number of factors including: the residence time which is influenced by the hydrodams, light, temperature, inputs from the shallow riverine lakes and nutrients (both N and P) which can limit growth if the supply is limited.

Chl-a is used in PC1 as a measure of all three core values (e.g. human health for recreation, ecosystem health, and mahinga kai).

PC1 short term (10 years) and long term (80 years) water quality targets for each subcatchment scale are based on the measured median values at those sites. These targets are listed alongside the median measured chl-a values for Waikato River monitoring sites in Table 3.3.

Median chl-a values measured in the Waikato River from 2010 to 2014 (Table 3-3 and Figure 3.9) show that concentrations in the upper catchments measured at Waikato at Ohaaki with a median value of 0.0015 mg/L, increase eight fold to 0.012 mg/L at Waikato at Tuakau Bridge.

Table 3-3: 2010 – 2014 median measured chl-a values for each Waikato River monitoring site and associated short term and long term water quality targets from PC1.

HRWO sub-catchment	Median measured values 2010-2014 (mg/L)	WQ targets - Median chl-a (mg/L)	
	Chl-a	Short Term	Long Term
Waikato at Ohaaki	0.0015	0.0015	0.0015
Waikato at Ohakuri	0.0032	0.0032	0.0032
Waikato at Whakamaru	-	-	0.0050
Waikato at Waipapa	0.0041	0.0041	0.0041
Waikato at Narrows	0.0055	0.0055	0.0050
Waikato at Horotiu Br	0.0062	0.0061	0.0050
Waikato at Huntly-Tainui Br	0.0060	0.0059	0.0050
Waikato at Mercer Br	0.0105	0.0100	0.0050
Waikato at Tuakau Br	0.012	0.0113	0.0050

These values are graphed and displayed in Figure 3.9, and the approximate location of other major waterbodies draining to the Waikato River in relation to monitored water quality sites; the hydro lakes and the Waipa River.

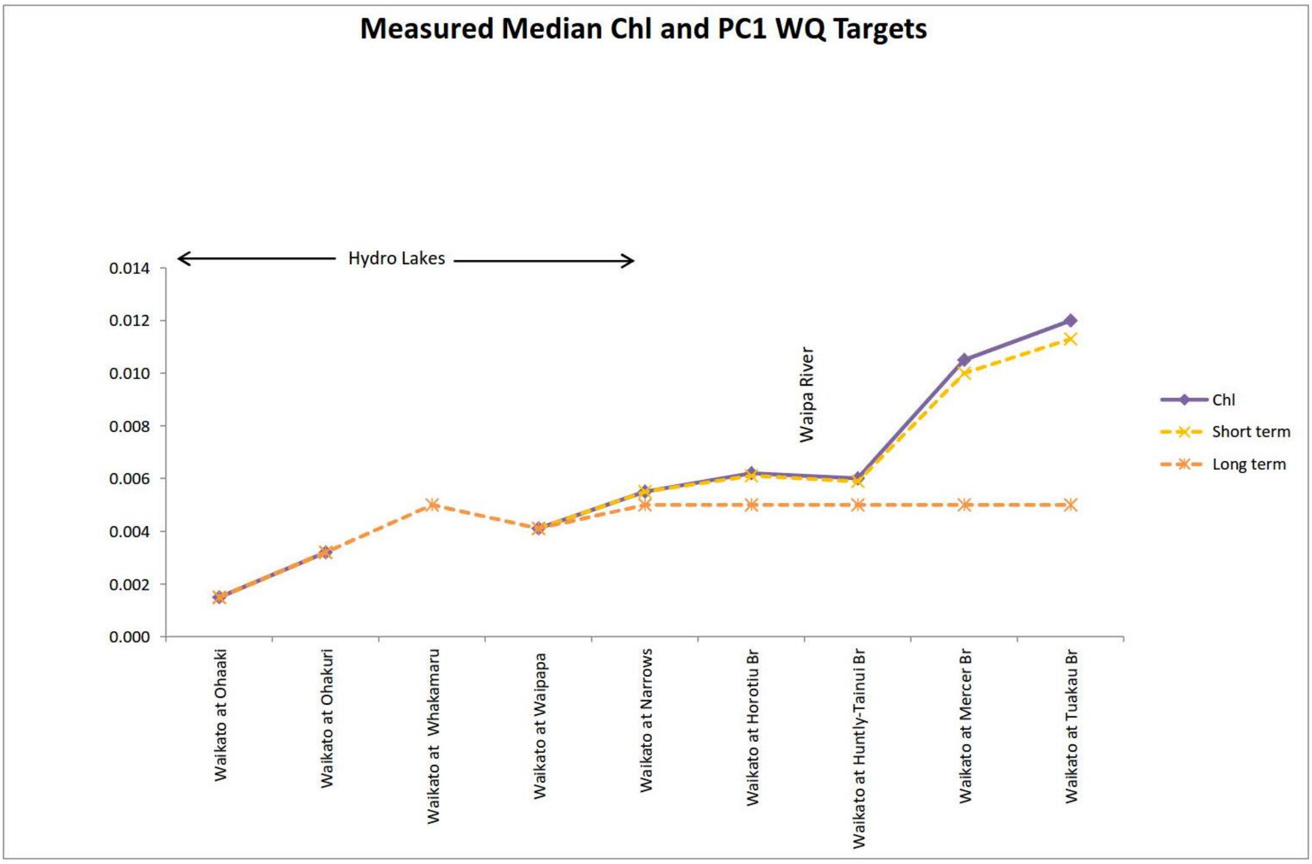


Figure 3.10: Graph of chl-a measured median values (2010-2014) and associated short term and long term water quality targets from PC1.

Chl-a median concentrations quadruple from Ohaaki to Narrows, likely demonstrating the influence of the hydrodams and nutrient loads in the upper catchment. A small decrease can be seen between Horotiu and Huntley-Tainui where the inflow from the Waipa River occurs, which does not support phytoplankton. There is a marked increase in concentration between Huntly-Tainui and Tuakau, likely a response to the inflows from the hypertrophic riverine lakes - Lake Whangape and Lake Waikare.

3.5 Water Clarity

The visual clarity of water, i.e. how far an observer can see through the water, is primarily determined by its water quality; in particular the concentrations of light-attenuating constitutes. Water clarity is directly measured in the water body as the horizontal sighting range of a black disc under base flow conditions. The main light-attenuating constituents are yellow substance (coloured dissolved organic suspended material), fine sediment (silts and clays) and phytoplankton (floating algae), and water itself. N and P are the key nutrients that contribute to phytoplankton growth, which is measured as chlorophyll *a*. Therefore the factors affecting water clarity can also be understood by measuring N, P, chlorophyll *a*, and sediment. Water clarity, encompassing all of these constituents, is a measurement of ecosystem health; and both water clarity and *E.coli* are used to assess the suitability of water for human health for recreation and mahinga kai practices.

PC1 short term (10 years) and long term (80 years) water quality targets for each subcatchment scale are based on the measured median values at those sites. These targets are listed alongside the median water clarity values measured from 2010 to 2014 for Waikato River monitoring sites in Table 3-4 and graphed in Figure 3.10.

Median water clarity values measured in the upper catchments of the Waikato River at Waikato at Ohaaki with a median value of 3.83 m, decreases over six fold to 0.61 m (median value) at Waikato at Tuakau Bridge.

Table 3-4 : 2010 – 2014 median measured water clarity values for each Waikato River monitoring site and associated short term and long term water quality targets from PC1.

HRWO sub-catchment	Median measured values 2010-2014 (m)	WQ targets - Median Clarity (m)	
	Clarity	Short Term	Long Term
Waikato at Ohaaki	3.83	3.8	3.8
Waikato at Ohakuri	3.44	3.4	3.4
Waikato at Whakamaru	1.87	2.0	3.0
Waikato at Waipapa	1.92	2.0	3.0
Waikato at Narrows	1.68	1.7	1.7
Waikato at Horotiu Br	1.35	1.4	1.6
Waikato at Huntly-Tainui Br	0.87	0.9	1.0
Waikato at Mercer Br	-	-	-
Waikato at Tuakau Br	0.61	0.7	1.0

These values are graphed and displayed in Figure 3.10, and the approximate location of other major waterbodies draining to the Waikato River in relation to monitored water quality sites; the hydro lakes and the Waipa River.

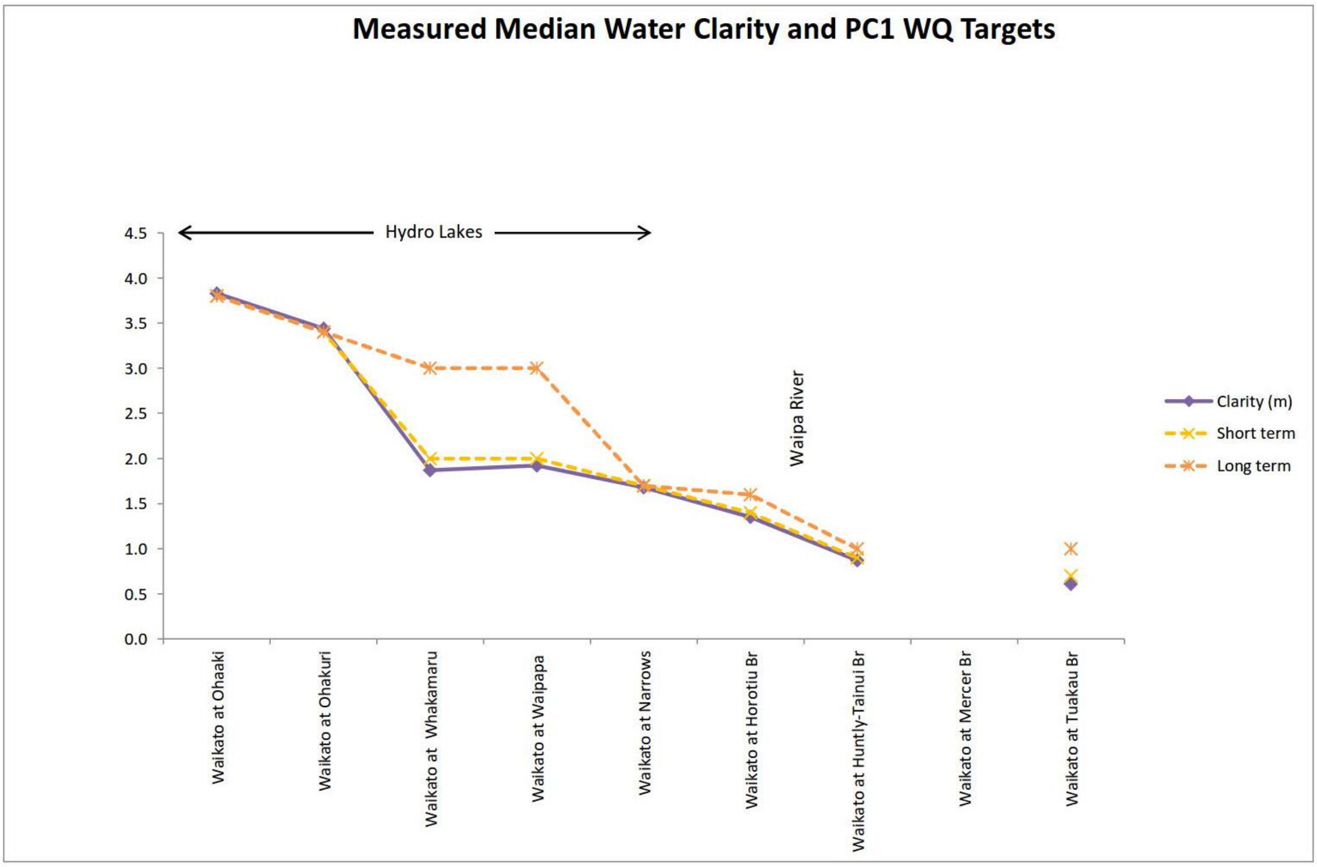


Figure 3.11 : Graph of water clarity measured median values (2010-2014) and associated short term and long term water quality targets from PC1.

Median water clarity measurements halve in value from Ohaaki (3.83 m) to Whakamaru (1.87 m). The decline in clarity slows down between Whakamaru and Waipapa before declining with greater speed between Waipapa and Huntley-Tainui. There is no data for Mercer; however the median clarity value at Tuakau Br is the lowest median value of 0.61 m.

Decreasing water clarity trends throughout the catchment generally reflect the increasing concentrations of other constituents that influence it, including nitrogen, phosphorous, sediment and chlorophyll *a*.

Horticultural land is concentrated in the Lower Waikato with poor water clarity largely influenced by upstream landuse and lakes processes. Horticultural land can be expected to have some impact with the discharge of sediment and nutrients.

3.6 E.coli

E. coli is used in PC1 as a measure of human health for recreation and mahinga kai, but is not a direct measure of ecosystem health. Unlike other land uses such as dairy or drystock farming, horticulture practices contribute very little to negligible amounts of *E. coli* in water ways, as illustrated in Figure 3.11 on the next page.

Note the NIWA modelling simplified the landuse assumptions compared with landuse layer supplied to Jacobs by NIWA for nutrient modelling. When calculating the *E. coli* load attributable to horticultural land Jacobs used the supplied landuse layer

Pie charts illustrating the proportion of horticulture land contributing to *E. coli* yields loads in each sub-catchment compared to other land use types are provided in Appendix B and C.

Horticulture has a minimal impact on E.coli loads in the overall Waikato River catchment and contributes less *E. coli* yields compared with dairy, sheep and beef and urban land use.

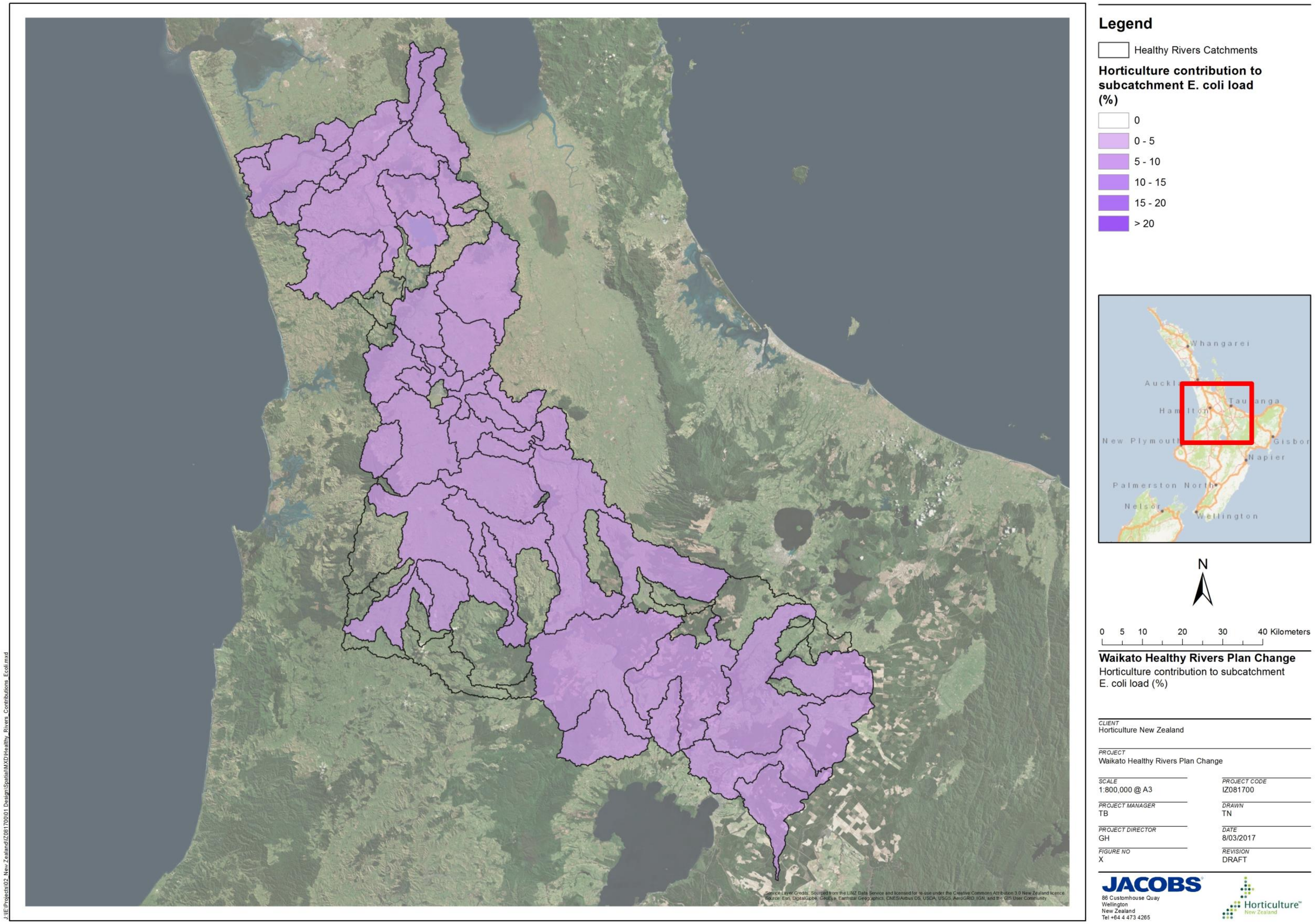


Figure 3.12: Contribution of E.coli loads from horticulture land use on a subcatchment scale.

4. Current allocation of responsibility for contaminant discharge

This section discusses three cases that discuss the proposed regime in PC1 to allocate responsibility for reducing contaminant discharges across activities and provides technical support for the Horticulture New Zealand submission.

The Horticulture New Zealand submission includes a range of proposed changes to the allocation regime proposed in the PC1 objectives, policies and rules.

The Horticulture New Zealand submission seeks an amendment of Objective four to ‘*recognise that PC1 is a transitional plan by inserting new c) “recognising that this plan change is transitional, to provide time to develop the tools required to more efficiently allocate responsibility for achieving contaminant reduction targets in the long-term*.”’

Horticulture New Zealand has submitted, that Policy 3 should be amended proposing*:*

> *Manage and require reductions in diffuse discharges of nitrogen, phosphorus, sediment and microbial pathogens from commercial vegetable production through a tailored, property or enterprise-specific approach to consenting discharges where:*
>
> a. *Flexibility is provided to undertake crop rotations on changing parcels of land for commercial vegetable production, while reducing average contaminant discharges over time; and*
>
> b. *The maximum area in production for a property or enterprise is established and capped utilising commercial vegetable production data sourced from the 10 years up to 2016; and*
>
> c. *~~Establishing a Nitrogen Reference Point for each property or enterprise~~; and*
>
> d. *A tailored reduction ~~A 10% decrease~~ in the diffuse discharge of nitrogen, phosphorus, and sediment across the sector recognising:*
>
>   - *the low risk of discharges of microbial pathogens from commercial vegetable production;*
>   - *the need to preserve aspects of commercial vegetable production required to maintain domestic supply of vegetables;*
>   - *the pressure on and scarcity of land suitable for commercial vegetable production. This pressure has recently increased as a result of greenfields expansion onto versatile land in the Auckland region.*
>   - *The level of prior implementation of Best or Good Management Practices; and*
>
> e. *Identified mitigation actions that are set out and implemented within timeframes specified in either a Farm Environment Plan and associated resource consent, or in specific requirements established by participation in a Certified Industry Scheme or a collective enterprise managing discharges as a group.*
>
> f. *Commercial vegetable production enterprises that can demonstrate an overall reduction in the combined discharges of nitrogen, phosphorus, sediment and microbial pathogens (compared to the existing activity) are enabled; and*
>
> g. *The degree of reduction in diffuse discharges of nitrogen, phosphorus, sediment and microbial pathogens is proportionate to the amount of current discharge (those discharging more are expected to make greater reductions), and the scale of water quality improvement required in the sub-catchment.*
>
> h *Consent will generally be granted for a term greater than 15 years*

i. An offset measure may be proposed in an alternative location or locations to the non-point source discharge, for the purpose of ensuring positive effects on the environment to lessen any residual adverse effects of the discharge(s) that will or may result from allowing the activity provided that the:

  - *i. Primary discharge does not result in any significant toxic adverse effect at the non-point source discharge location; and*
  - *ii. Offset measure provides an equivalent benefit to the values of freshwater specified in this plan; and*
  - *iii. Offset measure occurs preferably within the same sub-catchment in which the primary discharge occurs and if this is not practicable, then within the same Freshwater Management Unit or a Freshwater Management Unit located upstream, and*
  - *vi. Offset measure remains in place for the duration of the consent and is secured by consent condition.*

4.1 Leaching Rate Assumptions in the Water Quality Modelling

Horticulture New Zealand‘s submission seeks the removal of the proposed 10 % reduction in N, proposing instead *tailored reduction in the diffuse discharge of nitrogen, phosphorus, and sediment across the sector*.

The case study below discusses the leaching rate assumptions used in the nutrient modelling used to inform PC1. In our view the water quality modelling has limitations and while it is a useful tool for informing the impact of proposed policy and rules on water quality outcomes, care should be taken to avoid limitations in the modelling, driving policy development. In our view the leaching rates used in the water quality modelling are not comparable and that it is important to acknowledge that the water quality in the river is impacted by the load of contaminants rather than the leaching concentrations, and therefore targeting commercial vegetable growing with the highest N leaching reduction target, will achieve minimal environmental benefit.

Case Study – Nitrogen – Horticulture and Dairy Case Study	
Background	PC1 proposes an approach where a Nitrogen Reference Point is established for each property or enterprise and requires a degree of reduction in nitrogen (N) over time across the Waikato and Waipa catchments. Under Rule 3.11.5.5 existing commercial vegetable production is a controlled activity, subject to matters of control including provisions to achieve Policy 3(d). Policy 3(d) requires a 10% decrease in the diffuse discharge of nitrogen and that a tailored reduction in the diffuse discharge of phosphorus, sediment and microbial pathogens is achieved across the sector through the implementation of Best or Good Management Practices. Under Rule 3.11.5.3 dairy farming is a permitted activity where landuse is certified under a Certified Industry Scheme. Where the farm is not part of a Certified Industry Scheme the activity is controlled under Rule 3.11.5.4 subject to a range of matters. Under both the permitted and controlled rule, where a Nitrogen Reference Point exceeds the 75th percentile nitrogen leaching value, actions, timeframes and other measures are required 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. The development of policies and rules was informed by nutrient modelling undertaken by NIWA. The nutrient modelling methodology is described in the report: Modelling nutrient loads in the Waikato and Waipa River Catchments (Semadeni-Davies et al., 2015). One of the key assumptions in the nutrient modelling is that the nutrient leaching rates for the various landuses have been calculated in a manner that makes them comparable.

Nitrogen Leaching Rate Assumptions

The leaching rates assumed for the Horticultural sector were informed by the report: Nutrient Performance and Financial Analysis of Lower Waikato Horticulture Growers (Agribusiness Group, 2014); this report summarises Overseer modelling of typical Pukekohe vegetation rotations and the effectiveness of mitigation options. It also discusses the limitations of Overseer modelling for Horticulture. As is noted in paras 4.57 and 4.58 of the Horticulture NZ submission, the report models “worst case” rotations including winter cropping as a significant part of the rotation.

The nitrogen leaching rate assumed in the Healthy River nutrient modelling for all land classified as horticultural in the Waikato catchment was between 65 and 67 kg/ha/year.

Uncertainty exists in the modelling of nitrogen leaching from the dairy sector due to the non-disclosure of the data. As stated in Doole et al. (2016), detailed nitrogen-loss levels exist for individual dairy farms throughout the catchment; however, these are held by Fonterra and are unavailable for the purposes of policy simulation due to privacy restrictions.

Dairy data used for the Healthy River nutrient model was not released to Jacobs due to confidentiality agreements between Waikato University and Dairy NZ (pers. comms. Doole 2017). We note the report “Simulation of the proposed policy mix for the Healthy Rivers Wai Ora process” (Doole et al., 2016) refers to 410 farms; it’s unclear whether these are a sub-set of the 498 farms described in (Doole G. J., 2011). The nitrogen leaching rates from the 498 farms is reproduced from Doole et al. (2011) and presented in Figure 4.1: below.

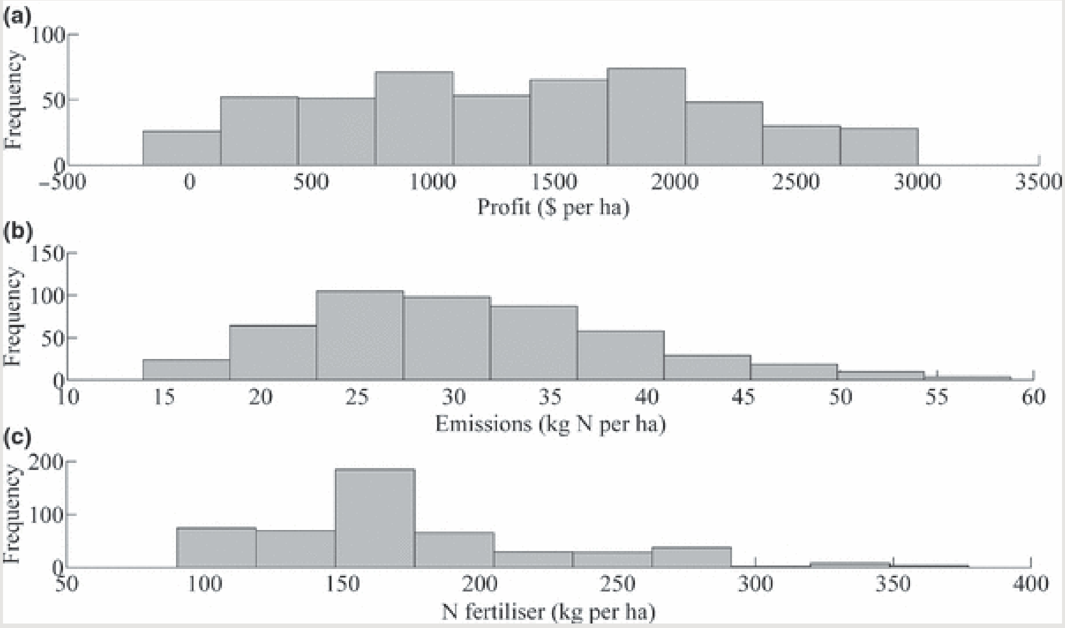


Figure 4.1: Probability distributions for (a) farm profit, (b) emissions, and (c) nitrogen fertiliser use from model output. Note that the histogram bin above the $0 per ha label on the *x*-axis in (a) contains a range of positive and negative values. (Source: Doole et al., 2011)

While the underlying data used for the nutrient modelling was not supplied, NIWA supplied the baseline average nutrient leaching rates for each sub-catchment by landuse. This data is summarised in Table 4-1.

Table 4-1: Statistics of nitrogen leaching rates assumed in the Healthy Rivers Nutrient Modelling. Source: Table 4-2 in Semadeni-Davies et al. (2015).

Land Use Type	Nitrogen leaching rates (N/kg/Ha)		
	Min	Max	Mean
Dairy	18.0	44.3	31.0
Forest	4.0	4.0	4.0

Horticulture	64.5	66.8	65.8
Misc	2.5	2.5	2.5
Dairy Support	15.6	27.2	22.0
Sheep and beef	10.2	11.8	10.9
Urban	12.0	12.0	12.0

When the dairy leaching rates are compared with those developed for Environment Canterbury (Lilburne et al., 2013), the leaching rates in the Environment Canterbury study have a much greater range from 9 kg N/ha/yr to 132 kg N/ha/year, with most values exceeding the Waikato study. In the same Lilburne study the vegetable leaching rates range from 9 – 70 kg N/ha/year. There are many reasons the results may differ between the Lilburne and Waikato dairy OVERSEER results, these include; climate, soils and farming systems, the reasons also include the version of OVERSEER used and the assumptions made when undertaking the OVERSEER modelling.

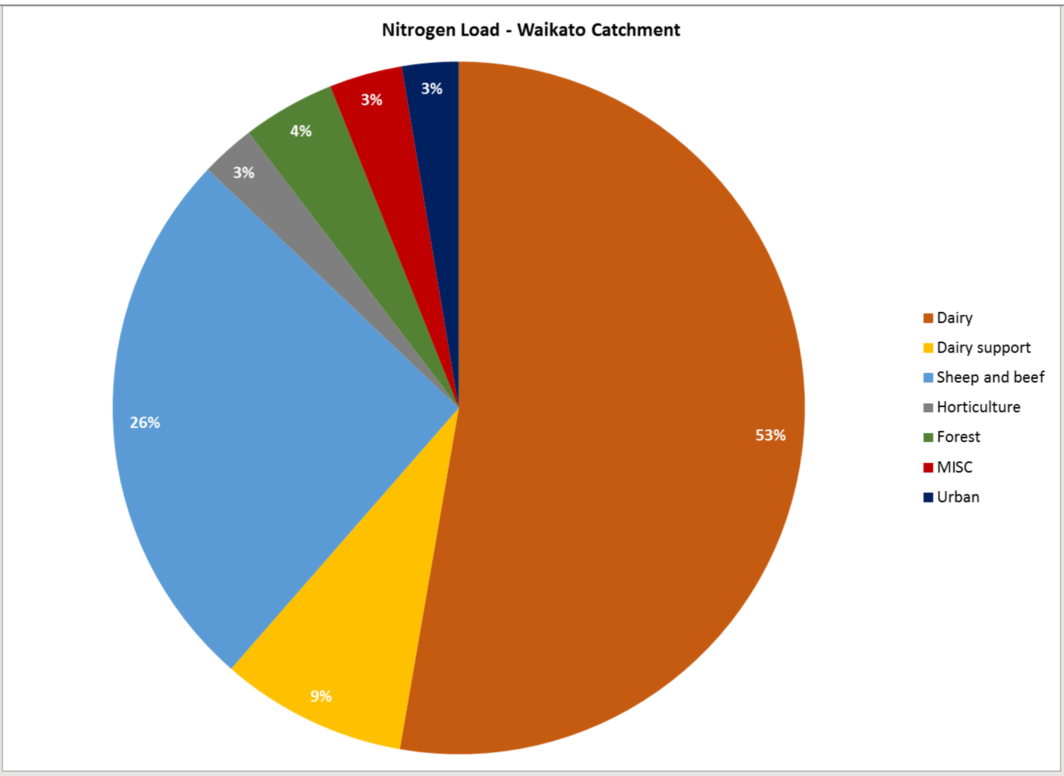
Mr Keenan from HortNZ has indicated to us he was shown a data table by a DairyNZ officer on 28 April 2016 containing nitrogen leaching minima and maxima and a 75th percentile for the Upper Waikato, Middle, Lower Waikato and Waipa. Mr Keenan was told these were from a more complete data set for the Waikato Region than the farms used in the modelling by Doole and presented above. The numbers provided by Mr Keenan were:

Catchment	75th Percentile	Min	Max
Central Waikato	34	12	99
Lower Waikato	30	8	83
Upper Waikato	59	8	155
Waipa	47	12	104

The data described by Mr Keenan, is more similar to the Environment Canterbury leaching assumptions, (Lilburne et al., 2013)

Given that the leaching rates developed for the various land uses were developed at different times, by different people for different purposes, caution should be applied when comparing leaching rates to one another. When considering the effects of diffuse discharges the load of the discharge is important. The loads is calculated by multiplying the leaching rate by land area, and while it is also uncertain given the limitations of the underlying leaching data, it does illustrate the proportion of the contribution to water quality per sector in a more meaningful way than comparing leaching data directly.

The PC1 baseline nutrient leaching assumptions on a sector basis are graphed in Figure 4.2. When the leaching assumptions used for the PC1 modelling are adopted, Horticulture contributes 3% of the N load discharged into the Waikato catchment, while 62% is contributed by the dairy sector (dairy and dairy support combined).

	 **Figure 4.2 : Nitrogen Load contributed by each sector - Waikato Catchment.**
Nitrogen reduction by the horticultural sector	The 10% nitrogen reduction by the horticultural sector proposed in Rule 3.11.5.5 would result in a reduction of 0.2% in nitrogen load to the Waikato catchment. The horticultural land is concentrated in the Lower Waikato catchment. Within the sub-catchments of the Lower Waikato, a greater proportional reduction would be expected. The Section 32 Evaluation Report (WRC, 2016a) discusses why the 75th percentile approach of Rule 3.11.5.4(iv) applied to dairy was not applied to horticulture stating; *"applying the concept of the 75th percentile to commercial vegetable production across the sector would effectively eliminate the growing of certain high-leaching crop types"*. The report refers to economic information from the sector indicating that a 10% reduction in nitrogen would have a significant income effect on the sector, so this was considered to be the limit for how much reduction could be made in the sector during this first stage of change. While the 10% nitrogen reduction is described as a "limit" for how much reduction could be made in the Section 32 evaluation, achieving this level of reduction is a matter of control under Rule 3.11.5.5. We note that the water quality modelling report that informed the policy direction states that *"a 5–10% reduction in nitrogen loss on horticulture farms is attained through improving the timing of nitrogen-fertiliser application and reducing the total amount applied (by around 10–15%)"* (Doole et al., 2016, p.17). It is unclear what, if any environmental benefit would be achieved by increasing the nitrogen leaching reduction requirement for horticultural land above what was modelled. The economic consequences of achieving the reduction are discussed in Agribusiness Group (2014). The "Mitigation 2" technique described in (Agribusiness Group, 2014) did achieve N leaching reductions in the order of 10%. It was described as having *"a substantial financial effect as the amount of N applied decreases from 10 to 40% due to the associated reductions in yield. It causes losses to be occurred from a point between the 10% and 20% reduction in N application which reflects the relative profitability of growing the crops"* (Agribusiness Group, 2014).
Nitrogen reduction by	The assumptions around the modelling of nitrogen reductions for dairy are described in Doole et al. (2016, p.8): *"A part of the proposed policy states that all dairy farmers with a leaching rate currently*

the dairy sector	*above the 75th percentile, assessed per Freshwater Management Unit (FMU), must reduce their nitrogen leaching level to that consistent with the 75th percentile by 2026."* This modelling assumption is consistent for farming activities with a Farm Environment Plan. The policy modelling report (Doole et al., 2016) describes the methodology for estimating the reduction in nitrogen leaching by applying the 75th percentile rule. They found that approximately a 4 - 6% reduction in nitrogen leaching for Dairy farms on FMU or grouped sub-catchment basis would be achieved. We tested this finding, using the baseline leaching data supplied by NIWA (averaged at sub-catchment level). We have assumed the mean nitrogen leaching rate of 31 kg N/ha and standard deviation 8.5 kg N/ha from the 498 Waikato dairy farms (Doole et al., 2011), with a normal distribution we calculated an estimated 75th percentile leaching rate of 36.8 kg N/ha. When this value is used to truncate the average leaching values we calculated a reduction of 5% overall. The total saving of nitrogen estimated by applying the 75th percentile to the dairy leaching data used for the Healthy Rivers nutrient modelling is 397 tonnes per year. This is equivalent to the whole of the nitrogen load for the horticultural sector assumed in the Healthy Rivers nutrient modelling (396 tonnes N /year). The modelling used for the Healthy Rivers process assumes the dairy leaching is normally distributed and states *"an assumption that nitrogen leaching is normally distributed within each FMU is justified by the fact that it cannot be rejected that the data for 410 individual farms generated by Doole (2012) is consistent with a normal distribution, at a 5% level of statistical significance."* (Doole et al., 2016, p.10). As we do not have access to the data used for the modelling we cannot review the suitability of the distribution selection, however we have undertaken some approximate calculations assuming mean and standard deviation for the 498 Waikato dairy farms (Doole et al., 2011) and a log-normal distribution. In this case we calculated a 75th percentile value leaching rate of 35.9 kg N/ha. The difference between using a log-normal distribution compared with a normal distribution (and assuming the mean and standard deviation from Doole et al., 2016)), is a nitrogen reduction of a further 1% (i.e., 6% for log-normal compared with 5% reduction for a normal distribution), which equates to a further 57 tonnes N/year. This equates to 14% of the nitrogen loss from the horticultural sector. Doole et al. (2016, p.16) discussed the economic impact of nitrogen reductions on dairy farms: *"There is broad anecdotal understanding that profit can increase or stay the same on dairy farms if reductions in nitrogen are low to moderate (Holland and Doole, 2014; Doole and Kingwell, 2015). Doole (2012) identified that a 10% reduction in nitrogen across a population of 410 actual dairy farms allowed a number of them to experience win-win outcomes"*.
Conclusion	The proposed 10% reduction in nitrogen leaching from the horticultural sector was not tested in the modelling report. A 10% reduction is likely to have negligible benefits over the 5% - 10% modelled reduction, given the small contribution of horticulture to the nitrogen load in the Waikato River. However, achieving a 10% reduction in nitrogen leaching for horticulture is predicted to have substantial financial effects (Agribusiness Group, 2014). The benefit from reducing nitrogen leaching from dairying is more tangible compared with reductions from horticulture; given a 5% reduction in dairy nitrogen leaching is equivalent to the total nitrogen leaching from horticulture in the catchment. The economic assessment of the modelled 5% reduction indicated dairy sector profits may be unaffected.

4.2 Nitrogen Mitigation and influence of Variation 6

Horticulture New Zealand's submission seeks recognition of the impact of Variation 6 on achieving the water quality targets in PC1.

This case study considers the impact of Variation 6 on the ability to reduce N leaching.

Case Study - Water Quality and Water Quantity – Water Care Abstraction

Background

For vegetable growers, the ability of use targeted irrigation to respond to market demand influences leaching and production. Variation 6 will see a drop in the allocation of irrigation water to farmers (including Horticulture) in the Waikato as a result of the increase in allocation granted to Watercare for Municipal Supply to Auckland City. The Watercare resource consent application to take 200,000 m^3/day from the Waikato River is currently being processed by Waikato Regional Council.

This abstraction and the consequential change in reliability will impact on Mana Atua values and Mana Tangata values. We discuss a scenario that will assess the changes in N leaching as a result of a 60% reduction in irrigation water availability, and how the Healthy Rivers seeks to manage the impact associated with this activity.

Variation 6 - Watercare Abstraction

Watercare has submitted a resource consent application to take 200,000 m^3/day from the Waikato River, in addition to the present authorised net water take of 150,000 m^3/day. This is a new proposed total of 350,000 m^3/day from the Waikato River. The proposed take will be approximately 36 km upstream of the river mouth in the vicinity of the existing Watercare Waikato River water supply intake location at Hayward Road, Tuakau.

Variation 6 sets allocation limits for all rivers and streams in the Waikato Region. During times of low flow, rates of take are reduced. Levels of priority apply during water shortages:

i. Priority SW-A activities: takes which have a zero net take, or for firefighting;

ii. Priority SW-B activities: stock watering supplies, takes for animal welfare and sanitation (including shed wash down and milk cooling), takes for perishable food processing, takes associated with electricity generation, all permitted and s14(3)(b) RMA takes, and **takes for domestic or municipal supply**;

iii. Priority SW-C activities: all other takes allocated within the primary allocable flow – **will include the irrigation takes in the Lower Waikato**;

iv. Priority SW-D activities: all other takes allocated water above the primary allocable flow – not applicable as there is no secondary allocation on the main-stem of the Waikato River;

v. Priority SW-E activities: takes for water harvesting.

Watercare already takes 150,000 m^3/day from the Waikato River, but the additional take would mean that the primary allocable flow of the lower river catchment would be exceeded or close to being exceeded (Table 4-3). There is also no secondary allocation available in the Waikato River. Because of this any additional water for irrigation in the future will be a non-complying activity due to the exceedance in primary allocation. Water takes for municipal and domestic supplies has a higher priority than irrigation. The current irrigation takes are priority SW-C which means that greater restrictions are placed on these users during times of water shortage rather than the SW-B for municipal supply.

The Government has also set targets to phase out over-allocation of water in catchments by 2030, which will cause further cutbacks in the volume of surface water takes for irrigation. Horticulture NZ has received information from WRC (pers comms Keenan 2017) which states that following the approval of the Watercare application, surface water takes will be reduced by up to 60 percent in 2030 in the Lower Waikato catchment.

Table 4-3: Allocable flow at Waikato River at coastal marine area (CMA)[1].

Location	Allocable Flow (m3/s)	Allocated (m3/s)	Allocation sought by Watercare (m3/s)	Total allocation (m3/s)[1]	Remaining allocation (m3/s)*
Waikato at CMA	18.7930	16.2205	2.314	18.535	0.258

*This does not take into account any consent applications that are currently being processed.

Current Horticultural

There is a total of 242 active (or current) water takes in the Waikato Region specifically for irrigation on horticultural properties[2]. This includes from both groundwater and surface water sources. These takes

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[1] Information sourced from the Waikato Regional Council Water Allocation Calculator: https://www.waikatoregion.govt.nz/environment/natural-resources/water/water-allocation-levels/ , accessed on 23 February 2017.

Irrigation Use	are mainly located in the Lower Waikato catchment, with some located in the Tamahere/Cambridge area.
Water Quality – the influence of irrigation on leaching	HortNZ is currently involved in projects to collect data on the link between irrigation, plant growth (nutrient uptake) and leaching. The Ministry for Primary Industries (MPI) Sustainable Farming Fund (SFF) Root Zone Reality Project and the HortNZ Northern Fluxmeters Project commenced in July 2014. The aim of these projects is to establish a network of passive-wick tension fluxmeters in commercial cropping farms in Canterbury, Manawatu, Hawke's Bay, and Matamata/Pukekohe, and use these to measure nutrient concentrations of N and P in leachate water. Sites provide a range of cropping systems, soil types, climatic conditions and management practices relevant to each region (Johnstone et al., 2015; Norris et al., 2016). The aim of the Root Zone Reality Project is to study long term patterns of N and P losses across a range of cropping farms and seasons, with the intent that these trials will continue until more data is collected across multiple crop rotations. The data will help to ensure good management practices are communicated and adopted by growers and regional councils (Norris et al., 2016). There are direct and documented links between irrigation, plant growth (nutrient uptake) and leaching. Understanding the relationship between these factors is important to enable an assessment of the effects that reduced irrigation availability will have on nitrogen leaching, and therefore water quality. These relationships are discussed in detail in this section, however the following overarching points are provided in order to provide context to the discussion: • Crop yield (growth) is controlled by the availability of water • The greater the yield, the greater the nutrient demand • Reduced plant available water can result in reduced yield, and therefore reduced nutrient uptake • Reduced nutrient uptake can result in increased risk of leaching • Increased leaching can result in water quality effects The above points are discussed in more detail below.
Plant available water and yield	WRC engaged Aqualinc (2009; 2013) to develop irrigation guidelines that better reflect the range of climate, soil conditions, crop rotations, and irrigation methods in the Waikato Region. Aqualinc (2009) used water balance computer modelling to determine these guidelines and the next stage (Aqualinc, 2013) involved field verification of the water use guidelines. Field investigations were conducted at six irrigated sites, which included four vegetable and two pasture sites. IRRICALC was used to model soil moisture response to irrigation. The study by Aqualinc (2013) shows that in field case studies on vegetable crops, irrigation water reliability increased crop production by an average of 29% in the 2010/2011 irrigation season, with production on a single farm increasing by up to 89%. It has also shown that the quality of the production of vegetables was higher in irrigated vegetables versus non-irrigated vegetables. The effect of irrigation was higher for vegetables because their water stress tolerance is lower than for pasture and the irrigation trigger for vegetable crops is 20% higher than the plant available water (PAW) value for pasture (Aqualinc, 2013). Graphs (Figure 6.1) from Aqualinc (2013) indicate how soil moisture fluctuates between field capacity, wilting point, and the 'preferred minimum soil moisture'. The field capacity is the maximum level of soil water available for plant extraction after gravitational drainage from a saturated condition falls to a rate that is insignificant. Wilting point is when soil profile is very dry and no soil water is available for plant extraction at -1,500 kPa (Aqualinc, 2013). By the time soil moisture reaches wilting point, vegetable crop plants are seriously damaged. Even when soil moisture drops below the 'preferred minimum soil moisture' plants become stressed and damage can occur resulting lower crop yields (pers comms Keenan 2017). If water shortages occur early in the crop's development, maturity may be delayed and yields are often reduced. If water shortage occurs late in the growing season, quality is often reduced even though total yields may not be affected. Therefore, water stress will always reduce the financial returns due to either

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[2] Information sourced from the Waikato Regional Council Data Catalogue: https://www.waikatoregion.govt.nz/services/data-catalogue/, accessed 13 February 2017. ALLOC_IRIS_WATER_TAKE_SEASONAL.

	low yield or poor quality (Kemble, 2000 as quoted in Aqualinc, 2013). Therefore it is considered best practice to manage soil moisture levels in the optimum range, between field capacity and the 'preferred minimum soil moisture', in order to maintain crop yields (identified on Figure 6.1 below) (pers comms Keenan 2017). The amount of fertiliser that is applied to a vegetable crop is determined based on the average yield that is expected to be grown that year. This average yield is based on average climatic conditions that can be expected in the region that the property is located in. Irrigation is used to maintain yields when drought conditions occur, and to provide a buffer from the natural variability of the weather. Irrigation doesn't necessarily result in soil drainage and corresponding N leaching events, if it is used to maintain soil moisture in the optimum range (Figure 6.2). N fertiliser is applied to vegetable crops and ideal conditions will result in the maximum uptake of applied N. The amount of applied fertiliser N remaining in the soil is less than would otherwise be under water stress conditions. As a result, there is likely to be less N leaching once additional rain drains through the soil. If water stress has occurred in the growth cycle of the vegetable crop, then crop quality is reduced and ideal conditions for growth will not occur resulting in lower production, lower plant uptake of N and greater potential for N leaching (pers comms Keenan 2017). If more rain falls than the average year, then it is expected that there will be more than average drainage through the soil profile and therefore greater than average N leaching. If irrigation is not available during droughts (or a drier than average year) then soil moisture is not maintained in optimum range for crop growth. There is then the potential for the additional N that has been applied for an average year, and has not been taken up by the poorly performing crop, to be leached through the soil profile when rain eventually does fall. By reducing the volume of water available for irrigation on horticultural properties, WRC has taken away one method of mitigating N leaching in the drier than average years. A Nitrogen Reference Point is required to be produced for the horticultural properties in accordance with Schedule B. The reference period for commercial vegetable production is the annual average N leaching loss from 1 July 2006 to 30 June 2016. It is accepted that there will be wet, dry and average years amongst this reporting period. WRC reserves control over the actions and timeframes to ensure that the diffuse discharge of nitrogen does not increase beyond the Nitrogen Reference Point for the property or enterprise. They also reserve control over the monitoring, record keeping, reporting and information provision requirements for the holder of the resource consent to demonstrate and / or monitor compliance with the Farm Environment Plan. Therefore it is unknown how often growers will be required to submit N leaching values to council once the Farm Environment Plans have been submitted and whether this will take into account dry or wet years.

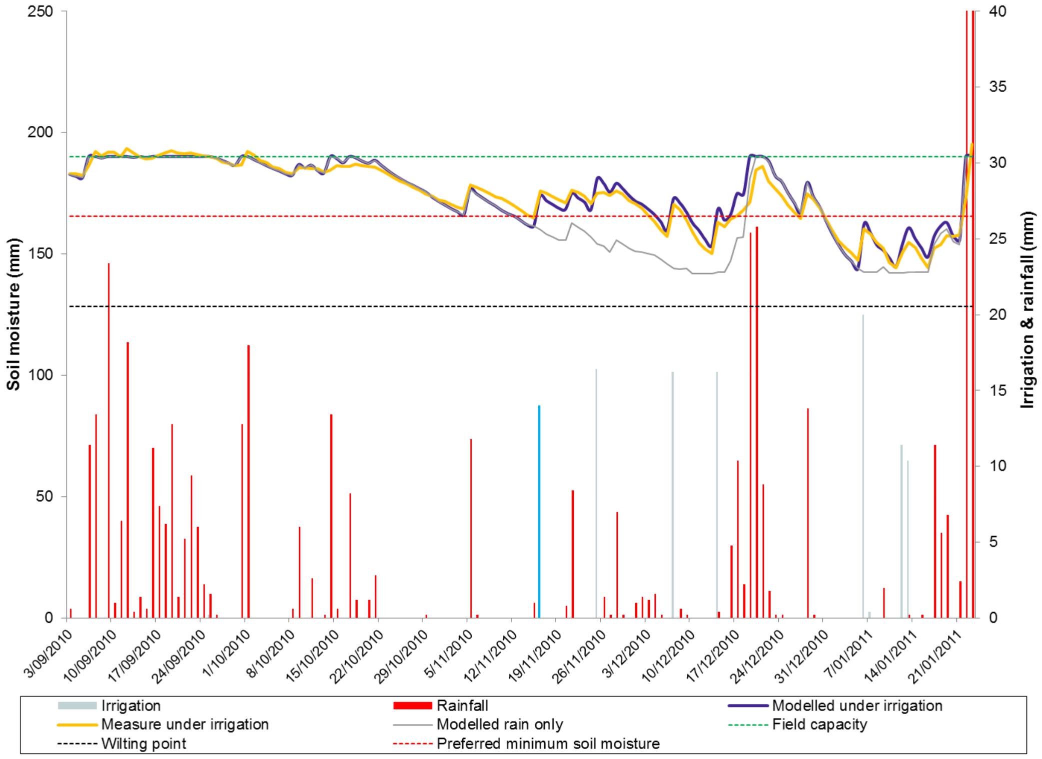

Figure 4.3: Modelled and measured change in soil-moisture, and soil-water parameters from Vege-4 site in Year 2 (from Aqualinc, 2013).

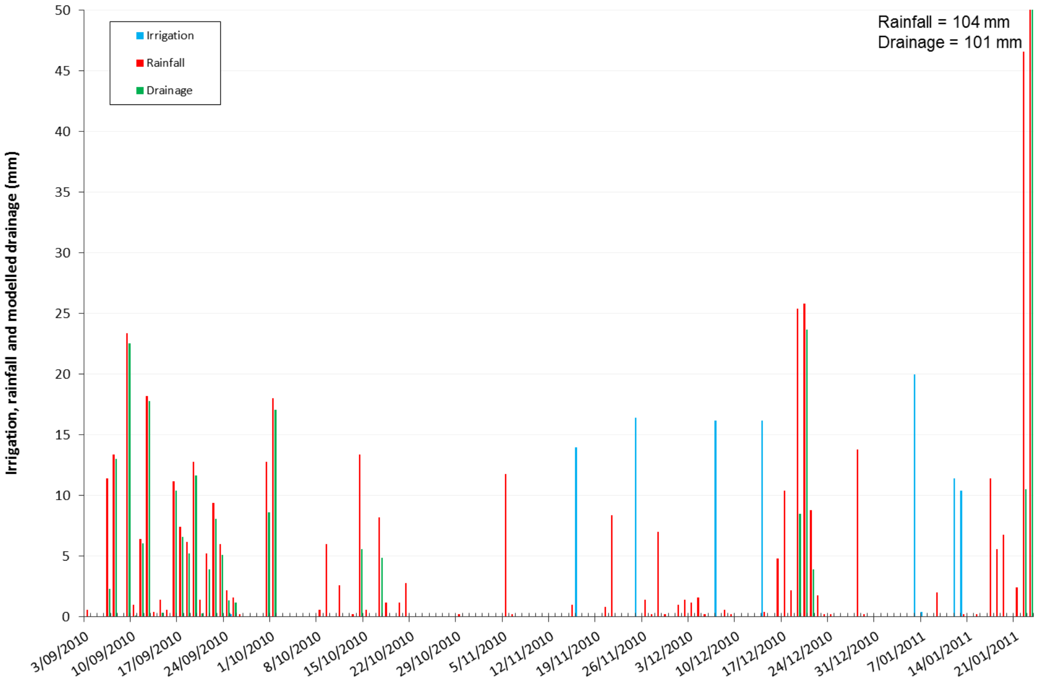

Figure 4.4: Measured irrigation and rainfall events, and modelled drainage under the rooting zone for Vege-4 site in Year 2 (from Aqualinc, 2013).

Targeted irrigation and control of

Target irrigation and how it can be used to control leaching was highlighted in a report by Agribusiness Group (2014). Three representative horticultural systems were modelled using OVERSEER, each characterised by a different rotation of vegetables, for the Lower Waikato region. The rotations that were modelled were an extensive rotation, intensive rotation, and traditional market-garden

leaching

arrangement. In general, leaching values ranged from 64 to 73 kg N/ha/yr (Table 4-4).

Three mitigation techniques were also applied to each system based on information from industry experts, prior research, and growers. The mitigations were limiting nitrogen fertiliser application, reducing nitrogen fertiliser application, and improved water management through altering standard irrigation practices. OVERSEER was used to estimate the nitrogen losses associated with these enterprises, while gross-margin analysis was used to assess the financial implications of adopting these alternative mitigation practices across the different farm systems.

The third mitigation technique modelled by Agribusiness Group (2014) was Active Water Management. It involved setting the option in OVERSEER from defining the actual amount of irrigation water applied to choosing the option to actively manage the application of irrigation water. In this way the model chooses to apply only the amount of water which is required by the crop and therefore limits the amount of excessive water running out the bottom of the soil profile or runoff from the top of the soil profile. The table below outlines that Mitigation 3 (M3) resulted in worthwhile amounts of N leaching mitigation in rotations which were heavily summer and therefore irrigation dependent.

Table 4-4: Whole Farm N leaching results (kg N/ha/yr) taken directly from Agribusiness Group (2014).

	Status Quo	M1	M2 10%	M2 20%	M2 30%	M2 40%	M3
Rotation 1	64	66	59	57	53	49	59
Rotation 2	65	61	57	54	51	47	63
Traditional Market Garden	73	69	65	59	51	44	65

Agribusiness Group (2014) states that Mitigation 3 is more of a theoretical improvement in efficiency of water use as it is unlikely to be carried out in practice because it requires static irrigation systems. The report also states that static irrigation systems are unlikely to be adopted because of the short crop rotational cycles in horticulture production. However a site visit to Southern Fresh in Tamahere recently showed that static irrigation systems were in use at this site and the implications of this will be discussed at a later date in our Farm Case Studies.

Leaching and water quality

We have discussed that if water stress has occurred in the growth cycle of the vegetable crop, then crop quality is reduced and ideal conditions for growth will not occur resulting in lower production, lower plant uptake of N, greater volumes of fertiliser N remaining in the soil, and greater potential for N leaching. This is more likely to happen during the summer period, and will occur if irrigation water is unavailable.

A study by Verburg (2016) that analysed chlorophyll, TP, and TN concentrations in the Waikato River shows that:

- Chl-a is typically lowest in winter and higher in spring, summer and autumn.
- In contrast, dissolved inorganic nitrogen and dissolved reactive phosphorus show seasonal patterns of higher concentrations in winter and minima in summer (dissolved nutrients show stronger patterns than TP and TN).
- TN:TP ratios are lowest in summer and autumn and highest in winter at all sites from Ohakuri downstream to Tuakau. This is evidence that occasional N limitation may occur during summer and autumn.

The outcome of the study by Verburg (2016) is that phosphorus is more important than nitrogen in controlling the annual median phytoplankton biomass in the Waikato at present and efforts to control phytoplankton biomass should focus most on controlling phosphorus. However, nitrogen limitation on phytoplankton biomass during summer and autumn can occur when N levels are reduced by catchment retention processes. The secondary focus should be on nitrogen control to help control summer/autumn chlorophyll *a* levels.

Therefore the lack of access of irrigation water during the summer months for horticultural properties will lead to an increase in N leaching. This may impact on water quality within the Waikato River at the critical time when the system may be N limited. This can exacerbate the chlorophyll problem during the

	summer/autumn period in the Waikato River.
Conclusion	The impact that the proposed Watercare surface water take will have on leaching losses from the horticultural sector were not testing in the modelling undertaken to inform PC1. Irrigation on horticultural properties during dry periods keeps N leaching under control without reducing yield. The combination of Variation 6 and the Healthy Rivers Plan Change combines to reduce the amount of horticultural food produced, however it will not necessarily deliver better water quality in the future.

4.3 Offset mitigation

Horticulture New Zealand proposes an amendment to Policy 3 to allow for offset mitigation for diffuse discharges from commercial vegetables.

A similar offset policy is proposed in the Plan for point-source discharges. Horticultural landuse has some parallels to urban land-uses associated with point-source offset policy, in that both activities are intensive with small land footprints, and therefore limited opportunities to achieve reductions in discharges without impacting in the viability of the activity.

The case study below discusses the water quality impact of the discharge from Lake Waikare on the Lower Waikato compared with horticulture and discusses how the effects of the point source discharge from Lake Waikare could be mitigated through the proposed off-set mitigation.

Case Study – Riverine Lakes and River Clarity	
Background	PC1 set targets for river clarity. The clarity attribute is an indicator for ecological health and for swimming.
Light-attenuating constituents	The visual clarity of the water in the Waikato and Waipa Rivers reflects the varying concentrations of the light-attenuating constituents present in it. The main constituents are dissolved yellow substance, phytoplankton, organic detritus and suspended silts and clays. The concentrations of these constituents vary in both time and space, and so too does the visual clarity of the river waters. On average, yellow substance was a minor contributor (c. 2%) to beam attenuation in the Waikato River during 2005–14. Even in the Waipa River its contribution was usually small (<5%), apart from at the most upstream site (where it was c. 8%). On average, phytoplankton contributed an estimated 50–60% of the observed beam attenuation in the section of the Waikato River upstream of the confluence with the Waipa River (at Ngaruawahia). Further downstream, phytoplankton contributed about one-third of beam attenuation on average. Non-algal beam attenuation, which can be mainly attributed to suspended silts and clays, is apparently responsible for the other 40–50% of the beam attenuation in the section of the Waikato River upstream of Ngaruawahia, and most of the beam attenuation in the reach downstream of there. Non-algal attenuation is expected to dominate beam attenuation in the Waipa River (Vant, 2015). NIWA (Yalden & Elliot, 2015) developed a model to predict change in clarity in the main stem of the Waikato in relation to PC1. In the clarity model, the key contributors to visual clarity in this study were considered to be yellow substance, phytoplankton and ‘other’ (assumed to be dominated by fine sediment). The contribution to visual clarity due to yellow substance was assumed to remain constant. Changes to nutrient concentrations affect changes to visual clarity through increased or decreased chlorophyll concentrations which provide an indicator of phytoplankton growth. Changes to sediment loads affect changes to visual clarity through the ‘other’ contributor.
Black disc visual clarity	Black disc visual clarity for the HRWO subcatchments were estimated from monitoring data provided by WRC as well as from the National Rivers Water Quality Network (NRWQN) run by NIWA. The median black disc values were calculated over a 5 year period 2010-2014 and are displayed in Table 4-5

below. For each black disc measurement (y_{BD}[m]), the beam attenuation coefficient was calculated as $c = {}^{4.8}/_{y_{BD}}$. The beam attenuation coefficient is made up of 3 key constituents: yellow substance, phytoplankton, and fine sediment. The contribution to beam attenuation from phytoplankton is estimated as $c_B = 0.47(Chl)^{0.65}$, where Chl is the chlorophyll concentration in mg m^{-3}.

Table 4-5: Median visual clarity and percent contribution to beam attenuation from each of the three key constituents.

HRWO sub-catchment	Visual clarity		Constituent contribution (%)			Median measured values 2010-2014			
	y_{BD} (m)	c (m^{-1})	c_Y – yellow substance	c_B - phytoplankton	c_S – fine sediment	TN (mg/L)	TP (mg/L)	TN/TP ratio	Chl-a(mg/L
Waikato at Ohaaki (3)	-	-	-	-	-	-	-	-	-
Waikato at Ohakuri	2	2.4	0	44	56	0.215	0.018	11.9	0.0032
Waikato at Whakamaru (5)	-	-	-	-	-	-	-	-	-
Waikato at Waipapa	1.6	3	1	36	63	0.336	0.026	13.1	0.0041
Waikato at Karapiro	-	-	-	-	-	-	-	-	-
Waikato at Narrows	1.6	3	1	52	47	0.41	0.029	14.3	0.0055
Waikato at Bridge St Br (1)	1.4	3.5	1	52	47	0.437	0.035	12.5	-
Waikato at Horotiu Br	1.4	3.6	1	47	52	0.441	0.038	11.8	0.0062
Waikato at Huntly-Tainui Br	0.9	5.5	2	31	67	0.585	0.047	12.5	0.006
Waikato at Rangiriri (4)	0.8	6.2	1	31	68	0.602	0.056	10.8	-
Waikato at Mercer Br (2)	0.6	8	1	28	71	0.662	0.054	12.2	0.0105
Waikato at Tuakau Br	0.5	9.4	1	27	72	0.595	0.056	10.6	0.012
Waikato at Port Waikato	-	-	-	-	-	-	-	-	-

Notes: 1. Chlorophyll is not measured at this site. The contribution to visual clarity resulting from phytoplankton is assumed to be the same as for Waikato at Narrows. 2. Black disc measurements are not available for this site. Median black disc visual clarity is estimated from Waikato at Huntly-Tainui Br. 3. Measured chlorophyll concentrations are consistently below detection at this site. 4. Chlorophyll is not measured at this site. The contribution to visual clarity resulting from phytoplankton is assumed to the same as for Waikato at Huntly-Tainui Br..5. Measured chlorophyll concentrations are considered unreliable for this site (see Verburg, 2015).

Chlorophyll conc. and clarity

An empirical relationship was developed to predict changes in chlorophyll concentrations in response to TN and TP concentrations. The coefficients of this relationship are weighted as a function of the TN/TP ratio, which allows the model to respond to changes in both nutrients at different levels of sensitivity under different nutrient-limitation regimes. Separate models were fitted for individual sites along the main-stem of the Waikato River. Chlorophyll concentrations are not measured in the tributaries or along the main-stem of the Waipa River, and contributions to visual clarity resulting from phytoplankton are considered negligible for these sites.

The model indicates contribution due to phytoplankton for the upper main stem Waikato River sites is generally high with Ohakuri at 44% and Waipapa at 36% before increasing to 52% at the Narrows site. The Narrows site is downstream from Karapiro dam, which is the final dam on the Waikato River.

	Downstream of the dams, the contribution of phytoplankton starts to decrease and drops to 27% at Tuakau. This implies that the relative contribution to phytoplankton has dropped by half by the time the flow reaches Tuakau, with the sediment contribution increasing below Narrows. The model uses median data, and makes assumptions around N:P limitation. The monitoring data and bioassay studies indicate inter-seasonal variability that the model does not represent, both in respect of nutrient limitation, and in respect of the relative contribution of fine sediment and chl-a to clarity, with chl-a having a greater influence on clarity in summer and low flow conditions (TLG, 2015). In the Lower Waikato the chl-a population is influenced by the main chl-a concentration in the main stem, which is influenced by a number of factors, including the residence time in the hydrodams and river and the upstream nutrient loads. Between Rangiriri and Mercer, the chl-a loads from Lake Waikare and Lake Whangape discharge to the Lower Waikato and contribute 27% of the summer-average chl-a, with approximately 8% contributed from Lake Waikare and 19% from Lake Whangape (Vant, 2015). The influence of the shallow lakes is therefore very significant on the clarity in the Lower Waikato. The clarity model used to inform PC1 was focused on the main stem, it is not clear modelled mitigations account for the ongoing contribution from the shallow lakes.
Visual clarity targets and management	PC1 requires a reduction in N and P from diffuse sources to improve the Waikato River clarity. In the short term, the Lake Freshwater Management targets are set only at the 80 year time horizon with the development of lake catchment plans over the next 10 years. The catchments for Lake Whangape and Lake Waikare contain some of the highest sediment yielding land in the Waikato catchment, as illustrated on the next page in Figure 5.1, and therefore catchment management for these lake catchments is likely to be critical in achieving the water quality targets for the Riverine Lakes FMU and also in reducing the impact of the discharges from these lakes on downstream receiving environments. The clarity targets set out in PC1 outline no short-term improvement in clarity at Huntly, but an improvement at Tuakau from the current level of 0.5 m to 0.6 m. It is unclear, to what degree the catchment management of other improvements identified for the Riverine Lakes will have been implemented in the next 10 years. The management of Lake Waikare to achieve its long–term water clarity target and to reduce its impact on downstream values is complicated by its function as part of the Lower Waikato Flood Scheme. In 1965 Lake Waikare was artificially lowered, and re-directed to flow away from the Waikato River and into the Whangamarino Wetland via the Pungarehu Canal. The water level in the lake is controlled within a small range (stipulated by a consent conditions) to provide flood storage in large and infrequent Waikato River floods, and to enable farming on the low lying land surrounding the lake and river (including horticultural land use). The modifications to Lake Waikare are likely to reduce the water quality discharges via the Pungarehu canal include: • The altered residence time in the lake due to the water level control rules on Lake Waikare, which require the Lake is kept artificially low to allow for flood storage. The consented minimum water level results in the Lake outlet gate on the Pungarehu canal closed for long-periods generally in summer. • The shallow water depth of the lake results in high turbidity due to wind re-suspension of lake bed sediment. The re-suspension of sediment results in the discharge of sediment in phosphorus into the Whangamarino Wetland and subsequent adverse ecological effects. The high turbidity also contributes to the challenge in re-establishing macrophytes in the Lake which, if established may improve the trophic state of the Lake • The flood protection of the “found” land surrounding the Lake and subsequent farming of this land, contributing the ongoing bank erosion on the lake edge.

	The discharge of waters from Lake Waikare into the Pungarehu Canal is controlled by a discharge consent (currently under review), which requires the management of sediment discharged from the lake. The focus on the effect of the Lake Waikare discharge are on the Whangamarino Wetland, rather than accounting for the impact of the Lake Waikare discharge on achieving the downstream (Whangamarino River and Waikato River) water quality targets. Policy 10 provides for discharges of regional significance, Policy 11 provides for offsetting, and Policy 12 provides for the best practicable option. These policies may provide a mechanism for the influence that the management of Lake Waikare for flood protection has on the water quality of Lake Waikare and the effects of the discharge of Lake Waikare on downstream water quality.
Conclusion	The contribution the Riverine lakes make to River clarity in the Waikato is significant and is likely to far exceed the impact of discharges from horticultural land. PC1 sets long term water quality targets for improvements for the Lakes, recognises that the improvement in the quality of the Lakes is likely to require both catchment management and lake interventions. For Lake Waikare, the offsetting policy provides a mechanism for addressing the contribution the flood protection scheme makes to the water quality in Lake Waikare and the subsequent downstream river water quality. The offset policy also provides a mechanism for the effects of the poor quality water from Lake Waikare to be addressed more quickly, than the timeframe that may be required to achieve the lake water quality targets. In the same way that an offset policy is likely to be useful for mitigating the effects of point source discharges it could also be useful in reducing the effects from horticultural land, which due to the intensity and small footprint, has fewer on-farm mitigation options compared with pastoral farming.

4.4 Farm Management Plans

Horticulture New Zealand seeks amendments to the Farm Management Plan Schedule1, part of Horticulture New Zealand's issue with the current plan is the lack of focus on managing losses from cultivation practices across broader rural land than that occupied by the vegetable sector. Horticulture New Zealand considers that a range of practices could be mandated across cultivated land.

Horticulture New Zealand's submission seeks changes to Schedule 1. The proposed schedule 1a includes a number of amendments and includes recognition of cultivated land outside of the horticultural sector, in Schedule 1a. The proposed Schedule 1b sets out specific criteria for commercial vegetable growers, including reference to *the Horticulture New Zealand Erosion & Sediment Control Guidelines for Vegetable Production Version 1.1 June 2014.* The proposed Schedule 1C, sets out specific criteria for sub catchment scale management plans.

The case study below utilises infra-red satellite imagery to identify bare earth within one sub-catchment, the Mangaone, where horticulture and other land uses take place.

Case Study – Bare Earth and Sediment Management – Mangaone Catchment	
Background	PC1 set targets for river clarity. The clarity attribute is an indicator for ecological health and for swimming. Sediment influences the clarity value, both due to turbidity and because erosion of soil contributes phosphorus load.
Farm Management Plan	The method used to estimate sediment generated from land was NZEEM. The NZEEM method does not differentiate between pasture and bare earth, however bare earth does generate more sediment than pasture and is recognised in the requirements for Farm Management Plans. Farm Management Plans include requirements for 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.
Landuse analysis	In order to examine the bare earth in the Mangaone catchment, infra-red satellite imagery was analysed to identify bare earth in the Mangaone catchment and to classify it by landuse. Figure 4.5 illustrates the bare earth in the Mangaone catchment captured by satellite imagery. Bare earth was derived using the Normalised Difference Vegetation Index in ArcGIS from Sentinel-2A imagery (captured 22/11/2016, 10m resolution). Bare earth areas less than 0.25 ha were ignored. The bare earth has been intersected with the landuse data used for the Healthy Rivers modelling. The landuse GIS layer was supplied to Jacobs by NIWA. We analysed the supplied landuse map against the satellite imagery. There are areas of bare earth classified as sheep and beef intensive and native vegetation that appear to be in horticultural production. The landuse category "other" includes arable. Our analysis of the satellite imagery indicates there is arable land within this catchment. Similarly bare earth within dairy and sheep and beef landuse appears to be classified correctly . Table 4-6 below provides the area and percentage of bare earth in the Mangaone catchment using the supplied landuse layer. Table 4-7 provides the same analysis, but with some of the land that was identified as either; native forest, sheep and beef or urban in the supplied land use layer, re-classified as horticulture. **Table 4-6: Bare earth proportion for the Mangaone Catchment using default WRC landuse data**

Land use	Total Area (ha)	Bare Earth (ha)	Proportion of bare earth in catchment
All other land uses	715	68	20%
Dairy	2150	53	16%
Horticulture	113	29	9%
Maize	224	65	19%
Native forest and scrub	216	19	6%
Plantation forest	39	0.2	0%
Sheep and beef - intensive	2089	79	24%
Urban	1215	22	6%

Table 4-7: Bare earth proportion for the Mangaone Catchment using adjusted horticultural landuse

Land use	Total Area (ha)	Bare Earth (ha)	Proportion of bare earth in catchment
All other land uses	708	60.5	18%
Dairy	2150	52.7	16%
Horticulture	182	97.3	29%
Maize	221	61.6	18%
Native forest and scrub	199	1.7	1%
Plantation forest	39	0.2	0%
Sheep and beef - intensive	2052	42.0	13%
Urban	1210	17.5	5%

Conclusion

The landuse and bare soil analysis indicates that horticultural land, while likely to have a higher proportion of bare earth compared with other land uses is likely to make up only small fraction of the bare earth on farm land within the Waikato Region, due to its small footprint.

In the Mangaone catchment, horticulture makes up 2% of the landuse, bare earth makes up 5% of the land within the catchment. Our estimate is the horticultural landuse makes up approximately 30% of the bare earth within the catchment, which means that 70% of the bare earth is within other land uses.

Managing the effect of soil erosion from cultivated land, will require measures are implemented on all land uses, including horticultural land**.**

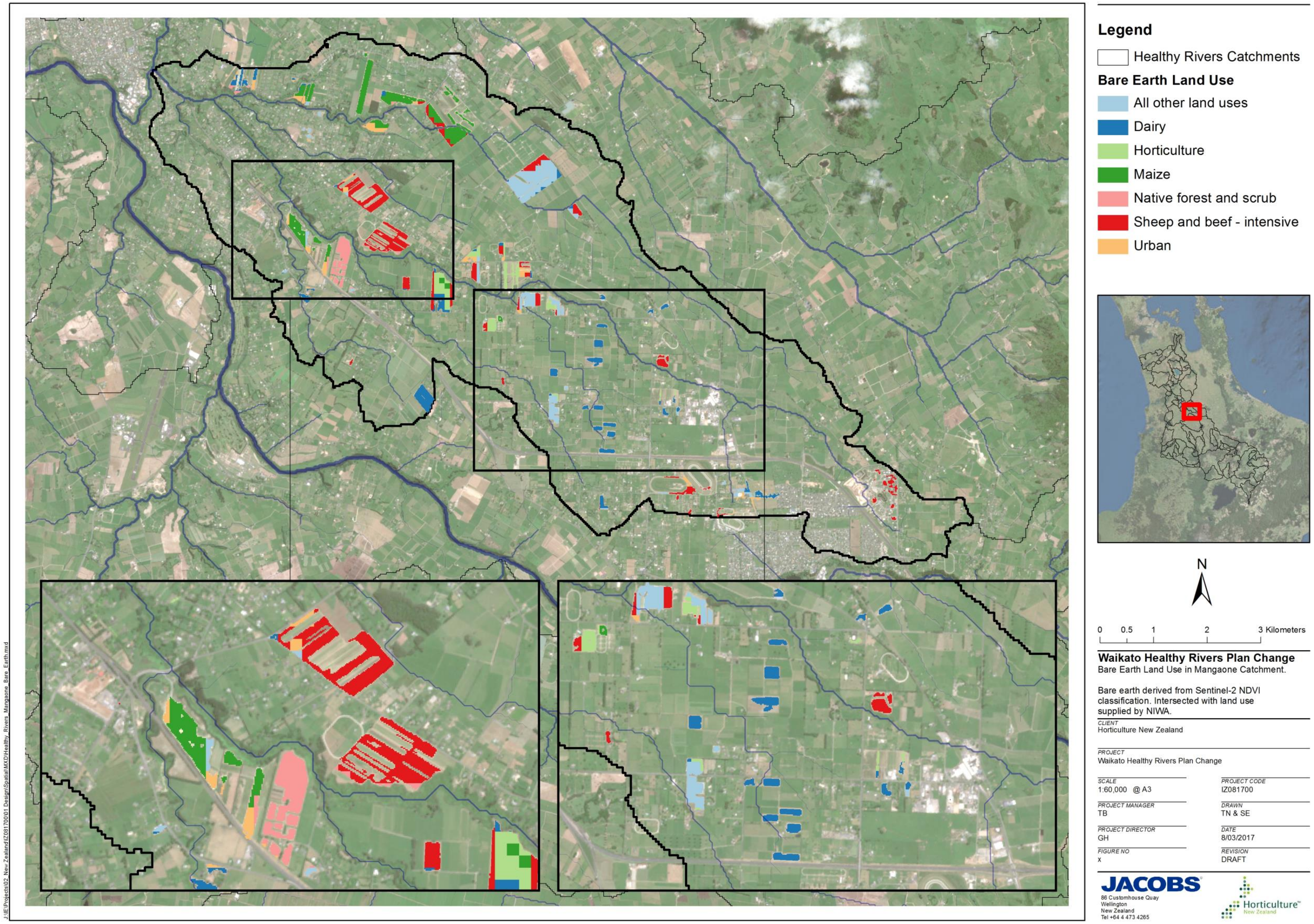

Figure 4.5 Mangaone Catchment, bare earth classified by the Healthy Rivers Landuse layer. (Landuse layer supplied to Jacobs by NIWA)

4.5 Sub-catchment Allocations

The Horticulture New Zealand submission proposes a change to Objective 3 to add the *or achievement of the contaminant load reduction targets specified for each subcatchment in Table 3.11.*

We requested catchment loads that were associated with the 10 year water quality targets from Waikato University, at the time of submission these loads have not been made available.

Graeme Doole suggested that we calculate them from the baseline leaching data supplied by NIWA and the documented mitigations.

We have attempted to calculate loads for TN, TP and E.coli, for those sites where it was possible. These loads should be updated with the modelled loads. It was not possible to calculate a catchment load for Chl-a from the data available.

4.5.1 The methodology for calculating the TN, TP and nitrate load was as follows:

- Take the baseline unattenuated sub-catchment loads for pastoral and horticulture landuses, supplied by NIWA, and apply the attenuation factors described in the nutrient modelling report (Semadeni-Davies, September 2015). The load for the additional landuses was added, and the routing factors were applied (TN only), point sources, geothermal inputs (TN only) and sediment-P loads were then added in each sub-catchment. Finally the reservoir attenuation factors were applied where applicable. The resultant load equalled attenuated cumulative sub-catchment loads described in the nutrient modelling report by Semadeni-Davies (2015).

- The baseline attenuated loads for each sub catchment, were consistent with those supplied to the CSG in the spreadsheet named:

  - EWDOCS_n3625036_v1_Load_data_for_CSG_including_minus_forestry

- The baseline and 10% reduction concentration for TN, TP, and nitrate loads were supplied in a spreadsheet named:

  - Concentration data for CSG

- The 10 year water quality concentration targets in PC1 are between the baseline concentrations and the 10% concentrations described in the CSG spreadsheet.

- For those sub-catchments where baseline concentration data was available, a linear relationship was assumed between the baseline and 10% concentration and this ratio was applied to the loads to calculate the attenuated load associated with the PC1 concentration. Where PC1 targets were not available for TN concentrations, the linear relationship between the baseline and 10% concentrations of nitrate was developed. This ratio was applied to the TN load, to calculate the attenuated nitrate load associated with the PC1 concentration. Using this method we have assume that the nitrate load per sub-catchment is similar to the TN load per catchment.

- The attenuation calculation described in step 1, was reversed, to calculate the unattenuated sub-catchment load. The unattenuated sub-catchment load does not include point source, geothermal inputs, or sediment-P loads from the catchment. For TN, the ultimate attenuation factor was applied to estimate N loads to come through groundwater lag.

- These calculations assume that:

  - Mitigations have been undertaken on pastoral and horticultural land only; and

  - Point source, geothermal, and sediment-P loads remain unchanged.

4.5.2 The methodology for calculating the E. coli load was as follows:

- Take unattenuated landuse E. coli yields supplied in Table 3-1 in the E.coli modelling report (Semadeni-Davies et al., September 2015). Multiply these by the land area per each land use in each sub-catchment. Sum these together to get total unattenuated yield per sub-catchment. Land use by area per sub-catchment was supplied from NIWA in the spreadsheet named:
  - Ecoli yields_Supplied by NIWA
- The unattenuated yields were converted to attenuated yields by a ratio, so that they matched the attenuated yields supplied in the spreadsheet, named above. Point sources of E.coli, and farm dairy effluent discharges (FDE) were added to each sub-catchment load. Reservoir attenuation factors were applied so that calculated total attenuated E.coli sub-catchment loads were consistent with the loads in the Semadeni-Davies et al. (2015) report and those supplied to the CSG in the spreadsheet named:
  - EWDOCS_n3625036_v1_Load_data_for_CSG_including_minus_forestry
- The baseline and 10% reduction concentration for E.coli was supplied in a spreadsheet named:
  - Concentration data for CSG
- The 10 year water quality concentration targets in PC1 are between the baseline concentrations and the 10% concentrations for 95th percentile E.coli described in the CSG spreadsheet. A linear relationship was assumed between the baseline and 10% concentration for 95th percentile E.coli and this ratio was applied to the loads to calculate the attenuated load associated with the PC1 concentration.
- The attenuation calculation described in step 1 and step 2 above, was reversed, to calculate the unattenuated sub-catchment load.
- These calculations assume that:
  - Point source and FDE loads remain unchanged.

Table 4-8 Estimated Subcatchment unattenuated loads for the short-term water quality targets (excluding point sources)

Site	FMU	Annual Median Chlorophyll a (mg/m3)		Annual Maximum Chlorophyll a (mg/m3)		Annual Median Total Nitrogen (mg/m3)		Annual Total Nitrogen Load t/yr	Annual Median Total Phosphorus (mg/m3)		Annual Total Phosphorus Load t/yr	Annual Median Nitrate (mg NO3-N/L)		Annual 95th percentile Nitrate (mg NO3-N/L)		Annual Nitrate Load t/yr	Annual Median Ammonia (mg NH4-N/L)		Annual Maximum Ammonia (mg NH4-N/L)		Annual Ammonia Load t/yr	95th percentile E. coli (E.coli/100mL)		Annual E.coli Load 10^15 organisms/yr	Clarity (m)	
		Short term	80 year	Short term	80 year	Short term	80 year	Short term	Short term	80 year	Short term	Short term	80 year	Short term	80 year	Short term	Short term	80 year	Short term	80 year	Short term	Short term	80 year	Short term	Short term	80 year
Upper Waikato Freshwater Management Unit																										
Waikato River at Ohaaki Br	Upper Waikato	1.5	1.5	13	13	134	134	255	10	10	18	0.039	0.039	0.062	0.062	255	0.002	0.002	0.013	0.013		70	70	1.00	3.8	3.8
Waikato River at Ohakuri Tailrace Br	Upper Waikato	3.2	3.2	11	11	206	160	554	17	17	50	0.084	0.084	0.172	0.172	555	0.003	0.003	0.017	0.017		15	15	2.16	3.4	3.4
Waikato River at Whakamaru Tailrace	Upper Waikato		5		25	260	160	364	20	20	31	0.101	0.101	0.23	0.23	364	0.003	0.003	0.01	0.01		60	60	1.39	2	3
Waikato River at Waipapa tailrace	Upper Waikato	4.1	4.1	25	25	318	160	552	25	20	48	0.164	0.164	0.32	0.32	552	0.007	0.007	0.017	0.017		162	162	2.23	2	3
Pueto Stm at Broadlands Rd Br	Upper Waikato											0.45	0.45	0.53	0.53	129	0.003	0.003	0.009	0.009		92	92	0.49	1.8	3
Torepatutahi Stm Vaile Rd Br	Upper Waikato											0.5	0.5	0.8	0.8	79	0.002	0.002	0.011	0.011		216	216	0.69		
Waiotapu Stm Homestead Rd Br	Upper Waikato											1.257	1	1.563	1.5	229	0.112	0.03	0.176	0.05		281	281	0.66		
Mangakara Stm (Reporoa) SH5	Upper Waikato											1.27	1	1.59	1.5	24	0.008	0.008	0.062	0.05		1584	540	0.07	0.9	1
Kawaunui Stm SH5 Br	Upper Waikato											2.58	2.4	2.85	1.5	32	0.006	0.006	0.079	0.05		2335	540	0.08	1.4	1.6
Waiotapu Stm Campbell Rd Br	Upper Waikato											0.915	0.915	1.1	1.1	48	0.291	0.24	0.315	0.05		18	18	0.18	1.2	1.6
Otamakokore Stm Hossack Rd	Upper Waikato											0.74	0.74	1.19	1.19	60	0.006	0.006	0.024	0.024		680	540	0.23	1.2	1.6
Whirinaki Stm Corbett Rd	Upper Waikato											0.77	0.77	0.87	0.87	10	0.002	0.002	0.012	0.012		98	98	0.06	2.7	3
Tahunaatara Stm Ohakuri Rd	Upper Waikato											0.555	0.555	0.83	0.83	204	0.003	0.003	0.015	0.015		783	540	0.69	1.3	1.6
Mangaharakeke Stm SH30 (Off jct SH1)	Upper Waikato											0.525	0.525	0.75	0.75	35	0.003	0.003	0.015	0.015		684	540	0.11	1.1	1.6
Waipapa Stm (Mokai) Tirohanga Rd Br	Upper Waikato											1.189	1	1.5	1.5	102	0.003	0.003	0.005	0.005		1147	540	0.52	1.2	1.6
Mangakino Stm Sandel Rd	Upper Waikato											0.65	0.65	0.86	0.86	222	0.003	0.003	0.012	0.012		251	251	0.77	1.8	3
Whakauru Stm SH1 Br	Upper Waikato											0.26	0.26	0.45	0.45	86	0.003	0.003	0.033	0.033		2106	540	0.23	0.8	1
Mangamingi Stm Paraonui Rd Br	Upper Waikato											2.76	2.4	3.12	1.5	113	0.091	0.03	0.296	0.05		2151	540	0.29	0.8	1
Pokaiwhenua Stm Arapuni - Putaruru Rd	Upper Waikato											1.68	1	2.04	1.5	484	0.002	0.002	0.02	0.02		1363	540	1.23	1.3	1.6
Little Waipa Stm Arapuni - Putaruru Rd	Upper Waikato											1.522	1	2.04	1.5	210	0.002	0.002	0.085	0.05		1377	540	0.69	1.5	1.6
Central Waikato Freshwater Management Unit																										
Waikato River Narrows Boat Ramp	Central Waikato	5.5	5	23	23	404	350	204	28	20	10	0.235	0.235	0.5	0.5	204	0.009	0.009	0.018	0.018		340	260	0.76	1.7	1.7
Waikato River Horotiu Br	Central Waikato	6.1	5	23	23	432	350	78	34	20	3	0.26	0.26	0.53	0.53	78	0.007	0.007	0.029	0.029		774	540	0.50	1.4	1.6
Karapiro Stm Hickey Rd Bridge	Central Waikato											0.52	0.52	1.689	1.5	94	0.008	0.008	0.031	0.031		4518	540	0.75	0.9	1
Mangawhero Stm Cambridge-Ohaupo Rd	Central Waikato											1.99	1	2.49	1.5	94	0.041	0.03	0.072	0.05		2920	540	0.30	0.3	1
Mangaonua Stm Hoeka Rd	Central Waikato											1.455	1	1.878	1.5	126	0.036	0.03	0.051	0.05		6372	540	0.44	1	1
Mangaone Stm Annebrooke Rd Br	Central Waikato											2.58	2.4	2.94	1.5	105	0.009	0.009	0.02	0.02		2052	540	0.35	0.9	1
Mangakotukutuku Stm Peacockes Rd	Central Waikato											0.8	0.8	1.788	1.5	55	0.077	0.03	0.132	0.05		11394	540	0.15	0.5	1
Waitawhiriwhiri Stm Edgecumbe Street	Central Waikato											0.88	0.88	1.24	1.24	36	0.256	0.24	0.318	0.05		5922	540	0.14	0.4	1
Kirikiriroa Stm Tauhara Dr	Central Waikato											0.815	0.815	1.572	1.5	14	0.096	0.03	0.183	0.05		2124	540	0.11	0.5	1
Lower Waikato Freshwater Management Unit																										
Waikato River Huntly-Tainui Br	Lower Waikato	5.9	5	19	19	562	350	314	43	20	9	0.365	0.365	0.9	0.9	314	0.005	0.005	0.015	0.015		1944	540	0.99	0.9	1
Waikato River Mercer Br	Lower Waikato	10	5	30	25	631	350	484	49	20	31	0.365	0.365	0.87	0.87	484	0.003	0.003	0.01	0.01		1494	540	2.82		

Waikato River Tuakau Br	Lower Waikato	11.3	5	37	25	571	350	156	50	20	9	0.325	0.325	0.88	0.88	156	0.003	0.003	0.008	0.008		1584	540	0.46	0.7	1
Komakorau Stm Henry Rd	Lower Waikato											1.279	1	4.4	3.5	414	0.25	0.24	0.419	0.4		3474	540	0.97	0.3	1
Mangawara Stm Rutherford Rd Br	Lower Waikato											0.765	0.765	2.76	1.5	695	0.103	0.03	0.172	0.05		4955	540	1.78	0.3	1
Awaroa Stm (Rotowaro) Sansons Br @ Rotowaro-Huntly Rd	Lower Waikato											0.7	0.7	1.19	1.19	35	0.021	0.021	0.089	0.05		1800	540	0.33	0.8	1
Matahuru Stm Waiterimu Road Below Confluence	Lower Waikato											0.715	0.715	1.689	1.5	113	0.016	0.016	0.059	0.05		6147	540	0.73	0.4	1
Whangape Stm Rangiriri-Glen Murray Rd	Lower Waikato											0.004	0.004	0.69	0.69	386	0.006	0.006	0.134	0.05		584	540	3.17	0.3	1
Waerenga Stm SH2 Maramarua	Lower Waikato											0.82	0.82	1.41	1.41	17	0.005	0.005	0.022	0.022		5098	540	0.18	0.9	1
Whangamarino River Jefferies Rd Br	Lower Waikato											0.625	0.625	1.842	1.5	117	0.012	0.012	0.147	0.05		4712	540	0.54	0.6	1
Mangatangi River SH2 Maramarua	Lower Waikato											0.11	0.11	1.12	1.12	174	0.005	0.005	0.038	0.038		5567	540	0.66	0.5	1
Mangatawhiri River Lyons Rd Buckingham Br	Lower Waikato											0.013	0.013	0.37	0.37	20	0.003	0.003	0.011	0.011		5108	540	0.08	1.6	1.6
Whangamarino River Island Block Rd	Lower Waikato											0.075	0.075	0.7	0.7	135	0.011	0.011	0.054	0.05		655	540	0.47	0.3	1
Whakapipi Stm SH22 Br	Lower Waikato											3.39	2.4	5.12	3.5	99	0.006	0.006	0.081	0.05		1773	540	0.25	1.1	1.1
Ohaeroa Stm SH22 Br	Lower Waikato											1.473	1	1.806	1.5	29	0.003	0.003	0.015	0.015		4667	540	0.10	0.8	1
Opuatia Stm Ponganui Rd	Lower Waikato											0.74	0.74	1.06	1.06	71	0.005	0.005	0.016	0.016		2898	540	0.73	0.6	1
Awaroa River (Waiuku) Otaua Rd Br Moseley Rd	Lower Waikato											1.369	1	2.31	1.5	32	0.021	0.021	0.135	0.05		1017	540	0.12	0.4	1
Waipa Waikato Freshwater Management Unit																										
Waipa River Mangaokewa Rd	Waipa											0.38	0.38	0.6	0.6	17	0.003	0.003	0.017	0.017		2417	540	0.18	1.5	1.6
Waipa River Otewa	Waipa											0.228	0.228	0.502	0.502	224	0.003	0.003	0.008	0.008		2036	540	1.76	2.1	2.1
Waipa River SH3 Otorohanga	Waipa											0.37	0.37	1.05	1.05	301	0.004	0.004	0.02	0.02		3289	540	0.94	1.2	1.6
Waipa River Pirongia-Ngutunui Rd Br	Waipa											0.565	0.565	1.27	1.27	977	0.008	0.008	0.023	0.023		4441	540	2.56	0.7	1
Waipa River Whatawhata Bridge	Waipa											0.673	0.673	1.319	1.319	612	0.009	0.009	0.026	0.026		3657	540	1.94	0.6	1
Ohote Stm Whatawhata/Horotiu Rd	Waipa											0.495	0.495	1.37	1.37	57	0.023	0.023	0.052	0.05		2142	540	0.19	0.6	1
Kaniwhaniwha Stm Wright Rd	Waipa											0.35	0.35	0.89	0.89	116	0.007	0.007	0.022	0.022		1917	540	0.53	0.9	1
Mangapiko Bowman Rd Stm	Waipa											1.369	1	2.49	1.5	592	0.022	0.022	0.076	0.03		7074	540	1.92	0.6	1
Mangaohoi Stm South Branch Maru Rd	Waipa											0.23	0.23	0.39	0.39	2	0.003	0.003	0.008	0.008		943	540	0.05	1.6	1.6
Mangauika Stm Te Awamutu Borough W/S intake	Waipa											0.21	0.21	0.28	0.28	4	0.002	0.002	0.003	0.003		1008	540	0.01	3.3	3.3
Puniu River Bartons Corner Rd Br	Waipa											0.65	0.65	1.28	1.28	511	0.007	0.007	0.029	0.029		2790	540	1.50	0.9	1
Mangatutu Stm Walker Rd Br	Waipa											0.38	0.38	0.88	0.88	152	0.003	0.003	0.012	0.012		738	540	0.61	1.5	1.6
Waitomo Stm SH31 Otorohanga	Waipa											0.52	0.52	0.83	0.83	45	0.008	0.008	0.025	0.025		1453	540	0.28	0.6	1
Mangapu River Otorohanga	Waipa											0.86	0.86	1.36	1.36	236	0.015	0.015	0.057	0.05		4284	540	1.34	0.7	1
Waitomo Stm Tumutumu Rd	Waipa											0.63	0.63	0.8	0.8	33	0.004	0.004	0.013	0.013		2241	540	0.23	1.1	1.6
Mangaokewa Stm Lawrence Street Br	Waipa											0.53	0.53	0.98	0.98	165	0.004	0.004	0.013	0.013		6224	540	1.87	1.4	1.6

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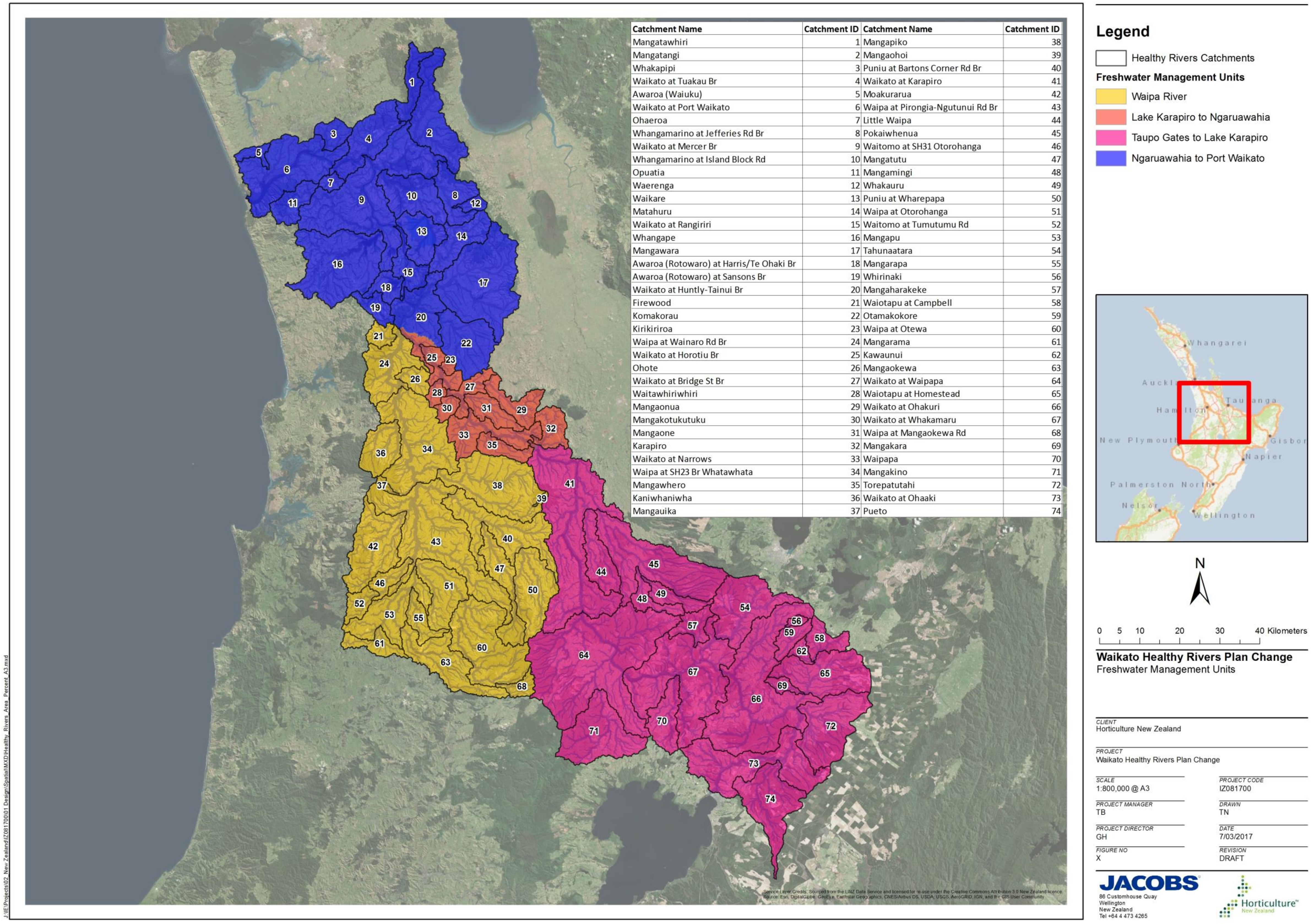
Appendix A. Healthy Rivers Catchments



Catchment Name	Catchment ID	Catchment Name	Catchment ID
Mangatawhiri	1	Mangapiko	38
Mangatangi	2	Mangaohoi	39
Whakapipi	3	Puniu at Bartons Corner Rd Br	40
Waikato at Tuakau Br	4	Waikato at Karapiro	41
Awaroa (Waiuku)	5	Moakurarua	42
Waikato at Port Waikato	6	Waipa at Pirongia-Ngutunui Rd Br	43
Ohaeroa	7	Little Waipa	44
Whangamarino at Jefferies Rd Br	8	Pokaiwhenua	45
Waikato at Mercer Br	9	Waitomo at SH31 Otorohanga	46
Whangamarino at Island Block Rd	10	Mangatutu	47
Opuatia	11	Mangamingi	48
Waerenga	12	Whakauru	49
Waikare	13	Puniu at Wharepapa	50
Matahuru	14	Waipa at Otorohanga	51
Waikato at Rangiriri	15	Waitomo at Tumutumu Rd	52
Whangape	16	Mangapu	53
Mangawara	17	Tahunaatara	54
Awaroa (Rotowaro) at Harris/Te Ohaki Br	18	Mangarapa	55
Awaroa (Rotowaro) at Sansons Br	19	Whirinaki	56
Waikato at Huntly-Tainui Br	20	Mangaharakeke	57
Firewood	21	Waiotapu at Campbell	58
Komakorau	22	Otamakokore	59
Kirikiriroa	23	Waipa at Otewa	60
Waipa at Wainaro Rd Br	24	Mangarama	61
Waikato at Horotiu Br	25	Kawaunui	62
Ohote	26	Mangaokewa	63
Waikato at Bridge St Br	27	Waikato at Waipapa	64
Waitawhiriwhiri	28	Waiotapu at Homestead	65
Mangaonua	29	Waikato at Ohakuri	66
Mangakotukutuku	30	Waikato at Whakamaru	67
Mangaone	31	Waipa at Mangaokewa Rd	68
Karapiro	32	Mangakara	69
Waikato at Narrows	33	Waipapa	70
Waipa at SH23 Br Whatawhata	34	Mangakino	71
Mangawhero	35	Torepatutahi	72
Kaniwhaniwha	36	Waikato at Ohaaki	73
Mangauika	37	Pueto	74

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Legend

☐ Healthy Rivers Catchments

Freshwater Management Units

- 🟨 Waipa River
- 🟥 Lake Karapiro to Ngaruawahia
- 🟪 Taupo Gates to Lake Karapiro
- 🟦 Ngaruawahia to Port Waikato

Waikato Healthy Rivers Plan Change
Freshwater Management Units

CLIENT
Horticulture New Zealand

PROJECT
Waikato Healthy Rivers Plan Change

SCALE
1:800,000 @ A3

PROJECT CODE
IZ081700

PROJECT MANAGER
TB

DRAWN
TN

PROJECT DIRECTOR
GH

DATE
7/03/2017

FIGURE NO
X

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DRAFT

JACOBS
86 Customhouse Quay
Wellington
New Zealand
Tel +64 4 473 4265

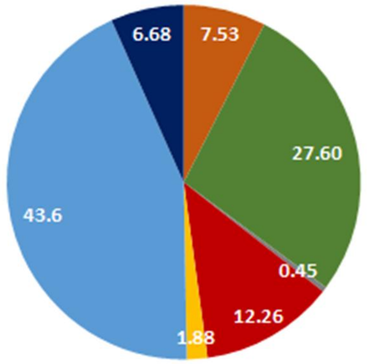
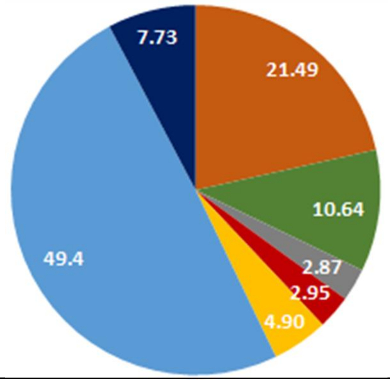
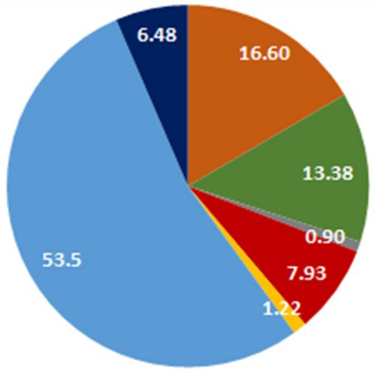
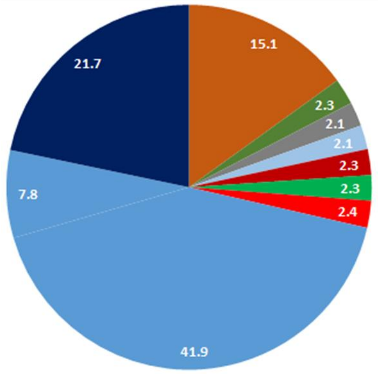
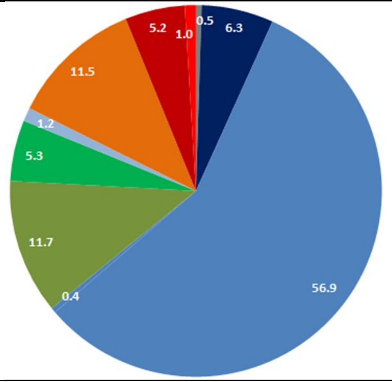
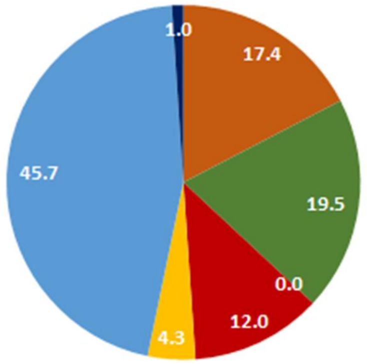
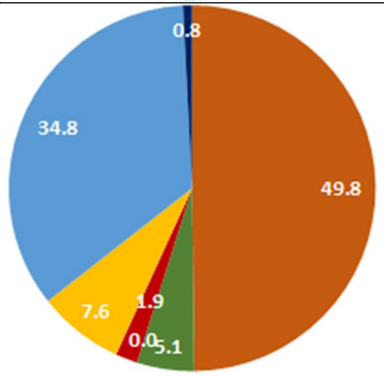
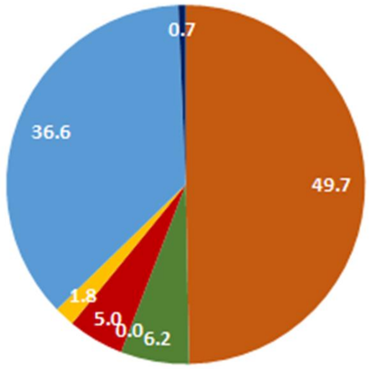
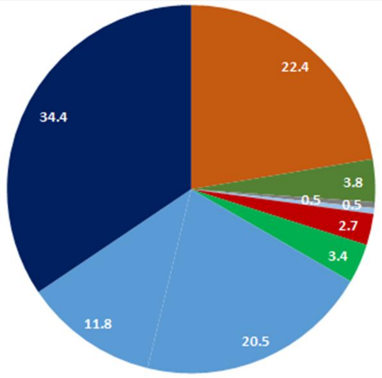
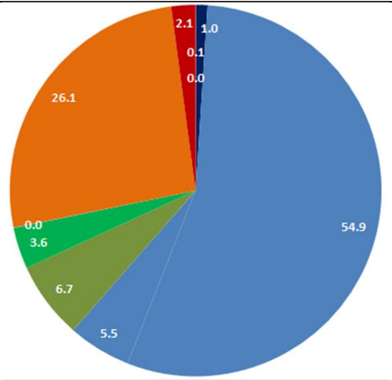
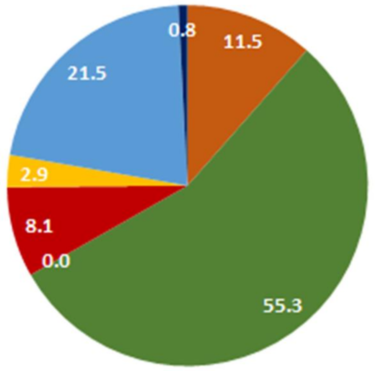
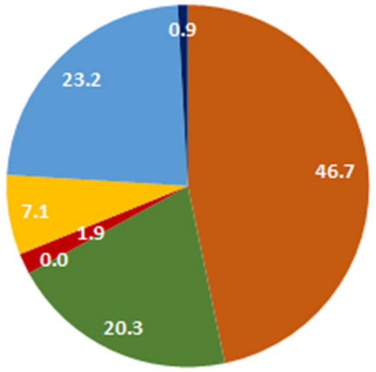
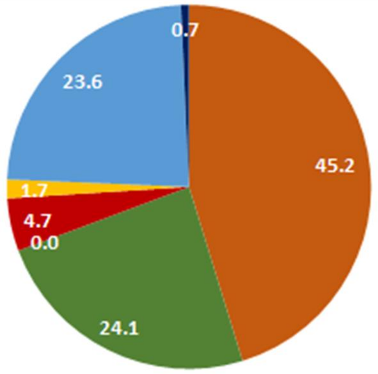
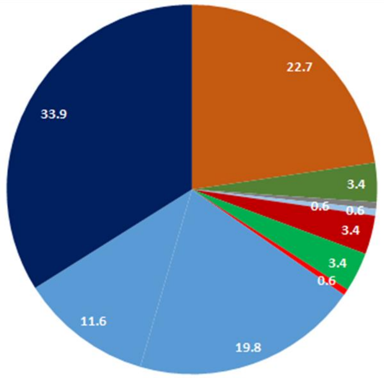
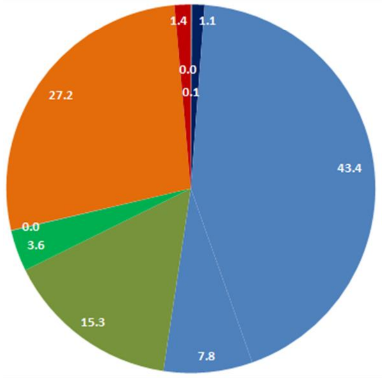
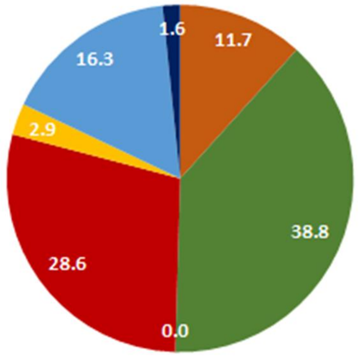
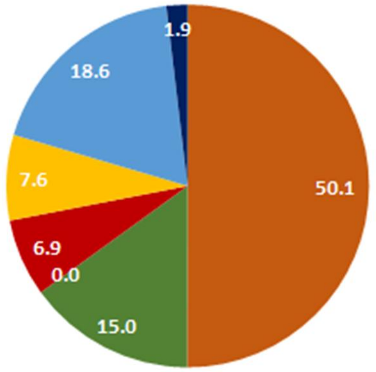
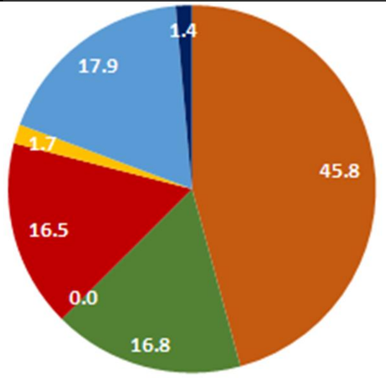
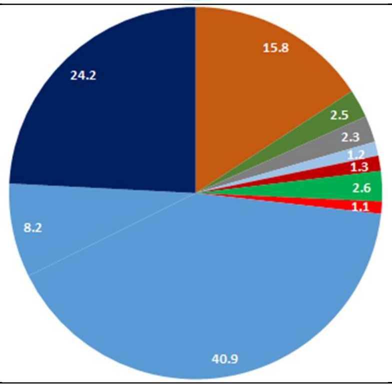
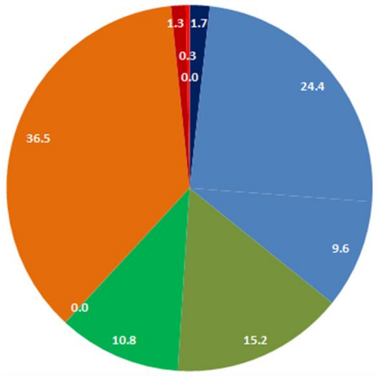
Horticulture™ New Zealand

Figure 4.6 Healthy Rivers Subcatchments and Freshwater Management Units.

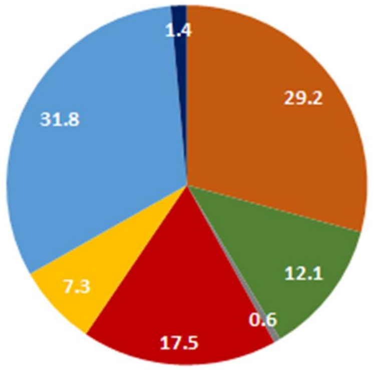
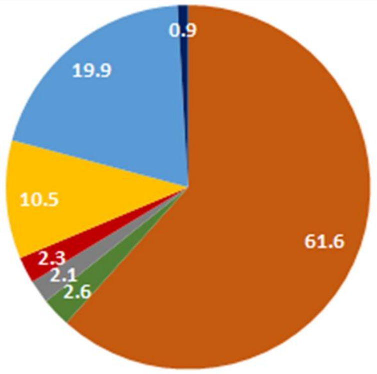
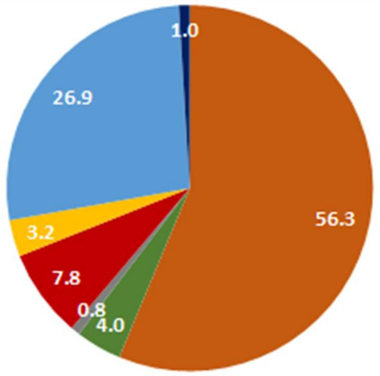
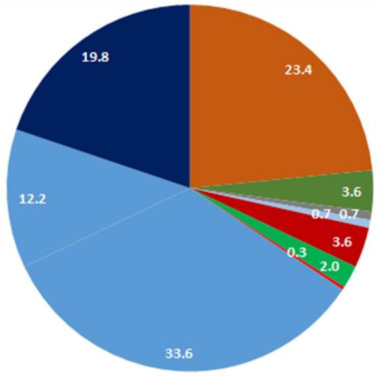
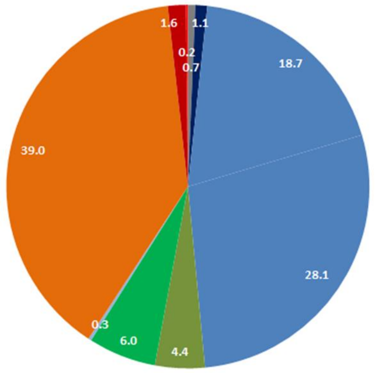
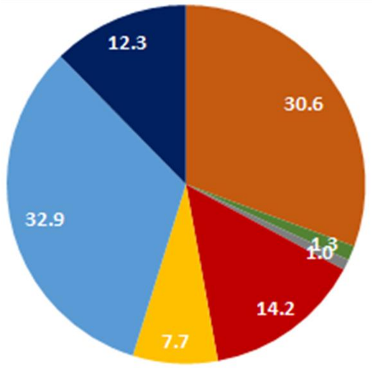
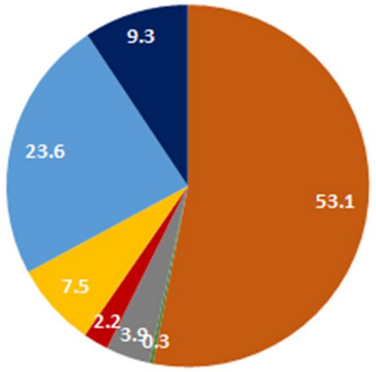
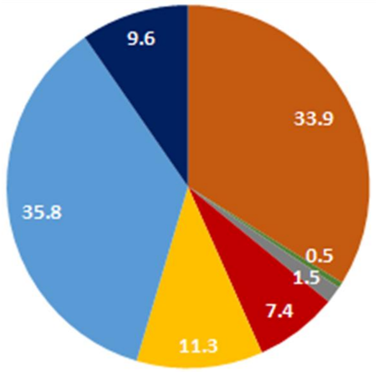
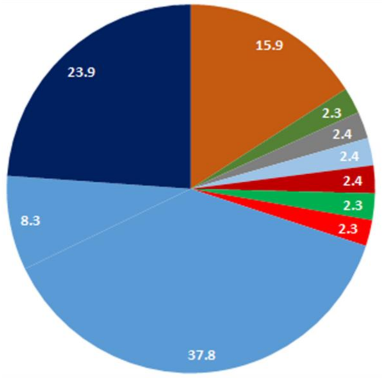
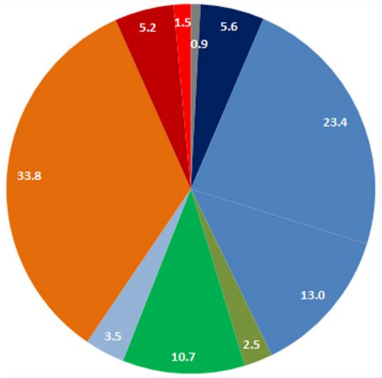
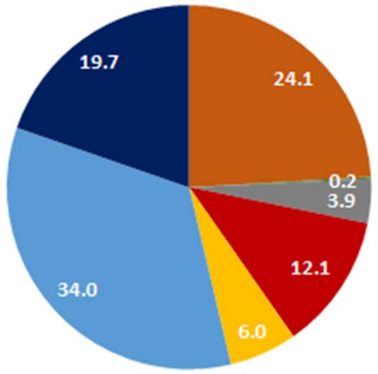
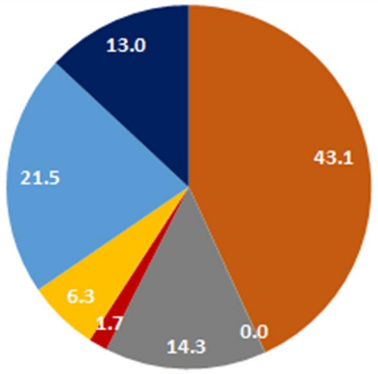
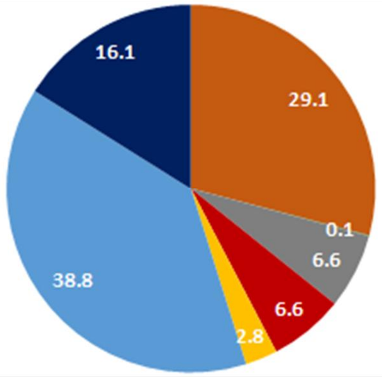
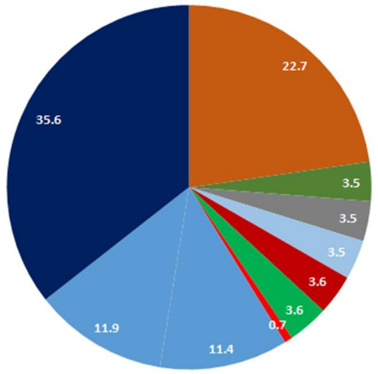
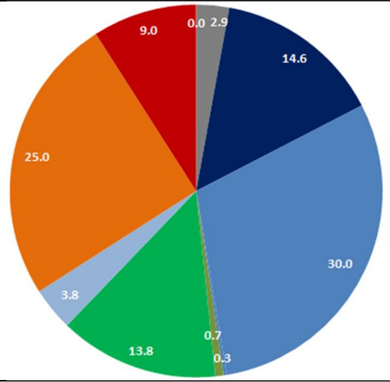
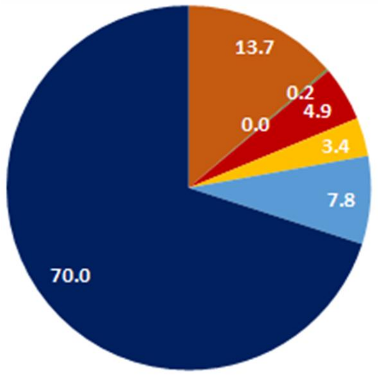
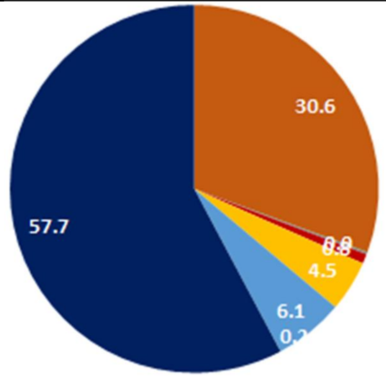
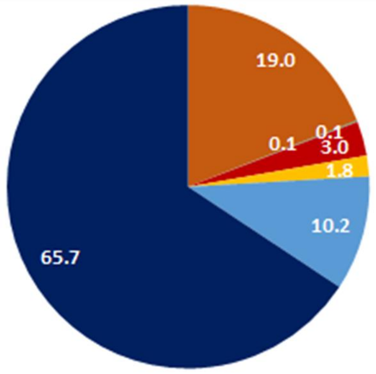
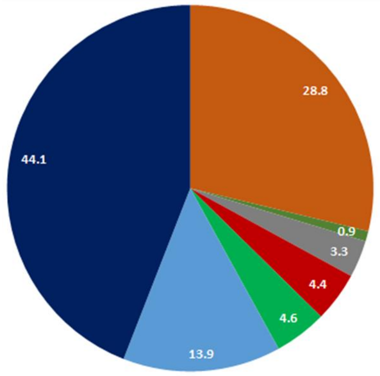
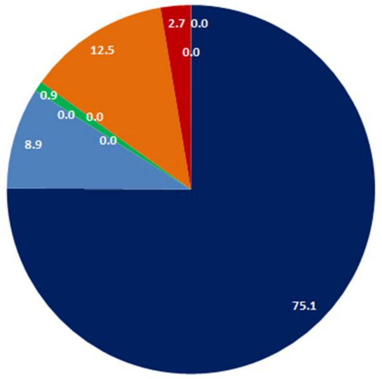
Appendix B. Proportions of land use and water quality constituent loads in selected subcatchments of the Waikato River Catchment

Appendix B: Proportion of land use type and unattenuated loads of nitrogen, phosphorus, and sediment and attenuated E.coli (excluding point-sources) in selected sub-catchments in the Waikato River Catchment

Units: Percentage

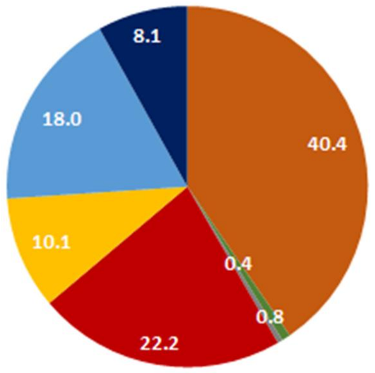
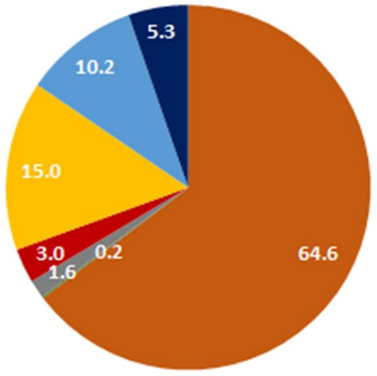
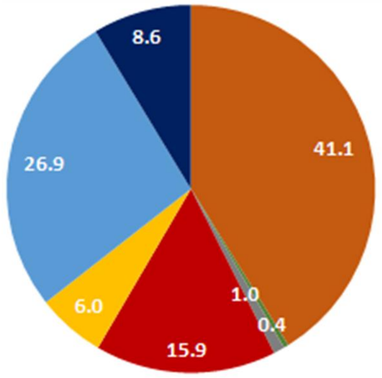
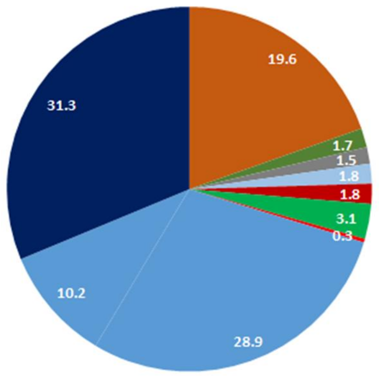
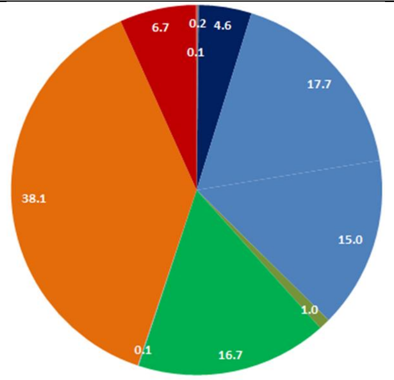
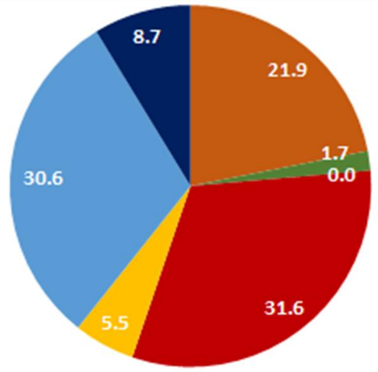
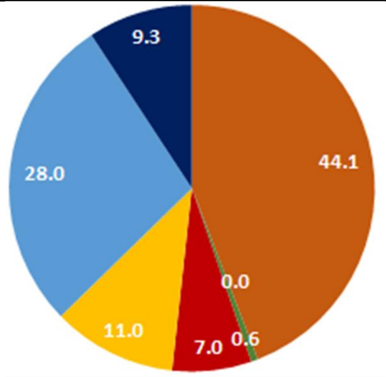
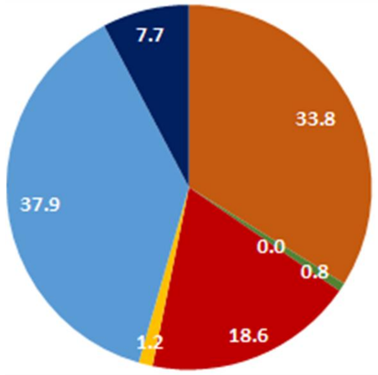
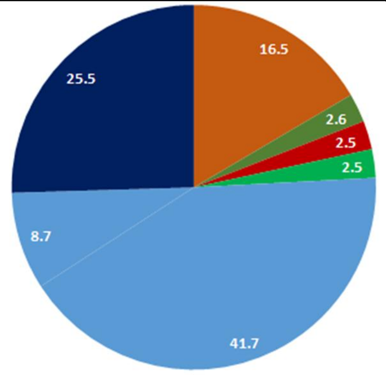
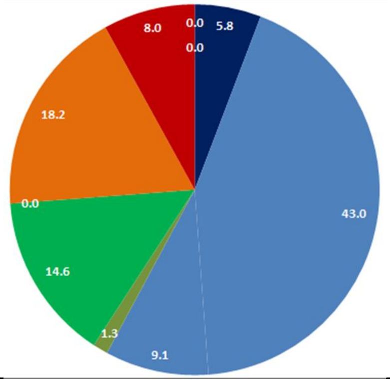
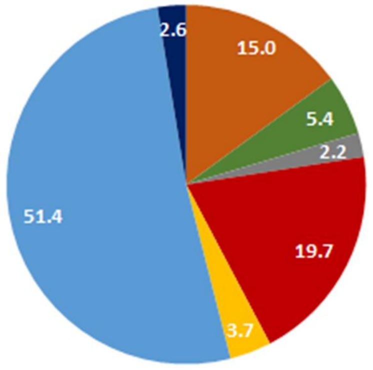
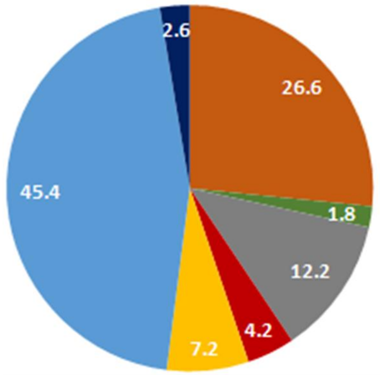
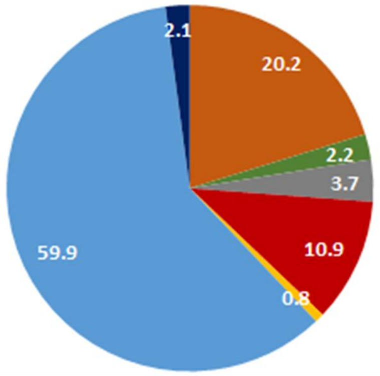
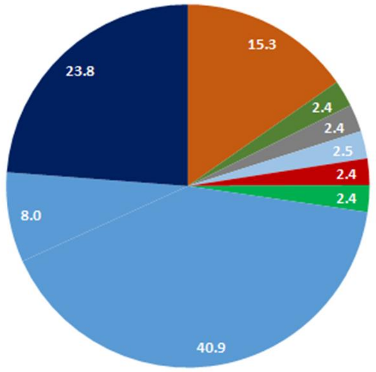
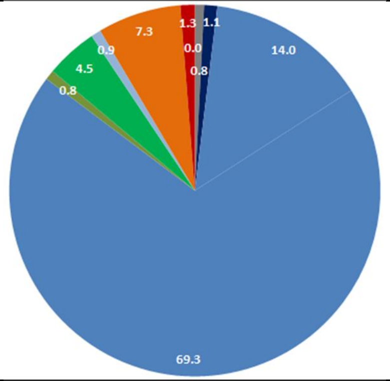
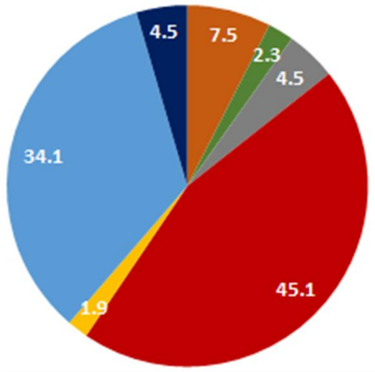
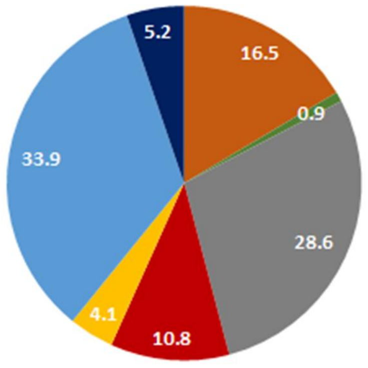
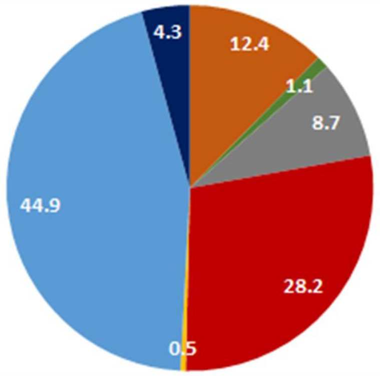
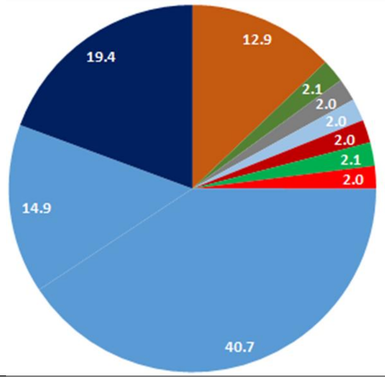
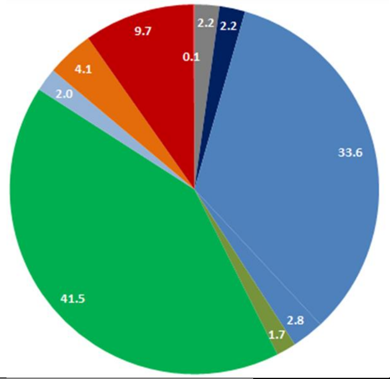
Sub-Catchment	Landuse Area	Nitrogen Load	Phosphorous Load	E. Coli Load	Sediment Yield
Waikato at Ohaaki					
Waikato at Ohakuri					
Waikato at Whakamaru					
Waikato at Waipapa					

■ Dairy ■ Forestry ■ Horticulture ■ Maize ■ Miscellaneous Scrub ■ Other Animal ■ Sheep and Beef - Hill and High ■ Sheep and Beef - Intensive ■ Urban ■ Dairy support

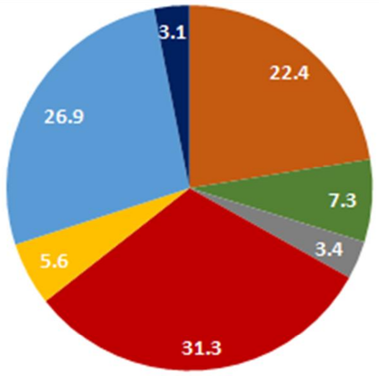
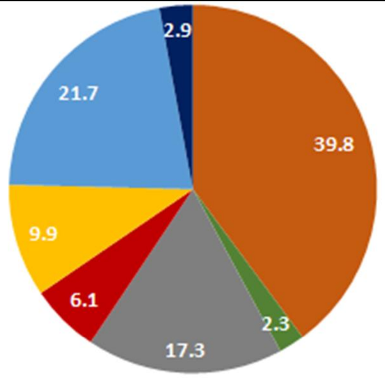
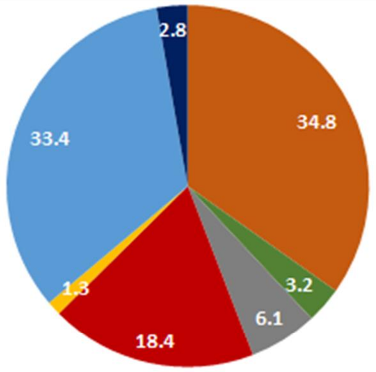
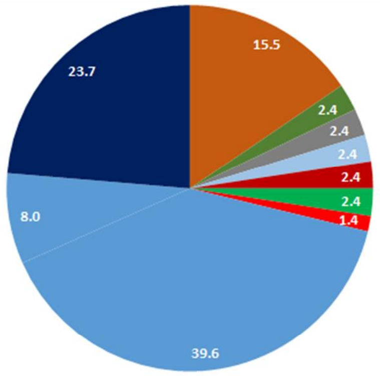
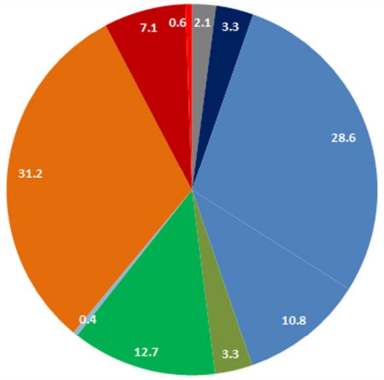
Sub-Catchment	Landuse Area	Nitrogen Load	Phosphorous Load	E. Coli Load	Sediment Yield
Waikato at Karapiro					
Waikato at Narrows					
Waikato at Bridge St Br.					
Waikato at Horotiu Br					

■ Dairy ■ Forestry ■ Horticulture ■ Maize ■ Miscellaneous ■ Native Forest & Scrub ■ Other Animal ■ Sheep and Beef - Hill and High ■ Sheep and Beef - Intensive ■ Urban

■ Dairy support

Sub-Catchment	Landuse Area	Nitrogen Load	Phosphorous Load	E. Coli Load	Sediment Yield
Waikato at Huntly-Tainui Br					
Waikato at Rangiriri					
Waikato at Mercer Br					
Waikato at Tuakau Br					

■ Dairy ■ Forestry ■ Horticulture ■ Maize ■ Miscellaneous ■ Native Forest & Scrub ■ Other Animal ■ Sheep and Beef - Hill and High ■ Sheep and Beef - Intensive ■ Urban
■ Dairy support

Sub-Catchment	Landuse Area	Nitrogen Load	Phosphorous Load	E. Coli Load	Sediment Yield
Waikato at Port Waikato					

■ Dairy ■ Forestry ■ Horticulture ■ Maize ■ Miscellaneous ■ Native Forest & Scrub ■ Other Animal ■ Sheep and Beef - Hill and High ■ Sheep and Beef - Intensive ■ Urban
■ Dairy support

Table 4-9 Horticulture N and P unattenuated load as a percentage of total sub-catchment unattenuated load. (taken from NIWA supplied spreadsheet)

Subcatchment	Horticulture Area as a percentage of subcatchment area	N load as percentage of total sub-catchment load	P load as a percentage of total sub-catchment load.
Pueto	0.1%	0.5%	0.1%
Waikato at Ohaaki	0.4%	2.9%	0.9%
Waikato at Ohakuri	0.0%	0.0%	0.0%
Torepatutahi	0.0%	0.0%	0.0%
Mangakara	0.0%	0.0%	0.0%
Waiotapu at Homestead	0.0%	0.0%	0.0%
Kawaunui	0.0%	0.0%	0.0%
Waiotapu at Campbell	0.0%	0.0%	0.0%
Otamakokore	0.0%	0.0%	0.0%
Whirinaki	0.0%	0.0%	0.0%
Waikato at Whakamaru	0.0%	0.0%	0.0%
Waipapa	0.2%	1.1%	0.3%
Tahunaatara	0.0%	0.0%	0.0%
Mangaharakeke	0.0%	0.0%	0.0%
Waikato at Waipapa	0.0%	0.0%	0.0%
Mangakino	0.0%	0.0%	0.0%
Mangamingi	0.0%	0.0%	0.0%
Whakauru	0.0%	0.0%	0.0%
Pokaiwhenua	0.0%	0.0%	0.0%
Little Waipa	0.0%	0.0%	0.0%
Waikato at Karapiro	0.6%	2.1%	0.8%
Karapiro	0.5%	2.5%	0.8%
Waikato at Narrows	1.0%	3.9%	1.5%
Mangawhero	0.9%	3.1%	1.3%
Waikato at Bridge St Br	3.9%	14.3%	6.6%
Mangaonua	1.1%	4.6%	1.7%
Mangakotukutuku	0.0%	0.1%	0.1%
Mangaone	1.7%	7.0%	2.7%
Waikato at Horotiu Br	0.0%	0.2%	0.1%
Waitawhiriwhiri	0.0%	0.0%	0.0%
Kirikiriroa	0.0%	0.0%	0.0%
Waipa at Mangaokewa Rd	0.0%	0.0%	0.0%
Waipa at Otewa	0.0%	0.0%	0.0%
Mangaokewa	0.0%	0.0%	0.0%
Mangarapa	0.0%	0.0%	0.0%
Mangapu	0.0%	0.0%	0.0%
Mangarama	0.0%	0.0%	0.0%
Waipa at Otorohanga	0.0%	0.0%	0.0%

Waipa at Pirongia-Ngutunui Rd Br	0.4%	1.1%	0.6%
Waitomo at Tumutumu Rd	0.0%	0.0%	0.0%
Waitomo at SH31 Otorohanga	0.0%	0.0%	0.0%
Moakurarua	0.0%	0.0%	0.0%
Puniu at Bartons Corner Rd Br	1.3%	3.7%	2.2%
Puniu at Wharepapa	0.0%	0.0%	0.0%
Mangatutu	0.0%	0.0%	0.0%
Mangapiko	0.1%	0.4%	0.2%
Mangaohoi	0.0%	0.0%	0.0%
Waipa at SH23 Br Whatawhata	0.4%	1.3%	0.8%
Mangauika	0.0%	0.0%	0.0%
Kaniwhaniwha	0.0%	0.0%	0.0%
Waipa at Waingaro Rd Br	0.7%	3.7%	1.4%
Ohote	0.3%	1.4%	0.5%
Firewood	0.0%	0.0%	0.0%
Waikato at Huntly-Tainui Br	0.4%	1.6%	1.0%
Komakorau	0.1%	0.4%	0.2%
Mangawara	0.0%	0.0%	0.0%
Waikato at Rangiriri	0.0%	0.0%	0.0%
Awaroa (Rotowaro) at Harris	0.0%	0.0%	0.0%
Awaroa (Rotowaro) at Sansons Br	0.0%	0.0%	0.0%
Waikato at Mercer Br	2.2%	12.2%	3.7%
Whangape	0.0%	0.0%	0.0%
Whangamarino at Island Block Rd	1.4%	10.0%	2.8%
Whangamarino at Jefferies Rd Br	0.3%	1.7%	0.6%
Waerenga	0.0%	0.0%	0.0%
Matahuru	0.0%	0.0%	0.0%
Waikare	0.7%	0.0%	0.0%
Opuatia	1.3%	8.8%	2.4%
Mangatangi	0.0%	0.2%	0.1%
Waikato at Tuakau Br	4.5%	28.6%	8.7%
Ohaeroa	6.1%	27.3%	9.5%
Mangatawhiri	0.0%	0.0%	0.0%
Whakapipi	21.4%	64.6%	32.7%
Awaroa (Waiuku)	1.1%	5.3%	1.7%
Waikato at Port Waikato	3.4%	17.3%	6.1%

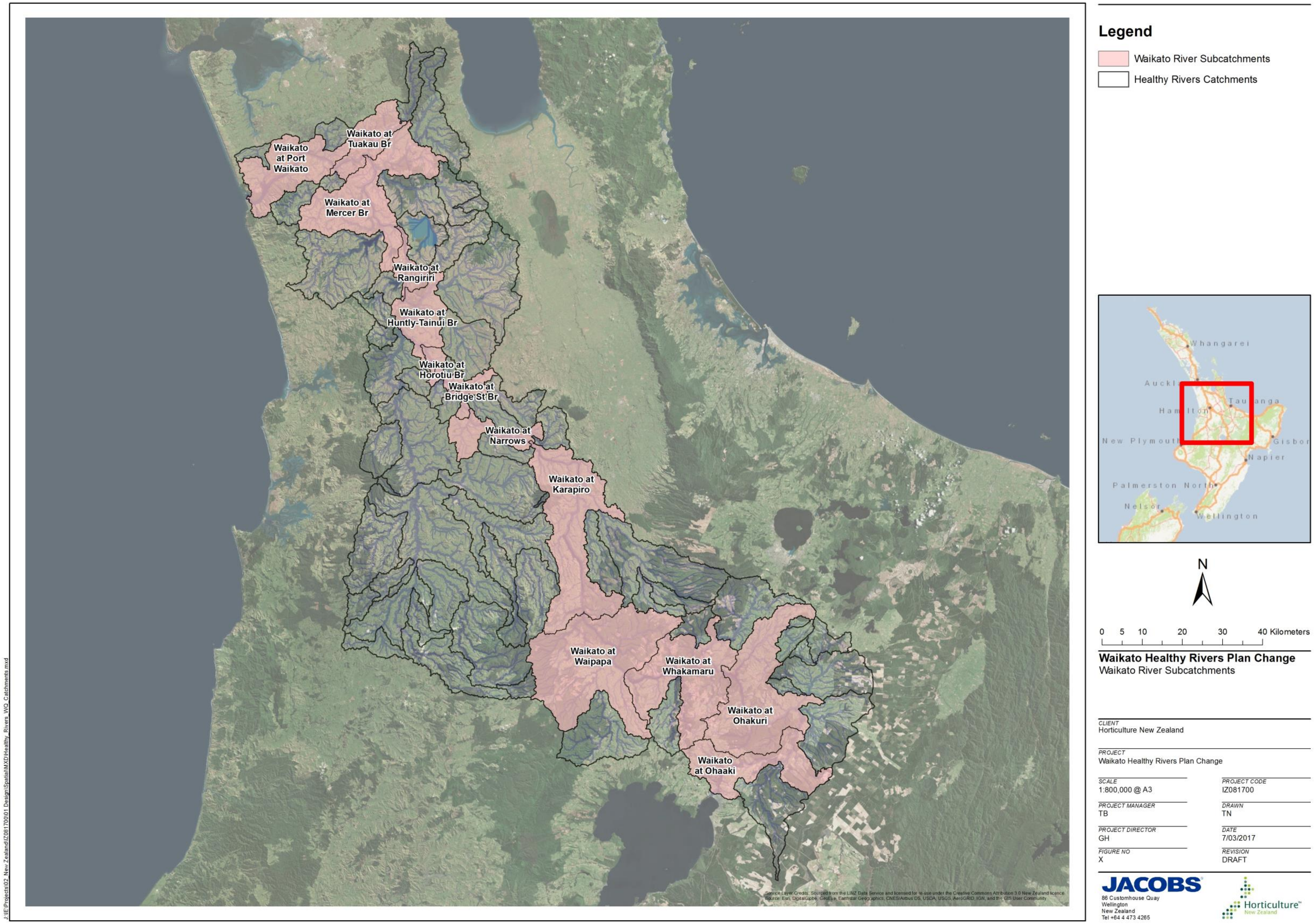
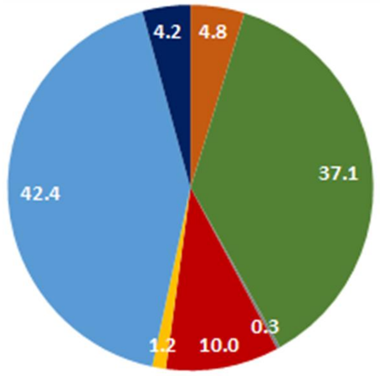
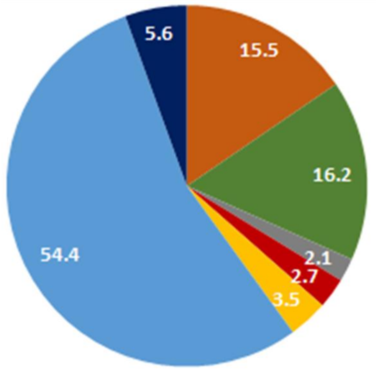
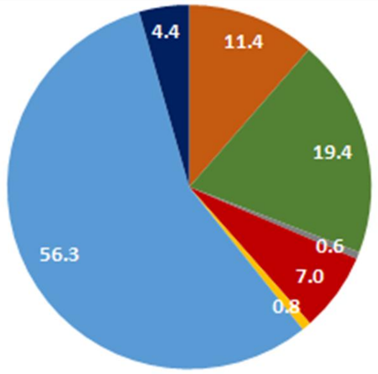
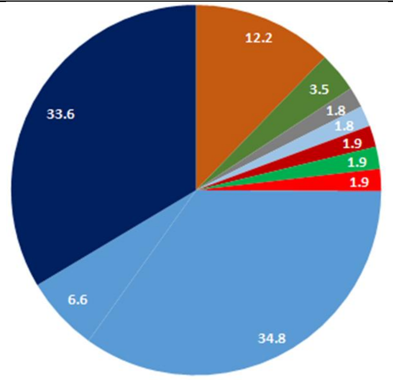
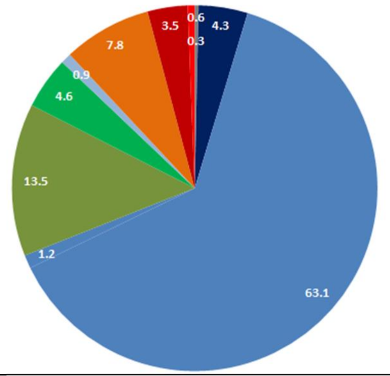
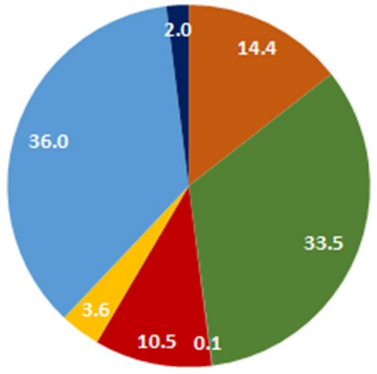
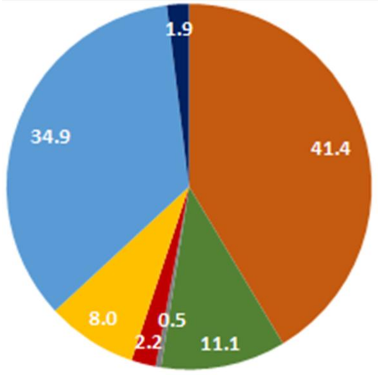
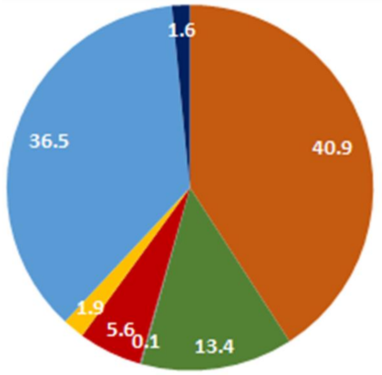
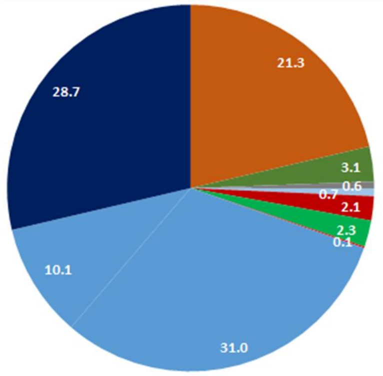
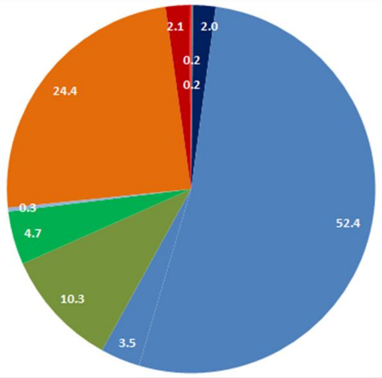
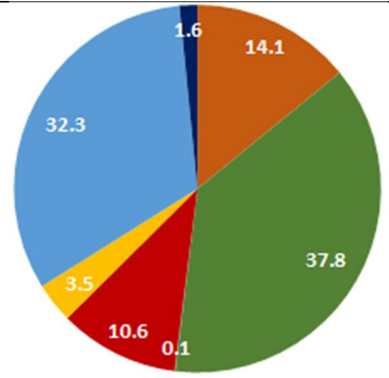
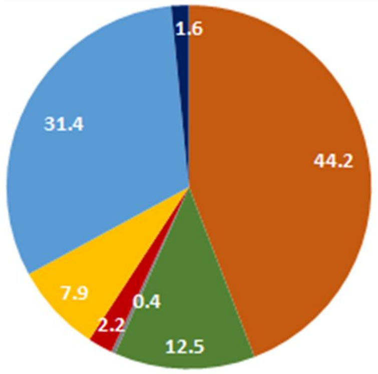
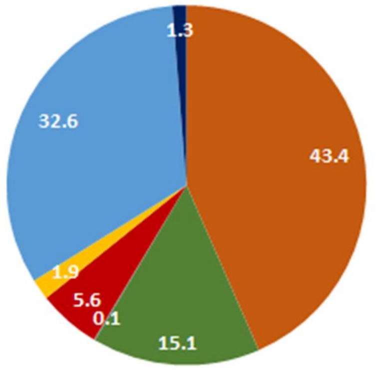
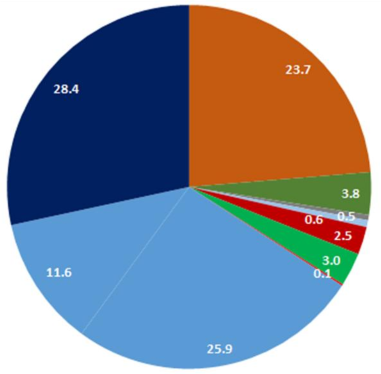
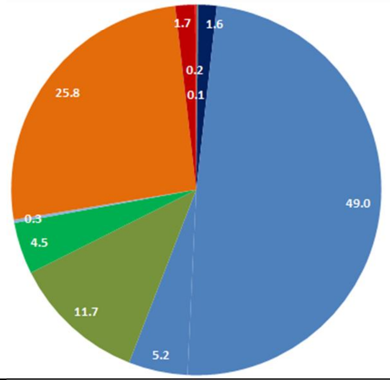
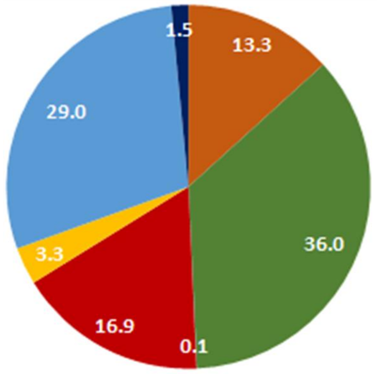
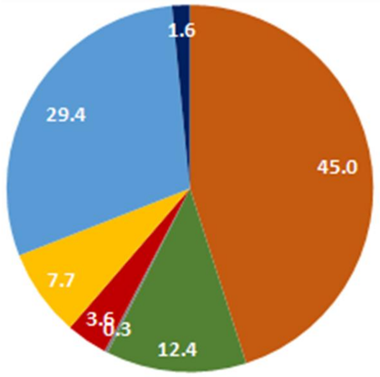
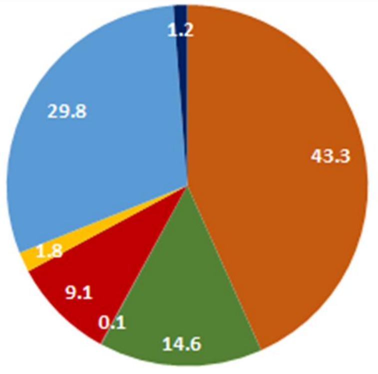
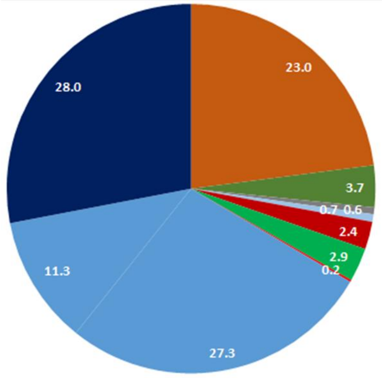
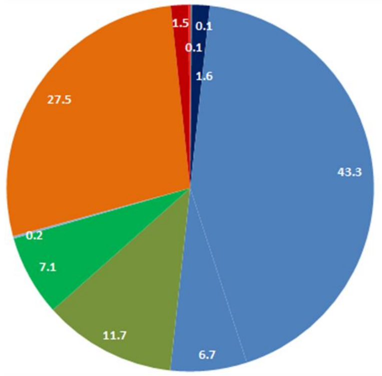


Figure 4.7 Selected subcatchments where unattenuated baseline contaminant loads for N, P and sediment and attenuated E.coli (supplied by NIWA and Landcare) have been graphed.

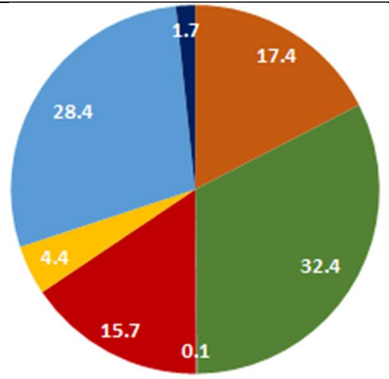
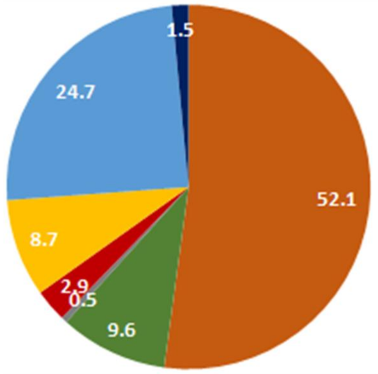
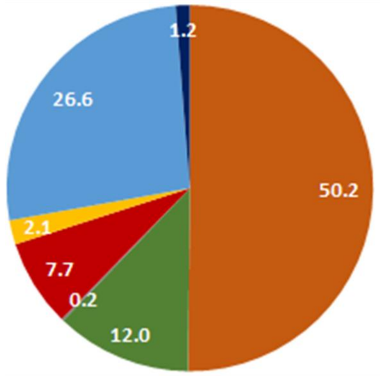
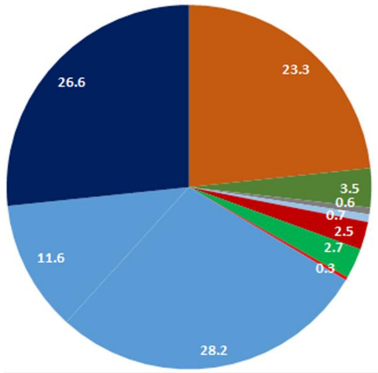
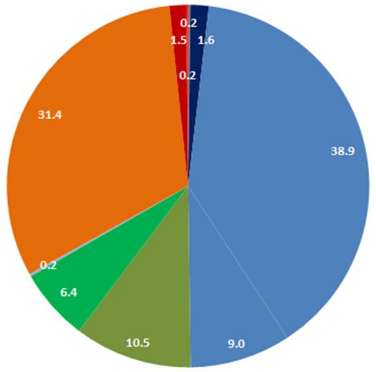
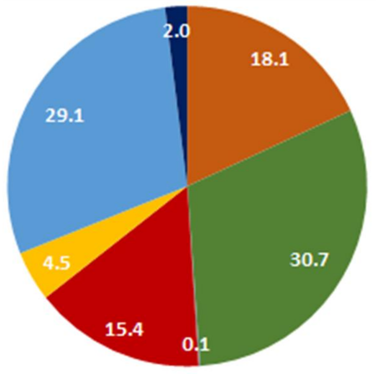
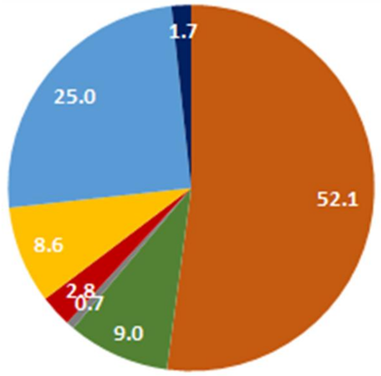
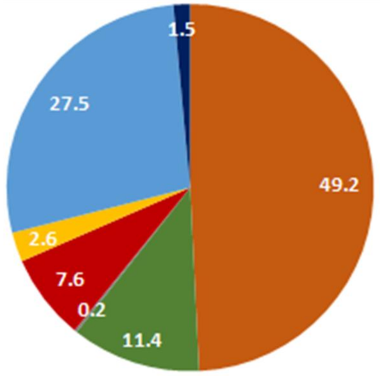
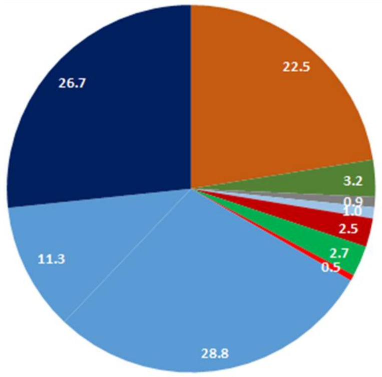
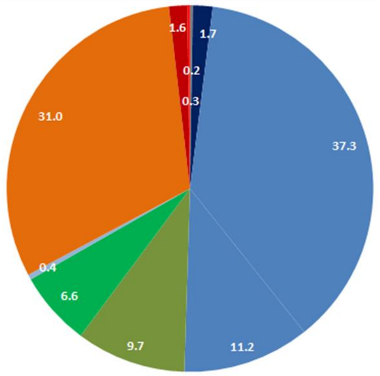
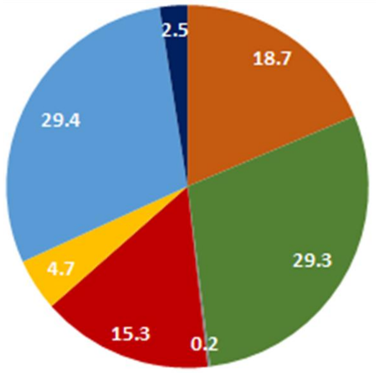
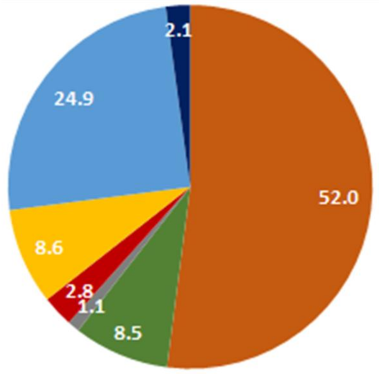
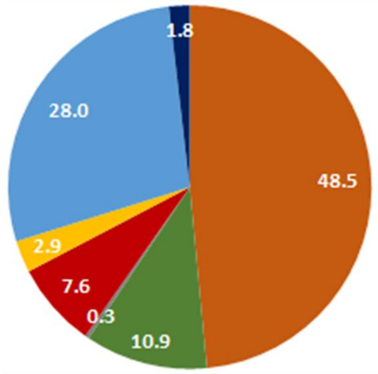
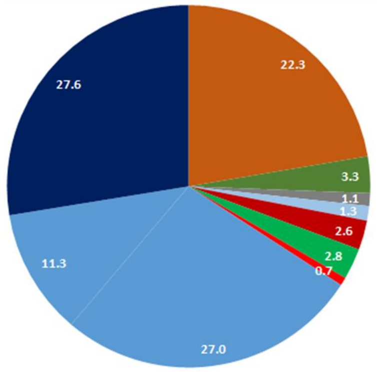
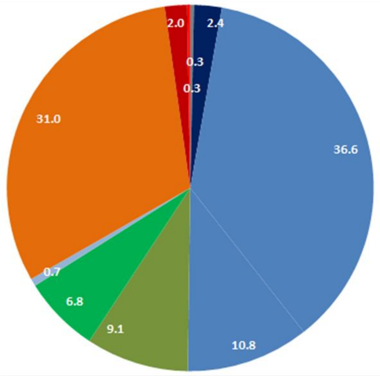
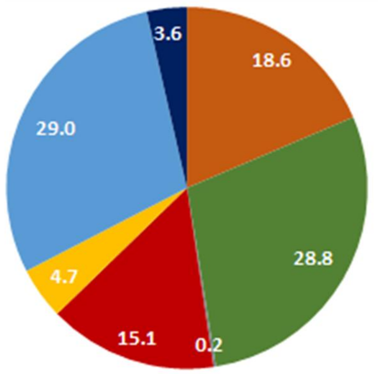
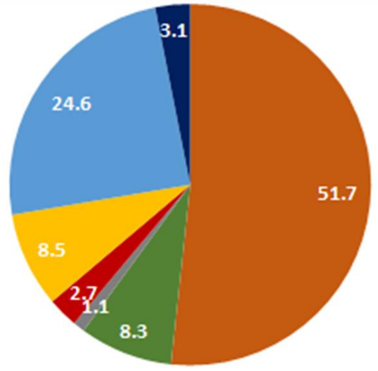
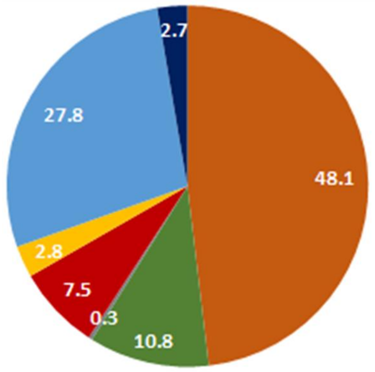
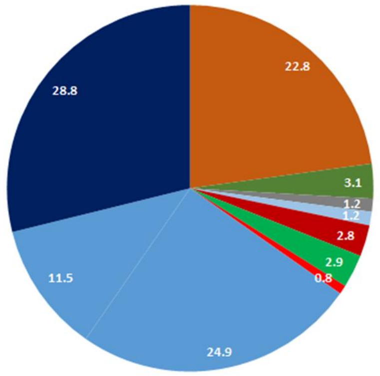
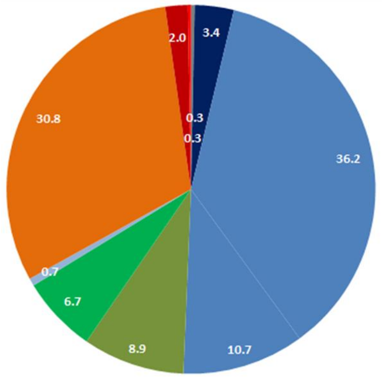
Appendix C. Graphed proportions of land use and water quality constituent cumulative loads along the Waikato River

Appendix C: Proportion of land use type and unattenuated cumulative loads of nitrogen, phosphorus and sediment and attenuated E.coli loads (excluding point-sources) in selected sub-catchments along the Waikato River

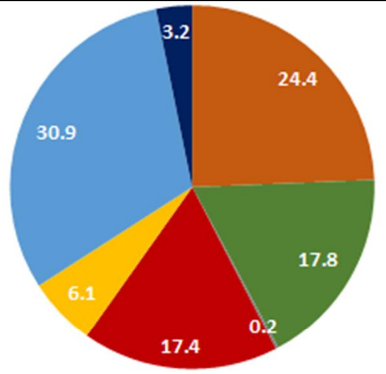
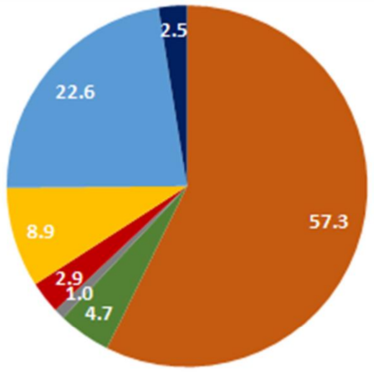
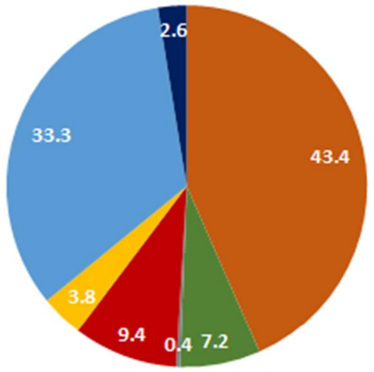
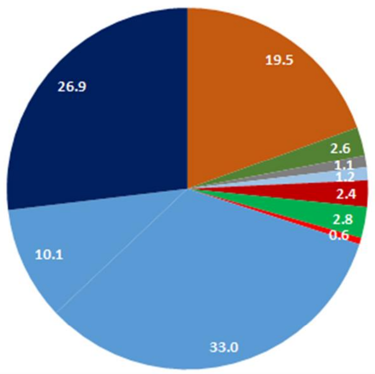
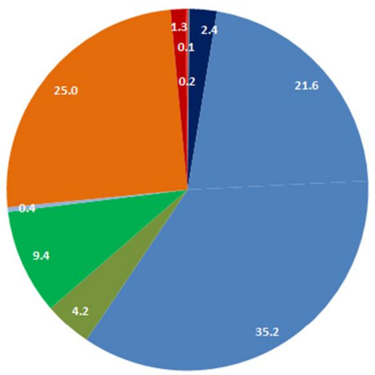
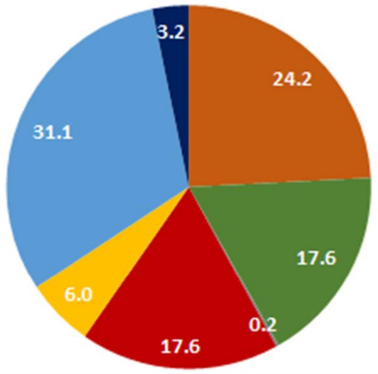
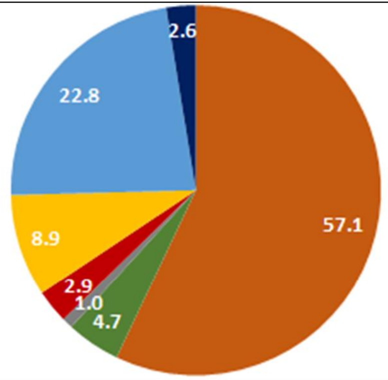
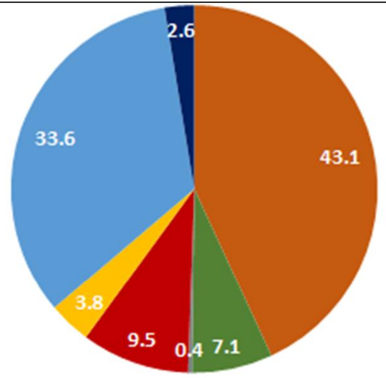
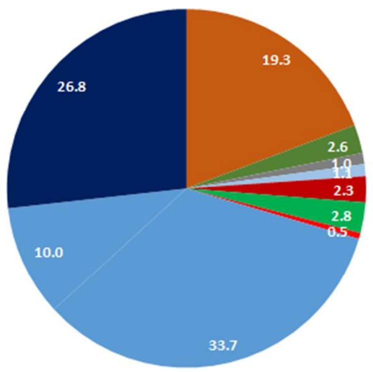
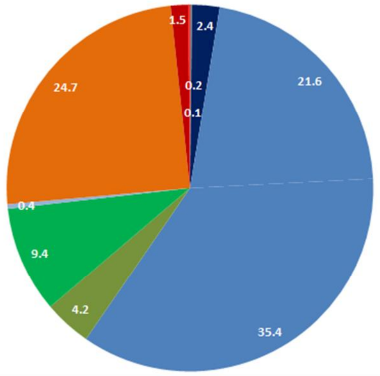
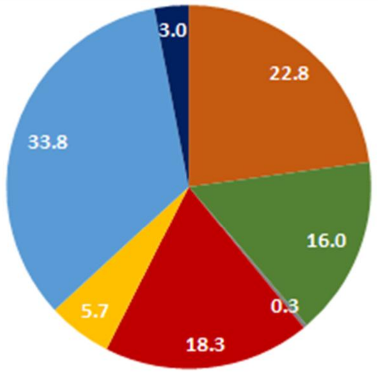
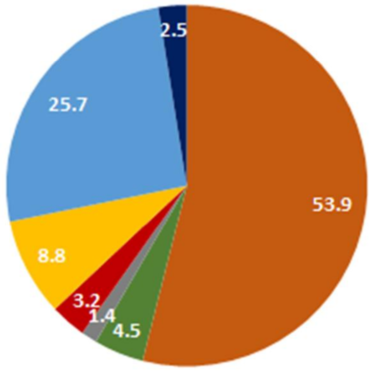
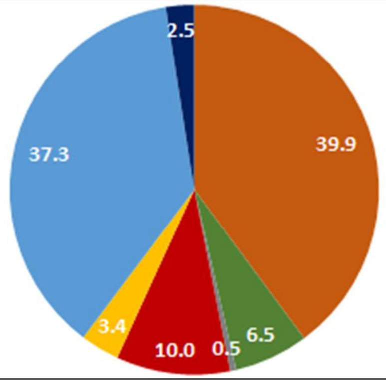
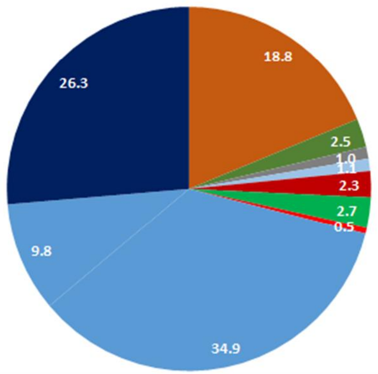
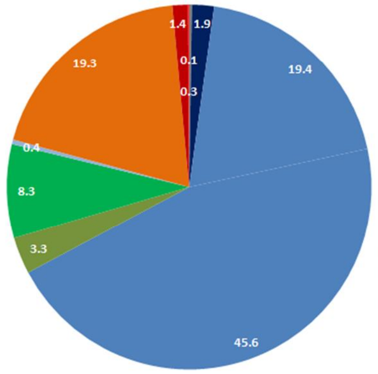
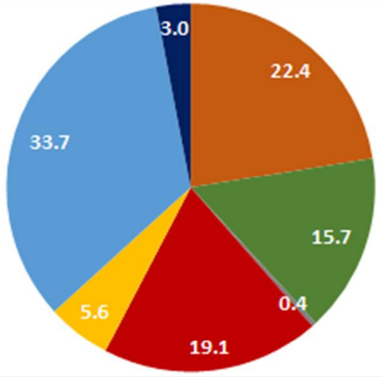
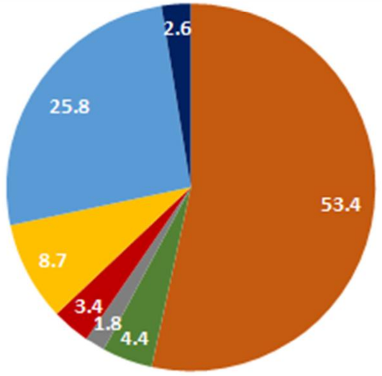
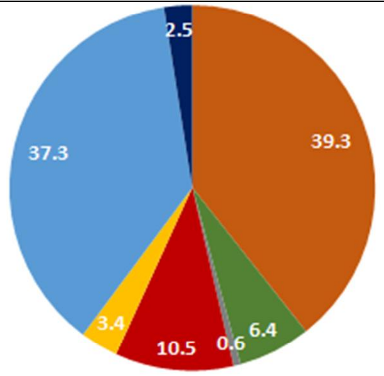
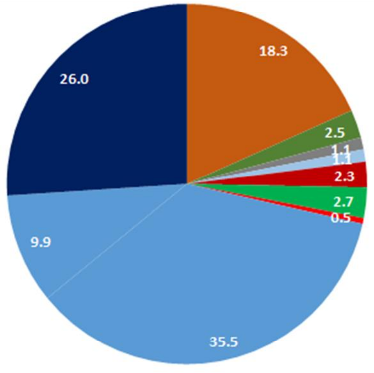
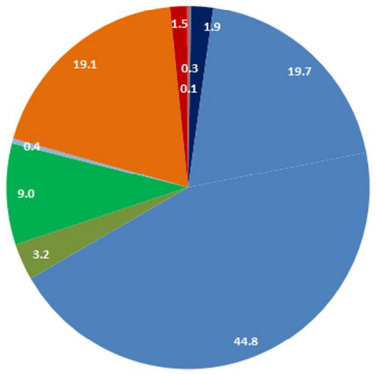
Units: Percentage

Sub-Catchment	Landuse Area	Nitrogen Load	Phosphorous Load	E. Coli Load	Sediment Yield
Waikato at Ohaaki					
Waikato at Ohakuri					
Waikato at Whakamaru					
Waikato at Waipapa					

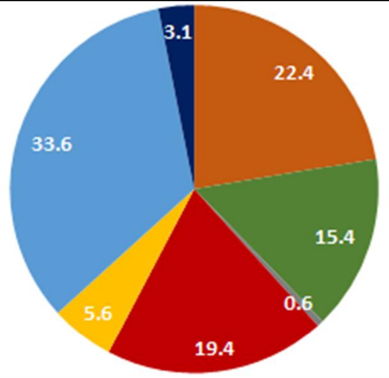
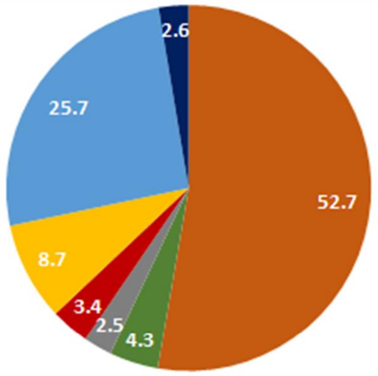
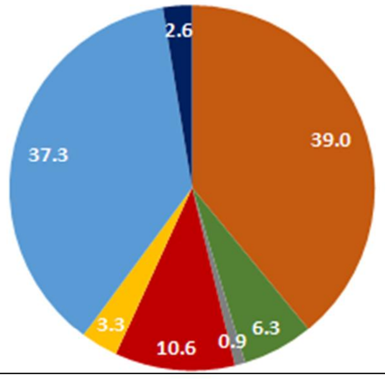
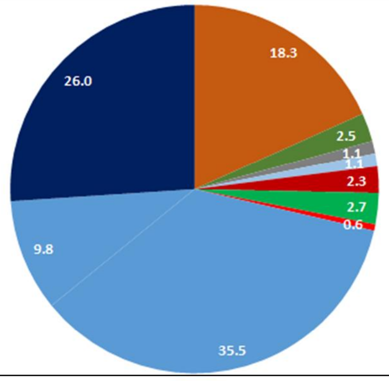
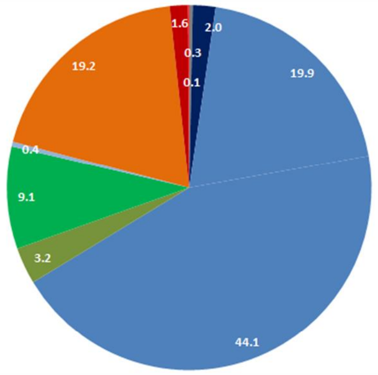
■ Dairy ■ Forestry ■ Horticulture ■ Maize ■ Miscellaneous Scrub ■ Other Animal ■ Sheep and Beef - Hill and High ■ Sheep and Beef - Intensive ■ Urban ■ Dairy support

Sub-Catchment	Landuse Area	Nitrogen Load	Phosphorous Load	E. Coli Load	Sediment Yield
Waikato at Karapiro					
Waikato at Narrows					
Waikato at Bridge St Br.					
Waikato at Horotiu Br					

■ Dairy ■ Forestry ■ Horticulture ■ Maize ■ Miscellaneous ■ Native Forest & Scrub ■ Other Animal ■ Sheep and Beef - Hill and High ■ Sheep and Beef - Intensive ■ Urban
■ Dairy support

Sub-Catchment	Landuse Area	Nitrogen Load	Phosphorous Load	E. Coli Load	Sediment Yield
Waikato at Huntly-Tainui Br					
Waikato at Rangiriri					
Waikato at Mercer Br					
Waikato at Tuakau Br					

■ Dairy ■ Forestry ■ Horticulture ■ Maize ■ Miscellaneous ■ Native Forest & Scrub ■ Other Animal ■ Sheep and Beef - Hill and High ■ Sheep and Beef - Intensive ■ Urban
■ Dairy support

Sub-Catchment	Landuse Area	Nitrogen Load	Phosphorous Load	E. Coli Load	Sediment Yield
Waikato at Port Waikato					

■ Dairy ■ Forestry ■ Horticulture ■ Maize ■ Miscellaneous ■ Native Forest & Scrub ■ Other Animal ■ Sheep and Beef - Hill and High ■ Sheep and Beef - Intensive ■ Urban

■ Dairy support

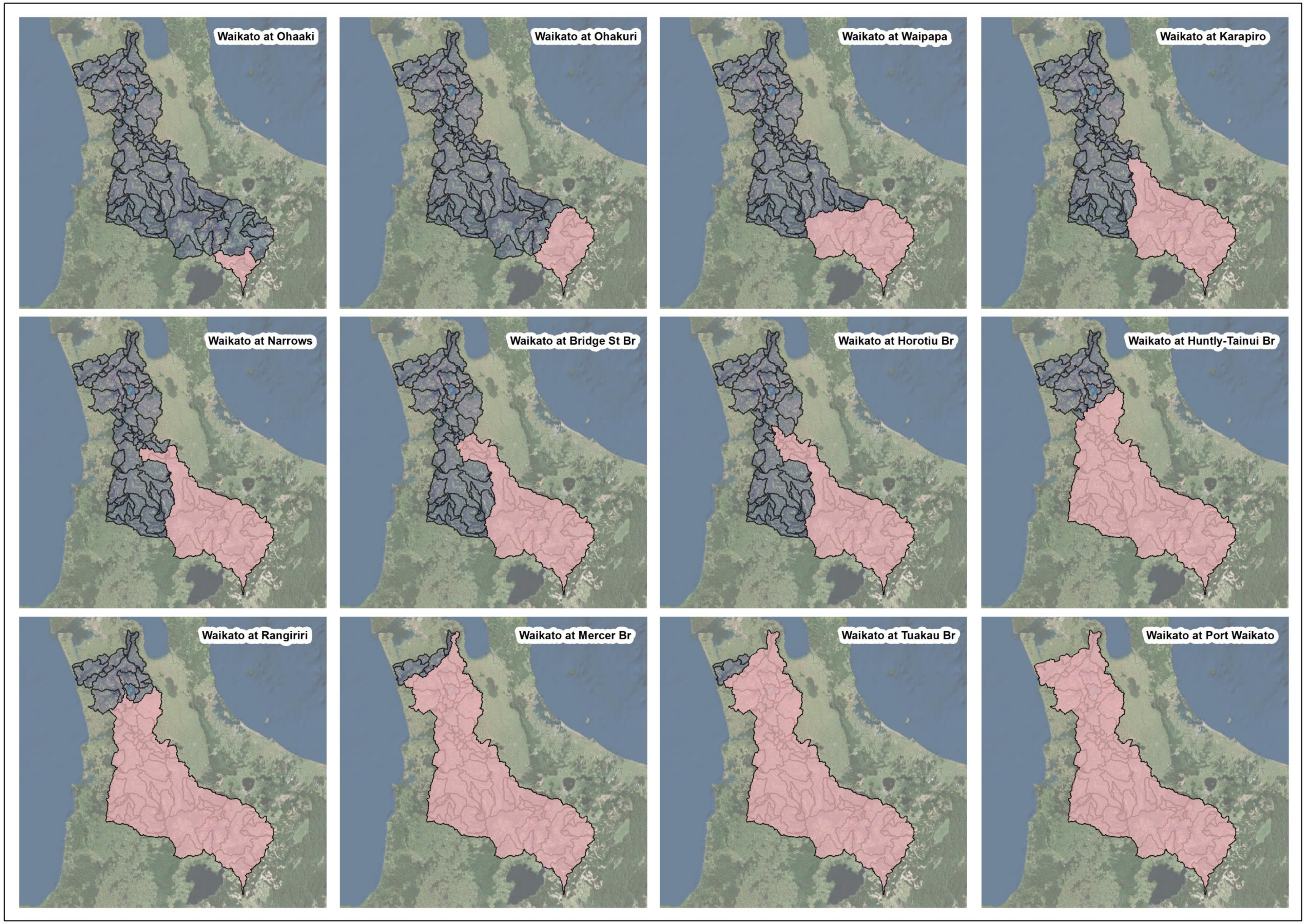


Figure 4.8 Selected subcatchments where unattenuated baseline cumulative contaminant loads for N, P and sediment and attenuated E.coli (supplied by NIWA and Landcare) have been graphed.