# CCC Instream Spring Water Quality Project – Waimairi and Wairarapa Stream

Prepared for

Christchurch City Council

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PATTLE DELAMORE PARTNERS LTD
295 Blenheim Road
Upper Riccarton, Christchurch 8041
PO Box 389, Christchurch 8140, New Zealand

Tel +64 3 345 7100  Fax +64 3 345 7101
Website http://www.pdp.co.nz
Auckland Tauranga Wellington Christchurch

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# Quality Control Sheet

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DOCUMENT CONTRIBUTORS

Prepared by

SIGNATURE

Byron Munro

Reviewed and Approved by

SIGNATURE P.F. Callander

Peter Callander

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## Executive Summary

Inputs of nitrogen and phosphorus are of concern to the surface waterways of Christchurch City because they contribute to nuisance biological growths within those waterways. They enter the waterways through groundwater seepage and through stormwater discharges to these waterways.

To investigate the contribution of nutrients via groundwater seepage, two surveys of flow measurements and water quality sampling have been carried out in September 2014 and March 2015 to characterise the seasonal variation in groundwater flow and nutrient input under baseflow conditions at the Waimairi and Wairarapa Streams, which are western headwaters of the Avon River. These two sampling occasions represent the seasonal variation in baseflow contributions with springtime characterised by a larger number of active springs in the headwaters, higher flows and generally higher nitrogen concentrations, with the opposite situation occurring in autumn due to drier weather conditions, greater groundwater abstraction and a lower input of land based recharge to the groundwater that feeds the stream flow.

The surveys focussed on the relative inputs from discrete spring inflows and also from general streambed seepage compared to total instream flow and nutrient composition. Measurements were made using seepage meters, mini piezometers, flow gauging and surface water sampling equipment. The direct measurement of the flow and nutrient contributions from these contrasting areas of the instream environments is a relatively unique and novel assessment approach that has the potential to greatly improve our understanding of effects within the instream environment.

The streams that were surveyed can be characterised into three broad zones of inflow patterns:

- an upstream zone with a high number of discrete spring vents, which had high inflow rates in September 2014 (0.1 – 0.2 L/s/m) but low inflow rates in March 2015 when many of the upstream springs were dry;
- a middle section of low inflow rates (0-0.05 L/s/m) with few discrete springs and lower groundwater pressures (either due to a loss of pressure from the upstream spring discharges (September 2014) or seasonally low groundwater pressures (March 2015));
- a downstream section with few discrete springs (apart from Fendalton Drain) but high general stream bed seepage (0.1-0.2 L/s/m) due to increased groundwater pressure.

As expected the discrete spring vents represent a higher concentration of inflow, with individual flow rates measured at 0.2 to 0.5 L/s. Indicative estimates of hydraulic conductivity have been made which suggest that spring vents have

values on the order of 100-300 m/day or greater compared to an indicative general streambed hydraulic conductivity value of less than 10 m/day. It is important to note that rates of inflow measured by seepage meters are expected to underestimate the true inflow rate because the seepage water places some constraint on the zone of inflow.

The increased inflows at the western, upstream, springs appear to reduce the hydraulic head in the groundwater immediately downstream such that relatively little general groundwater streambed seepage occurs in the reach immediately downstream of the main spring locations. However, further downstream, where the hydraulic gradient across the streambed will be greater, the general rate of groundwater inflow to the streams is of a similar scale to the western upstream zone, regardless of whether it is dominated by springfed streams (high concentrated flows, measured at 3-9 L/s/$m^2$, over a small area) or general streambed seepage (lower inflows, measured at 1-4x$10^{-4}$ L/s/$m^2$ across a larger area.

Water chemistry was primarily assessed by comparing concentrations of chloride (a conservative chemical tracer), nitrogen species and dissolved reactive phosphorus (DRP). Chemical concentrations were generally similar between the two surveys and between discrete spring vents, general streambed seepage and stream flow, with the exception that Wairarapa Stream had generally lower chloride and total nitrogen concentrations and higher DRP concentrations in March 2015 compared to September 2014. The higher spring time inputs of chloride and nitrogen likely reflect a higher proportion of land based recharge relative to low nutrient Waimakariri River seepage in the groundwater that feeds the streams compared to the conditions that exist in March. The DRP concentrations are perhaps more affected by localised stream bed conditions which will release DRP from sediments when anoxic and instream concentrations will vary with plant uptake or die-back.

The measured total nitrogen concentrations were observed to be higher in the Waimairi Stream compared to the Wairarapa, for both sampling rounds, which is likely due to differences in land use recharge in the groundwater recharge zones that feed the stream headwaters. Such a finding is consistent with the generally increasing influence of land use activities at more southerly locations away from the Waimakariri River (i.e. Waimairi Stream, relative to the more northerly located Wairarapa Stream) due to a lessening dilution effect from low nutrient Waimakariri River seepage recharge to the groundwater system with increasing distance from that river system.

Overall, chloride concentrations generally ranged from 8-14 mg/L (4-10 mg/L in Wairarapa Stream in March 2015), total nitrogen from 2-4 mg/L in Waimairi Stream and 1-1.6 mg/L in Wairarapa Stream and DRP <0.02 mg/L (although up to 0.03 mg/L in Wairarapa Stream in March 2015).

However, there were some localised nutrient input exceptions such as a higher total nitrogen and DRP concentration in a spring vent in Wairarapa Stream, a low total nitrogen concentration and elevated DRP concentration at a general streambed seepage sample at Waimairi Stream. These more variable results likely represent localised conditions around discrete sampling points that do not appear to have a big influence on the overall instream concentration.

Concentrations of nitrogen are generally lower at the downstream end of the streams, which may reflect higher concentrations in the shallowest groundwater being skimmed off into the streams at the upstream end and slightly deeper lower concentration water enters the lower reaches of the stream. Downstream DRP changes were more variable, with the March 2015 survey showing lower concentrations in Waimairi Stream and higher concentrations in the Wairarapa Stream, but the September 2014 surveys showing no significant downstream change in either stream. This variability likely reflects the complex interaction between the degree of streambed sediment reducing conditions and instream plant uptake and die-back.

Nitrate is the dominant form of nitrogen in all samples with the exception of a general streambed seepage sample from Waimairi Stream which had a total nitrogen concentration of 0.62 mg/L which was predominately comprised of ammonia-N at 0.59 mg/L, possibly due to anaerobic digestion of organic matter in low permeability streambed sediments. A small proportion of organic N is also present in most of the samples from the September 2014 sampling round, but not present in the March 2015 sampling round. The nitrate-N concentrations in discrete spring inflows and general streambed seepage are similar to concentrations measured in shallow wells in the general vicinity of the western headwaters.

Because there is no overall pattern of concentration differences between discrete spring vents and general streambed seepage and concentrations are generally within a similar range (apart from a few isolated variations), the mass flux calculations for the different chemical components in the stream generally follow the pattern of increasing flow downstream, with some variability potentially due to nutrient uptake by aquatic plants.

The results indicate that nitrogen and phosphorus concentrations in Christchurch City surface waterways are elevated, primarily due to groundwater inflows through both discrete spring vents and general streambed seepage (although with some localised exceptions). In particular, most nitrogen samples in Waimairi Stream and some in Wairarapa Stream exceeded guideline values in Environment Canterbury's proposed Land and Water Regional Plan (pLWRP) for spring fed plains urban streams. As a result it may be impractical to propose that urban stormwater management can address elevated nutrient concentrations in these waterways.

# Table of Contents

## Table of Tables

## Appendices

# 1.0 Introduction

The springfed waterways in Christchurch are an important characteristic of the city environment. During dry periods the flow in Christchurch's springfed waterways is sourced entirely from groundwater seepage with inflows occurring at concentrated points which are visible as high inflow springs, as well as more general seepage through the stream bed strata and also intermittent stormwater inflows.

One of the main contaminants of concern for these waterways is nitrogen, which at elevated concentrations can result in proliferation of aquatic plants or algae. A recent pilot study in the Avon River catchment has suggested that instream springs may contribute nitrogen to waterways (Whyte,2014; Appendix A).

In order to understand the relative contribution of water and nitrogen entering the waterways through discrete springs and general streambed seepage, Christchurch City Council (CCC) has engaged Pattle Delamore Partners Ltd (PDP) to design and implement a detailed field study that establishes the relative contribution of water and nitrogen from discrete springs relative to general streambed seepage. The approach that has been adopted for this study involves the direct measurement of the flow and nutrient contributions from contrasting areas of the instream environments. This is a relatively unique and novel assessment approach that has the potential to greatly improve our understanding of effects within the instream environment.

An improved understanding of these contributions to the waterways will assist in future monitoring and management of the waterways and of stormwater systems which also contribute flow to the waterways. The information will help in understanding the origin of nitrogen entering the waterways which will assist in determining what water quality impacts can realistically be achieved by the management of the CCC stormwater system.

# 2.0 Background

The concentrations of nitrogen in Christchurch's urban waterways tend to be higher in the upper catchments and decrease with increasing distance downstream (Hayward et al 2009, Bartram 2013, Whyte 2013, Margetts, 2015a). In addition, monitoring of stormwater outfalls within Christchurch shows low levels of nitrogen within the stormwater (Margetts 2014, Margetts, 2015b). High levels of nitrogen are recorded in Christchurch's shallow groundwater due to intensive agricultural land use (Wong & Hanson 2012), which is typically located in the upper reaches of these catchments. Therefore, as the waterways in Christchurch are spring-fed, higher nitrogen levels in the upper catchments have been attributed to this nitrate-rich groundwater recharging the streams (Hayward et al 2009, Bartram 2013). However, no sampling has specifically been carried out to test the water quality of these instream (i.e. rheocrene) springs relative to general seepage occurring through the streambed to scientifically assess this assumption that nitrogen inputs predominately come from springs.

Currently, all waterways in Christchurch generally fail to meet the ANZECC (2000) nitrate-nitrite-nitrogen water quality guideline trigger value for excessive plant growth (0.444 mg/L) and many sites also exceed the pLWRP toxicity level for dissolved inorganic nitrogen (the sum of nitrate-nitrite-nitrogen plus ammonia; 1.5 mg/L) (Bartram 2013, Whyte 2013, Margetts 2015a). In the Environment Canterbury 2012 groundwater annual survey of 289 wells, the median concentration of nitrate-N recorded was 4.2 mg/L and the maximum was 64 mg/L (Wong & Hanson 2012). Therefore, these elevated nitrogen concentrations in groundwater are expected to be contributing to the exceedance of water quality guideline values in the springfed streams.

The information gained from this study will help inform the Avon Stormwater Management Plan (and SMPs for other Christchurch urban catchments), which aims to treat a large proportion of stormwater prior to discharge to the Avon River. The higher levels of nitrogen in the upper reaches of this catchment were considered to be of concern, as the input of these contaminants may mean that receiving water quality goals are not met, regardless of stormwater treatment. Therefore it was decided that the Council should undertake instream spring water quality testing, to identify whether elevated nutrients were present within springs.

This study is relatively unique. A search of the literature showed that testing of the water quality of discrete instream springs, and how this influences stream water quality, does not appear to have been previously undertaken either in New Zealand or overseas. The exception to this is a study in Kentucky, USA, which recorded springs within the banks and channel of a coastal plain stream discharging volatile organic compounds to the stream (LaSage et al. 2008). Spring sampling in this Kentucky study was undertaken by immersing sampling containers in springs or collecting spring water using a seepage meter.

## 3.0 Previous Works

A pilot study was initiated by CCC in October 2013 to determine the feasibility of sampling and to also quickly obtain some preliminary sampling data before groundwater levels dropped for the year (Whyte, 2014). This study can be found in Appendix A. Samples were taken from three springs and were analysed for nitrogen, as well as a range of other parameters. For this study the spring water samples were collected manually from low inside the stream vents (Avon River and Wai-iti Stream springs) or directly from discharge from the bank (Wairarapa Stream spring). A stream sample was also taken at each of the sites from the water column immediately upstream of each spring.

The springs in this pilot study all recorded high concentrations of nitrogen, in line with that recorded in the adjacent water columns. One-off guideline exceedances for spring samples were also recorded for total phosphorus (at the Wai-iti Stream spring; the water column sample was below guidelines). Overall, this pilot study suggests that springs do contribute contaminants to waterways, in particular, nitrogen.

However certain aspects of the experimental design were recommended to be improved in order to draw a definitive conclusion regarding the sources of nitrogen, these are listed below.

- Sampling of water using a seepage meter to allow definitive collection of spring water before it mixes with stream water, and to allow sampling of seeping springs (springs with visible vents were only sampled during the pilot study due to the difficulties of sampling seeps)
- Sampling of stream water quality immediately upstream and downstream of each spring, or zone of springs, to tease out the influence of spring water on stream water quality
- Assessment of temporal trends (e.g. monthly sampling throughout the year where spring levels allow, or weekly sampling during the spring season when groundwater levels are highest) and spatial trends (e.g. sampling springs from top to bottom of catchments where possible – seepage springs would be required to be sampled to achieve this)
- Measurements of stream flow and discharge rates at the time of sampling
- Quantification of the aquifer characteristics at the location of each spring and groundwater input into each of the streams
- Details of the substrate underlying the location of the springs
- Recording of the spring characteristics, including but not limited to, vent diameter, depth of spring and relationship to stream (e.g. connected by channel or within main channel)

This pilot study recommended that a more detailed investigation, taking into account the above recommendations, should be conducted to confirm the contribution of contaminants into waterways from springs.

## 4.0 Christchurch Hydrologic Setting

The three main rivers within the city of Christchurch are the Styx, Avon, and Heathcote Rivers. Along the north-western edge is the Otukaikino Stream, which discharges to the Waimakariri River and along the south-western edge of the city is the Halswell River which drains to Te Waihora Lake Ellesmere. All these rivers are spring-fed, with the three main urban rivers running through the most populated areas of the city, as shown in Appendix B, Figure 1.

The hydrogeological setting of Christchurch consists of alluvial deposits (termed the Springston formation (spy)) occurring across the west of the city extending down from the Canterbury plains; and marine, swamp and silt deposits occurring towards the east of the city (termed the Christchurch formation (ch)) (Cameron, S. G., 1993). The gravel strata that occur in the western areas of Christchurch form highly productive aquifers which extend eastwards towards the coast. However, the lower permeability strata that occur towards the eastern side of Christchurch form a confining layer overlaying these gravels, this confining layer becomes generally progressively thicker towards the east (Pattle Delamore Partners Limited, 2013). The location of the confining layer and the geological map are presented in Figure 2, Appendix B and shows where the lower permeability surface strata are more than 3 m thick. Underlying this confining layer is the uppermost part of the artesian aquifer system, known as the Riccarton Gravels. This is the first of a layered sequence of gravel aquifers from which Christchurch gains its water supply. The confining layer comprises generally fine grained strata which confines the Riccarton gravel aquifer, however within this confining layer there can be localised seams or lenses of gravels that can provide a permeable pathway for shallow groundwater flow. An example of this pattern of strata is shown by the driller's log of bore M35/1646, with the Riccarton gravels occurring at a depth below 18.3 m bgl. This bore log can be found in Appendix D.

Natural groundwater discharge in Christchurch is mostly provided from two different mechanisms; seepage through streambed gravels entering a river system, which generally occur outside the confining layer; or through artesian spring discharge, which generally occur in areas underlain by the confining layer. Seepage of groundwater will generally occur through the bed of a surface waterway wherever groundwater pressures are higher than the stream bed level. The occurrence of springs represents a discrete concentration of this seepage. In the unconfined aquifers at the western headwaters of Christchurch urban waterways, groundwater seepage through streambed gravels occurs where the stream channel intersects the water bearing gravels. Further east, artesian springs occur where a confining layer is located above a water-bearing aquifer, with a hydraulic head greater than ground or streambed level. This pressurised groundwater forms natural pipes through weak points in the confining layer, and discharge via spring vents. Artesian spring water is thought to flow from both the water-table aquifer and the uppermost confined aquifer (Cameron, 1993).

Artesian spring flow is dependent on a number of hydrologic and geologic factors. These include the amount and frequency of water inflow, the hydraulic conductivity of the aquifer, the water pressures within the aquifer, and the hydraulic gradient. To a lesser degree, influences outside the aquifer such as atmospheric pressure systems and ocean tides will also influence the performance of an artesian spring system by altering aquifer pressures (Smith, 2003). Formation of an artesian spring will occur when aquifer pressures reach and exceed ground or streambed level at a point where localised weaknesses in the overlying confining layer allows groundwater to move to the surface. As the confining layer within Christchurch is typically made up of fine-grained sediments, when groundwater moves upwards through this layer under pressure surface, erosion and fluid transportation of the confining layer material can occur. Over time this erosion will increase the spring size and discharge rate until the spring system reaches equilibrium. This effect can lead to “swarms” of spring vents occurring, especially in areas where the confining layer is thin, or the spring may remain as one large vent, as is often the case when thick confining layers are present (Smith, 2003).

In addition to natural groundwater recharge into these waterways, there are other anthropogenic and natural recharges into waterways, such as:

- Stormwater discharges, including agricultural and urban runoff
- Industrial discharges, i.e. dewatering water, air conditioning water etc.

Typically these discharges will either be derived from stormwater generation i.e. rainfall on the relevant catchment, or from abstracted bore water used for industrial purposes.

## 5.0 Sampling Approach

It was been decided that the best way to initiate the detailed study was to identify a suitable river reach that experiences elevated nitrogen concentrations in the headwaters under baseflow conditions and receives inflows from a combination of discrete high flow vents and general diffuse streambed seepage. Then carry out an initial sampling survey of this specific reach. This sampling survey would consist of measurements of both the quantity and quality of the inflows to compare the relative contributions of nitrogen and flow from spring vents and diffuse streambed seepage. The results from this initial indicative survey will then be evaluated to determine the applicability of the survey method across a wider range of Christchurch springfed streams. The initial steps in developing the sampling approach are detailed below.

### 5.1 Defining the Survey

The aim of this survey is to define the water quality of instream springs, and how this influences stream water quality, with specific regard to nutrient and other contaminant concentrations. In order to achieve this aim, a suitably affected urban waterway reach, experiencing elevated nutrient concentrations under baseflow conditions was required to be identified and sampled. The suitable reach was identified through conducting a review of the CCC surface water quality data and sampling locations, and Environment Canterbury (ECan) flow information, and comparing flow related patterns and nutrient concentrations. The location of CCC surface water sampling points and flow recorders is shown in

Appendix B, Figure 3. This information was then compared to the nutrient concentrations in shallow groundwater wells located in the areas adjacent to the waterway reaches.

The location of recorded spring vents within these urban waterway reaches, identified in CCC and ECan databases are shown in Figure 4, Appendix B. Based on this information, a preferred set of reaches for the initial sampling survey were identified that fulfilled the following characteristics:

- High nitrogen concentrations in surface water under baseflow conditions,
- High nitrogen in groundwater in the general upstream area,
- Contrasting inflow pattern with some discrete high flow vents as well as areas of general diffuse streambed seepage.

## 5.2 Selection Process of Initial Survey Reaches

As a first selection step, all CCC surface water quality sites at the uppermost reach of the waterways were included and the rest of sites were excluded from the dataset. The selected subset of headwater sites were then analysed to identify reaches experiencing elevated nutrient concentrations (Table 1, Appendix C).

The sites were then ranked according to a general nutrient enrichment classification for Canterbury waterways, as shown in Table 1 (Stevenson et al 2010).

Table 1: General Nutrient Enrichment Classification for Canterbury Waterways

| Dissolved Inorganic Nitrogen (mg/L) | Key | Dissolved Reactive Phosphorus (mg/L) |
|---|---|---|
| > 2 | Excessive | > 0.03 |
| 0.44 - 2 | Enriched | 0.009 - 0.03 |
| 0.17 - 0.44 | Moderately enriched | 0.003 - 0.009 |
| 0.03 - 0.17 | Low Level Enrichment | |
| < 0.03 | Unenriched | <0.003 |

All available flow information was obtained for the Christchurch region from ECan and reviewed in order to establish flow related patterns compared to nutrient concentrations. Flow recordings from automatic flow gauging stations provided the most appropriate data, although located lower down in selected stream reaches, flow data was extrapolated to provide an indication of flow condition upstream. The selected surface water quality sites were then ranked based on baseline flows and relationships with nutrient concentrations, and also reviewed against recorded spring vents in the relevant reach.

The selected CCC high nutrient stream reaches were then compared to the general pattern of surrounding groundwater nutrient concentrations, as shown in Figure 5, Appendix B.

Final selection was made based on analysis of the available information described above.

### 5.2.1 Summary of Suitable Reaches

Results presented below are based on the following summarised selection criteria:

- Good quality information of high nitrogen concentrations in surface water under baseflow conditions;
- Good quality information of high nitrogen in groundwater in the general upstream area; and
- Existence of upper catchment spring vents;

Upper Avon Catchment

Selected Reaches: Waimairi Stream and Wairarapa River (Table 1, Appendix C).

The Upper Avon Catchment is considered the preferred area for a more detailed investigation. Nutrient concentrations in the Upper Avon Catchment are considered excessive (Table 1), and although not at high as in the Upper Heathcote Catchment, nutrient concentrations appeared to be more stable under baseflow conditions (Figure 6). The CCC site on the Avon River at Mona Vale which is below the confluence of the Waimairi and Wairarapa River had elevated nutrient concentrations, suggesting additional sources. Several known springs have been identified along the Okeover Stream and are a source of nutrient contribution observed at Mona Vale. Furthermore, eleven springs were identified in the upper Waimairi Stream and twelve in the upper Wairarapa Stream. Three long-term shallow wells in the upper catchment were also identified, all of which provided good water quality information and showed elevated nitrogen concentrations.

Upper Heathcote Catchment

Selected Reach: Heathcote River at Templetons Road to Curletts (Table 1, Appendix C).

The Upper Heathcote Catchment was considered the next most suitable area for investigation. Although nutrient, primarily nitrogen concentrations were very elevated, they were not considered stable and were shown to fluctuate at baseline flows (Figure 6, Appendix B). Available information suggests springs are located between CCC sites Templeton Road (HEATH08) and Curletts Road (HEATH10), rather than in the upper catchment like the Avon. One long-term monitoring shallow well was identified in the upper catchment which displayed highly elevated nitrogen concentrations (> 4 mg/L).

Upper Halswell Catchment

Not considered appropriate for the next stage of investigation. Although high nitrogen concentrations, suitable supporting information was limited.

Upper Styx Catchment

Not considered appropriate for the next stage of investigation, low nutrient concentrations.

Otukaikino Catchment

Not considered appropriate for the next stage of investigation, low nutrient concentrations.

## 5.3 Summary

In summary, it has been determined that a more detailed field survey should be conducted in the Upper Avon Catchment, primarily the Waimairi Stream and Wairarapa Stream. The Okeover stream which confluences above Avon River at Mona Vale, is also considered appropriate should the next stage of investigation be expanded.

# 6.0 Sampling

Figure 6, Appendix B, indicates that seasonal high nitrate concentrations typically occur in the summer/autumn low flow months, further to this the effects of elevated nitrates in the river system are likely to be more significant during these times of low flow. Therefore, summer/autumn was considered to be the most important period to determine nitrate sources. However, as the groundwater pressure will typically be low during this period, some springs will not be active during this period. Therefore, it was proposed to carry out two sampling rounds, one in spring, when spring flow should be at its highest and late summer when instream nitrate levels are typically highest.

Water samples were analysed for nitrate-N, nitrite-N, ammonia-N, total kjeldahl nitrogen (TKN), total nitrogen, dissolved reactive phosphorus (DRP), chloride, calcium and magnesium. Field measurements of pH, electrical conductivity and temperature were made.

## 6.1 Initial Spring Inspection

The first step of the sampling survey was undertaking the initial walkover of the two stream reaches. This walkover was undertaken in June 2014 to identify vent locations (qualitatively assessing their size and relative flow contribution), and to determine the most suitable location for flow gaugings, surface water sampling and seepage meter and mini-piezometer measurements.

Both Wairarapa and Waimairi Streams were inspected from their western headwaters through to Mona Vale. A number of discrete spring vents were observed and their locations are plotted in Figures 7 and 8, Appendix B.

Table 1, Appendix C, describes the observations from the springs. The main areas of spring locations can be identified as:

Waimairi Stream (Figure 7)

- two upstream springs (#10 & 11) near the south-east corner of Burnside Park;
- A large cluster of springs (#2-9) upstream of Greers Road;
- an isolated small spring (#1) up stream of Ilam Road; and
- four distributed springs along Fendalton Drain, near Mona Vale.

Wairarapa Stream (Figure 8)

- a large cluster of springs between Greers Road and Jellie Park (#3-11); and
- a discrete spring in the lower reaches of Wairarapa Stream (#1).

There have been no discrete springs identified in the reaches between these main groupings. It is noted that the Wairarapa Spring 2 located on a tributary of the Wairarapa Stream actually appears to be a cooling water discharge from the Jellie Park recreational complex.

Based on the observation made during the initial stream walkovers, the streams were split up into discrete sections to identify the different contributions and effects of inflows from tributaries, zones of spring vents and reaches of general streambed seepage. The flow gauging and seep sampling points were selected based on identifying these contributions, and are shown in Appendix B, Figures 9 and 10, for the Waimairi and Wairarapa Streams respectively. Table 2 lists and describes the different zones of contribution identified in these waterways, as well as the relevant sampling points from within these zones. These contributing zones are also shown in Appendix B, Figure 11.

Table 2: Contributing Zones for Waimairi and Wairarapa Streams

| Section Name | Notes | Sampling Points within this Zone |
|---|---|---|
| Waimairi Tributary 1 (Upper) | | Not sampled as no flow encountered during either sampling round |
| Waimairi Spring Zone 1 | | Not sampled as no flow encountered either during sampling round |
| Waimairi Spring Zone 2 | | WaimSM3, WaimFG4 |
| Waimairi Spring Zone 3 | | WaimSM4, WaimFG5 |
| Waimairi Tributary 2 | Waimairi true-right tributary | WaimFG6 |
| Waimairi Seepage Zone 1 | | WaimFG7 |
| Waimairi Seepage Zone 2 | | WaimSM5,WaimFG9 |
| Waimairi Tributary 3 | Fendalton Drain | WaimSM6, WaimFG9 |
| Wairarapa Spring Zone 1 | | WairSM1, WairSM2, WairFG2 |
| Wairarapa Tributary 1 | Jellie Park Cooling water Discharge | WairFG3 |
| Wairarapa Seepage Zone 1 | | WairSM3, WairFG5, WairFG6 |
| Wairarapa Tributary 2 | Wai-iti Stream | |
| Wairarapa Seepage Zone 2 | | WairSM4, WairFG7a |
| Wairarapa Spring Zone 2 | | WairSM5, WairFG7b |

## 6.2 Sampling Plan

Based on the discrete springs identified during the initial spring inspection, a sampling plan was developed, in order to assess the relative flow and nutrient inputs from springs and general streambed seepage for both the Waimairi and Wairarapa Streams. This assessment was carried out by upstream-downstream comparisons and by discrete sampling of streambed seepage and spring vents, specifically utilising the following measurements:

### Streamflow Gauging and Sampling of Streamflow

Streamflow gaugings are undertaken to provide a measure of the change in flow. Sampling at these locations also provides a measure of the change in nutrient content. The monitoring sites are selected to provide a comparison between the contribution from areas where springs occur and areas where general streambed seepage occurs, as well as incoming stream tributaries.

### Discrete Sampling of Streambed Seepage and Spring Vents

In between the gauging points, discrete monitoring of flow through the streambed, both general streambed seepage and selected spring vents was undertaken. This was achieved by:

- seepage meters, which allow the measurement of groundwater seepage rates and the collection of samples of that seepage for laboratory analysis.
- mini-piezometers, which allow measurements of the groundwater pressure that drive the seepage inflow and, when combined with the seepage meter readings, allows the hydraulic conductivity of the streambed to be determined.

## 6.3 Sampling Equipment

Specific sampling equipment and procedures were required to be developed for this sampling. These are explained in detail below.

### 6.3.1 Streamflow Gauging and Sampling of Streamflow

Flow gauging measurements were made using a hand held Acoustic Doppler Velocimeter (Flow Tracker) across a transect of the stream where there was little turbulence and also parallel banks. PDP flow gauging procedures were followed, which have been developed in accordance to the National Environmental Monitoring Standard (NEMS): Open Channel Flow Measurement (June 2013). Specifically the one-point method was used, this involves velocity observations at 0.6 of the depth below the surface. The observed value at this point is taken as the mean velocity in the vertical. A minimum of 22 verticals (measuring points across the stream) were taken on all channels, where the total width was greater than 1 m.

### 6.3.2 Discrete Sampling of Streambed Seepage and Spring Vents

Seepage Meters

Seepage meters allow for the measurement of groundwater seepage rates and the collection of samples of that seepage for laboratory analysis. As this is not standard sampling equipment, specific seepage meters had to be made up. Separate seepage meters were required to be developed to sample the streambed seepage and spring vents.

The seepage meter developed to sample from the spring vents was required to be able to handle large flows (up to 5 L/s) and be of sufficient size to fully encompass a spring vent and create a secure seal with the streambed substrate. The seepage sampler that was developed is shown in Figure 12a, Appendix B, and has a diameter of 0.565 m.

The seepage meter developed for sampling of the general streambed seeps consisted of a smaller seepage meter attached to a sealed sanitary sampling bag. This allows for any water seeping through the general streambeds to collect in the sampling bag. A picture of this meter is shown in Figure 12b, Appendix B and has a diameter of 0.23 m.

Mini-Piezometers

Mini-Piezometers allow for the measurement of the groundwater pressure that drives the seepage inflow. Two varieties of temporary piezometers were used to conduct these measurements. One large metal slotted piezometer (40 mm diameter, screen height of 300 mm), which is able to be hammered into the streambed substrate, this is shown in the field in Figure 13, Appendix B. And a smaller slotted screen (10 mm diameter, screen height of 42 mm) which connects to a thin piece of tubing, this device is typically used for soil gas sampling.

## 6.4 Field observations

A variety of sampling equipment was required to be taken to each sampling location as each sampling site was unique and the most suitable sampling method varied. The methods described above, were used where applicable, as 'best practice'. However due to specific site constraints, these methods were not able to be used at every site. Some of the issues arising and ultimate sampling method are explained below.

Spring Vent Seepage meter

Some of the streambed substrate encountered at the sampling sites was not suitable to create a secure seal with the seepage meter. This was addressed by creating a more secure seal by packing bentonite around the outside of the meter. If this was unsuccessful, then an alternative method of isolating spring flow, as described below, was used.

Springs flow under artesian pressure and emerge through weak points of a confining layer, typically through 'the path of least resistance'. The process of placing the seepage meter over top of a spring vent and forcing water out of the outflow pipe, increases the resistance associated with a vent, therefore a new 'path of least resistance' can form and a new spring vent can emerge adjacent to the original vent.

This was a typical response at many of the sampled springs. There were two options to address this issue, either increase the outlet pipe on the seepage meter which was difficult to accomplish in the field, or isolate the spring vent flow using an open ended pipe (infiltration ring). This alternative method of isolating spring flow was used for a large number of springs. This pipe section was hammered into the stream bed substrate surrounding the vent and left to self-purge for an extended period of time. Sampling was taken from the centre of the pipe section after a sufficient purging volume had been discharged. This method also allowed us to visually gauge the pressure of the spring water by comparing the difference in head levels between the spring vent and surrounding water level. Several techniques were used to try and assess the flow rate of the specific vent using this method, the pipe section was either tilted and the emerging flow was captured in a bucket and timed to estimate flow rate, or a pump was inserted into the pipe section and pump water out to reduce the flow rate to the ambient pressure level (stream water level), this was difficult to achieve as the flow rates of the spring were higher than the flow rate of the available pumps. Furthermore by modifying the head of the spring vent, by increasing the outlet height using the pipe section, the flow rate values obtained were considered a very rough estimate. However as spring vents were typically located in zones, the flow rate of an individual vent was not considered as important for assessing the inflow compared to the result of springs through the entire zone, which was accounted for using the flow gauger. Flow rates for individual spring vents were not estimated for the second round of the survey due to the issues identified above.

General Streambed Seepage Meter

The observed flow rates in the general streambed seepage meter were very small 10 – 50 ml/hour; these flow rates were too small to collect sufficient volumes for the sample bottles. Leaving the flowmeters in the stream for longer duration, risked public tampering with the system. Therefore in order to collect a sample of groundwater that is entering the stream through general streambed seepage, the large metal slotted piezometer hammered into the streambed substrate in order to measure the pressure of the underlying groundwater, was used. Water was pumped from this piezometer at low flows for an extended period of time until approximately 3 well volumes were purged, according to PDP's groundwater sampling procedures, and this groundwater was sampled. It is considered that this water is representative of general streambed seepage as both of the streams are gaining streams, i.e. the piezometric pressure is positive in the groundwater underlying these streams. When this piezometer was installed bentonite was used to create a seal around the top of this pipe to avoid the flow of stream water down the casing.

The smaller slotted screen (10 mm diameter, screen height of 42 mm) which connected to a thin piece of tubing was not used during sampling. This method was also not used during the second round of sampling due to concerns regarding pumping water from below the stream changing the seepage water chemistry and also concerns over whether the stream water could be excluded from inflowing into the piezometer.

## 7.0 Results

Two sampling rounds were completed to align with the expected seasonal high and low groundwater levels. These were completed in September 2014 and March 2015.

## 7.1 September 2014 Sampling Round

The first sampling round of this project was undertaken between 8 and 12 September 2014, this coincided with the typical time of seasonal high groundwater levels. A figure displaying where field measurements were taken is shown in Figure 14, Appendix B. The upper most flow gauge point on the Wairarapa Spring (WAIRFG1) was not gauged or sampled, as there was no flow at this point and flow emerged at a spring vent at the upper end of the spring zone which contains WAIRSM1 and WAIRSM2. The upper three sampling points in the Waimairi Stream were also not sampled as the flow in this stream emerged below these points at the time of sampling, therefore results were not generated for Waimairi Tributary 1 (Upper) and Waimairi Spring Zone 1, as well. This is demonstrated through the flowrate gauged at WAIMFG3 which returned the very low flow rate of 1.3 L/s, indicating no substantial source of flow above this point.

The difference in the point of flow emergence indicates that the flow regime in the streams has varied between the time of the initial stream walkover (June 2014) and the sampling round (September 2014). Further to this, it was noted that during the initial stream walkover, a CCC drinking water well was being developed in the upper catchment of the Waimairi Stream which was discharging development water into the Waimairi Stream via a sediment pond. However this potential interference to the sampling survey was not occurring during the September 2014 (or March 2015) sampling period.

Tables displaying the field measurements and lab results for the sampling points are displayed in Figure 14, Appendix B, can be found in Table 3a, Appendix C. The result for each of the streams, in terms of contributing flow and water chemistry, are summarised below.

## 7.2 March 2015 Sampling Round

The second sampling round of this project was undertaken between 23 and 26 March 2015 which coincided with the typical time of seasonal low groundwater levels.

It was intended that the sampling points sampled in the September 2014 would be resampled, where possible, in the March 2015 sampling round. As there was significant reduction in flow between these two sampling rounds, many of these points could not be sampled. Additional samples were also undertaken in areas where analysis was limited in the first survey, especially where tributaries enter the main flow of the Wairarapa and Waimairi Streams. The location of the field measurements taken in this sampling round are shown in Figure 15, Appendix B.

Tables displaying the field measurements and lab results for the sampling points displayed in Figure 15, Appendix B, can be found in Table 3b, Appendix C. The result for each of the streams, in terms of contributing flow and water chemistry, are summarised below.

# 8.0 Flow Results

As the sampling results consisted of a combination of flow gauging points, instream samples, general streambed seepage meters and spring vent measurements, an initial review of the flow gauging data was conducted to determine the pattern in flow rates, and also the flow generated in the separate contributing zones.

## 8.1 Waimairi Stream

### 8.1.1 Flow Gaugings

The flowrate gauged along the Waimairi Stream in the September 2014 and March 2015 sampling round are plotted in Appendix B, Figure 16. This plot shows that the Waimairi Stream is gaining flow with distance downstream from the uppermost sampling point. Two flow gauging points on the Waimairi Stream in the September 2014 round, included on the plots, are composite results. This was due to sampling and gauging of tributaries, instead of the main flow. These composites are summarised below in Table 3. The gauging points were adjusted in the March 2015 round to avoid requiring composite points.

Table 3: Composite Monitoring Points

| Name | Details | Calculations |
|---|---|---|
| WAIMFG6a | Represents the main flow downstream of where the tributary sampled in WAIMFG6 enters the Waimairi Stream. | WAIMFG5 + WAIMFG6 |
| WAIMFG10 | Represents the main flow downstream of the confluence of Fendalton Drain and Waimairi Stream. | WAIMFG8 + WAIMFG9 |

A summary of the flowrate results is shown in Table 4 below. Based on these results, the contributing flow from the two tributaries that entered the Waimairi Stream has been estimated. The main tributary entering Waimairi Stream is the Waimairi Stream true right branch, which enters the main flow at Barlow St. This tributary was gauged (WAIMFG6) and contributed 93.1 L/s to the main flow in the September 2014 sampling round and 5.3 L/s in the March sampling round. The Fendalton Drain enters the Waimairi Stream near Mona Vale and was gauged (WAIMFG8) to contribute 55.6 L/s in the September 2014 sampling round. Instead of gauging point WAIMFG8 again in the March 2015 sampling round, the main Waimairi Stream flow was gauged upstream (WAIMFG9) and downstream (WAIMFG8A), the difference in flows between theses points, and therefore the March 2015 flow of the Fendalton Drain, was 40 L/s.

Table 4: Waimairi Flow Gauging points

| Full Name | Description | Chainage[1] | September 2014 | | March 2015 | |
|---|---|---|---|---|---|---|
| | | | Stream Flow (L/s) | Rate of Flow Increase (L/s/m) | Stream Flow (L/s) | Rate of Flow Increase (L/s/m) |
| WAIM FG3 | Flow emergence | 0 | 1.30 | - | - | - |
| WAIM FG4 | D/S end of Spring Zone 2 | 307 | 69.80 | 0.223 | - | - |
| WAIM FG5 | Midpoint of Seepage Zone 1 | 868 | 74.70 | 0.009 | - | - |
| WAIM FG6a (composite) | D/S of the confluence of Waimairi Stream is the Waimairi Stream true right branch | 1,500 | 167.80 | - | - | - |
| WAIM FG6B | Non-composite sample of WAIMFG6a | 1500 | | | 8.3 | |
| WAIM FG7 | D/S end of Seepage Zone 2 | 2,195 | 199.40 | 0.045 | 8.3 | 0 |
| WAIM FG9 | D/S end of Seepage Zone 3 | 3,552 | 412.50 | 0.157 | 189 | 0.133 |
| WAIM FG10 (composite) | D/S of confluence of Waimairi and Fendalton Drain. | 3,572 | 468.10 | - | - | - |
| WAIM FG8A | Non-composite sample of WAIMFG10. | 3,572 | 468.10 | - | 229 | - |

1. *m from highest sampling point*

The comparative calculations of the rate of flow increase between gauging points shows that the greatest rate of increase in the September 2014 sampling round occurs at the main spring inflow zone (between WAIMFG3 and FG4) where springs 2 – 9 occur. During the March 2015 sampling round there was no flow observed in this area of the stream. As observed in the September 2014 sampling round, downstream of that area there are few springs but the average rate of seepage increases in a downstream direction from 0.009 L/s/m to 0.157 L/s/m which coincide with higher groundwater pressures across the streambed, i.e. the upward hydraulic gradient from the underlying groundwater increases in a downstream direction. The rate of inflow in the area between WAIMFG7 and WAIMFG8 remained relatively consistent across both sampling rounds. This indicates that groundwater pressures remain relatively consistent across this area, and this section of the stream provides the majority of the baseflow to the stream in low flow conditions.

### 8.1.2 Seepage

Flow rates were also recorded from the seepage meters in the September 2014 sampling round, giving estimates of the flow from both the discrete spring vents and general streambed seepage. The flow rates recorded at the four seepage meter points in the Waimairi Stream are outlined in Table 5.

Table 5: Waimairi Seepage Meter points – September 2014

| Sampling Point | Chainage (m from highest flow gauge point) | Type of Seep | Seep Flow (L/s/m$^2$) |
|---|---|---|---|
| WAIMSM3 | 252 | Vent | 8.13 |
| WAIMSM4 | 1,447 | General Streambed | 2.64E-04 |
| WAIMSM5 | 2,429 | General Streambed | 2.06E-04 |
| WAIMSM6 | 3,552 | Vent | 4.23 |

Whilst these measurements give an indication of the relative seepage differences between spring vents and general streambed seepage, the requirement to impede the natural flow when making the seepage measurements, as described in Section 3.2, ultimately underestimate the true flow. Due to the inconsistencies and highlighted issues with this method, measurements of the seepage flow rates from the seepage meters was not undertaken in the March 2015 sampling round.

The flow rate attributed to each of the contributing zones in the Waimairi Stream, as described in Table 2 and Figure 11 (Appendix B), for both sampling rounds is shown in Figure 17 (Appendix B). For the September 2014 round this figure shows a rapid increase in flow in Spring Zone 2, in the March sampling round there was no flow present in this section of the stream. There is very little change in streambed flow in Spring Zone 3 in either sampling round, but then a progressive increase in streambed inflow is shown as the upward groundwater gradient increases in a downstream direction from Spring Zone 3, to Seepage Zone 1, to Seepage Zone 2 in the September sampling round. It is worth noting that Spring Zone 3 only has one identified spring within its reach, and it is expected that the large number of spring inflows from Spring Zone 2 will lessen the groundwater pressures (and gradient across the streambed) for the area immediately downstream (i.e. Spring Zone 3). In the March sampling round there was no observed flow increase in Seepage Zone 1, however there was a substantial increase in streambed inflow in Seepage Zone 2, similar to the September sampling round, this indicates that groundwater inflow remains relatively constant in this section of the stream and this section provides the majority of the baseflow in low flow conditions.

### 8.1.3 Waimairi Streambed Hydraulic Conductivity

During the seepage measurements, the hydraulic head of the seepage was recorded. These measurements, relative to the water level in the stream, at that measurement point are provided in Table 6 below.

Table 6: Relative head levels of seepage in Waimairi Stream – September 2014

| Section | Type of Seep | Seepage Head (m above or below stream water level) |
|---|---|---|
| WAIMSM3 | Vent | 0.063 |
| WAIMSM4 | General Streambed | -0.034 |
| WAIMSM5 | General Streambed | -0.087 |
| WAIMSM6 | Vent | 0.075 |

The hydraulic conductivity of the substrate underlying the stream can be estimated using Darcy's equation for hydraulic conductivity, as shown below:

$$\Delta Q = -KiA$$

Where $\Delta Q$ is the change in flow across a section of streambed; K is the hydraulic conductivity of the section of streambed across which the change of flow occurs; $i$ is the hydraulic gradient across the section of streambed; and A is the area of streambed across which the change of flow occurs.

As shown in Table 6, there is a negative (downwards) hydraulic gradient at the two general streambed seepage points, which may indicate that the relatively low permeability sediments into which the piezometer was driven had not reached equilibrium, or it indicates that this is a losing reach of the stream at the measuring point, and that the streambed seepage which accounts for the observed increase in flow within the overall seepage zone, must occur elsewhere within the overall gaining reach.

The hydraulic gradient for the two spring zones is uncertain because whilst the water pressure at the vent can be measured, the depth from which this higher pressure originates from is unknown. However, as an indicative calculation, it has been assumed that the measured head represents a difference occurring over a 3 m distance. The calculation values are summarised below in Table 7.

Table 7: Hydraulic Conductivity in Waimairi Seepage Zones – September 2014

| Section | Length of Section (m) | Area[1] ($m^2$) | Depth below streambed of seepage head measurement (m) | Hydraulic Gradient | Flow increase ($m^3/s$) | Hydraulic Conductivity (m/day) |
|---|---|---|---|---|---|---|
| Waimairi Spring Zone 2 (WaimSM3) | 307 | 921 | 3[2] | 0.021 | 0.0698 | 312 |
| Waimairi Spring Zone 3 (WaimSM6) | 498 | 1494 | 3[2] | 0.025 | 0.0556 | 129 |

1. *This value was calculated assuming a standard stream width of 3 m*
2. *This is an arbitrarily assumed depth from which the hydraulic head of the vent originates*

In reality, the hydraulic conductivity in the spring zones is a combination of higher inflows through the vents and lower inflows through the general streambed, so the hydraulic conductivity of the vents may be even greater than the values indicated in Table 7. These calculations were not carried out for the March 2015 sampling round.

## 8.2 Wairarapa Stream

### 8.2.1 Flow Gaugings

The flowrates measured at the flow gauging points along the Wairarapa Stream in the September 2014 and March 2015 sampling rounds are plotted in Figure 18, Appendix B. This plot shows that the Wairarapa Stream is also gaining flow with distance downstream from the uppermost sampling point. The location of tributaries, and their estimated flow, is also indicated on this plot. A summary of these results is shown in Table 8 below.

Table 8: Wairarapa Flow Gauging points

| Full Name | Description | Chainage[1] | September 2014 |  | March 2015 |  |
|---|---|---|---|---|---|---|
|  |  |  | Stream Flow (L/s) | Rate of Flow Increase (L/s/m) | Stream Flow (L/s) | Rate of Flow Increase (L/s/m) |
| WAIR FG2 | D/S of Spring Zone 1 | 291 | 45.50 | 0.156 | 2.10 | 0.007 |
| WAIR FG4 | D/S of Wairarapa Stream and Jellie Park tributary confluence. Midpoint of Seepage Zone 1 | 381 | 129.20 | 0.609[1] | 49.10 |  |
| WAIR FG5 | D/S of Seepage Zone 1 | 1,052 | 177.90 | 0.073 | 47.60 | 0.008 |
| WAIR FG6 | D/S of Wairarapa Stream and Wai-iti Stream confluence | 1,093 | 218.50 | - | 60.60 | -0.037 |
| WAIR FG7A | D/S of Seepage Zone 2 | 2,475 | 228.30 | 0.007 | 77.80 | 0.009 |
| WAIR FG7B | D/S of Spring Zone 2 | 2,632 | 257.60 | 0.186 | 114.20 | 0.110 |
| WAIR FG9A |  | 3432 |  |  | 207.40 | 0.046 |
| WAIR FG9B |  | 3482 |  |  | 256.80 |  |
| WAIR FG8 | D/S of Seepage Zone 3 | 4,448 | 576.90 | 0.176[2] | 355.00 | 0.051 |

1. *This value has been calculated excluding the 35 L/s that the Jellie Park Tributary contributes to the stream (WairFG3)*
2. *This value is possibly affected by the inflow of Taylors Drain*

Based on the flow gauging results, the contributing flow from three tributaries entering the Wairarapa Stream, the inflow from Jellie Park cooling water discharge and the Wai-iti Stream, has been estimated. The inflow from Jellie park cooling water discharge was gauged in WAIRFG3 and contributed 35.0 L/s to the main flow in the September 2014 sampling round and 41.2 L/s in the March 2015, although these gaugings were not completed to full QA/QC procedures due to the weir design and may have underestimated the flowrate of this tributary. Therefore the flow result, and the rate of flow increase at WAIRFG4, may not be reliable.

The Wai-iti Stream was estimated, by calculating the difference between the gauging results for WAIRFG6 and WAIRFG5, to be 40.6 L/s for the September sampling round and 13 L/s for the March 2015 sampling round. The inflow from Taylors Drain, which enters the Wairarapa Stream between WAIRFG7b and WAIRFG8, was not estimated due to the limited sampling that occurred in the adjacent region in the September 2014 sampling round. As a result of the unknown inflow of Taylors Drain, additional flow gaugings were undertaken in the March 2015 sampling round in the area to define the exact inflow from Taylors Drain. This inflow was estimated, by calculating the difference between the gauging results for WAIRFG9A and WAIRFG9B, to be 49.4 L/s for the September sampling round.

The rate of flow increase indicates that the two spring vent zones upstream of the WAIRFG2 and WAIRFG7A both have high inflow rates compared to the general streambed seepage zones upstream of WAIRFG5 and WAIRFG7A in the September 2014 sampling round. The spring vent zone upstream of WAIRFG7A also had a high inflow rate compared to the other seepage zones. As with the Waimairi Stream the most downstream seepage zone also indicates a higher seepage rate, which is perhaps indicative of higher upward groundwater gradients at the more downstream locations. The influence of Taylors Drain can be observed in the March 2015 flow gauging plot, if a similar relationship occurred in the September 2014 round, this indicates that noted increase between WAIRFG7B and WAIRFG8 is dominated by the inflow from streambed seepage, as opposed to the inflow from Taylors Drain.

### 8.2.2 Seepage

As with the Waimairi Stream, flow rates were also recorded from the seepage meters in the September 2014 sampling round, giving estimates of the flow from both the discrete spring vents and general streambed seepage. These measurements were carried out at six sites in the Wairarapa Streams, as outlined in Table 9. These measurements were not carried out for the March 2015 sampling round.

Table 9: Wairarapa Seepage Meter points – September 2014

| Sampling Point | Chainage (m from highest flow gauge point) | Type of Seep | Seep Flow (L/s/m$^2$) |
|---|---|---|---|
| WAIRSM1 | 0 | Vent | 3.25 |
| WAIRSM2 | 132 | Vent | 4.23 |
| WAIR SM3 | 857 | General Streambed | 2.65E-04 |
| WAIR SM4 | 1581 | General Streambed | 4.01E-04 |
| WAIR SM5 | 2511 | Vent | 4.88 |
| WAIR SM6 | 2957 | General Streambed | 1.00E-04 |
| WAIRSM1 | 0 | Vent | 3.25 |

As noted for Waimairi Stream, these measurements provide a comparative measure between vents and general streambed seepage although in both cases they are expected to underestimate the full inflow rates.

Figure 19 shows the flow pattern for the different stream segments shown in Figure 11 and summarised in Table 2 for both sampling rounds. It shows the highest rates of inflow in the two spring zones and in the downstream general seepage zones in the September 2014 sampling round, where upwards hydraulic pressures will be the greatest. In the March 2015 sampling round, the contributing zones in the upper section of the stream reduce, due to the lower hydraulic pressures, and the flow of the stream is dominated by the Jellie Park discharge water, Spring Zone 2 and the bottom Seepage zone.

### 8.2.3 Wairarapa Streambed Hydraulic Conductivity

As for the Waimairi Stream, the hydraulic head of the seepage in the Wairarapa Stream was recorded during the seepage measurements in the September 2014 sampling round. These measurements, relative to the water level in the stream at that measurement point, are provided in Table 10 below.

Table 10: Relative head levels of seepage in Wairarapa Stream – September 2014

| Section | Type of Seep | Seepage Head (m above or below stream water level) |
|---|---|---|
| WAIRSM1 | Vent | 0.105 |
| WAIRSM2 | Vent | 0.050 |
| WAIRSM3 | General Streambed | -0.002 |
| WAIRSM4 | General Streambed | 0.015 |
| WAIRSM5 | Vent | 0.055 |
| WAIRSM6 | General Streambed | -0.010 |

As shown in Table 10, there is a negative (downward) hydraulic gradient at two out of the three general streambed seepage points, which may indicate that the relatively low water level measurement in the piezometer had not reached equilibrium, or that these are losing reaches at the point of measurement and the streambed seepage which accounts for the observed increase in flows within the overall seepage zones must occur elsewhere in the reach. The seepage meter at WAIRSM4 however returned a positive (upward) hydraulic gradient, this allowed the hydraulic conductivity of the streambed in Wairarapa Seepage Zone 2 to be estimated using Darcy's equation. This equation and the relevant variables are detailed in Section 8.1.3.

The hydraulic conductivity and the relevant variables are displayed below in Table 11. The hydraulic gradient for the spring zones has also been calculated (assuming a distance of 3 m), as it is not known at what depth the artesian aquifer, which the spring is generated from, occurs.

Table 11: Hydraulic Conductivity in Wairarapa Seepage Zones – September 2014

| Section | Length of Section (m) | Area[1] ($m^2$) | Depth below streambed of seepage head measurement (m) | Hydraulic Gradient | Flow increase ($m^3$/s) | Hydraulic Conductivity (m/day) |
|---|---|---|---|---|---|---|
| Wairarapa Seepage Zone 2 (WairSM4) | 1420 | 4260 | 0.475 | 0.032 | 0.01 | 6.4 |
| Wairarapa Spring Zone 1 (WairSM1 and WairSM2) | 291 | 874 | 3[2] | 0.026 | 0.0455 | 174 |
| Wairarapa Spring Zone 2 (WairSM5) | 157 | 472 | 3[2] | 0.018 | 0.0293 | 292 |

1. *This value was calculated assuming a standard steam width of 3 m*
2. *This is an arbitrarily assumed depth from which the hydraulic head of the vent originates*

In reality, the hydraulic conductivity in the spring zones is a combination of higher inflows through the vents and lower inflows through the general streambed, so the hydraulic conductivity of the vents may be even greater than the values indicated in Table 11. Due to these limitations none of these calculations have been carried out for the March 2015 sampling round.

# 9.0 Water Chemistry Results

All of the flow gauging spring vents and general streambed seepage points had water samples taken. These samples were analysed for nitrate-N, nitrite-N, ammonia-N, TKN, total nitrogen, DRP, chloride, calcium and magnesium. Field measurements were also made for pH, electrical conductivity and temperature. The sampling results for the September 2014 sampling rounds are shown in Table 3a, and the March 2015 sampling round in Table 3b, Appendix C. The sampling results for each stream reach are summarised below.

## 9.1 Waimairi Stream

### 9.1.1 Concentrations

During the September 2014 sampling round, two samples were collected from spring vents (WAIMSM3 and WAIMSM6), two samples were taken from general streambed seepage (WAIMSM4 and WAIMSM5) and seven samples from the stream itself (WAIMFG3, WAIMFG4, WAIMFG5, WAIMFG7 and WAIMFG9, as well as the composite WAIMFG6a (composite) and WAIMFG10 (composite)). It was intended that during the March 2015 sampling round that all of the sampling points from the September 2014 round would be resampled, however due to the changes in flow characteristics between the two rounds, many of the points had no flow present and were not able to be sampled. Additional samples were also taken to avoid the requirement of composite samples.

During the March 2015 sampling round only one sample was collected from a spring vent (WAIMSM6), no samples were taken from general streambed seepage, and five samples from the stream itself (WAIMFG6, WAIMFG6B, WAIMFG7, WAIMFG9 and WAIMFG8A). Figures 20a – 22b (Appendix B) shows the relative concentrations for the following key indicator parameters for both sampling rounds:

- Chloride – a conservative component that migrates in an unimpeded manner through groundwater and surface water
- Total Nitrogen – one of the main nutrients that affects periphyton growth
- DRP – the other main nutrient affecting periphyton growth.

The chloride concentration in the Waimairi Stream (Figure 20a and Figure 20b) is seen to be relatively consistent in both sampling rounds, across the stream flow measurements upstream of WAIMFG7 (with an observed range of 11.0 – 14.0 mg/L). There is a corresponding reduction in the chloride concentration at the downstream sites and as the flow increases (downstream of WAIMFG9), where the concentration ranges from is 8.6 – 8.8 mg/L in the March 2015 sampling round and 10.6 – 11.0 mg/L in the September 2014 round. The chloride concentrations in WAIMSM6 are consistently low across both sampling rounds, returning concentration ranging from 8.2 – 9.0 mg/L. Therefore the reduction in chloride concentration in the stream flow may be attributed to the large inflow of groundwater below WAIMSM5 with low chloride concentrations similar to that measured in WAIMSM6.

The total nitrogen concentrations also vary across the stream length, with the concentrations lowest in the upper and lower flow gauge points in the September 2014 round. The total nitrogen measurements from the general stream bed seepage vary quite considerably, the two measured concentrations vary from 0.62 mg/L to 3.6 mg/L. Across both sampling rounds, the total nitrogen concentrations in stream flow drop as the streamflow increases after WAIMFG7. Furthermore the total Nitrogen concentrations are slightly lower in the March 2015 sampling round, which matches the change in chloride concentrations.

As shown in Figure 22a, the DRP concentrations in the September 2014 sampling round are dominated by the general streambed seepage WAIMSM4. This sampling point returned a concentration of 0.13 mg/L, which is significantly higher than the concentrations returned for the remainder of the measurements, which had concentrations varying from 0.0036 – 0.0070 mg/L. Excluding the WAIMSM4 measurement, the DRP concentrations in the March 2015 are considerably higher than the September 2014 round. The March 2015 round had DRP concentrations varying from 0.0084 – 0.0270 mg/L. Although, there is a notable reduction in DRP concentration downstream of WAIMFG7. This is especially notable in the spring vent sample WAIMSM6 which was sampled in both sampling rounds and returned a concentration of 0.0070 mg/L in the September 2014 round, compared to the 0.013 mg/L in March 2015. This indicates that the DRP concentrations in spring vents and stream flow increase during low flow conditions. These variable DRP concentrations at different locations (September 2014) and at times of low flow (March 2015) potentially relate to localised variations in redox conditions in streambed sediments, for example, more anoxic conditions in sediments at low flows and die-back of aquatic plants in autumn. A similar situation is reported in Fitzgerald et al (2015) who found elevated levels of soluble reactive phosphorus (SRP) in streambed areas where groundwater fluxes were lower and geochemically reduced conditions were present. They attribute these local streambed sediments as the likely source of the SRP.

In terms of the specific nitrogen species Figure 23a and 23b shows their relative contributions for each sampling round. As shown, the typical composition of nitrogen in the Waimairi Stream is dominated by nitrate-N, with a small amount of organic nitrogen present in the September 2014 sampling round, this organic nitrogen component appears to decrease with distance downstream. Very little organic nitrogen was observed in any of the sampling during the March 2015 round, where nitrate-N dominates heavily, even in the spring vent sample. The majority of the September 2014 results follow this typical pattern, with the exception of WAIMSM4 which had a low total nitrogen concentration (0.62 mg/L) and a very high ammonia-N concentration (0.59 mg/L). This high concentration may be a result of anaerobic digestion of organic nitrogen in the tight streambed sediments.

### 9.1.2 Flow Gauging Points

The mass flux (i.e. the total mass of contaminant contained in the flow per unit of time) was calculated for all of the flow gauging points in both rounds and is displayed in Table 4a and 4b, Appendix C. This mass flux was calculated by multiplying the concentration of the specific contaminant by the flowrate to calculate the mass (grams) of a particular chemical compound. Figures displaying the accumulating mass flux of nitrate-N, ammonia-N, total nitrogen, DRP, chloride, calcium and magnesium at each of the flow gauging points within the Waimairi Stream can be found in Figures 24a – 26b, Appendix B.

In general, the masses of the sampled compounds increase with distance downstream and with increasing flowrate, this indicates that the biological demand for these chemical compounds is less than the rate of input. The greatest mass flux occurs for calcium and chloride, on account of their higher concentration (Figure 24a and 24b). In both sampling rounds, the total nitrogen and nitrate-N value were very similar, with ammonia-N concentration being much lower. This indicates that the total nitrogen concentration is dominated by nitrate-N. Lower mass fluxes (Figure 26a and 26b) occur for ammonia-N and DRP. They show similar increases downstream, with the exception of ammonia-N which decreased between WaimFG4 and WaimFG5 in the September 2014 sampling round (Figure 26a), although this may be an artefact of measurement variability.

### 9.1.3 Contributing Zones

In order to determine the contribution of contaminants into the main flow from the separate flow inputs, general tributary, streambed seepage and discrete spring vents, the mass flux for each sampled contaminant has been calculated for each of the recharge zones described in Table 2. This contributing mass requires a concentration and flowrate in order to be calculated. The concentrations were either taken from the seepage sampling results where possible, or from the difference between two flow gauge points, calculated using the mass difference between an upstream and downstream flow gauge point. For the flow calculations, as noted earlier (Section 8.1.3), the flowrates recorded in the seepage meters during the September 2014 sampling round will often underestimate the actual seepage flow input, therefore the flow was calculated as the differences in flow between flow gauging points.

Furthermore, the concentrations returned from some of the seepage meter were also not used (WAIMSM4), instead the concentration was calculated as the difference in mass flux between two flow gauge points. This method was usually required where the concentration results of the seepage meters did not correlate with the observed change in mass between the flow gauge points, due to the localised characteristics of the seepage meter samples. These results are detailed in Table 3a and 3b in Appendix C, with columns detailing how each concentration and mass balances were calculated.

A plot comparing the total nitrogen mass from these calculated zones and the nitrogen mass from the flow gauging points for both sampling rounds are displayed in Figure 27a and 27b, Appendix B, and in general shows a good correlation between these calculated zones and flow gauging point data, especially in the March 2015 sampling round. It is noted that there is a discrepancy between the mass flux recorded at the flow gauge point (WAIMFG9, 2.9 mg/L) and the estimation of the accumulating nitrogen mass in Waimairi Seepage Zone 2 during the September 2014 sampling round, which is due to the WAIMSM5 nitrogen concentration (3.6 mg/L) being used to calculate the mass flux within this zone. The difference may be due to the nitrate-N dominating the total nitrogen in the March 2015 sampling round, compared to the September 2014 round, especially at the lower end of the stream. The seepage meter concentration either overestimates the overall general streambed seepage in this zone, or biological activity within the streambed reduces the nitrogen concentration within the seepage to the concentration observed in the streamflow. Figures displaying the mass flux of nitrate-N, ammonia-N, TKN, total nitrogen, DRP, chloride, calcium and magnesium for each of these zones during both sampling rounds can be found in Figures 28a – 30b, Appendix B.

All of the relationships observed are similar to those observed in Section 9.1.2, i.e. increasing mass in both streams with distance downstream. The main focus of analysing the results in this way was to gauge the relative contaminant contribution of the different zones to the total contaminant of these streams.

The total nitrogen mass in the Waimairi Stream shows varying inputs of nitrogen, with a large amount of nitrogen entering the stream through the main tributary of the Waimairi Stream.

The relative flow inputs and concentrations of each of these zones in the Waimairi Stream for a select set of contaminants are shown in Table 12 for both sampling rounds.

Table 12: Inputs from Waimairi Contributing Zones

| Full Name | Sampling Round | Flow (L/s) | Flow per unit Area (L/s/m) | Total Nitrogen (mg/L) | DIN (mg/L) | DRP (mg/L) |
|---|---|---|---|---|---|---|
| Waimairi Spring Zone 2 | Sept 2014 | 69.8 | 0.227[1] | 3.20 | 3.20 | 0.0040 |
| | March 2015 | - | - | - | - | - |
| Waimairi Spring Zone 3 | Sept 2014 | 4.9 | 0.004 | 3.00 | 2.9 | 0.0105 |
| | March 2015 | 3 | 0.003 | 2.09 | 2.09 | 0.02 |
| Waimairi Tributary 2 | Sept 2014 | 93.1 | - | 3.60 | 3.70 | 0.0037 |
| | March 2015 | 5.3 | - | 3.20 | 3.20 | 0.02 |
| Waimairi Seepage Zone 1 | Sept 2014 | 31.6 | 0.045 | 3.13 | 3.07 | 0.0200 |
| | March 2015 | 0 | 0 | - | - | - |
| Waimairi Seepage Zone 2 | Sept 2014 | 213.1 | 0.157 | 3.60 | 3.70 | 0.0036 |
| | March 2015 | 180.7 | 0.063 | 2.59 | 2.49 | 0.01 |
| Waimairi Tributary 3 | Sept 2014 | 55.6 | 0.119[2] | 2.40 | 2.30 | 0.0070 |
| | March 2015 | 40 | 0.086 | 2.5 | 2.5 | 0.013 |

1. *This section includes the 1.3 L/s recorded in WaimFG3.*
2. *This tributary, Fendalton Drain, had a length of 465.5 m from the where the flow emerges (vent sampled at WaimSM6), which corresponds to a rate of flow increase of 0.119 L/s/m.*

The estimated contribution of springs, individual tributaries and general seepage to the nutrients present for both sampling rounds in the stream has been estimated in Table 13. Note the Fendalton Drain has been included in the spring calculation section as its entire flow was generated via spring flow. There also is some discrepancy between the total mass at the final flow gauge point and the estimated total mass generated from the zones, this is as a result of estimating the spring and seepage concentrations using the measured seep results, and is possibly related to the biological and chemical processes between the flow gauge points.

Table 13: Estimated Inputs from Waimairi Contributing Zones

| Recharge Zone | Sampling Round | Flow (L/s & %) | | Total Nitrogen (g/s & %) | | DRP (g/s & %) | |
|---|---|---|---|---|---|---|---|
| Springs | Sept 2014 | 125.4 | 27% | 0.372 | 23% | 6.88E-04 | 28% |
| | March 2015 | 43.00 | 19% | 0.11 | 18% | 5.77E-04 | 27% |
| General Streambed Seepage | Sept 2014 | 249.6 | 53% | 0.881 | 55% | 1.45E-03 | 58% |
| | March 2015 | 180.7 | 79% | 0.468 | 79% | 1.43E-03 | 68% |
| Waimairi True-right Tributary | Sept 2014 | 93.1 | 20% | 0.335 | 21% | 3.44E-04 | 14% |
| | March 2015 | 5.3 | 2% | 0.017 | 3% | 1.01E-04 | 5% |
| Total Mass at downstream sampling point (WaimFG10/WAIMFG8A) | Sept 2014 | 468.1 | - | 1.302 | - | 2.65E-02 | - |
| | March 2015 | 229 | - | 0.60 | - | 2.98E-03 | - |

The results indicate that the relative contribution of nutrients from springs, and general streambed seepage, is closely correlated to the relative contributions of the flow on account of little significant variation in concentrations.

## 9.2 Wairarapa Stream

### 9.2.1 Concentrations

During the September 2014 sampling round within Wairarapa Stream, three samples were collected from spring vents (WAIRSM1, WAIRSM2 and WAIRSM5), three samples were taken from general streambed seepage (WAIRSM3, WAIRSM4 and WAIRSM6) and seven samples from the stream itself (WAIRFG2, WAIRFG4 WAIRFG5, WAIRFG6, WAIRFG7A, WAIRFG7B and WAIRFG8, as well as a sample out of the Jellie Park tributary (WAIRFG3). As with the Waimairi Stream, it was the intention to resample all of the sites sampled in the September 2014 round, however this was not possible due to the changes in flow between these two rounds. In the March 2015 sampling round, one spring vent and seepage meter sample were collected (WAIRSM6 and WAIRSM5 respectively). Nine samples from the stream itself (WAIRFG2, WAIRFG4 WAIRFG5, WAIRFG6, WAIRFG7A, WAIRFG7B, WAIRFG9A, WAIRFG9B and WAIRFG8, as well as a sample out of the Jellie Park tributary (WAIRFG3). Figures 31a – 33b shows the relative concentrations for the following key indicator parameters:

- Chloride – a conservative component that migrates in an unimpeded manner through groundwater and surface water
- Total Nitrogen – one of the main nutrients that affects periphyton growth
- DRP – the other main nutrient affecting periphyton growth.

The chloride concentration in the Wairarapa Steam (Figure 31a) is seen to be relatively consistent across the stream flow measurements (9.3 – 13.0 mg/L) during the September 2014 sampling round. There is more variation noted in the general streambed seepage measurements. Although no clear pattern is observed in this data. The chloride concentrations in the March 2015 round are noted as being generally lower than the September 2014 round. In the March 2015 sampling round there is a notable reduction in chloride concentration in the stream flow below WAIRFG7A. This area of decreasing concentration corresponds to an area where the flowrate rapidly increases and a zone of springs occurs. One of the springs in this zone, WAIRSM5, was sampled and had a correspondingly low chloride concentration, although the seepage meter result WAIRSM6 is relatively high. In the September 2014 sampling round the chloride concentration in WAIRSM5 was 9.8 mg/L compared to the March 2015 sampling round which had a concentration of 6.1 mg/L. This may reflect lower seasonal groundwater concentrations at times of lower groundwater levels due to less rainfall recharge during summer relative to the more constant input of low nutrient Waimakariri River seepage.

The total nitrogen concentrations are seen to be consistent across the stream length in the stream flow measurements. The concentrations are relatively consistent across the two sampling rounds, especially in terms of streambed seepage and spring vents. Although, the stream flow concentrations were noted as being slightly lower in the March 2015 sampling round. In both rounds the spring vent WAIRSM5 has the highest concentration of total nitrogen. The other interesting observation is the reduction in total nitrogen concentration between WAIRFG9A and WAIRFG9B, where Taylors Drain enters the Wairarapa Stream. This indicates that Taylors Drain has a low concentration of total nitrogen.

As shown in Figure 33a, the DRP concentrations in September 2014 sampling round are dominated by WAIRSM5, this sampling point returned a concentration of 0.092 mg/L, which is significantly higher than the concentrations returned for this round which had concentrations varying from 0.0015 – 0.0094 mg/L. WAIRSM5 did not have a correspondingly high concentration in the March 2015 sampling round, having a concentration of 0.0025 mg/L, which was consistent with the stream flow samples. This points to an influence from localised, but variable, streambed sediment conditions potentially affected by the build-up and flushing out of organic matter. In March 2015 it is noted that the DRP concentrations are lower upstream of WAIRFG7A where the samples all returned concentrations of 0.0015 mg/L, compared to downstream of WAIRFG7A where the concentrations varied from 0.026 – 0.028 mg/L, indicating greater DRP input and less plant uptake in the downstream direction at that time. As noted previously, these spatial and temporal changes in DRP concentrations are likely due to variable redox conditions in streambed sediments.

In terms of the specific nitrogen species, Figure 34a and Figure 34b shows their relative contributions. As shown, the typical composition of nitrogen in the Wairarapa Stream is heavily dominated by nitrate-N, with a small amount of organic nitrogen present. It is noted that in general, the general streambed seepage results had higher organic nitrogen components in the September 2014 sampling round. The organic nitrogen present in the stream appears to have dropped between the two sampling rounds, with very little organic nitrogen present in the March 2015 round, with the exception of the streambed seepage sample, WAIRSM6. In the September 2014 sampling round the furthest downstream stream flow sample was heavily dominated by organic nitrogen, and had increased percentages of ammonia-N and nitrite-N. This change in composition may be due to biological process in the stream, especially given the streams slow moving and heavily silted nature in this area which would likely be associated with a build-up of organic matter. This is discussed further in Section 5. The increased ammonia-N concentration may be a result of anaerobic digestion of organic nitrogen in the tight streambed sediments.

The dissolved inorganic nitrogen (DIN) results from the seepage meters can be compared to the range from the shallow groundwater monitoring well M35/2557 (17 m deep) plotted in Figure 5, Appendix B. The DIN concentrations in M35/2557 vary between 0.207 – 5.70 mg/L, with a median of 1.00 mg/L across 56 samples between 1987 and 2011. This range is in general agreement with the seepage meter results for DIN in the Wairarapa Stream for both rounds, which returned a range of 0.55 – 2.2 mg/L, with a median value of 1.4, across seven samples.

### 9.2.2 Flow Gauging Points

The mass flux for the flow gauging points in the Wairarapa Stream were calculated using the same method as the Waimairi Stream and is displayed in Table 4a and 4b, Appendix C. Figures displaying the mass flux of nitrate-N, ammonia-N, total nitrogen, DRP, chloride, calcium and magnesium at each of the monitoring points for both sampling rounds within the Wairarapa Stream can be found in Figures 35a – 37b, Appendix B.

The mass of total nitrogen is seen to increase in both streams with distance downstream in both sampling rounds. It was noted that in the September 2014 round that, while the total nitrogen increases with distance downstream, the nitrate-N mass decreases below WAIRFG7A and ammonia-N increases. This is expected to be due to organic matter in the streambed creating a reducing environment to increase the proportion of nitrogen in ammonia form relative to nitrate.

The mass of DRP, chloride, calcium and magnesium, typically showed very similar responses to the total nitrogen i.e. increasing mass in both streams with distance downstream.

### 9.2.3 Contributing Zones

The mass of specific contaminant contributed by the tributaries, general streambed seepage and discrete spring vents, was calculated for the Wairarapa Stream using the same method as the Waimairi Stream. As with the Waimairi Stream, some of the contributing zone concentrations have been calculated using the difference between the flow gauging points, as opposed to using the seepage meter results. This is due to the concentrations measured at the seepage meter points not corresponding to the observed differences noted between the flow gauging points. These results are presented in Table 3a and 3b in Appendix C, which includes the details of which flow and concentration information was used in the mass balance calculations.

A plot comparing the total nitrogen mass from these calculated zones and the nitrogen mass from the flows gauging points for both sampling rounds are displayed in Figure 38a and 38b, Appendix B, and in general shows a good correlation between these calculated zones and flow gauging point data.

Figures displaying the mass flux of nitrate-N, nitrite-N, ammonia-N, TKN, total nitrogen, DRP, chloride, calcium and magnesium for each of these zones and both sampling rounds can be found in Figures 39a – 41b, Appendix B.

All of the relationships observed are similar to those observed in Section 9.2.2 i.e. increasing mass in both streams with distance downstream. The main focus of analysing the results in this way was to gauge the relative contribution of the different zones to the contaminant and flow of these streams. This is able to be observed through the relative gradients of the sections of each plot. The sections of each plot which rise vertically indicate where tributaries enter the main flow.

The total nitrogen mass in the Wairarapa Stream is seen to rise with each tributary entering the main flow and each of the spring zones, apart from where Taylors Drain enters the main flow, where the total nitrogen decreases slightly. The mass of chloride, calcium and magnesium showed a typical increase of mass over the distance downstream. The mass of DRP in the Wairarapa Stream increased dramatically in Wairarapa Spring Zone 2 in the September 2014, which is opposite to what was observed in the flow gauging data. This dramatic increase corresponds to the elevated DRP concentration in spring vent sample

WairSM5 in September 2014 (Figure 33a). In the March 2015 sampling round the DRP concentration increases consistently across all of the recharge zones.

Table 14 below indicates the relative flow inputs and concentrations of each of these zones for a select set of contaminants.

Table 14: Inputs from Wairarapa Contributing Zones – September 2014

| Full Name | Sampling Round | Flow (L/s) | Flow per unit Area (L/s/m) | Total Nitrogen (mg/L) | DIN (mg/L) | DRP (mg/L) |
|---|---|---|---|---|---|---|
| Wairarapa Spring Zone 1 | Sept 2014 | 45.5 | 0.156 | 1.55 | 1.45 | 0.0075 |
| | March 2015 | 2.1 | 0.007 | 1.100 | 1.10 | 0.0150 |
| Wairarapa Tributary 1 | Sept 2014 | 35 | - | 1.60 | 1.40 | 0.0034 |
| | March 2015 | 41.2 | 0.000 | 1.30 | 1.30 | 0.0150 |
| Wairarapa Seepage Zone 1 | Sept 2014 | 97.4 | 0.128 | 1.50 | 1.50 | 0.0015 |
| | March 2015 | 4.3 | 0.006 | 1.40 | 1.40 | 0.0150 |
| Wairarapa Tributary 2 | Sept 2014 | 40.5 | - | 1.60 | 1.50 | 0.0074 |
| | March 2015 | 13 | 0.000 | 1.30 | 1.30 | 0.0150 |
| Wairarapa Seepage Zone 2 | Sept 2014 | 10 | 0.007 | 1.30 | 1.10 | 0.0069 |
| | March 2015 | 17.2 | 0.012 | 1.75 | 1.30 | 0.0738 |
| Wairarapa Spring Zone 2 | Sept 2014 | 29.3 | 0.186 | 2.30 | 2.10 | 0.0920 |
| | March 2015 | 36.4 | 0.231 | 2.20 | 2.20 | 0.0250 |
| Wairarapa Seepage Zone 3[1] | Sept 2014 | 319 | 0.176 | 1.50 | 1.30 | 0.0061 |
| Wairarapa Seepage Zone 3a[1] | March 2015 | 93.2 | 0.113 | 1.40 | 0.55 | 0.0120 |
| Wairarapa Tributary 3[1] | March 2015 | 49 | 0.000 | -0.16[2] | -0.16[2] | 0.0367 |
| Wairarapa Seepage Zone 3b[1] | March 2015 | 98.2 | 0.099 | 1.82 | 1.82 | 0.0244 |

1. *Note in order to determine the inflow from Taylors Drain, additional sampling points were added into Wairarapa seepage zone 3 in the March 2015 sampling round. Wairarapa seepage zone 3 represents the original Wairarapa seepage zone 3 upstream of Taylors Drain and Wairarapa seepage zone 3b represents Wairarapa seepage zone 3 downstream of Taylors Drain.*
2. *The instream total nitrogen and DIN concentrations decreased downstream of where Taylors Drain entered the main flow, therefore these results are negative.*

The estimated contribution of springs, individual tributaries and general seepage to the nutrients present in the stream has been estimated in Table 15. Note for the September 2014 round, the Wairarapa Seepage Zone 3 has not been included in the general streambed seepage category, as the inflow from Taylors Drain was not gauged. This meant that the flow contributed was unable to be differentiated between general streambed seepage and tributary inflow. However as additional flow gauging to determine the exact inflow of the Taylors Drain, occurred during the March 2015 sampling round, the respective values have been included in the general streambed seepage and tributary inflow categories. Also, note there is some discrepancy between the total mass at the final flow gauge point and the estimated total mass generated from the zones, this is as a result of the estimating the spring and seepage concentrations using the measured seep results, and is possibly related to the biological and chemical processes between the flow gauge points.

Table 15: Estimated Inputs from Waimairi Contributing Zones

| Recharge Zone | Sampling Round | Flow (L/s & %) | | Total Nitrogen (g/s & %) | | DRP (g/s & %) | |
|---|---|---|---|---|---|---|---|
| Springs | Sept 2014 | 74.8 | 29% | 0.138 | 33% | 3.03E-03 | 83% |
| | March 2015 | 38.5 | 11% | 0.082 | 17% | 9.42E-04 | 11% |
| General Streambed Seepage | Sept 2014 | 107.4 | 42% | 0.159 | 38% | 2.15E-04 | 6% |
| | March 2015 | 212.9 | 60% | 0.346 | 70% | 4.85E-03 | 58% |
| Wairarapa Tributaries | Sept 2014 | 75.5 | 29% | 0.121 | 29% | 4.20E-04 | 11% |
| | March 2015 | 103.2 | 29% | 0.063 | 13% | 2.61E-03 | 31% |
| Total Mass at downstream sampling point[1] | Sept 2014 (WAIRFG7B) | 257.6 | - | 0.412 | - | 9.79E-04 | - |
| | March 2015 (WAIRFG8) | 355 | - | 0.462 | - | 9.59E-03 | - |

1. *As Wairarapa Seepage Zone 3 was excluded from the September 2014 sampling round, the lowest sampling point was WAIRFG7B, however this zone was included in the March 2015 round therefore the lowest sampling point was WAIRFG8.*

The spring flow is shown to contribute the majority of DRP to the stream in the September 2014 sampling round, and overestimates the total DRP present in the streamflow at this point. This result is due to the high DRP recorded in the discrete sample of spring vent flow from WAIRSM5, this is shown in Figure 42, Appendix B and discussed further in Section 10.0. During the March 2015 round the DRP masses remain consistent with the flow inputs, therefore any difference in DRP concentration are driven by differences in flow.

In the September 2014 round the total nitrogen concentrations remain relatively consistent with the flow contribution of each of these recharge sources, therefore the relative inputs between springs and general streambed seepage are largely driven by difference in their flow contributions. During the March

2015 round the tributaries of the Wairarapa contributed significantly less nitrogen compared to their contributing flow (contributes 29% of the flow, but only 13% of TN mass), this is likely due to the decreasing total nitrogen masses observed as Taylors Drain enters the main flow.

## 9.3 Guidelines

A number of the results returned are above the relevant guidelines for urban waterways. These transgressions are outlined in Table 6a and 6b, Appendix C. A number of water quality parameters in spring, general streambed seep and instream all exceeded the receiving water guidelines.

Of note, all samples, except for one, across both sampling rounds exceeded the guidelines for nitrogen (nitrate-nitrite-nitrogen and total nitrogen) stated in ANZECC (2000) (90% protection), with approximately 50% exceeding the dissolved inorganic nitrogen guidelines (PLWRP,). In the September 2014 sampling round the DIN exceedances were typically in the lower catchment, however in the March 2015 round these exceedances generally only occurred in the upper catchment. These exceedances are driven by high levels of nitrate-N, which forms the major component of all three of these nitrogen measurements.

Two sampling locations exceeded the guideline for DRP in the September 2014 sampling round, these were both from seepage samples. In the March 2015 sampling round, nine samples exceeded this limit and they were all stream flow samples.

# 10.0 Discussion

The sampling results indicate that generally similar concentrations of nutrients can occur between spring vents and general streambed seepage, so that their overall contribution is generally related to their flow input, especially during the September 2014 round. Spring vents provide much greater inflow per unit area, although they occupy a smaller area of streambed so that overall, most flow input is derived from areas of general streambed seepage inflow, particularly towards the downstream end of the surveyed reaches. Figure 43a and 43b, Appendix B have been prepared to show the relative zones of flow and nutrient input in the September 2014 and March 2015 sampling rounds. These zones are categorised by:

- An upstream inflow zone dominated by spring vents
- A general streambed seepage zone with relatively little inflow, likely due to the lowered groundwater pressures caused by the spring vents immediately upstream; and
- An increasing rate of general streambed seepage inflow as groundwater pressure increases in an easterly (downstream) direction.

In the March 2015 round the inflows did not reduce consistently across the zones of flow, as the hydraulic pressures were lower, such that the inflow from the upstream zone dominated by spring vents reduced, or stopped flowing completely (although it was difficult to observe this in the Wairarapa Stream, as the Jellie Park discharge maintained flow at the upper reaches of this stream). The inflow from the lower general streambed seepage inflow pressure increases in an easterly (downstream) direction and appears to remain relatively constant across the two sampling periods, although both general seepage zones have slightly lower inflows in Waimairi Stream in March 2015. Therefore this lower general seepage section represents the majority of the inflow in low flow conditions (March 2015) and the recharge zone for this groundwater is likely to have the most influence on the low flow chemistry, and nutrient inputs, to these streams.

The total nitrogen contribution to the streams generally remained consistent with the flow input. It was noted that the Waimairi Stream had higher in-stream total nitrogen concentrations compared to the Wairarapa Stream. This variation could be attributed to different land uses in the upstream catchments consistent with the general pattern of higher concentrations in groundwater with greater distance from the Waimakariri River.

Observed Nitrogen concentrations decreased in the lower sections of the streams, this is likely a result of the dilution of the total masses as the flow increases, and indicates that the general streambed seepage in the lower section of the streams introduces nitrogen at a lower concentration compared to the upper sections of these streams. That may reflect higher concentrations in the shallowest groundwater being skimmed off into the upstream reaches of the stream, with slightly lower concentration deeper groundwater emerging into the stream at the more downstream locations.

The DRP concentrations were generally higher in the March 2015 sampling round, compared to the September 2014. Therefore, the increase was not being offset by macrophyte growth in the summer months. Further to this, the portion of organic nitrogen making up the total nitrogen, is noted as decreasing in March 2015, compared to the September 2014 sampling round. This indicates that there were other conditions limiting periphyton growth in the stream in March 2015, rather than just nutrient concentrations. This sampling result was consistent with observations from the field, where there was no obvious increase in periphyton or macrophytes present within the stream reaches between the two sampling rounds.

The nitrogen results have been compared to the shallow groundwater monitoring well M35/2557 (17 m deep), located in the upper Avon Catchment (as plotted in Figure 5). A total of 14 nitrate-nitrogen samples were taken from this well between 2000 – 2011, and returned results with a large variation. The nitrate – nitrogen concentration ranged from 0.2 – 3.0 mg/L. The average nitrate –

nitrogen was 1.16 mg/L, while the median was 0.85 mg/L. This compares to an overall range in all of the seepage meters across both streams, during both sampling rounds, of 0.09 – 3.4 mg/L (average: 1.75 mg/L; and median 1.5 mg/L). Therefore, the seepage meter water samples are generally equivalent to expected groundwater concentrations in the upper catchment. Interestingly, the nitrate-nitrogen concentrations from seepage meters in the Waimairi Stream (median of 2.4 mg/L) were typically higher than the seepage meter results from the Wairarapa Stream (median of 1.4 mg/L). This may reflect the greater influence of land based recharge relative to Waimakariri River seepage in Waimairi Stream relative to Wairarapa Stream

The concentrations observed in the seepage meters are more likely to contain spikes, than the in-stream results, due to the much more localised sampling area (examples of this include the September 2014 DRP sample in WAIRSM5 and WAIMSM4 and the total nitrogen concentrations in WAIMSM4 in both sampling rounds). These variations are expected to be as a result of the land use in the recharge zone for this groundwater and the chemical compositions of soil layers, which the seepage passes through. This is best observed through the total nitrogen concentration in WAIRSM5, which remains consistent across both sampling rounds, while a larger variation is observed throughout the flow gauge samples. The DRP mass in the Wairarapa Stream displayed an interesting pattern between WAIRFG7a and WAIRFG7b in the September 2014 sampling round, while the instream sampling displayed a decrease in total mass present between the two sampling points, the discrete sample of the seep between these two points (WAIRSM5) returned a very high DRP concentration, indicating localised and variable stream bed conditions influencing the release of DRP. The spatial and temporal changes in DRP concentrations are likely due to variable redox conditions in streambed sediments, with high localised conditions associated with reduced conditions in streambed sediments (as also reported in Fitzgerald et al, 2015).

The correlation between the calculated zones and the flows gauging points for DRP for the Wairarapa Stream is poor, with the seep sampling indicating that a greater mass of DRP has entered this waterway than observed in the instream samples. This is possibly due to phosphorus being the limiting nutrient for organic growth in the Wairarapa Stream, so when it is introduced it is likely assimilated in organic matter. The Waimairi Stream did not show this pattern, and the correlation between the calculated zones and the flow gauging points for DRP for the Waimairi Stream is relatively good.

## 11.0 Conclusion

Two detailed sampling surveys have been undertaken involving monitoring of flows and water quality in the Waimairi and Wairarapa Streams to compare in stream measurements with the inflows emerging from spring vents and general streambed seepage. This direct measurement of flow and nutrient contributions is a relatively novel approach to studying inputs to the instream environment. The results show patterns of flow with an upper inflow zone dominated by springs, many of which dry up at times of low groundwater levels, with downstream zones dominated by general streambed seepage which increases as groundwater pressures increase in a downstream direction.

Nutrient concentrations for both total nitrogen and DRP show occasional variable inputs at discrete sampling points, possible due to localised streambed conditions, but generally most measurements are at similar concentrations to both groundwater and instream concentrations, with a tendency to decrease in a downstream direction.

The results of this survey indicate that CCC stormwater management measures may not be able to achieve in-stream nutrient concentrations because of the input from groundwater.

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# Appendix A: Pilot Study

## APPENDIX A: INSTREAM SPRING WATER QUALITY PILOT STUDY REPORT

# INSTREAM SPRINGS WATER QUALITY: PILOT STUDY

### Background

The concentrations of nitrogen in Christchurch waterways tend to be higher in the upper catchments and decrease with increasing distance downstream (Hayward et al 2009, Bartram 2013, Whyte 2013). High levels of nitrogen are recorded in Christchurch groundwater due to intensive agricultural land use (Wong & Hanson 2012), which is typically located in the upper reaches of these catchments. Therefore, as the waterways in Christchurch are spring-fed, higher nitrogen levels in the upper catchments have been attributed to this nitrate-rich groundwater discharging to streams (Hayward et al 2009, Bartram 2013). However, no sampling has specifically been carried out to test the water quality of these instream (i.e. rheocrene) springs to confirm this theory.

Currently, all waterways in Christchurch generally fail to meet the ANZECC (2000) nitrate-nitrite-nitrogen water quality guideline trigger value for excessive plant growth (0.444 mg/L; Bartram 2013, Whyte 2013). In the Environment Canterbury 2012 groundwater annual survey of 289 wells, the median level of nitrate nitrogen recorded was 4.2 mg/L and the maximum was 64 mg/L (Wong & Hanson 2012). Therefore, it is plausible that if these levels discharge directly to waterways via springs, this could contribute to these exceedances, even following dilution of spring water with stream water.

A search of the literature showed that testing of the water quality of instream springs, and how this influences stream water quality, does not appear to have been previously undertaken either in New Zealand or overseas. The exception to this is a study in Kentucky, USA, which recorded springs within the banks and channel of a coastal plain stream discharging volatile organic compounds to the stream (LaSage et al. 2008). Spring sampling in this Kentucky study was undertaken by immersing sampling containers in springs or collecting spring water using a seepage meter.

The impetus behind this project was the Avon Stormwater Management Plan, which aims to treat a large proportion of stormwater prior to discharge to the Avon River. The higher levels of nitrogen in the upper reaches of this catchment were considered to be of concern, as the input of these contaminants may mean that receiving water quality goals are not met, regardless of stormwater treatment. Therefore it was decided that the Council should undertake instream spring water quality testing, to identify whether contaminants were present within springs. A pilot study was initiated in October 2013 to determine the feasibility of sampling and to also quickly sample before groundwater levels dropped for the year. Spring samples were analysed not just for nitrogen, but a range of other parameters as well.

### Methods

*Study sites*

Three springs were sampled during the pilot study: one in the Avon River (Figure 1; N5742620 E2474670; 84D Avonhead Road), one within Wairarapa Stream (Figure 2; N5744442 E2476199; Jellie Park) and one within Wai-iti Stream (Figure 3; N5744532 E2476969; 39 Brookside Terrace). These springs were chosen as they had obvious vents that could easily be sampled without inadvertently collecting stream water. The Avon River and Wai-iti Stream springs had defined vents within the stream bed, and the Wairarapa Stream spring discharged directly from the bank of the stream (Plates 1 – 3). The estimated distance upgradient (based on the groundwater flow direction detailed on Environment Canterbury's online GIS) to the nearest agricultural land use was ~2.5 kilometres for the Avon River and Wairarapa Stream springs, and ~3 kilometres for the Wai-iti Stream spring.

A number of additional springs were identified during the pilot study, but were unable to be sampled due to the springs 'dropping' before samples could be taken. These additional springs (plus other potential springs in other catchments) are detailed in Appendix A. These springs could be sampled in future studies.

**Figure 1 Location of Avon River spring**

Figure 2 Location of Wairarapa Stream spring

Figure 3 Location of Wai-iti Stream spring

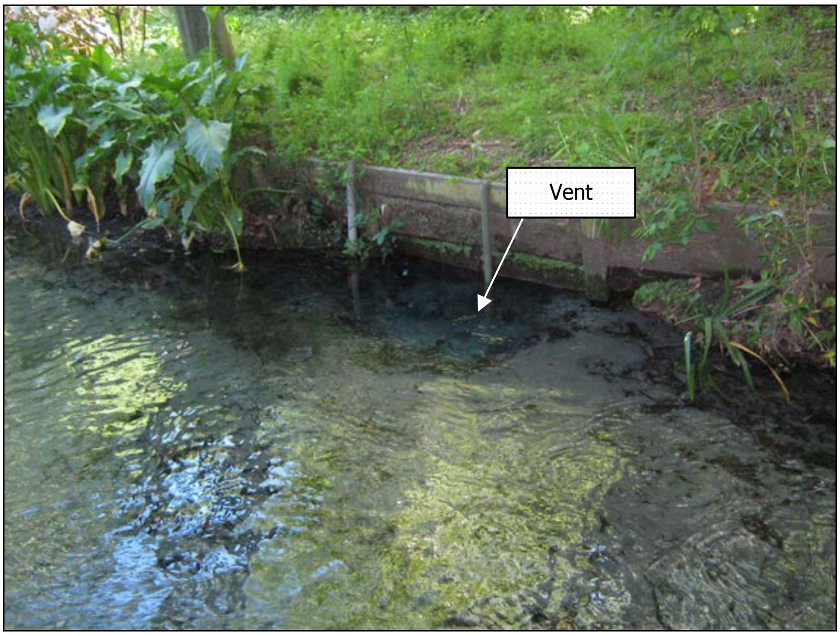

**Plate 1 Avon River spring**

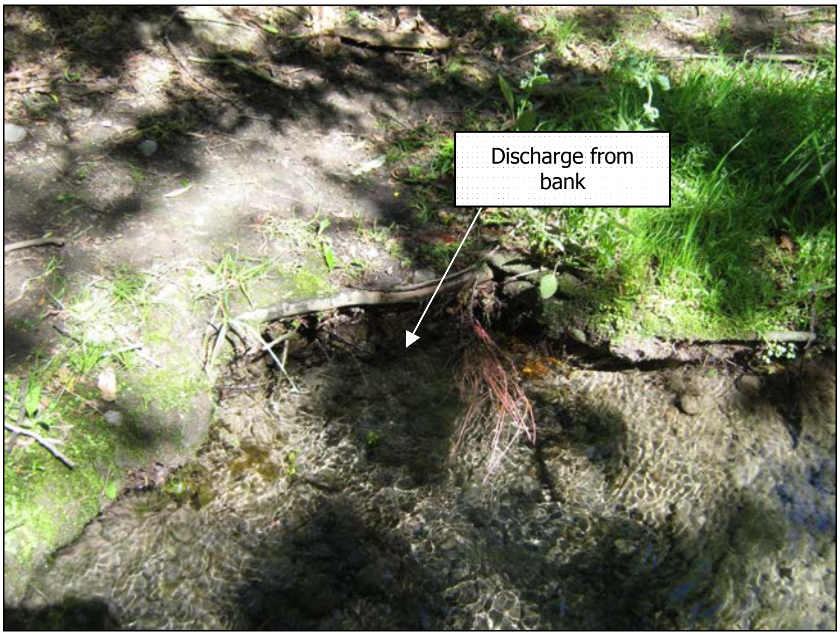

**Plate 2 Wairarapa Stream spring**

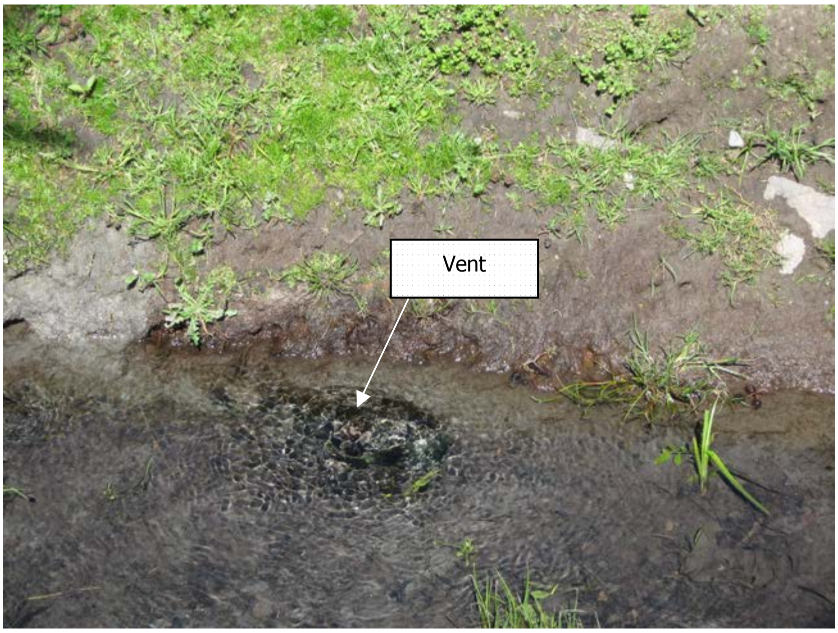

**Plate 2 Wai-iti Stream spring**

*Experimental design*

Spring and stream water quality samples were collected during fine weather on the 29th October 2013. Spring water samples were collected manually from low inside the stream vents (Avon River and Wai-iti Stream springs) or directly from the discharge from the bank (Wairarapa Stream spring). A stream sample was also taken at each of the sites from the water column immediately upstream of each spring. Spring and stream samples were then both chilled and sent to the laboratory for processing.

Stream habitat data at each of the sites was also collected in accordance with the Harding et al (2009) P1 stream habitat assessment protocol. This protocol involves collection of channel (e.g. wetted width, flow types), bank (e.g. stability), instream (e.g. substrate, presence of macrophytes and periphyton), riparian (e.g. plant composition) and catchment (e.g. land use) characteristics. Photos of the waterway and springs were also taken at the time of sampling.

Spring and stream samples were analysed at the Christchurch City Council laboratory[2] for the following parameters:

- *Escherichia coli (E. coli)*
- pH
- conductivity
- nitrate, nitrite, ammonia nitrogen, dissolved inorganic nitrogen, nitrate-nitrite-nitrogen and total nitrogen
- dissolved copper, dissolved lead and dissolved zinc

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[2] This laboratory is accredited by International Accreditation New Zealand; hydrocarbon analyses were undertaken in accordance with modified United Stated Environmental Protection Authority Method 200.8 and all other analyses were in accordance with American Public Health Association 22nd Edition 2012 methods

- dissolved reactive phosphorus and total phosphorus
- BTEX (hydrocarbons)

*Data analysis*

Due to the small number of samples taken, only basic statistical analyses were able to be undertaken (i.e. tests for significance were unable to be conducted).

## Results

*Stream habitat*

The stream substrate at the Avon River spring consisted of predominantly mud, with some silt/sand, gravel and cobble, and the bed was moderately stable. The stream channel was strongly sinuous and the average wetted channel width was three metres. The flow type was mainly run, and the adjacent and catchment land use was urban. This spring had a sulphurous odour. Riparian vegetation provided partial shading at this site.

At the location of the Wairarapa Stream spring, the stream substrate consisted of largely gravel, with some cobble, sand/silt and mud. The stream bed was moderately stable, the channel was weakly sinuous and the wetted channel width was three metres. Flow at this location consisted of riffle and run types. The adjacent land use was reserve and urban, and the catchment land use was urban. Partial shading of the streambed was provided by the riparian vegetation.

Mud formed the only visible stream substrate at the location of the Wai-iti Stream spring and the stream bed was moderately stable. The stream channel was weakly sinuous and the wetted channel width was two metres. The flow habitat at this site was solely run, and the adjacent and catchment land use was urban. The channel was open and unshaded.

*Spring & stream water quality*

A number of water quality parameters in both spring and water column samples exceeded the receiving water guidelines (Table 1). Of note, all spring and water column samples exceeded the guidelines for nitrogen (nitrate-nitrite-nitrogen, dissolved inorganic nitrogen and total nitrogen). These exceedances appear to be largely driven by high levels of nitrate nitrogen, which forms a component of all three of these nitrogen measurements. Mean levels of nitrogen concentrations were similar between spring and water column samples (Figure 4).

In addition to these nitrogen exceedances, the Wai-iti Stream spring exceeded the guidelines for total phosphorus, although the water column did not. The Avon River site also exceeded guidelines levels for conductivity in both the spring and water column sample. The water column at the Wai-iti Stream site recorded concentrations of dissolved copper above guidelines levels, but the spring at this location recorded levels below the guideline.

No exceedances in *E. coli*, pH, total ammonia, dissolved lead, dissolved zinc or dissolved reactive phosphorus were recorded in any of the samples. There were also no exceedances for any of the hydrocarbon constituents.

Eight spring samples recorded higher concentrations in some of the parameters than the adjacent water column samples; however, these were only marginally higher. The spring sample at Wai-iti Stream recorded substantially higher total phosphorus levels than the water column sample.

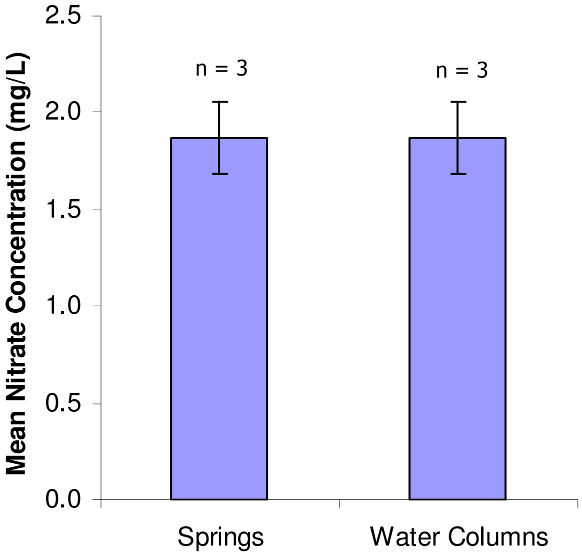

**Figure 4** **Mean concentration of nitrate in spring and water column samples**

## Table 1 Concentrations of water quality parameters recorded in spring and water column samples

| Parameter | Receiving Water Quality Guideline | Avon River | | Wairarapa Stream | | Wai-iti Stream | |
|---|---|---|---|---|---|---|---|
| | | Spring | Water Column | Spring | Water Column | Spring | Water Column |
| *Escherichia coli* (MPN/100mL) | 550[3,3] | <1 | 240 | <1 | 30 | 8 | 140 |
| pH | 6.5-8.5[4] | 7.2 | 7.3 | 7.2 | 7.3 | 7.0 | 7.2 |
| Conductivity (µS/cm) | 175[5] | 182 | 184 | 131 | 130 | 155 | 159 |
| Nitrate (mg/L) | - | 1.8 | 2.0 | 1.7 | 1.5 | 2.1 | 2.1 |
| Nitrite (mg/L) | - | <0.001 | 0.002 | <0.001 | 0.002 | <0.001 | 0.003 |
| Nitrate-nitrite-nitrogen (mg/L) | 0.444[5] | 1.8 | 2.0 | 1.7 | 1.5 | 2.1 | 2.1 |
| Total ammonia (mg/L) | 0.9[3,6] | 0.024 | 0.022 | 0.007 | 0.015 | 0.010 | 0.017 |
| Dissolved inorganic nitrogen (mg/L) | 1.5[3] | 1.8 | 2.0 | 1.7 | 1.5 | 2.1 | 2.1 |
| Total nitrogen (mg/L) | 0.614[5] | 4.6 | 4.5 | 1.7 | 1.8 | 2.9 | 2.4 |
| Dissolved copper (mg/L) | 0.00356[7] | <0.002 | <0.002 | <0.002 | <0.002 | 0.003 | 0.0043 |
| Dissolved lead (mg/L) | 0.01554[6] | <0.0015 | <0.0015 | <0.0015 | <0.0015 | <0.0015 | <0.0015 |
| Dissolved zinc (mg/L) | 0.02970[6] | 0.008 | 0.011 | 0.011 | 0.010 | 0.005 | 0.010 |
| Dissolved reactive phosphorus (mg/L) | 0.016[3] | 0.0055 | 0.0064 | 0.0055 | 0.0064 | 0.0097 | 0.011 |
| Total phosphorus (mg/L) | 0.033[5] | 0.006 | 0.011 | 0.006 | 0.011 | 0.084 | 0.019 |
| BTEX: Benzene (mg/L) | 1.3[5] | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| BTEX: O-xylene (mg/L) | 0.47[5] | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| BTEX: 1-2-4-trimethlybenzene, 1-3-5-trimethlybenzene, ethylbenzene, iso-propylbenzene, m-& p-xylene, n-butylbenzene, n-butylbenzene, p-isopropyl toluene, sec-butylbenzene, tert-butyl benzene & toluene (mg/L) | - | All <0.0001 | All <0.0001 | All <0.0001 | All <0.0001 | All <0.0001 | All <0.0001 |

*Shaded values indicate concentrations above the relevant guideline levels*

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[3] Ministry for the Environment (2003)

[4] Environment Canterbury Proposed Canterbury Land & Water Regional Plan (2012)/Natural Resources Regional Plan (2011)

[5] Biggs (1988)

[6] ANZECC (2000)

[7] ANZECC (2000); hardness modified

## Conclusions

The springs in this pilot study all recorded high levels of nitrogen, in line with that recorded in the adjacent water columns. These nitrogen levels in spring water are likely due to agricultural land use in the upper catchments (Hayward et al 2009, Wong & Hanson 2012, Bartram 2013), as discussed in the introduction of this document. One-off guideline exceedances for spring samples were also recorded for conductivity (at the Avon River spring; the water column sample also exceeded guidelines) and total phosphorus (at the Wai-iti Stream spring; the water column sample was below guidelines). The phosphorus exceedance may be related to upgradient agricultural and urban land use practices (Waterwatch Canterbury 2012). The high conductivity may have been due to soils at this location, the high nitrogen levels at this site, or general agricultural or urban activities (Waterwatch Canterbury 2012). Overall, this pilot study suggests that springs do contribute contaminants to waterways, in particular, nitrogen.

The discharge of contaminated spring water has management implications for the Avon and other Stormwater Management Plans, as stormwater treatment may not result in a reduction in contaminant levels within waterways. It is doubtful that any management of spring discharges could be implemented. Instead land use practices should be improved to prevent leaching of contaminants into soil and groundwater, which is being addressed in part through the Ministry for the Environment National Environmental Standards and Environment Canterbury regulations. It may be that consent conditions for nitrogen in stormwater management plans will need to be less onerous, to reflect other contributors of this parameter into waterways.

Ideally, more detailed research should be conducted, however, to confirm the contribution of contaminants into waterways from springs. This research could potentially be undertaken by a student from one of the universities. Future studies would benefit from an experimental design that included:

- Sampling of water using a seepage meter to allow definitive collection of spring water and not stream water, and to allow sampling of seeping springs (springs with visible vents were only sampled during the pilot study due to the difficulties of sampling seeps)
- Sampling of stream water quality immediately upstream and downstream of each spring, to tease out the influence of spring water on stream water quality
- Assessment of temporal trends (e.g. monthly sampling throughout the year where spring levels allow, or weekly sampling during the spring season when groundwater levels are highest) and spatial trends (e.g. sampling springs from top to bottom of catchments where possible – seepage springs would be required to be sampled to achieve this)
- Measurements of stream flow and discharge rates at the time of sampling
- Testing of suspended solids, temperature, dissolved oxygen, cations and anions (e.g. calcium, magnesium, sodium and potassium)
- Quantification of the aquifer characteristics at the location of each spring and groundwater input into each of the streams
- Details of the soils in the location of the springs
- Recording of the spring characteristics, including but not limited to, vent diameter, depth of spring and relationship to stream (e.g. connected by channel or within main channel)

**Dr Belinda Whyte**
Waterways Planner - Ecologist
Asset & Network Planning
Network Planning - Greenspace
DDI 03 941 8264
belinda.whyte@ccc.govt.nz

January 2014

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# APPENDIX A:
# POTENTIAL FUTURE SPRING SAMPLING LOCATIONS[8]

**Figure A1 Location of potential spring sampling site on Ilam Stream**

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[8] Other potential springs not shown in the maps in this appendix include: Kaputone headwaters and Redwood springs

Figure A2 Location of potential spring sampling site on the Avon River in Corfe Reserve (downstream of spring sampled in this pilot study)

Figure A3 Location of potential spring sampling site on Waimairi Stream

**Figure A4** Location of potential spring sampling site (exact location within landparcel to be confirmed), which discharges directly to Russley Road Drain

# APPENDIX B: PAPER OUTLINING POTENTIAL SPRING SAMPLING TECHNIQUE

UF UNIVERSITY of FLORIDA
IFAS Extension

AE465

# Seepage Meters for Measuring Groundwater–Surface Water Exchange[1]

Christopher J. Martinez[2]

## Introduction

Seepage meters are instruments for measuring the flow of water between groundwater and a surface water body such as a lake, wetland, estuary, or stream (Figure 1). Seepage meters can be constructed inexpensively from readily available materials and can be custom-built for specific applications. When flow measurements from seepage meters are combined with hydraulic head measurements from mini-piezometers (see: http://edis.ifas.ufl.edu/AE454), the hydraulic conductivity of the bottom sediment can be calculated. This document is intended to aid those who are engaged in surface water–groundwater exchange studies in cost-effective construction, installation, and use of seepage meters.

## Useful Terms and Information

Hydraulic head: A measure of the total energy (both potential and kinetic) at a point in the water column and is expressed in units of height (e.g., feet or meters). The hydraulic head (h) is the sum of the elevation head, water pressure head, and water velocity head.

Hydraulic gradient: The hydraulic gradient is the difference in hydraulic head between two points that are separated by some distance and is usually written as: dh/dl, where *dh* is the difference in hydraulic head between two points and *dl* is the distance between the two points. Fluids flow 'downhill' from points of high hydraulic head to points of low hydraulic head.

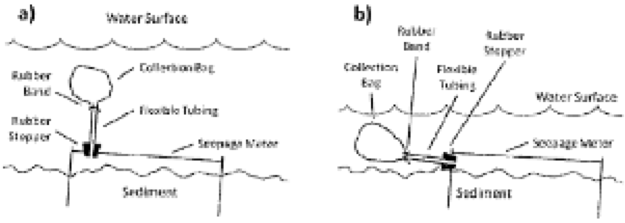

Figure 1. Cross-section view showing a typical installation of a seepage meter at left (a) and for an installation in shallow water (b). (adapted from Lee and Cherry 1978).

Hydraulic conductivity: The hydraulic conductivity (K) is a property of soil and sediment that is a measure of the ease that water can be transmitted through pore spaces. It is a useful property for conducting water budgets and hydrologic modeling studies and can be measured using a variety of laboratory and field techniques.

Darcy's Law: An equation that can be used to compute flow (Q) of water through a porous media using the hydraulic conductivity of the media (K), the hydraulic gradient (dh/dl), and the cross-sectional area of flow (A). Mathematically: $Q/A = -K * dh/dl$

Correction coefficient: A coefficient that the measured seepage is multiplied by to determine the actual rate of seepage. The correction coefficient compensates for inefficiencies in flow in the meter, any restriction to flow through the connection between the bag and the seepage meter, and any resistance to movement of the bag.

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[1] This document is AE465, one of a series of the Agricultural and Biological Engineering Department, UF/IFAS Extension. Original publication date August 2013. Visit the EDIS website at http://edis.ifas.ufl.edu.

[2] Christopher J. Martinez, Assistant Professor, Agricultural and Biological Engineering Department; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611

Seepage meter: An instrument that can be used to determine the rate of flow across the sediment–water interface (and described in detail in this document).
Mini-piezometer: Sometimes called a potentiomanometer, a mini-piezometer is an instrument that can be used to determine the hydraulic gradient between groundwater and surface water (mini-piezometers are described in: http://edis.ifas.ufl.edu/AE454).

## How a Seepage Meter Works

The basic concept of a seepage meter is to enclose and isolate an area of the sediment–surface water interface with a cylinder that is open at its base and vented at the top to a plastic collection bag (Figure 1). The change in the volume of water in the collection bag over a measured time interval is used to determine the direction and rate of flow between surface water and groundwater. A gain in water volume in the collection bag indicates that flow is occurring from groundwater to surface water, while a loss in water volume indicates that flow is occurring from surface water to groundwater.

Seepage meters have an advantage over other methods of measuring groundwater–surface water exchange since flow measurements can be made without measurements of the hydraulic conductivity of the sediment. Seepage meters are particularly useful when many measurements are needed in order to characterize groundwater–surface water exchange in different segments of a water body.

## Materials and Tools Required

Materials

- Top or bottom of a 55 gallon cylindrical drum or something similar
- Rubber stopper with a single hole drilled in the center to accept tubing
- Clear, flexible tubing that will fit snugly into the hole in the rubber stopper
- Rubber band to secure collection bag to tubing
- Plastic collection bag. The size will depend on the rate of seepage and the period that measurements are made, a larger bag will be needed for longer measurement periods and locations with larger rates of seepage. A collection bag that is 1 liter or larger is generally recommended. The bag chosen should be sturdy and free of leaks.

Tools

- Drill and bit to drill vent hole on seepage meter
- Rubber mallet to aid in seating the seepage meter into the sediment, if needed
- Graduated cylinder to measure the volume of water in the collection bag at the beginning and end of the measurement

## Construction and Installation

Drill the vent hole near one edge of the top of the seepage meter (i.e., the top of the 55 gallon drum). When installed, the side of the seepage meter with the vent hole will be left slightly elevated allowing any gas to freely escape (Figure 1a). In shallow water conditions, a vent hole can be drilled on the side of the seepage meter, allowing the collection bag to remain submerged (Figure 1b). The collection bag must be submerged in order to maintain the same hydraulic head in the seepage meter and surrounding surface water.

To install the seepage meter into the bottom sediment, find a location that is free of vegetation, debris, and large rocks. Since the direction and rate of flow may vary by location, it is recommended that several seepage meters are installed. To install the seepage meter, slowly drive it into the sediment until an adequate seal is achieved. A depth of 8 cm is considered to be adequate unless the sediment is extremely soft (Lee and Cherry 1978). The seepage meter can be twisted or pushed (with the help of the rubber mallet, if needed), leaving it one to three inches above the sediment surface. The seepage meter lid should not contact the sediment. Remember to leave the side with the vent hole slightly elevated relative to the rest of the seepage meter. Once installed it may be desirable to allow the sediment time to equilibrate following possible compression of the sediment during installation (1–24 hours, depending on the nature of the sediment).

### Non-flowing water applications

For non-flowing or very low flow applications, such as a lake, wetland, or relatively slow-moving estuary or stream, the seepage meter is ready to be used. For higher flow conditions, however, additional measures are needed to ensure accurate measurements.

### Flowing water applications

Seepage meters were originally designed for use in low- or no-flow applications such as lakes and estuaries where issues related to current and scour are generally small. In flowing applications, such as rivers and streams, scour can lead to a breach in the seal around the seepage meter, and flow across the seepage meter collection bag can alter the hydraulic head and induce seepage flow.

The effect of scour can be significantly reduced by using more streamlined, low-profile seepage meters (Figure 2). The seepage flow induced by flowing water can be significantly reduced by isolating the seepage meter collection bag from the flowing current. Streamlined seepage meters can minimize the disturbance of the sediment caused by the flowing water and can allow water and sediment to readily pass over the meter, making the seepage meter more similar to the surrounding streambed. Streamlined seepage meters can be constructed from readily available materials including plastic lids and garbage cans. Locating the collection bag in a protective housing near the stream bank where the current is much lower can minimize seepage induced by the flowing water. For more information on flowing water applications, please refer to the article by Rosenberry (2008) and the online document by Rosenberry et al. (2008; http://pubs.usgs.gov/tm/04d02/pdf/TM4-D2-chap2.pdf).

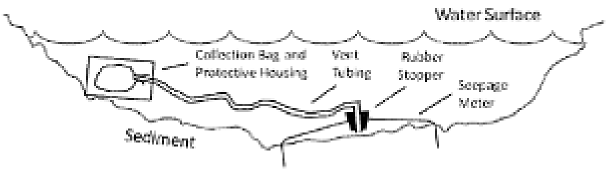


Figure 2. A streamlined seepage meter with protective housing for the collection bag located in a low-flow area near the stream bank.

## Measuring the Volume and Direction of Flow between Surface Water and Groundwater

The flow and direction of flow between groundwater and the overlying surface water is measured by the change in volume of water in the collection bag over a known period of time. The time that will be needed for an accurate measurement will vary for each application, with locations with low seepage requiring more time. One to two hours is a recommended starting point. If there does not appear to be a change in volume after 1–2 hours, repeat using a longer time period. If, after 1–2 hours the collection bag is completely full or completely empty, then the measurement should be repeated using a shorter time period.

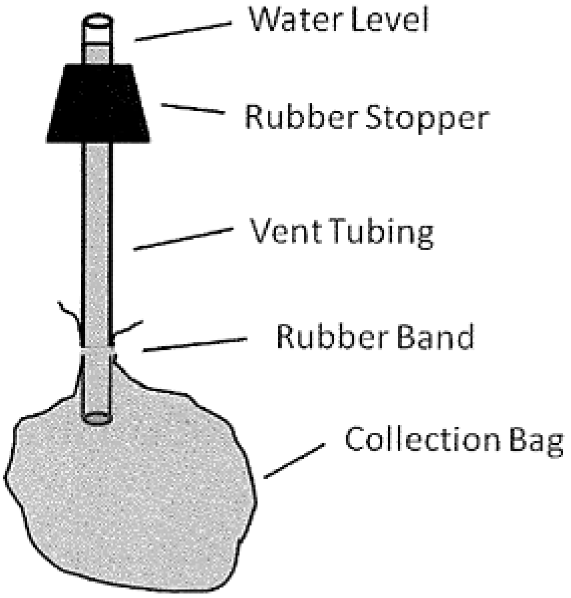


Figure 3. The collection bag assembly with the vent tube inserted through the rubber stopper and attached to the collection bag that has been purged of air.

Once the sediment around the seepage meter has been allowed to equilibrate, insert the vent tube into the rubber stopper (Figure 3). The tube should fit tightly within the stopper. Fill the collection bag with a known volume of water using the graduated cylinder. If the direction of seepage flow is not yet known, it is recommended that the bag be filled half way (the bag can be empty if flow is already known to be upwards or filled completely if flow is known to be downwards). Attach the bag to the tube-side of the tube/stopper assembly using the rubber band (Figure 3). Next, holding the bag assembly stopper-end-up, squeeze the bag allowing air to escape (be careful not to allow water to overflow out of the tube, if this happens the volume of water will need to be remeasured). Place a finger over the tube opening once the air has been removed. The collection bag assembly is now ready to be installed on the seepage meter to begin the measurement of groundwater–surface water exchange.

Install the collection bag assembly on the seepage meter, making sure that the rubber stopper fits snugly in the vent hole that was drilled in the seepage meter. Be sure to record the time that the assembly was installed since this will be needed to determine the rate of flow between groundwater and surface water.

Once the scheduled time has elapsed, the collection bag is removed so that the volume of water in it can be measured. To remove the collection bag, carefully remove the rubber stopper and vent tube assembly from the top of the seepage meter, placing a finger over the end of the tube. Remove the stopper/bag assembly from the water, and pour the water from the bag into the graduated cylinder. This gives the final water volume ($V_{Final}$), which can be used with the starting water volume ($V_{Start}$) and the elapsed time to determine the rate of seepage:

A positive value of Q means that the direction of flow is upwards from groundwater to surface water. A negative value of Q means that the direction of flow is downwards, from surface water to groundwater. Seepage measurements are often multiplied by a correction factor to account for frictional head loss through the components of the meter. More information on correction factors can be found in Rosenberry et al. (2008; http://pubs.usgs.gov/tm/04d02/pdf/TM4-D2-chap2.pdf).

$$Q = \frac{dV}{dt} = \frac{V_{Final} - V_{Start}}{\text{Elapsed Time}}$$

Figure 4.

## Combining Mini-Piezometer Measurements with Seepage Meter Measurements to Determine Sediment Hydraulic Conductivity

Mini-piezometers are very useful for making measurements of the hydraulic gradient (dh/dl) between groundwater and surface water using readily available materials (see: http://edis.ifas.ufl.edu/AE454). When used together with the seepage flow rate from a seepage meter, they can be used to calculate the hydraulic conductivity of the sediment using Darcy's Law:

Q is the measured flow from the seepage meter, A is the cross-section area of the seepage meter through which flow occurred, and dh/dl is the hydraulic gradient measured using a mini-piezometer. Equation 2 can be rearranged to solve for the hydraulic conductivity. When doing so, be sure to use consistent units.

## Some Final Remarks

Seepage meter measurements can only provide information on the direction and rate of flow at the time and location the measurements are taken. Flow rates and directions between groundwater and surface water can be dynamic and change over time and space, particularly in response to seasonal streamflow and weather conditions. To fully characterize the groundwater–surface water exchange that occurs in a particular water body, it is recommended that multiple measurements be made at several locations and under different hydrologic conditions and times of year. Due to their simplicity and low cost, seepage meters can also be useful for educational field demonstrations in the environmental sciences.

$$K = -\frac{Q}{A} \times \frac{dl}{dh}$$

Figure 5.

## References

Lee, D. R. 1977. A device for measuring seepage flux in lakes and estuaries. *Limnology and Oceanography* 22(1): 140-147.

Lee, D. R. and J. A. Cherry. 1978. A field exercise on groundwater flow using seepage meters and mini-piezometers. *Journal of Geological Education* 27: 6-10.

Rosenberry, D. O. 2008. A seepage meter designed for use in flowing water. *Journal of Hydrology* 359: 118-130.

Rosenberry, D. O., LaBaugh, J. W., and R. J. Hunt. 2008. Use of monitoring wells, portable piezometers, and seepage meters to quantify flow between surface water and ground water. In: Rosenberry, D. O. and J. W. LaBaugh (Eds.), *Field Techniques for Estimating Water Fluxes Between Surface Water and Ground Water*. United States Geological Survey Techniques and Methods, Chapter 4-D2, pp. 39-70. http://pubs.usgs.gov/tm/04d02/

Sanders, L. L. 1998. *A Manual of Field Hydrogeology*. Prentice Hall, Upper Saddle River, NJ.

# Appendix B: Figures

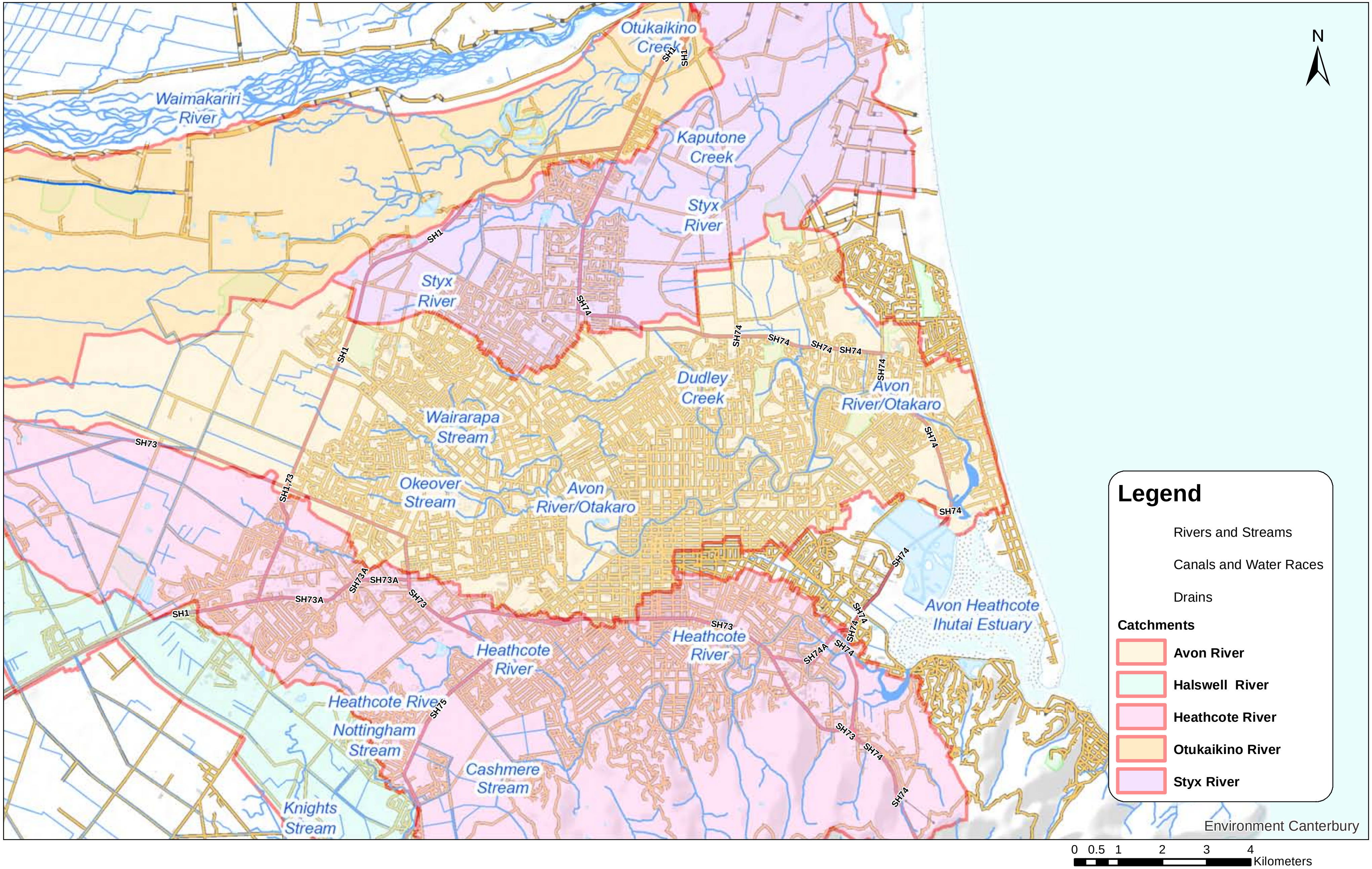


FIGURE 1: CHRISTCHURCH URBAN WATERWAYS

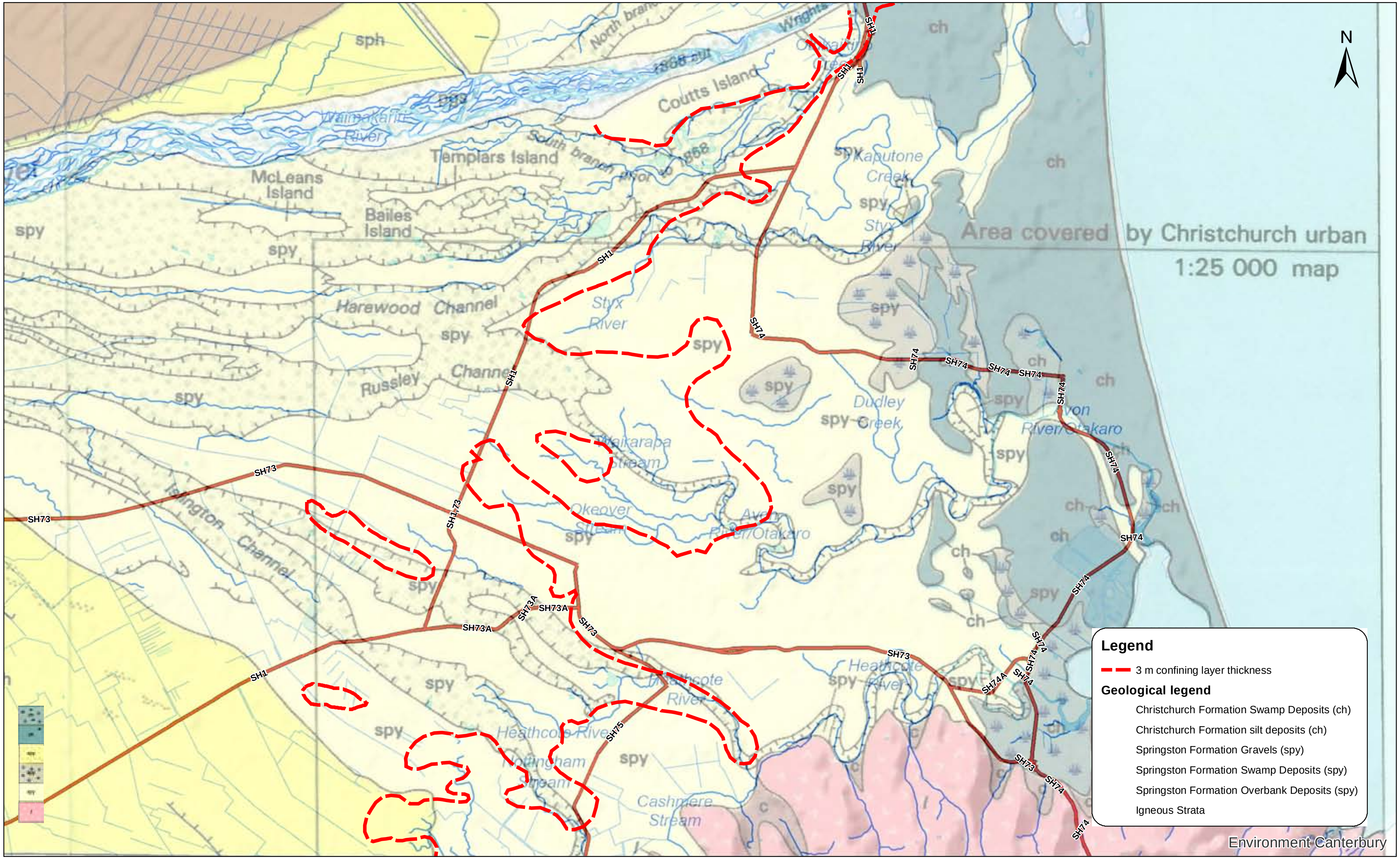


FIGURE 2 :CHRISTCHURCH GELOGICAL MAP AND LOCATION OF 3 M CONFINING LAYER BOUNDARY

SCALE : 1:115,549 (A4)

Kilometers

0 0.75 1.5 3 4.5 6

Document Path: S:\C02982\500\Projects\C02982500R001_F002.mxd

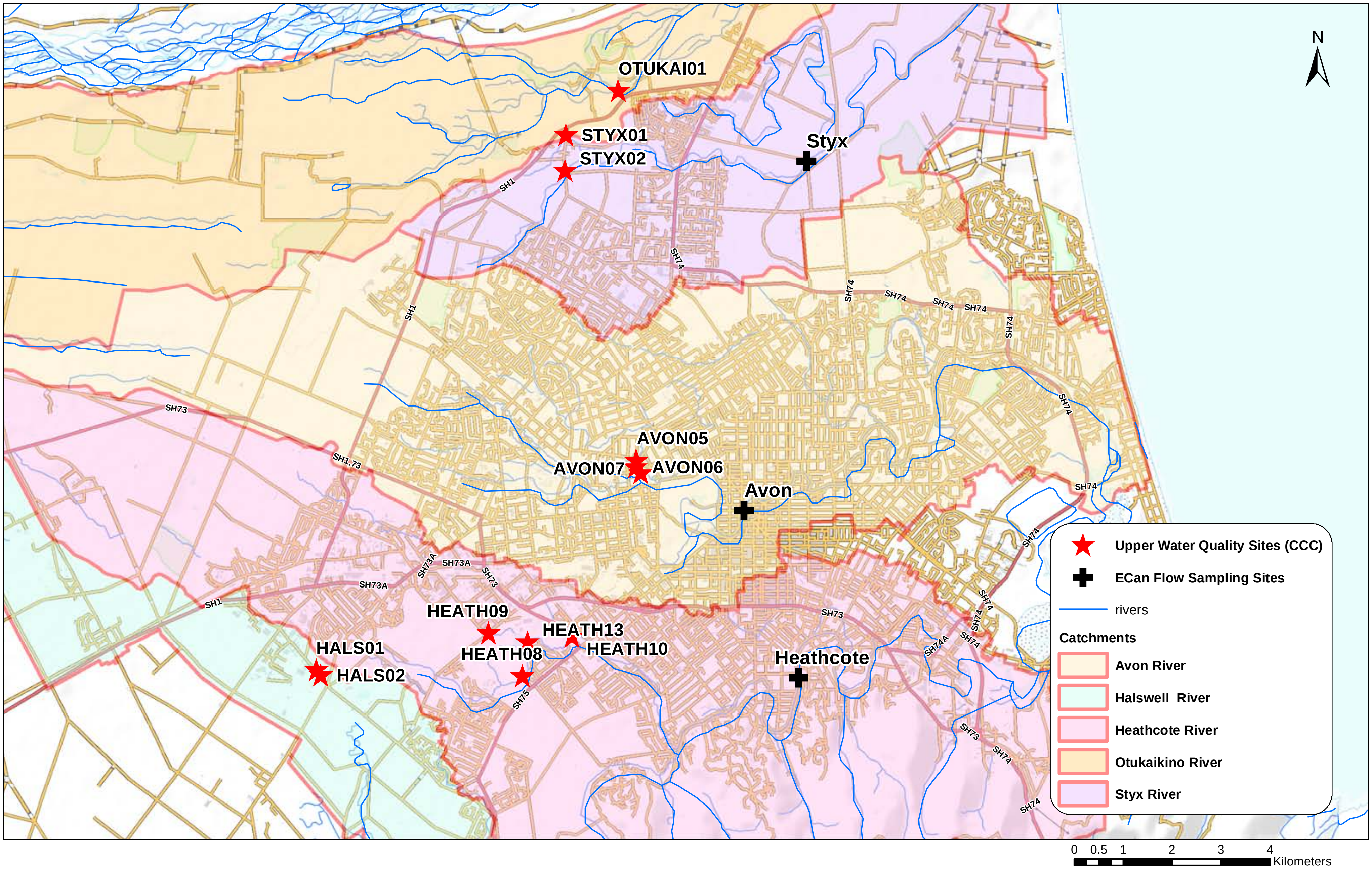


FIGURE 3: UPPER CATCHMENT CCC WATER QUALITY SITES 2014

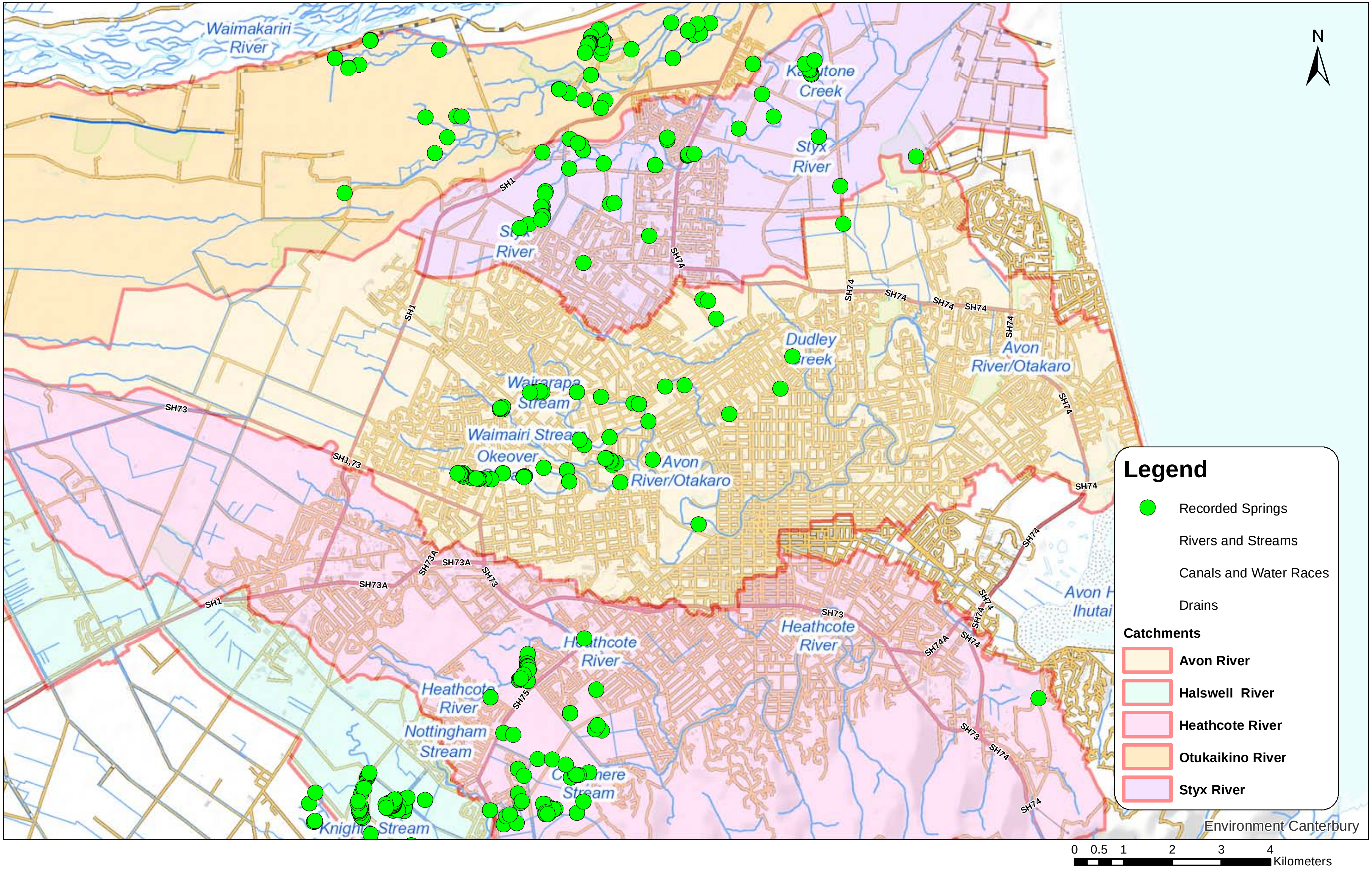


FIGURE 4: LOCATION OF ALL ECAN RECORDED SPRING VENTS SEPTEMBER 2014

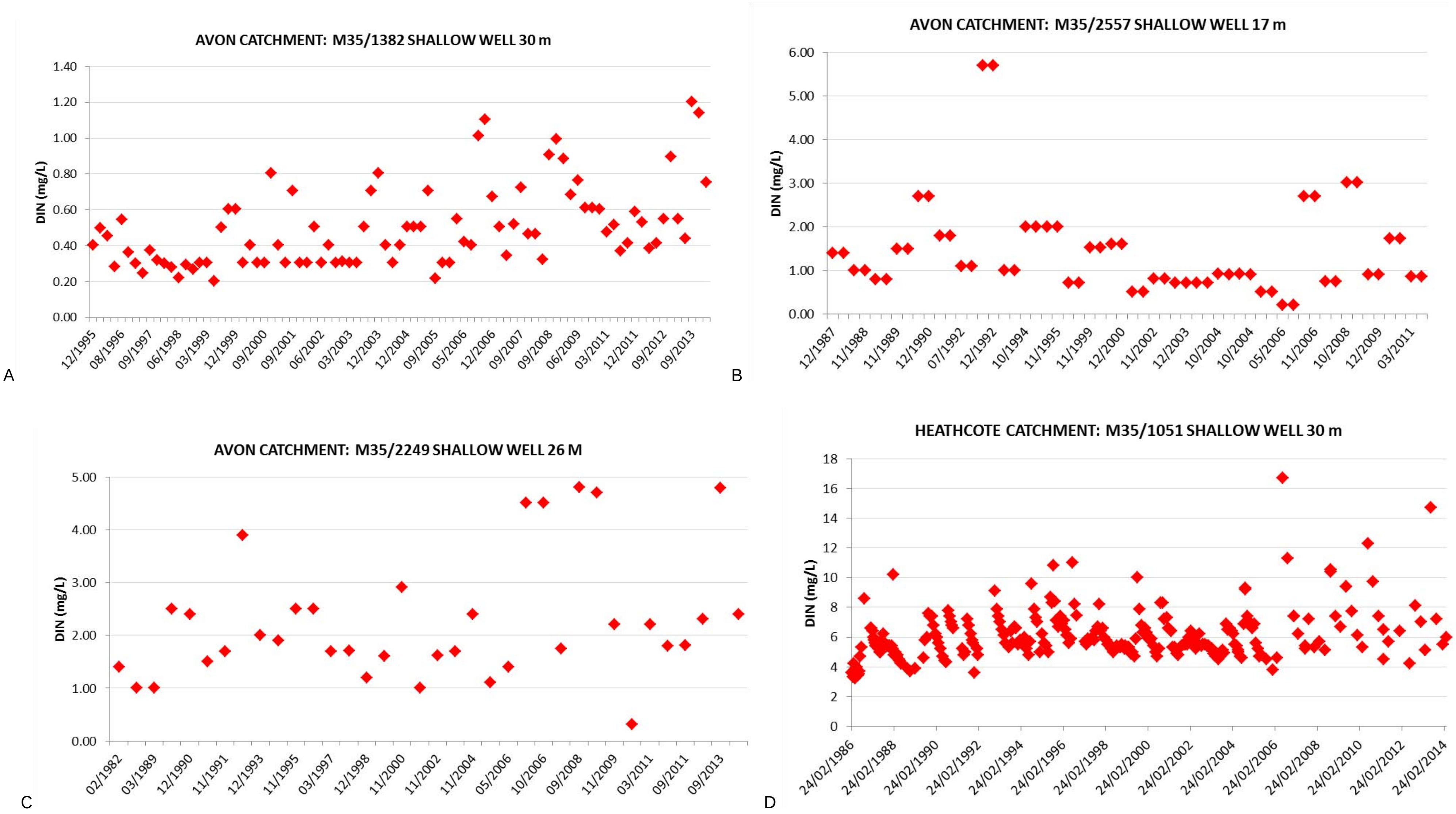
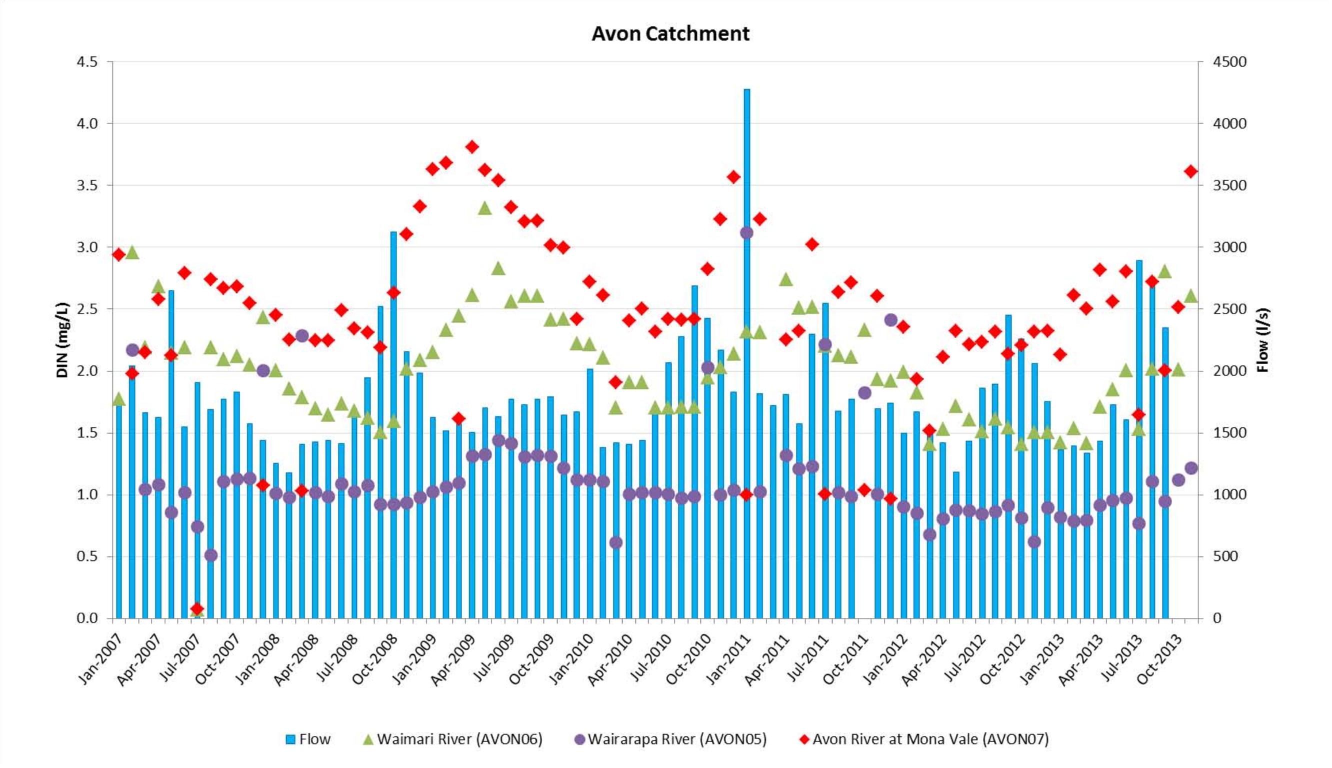
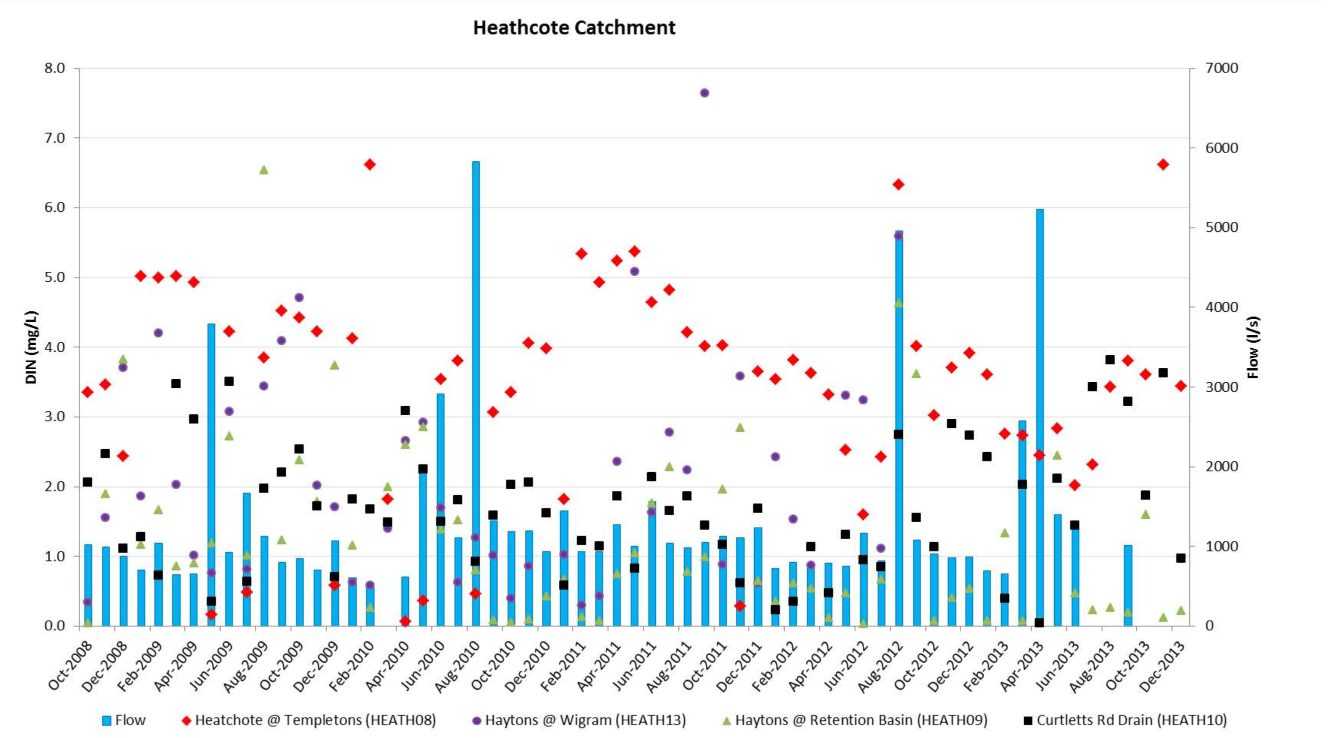


Figure 5: Dissolved Inorganic Nitrogen Concentrations and Flow in the Upper Avon Catchment



Dissolved Inorganic Nitrogen Concentrations and Flow in the Upper Avon Catchment.



Dissolved Inorganic Nitrogen Concentrations and Flow in the Upper Heathcote Catchment

Figure 6: Dissolved Inorganic Nitrogen Concentrations and Flow

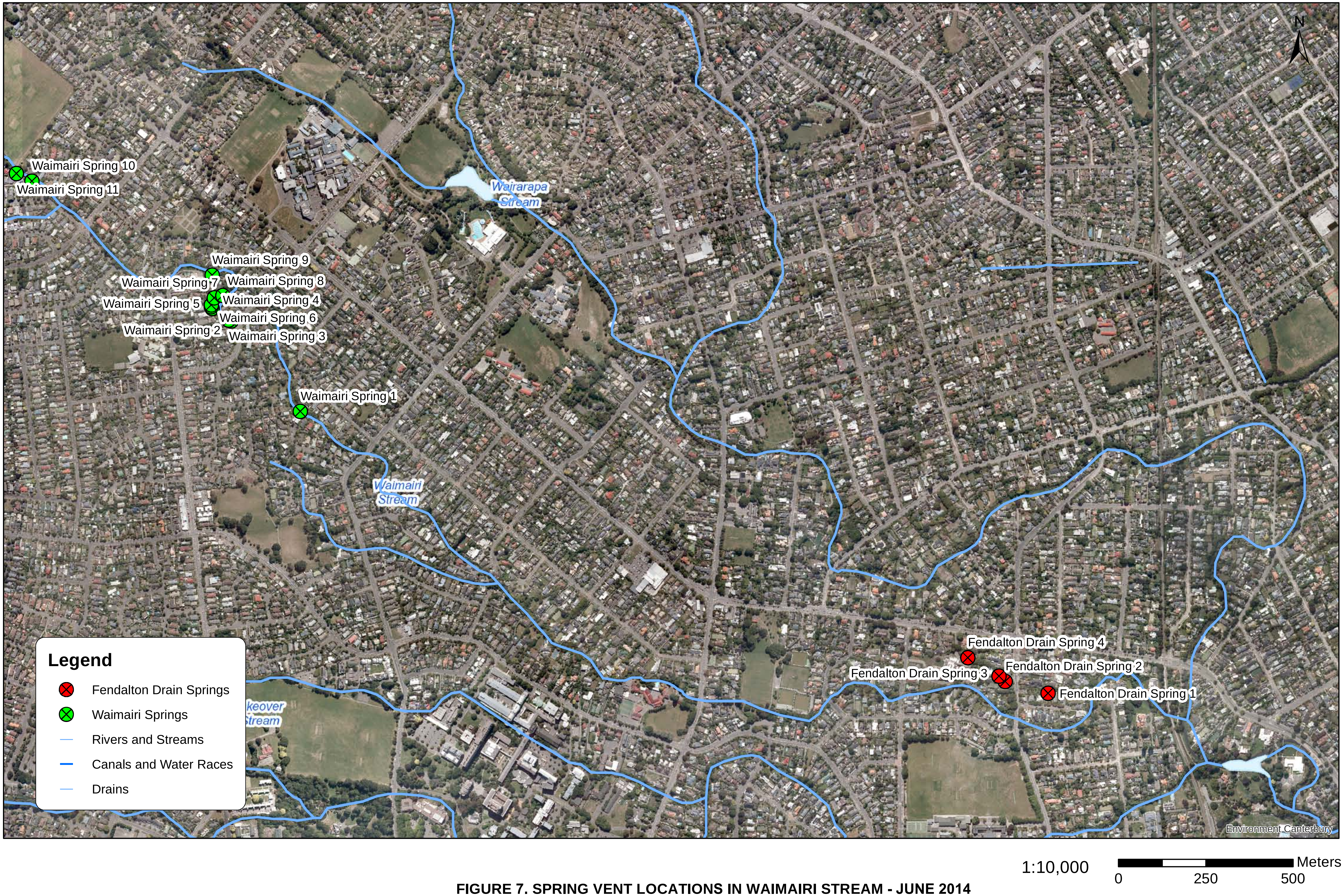
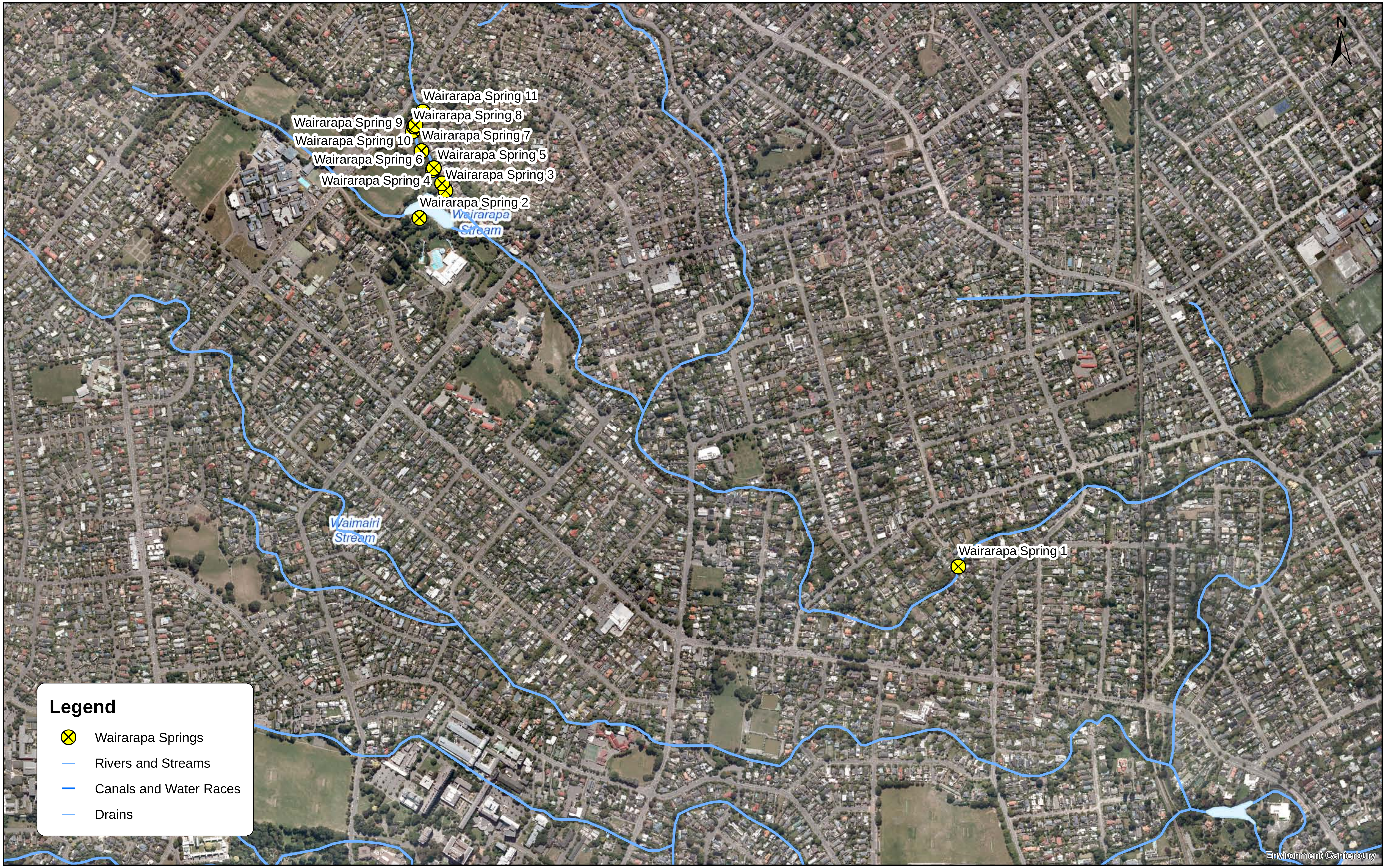


**FIGURE 7. SPRING VENT LOCATIONS IN WAIMAIRI STREAM - JUNE 2014**



1:10,000

0 250 500 Meters

FIGURE 8. SPRING VENT LOCATIONS IN WAIRARAPA STREAM - JUNE 2014

Figure 9: Proposed Sampling and Gauging points in the Waimairi Stream

Figure 10: Proposed Sampling and Gauging points in the Wairarapa Stream

1:6,000

0 150 300 Meters

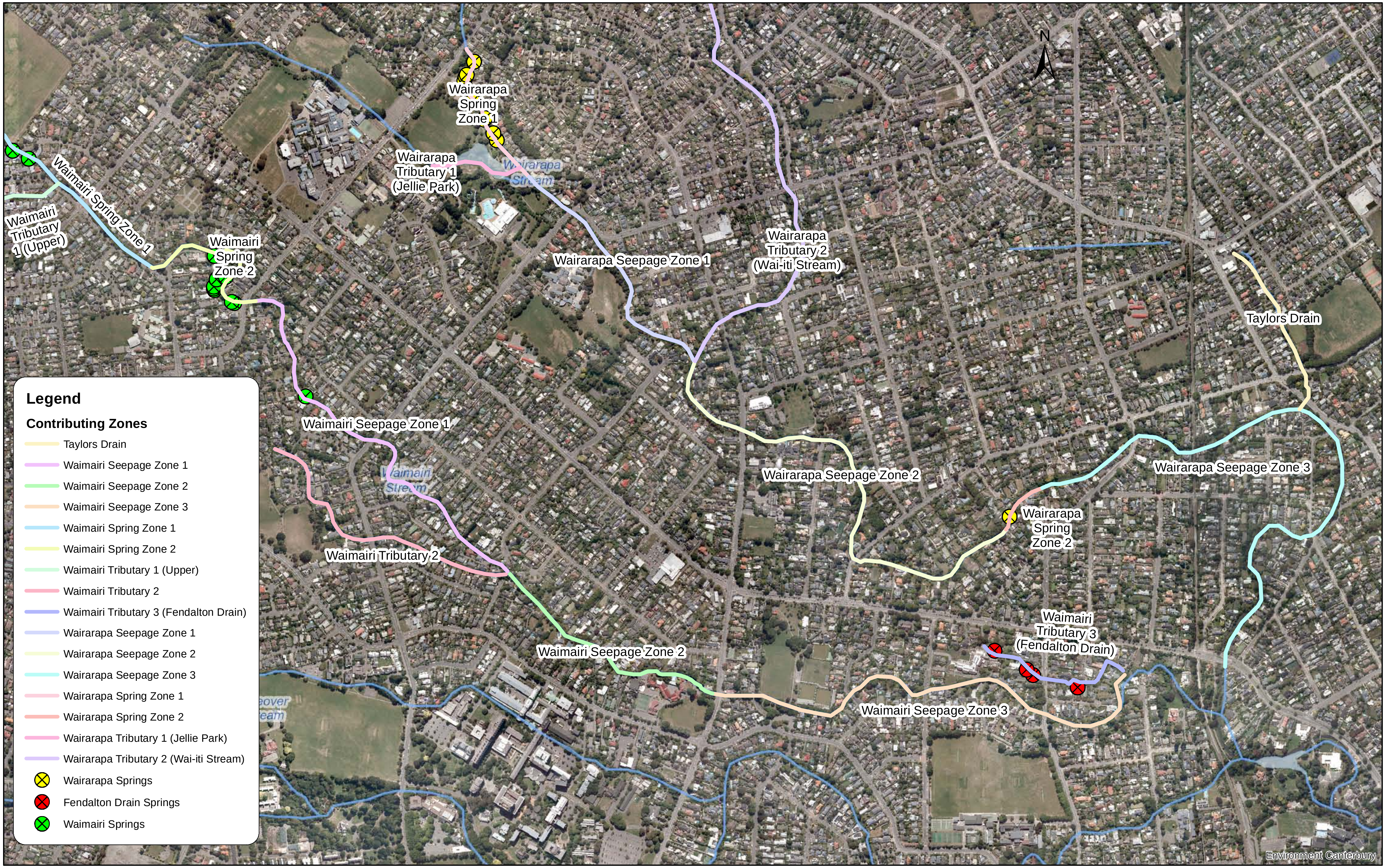


FIGURE 11. WAIMAIRI AND WAIRARAPA STREAM CONTRIBUTING ZONES

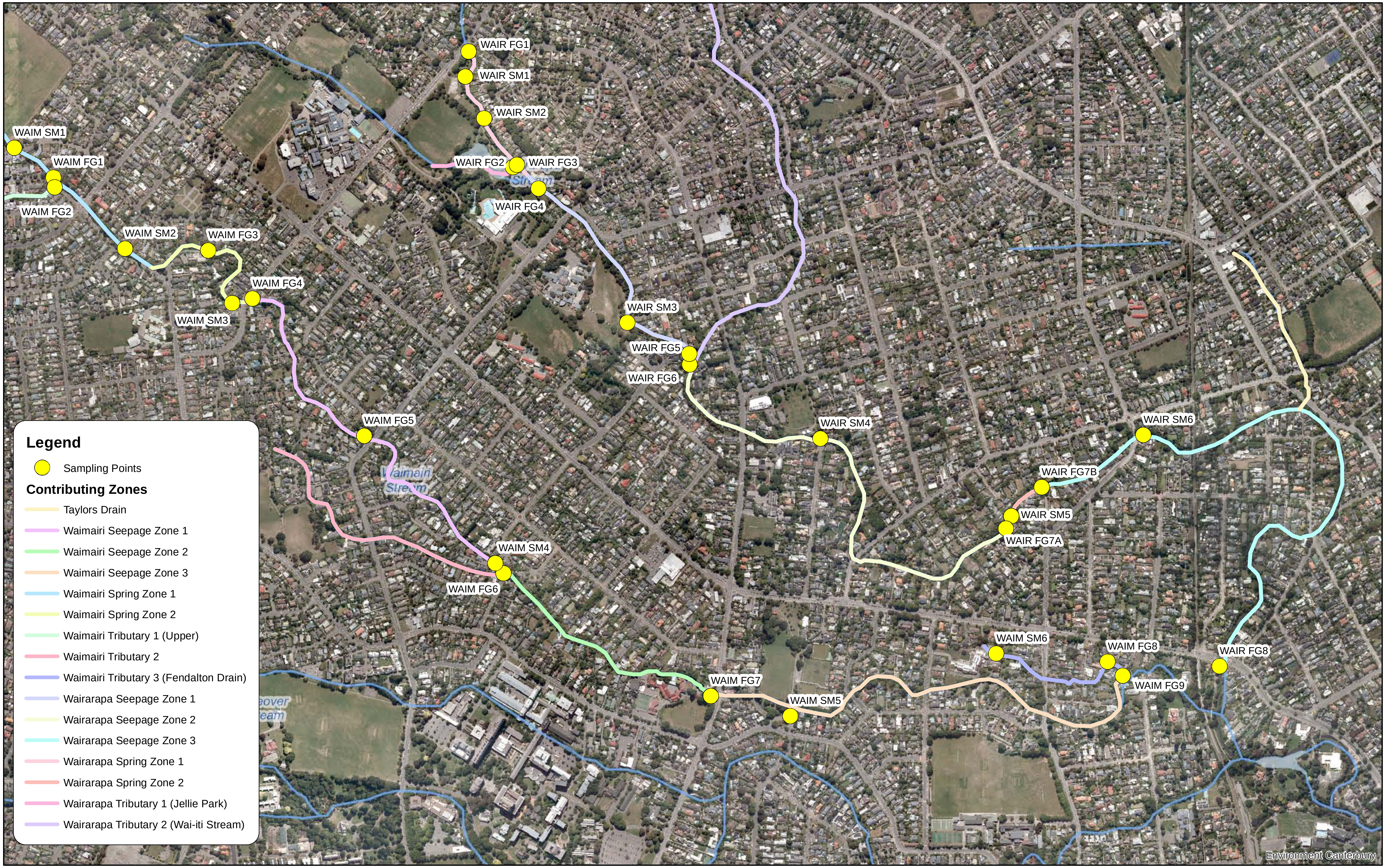
1:10,000

Meters
0 250 500

Figure 12a: Large Spring Vent Seepage Meter

Figure 12b: General Streambed Seepage Meter

Figure 13: Large Slotted Temporary Piezometer



Meters
0 250 500

1:10,000

FIGURE 14. SAMPLING POINTS - September 2014

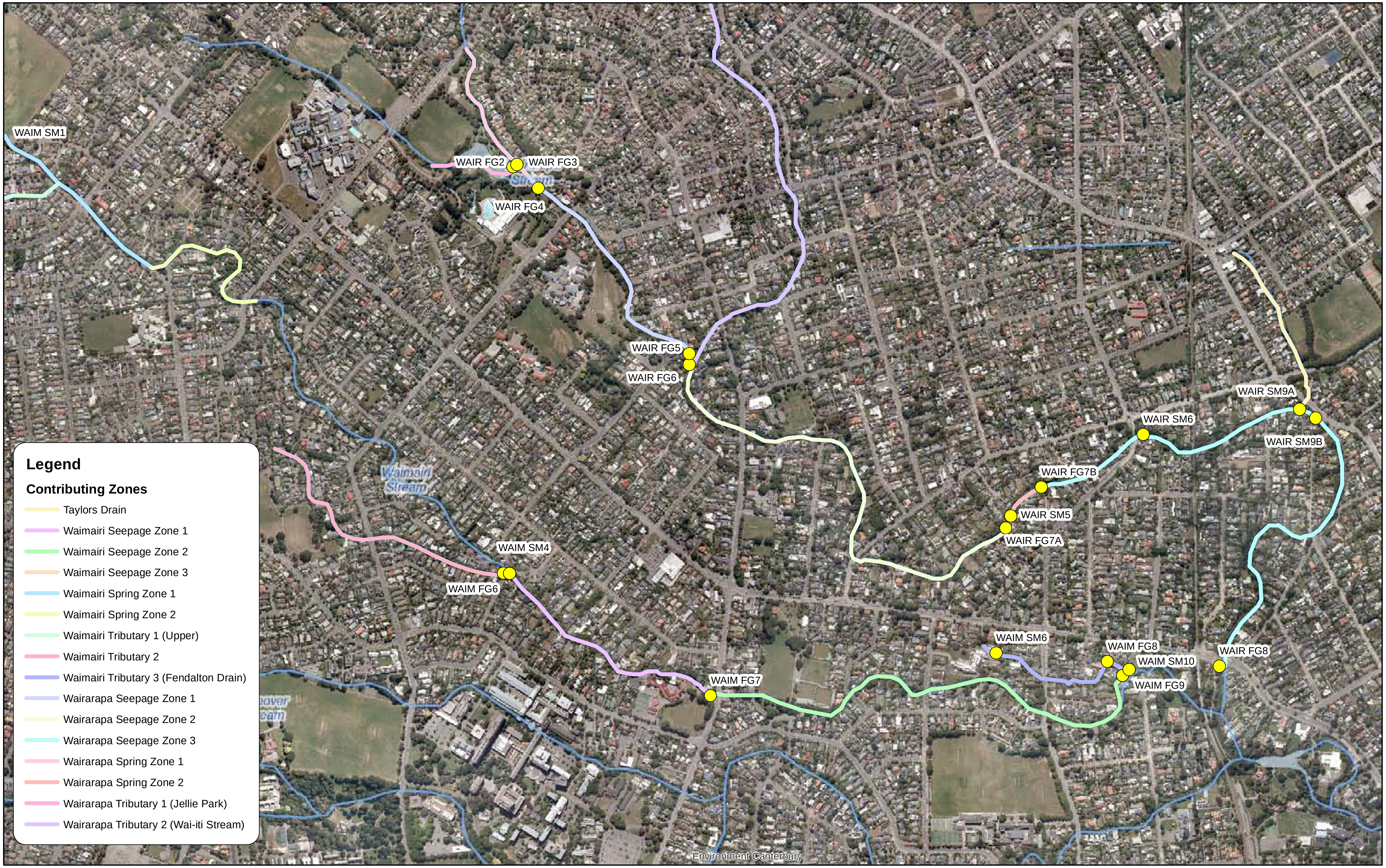


FIGURE 15. SAMPLING POINTS - MARCH 2015

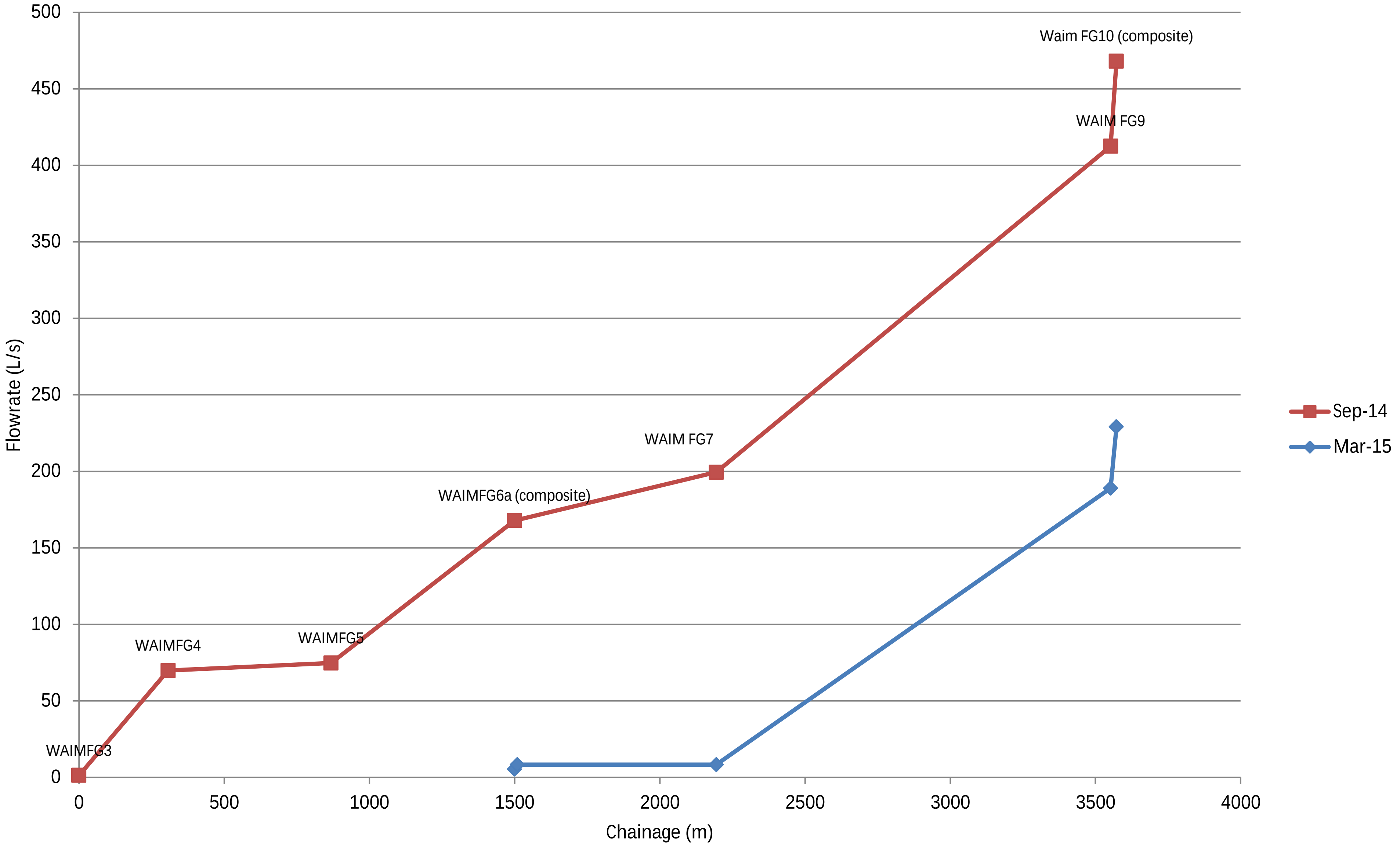


Figure 16: Flowrate at Flow Gauging Points in Waimairi Stream

Figure 17: Flowrate in Recharge Zones in Waimairi Stream

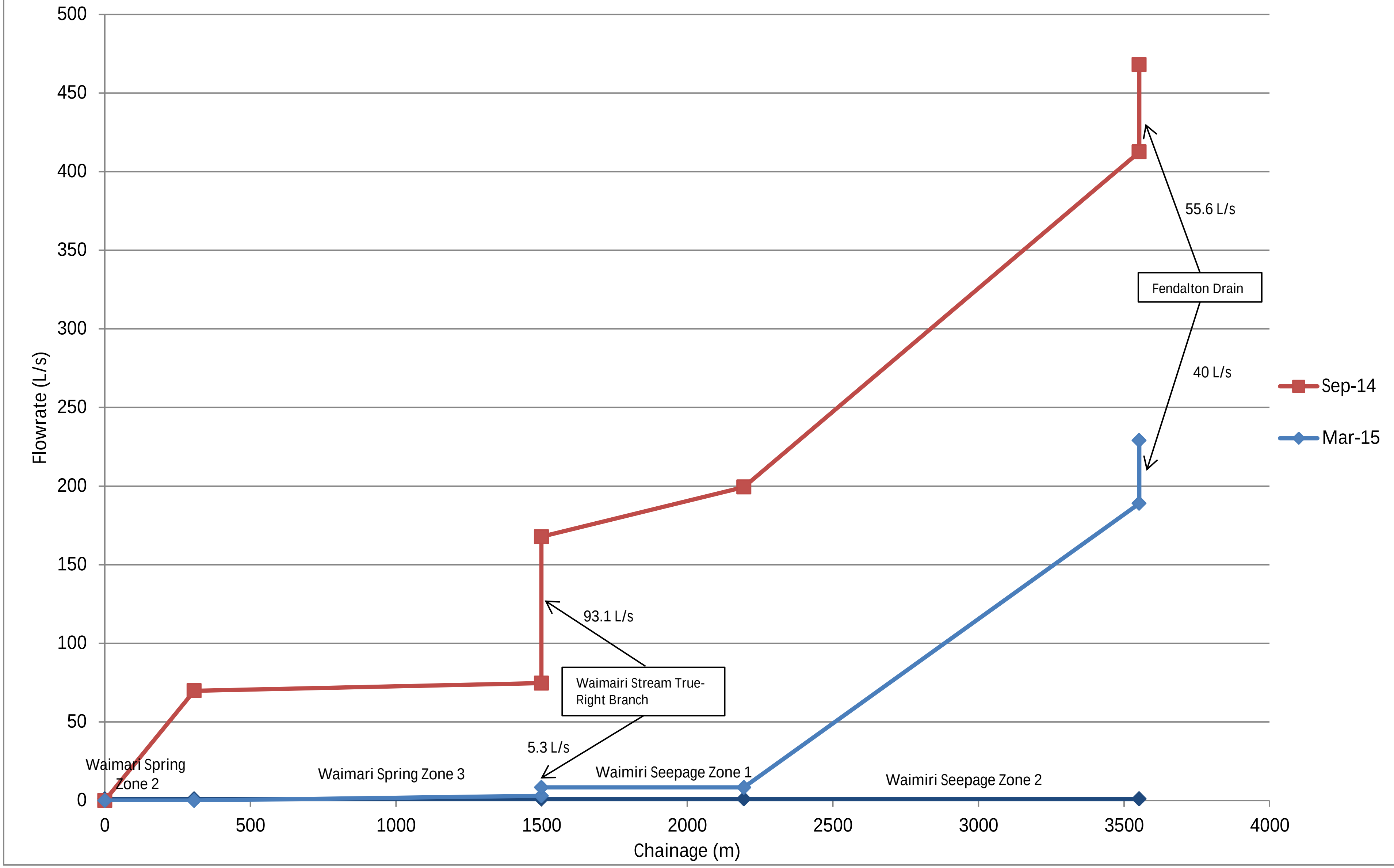


Figure 18: Flowrate at Flow Gauging Points in Wairarapa Stream

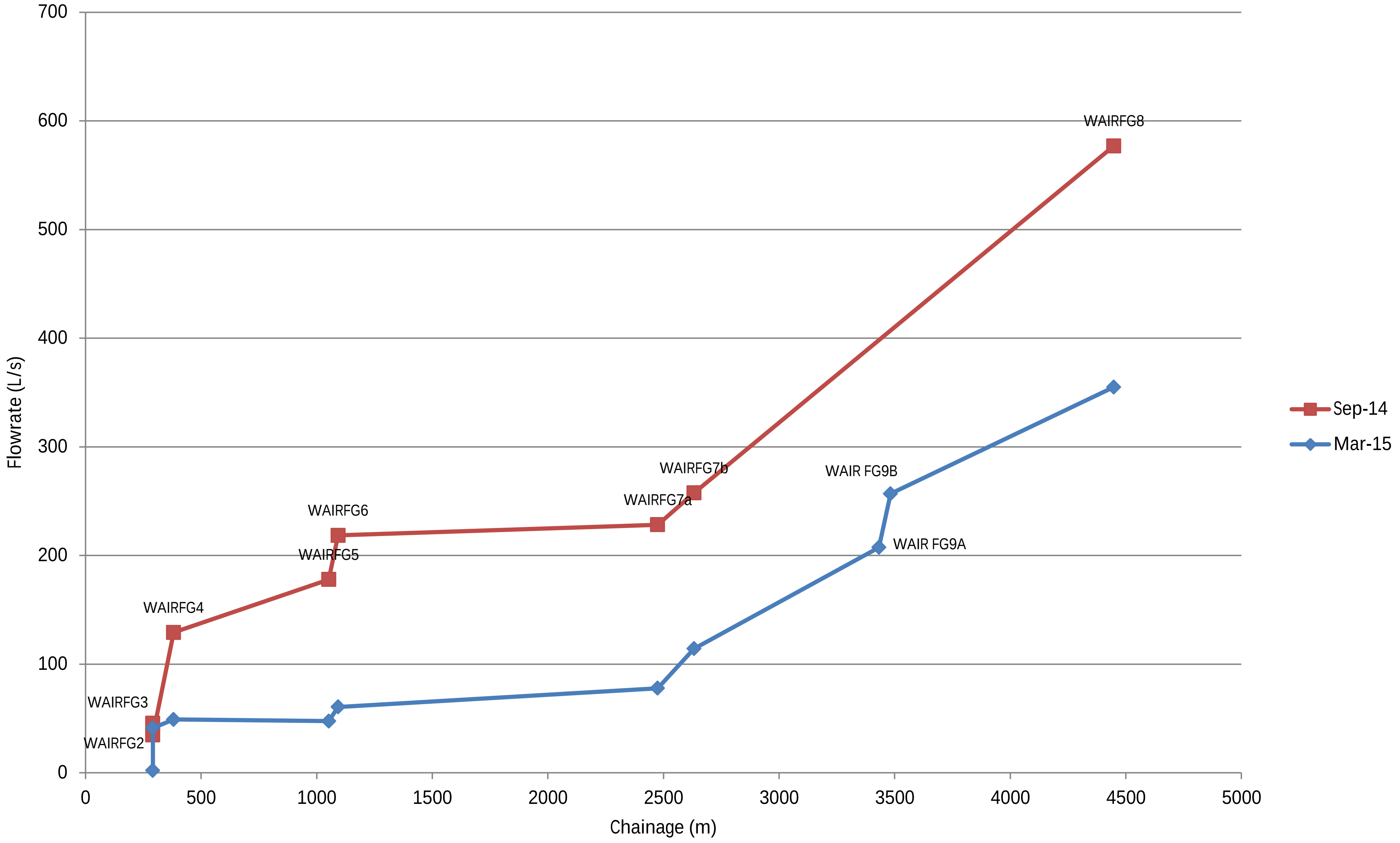
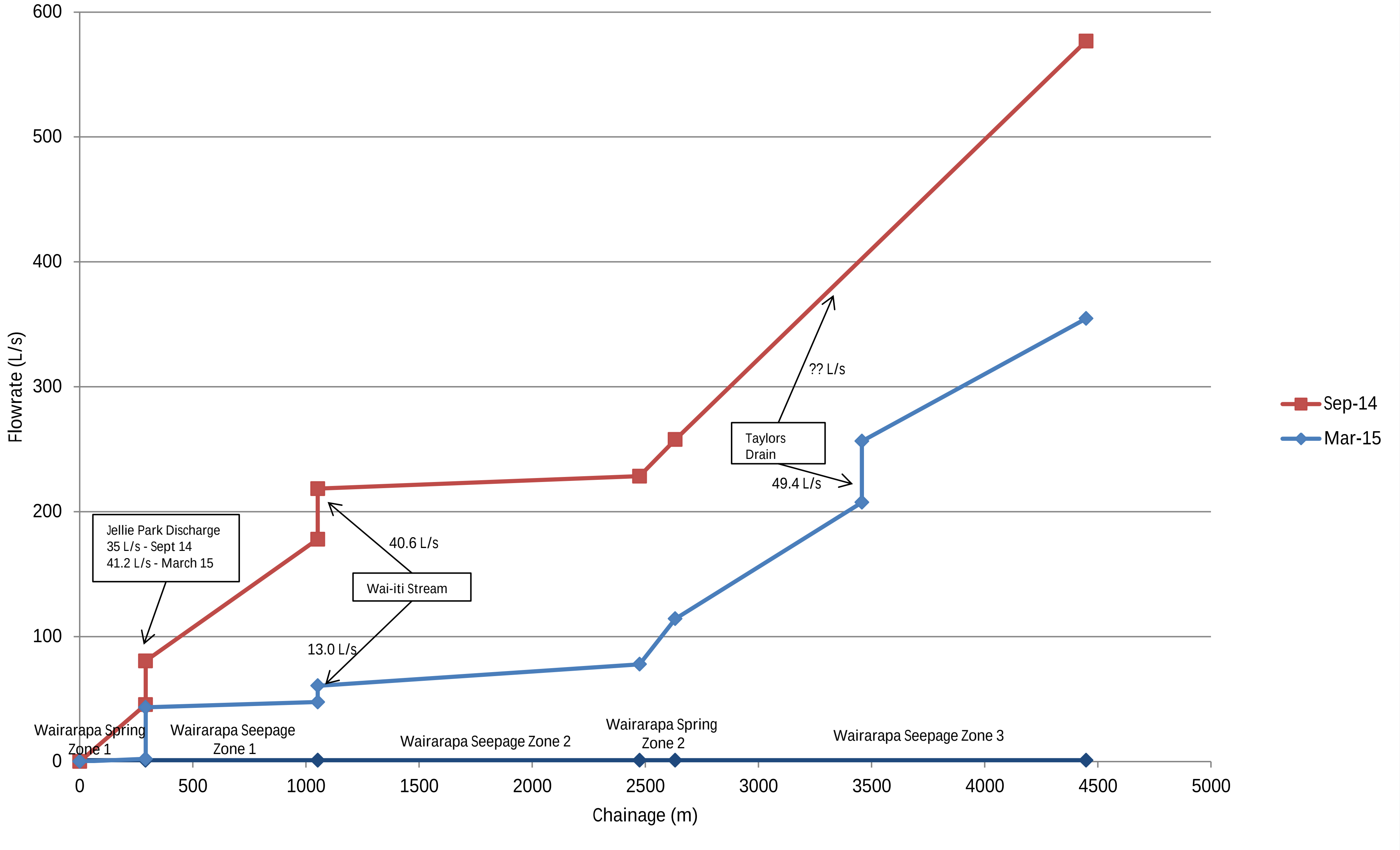


Figure 19: Flowrate in Recharge Zones in Wairarapa Stream



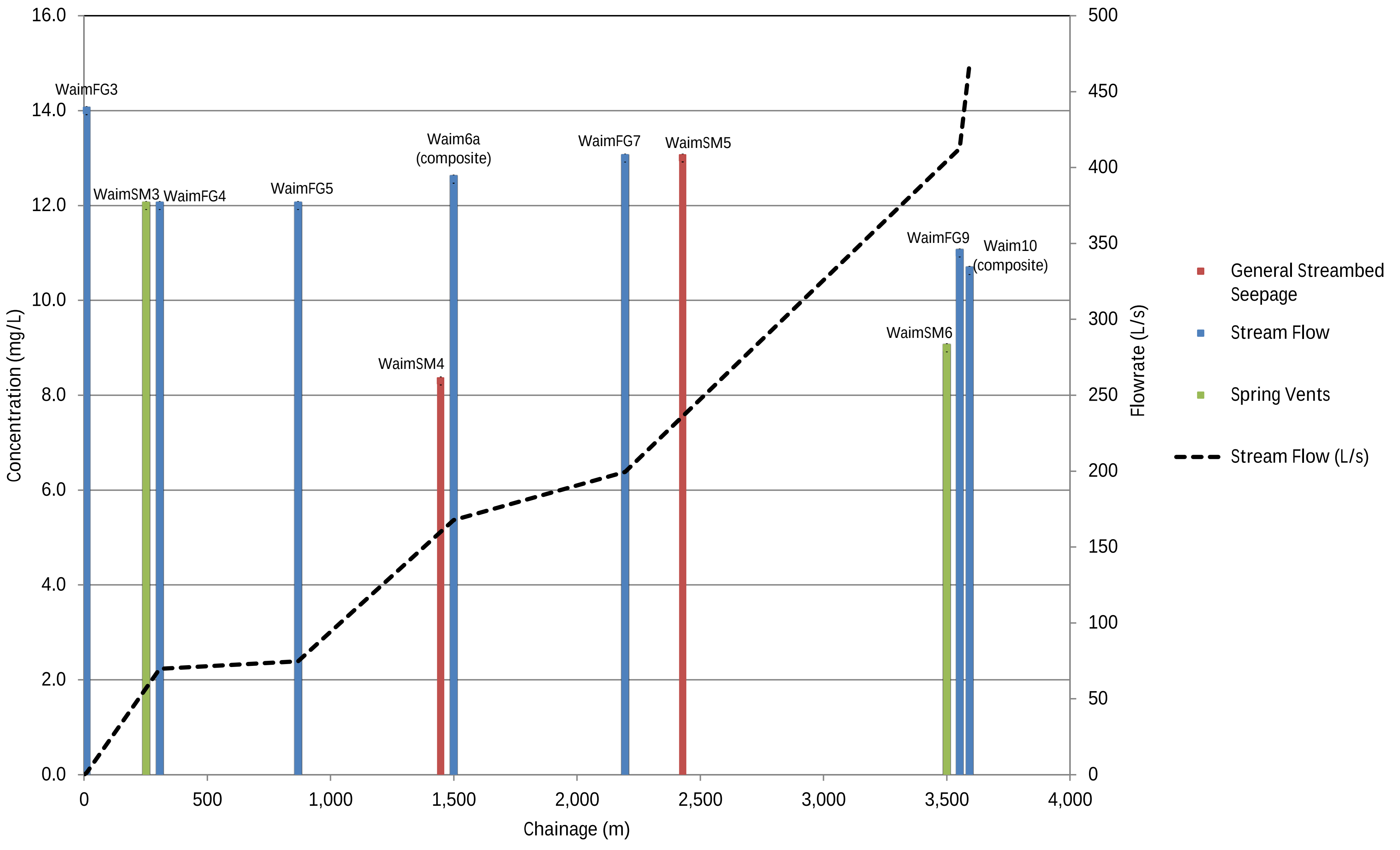


Figure 20a: Chloride Concentrations in Waimairi Stream - September 2014

# Figure 20b: Chloride Concentrations in Waimairi Stream - March 2015

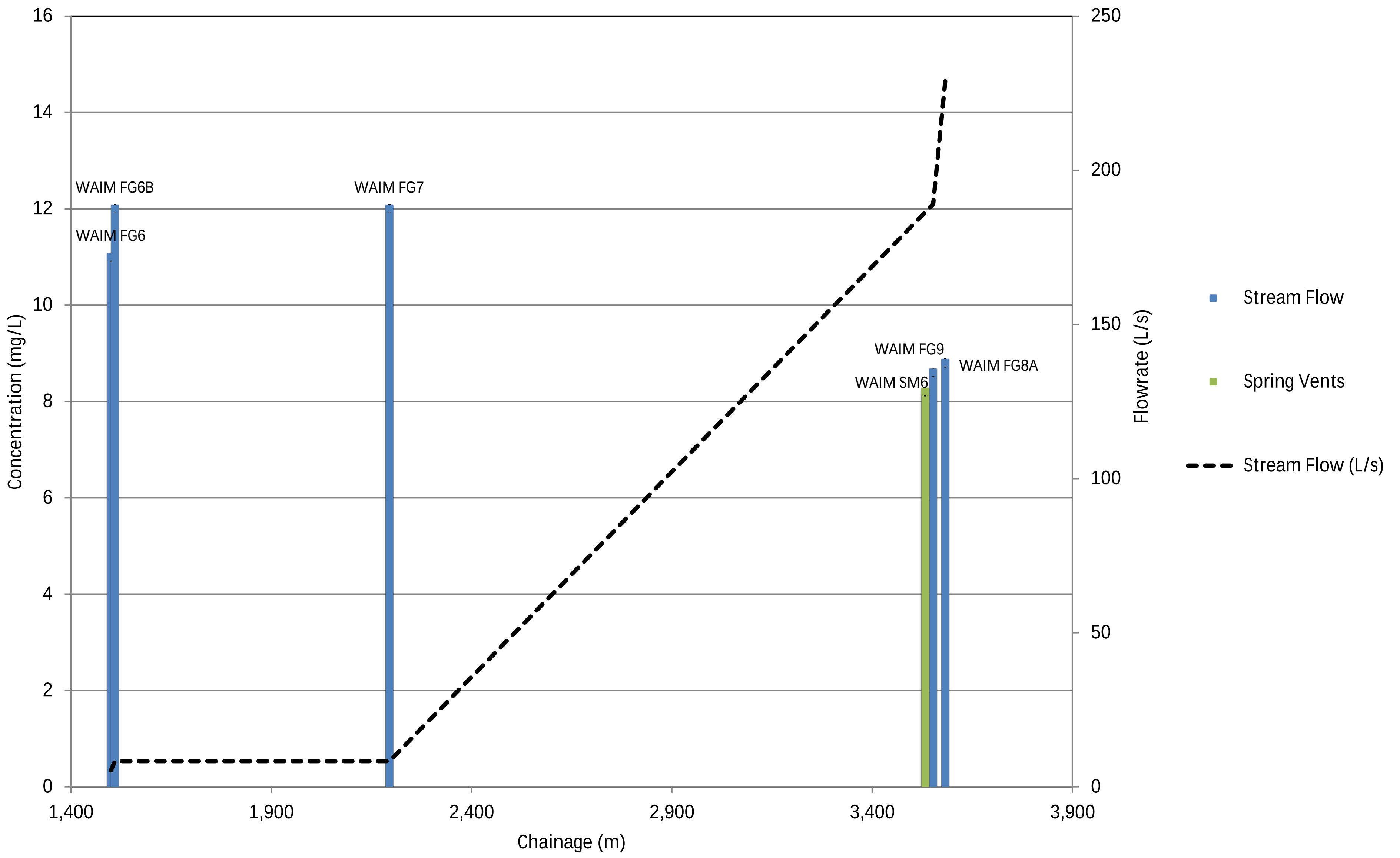
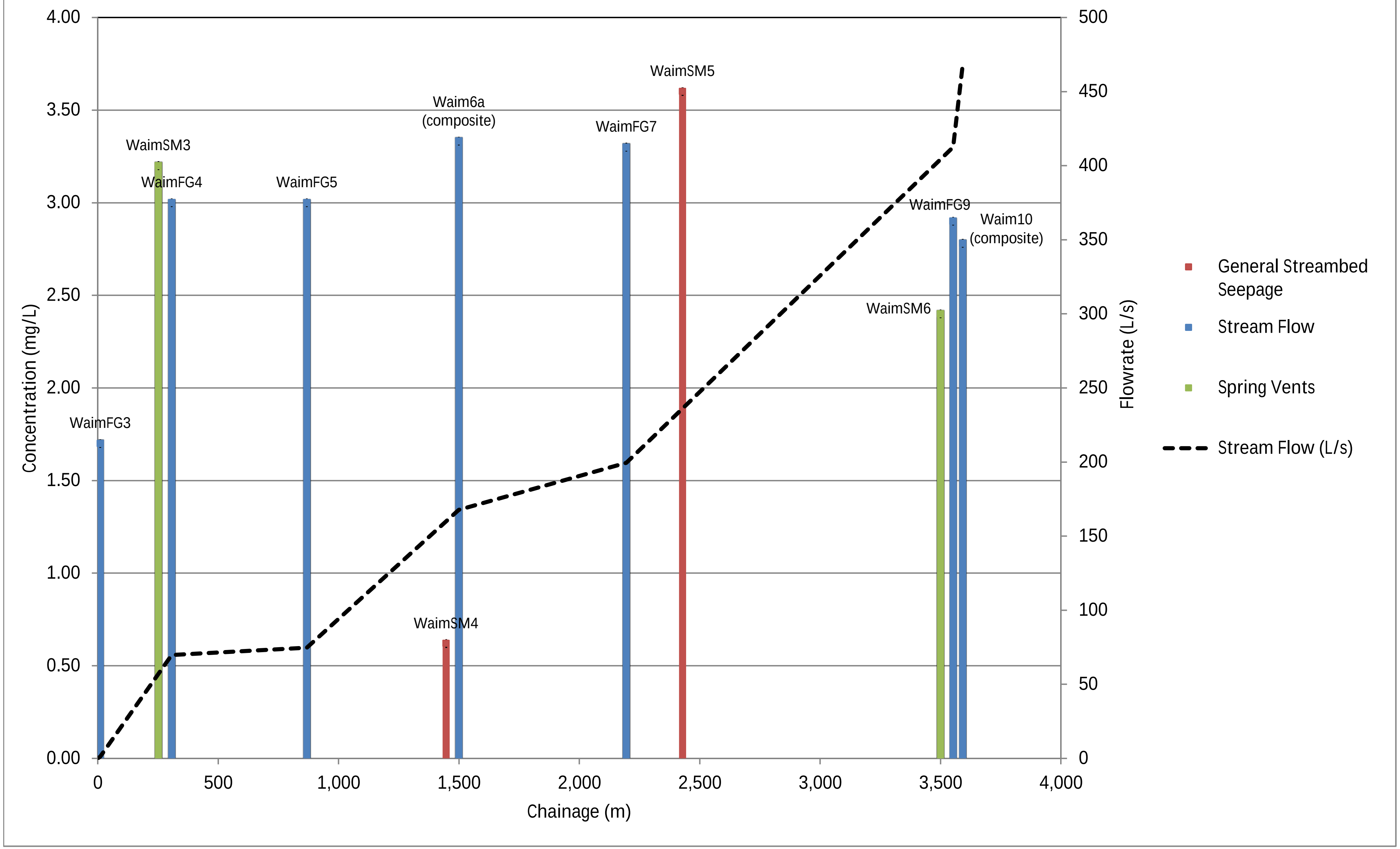


Figure 21a: Total N Concentrations in Waimairi Stream - September 2014



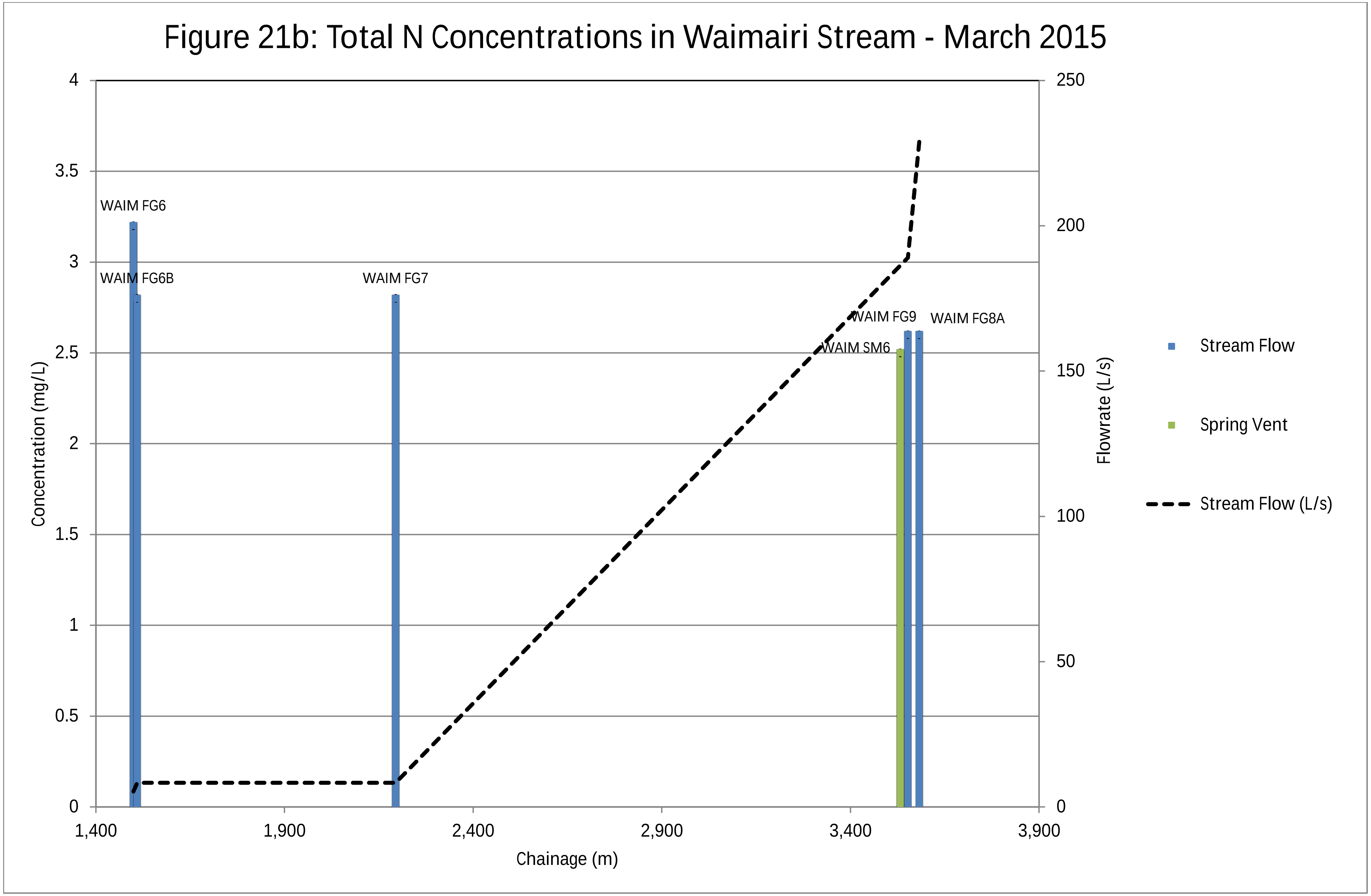


Figure 21b: Total N Concentrations in Waimairi Stream - March 2015
Concentration (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
4
Flowrate (L/s)
0
50
100
150
200
250
Chainage (m)
1,400
1,900
2,400
2,900
3,400
3,900
WAIM FG6
WAIM FG6B
WAIM FG7
WAIM FG9
WAIM SM6
WAIM FG8A
Stream Flow
Spring Vent
Stream Flow (L/s)

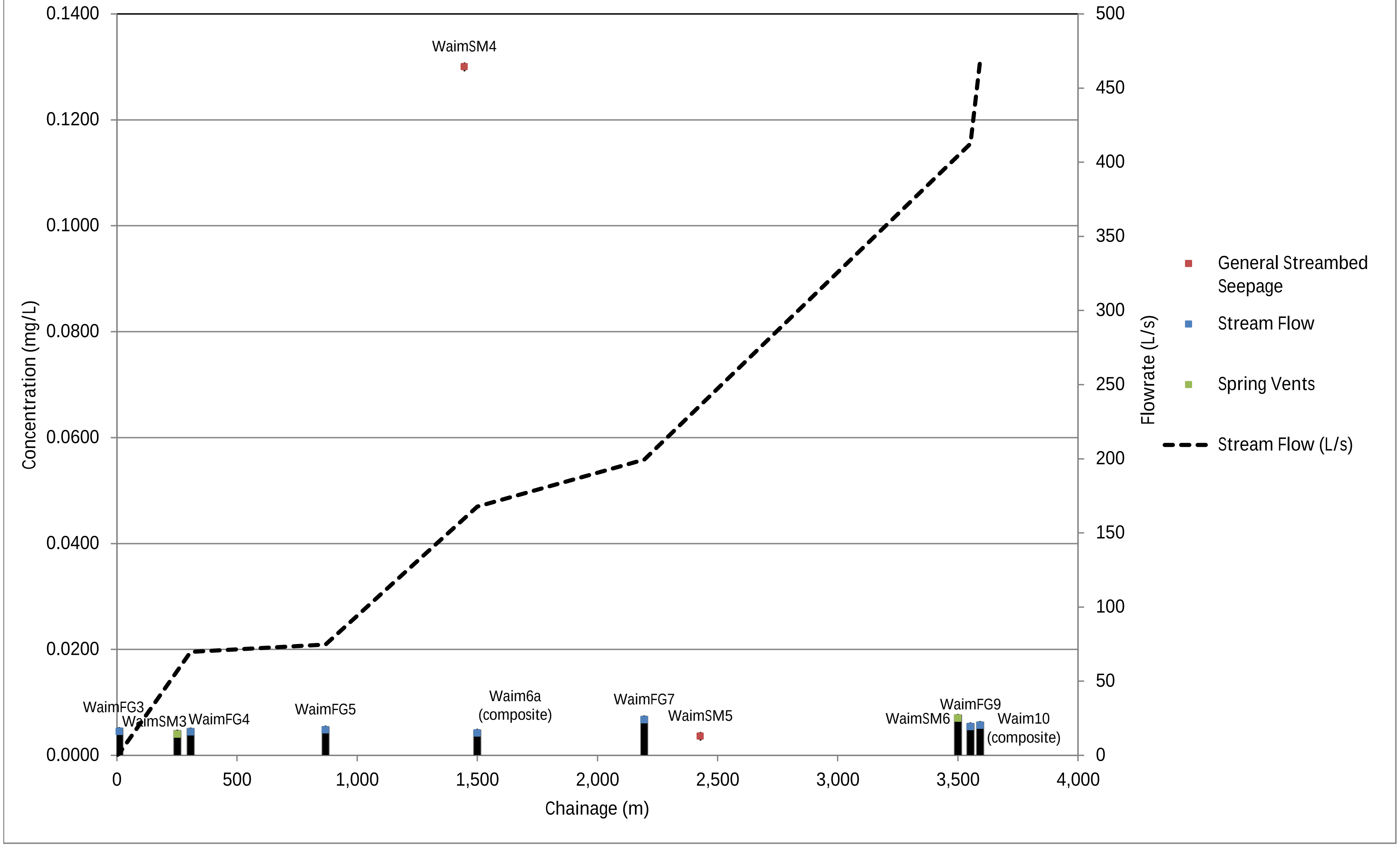
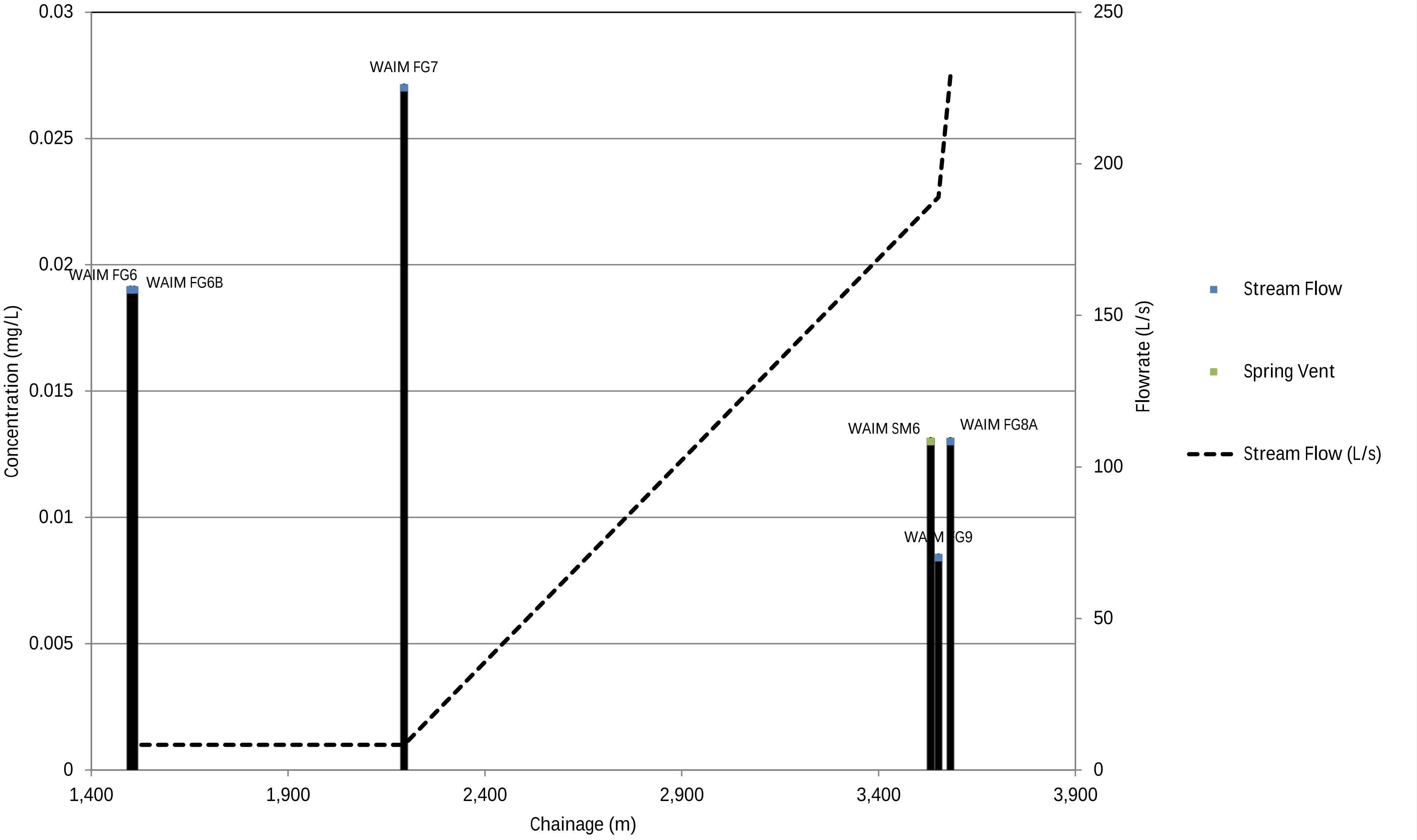


Figure 22a: DRP Concentrations in Waimairi Stream - September 2014

## Figure 22b: DRP Concentrations in Waimairi Stream - March 2015



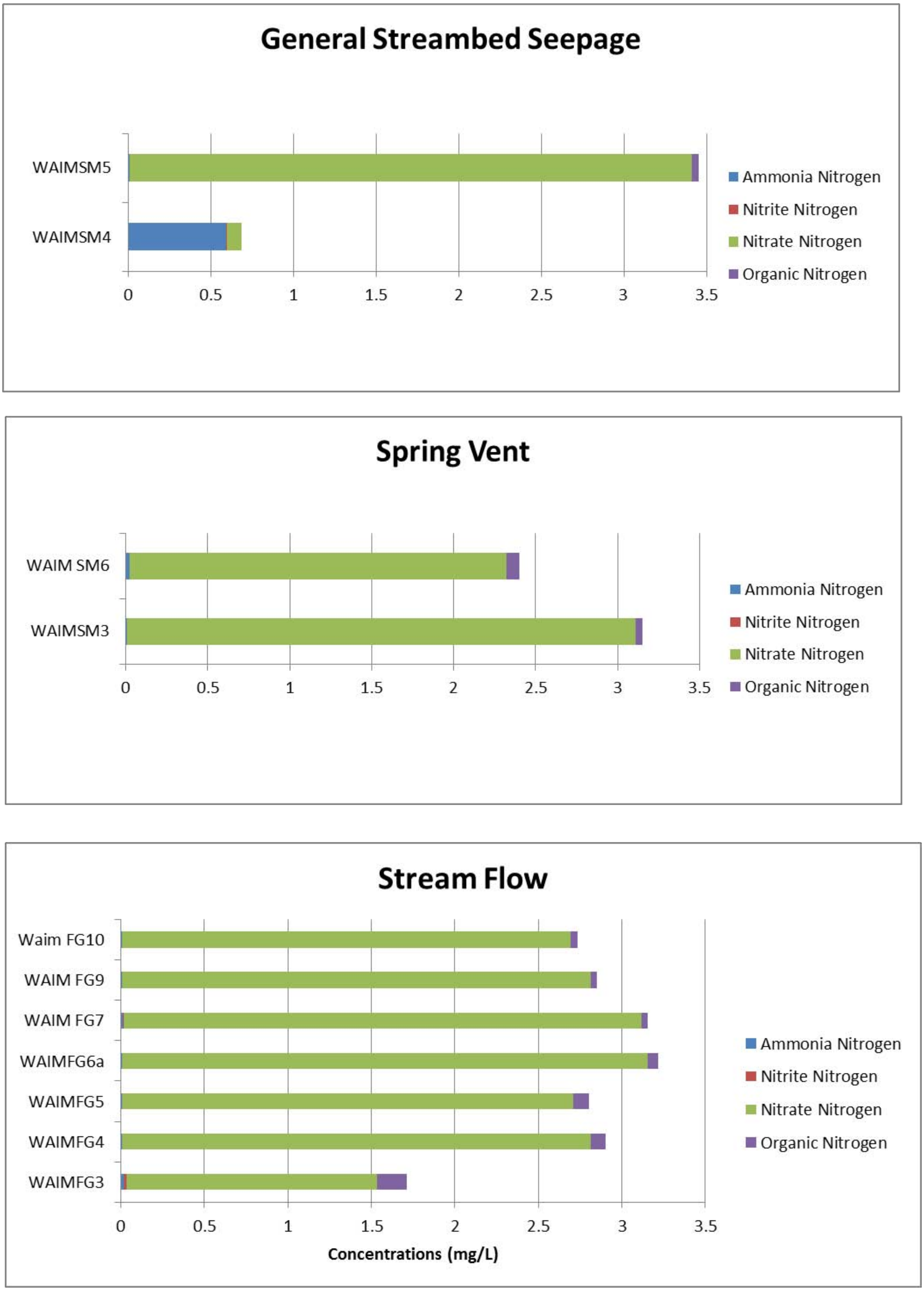
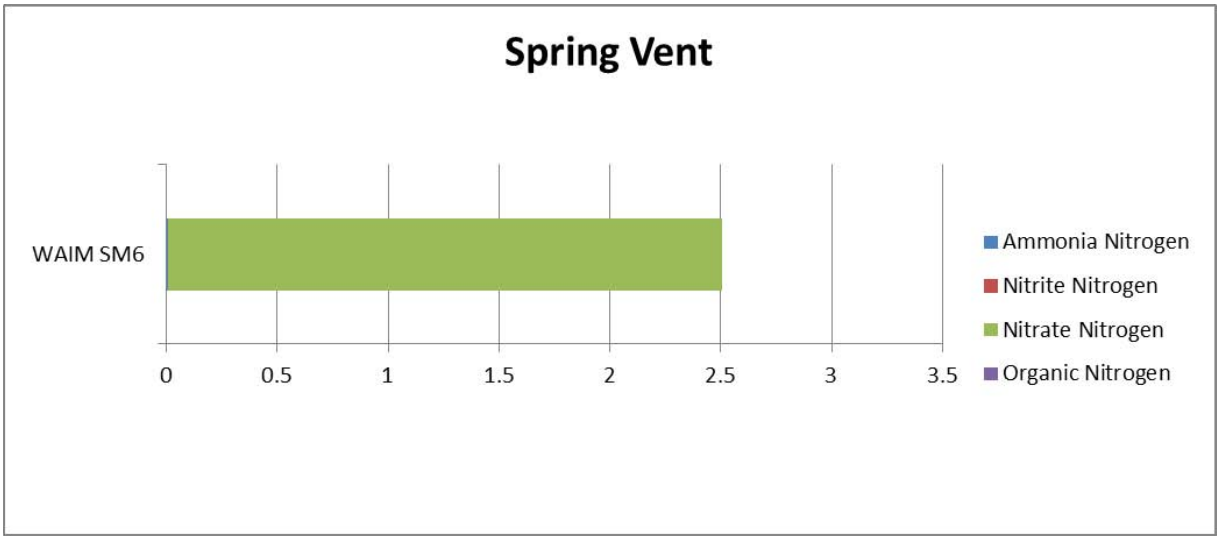


Figure 23a: Waimairi Nitrogen Species Composition – September 2014



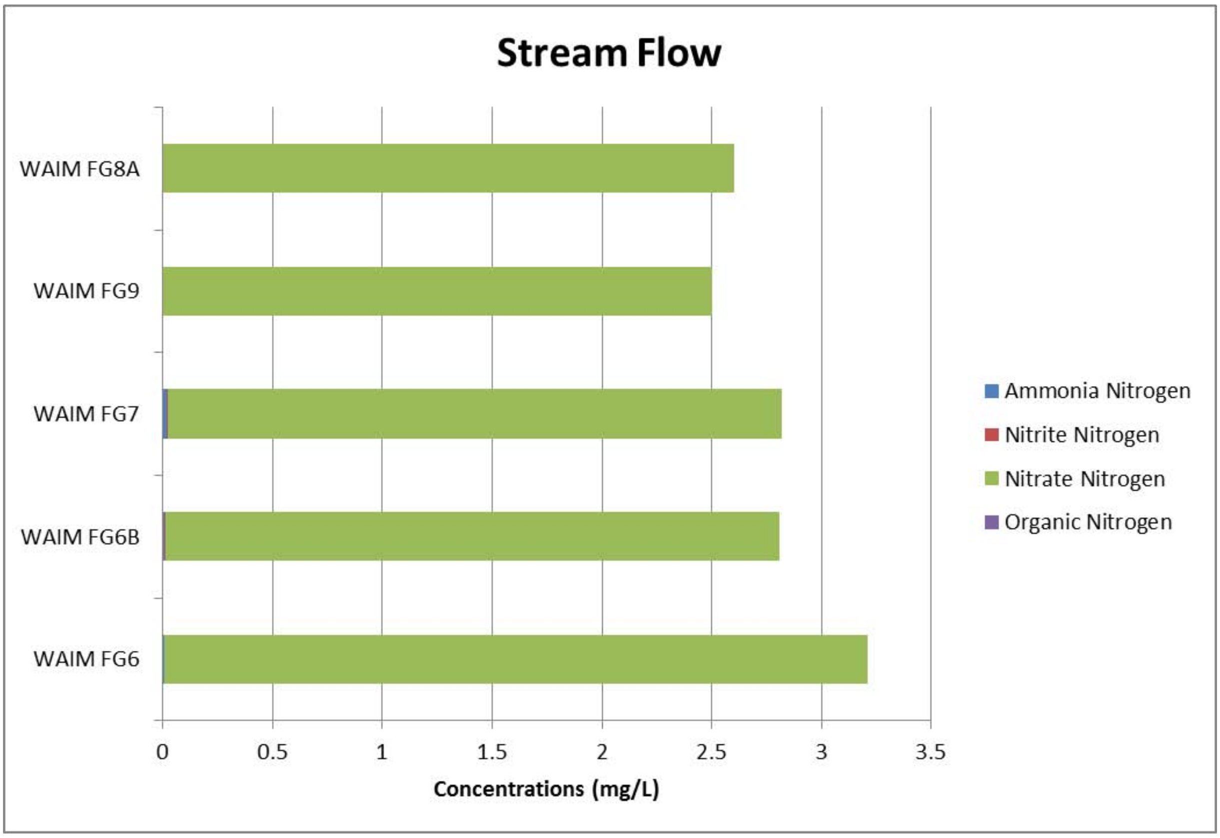


Figure 23b: Waimairi Nitrogen Species Composition – March 2015

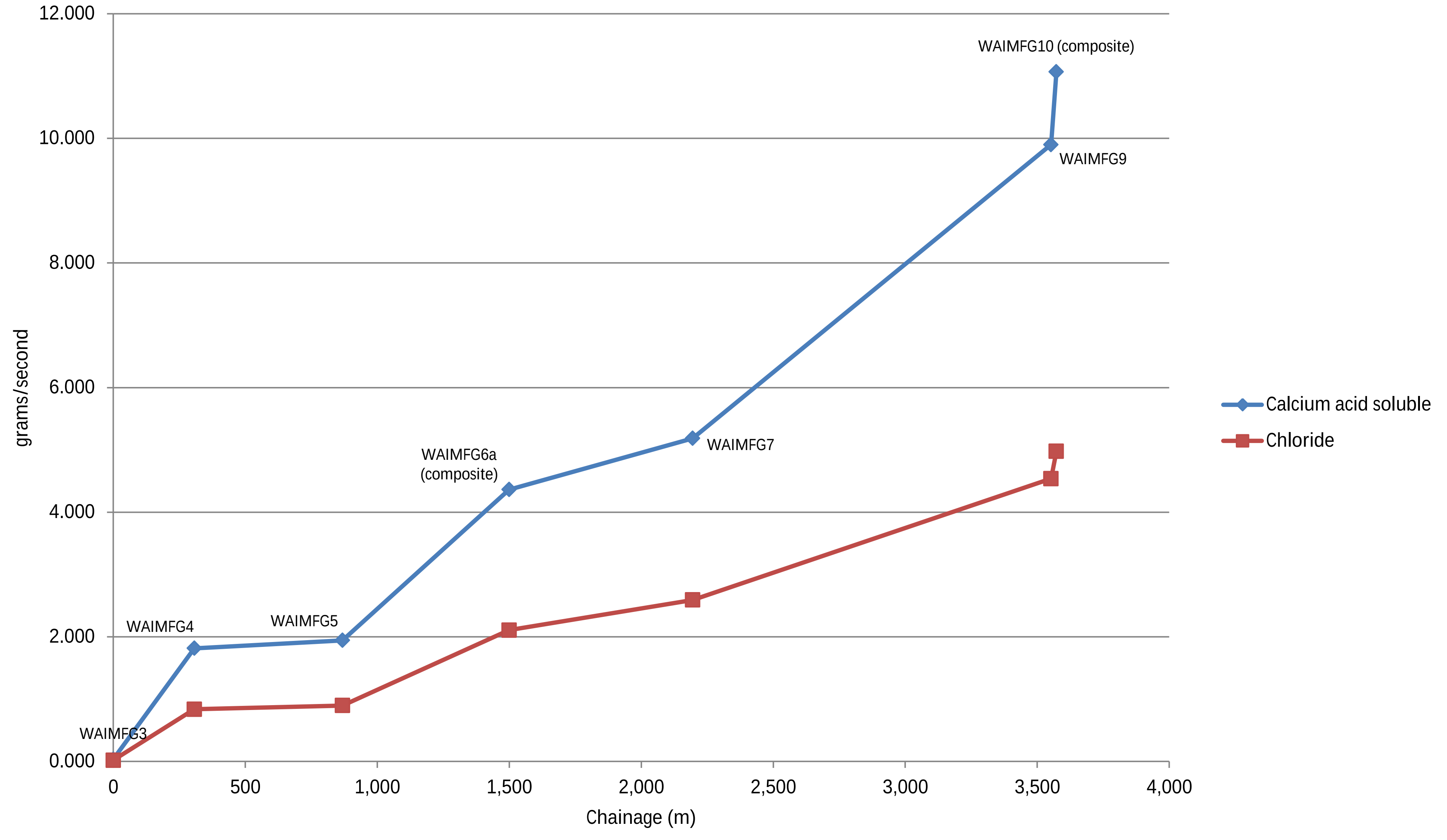
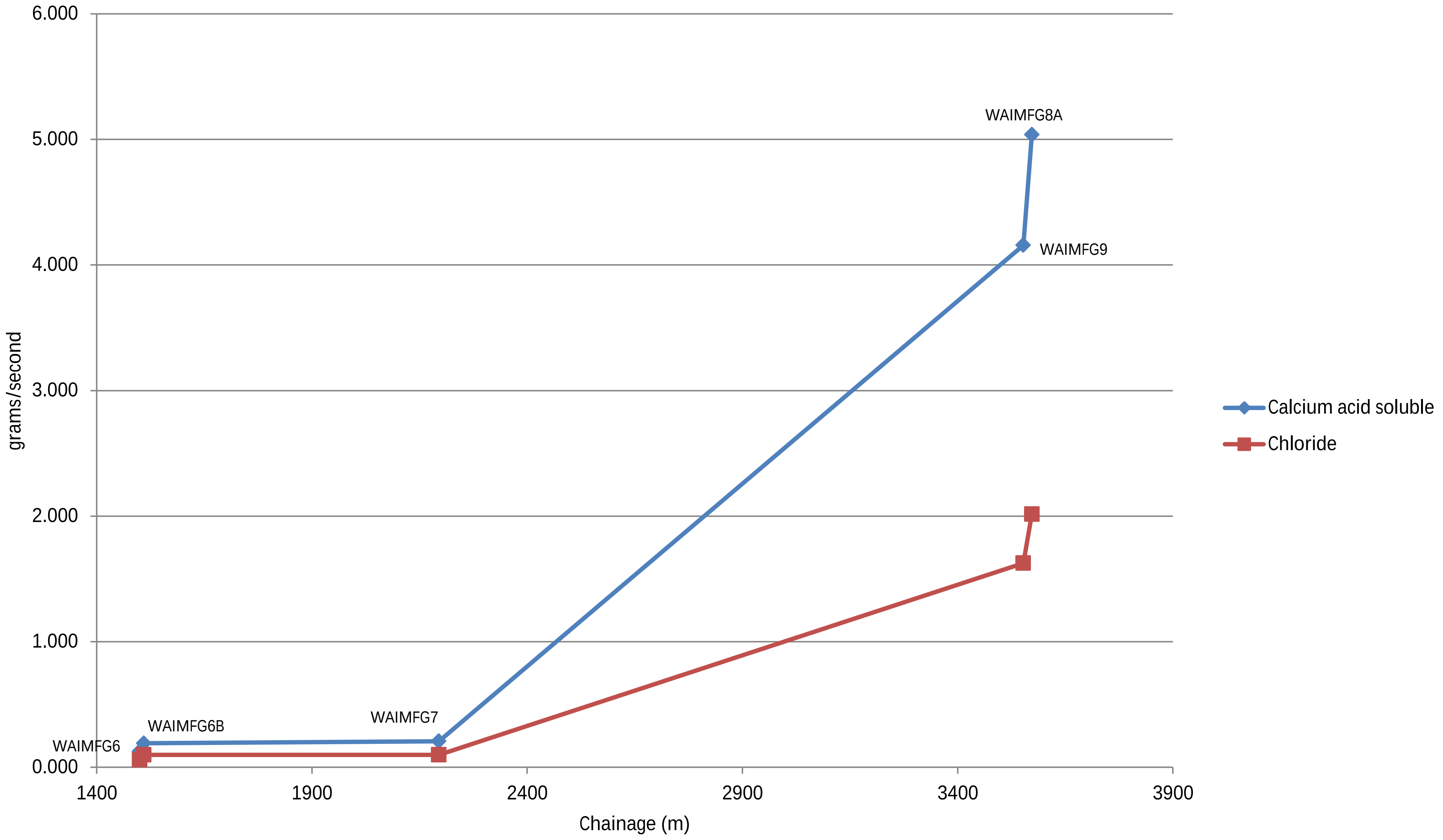


Figure 24a: Accumulating Masses at Flow Gauging Points in Waimairi Stream - September 2014

Figure 24b: Accumulating Masses at Flow Gauging Points in Waimairi Stream - March 2015



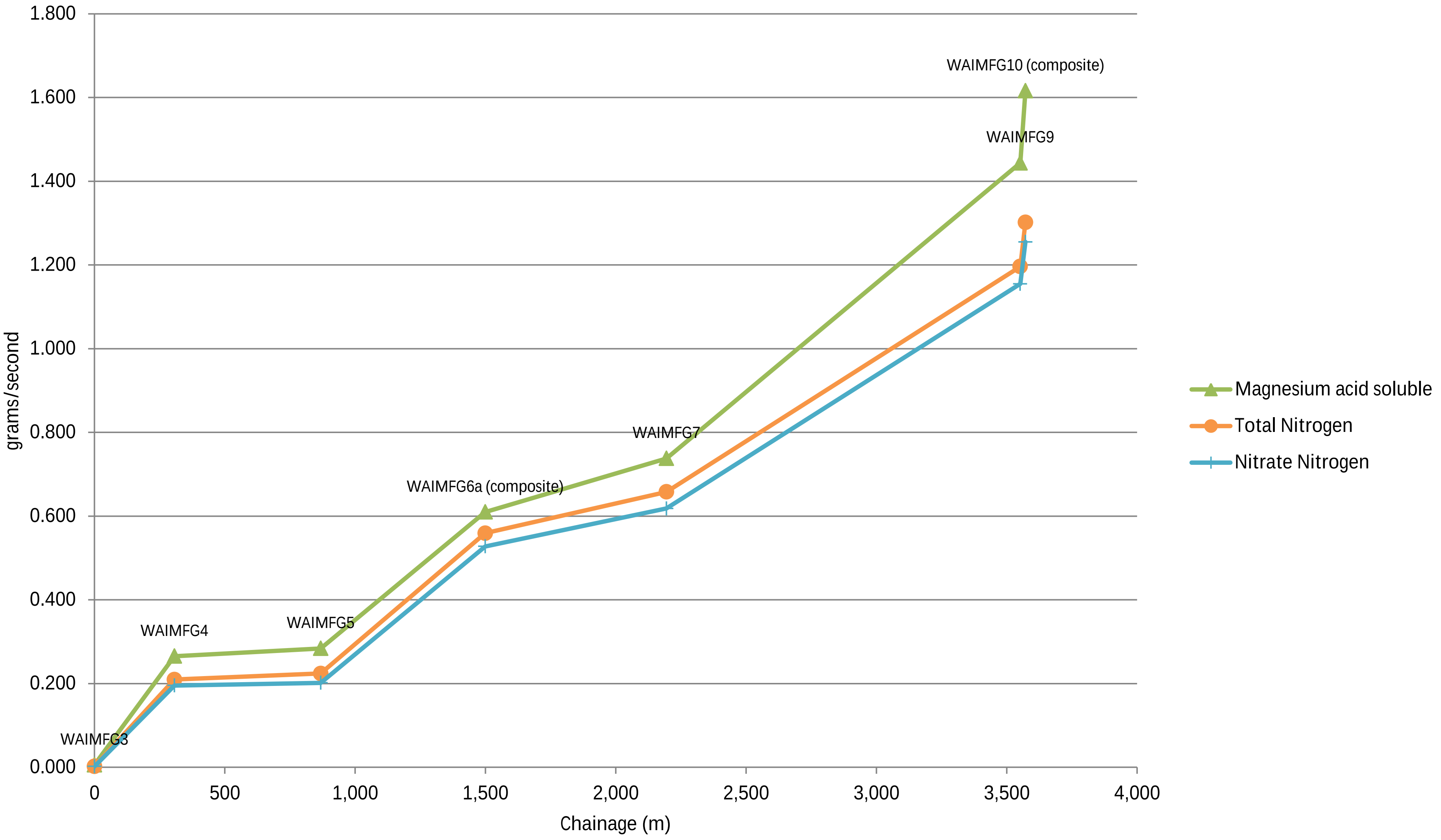


Figure 25a: Accumulating Masses at Flow Gauging Points in Waimairi Stream - September 2014

Figure 25b: Accumulating Masses at Flow Gauging Points in Waimairi Stream - March 2015

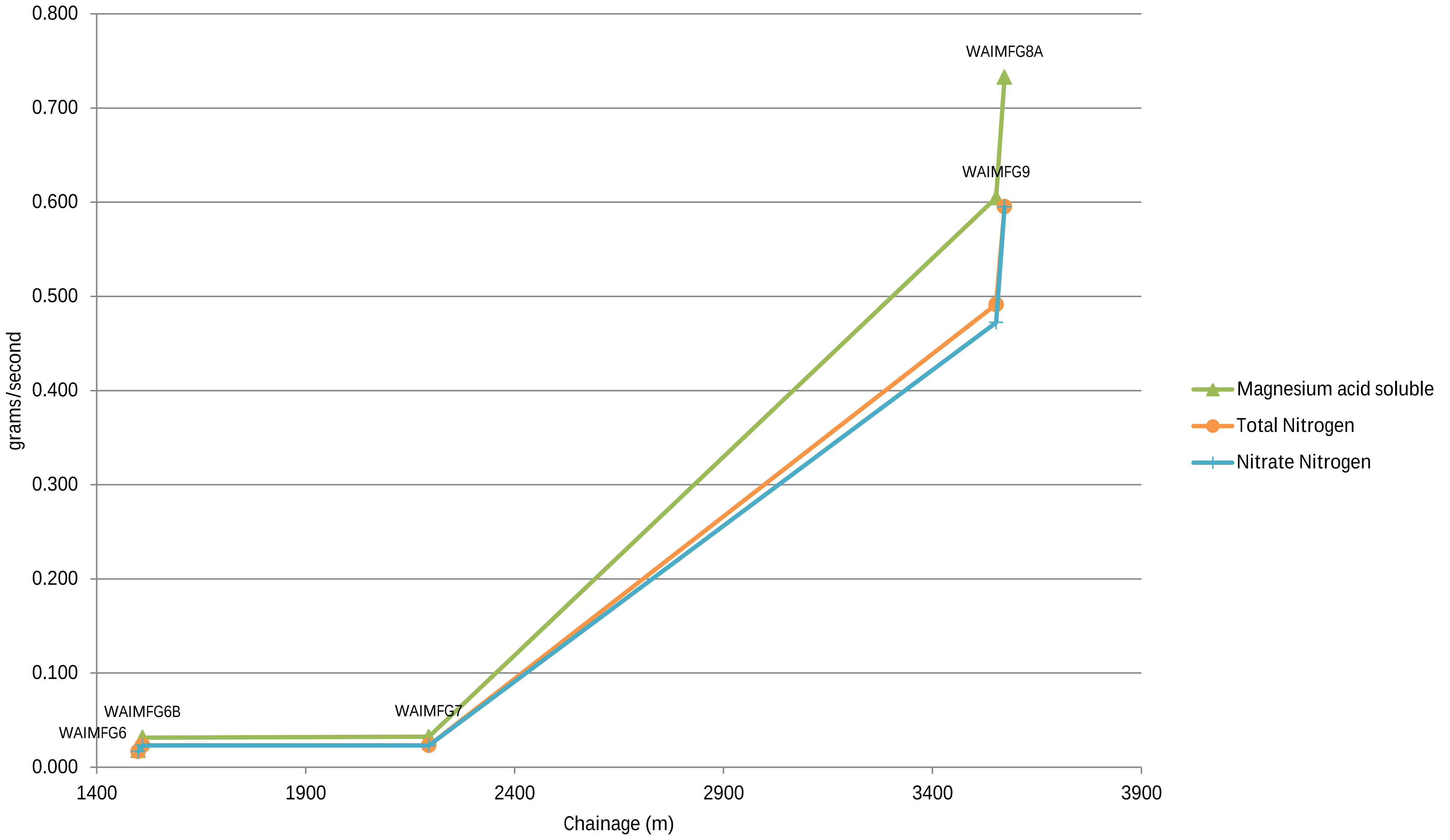
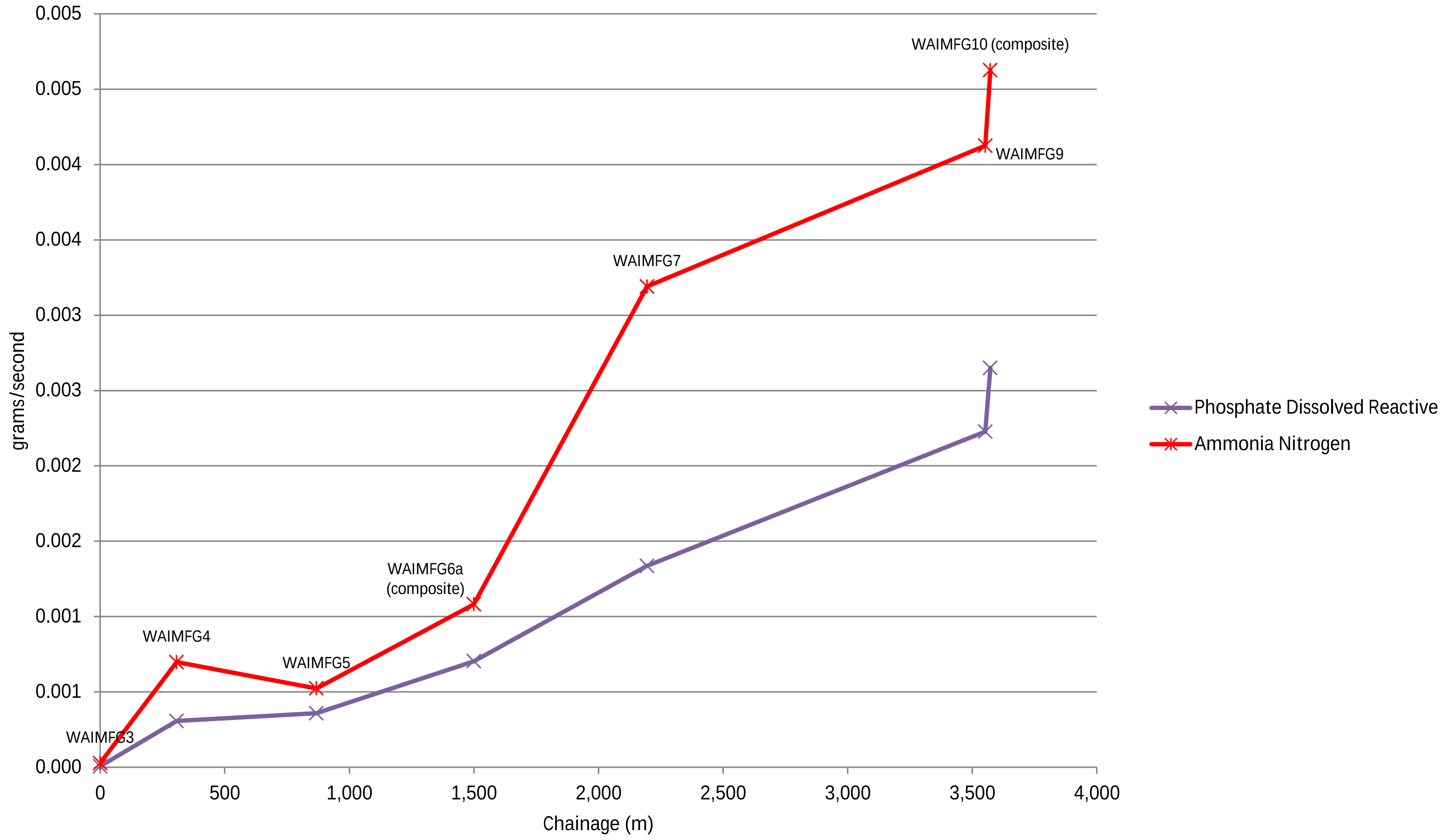


Figure 26a: Accumulating Masses at Flow Gauging Points in Waimairi Stream - September 2014



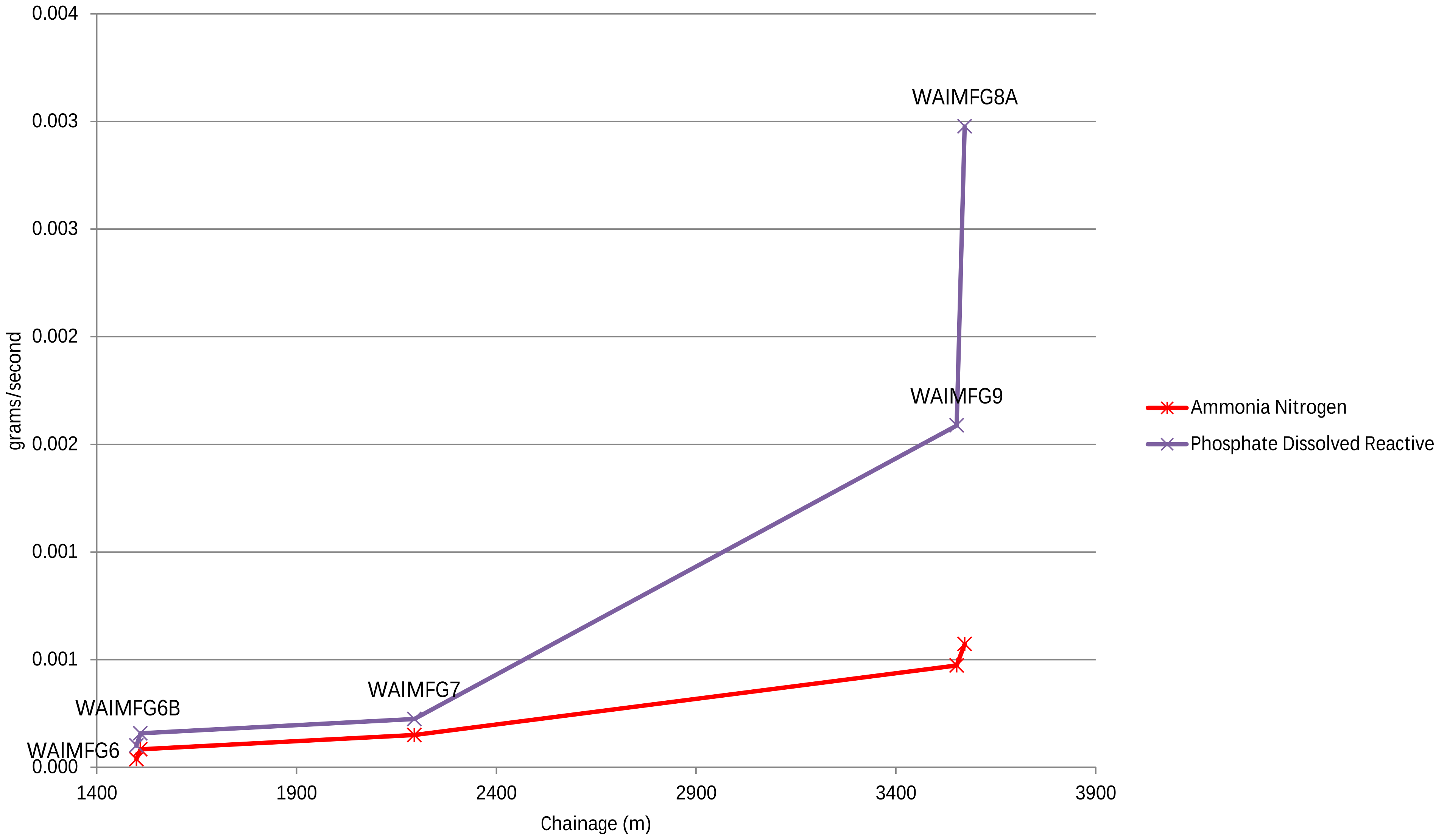


Figure 26b: Accumulating Masses at Flow Gauging Points in Waimairi Stream - March 2015

Figure 27a: Comparison of TN Masses at Flow Gauging Points compared to Contributing Zones in Waimairi Stream - September 2014

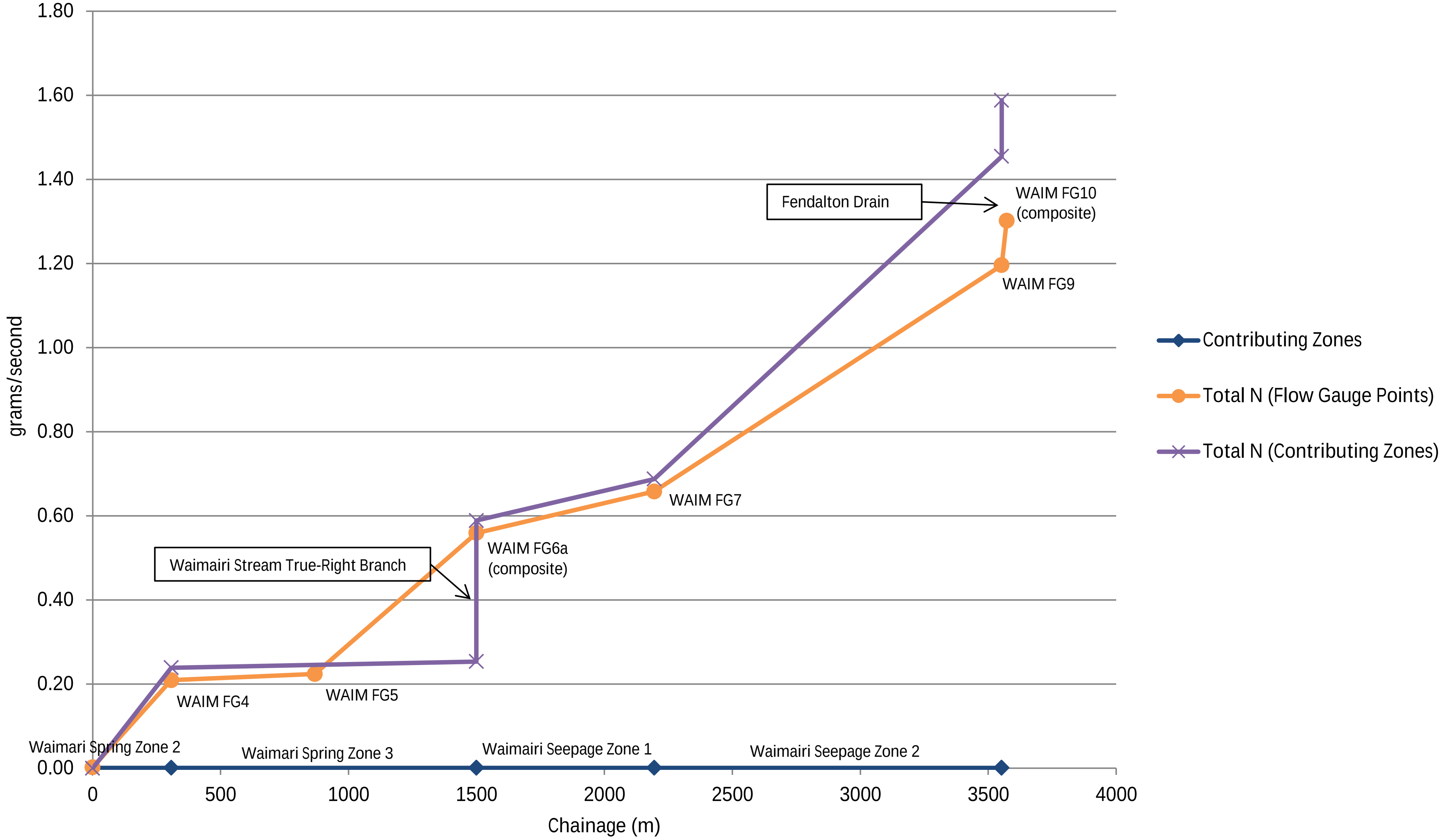
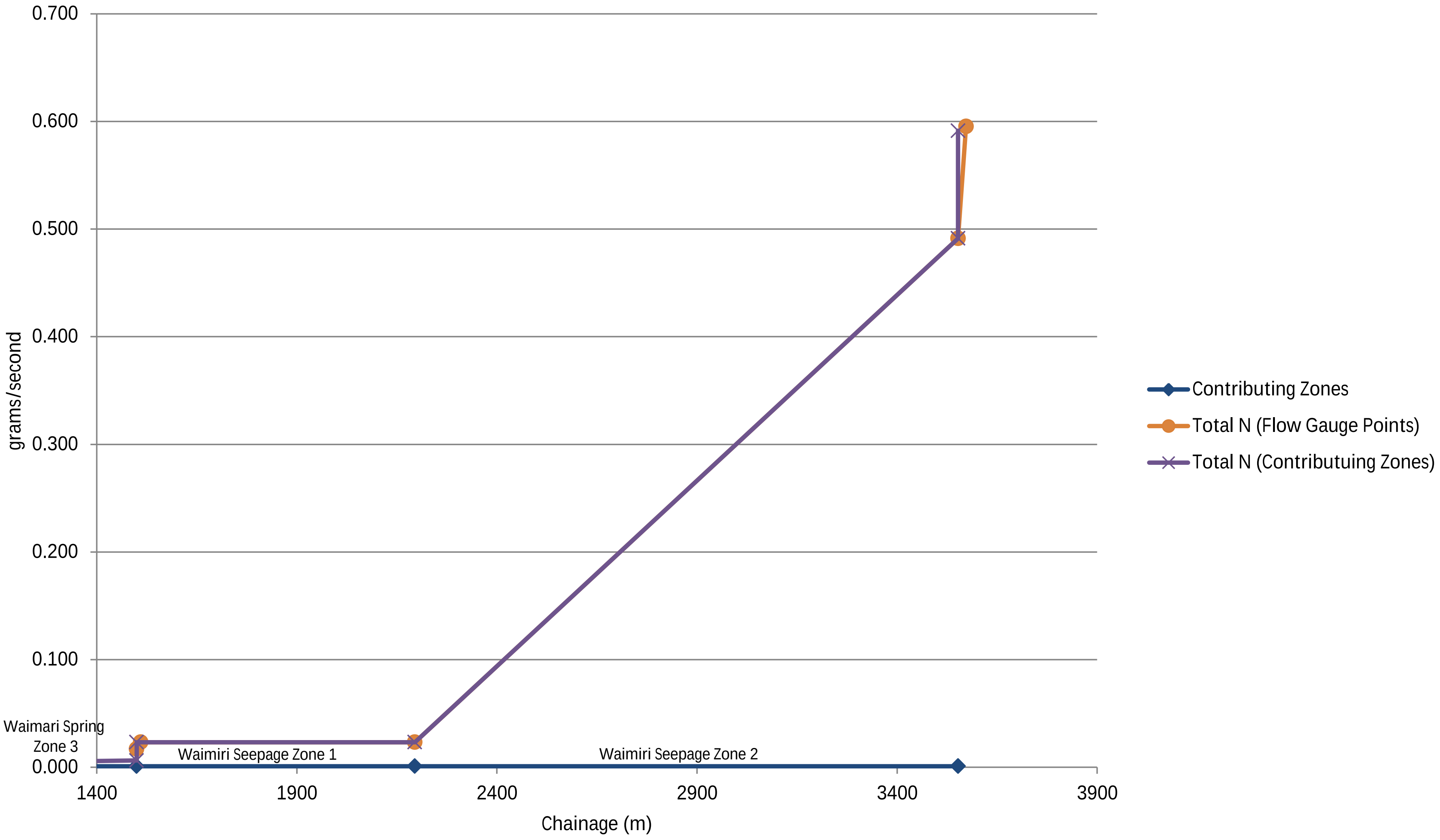


Figure 27b: Comparison of TN Masses at Flow Gauging Points compared to Contributing Zones in Waimairi Stream - March 2015



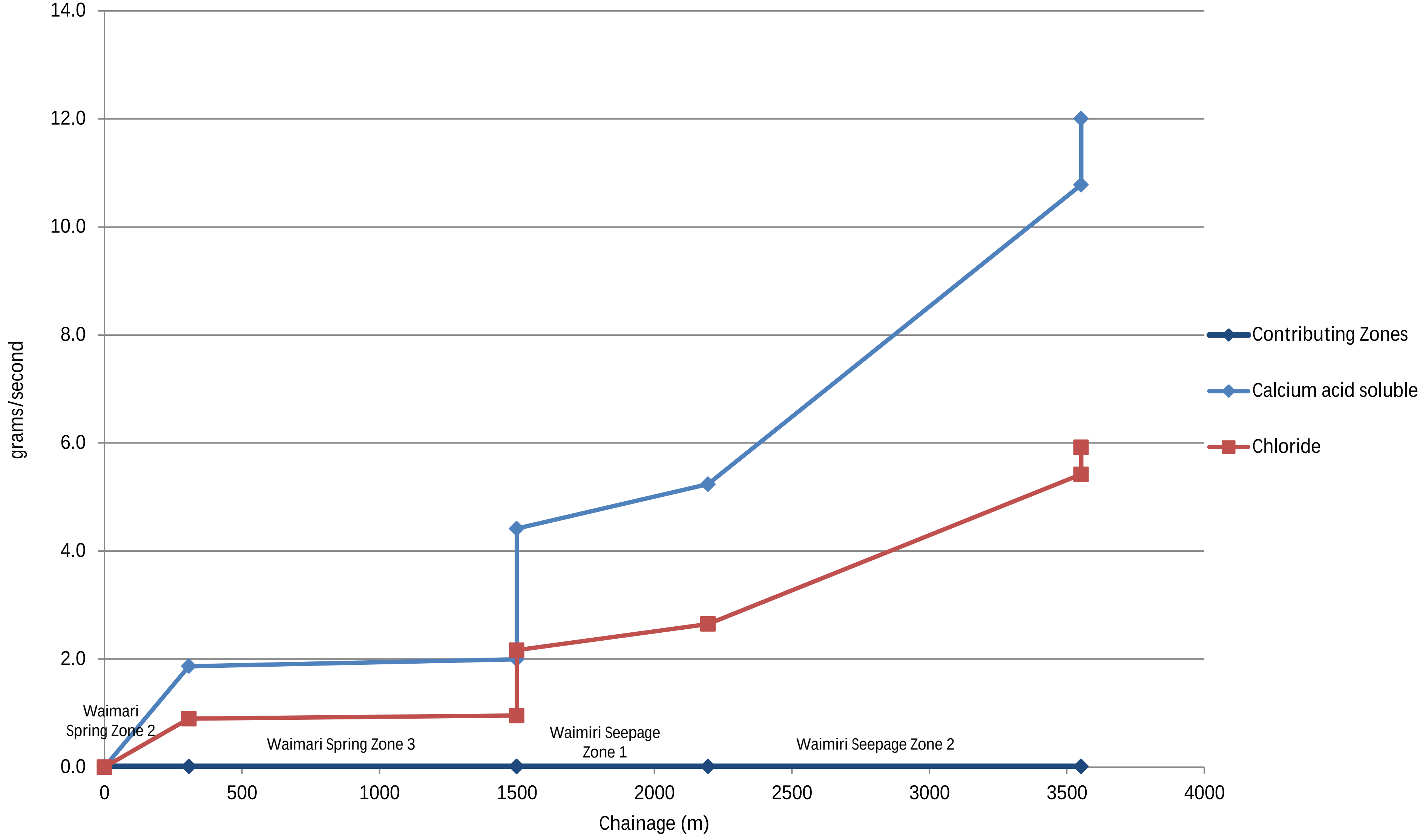
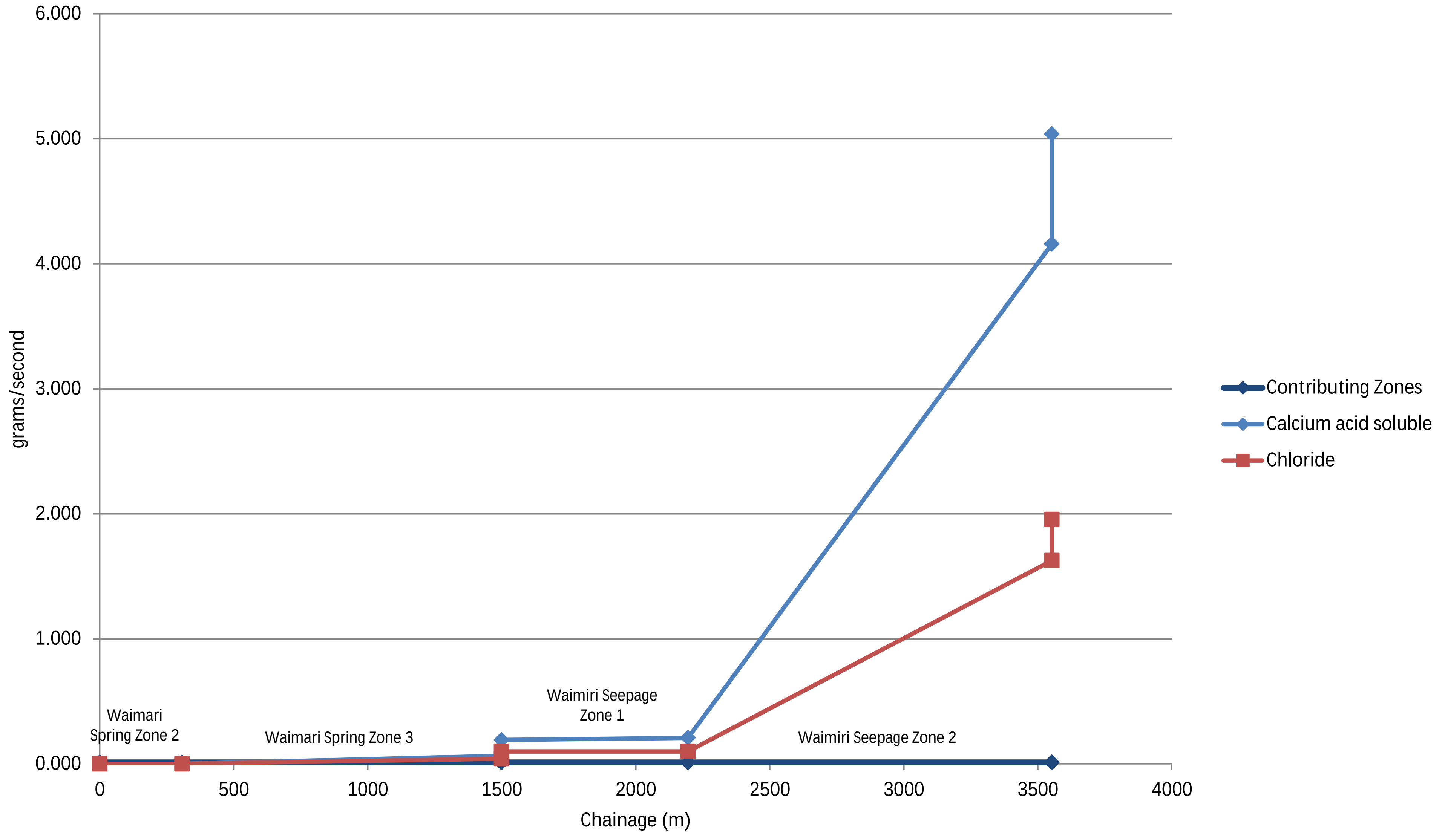


Figure 28a: Accumulating Masses at Contributuing Zones in Waimairi Stream - September 2014

Figure 28b: Accumulating Masses at Contributing Zones in Waimairi Stream - March 2015



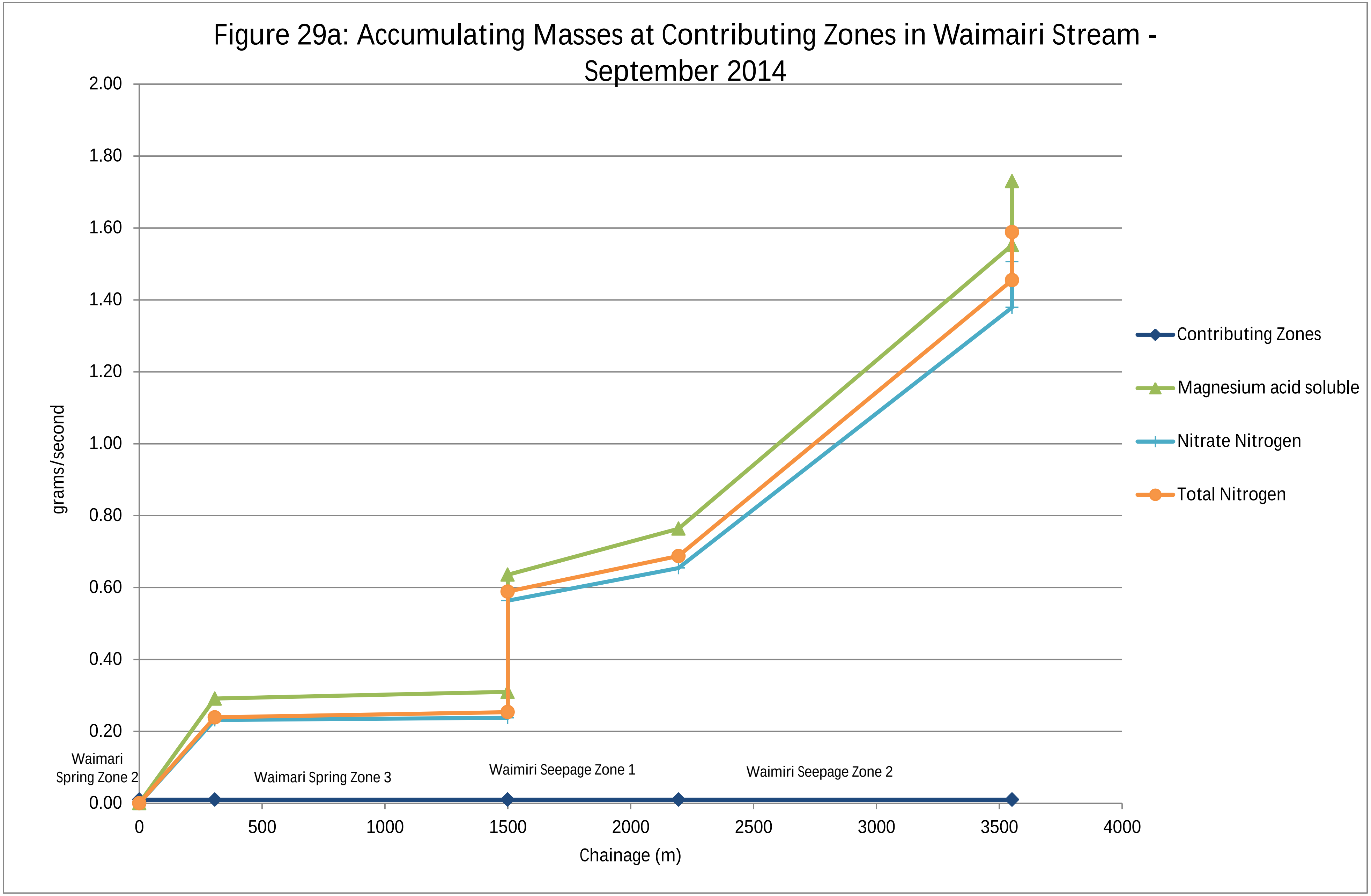


Figure 29a: Accumulating Masses at Contributing Zones in Waimairi Stream - September 2014
grams/second
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
500
1000
1500
2000
2500
3000
3500
4000
Chainage (m)
Waimari Spring Zone 2
Waimari Spring Zone 3
Waimiri Seepage Zone 1
Waimiri Seepage Zone 2
Contributing Zones
Magnesium acid soluble
Nitrate Nitrogen
Total Nitrogen

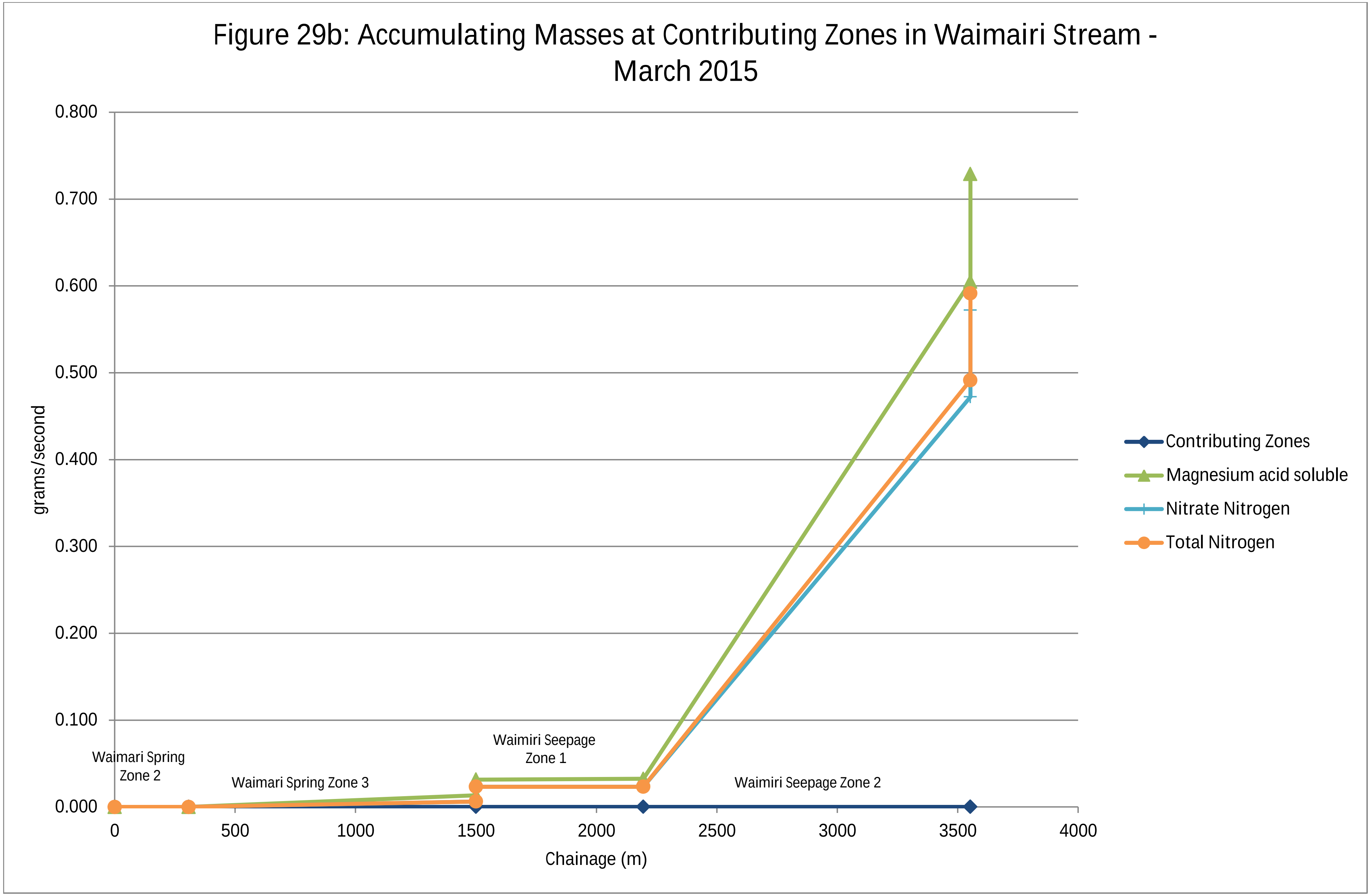
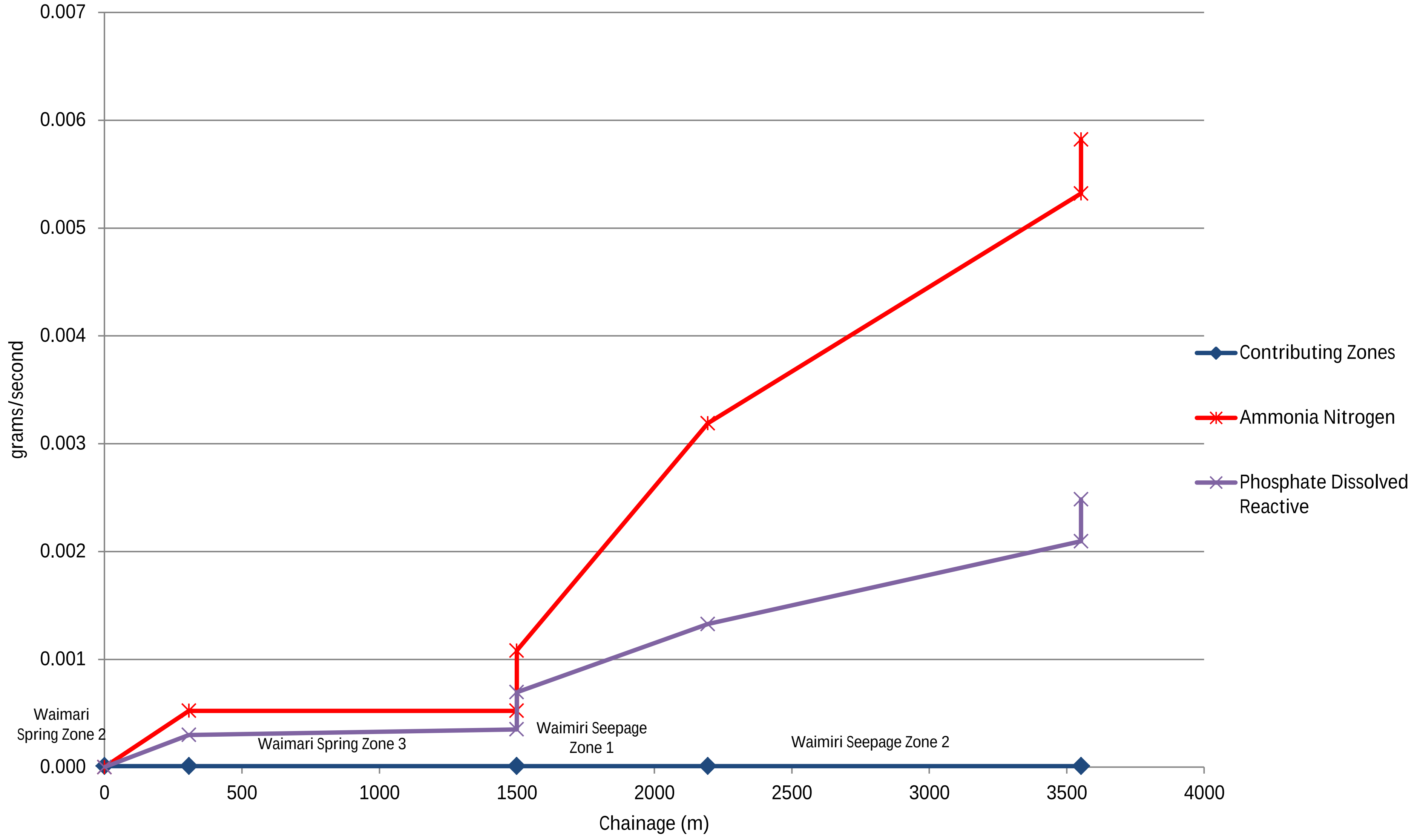


Figure 29b: Accumulating Masses at Contributing Zones in Waimairi Stream - March 2015

Figure 30a: Accumulating Masses at Contributing Zones in Waimairi Stream - September 2014



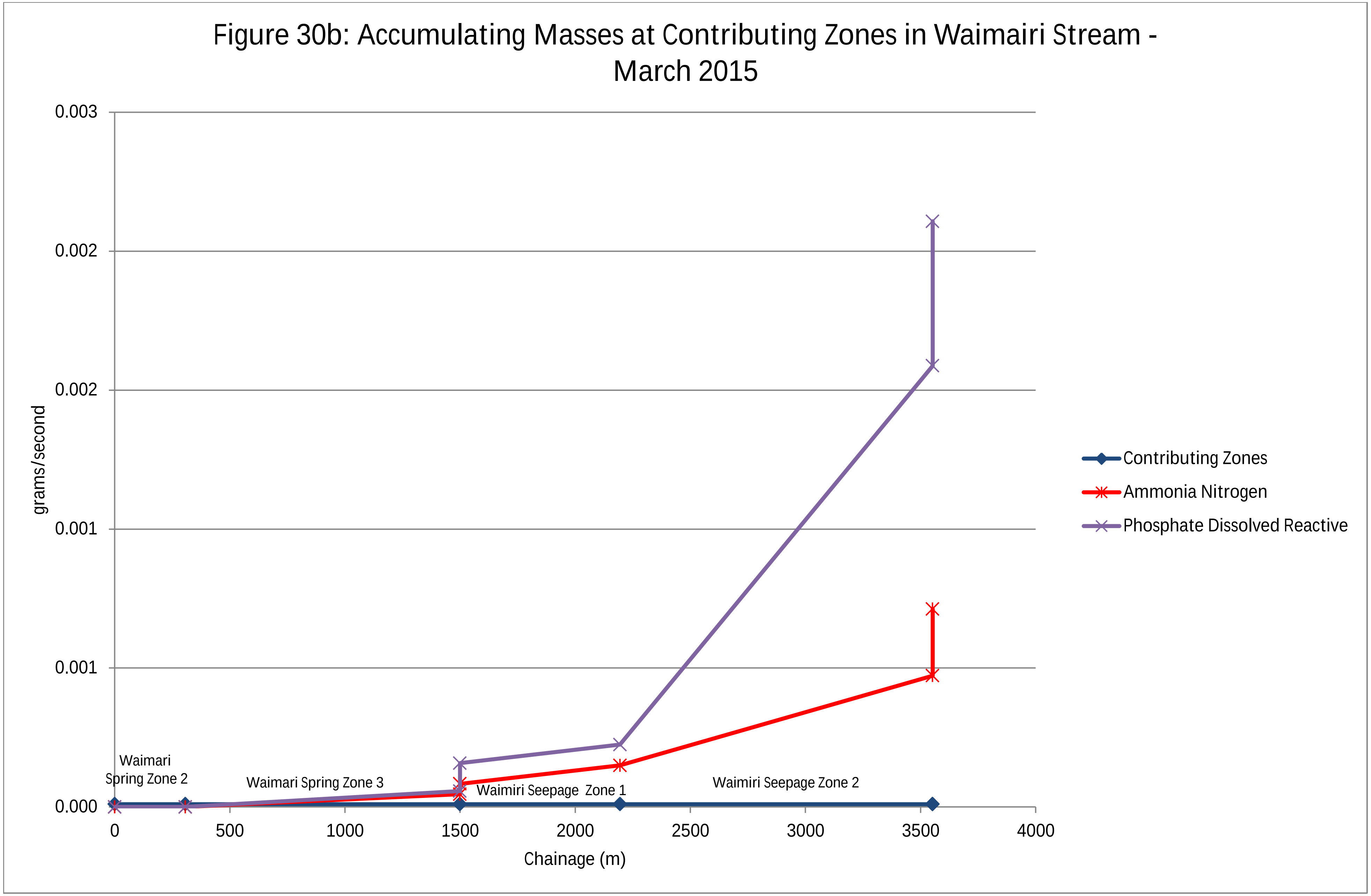


Figure 30b: Accumulating Masses at Contributing Zones in Waimairi Stream - March 2015

Figure 31a: Chloride Concentratons in Wairarapa Stream - September 2014

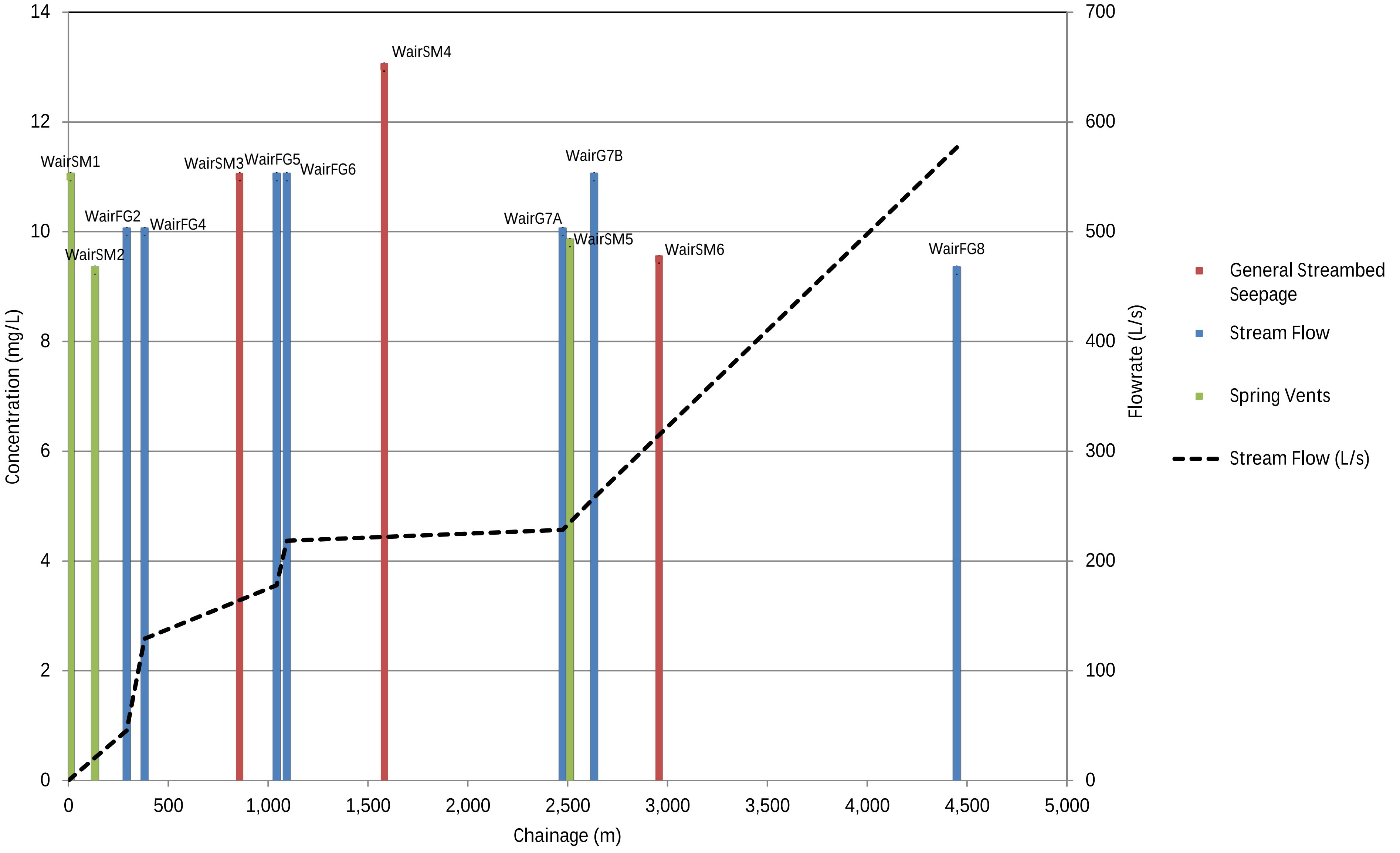


Figure 31b: Chloride Concentratons in Wairarapa Stream - March 2015

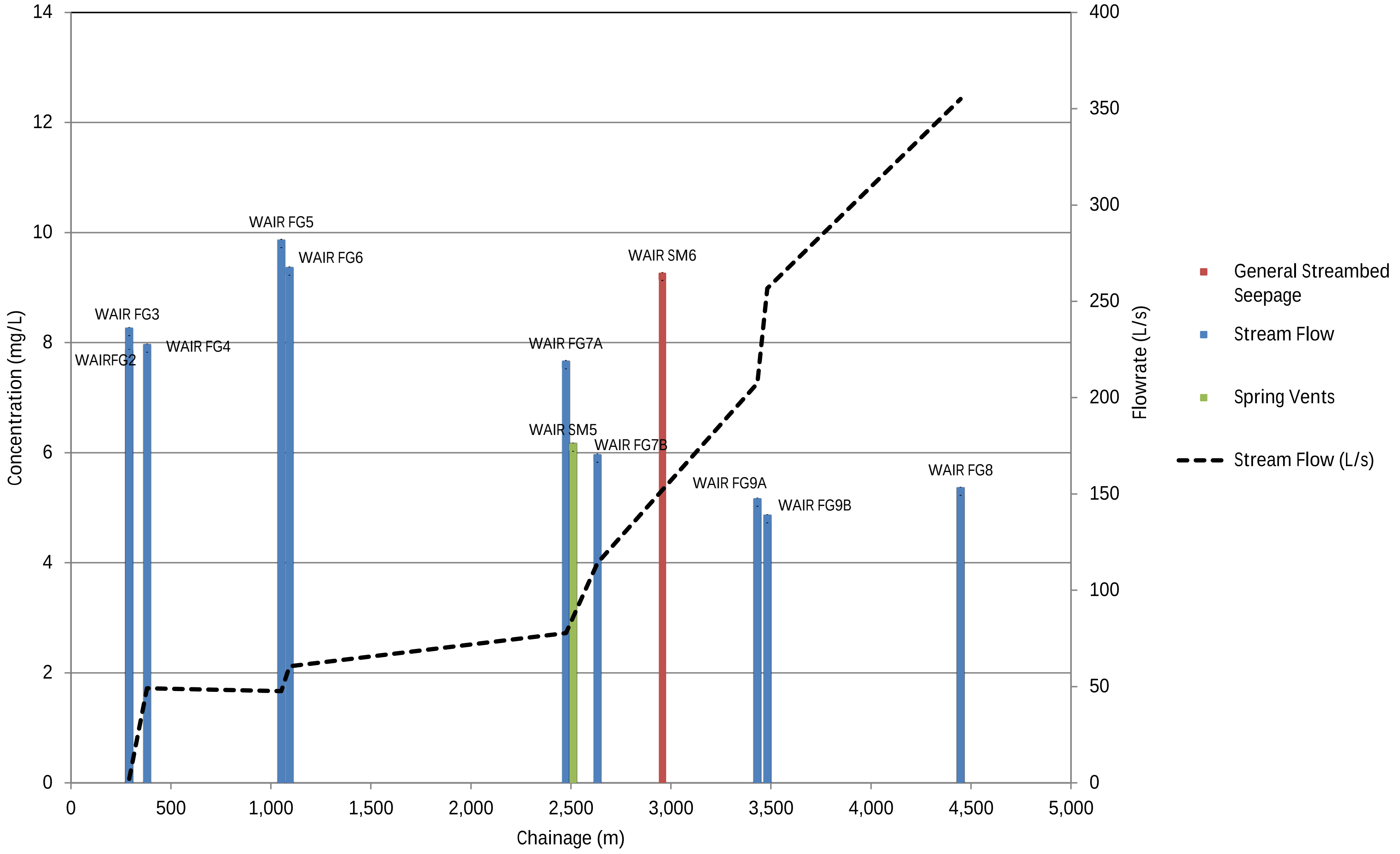
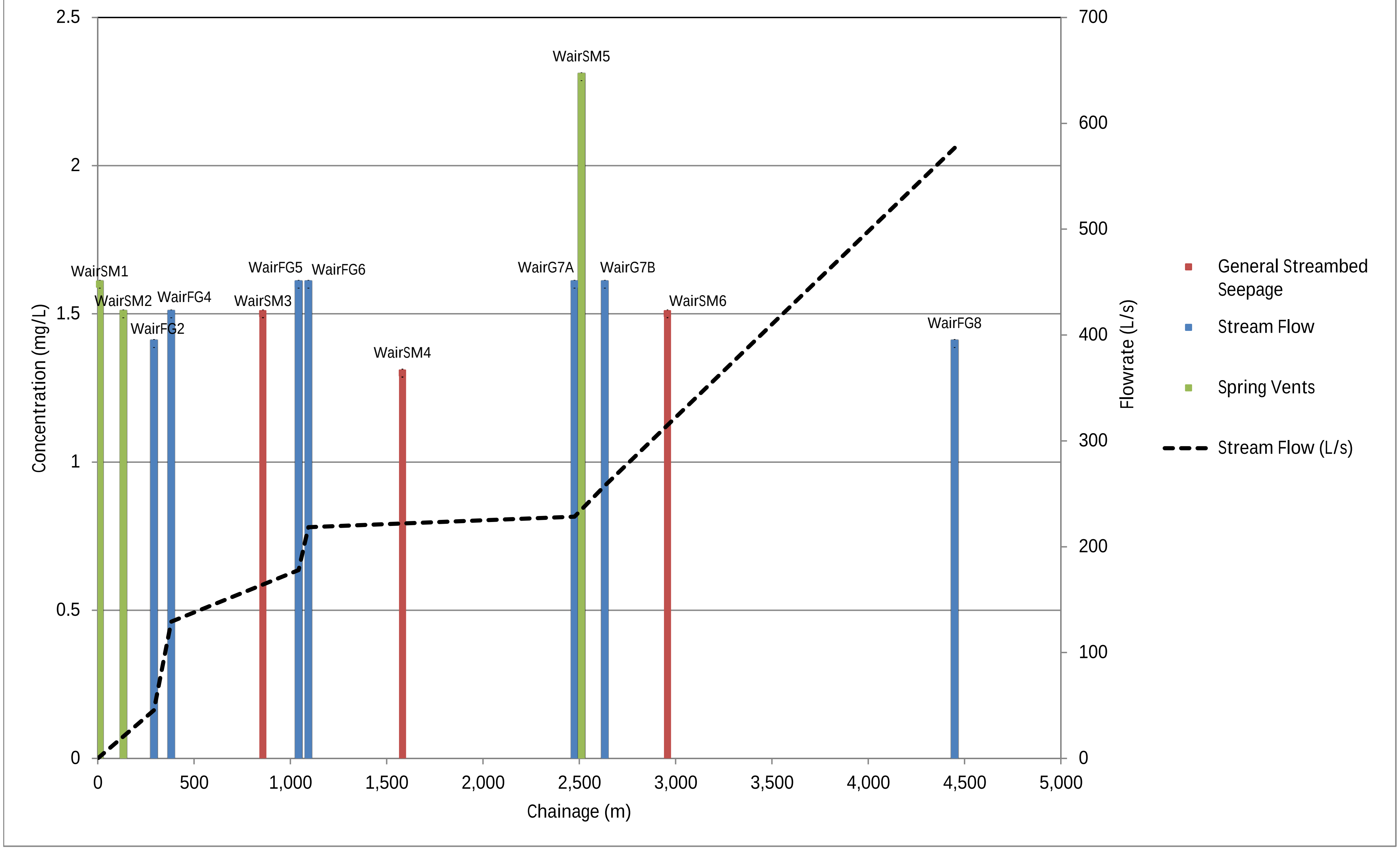


Figure 32a: Total N Concentrations in Wairarapa Stream - September 2014



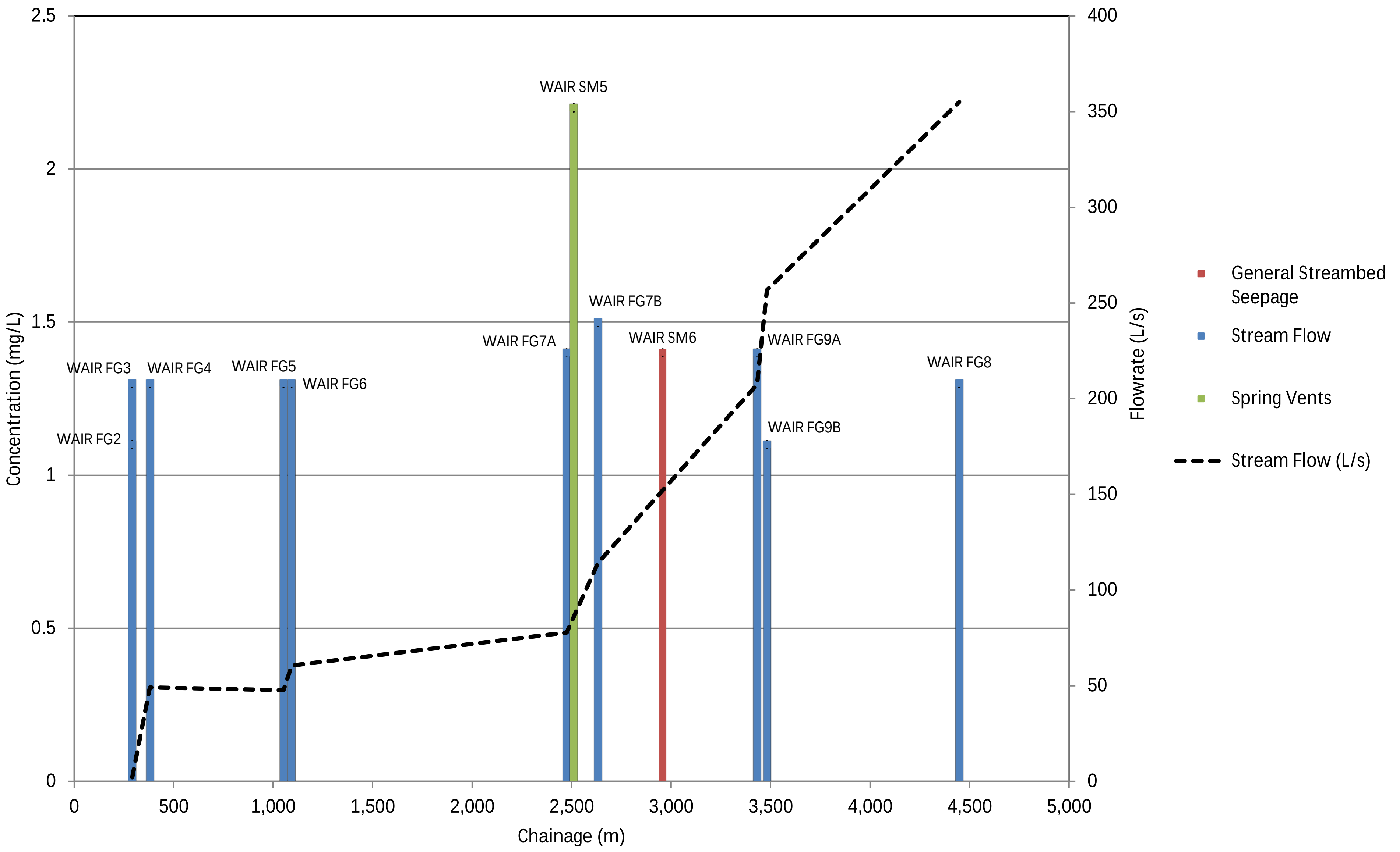


Figure 32b: Total N Concentratons in Wairarapa Stream - March 2015

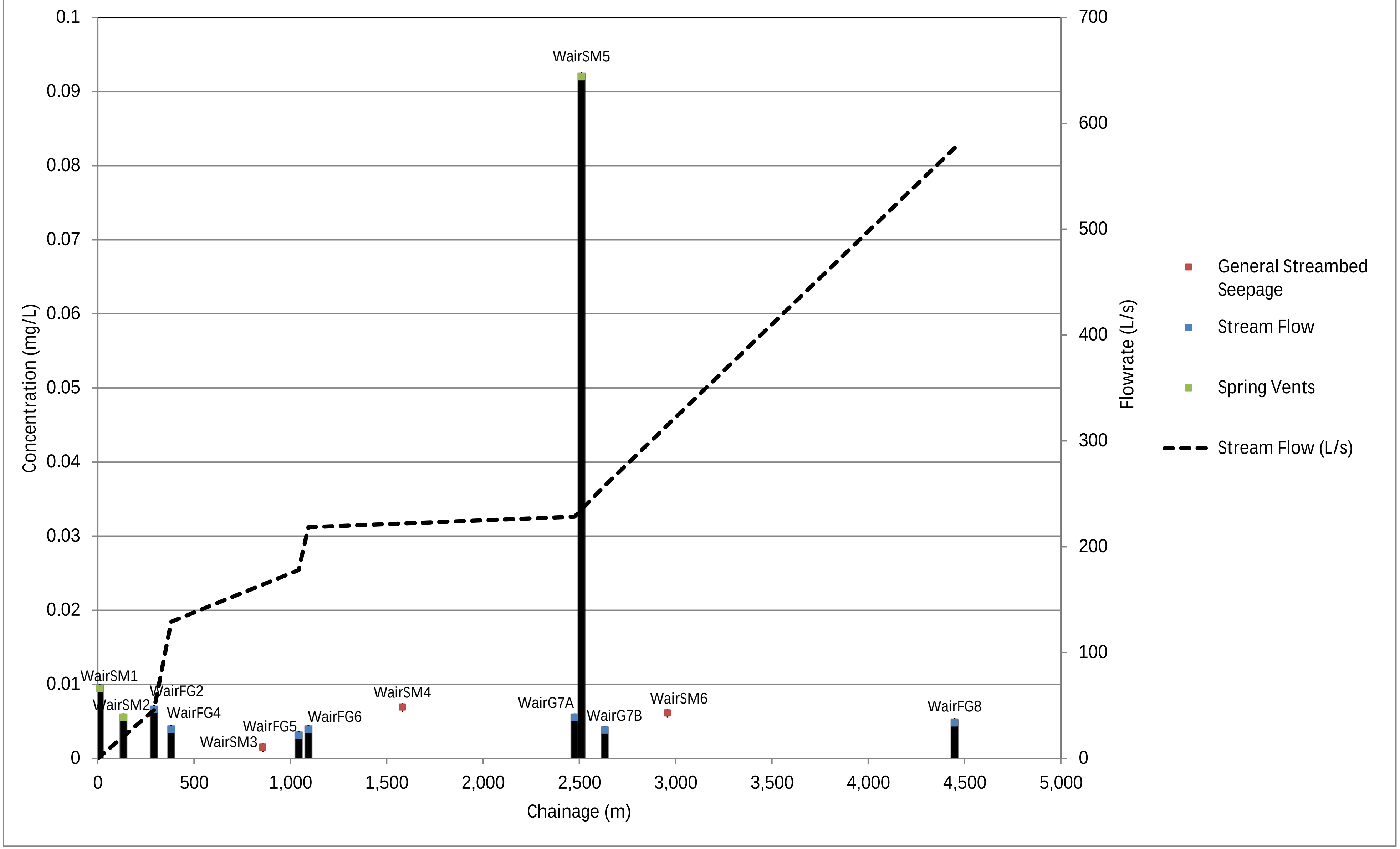
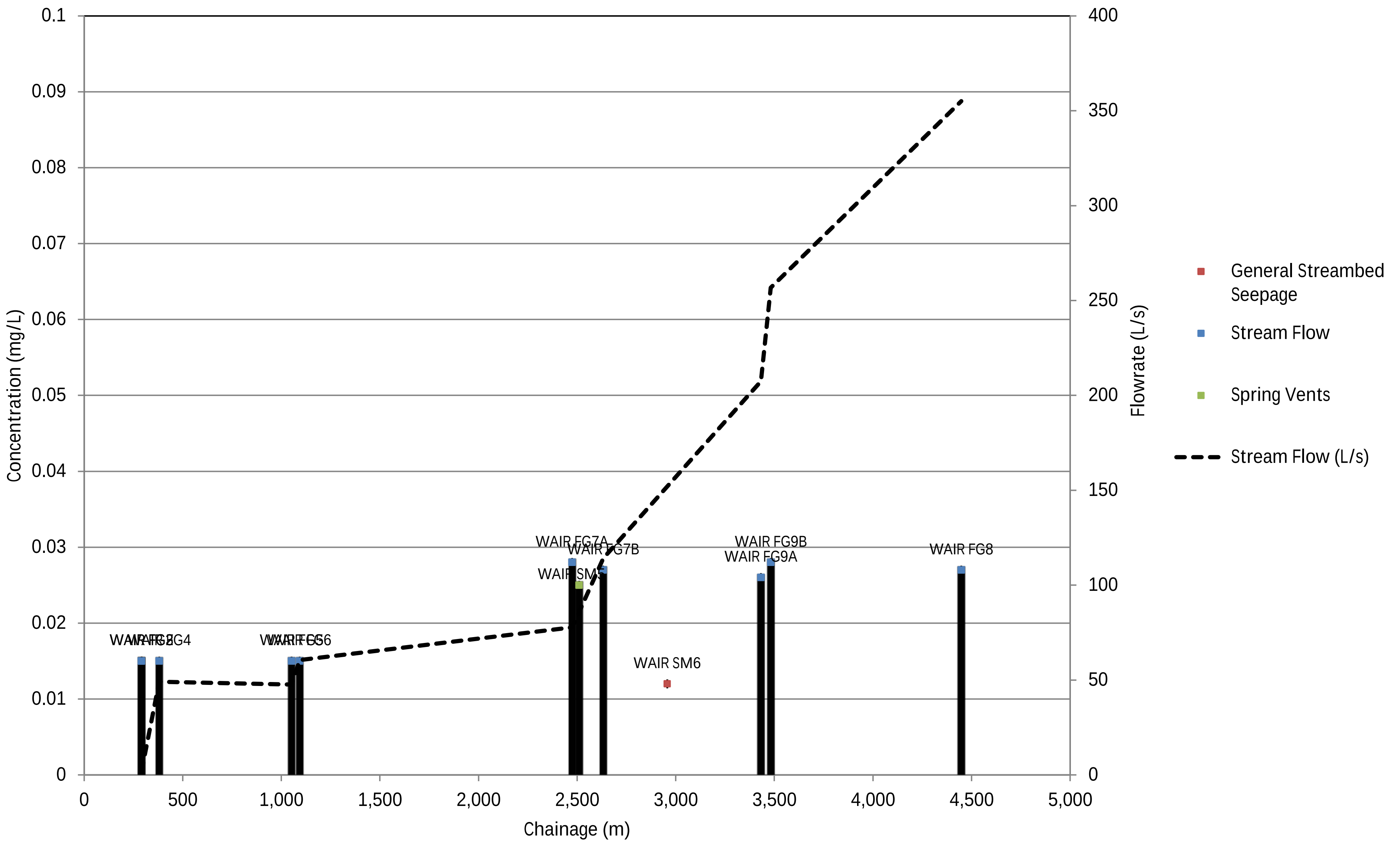


Figure 33a: DRP Concentrations in Wairarapa Stream - September 2014

Figure 33b: DRP Concentratons in Wairarapa Stream - March 2015



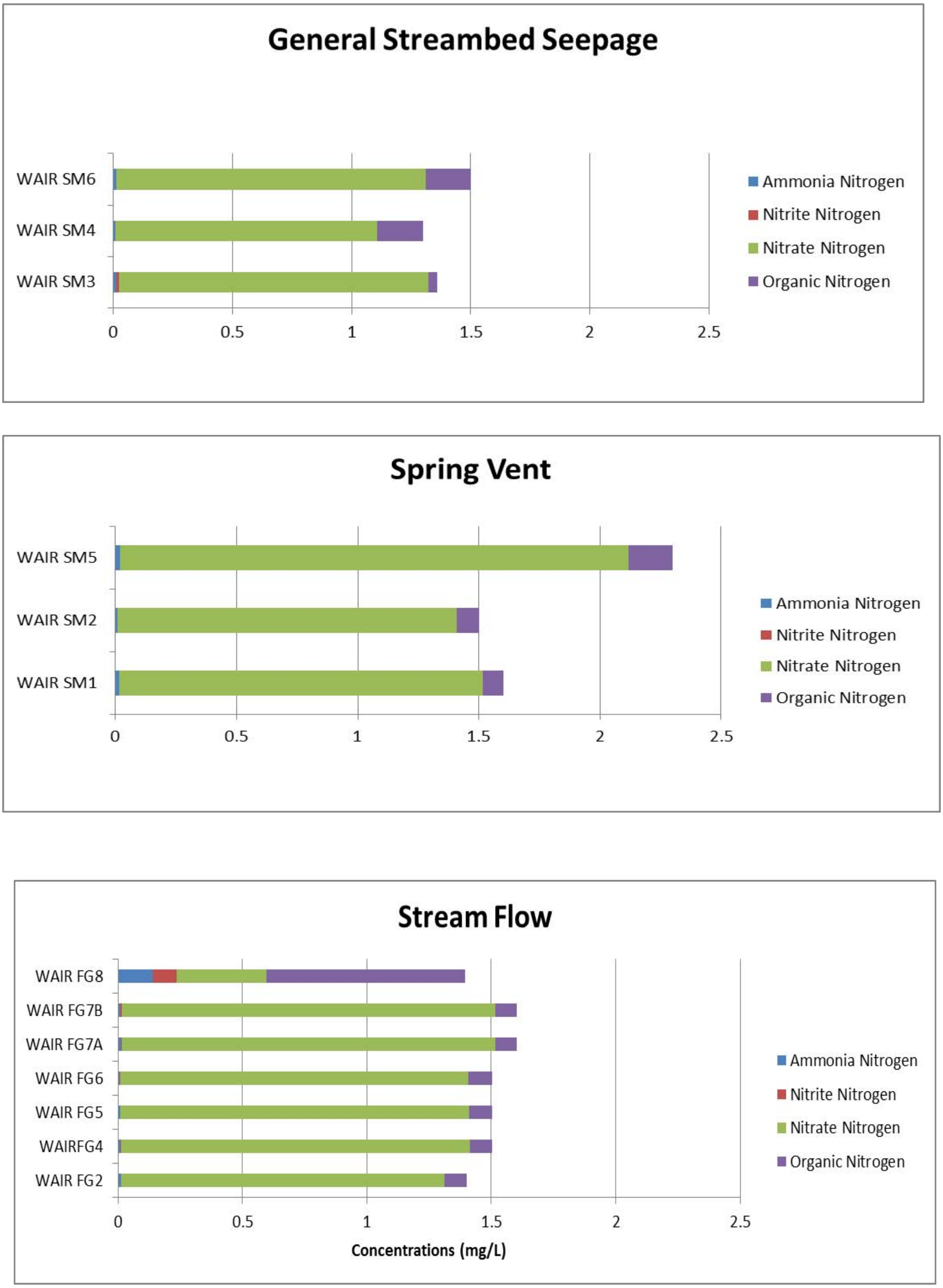


Figure 34a: Wairarapa Nitrogen Species Composition – September 2014

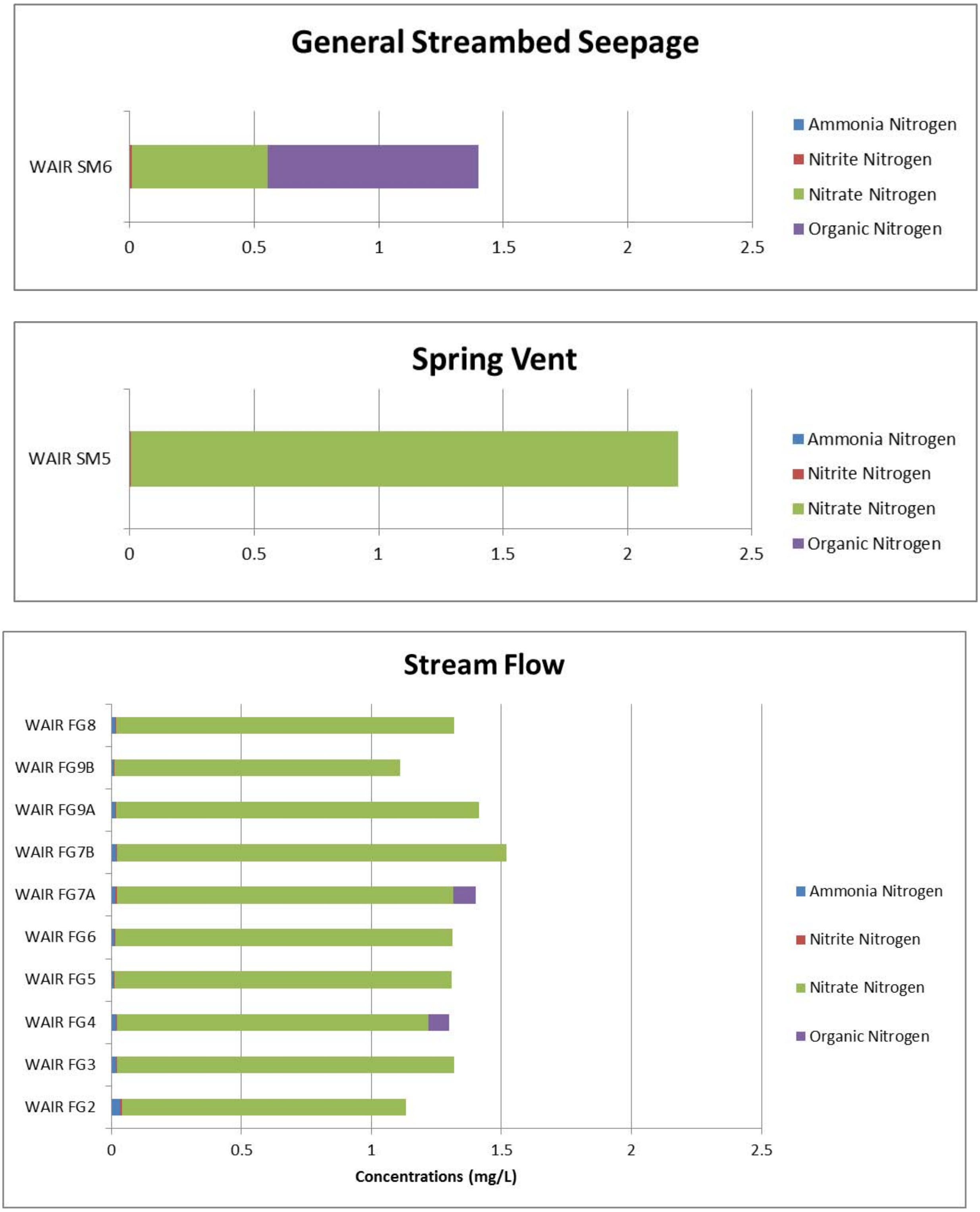


Figure 34b: Wairarapa Nitrogen Species Composition – March 2015

Figure 35a: Accumulating Masses at Flow Gauging Points in Wairarapa Stream - September 2014

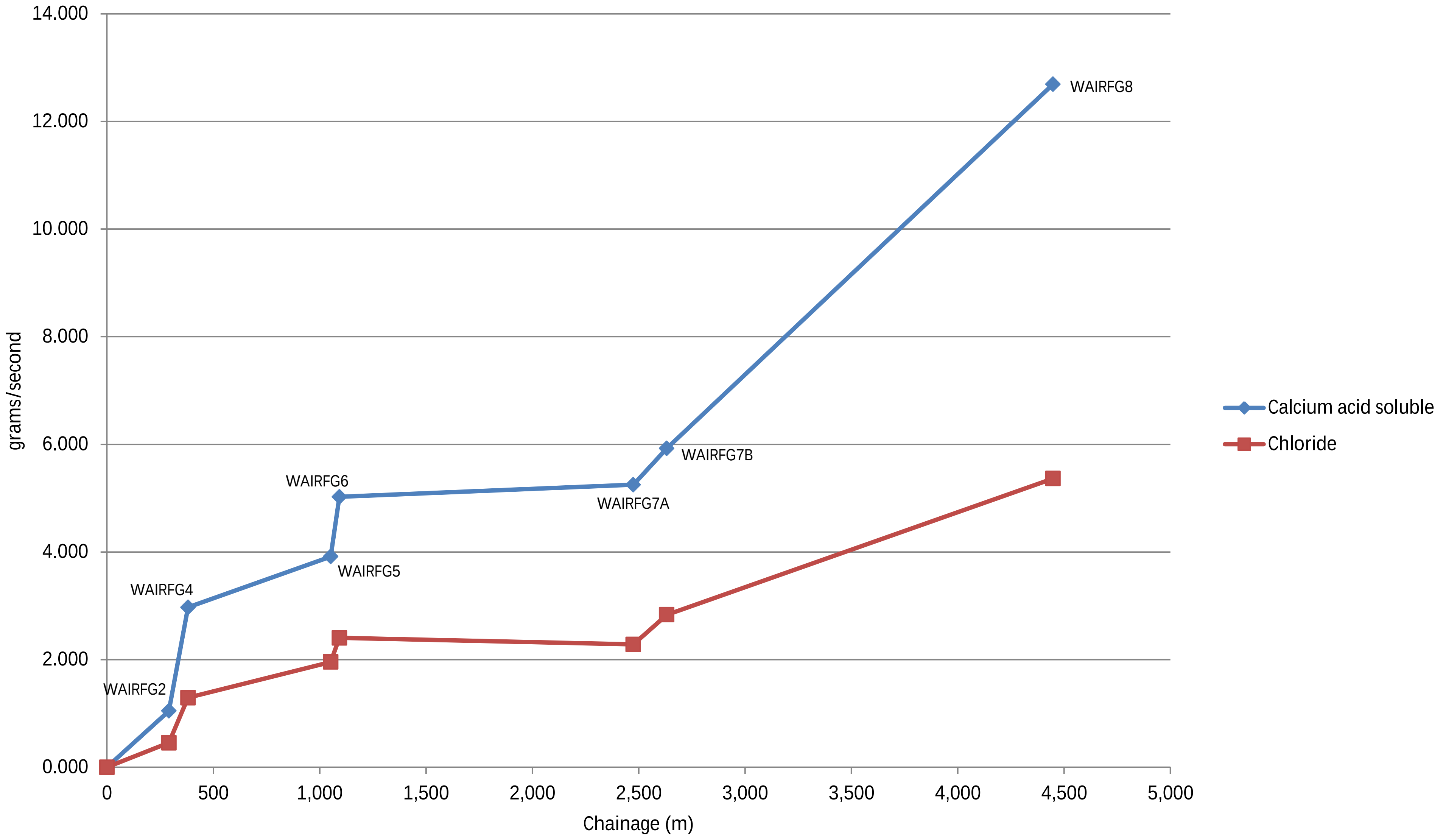
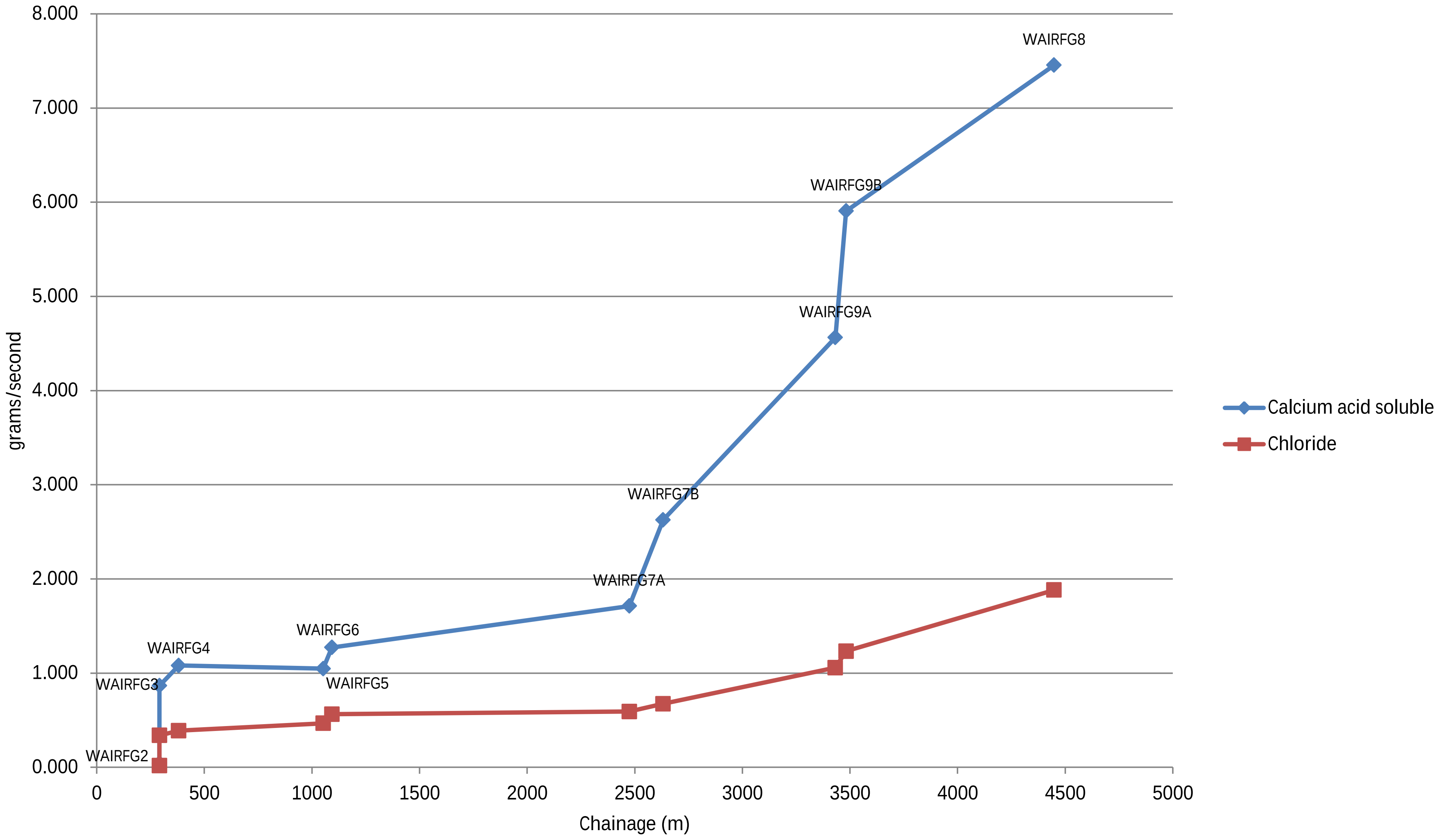


Figure 35b: Accumulating Masses at Flow Gauging Points in Wairarapa Stream - March 2015



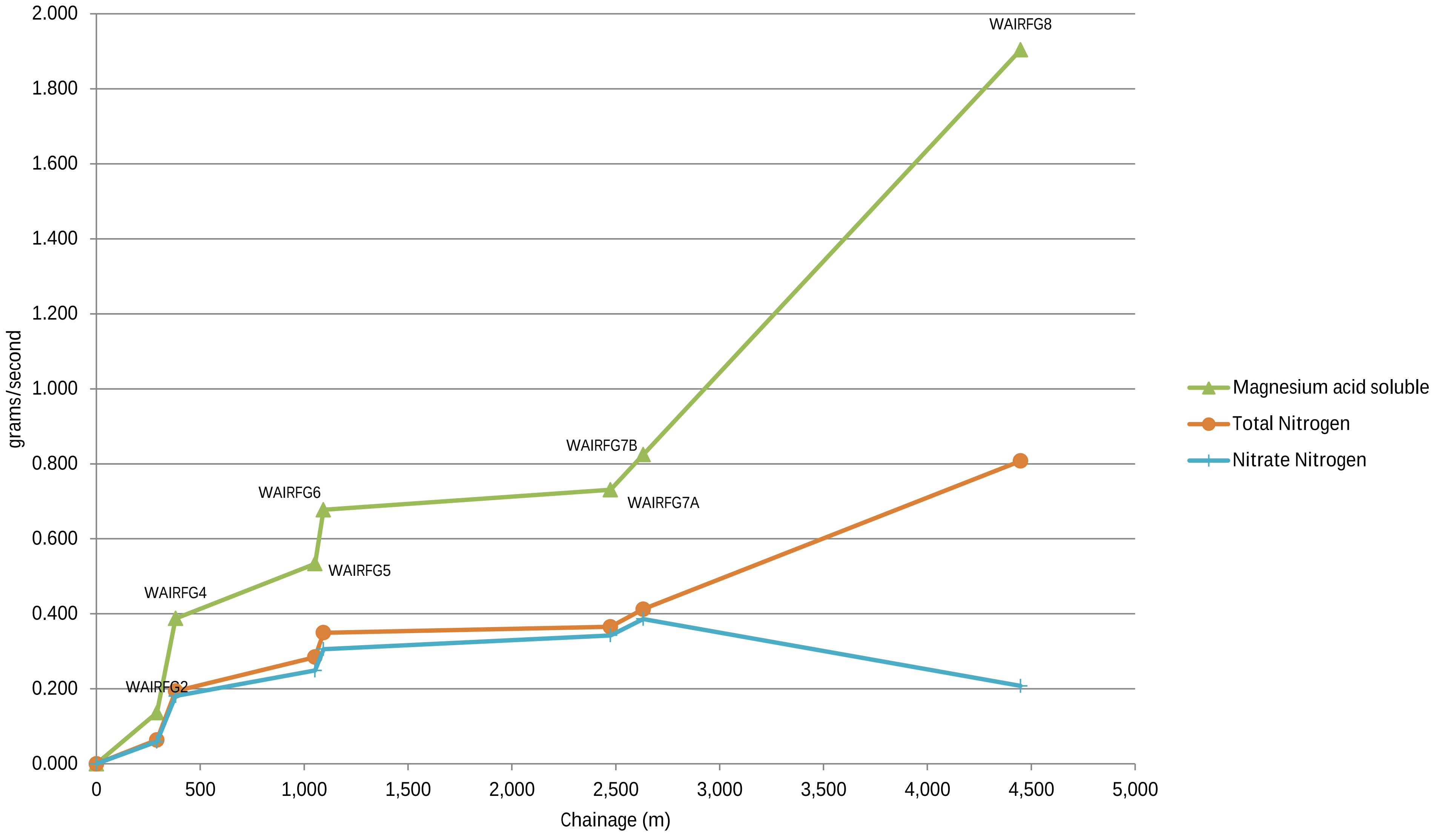


Figure 36a: Accumulating Masses at Flow Gauging Points in Wairarapa Stream - September 2014

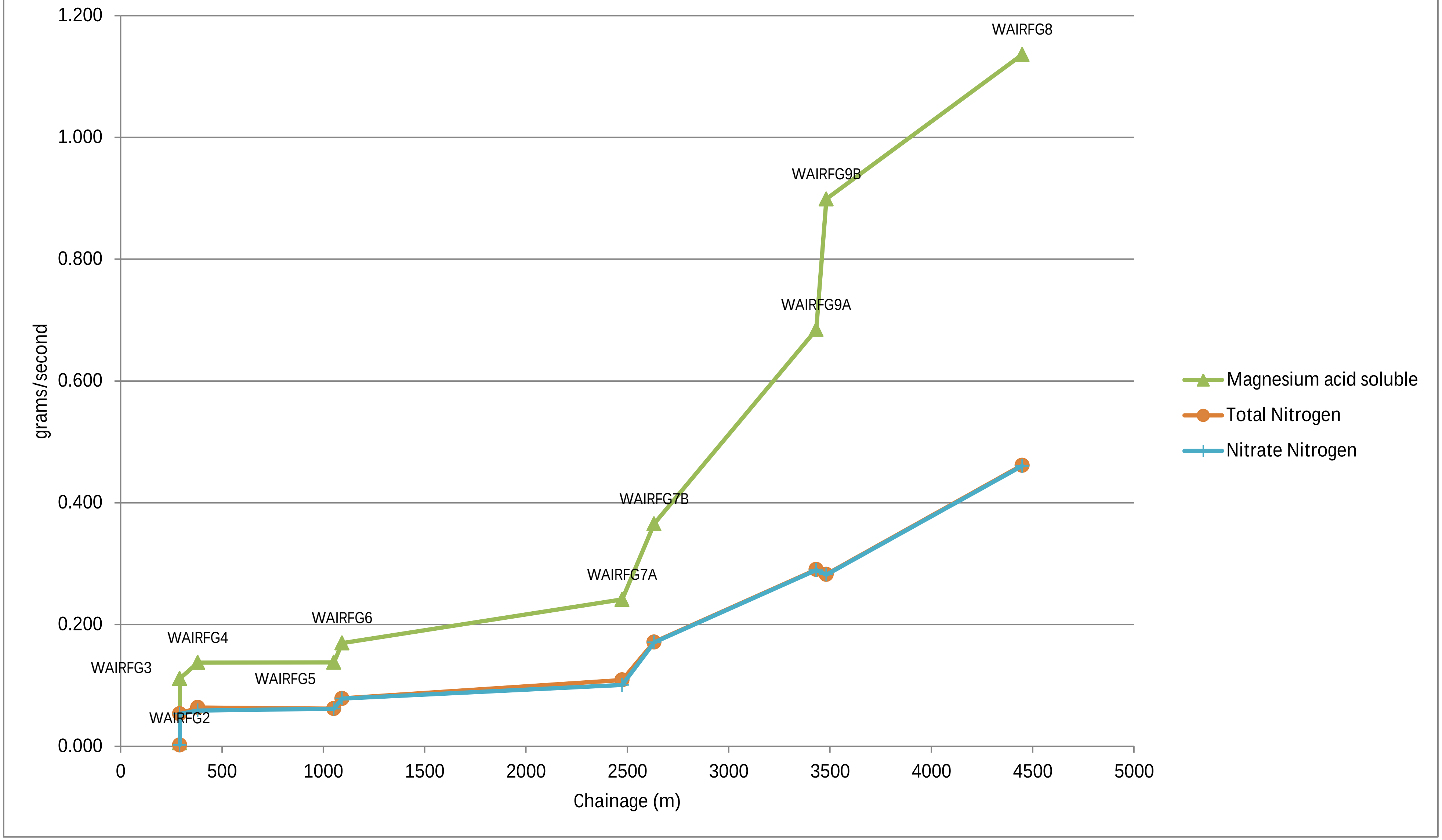


Figure 36b: Accumulating Masses at Flow Gauging Points in Wairarapa Stream - March 2015

Figure 37a: Accumulating Masses at Flow Gauging Points in Wairarapa Stream - September 2014

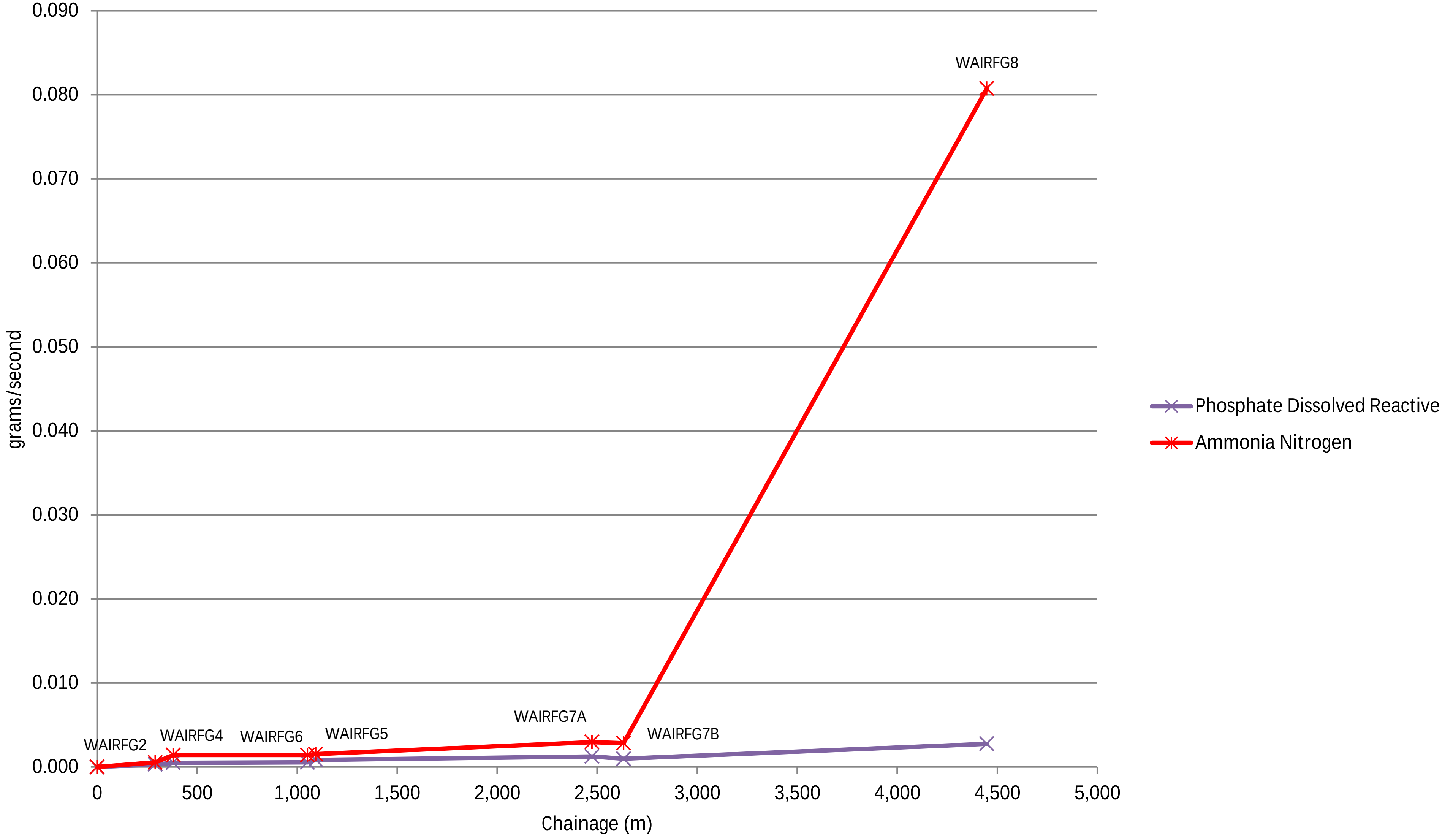
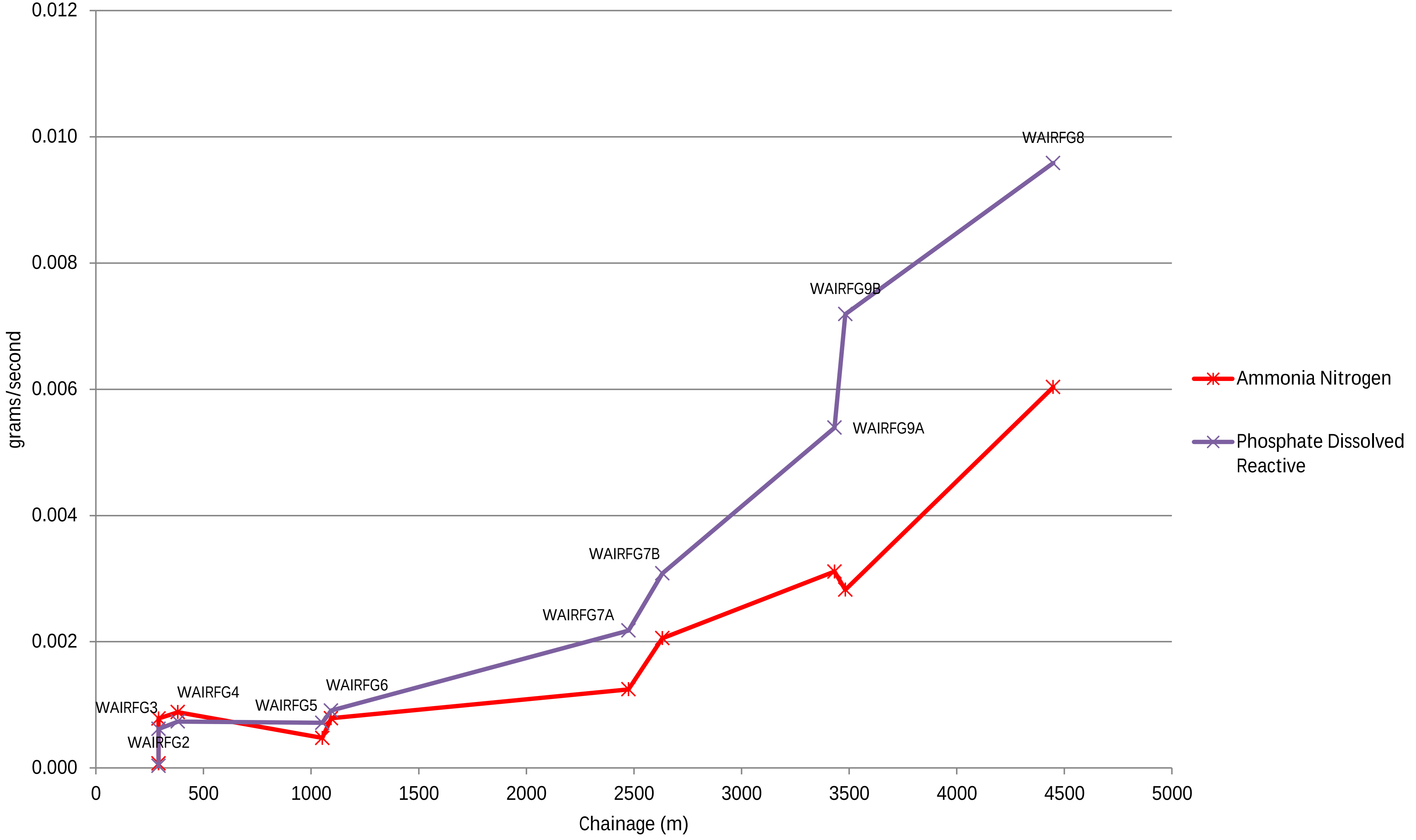
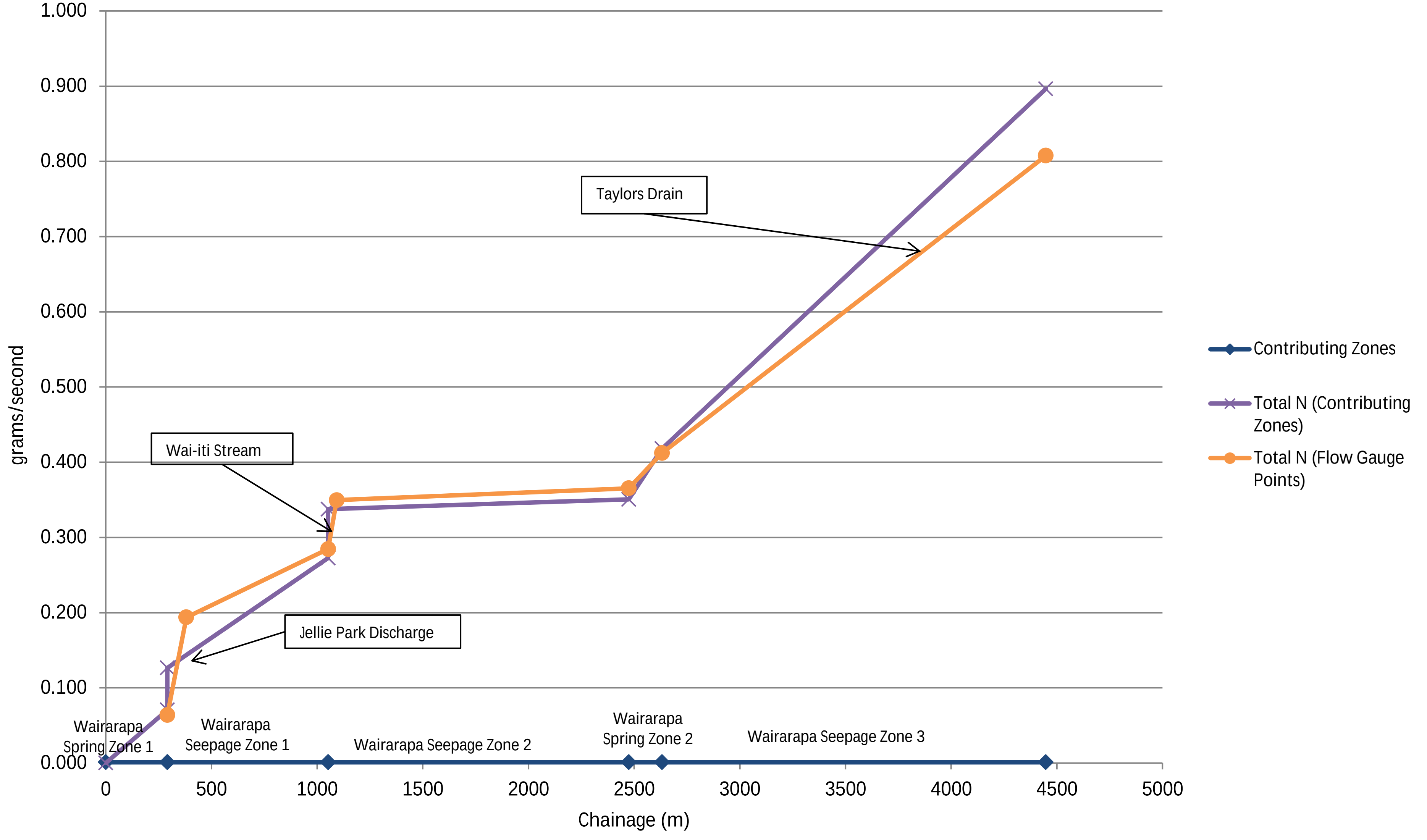


Figure 37b: Accumulating Masses at Flow Gauging Points in Wairarapa Stream - March 2015



## Figure 38a: Comparison of TN Masses at Flow Gauging Points compared to Contributing Zones in Wairarapa Stream - September 2014



# Figure 38b: Comparison of TN Masses at Flow Gauging Points compared to Contributing Zones in Wairarapa Stream - March 2015

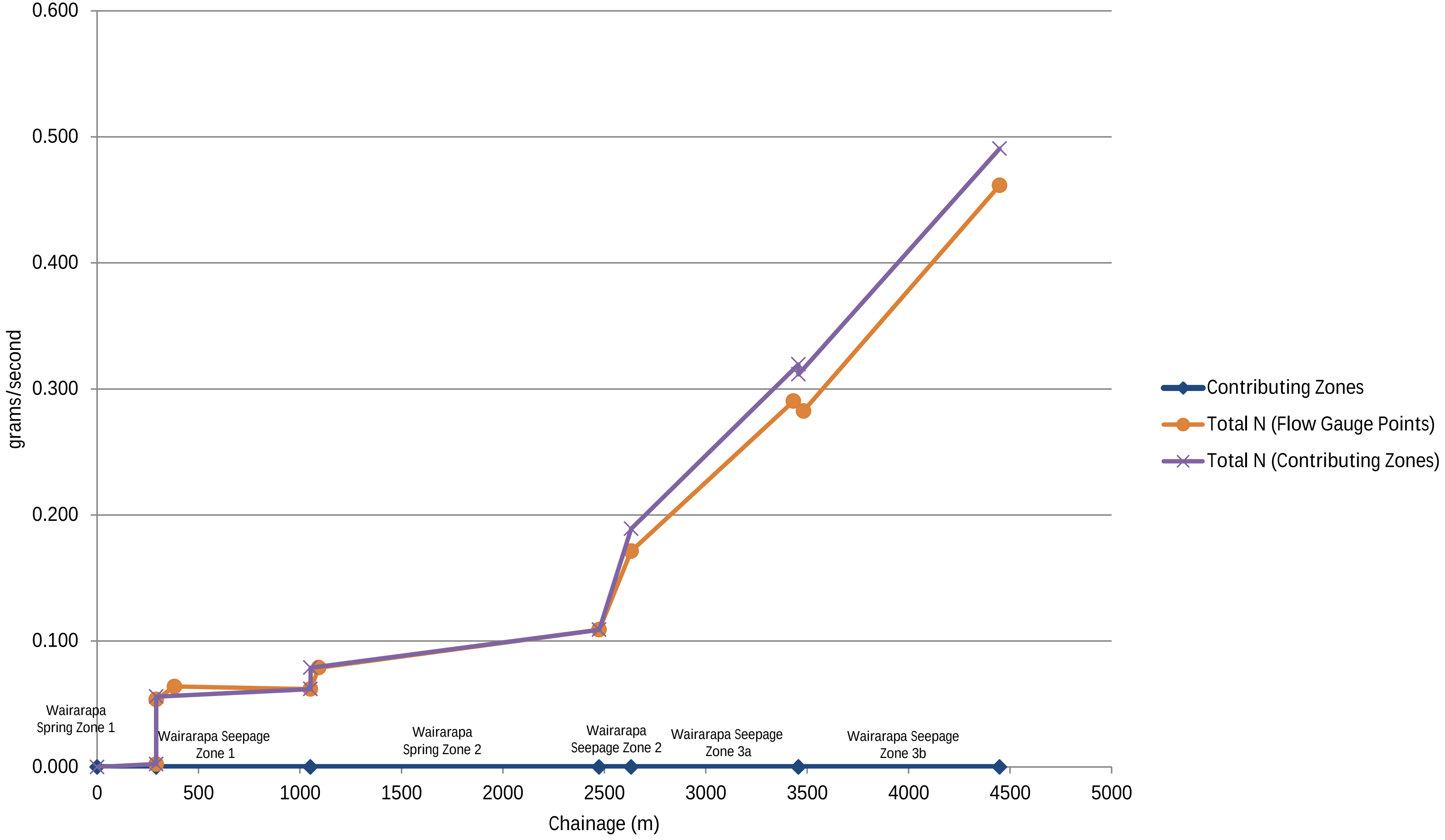


Figure 39a: Accumulating Masses at Contributing Zones in Wairarapa Stream - September 2014

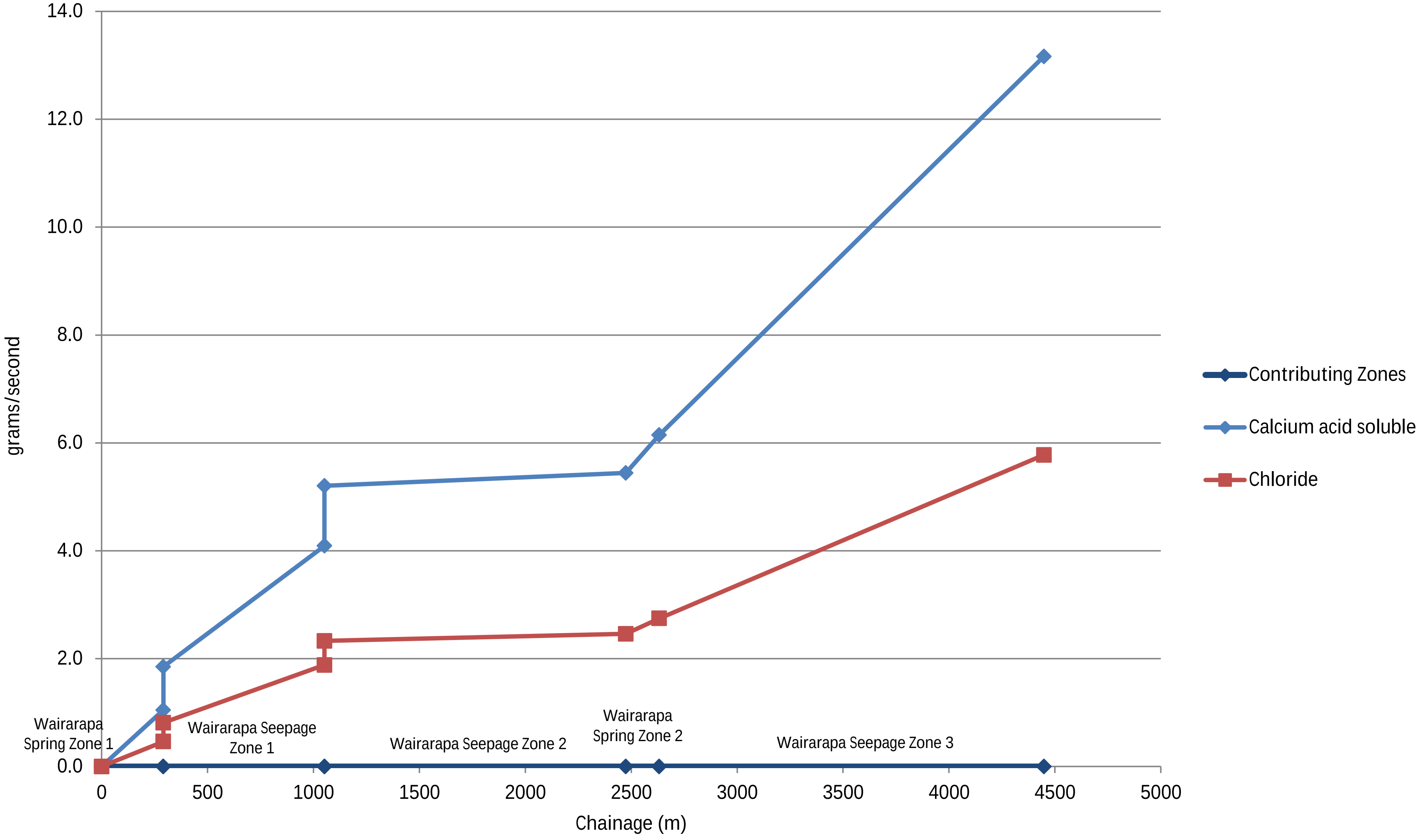


Figure 39b: Accumulating Masses at Contributing Zones in Wairarapa Stream - March 2015

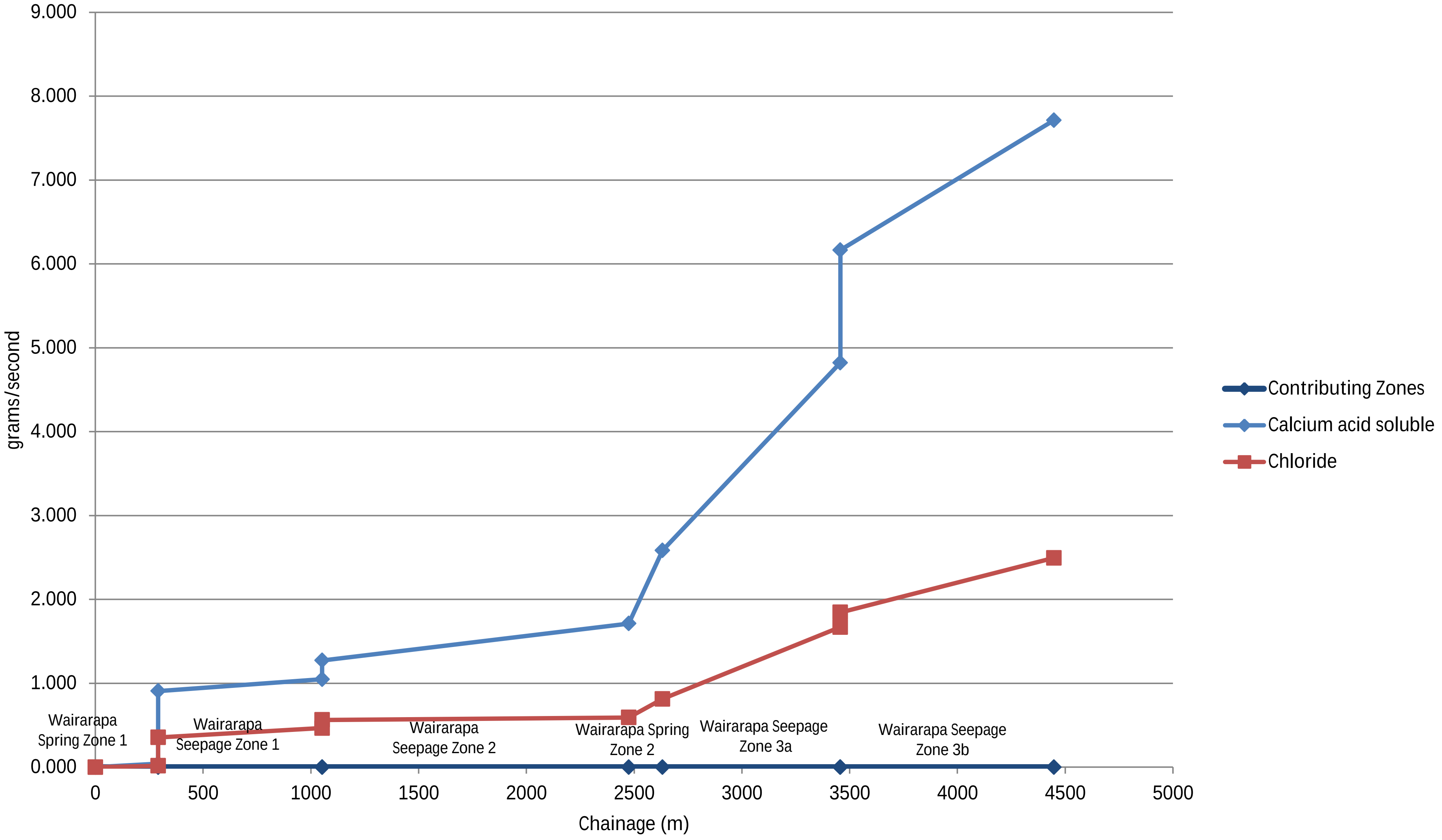
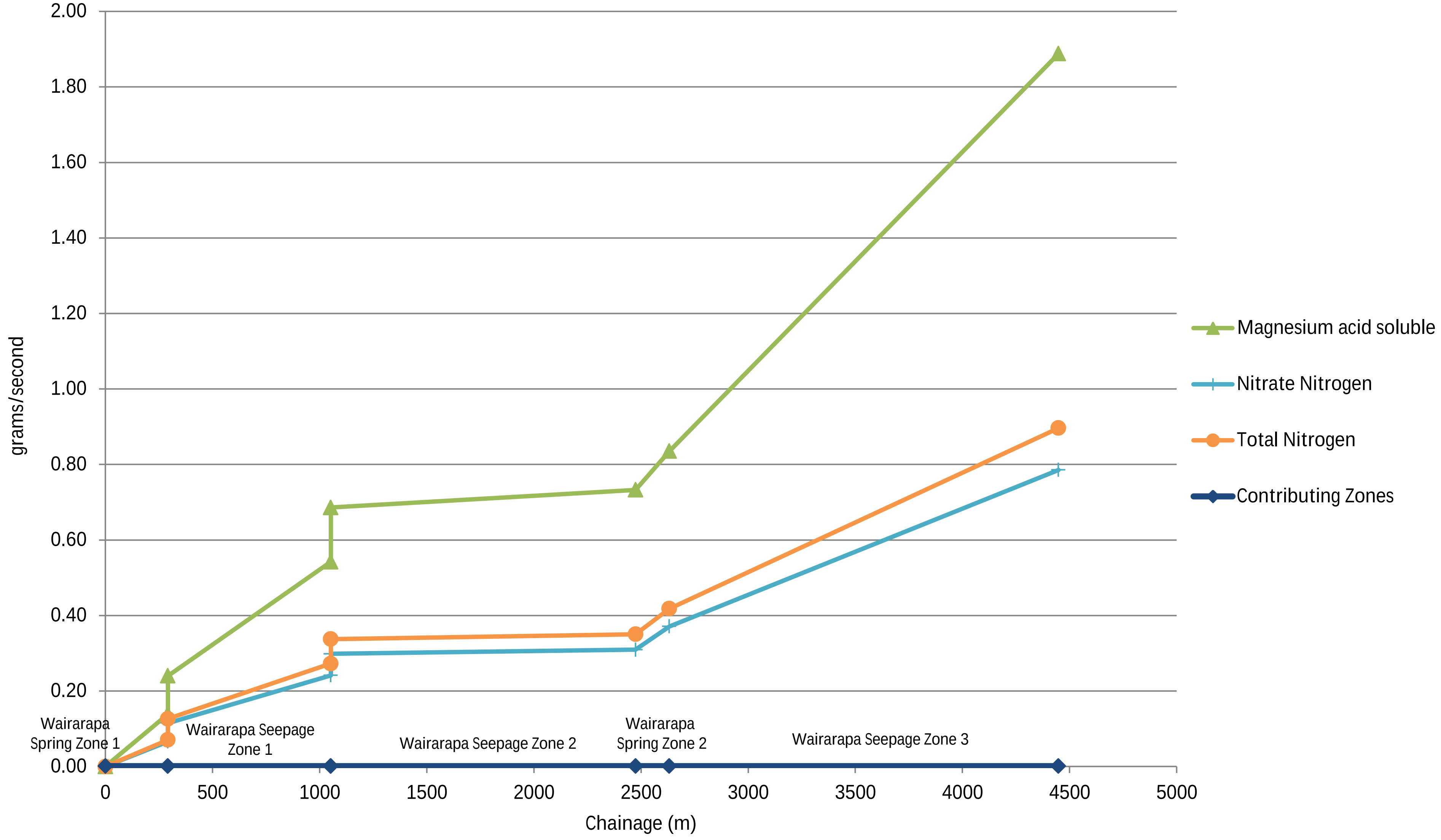


Figure 40a: Accumulating Masses at Contributing Zones in Wairarapa Stream - September 2014



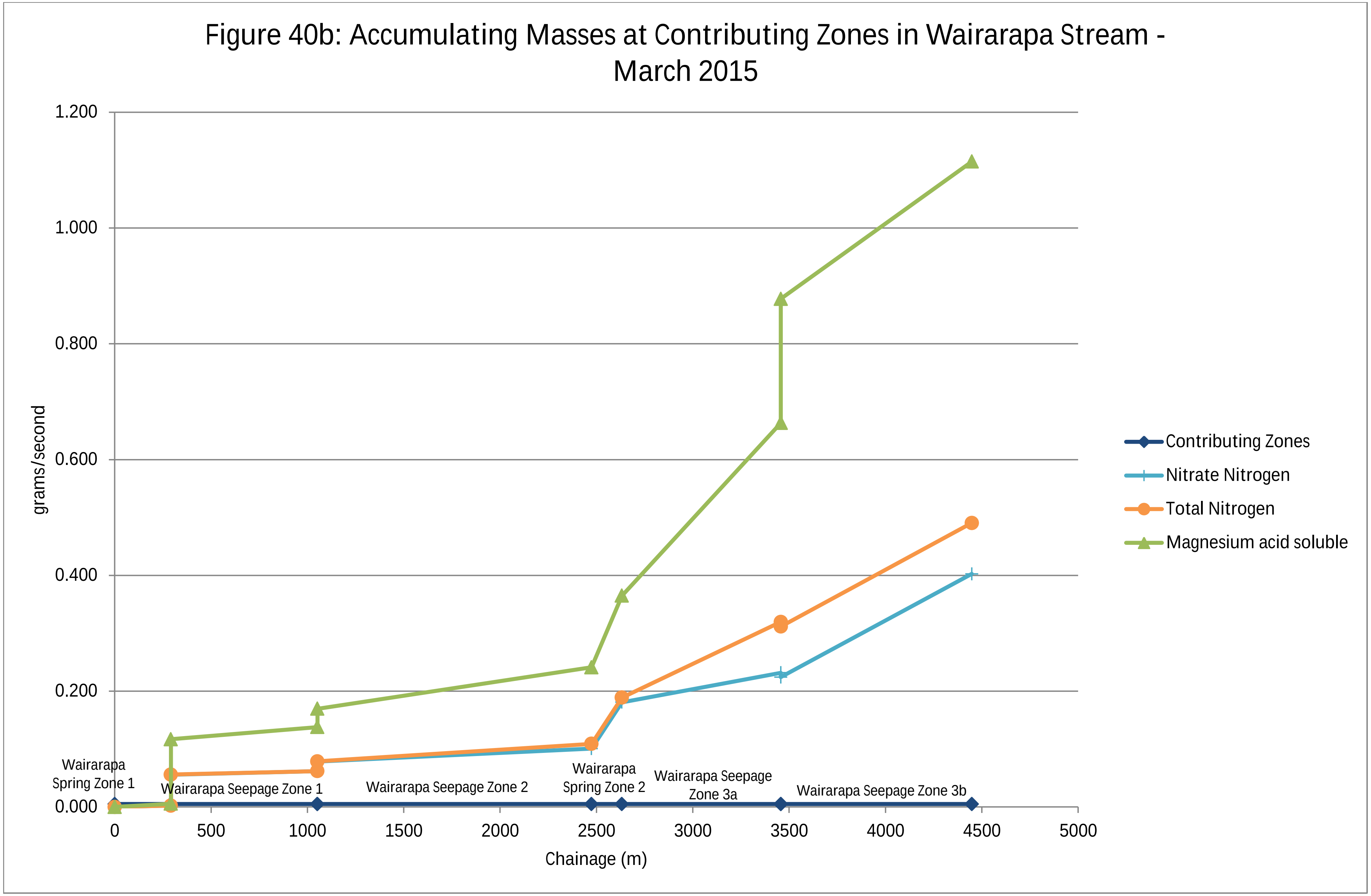
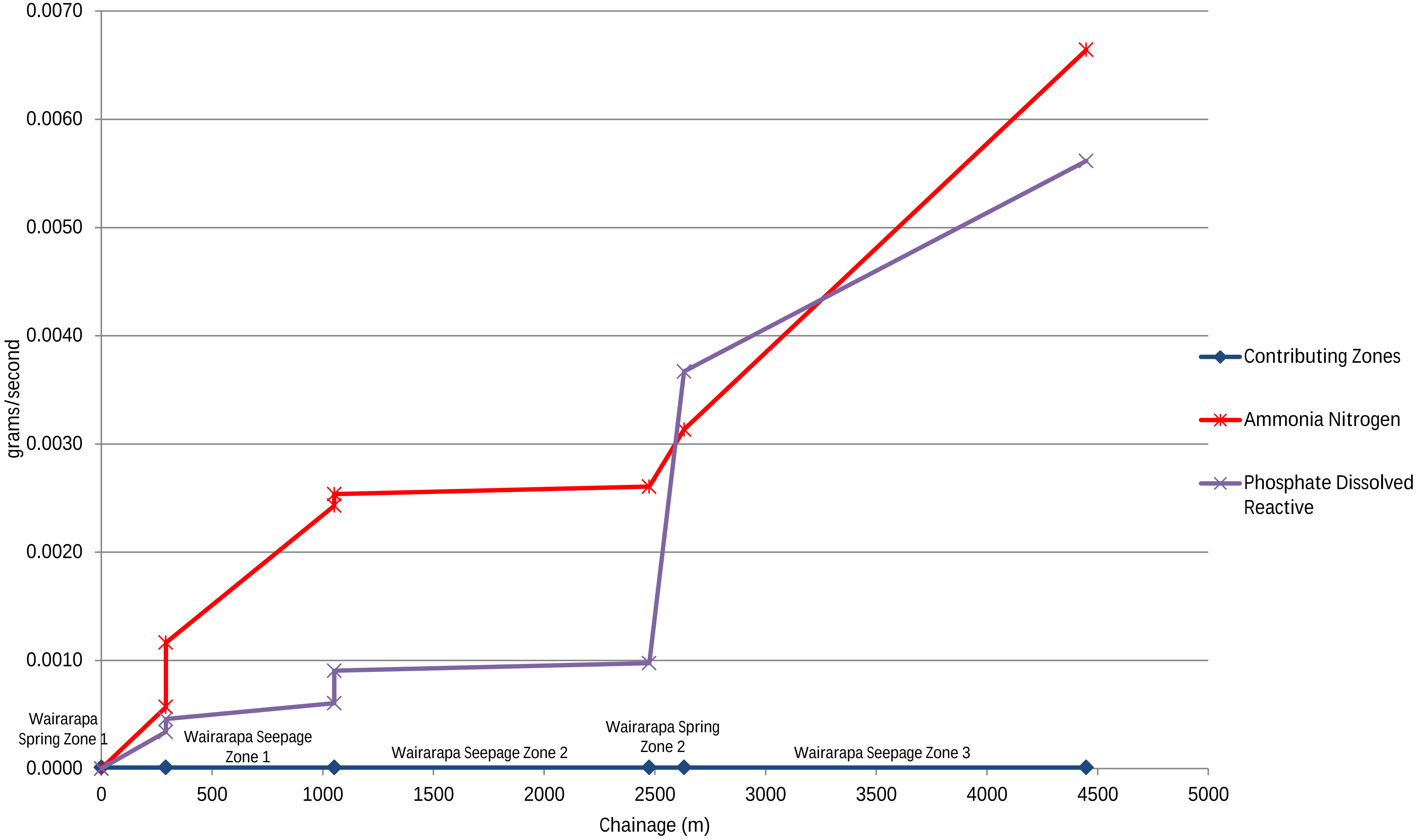


Figure 40b: Accumulating Masses at Contributing Zones in Wairarapa Stream - March 2015

Figure 41a: Accumulating Masses at Contributing Zones in Wairarapa Stream - September 2014



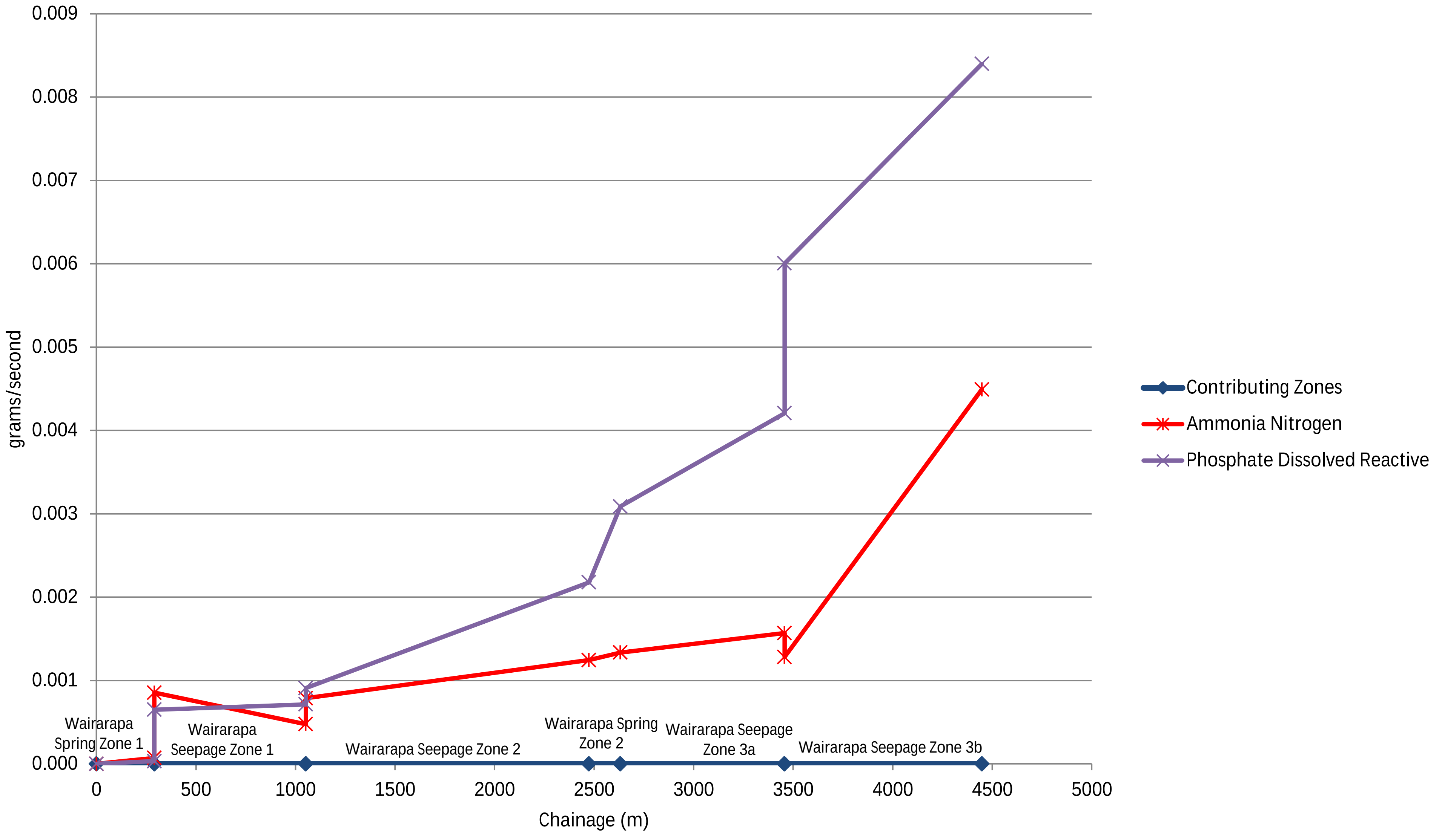


Figure 41b: Accumulating Masses at Contributing Zones in Wairarapa Stream - March 2015

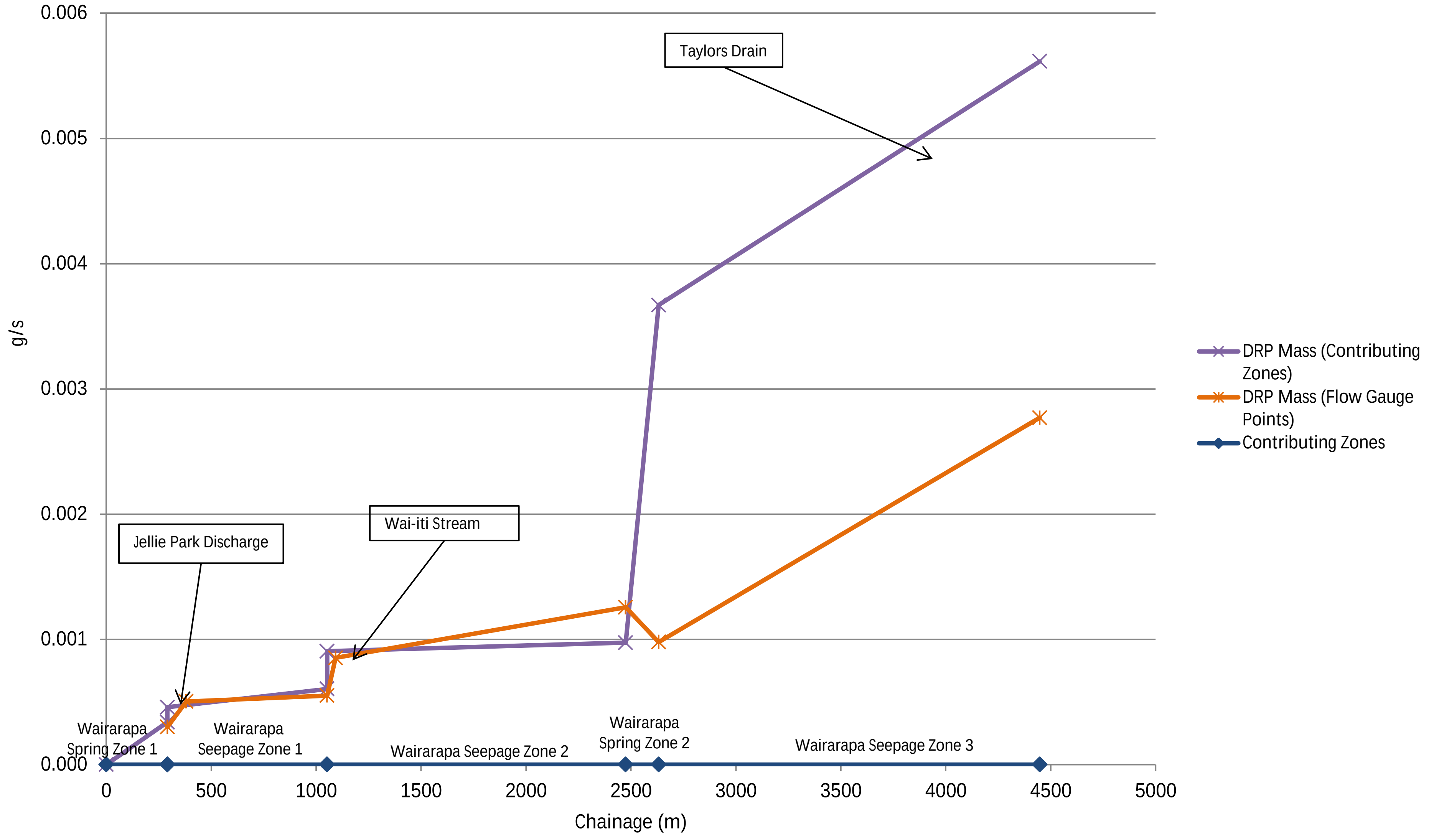


Figure 42: Comparison of DRP Masses at Flow Gauging Points compared to Contributing Zones in Wairarapa Stream - September 2014

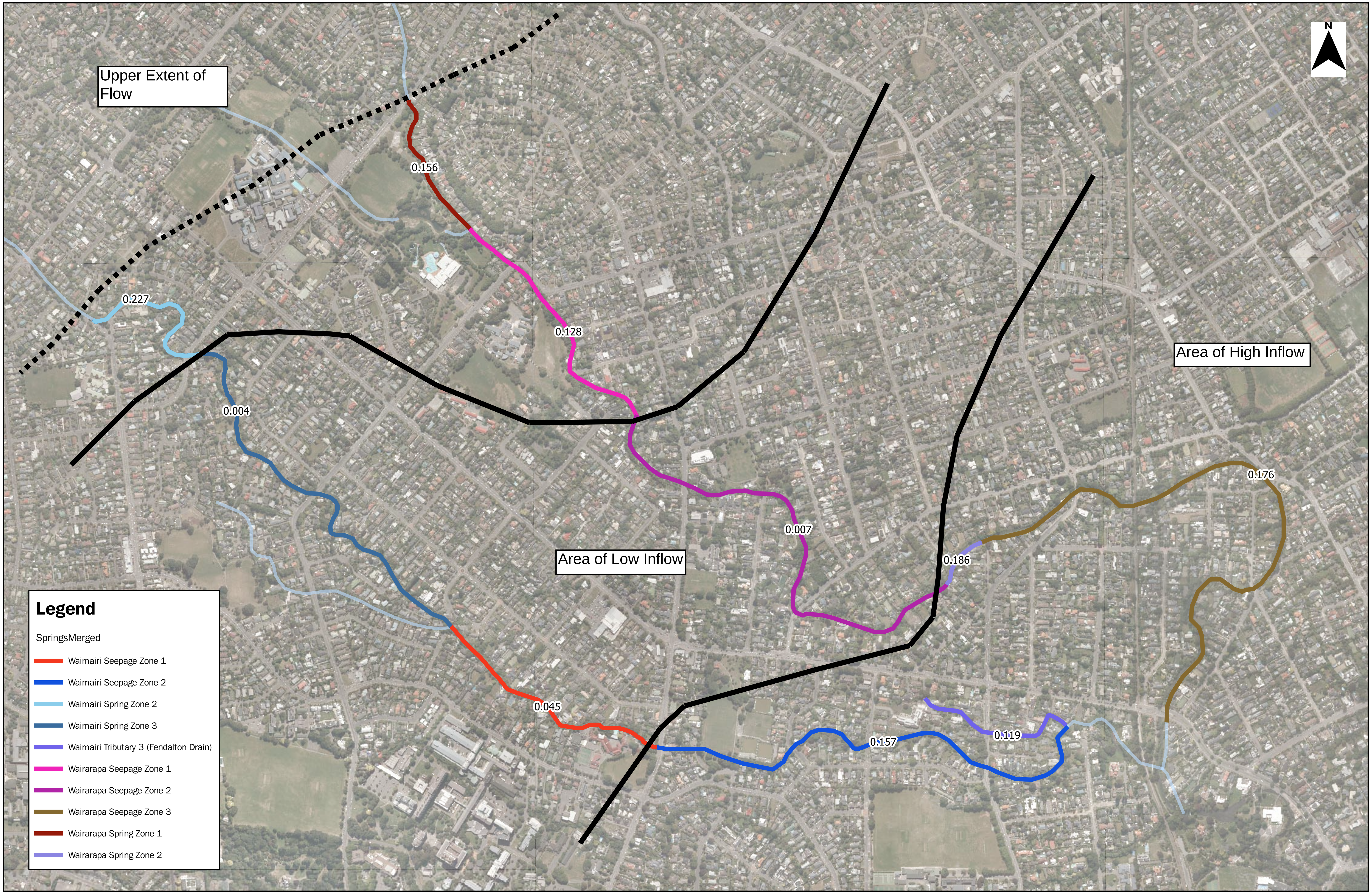


FIGURE 43a: RATE OF FLOW INCREASE PER UNIT LENGTH (L/s/m) - September 2014

1:10,000

150 0 150 300 450 600 m

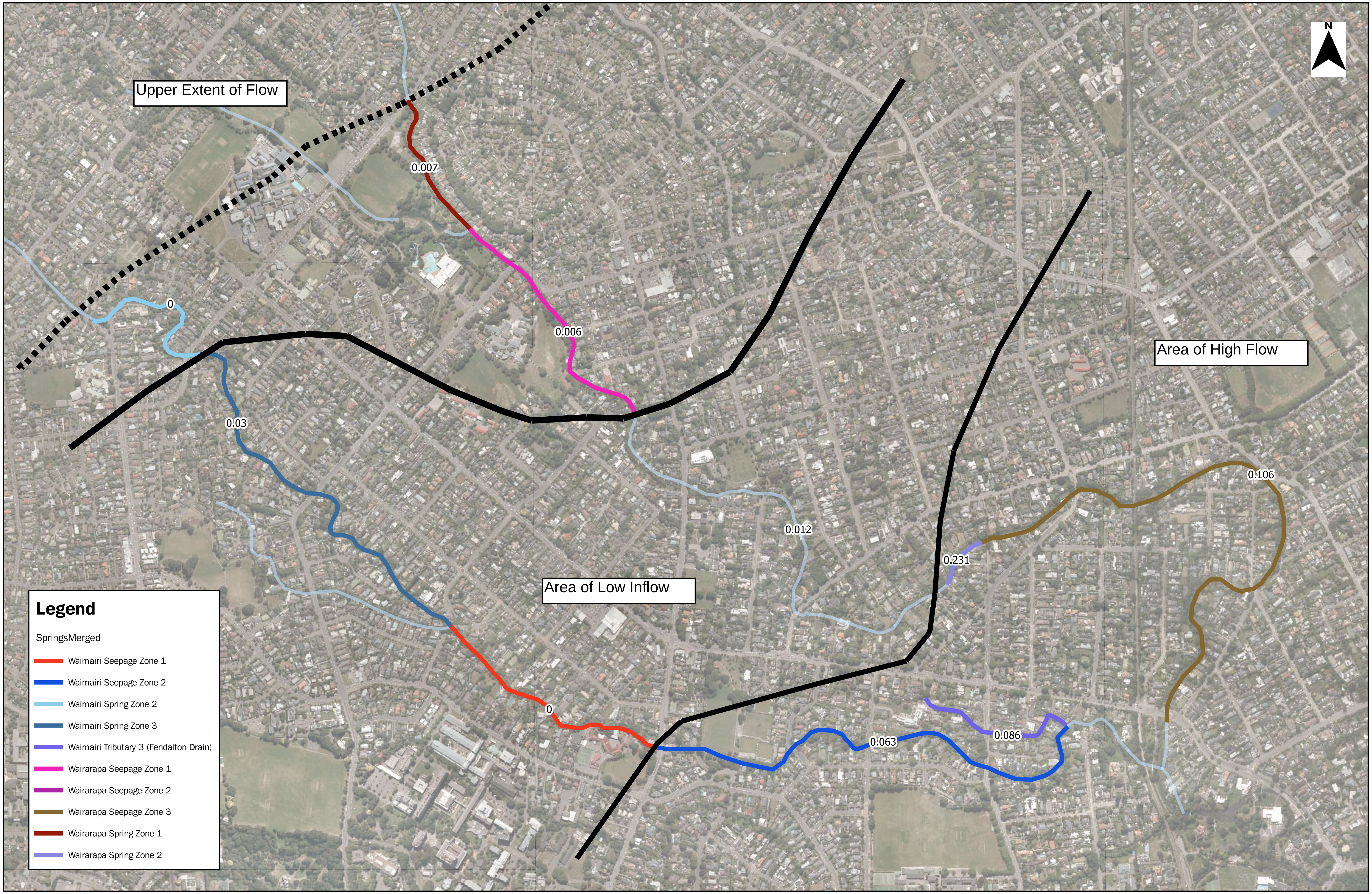


FIGURE 43b: RATE OF FLOW INCREASE PER UNIT LENGTH (L/s/m) - March 2015

1:10,000

150 0 150 300 450 600 m

# Appendix C: Tables

Table 1, Appendix C. Site selection process and ranking scores, note nutrient concentrations are presented as median (mg/L)).

| Rank | Catchment | ID | Site Description | DIN | DRP | Flow Data | Upper Springs | Upper Wells DIN |
|---|---|---|---|---|---|---|---|---|
| **1** | Upper Avon | AVON06 | Waimairi Stream | 2.01 | 0.01 | YES | 11 | M35/2249= 1.85 |
| | | AVON05 | Wairarapa Stream | 1.02 | 0.01 | YES | 12 | M35/2257 = 1.00 |
| | | AVON07 | Avon River at Mona Vale | 2.44 | 0.01 | YES | | M35/1382 = 0.45 |
| **2** | Upper Heathcote | HEATH08 | Heathcote River at Templetons Rd | 3.43 | 0.01 | YES | 14 between Templeton and Curletts Road | M35/2474 = 5.60 |
| | | HEATH13 | Haytons Drain at Wigram Rd | 1.70 | 0.30 | YES | | |
| | | HEATH10 | Curletts Road Drain US Heathcote | 1.65 | 0.04 | YES | | |
| | | HEATH09 | Haytons Drain at Retention Basin | 0.79 | 0.47 | YES | | |
| **3** | Upper Halswell | HALS01 | Halswell Retention Basin inlet | 3.79 | 0.08 | Lower in catchment | Lower in catchment | No further analysis |
| | | HALS02 | Halswell Retention Basin outlet | 3.32 | 0.05 | | | |
| **4** | Uppper Styx | STYX02 | Styx River at Gardiners Rd | 0.63 | 0.01 | Low nutrient concentrations, no further analysis | | |
| | | STYX01 | Smacks Creek at Gardiners Rd | 0.70 | 0.01 | | | |
| **5** | Otukaikino | OTUKAI01 | Otukaikino at Groynes inlet | 0.30 | 0.01 | | | |

## Table 2, Appendix C: Springs Observed during Initial Walkover – June 2014

| Spring ID | NZTMX | NZTMY | Latitude | Longitude | Observation Date | Qualative Size (S, M or L) | Qualative Contibution to flow (%) | Notes |
|---|---|---|---|---|---|---|---|---|
| Wairarapa Spring 1 | 1567671 | 5181719 | 43.51676 | 172.60000 | 5/06/2014 | S | <5% | Large vent, but no obvious flow. Potentially other small vents in area. |
| Wairarapa Spring 2 | 1566176 | 5182687 | 43.50798 | 172.58157 | 5/06/2014 | L | >50% | Jellie Park intercepted spring. |
| Wairarapa Spring 3 | 1566248 | 5182764 | 43.50730 | 172.58245 | 5/06/2014 | S | <5% | Small vent, with relatively small flow. |
| Wairarapa Spring 4 | 1566239 | 5182784 | 43.50711 | 172.58235 | 5/06/2014 | M | 20% | Bank seep, true left bank. Possibly CCC pilot study site. |
| Wairarapa Spring 5 | 1566213 | 5182821 | 43.50677 | 172.58203 | 5/06/2014 | S | 5% | Bank seep, true right bank. |
| Wairarapa Spring 6 | 1566216 | 5182826 | 43.50673 | 172.58206 | 5/06/2014 | S | <5% | Adjacent to true left bank, oppisite Wairarapa Spring 5. |
| Wairarapa Spring 7 | 1566182 | 5182873 | 43.50631 | 172.58165 | 5/06/2014 | M | 10% | Adjacent to true right bank. |
| Wairarapa Spring 8 | 1566158 | 5182929 | 43.50581 | 172.58136 | 5/06/2014 | M | 20% | Hard on true right bank - not bank seep though. |
| Wairarapa Spring 9 | 1566162 | 5182941 | 43.50569 | 172.58140 | 5/06/2014 | S | 10% | Small vent. |
| Wairarapa Spring 10 | 1566165 | 5182946 | 43.50565 | 172.58144 | 5/06/2014 | S | 10% | Small vent, just upstream from Wairarapa Stream 9. |
| Wairarapa Spring 11 | 1566186 | 5182982 | 43.50532 | 172.58170 | 5/06/2014 | M | 30% | Relatively large vent, adjacent to true right bank. |
| Fendalton Drain Spring 1 | 1567860 | 5181245 | 43.5210 | 172.6023 | 23/06/2014 | S | 0% | Two vents, with no obvious flow. |
| Fendalton Drain Spring 2 | 1567737 | 5181279 | 43.5207 | 172.6008 | 23/06/2014 | M | 10% | Pipe into stream, constant flow. 2nd pipe 1 m U/S. |
| Fendalton Drain Spring 3 | 1567719 | 5181294 | 43.5206 | 172.6006 | 23/06/2014 | L | >50% | Flow out of concrete headwall. Large flow. Possible spring. |
| Fendalton Drain Spring 4 | 1567630 | 5181347 | 43.5201 | 172.5995 | 23/06/2014 | M | 50% | Many vents. Upper source of water in drain. |
| Waimairi Spring 1 | 1565718 | 5182053 | 43.5137 | 172.5759 | 23/06/2014 | M | Unknown | Obvious vent, with minimal flow |
| Waimairi Spring 2 | 1565520 | 5182312 | 43.5113 | 172.5734 | 23/06/2014 | M | 40% | Obvious vent on true right bank with very good flow. 1 m U/S of bridge |
| Waimairi Spring 3 | 1565513 | 5182315 | 43.5113 | 172.5733 | 23/06/2014 | M | 10% | Two vents adjacent to each other. True right bank. 20 m U/S of WaimairiSpring 2 |
| Waimairi Spring 4 | 1565465 | 5182348 | 43.5110 | 172.5727 | 23/06/2014 | M | 30% | Two vents adjacent to each other. True left bank. 20 m U/S of Waimairi Spring 2 |
| Waimairi Spring 5 | 1565463 | 5182353 | 43.5110 | 172.5727 | 23/06/2014 | S | 5% | 3 m U/S of Waimairi Spring 4. True left bank. |
| Waimairi Spring 6 | 1565463 | 5182358 | 43.5109 | 172.5727 | 23/06/2014 | L | 30% | 3 m U/S of Waimairi Spring 5. Located in bank indentation on true left bank. |
| Waimairi Spring 7 | 1565471 | 5182378 | 43.5107 | 172.5728 | 23/06/2014 | L | 5% | Loacted in bank indentation pool, true right bank |
| Waimairi Spring 8 | 1565496 | 5182385 | 43.5107 | 172.5731 | 23/06/2014 | L | 30% | Loacted in bank indentation pool, true right bank |
| Waimairi Spring 9 | 1565465 | 5182443 | 43.5101 | 172.5728 | 23/06/2014 | S | 5% | On true right bank. Cleaned sediment observed |
| Waimairi Spring 10 | 1564949 | 5182713 | 43.5077 | 172.5664 | 23/06/2014 | S | <5% | True left bank in eroded area. Many vents along eroded bank, maybe GW emergence |
| Waimairi Spring 11 | 1564905 | 5182735 | 43.5075 | 172.5658 | 23/06/2014 | Unknown | 50% | Possible GW emergence |

## Table 3a, Appendix C: September 2014 Field Measurements and Lab Results (If not otherwise specified, all concentrations are in mg/L)

| Full Name | NZTMX | NZTMY | Sample Date | Time | Type of Seep and sampling method | Stream Flow ($m^3/s$) | Seep Flow (L/s) | Seep Head Level (m stream bed level) | Stream depth (m) | pH | Cond (uS/m) | Temp (C°) | Ammonia Nitrogen | Nitrate + Nitrite Nitrogen | Nitrite Nitrogen | Total Nitrogen | Total Kjeldahl Nitrogen | Calcium acid soluble | Magnesium acid soluble | Total Hardness | Nitrate Nitrogen | Phosphate Dissolved Reactive | Chloride | Dissolved Inorganic Nitrogen |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wairarapa Flow Gauge 2 | 1566314 | 5182882 | 8/09/2014 | 1150 | - | 0.0455 | - | - | - | 6.1 | 171.9 | 13.2 | 0.012 | 1.3 | 0.001 | 1.4 | 0.1 | 23 | 3 | 70 | 1.3 | 0.0066 | 10 | 1.3 |
| Wairarapa Flow Gauge 3 | 1566303 | 5182876 | 8/09/2014 | 1120 | - | 0.0349 | - | - | - | 6.73 | 174.6 | 12.5 | 0.017 | 1.4 | 0.004 | 1.6 | 0.2 | 23 | 2.9 | 69 | 1.4 | 0.0034 | 10 | 1.4 |
| Wairarapa Flow Gauge 4 | 1562925 | 5183901 | 8/09/2014 | 1020 | - | 0.1292 | - | - | - | 6.42 | 174.1 | 12.4 | 0.011 | 1.4 | 0.002 | 1.5 | 0.1 | 23 | 3 | 70 | 1.4 | 0.0039 | 10 | 1.4 |
| Wairarapa Flow Gauge 5 | 1566792 | 5182357 | 10/09/2014 | 1110 | - | 0.1779 | - | - | - | 6.62 | 170.8 | 12.4 | 0.008 | 1.5 | 0.002 | 1.6 | 0.1 | 22 | 3 | 67 | 1.4 | 0.0031 | 11 | 1.5 |
| Wairarapa Flow Gauge 6 | 1566792 | 5182327 | 10/09/2014 | 820 | - | 0.2185 | - | - | - | 6.64 | 178.5 | - | 0.007 | 1.5 | 0.002 | 1.6 | 0.1 | 23 | 3.1 | 70 | 1.4 | 0.0039 | 11 | 1.5 |
| Wairarapa Flow Gauge 7a | 1567671 | 5181872 | 9/09/2014 | 1500 | - | 0.2283 | - | - | - | 6.43 | 160.7 | 13.9 | 0.013 | 1.5 | 0.003 | 1.6 | 0.1 | 23 | 3.2 | 71 | 1.5 | 0.0055 | 10 | 1.5 |
| Wairarapa Flow Gauge 7b | 1567770 | 5181986 | 10/09/2014 | 1300 | - | 0.2576 | - | - | - | 6.95 | 171.2 | 13.6 | 0.011 | 1.5 | 0.004 | 1.6 | 0.1 | 23 | 3.2 | 71 | 1.5 | 0.0038 | 11 | 1.5 |
| Wairarapa Flow Gauge 8 | 1568264 | 5181489 | 9/09/2014 | 1040 | - | 0.5769 | - | - | - | 6.81 | 157.9 | 12 | 0.14 | 0.46 | 0.096 | 1.4 | 0.94 | 22 | 3.3 | 69 | 0.36 | 0.0048 | 9.3 | 0.6 |
| Wairarapa Seepage Meter 1 | | | 8/09/2014 | 1340 | Vent – infiltration ring | - | 0.2 | 0.365 | 0.26 | 5.83 | 188.1 | 12.1 | 0.016 | 1.5 | 0.001 | 1.6 | 0.1 | 22 | 2.7 | 66 | 1.5 | 0.0094 | 11 | 1.5 |
| Water Column u/s of Seep | - | - | - | - | - | - | - | - | - | 5.56 | 186.4 | 12.2 | | | | | | | | | | | | |
| Wairarapa Seepage Meter 2 | 1566223 | 5183011 | 8/09/2014 | 1415 | Vent – infiltration ring | - | 0.26 | 0.28 | 0.23 | 6.41 | 166.3 | 12.8 | 0.009 | 1.4 | 0.001 | 1.5 | 0.1 | 24 | 3.4 | 74 | 1.4 | 0.0055 | 9.3 | 1.4 |
| Water Column u/s of Seep | - | - | - | - | - | - | - | - | - | 6.14 | 172.8 | 12.8 | | | | | | | | | | | | |
| Wairarapa Seepage Meter 3 | 1566620 | 5182444 | 11/09/2014 | 900 | Gravel - large metal slotted piezometer | - | 9.18E-06 | 0.278 | 0.28 | 6.66 | 164.4 | 8.2 | 0.013 | 1.5 | 0.009 | 1.5 | 0.05 | 23 | 3.1 | 70 | 1.3 | 0.0015 | 11 | 1.5 |
| Water Column u/s of Seep | - | - | - | - | - | - | - | - | - | 6.86 | 149.9 | 10.7 | | | | | | | | | | | | |
| Wairarapa Seepage Meter 4 | 1567156 | 5182122 | 10/09/2014 | | Gravel - large metal slotted piezometer | - | 1.39E-05 | 0.291 | 0.31 | 6.12 | 216 | 10.3 | 0.007 | 1.1 | 0.0005 | 1.3 | 0.2 | 24 | 4.7 | 79 | 1.1 | 0.0069 | 13 | 1.1 |
| Water Column u/s of Seep | - | - | - | - | - | - | - | - | - | 6.4 | 173.2 | 12.9 | | | | | | | | | | | | |
| Wairarapa Seepage Meter 5 | 1567685 | 5181907 | 9/09/2014 | | Vent –Large seepage meter | - | 0.3 | 0.385 | 0.33 | 5.95 | 162 | 12.6 | 0.018 | 2.1 | 0.001 | 2.3 | 0.2 | 24 | 3.5 | 74 | 2.1 | 0.092 | 9.8 | 2.1 |
| Water Column u/s of Seep | - | - | - | - | - | - | - | - | - | 6.51 | 150.2 | 12.9 | | | | | | | | | | | | |
| Wairarapa Seepage Meter 6 | 1568052 | 5182132 | 9/09/2014 | | Gravel - large metal slotted piezometer | - | 3.47E-06 | 0.23 | 0.24 | 6.74 | 153.7 | 11.8 | 0.011 | 1.3 | 0.001 | 1.5 | 0.2 | 22 | 3.3 | 69 | 1.3 | 0.0061 | 9.5 | 1.3 |
| Water Column u/s of Seep | - | - | - | - | - | - | - | - | - | 6.72 | 160.9 | 12.2 | | | | | | | | | | | | |
| Waimairi Flow Gauge 3 | 1565457 | 5182644 | 12/09/2014 | 1445 | - | 0.0013 | - | - | - | 6.56 | 210 | 13.3 | 0.021 | 1.5 | 0.013 | 1.7 | 0.2 | 26 | 4.4 | 83 | 1.5 | 0.0045 | 14 | 1.5 |
| Waimairi Flow Gauge 4 | 1565579 | 5182510 | 12/09/2014 | 1240 | - | 0.0698 | - | - | - | 5.97 | 201 | 12.6 | 0.01 | 2.9 | 0.001 | 3 | 0.1 | 26 | 3.8 | 81 | 2.8 | 0.0044 | 12 | 2.9 |
| Waimairi Flow Gauge 5 | 1565890 | 5182130 | 12/09/2014 | 1130 | - | 0.0747 | - | - | - | 6.43 | 201 | 12.6 | 0.007 | 2.9 | 0.002 | 3 | 0.1 | 26 | 3.8 | 81 | 2.7 | 0.0048 | 12 | 2.9 |
| Waimairi Flow Gauge 6 | 1566277 | 5181748 | 12/09/2014 | 1030 | - | 0.0931 | - | - | - | 6.41 | 203 | 12.1 | 0.006 | 3.7 | 0.001 | 3.6 | 0.05 | 26 | 3.5 | 79 | 3.5 | 0.0037 | 13 | 3.7 |
| Waimairi Flow Gauge 7 | 1566852 | 5181407 | 11/09/2014 | 1500 | - | 0.1994 | - | - | - | 6.45 | 167.8 | 12.7 | 0.016 | 3.3 | 0.002 | 3.3 | 0.05 | 26 | 3.7 | 80 | 3.1 | 0.0067 | 13 | 3.3 |
| Waimairi Flow Gauge 8 | 1567953 | 5181502 | 11/09/2014 | 1140 | - | 0.0556 | - | - | - | 6.06 | 135.6 | 13.1 | 0.009 | 2.1 | 0.001 | 1.9 | 0.05 | 21 | 3.1 | 65 | 1.8 | 0.0076 | 7.9 | 2.1 |
| Waimairi Flow Gauge 9 | 1567995 | 5181463 | 11/09/2014 | 1100 | - | 0.4125 | - | - | - | 6.19 | 158.9 | 12 | 0.01 | 3.1 | 0.001 | 2.9 | 0.05 | 24 | 3.5 | 74 | 2.8 | 0.0054 | 11 | 3.1 |
| Waimairi Seepage Meter 3 | | | 12/09/2014 | 1430 | Vent – infiltration ring | - | 0.5 | 0.373 | 0.31 | 7.01 | 203 | 12.7 | 0.007 | 3.2 | 0.0005 | 3.2 | 0.05 | 25 | 3.9 | 78 | 3.1 | 0.004 | 12 | 3.2 |
| Water Column u/s of Seep | - | - | - | - | | - | - | - | - | 6.6 | 199 | 12.4 | | | | | | | | | | | | |
| Waimairi Seepage Meter 4 | 1566253 | 5181776 | 12/09/2014 | 1630 | G Gravel - large metal slotted piezometer | - | 9.13E-06 | 0.157 | 0.191 | 6.63 | 242 | 13.6 | 0.59 | 0.098 | 0.007 | 0.62 | 0.52 | 28 | 5.8 | 94 | 0.09 | 0.13 | 8.3 | 0.69 |
| Water Column u/s of seep | - | - | - | - | - | - | - | - | - | 6.83 | 199 | 12.1 | | | | | | | | | | | | |
| Waimairi Seepage Meter 5 | 1567072 | 5181352 | 12/09/2014 | 1530 | Gravel - large metal slotted piezometer | - | 7.12E-06 | 0.023 | 0.11 | 6.57 | 173.4 | 12.3 | 0.01 | 3.7 | 0.0005 | 3.6 | 0.05 | 26 | 3.7 | 80 | 3.4 | 0.0036 | 13 | 3.7 |
| Water Column u/s of seep | - | - | - | - | Water Column u/s of Seep | - | - | - | - | 6.95 | 159.9 | 11.3 | | | | | | | | | | | | |
| Waimairi Seepage Meter 6 | 1567644 | 5181525 | 11/09/2014 | 1345 | Vent – infiltration ring | - | 0.26 | 0.272 | 0.197 | 6.41 | 145.1 | 12.3 | 0.022 | 2.3 | 0.001 | 2.4 | 0.1 | 22 | 3.2 | 68 | 2.3 | 0.007 | 9 | 2.3 |
| Water Column u/s of seep | - | - | - | - | - | - | - | - | - | 6.2 | 171.6 | 11 | | | | | | | | | | | | |
| 🟨 | Below detection Level, reported as half detection level | | | | | | | | | | | | | | | | | | | | | | | |

# Table 3b, Appendix C: March 2015 Field Measurements and Lab Results (If not otherwise specified, all concentrations are in mg/L)

| Full Name | NZTMX | NZTMY | Sample Date | Time | Type of Seep and sampling method | Stream Flow ($m^3/s$) | Seep Flow (L/s) | Seep Head Level (m stream bed level) | Stream depth at measuring point (m) | pH | Cond (uS/m) | Temp (C°) | Ammonia Nitrogen | Nitrate + Nitrite Nitrogen | Nitrite Nitrogen | Total Nitrogen | Total Kjeldahl Nitrogen | Calcium acid soluble | Magnesium acid soluble | Total Hardness | Nitrate Nitrogen | Phosphate Dissolved Reactive | Chloride | Dissolved Inorganic Nitrogen |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Waimairi Flow Gauge 6 | 1566277 | 5181748 | 24/03/2015 | 1315 | | 0.0053 | - | - | - | 6.84 | 196 | 17.1 | 0.007 | 3.2 | 0.003 | 3.2 | 0.05 | 24 | 3.4 | 74 | - | 0.019 | 11 | 3.2 |
| Waimairi Flow Gauge 6B | 1566284 | 5181561 | 24/03/2015 | 1400 | | 0.0083 | - | - | - | 6.6 | 218 | 17.2 | 0.01 | 2.8 | 0.002 | 2.8 | 0.05 | 23 | 3.8 | 73 | - | 0.019 | 12 | 2.8 |
| Waimairi Flow Gauge 7 | 1566852 | 5181407 | 25/03/2015 | 1245 | | 0.0083 | - | - | - | 7.44 | 153.2 | 14.9 | 0.018 | 2.8 | 0.006 | 2.8 | 0.05 | 25 | 3.9 | 78 | - | 0.027 | 12 | 2.8 |
| Waimairi Flow Gauge 8A | 1568004 | 5181294 | 26/03/2015 | 730 | | 0.229 | - | - | - | 7.09 | 137.7 | 13.8 | 0.0025 | 2.6 | 0.002 | 2.6 | 0.05 | 22 | 3.2 | 68 | - | 0.013 | 8.8 | 2.6 |
| Waimairi Flow Gauge 9 | 1567995 | 5181463 | 26/03/2015 | 745 | | 0.189 | - | - | - | 7.21 | 137.6 | 13.9 | 0.0025 | 2.5 | 0.001 | 2.6 | 0.1 | 22 | 3.2 | 68 | - | 0.0084 | 8.6 | 2.5 |
| Waimairi Seepage Meter 6 | 1567644 | 5181525 | 25/03/2015 | 1115 | Vent – infiltration Rings | - | - | - | - | 7.13 | 134.5 | 13.6 | 0.006 | 2.5 | 0.0005 | 2.5 | 0.05 | 22 | 3.1 | 68 | - | 0.013 | 8.2 | 2.5 |
| Wairarapa Flow Gauge 2 | 1566314 | 5182882 | 24/03/2015 | 1135 | | 0.0021 | - | - | - | 6.97 | 156.7 | 16.4 | 0.034 | 1.1 | 0.007 | 1.1 | 0.05 | 20 | 2.7 | 61 | - | 0.015 | 7.8 | 1.1 |
| Wairarapa Flow Gauge 3 | 1566303 | 5182876 | 24/03/2015 | 1120 | | 0.0412 | - | - | - | 7.09 | 157.8 | 14 | 0.019 | 1.3 | 0.002 | 1.3 | 0.05 | 21 | 2.7 | 64 | - | 0.015 | 8.2 | 1.3 |
| Wairarapa Flow Gauge 4 | 1562925 | 5183901 | 24/03/2015 | 1045 | | 0.0491 | - | - | - | 6.72 | 158.1 | 14.1 | 0.018 | 1.2 | 0.003 | 1.3 | 0.1 | 22 | 2.8 | 66 | - | 0.015 | 7.9 | 1.2 |
| Wairarapa Flow Gauge 5 | 1566792 | 5182357 | 24/03/2015 | 930 | | 0.0476 | - | - | - | 6.91 | 164.5 | 13.5 | 0.01 | 1.3 | 0.003 | 1.3 | 0.05 | 22 | 2.9 | 67 | - | 0.015 | 9.8 | 1.3 |
| Wairarapa Flow Gauge 6 | 1566792 | 5182327 | 24/03/2015 | 840 | | 0.0606 | - | - | - | 7.04 | 165.8 | 13.3 | 0.013 | 1.3 | 0.004 | 1.3 | 0.05 | 21 | 2.8 | 64 | - | 0.015 | 9.3 | 1.3 |
| Wairarapa Flow Gauge 7A | 1567671 | 5181872 | 23/03/2015 | 1430 | | 0.0778 | - | - | - | 6.99 | 143.6 | 15.6 | 0.016 | 1.3 | 0.005 | 1.4 | 0.1 | 22 | 3.1 | 68 | - | 0.028 | 7.6 | 1.3 |
| Wairarapa Flow Gauge 7B | 1567770 | 5181986 | 23/03/2015 | 1300 | | 0.1142 | - | - | - | 7.16 | 143.2 | 15.5 | 0.018 | 1.5 | 0.004 | 1.5 | 0.05 | 23 | 3.2 | 71 | - | 0.027 | 5.9 | 1.5 |
| Wairarapa Flow Gauge 8 | 1568264 | 5181489 | 23/03/2015 | 920 | | 0.355 | - | - | - | 6.66 | 136.8 | 14.3 | 0.017 | 1.3 | 0.003 | 1.3 | 0.05 | 21 | 3.2 | 66 | - | 0.027 | 5.3 | 1.3 |
| Wairarapa Flow Gauge 9A | 1568476 | 5182017 | 23/03/2015 | 1130 | | 0.2074 | - | - | - | 6.75 | 139.6 | 14.8 | 0.015 | 1.4 | 0.004 | 1.4 | 0.05 | 22 | 3.3 | 69 | - | 0.026 | 5.1 | 1.4 |
| Wairarapa Flow Gauge 9B | 1568522 | 5181991 | 23/03/2015 | 1035 | | 0.2568 | - | - | - | 6.83 | 143.9 | 15.1 | 0.011 | 1.1 | 0.002 | 1.1 | 0.05 | 23 | 3.5 | 72 | - | 0.028 | 4.8 | 1.1 |
| Wairarapa Seepage Meter 5 | 1567685 | 5181907 | 23/03/2015 | 1415 | Vent – infiltration Rings | - | - | - | - | 6.67 | 149.1 | 14.6 | 0.0025 | 2.2 | 0.0005 | 2.2 | 0.05 | 24 | 3.4 | 74 | - | 0.025 | 6.1 | 2.2 |
| Wairarapa Seepage Meter 6 | 1568052 | 5182132 | 25/03/2015 | 1130 | Gravel – Small seepage meter | - | - | - | - | - | - | - | 0.0025 | 0.55 | 0.004 | 1.4 | 0.85 | 24 | 3.2 | 73 | - | 0.012 | 9.2 | 0.55 |
| 🟨 | Below detection Level, reported as half detection level | | | | | | | | | | | | | | | | | | | | | | | |

## Table 4a, Appendix C. Flow Gauging Points – September 2014

| Full Name | Chainage | Stream Flow (L/s) | Ammonia Nitrogen | Ammonia Nitrogen Mass Flux | Nitrate+Nitrite Nitrogen | Nitrate+Nitrite Nitrogen Mass Flux | Nitrite Nitrogen | Nitrite Nitrogen Mass Flux | Total Nitrogen | Total Nitrogen Mass Flux | Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen Mass Flux | Calcium acid soluble | Calcium acid soluble Mass Flux | Magnesium acid soluble | Magnesium acid soluble Mass Flux | Total Hardness | Total Hardness Mass Flux | Nitrate Nitrogen | Nitrate Nitrogen Mass Flux | Phosphate Dissolved Reactive | Phosphate Dissolved Reactive Mass Flux | Chloride | Chloride Mass Flux | Dissolved Inorganic Nitrogen | Dissolved Inorganic Nitrogen Mass Flux | Organic Nitrogen | Organic Nitrogen Mass Flux |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | L/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s |
| WAIR FG2 | 291 | 45.5 | 0.012 | 5.46E-04 | 1.3 | 5.92E-02 | 0.001 | 4.55E-05 | 1.4 | 0.0637 | 0.1 | 4.55E-03 | 23 | 1.05 | 3 | 0.1365 | 70 | 3.19 | 1.3 | 0.0592 | 0.0066 | 3.00E-04 | 10 | 0.455 | 1.3 | 0.059 | 0.088 | 0.0040 |
| WAIR FG4 | 381 | 129.2 | 0.011 | 1.42E-03 | 1.4 | 1.81E-01 | 0.002 | 2.58E-04 | 1.5 | 0.1938 | 0.1 | 1.29E-02 | 23 | 2.97 | 3 | 0.3876 | 70 | 9.04 | 1.4 | 0.1809 | 0.0039 | 5.04E-04 | 10 | 1.292 | 1.4 | 0.181 | 0.089 | 0.0115 |
| WAIR FG5 | 1,052 | 177.9 | 0.008 | 1.42E-03 | 1.5 | 2.67E-01 | 0.002 | 3.56E-04 | 1.6 | 0.28464 | 0.1 | 1.78E-02 | 22 | 3.91 | 3 | 0.5337 | 67 | 11.92 | 1.4 | 0.2491 | 0.0031 | 5.51E-04 | 11 | 1.957 | 1.5 | 0.267 | 0.092 | 0.0164 |
| WAIR FG6 | 1,093 | 218.5 | 0.007 | 1.53E-03 | 1.5 | 3.28E-01 | 0.002 | 4.37E-04 | 1.6 | 0.3496 | 0.1 | 2.19E-02 | 23 | 5.03 | 3.1 | 0.6774 | 70 | 15.30 | 1.4 | 0.3059 | 0.0039 | 8.52E-04 | 11 | 2.404 | 1.5 | 0.328 | 0.093 | 0.0203 |
| WAIR FG7A | 2,475 | 228.3 | 0.013 | 2.97E-03 | 1.5 | 3.42E-01 | 0.003 | 6.85E-04 | 1.6 | 0.36528 | 0.1 | 2.28E-02 | 23 | 5.25 | 3.2 | 0.7306 | 71 | 16.21 | 1.5 | 0.3425 | 0.0055 | 1.26E-03 | 10 | 2.283 | 1.5 | 0.342 | 0.087 | 0.0199 |
| WAIR FG7B | 2,632 | 257.6 | 0.011 | 2.83E-03 | 1.5 | 3.86E-01 | 0.004 | 1.03E-03 | 1.6 | 0.41216 | 0.1 | 2.58E-02 | 23 | 5.92 | 3.2 | 0.8243 | 71 | 18.29 | 1.5 | 0.3864 | 0.0038 | 9.79E-04 | 11 | 2.834 | 1.5 | 0.386 | 0.089 | 0.0229 |
| WAIR FG8 | 4,448 | 576.9 | 0.14 | 8.08E-02 | 0.46 | 2.65E-01 | 0.096 | 5.54E-02 | 1.4 | 0.80766 | 0.94 | 5.42E-01 | 22 | 12.69 | 3.3 | 1.9038 | 69 | 39.81 | 0.36 | 0.2077 | 0.0048 | 2.77E-03 | 9.3 | 5.365 | 0.6 | 0.346 | 0.800 | 0.4615 |
| WAIM FG3 | 0 | 1.3 | 0.021 | 2.73E-05 | 1.5 | 1.95E-03 | 0.013 | 1.69E-05 | 1.7 | 0.00221 | 0.2 | 2.60E-04 | 26 | 0.03 | 4.4 | 0.0057 | 83 | 0.11 | 1.5 | 0.0020 | 0.0045 | 5.85E-06 | 14 | 0.018 | 1.5 | 0.002 | 0.179 | 0.0002 |
| WAIM FG4 | 307 | 69.8 | 0.01 | 6.98E-04 | 2.9 | 2.02E-01 | 0.001 | 6.98E-05 | 3 | 0.2094 | 0.1 | 6.98E-03 | 26 | 1.81 | 3.8 | 0.2652 | 81 | 5.65 | 2.8 | 0.1954 | 0.0044 | 3.07E-04 | 12 | 0.838 | 2.9 | 0.202 | 0.090 | 0.0063 |
| WAIM FG5 | 868 | 74.7 | 0.007 | 5.23E-04 | 2.9 | 2.17E-01 | 0.002 | 1.49E-04 | 3 | 0.2241 | 0.1 | 7.47E-03 | 26 | 1.94 | 3.8 | 0.2839 | 81 | 6.05 | 2.7 | 0.2017 | 0.0048 | 3.59E-04 | 12 | 0.896 | 2.9 | 0.217 | 0.093 | 0.0069 |
| WAIM FG6a (composite) | 1,500 | 167.8 | 0.0023 | 1.08E-03 | 1.1987 | 5.61E-01 | 0.0005 | 2.43E-04 | 1.1947 | 0.55926 | 0.0259 | 1.21E-02 | 9.3202 | 4.36 | 1.3025 | 0.6097 | 28.6383 | 13.41 | 1.1270 | 0.5275 | 0.0015 | 7.03E-04 | 4.5005 | 2.107 | 1.1987 | 0.561 | 0.066 | 0.0110 |
| WAIM FG7 | 2,195 | 199.4 | 0.016 | 3.19E-03 | 3.3 | 6.58E-01 | 0.002 | 3.99E-04 | 3.3 | 0.65802 | 0.05 | 9.97E-03 | 26 | 5.18 | 3.7 | 0.7378 | 80 | 15.95 | 3.1 | 0.6181 | 0.0067 | 1.34E-03 | 13 | 2.592 | 3.3 | 0.658 | 0.034 | 0.0068 |
| WAIM FG9 | 3,552 | 412.5 | 0.0100 | 4.13E-03 | 3.1 | 1.28E+00 | 0.001 | 4.13E-04 | 2.9 | 1.19625 | 0.05 | 2.06E-02 | 24 | 9.90 | 3.5 | 1.4438 | 74 | 30.53 | 2.8 | 1.1550 | 0.0054 | 2.23E-03 | 11 | 4.538 | 3.1 | 1.279 | 0.040 | 0.0165 |
| WAIM FG10 (composite) | 3,572 | 468.1 | 0.0099 | 4.63E-03 | 2.9812 | 1.40E+00 | 0.0010 | 4.68E-04 | 2.7812 | 1.30189 | 0.0500 | 2.34E-02 | 23.6437 | 11.07 | 3.4525 | 1.6161 | 72.9310 | 34.14 | 2.6812 | 1.2551 | 0.0057 | 2.65E-03 | 10.6318 | 4.977 | 2.9812 | 1.396 | 0.040 | 0.0188 |

## Table 4b, Appendix C. Flow Gauging Points – March 2015

| Full Name | Chainage | Stream Flow (L/s) | Ammonia Nitrogen | Ammonia Nitrogen Mass Flux | Nitrate+Nitrite Nitrogen | Nitrate+Nitrite Nitrogen Mass Flux | Nitrite Nitrogen | Nitrite Nitrogen Mass Flux | Total Nitrogen | Total Nitrogen Mass Flux | Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen Mass Flux | Calcium acid soluble | Calcium acid soluble Mass Flux | Magnesium acid soluble | Magnesium acid soluble Mass Flux | Total Hardness | Total Hardness Mass Flux | Nitrate Nitrogen | Nitrate Nitrogen Mass Flux | Phosphate Dissolved Reactive | Phosphate Dissolved Reactive Mass Flux | Chloride | Chloride Mass Flux | Dissolved Inorganic Nitrogen | Dissolved Inorganic Nitrogen Mass Flux |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s |
| WAIRFG2 | 291 | 2.1 | 0.034 | 7.14E-05 | 1.1 | 2.31E-03 | 0.007 | 1.47E-05 | 1.1 | 2.31E-03 | 0.05 | 1.05E-04 | 20 | 4.20E-02 | 2.7 | 5.67E-03 | 61 | 1.28E-01 | 1.09 | 2.30E-03 | 0.015 | 3.15E-05 | 7.8 | 1.64E-02 | 1.1 | 2.31E-03 |
| WAIRFG3 | 291 | 41.2 | 0.019 | 7.83E-04 | 1.3 | 5.36E-02 | 0.002 | 8.24E-05 | 1.3 | 5.36E-02 | 0.05 | 2.06E-03 | 21 | 8.65E-01 | 2.7 | 1.11E-01 | 64 | 2.64E+00 | 1.30 | 5.35E-02 | 0.015 | 6.18E-04 | 8.2 | 3.38E-01 | 1.3 | 5.36E-02 |
| WAIRFG4 | 381 | 49.1 | 0.018 | 8.84E-04 | 1.2 | 5.89E-02 | 0.003 | 1.47E-04 | 1.3 | 6.38E-02 | 0.1 | 4.91E-03 | 22 | 1.08E+00 | 2.8 | 1.37E-01 | 66 | 3.24E+00 | 1.20 | 5.88E-02 | 0.015 | 7.37E-04 | 7.9 | 3.88E-01 | 1.2 | 5.89E-02 |
| WAIRFG5 | 1,052 | 47.6 | 0.01 | 4.76E-04 | 1.3 | 6.19E-02 | 0.003 | 1.43E-04 | 1.3 | 6.19E-02 | 0.05 | 2.38E-03 | 22 | 1.05E+00 | 2.9 | 1.38E-01 | 67 | 3.19E+00 | 1.30 | 6.17E-02 | 0.015 | 7.14E-04 | 9.8 | 4.66E-01 | 1.3 | 6.19E-02 |
| WAIRFG6 | 1,093 | 60.6 | 0.013 | 7.88E-04 | 1.3 | 7.88E-02 | 0.004 | 2.42E-04 | 1.3 | 7.88E-02 | 0.05 | 3.03E-03 | 21 | 1.27E+00 | 2.8 | 1.70E-01 | 64 | 3.88E+00 | 1.30 | 7.85E-02 | 0.015 | 9.09E-04 | 9.3 | 5.64E-01 | 1.3 | 7.88E-02 |
| WAIRFG7A | 2,475 | 77.8 | 0.016 | 1.24E-03 | 1.3 | 1.01E-01 | 0.005 | 3.89E-04 | 1.4 | 1.09E-01 | 0.1 | 7.78E-03 | 22 | 1.71E+00 | 3.1 | 2.41E-01 | 68 | 5.29E+00 | 1.30 | 1.01E-01 | 0.028 | 2.18E-03 | 7.6 | 5.91E-01 | 1.3 | 1.01E-01 |
| WAIRFG7B | 2,632 | 114.2 | 0.018 | 2.06E-03 | 1.5 | 1.71E-01 | 0.004 | 4.57E-04 | 1.5 | 1.71E-01 | 0.05 | 5.71E-03 | 23 | 2.63E+00 | 3.2 | 3.65E-01 | 71 | 8.11E+00 | 1.50 | 1.71E-01 | 0.027 | 3.08E-03 | 5.9 | 6.74E-01 | 1.5 | 1.71E-01 |
| WAIRFG9A | 3,432 | 207.4 | 0.015 | 3.11E-03 | 1.4 | 2.90E-01 | 0.004 | 8.30E-04 | 1.4 | 2.90E-01 | 0.05 | 1.04E-02 | 22 | 4.56E+00 | 3.3 | 6.84E-01 | 69 | 1.43E+01 | 1.40 | 2.90E-01 | 0.026 | 5.39E-03 | 5.1 | 1.06E+00 | 1.4 | 2.90E-01 |
| WAIRFG9B | 3,482 | 256.8 | 0.011 | 2.82E-03 | 1.1 | 2.82E-01 | 0.002 | 5.14E-04 | 1.1 | 2.82E-01 | 0.05 | 1.28E-02 | 23 | 5.91E+00 | 3.5 | 8.99E-01 | 72 | 1.85E+01 | 1.10 | 2.82E-01 | 0.028 | 7.19E-03 | 4.8 | 1.23E+00 | 1.1 | 2.82E-01 |
| WAIRFG8 | 4,448 | 355 | 0.017 | 6.04E-03 | 1.3 | 4.62E-01 | 0.003 | 1.07E-03 | 1.3 | 4.62E-01 | 0.05 | 1.78E-02 | 21 | 7.46E+00 | 3.2 | 1.14E+00 | 66 | 2.34E+01 | 1.30 | 4.60E-01 | 0.027 | 9.59E-03 | 5.3 | 1.88E+00 | 1.3 | 4.62E-01 |
| WAIMFG6 | 1,500 | 5.3 | 0.007 | 3.71E-05 | 3.2 | 1.70E-02 | 0.003 | 1.59E-05 | 3.2 | 1.70E-02 | 0.05 | 2.65E-04 | 24 | 1.27E-01 | 3.4 | 1.80E-02 | 74 | 3.92E-01 | 3.20 | 1.69E-02 | 0.019 | 1.01E-04 | 11 | 5.83E-02 | 3.2 | 1.70E-02 |
| WAIMFG6B | 1,510 | 8.3 | 0.01 | 8.30E-05 | 2.8 | 2.32E-02 | 0.002 | 1.66E-05 | 2.8 | 2.32E-02 | 0.05 | 4.15E-04 | 23 | 1.91E-01 | 3.8 | 3.15E-02 | 73 | 6.06E-01 | 2.80 | 2.32E-02 | 0.019 | 1.58E-04 | 12 | 9.96E-02 | 2.8 | 2.32E-02 |
| WAIMFG7 | 2,195 | 8.3 | 0.018 | 1.49E-04 | 2.8 | 2.32E-02 | 0.006 | 4.98E-05 | 2.8 | 2.32E-02 | 0.05 | 4.15E-04 | 25 | 2.08E-01 | 3.9 | 3.24E-02 | 78 | 6.47E-01 | 2.79 | 2.32E-02 | 0.027 | 2.24E-04 | 12 | 9.96E-02 | 2.8 | 2.32E-02 |
| WAIMFG9 | 3,552 | 189 | 0.0025 | 4.73E-04 | 2.5 | 4.73E-01 | 0.001 | 1.89E-04 | 2.6 | 4.91E-01 | 0.1 | 1.89E-02 | 22 | 4.16E+00 | 3.2 | 6.05E-01 | 68 | 1.29E+01 | 2.50 | 4.72E-01 | 0.0084 | 1.59E-03 | 8.6 | 1.63E+00 | 2.5 | 4.73E-01 |
| WAIMFG8A | 3,572 | 229 | 0.0025 | 5.73E-04 | 2.6 | 5.95E-01 | 0.002 | 4.58E-04 | 2.6 | 5.95E-01 | 0.05 | 1.15E-02 | 22 | 5.04E+00 | 3.2 | 7.33E-01 | 68 | 1.56E+01 | 2.60 | 5.95E-01 | 0.013 | 2.98E-03 | 8.8 | 2.02E+00 | 2.6 | 5.95E-01 |

## Table 5a, Appendix C. Recharge Zones – September 2014

| Full Name | Flow | Concentration | Chainage Start | Chainage End | Length of Section | Flow (L/s) | Ammonia Nitrogen | Ammonia Nitrogen Accumulating Mass in Recharge Zones | Nitrate+Nitrite Nitrogen | Nitrate+Nitrite Nitrogen Accumulating Mass in Recharge Zones | Nitrite Nitrogen | Nitrite Nitrogen Accumulating Mass in Recharge Zones | Total Nitrogen | Accumulating TN in Recharge Zones | Organic Nitrogen | Organic Nitrogen Accumulating Mass in Recharge Zones | Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen Accumulating Mass in Recharge Zones | Calcium acid soluble | Calcium acid soluble Accumulating Mass in Recharge Zones | Magnesium acid soluble | Magnesium acid soluble Accumulating Mass in Recharge Zones | Total Hardness | Total Hardness Accumulating Mass in Recharge Zones | Nitrate Nitrogen | Nitrate Nitrogen Accumulating Mass in Recharge Zones | Phosphate Dissolved Reactive | Phosphate Dissolved Reactive Accumulating Mass in Recharge Zones | Chloride | Chloride Accumulating Mass in Recharge Zones | Dissolved Inorganic Nitrogen | Dissolved Inorganic Nitrogen Accumulating Mass in Recharge Zones |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s |
| Wairarapa Spring Zone 1 | WairFG4 | Average (WairSM1 & WairSM2) | 0 | 291 | 291 | 45.5 | 0.013 | 5.69E-04 | 1.45 | 6.60E-02 | 0.00100 | 4.55E-05 | 1.55 | 7.05E-02 | 0.0875 | 3.98E-03 | 0.10 | 4.55E-03 | 23.0 | 1.05 | 3.05 | 0.139 | 70.00 | 3.19 | 1.45 | 0.066 | 0.0075 | 3.39E-04 | 10.15 | 0.46 | 1.45 | 0.066 |
| Wairarapa Tributaryutary 1 | WairFG3 | Jellie Park Discharge (Wair FG3) | 291 | 291 | - | 35.0 | 0.017 | 1.16E-03 | 1.40 | 1.15E-01 | 0.00400 | 1.86E-04 | 1.60 | 1.27E-01 | 0.1830 | 1.04E-02 | 0.20 | 1.16E-02 | 23.0 | 1.85 | 2.90 | 0.240 | 69.00 | 5.60 | 1.40 | 0.115 | 0.0034 | 4.58E-04 | 10.00 | 0.81 | 1.40 | 0.115 |
| Wairarapa Seepage Zone 1 | WairFG5- WairFG4 | WairSM3 | 291 | 1052 | 761 | 97.4 | 0.013 | 2.43E-03 | 1.50 | 2.61E-01 | 0.00900 | 1.06E-03 | 1.50 | 2.73E-01 | 0.0370 | 1.40E-02 | 0.05 | 1.64E-02 | 23.0 | 4.09 | 3.10 | 0.542 | 70.00 | 12.42 | 1.30 | 0.242 | 0.0015 | 6.04E-04 | 11.00 | 1.88 | 1.50 | 0.261 |
| Wairarapa Tributary 2 | WairFG6- WairFG5 | Wai-iti Stream (WairFG6 - WairFG5) | 1052 | 1052 | - | 40.5 | 0.003 | 2.54E-03 | 1.50 | 3.22E-01 | 0.00200 | 1.14E-03 | 1.60 | 3.38E-01 | 0.0976 | 1.79E-02 | 0.10 | 2.05E-02 | 27.4 | 5.20 | 3.55 | 0.686 | 83.35 | 15.79 | 1.40 | 0.298 | 0.0074 | 9.05E-04 | 11.03 | 2.33 | 1.50 | 0.322 |
| Wairarapa Seepage Zone 2 | WairFG7a- WairFG6 | WairSM4 | 1052 | 2475 | 1423 | 10.0 | 0.007 | 2.61E-03 | 1.10 | 3.33E-01 | 0.00050 | 1.15E-03 | 1.30 | 3.51E-01 | 0.1930 | 1.99E-02 | 0.20 | 2.25E-02 | 24.0 | 5.44 | 4.70 | 0.733 | 79.00 | 16.58 | 1.10 | 0.309 | 0.0069 | 9.74E-04 | 13.00 | 2.46 | 1.10 | 0.333 |
| Wairarapa Spring Zone 2 | WairFG7b- WairFG7a | WairSM5 | 2475 | 2632 | 157 | 29.3 | 0.018 | 3.13E-03 | 2.10 | 3.95E-01 | 0.00100 | 1.18E-03 | 2.30 | 4.18E-01 | 0.1820 | 2.52E-02 | 0.20 | 2.83E-02 | 24.0 | 6.15 | 3.50 | 0.835 | 74.00 | 18.75 | 2.10 | 0.371 | 0.0920 | 3.67E-03 | 9.80 | 2.75 | 2.10 | 0.395 |
| Wairarapa Seepage Zone 3 | WairFG8 - WairFG7b | WairSM6 (Includes Taylors Drain and other sources) | 2632 | 4448 | 1816 | 319.0 | 0.011 | 6.64E-03 | 1.30 | 8.09E-01 | 0.00100 | 1.50E-03 | 1.50 | 8.96E-01 | 0.1890 | 8.55E-02 | 0.20 | 9.21E-02 | 22.0 | 13.16 | 3.30 | 1.888 | 69.00 | 40.76 | 1.30 | 0.786 | 0.0061 | 5.62E-03 | 9.50 | 5.78 | 1.30 | 0.809 |
| Waimairi Spring Zone 2 | WaimFG4 | Waim SM3 | 0 | 307 | 307 | 69.8 | 0.007 | 5.23E-04 | 3.20 | 2.39E-01 | 0.00050 | 3.74E-05 | 3.20 | 2.39E-01 | 0.0460 | 3.21E-03 | 0.05 | 3.74E-03 | 25.0 | 1.87 | 3.90 | 0.291 | 78.00 | 5.83 | 3.10 | 0.232 | 0.0040 | 2.99E-04 | 12.00 | 0.90 | 3.20 | 0.239 |
| Waimairi Spring Zone 3 | WaimFG5-WaimFG4 | WaimFG5-WaimFG4 | 307 | 1500 | 1193 | 4.9 | 0.000 | 5.23E-04 | 2.90 | 2.53E-01 | 0.01624 | 1.17E-04 | 3.00 | 2.54E-01 | 0.1000 | 3.70E-03 | 0.10 | 4.23E-03 | 26.0 | 1.99 | 3.80 | 0.310 | 81.00 | 6.22 | 1.28 | 0.238 | 0.0105 | 3.50E-04 | 12.00 | 0.96 | 2.90 | 0.253 |
| Waimairi Tributary 2 | WaimFG6 | Wairmari TR Tributary (WaimFG6) | 1500 | 1500 | - | 93.1 | 0.006 | 1.08E-03 | 3.70 | 5.98E-01 | 0.00100 | 2.10E-04 | 3.60 | 5.89E-01 | 0.0440 | 7.80E-03 | 0.05 | 8.88E-03 | 26.0 | 4.42 | 3.50 | 0.636 | 79.00 | 13.58 | 3.50 | 0.564 | 0.0037 | 6.95E-04 | 13.00 | 2.17 | 3.70 | 0.598 |
| Waimairi Seepage Zone 1 | WaimFG7- WaimFG6- WaimFG5 | WaimFG7-WaimFG6 - WaimFG5 | 1500 | 2195 | 695 | 31.6 | 0.067 | 3.19E-03 | 3.07 | 6.95E-01 | 0.00495 | 3.66E-04 | 3.13 | 6.88E-01 | 0.0000 | 7.80E-03 | 0.00 | 8.88E-03 | 26.0 | 5.24 | 4.05 | 0.764 | 80.58 | 16.12 | 2.87 | 0.654 | 0.0200 | 1.33E-03 | 15.36 | 2.65 | 3.07 | 0.695 |
| Waimairi Seepage Zone 2 | WaimFG9-WaimFG7 | WaimSM5 | 2195 | 3552 | 1358 | 213.1 | 0.010 | 5.32E-03 | 3.7 | 1.48E+00 | 0.00050 | 4.73E-04 | 3.6 | 1.45E+00 | 0.0400 | 1.63E-02 | 0.05 | 1.95E-02 | 26.0 | 10.78 | 3.70 | 1.552 | 80.00 | 33.17 | 3.40 | 1.379 | 0.0036 | 2.09E-03 | 13.00 | 5.42 | 3.70 | 1.483 |
| Waimairi Tributary 3 | WaimFG8 | Fendalton Drain (Waim SM6) | 3552 | 3552 | - | 55.6 | 0.009 | 5.82E-03 | 2.30 | 1.61E+00 | 0.00100 | 5.29E-04 | 2.40 | 1.59E+00 | 0.0910 | 2.14E-02 | 0.10 | 2.51E-02 | 22.0 | 12.00 | 3.20 | 1.730 | 68.00 | 36.95 | 2.30 | 1.507 | 0.0070 | 2.48E-03 | 9.00 | 5.92 | 2.30 | 1.611 |

Table 5b, Appendix C. Recharge Zones – March 2015

| Full Name | Flow | Concentration | Chainage Start | Chainage End | Length of Section | Flow (L/s) | Ammonia Nitrogen | Ammonia Nitrogen Accumulating Mass in Recharge Zones | Nitrate+Nitrite Nitrogen | Nitrate+Nitrite Nitrogen Accumulating Mass in Recharge Zones | Nitrite Nitrogen | Nitrite Nitrogen Accumulating Mass in Recharge Zones | Total Nitrogen | Accumulating TN in Recharge Zones | Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen Accumulating Mass in Recharge Zones | Calcium acid soluble | Calcium acid soluble Accumulating Mass in Recharge Zones | Magnesium acid soluble | Magnesium acid soluble Accumulating Mass in Recharge Zones | Total Hardness | Total Hardness Accumulating Mass in Recharge Zones | Nitrate Nitrogen | Nitrate Nitrogen Accumulating Mass in Recharge Zones | Phosphate Dissolved Reactive | Phosphate Dissolved Reactive Accumulating Mass in Recharge Zones | Chloride | Chloride Accumulating Mass in Recharge Zones | Dissolved Inorganic Nitrogen | Dissolved Inorganic Nitrogen Accumulating Mass in Recharge Zones |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s | mg/L | g/s |
| Wairarapa Spring Zone 1 | WairFG4 | WAIMFG2 | 0 | 291 | 291 | 2.1 | 0.034 | 7.14E-05 | 1.10 | 2.31E-03 | 0.007 | 1.47E-05 | 1.10 | 2.31E-03 | 0.050 | 1.05E-04 | 20.0 | 4.20E-02 | 2.70 | 5.67E-03 | 61.0 | 1.28E-01 | 1.09 | 2.30E-03 | 0.015 | 3.15E-05 | 7.80 | 1.64E-02 | 1.10 | 2.31E-03 |
| Wairarapa Tributary 1 | WairFG3 | Jellie Park Discharge (Wair FG3) | | 291 | | 41.2 | 0.019 | 8.54E-04 | 1.30 | 5.59E-02 | 0.002 | 9.71E-05 | 1.30 | 5.59E-02 | 0.050 | 2.17E-03 | 21.0 | 9.07E-01 | 2.70 | 1.17E-01 | 64.0 | 2.76E+00 | 1.30 | 5.58E-02 | 0.015 | 6.50E-04 | 8.20 | 3.54E-01 | 1.30 | 5.59E-02 |
| Wairarapa Seepage Zone 1 | WairFG5- WairFG4 | WairFG5-WAIRFG3-WAIRFG2 | 291 | 1052 | 761 | 4.3 | -0.088 | 4.76E-04 | 1.40 | 6.19E-02 | 0.011 | 1.43E-04 | 1.40 | 6.19E-02 | 0.050 | 2.38E-03 | 32.6 | 1.05E+00 | 4.91 | 1.38E-01 | 98.7 | 3.19E+00 | 1.39 | 6.17E-02 | 0.015 | 7.14E-04 | 26.11 | 4.66E-01 | 1.40 | 6.19E-02 |
| Wairarapa Tributary 2 | WairFG6- WairFG5 | Wai-iti Stream (WairFG6 - WairFG5) | | 1052 | | 13.0 | 0.024 | 7.88E-04 | 1.30 | 7.88E-02 | 0.008 | 2.42E-04 | 1.30 | 7.88E-02 | 0.050 | 3.03E-03 | 17.3 | 1.27E+00 | 2.43 | 1.70E-01 | 53.0 | 3.88E+00 | 1.29 | 7.85E-02 | 0.015 | 9.09E-04 | 7.47 | 5.64E-01 | 1.30 | 7.88E-02 |
| Wairarapa Seepage Zone 2 | WairFG7a- WairFG6 | WairSM7a-WAIM6 | 1052 | 2475 | 1423 | 17.2 | 0.027 | 1.24E-03 | 1.30 | 1.01E-01 | 0.009 | 3.89E-04 | 1.75 | 1.09E-01 | 0.276 | 7.78E-03 | 25.5 | 1.71E+00 | 4.16 | 2.41E-01 | 82.1 | 5.29E+00 | 1.29 | 1.01E-01 | 0.074 | 2.18E-03 | 1.61 | 5.91E-01 | 1.30 | 1.01E-01 |
| Wairarapa Spring Zone 2 | WairFG7b- WairFG7a | WairSM5 | 2475 | 2632 | 157 | 36.4 | 0.003 | 1.34E-03 | 2.20 | 1.81E-01 | 0.001 | 4.07E-04 | 2.20 | 1.89E-01 | 0.050 | 9.60E-03 | 24.0 | 2.59E+00 | 3.40 | 3.65E-01 | 74.0 | 7.98E+00 | 2.20 | 1.81E-01 | 0.025 | 3.09E-03 | 6.10 | 8.13E-01 | 2.20 | 1.81E-01 |
| Wairarapa Seepage Zone 3a | SM9a-SM7b | WAIRSM6 | 2632 | 3457 | 825 | 93.2 | 0.003 | 1.57E-03 | 0.55 | 2.32E-01 | 0.004 | 7.80E-04 | 1.40 | 3.19E-01 | 0.850 | 8.88E-02 | 24.0 | 4.82E+00 | 3.20 | 6.63E-01 | 73.0 | 1.48E+01 | 0.55 | 2.32E-01 | 0.012 | 4.21E-03 | 9.20 | 1.67E+00 | 0.55 | 2.32E-01 |
| Wairarapa Tributary 2 | SM9b-SM9a | SM9b-SM9a | | 3457 | | 49.0 | -0.006 | 1.28E-03 | -0.16 | 2.25E-01 | -0.006 | 4.64E-04 | -0.16 | 3.12E-01 | 0.050 | 9.13E-02 | 27.4 | 6.17E+00 | 4.38 | 8.78E-01 | 85.3 | 1.90E+01 | -0.15 | 2.24E-01 | 0.037 | 6.00E-03 | 3.57 | 1.85E+00 | -0.16 | 2.25E-01 |
| Wairarapa Seepage Zone 3b | WAIRSM8-WAIRSM9b | WAIRSM8-WAIRSM9b | 3457 | 4448 | 991 | 98.2 | 0.033 | 4.49E-03 | 1.82 | 4.04E-01 | 0.006 | 1.02E-03 | 1.82 | 4.91E-01 | 0.050 | 9.62E-02 | 15.8 | 7.71E+00 | 2.42 | 1.11E+00 | 50.3 | 2.39E+01 | 1.82 | 4.03E-01 | 0.024 | 8.40E-03 | 6.61 | 2.49E+00 | 1.82 | 4.04E-01 |
| Waimairi Spring Zone 2 | - | - | 0 | 307 | 307 | 0.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Waimairi Spring Zone 3 | WAIMFG6B-WAIMFG6 | WAIMFG6B-WAIMFG6 | 307 | 1500 | 1193 | 3.0 | 0.015 | 4.59E-05 | 2.09 | 6.28E-03 | 0.000 | 7.00E-07 | 2.09 | 6.28E-03 | 0.050 | 1.50E-04 | 21.2 | 6.37E-02 | 4.51 | 1.35E-02 | 71.2 | 2.14E-01 | 2.09 | 6.28E-03 | 0.019 | 5.70E-05 | 13.77 | 4.13E-02 | 2.09 | 6.28E-03 |
| Waimairi Tributary 2 | WaimFG6 | Wairmari TR Trib (WaimFG6) | | 1500 | | 5.3 | 0.007 | 8.30E-05 | 3.20 | 2.32E-02 | 0.003 | 1.66E-05 | 3.20 | 2.32E-02 | 0.050 | 4.15E-04 | 24.0 | 1.91E-01 | 3.40 | 3.15E-02 | 74.0 | 6.06E-01 | 3.20 | 2.32E-02 | 0.019 | 1.58E-04 | 11.00 | 9.96E-02 | 3.20 | 2.32E-02 |
| Waimairi Seepage Zone 1 | WaimFG7-WaimFG6b | WaimFG7-WaimFG6b | 1500 | 2195 | 695 | 0.0 | - | 1.49E-04 | - | 2.32E-02 | - | 4.98E-05 | - | 2.32E-02 | - | 4.15E-04 | - | 2.08E-01 | - | 3.24E-02 | - | 6.47E-01 | - | 2.32E-02 | - | 2.24E-04 | - | 9.96E-02 | - | 2.32E-02 |
| Waimairi Seepage Zone 2 | WaimFG9-FG7 | WaimFG9-FG7 | 2195 | 3552 | 2857 | 180.7 | 0.002 | 4.73E-04 | 2.49 | 4.73E-01 | 0.001 | 1.89E-04 | 2.59 | 4.91E-01 | 0.102 | 1.89E-02 | 21.9 | 4.16E+00 | 3.17 | 6.05E-01 | 67.5 | 1.29E+01 | 2.49 | 4.72E-01 | 0.008 | 1.59E-03 | 8.44 | 1.63E+00 | 2.49 | 4.73E-01 |
| Waimairi Tributary 3 | Waim8a-FG9 | Fendalton Drain (Waim SM6) | | 3552 | | 40.0 | 0.006 | 7.13E-04 | 2.50 | 5.73E-01 | 0.001 | 2.09E-04 | 2.50 | 5.91E-01 | 0.050 | 2.09E-02 | 22.0 | 5.04E+00 | 3.10 | 7.29E-01 | 68.0 | 1.56E+01 | 2.50 | 5.72E-01 | 0.013 | 2.11E-03 | 8.20 | 1.95E+00 | 2.50 | 5.73E-01 |

Table 6a, Appendix C. Comparison to Relevant Guidelines (If not otherwise specified, all concentrations are in mg/L) – September 2014

|  | Receiving Water Quality Guidelines | WAIRSM1 | WAIRSM2 | WAIRFG3 | WAIRFG2 | WAIRFG4 | WAIRFG7A | WAIRSM6 | WAIRSM5 | WAIRFG8 | WAIRFG6 | WAIRFG5 | WAIRSM4 | WAIRFG7B | WAIMSM6 | WAIMFG7 | WAIRSM3 | WAIMFG9 | WAIMFG8 | WAIMFG6 | WAIMFG4 | WAIMFG3 | WAIMSM5 | WAIMSM4 | WAIMSM3 | WAIMFG5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammonia Nitrogen | 1.43[1] | 0.016 | 0.009 | 0.017 | 0.012 | 0.011 | 0.013 | 0.011 | 0.018 | 0.14 | 0.007 | 0.008 | 0.007 | 0.011 | 0.022 | 0.016 | 0.013 | 0.01 | 0.009 | 0.006 | 0.01 | 0.021 | 0.01 | 0.59 | 0.007 | 0.007 |
| Nitrate+ Nitrite Nitrogen | 0.444[1] | 1.5 | 1.4 | 1.4 | 1.3 | 1.4 | 1.5 | 1.3 | 2.1 | 0.46 | 1.5 | 1.5 | 1.1 | 1.5 | 2.3 | 3.3 | 1.5 | 3.1 | 2.1 | 3.7 | 2.9 | 1.5 | 3.7 | 0.098 | 3.2 | 2.9 |
| Nitrite Nitrogen | - | 0.001 | 0.001 | 0.004 | 0.001 | 0.002 | 0.003 | 0.001 | 0.001 | 0.096 | 0.002 | 0.002 | 0.0005 | 0.004 | 0.001 | 0.002 | 0.009 | 0.001 | 0.001 | 0.001 | 0.001 | 0.013 | 0.0005 | 0.007 | 0.0005 | 0.002 |
| Total Nitrogen | 0.614[1] | 1.6 | 1.5 | 1.6 | 1.4 | 1.5 | 1.6 | 1.5 | 2.3 | 1.4 | 1.6 | 1.6 | 1.3 | 1.6 | 2.4 | 3.3 | 1.5 | 2.9 | 1.9 | 3.6 | 3 | 1.7 | 3.6 | 0.62 | 3.2 | 3 |
| Total Kjeldahl Nitrogen | - | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.94 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.1 | 0.2 | 0.05 | 0.52 | 0.05 | 0.1 |
| Calcium acid soluble | - | 22 | 24 | 23 | 23 | 23 | 23 | 22 | 24 | 22 | 23 | 22 | 24 | 23 | 22 | 26 | 23 | 24 | 21 | 26 | 26 | 26 | 26 | 28 | 25 | 26 |
| Magnesium acid soluble | - | 2.7 | 3.4 | 2.9 | 3 | 3 | 3.2 | 3.3 | 3.5 | 3.3 | 3.1 | 3 | 4.7 | 3.2 | 3.2 | 3.7 | 3.1 | 3.5 | 3.1 | 3.5 | 3.8 | 4.4 | 3.7 | 5.8 | 3.9 | 3.8 |
| Total Hardness (as CaCO3) | - | 66 | 74 | 69 | 70 | 70 | 71 | 69 | 74 | 69 | 70 | 67 | 79 | 71 | 68 | 80 | 70 | 74 | 65 | 79 | 81 | 83 | 80 | 94 | 78 | 81 |
| Nitrate Nitrogen | - | 1.5 | 1.4 | 1.4 | 1.3 | 1.4 | 1.5 | 1.3 | 2.1 | 0.36 | 1.4 | 1.4 | 1.1 | 1.5 | 2.3 | 3.1 | 1.3 | 2.8 | 1.8 | 3.5 | 2.8 | 1.5 | 3.4 | 0.09 | 3.1 | 2.7 |
| Phosphate Dissolved Reactive | 0.016[2] | 0.0094 | 0.0055 | 0.0034 | 0.0066 | 0.0039 | 0.0055 | 0.0061 | 0.092 | 0.0048 | 0.0039 | 0.0031 | 0.0069 | 0.0038 | 0.007 | 0.0067 | 0.0015 | 0.0054 | 0.0076 | 0.0037 | 0.0044 | 0.0045 | 0.0036 | 0.13 | 0.004 | 0.0048 |
| Chloride | - | 11 | 9.3 | 10 | 10 | 10 | 10 | 9.5 | 9.8 | 9.3 | 11 | 11 | 13 | 11 | 9 | 13 | 11 | 11 | 7.9 | 13 | 12 | 14 | 13 | 8.3 | 12 | 12 |
| Dissolved Inorganic Nitrogen | 1.5[2] | 1.5 | 1.4 | 1.4 | 1.3 | 1.4 | 1.5 | 1.3 | 2.1 | 0.6 | 1.5 | 1.5 | 1.1 | 1.5 | 2.3 | 3.3 | 1.5 | 3.1 | 2.1 | 3.7 | 2.9 | 1.5 | 3.7 | 0.69 | 3.2 | 2.9 |

|  |  |
|---|---|
| 🟨 | Below detection Level, reported as half detection level |
| BOLD | Above Guideline Values |

1. ANZECC (2000) (90% Protection)
2. Table WQL16 Water quality standards for surface waters in the Canterbury region - Springfed Plains Urban, Proposed Land and Water Regional Plan (2013)

Table 6b, Appendix C. Comparison to Relevant Guidelines (If not otherwise specified, all concentrations are in mg/L) – March 2015

|  | Receiving Water Quality Guidelines | WAIMFG6 | WAIMFG6B | WAIMFG7 | WAIMFG8A | WAIMFG9 | WAIMSM6 | WAIRFG2 | WAIRFG3 | WAIRFG4 | WAIRFG5 | WAIRFG6 | WAIRFG7A | WAIRFG7B | WAIRFG8 | WAIRFG9A | WAIRFG9B | WAIRSM5 | WAIRSM6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammonia Nitrogen | 1.43[1] | 0.007 | 0.01 | 0.018 | 0.0025 | 0.0025 | 0.006 | 0.034 | 0.019 | 0.018 | 0.01 | 0.013 | 0.016 | 0.018 | 0.017 | 0.015 | 0.011 | 0.0025 | 0.0025 |
| Nitrate+ Nitrite Nitrogen | 0.444[1] | 3.2 | 2.8 | 2.8 | 2.6 | 2.5 | 2.5 | 1.1 | 1.3 | 1.2 | 1.3 | 1.3 | 1.3 | 1.5 | 1.3 | 1.4 | 1.1 | 2.2 | 0.55 |
| Nitrite Nitrogen | - | 0.003 | 0.002 | 0.006 | 0.002 | 0.001 | 0.0005 | 0.007 | 0.002 | 0.003 | 0.003 | 0.004 | 0.005 | 0.004 | 0.003 | 0.004 | 0.002 | 0.0005 | 0.004 |
| Total Nitrogen | 0.614[1] | 3.2 | 2.8 | 2.8 | 2.6 | 2.6 | 2.5 | 1.1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 | 1.5 | 1.3 | 1.4 | 1.1 | 2.2 | 1.4 |
| Total Kjeldahl Nitrogen | - | 0.05 | 0.05 | 0.05 | 0.05 | 0.1 | 0.05 | 0.05 | 0.05 | 0.1 | 0.05 | 0.05 | 0.1 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.85 |
| Calcium acid soluble | - | 24 | 23 | 25 | 22 | 22 | 22 | 20 | 21 | 22 | 22 | 21 | 22 | 23 | 21 | 22 | 23 | 24 | 24 |
| Magnesium acid soluble | - | 3.4 | 3.8 | 3.9 | 3.2 | 3.2 | 3.1 | 2.7 | 2.7 | 2.8 | 2.9 | 2.8 | 3.1 | 3.2 | 3.2 | 3.3 | 3.5 | 3.4 | 3.2 |
| Total Hardness (as CaCO3) | - | 74 | 73 | 78 | 68 | 68 | 68 | 61 | 64 | 66 | 67 | 64 | 68 | 71 | 66 | 69 | 72 | 74 | 73 |
| Nitrate Nitrogen | - | 3.20 | 2.80 | 2.79 | 2.60 | 2.50 | 2.50 | 1.09 | 1.30 | 1.20 | 1.30 | 1.30 | 1.30 | 1.50 | 1.30 | 1.40 | 1.10 | 2.20 | 0.55 |
| Phosphate Dissolved Reactive | 0.016[2] | 0.019 | 0.019 | 0.027 | 0.013 | 0.0084 | 0.013 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.028 | 0.027 | 0.027 | 0.026 | 0.028 | 0.025 | 0.012 |
| Chloride | - | 11 | 12 | 12 | 8.8 | 8.6 | 8.2 | 7.8 | 8.2 | 7.9 | 9.8 | 9.3 | 7.6 | 5.9 | 5.3 | 5.1 | 4.8 | 6.1 | 9.2 |
| Dissolved Inorganic Nitrogen | 1.5[2] | 3.2 | 2.8 | 2.8 | 2.6 | 2.5 | 2.5 | 1.1 | 1.3 | 1.2 | 1.3 | 1.3 | 1.3 | 1.5 | 1.3 | 1.4 | 1.1 | 2.2 | 0.55 |
| 🟨 | Below detection Level, reported as half detection level | | | | | | | | | | | | | | | | | | |
| BOLD | Above Guideline Values | | | | | | | | | | | | | | | | | | |

1. ANZECC (2000) (90% Protection)
2. Table WQL16 Water quality standards for surface waters in the Canterbury region - Springfed Plains Urban, Proposed Land and Water Regional Plan (2013)

# Appendix D: M35/1646 Well Card

**Bore or Well No:** M35/1646
**Well Name:**
**Owner:** HARRISON, J.

Environment Canterbury
Your regional council

| | | | |
|---|---|---|---|
| **Street of Well:** | CRANFORD ST | **File No:** | |
| **Locality:** | PAPANUI | **Allocation Zone:** | Christchurch/West Melton |
| **NZTM Grid Reference:** | BX24:69699-84386 QAR 4 | **CWMS Zone:** | Christchurch - West Melton |
| **NZTM X-Y:** | 1569699 - 5184386 | | |
| **Location Description:** | | **Uses:** | |
| **ECan Monitoring:** | | | |
| **Well Status:** | Not Used | | |

| | | | |
|---|---|---|---|
| **Drill Date:** | 28 Feb 1972 | **Water Level Count:** | 0 |
| **Well Depth:** | 25.40m -GL | **Strata Layers:** | 10 |
| **Initial Water Depth:** | 3.70m -MP | **Aquifer Tests:** | 0 |
| **Diameter:** | 152mm | **Yield/Drawdown Tests:** | 1 |
| **Measuring Point Ait:** | 5.00m MSD QAR 3 | **Highest GW Level:** | |
| **GL Around Well:** | 0.00m -MP | **Lowest GW Level:** | |
| **MP Description:** | | **First Reading:** | |
| | | **Last Reading:** | |
| **Driller:** | A M Bisley & Co | **Calc. Min. (Below MP):** | -0.20m -MP |
| **Drilling Method:** | Cable Tool | **Last Updated:** | 08 Nov 2013 |
| **Casing Material:** | | **Last Field Check:** | |
| **Pump Type:** | Unknown | | |
| **Yield:** | 19 l/s | **Aquifer Type:** | Flowing Artesian |
| **Drawdown:** | 3 m | **Aquifer Name:** | Riccarton Gravel |
| **Specific Capacity:** | 6.33 l/s/m | | |

**Screens:**

| Screen No. | Screen Type | Top (m) | Bottom (m) | Diameter (mm) | Leader Length (mm) | Slot Size (mm) | Slot Length (mm) |
|---|---|---|---|---|---|---|---|
| 1 | Galvanised (Nold) | 22.3 | 25.3 | | | | |

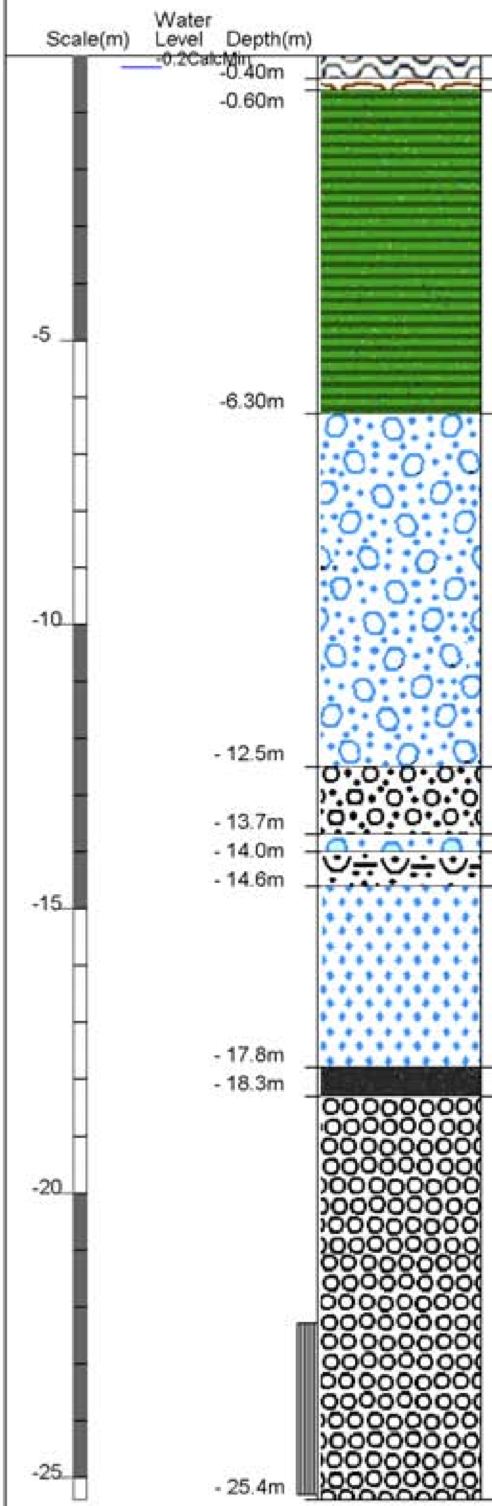
**Step Tests:**

| Step Test Date | Step | Yield (l/s) | Drawdown | Duration (mins) |
|---|---|---|---|---|
| 28 Feb 1972 | 1 | 19 | 3 | |

**Aquifer test date(s) where this is an observation bore**

# Borelog for well M35/1646

Gridref: M35:797-460  Accuracy : 4  (1=high, 5=low)
Ground Level Altitude : 5 +MSD
Driller    : A M Bisley & Co
Drill Method : Cable Tool
Drill Depth  : -25.4m    Drill Date : 28/02/1972



| Depth(m) | Full Drillers Description | Formation Code |
|---|---|---|
| -0.40m | Topsoil | sp? |
| -0.60m | Topsoil & roots | sp? |
| -6.30m | Grey clay & peat | sp? |
| - 12.5m | Blue gravel & sand | sp? |
| - 13.7m | Blue small gravel & sand | sp? |
| - 14.0m | Blue gravel & sandy clay | sp? |
| - 14.6m | Blue sandy clay & shells | ch |
| - 17.8m | Blue fine sand | ch |
| - 18.3m | Brown peat & roots | ch |
| - 25.4m | Grey/Brown gravel | ri |