Research report

CAREX science contribution to Living Water in the LII/Ararira River from 2018–2020

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Executive Summary

In 2018 the UC CAREX team became a Strategic Partner with Living Water. CAREX's main role was to test and develop solutions to water quality and freshwater ecological health issues in the Ararira/LII River, which feeds Lake Ellesmere/Te Waihora, Canterbury. Over the following two years CAREX clarified the major issues in the catchment; flooding, excessive invasive weeds, high sediment levels, high nutrients (primarily nitrate), and damage to waterway ecology due to drain clearance activities.

An extensive water quality network involving 27 sites was set up and water quality measured over 18 months. These sites focused on four Fonterra farms and five main roadside drains. Synoptic water quality surveys of springs were conducted as well as hydrological data, and macrophyte, benthic invertebrate and fish surveys across the catchment. These studies clarified that many of the on-farm waterways were ephemeral while the roadside drains flowed all year round.

Water quality data indicated that Nitrate-nitrogen was an issue in the west of catchment with concentrations over 12 mg/L. Two trials were conducted to try to reduce in-stream nitrate levels; an open ditch bioreactor and a 700 m long two stage channel. As far as we are aware both of these tools had not been trialled in NZ previously. Unfortunately the waterway in which these were constructed dried before the first set of data could be collected. Excessive fine sediment was also identified as an issue and six sediment traps were constructed. During the design of the sediment traps a quick reference table was developed to assist in designing the best dimensions of the trap depending on waterway wetted width and water velocity.

Benthic invertebrate communities were poor, of the 21 sites sampled four were rated as moderately polluted and 17 as probably severely polluted (based on MCI scores). A total of eight fish species were collected (most common were longfin and shortfin eels, brown trout, īnanga, common and upland bullies).

Future monitoring, lesson learned and potential future research are discussed.

Introduction

In 2017 Living Water approached the University of Canterbury CAREX team (Canterbury Waterway Rehabilitation Experiment) to work with Living Water as a Strategic Partner to provide scientific advice and expertise.

The purpose of the Strategic Partnership was to develop and accelerate the uptake of agricultural waterway transformation interventions and approaches across New Zealand.

The partners shared the following objectives:

- *To enhance and share collective strengths, capability and resources to achieve the transformation of New Zealand's agricultural drains into healthy functioning waterways.*
- *To develop and test solutions to achieve agricultural waterway restoration.*
- *To scale solutions to generate catchment-wide, regional and national policy change.*
- *To establish more effective trust-based partnerships between scientists, communities and decision makers to achieve freshwater restoration outcomes.*

Specifically, CAREX agreed to provide general advice to Living Water and to focus on objective 2 to undertake scientific research in the Ararira/LII River near Lincoln, Canterbury.

The catchment

The Ararira/LII River is one of four major rivers that feed Lake Ellesmere/Te Waihora, Canterbury. The lake is the largest coastal lake in New Zealand and is in a highly degraded state with poor water clarity and high nutrients. The inflow waterways have discharged fine sediment, nutrients, faecal bacteria and other contaminants into the lake for decades.

The Ararira/LII river discharge (at Pannetts Rd) ranged from 1.87–2.16 m^3s^{-1} during 2020. The river is approximately 30 m wide at this point and not wadeable. The catchment is generally flat, the highest point being approximately 26 m asl. Intensive agriculture dominates the catchment comprising primarily dairying, with some cash crops and deer farming. The headwaters include the township of Lincoln (est population 8,100 in June 2020) and has been experiencing increasing urban expansion. The town population has increased by about 20% in the two years from 2018–2020. This growth will change the hydrology of the catchment, increasing stormwater flows and potentially impacting ground and surface water quality.

The Ararira/LII River is a spring-fed river sourced from numerous significant springs (e.g. 30+ which form ponds with outflows) clustered in the headwaters, primarily around Lincoln (Fig. 1). Water chemistry in numerous springs was tested during this project and a map appears later in the document. The main surface waterways are;

Liffey Spring/Stream (*0.04 m^3s^{-1}),

Sergeants Rd roadside drain (*0.03 m^3s^{-1}),

Days Rd roadside drains (*0.02 m^3s^{-1}),

Powells Rd roadside drains (*0.01 m^3s^{-1}), and

K1 on-farm drain (*0.04 m^3s^{-1}). Also referred to as Old Sergeants drain (includes K-A, K-C and 8 in Fig 1)

*Data for autumn 2020, shows K1 and Sergeants Roadside drains are the major drain discharge contributors Ararira/LII River.

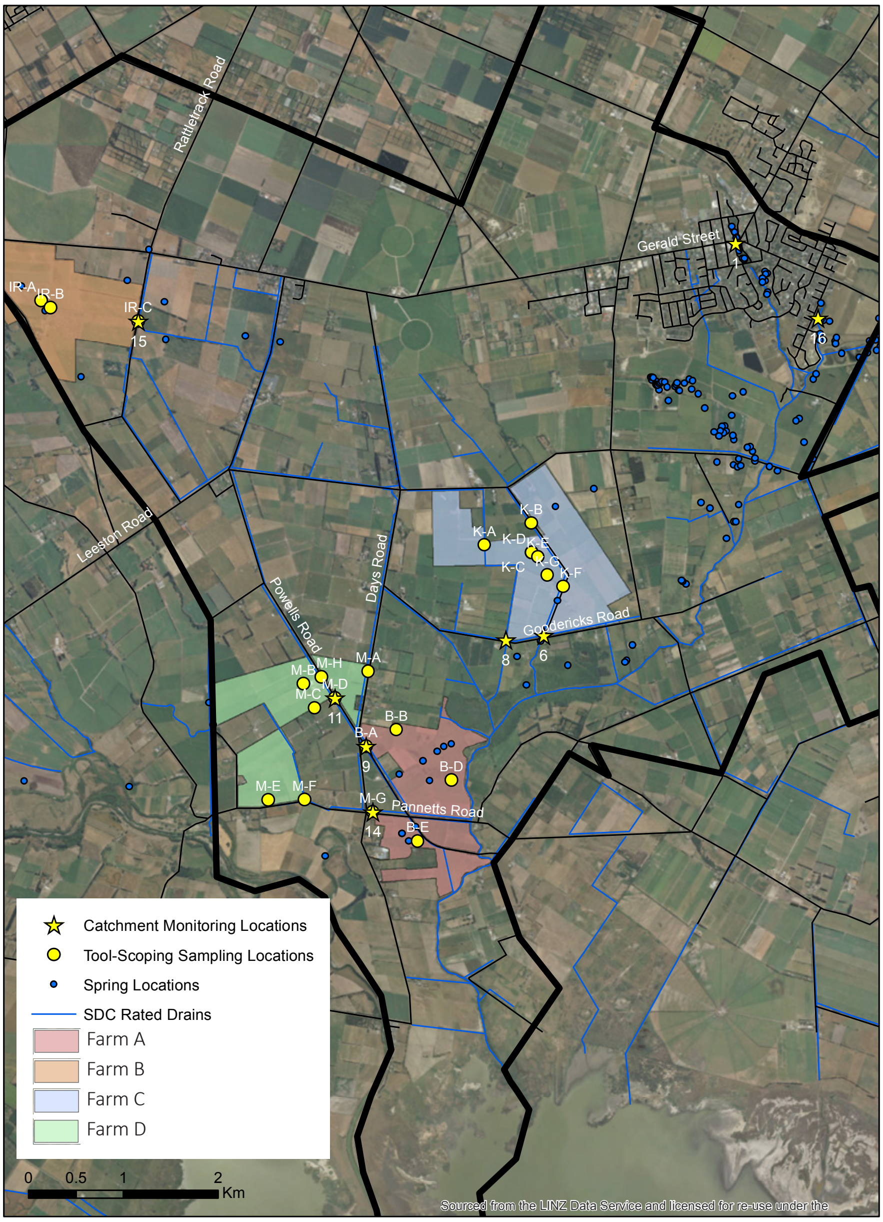


Figure 1. Catchment sites sampled by CAREX (large stars), and the additional sites identified by Instream Consulting (small stars). The four Fonterra farms are A (pale green), B (pale brown), C (brown), D (green). These farms were selected by Living Water.

The farms

There are six Fonterra farms within the catchment, four of these (Farms A, B, C & D) were the focus of intensive on-farm water quality monitoring. The remaining two farms had small waterways contributing minor flows to the LII.

Identifying the main issues

Our first steps were to hold discussions with Living Water staff and review existing reports and data on the catchment to determine what was known about water issues, water quality and catchment waterway health. We then interviewed landowners and other stakeholders to clarify their water quality and water management concerns.

Early on in the Living Water design process a decision had been made to focus on four Fonterra farms in the catchment. Unfortunately this created an immediate challenge as landowners were not selected based on their personal commitment to improve water management practices and willingness to adopt new ideas. Having keen, interested and committed landowners, willing to change and embrace new ideas is absolutely essential to successful uptake and achieving change in a catchment. Good landowners can become champions for this type of project who will be leaders and "positive influencers" to their neighbours. A further important stakeholder is local government, and having interested and supportive local government staff is also essential to bring about change. As our involvement developed we discussed expanding to other farms, however the time available in the project was insufficient to develop relationships with new landowners.

The main issues identified by landowners were (Fig. 2);

- Flooding of farm fields. In the lower catchment closer to Lake Ellesmere/Te Waihora fields could be too wet to farm for much of the winter. In the upper catchment extreme storms could cause widespread flooding.
- Excessive aquatic weeds (macrophytes) particularly during spring and summer. These weeds grow annually and can completely clog on-farm waterways and roadside drains. These waterways are typically 1–3 m wide and the weeds are dominated by two introduced species; Monkey Musk (*Erythrante guttata*) and Watercress (*Nasturtium microphyllum*).
- Drain cleaning - annual "cleaning" occurs in many roadside drains to remove excessive invasive macrophytes and fine sediment. The sediment removal severely disrupts the bed, damaging habitat and removing freshwater invertebrates and fish. Material from the bed is also left on the banks causing very steep banks. This can result in bank slumping and creates sources of sediment addition into the waterways.

Additional issues subsequently identified were;

- High nutrient concentrations in waterways. Of particular concern was very high nitrate-nitrogen in part of the catchment (e.g. 11–16 mg/L nitrate) and localised high phosphorus (e.g. 0.3 mg/L).
- Excessive fine sediment was one of the main reasons for drain cleaning. It was suggested by one stakeholder that most of the catchment had naturally high fine sediment.
- Poor in-stream habitat. Decades of draining cleaning resulted in poor bed condition and degraded habitat for invertebrates and fish.
- Waterway health (i.e. benthic invertebrate and fish communities) were in poor condition.

Occasional issues;

- Our sampling and previous samples by Instream Consulting (2017) identified high *E.coli* readings irregularly at some monitoring sites (e.g. 3400 cfu/100 ml).

Figure 2. The issues raised in preliminary discussions were (A) flooding, (B) macrophytes, (C) drain cleaning, and (D) excessive fine sediment.

Understanding catchment morphology

One of our first tasks was to become familiar with the physical drainage network of the catchment. This involved determining where all the tributaries and waterways were and how they are connected. We focussed on the four Fonterra farms and roadside waterways. No map existed of which drains had permanent or ephemeral flows and importantly which direction they flowed and which roadside drains they fed (Fig. 3).

We identified and mapped all on-farm drains in the four farms. These included over 50 field-side drains totalling 18.4 km of waterways. The majority of on-farm drains were ephemeral and flowed mainly during the winter and early spring months. The maximum extent of drying was approximated in February 2020 (Fig. 4).

However, significant portions of Farm A became waterlogged during winter and these waterways retain water for longer than on other farms.

Sub-surface tile drains were rare in the catchment, with Farm C being an exception with several tile drains below their duck pond. During our two year program several tile drains were constructed in the headwaters of Farm B.

The discovery that on-farm drains were ephemeral resulted in a major change in our approach. Previous rehabilitation tools our team had trialled were designed for permanently flowing systems.

The uncertainty of flow timing, duration and frequency meant that conducting experiments in on-farm drains would be problematic and risky. As a result we shifted our primary effort to permanently flowing waterways (i.e. Roadside waterways), except for Farm B, which offered significant logistical and landowner collaboration advantages.

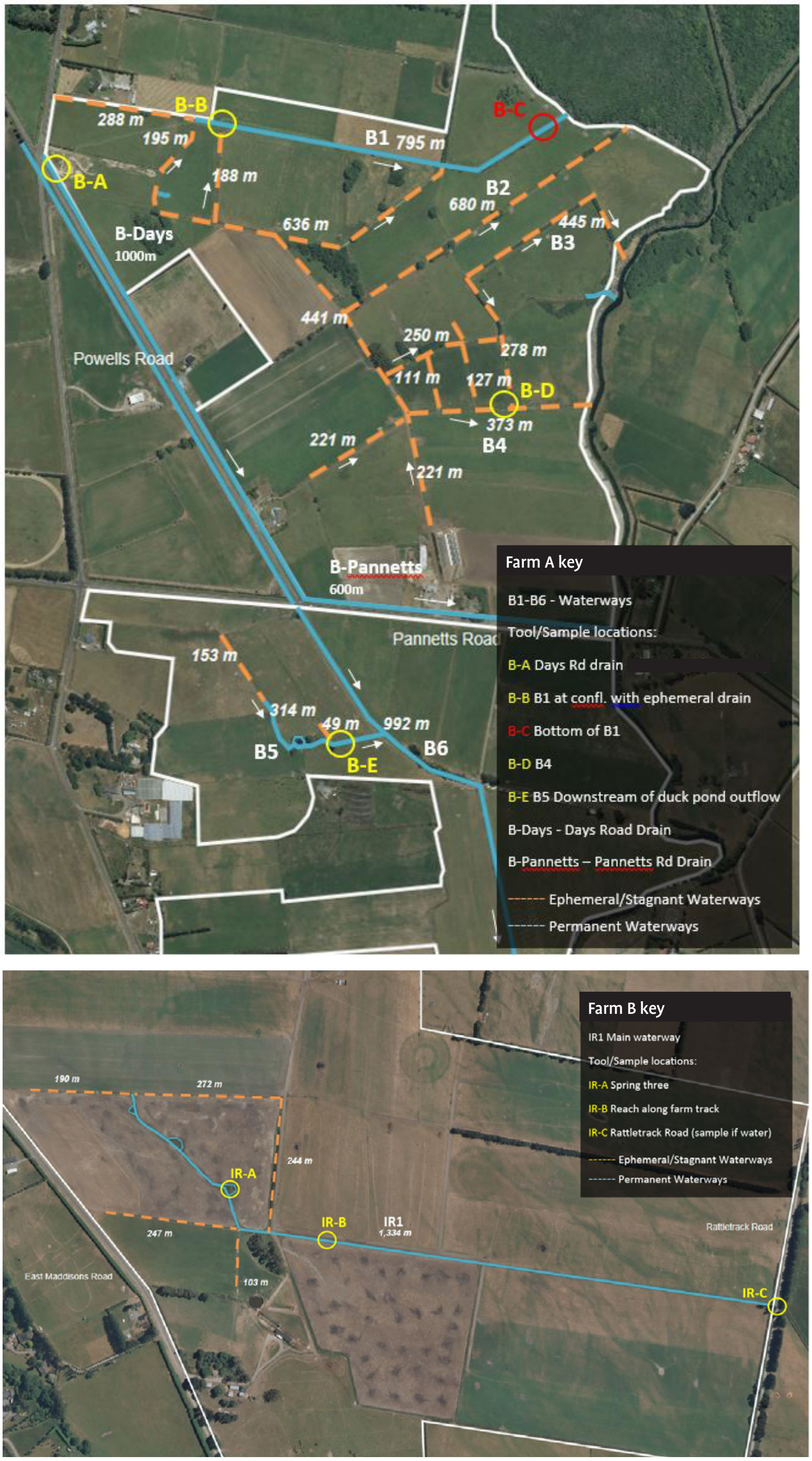
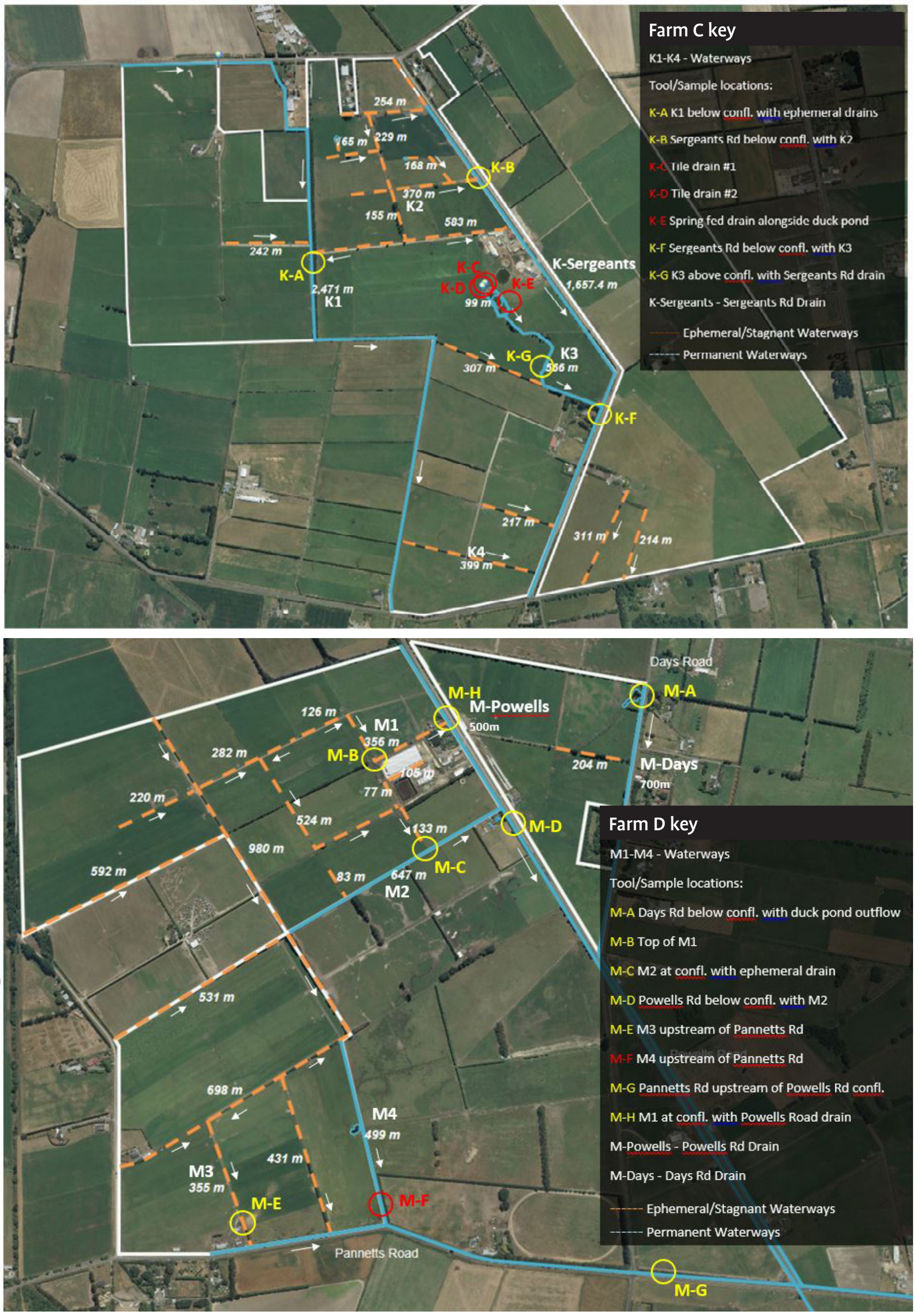


Figure 3. Fonterra farms, arrows indicate direction of water flow when wet.

Figure 3 continued. Fonterra farms, arrows indicate direction of water flow when wet.



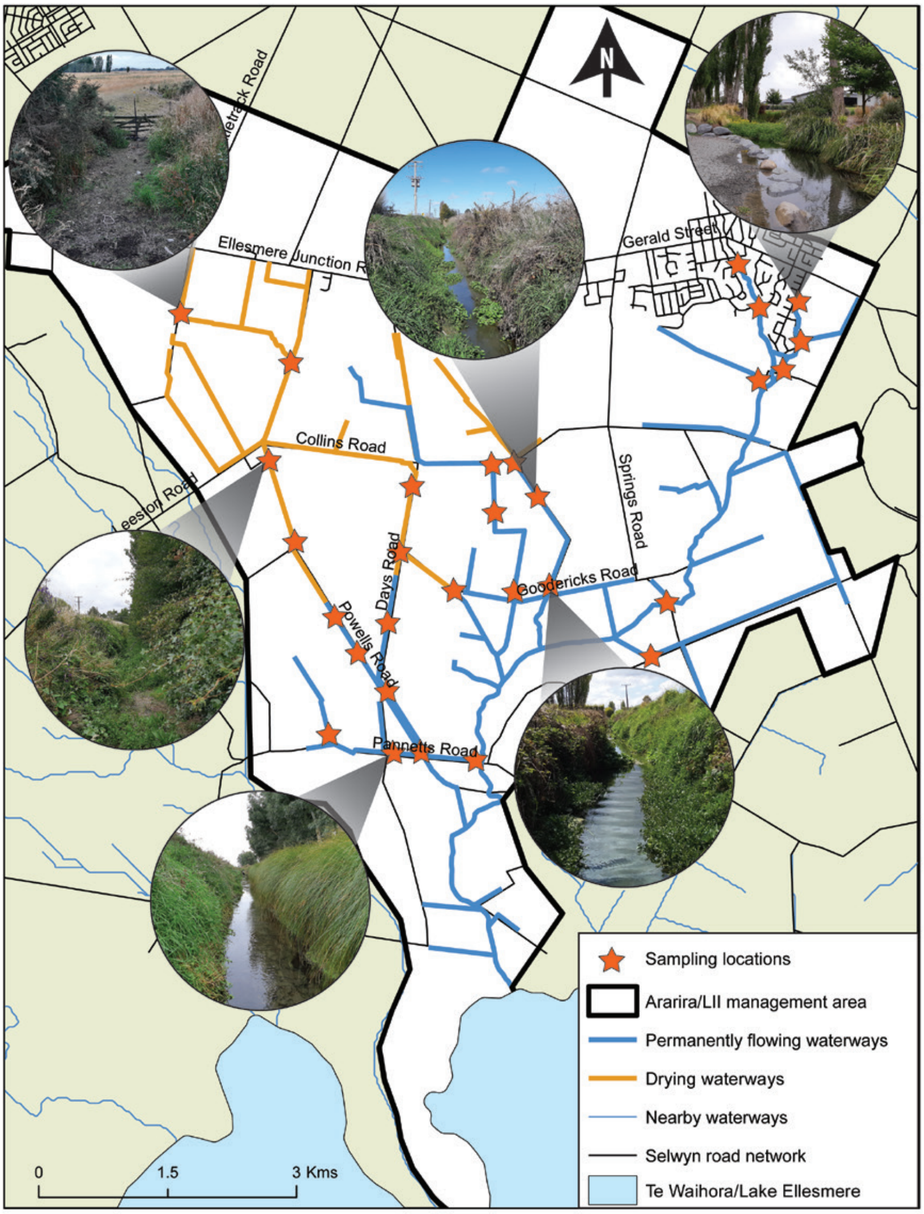


Figure 4. Extent of network drying in February 2020.

Developing a long-term discharge and water quality monitoring plan

Having identified the locations of on-farm and major roadside waterways we designed a monitoring program which covered much of the catchment. The number and location of sites was a trade-off between good coverage, time and cost. This initial design included on-farm sites, as early on we were not aware of the highly ephemeral nature on these waterways. The number and location of sites changed as we reviewed our data and priorities.

The main principles of the monitoring plan were;

- To quantify the discharge levels, and flood and drying frequency from main tributary waterways across the catchment. Our aim was to identify the main sources of water feeding the LII.
- To have a good spatial coverage of the catchment and collect data from all main waterways.
- Sites were chosen for accessibility. Several sites were dropped as they became very difficult to access in winter.
- We wanted to identify waterways that we could use for rehabilitation/ restoration trials. Practically these would be wadeable waterways (e.g. <3 m wide & <1.5 m deep).
- We did not measure the mainstem of LII, as any rehabilitation/restoration trials in the mainstem would be politically and technically challenging and would take years.
- Our focus was on farmland rather than Lincoln township.

As a result, we selected 27 sites for longer-term monitoring (Table 1)(other sites were used for one-off sampling); 13 sites were roadside waterways and 14 on-farm drains.

The headwaters of the catchment has numerous spring systems with unknown nutrient concentrations. As a result we conducted a limited synoptic survey of springs.

What did we monitor?

Continuous discharge levels were estimated at 10 sites using stage height recorders from Dec 2018–Nov 2020. Stage heights give an estimate of water level, however these then needed to be calibrated at different flows. We then conducted real-time measurements of actual depth, wetted width of the waterway and water velocity during monthly visits. Stage height data can also be confounded when the waterway is full of aquatic weeds during summer-spring. The weeds artificially raise the water level and reduce water velocity.

In order to determine the magnitude of various contaminants and stressors we sampled a range of water chemistry variables. Specifically, pH, Specific conductivity, Dissolved oxygen, Temperature, Turbidity, Nitrate-Nitrogen N-NO_3, Phosphorous DRP, and *E.coli*) were measured monthly from May 2018 - March 2020 (Table 1). After identifying high nitrate levels in the western headwaters we conducted an extensive weekly sampling of multiple points along this sub-catchment (Powells) for six weeks. Springs were identified as a possible source of poor water quality, so an intensive spring survey was conducted in order to understand nitrate levels from the groundwater, as a result 18 springs across the catchment were sampled on a single occasion in May 2019.

A suggestion had been made to that the catchment waterways were dominated by naturally highly sediment and that this was the natural condition of these systems. To estimate the magnitude of the sediment issue we used three approaches;

To test the dominance of sediment across the catchment we conducted a one-off survey of the main roadside waterways in December 2019. We found that the beds of roadside waterways in most of the upper catchment were dominated by gravel substrate that had been covered by fine sediment (Fig. 5), while in the lower catchment some waterways did have sections of deep fine sediment and clays.

Additionally, at all on-farm sites we measured sediment depth monthly. The sediment depth was monitored with three transects (each with five random depth measurements) across the waterway. Transects were randomly positioned along a 20 m reach and sediment measured with a ruler.

In order to quantify sediment loads and transport more intensive sediment data was collected at five sites and suspended sediment during flood events was collected at 10 sites (Fig. 6).

Macrophytes, especially invasive species can become a significant issue for flood control and water management. During spring and summer farm waterways can become completely clogged by invasive macrophytes. Macrophyte cover (species list + % cover) was measured at all on-farm sites monthly from May 2018–Mar 2020.

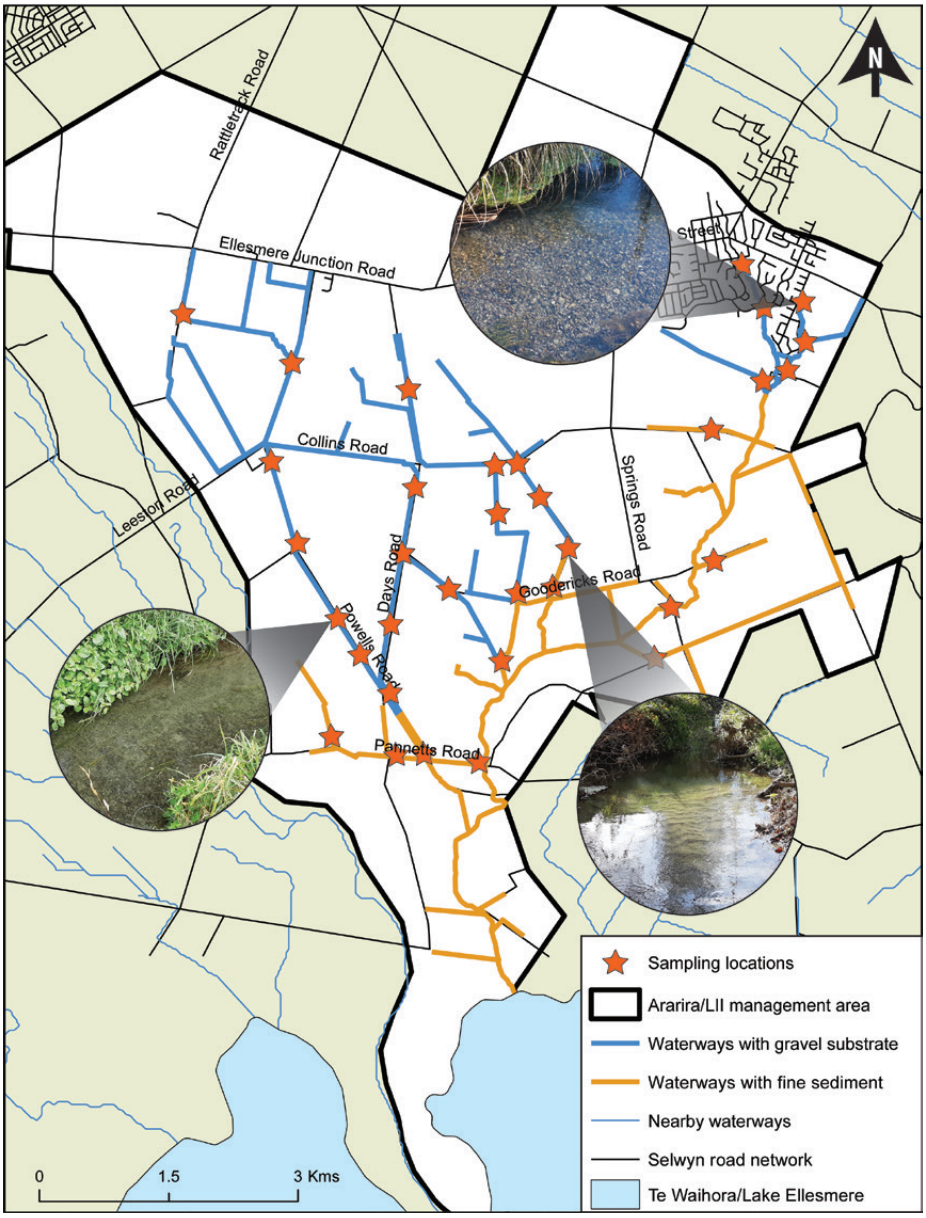


Figure 5. Map of sediment type and coverage across the catchment

Benthic invertebrates were sampled at all sites on a single occasion. Invertebrates were sampled with a composite kick-net (0.5 mm mesh) using protocols of Stark *et al* (2001).

Fish were sampled using a three pass back-pack electric fishing technique on a single occasion at all roadside sites (14 sites).

Figure 6. Flood (suspended sediment) collectors and bed load sediment tiles

Table 1. Monthly Catchment & on-farm monitoring sites in Arariri/LII catchment sampled between May 2018 – March 2020 (Fig. 2-5). WC = Water chemistry, M = macrophytes species, cover, SH = Stage height recorders (discharge), SB = sediment bedload (carpet tiles), SS = Suspended Sediment (flood pottles).

Site codes	Location/Farm	Roadside	Sampling				
Catchment sites							
1	Lincoln town	+	WC	SH			
6	Sergeants Rd	+	WC	SH		SB	SS
8	K1, Goodericks Rd***	+	WC	SH		SB	SS
10	Pannetts/LII	+					SS
12	Powells/Pannets	+	WC			SB	SS
16	Liffey Springs	+	WC	SH			
On farm sites (Catchment site number)							
IR-A	Farm B		WC	M	SH		
IR-B			WC	M	SH		
IR-C (15)**		+	WC	M	SH		
M-A	Farm D	+	WC	M			SS
M-B			WC	M			
M-C			WC	M	SH		
M-D (11)**		+	WC	M	SH		SS
M-E			WC	M			
M-F			WC	M			
M-G (14)**		+	WC	M	SH	SB	SS
M-H		+	WC	M			SS
K-A	Farm C		WC	M			SS
K-B		+	WC	M			SS
K-C*			WC				
K-D*			WC				
K-E*			WC	M			
K-F		+	WC	M			
K-G			WC	M			
B-A (9)**	Farm A	+	WC	M	SH	SB	
B-B			WC	M			
B-D			WC	M	SH		
B-E			WC	M			

*Sites were dropped after first sampling due to low flow conditions at these sites (K-C and K-D denote tile drains that flowed into a channel, K-E, which had had little to no flow and was stagnating as a result).

**Catchment sites 9, 11, 14 and 15 matched to "on-farm" sites.

***K1 has also been referred to as "Sergeants-New".

Determining water quality and stream health

Water quality

A number of standard water quality parameters were measured (e.g., pH, Dissolved oxygen, and temperature) and in general were not found to be significant issues in the catchment (Fig. 7). Both Dissolved oxygen and temperature vary diurnally and seasonally. Dissolved oxygen concentrations did change markedly when invasive macrophytes clogged the waterways. These macrophytes produced oxygen during the day and use oxygen at night, so waterways can become anoxic on occasions, however we did not observe this. Furthermore, high summer temperatures can support rapid macrophytes and algal growth and stress benthic invertebrates and fish. However, as many of the on-farm waterways dried during late spring-early summer the drying killed off algae and all aquatic animal life.

High nutrients were expected in the catchment. However initial sampling indicated nitrate was particularly high (compared to the rest of the country) i.e. approx. 2 mg/L. However as monitoring progress very high nitrate (e.g., approx. 12 mg/L) was recorded in the western headwaters of the catchment (Fig. 8). This high nitrate concentration was detected on Farm B and was also recorded in a spring attached to this waterway. This discovery led to us conducting a synoptic survey throughout the catchment. Despite intensive sampling we were not able to determine if this high nitrate was sourced from shallow or deep groundwater. To determine the source was beyond the scope of our investigations.

Also after intensive sampling, one reach along Pannetts Road also showed high phosphorus (DRP). The high phosphorus was localised to this one waterway and again no definitive source was identified. The ratio of N:P at this site was above the Redfield ratio (16:1) and indicated that the waterway was nitrogen limited rather than phosphorus limited. This means that increasing nitrogen into these system could result in excessive weed growth.

Human health bacteria (*E. coli*) was not identified as a significant issue (aside from occasional spikes).

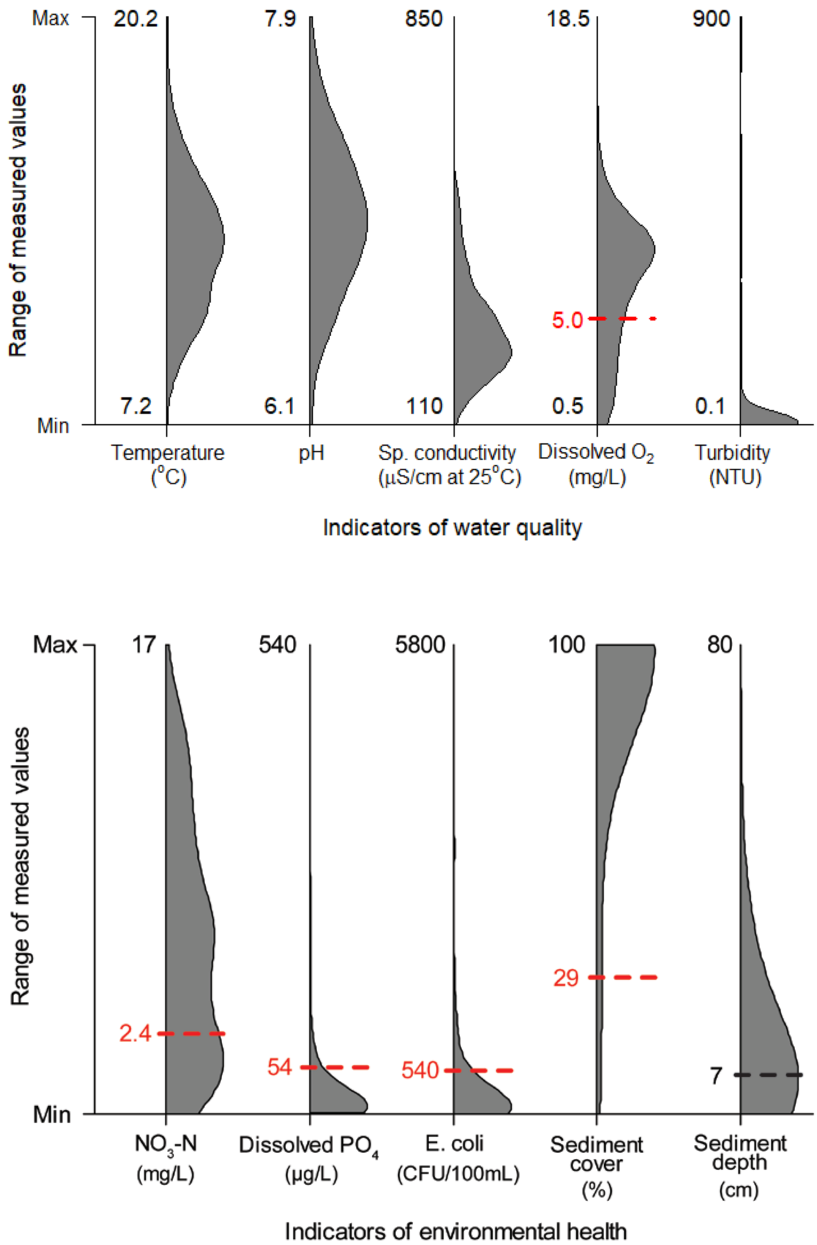


Figure 7. The range of water quality indicators sampled between May 2018 and March 2020. The width of the bar reflects the frequency of values in this range. The maximum and minimum values are shown. The dashed line denotes the bottom line from the NPS-FM. n = 450 monitoring events across 27 sites

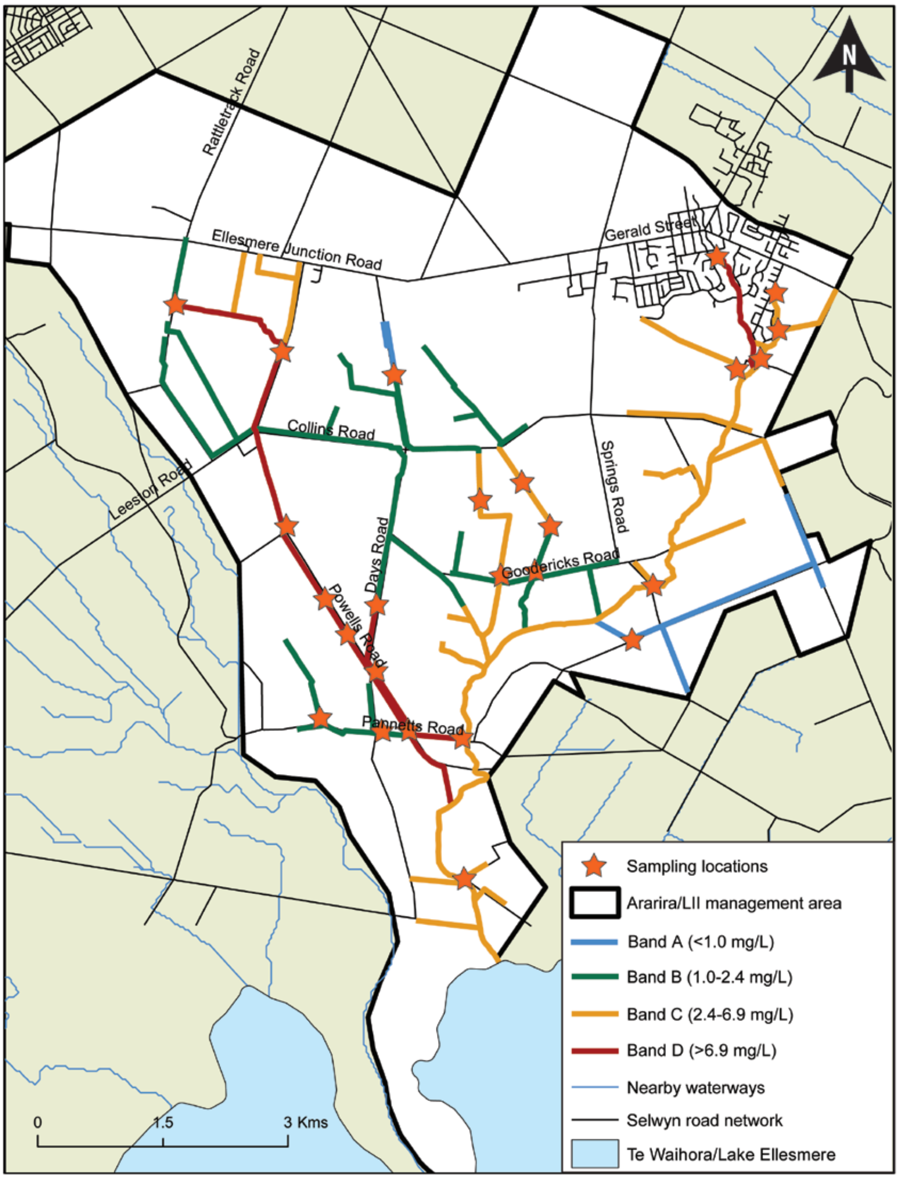


Figure 8. Map of catchment nitrate-nitrogen values from data collected between May 2018 and March 2020. The bands indicate NPS-FM(2020) nitrate bands.

Stream health

Benthic macroinvertebrates are commonly used to measure stream health. A number of different metrics can be used to interpret macroinvertebrate data. We calculated taxonomic richness, and Macroinvertebrate Community Index (MCI & SQMCI) (Stark *et al* 1998). From the 21 sites sampled a total of 37 taxa were recorded with no mayfly or stonefly taxa and eight caddis taxa (although mayflies have been observed in mid-Days and Powells Road waterways). The highest number of taxa recorded at any site was 18 and the lowest was 2. Based on the MCI scores four sites were rated moderately polluted and 17 as probably severely polluted (Table 2; Fig. 9). Freshwater crayfish (kēkēwai or kōura) were collected in Liffey Stream in near Lincoln township.

Fish data was combined with information from Instream Consulting, and a total of 8 species were recorded in the catchment (Longfin and Shortfin eel, īnanga, upland and common bullies, brown trout, rudd and smelt). Both species of eels were distributed widely throughout the catchment, whereas īnanga were absent in the western tributaries and waterways prone to drying. The pest fish Rudd was found in a single site in the headwaters near Lincoln (Fig. 10).

Table 2. Macroinvertebrate survey at 21 sites on 7–8 May 2019. Sampling was done using a composite kicknet (0.5 mm mesh) and followed the standard sampling protocols (Stark et al. 2001). Sites with () indicate catchment monitoring site numbers.

Site code	Location	Taxon richness	MCI	SQMCI
Catchment sites				
1	Lincoln town	13	71	4.4
6	Sergeants Rd	9	87	4.2
8	K1, Goodericks Rd	10	76	2.1
16	Liffey Springs	14	73	2.9
On-farm sites (Catchment site number)				
IR-A	Farm B	6	77	2.8
IR-B		6	77	3.5
IR-C (15)		DRY		
M-A	Farm D	11	84	4.3
M-C		4	55	3.1
M-D (11)		18	80	3.8
M-E		2	50	1.0
M-F		2	40	1.4
M-G (14)		9	67	3.7
M-H		18	82	3.9
K-A	Farm C	12	63	2.9
K-B		11	62	4.0
K-F		8	58	2.2
K-G		8	65	3.4
B-A (9)	Farm A	11	77	3.9
B-B		8	75	3.9
B-D		3	47	1.5
B-E		13	71	3.9

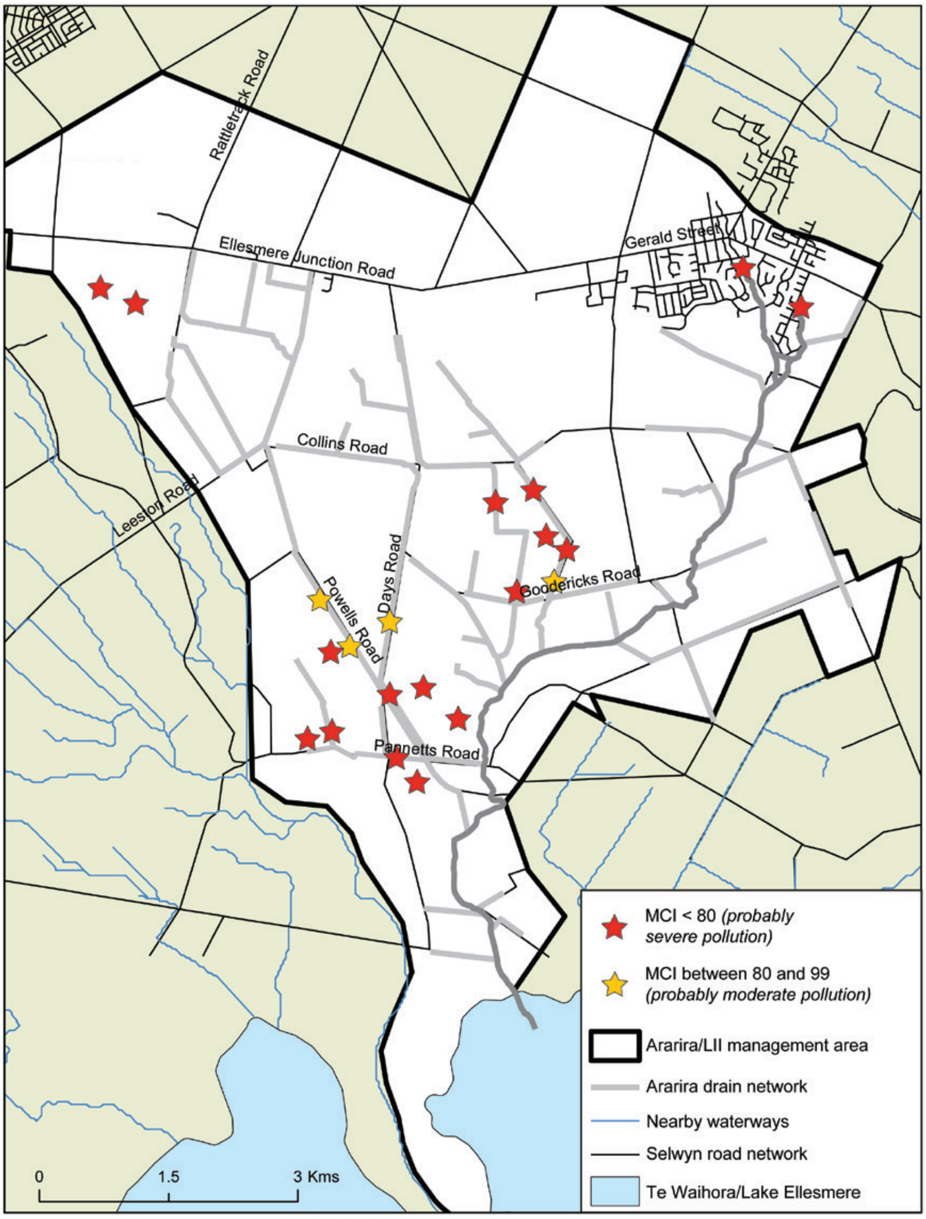
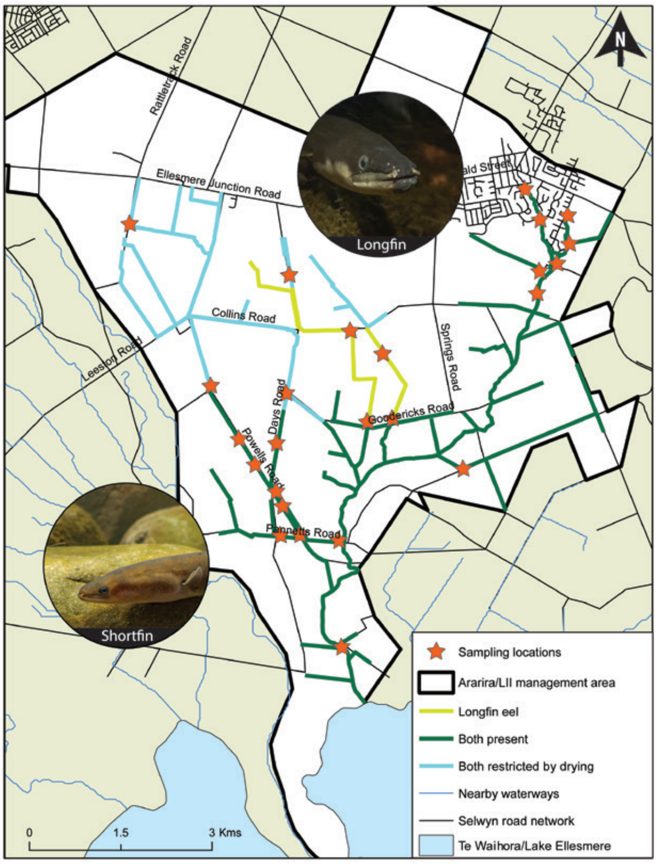
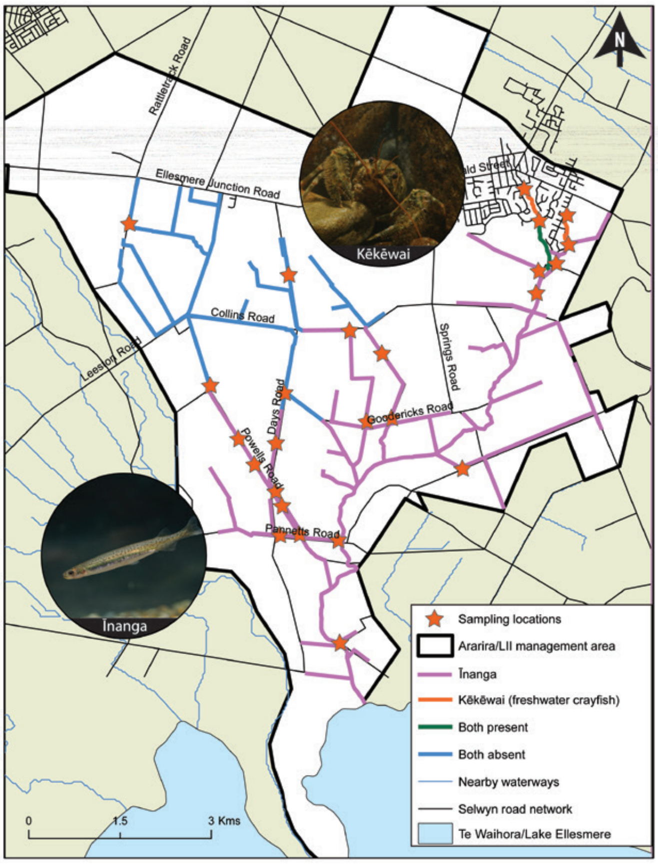


Figure 9. The Macroinvertebrate Community Index (MCI) for 21 sites across the Ararira/ LII catchment.

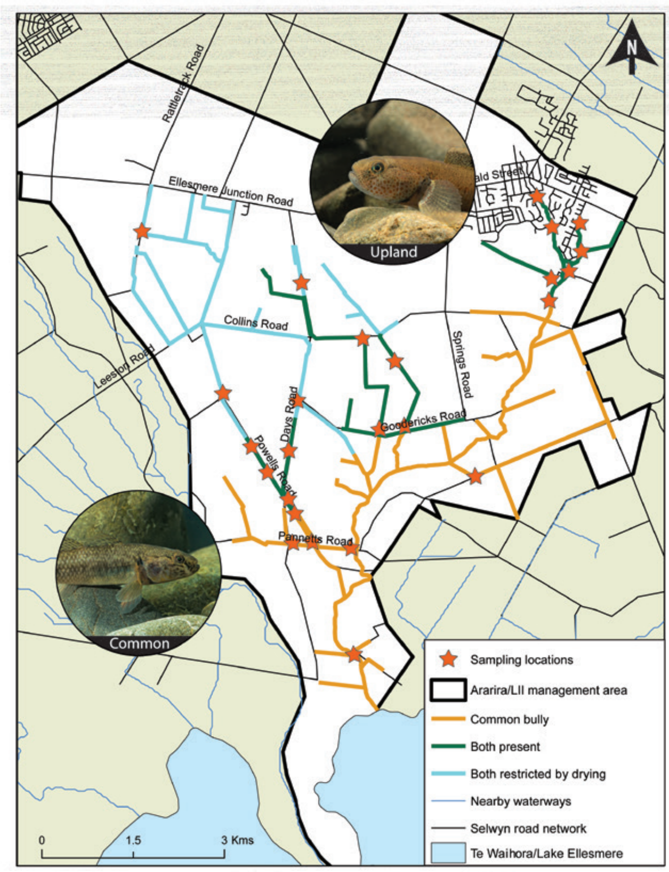
Distribution of freshwater fauna: Tuna (longfin and shortfin eels)



Distribution of freshwater fauna: Īnanga and kēkēwai



Distribution of freshwater fauna: Tīpokopoko/kokopura (bullies)



Distribution of freshwater fauna: Brown trout and rudd

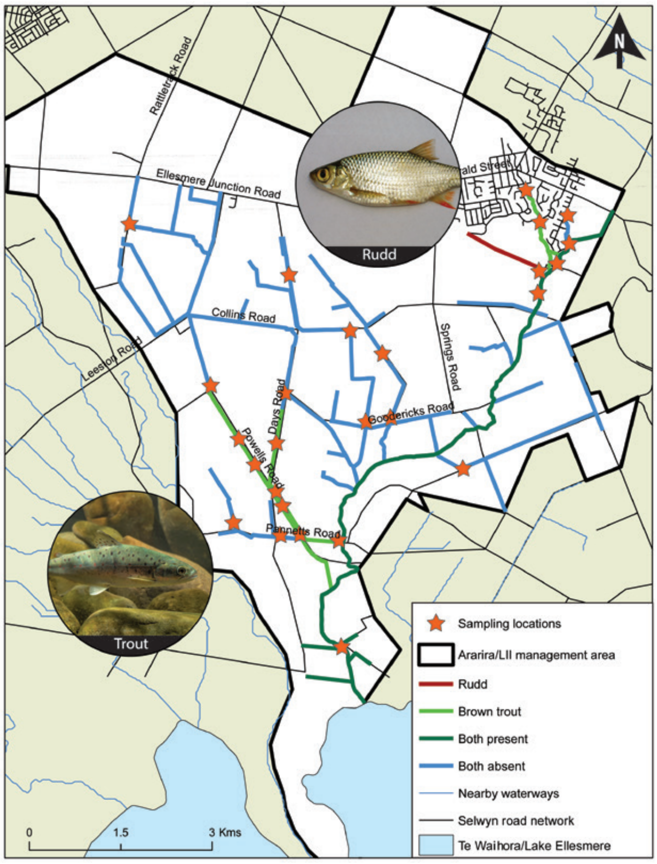


Figure 10. Map of fish distributions.

Rehabilitation tool trials

High Nitrate

High levels of nitrate are often an important issue in agricultural waterways. A comparison between on-farm and roadside drains, showed that the highest values for nitrate-nitrogen were measured at on-farm sites. The synoptic spring survey highlighted that it was only the groundwater on the western side of the catchment that had high nitrate-nitrogen (6+ mg/L), with the eastern springs generally recording <2.5 mg/L nitrate-nitrogen.

The weekly monitoring of the Powells Road sub-catchment identified that the high nitrate along the Powells Road waterways was linked to the groundwater from the Farm B.

Initially treating high nutrient concentrations should be dealt with by farm and land management. In this case high nutrients, specifically nitrate, seemed to be primarily sourced from springs and we wanted to test in-stream nutrient reduction tools.

We had several options, which we reduced to three;

- Treating nitrate in the water using bioreactors
- Trialling a two-stage channel
- Floating wetland plants

Each of these approaches has advantages and disadvantages. However, the waterway on Farm B had ephemeral flows and so all three of these approaches would have their effectiveness disrupted by drying and re-wetting. An advantage of this farm was that we had a very long waterway to work with (approx. 900 m), all of which was a non-rated drain with a single landowner. A non-rated drain meant that the local Drainage Committee does not manage the drain and so regular drain cleaning to remove macrophytes and sediment does not occur. With these factors in mind we opted for a combination of an open channel bioreactor followed by a two stage channel. Both of these had not been used in New Zealand previously.

An Open channel bioreactor is also known as a "reactive ditch" (Pfannerstill *et al.*, 2016). Bioreactors have been widely trialled overseas and use organic matter (typically wood chips) to accelerate denitrification. The Denitrification process is a natural process which involves bacteria converting nitrate in water to nitrogen gas. Denitrification can occur in any wet high nitrate environment where bacteria and fungi decompose organic matter in anaerobic conditions. There can be other compounds released, such as sulphur. Unlike many other bioreactors this system calls for placing exposed wood chips directly in the water, rather than burying them (Fig. 11). Unfortunately, the waterway dried within a few weeks of us setting up the reactive ditch bioreactor so we were not able to measure changes in nitrate prior to drying. We did experience two issues. Firstly, algae grew rapidly and covered the top layer of the bags. The algal growth was not surprising considering the waterway receives high nitrate, warm temperatures, plentiful sunlight and no floods. Long-term this algae would be reduced by drying and riparian shading. The second issue was that a number of bags split along their sown seams, spilling their wood chips. The bags were sown by the timber supplier and although the bags themselves were sturdy the seams were not.

Our second approach was to construct a two-stage channel (Fig. 11). A two stage channel (or ditch) is a modification of the waterway cross-section to add mini-flood plains or benches inside the existing channel. The benches are designed so that when the waterway receives higher flows they will flood and reduce water velocity thus causing sediment to drop out. As the flood recedes water pools on the benches and denitrification occurs (Febria & Harding 2018). These benches can also be planted (e.g., with grasses or *Carex* spp.) to provide shading, trap more sediment and further increase denitrification. Two stage channels have been widely constructed in USA and this waterway is the first fully sized one in New Zealand. Our Two Stage channel is approx. 700 m long.

At the time of this report both the bioreactor and two stage channel were dry and therefore we have no data on their performance.

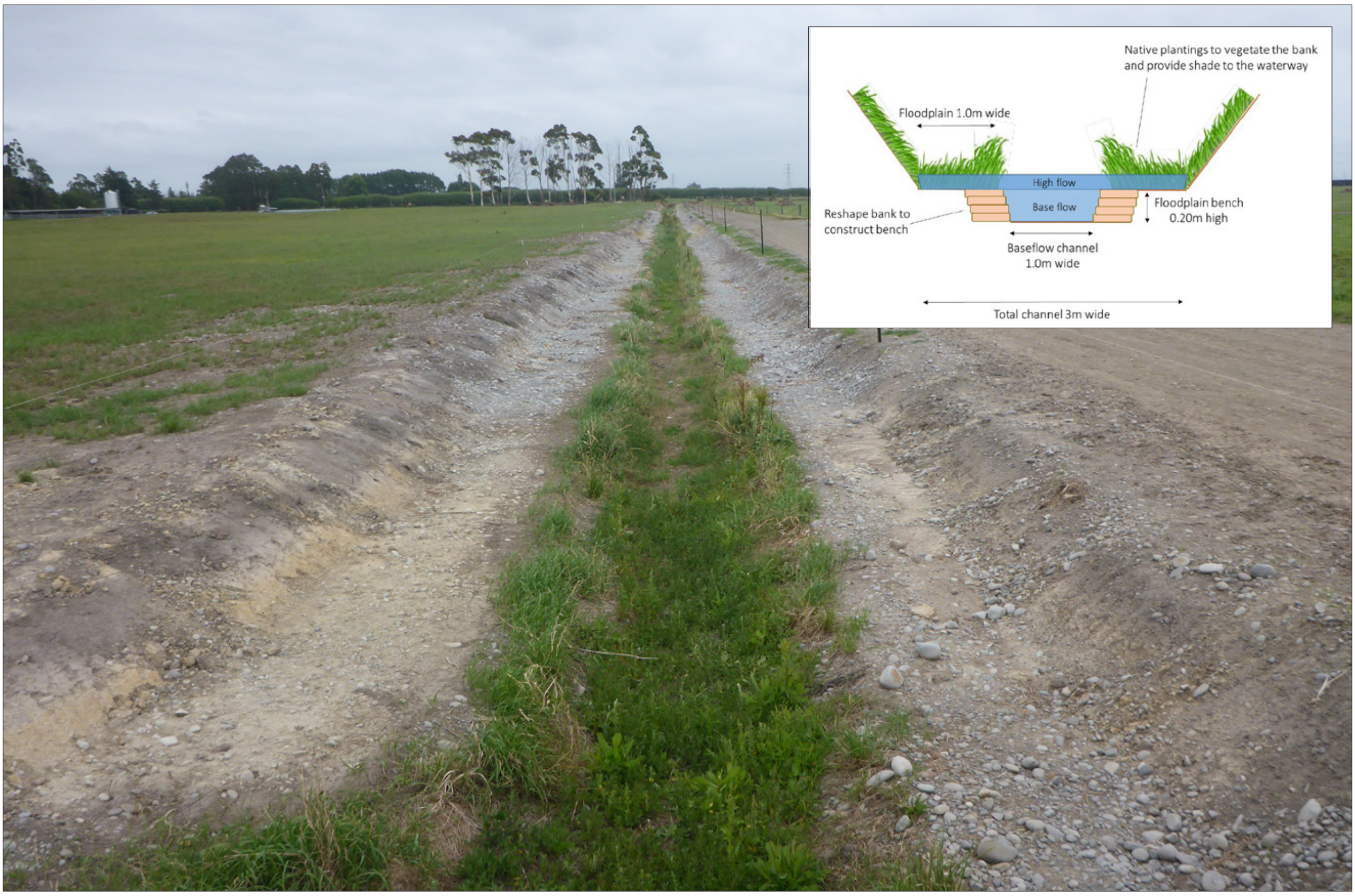


Figure 11. Bioreactor (A) before and (B) after construction the two stage channel began. The height of the benches was determined from the stage height hydrographs.

Understanding sediment transport through the catchment

In order to understand fine sediment transport through the catchment we quantified sediment movement during normal base flow conditions (bed load) and during several flood events (suspended sediment). The catchment was divided into five major sub-catchments based on major waterways; Pannetts, Powells, Days, and Sergeants roadside waterways and K1 on-farm waterway.

During floods suspended sediment was measured at 10 sites using simple, low cost collectors. Flood collectors were designed to collect sediment filled water as the flood waters rose. Collected sediment was dried, ashed (at 550º C for 1 hr to remove organic matter) and weighed to give a dry weight for each sample (ash free dry weight). The sediment from each collector was extrapolated to whole-stream loads using the closest stage height logger. Each site had floods of different sizes. After correcting for this, we determined K1 and Pannetts waterways had high sediment loads (Table 3).

Bed load sediment was estimated using tiles covered with carpet which were sunk into the bed to be even with the bed surface. These were placed at five sites and sampled on six occasions between Sept 2019 – Sept 2020. Surprisingly, a low discharge waterway (i.e., Pannetts) had the highest daily bed loads, and with K1, indicating these two systems probably had high sediment reservoirs and potentially high sources of sediment. A riparian survey of the catchment showed that K1 also had sections of steep, exposed banks, which may be the source of much of the sediment input (Fig. 12).

Overall, we estimated K1 contributed approximately the same amount of sediment as the other four waterways combined, most of which was bed load (Table 3). However, Pannetts also had relatively high sediment loads despite its smaller size, and it has a phosphate issue.

Table 3. The projected annual sediment loads of both flood and bed contributions. These number are probably underestimates, but we expect the pattern to remain unchanged. Pannetts (red), Powells (blue), Days (green), K1 (light blue) and Sergeants (purple).

Sub-catchment	Flood load (kg/yr)	Bed load (kg/yr)
Pannetts Rd	344	2120
Powells Rd	386	1288
Days Rd	287	2069
K1	551	6691
Sergeants Rd	185	706

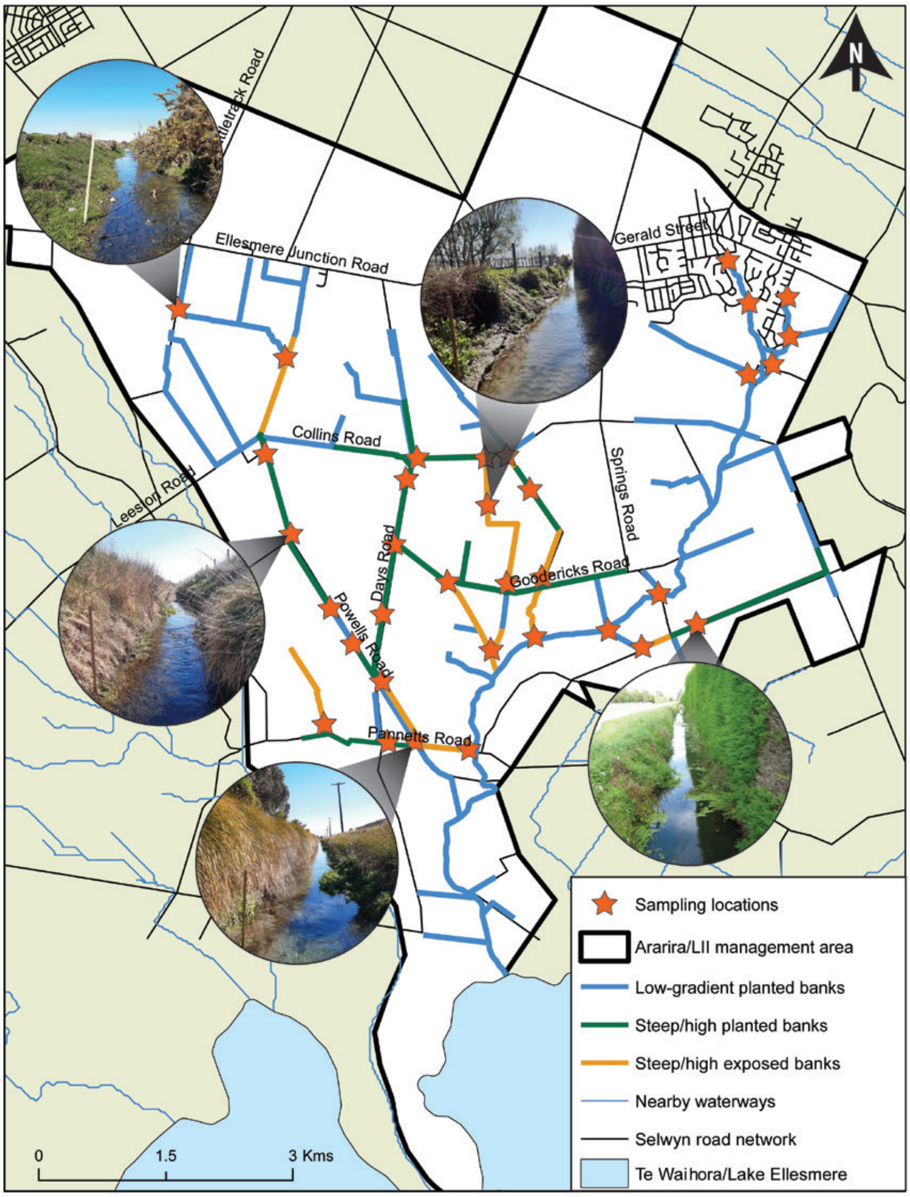


Figure 12. The state of riparian banks across the Ararira/LII catchment in three grades depending on the potential for sediment addition being low (blue), moderate (green) or high (yellow). Exposed banks are likely sources of sediment erosion and input into waterways.

Sediment tool trials

Ideally sources of sediment (e.g., eroding and collapsing banks) should be identified and managed, however in most cases we were not able to get most stakeholders to engage in bank stabilisation. Most were concerned with de-stabilising the banks as they were unwilling to widen their riparian zones. Widening the riparian buffer and re-battering would have made a marked improvement. Furthermore, we also believe that some sediment was a legacy from long-term additions.

As several systems had high daily bed loads of sediment we proposed constructing sediment traps a tool to capture excessive sediment. Getting permission and consents to do this was a very long process. Five sediment traps were installed in November 2020; four on farms (two on K1) and one roadside drains (Sergeants Rd). These were positioned to target areas of high sediment loads (Fig. 13; Table 5). A sixth trap was installed on Farm B waterway to protect the bioreactor from being clogged by silt.

To be effective at reducing sediment transport down the catchment multiple traps would be needed.

We put considerable effort into designing and testing traps. Using equations from Raudkivi (1993) we designed traps that should capture approximately 50% of fine silt moving through the trap until they were approximately half filled. To make this design user-friendly, we modified these site-specific designs into a table based on water velocity and stream width (Table 6; Fig. 14).

In order to disseminate these design features and ideas to a wider audience we produced a video (URL: https://www.youtube.com/watch?v=BMUJn9zL2y8).

Table 5. The six sediment traps constructed in the Ararira/LII catchment using our table for designing appropriately-sized traps. These sites were chosen to target areas of high sediment loads, with the exception of Farm B, which was constructed to protect the downstream bioreactor from becoming clogged by silt.

Location	Stream measurements		Trap dimensions	
	Wetted width (m)	*Water velocity (ms^{-1})*	*Length (m)*	*Depth (m)*
Farm B*	2.0	0.48	14.5	0.75
Farm E	1.8	0.33	10	0.75
Farm F	1.3	0.38	10	0.5
Sergeants	2.2	0.30	10	0.75
K1	2.5	0.52	13	0.75
Powells	3.6	0.42	15	1.0

*The sediment trap was constructed upstream of the bioreactor.

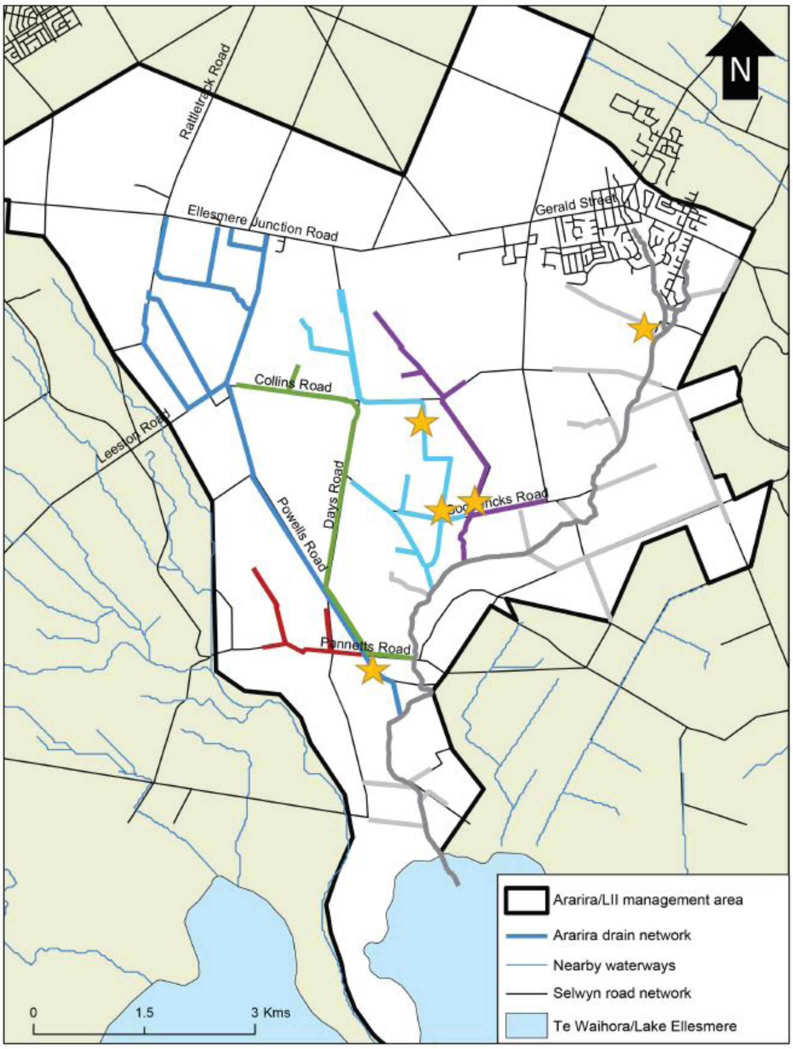


Figure 13. The locations of the five sediment traps across the Ararira/LII catchment. The site is the northeast of the catchment was chosen following discussions with the local drainage committee. The five sub-catchment that were selected for sediment monitoring are highlighted in colour: Pannetts (red), Powells (blue), Days (green), K1 (light blue) and Sergeants (purple).

Sediment trap dimensions based on stream width & water speed

Suggested trap Length x Depth		Average width (m)		
		<1.5	1.5-3.0	3.0-4.5
Water velocity (ms^{-1})	<0.2	4.0 x 0.5	7.0 x 0.75	9.0 x 1.0
	0.2-0.4	7.0 x 0.5	10.0 x 0.75	12.0 x 1.0
	0.4-0.6	10.0 x 0.5	13.0 x 0.75	15.0 x 1.00

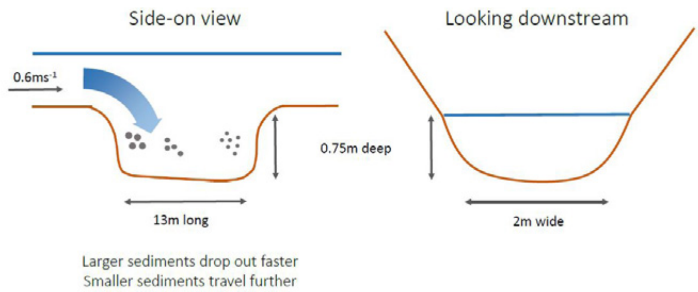


Figure 14. Quick sediment trap design dimensions and example of sediment trap design profiles

Proposed future monitoring

Open channel bioreactor

Only to be done when waterway is flowing and has had water for at least two weeks.

To assess the effectiveness of this bioreactor we recommend monthly water samples of nitrate-nitrogen concentrations at two locations. These locations would be approximately 5 m upstream and 5 m downstream of the last woodchip bag. In addition, if practicable, spot measurements of dissolved oxygen at the same locations would be useful. Monthly discharge (i.e., wetted width, depth and water velocity at a single transect with a minimum of three depth and velocity readings) should also be measured upstream and downstream of the bioreactor. This data will show if the bioreactor is removing nitrate and using discharge data should enable a calculation of how much nitrate is being removed.

We estimate that if this bioreactor works effectively it might remove 25+% of the nitrate from the water. The wood chips should last 5+ yrs, however we are uncertain of the life of the wood chip bags.

Two-stage channel

When water is flowing along the two stage channel we recommend monthly nitrate-nitrogen (water grab sample), and turbidity (measured with a field meter in NTUs or water clarity tube) be measured immediately upstream and downstream.

The two stage channel needs to experience about 10+ floods of the benches per annum to have any effect on nitrate, sediment and *E.coli* transport. If this occurs, we estimate the two-stage channel might remove 30+% of the nitrate. In theory, the two stage should involve no maintenance for decades, and the benches should be planted with ground plants and low shading plants (e.g. *Carex* spp).

Sediment traps

There are six sediment traps in the catchment, and we recommend that at least three of the traps should be monitored. Ideally this might be done monthly. The intensity of monitoring will depend on the resources (time and staff) available. We propose a tiered approach depending on resources.

- The minimum would be a visual assessment of how full the traps are getting. This would include a visual % estimate of fullness.
- It would be preferable to take some actual measurements of the depth of sediment in the upstream end of the trap and at the downstream end of the trap. These measurement could be taken by standing outside the trap and using a ruler to measure sediment depth in the trap.

The aim of this sampling would be to determine how quickly the traps are filling and need to be clean and estimate the amount of sediment being transported down the waterway.

Lessons learned and recommendations

Landowner and Council engagement – Developing a successful program across a catchment to bring about positive change requires early identification and engagement with key landowners and local government staff. These people must be committed to improve water management practices and willingness to adopt new ideas. Good landowners can become champions who will be "positive influencers" to their neighbours. In our opinion, advisors and project staff who are "outsiders" will always struggle to achieve widespread changes practices in a catchment.

Partnerships & trust – Time needs to be allowed to build trust and develop partnerships. Trust, good relationships and developing the right contacts in a catchment takes many years to achieve (e.g., 2+ years). Landowners and stakeholders need to become confident that advisors and partners will be there for the long haul.

Catchment network – A clear understanding of the catchment network and issues throughout the catchment is essential to help bring about best solutions. It took us 1–2 years of talking to stakeholders and monitoring hydrology and water quality to properly understand where to put our efforts.

Flow permanence – Discovering that almost all of the on-farm waterways were ephemeral was a major discovery which caused us to serious rethink our actions. The majority of restoration/rehabilitation tools for improving water quality and freshwater ecological communities assume the waterway has permanent water.

Start at the top – Our previous research strongly indicated that restoration efforts should start at the very top of the catchment. Two years research in the Ararira confirmed this. Nutrient and sediment issues need to be addressed starting from the top and working downstream. For example, bank management and multiple sediment traps starting at the top are required to reduce sediment output from K1 waterway.

Sediment management – A major issue throughout the catchment was excessive fine sediment. Some of this may have been natural catchment geology, however we identified significant areas of poor sediment management particularly collapsed banks. Poor waterway cleaning practices resulted in over deepened waterways and steep high banks which were often unstable and prone to erosion during floods.

Bank re-battering – Bank re-battering to reduce bank slope and create stable banks is an essential first step in sediment control. Bank re-battering should always be considered before any riparian planting is untaken. Planting on unstable banks can create significant long-term problems and waste resources, money and become demoralising to stakeholders.

Riparian planting – This catchment does not currently have many pivot irrigators or tile drains, however Farm B is planning to install pivots. Riparian planting needs to be carefully designed to deal with these two structures. Thus planting needs to be low growing vegetation, but still be able to provide shading to reduce excessive aquatic plants. Tile drains need to end as soon as they enter the riparian zone and not be laid so that they go under the planting (as is often the case).

Two stage channel – We strong believe that multiple restoration tools are usually needed to address different issues. However, in the Ararira widespread construction of Two stage channels does have the potential to address flood, drain cleaning, nutrient, sediment & *E.coli* issues all at once. That tool has the added advantage of working in ephemeral systems. In this catchment converting long sections of the roadside and other drains (e.g. K1, Sergeants, Powells and Days Roads) into two stage channels could markedly improve water quality and ecosystem health across the entire catchment. However, these would need to be 500+ m long, and importantly this solution would not be possible without local government agreement.

Consents – Gaining consents for in-stream works which will actual improve the waterways is currently a major barrier. The current regulations and consenting process is not designed to encourage in-stream restoration. The cost for consenting is onerous, and will continue to discourage landowners from taking action. Furthermore, the time taken to process and get a consent is prohibitive to any project which might run for 1–2 years.

Effective communication of ideas – This is critical to the purpose of this work. During the project we recorded thousands of social media hits and video views and were surprised by the large number of "retweets", "likes" etc. Developing an effective multi-layered communication strategy at the beginning would be a useful approach to creating a pathway to communicate ideas and help bring about change.

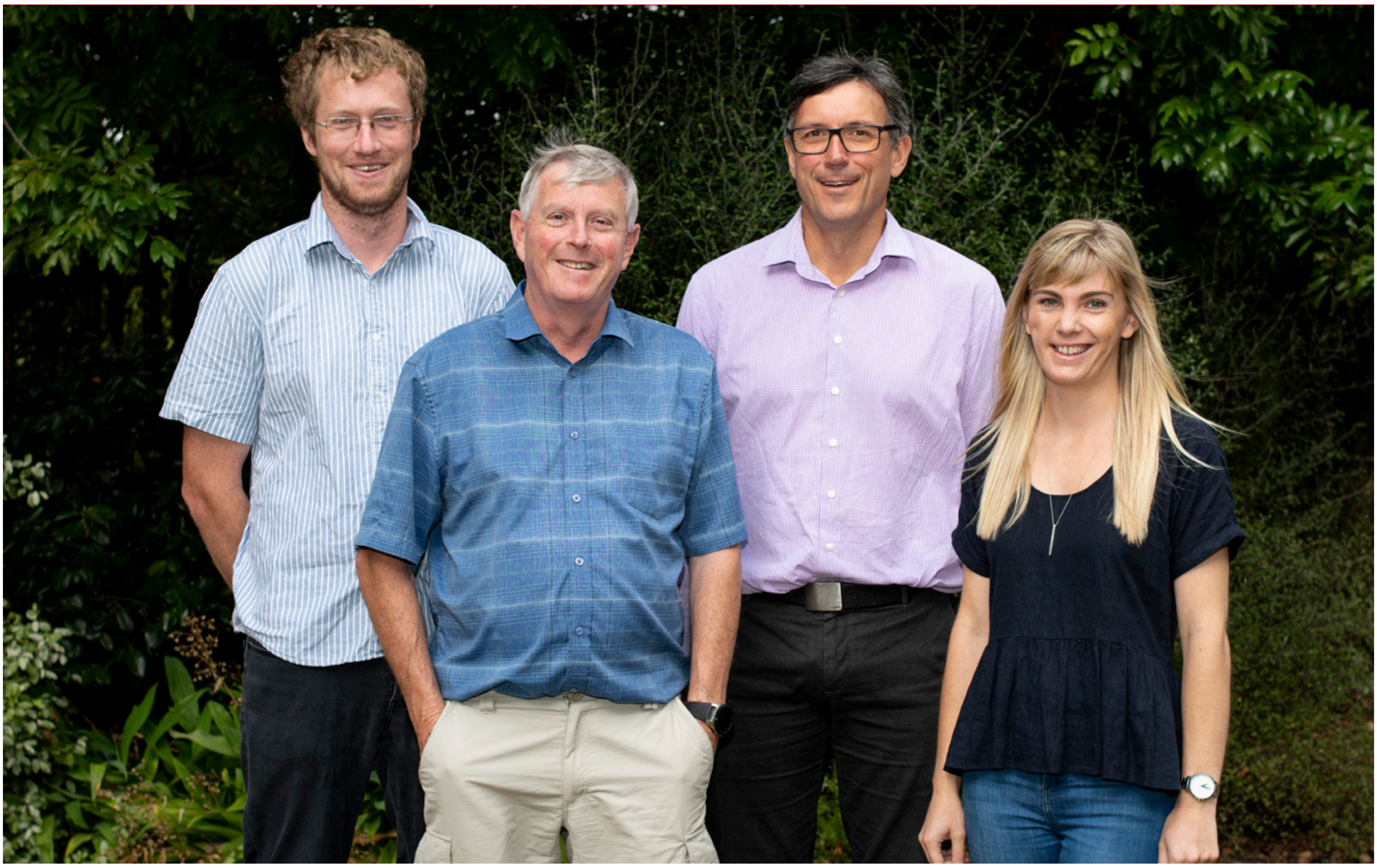
Potential future research

Future research which we would have undertaken would have included;

- Trialling the effectiveness of floating wetland plants compared to bioreactors and two stage channels. The ephemeral nature of our farm waterways meant that floating wetlands would probably be of limited value in this catchment as they would die off each year. However, combining tools e.g., floating wetlands and bioreactors at different locations (along roadside drains) across the catchment network could produce enhanced nutrient control.
- Quantify the impact of re-battering and planting combined on reducing sediment inputs into a waterway. We have seen re-battering work as a tool to reduce bank erosion, however we have no data on how much sediment inputs might be reduced by this and combined actions.
- We believe there is a need to trial multiple sediment traps along a single waterway. To truly reduce sediment export from a catchment a succession of multiple traps along the system would be needed.


Alex Barclay and Felix doing field work

Acknowledgements



CAREX team members. Chris Meijer, Jon Harding Angus McIntosh and Hayley Devlin

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Catherine Febria

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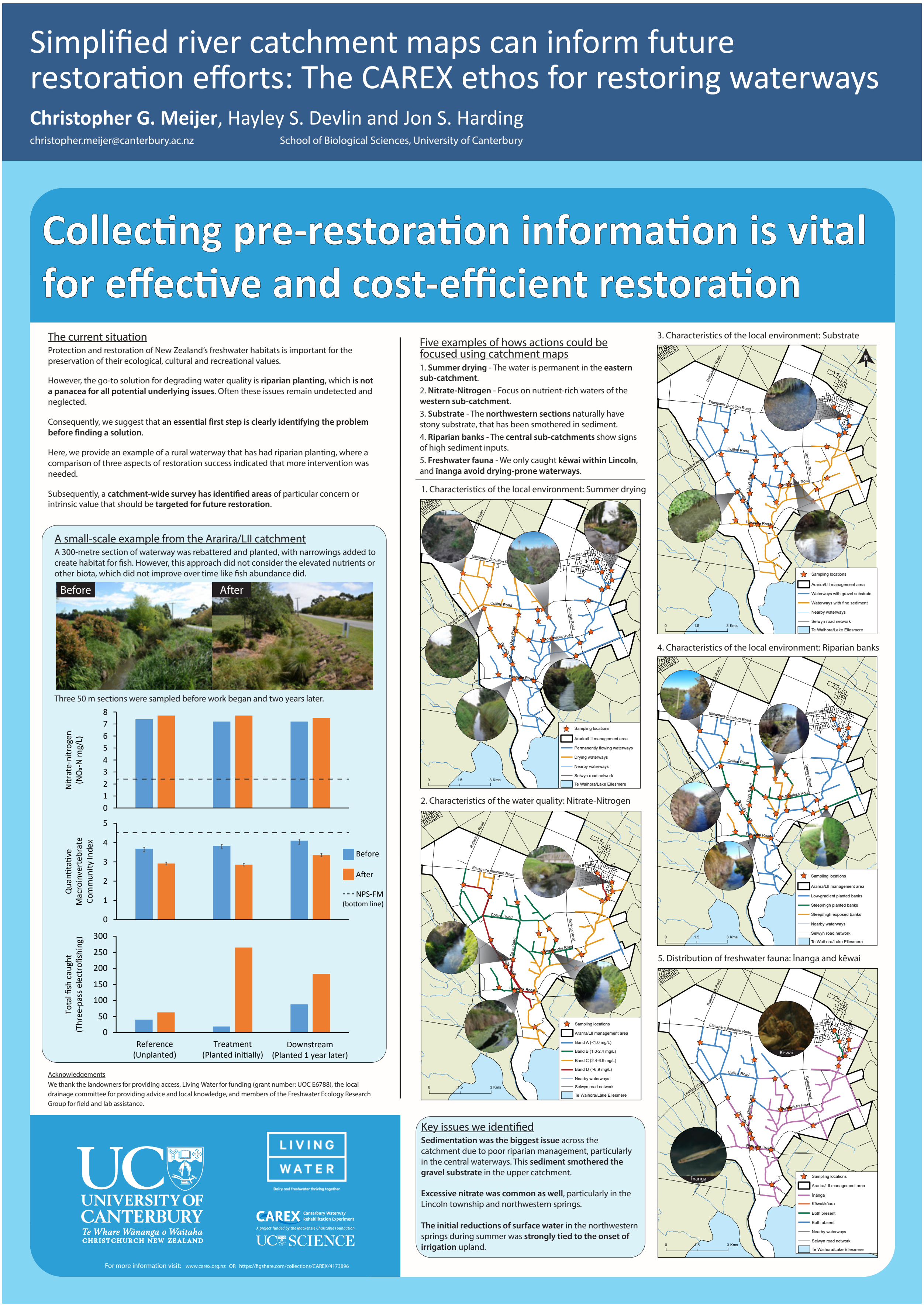
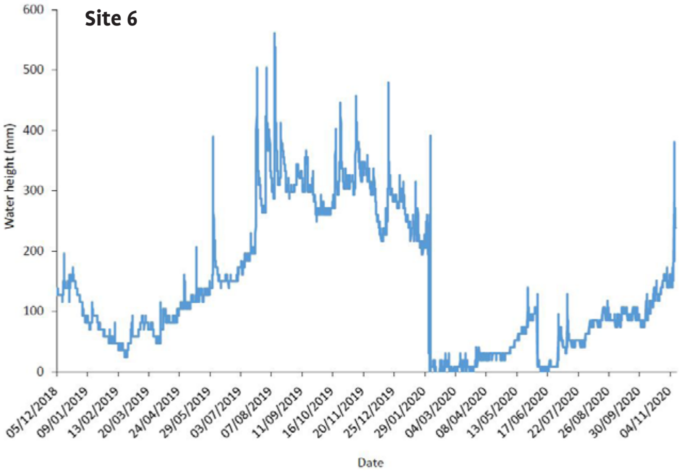
Electric fishing

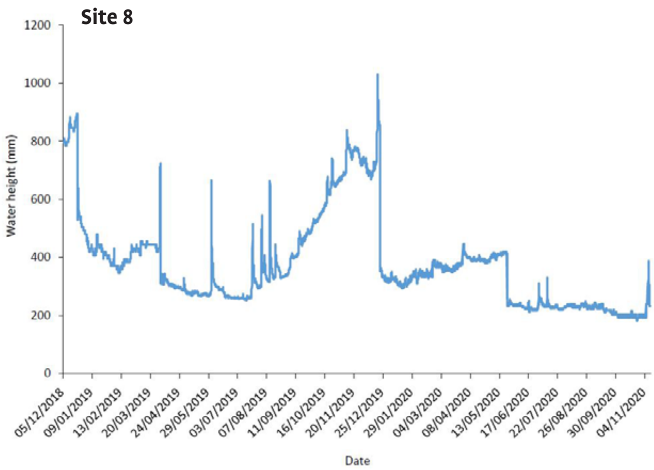
Appendices

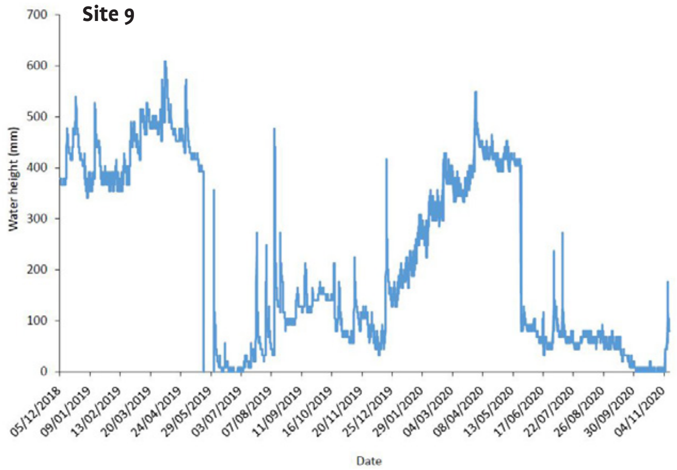
Appendix 1. Poster presented at NZFSS conference Dec 2020

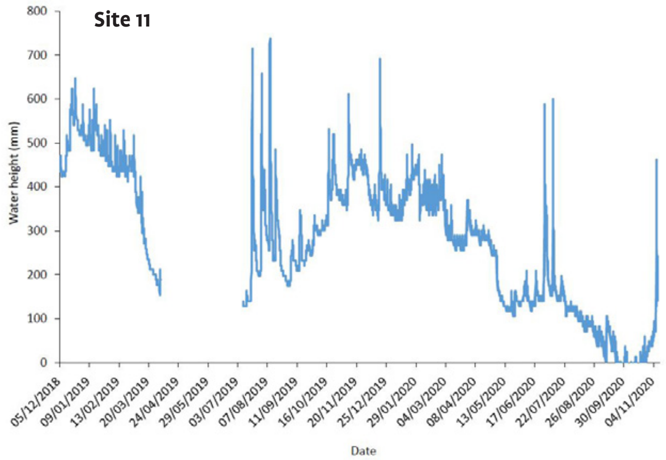


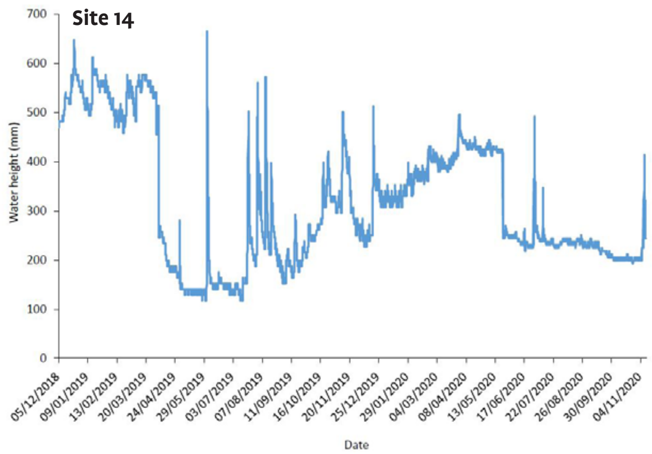
Appendix 2. Hydrographs











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