MANAGING OUR ENVIRONMENT

Nitrogen and Phosphorus Loads to Rivers in the Manawatu-Wanganui Region : An Analysis of Low Flow State :

Technical Report to Support Policy Development

horizons regional council

one plan
MO TE ITI MO TE RAHI

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August 2007

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EXECUTIVE SUMMARY

The growth of nuisance periphyton in many rivers and streams of the Manawatu-Wanganui Region is a significant environmental issue, requiring the reduction of nitrogen and phosphorus loads to surface water. Timeframes and implementation of reductions in point source dissolved reactive phosphorus, attempted through the Manawatu Catchment Water Quality Regional Plan, have not achieved the environmental outcomes sought.

New water quality standards in the Proposed One Plan (Proposed Regional Policy Statement and Regional Plan) for dissolved reactive phosphorus, soluble inorganic nitrogen and other contaminants have been applied to all waterways in the Region at flows less than three times the median (Ausseil & Clark, 2007a). In most water management zones the Proposed One Plan dissolved reactive phosphorus standard is more stringent than the Manawatu Catchment Water Quality Regional Plan. Ensuring discharges to water comply with the proposed standards will be pivotal to achieving the desired water quality outcomes.

Existing State of the Environment and compliance water quality monitoring data was used, together with continuous hydrological data to calculate loads across a number of catchments to assess the relative contributions of point and non-point source nutrient loads. Emphasis was given to low flow conditions; specifically mean annual low flow and half median flow.

At low flows, the proposed nutrient standards were exceeded at a number of locations. Although nitrogen and phosphorus loads were estimated from a variety of data sources and loadings calculations of this nature can have considerable biases, the results were indicative of ongoing nutrient enrichment issues resulting from both point source and non-point sources at low flows. Phosphorus loads were attributed to point sources whereas in many catchments, nitrogen appeared to be non-point sourced.

This report recommends a number of areas for further monitoring to better validate these results, and suggests the following changes to compliance and State of the Environment monitoring:

1. State of the Environment and compliance data should be collected on the same day, at similar flows within water management zones.
2. The effect of mixing zones and inflowing tributaries or confluences in relation to discharge sampling location needs examination. For significant discharges, mixing zones should be determined by mixing trials.
3. Flow should be gauged at the same time and location of water sample collection to establish flow relationships to the nearest continuous flow recorder.
4. The volumes of effluent discharged should be measured continuously, with results telemetered to the Regional Council for significant discharges, whereas smaller discharges should provide daily discharge volumes regularly.
5. Data derived from compliance and State of the Environment monitoring should be publicly available. Consideration should be given to making this data available via the internet to show compliance with receiving water standards and consent conditions.

Summary table of compliance with proposed nitrogen and phosphorus standards during low flows at 17 State of the Environment (SOE) monitoring sites in the Manawatu-Wanganui Region between 1989 and 2006.

SOE Monitoring Site	SIN			DRP		
	meets SIN standard at MALF	meets SIN standard at ½ median*	predominant SIN source	meets DRP standard at MALF	meets DRP standard at ½ median*	predominant DRP source
Manawatu at Weber Road	✗	✗	non-point	✗	✓	geology/unknown
Manawatu at Hopelands	✗	✗	non-point	✗	✗	point source
Mangatainoka at SH2	✗	✗	non-point	✗	✗	point source
Manawatu at Teachers College	✗	✓	non-point	✓	✓	-
Manawatu at Opiki Bridge	✗	✓	point source	✗	✗	point source
Oroua at Awahuri Bridge	✗	✗	point source	✗	✗	point source
Rangitikei at Pukeokahu*	✓	✓	-	✗	✗	natural geology
Hautapu at NIWA station Taihape	✓	✓	-	✗	✓	geology/unknown
Hautapu upstream Rangitikei	✗	✓	point source	✗	✗	point source
Rangitikei at Mangaweka	✓	✓	-	✓	✓	-
Rangitikei at Vinegar Hill	✓	✓	-	✓	✓	-
Whanganui at Cherry Grove*	✗	✗	non-point	✓	✓	-
Whanganui at Te Maire*	✗	✓	non-point	✗	✓	point source
Whanganui at Pipiriki	✓	✓	-	✓	✓	-
Whangaehu at Kauangaroa*	✓/ ✗	✓	non-point	✗	✓	point source
Mangawhero at DoC Headquarters	✓	✓	-	✗	✗	natural geology
Owahanga at Branscombe Bridge	✓	✓	-	✗	✓	point source

Key: ✗: Does not meet the standard; ✓: Meets the DRP standard; ✓: Meets the SIN standard

* or 75th percentile flow at sites affected by the Tongariro Power Development (TPD)

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1. Introduction and Scope

1.1 Introduction

The growth of nuisance periphyton in the rivers and streams of the Manawatu-Wanganui Region is a significant environmental issue, requiring the reduction of nitrogen and phosphorus loads to surface water. Nutrient contamination enters freshwater from direct 'point source' discharges and by diffuse 'non-point source' run-off and sub-surface leaching.

Controls on point source nutrient discharges have been applied through different regulatory methods in the past. Non-point source nutrient pollution has been an emerging issue in the management of freshwaters in New Zealand within the last decade. However, setting water quality standards to guide the control of non-point diffuse nutrient enrichment is one of the major challenges currently facing freshwater resource managers in New Zealand (Scarsbrook, 2006).

Nutrient standards for all rivers in the Region are proposed in the One Plan (Horizons' second generation combined Regional Plan and Policy Statement) which will apply to both point and non-point sources (Roygard & McArthur, 2007). This report uses the proposed standards from the One Plan (Ausseil & Clark, 2007a) to assess point source and non-point nutrient loads during low flows for all rivers that receive significant point source nutrient contamination.

1.2 Project Scope

This report documents the process undertaken to calculate nutrient contaminant loads for rivers and streams in the Manawatu-Wanganui Region to compare the contribution of nutrient inputs, from point source and non-point sources, with proposed water quality standards at low flows.

Nutrient standards for flowing waters are typically defined as contaminant concentrations. The loading of a particular contaminant that a river can receive, and still remain within a concentration standard depends on the flow in the river ie. when the river is at higher flow it takes a greater quantity of nutrient to make the river reach the defined concentration threshold. For example, the ANZECC guideline for SIN in lowland river sites is 0.444 g/m^3. To be within this nutrient standard at a flow of 2 m^3/s the loading input of SIN to a river must be less than 0.888 g SIN/s (2 m^3/s * 0.444 g SIN/m^3) which equates to a maximum limit of 76 kg SIN/day if the flow remains at 2 m^3/s.

In its broadest sense using loads to measure contaminants accounts for the variability in flow over the period of sampling and provides a way of managing nutrients from different sources, within specified flows, to achieve concentration based standards. For example, if the flow is between X and Y flow percentiles then the loading the river can receive to stay within nutrient standards is Z. The loading 'Z' can then be split between NPS and PS inputs for management purposes.

The scope of this report is limited to all water management zones and sub-zones (McArthur *et al*., 2007) that are subject to significant point source nutrient contributions for which adequate information could be collected or estimated. The scope of this report encompasses current consented discharges to surface water and those discharging under existing use rights, pursuant to the RMA (1991). A 'significant' discharge was defined as any discharge of treated human sewage effluent to surface water, any industrial discharge to surface water (ie. wool scour or wood processing wastes) or any food processing discharge (ie. milk or meat processing waste).

Consents relating to the discharge of sediment, water, stormwater, landfill leachate, vegetable wash water and other minor discharges assumed not to have a significant nutrient component were removed from the calculation of point source loads. However, any nutrient load contributed from these discharges is included within the non-point source load calculations (Ledein *et al.,* 2007; Roygard & McArthur, 2007).

The large nutrient contribution made by dairy discharges to water in the Manawatu River catchment in the past warranted separate analysis of dairy discharges for the Manawatu River catchment load calculations.

1.2.1 Project Aims

This report seeks to:

- document the methodology used to estimate nutrient loads at State of the Environment (SOE) sites and point source discharges to surface water,
- briefly outline the assumptions and limitations underlying the estimation methods and the interpretation of results,
- measure the contributions of nutrient loads from point and non-point sources at low flows,
- compare nutrient loads against proposed nutrient standards from the One Plan, and
- identify which river catchments, affected by point source discharges, are likely to exceed the nutrient standards at low flows.
- recommend improvements to SOE and compliance monitoring programmes and public access to water quality data.

1.2.2 Planning Context

A key objective in setting water quality standards for all waterbodies in the Region through the Proposed One Plan was the protection of cultural/recreational, social/economic and ecosystem values (Ausseil & Clark, 2007c).

Determining the low flow state of the Region's rivers, with respect to nutrient loads, builds on the development of water quality standards and other water-focused technical support for the Proposed One Plan (Figure 1) and provides a sound basis for the direction of policy to target the nutrient issue.

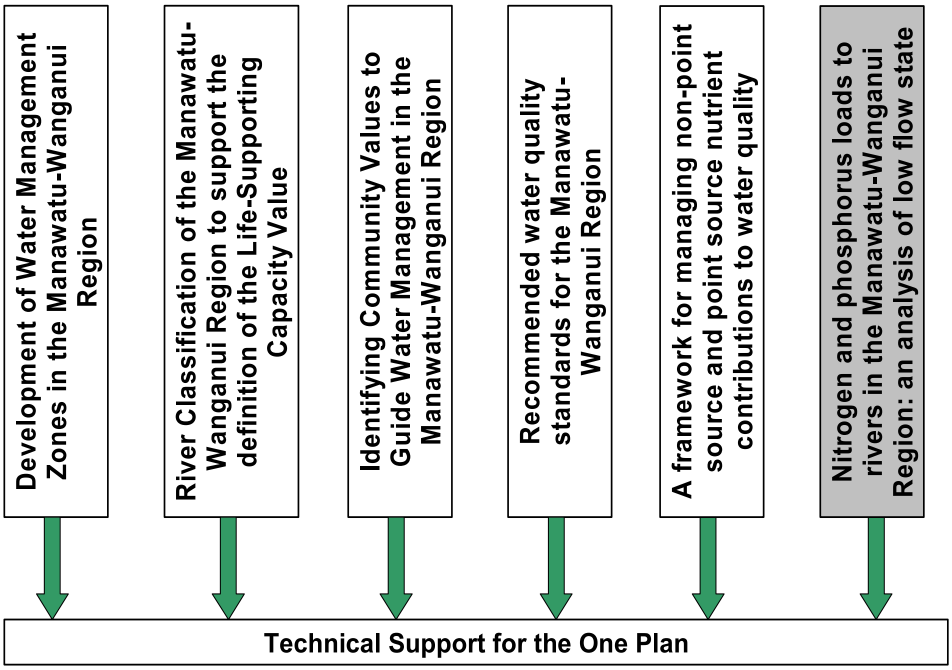


Figure 1: Water quality focussed technical reports supporting the One Plan.

Prior to the notification of the Proposed One Plan, the only catchment with nutrient standards in the Horizons Region was the Manawatu River catchment. The nutrient standards in the Manawatu Catchment Water Quality Regional Plan (1999) (MCWQRP) were only applied to dissolved reactive phosphorus (DRP) at flows equal to or below half median and ammoniacal nitrogen (ammonia). For more information on standards from the MCWQRP see Ausseil & Clark (2007a).

No soluble inorganic nitrogen standards were applied to any catchment prior to the One Plan. Recommendations from an expert panel on the management of limiting nutrients to control periphyton growth strongly identified the need to control both nitrogen and phosphorus within river systems (Wilcock *et al.*, 2007).

1.2.3 Peer Review

This report has benefited significantly from the comments of internal and external reviewers, which the authors appreciate. Copies of the external peer review reports can be made available on request.

1.3 Background

1.3.1 The Impacts of Nitrogen and Phosphorus

Nutrient enrichment is caused by the contamination of freshwaters by elevated levels of bio-available forms of nitrogen and phosphorus. Concentrations of soluble nitrogen and phosphorus in excess of natural background levels can cause nuisance periphyton (algal) proliferation on the beds of lakes, rivers and streams. In some cases (particularly in lakes and confined waters) nutrient enrichment can contribute to the formation of algal blooms suspended within the water column, which can be toxic to humans and animals in some circumstances.

Periphyton (and macrophytes in some waterways) make up the primary productive base of the aquatic food chain (Winterbourn, 2004) and are an important component of functioning aquatic ecosystems (Biggs, 2000). However, proliferation of periphyton reduces the aesthetic and recreational appeal of waterbodies and can negatively impact on aquatic biodiversity, portability of stock and human drinking water, and physically clog irrigation and water supply intakes.

Many rivers and streams currently experience considerable blooms of filamentous algal growth when suitable conditions persist (eg. gravel/cobble substrate, high sunlight intensity, open channel form, extended duration of stable flows and high soluble nutrient loads). (Ausseil & Clark, 2007a; Death & Death, 2005).

Reducing the incidence and extent of nuisance periphyton growth during low flow conditions will require a reduction in the loads of nutrients, specifically nitrogen and phosphorus year-round (Wilcock *et al.,* 2007). Such reductions in nutrient load will require clear identification of the relative contributions of nutrient sources, as well as identifying when these sources influence nutrient concentrations (Roygard & McArthur, 2007).

1.3.2 The Importance of Understanding Nutrient Loads at Low Flows

The mainly rain-fed river catchments of the Manawatu-Wanganui Region can experience prolonged period of low flows. The seasonality and duration of reduced flow events varies depending on the individual catchment characteristics and climatic conditions.

Low flows can be significant stressors to aquatic ecosystems as water temperatures may reach or exceed the thermal tolerance limits of fish and invertebrates. In addition to thermal stress, aquatic organisms can experience considerable diurnal dissolved oxygen fluctuations as a result of periphyton proliferation. The high respiration rate of large growths of periphyton causes dissolved oxygen depletion at night, which can be lethal to invertebrates and fish.

Ammonia can be a significant component of soluble inorganic nitrogen (SIN), depending on nature of point source discharges, level of effluent treatment and dilution from river flows. High concentrations of ammonia because of decreased dilution during low flows and high point source discharge concentrations may exceed the toxic thresholds of aquatic organisms, particularly fish. The toxicity of ammonia to aquatic life changes in relation to temperature and pH; low flows can further exacerbate toxic effects.

It is necessary to improve the quality of surface water during low flow conditions, although low flow improvements may require contaminant

management at all flows, year-round (Wilcock *et al.,* 2007). This report identifies two flows to be representative of low flow conditions:
1) Mean Annual Low Flow (MALF) and
2) Half median flow (or 75th percentile flow) in rivers with regulated flow regimes such as the Tongariro Power Development (TPD).

Understanding the relative contribution of point source and non-point source nutrient loads at low flows may provide a less complicated first step to managing the combined mechanisms which cause surface water enrichment, by removing the influence of catchment run-off and overland flow.

2. Data Sources

2.1 Water Quality Monitoring

2.1.1 State of the Environment Data

With the inception of the Resource Management Act in 1991, Regional Councils were statutorily required to implement State of the Environment (SOE) monitoring programmes. Historically, water quality data had been collected from several sites in the Region, including: Manawatu at Weber Road, Manawatu at Teachers College, Manawatu at Opiki Bridge, Rangitikei at Kakariki, Rangitikei at Mangaweka, Whanganui at Te Maire and Whanganui at Paetawa. While some data exists for the period to 1989, most of the water quality data used in this report was collected between 1993 and the present day.

In the Manawatu-Wanganui Region, SOE water quality samples are collected on a monthly basis from 92 surface water sites. The data derived from these samples are stored in Horizons water quality database ‘Qualarc’. Some sites are monitored every year while others are monitored for one year in every three. Six of these sites are monitored every year by NIWA as part of the National Rivers Water Quality Network. Several contaminant and water quality variables are measured in the field at each site. This report uses the results of samples analysed in the laboratory for DRP and a composite SIN value obtained by adding the concentrations of various nitrogen species present in the sample.

2.1.2 Compliance Monitoring

Point source discharge data is collected by consent holders to satisfy the conditions of their consent. The conditions of each consent determine the frequency and location of sampling along with the range of variables requiring measurement. Samples are collected either by the Permit Holder or by Horizons Environmental Compliance staff.

Data derived from samples collected by Horizons staff upstream and downstream of the discharge to surface water, as well as from the final discharge of effluent treatment systems are stored in the Qualarc database. Much of the data derived from self-monitoring samples by Permit Holders is submitted to Horizons on an annual basis and stored within individual compliance monitoring records. DRP and composite SIN concentration data was used to calculate the magnitude of point source loads for this report.

Data from compliance monitoring between 1993 and 2006 was used, although any results from consents which had ceased during this period were not included in the load calculations as they were not considered relevant to the current nutrient state of the River.

2.1.3 Non-Point Source Nutrient Loads

The load of a nutrient at a given sampling location may be calculated from the concentration of that nutrient and the flow in the river at the location and time of sampling, as shown in Equation 1:

Equation 1

$$Load\,(mass/time) = concentration\ (mass/volume) * \ flow\ (volume/time)$$

The total load of nutrient present at any point of the catchment comprises a contribution from point sources (PS load) and a component from non-point sources (NPS load). Non-point source was determined as the net nutrient load (calculated from the SOE monitoring data) minus the load derived from point sources, as shown in :

Equation 2

$$NPS\ load = Total\ load - PS\ load$$

2.1.4 Flow Data

Flow data was extracted from Horizons hydrometric archives which uses continuous flow records taken at 15-minute intervals. Additional flow data was obtained from NIWA hydrometric databases, whilst other flows were simulated from relationships to the nearest continuous recorder or from historic gaugings (Appendix 2).

Owing to quality assurance issues, validated flow data was not available for the period after 2005. In most cases SOE water quality samples could only be paired with flow data from 1993 to 2005 to create in-river loads of DRP and SIN.

It should be noted that not all data used in these calculations has been through the full quality assurance procedure. These results should therefore be regarded as indicative and should not be used for any purpose other than that intended within this report.

Flow statistics to calculate the proposed nutrient standards at ½ median, 75th percentile (for reduced flows that occur as a result of the Tongariro Power Development) or mean annual low flow (MALF) were derived from a report compiled on behalf of Horizons by NIWA (Henderson & Diettrich, 2007).

3. Methods for Calculating Nutrient Loads

3.1 Flow-Stratified Load Calculation

Initially, the main objective of this investigation was to assess the impact of point source (and by inference non-point source) contributions of nitrogen and phosphorus to water management zones in the Region at all flows using the flow-stratified downstream minus upstream load calculation method for each 10th flow percentile category.

In general, point source discharges tend to be less dependent on rainfall events than non-point source discharges. As a consequence, the load from the discharge should be fairly constant, or determined by factors other than rainfall. Under low-flow conditions, however, mobilisation of N and P from the catchment will be reduced to what is present in the baseflow. The NPS load will therefore be primarily restricted to soluble material.

A complex relationship exists between stream flow and nutrient concentration (Figure 2). Under some circumstances, an increase in flow may dilute nutrient concentrations. The load transported during this period may be increased or decreased, depending upon the source of the load (eg. overland flow from highly erodible land will increase phosphorus loads with increased rainfall and flow). Under low flow conditions, however, it is likely that concentrations will increase.

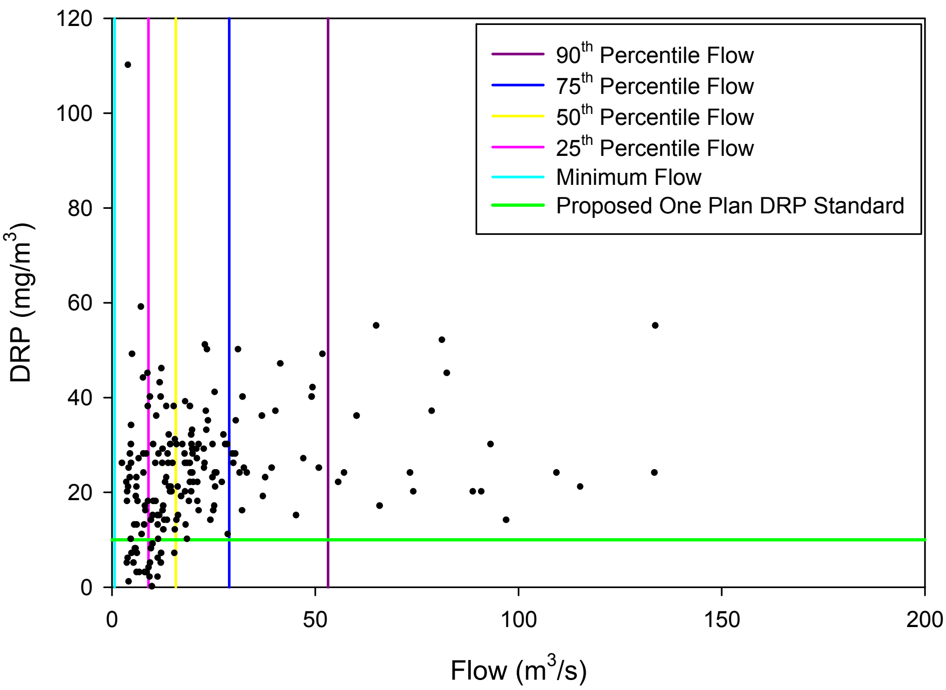


Figure 2: DRP concentrations from samples collected at various flows at the Manawatu at Hopelands flow recorder from 1989-2005. The flow percentiles demonstrate the percentage of time flows occur at the site.

A convenient way to achieve this requirement is to stratify or categorise all data (flow and associated concentration data) according to flow. In order to assess the point source nutrient load across the whole flow distribution, the discharge concentrations were then stratified or classified into ten flow percentile categories across the flow distribution. SOE and compliance monitoring is carried out on a monthly basis or more regularly according to resource consent requirements, regardless of flow. Over time, therefore, the samples collected will represent water quality over a wide range of flow conditions.

Data derived from the compliance monitoring programme upstream and downstream of all significant discharges to water and accurate measurements of flow at the time of sampling were required. The upstream nutrient load was subtracted from the downstream load, in order to determine the load added by the discharge for each sampling occasion (Equation 3).

Equation 3

$$Effluent\ load = downstream\ load - upstream\ load$$

Loads were then stratified across the ten flow percentile categories or ‘bins’. To relate the point source nutrient load for each flow percentile bin to the load measured in the river at downstream SOE sites, the SOE loads were also flow-stratified. By inference, the SOE load minus the point source discharge load for each percentile bin should approximate the non-point source nutrient contribution (Equation 2).

The limitations as a result of sample size, instream sample availability and flow measurements at the discharge points meant that this analysis method could not be undertaken and another, more generalised method would need to be used. Many of the data and sampling limitations are noted for each catchment in the appendices.

3.2 Estimated Daily Load at Low Flows

Because of the difficulties noted above, the scope of this investigation was narrowed to the relationship of nutrient concentration to flow using estimated daily loads during low flow periods. To find a pragmatic basis for the comparison of data of varying quality, an average daily load of nitrogen or phosphorus was calculated, using the methods described below.

3.2.1 Point Source Nutrient Loads

Average daily nutrient loads from point source discharges were calculated by multiplying the average concentration of nitrogen and phosphorus in the effluent (Equation 1), prior to discharge into surface water, by either the average measured discharge volume, or in the case of many domestic sewage discharges, the estimated dry weather flow of effluent per day (see Appendix 1).

3.2.2 SOE Nutrient Loads

Average daily nutrient loads at SOE sites near discharge points were calculated from all SOE samples taken at or below half median flow (or in the case of TPD affected sites the 75th percentile flow) (see Appendix 2). Flow records for each SOE sampling occasion were paired with nitrogen and phosphorus concentrations and loads were determined using Equation 1. Instantaneous SOE loads (g/s) were multiplied by the number of seconds in a day in order to have units comparable with daily point source load estimates (kg/day).

3.2.3 Proposed Nutrient Loads

In order to compare the average daily load from a point source discharge and the average daily in-river load at low flows to concentration-based standards proposed in the One Plan, the standard needed to be converted from concentrations to daily loads at known flows. Flow statistics for half median, 75th percentile flow (at TPD affected sites) and mean annual low flow (MALF) (m^3/s) were multiplied by a constant (number of seconds in the day) and then multiplied by the concentration of the nutrient standard (g/m^3) to achieve a target nutrient load (kg/day).

3.3 Assumptions and Limitations

3.3.1 Limitations of Load Calculations

Monthly nutrient sampling is not ideal for calculating nutrient loads to rivers (Richards, 1998; Roygard & McArthur, 2007; EPA, 2003). However, Regional Councils need to consider the best sampling programme that can be achieved with the limited resources available. The precision of pollution load estimates from monthly sampling has been widely examined in the international literature (Ferguson, 1987; Richards & Holloway, 1987 as cited in Richards, 1998; EPA, 2003), however, monthly sampling still remains the most practical regime for large scale monitoring such as Regional SOE programmes or the National River Water Quality Network.

3.3.2 Assumptions Underlying the Interpretation of Results

1. The relative proportion of point source to non-point source nutrient load varies with river flow and catchment rainfall.

2. The non-point source contribution of phosphorus is low during low flows.

3. The cumulative nutrient impact of all minor discharges is considered within the non-point source nutrient contribution.

4. There is no nutrient attenuation by periphyton within the river between point source discharges and SOE sites. SIN and DRP are considered to be conservative.

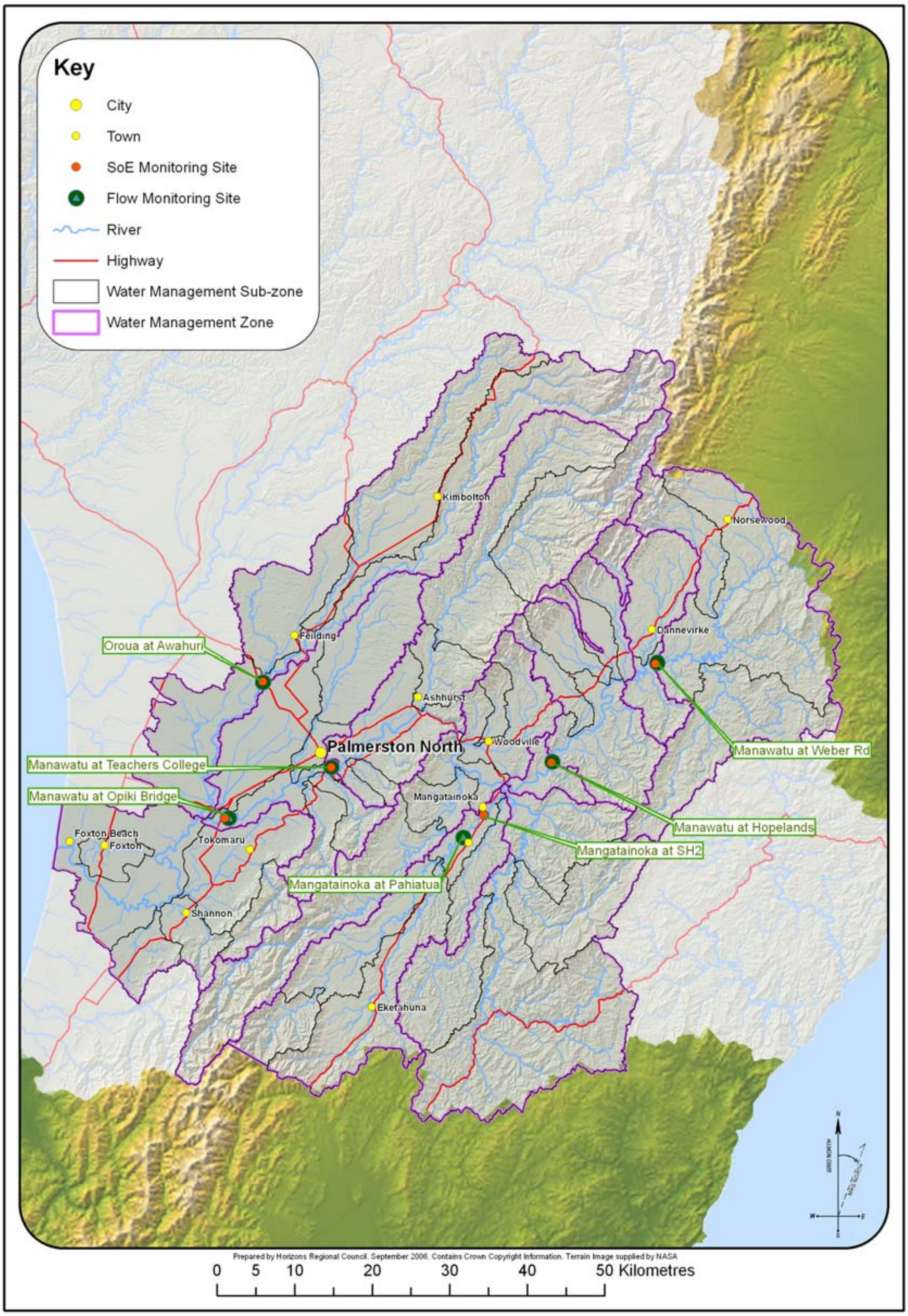
5. There is no nutrient retention within or release from river-bed sediments.

6. Loads calculated from spot samples are representative of average daily loads.

7. Estimated discharge volumes are representative of average, dry weather discharge flows.

8. Nutrient loads at SOE sites and from point and non-point sources were constant over the period of record analysed.

4. Manawatu River Catchment Nutrient Status

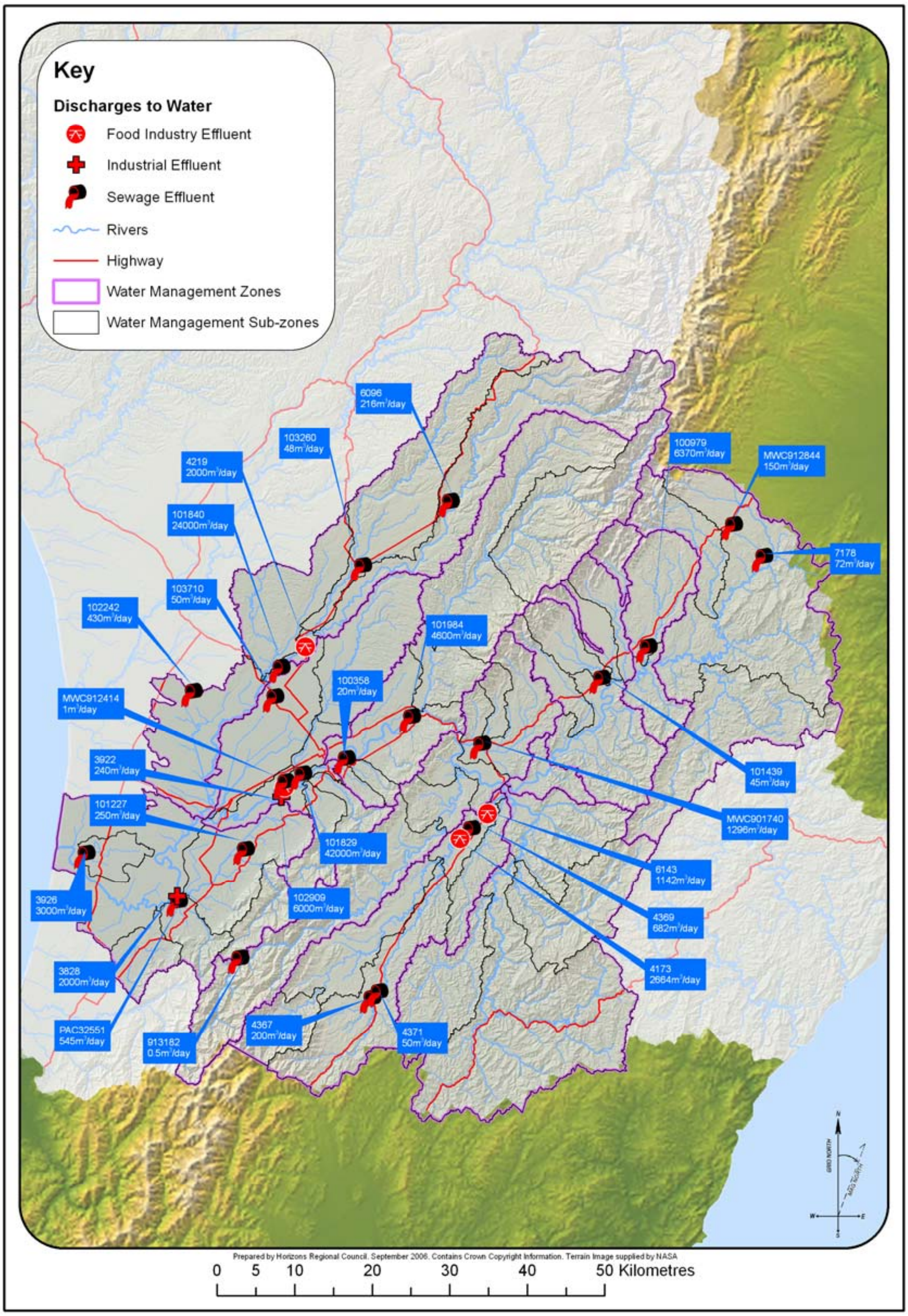


Map 1: Overview of the Manawatu River catchment showing cities, townships, State of the Environment (SOE) monitoring sites and flow recorders.

The total number of discharge to surface water permits in the Manawatu catchment (current or expired and under existing use rights) was 288 at the end of 2006. These consents covered a range of activities from minor discharges (see Section 1.1) which were removed from the dataset (n=197), to dairyshed discharges (n=66) which are covered below. The remaining consents considered for their significant contribution to point source nutrient enrichment of the Manawatu catchment (Table 1) encompassed a variety of waste-producing activities including fellmongery, domestic sewage effluent, food manufacturing and processing wastes (Map 2).

Table 1: Number of significant consented discharges to the Manawatu River catchment from 1993 to 2006.

Year	Significant Discharges to Surface Water
1993	13
1994	13
1995	15
1996	20
1997	25
1998	25
1999	25
2000	25
2001	25
2002	24
2003	24
2004	24
2005	24
2006	25



Map 2: Significant discharges to surface water in the Manawatu River catchment and consented maximum daily volume (m^3/day).

4.1 What does our SOE monitoring tell us about the nutrient status of the Manawatu River at low flows?

4.1.1 SOE Nutrient Concentrations

SIN in the Manawatu River at flows less than half median often exceed the proposed SIN standards (Figure 3). The Manawatu at Hopelands and Weber Road SOE sites show concentrations of SIN in excess of the proposed standard in more than 50% of the samples. Considering that the position of these SOE sites is relatively high in the upper Manawatu catchment, the elevated SIN concentrations are of some concern. It appears that there is a considerable increase in SIN concentrations occurring in the 31 km between the Weber Road and Hopelands SOE sites. Numerical values for all proposed SIN and DRP standards for the Horizons Region can be found in Appendix 4.

Concentrations of SIN at the Teachers College SOE site exceed the proposed SIN standard in approximately 25% of the samples, but are largely within the target values. The mean SIN concentration increases between the Teachers College and Opiki Bridge sites; at Opiki the concentrations of SIN exceed the proposed standard in nearly 50% of the samples. However, the mean concentration at Opiki Bridge is lower than Hopelands, even though these sites are in lowland reaches of the river where SIN concentrations would be expected to be higher.

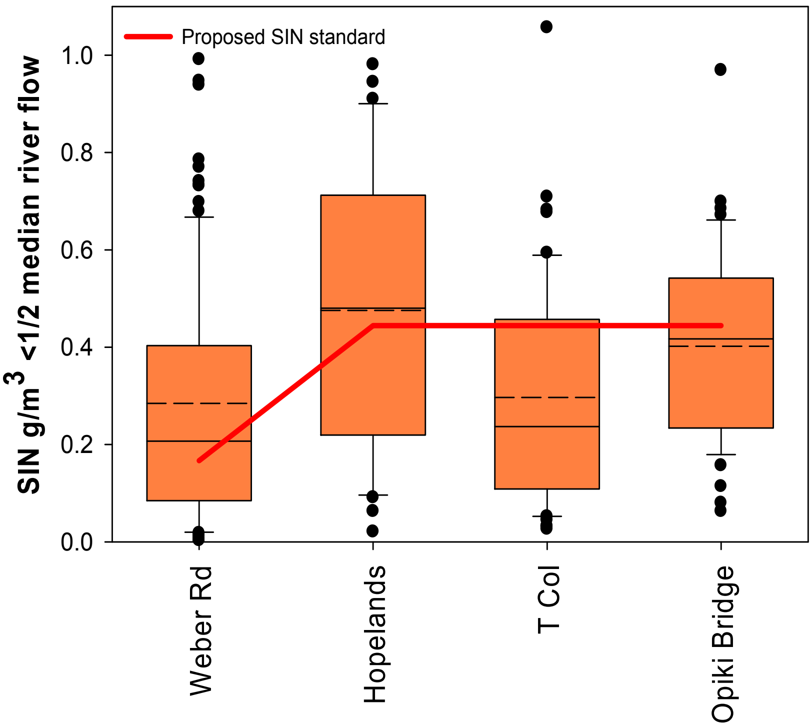


Figure 3: SIN concentrations in samples collected from State of the Environment sites on the mainstem of the Manawatu River, January 1989-July 2005 at flows below ½ median. (Solid midpoint line = median, dashed midpoint line = mean).

DRP concentrations in samples collected at flows equal to or below half median exceed the proposed standard in approximately 25% of the samples from Weber Road, almost 75% of the samples from Hopelands and in 100% of the samples from Opiki (Figure 4). However, like the soluble inorganic nitrogen concentrations, the Teachers College site is below the DRP standard for most samples.

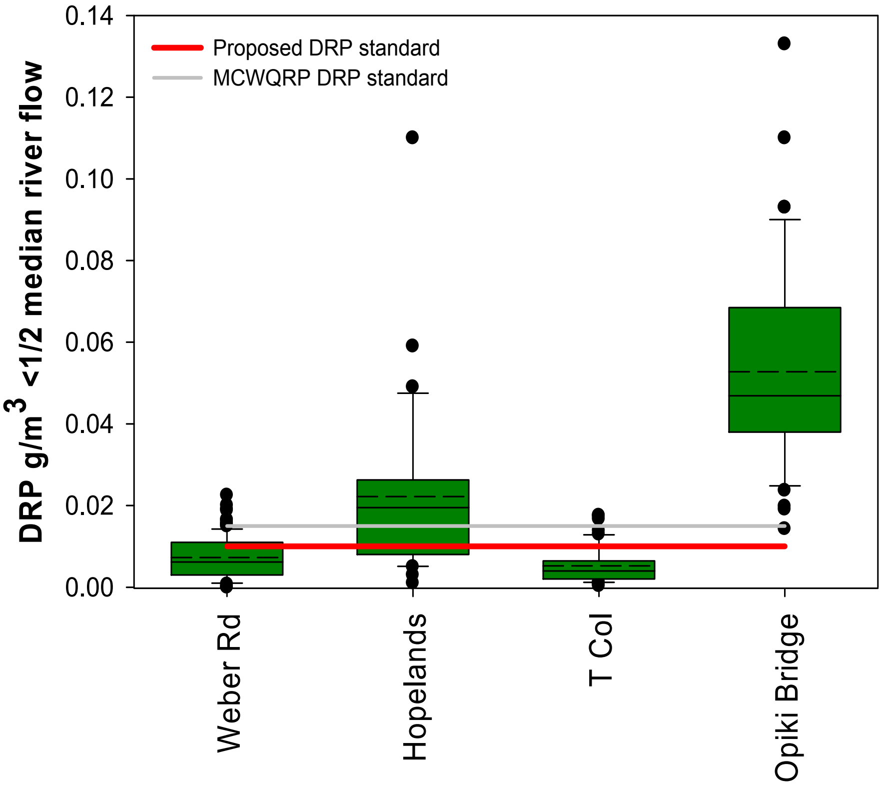


Figure 4: DRP concentrations in samples collected at State of the Environment sites on the mainstem of the Manawatu River, January 1989-July 2005 at flows below ½ median. (Solid midpoint line = median, dashed midpoint line = mean).

4.1.2 SOE Nutrient Loads

The proposed nitrogen and phosphorus standards have been recalculated using half median and mean annual low flow (MALF) statistics for each of the SOE monitoring sites. Figure 5 shows average daily loads of SIN exceed the proposed standard at flows less than half median at the Weber Road, Hopelands, Mangatainoka at SH2, and Oroua at Awahuri Bridge sites. As flows approach the mean annual low flow (MALF), all sites potentially surpass the proposed standard.

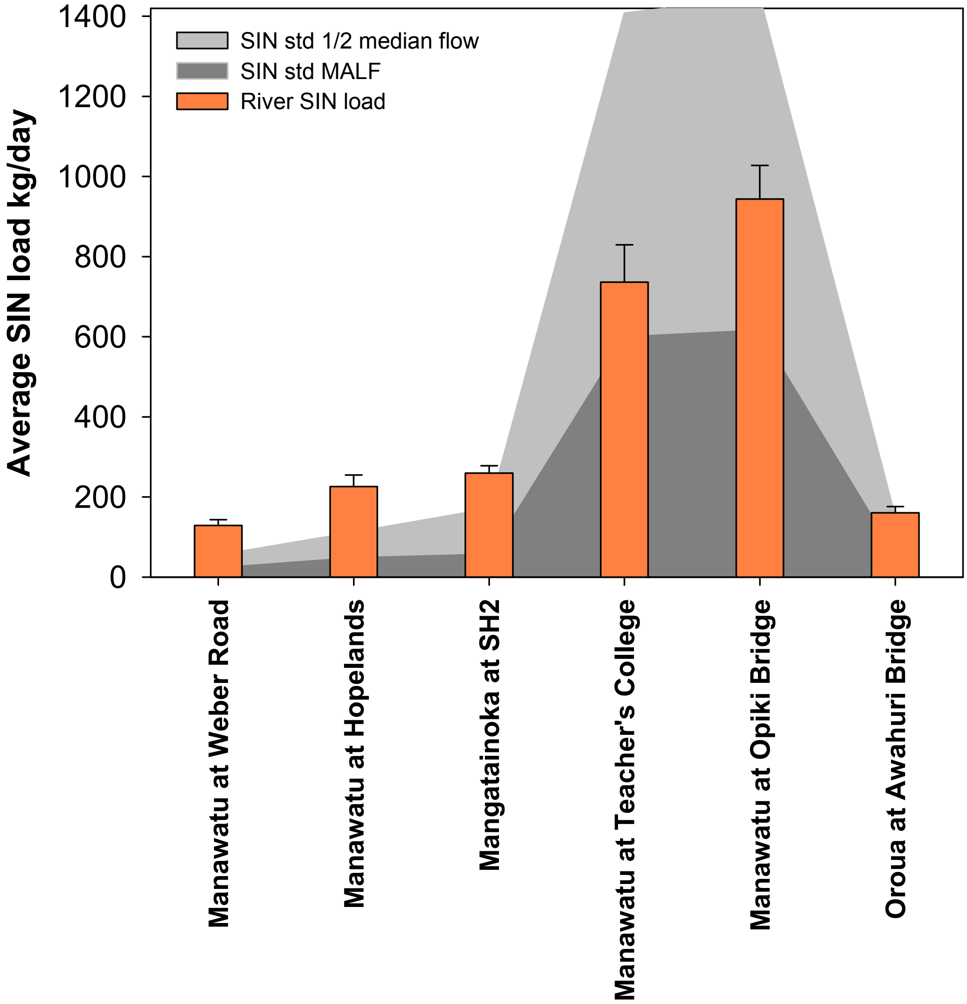


Figure 5: Average daily loads of SIN at State of the Environment monitoring sites in the Manawatu River catchment between January 1989 and July 2005 from samples taken at or below half median flow (bars ±1SE).

DRP loads at flows of half median or less (Figure 6) have the potential to exceed the proposed standard occasionally at the Mangatainoka at SH2 site; and always at the Manawatu at Hopelands, Opiki Bridge and Oroua at Awahuri Bridge sites. The Manawatu at Weber Road site will potentially exceed the standard as flows recede below half median towards MALF. The Teachers College site is just within the standard at mean annual low flows.

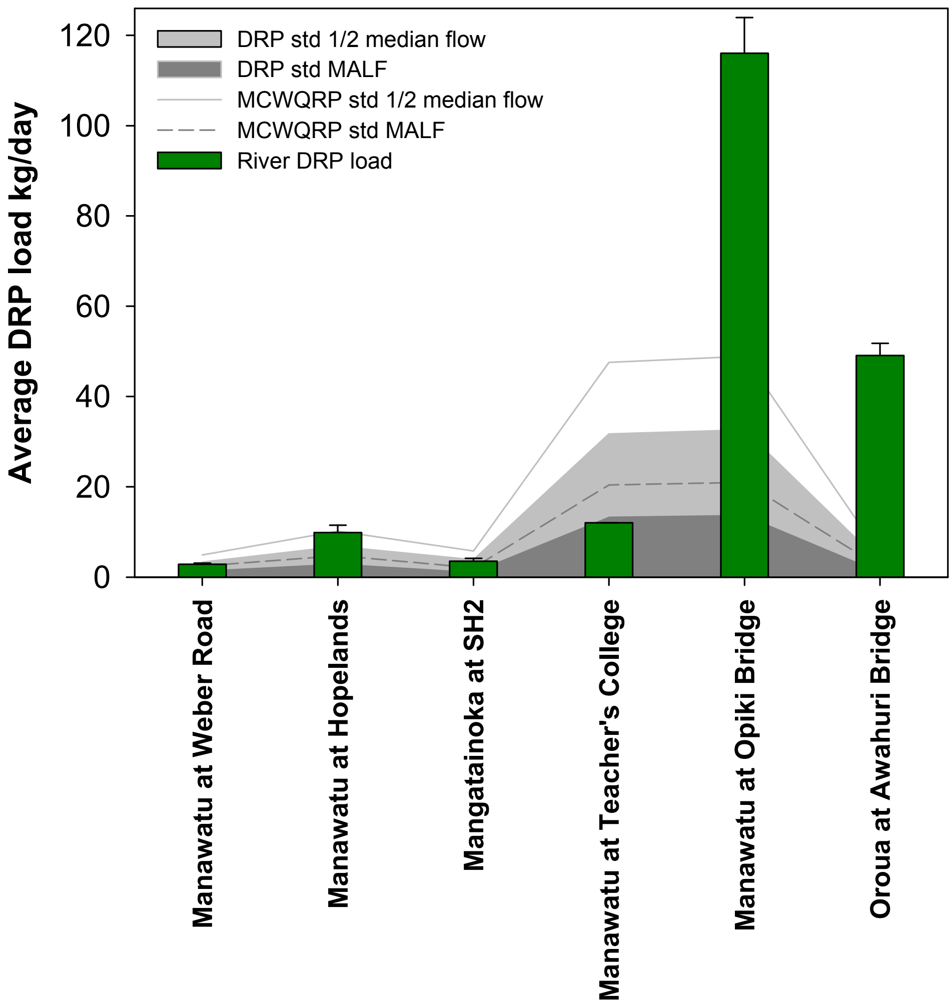


Figure 6: Average daily loads of DRP at State of the Environment monitoring sites in the Manawatu River catchment between January 1989 and July 2005 from samples taken at or below half median flow (bars ±1SE).

4.2 What are the sources of nutrient enrichment in the Manawatu catchment?

4.2.1 Dairy Discharges

Prior to 2000, dairy shed effluent made a considerable contribution to point source discharges consents to surface water in the Manawatu catchment. Changes in farm management practices, public awareness of nutrient enrichment issues and Horizons policy have caused a dramatic reduction in the number of discharges (from a maximum of 343 in 1996 to 66 in 2006). Consequently the total load of nutrients discharged directly to the Manawatu River catchment from dairyshed effluent has reduced considerably (Figure 7 and Figure 8).

Average SIN and DRP loads from dairy discharges were calculated from maximum consented volumes and average SIN (110 g/m^3) and DRP (20 g/m^3) concentrations in dairy discharges (Bolan, 2004; Hickey *et al.,* 1989).

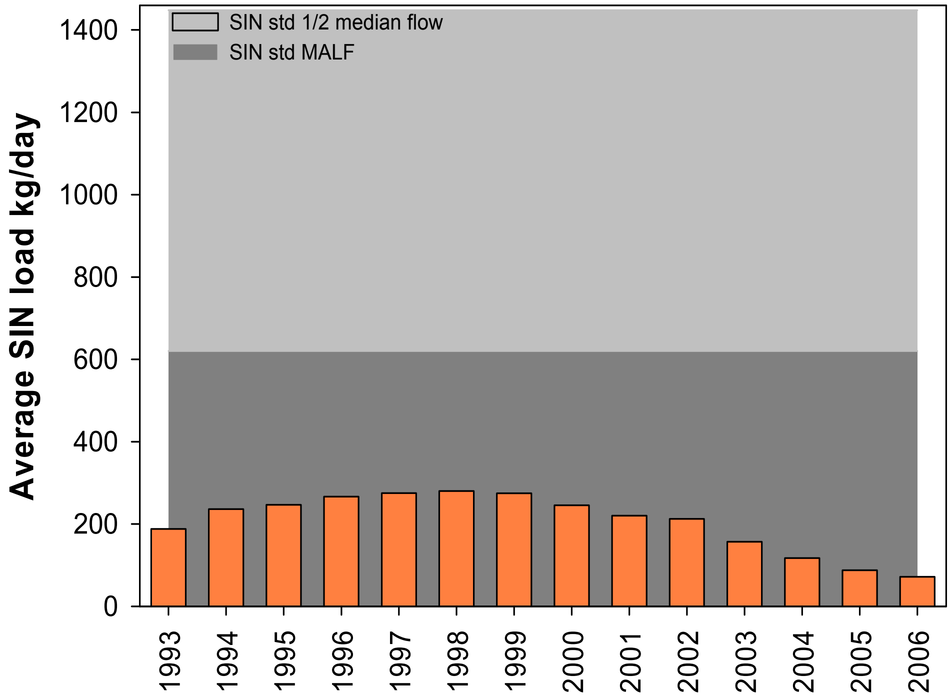


Figure 7: Average daily SIN loads from all consented dairy discharges to surface water in the Manawatu River catchment from 1993-2006. Load SIN standards have been calculated from synthetic flow statistics for the Manawatu at Opiki Bridge site.

Although the number of consents for the discharge of dairy shed effluent to the catchment has been high in the past, average loads of SIN from dairy discharges alone do not cause exceedence of the proposed standard when calculated for the whole catchment using the Opiki Bridge flow statistics. However this does not mean that in some locations (especially small streams) these discharges do not, or have not in the past, exceeded the standard at the point of discharge, particularly at low flows.

The relationship of dairy discharge phosphorus loads over time shows that the policies implemented through the Manawatu Catchment Water Quality Regional Plan (MCWQRP) have been successful in reducing direct phosphorus inputs to surface water from dairy discharges. The reduction in DRP load has brought the whole-catchment daily average, calculated for flows in the Manawatu River at Opiki Bridge, below the proposed standard for the Coastal Manawatu water management zone (McArthur *et al.,* 2007). Many of the remaining dairy discharges to the Manawatu catchment enter the catchment waterways below the boundary of the Coastal Manawatu WMZ, therefore the total upstream discharge load has been compared to the standard at this point (0.015g/m^3).

The reduction in direct discharges to surface water is likely to continue into the future, and many of the discharge permits held for dairy shed effluent in 2006 were of a short duration to allow for the upgrade of farm systems to land-based effluent application. However, as with SIN loadings above, discharges may have exceeded, or continue to exceed, the DRP standard in localised reaches at times of low flow, and the cumulative impacts of all discharges to water is not explained by Figure 8.

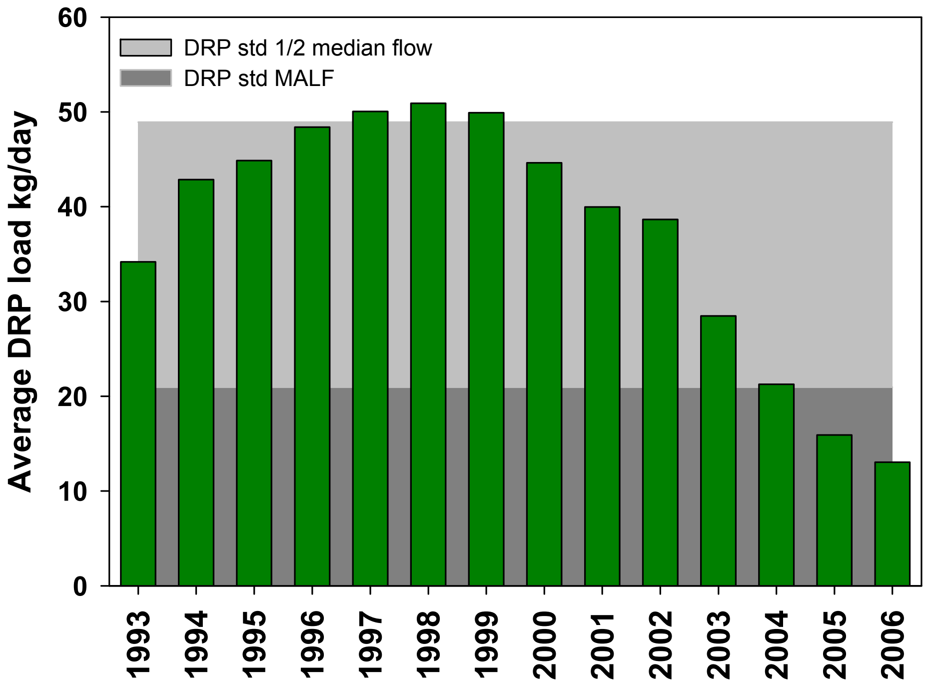


Figure 8: Average daily DRP loadings from consented dairy discharges to surface water in the Manawatu River catchment from 1993-2006. MCWQRP DRP standard loads have been calculated from flow statistics for the Manawatu at Opiki Bridge site.

4.2.2 Point Source Nutrient Loads

Average daily point source loads for the Manawatu catchment have been calculated for each river that receives point source discharges. Figure 9 shows a large contribution of SIN from point sources in the reach from the Teachers College to Opiki Bridge SOE sites and in the Oroua River. However, many of the SOE loads are not explained by point source SIN inputs and are therefore likely to be non-point source in origin.

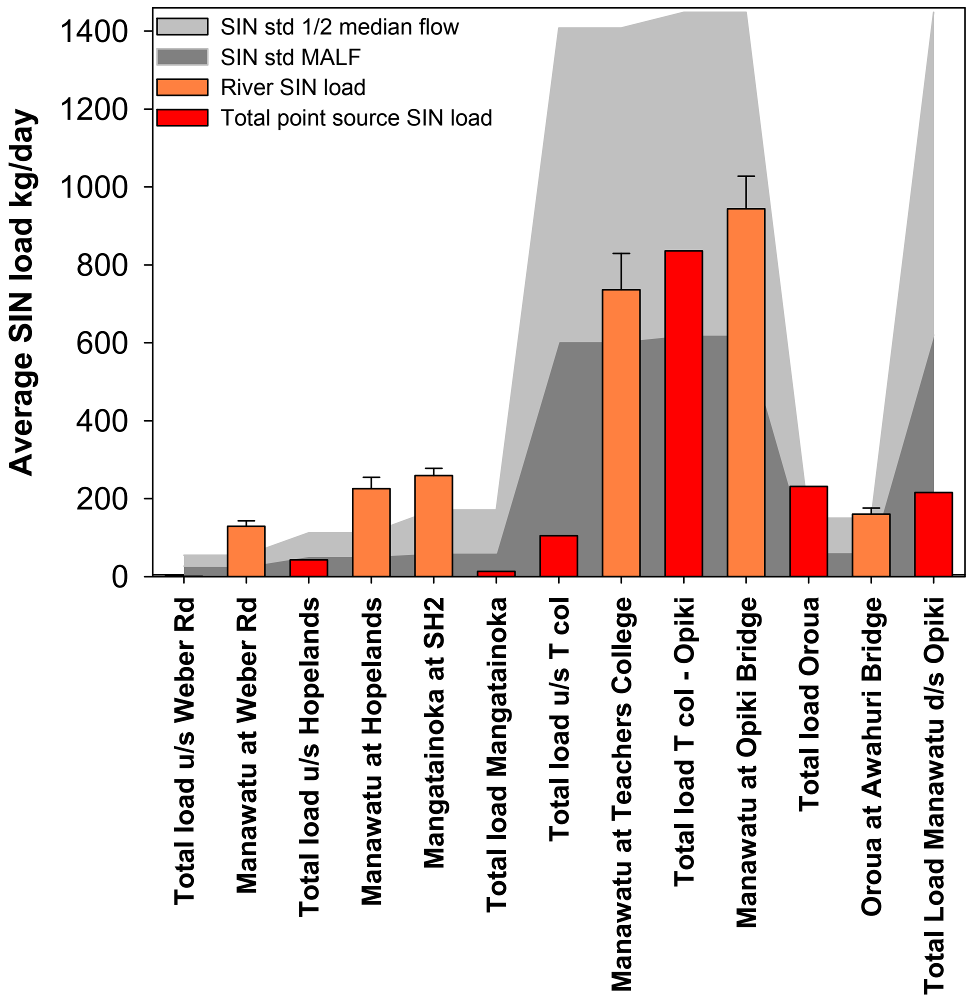


Figure 9: Average daily loads of SIN at State of the Environment (SOE) sites (orange bars ±1SE – from samples collected below ½ median flow) and from point source discharges (red bars – estimated loads) in the Manawatu catchment, January 1989-July 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

Figure 10 shows relatively high point source loads of DRP to the Manawatu catchment between the Weber Road and Hopelands SOE sites, in the Mangatainoka River, between the Teachers College and Opiki Bridge SOE sites and in the Oroua River. In order to identify the specific sources of point source contaminant loads of SIN and DRP, further analysis has been carried out on a discharge by discharge basis below.

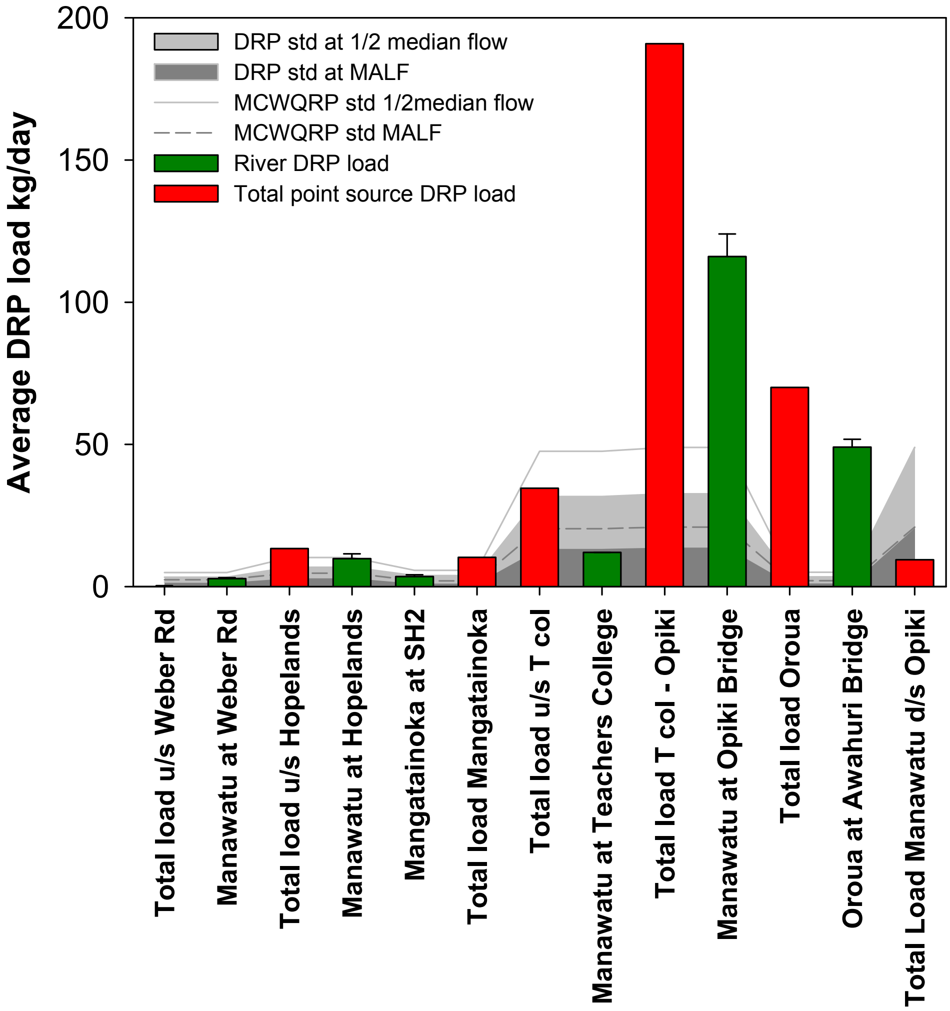


Figure 10: Average daily loads of DRP at State of the Environment (SOE) sites (green bars ±1SE - from samples collected below ½ median flow) and from point source discharges (red bars – estimated loads) in the Manawatu catchment, January 1989-July 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

4.3 Upper Manawatu catchment

4.3.1 Point Source vs. SOE Nutrient Loads

The Manawatu at Weber Road SOE monitoring site is approximately 74 km downstream from the source of the Manawatu River and is just upstream of the township of Dannevirke (Map 1). An upstream tributary, the Mangarangiora Stream, receives a small point source discharge of domestic sewage effluent from the township of Norsewood.

The Manawatu at Hopelands SOE site is approximately 30 km downstream of the township of Dannevirke. Two tributary streams (the Mangatera and Oruakeretaki Streams), which enter the Manawatu River between the Weber Road and Hopelands sites, contain domestic sewage effluent from the Dannevirke township and the PPCS Oringi meat works respectively (Map 2).

The Manawatu at Hopelands site is upstream of the confluence of the Manawatu with major inflowing tributaries the Tiraumea (which includes the Mangatainoka River with associated sewage and industrial discharges to water) and the Mangahao. Below these major confluences the mainstem of the river enters the Manawatu Gorge. Also entering the Manawatu above the Gorge is the Mangaatua Stream, which carries domestic sewage effluent from the township of Woodville.

Immediately below the Manawatu Gorge is the Pohangina River confluence. Between that point and the Manawatu at Teachers College SOE site at Palmerston North the river receives a direct discharge of domestic sewage effluent from the township of Ashhurst, as well as the Aokautere Stream tributary, which receives a small domestic sewage effluent discharge from the township of Aokautere.

Additionally, the Upper Manawatu catchment point source figures include estimations of the total load of SIN and DRP from point source dairy shed discharges within the catchment upstream of the Teachers College site. These loads are based on 2006 dairy discharge permit volumes and average nutrient concentrations.

The elevated loads of SIN measured at the Teachers College SOE site (Figure 11) (averaged from samples taken at flows less than or equal to half median) are consistent with other SOE sites within the Upper Manawatu catchment. The average SOE load measured at Teachers College exceeds the proposed SIN standard when flows in the Manawatu River reduce to the MALF. Total point source inputs to the river only make up approximately 14% of the measured SIN load in the Upper Manawatu catchment. By inference, non-point diffuse sources are contributing 86% of the SIN at low flows.

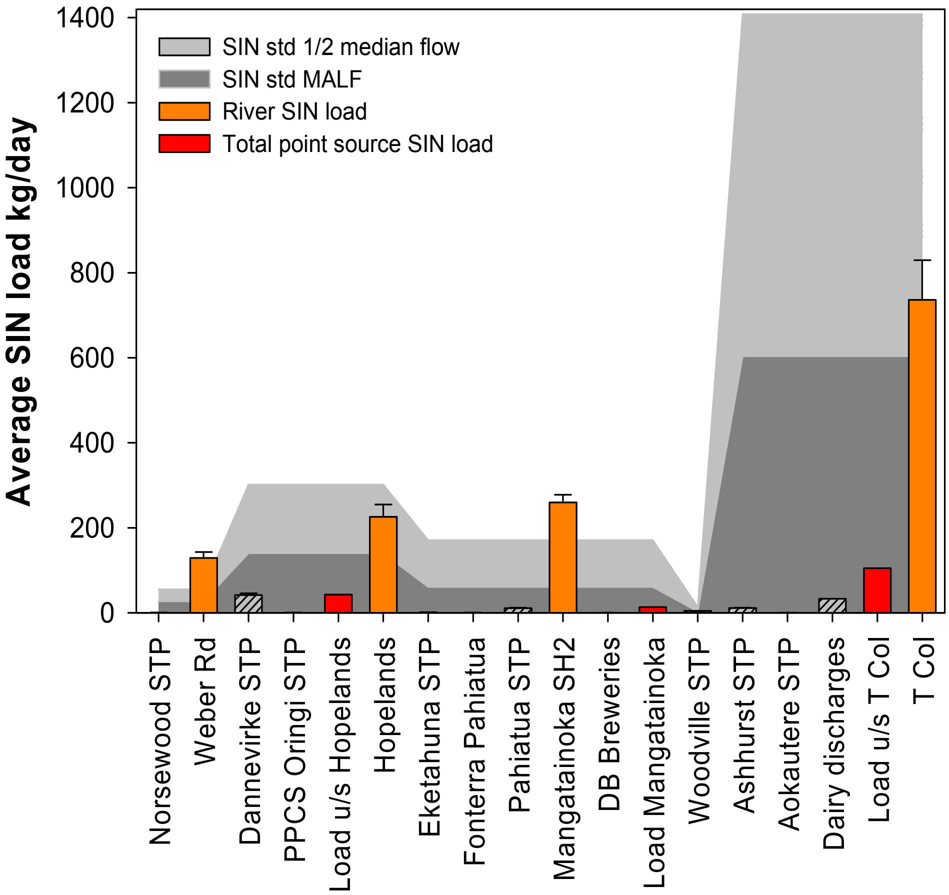


Figure 11: Average daily loads of SIN at State of the Environment (SOE) sites (orange bars ±1SE - from samples collected below ½ median flow) and from point source discharges (hashed bars - individual estimated loads, red bars – cumulative load estimates) in the upper Manawatu catchment, January 1989 - July 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

By contrast, the DRP load measured at the Teachers College SOE site (Figure 11) was low in comparison to other SOE sites in the catchment. The average DRP load measured at this site is 11% less than the proposed standard at MALF. However, the total load from point source inputs upstream of Teachers College is 2.9 times greater than that measured in the river. The total point source inputs of DRP are enough to exceed the proposed standard at flows above ½ median at Teachers College.

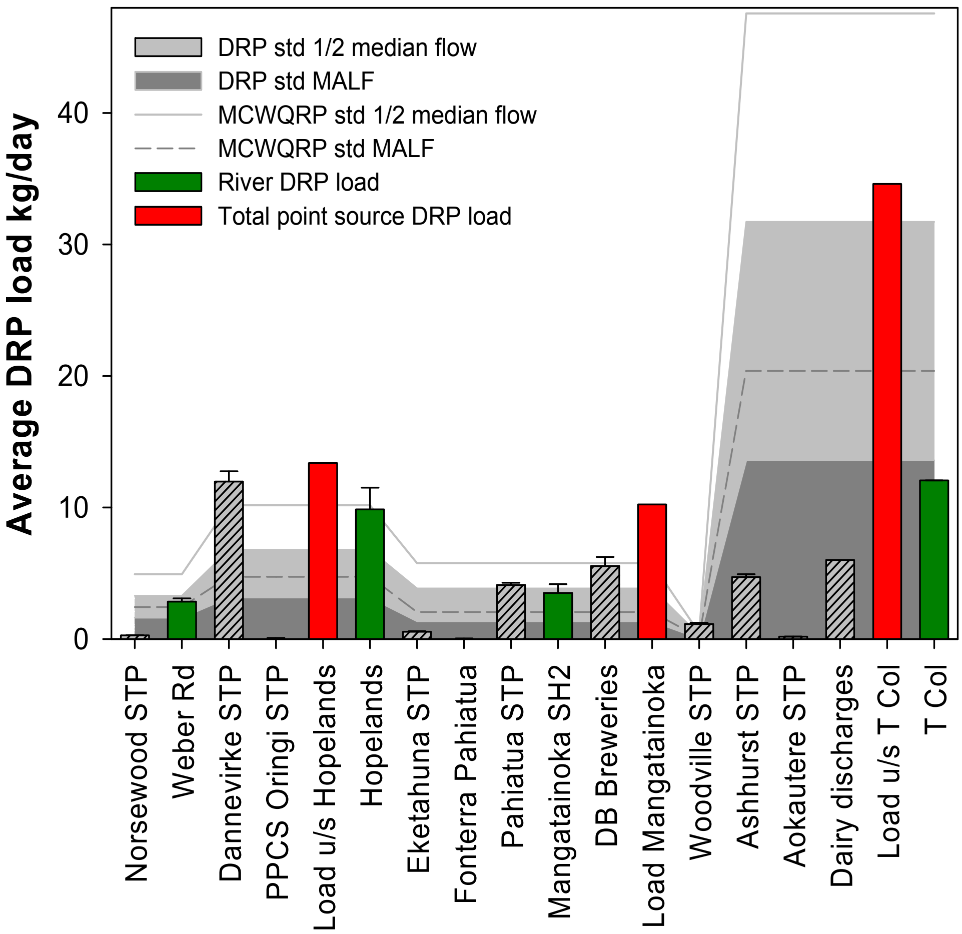


Figure 12: Average daily loadings of DRP at State of the Environment (SOE) sites (green bars ±1SE - from samples collected below ½ median flow) and from point source discharges (hashed bars – individual estimates, red bars – cumulative estimated loads) in the upper Manawatu catchment, January 1989-July 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

The large difference between the low level of DRP measured at the Teachers College SOE site and the total point source DRP load may be attributed to:

- immobilisation of phosphorus in river sediments, or
- wide scale attenuation of DRP by periphyton growing on the substrate.

Attenuation of DRP by periphyton biomass is particularly relevant to the reach of the Manawatu between the confluence with the Pohangina River (at the end of the Gorge) and the Teachers College site as the river has a wide, open, cobble bed which provides ideal substrate for periphyton growth during periods of stable flow. In an analysis of compliance with the proposed One Plan standards, Ausseil & Clark (2007a) found that the Teachers college site exceeded 120 mg Chl *a* /m^2 on two out of six sampling occasions.

4.4 Manawatu catchment – upstream of Hopelands

4.4.1 Sources of Nitrogen Upstream of Hopelands

Average daily SIN loads (at flows equal to or less than half median flow) measured in the Manawatu River at Hopelands are approximately five times greater than the total average daily load from point source inputs upstream of the Hopelands monitoring site (Figure 13). The average daily SIN load in the Manawatu River at Hopelands will exceed the proposed SIN standard when flows in the Manawatu River recede to the MALF.

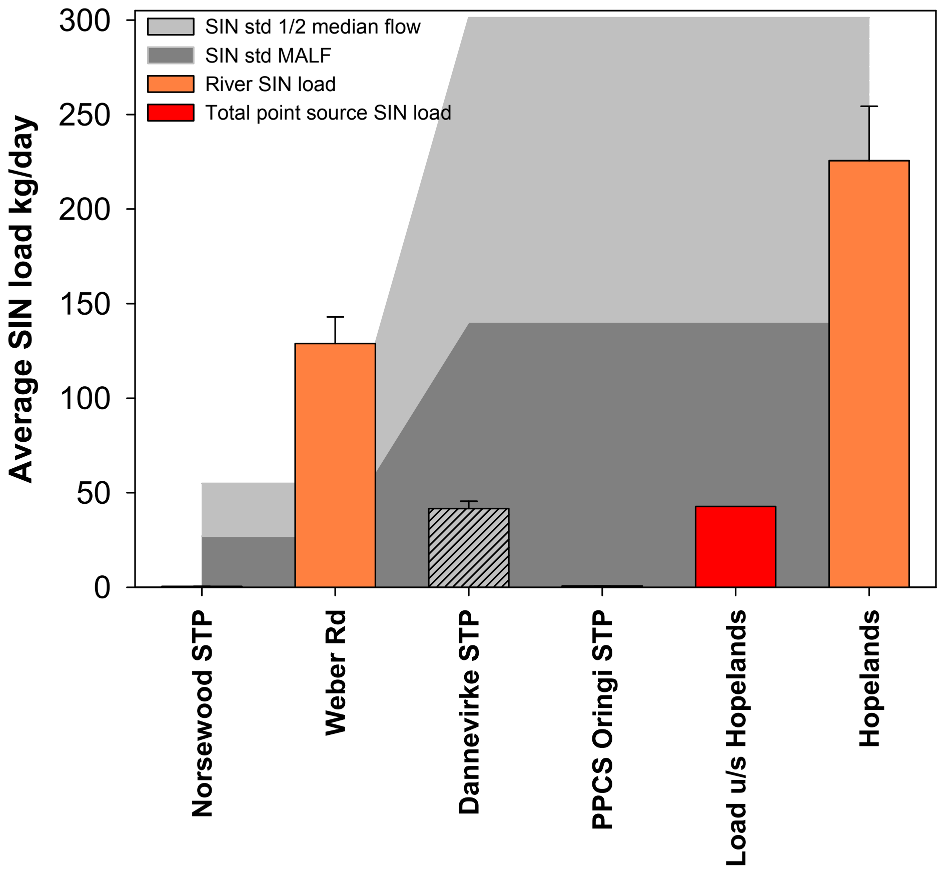


Figure 13: Average daily SIN loads at State of the Environment (SOE) sites (orange bars ±1SE - from samples collected below ½ median flow) and from point source discharges (hashed bars – individual load estimates, red bars – cumulative load estimates) in the Manawatu catchment upstream of Hopelands, January 1989-July 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

Dannevirke Sewage Treatment Plant (STP) makes the greatest contribution to the point source SIN load. The total daily average SIN load of point source inputs alone is not likely to exceed the proposed SIN standard in the Manawatu River at Hopelands, even when the river flows reduce to the MALF. However, when the discharged SIN loads from Dannevirke STP are compared to the proposed Sin standards within the receiving waters of the Mangatera Stream (Table 2), it can be seen that the STP load has a significant effect within this small tributary stream.

Table 2: Comparison of estimated nutrient loads from the Dannevirke sewage treatment plant (STP) discharge with Manawatu Catchment Water Quality Regional Plan (MCWQRP) and Proposed One Plan nutrient standards.

Nutrient	Estimated discharge Dannevirke STP	MCWQRP Standard		Proposed One Plan Standard	
		½ Median	MALF	½ Median	MALF
DRP	11.98	0.58	0.29	0.38	0.19
SIN	41.61	n/a	n/a	17.07	8.44

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Mangatera Stream.

Although the Dannevirke STP makes a significant SIN contribution to the Mangatera Stream, cumulatively, when loads are compared to the standard calculated for flows less than ½ median and MALF at the Hopelands SOE site, it appears that the major contribution of SIN in the Manawatu upstream of Hopelands is from non-point sources.

4.4.2 Sources of Phosphorus Upstream of Hopelands

Average daily DRP loads at SOE sites in the upper Manawatu catchment exceed the proposed DRP standard when the river is at MALF. The standard will also be exceeded at times when the river is at or below half median.

Unlike the SIN results, total average daily loads of DRP from point source discharges are 1.4 times greater than the measured load from the SOE site at Hopelands (Figure 14). By far the largest contributor of DRP to the total load is the Dannevirke STP discharge (90%). The small difference between the total average daily DRP load and the measured load in the river may be the result of a combination of factors, such as the immobilisation of phosphorus within river sediments, or attenuation of DRP by periphyton growths on the river substrate between the discharge sites and the SOE monitoring site. In an analysis of compliance with the proposed One Plan standards for periphyton biomass, Ausseil & Clark (2007a) found that the Manawatu at Hopelands site exceeded 120 mg Chl *a* /m^2 on five out of eight sampling occasions.

Figure 14 shows the Dannevirke STP load expressed against the target DRP standard load in the Manawatu at Hopelands. However, the effect of this discharge is even more marked when compared with the target loads based on flows within the receiving waters of the Mangatera Stream (Table 2).

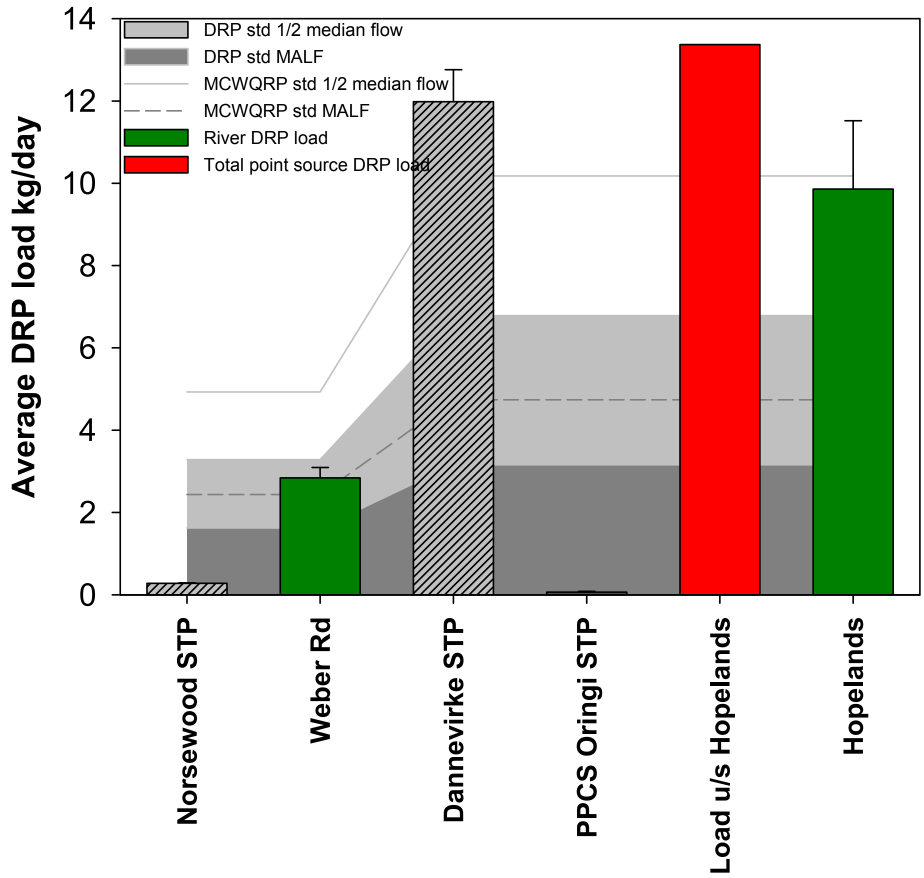
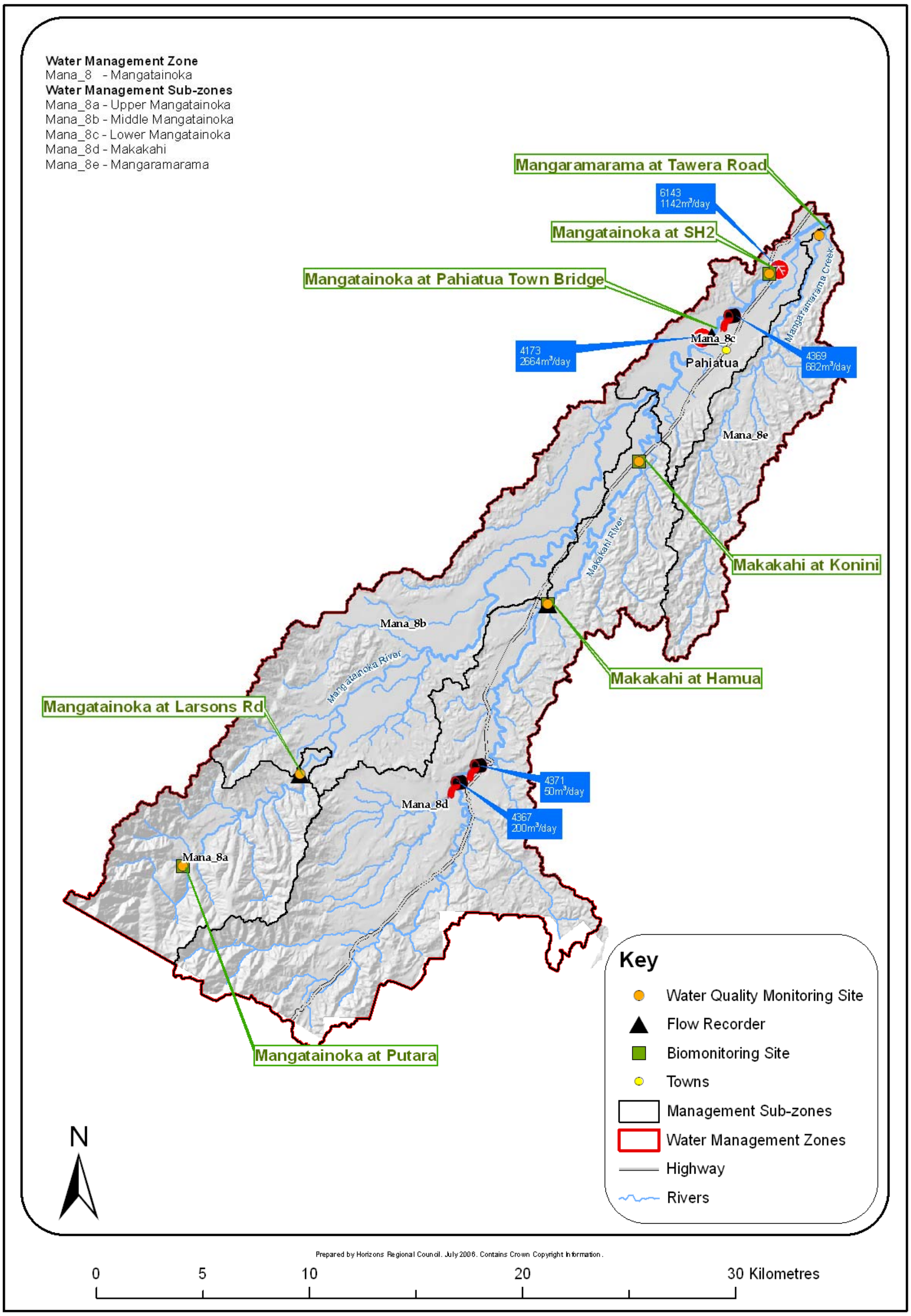


Figure 14: Average daily DRP loads at State of the Environment (SOE) sites (green bars ±1SE - from samples collected below ½ median flow) and from point source discharges (hashed bars – individual load estimates, red bars – cumulative loads) in the Manawatu catchment upstream of Hopelands, January 1989-July 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

As of November 2004 the consent for the Dannevirke STP discharge required the removal of phosphorus from the effluent (to a concentration of 0.001 gDRP/m^3) to achieve the MCWQRP standard (0.015 gDRP/m^3) in the Mangatera Stream at all flows equal to or less than ½ median (410 l/s) between November and April.

The implementation of consent conditions for this discharge has not been effective in achieving the desired DRP standard in the effluent or the receiving waters. Further regulation is likely to be required to alleviate the high loads of DRP discharged to the Mangatera Stream and ultimately the Manawatu River above Hopelands.

4.5 Mangatainoka River Catchment Nutrient Status



Map 3: Overview of the Mangatainoka River catchment showing townships, State of the Environment (SOE) monitoring sites and significant point source discharges to water.

State of the Environment monitoring is undertaken at the State Highway 2 Bridge over the Mangatainoka River. This site is approximately 3.5 km downstream of the Pahiatua STP discharge but is immediately upstream of the DB Breweries discharge. The Mangatainoka at SH2 site is approximately 64 km downstream of the source of the river and just over 7 km upstream of the confluence with the Tiraumea River, which is just upstream of the confluence with the Manawatu (Map 3).

4.5.1 Sources of Nitrogen in the Mangatainoka River

The average daily SIN load measured at the Mangatainoka at SH2 monitoring site is approximately fifteen times greater than the total load from point source inputs to the river (Figure 15). Pahiatua STP makes a substantial contribution to the total load from point sources but this load is very low relative to the in-river SOE load and does not come close to reaching the SIN standard, even at flows as low as MALF.

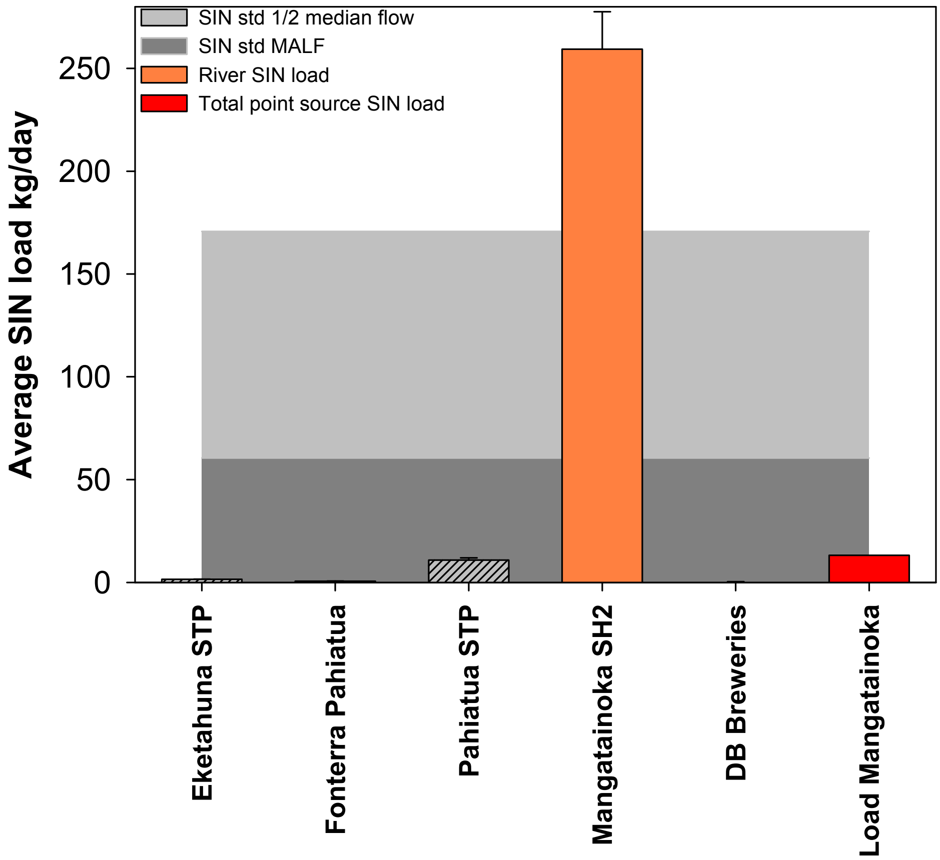


Figure 15: Average daily SIN loadings at State of the Environment (SOE) sites (orange bars ±1SE - from samples collected below ½ median flow) and from point source discharges (hashed bars – individual estimated loads, red bars – cumulative loads) in the Mangatainoka catchment, January 1989-July 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

The Mangatainoka SIN loads are similar to the scenario in the Manawatu upstream of Hopelands; the average daily load measured at the SOE site exceeds the SIN standard at all times when the river is at or below half median flow.

4.5.2 Sources of Phosphorus in the Mangatainoka River

The average daily DRP load measured in the river at the Mangatainoka at SH2 SOE site is slightly less than the total load from point source inputs upstream of the site (Figure 16). The SOE load of DRP in the river may be less than the total point source contribution upstream of the site (ie. the Pahiatua STP) because of removal of DRP by periphyton growth on the substrate of the river between the discharge points and the SOE site. In an analysis of compliance with the proposed One Plan standards for periphyton biomass, Ausseil & Clark (2007a) found that the Mangatainoka at SH2 site exceeded 120 mg Chl *a* /m^2 on only one out of eight sampling occasions.

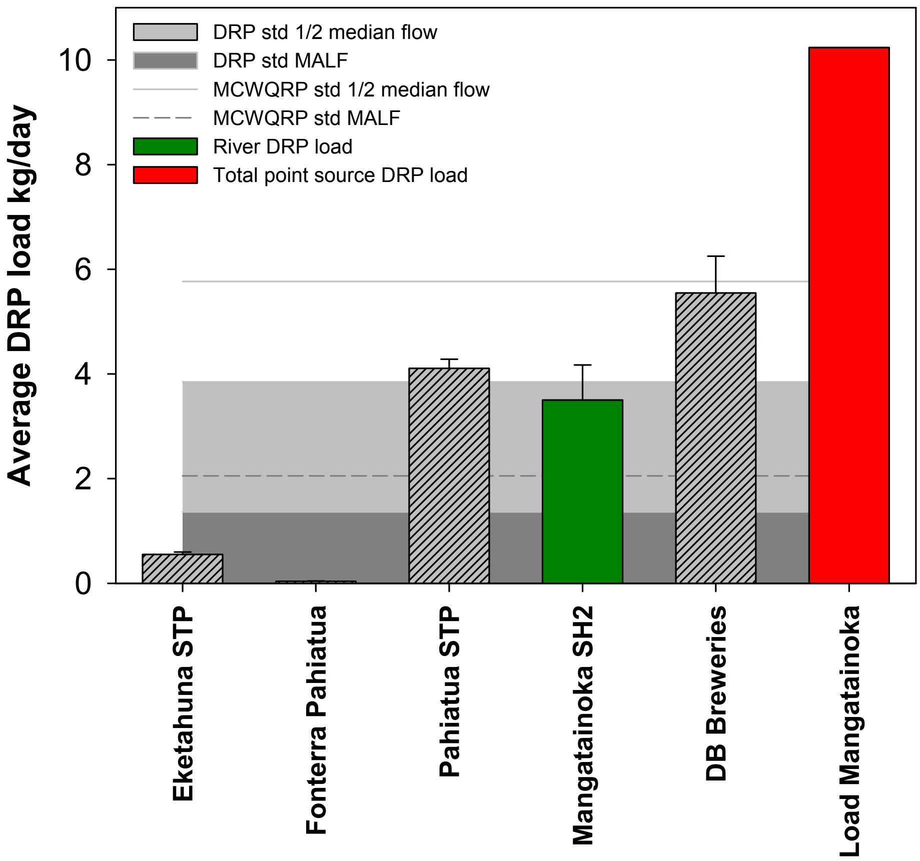


Figure 16: Average daily DRP loads at State of the Environment (SOE) sites (green bars ±1SE - from samples collected below ½ median flow) and from point source discharges (hashed bars – individual load estimates, red bars – cumulative loads) in the Mangatainoka catchment, January 1989-July 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

The Pahiatua STP discharge makes a large contribution to the average total daily DRP load. However, also of note is the DB Breweries discharge downstream of the SOE site which contributes a more substantial load than the Pahiatua STP (Table 3). Effectively, the position of this discharge downstream from the monitoring site means the DRP load from this discharge is not accounted for in the SOE figures. DB Breweries have recently begun trialing low-phosphorus detergents in order to reduce the DRP load from this discharge; results from the monitoring of this trial were not available at the time of writing.

Table 3: Comparison of estimated DRP loads from discharges to surface water in the Mangatainoka catchment with Manawatu Catchment Water Quality Regional Plan (MCWQRP) and Proposed One Plan nutrient standards.

Discharge	Estimated discharge DRP load	MCWQRP Standard		Proposed One Plan Standard	
		½ Median	MALF	½ Median	MALF
Eketahuna STP	0.55	5.77	2.04	3.84[1]	1.36[1]
Fonterra Pahiatua	0.04				
Pahiatua STP	4.11				
DB Breweries	5.55				

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Mangatainoka River at Pahiatua.

Without taking the DB Breweries discharge into account, the total point source and SOE loads exceed the proposed DRP standard when the river flow recedes to the MALF. If the load from DB Breweries is added to the total point source load (as shown in Figure 16) the standard is exceeded at all flows equal to or below half median.

It is strongly recommended that future SOE monitoring is undertaken at the bottom of the Mangatainoka catchment to accurately capture all nutrient loads to the river.

4.6 Lower Manawatu Catchment – downstream of Teachers College

The Manawatu at Opiki Bridge SOE site is approximately 23 km downstream of the Teachers College site and 54 km upstream of the Manawatu Estuary. Loads were estimated using a modeled flow series for the Manawatu at Opiki Bridge. It is preferable to monitor in-river nutrient loads at the downstream end of catchments to capture all nutrient inputs in the SOE monitoring. However, tidal influences stretch far inland on the Manawatu River, confounding nutrient measurement and flow monitoring within the tidal zone.

The Manawatu at Opiki Bridge SOE site is upstream of most of the lower Manawatu dairy, Feilding, Kimbolton, Rongotea, Tokomaru, Shannon and Foxton STPs, AFFCO NZ and PPCS Shannon discharges; therefore the average daily load measured in the Manawatu at Opiki does not capture many of the point source inputs to the lower catchment and tributaries. Further

1 The Eketahuna STP discharge load has not been compared with the target load standard for the receiving waters of the Makakahi River (a tributary of the Mangatainoka River, Map 3) because of a lack of adequate flow and water quality data at the discharge point. It is recommended that further monitoring is undertaken to assess compliance with proposed standards at the point of discharge.

investigation of the extent of tidal influences, in relation to State of the Environment monitoring in the lower Manawatu River, is strongly recommended.

4.6.1 Point Source vs. SOE Nutrient Loads

Palmerston North City Council (PNCC) sewage discharge makes a major contribution to the SIN load measured at the Manawatu at Opiki Bridge SOE site (Figure 17). The average SIN load measured at this site is comparable to the inputs from upstream point sources and will exceed the proposed SIN standards when flows in the river are between ½ median and MALF (Table 4). The comparable point source and SOE loads of SIN in the lower river are quite different from the relationship between point source and SOE loads in the Upper Manawatu, where point sources make only a minor contribution to the cumulative in-river SIN load at flows at or below half median.

Table 4: Comparison of estimated SIN loads from discharges to the Manawatu River between Teachers College and Opiki Bridge with Manawatu Catchment Water Quality Regional Plan (MCWQRP) and Proposed One Plan standard.

Discharge	Estimated discharge load	MCWQRP Standard		Proposed One Plan Standard	
		½ Median	MALF	½ Median	MALF
PNCC STP	782.84	n/a	n/a	1448.11	620.19
Longburn STP	1.40				
Fonterra Longburn[2]	31.78				
NZ Pharm.	5.18				

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Manawatu at Opiki Bridge flow recorder.

In the Oroua catchment which joins the Manawatu River downstream of the Opiki Bridge site, loads measured at the Oroua at Awahuri Bridge have the potential to exceed the proposed SIN standards at or below ½ median flows. Feilding sewage makes a large contribution to the total SIN load in the lower Oroua River. The Oroua catchment is explored in more detail in Figure 19 and Figure 20 below.

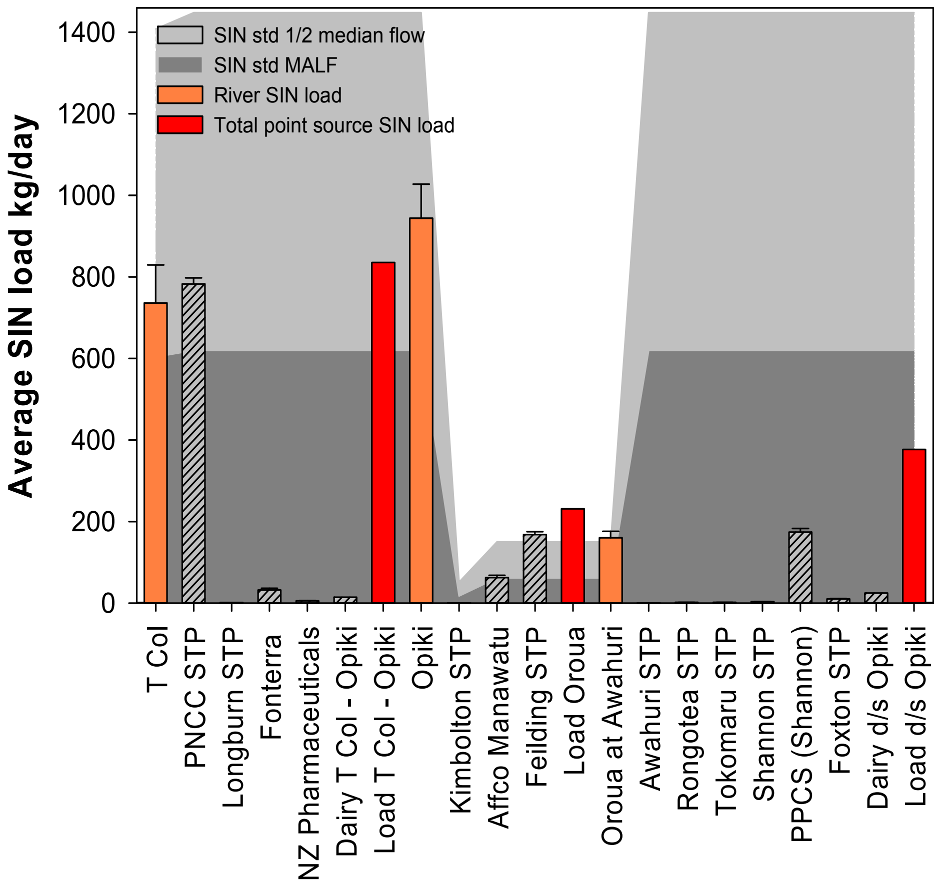


Figure 17: Average Daily SIN loads at State of the Environment (SOE) sites (Orange bars ±1SE – from samples collected below ½ median flow) and from point source discharges (hashed bars – individual load estimates, red bars – cumulative loads) in the Manawatu catchment downstream of Teachers College, January 1989-July 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

The average daily DRP loads measured at the Manawatu at Opiki SOE site, at flows equal to or less than half median, were more than one third less than the total load from point source discharges between Teachers College and Opiki Bridge (Figure 18). The largest contributor to the DRP load in this reach is the Palmerston North City Council (PNCC) sewage discharge (Table 5). The difference between the estimated point source loads and the DRP loads measured in the river can be attributed to several factors, including:

- immobilisation of phosphorus in river sediments; and/or
- attenuation of DRP by periphyton growth on the river substrate between Teachers College and Opiki Bridge.

In an analysis of compliance with the proposed One Plan standards for periphyton biomass, Ausseil & Clark (2007a) found that the Manawatu at Opiki site exceeded 120 mg Chl *a* /m^2 on one out of four sampling occasions. This reach of the river (like that upstream of Teachers College) has ideal open, cobble substrate for high periphyton biomass at stable flows.

Table 5: Comparison of estimated DRP loads from discharges to the Manawatu River between Teachers College and Opiki Bridge with Manawatu Catchment Water Quality Regional Plan (MCWQRP) and Proposed One Plan standard.

Discharge	Estimated discharge load	MCWQRP Standard		Proposed One Plan Standard	
		½ Median	MALF	½ Median	MALF
PNCC STP	140.22	48.92	20.95	32.62	13.97
Longburn STP	0.57				
Fonterra Longburn[2]	46.45				
NZ Pharm.	0.99				

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Manawatu at Opiki Bridge flow recorder.

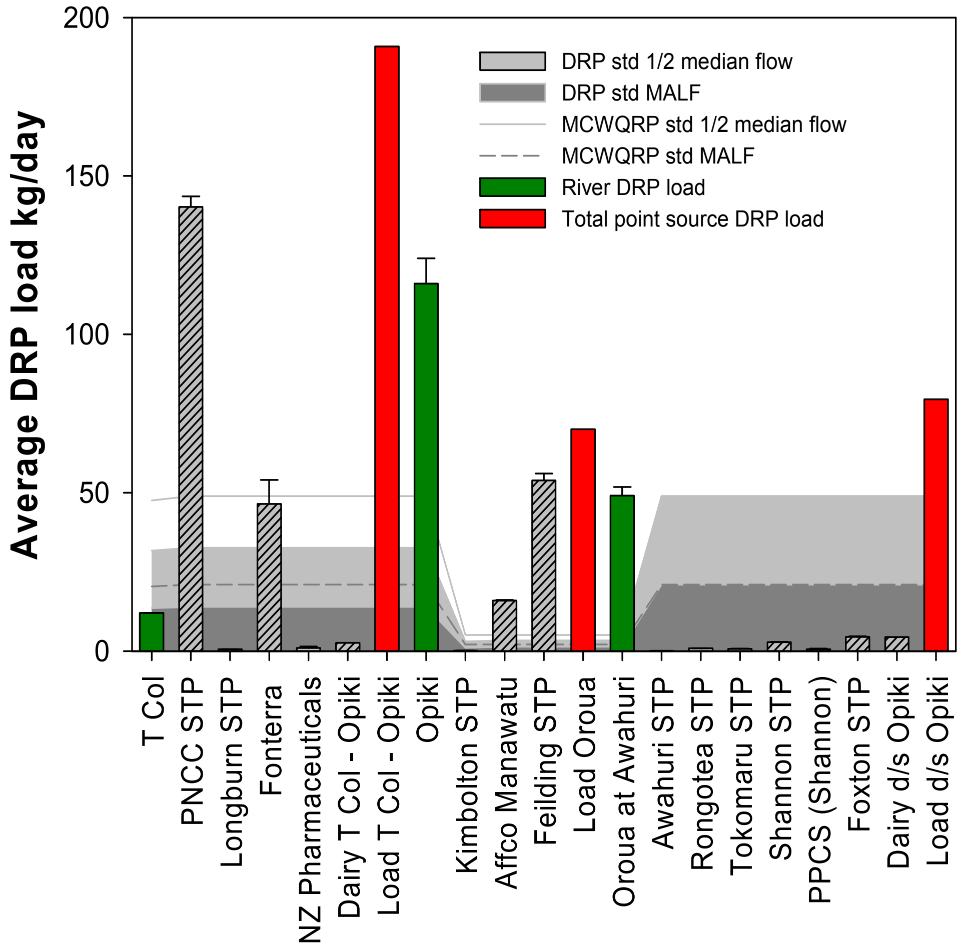


Figure 18: Average daily DRP loadings at State of the Environment (SOE) sites (green bars ±1SE – samples collected below ½ median flow) and from point source discharges (hashed bars – individual load estimates[2], red bars – cumulative loads) in

[2] Fonterra Longburn DRP and SIN loads to the Manawatu River are included in the average point source loads for historical perspective only, as the discharge has been removed from the river when flows are equal to or below half median since May 2005. Future calculation of loadings at or less than half median should not include estimates of these loads.

the Manawatu catchment downstream of Teachers College, January 1989 - July 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

4.6.2 Sources of Nitrogen in the Oroua River

The Oroua at Awahuri Bridge SOE site is approximately 8 km downstream of the township of Feilding and reasonably low in the Oroua River catchment (approximately 100 km from the source of the river and 31 km upstream of the confluence with the Manawatu River). Although only a moderately sized tributary of the Manawatu, the Oroua River receives high nutrient loads from point source discharges during low flows.

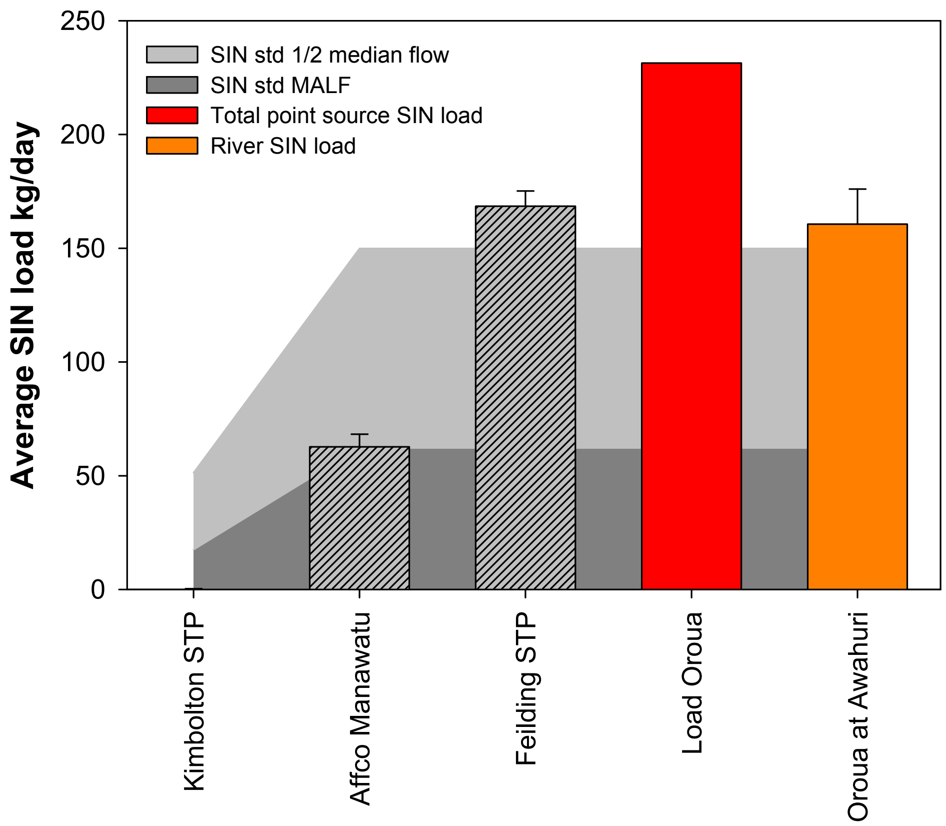


Figure 19: Average Daily SIN loadings at State of the Environment (SOE) sites (orange bars ±1SE – samples collected from below ½ median flow) and from point source discharges (hashed bars – individual estimated loads, red bars – cumulative loads) in the Oroua catchment, January 1989-July 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

Figure 19 shows the point source contributions of SIN to the Oroua River in relation to the SIN measured at the Oroua at Awahuri Bridge site at flows equal to or less than half median. Daily average loads from the Feilding STP discharge exceed the proposed SIN standard at ½ median flows or less (Table 6). As flow recedes to the MALF, the Affco meat processing discharge also has the capacity to exceed the proposed standard at the discharge point.

Table 6: Comparison of estimated SIN loads from discharges to the Oroua River with Manawatu Catchment Water Quality Regional Plan (MCWQRP) and Proposed One Plan standard.

Discharge	Estimated discharge load	MCWQRP Standard		Proposed One Plan Standard	
		½ Median	MALF	½ Median	MALF
Kimbolton STP*	0.26	n/a	n/a	51.25	17.47
Affco Manawatu+	62.66	n/a	n/a	149.92	62.15
Feilding STP+	168.49				

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Oroua River at Almadale and the Oroua River at Awahuri Bridge+.*

The high contribution of point source SIN loads to the Oroua is in direct contrast to the main source of SIN loads in the Mangatainoka, an upper Manawatu tributary of relatively comparable size. The recurring pattern, reflected by the differences in SIN source, appears to be that in the lower Manawatu River and tributaries, SIN loads are more often of point source than non-point source origin at low flows.

4.6.3 Sources of Phosphorus in the Oroua River

The total DRP loads to the Oroua River exceed the proposed DRP standard at flows equal to or less than ½ median and MALF (Figure 20). Both the AFFCO and Feilding STP discharges have the capacity to exceed the standard individually, making their cumulative contribution to DRP loads in the Oroua River extremely high (Table 7).

Table 7: Comparison of estimated DRP loads from discharges to the Oroua River with Manawatu Catchment Water Quality Regional Plan (MCWQRP) and Proposed One Plan standard.

Discharge	Estimated discharge load	MCWQRP Standard		Proposed One Plan Standard	
		½ Median	MALF	½ Median	MALF
Kimbolton STP*	0.17	5.07	2.10	3.07	1.05
Affco Manawatu+	15.97	5.07	2.10	3.38	1.40
Feilding STP+	53.89				

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Oroua River at Almadale and the Oroua River at Awahuri Bridge+.*

The measured SOE load at Awahuri Bridge exceeds the proposed DRP standard at all times when flows are at or below half median. The total point source load is moderately higher than the SOE load; this difference can be explained by a combination of the effects of attenuation of DRP by periphyton, immobilization of phosphorus in river sediments, and/or some over-estimation of the total point source load.

In an analysis of compliance with the proposed One Plan standards for periphyton biomass, Ausseil & Clark (2007a) found that the Oroua River at Awahuri Bridge site exceeded 120 mg Chl *a* /m^2 on three out of eight sampling occasions. This reach of the river (like that upstream of Teachers College) has ideal open, cobble substrate for high periphyton biomass at stable flows.

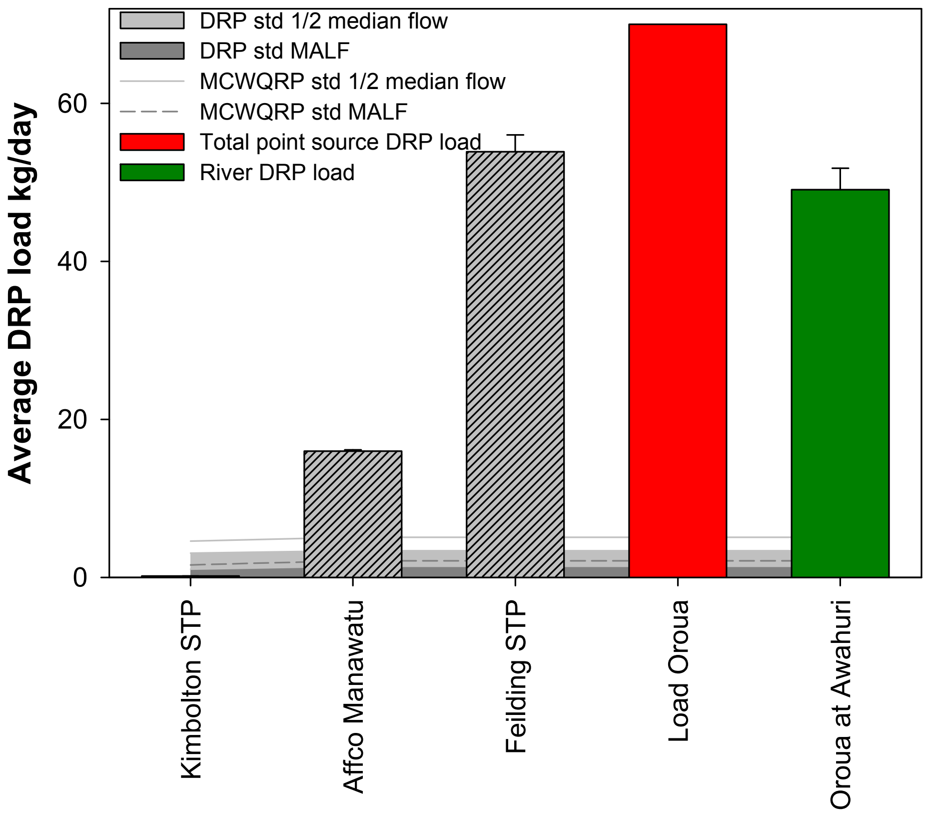


Figure 20: Average daily DRP loadings at State of the Environment (SOE) sites (green bars ±1SE - samples collected from below ½ median flow) and from point source discharges (hashed bars – individual estimated loads, red bar – cumulative load) in the Oroua catchment, January 1989-July 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

4.7 Conclusions and Recommendations - Manawatu Catchment

SIN concentrations and average daily loads were high throughout the Manawatu River catchment. The proposed SIN standards were often exceeded at SOE sites on the Manawatu mainstem and in the Mangatainoka River.

The source of nitrogen enrichment at low flows differs between the upper and lower Manawatu water management zones. The upper Manawatu SOE sites (Weber Road, Hopelands and Mangatainoka at SH2) have very high non-point source nitrogen loads that exceed the proposed standard, whereas the lower Manawatu SOE sites (Opiki Bridge and the Oroua at Awahuri Bridge) have high point source nitrogen loads.

Nitrogen loads in the Manawatu at Teachers College and Opiki do not breach the proposed SIN standard at ½ median but are still high enough to exceed the standard as flows recede to the MALF. The Oroua at Awahuri Bridge has high nitrogen loads which exceed the proposed SIN standard almost all of the time at ½ median flows or less. Palmerston North STP, Affco, Feilding STP and PPCS (Shannon) make the most significant contributions to SIN loads in the lower Manawatu.

DRP concentrations and loads are high at most sites at low flows. All sites, except the Manawatu at Teachers College, exceed the proposed DRP standard. Point source discharges are the main contributors of DRP at low flows for both the upper and lower Manawatu catchments.

Phosphorus loads in the Lower Manawatu and Oroua Rivers are alarmingly high. The DRP load at Opiki Bridge site is at least three times the proposed standard and more than ten times the standard in the Oroua at Awahuri Bridge. These estimated average loads are a direct result of the Palmerston North STP, Affco and Feilding STP discharges, each one of which individually breaches the proposed DRP standards as well as the current MCWQRP standards.

The total load of phosphorus from point sources downstream of Opiki exceeds the DRP standard at flows ½ median or less. Most of this load is contributed by the Oroua catchment (Feilding STP and Affco) which enters the Manawatu mainstem just downstream of Opiki.

4.7.1 Recommendations for further investigation – Upper Manawatu

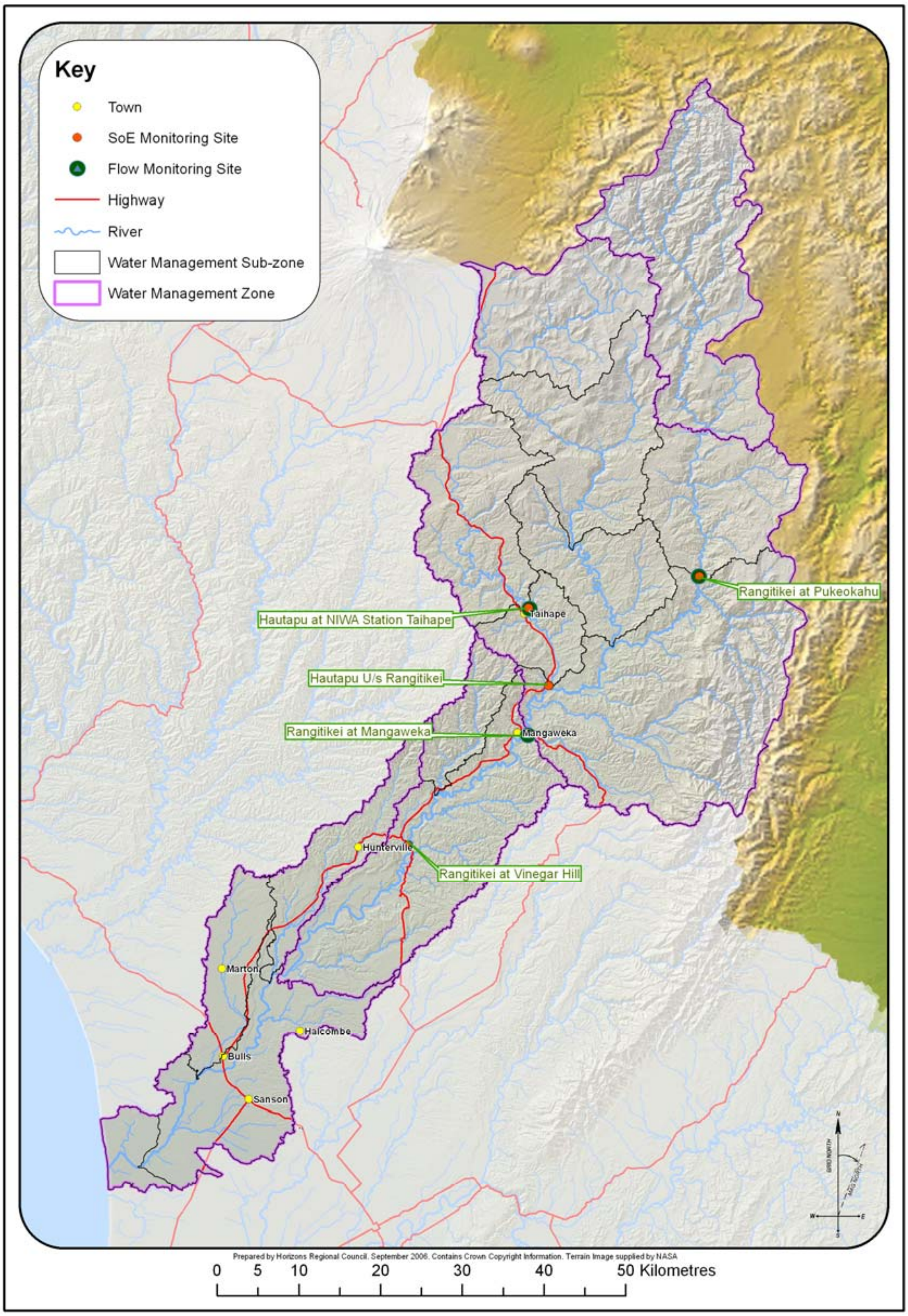
1. In order to better evaluate the extremely high non-point source nitrogen loads and point source DRP loads to the Mangatainoka River at low flows, SOE monitoring should be undertaken at the bottom of the lower Mangatainoka sub-zone to better capture all of the nutrient inputs upstream.
2. An investigation of the sources of DRP in the Manawatu catchment upstream of Weber Road should be undertaken.
3. Investigation of the relationship between periphyton biomass and DRP concentrations in the Manawatu between Hopelands and Teachers College is needed to determine what (if any) attenuation of DRP is occurring there.
4. Investigation of SIN inputs at low flows (via leaching) to the water management sub-zones of the upper Manawatu and Mangatainoka.

4.7.2 Recommendations for further investigation – Lower Manawatu

1. An investigation of the relationship between periphyton biomass and SIN and DRP concentrations at reaches with gravel/cobble substrates below Teachers College and in affected tributaries (ie. the Oroua River).

2. SOE sampling downstream of the Opiki Bridge site and at the bottom of tributary sub-zones to ascertain loads and sources of nitrogen and phosphorus in the Lower and Coastal Manawatu water management zones.
3. Investigation of the tidal influence on the lower Manawatu catchment is needed to allow for accurate analysis of SOE samples in these areas.

5. Rangitikei River Catchment Nutrient Status

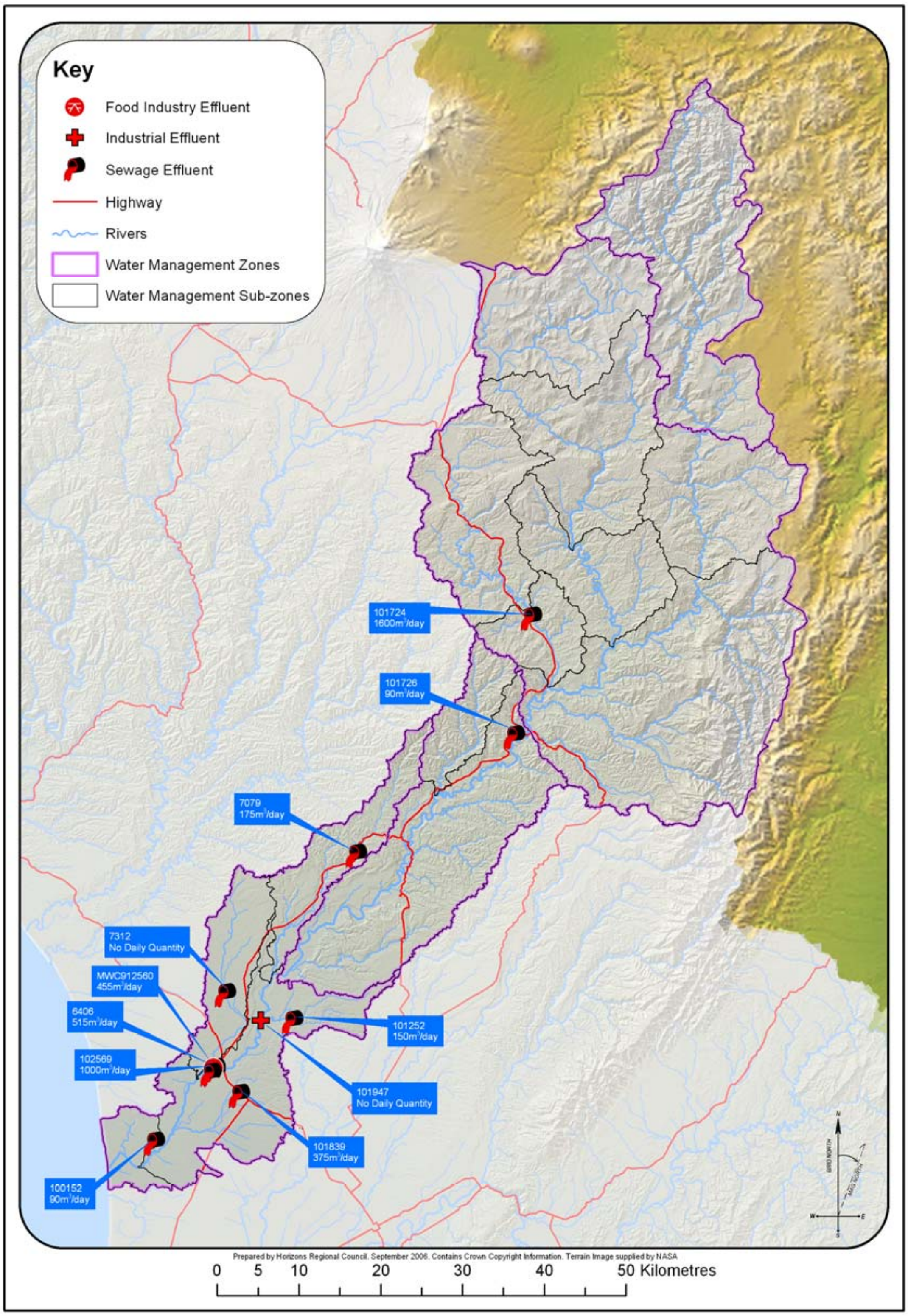


Map 4: Overview of Rangitikei River catchment showing cites, townships, State of the Environment (SOE) monitoring sites and flow recorders.

The total number of discharge to surface water permits in the Rangitikei River catchment (current or expired and under existing use rights) was 54 at the end of 2006. These consents covered a range of activities from minor discharges (see Section 1.1) which were removed from the dataset (n= 36), to dairy shed discharges (n=6). The remaining consents considered for their significant contribution to point source nutrient enrichment of the Rangitikei catchment (Table 8) included discharges from activities such as treated domestic sewage effluent, food manufacturing and processing (meat industries) and wool scouring wastes (Map 5). Although the 2006 consent figures include the Feltex Wool Scour discharge at Kakariki, this discharge is no longer operating from this site and should not be included in any future analysis.

Table 8: Number of significant consented discharges to the Rangitikei River catchment from 1993 to 2006.

Year	Significant Discharges to Surface Water
1993	11
1994	11
1995	12
1996	12
1997	12
1998	12
1999	12
2000	12
2001	12
2002	12
2003	13
2004	13
2005	12
2006	12



Map 5: Significant discharges to surface water in the Rangitikei River catchment.

5.1 What does our SOE monitoring tell us about the nutrient status of the Rangitikei River at low flows?

5.1.1 SOE Nutrient Concentrations

The concentrations of SIN (Figure 21) and DRP (Figure 22) in samples taken from SOE sites when the river is at or below half median flow (or the 75th percentile flow at sites affected by the Tongariro Power Development [TPD] – see Glossary) in the Hautapu and Rangitikei Rivers are presented below.

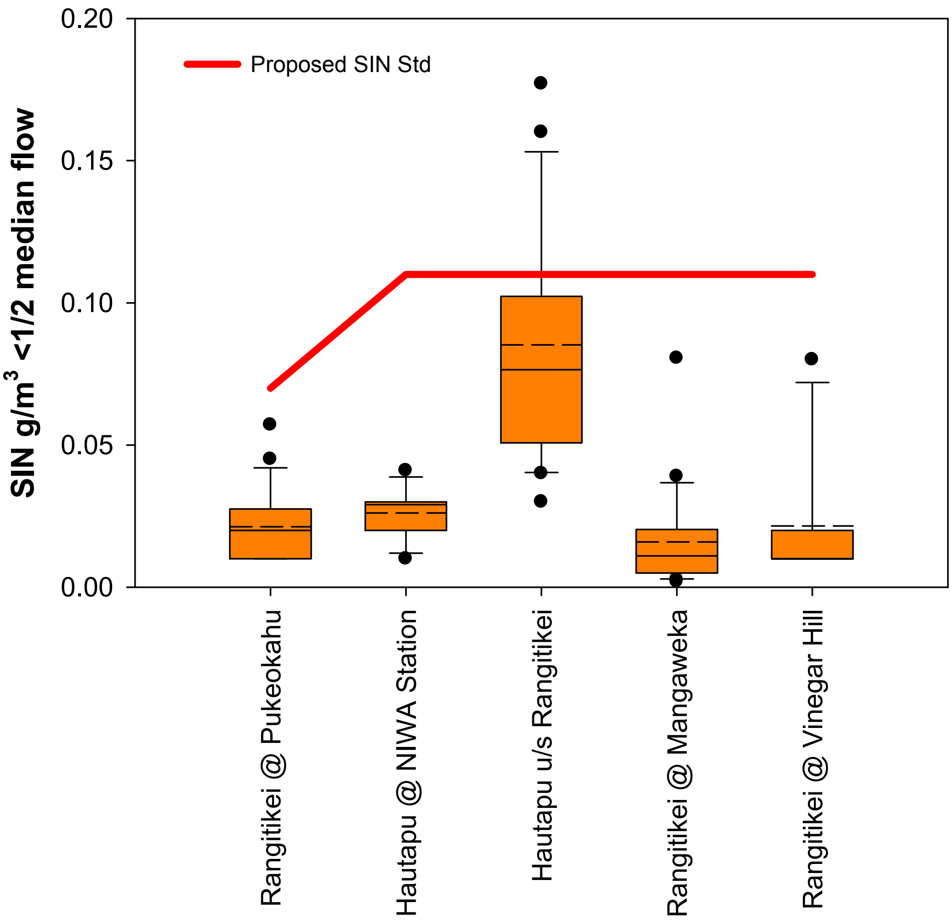


Figure 21: SIN concentrations in samples collected from State of the Environment monitoring sites in the Rangitikei and Hautapu Rivers, December 1998-October 2005 at flows equal to or less than ½ median (Solid midpoint line = median, dashed midpoint line = mean).

SIN concentrations measured at SOE sites at flows equal to or below half median are below the proposed standard in 100% of the samples collected from the Rangitikei mainstem. The only site at which the standard is occasionally breached at these flows is the Hautapu upstream of the Rangitikei confluence.

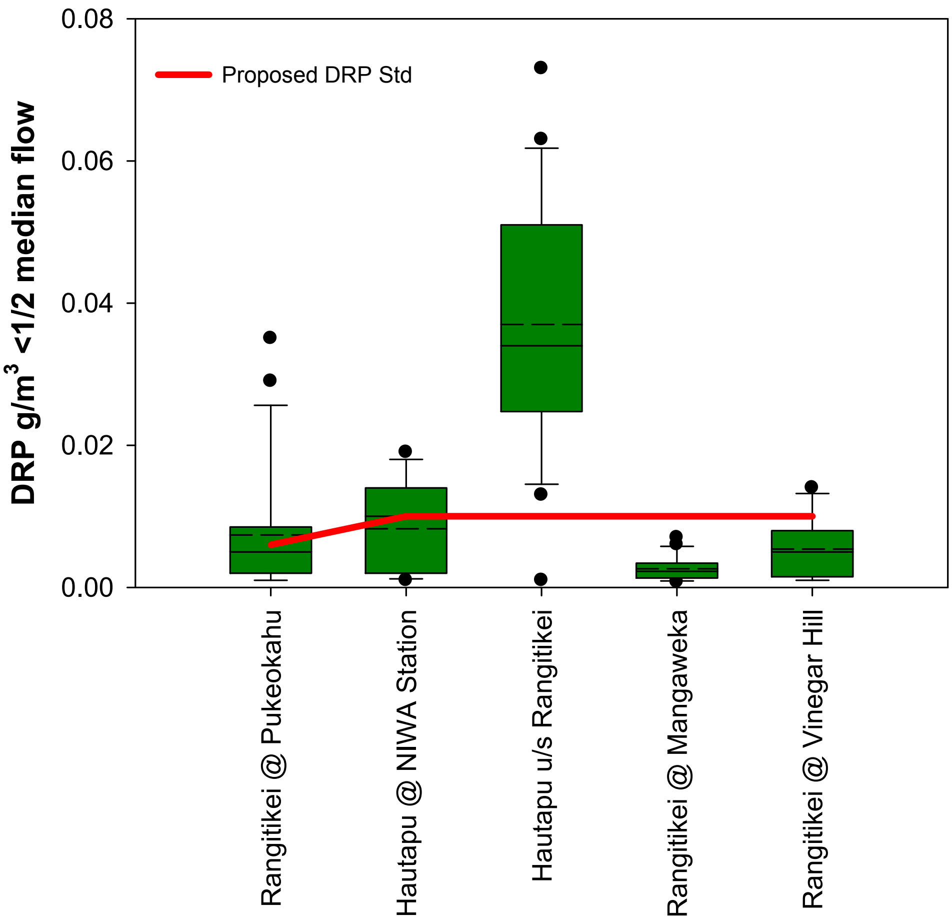


Figure 22: DRP concentrations in samples collected at State of the Environment monitoring sites in the Rangitikei and Hautapu Rivers, December 1998-October 2005 at flows equal to or less than ½ median (Solid midpoint line = median, dashed midpoint line = mean).

DRP concentrations exceed the proposed standard in 50% of samples collected from the Rangitikei at Pukeokahu and Hautapu at NIWA Station Taihape sites. They almost always exceed the proposed standard in the Hautapu upstream of the Rangitikei confluence and occasionally at the Rangitikei at Vinegar Hill site. Rangitikei at Mangaweka is the only site at which 100% of the DRP samples were within the proposed standard.

5.1.2 SOE Nutrient Loads

Average daily SIN loads at sites in the mainstem of the Rangitikei and from point source inputs (Figure 23) were well below the proposed SIN standard. Although the total point source load downstream of Mangaweka does not appear to breach the proposed SIN standard, there are no downstream SOE sites with paired nutrient samples and flow measurements to accurately assess the impact of point source SIN loads to the lower Rangitikei River. Additional downstream sites have been included in updated SOE monitoring programmes, but without an adequate sample size or paired flow measurement at the time of sampling, accurate loadings cannot be calculated.

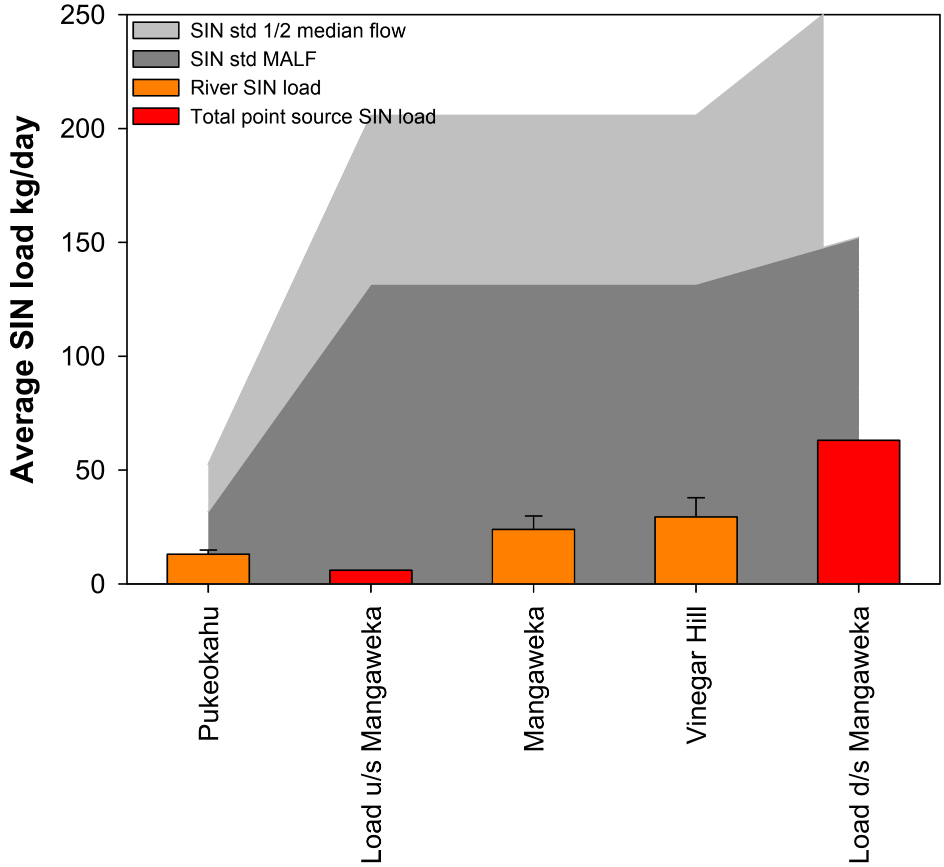


Figure 23: Average daily loads of SIN at State of the Environment (SOE) sites (orange bars ±1SE – samples collected from below ½ median flow) and from point source discharges (red bars) in the Rangitikei catchment, December 1998-October 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

DRP loads at SOE sites and from point source inputs to the mainstem Rangitikei River (Figure 24) were sometimes above the proposed DRP standard at the Pukeokahu SOE site, although there are no consented point source inputs to the upstream catchment. There is some evidence to suggest that phosphorus inputs to the Rangitikei may be naturally elevated due to the composition of the underlying catchment geology (Snelder *et al.,* 2004; Ausseil & Clark, 2007b). Total point source DRP loads downstream of Vinegar Hill have the potential to breach the proposed standard at low flows, although in-river measurement of DRP loads cannot be calculated due to the lack of paired SOE samples and flow data in the lower Rangitikei.

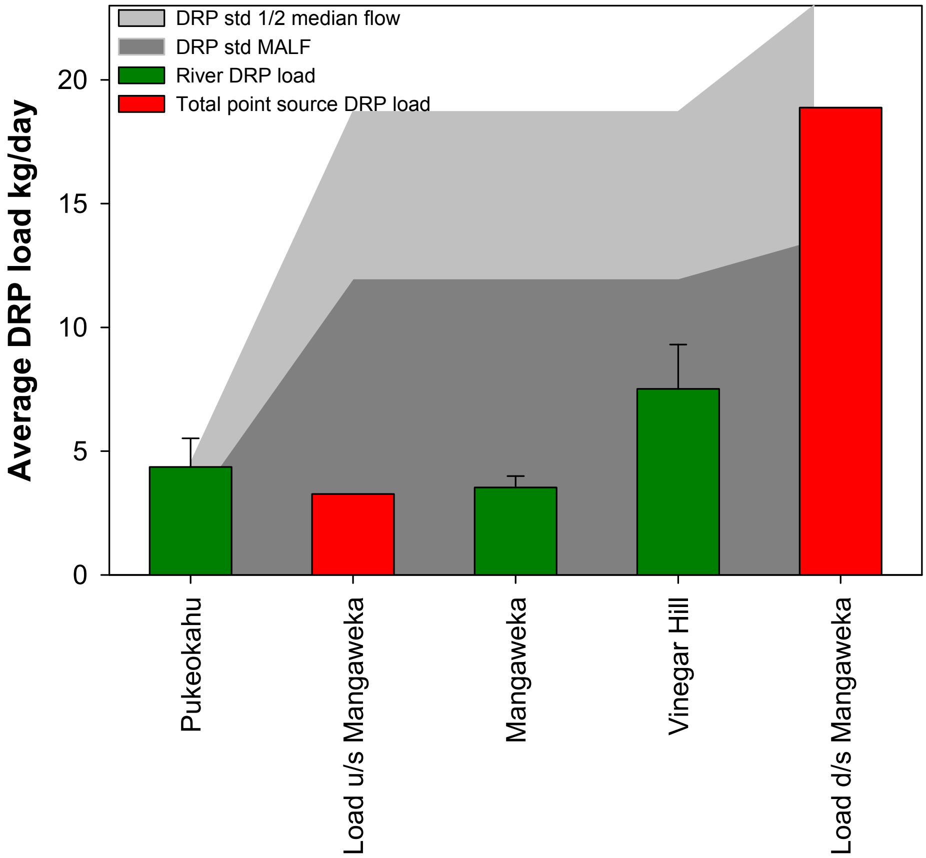


Figure 24: Average daily loads of DRP at State of the Environment (SOE) sites (green bars ±1SE - samples collected below ½ median flow) and from point source discharges (red bars) in the Rangitikei catchment, December 1998-October 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

5.1.3 Rangitikei Catchment Point Source vs. SOE Nutrient Loads

In order to understand the sources of nutrient contamination of the Rangitikei and Hautapu Rivers, the point source loadings of SIN and DRP have been calculated for each major discharge to surface water in the catchment.

SIN loads from point sources (Figure 25) appear to be most problematic in tributaries rather than the mainstem of the Rangitikei River catchment. Hunterville, Halcombe and Marton STP discharges appear to exceed the proposed SIN standard at flows equal to or less than half median. Taihape STP causes the downstream SOE site (Hautapu u/s Rangitikei confluence) to exceed the standard as flows recede to the MALF. The high nutrient loadings in the tributaries of the Rangitikei can be mainly attributed to the low dilution factor provided by the receiving waters of the Porewa, Rangitawa and Tutaenui Streams (in relation to the Hunterville, Halcombe and Marton STP discharges respectively). During summer, these tributary streams are known to experience extreme low flows (in the case of the Porewa) or dry up completely (Rangitawa and Tutaenui), providing no adequate receiving environment for these discharges.

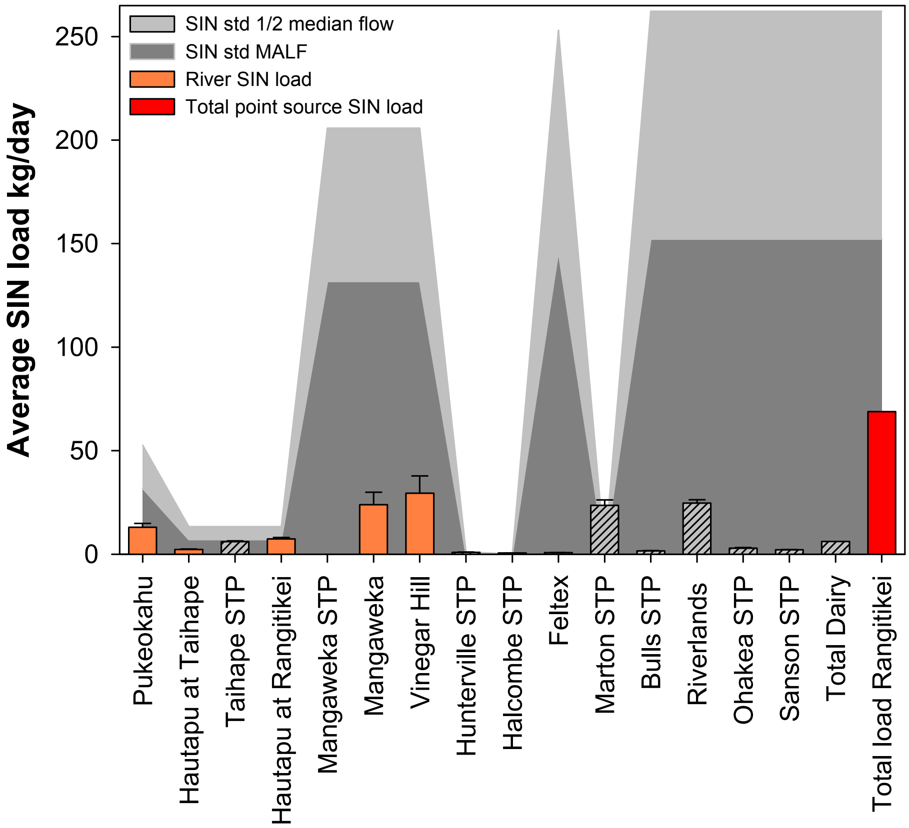


Figure 25: Average daily loads of SIN at State of the Environment (SOE) sites (orange bars ±1SE - samples collected below ½ median flow) and from point source discharges (hashed bars – individual estimated loads, red bars – cumulative loads) in the Rangitikei catchment, December 1998-October 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

DRP loads from point sources (Figure 26) show a similar pattern to SIN. Hunterville, Halcombe and Marton STP discharges have DRP loads in excess of the standards in the Porewa, Rangitawa and Tutaenui Streams respectively. However, unlike the SIN loads, Taihape STP clearly exceeds the proposed DRP standard for the Hautapu River at all times when the flow is equal to or less than half median. The Hautapu River is examined in further detail in Figure 27 and Figure 28 below.

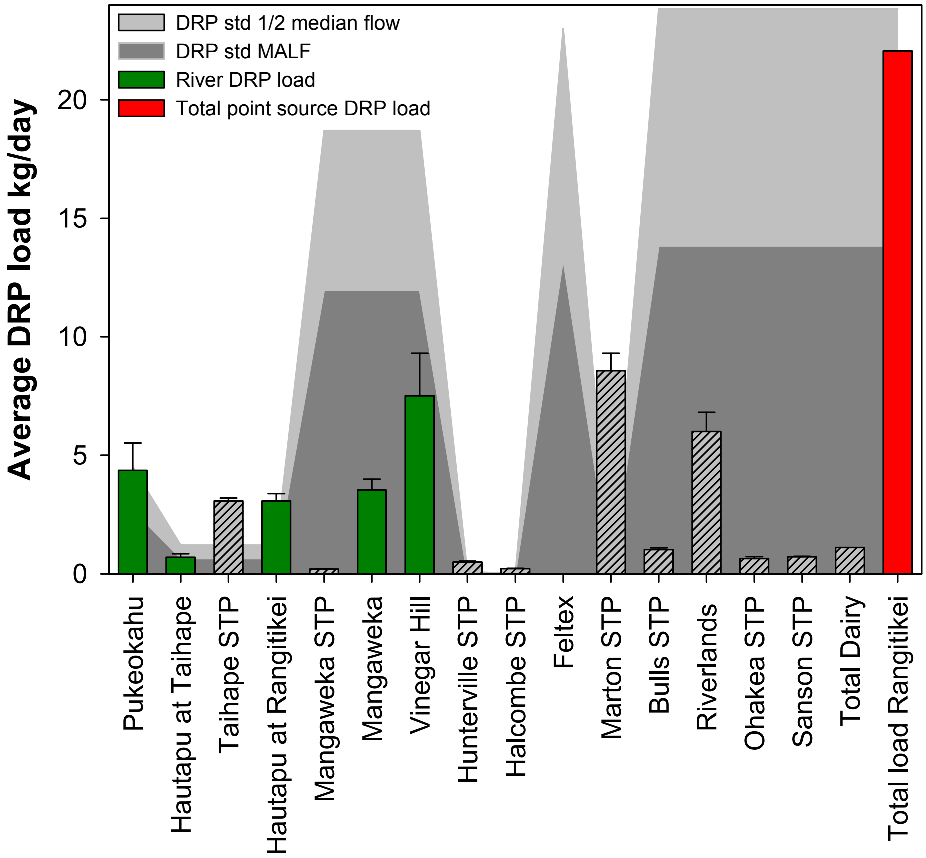


Figure 26: Average daily loads of DRP at State of the Environment (SOE) sites (green bars ±1SE - samples collected below ½ median flow) and from point source discharges (hashed bars – individual estimated loads, red bars – cumulative loads) in the Rangitikei catchment, December 1998-October 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

5.1.4 Hautapu River Nutrient Loads

The Hautapu River receives point source nutrient contributions from the Taihape STP discharge. As mentioned above, the in-river SOE measurement of SIN downstream of the Taihape STP discharge exceeds the proposed standard at flows nearing MALF (Figure 27) and exceeds the proposed DRP standard at all flows half median or less (Figure 28).

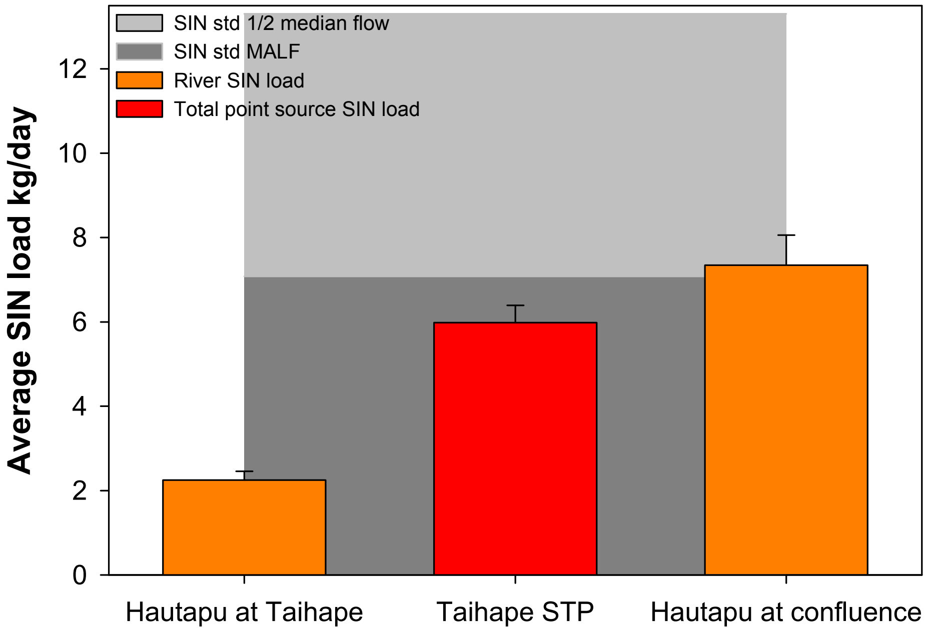


Figure 27: Average daily SIN loadings at State of the Environment (SOE) sites (orange bars ±1SE - samples collected below ½ median flow) and from the Taihape STP discharge (red bar ±1SE - estimated load) in the Hautapu River, December 1998-October 2005. SIN standards (grey scale areas) are calculated for the flow at the SOE site.

The background DRP load upstream of the Taihape STP discharge exceeds the proposed standard at flows nearing the MALF, suggesting either naturally high DRP levels (as appears to be the case in the Rangitikei mainstem at Pukeokahu) or some other point source DRP inputs to the Hautapu upstream of Taihape. High background DRP loads aside, the DRP contribution from the Taihape STP is more than twice the standard at half median flow (Table 9). This is reflected in the in-river load measured just upstream of the Rangitikei confluence which is well above the proposed DRP standard at low flows.

Table 9: Comparison of estimated nutrient loads from the Taihape sewage treatment plant (STP) discharge with Proposed One Plan nutrient standards.

Nutrient	Estimated discharge Taihape STP	Proposed One Plan Standard	
		½ Median	MALF
DRP	3.07	1.21	0.64
SIN	5.98	13.31	7.08

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Hautapu River.

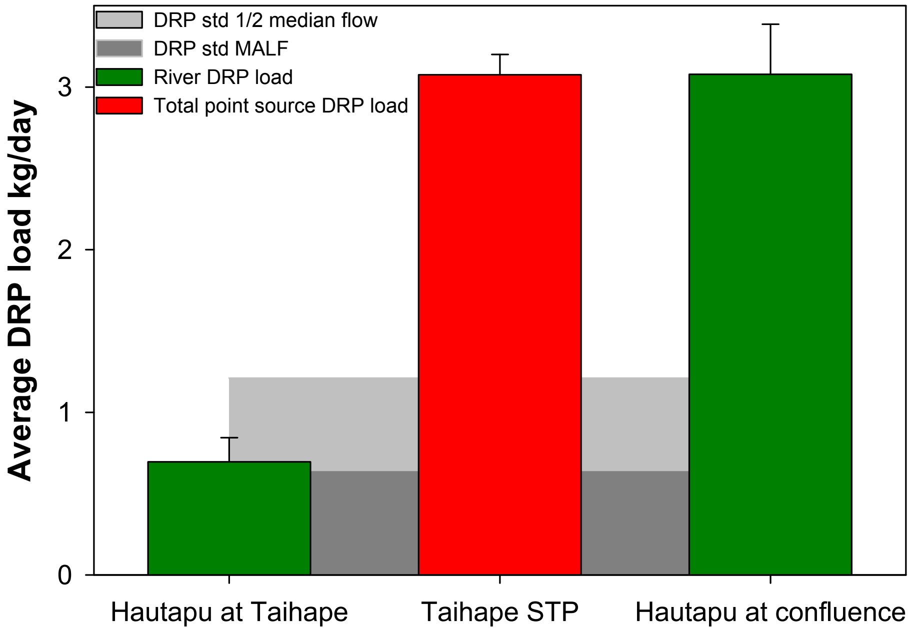


Figure 28: Average daily DRP loadings at State of the Environment (SOE) sites (green bars ±1SE - samples collected below ½ median flow) and from the Taihape STP discharge (red bar ±1SE - estimated load) in the Hautapu River, December 1998-October 2005. DRP standards (grey scale areas) are calculated for the flow at the SOE site.

5.2 Conclusions and Recommendations – Rangitikei River Catchment

SIN concentrations and daily average loads were not high in the upper Rangitikei mainstem. However, data was not available to evaluate the lower Rangitikei River catchment and tributaries. SIN in the Hautapu River has the potential to exceed the proposed standard, mainly due to the addition of point source SIN from Taihape STP at low flows. Point source SIN loads to the lower Rangitikei tributaries (the Porewa, Rangitawa and Tutaenui Streams) appear to exceed the proposed standard by a considerable amount at low flows.

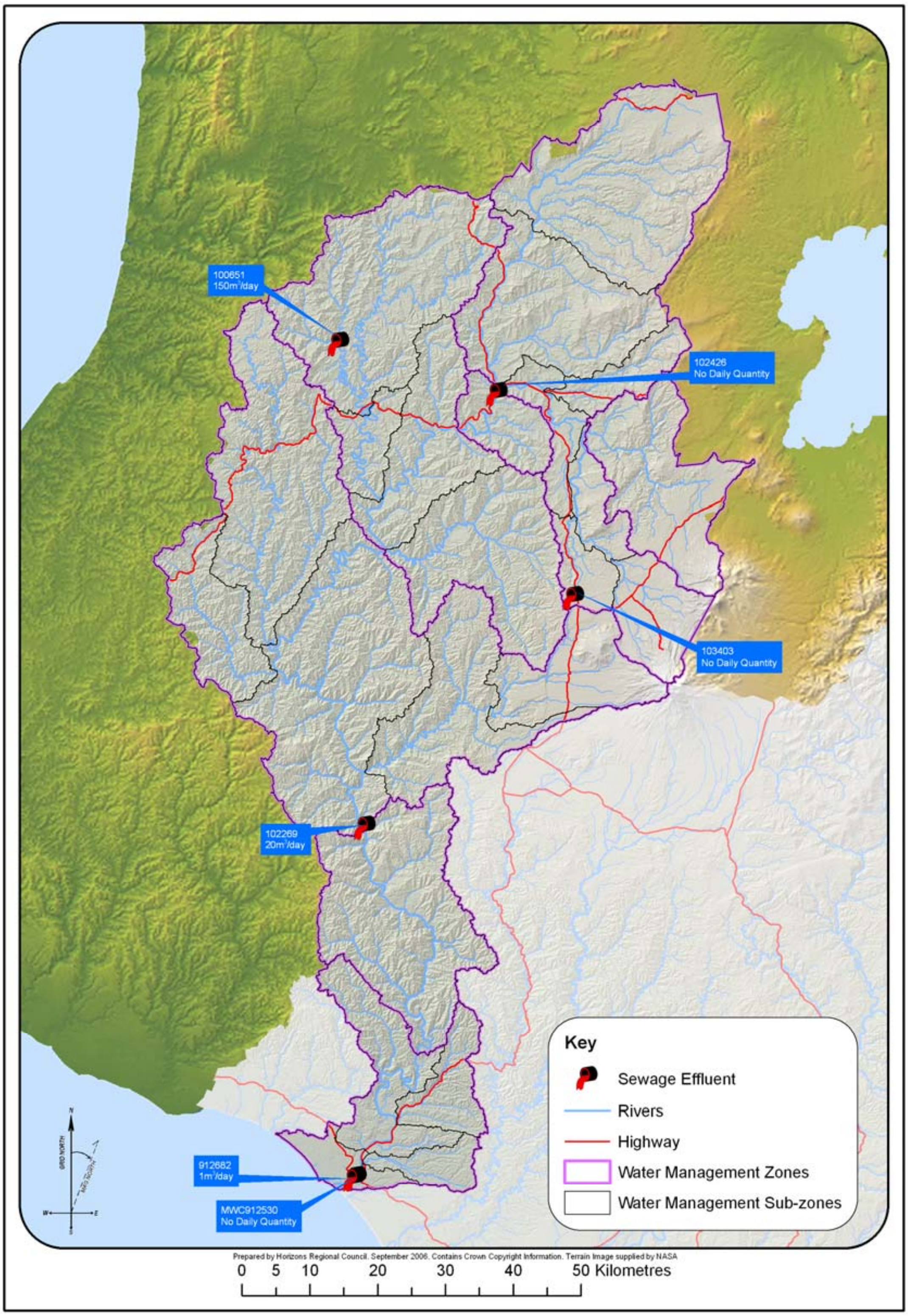
DRP appears to be naturally elevated (due to high phosphorus in the underlying catchment geology) in the upper Rangitikei River catchment. Generally speaking, DRP loads do not exceed the proposed standard in the mid reaches of the Rangitikei mainstem. However, there is some evidence to suggest that the total point source load of DRP entering the Rangitikei and tributaries downstream of Mangaweka may exceed the standard at flows less than half median.

Point source contributions of DRP at low flows exceed the proposed standard in all tributaries subject to discharges (the Hautapu, Porewa, Rangitawa and Tutaenui). The low flows in these tributaries do not appear to provide sufficient dilution for the discharge volumes and concentrations they receive.

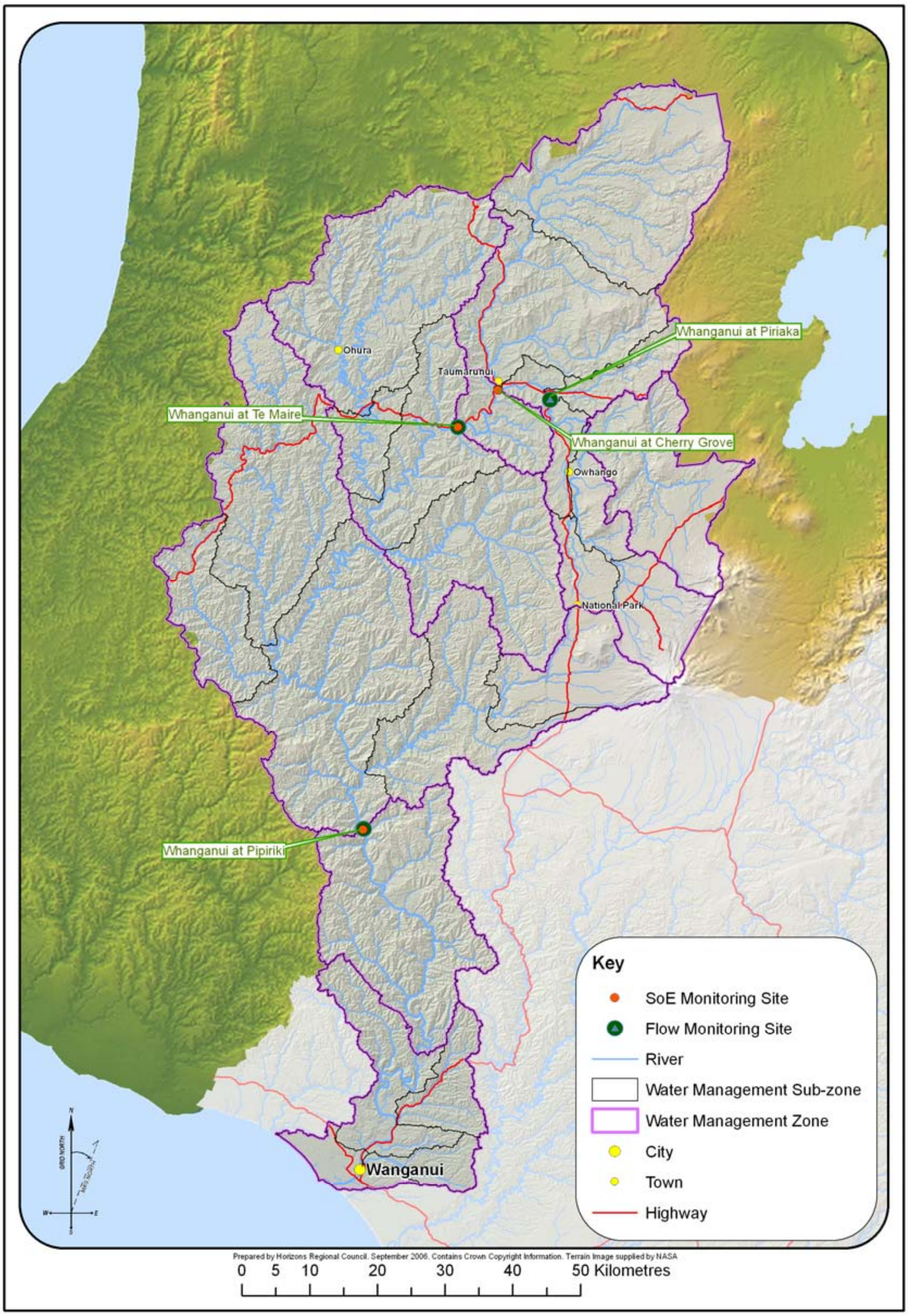
5.2.1 Recommendations for further investigation – Rangitikei

1. Analysis of nutrient loads to the lower Rangitikei River (below Mangaweka) and tributaries should be a priority in order to assess the relative contribution of point and non-point source of nitrogen and phosphorus.
2. The potential background DRP load in the upper Rangitikei mainstem and tributaries, as a result of geology, requires further investigation.
3. An assessment of the health of tributaries affected by high point source nutrient loads is required in the Hautapu River and Porewa, Rangitawa and Tutaenui Streams.
4. A targeted compliance investigation is required in the Hautapu River Catchment.

6. Whanganui River Nutrient Status



Map 6: Overview of the Whanganui River catchment showing cites, townships, State of the Environment (SOE) monitoring sites and flow recorders.



Map 7: Significant discharges to surface water in the Whanganui River catchment.

The total number of discharge to surface water permits in the Whanganui catchment (current or expired and under existing use rights) was 42 at the end of 2006. These consents covered a range of discharges (see Section 1.1) which were removed from the dataset (n=37), including dairyshed discharges (n=3). The remaining five consents considered for their potential contribution to point source nutrient enrichment of the Whanganui catchment (Table 10) were from domestic sewage effluent discharges (Map 7).

Table 10: Number of significant consented discharges to the Whanganui River catchment from 1993 to 2006.

Year	Significant Discharges to Surface Water
1993	7
1994	8
1995	8
1996	8
1997	8
1998	7
1999	7
2000	6
2001	6
2002	6
2003	6
2004	5
2005	5
2006	5

6.1 What does our SOE monitoring tell us about the nutrient status of the Whanganui River at low flows?

6.1.1 SOE Nutrient Concentrations in the Whanganui River

SIN concentrations in SOE samples collected at or below half median (or 75th percentile flow at TPD affected sites – see glossary) show that the proposed SIN standard is exceeded more than 50% of the time in the Whanganui River at Cherry Grove, more than 25% of the time at Te Maire and very occasionally at Pipiriki (Figure 29).

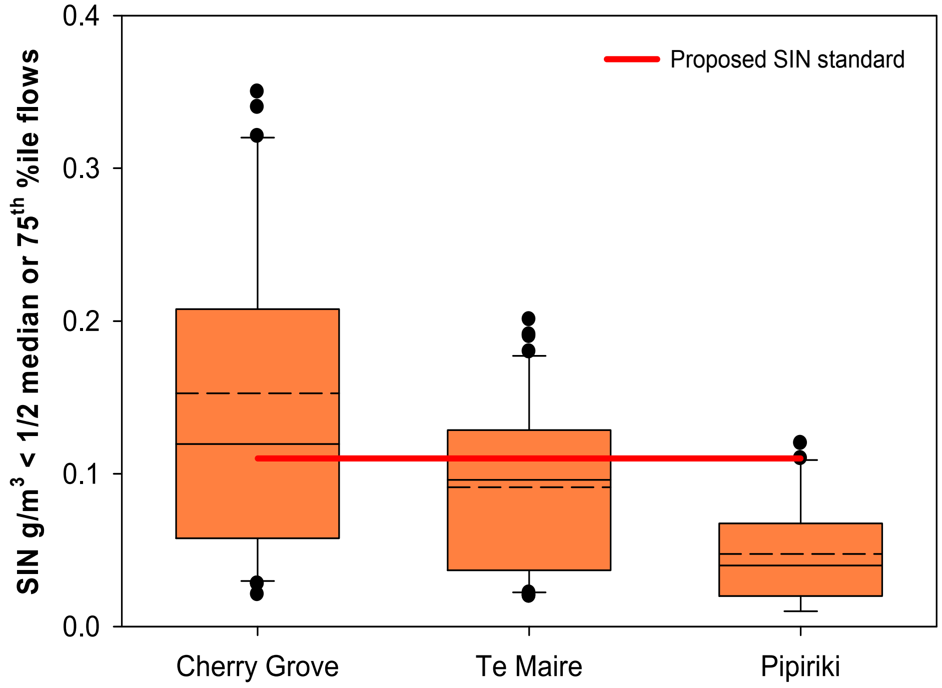


Figure 29: SIN concentrations in samples collected from State of the Environment sites in the Whanganui River, August 1991-March 2005 at flows equal to or less than ½ median (or the 75th percentile flow at sites affected by the TPD diversion). (Solid midpoint line = median, dashed midpoint line = mean.)

DRP concentrations in samples collected below half median (or 75th percentile flow in rivers affected by the TPD) only occasionally exceed the proposed DRP standards at SOE monitoring sites on the Whanganui River (Figure 30), although approximately 25% of the samples collected from Te Maire appear to be above the standard, with two outlying samples of very high concentration.

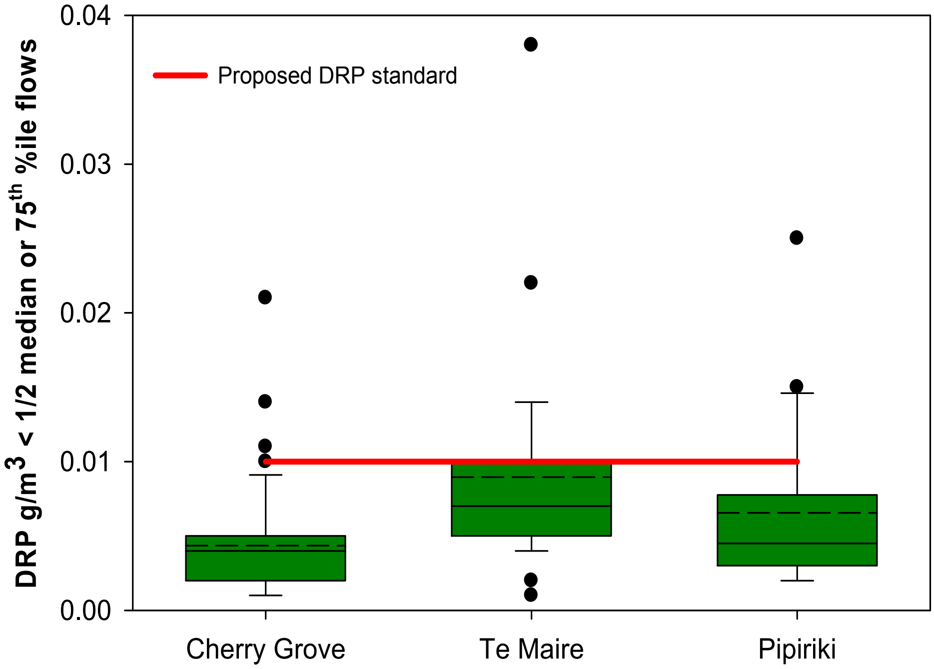


Figure 30: DRP concentrations in samples collected from State of the Environment sites in the Whanganui River, August 1991-March 2005 at flows below ½ median (or the 75th percentile flow at sites affected by the TPD diversion). (Solid midpoint line = median, dashed midpoint line = mean.)

6.1.2 Point Source vs. SOE Nutrient Loads in the Whanganui River catchment

Whanganui at Pipiriki is the most downstream site in the catchment for which paired nutrient and flow data could be compared through the use of a simulated flow record (M. Watson *pers. comm.).* This site is immediately upstream of the Pipiriki STP discharge and does not account for any additional nutrient loads from that source.

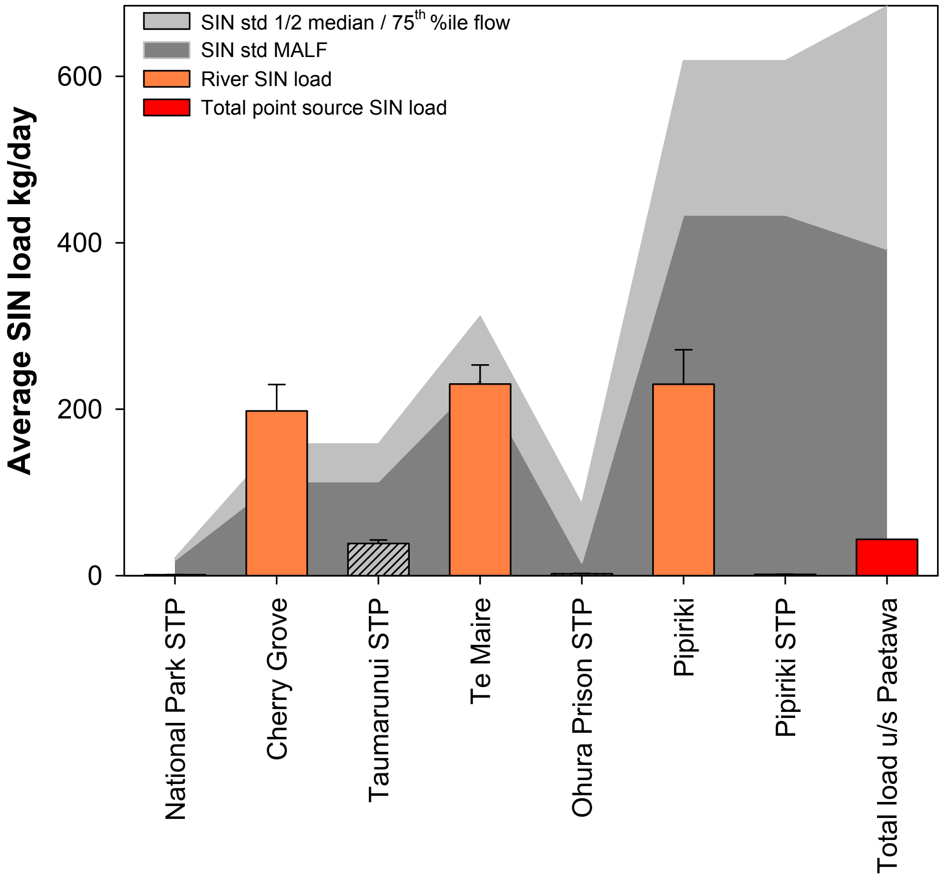


Figure 31: Average daily loads of SIN at State of the Environment (SOE) sites (orange bars ±1SE - samples collected below ½ median flow or 75th percentile flow) and from point source discharges (hashed bars – individual load estimate, red bars – cumulative loads) in the Whanganui River, August 1991-March 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

SIN from point sources appeared to make only a minor contribution to the high SIN loads at SOE sites on the Whanganui River (Figure 31 and Table 11). By inference, the main contributor of SIN to the Whanganui River at low flows is likely to be from non-point sources, particularly in the catchment upstream of Cherry Grove.

Table 11: Comparison of estimated nutrient loads from the Taumarunui sewage treatment plant (STP) discharge to the Whanganui River with the Proposed One Plan nutrient standards.

Nutrient	Estimated discharge Taumarunui STP	Proposed One Plan Standard	
		75th percentile flow	MALF
DRP	12.78	14.36	10.28
SIN	38.65	157.96	113.11

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Whanganui River at Piriaka flow recorder.

The Taumarunui STP discharge makes the most significant contribution to DRP loads in the Whanganui River between Cherry Grove and Te Maire, elevating the in-river DRP load above the proposed standard at flows between the 75th percentile and MALF (Figure 32). The point source load from the Taumarunui STP alone has the capacity to exceed the proposed DRP standard as flow recedes to the MALF at the point of discharge (Table 11).

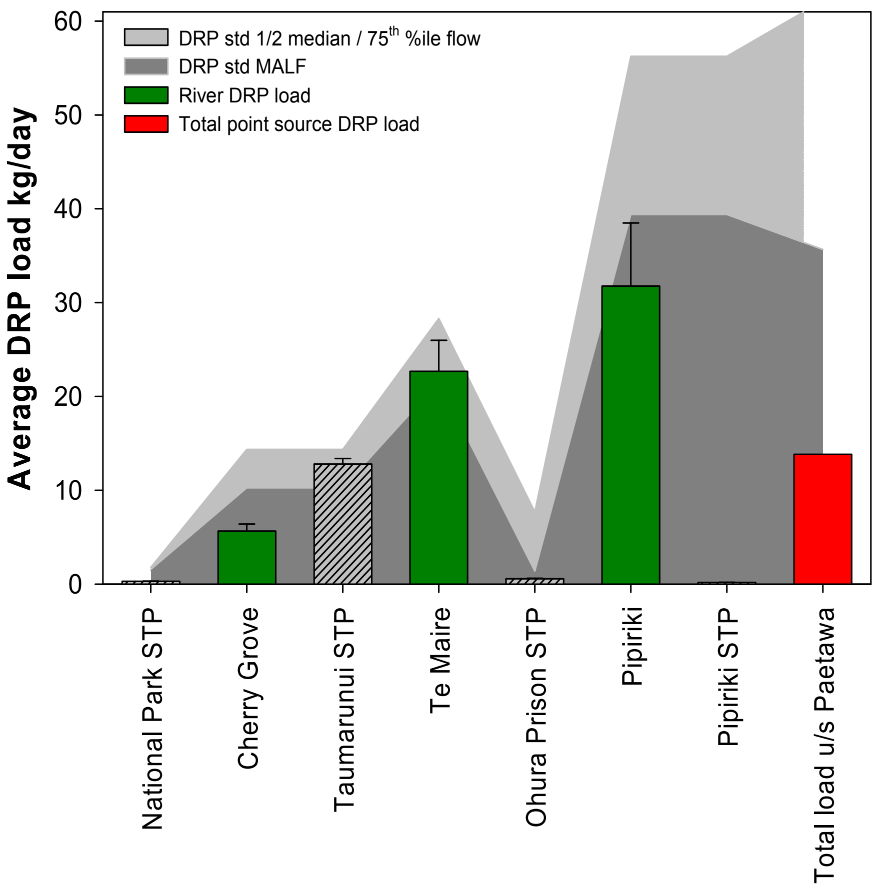


Figure 32: Average daily loads of DRP at State of the Environment (SOE) sites (green bars ±1SE - samples collected below ½ median flow or 75th percentile flow) and from point source discharges (hashed bars – individual load estimate, red bars – cumulative loads) in the Whanganui River, August 1991-March 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

In an analysis of compliance with the proposed One Plan standards for periphyton biomass, Ausseil & Clark (2007a) found that the Whanganui River at Te Maire site exceeded 120 mg Chl *a* /m^2 on one out of eight sampling occasions.

6.2 Conclusions and Recommendations – Whanganui River Catchment

SIN loads are elevated above the proposed standard in the upper Whanganui catchment at Cherry Grove. However, the load remains constant and is diluted by inflowing tributaries at the downstream SOE sites and does not exceed the proposed SIN standard. Given the low point source nitrogen loads at low flows, non-point sources make the greatest contribution to SIN loads in the upper Whanganui River catchment.

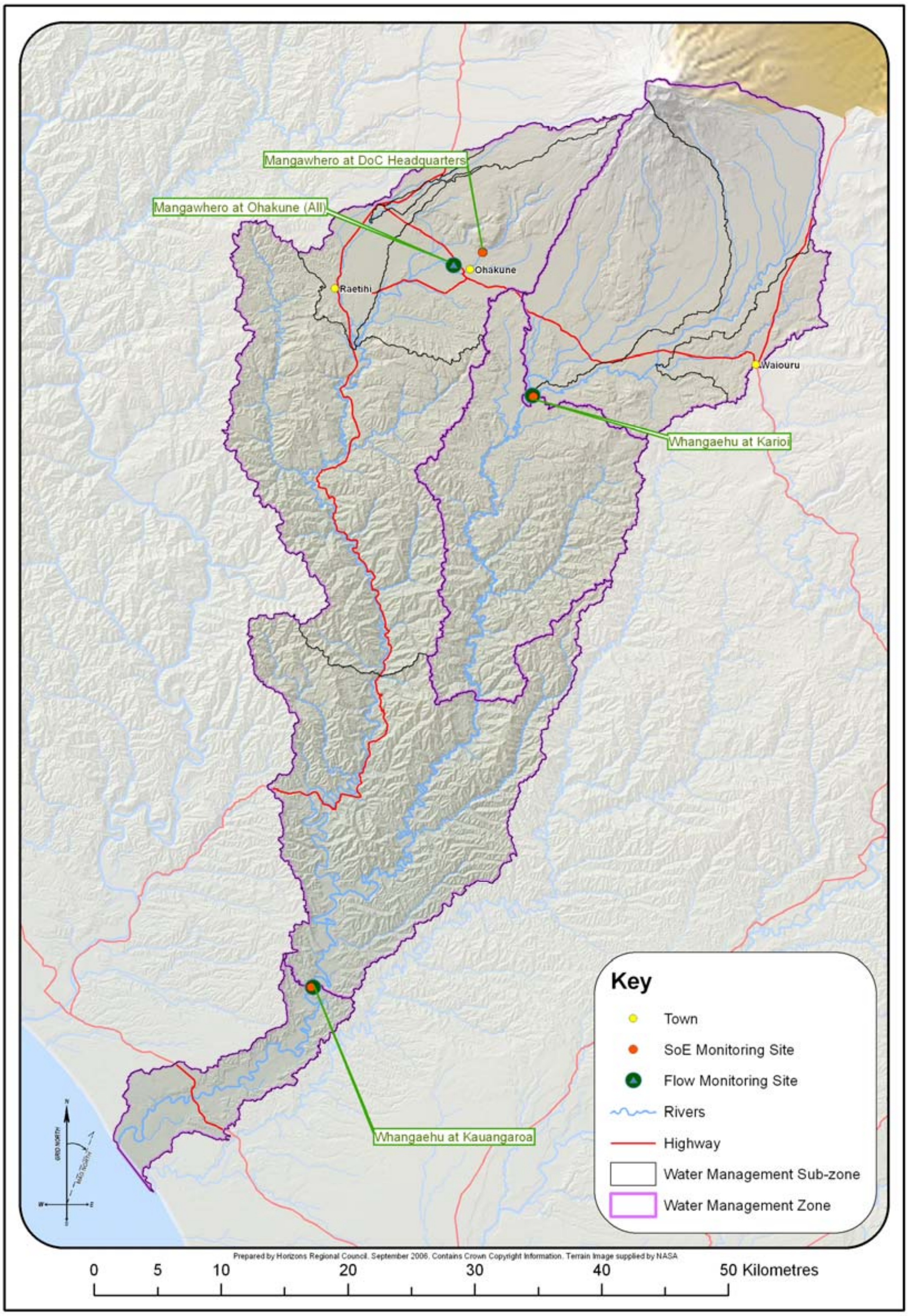
DRP loads are generally low in the upper Whanganui. However the Te Maire SOE site potentially exceeds the proposed standard at low flows, mainly due to the point source contribution of DRP from the Taumarunui STP discharge.

SOE monitoring sites downstream of Pipiriki (in the mid to lower reaches of the Whanganui) do not have long periods of flow record available to calculate loads from nutrient data. Thus the nutrient load of the lower Whanganui River is currently unknown.

6.2.1 Recommendations for further investigation – Whanganui River

1. More samples of paired nutrient and flow data are required at the Paetawa SOE site further down the Whanganui catchment in order to assess the nutrient status of the lower Whanganui River.
2. An investigation of the sources of SIN in the Upper Whanganui (above Cherry Grove) is required.
3. Further investigation of DRP loads to the Whanganui River from the Taumarunui STP is required, particularly at low flows.

7. Whangaehu River Catchment Nutrient Status

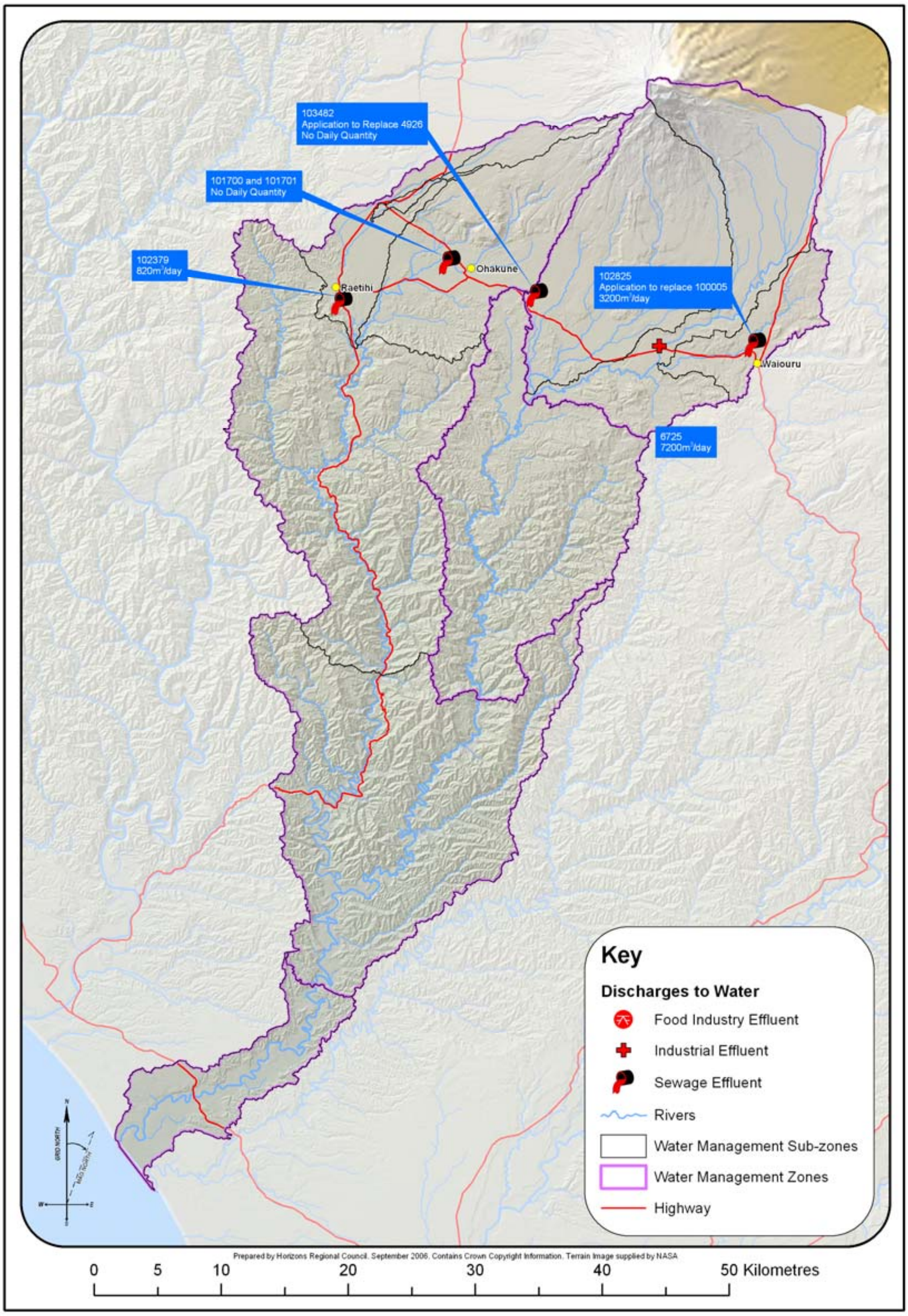


Map 8: Overview of the Whangaehu River catchment showing townships, State of the Environment (SOE) monitoring sites and flow recorders.

The total number of discharge to surface water permits in the Whangaehu catchment (current or expired and under existing use rights) was 38 at the end of 2006. These consents covered a range of minor discharges (see Section 1.1) which were removed from the dataset (n=33), including dairyshed discharges (n=4). The remaining five consents considered for their potential contribution to point source nutrient enrichment of the Whanganui catchment (Table 10) were from domestic sewage effluent and industrial pulp and paper waste discharges (Map 7).

Table 12: Number of significant consented discharges to the Whanganui River catchment from 1993 to 2006.

Year	Significant Discharges to Surface Water
1993	4
1994	4
1995	4
1996	5
1997	6
1998	6
1999	6
2000	4
2001	4
2002	4
2003	4
2004	4
2005	5
2006	5



Map 9: Significant discharges to surface water in the Whangaehu River catchment.

7.1 What does our SOE monitoring tell us about the nutrient status of the Whangaehu, Mangawhero and Makotuku Rivers at low flows?

7.1.1 Point Source vs. SOE Nutrient Loads in the Whangaehu River catchment

Point sources appear to make a large contribution of SIN to the Whangaehu River upstream of Karioi (Winstone Pulp), particularly in the Waitangi Stream (Waiouru Army STP discharge), the Mangawhero River (Ohakune STP) and the Makotuku River (Raetihi STP). However, the in-river SIN load in these catchments cannot be quantified due to a lack of nutrient data from relevant downstream SOE sites.

Table 13: Comparison of estimated SIN loads from discharges to the Whangaehu catchment with Proposed One Plan standard.

Discharge	Estimated discharge load	Flow recorder site	Proposed One Plan Standard	
			½ Median/75th percentile*	MALF
Winstone Pulp	35.61	Whangaehu at Karioi	59.23*	49.86
Waiouru Army STP	25.76	Waitangi at Tangiwai	6.3*	4.10
Rangataua STP	0.07	Tokiahuru at Junction	34.61*	29.16
Ohakune STP	15.14	Mangawhero at Ohakune	5.62	4.52
Raetihi STP	1.27	Makotuku at SH49	1.35	0.70

Note: All figures expressed as loads in kg/day; standards are calculated loads based on statistics for the nearest flow recorders as above.

The total point source load to the Whangaehu catchment, when compared to the in-river SOE load at Kauangaroa, only appears to contribute less than 50% of the measured SIN load at flows less than the ½ median or 75th percentile flow (see Glossary). This may indicate some non-point source SIN contamination of the Whangaehu occurring in the 110 kms between the Whangaehu at Karioi SOE site in the upper catchment (where the major point source input occurs) and the Kauangaroa site in the lower catchment (Map 8 and Map 9), though there is little data in the upper and middle reaches of the catchment for accurate comparison. The SIN load at Kauangaroa has the potential to exceed the SIN standard when flows are between ½ median and the MALF.

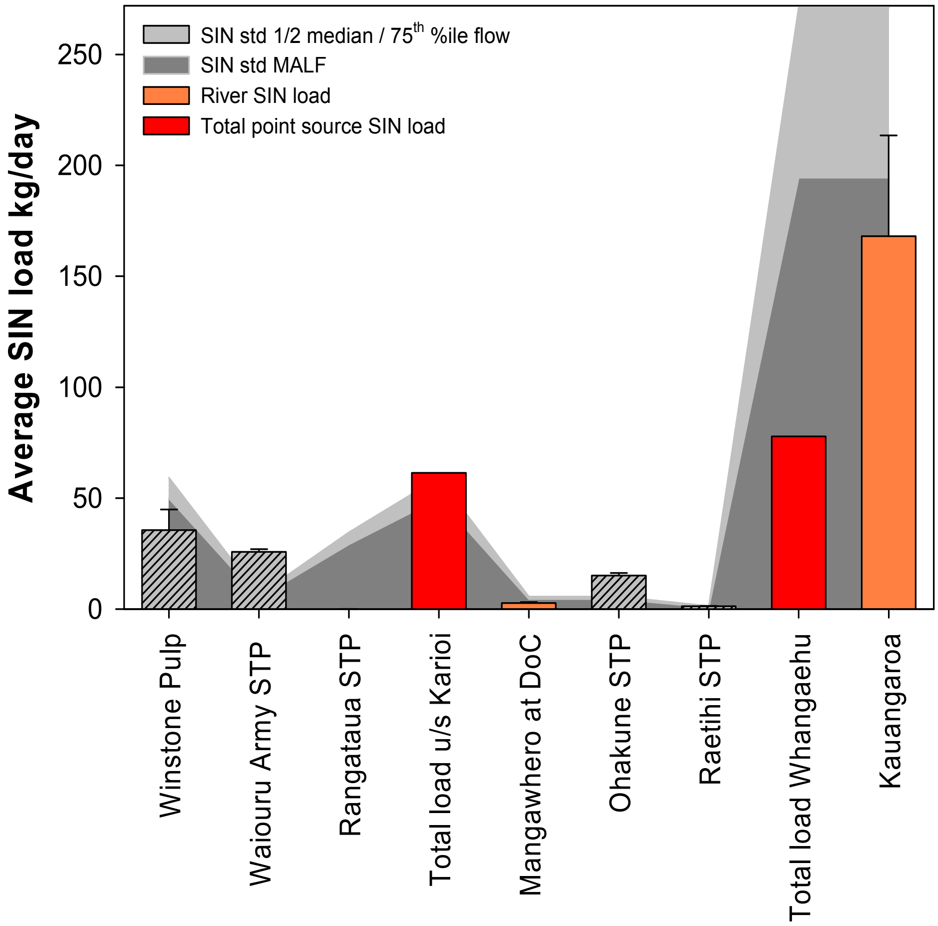


Figure 33: Average daily loads of SIN at State of the Environment (SOE) sites (orange bars ±1SE – samples collected below ½ median or 75th percentile flows) and from point source discharges (hashed bars – individual estimated loads, red bars – cumulative load) in the Whangaehu catchment, July 1991-August 2005. SIN standards (grey scale areas) are calculated for the flow at each SOE site.

Point source DRP loads to the Whangaehu catchment upstream of Karioi (Winstone Pulp), the Waitangi Stream (Waiouru Army STP), the Mangawhero River (Ohakune STP) and Makotuku River (Raetihi STP) exceed the proposed DRP standard at the points of discharge (Table 14). However, confirmation of the effects of these estimated loads on in-river nutrient concentrations cannot be quantified because of a lack of data collection from the upper and middle catchment SOE sites.

Table 14: Comparison of estimated DRP loads from discharges to the Whangaehu catchment with Proposed One Plan standard.

Discharge	Estimated discharge load	Proposed One Plan Standard	
		½ Median/75th percentile*	MALF
Winstone Pulp	32.83	5.08*	4.27
Waiouru Army STP	4.83	0.57*	0.46
Rangataua STP	0.03	2.97*	2.50
Ohakune STP	5.04	0.48	0.39
Raetihi STP	0.47	0.12	0.06

Note: All figures expressed as loads in kg/day; standards are calculated loads based on statistics for the nearest flow recorders as above.

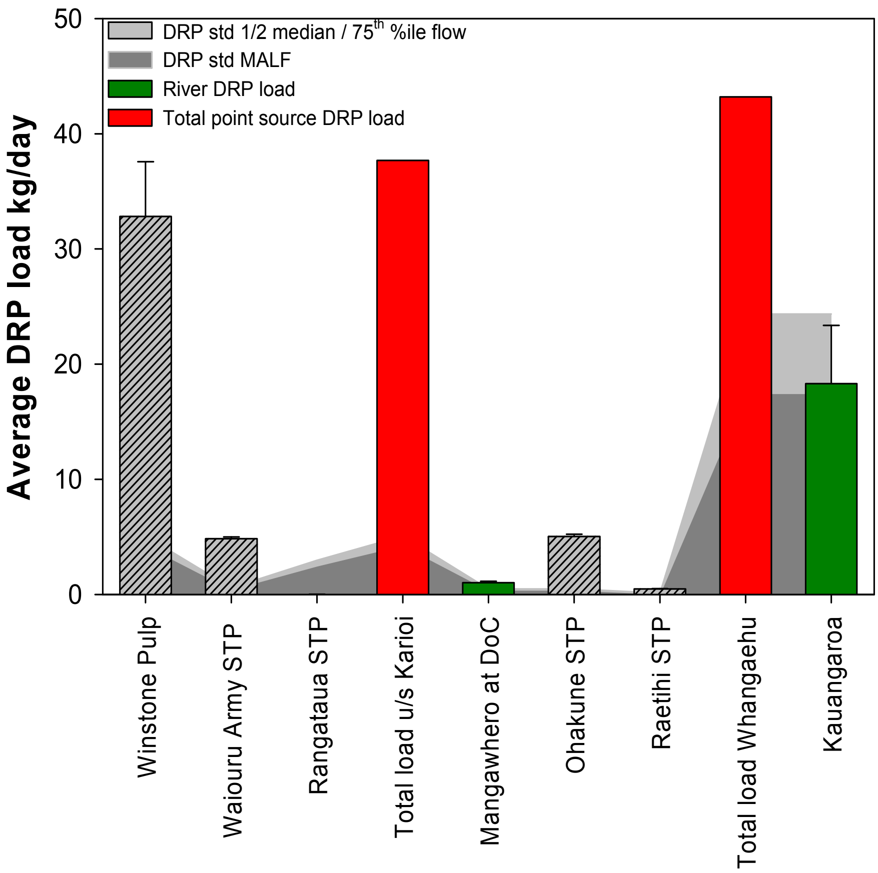


Figure 34: Average daily loads of DRP at State of the Environment (SOE) sites (green bars ±1SE – samples collected below ½ median or 75th percentile flows) and from point source discharges (hashed bars – individual estimated loads, red bars – cumulative load) in the Whangaehu catchment, July 1991-August 2005. DRP standards (grey scale areas) are calculated for the flow at each SOE site.

Downstream in-river DRP loads at Kauangaroa potentially exceed the proposed standard at MALF. In addition to the high point source DRP loads (Table 14), natural background levels of DRP may be elevated within these catchments due to the volcanic-acidic nature of the underlying geology

(Snelder *et al.,* 2004; Ausseil & Clark 2007b). This is illustrated by DRP loads in excess of the proposed standard in the Mangawhero at DoC Headquarters site where the upstream catchment is in National Park.

The large discrepancy between the total point source DRP load estimate and the DRP load calculated from samples collected from the Whangaehu at Kauangaroa site is likely to be a result of the high potential for DRP attenuation over the large river distance between the point source discharge sites and the SOE site (Map 8 and Map 9).

7.2 Conclusions and Recommendations – Whangaehu, Mangawhero and Makotuku River Catchments

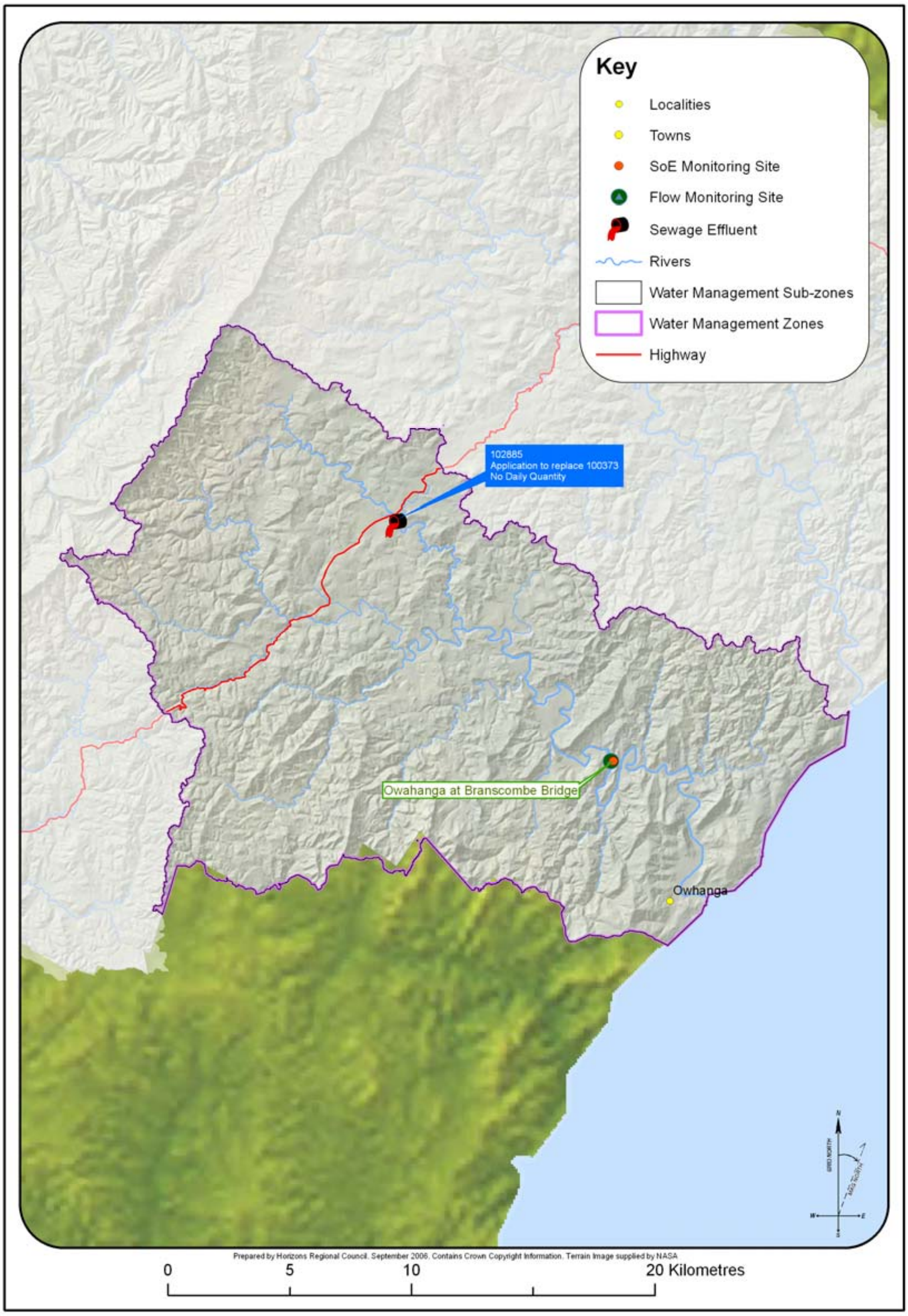
State of the Environment (SOE) nutrient data is not available for the upper Whangaehu River catchment. Load calculations suggest that total point source loads of SIN may exceed the proposed standard in the upper Whangaehu, Mangawhero and Makotuku River catchments. However, the SIN load measured near the lower reaches of the Whangaehu River at Kauangaroa suggests that the estimated point source load to the catchment only explains half of the SIN load (which may potentially exceed the standard at low flows). This indicates additional non-point source inputs of SIN.

Total point source DRP loads are extremely high in the upper Whangaehu, Mangawhero and Makotuku water management sub-zones. There is a high probability, given the underlying volcanic geology of these catchments, that the background DRP concentrations are naturally high also. Further sample collection from SOE sites in the upper to middle reaches of the catchment is required to measure the background DRP loads and the downstream impact of the point source discharge inputs.

7.2.1 Recommendations for further investigation – Whangaehu, Mangawhero and Makotuku River catchments

1. SOE monitoring at all sites within the Whangaehu should include nitrogen and phosphorus sampling.
2. Background natural DRP levels require investigation.
3. Point source DRP loads also require further investigation.
4. Non-point SIN loads need investigating in the upper and middle reaches of the water management sub-zones.

8. Owahanga River Catchment Nutrient Status



Map 10: Overview of the Owahanga River catchment showing townships, State of the Environment (SOE) monitoring sites, flow recorders and significant discharges to surface water.

The total number of discharge to surface water permits in the Owahanga catchment (current or expired and under existing use rights) was four at the end of 2006. These consents covered minor discharges (see Section 1.1) which were removed from the dataset (n=3) and there are no dairyshed discharges to water in this catchment. The only consent considered to potentially contribute to point source nutrient enrichment of the Owahanga catchment (Table 15) is the domestic sewage effluent discharge from the township of Pongaroa (Map 10).

Table 15: Number of consented discharges to the Owahanga River catchment from 1993 to 2006.

Year	All discharges to surface water	Significant Discharges to Surface Water
1993	0	0
1994	1	1
1995	1	1
1996	4	1
1997	4	1
1998	4	1
1999	4	1
2000	4	1
2001	5	1
2002	5	1
2003	5	1
2004	5	1
2005	4	1
2006	4	1

8.1 What does our SOE monitoring tell us about the nutrient status of the Owahanga River at low flows?

8.1.1 Point Source vs. SOE Nutrient Loads in the Owahanga River Catchment

DRP loads in the Owahanga River at Branscombe Bridge exceed the proposed DRP standard as flows recede towards the MALF. Sixty-four percent of this DRP contamination can be attributed to the point source load from the Pongaroa STP discharge at low flows (Table 16).

Table 16: Comparison of estimated nutrient loads from the Pongaroa sewage treatment plant (STP) discharge to the Owahanga River with the Proposed One Plan nutrient standards.

Nutrient	Estimated discharge Pongaroa STP	Proposed One Plan Standard	
		½ median flow	MALF
DRP	0.11	0.97	0.05
SIN	0.33	10.76	0.56

Note: All figures expressed as loads in kg/day; standards are calculated loads based on flow statistics for the Owahanga River at Branscombe Bridge flow recorder.

The Pongaroa STP contributes 27% of the in-river SIN load at flows less than ½ median, inferring that there is some non-point SIN contribution at low flows. However, the SIN loads are unlikely to exceed the proposed standards, even at the MALF.

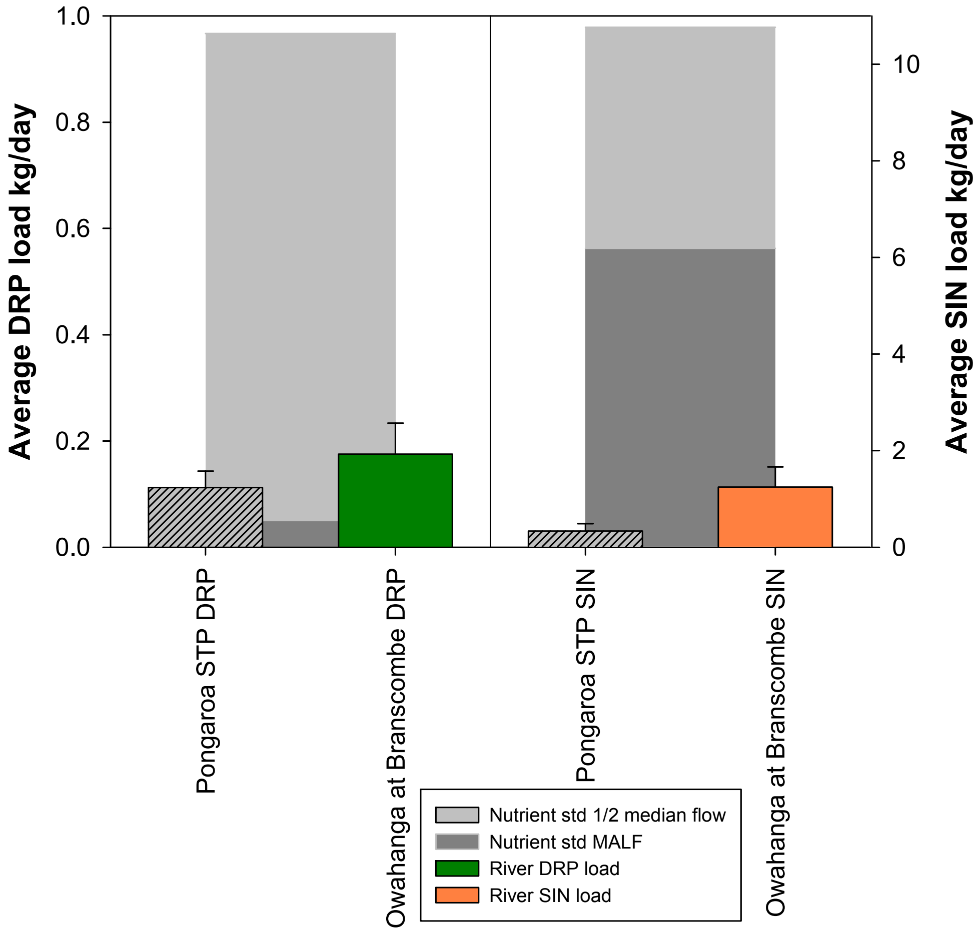


Figure 35: Average daily loads of SIN (orange bar) and DRP (green bar) at State of the Environment (SOE) sites and from point source discharge (hashed bar) to water in the Owahanga catchment, July 2000-June 2004 (bars ±1SE). SIN and DRP standards (grey scale areas) are calculated for the flow at Owahanga at Branscombe Bridge SOE site.

8.2 Conclusions and Recommendations – Owahanga River Catchment

SIN loads in the Owahanga River are not high at low flows. Point source discharges do not contribute significantly to SIN loads but do account for most of the DRP load at low flows. The DRP load has the potential to exceed the proposed standard at low flows.

8.2.1 Recommendations for further investigation – Owahanga River

1. Better characterisation of the Pongaroa STP is required for more accurate analysis in the future.

2. Further examination of nutrient loads is required to better understand the non-point source inputs.

9. Regional Analysis

9.1.1 Significant Discharges at Low Flows

Of the 44 significant discharges (Table 17) to surface water in the Manawatu-Wanganui Region analysed in this report, two no longer discharge at low flows and nine sites cannot be compared to the proposed standards at the point of discharge due to lack of flow data. Of the 33 remaining discharges, less than half meet the SIN and DRP standards at all flows under half median. Five of the discharges do not meet either standard at any low flow.

9.1.2 SOE sites at Low Flows

Of the 17 SOE sites in catchments associated with significant discharges to water, only three met both the SIN and DRP standards at all flows under half median (Table 18). Three sites did not meet either standard at any low flow and the remaining 11 sites exceeded the SIN and/or DRP standard less than half median or MALF. The three sites which exceed both standards at all low flows were in the Manawatu River catchment. High SIN loads in the upper Manawatu were predominantly influenced by non-point source inputs, whereas all sites with high DRP loads (and the SIN load in the Oroua River) were the result of point source discharges.

In most cases, high SIN loads measured in the river were the result of non-point source contamination, whereas sites which exceeded the DRP standard were either as a result of high background phosphorus levels related to geology (at pristine upper catchment sites) or point source influences.

Table 17: Summary of 44 significant discharges to water and compliance with proposed water quality standards for nitrogen and phosphorus in the Manawatu-Wanganui Region between 1993 and 2006 at flows less than half median.

Discharge to surface water	SIN		DRP	
	meets SIN standard at MALF	meets SIN standard at ½ median*	meets DRP standard at MALF	meets DRP standard at ½ median*
Norsewood STP	✓	✓	✓	✓
Dannevirke STP	✓	✓	✗	✗
PPCS (Oringi)	✓	✓	✓	✓
Eketahuna STP	✓	✓	✓	✓
Fonterra (Pahiatua)	✓	✓	✓	✓
Pahiatua STP	✓	✓	✗	✗
DB Breweries	✓	✓	✗	✗
Woodville STP	✗	✓	✗	✗
Ashhurst STP	✓	✓	✓	✓
Aokautere STP	✓	✓	✓	✓
PNCC STP	✗	✓	✗	✗
Longburn STP	✓	✓	✓	✓
Fonterra (Longburn)	-	-	-	-
NZ Pharmaceuticals	✓	✓	✓	✓
Kimbolton STP	✓	✓	✓	✓
Affco Manawatu Ltd	✗	✓	✗	✗
Feilding STP	✗	✗	✗	✗
Awahuri STP☹	-	-	-	-
Rongotea STP☹	-	-	-	-
Tokomaru STP☹	-	-	-	-
Shannon STP☹	-	-	-	-
Foxton STP☹	-	-	-	-
PPCS (Shannon)	✓	✓	✓	✓
Taihape STP	✓	✓	✗	✗
Mangaweka STP	✓	✓	✓	✓
Hunterville STP	✗	✓	✗	✗
Halcombe STP	✗	✗	✗	✗
Feltex	-	-	-	-
Marton STP	✗	✗	✗	✗
Bulls STP	✓	✓	✓	✓
Riverlands (Manawatu Ltd)	✓	✓	✓	✓
Ohakea STP☹	-	-	-	-
Sanson STP☹	-	-	-	-

* or 75th percentile flow at sites affected by the Tongariro Power Development (TPD)

☹ No flow available at point of discharge to compare with standard

National Park STP[☹]	-	-	-	-
Taumarunui STP	✓	✓	✗	✓
Ohura Prison STP	✓	✓	✓	✓
Pipiriki STP	✓	✓	✓	✓
Winstone Pulp	✓	✓	✗	✗
Waiouru Army Camp STP	✗	✗	✗	✗
Rangataua STP[☹]	-	-	-	-
Ohakune STP	✗	✗	✗	✗
Raetihi STP	✗	✓	✗	✗
Pongaroa STP	✓	✓	✗	✓

Key: ✗:Does not meet the standard; ✓: Meets the DRP standard; ✓: Meets the SIN standard

Table 18: Summary table of compliance with proposed nitrogen and phosphorus standards during low flows at 17 State of the Environment (SOE) monitoring sites in the Manawatu-Wanganui Region between 1989 and 2006.

SOE Monitoring Site	SIN			DRP		
	meets SIN standard at MALF	meets SIN standard at ½ median*	predominant SIN source	meets DRP standard at MALF	meets DRP standard at ½ median*	predominant DRP source
Manawatu at Weber Road	✗	✗	non-point	✗	✓	geology/unknown
Manawatu at Hopelands	✗	✗	non-point	✗	✗	point source
Mangatainoka at SH2	✗	✗	non-point	✗	✗	point source
Manawatu at Teachers College	✗	✓	non-point	✓	✓	-
Manawatu at Opiki Bridge	✗	✓	point source	✗	✗	point source
Oroua at Awahuri Bridge	✗	✗	point source	✗	✗	point source
Rangitikei at Pukeokahu	✓	✓	-	✗	✗	natural geology
Hautapu at NIWA station Taihape	✓	✓	-	✗	✓	geology/unknown
Hautapu upstream Rangitikei	✗	✓	point source	✗	✗	point source
Rangitikei at Mangaweka	✓	✓	-	✓	✓	-
Rangitikei at Vinegar Hill	✓	✓	-	✓	✓	-
Whanganui at Cherry Grove	✗	✗	non-point	✓	✓	-
Whanganui at Te Maire	✗	✓	non-point	✗	✓	point source
Whanganui at Pipiriki	✓	✓	-	✓	✓	-
Whangaehu at Kauangaroa	✓/ ✗	✓	non-point	✗	✓	point source
Mangawhero at DoC Headquarters	✓	✓	-	✗	✗	natural geology
Owahanga at Branscombe Bridge	✓	✓	-	✗	✓	point source

Key: ✗:Does not meet the standard; ✓: Meets the DRP standard; ✓: Meets the SIN standard

* or 75th percentile flow at sites affected by the Tongariro Power Development (TPD)

10. Conclusions

In undertaking a study of the state of nutrient loads it was expected that point source contributions would have an overriding influence on SIN and DRP loads measured at SOE sites downstream at low flows. Although this is the case for DRP, the degree to which non-point sources influence soluble nitrogen loads at low flows was higher than expected, even when nitrate leaching was taken into account.

Previous investigations of sites in the upper Manawatu catchment have suggested high non-point source contributions of SIN (95%) on an annual basis across all flows (Ledein *et al.,* 2007). Annual calculations at all flows also showed high DRP inputs from non-point sources (45–70%).

The low likelihood for phosphorus to enter the river from NPS during dry conditions (due to low rainfall and, consequently low run-off rates), was expected and is reflected in the high point source DRP load at many sites. For example, the Manawatu, Oroua and Hautapu River SOE sites were strongly subject to DRP loads from point sources under low flow conditions.

Clearly this is not the case for SIN. Despite the low rainfall and run-off associated with low flows, non-point source SIN still reaches surface waters in large amounts in the upper Manawatu, Mangatainoka and upper Whanganui (upstream of Cherry Grove) catchments in particular.

10.1 Non-point Source Nitrogen Reduction

In catchments where the SIN standard is exceeded under conditions of low flow, reducing the non-point source nitrogen load to the river will require a better understanding of these sources and consequently, implementation of effective control measures such as year-round controls on intensive land use activities (Clothier *et al.,* 2007).

10.2 Point Source Phosphorus Reduction

Attempts made through the MCWQRP to reduce point source DRP loads to rivers in the Manawatu catchment have not achieved the environmental outcomes sought. Of the 23 significant point source discharges to the Manawatu catchment, only Fonterra (Longburn) has consistently proven their intent to comply with the requirement to remove their DRP contribution from the river at low flows by not discharging at flows below half median by 2009.

Concentration-based standards for DRP and SIN in the Proposed One Plan will come into effect as soon as the Plan is operative. These standards apply in all waterways, at all flows less than three times the median (Ausseil & Clark, 2007a). In most water management zones (McArthur *et al.,* 2007) the DRP standard will be more stringent than that prescribed by the MCWQRP, with the exceptions of the lower Manawatu and Oroua Rivers, where the DRP standard remains the same.

10.3 Point Source Monitoring

Currently the variability in consent requirements to adequately collect nutrient and other contaminant samples and report discharge volumes means it is unknown whether Permit Holders are complying with current Plan standards until records are submitted (often annually) and analysed. For example, of the 44 significant discharges to water in the Region, only 15 (Appendix 1) have discharge volume measurements accurate enough to enable the calculation of loads. Real-time, telemetered volumes will significantly improve the effectiveness of discharge monitoring throughout the Region.

Sampling protocols and laboratory analysis undertaken as self-monitoring by Permit Holders was not consistent with SOE sampling undertaken by Horizons. Non-compliance by Permit Holders with consent requirements to provide monitoring records often meant information was not available from many discharges. Self-monitoring data was also stored in a haphazard fashion and was difficult and time-consuming to collate before analysis was undertaken.

Compliance monitoring data (both self-monitoring and Council monitoring) was, at times, not collected beyond the expiry of consents, although many significant discharges were still operating under existing use rights while new applications were processed. Periods of record within compliance monitoring datasets were not consistent, or were small, disjointed, or ceased without any justification.

DRP and SIN samples, taken from upstream and downstream of point source discharges for compliance monitoring purposes were particularly inaccurate, and often had higher upstream contaminant concentrations than downstream samples, or no available flow record for the sampling period, making the data collected from instream samples too unreliable for flow stratified load calculation methods.

An automated system for collection and collation of compliance monitoring data in a regular and timely manner from discharge consent holders would significantly reduce the time taken for processing and analysis of data and allow timely and transparent assessment of compliance with consent conditions and Plan standards.

The coordination of compliance and SOE sampling runs at the same flow (by sampling both on the same day) within each water management zone would resolve many of the issues raised in this report and allow for a more robust method of assessing nutrient loads to waterways in the future.

10.4 Recommendations to improve monitoring effectiveness and data quality

1. SOE and compliance data should be monitored on the same day, at similar flows and if possible by the same person/team within water management zones.
2. The effect of mixing zones and inflowing tributaries or confluences in relation to discharge sampling location needs examination. For significant discharges mixing zones should be determined by mixing trials.

3. Flow should be gauged simultaneously with sample collection; relationships should be developed between flows derived from these gaugings and those from continuous flow recorders where possible.
4. The effluent discharge volumes of all significant consents should be measured continuously and telemetered to Horizons databases. Daily records should be collected and submitted regularly for smaller discharges.
5. Compliance and SOE monitoring should be publicly available and transparent, if possible via the internet, and updated automatically to ensure compliance with the proposed standards and consent conditions.

10.4.1 Further Research

Further investigation of nutrient loads in water management zones not affected by point source discharges is required to adequately gauge the influence of non-point source enrichment throughout the Region. An investigation of the relative contributions of PS and NPS at all flows is also needed. Additionally, the influence of seasonal changes to land use activities on the relationship between nutrient loads and flow should also be considered.

Investigations of other discharge sources and contaminants should be undertaken as soon as resources permit in order to assess the impact of activities such as stormwater, landfill leachate and sediment discharges to water.

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12. Glossary

½ Median Flow	Half of the 50th percentile flow statistic
75th Percentile flow	The 75th percentile flow was selected as a surrogate for the ½ median flow statistic in rivers affected by abstraction and/or diversion of flow for the TPD because the regulation of flows as required by resource consent conditions creates an unnatural flow duration curve. This unnatural flow regulation causes a ½ median flow statistic that is less than the MALF in these rivers (Henderson & Diettrich, 2007).
Chl *a*	Chlorophyll *a* – a pigment measured as a surrogate for periphyton biomass
DRP	Dissolved Reactive Phosphorus
MALF	Mean Annual Low Flow
MCWQRP	Manawatu Catchment Water Quality Regional Plan (1999)
NIWA	National Institute of Water and Atmospheric Research
SIN	Soluble Inorganic Nitrogen
SOE	State of the Environment
STP	Sewage Treatment Plant
TPD	Tongariro Power Development (Genesis Energy)
WMZ	Water Management Zone – geographical catchment unit for resource management within the Horizons Region (McArthur *et al.*, 2007)

13. Appendices

13.1 Appendix 1

Catchment	Site	Average Volume from Discharge	Water Quality Data and Dates Used
Manawatu Upstream Teachers College	Norsewood Sewage	50 m³/day	Norsewood Tararua D.C Secondary Ox. Pond wastes (Qualarc Site 1108 n=41) June 1990 – April 2006
	Dannevirke Sewage	3082 m³/day	Dannevirke Tararua D.C Tertiary Ox. Pond wastes (Qualarc Site 1119 n=33) December 1989 – April 2006
	PPCS Oringi – Wastewater	86.3 m³/day	Richmond Oringi Ltd. Secondary Ox. Pond wastes (Qualarc Site 1109 n=41) December 1989 – April 2006
	Eketahuna Sewage	336 m³/day	Eketahuna Tararua D.C. Imhoff Tank (Qualarc Site 1182 n=48) and Eketahuna Tararua D.C. Secondary Oxidation Pond Waste (Qualarc Site 1104 n=57) August 1989 – April 2006 Combined loads
	Pahiatua Sewage	1020 m³/day	Pahiatua Tararua D.C Secondary Ox. Pond Wastes (Qualarc Site 1111n=52 DRP and 34 SIN) August 1989 – April 2006
	Fonterra (Pahiatua) – Condensate	1014 m³/day	Kiwi Cooperative – Mangamutu Condensate Discharge (Qualarc Site 193 n=51) January 1990 – April 2006
	DB Breweries – Brewery Effluent	389.8 m³/day	Tui Brewery/Secondary Treated Waste (Qualarc site 191 n=50) January 1990 – July 2006
	Woodville Sewage	700 m³/day	Woodville Tararua D.C Secondary Ox. Pond (Qualarc Site 1114 n=59) September 1989 – April 2006
	Ashhurst Sewage	767 m³/day	Ashhurst Palmerston N.C.C Secondary Ox. Pond Waste (Qualarc Site 1103) September 1989 – January 2005
	Aokautere Sewage	20 m³/day	Aokautere Palmerston N.C.C Secondary Ox. Pond Waste (Qualarc Site 1102 n=25 SIN n=43 DRP) August 1989 – December 2003
Manawatu Downstream Teachers College	NZ Pharmaceuticals	1528.9 m³/day	NZ Pharmaceuticals Ltd Raw Waste (Qualarc Site 194) March 1990 – April 2005
	Fonterra (Longburn) – Wastewater	1336.5 m³/day	Kiwi Cooperative – Longburn Raw Milk Waste (Qualarc Site 192) January 1990 – December 2004
	Longburn Sewage	150.6 m³/day	Longburn Manawatu DC Secondary Ox. Pond Qualarc Site (1107) August 1989 – June 2002
	Palmerston North Sewage	28754.7 m³/day	PNCC Self-monitoring data September 1993 – August 23006
	Awahuri Sewage	25.1 m³/day	Awahuri MDC Single Oxidation Lagoon (Qualarc Site 1124) September 1994 – November 2002
	Kimbolton Sewage	18 m³/day	Kimbolton Manawatu D.C. Oxidation Pond Waste (Qualarc Site 1131 n=15) June 1991 – February 2002
	Affco NZ ltd.	972 m³/day	Manawatu Beef Packers Secondary Treated Wastes (Qualarc Site 190) February 1990 – October 2003
	Feilding Sewage	7204 m³/day	Feilding STP Manawatu D.C. (Qualarc site 1183 n=56) March 1990 – November 2004
	Rongotea Sewage	117.4m³/day	Rongotea MDC Secondary Oxidation Pond Waste (Qualarc Site 1112) August 1989 – June 2002

Catchment	Site	Average Volume from Discharge	Water Quality Data and Dates Used
	Tokomaru Sewage	160 m^3/day	Tokomaru Horowhenua DC primary Ox. Pond Wastes (Qualarc Site 1092) June 1990 – January 2006
	Shannon Sewage	540 m^3/day	Shannon Horowhenua DC Secondary Ox. Pond Wastes (Qualarc Site 1113) September 1989 – March 2006
	Foxton Sewage	1187.8 m^3/day	Foxton Horowhenua DC Secondary Ox. Pond Wastes (Qualarc Site 1105) April 1989 – November 2005
	PPCS Shannon	568.9 m^3/day	Richmond Oringi Ltd. Secondary Treated Waste (Qualarc Site 195) February 1990 – March 2006
	Taihape Sewage	928 m^3/day	Taihape Rangitikei DC Single Ox. Pond Wastes (Qualarc Site 1122 n=66) November 1989 – March 2005
	Mangaweka Sewage	33 m^3/day	Outlet Effluent Self-monitored July 2005 – June 2006 (n=27) NB there is no SIN data for this site
	Hunterville Sewage	203.4 m^3/day	Hunterville Rangitikei D.C Secondary Oxidation Pond Waste (Qualarc Site 1115 n = 36) and Self-monitoring data (n=8) February 1993 –March 2006
	Halcombe Sewage	40.2 m^3/day	Halcombe Manawatu D.C Secondary Oxidation Pond Waste (Qualarc Site 1094 n=30) and Self-monitoring data (n=18) February 1993 – November 2005
	Feltex Carpets Ltd – Wastewater	280 m^3/day	Feltex NZ Ltd. Kakariki (Qualarc Site 169 n=38) February 1993 – March 2005
	Marton Sewage	2700 m^3/day	Self-monitoring Data (n=44) February 1993 – March 2006
	Bulls Sewage	172.8 m^3/day	Bulls Rangitikei D.C Secondary Oxidation Pond Waste (Qualarc Site 1093 n = 33) and Self-monitoring data (n=18) July 2002 – June 2006
	Riverlands Manawatu – Wastewater	258.3 m^3/day	Riverlands Manawatu Secondary Treated Waste (Qualarc Site 181 n=40) October 1993 – January 2006
	Ohakea Sewage	287.5 m^3/day	Ohakea Base RNZAF Effluent Outfall (Qualarc site 1963 n=9) October 2002 – February 2006
	Sanson Sewage	117.5 m^3/day	Sanson Manawatu D.C Secondary Oxidation Pond Waste (Qualarc Site 1101 n=28) and Self-monitoring data (n=23) July 1993 – December 2005
Whanganui	National Park Sewage	375 m^3/day	National Park Ruapehu D.C Secondary Oxidation Pond Waste (Qualarc Site 1096 n=48) July 1991 – February 2006
	Taumarunui Sewage	2000 m^3/day	Taumarunui Ruapehu D.C Primary Settled Sewage Waste (Qualarc Site 1173 n=45) November 1993 – March 2006
	Ohura Prison Sewage	70 m^3/day	Self-monitored data (Effluent n=15) February 1998 – October 2004
	Pipiriki Sewage	20 m^3/day	Pipiriki Ruapehu D.C Sand Filt. Septic Tank Waste (Qualarc Site 1171 n=22) December 1991 – September 2001
Whangaehu	Winstone Forest Products (Karioi)	3876 m^3/day	Winstone Pulp International Primary Treated Wastewater (Qualarc site 189 n=13) December 1999 – April 2005
	Waiouru Army Base Sewage	1494.5 m^3/day	Waiouru M.C. Secondary Sewage Wastes (Qualarc Site 1187 n=69) July 1990 – April 2006

Catchment	Site	Average Volume from Discharge	Water Quality Data and Dates Used
	Rangataua Sewage	30 m^3/day	Rangataua Ruapehu D.C Secondary Oxidation Pond Waste (Qualarc Site 1099 n=43) August 1990 – April 2006
	Ohakune Sewage	1400 m^3/day	Ohakune Ruapehu D.C Secondary Oxidation Pond Waste (Qualarc Site 1097 n=51) November 1989 – February 2005
	Raetihi Sewage	214 m^3/day	Raetihi Ruapehu D.C Secondary Oxidation Pond Waste (Qualarc Site 1098 n =51) November 1989 – November 2005
Owahanga	Pongaroa Sewage	56. 9 m^3/day	Pongaroa Tararua D.C Secondary Oxidation Pond Waste (Qualarc Site 1133 n=51) September 1992 – November 2006

13.2 Appendix 2

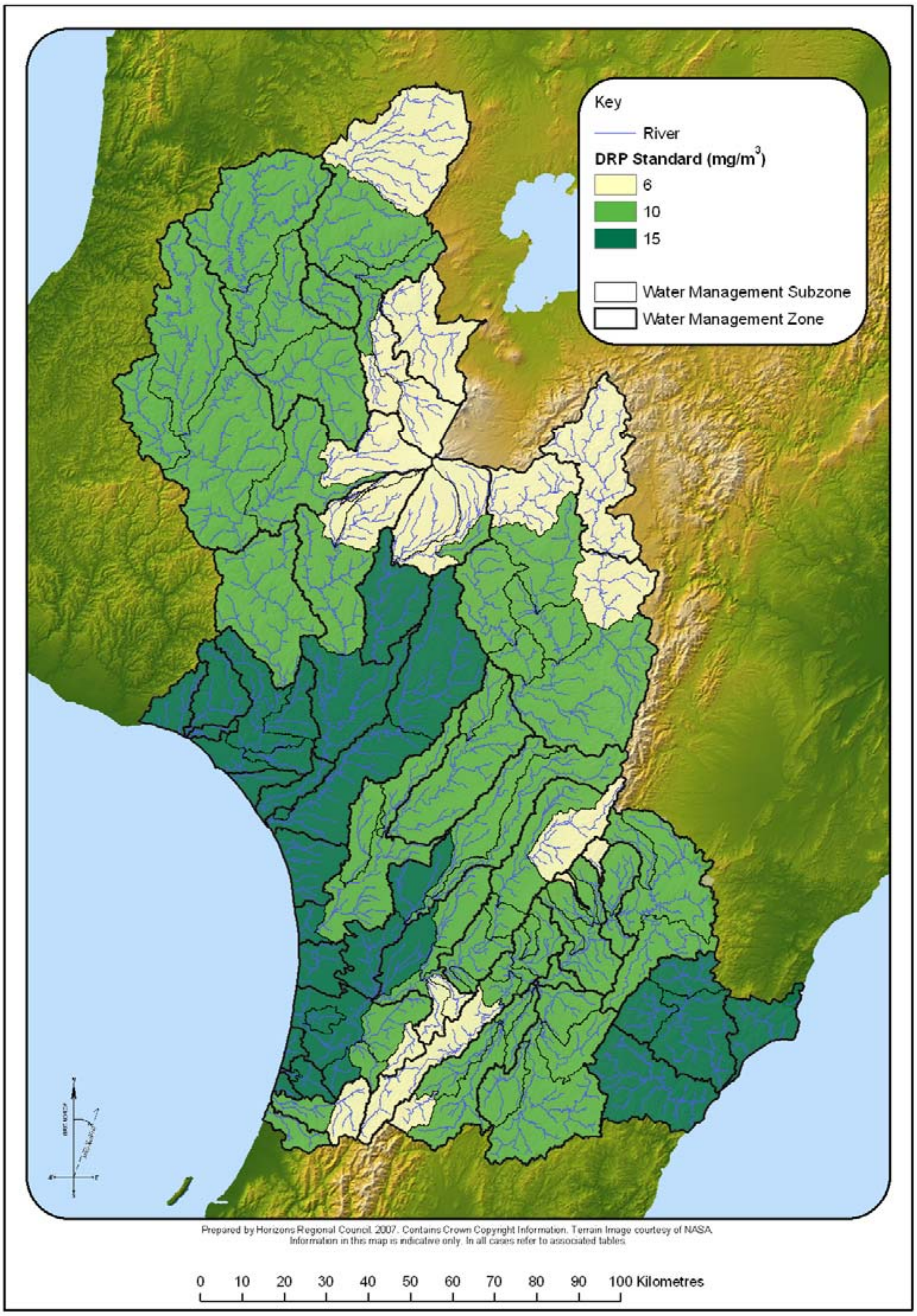
Catchment	River	Site	Existing data		Flow Statistic (m^3/s)	
			Spot WQ sampling	Continuous Flow recording	MALF	½ med
Manawatu	Manawatu	Weber Road	Extensive[N] January 1989 – May 2005 (n=202)	Manawatu at Weber Road January 1989 – May 2005 [N]	1.879	3.803
	Manawatu	Hopelands	Extensive January 1993 – August 2006 (n=165)	Manawatu at Hopelands January 1993 – October 2005	3.734	7.852
	Mangatainoka	SH2 Bridge	Extensive January 1994 – April 2005 (n=155)	Mangatainoka at Pahiatua All January 1994 – April 2005	1.578	4.45
	Manawatu	Teachers College	Extensive[N] January 1989 – May 2005 (n=202)	Manawatu at Teachers College[3] January 1989 – May 2005 [N]	15.735	36.702
	Manawatu	Opiki Bridge	Extensive[N] January 1989 – May 2005 (n=202)	Manawatu at Opiki January 1997 – April 2005 [4(N)]	15.9	37.569
	Oroua	Awahuri Bridge	Extensive July 1993 – March 2005 (n=141)	Oroua at Awahuri Bridge July 1993 – March 2005	1.62	3.908
Rangitikei	Rangitikei	Pukeokahu	Extensive March 1999 – October 2005 (n=83)	Rangitikei at Pukeokahu[5] March 1999 – October 2005	5.25	8.689
	Hautapu	NIWA Station Taihape	Extensive October 1989 – March 2005 (n=56)	Hautapu at Taihape All October 1989 – March 2005	0.745	1.4
	Hautapu	U/s Rangitikei	Extensive July 1998 – March 2005 (n=84)	Hautapu at Taihape All July 1998 – March 2005	0.745	1.4
	Rangitikei	Mangaweka	Extensive[N] January 1993 – May 2005 (n=149)	Rangitikei at Mangaweka January 1993 – May 2005	13.859	21.648
	Rangitikei	Vinegar Hill	Extensive December 1998 – February 2005 (n=39)	Rangitikei at Mangaweka December 1998 - February 2005	13.859	21.648
Whanganui	Whanganui	Cherry Grove	Extensive	Whanganui at Piriaka January 1997 – December 2003	11.901	16.62[6]
	Whanganui	Te Maire	Extensive March 1992 – February 2005 (n=40)	Whanganui at Te Maire March 1992 – February 2005	24.938	32.767[7]
	Whanganui	Pipiriki	Extensive	Whanganui at Pipiriki Hydrotelrating[8] July 1998 – March 2007	45.6	65.1
Whangaehu	Whangaehu	Karioi recorder	Good	Whangaehu at Karioi January 1997 – February 2000	8.244	9.793[9]
	Mangawhero	DoC Headquarters	Extensive	Mangawhero at Ohakune All May 1998 – August 2005	0.748	0.93

3 Manawatu at Palmerston North All Flow statistics are used for the NIWA Teachers College data
4 Manawatu at Opiki Flow Statistics provided by Marianne Watson
5 Due to Hydroelectricity schemes the flow statistic for this site is from the NIWA Flow Statistics Report: Rangitikei at Pukeokahu (32763), Jul 1999 to Jul 2005 (post Diversion)
6 The 75th percentile flow is used for Whanganui at Piriaka due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whanganui at Piriaka (33356), Jul 1993 to Jul 2003 (Planning Tribunal 1990)
7 The 75th percentile flow is used for Whanganui at Te Maire due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whanganui at Te Maire (33302), Jul 1993 to Jul 2004 (Planning Tribunal 1990)
8 Whanganui at Pipiriki Statistics provided by Marianne Watson
9 The 75th percentile flow is used for Whangaehu at Karioi due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whangaehu at Karioi (33107) Jul 1979 to Jul 2003 (post Diversion)

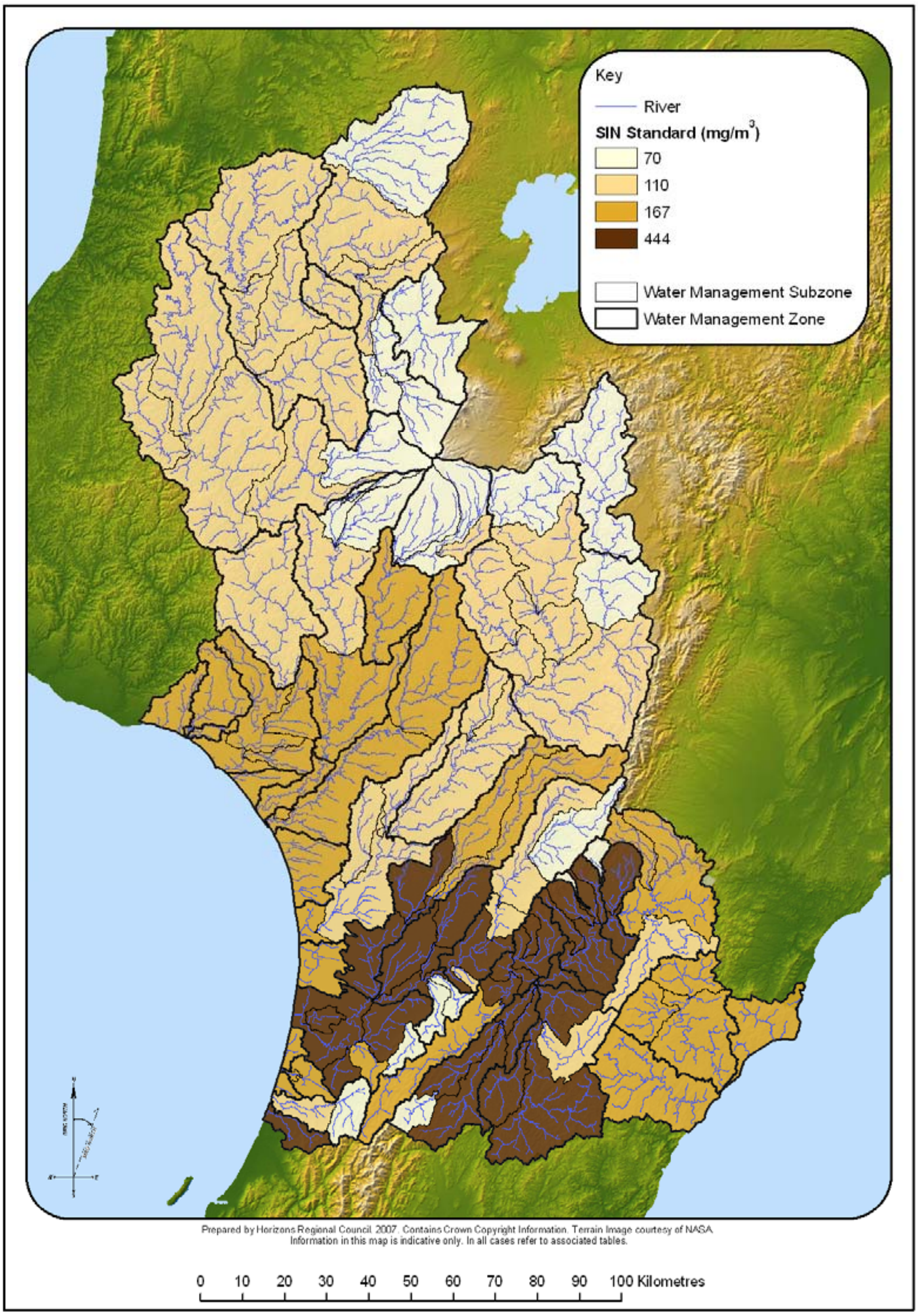
	Whangaehu	Kauangaroa	Extensive July 1991 – June 2002 (n=36)	Whangaehu at Kauangaroa July 1991 – June 2002	13.48	18.791[10]
Owahanga	Owahanga	Branscombe Bridge	Good July 2000 – June 2004 (n=23)	Owahanga at Branscombe Bridge July 2000 – June 2004 (n=23)	0.039	0.746

[10] The 75th percentile flow is used for Whangaehu at Kauangaroa due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whangaehu at Kauangaroa (33101) Jul 1979 to Jul 2004 (post Diversion)

13.3 Appendix 3



Map 1: DRP Standard by Management Sub-Zone in the Manawatu-Wanganui Region (see Appendix 4 for numerical values by water management sub-zone).



Map 2: SIN Standard by Management Sub-Zone in the Manawatu-Wanganui Region (see Appendix 4 for numerical values by water management sub-zone).

13.4 Appendix 4

Table 1: Proposed Water Quality Standards for streams and rivers in Water Management Sub-zones (Ausseil & Clark, 2007a).

Column in Table 2		Recommended standard wording
Header	Sub-header	
pH	Range	The pH of the water shall be within the range […] to […]
	Δ	The pH of the water shall not be changed by more than […]
Temp (°C)	<	The temperature of the water shall not exceed […] degrees Celsius.
	Δ	The temperature of the water shall not be changed by more than […] degrees Celsius.
DO (%SAT)	<	The concentration of dissolved oxygen shall exceed […]% of saturation
BOD_5 (g/m^3)	<	The five-day biochemical oxygen demand shall not exceed […] grams per cubic metre.
POM (g/m^3)	<	The concentration of particulate organic matter shall not exceed […] grams per cubic metre.
Periphyton	Chl *a* (mg/m^2)	The algal biomass on the stream or river bed shall not exceed […] milligrams of chlorophyll a per square metre.
	% cover	The maximum cover of visible stream or river bed by periphyton (as filamentous algae more than 2 centimetres long) shall not exceed […] %
DRP (mg/m^3)	<	The annual average concentration of dissolved reactive phosphorus when the river flow is at or below three times the median flow shall not exceed […] milligrams per cubic metre, unless natural levels already exceed this standard.
SIN (mg/m^3)	<	The annual average concentration of soluble inorganic nitrogen when the river flow is at or below three times the median flow shall not exceed […] milligrams per cubic metre.
QMCI		The quantitative macroinvertebrate index shall exceed […], unless natural physical conditions are outside the scope of application of the QMCI.
Ammonia (mg/m^3)	<	The concentration of ammonia nitrogen shall not exceed […] milligrams per cubic metre.
Toxicants	<	For toxicants not otherwise defined in these standards, the concentration of toxicants in the water shall not exceed the trigger values defined in the 2000 ANZECC guidelines Table 3.4.1 with the level of protection of […]% of species.
Clarity (m)	<m	The clarity of the water when the river flow is at or below median flow shall exceed […] metres (m)
	<3 x m	The clarity of the water when the river flow is at or below three time the median flow shall exceed […] metres (m)
	% Δ	The clarity of the water shall not be changed by more than […] %. This standard applies at all river flows.

Note: Soluble Inorganic Nitrogen (SIN) concentration is measured of the sum of nitrate nitrogen, nitrite nitrogen and ammonia nitrogen

Table 2: Water quality standards for rivers and streams in Water Management Sub-zones of the Manawatu-Wanganui Region.

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m³)	POM (g/m³)	Periphyton		DRP (mg/m³)	SIN (mg/m³)	QMCI	Ammonia (mg/m³)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m²)	% cover	<	<		<		< m	< 3 xm	**% Δ**
Upper Manawatu (Mana_1)	Upper Manawatu (Mana_1a)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	167	6	400	99	3	1.6	20
	Mangatewainui (Mana_1b)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	167	6	400	99	3	1.6	20
	Mangatoro (Mana_1c)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	110	6	400	99	3	0.5	20
Weber-Tamaki (Mana_2)	Weber-Tamaki (Mana_2a)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Mangatera (Mana_2b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
Upper Tamaki (Mana_3)	Upper Tamaki	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
Upper Kumeti (Mana_4)	Upper Kumeti	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
Tamaki-Hopelands (Mana_5)	Tamaki-Hopelands (Mana_5a)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Lower Tamaki (Mana_5b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
	Lower Kumeti (Mana_5c)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
	Oruakeretaki (Mana_5d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
	Raparapawai (Mana_5e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
Hopelands-Tiraumea (Mana_6)	Hopelands-Tiraumea	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
Tiraumea (Mana_7)	Upper Tiraumea (Mana_7a)	7 to 8.5	0.5	23	3	70	2	5	120	30	10	444	5	400	95	2	0.5	30
	Lower Tiraumea (Mana_7b)	7 to 8.5	0.5	23	3	70	2	5	120	30	10	444	5	400	95	2	0.5	30
	Mangaone River (Mana_7c)	7 to 8.5	0.5	23	3	70	2	5	200	30	10	444	5	400	95	1.6	0.5	30
	Makuri (Mana_7d)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	110	6	400	99	3	1.6	20
Mangatainoka (Mana_8)	Upper Mangatainoka (Mana_8a)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Middle Mangatainoka (Mana_8b)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Lower Mangatainoka (Mana_8c)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Makakahi (Mana_8d)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Mangaramarama (Mana_8e)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	444	5	400	95	1.6	0.5	30

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m^3)	POM (g/m^3)	Periphyton		DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Ammonia (mg/m^3)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m^2)	% cover	<	<		<		< m	< 3 xm	**% Δ**
Upper Gorge (Mana_9)	Upper Gorge (Mana_9a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Mangapapa (Mana_9b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Mangaatua (Mana_9c)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Upper Mangahao (Mana_9d)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	167	6	320	99	3	2	20
	Lower Mangahao (Mana_9e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
Middle Manawatu (Mana_10)	Middle Manawatu (Mana_10a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Upper Pohangina (Mana_10b)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Middle Pohangina (Mana_10c)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
	Lower Pohangina (Mana_10d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
	Aokautere (Mana_10e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
Lower Manawatu (Mana_11)	Lower Manawatu (Mana_11a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Turitea (Mana_11b)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Kahuterawa (Mana_11c)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Upper Mangaone Stream (Mana_11d)	7 to 8.5	0.5	24	3	60	2	5	200	30	10	444	5	400	95	2.5	1.6	30
	Lower Mangaone Stream (Mana_11e)	7 to 8.5	0.5	24	3	60	2	5	200	30	10	444	5	400	95	2.5	1.6	30
	Main Drain (Mana_11f)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	444	5	400	95	2.5	1.6	30
Oroua (Mana_12)	Upper Oroua (Mana_12a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	167	5	400	95	2.5	1.6	30
	Middle Oroua (Mana_12b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Lower Oroua (Mana_12c)	7 to 8.5	0.5	24	3	70	2	5	200	30	15	444	5	400	95	2.5	1.6	30
	Kiwitea (Mana_12d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	167	5	400	95	2.5	1.6	30
	Makino (Mana_12e)	7 to 8.5	0.5	24	3	70	2	5	120	30	15	444	5	400	95	2.5	1.6	30
Coastal Manawatu (Mana_13)	Coastal Manawatu (Mana_13a)	7 to 8.5	0.5	24	3	70	2	5	200	30	15	444	5	400	95	2.5	1.6	30
	Upper Tokomaru (Mana_13b)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton		DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Ammonia (mg/m^3)	Tox.	Clarity (m)		
		Range	Δ	<	Δ	>	<	<	Chl *a* (mg/m^2)	% cover	<	<		<		< m	< 3 xm	% Δ
	Lower Tokomaru (Mana_13c)	7 to 8.5	0.5	24	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Mangaore (Mana_13d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	167	5	400	95	2.5	1.6	30
	Koputaroa (Mana_13e)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	444	5	400	95	2.5	1.6	30
	Foxton Loop (Mana_13f)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	444	5	400	95	2.5	1.6	30
Upper Rangitikei (Rang_1)	Upper Rangitikei	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3.4	2	20
Middle Rangitikei (Rang_2)	Middle Rangitikei (Rang_2a)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3.4	2	20
	Pukeokahu – Mangaweka (Rang_2b)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	110	6	320	99	3.4	1.6	20
	Upper Moawhango (Rang_2c)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Middle Moawhango (Rang_2d)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Lower Moawhango (Rang_2e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
	Upper Hautapu (Rang_2f)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	110	6	400	99	3	1.6	20
	Lower Hautapu (Rang_2g	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
Lower Rangitikei (Rang_3)	Lower Rangitikei (Rang_3a)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	110	6	400	99	3	1.6	20
	Makohine (Rang_3b)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
Coastal Rangitikei (Rang_4)	Coastal Rangitikei (Rang_4a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
	Tidal Rangitikei (Rang_4b)	7 to 8.5	0.5	24	3	70	2	5	200	30	15	167	5	400	95	2.5	1.6	30
	Porewa (Rang_4c)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Tutaenui (Rang_4d)	7 to 8.5	0.5	24	3	60	2	5	200	30	10	110	5	400	95	2.5	1.6	30
Upper Whanganui (Whai_1)	Upper Whanganui	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
Cherry Grove (Whai_2)	Cherry Grove (Whai_2a)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Upper Whakapapa (Whai_2b)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Whakapapa (Whai_2c)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Piopiotea (Whai_2d)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m³)	POM (g/m³)	Periphyton		DRP (mg/m³)	SIN (mg/m³)	QMCI	Ammonia (mg/m³)	Tox.	Clarity (m)		
		Range	Δ	<	Δ	>	<	<	Chl *a* (mg/m²)	% cover	<	<		<		< m	< 3 xm	% Δ
	Pungapunga (Whai_2e)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Upper Ongarue (Whai_2f)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Ongarue (Whai_2g)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
Te Maire (Whai_3)	Te Maire	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
Middle Whanganui (Whai_4)	Middle Whanganui (Whai_4a)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Upper Ohura (Whai_4b)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Lower Ohura (Whai_4c)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Retaruke (Whai_4d)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
Pipiriki (Whai_5)	Pipiriki (Whai_5a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
	Tangarakau (Whai_5b)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Whangamomona (Whai_5c)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Upper Manganui o te Ao (Whai_5d)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3.4	2	20
	Lower Manganui o te Ao (Whai_5e)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	110	6	320	99	3.4	1.6	20
Paetawa (Whai_6)	Paetawa	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
Lower Whanganui (Whai_7)	Lower Whanganui (Whai_7a)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Coastal Whanganui (Whai_7b)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Upokongaro (Whai_7c)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Matarawa (Whai_7d)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Upper Whangaehu (Whau_1)	Upper Whangaehu (Whau_1a)	7 to 8.2[(a)]	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Waitangi (Whau_1b)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Tokiahuru (Whau_1c)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
Middle Whangaehu (Whau_2)	Middle Whangaehu	7 to 8.5[(a)]	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Lower Whangaehu (Whau_3)	Lower Whangaehu (Whau_3a)	7 to 8.5[(a)]	0.5	22	3	70	2	5	200	30	15	167	5	400	95	2	0.5	30

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton		DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Ammonia (mg/m^3)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m^2)	% cover	<	<		<		< m	< 3 xm	**% Δ**
	Upper Makotuku (Whau_3b)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Makotuku (Whau_3c)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Upper Mangawhero (Whau_3d)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Mangawhero (Whau_3e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
Coastal Whangaehu (Whau_4)	Coastal Whangaehu	7 to 8.5[(a)]	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Turakina (Tura_1)	Upper Turakina (Tura_1a)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Lower Turakina (Tura_1b)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Ratana (Tura_1c)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Ohau (Ohau_1)	Upper Ohau (Ohau_1a)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Ohau (Ohau_1b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
Owahanga (Owha_1)	Owahanga	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
East Coast (East_1)	East Coast	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Akitio (Akit_1)	Upper Akitio (Akit_1a)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Lower Akitio (Akit_1b)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Waihi (Akit_1c)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Northern Coastal (West_1)	Northern Coastal	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Kai Iwi (West_2)	Kai Iwi	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Mowhanau (West_3)	Mowhanau	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Kaitoke Lakes (West_4)	Kaitoke Lakes	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Southern Wanganui Lakes (West_5)	Southern Wanganui Lakes	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Northern Manawatu Lakes (West_6)	Northern Manawatu Lakes	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Waitarere (West_7)	Waitarere	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Lake Papaitonga (West_8)	Lake Papaitonga	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m³)	POM (g/m³)	Periphyton		DRP (mg/m³)	SIN (mg/m³)	QMCI	Ammonia (mg/m³)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m²)	% cover	<	<		<		< m	< 3 xm	**% Δ**
Waikawa (West_9)	Waikawa	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
Lake Horowhenua (Hoki_1)	Lake Horowhenua (Hoki_1a)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
	Hokio (Hoki_1b)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30

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