HEKEAO / HINDS
WATER ENHANCEMENT TRUST

Hekeao / Hinds Environmental Enhancement Projects

Year 6 Annual Report

(June 2021 – May 2022)

Dr Brett Painter (HHWET Executive Director)

	Name	**Date**
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Hekeao / South Hinds River NRR1 site in March, June and October 2021 (Source: HHWET)

Chairman’s Foreword

I am privileged to present this Chairman’s Foreword on behalf of HHWET.

The goals of HHWET are to:

- Target and protect drinking water supplies;
- Enhance groundwater quality;
- Improve baseflows to spring-fed streams and rivers for ecological, cultural and social values; and
- Improve and sustainably manage groundwater storage.

This Year 6 report clearly shows that the projects undertaken by HHWET in line with its goals, can and do make a positive difference to the Hekeao Hinds Catchment.

Our Year 6 work has been completed with our Managed Aquifer Recharge and Near River Recharge operations achieving a recharge volume of 7.2 M m^3 for the year. This is 52% of the volume achieved in the preceding year. This drop in performance is due to the late May 2021 rainfall event that caused widespread flooding in the catchment resulting in all HHWET sites being turned off from early June until late October.

During Year 6 no new recharge sites have been commissioned but some existing sites have been extended, developed and automated. Maximum available flow rate remains at 500 l/s. Workstreams undertaken by HHWET this year include a Groundwater Nutrient Recycling case study completed and published. The eClean bioreactor technology and constructed wetlands have been proposed and advanced in conjunction with Mid Canterbury Catchment Collective and MHV Water.

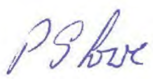
HHWET was fortunate in 2020 to secure funding from Central Government in the form of the Provincial Growth Fund. I am pleased to report all deliverables required by PGF have been achieved and confirmed, and this project is now complete.

Agreement was reached with Canterbury Regional Council to finalise Long Term Plan targeted rates for this project. What this means is that the Hekeao Hinds community, through Environment Canterbury’s Plan Change 2 process, has taken responsibility for the past environmental decline in our catchment, is taking action to actively reverse that decline, and is also funding that work.

The focus for HHWET in Year 7 will be to secure resource consents to allow MAR / NRR as a supplementary use to the RDRML parent consent and the necessary discharge consents to allow MAR / NRR over a much larger area than at present. Any delays in this process will set the clock back on environmental benefits gained in the Hekeao Hinds catchment.

As chairperson I would like to take the opportunity to thank all HHWET Trustees, our Executive Director Dr Brett Painter, and MHV Water MAR Scheme operational staff Murray Neutze and hydrogeologist Justin Legg for their continued valued contributions to this project.

To have the opportunity to work on a project that demonstrates measurable environmental benefits in the Hekeao Hinds Catchment is indeed a privilege.



Peter Lowe
Chairperson
Hekeao Hinds Water Enhancement Trust

Acknowledgements

The author wishes to thank the Hekeao / Hinds Water Enhancement Trust (HHWET) for project oversight, Mark Webb (Central South Island Fish and Game) for the fish survey monitoring and analysis, Pattle Delamore Partners and EOS Ecology for technical support, MHV Water, RDRML, Lincoln Agritech and Environment Canterbury field staff for monitoring information, and all report reviewers.

Executive summary

Background:

New Zealanders want clean rivers, streams and waterways. We want to be able to swim in, fish, gather mahinga kai, enjoy and most importantly drink from our freshwater sources. We also want our future generations to enjoy that same opportunity.

The Hekeao/Hinds catchment is within the borders of Mid Canterbury. The Pacific Ocean forms our eastern coastline, and the Southern Alps form the western boundary. We are bordered to the north by the Hakatere/Ashburton River and to the south by the Rakitata/Rangitata River. This farming area is among the most productive irrigated agricultural districts in New Zealand.

The problem:

Increased farming intensity, climate change and other demands on our water resource have resulted in adverse environmental effects – namely reduced water quantity and also reduced quality because of increased nitrate concentrations (and microbial contamination in some places). The Hekeao/Hinds community have recognised this and are addressing these catchment scale environmental issues, both through on-farm changes and catchment scale enhancements. HHWET are leading catchment scale enhancements and are also contributing to on-farm initiatives.

HHWET's goals are to:

- Target and protect drinking water supplies;
- Enhance groundwater quality;
- Improve baseflows to spring-fed streams and rivers for ecological, cultural and social values; and
- Improve and sustainably manage groundwater storage (levels).

In order to achieve these goals, HHWET are trialling and implementing several complementary tools to help address water quality and quantity issues. These include Managed Aquifer Recharge (MAR), Near River Recharge (NRR), Targeted Stream Augmentation (TSA), irrigation nutrient recycling, constructed wetlands, and bioreactors.

The reporting of progress towards these goals focusses on the contribution of the trialled tools to Plan Change 2 to Environment Canterbury's Land and Water Regional Plan (LWRP PC2). PC2 includes the following targets to be met by 2035:

- Reduce on-farm nitrogen losses by 36%;
- Reduce median annual shallow groundwater concentrations of nitrate-nitrogen to less than 6.9 mg/l;
- Reduce median annual hill-fed lowland waterway concentrations of nitrate-nitrogen to less than 3.8 mg/l; and
- Reduce median annual spring-fed plains waterway concentrations of nitrate-nitrogen to less than 6.9 mg/l.

In addition, the Freshwater National Policy Statement 2020 came into force on 3 September 2020. Its goals of stopping further degradation and loss, reversing past damage, and addressing water allocation issues align with PC2 goals, though the required water quality and quantity targets may be different when implemented though a new Regional Plan.

Our objectives:

During Year 6 (2021-22), HHWET concluded a Provincial Growth Fund project and began a new project phase funded by a Targeted Rate to Hekeao / Hinds Plains landowners, through Environment Canterbury's Long-Term Plan. This resulted in new arrangements with project partners Ashburton District Council, Rangitata Diversion Race Management Ltd, Central South Island Fish and Game, and MHV Water. HHWET objectives to March 2022 were largely achieved and the following new objectives were set through to 30 June 2024:

Governance

1. Long term agreements in place with MAR Scheme operators (monitoring and distribution), partners and landowners.
2. HHWET Purposes and Functions reviewed on an annual basis.
3. Business Case Addendum confirmed by 31 December 2023 as a support document for 2024 Long Term Plan funding processes.
4. Annual report and annual accounts externally reviewed on an annual basis.

Communications

5. Communications Plan reviewed and updated on an annual basis.
6. Communication opportunities identified and actioned (including local organisations, educational institutions, tangata whenua, media and conferences).
7. Engage with and inform Essential Freshwater / Te Mana o te Wai processes where relevant.

Enabling Regulatory Environment

8. Long term HHWET Ltd take, use and discharge consents confirmed for a combined MAR / NRR Scheme of at least 3700 l/s flowrate (equivalent to a maximum of 117 million m^3/year).
9. Additional short term (e.g., construction) consents secured as required.
10. Additional permissions (e.g., DOC) secured as required.

Access to water

11. Long term agreements in place with parent consent holders for MAR supply flowrate of at least 3700 l/s (equivalent to a maximum of 117 million m^3/year).

Proof of concept

12. Operational MAR / NRR sites in target areas with demonstrated potential to recharge a combined flowrate of at least 3700 l/s (equivalent to a maximum of 117 million m^3/year).
13. MAR / NRR Scheme size reviewed by 30 October 2023 for the purpose of updating long term Scheme size estimations and the Scheme Business Case.
14. Monitoring Plan reviewed and updated on an annual basis.
15. Methods of managing bacterial contamination and suspended sediment to reduce MAR supply shutdowns reviewed and updated on an annual basis.

16. MAR / NRR Scheme infrastructure in place that provides compliant, safe, efficient and reliable operation.
17. Groundwater Irrigation Nutrient Recycling concept actively supported through development and implementation.
18. Targeted Stream Augmentation concept actively supported through further development and implementation.
19. Constructed wetland and bioreactor concepts actively supported through further development and implementation.
20. Additional research and development concepts relevant to HHWET Purposes actively considered.

Collaboration

21. Collaborative opportunities actively sought with potentially complementary groups.
22. Site co-benefits identified and actively implemented on a site-by-site basis, seeking external funding support where possible.
23. Support (including supervision) provided for tertiary and post-graduate students where their subject matter is relevant to Trust Purposes and Objectives.

What we did:

Progress to address these priorities during Year 6 (2021-22) is summarised as follows:

a. Governance
- An Operations Agreement was finalised with MHV Water.
- A Site Access Agreement Template was finalised.
- The HHWET-Environment Canterbury Funding and Reporting Agreement was finalised.
- HHWET monitoring requirements were finalised for incorporation into the HHWET-MHV Water Monitoring Agreement.
- The ADC/HHWET/MHV Water discussion regarding water race multi use was progressed.

b. Communications
- The HHWET website (www.hhwet.org.nz) and Facebook profile (@HekeaoHindsWET) reached an increasing number of people, with website redevelopment progressed for implementation during Year 7.
- Wider communications were achieved through an article on Irrigation Nutrient Recycling in the Irrigation NZ magazine and articles in local media.

c. Enabling Regulatory Environment
- CRC210832 for supplementary take and use 500 l/s for MAR / NRR through to 2029 was granted.
- CRC210830 for discharge of 300 l/s at MAR01 through to 2029 was granted.
- New supplementary use, MAR discharge and NRR discharge consent applications were drafted.

d. Access to water
- The RDRML Water Supply and RDR Water Access Agreements were progressed.

e. Proof of concept
- The Irrigation Nutrient Recycling concept was finalised and shared through the HHWET website, HHWET Facebook page, groundwater irrigator meetings, MHV Water shareholders, HHWET presentations and the Irrigation NZ magazine.
- HHWET are a project partner in the trialling of the eClean bioreactor in Hekeao / Hinds.

- Rubicon gates were installed at MAR / NRR sites for improved flow control.
- Multiple basins/races and/or buried perforated pipes were installed to improve MAR site performance.
- Suspended sediment and *E. coli* were further investigated to find ways of minimising their risk to MAR / NRR operations and ecosystem health.
- Potential lower catchment constructed wetland sites were investigated.
- High flow testing was undertaken at potential new and expanded MAR / NRR sites to inform new discharge consent processes.

What we found:

Key learnings from Year 6 (2021-22) include:

- Analysis methods (equivalent rainfall year comparisons and moving average comparisons) have been found to reduce the dominating influence of rainfall on annual water quality and water quantity monitoring information.
- Analysis of LWRP PC2 median annual groundwater nitrate concentrations using the above methods suggests that increases in nitrate-N concentrations peaked around 2015 and have been relatively stable since.
- Analysis of annual average Hekeao Hinds River flows at Poplar Road for 'before MAR / NRR' and 'after MAR / NRR' produced a 112% increase in average flow for the 2020/21 versus 2015/16 'dry' year comparison. This is a 460 l/s increase. The 620 l/s maximum potentially contributing discharge from NRR and MAR sites during this period is expected to have been a significant contributor to this increase. Other potential influences include preceding groundwater conditions and the timing of rainfall and irrigation activities.
- Analysis of contributions of lower Hekeao / Hinds River tributaries to lower Hekeao / Hinds River water quality shows that the 14% improvement in Taylors Drain nitrate-nitrate-nitrogen (NNN) in the 'dry' year comparison (2015/16 and 2020/21) is the primary positive contribution to a 6% improvement in lower Hekeao Hinds River NNN. For the same equivalent 'wet' year comparison (2017/18 and 2020/22), the water quality improvements are 31% for Taylors Drain and 14% for the lower Hekeao Hinds River NNN. Water quality in Taylors Drain is influenced by MAR / NRR due to Hekeao Hinds River losses to the true left which end up in Taylors Drain.

What does it mean?

Raw monitoring data for Hekeao Hinds water quantity and quality will continue to be dominated by rainfall variation, but the chosen analysis techniques and the increasing length of datasets enable the other influences on water quality and quantity to be more visible in surface and groundwater monitoring. Potential influencers will be assessed further as relevant information is identified.

The key learnings are consistent with hydrogeological understanding of the Hekeao Hinds Plains, where on-farm improvements and environmental enhancements are expected to contribute to measurable improvements more quickly in the faster moving Hekeao Hinds River system and more slowly in the slower moving groundwater system. Groundwater monitoring results continue to provide encouragement that MAR is a useful contributor to groundwater quality improvements and that increasing the scale of MAR operations toward LWRP PC2 expectations is justifiable provided the required on-farm improvements also continue according to PC2 targets.

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1 Introduction

Plan Change 2 to Canterbury Regional Council's (CRC's) Land and Water Regional Plan (PC2) includes requirements to reduce on-farm nitrogen leaching by up to 36% by 2035 and reduce median annual shallow groundwater concentrations of nitrate-N to a target of <6.9 mg/l by 2035. The PC2 2035 target for the lower Hekeao / Hinds River is 3.8 mg/l nitrate-N. PC2 assumes that environmental enhancements such as MAR will be required to meet these targets. It is possible that LWRP changes in response to the New Zealand Government's "Essential Freshwater" package may result in further changes to targets and/or monitoring at some point in the future, but PC2 remains active in the meantime.

Table 1-1 (below) shows that the total recharged MAR volume in Year 6 was approximately 7.21 million m^3, which is only 52% of the 13.85 million m^3 recharged in Year 5. The key reasons for this decrease were the high groundwater levels and damage to NRR1 as a result of the May 2021 heavy rainfall event. When groundwater levels are high, the system has limited capacity to take additional recharge (e.g., via MAR or NRR). There can also be a perception that MAR / NRR operations following heavy rainfall events contribute in a significant way to the effects of these rainfall events (such as flooding). As the amount of MAR / NRR that can currently be delivered (129,600 m^3 over 3 days) is less than 0.1% of the rain that fell across the Hekeao Hinds Plains from 29-31 May 2021 (>200 million m^3), MAR / NRR operations following this event would have been very unlikely to measurably increase risks such as flooding. However, MAR / NRR operations (if the water could physically recharge) would also not measurably improve water quality during this time due to the dominating water quality effects of the rainfall recharge. For these reasons, MAR sites were turned off from the beginning of June until the second week of October 2021, except for a few low flow trials to check recharge rates at different groundwater levels (see Figure 1-1). In addition to turning off for these reasons, NRR1 was also turned off for the same period to undertake repairs and construct new recharge basins.

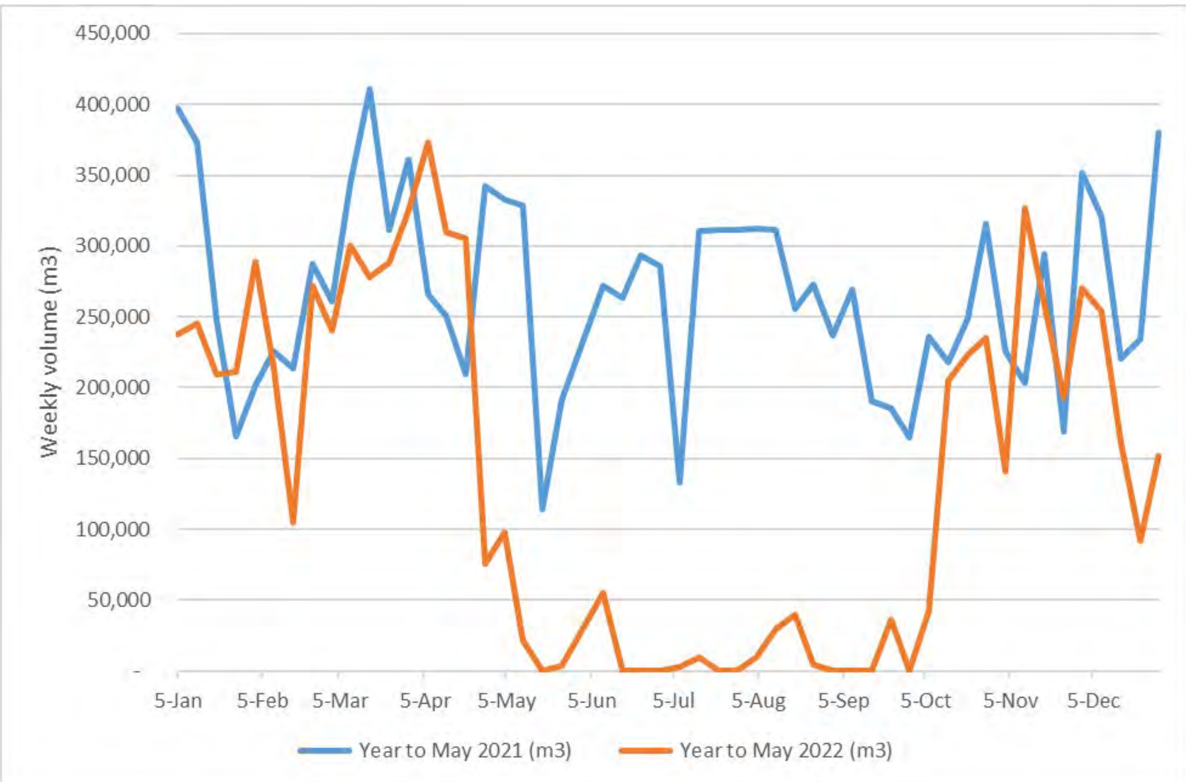

Figure 1-1: Total MAR / NRR weekly volume for Year 5 (2020/21) and Year 6 (2021/22). Source: HHWET.

Table 1-1: Year 6 Hekeao / Hinds MAR / NRR recharge

	MAR Volume (cubic metres)
Delivered to South Hinds NRR1 Site	1,271,575
Delivered to MAR Pilot Site #1	1,640,225
Delivered to MAR Sites #2-18	4,275,624
Distribution system recharge (race "losses" when MAR water-only delivered)	25,920
Total Year 6 recharged flow	**7,213,344**

The nitrate-N PC2 update to 30 June 2022 in Figure 1-2 shows median nitrate-N concentrations in PC2-specified "shallow" wells across the Hekeao / Hinds Plains alongside annual Ashburton rainfall. Rainfall for the last two years is presented as a complete line (for measured rainfall) and a dotted line (where the 155 mm of rainfall that fell from 29-31 May 2021, is moved to the following year). The dotted line provides a more useful comparison with measured nitrate-N concentrations, as the heavy rain event resulted in significant movement of nutrients through the soil profile, groundwater and surface water systems which were measured throughout Year 6 (2021-22). Figure 1-2 shows the adjusted 2021-22 year as one of the four wettest years and one of the four highest years for median nitrate-N concentrations since 2006. Other years with high median nitrate-N concentrations in Figure 1-2 either occurred in the same year as high rainfall totals or in the following year. Catchment scale enhancements such as MAR and NRR are not currently expected to significantly improve groundwater quality during periods of high groundwater levels due to the amount of soil and legacy groundwater nutrients mobilised by the rainfall events.

Over time, as the concentrations of legacy nutrients reduce and on-farm/catchment scale enhancements increase in magnitude, the impact of these enhancements are expected to become more noticeable. Given the dominating influence of rainfall over other factors affecting surface and groundwater quality and quantity, at an annual timescale the rainfall variation influence can be reduced by only comparing annual water quality and quantity results between years with similar annual rainfall. Within these comparisons, rainfall intensity, rainfall timing and initial groundwater conditions are still likely to contribute to concentration variance, but these contributions are expected to be less significant than that of total rainfall. For Figure 1-2, 'wet' year comparisons can be undertaken for 2018[1] and 2022 monitoring results, while 'dry' year comparisons can be undertaken for 2016 and 2021 results. There was no MAR or NRR prior to June 2016, and only one MAR site prior to scheme expansion in late 2018. The 2018/22 and 2016/21 equivalent annual rainfall comparisons are therefore the first 'before' and 'during' comparisons for MAR / NRR. Adjusted rainfall totals were <1% higher for 2022 compared with 2018. The annual median PC2 nitrate-N concentration was 2% higher in 2022. Adjusted rainfall totals were 4% lower in 2021 compared with 2016. The annual median PC2 nitrate-N concentration was 6% lower in 2021. Acknowledging the multiple potential concentration influencers noted above, these results suggest no significant change in median nitrate-N groundwater concentrations for the recent 'wet' and 'dry' year comparisons. Earlier comparisons (e.g., 2008, 2010, 2012) show increasing nitrate-N concentration for similar annual rainfall.

It will take many years of monitoring before enough similar annual rainfall total sets can be utilised for more in-depth trend analysis. In the meantime, another analysis option is the moving average, which smooths out the rainfall influence by calculating the average of the annual median concentrations over a multi-year time period. As an example, the gold dotted line in Figure 1-2 shows the five-year moving average nitrate-N concentration increasing until 2015, then stabilising. Rainfall variation in five-year averages is still 40% for this dataset. This variation reduces to 10% for a ten-year moving average, but the analysis can then only begin in 2015. Section 5.1 includes further discussion on this topic.

[1] Hydrologic years, to the year ending 30 June.

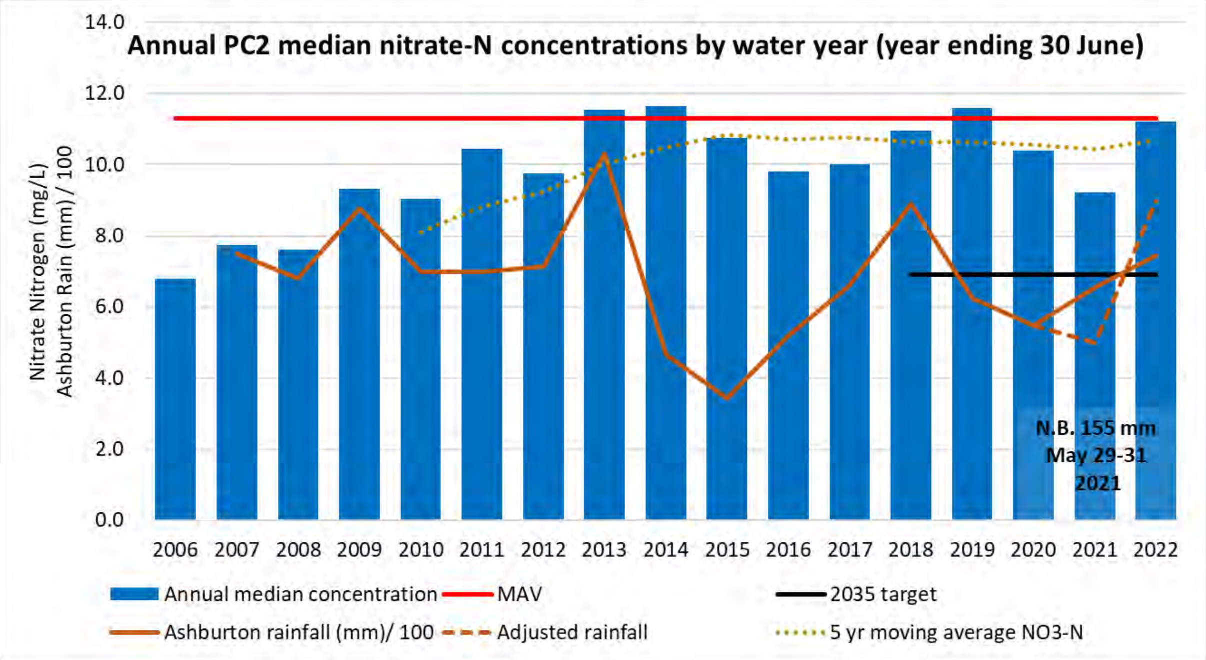

Figure 1-2: Plan Change 2 to Canterbury's Land and Water Regional Plan – Hekeao / Hinds Plains median annual nitrate-nitrogen concentrations plus Ashburton annual rainfall (Source: CRC)

This report focusses on NRR and MAR operational updates, key monitoring information and analysis. Updates are also provided on the other catchment-scale enhancements, which are at an earlier stage of development. Consent compliance monitoring results are presented in the Annual Compliance Report (HHWET, 2022).

Figure 1-3 presents the NRR and MAR sites operational during 2021-22 and Table 1-2 presents their key performance indicators. Testing of MAR source water ensures that it is of high quality. Nitrate-nitrogen, suspended sediment and *E. coli* are the key source quality parameters (as indicators of water quality, MAR clogging risk and down-gradient drinking water risk respectively). Source water from the Rakitata/Rangitata River remained very low in nitrate-nitrogen (<0.2 mg/l) throughout 2021-22 monitoring, though turbidity continued to vary significantly (Table 1-3) and was higher from the 40th to the 90th percentiles than previous years (Figure 1-4). Guidance documents (Golder, 2020; NRMMC, 2009) recommend keeping turbidity in MAR source water less than 10 NTU. Table 1-3 shows that this guideline was exceeded at the RDR Intake almost all the time in 2021-22, however turbidity does reduce as the water travels through the distribution system. Site shutdowns for *E. coli* exceedance totalled 36 (Table 1-2), up from the previous two years and occurring over 30 operational weeks (the lowest to date). It is concluded that the high rainfall in 2021-22 (Figure 1-2) contributed to high turbidity, high *E. coli* exceedance, and the low number of operational weeks.

E. coli is an indicator species used for microbial pathogens, which can pose a contamination risk from faecal material. However, *E. coli* is not necessarily an indicator of human health risk and high concentrations can be present that are not associated with any human health risk (Ishill et al, 2006; ESR, 2019). Through the course of this trial, we have identified four key *E. coli* sources relevant to MAR site management:

1. Birds roosting on water storage ponds;
2. Stock grazing near open water races;
3. Organic plant matter in water races; and
4. Suspended sediment arriving from the Rangitata River.

E. coli from birds roosting on water storage ponds were investigated via an *E. coli* source tracking study during 2018-19. The implementation of a solar powered, laser bird scarer on key storage ponds (with a second bird scarer added in 2021) has contributed to a significant reduction in site shutdowns for *E. coli* exceedance (>=700 MPN/100 ml) for sites down-gradient from water storage ponds. Improved management of water race bank grazing has reduced the risk from irrigation water races. MAR 10 has been our key site for organic plant matter issues from Eucalyptus trees. Investigations to reduce this risk are on-going.

E. coli attached to suspended sediment in the Rakitata/Rangitata River is not expected to be from fresh faecal sources (mammal or avian) due to the travel time and low stocking intensity in the upper Rakitata/Rangitata catchment. Instead, it is likely to be a combination of two 'naturalised' *E. coli* sources:

- Derived from a mammalian/avian faecal origin, but the bacteria have been able to naturalise (replicate) in sediment. Some of these bacteria can still pose human health risks; and
- Escherichia cryptic clades (rarely identified in humans or mammals), most of which are unlikely to cause human health issues.

Due to the challenges associated with assessing naturalised *E. coli* in respect to human health risk as well as the chance that some of these bacteria could pose such a health risk, all *E. coli* in MAR source water is regarded as an indicator of a potential pathogen. Updated modelling of *E. coli* die-off in Hekeao Hinds groundwater (based on Waikirikiri / Selwyn NRR commissioning analysis and developed for an upcoming HHWET consenting process) has concluded that an increase in the current trigger value from 700 to 1000 MPN/100 ml is appropriate for protecting shallow domestic groundwater bores that are at least 340 m down-gradient. The key management tool for avoiding this trigger level is to hold high turbidity / high *E. coli* water in a water storage pond for multiple days before distributing it to a MAR site. This significantly reduces clogging risk as well as *E. coli* risk.

Table 1-2: MAR site performance information for Year 6 (June 2021 – May 2022 inclusive)

June 2021-May 2022	Maximum recharge rate (l/s)	Total recharge volume (m^3)	Weeks in operation	*E. coli* shutdowns	Notes
1 – Lagmhor Pilot	122	1,640,225	30	2	
2 – Timaru Track	72	414,430	26	4	
3 - Walls	19	14,582	7	0	Supply limited to ~30 l/s. Low priority when limited supply.
6 – BCI/Howden	15	180,699	29	2	Supply limited to ~25 l/s
7 - Lobblin	200	963,760	27	4	
8 - Lacmor	14	5,016	2	0	Low priority when limited supply.
9 – Riverbank	41	281,815	30	1	
10 - Foster	35	185,800	23	7	
12 - Slee	56	423,990	23	3	
13 – Hills view	35	373,433	27	2	
16 - Broadfields	18	183,722	29	0	
17b – Jones (NRR site)	100	953,593	26	6	
18 - McDougall	39	294,784	22	5	
NRR1 - South Hinds	350	1,271,575	30		
MH race losses	43	25,920	1		

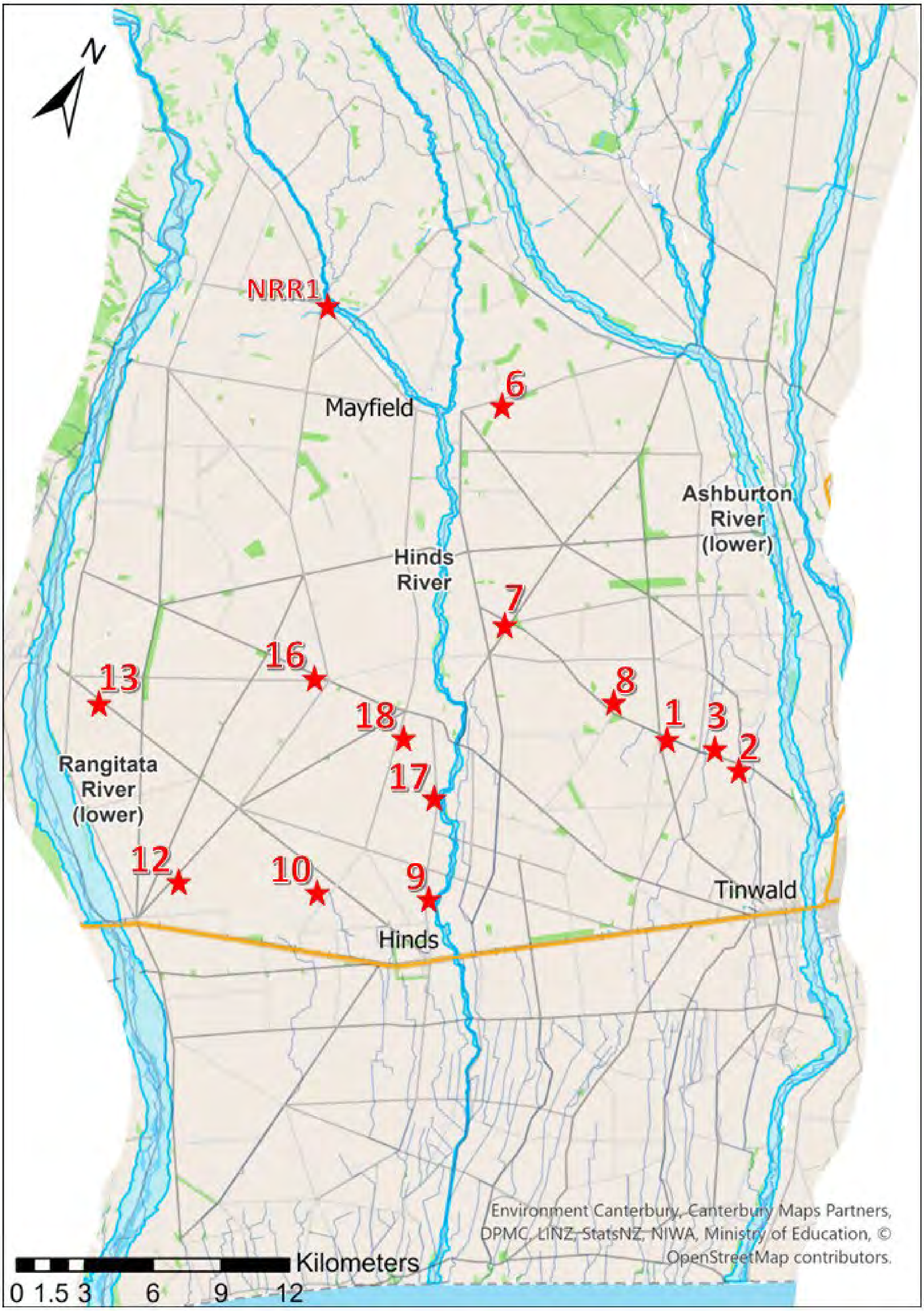

Figure 1-3: Hekeao / Hinds NRR / MAR sites operational during 2021-22

Table 1-3: RDR Intake turbidity distribution for Year 6 (2021-22)

Percentile	RDR Intake Turbidity (NTU)
10	28
20	33
30	38
40	46
50	62
60	90
70	138
80	223
90	691
100	2840

Figure 1-4: Comparison of RDR Intake turbidity distribution (Source: RDRML)

2 Hekeao / Hinds River Project

Chapter 2 of the Year 5 (2020-21) HHWET report provides an introduction to the Hekeao / Hinds Plains hydrogeology and the reasoning behind the Hekeao / Hinds River Project (HHRP). The purpose of the HHRP is to assist in improving the ecosystem health of the whole Hekeao / Hinds River system (in combination with relevant land management practices and other concepts such as constructed wetlands and bioreactors). One of its specific goals is to contribute positively to Canterbury's Land and Water Regional Plan (Plan Change 2) 2035 annual median target of 3.8 mg/l nitrate-N (measured as nitrate-nitrite-N) in the lower Hekeao / Hinds River for 90% aquatic species protection. The key HHRP activity is the addition of clean water to the river system via the concept of Near River Recharge (NRR). NRR is like MAR in that it involves recharging groundwater via leaky basins, wetlands and / or races. However, NRR sites are close enough to contribute directly (via shallow groundwater) to the river reach immediately adjacent and down-gradient of the discharge site.

NRR sites are designed to ensure that water is always filtered through alluvial material before mixing with natural river system water. This filtering process modifies the temperature and potentially the chemistry of NRR water through mixing with groundwater and ensures that there is no direct mixing of NRR water with river water. The shallow groundwater table around NRR sites is raised, which supports the establishment of native plants. The aquatic life of supported wetlands and river reaches is enhanced. Other biodiversity initiatives, such as protection of valued terrestrial plants and / or wildlife, can be progressed at NRR sites as added value.

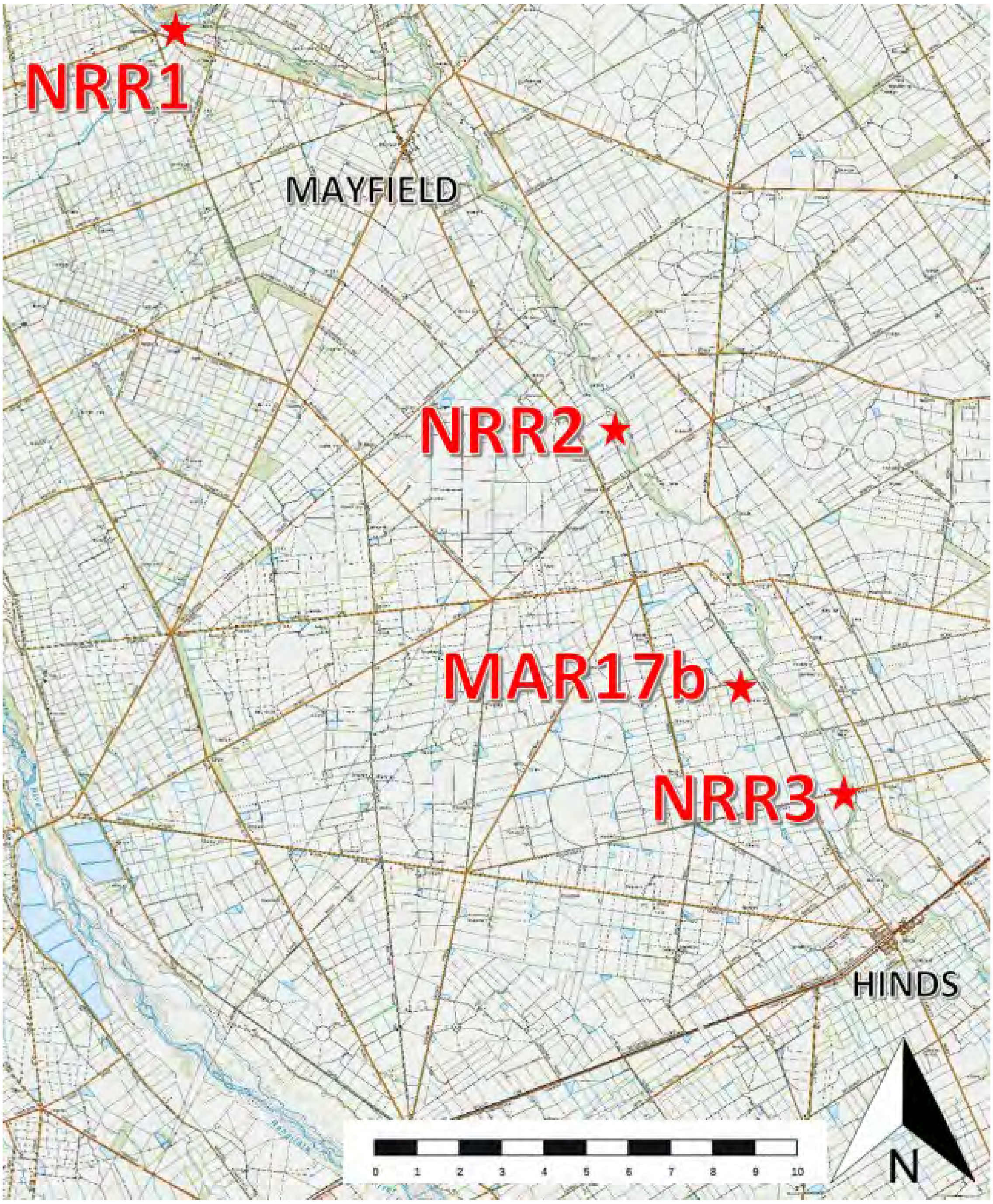

Figure 2-1: HHRP sites

Figure 2-1 shows the location of four current and potential NRR sites. The first site (NRR1) has been operational since September 2018 (Figure 2-2). MAR17b (classified as a MAR site but close enough to the Hekeao / Hinds River to also provide Near River Recharge) began operation in June 2020. During 2020-21, assessment and preliminary design processes were undertaken for NRR2 and NRR3 to support consent applications in 2022-23.

2.1 NRR1 – South Branch Hekeao / Hinds River

This site receives Rakitata / Rangitata River water, via siphon, directly from the Rangitata Diversion Race (RDR). Current maximum consented supply flow is 210 l/s; however, the construction of Phase 2 recharge basins has enabled supply flow up to 350 l/s to be trialled (under compliance discretion) as part of assessments for a long-term discharge consent. In addition to the recharge channels and basins, lizard habitat (under DOC Covenant) has been created away from the flood plain, an oxbow wetland (with potential to establish Kōwaro / Canterbury mudfish habitat) has been rehabilitated and is supported by the raised local groundwater due to NRR, and native plants (wetland and dryland) have been reintroduced.

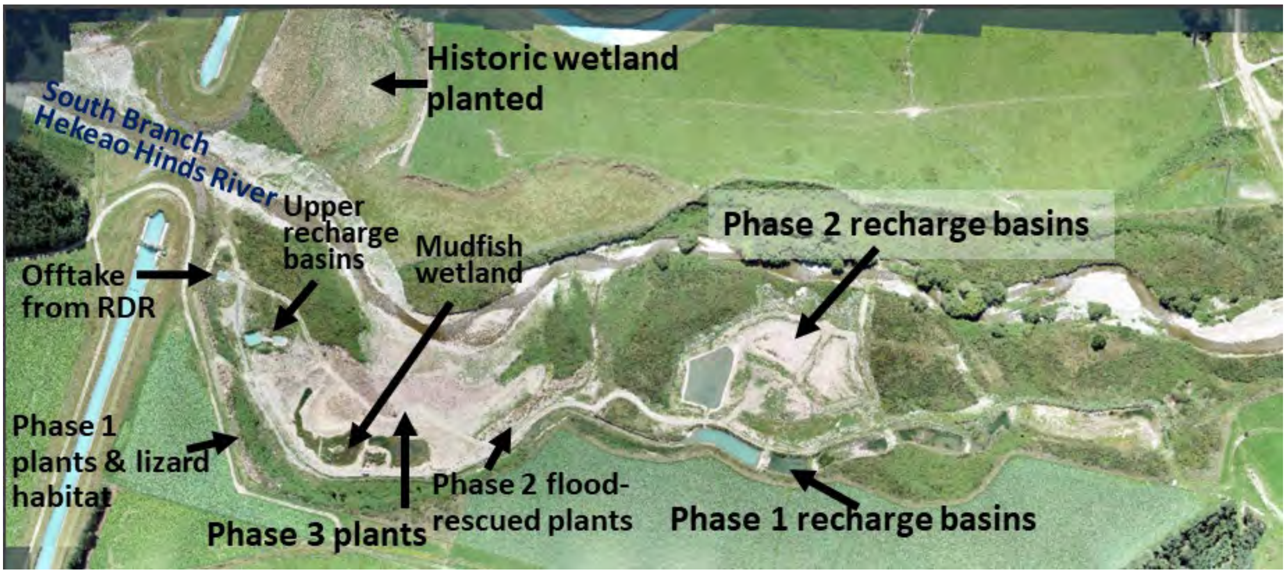

Figure 2-2: NRR1 site overview (2021-22)

From May 29, 2021, three times the average May rainfall fell over a period of 7 days. Flows in the south Branch Hekeao / Hinds River exceeded 200 m^3/s, caused significant damage to this site. Prior to this event, flooding risk to the oxbow wetland, recharge race and recharge basins had been evaluated, and multiple high flow channels had been created to divide high river flows and distribute the risk (top photo, Figure 2-3). While this may have been sufficient for the <70 m^3/s floods previously experienced at the site since 2018, it was not sufficient for a 200 m^3/s flood (middle photo, Figure 2-3). The initial recovery phase involved the creation of a smoother channel for the river to flow past the NRR site then the construction of more significant riverbanks on the true left and right (lower photo, Figure 2-3).

Figure 2-3 also shows that the lower half of the oxbow wetland was destroyed by the flood. The remaining portion of the wetland was retained and extended into the area protected from flooding (by the presence of the Rangitata Diversion Race). The new wetland was divided into three sections. The top section intercepts the raised groundwater created by the initial recharge basins; the middle (clay-lined) wetland is being prepared for the introduction of Kōwaro / Canterbury mudfish and the lower portion (with unlined connection to shallow groundwater) provides secondary habitat for fish that escape from the middle wetland. The clay-lining of the middle wetland ensures that water remains when the adjacent river and/or NRR supply are insufficient to provide continuous supply. The lower wetland recharges shallow groundwater and feeds the recharge race through a rock bund when levels are high enough. Water travels between wetland sections by moving through and over the top of the bunds.

The damage to the recharge race and basins was also repaired and three new basins constructed. The new basins have doubled the NRR1 recharge capacity from ~200 l/s to ~400 l/s. Figure 2-4 shows the original (right) and new (left) basins being refilled after the repair/construction process. Figure 2-5 shows the flooded portion of the NRR site on 31 May 2021, when river flow was less than half the peak flow of ~200 m^3/s on the previous day. In the centre of the photo are three large trees, which had been washed down the river and dug into the sediment at the top of the raised Phase 2 planted area. This seems to have saved the planted area from significant scouring. The plants were able to be dug out of the sediment and have recovered very well. (Figure 2-6). Approximately 8,000 new Phase 3 native plants were then installed, bring the total native plantings in the vicinity to approximately 14,000. These plantings are considered to have contributed to increased bird life in the area, with new birds spotted near NRR1 since 2018 including Australasian Bittern, Marsh Crake, Bellbird, Kingfisher, and White Heron.

Figure 2-3: Hekeao / South Hinds River NRR1 site in March, June and October 2021 (Source: HHWET)

Figure 2-4: NRR1 site original (right) & new (left) recharge basins, October 2021 (Source: HHWET)

Figure 2-5: NRR1 site flooding, 31 May 2021 (Source: RDRML)

Figure 2-6: NRR1 plants rescued from flood debris (left) and then again ~12 months later (right)

Table 2-1 and Figure 2-7 present the monitoring requirements for NRR1 consent CRC210704, with key compliance monitoring results presented in the annual compliance monitoring report. Recharge source water has remained low in nitrate-N and *E. coli* since 2018, but turbidity varies significantly with Rakitata/Rangitata River flow (Table 2-2), meaning that turbidity levels can be very variable. The turbidity trigger for ceasing MAR operations at this site has been set at 100 NTU, with operations resuming when turbidity is below 60 NTU. This is a higher trigger than at other MAR sites as sediment is relatively easy to clean from the recharge basins. Site shutdowns to date for high turbidity occur approximately 20% of the time (with the RDR at Sandtrap turbidity meter used until 3/9/2021 while the NRR1 meter was awaiting a replacement – see Table 2-2 and Figure 2-8). As discussed in Section 1, 2021-22 had the highest prevalence of high turbidity since the project began. The site is also shut down when there are high flows in the adjacent south Hekeao / Hinds River (>5000 l/s), which, to date, have occurred 1.6% of the time.

Table 2-1: NRR1 Monitoring (CRC210704)

Monitoring Category	Parameter	Location	Parameters	Minimum Sampling Frequency
Quantity	Recharge source water	Project Siphon from RDR	flow/stage	15-minute
	River upstream (control)	ECan South Branch upstream of project (#69001)	flow/stage	15-minute
	River downstream (effects)	Temporary Gauge on South Branch at Lower Downs Bridge	flow/stage	15-minute
	Site groundwater Levels	BY19/0107	water level	Hourly
	Groundwater Levels	ADC monitoring information from Mayfield Community Supply - K37/3290	water level	Hourly
Quality	Groundwater Quality	ADC monitoring information from Mayfield Community Supply - K37/3290	Nitrate-Nitrogen, *E. coli* bacteria	Monthly sampled by ADC
	Site groundwater quality	BY19/0107	Nitrate-Nitrogen, *E. coli* bacteria	Monthly
	Source (recharge) water	Project Discharge Siphon	Nitrate-Nitrogen, *E. coli* bacteria, Turbidity, TSS	Monthly, except Turbidity which is measured hourly
	River upstream (control)	Site Inflow Source (#SQ35799)	Nitrate-Nitrogen, *E. coli* bacteria, Turbidity, TSS	Monthly
	River downstream (receiving waters)	Temporary Gauge on South Branch at Lower Downs Bridge	Nitrate-Nitrogen, *E. coli* bacteria, Turbidity, TSS, DRP	Monthly
Aquatic Ecology	River downstream (effects)	Recharge Above Temporary Gauge on South Branch at Lower Downs Bridge	Electro-fishing Survey, didymo	Annually (Fish and Game, ECan)

Table 2-2: NRR1 intake turbidity distribution for the period from 3/9/2021 to 31/5/2022

Percentile	Turbidity, 3/9/2021- 31/5/2022 (NTU)
10	6
20	8
30	10
40	15
50	23
60	41
70	46
80	77
90	161
100	1,190

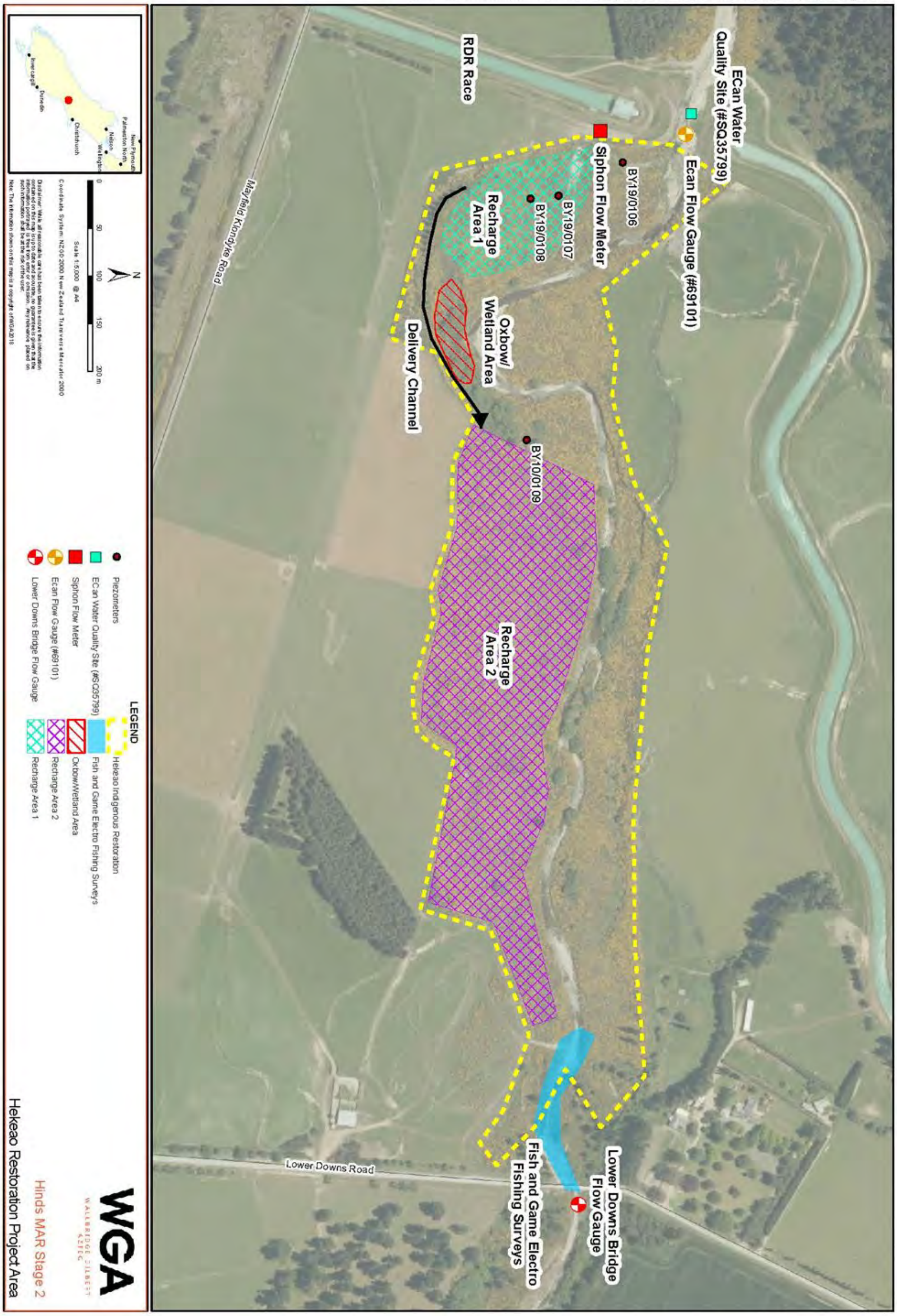

Figure 2-7: NRR1 monitoring points (Source: HHWET Year 2 report)

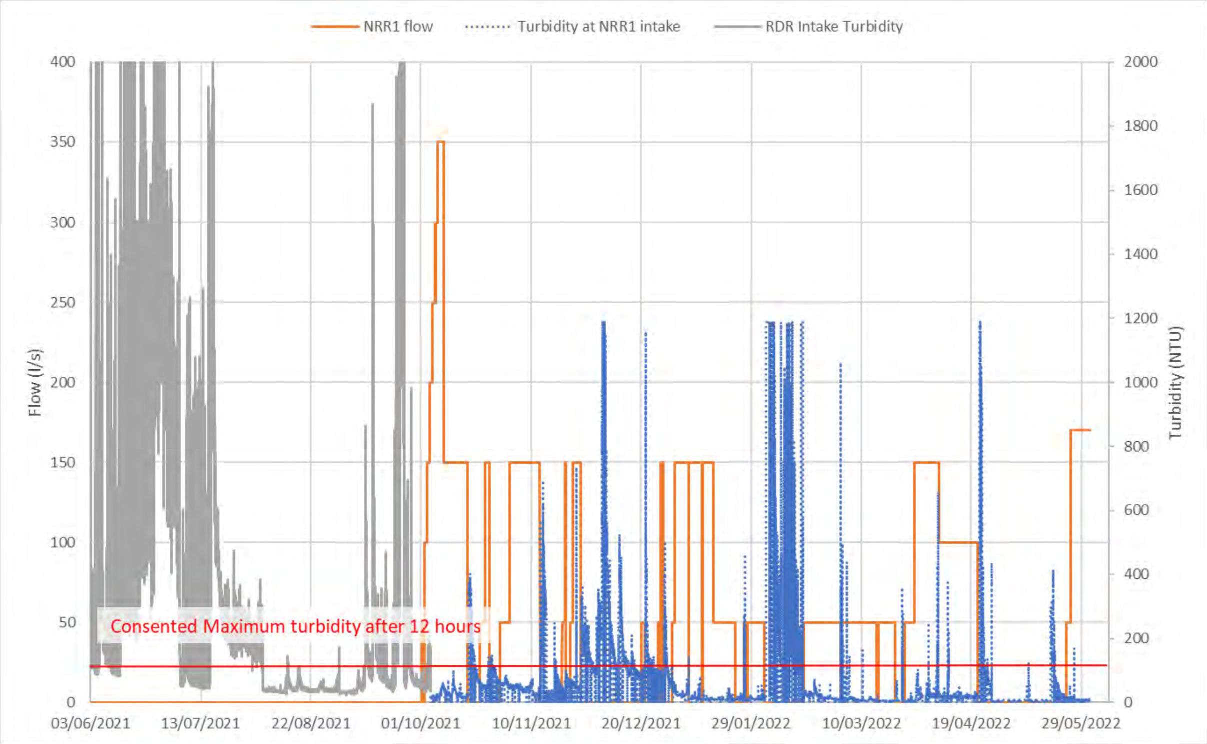

Figure 2-8: NRR1 turbidity monitoring (Source: HHWET)

2.1.1 Water quantity monitoring

Figure 2-9 compares up-gradient Hekeao / Hinds River flow (RDR Siphon #69101) with NRR1 flow and down-gradient river flow (Lower Downs #69106). When the NRR1 site is turned on site #69106 responds within a day, showing a flow increase less than the supplied NRR1 flow. This suggests that NRR1 flow is recharging local groundwater as well as the river. Sites #69101 and #69106 produce similar flows when the NRR1 site is turned off, thus flow differences can be attributed to NRR1 recharge. The flow differences vary with river flow, but the low river flow periods in February 2020 and April 2021 suggest that up to 60 l/s may be recharging groundwater at the site (i.e., not reaching the local river reach). The median Year 3-5 flows of 100 l/s at Site #69101 and 168 l/s at Site #69106 suggest a 68% increase in median flow due to NRR1 recharge. The proportion of time the reach flowed at less than 50 l/s also reduced from 33% to 6%, which is a significant improvement for fish in this reach.

Year 6 (2021-22) flow at #69101 shows flows of less than 150 l/s only occurred during October/November 2021. This is a shorter total duration of low flows than previous years. The May 2021 flood destroyed the #69106 flow recorder, and it is unlikely to be re-established. This flood also resulted in the shortest operating year and smallest annual recharge volume at NRR1 to date. NRR1 flow is shown to briefly peak at 350 l/s in early October 2021. This was due to a high flow test (with compliance discretion) to support a consent application for the upgraded NRR1 site. Flow was increased in 50 l/s increments over a week, held at 350 l/s for two days, then reduced back to 150 l/s. During the 350 l/s recharge days, all six original basins and the top new basin were at capacity, however, new basins two and three were below capacity (see Figure 2-4). This informed a consent application for increasing maximum recharge rate from 210 l/s to 410 l/s.

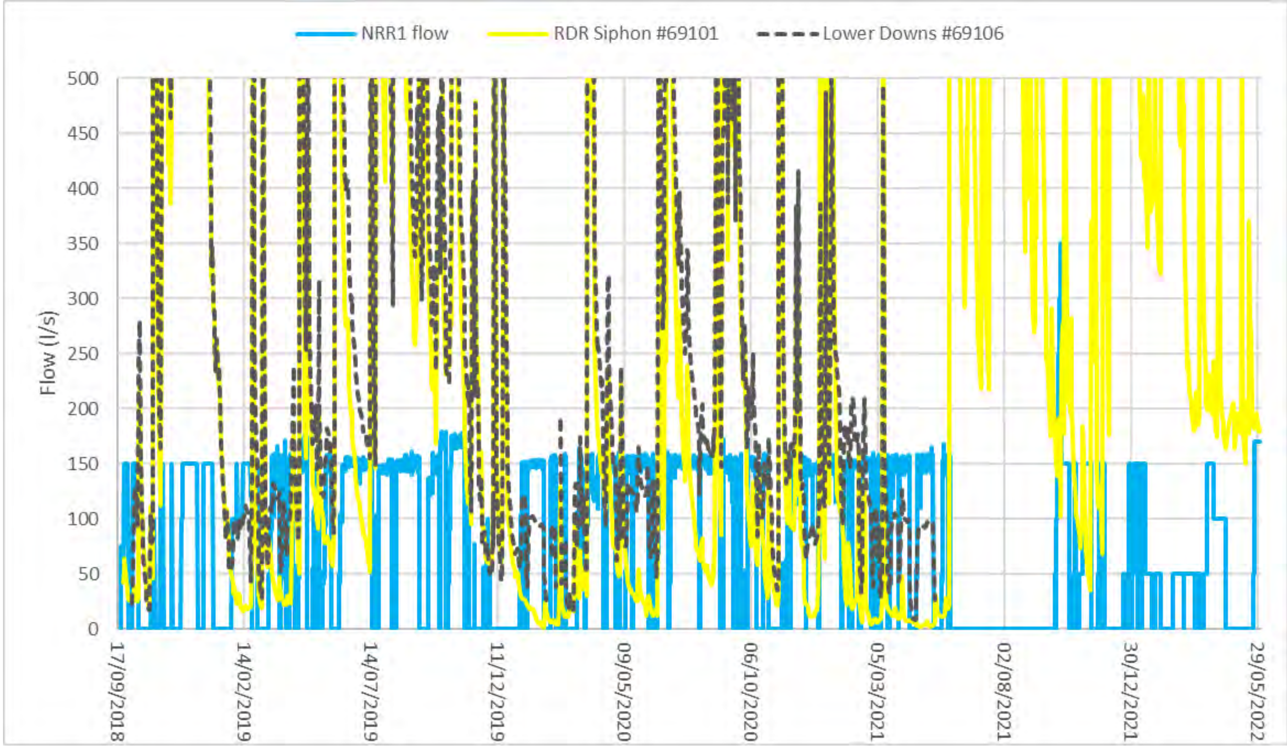

Figure 2-9: NRR1 and Hekeao / Hinds River flow (Source: HHWET, CRC)

NRR1 effects on down-gradient surface flow and nearby groundwater are presented in the Year 4 Annual Report (HHWET, 2020). Figure 2-10 presents the location of groundwater bores and flow site #69106, plus minimum depth to groundwater contours in green (increasing with increasing distance from the river). Barrell et al. (1996) suggested that the Montalto Fault line, along Lower Downs Rd (site #69106), may cause localised controls on groundwater flow, though there is not sufficient data collected for this project to show any effects from this. The Year 4 study showed that, for river flows of up to 500 l/s at the Lower Downs Road Bridge (site #69106 - 6 km upstream from the confluence with the North Branch), all flow is recharged to groundwater by approximately 3 km upstream from the confluence. For higher flows, groundwater recharge in this reach is at least 350-450 l/s, with the remainder of the flow retained within the river.

Groundwater levels in the shallow (2.3 m deep) bore (BY20/0222) respond quickly to increases in flows at #69106, with subsequent increases in flow in Silverstream, which occupies a lower elevation just north of the Hekeao / Hinds South branch. Silverstream also receives recharge flow from the Hekeao / Hinds North Branch when this is flowing. Silverstream provides the only surface flow at the confluence of the Hekeao / Hinds South and North Branches during low flow conditions, and during these periods, NRR1 flow can therefore be expected to measurably increase Silverstream flows as well as the Hekeao / Hinds South Branch immediately below the NRR1 site. To improve habitat, key reaches of Silverstream have had their banks planted, which will decrease water temperature via shading and improve riparian habitat for birds and insects.

The Year 4 study also considered NRR1 recharge effects to the true right of the Hekeao / Hinds South Branch via analysis of the four bores presented in Figure 2-10. Of these bores, K37/0278 is shallow (depth 16 m) while the other three are deep (84 to 145 m). K37/0278 was found to respond quickly (within days) to freshes of greater than 500 l/s (Figure 2-11); that is when the Hekeao / Hinds South Branch is flowing down to its confluence with the North Branch. When only Silverstream is flowing, K37/0278 still shows small fluctuations, suggesting that the two are connected near the confluence of the three Hekeao / Hinds River tributaries as well as the South Branch above the confluence. We can therefore conclude that K37/0278 groundwater levels are influenced by NRR1 recharge. In 2021-22, the bore reached its highest level to date (1.4 m below ground) during the May 2021 flood. Groundwater level changes followed river flow changes, as in previous years, and were higher on average due to the higher-than-average river flows and land surface recharge.

The Year 4 South Branch recharge study (HHWET, 2020) shows river losses between the Lower Downs Bridge (site #69106) and the confluence with the North Branch Hekeao / Hinds River. Cumulatively, this evidence still suggests that increased NRR1 flowrates / flow volume will be beneficial for shallow groundwater levels on both sides of the South Branch when groundwater levels are low.

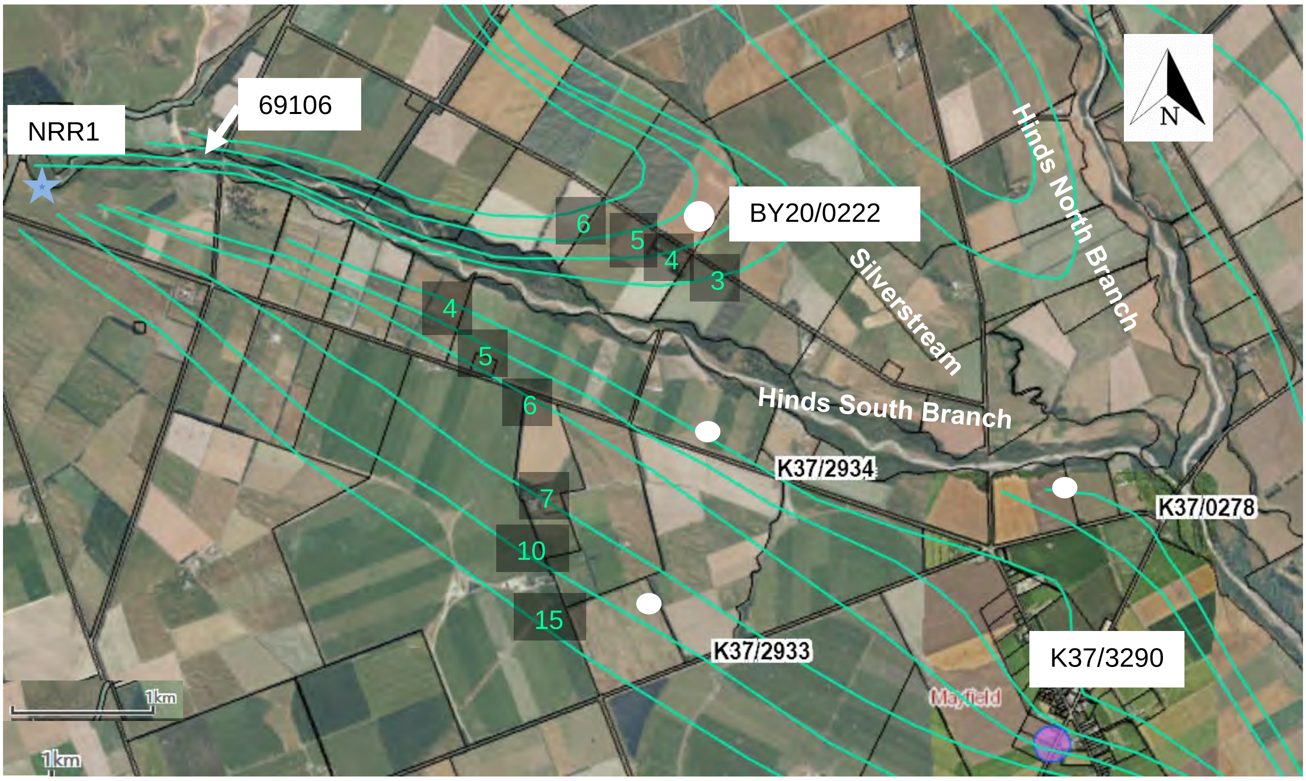

Figure 2-10: NRR1 down-gradient monitoring wells and minimum depth to groundwater contours (in m) (Source: Canterbury Maps)

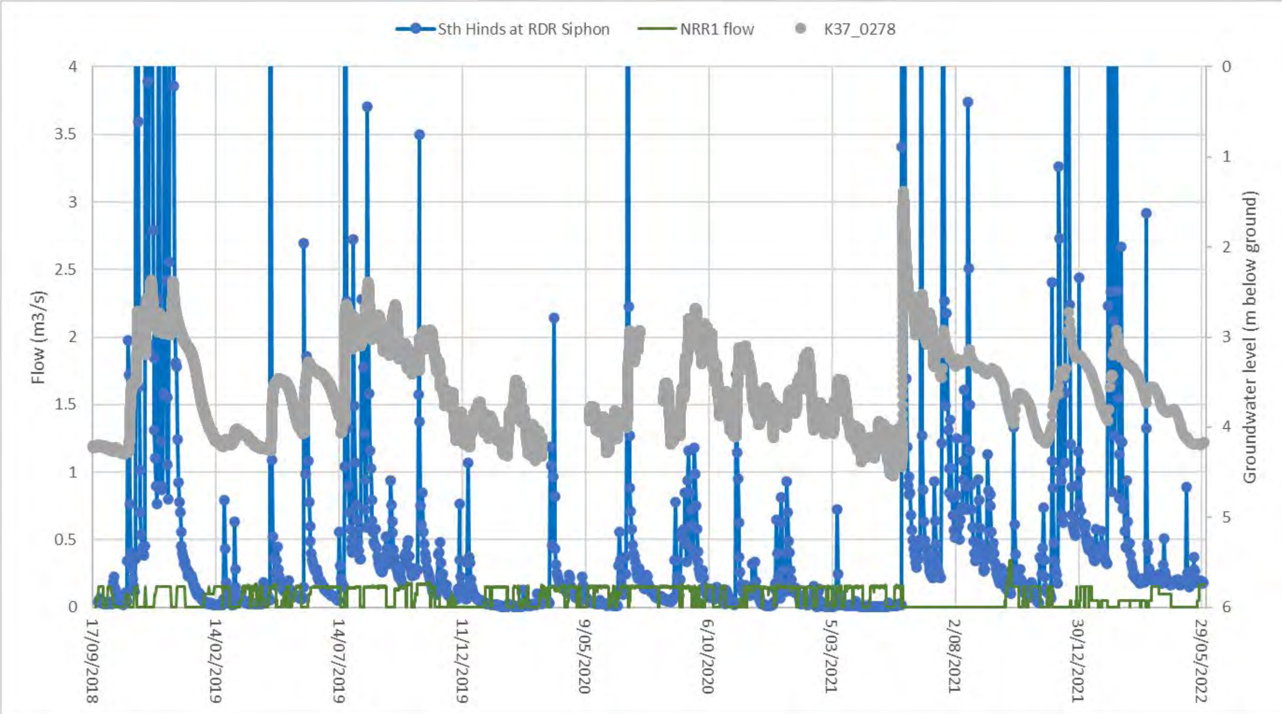

Figure 2-11: NRR1 flow, Hinds River flow and K37/0278 groundwater level (Source: HHWET, CRC)

Figures 2-12 and 2-13 compare Hekeao / Hinds River flows (up to 4 m^3/s) at the RDR Siphon (up-gradient from NRR1), NRR1 flow and depth to groundwater in bore K37/2934 and the Mayfield community supply bore (K37/3290). These deep (145 m and 119 m respectively) bores show a delayed (at least 25 days), damped response to major rainfall events (with river flows used as a surrogate for land surface recharge from rainfall in Figures 2-12 and 2-13) and declining levels at other times. In addition, K37/3290 shows significant daily variation in response to pumping. During the 2015/16 drought the groundwater levels in this bore dropped approximately 25 m (from a high in 2014 to more than 119 m below ground level). This evidence suggests the bores are in an aquifer with significant groundwater level variation and groundwater level changes primarily determined by significant weather events and long-term weather patterns.

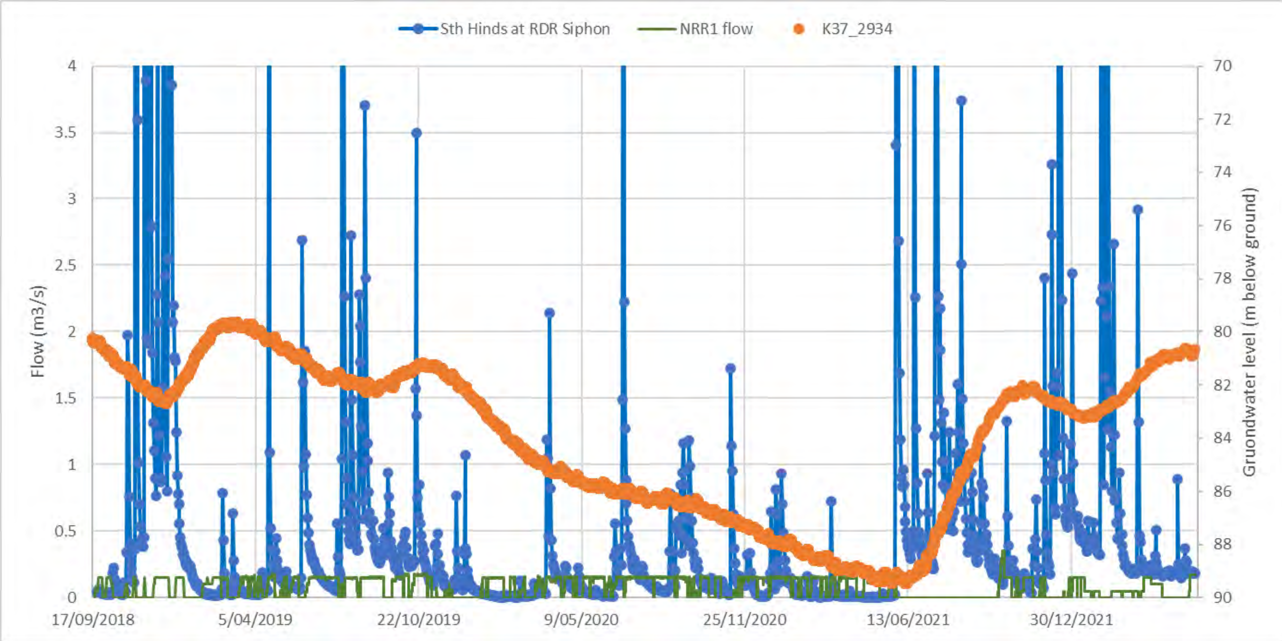

Figure 2-12: NRR1 flow, Hekeao / Hinds River flow and K37/2934 groundwater level (Source: HHWET, CRC)

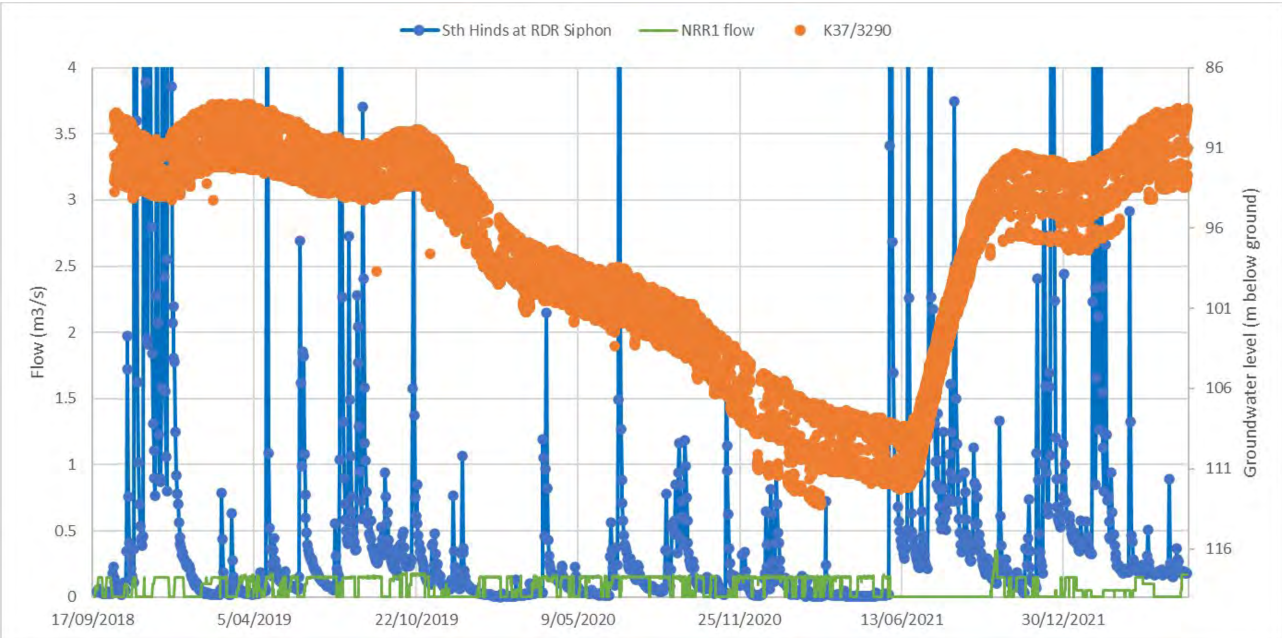

Figure 2-13: NRR1 flow, Hekeao / Hinds River flow and K37/3290 groundwater level (Source: HHWET, CRC, ADC)

2.1.2 Water quality monitoring

The key risks with regards to water quality are *E. coli* and nitrate-N. (The advice note for discharge consent CRC210704 required consideration of an *E. coli* and a nitrate source water trigger level for site shutdown following its first year of operation, to ensure protection of the receiving environment). The Year 4 report analysis results (HHWET, 2020) showed that high quality water is being recharged and therefore *E. coli* or nitrate trigger levels for site shutdown were not required, and hence these are no longer monitored for. Nitrate-N in the Mayfield community bore (K37/3290) continues to stay at around 2-3 mg/l. Year 4 analyses also showed that water quality in BY19/0107 (6 m deep, see Fig. 2-7 for location) is more representative of nearby river water than NRR1 source water. Therefore, for the replacement NRR1 discharge consent, groundwater monitoring is proposed to be moved to BY19/0108, which is situated down-gradient from recharge basins.

In the adjacent river reach (as measured at RDR Siphon, at Site #69101), nitrate and *E. coli* was shown to increase after rain events. In order to minimise the potential contribution of nearby Gawler Downs tributaries (entering the south Branch Hekeao Hinds from the true left, between the RDR siphon and the Lower Downs Bridge) to this increase in contaminants, paddocks at the base of these tributaries are being fenced off, stock are excluded, and native plants introduced to filter sediment, nutrients and bacteria. 1.5 ha was planted in October 2021, with the remaining 1 ha expected to be planted in Autumn 2023. This will bring the total native plantings in the vicinity to approximately 18,000.

2.1.3 Aquatic Ecology monitoring

The Hekeao / Hinds River is a priority for restoration of ecosystem health and recreation amenity, as part of the HHWET enhancement projects. To monitor long term changes in fish diversity and population sizes and any potential NRR influence, Central South Island Fish and Game, along with CRC, implemented monitoring surveys in 2017. Surveys comprise an assessment of fish diversity and abundance by electric fishing at two sites in the lower river, below SH1, and one upper river site downstream from the NRR1 site as detailed in Table 2-1 (aquatic ecology monitoring). All sites are 30 m long with upstream and downstream nets used to enable diminishing-return population estimates to be calculated.

At the Hekeao / South Branch Hinds site only three fish species have been found during the October-December surveys: Upland bully, Canterbury galaxias, and a single adult long finned eel. In an additional electric fishing survey in May 2019, two brown trout at 180mm and 187mm, were caught at this site. Figure 2-14 shows a step change in Upland bully and Canterbury galaxias populations since NNR1 began operations in late 2018. The May 2021 flood did not have a detrimental impact on either species, with the largest total to date recorded in the May 2022 survey. The lack of eels and trout combined with improved flows due to NRR1 are likely to be key contributors to increased population levels for Canterbury galaxias and Upland bully.

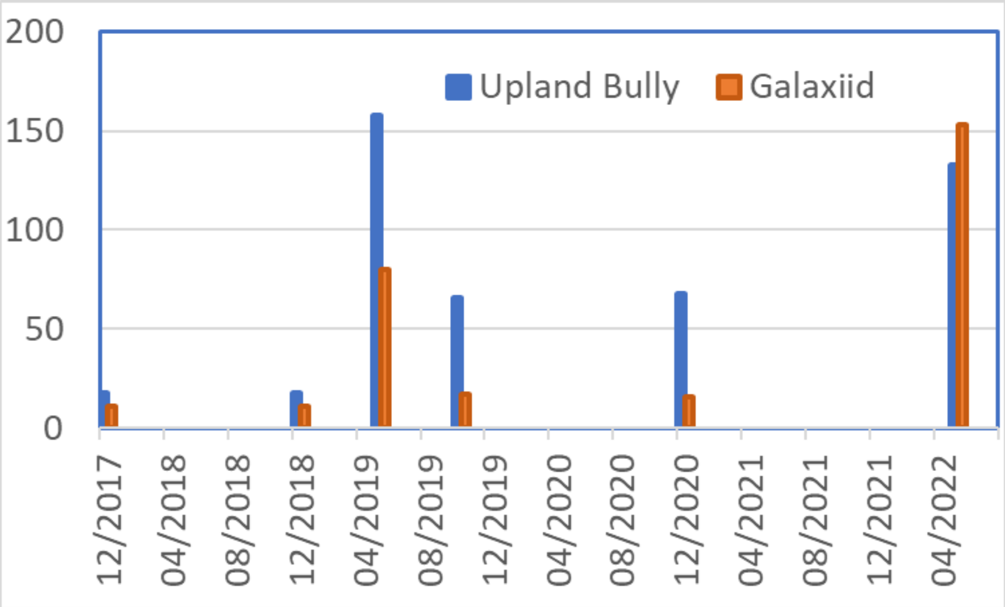

Figure 2-14: Hekeao / South Branch Hinds River at Lower Downs Rd Bridge, annual fish population estimates per 30 lineal metres, 2017 – 2022 (Source: Central South Island Fish and Game)

Additional aquatic ecological monitoring was initiated above (RDR Siphon) and below (Lower Downs Bridge) the NRR1 site for the first 18 months following NRR1 commissioning in September 2018. This consisted of monthly invertebrate monitoring, carried out using the Stream Health Monitoring and Assessment Kit (SHMAK) method, and quarterly fish monitoring, using a single pass electric fishing machine method (EFM), over a 50m reach, to provide a semi-quantitative estimate of fish abundance and species present. The results of this study showed higher populations of Canterbury galaxias and bully species at the Lower Downs Bridge site compared to the RDR Siphon site, plus invertebrate communities at both sites that are reflective of good water quality and habitat under relatively stable flow conditions (see Dynes, 2020 and HHWET, 2020).

The NRR1 wetland Management Plan (McMurtrie 2020a) specifies a range of monitoring requirements to confirm habitat suitability prior to actioning the Kōwaro Transfer Plan (McMurtrie 2020b) and DOC Kōwaro Transfer Permit (Authorisation number 82103-OTH). Telemetered equipment to monitor temperature, water level and dissolved oxygen in the primary and downstream wetlands was installed in Autumn 2022. Monitoring results will be reported alongside habitat and fish surveys in future Annual Reports.

2.2 MAR17b – Lennies Road

A second active NRR site (MAR17b) is close to Lennies Road. This site began operations in June 2020, so has now completed two full years of operation. MAR17b (Figure 2-15) is covered by MAR discharge consent CRC210702 and has a maximum discharge flowrate of 100 l/s. However, its proximity to the Hekeao / Hinds River (between 250 and 700 m) means that under no or low flow river conditions, we can expect this site to raise shallow groundwater levels close to the river and therefore contribute to surface river flow when local groundwater levels are high enough. An advantage of situating a MAR / NRR site close to, but outside, the immediate flood plain is a lower risk of sustaining damage in a flood event, and no flooding damage occurred at this site following the May 2021 floods.

Figure 2-15: MAR17b, with Hekeao / Hinds River margins in the background (Source: M. Neutze)

Section 2.2 of the Year 5 Annual Report presents an analysis of the positive contribution of MAR17b to Hekeao Hinds River flows during the 2020-21 summer period. Natural river flows were higher during the 2021-22 summer than the previous summer, so a comparative assessment was not undertaken this year. Following an operational shutdown after the May 2021 floods due to high groundwater levels, MAR17b continued to recharge within the range of rates achieved prior to the floods (Figure 2-16). Over 2.5 million m^3 has been recharged at MAR17b over the past two years, making it the second most productive MAR site after MAR01 (the Pilot site). An increase in maximum discharge rate to 180 l/s is proposed for the replacement discharge consent in process.

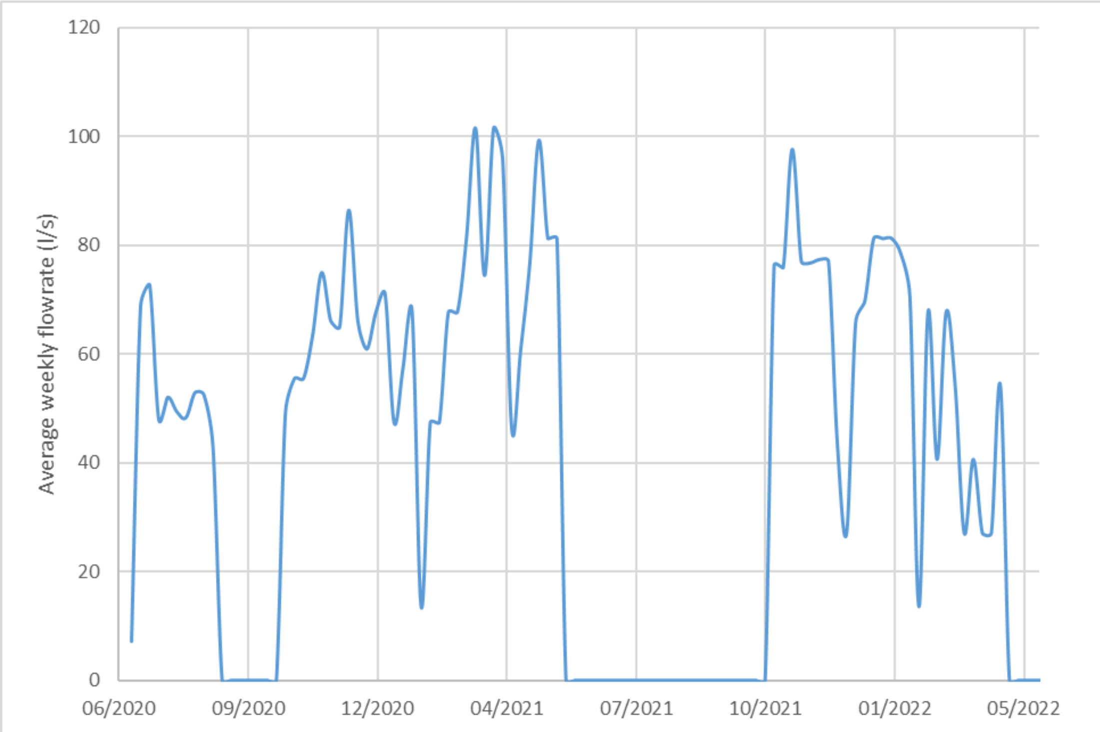

Figure 2-16: MAR17b discharge average weekly flowrate (Source: HHWET)

2.3 NRR2 and NRR3 – Next steps NRR sites

As noted at the beginning of this chapter, the purpose of the NRR sites is to assist in improving the ecosystem health of the whole Hekeao / Hinds River system. Anticipated benefits (particularly during low flow/groundwater periods) include increased flow, decreased water temperature, increased groundwater levels, decreased nitrate concentrations, and increased fish habitat. With NRR1 and MAR17b producing measurable benefits to date, two further sites have been identified and assessed with the aim of providing similar benefits in other reaches of the river. Key to the position of these sites is the presence of an existing MHV Water discharge race and available land for recharge basins with relatively low flooding risk.

Figure 2-17: NRR sites and spring locations (Source: Canterbury Maps)

Figure 2-17 shows NRR2 (just upriver from the Pooles Road crossing) and NRR3 (at the Winslow / Fountaines Rd crossing), situated either side of MAR17b. NRR2 is located in a reach of the Hekeao / Hinds River that is often dry, with river recharge and other shallow groundwater emerging in nearby springs (green dots in Figure 2-17, mostly to the true left) which feed a series of drains that discharge back into the Hekeao / Hinds River further downstream. The aim of NRR2 is to increase flows in these drains by recharging groundwater with low nutrient water. This will occur when they are not naturally running at above average flows, and will contribute to improved ecosystem health in the lower Hekeao / Hinds River due to both increased flow rates during periods of below average flows and higher quality water.

NRR3 is approximately 12 km upriver from the perennial reach of the Hekeao / Hinds River, which begins down-river from SH1. Together with the anticipated up-river flow support provided by NRR1, NRR2 and MAR17b, NRR3 could enable a significant increase in the length of the flowing reach of the river when, without NRR, it would otherwise be dry to below the SH1 bridge.

During Year 6, flood modelling, preliminary design (e.g., Figure 2-18) and consent planning assessments were completed for NRR2 and NRR3 to add to the river engineering, ecological and cultural assessments completed in Year 5. The flood of May 29-31, 2021, provided additional information for fine tuning the flood modelling and design processes for these sites.

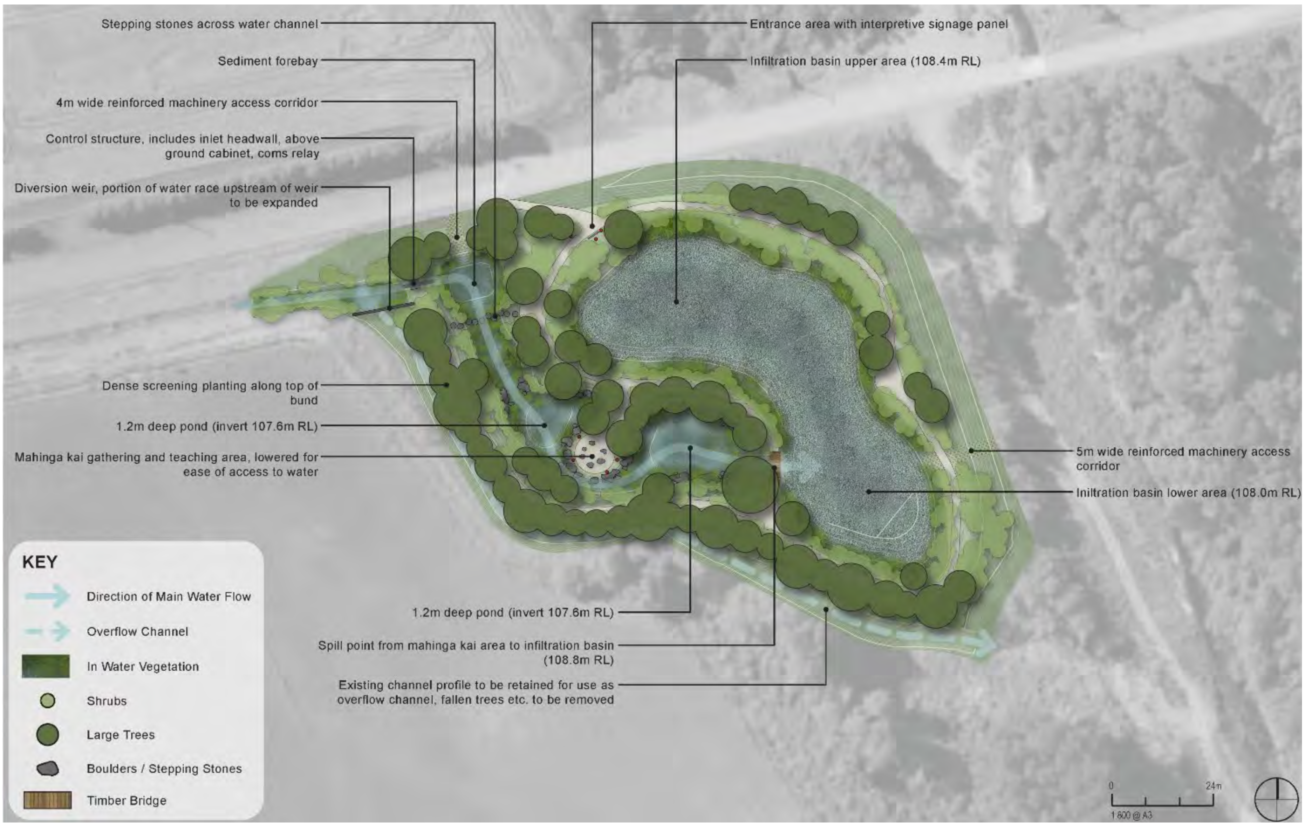

Figure 2-18: Draft concept for NRR3 site (Source: Boffa- Miskell)

2.4 Lower Hekeao / Hinds River

The lower Hekeao / Hinds River is a groundwater-fed waterway most of the time, supplied via springs in and near the riverbed as well as by one of its four primary groundwater-fed tributaries (Northern, Taylors, O'Shaughnessy's, and Montgomery's Drains – see Figure 2-19). Water quality and quantity at the Hekeao / Hinds River Lower Beach Road monitoring site is therefore influenced by climate, land management and enhancement activities through the central portion of the Hekeao / Hinds Plains up to the foothills. No other single current monitoring site across the catchment covers a greater proportion of the catchment.

The lower catchment waterways support valued mahinga kai, native fish and non-native fish habitat. Due to the complexities of the catchment influences on these waterways and their high ecosystem values, the Ashburton Zone Committee recommended the formation of the Hinds Drains Working Party in 2014 to develop a set of action / management plans. The Hinds Drains Working Party Final Recommendations were duly delivered in early 2016. In mid-2022 a 5-year summary of progress to date was prepared and discussed with the Hinds Drains Working Party (HDWP, 2022). The 2016 HDWP Report made 16 key recommendations to the Ashburton Zone Committee, with the key recommendations divided into a total of 86 specific actions. Table 2-3 shows that nearly half of all actions have been mostly or fully achieved to date. Only ~13% of actions are yet to begin.

Specific recommendations are relevant to HHWET activities and the lower Hekeao / Hinds River. These are summarised, along with progress to date, in Table 2-4. The 19 relevant actions (under 7 recommendations) comprise 22% of the total HDWP actions. Very good progress is shown under 5 of these recommendations, with on-going efforts to clarify and confirm the status of remaining consented Hekeao Hinds River surface water takes. The two recommendation areas noting “some work still to do” are ‘Native Species’ and ‘Sports Fishery and Waterfowl’. While it is acknowledged that it will take time for positive changes across the Hekeao / Hinds Plains to result in habitat resilience improvements for native and non-native fish, this review highlights the importance of targeting highly valued species and habitats in enhancement projects. A further progress review is intended in 2024/25, providing HHWET and other relevant parties with a timeframe to achieve tangible progress against these recommendations.

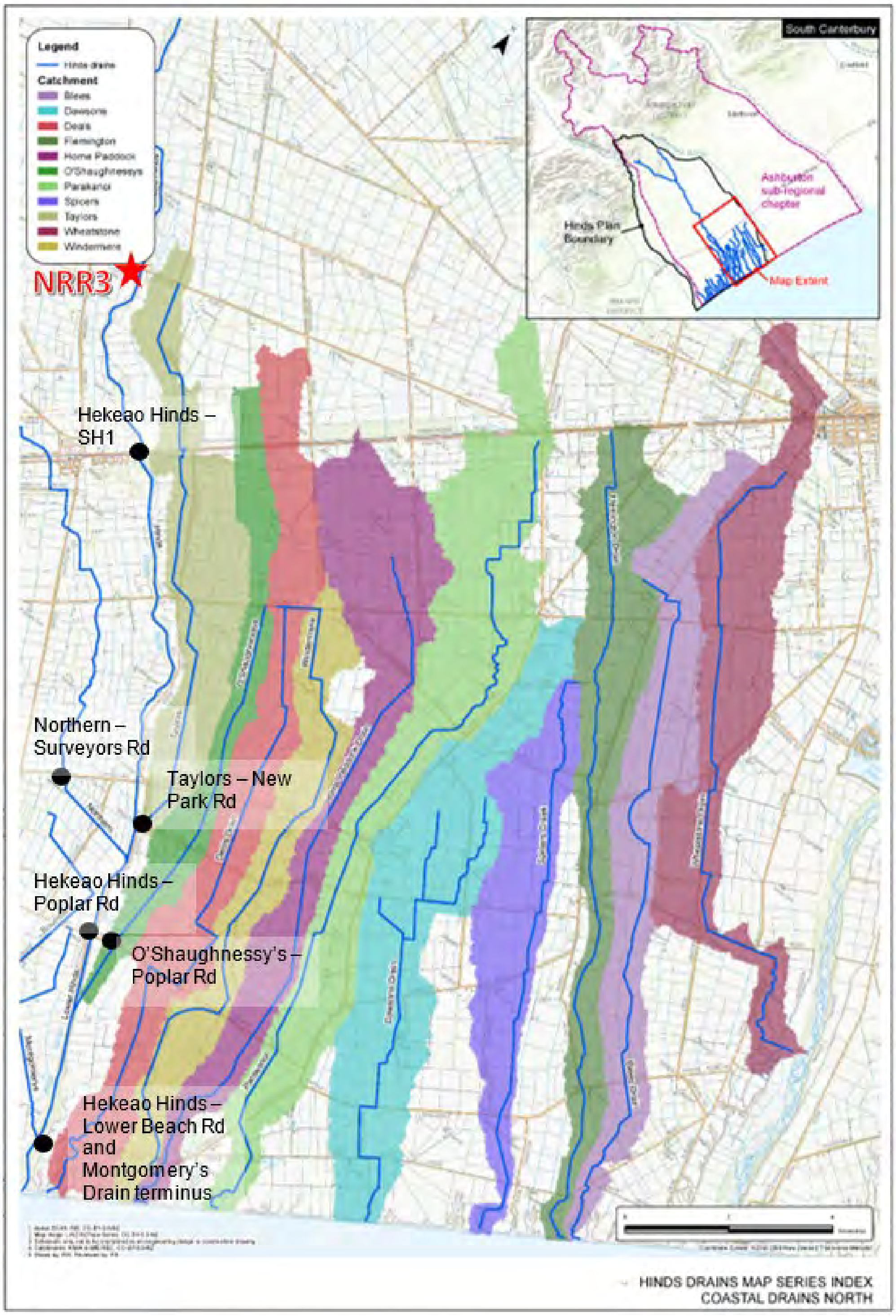

Figure 2-19: Hekeao / Hinds River monitoring sites (Source: HDWP)

Table 2-3: HDWP Progress Review summary (HDWP, 2022)

% of actions	Progress against recommendations
29	Complete or fully achieved.
20	Mostly achieved. Good progress made to date.
36	In progress. Some work still to do.
5	Not started.
4	Not applicable or eligible yet.
4	Still requires investigation.

Table 2-4: HDWP progress specifically relevant to HHWET activities (from HDWP, 2022)

Recommendation	Action	Progress to date
4.1 MINIMUM FLOWS AND MINIMUM FLOW MEASURING SITES	4.1.1 Measure impact of MAR & TSA; then develop new minimum flow and allocation regimes.	The HHWET report provides an update on MAR/NRR/TSA programmes and the monitoring these are undertaking to establish the impacts they have on drain flows & groundwater levels. PC7 extended the date for establishing minimum flows to 2030. TSA is also being considered for drains south of Eiffelton Scheme. Requires low nitrate-N water and clarity on consenting (e.g., new non-consumptive consent, supplementary access to existing irrigation consents, or consent transfer via LWRP Rule 13.5.30 condition 1).
	4.1.4 No new abstractions are possible.	No new abstractions have been granted, excepting switches from surface water or stream depleting groundwater to deep groundwater. At 8/3/22 Valetta Groundwater A-block is 150% allocated. Mayfield-Hinds Groundwater A-Block is 95% allocated. The rules in the plan establish the swaps to deep groundwater - Rule 13.5.30.
4.7 EFFECTIVENESS OF MAR AND TSA & LONG-TERM IMPACTS ON THE DRAINAGE NETWORK	4.7.1 Key points to recommendation.	MAR projects are putting water into the aquifer system as it is available. Because of constraints on flows, gains in biodiversity & flows are yet to be realised. Planning is underway to rectify this. The Hinds River has shown an increase in flowing length with MAR effects creating an increase in biodiversity and decrease in nitrates.
	4.7.2 Policies and rules relating to MAR & TSA.	New PC7 Rules (5.191-5.193) and Schedule 32 MAR Plan. These provisions are included in the decisions version of PC7.
	4.7.3 MAR pilot Governance.	Governance Group was established with representation as recommended.
	4.7.4 Governance post-MAR trial.	Governance for MAR has been established via the Hekeao/Hinds Water Enhancement Trust. Ongoing funding has been secured in Environment Canterbury's LTP via a target rate for the project.

4.8 **IN-STREAM AND HABITAT RESTORATION INCLUDING FISH PASSAGE**	4.8.2 Trial fish habitat enhancement techniques - lower Hinds River.	A joint project between Environment Canterbury and Fish & Game with Fonterra funding support has trialled creating fish habitat in the lower Hinds by placements of large rocks. The large flood in June 2021 has filled in gravel around the rocks, but rocks remain and will continue to interact with further floods to create habitat features. This work has led to further trials of different rock weir designs (outside of the Hinds Drain). Further liaison with the River Engineers is needed to develop opportunities for habitat creation associated with gravel and river works. Artificial river mouth opening has not yet been investigated, as secure river flows are needed to maintain openings, so work on improving Hinds flow should be completed first. Observations indicate that NRR is having a positive impact on allowing access for fish from Hinds River to Tributaries below SH1. No specific monitoring has been undertaken.
4.11 **NATIVE SPECIES**	4.11.1 Native species priority.	Work underway on improving water flow & quality and riparian management will all contribute to improving native fish species potential habitat in all drains.
	4.11.2 Canterbury mudfish habitats identified and protected.	DOC is undertaking habitat surveys as staffing and resources allow. It is acknowledged that changes in flows, including stockwater race closures, are impacting on mudfish habitat. Possible future action - surveys & development of enhancement plans could be led by other providers if funding was available. Consider flow enhancement via TSA. DOC has been involved in two such projects in the Selwyn District. No habitat enhancement has occurred as yet.
	4.11.3 Fish habitat enhancement post water augmentation.	Not yet due as water augmentation has not begun, however, work that is already underway on improving riparian and springhead management will contribute to this recommendation if water augmentation occurs.
4.12 **IMPROVE OPPORTUNITIES TO GATHER SAFE MAHINGA KAI**	4.12 Cress sites - Flemington Drain and Swamp Drain.	Two sites have been established with management agreed between landowners, rating district and Environment Canterbury. Ongoing challenges are low flows, and monkey musk dominating water cress at sites. HHWET have agreed to an oversight role. Arowhenua involvement sought for feedback on use of these sites, and support for taonga species to be re-established and strengthened.
	4.12 Development of Mahinga Kai and Hinds	South Hinds NRR consented and operational since 2018. One mid-Hinds NRR site operational since 2020.

	Near River Recharge site.	Two further NRR sites currently in consenting process. Mana whenua involvement in mahinga kai opportunities at south Hinds NRR (lizard habitat, Kōwaro/mudfish wetland and native forest). Further mahinga kai area planned for NRR3 at Winslow Rd.
	4.12 Explore opportunities of having some drains with permanent flows via augmentation.	TSA is also being considered for drains south of Eiffelton Scheme. Requires low nitrate-N water and clarity on consenting (e.g., new non-consumptive consent, supplementary access to existing irrigation consents, or consent transfer via LWRP Rule 13.5.30 condition 1).
	4.12 Enhance Hinds River flow via consent transfers and MAR/NRR.	See above for NRR progress and Rec 4.14.1 for details regarding surface water takes.
4.13 SPORTS FISHERY AND WATERFOWL	4.13.2 Improve flow and habitat and reduce nutrient enrichment in Hinds River to reinstate trout fishery below SH1.	Flow improvements being actioned under MAR/NRR, consent swaps to deep groundwater or surrenders. Improvements in farm practices and MAR/NRR are hoped to contribute to reducing nutrient enrichment. Targeted Stream Augmentation (TSA) recommended with direct benefit to the lower Hinds River and/or tributaries. One trial of habitat enhancement to create pools in lower Hinds completed.
	4.13.3 Consideration of trout fisheries if MAR programmes provide flow certainty in larger drains.	Not yet due - flow certainty not yet restored.
4.14 HINDS RIVER	4.14.1 Surrender surface water takes.	In progress. Some takes may not be allowed to reconsent after expiry.
	4.14.2 Find solution to enhance permanent flow of lower Hinds River.	HHWET have all necessary consent documentation reports at an advanced stage. HDWP Report just states that there needs to be an agreed solution. It does not say the site needs to be consented and/or operational.
	4.14.3 Process for available water from RDR maintenance programme.	This is "in process" via a supplementary consent application to use RDRML water for the purpose of MAR / NRR. The use has been approved in principle by RDRML and the consent application will be lodged in the coming months.

To inform actions and progress toward relevant HDWP and LWRP objectives, CRC and Fish & Game undertake surface water quality and aquatic ecosystem health monitoring along the Hekeao / Hinds River and some of its lower catchment contributing drains (Northern and Taylors). Additional surface water quality monitoring of O'Shaughnessy's and Montgomery's Drains was also initiated by MHV Water in 2020/21. These are of relevance to lower Hekeao / Hinds River water quality. Key surface water monitoring points in the lower catchment are noted on Figure 2-19, with Hekeao / Hinds River flow and water quality monitoring presented on Figure 2-20.

PC2 sets two targets to be met for the lower Hekeao / Hinds River by 2035; an annual median nitrate-nitrogen (NO_3-N) of 3.8 mg/l and an annual NO_3-N 95th percentile of 5.6 mg/l. These are measured in surface water as nitrate-nitrite-nitrogen (NNN). Data is annualised to hydrological years (1 July to 30 June). Progress to date is presented in Figures 2-20 and 2-21. For the monthly data in Figure 2-20, the aim is to increase the number of blues dots (NNN concentration) below the red line (PC2 target), so that very few (<5%) blue dots sit above the red line by 2035. Figure 2-20 shows a general correlation between flow and concentration (i.e., lower concentrations during periods of lower flow such as 2015/16 and 2020/21), but an apparent time lag between flow rate decreases and concentration decreases (such as 2014/15 and 2019/20). This is consistent with the Hekeao / Hinds groundwater system, where water quantity changes occur faster than water quality changes, as groundwater levels are driven by a pressure response, whereas water quality is controlled by water particle transport. As previously noted, the 2021/22 year was a higher flow year and the 2035 target was only met for two months of the year. For the 2020/21 (low flow) year, this target was met for six months of the year.

As discussed for Figure 1-2, due to the dominating influence of rainfall recharge on water quality and quantity, the most practical way of tracking progress towards 2035 targets is by comparing years with similar annual rainfall. The average annual flow comparison for Hekeao Hinds River at Poplar Road (Figure 2-20) is presented in Table 2-5. The 112% increase in average flow in the 2015/16 and 2020/21 'dry' year comparison equated to a 460 l/s increase. The 620 l/s maximum potentially contributing discharge from NRR and MAR sites during this period is expected to have been a significant contributor to this increase. Further discussion on the 2020/21 summer flows is provided in the HHWET 2020/21 Annual report.

Table 2-5: 'Wet' and 'Dry' year flow comparisons for Hekeao Hinds River at Poplar Road

Average annual flow (Year ending 30 June)	2022/2018 (Wet years)	2021/2016 (Dry years)
Hekeao Hinds River (Poplar Road)	-36%	+112%

Figure 2-21 presents the annual median NNN concentration for the lower Hekeao / Hinds River alongside annual Ashburton rainfall and the 2035 PC2 target. As with Figure 2-20 a correlation can be seen between rainfall and concentration, except where the water quality change lags behind the water quantity change (e.g., 2014/15). For the 'wet' year comparison, the annual median was 8.3 mg/l nitrate-N for 2017/18 and 7.1 mg/l for 2021/22. This is a **14% improvement** for nearly identical annual rainfall (noting the other potentially contributing factors such as antecedent conditions and rainfall timing/distribution). A similar 'dry year' comparison is possible between 2015/16 and 2020/21. The annual median was 6 mg/l nitrate-N for 2015/16 and 5.6 mg/l for 2020/21. This is a **6% improvement** and, combined with the 'wet year' comparison, shows an encouraging trajectory toward the PC2 2035 target. It is noted that future regional land and water plans will eventually provide new target/s and/or timeframe/s.

Contributions of lower Hekeao / Hinds River tributaries to lower Hekeao / Hinds River water quality are presented in Figures 2-22 and 2-23. These tributaries are the primary contributor to lower Hekeao / Hinds flow when the river is not flowing at SH1. Water quality in Taylors Drain is significantly better than the other drains due to its high proportion of river recharge (including Near River Recharge). Repeating the Figure 2-21 comparisons for Figure 2-23 (Taylors Drain) produces a **31% improvement** in annual median NNN between 2017/18 and 2021/22, and a **14% improvement** between 2015/16 and 2020/21. For Northern Drain, annual median NNN was the same in 2017/18 and 2021/22, and increased by 16%

between 2015/16 and 2020/21. The only reason identified to date for the improvement in Taylors Drain water quality is Near River Recharge. Table 2-6 summarises these results.

Table 2-6: 'Wet' and 'Dry' year water quality comparisons for lower Hekeao Hinds waterways

Annual median NNN (Year ending 30 June)	2022/2018 (Wet years)	2021/2016 (Dry years)
Taylors Drain	-31%	-14%
Northern Drain	0%	+16%
Hekeao Hinds River (Lower Beach Road)	-14%	-6%

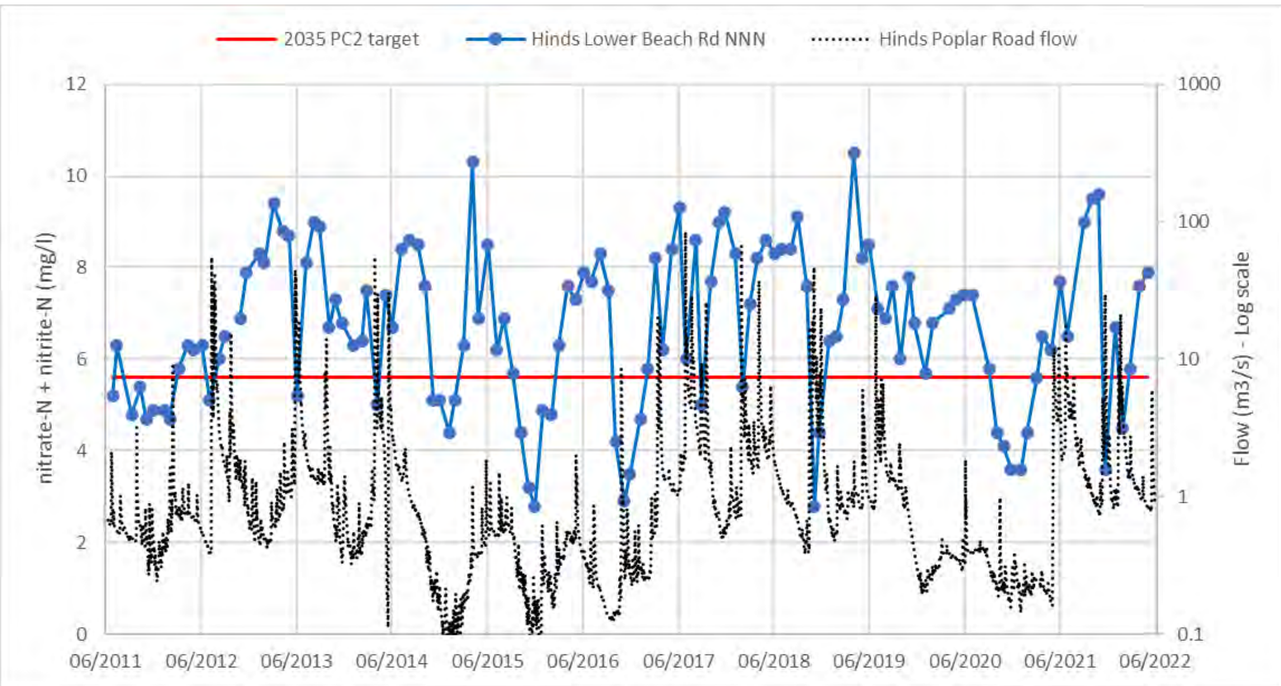

Figure 2-20: Hekeao / Hinds River flow at Poplar Rd and Nitrate-Nitrite-Nitrogen concentrations at Lower Beach Rd (Source: CRC)

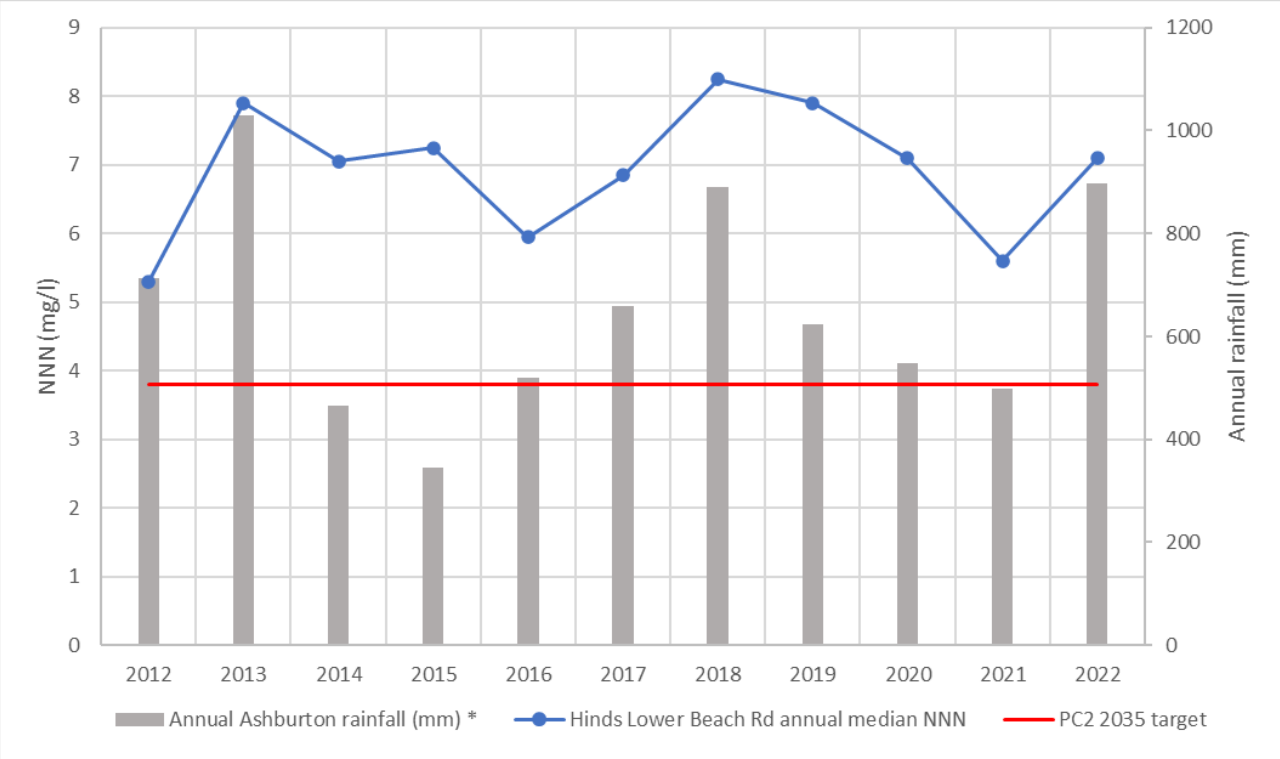

Figure 2-21: Annual (year ending 30 June) Ashburton rainfall and annual median Nitrate-Nitrite-Nitrogen concentrations for the Hekeao / Hinds River at Lower Beach Rd (Source: CRC)

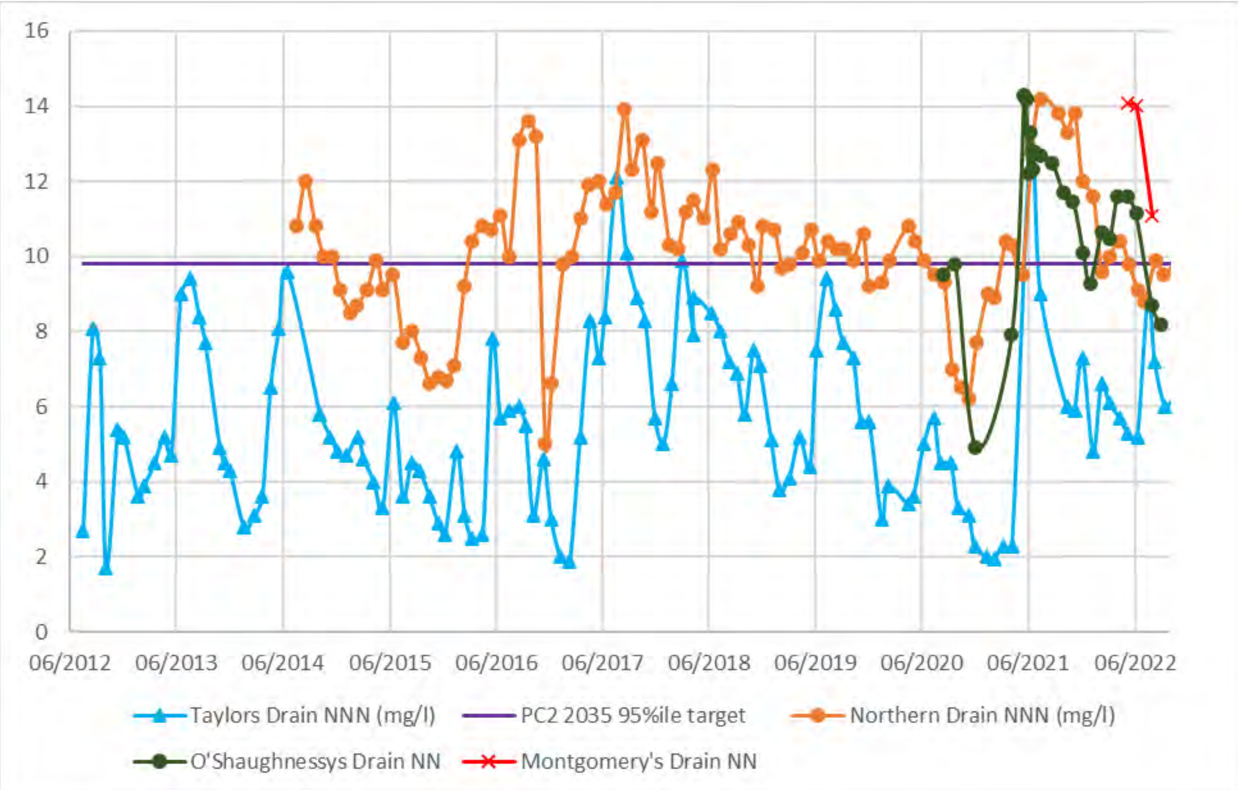

Figure 2-22: Lower Hekeao / Hinds River tributary NNN concentrations (Source: CRC)

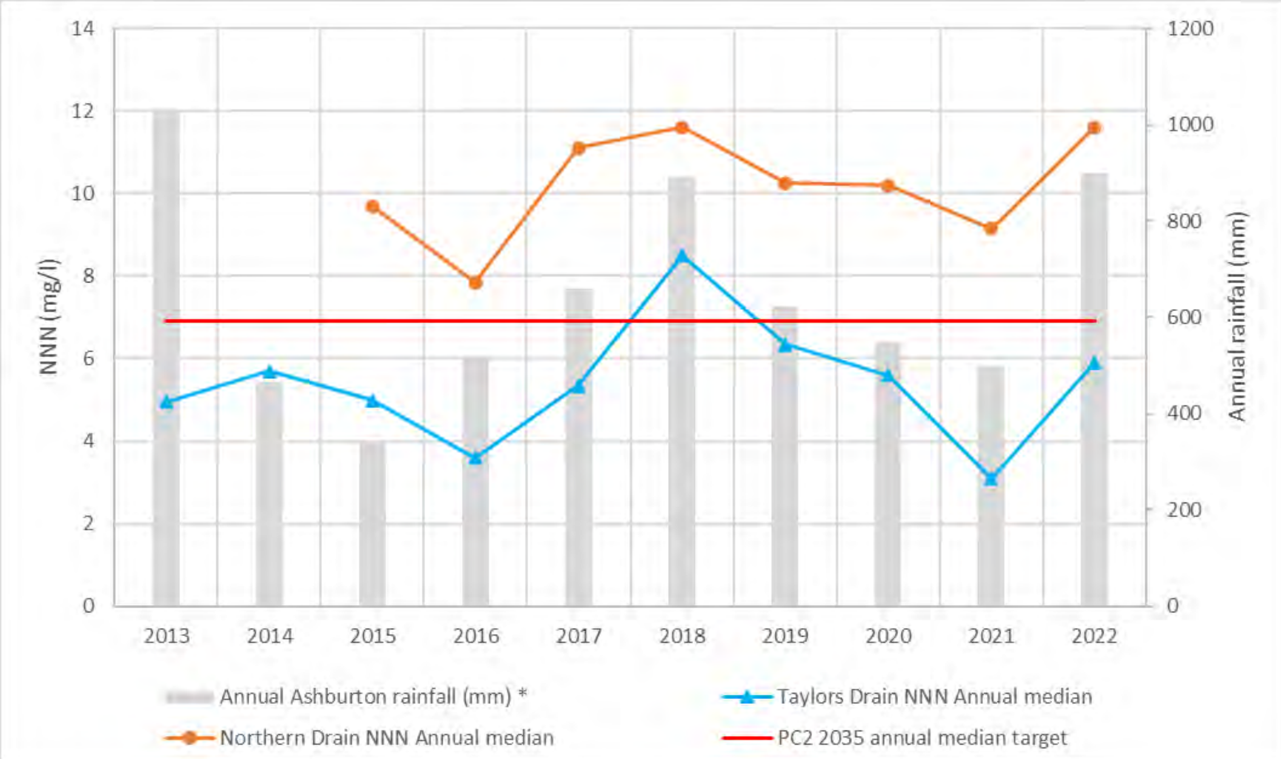

Figure 2-23: Ashburton rainfall plus annual (year ending 30 June) median NNN concentrations for lower Hekeao / Hinds River tributaries (Source: CRC)

The QMCI (Quantitative Macroinvertebrate Community Index) is based on the tolerance or sensitivity of species (taxa) to organic pollution and nutrient enrichment. Figure 2-24 presents the QMCI scores derived from monitoring at SH1, Poplar Rd and Lower Beach Rd sites, indicating aquatic ecosystem health is variable and responds to annual climatic and flow conditions in the Hekeao / Hinds River. In most years the QMCI score is highest at Lower Beach Rd. Aquatic health is also generally better in drier years than wetter years. The effect of NRR via Taylors Drain is likely to have a greater influence on QMCI scores at Hinds River – Poplar Road than at Lower Beach Road, as Taylors Drain enters the Hekeao Hinds River approximately 2 km upstream from Poplar Road. The ‘wet’ and ‘dry’ year comparisons for Hekeao Hinds River at Poplar Road in Table 2-7 support this expectation, with greater improvements in wet year QMCI comparisons than dry year comparisons (as with Taylors Drain water quality improvements). ‘Wet’ and ‘dry’ year QMCI and NNN comparisons (Table 2-7 vs Table 2-6) for Hekeao Hinds River at Lower Beach Road do not provide similar correlations.

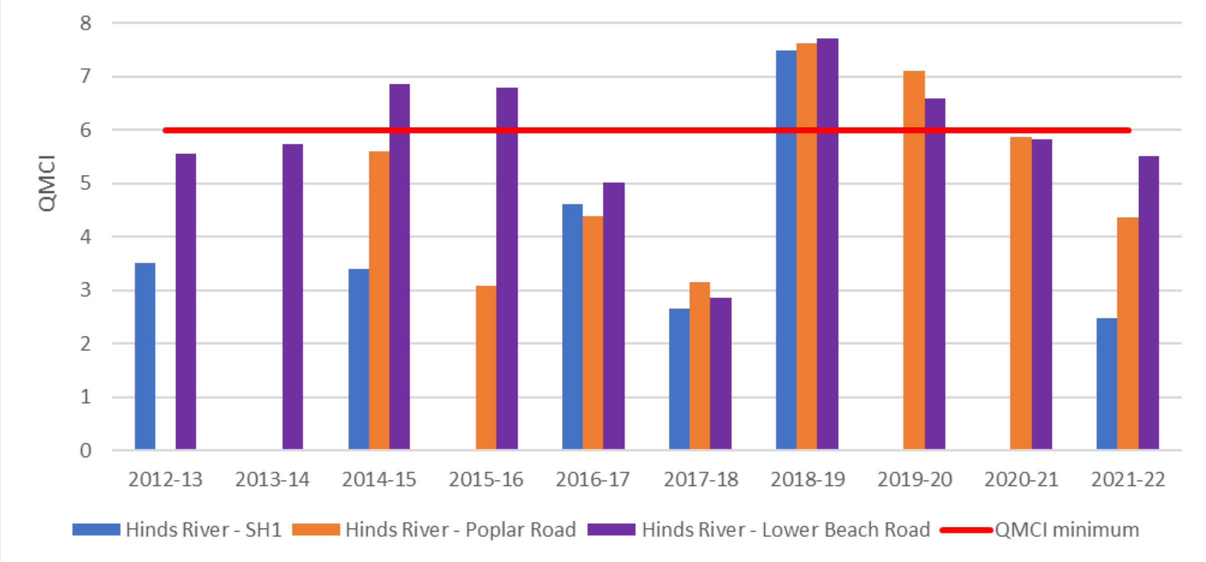

Figure 2-24: QMCI Scores for three lower Hekeao / Hinds River sites (Source: CRC[2])

Table 2-7: 'Wet' and 'Dry' year QMCI comparisons for lower Hekeao Hinds River

Annual QMCI	2022/2018 (Wet years)	2021/2016 (Dry years)
Hekeao Hinds River (Poplar Road)	+38%	+91%
Hekeao Hinds River (Lower Beach Road)	+92%	-14%

Lower Hekeao / Hinds fish surveys comprise annual assessment of fish diversity and abundance by electric fishing at two sites in the lower river – one about 0.4 km above the coastal lagoon and the other just above Poplar Rd (about 6 km above the lagoon). Total surveyed population size is presented in Figure 2-25. The 2021 Above Lagoon population was dominated by bluegilled bully and the 2022 population was dominated by common smelt. Seven of the nine fish species caught in the lower river were migrant species requiring passage to and from the sea to complete their life cycles. Webb (2021) notes that their presence suggests the Hekeao / Hinds River mouth is open frequently enough to enable fish migration. While the NRR contribution of flow support with high quality water can be assumed to be positive for fish populations and macroinvertebrates, direct links between NRR volume and fish populations / QMCI are unlikely to be measurable, given the more significant influence provided by rainfall / flow.

[2] This work uses material sourced from Hilltop Manager database and the SOE streamhealth dataset stored in the Streamhealth MS Access database, which is licensed under a Creative Commons Attribution 4.0 International licence by Environment Canterbury.

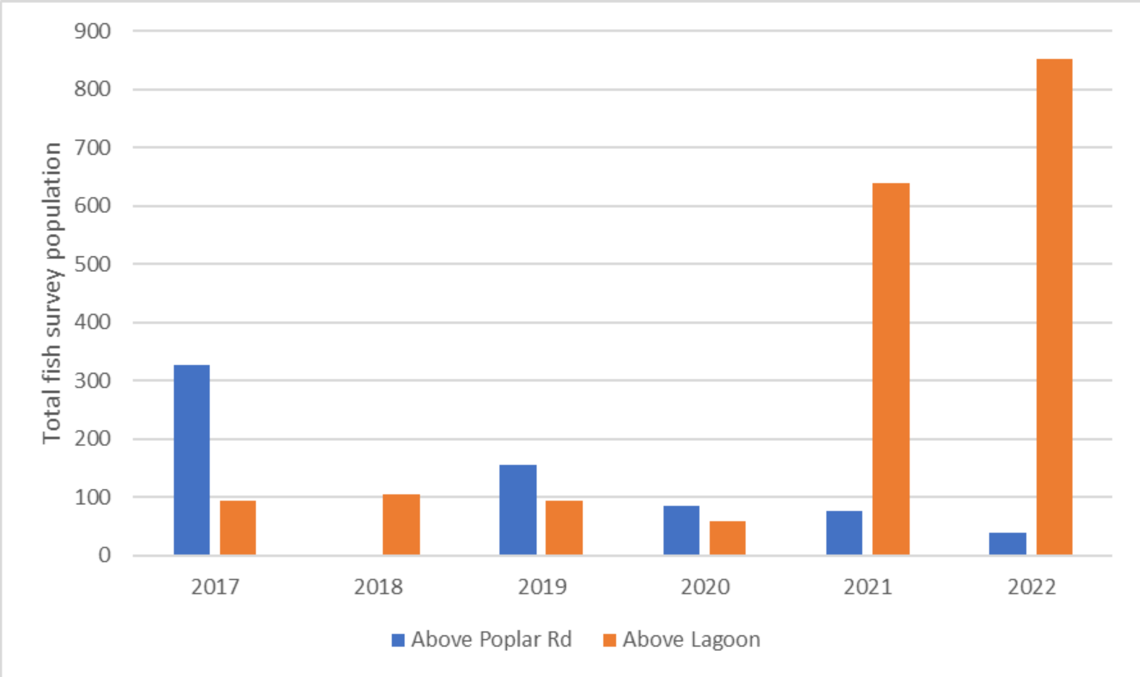

Figure 2-25: Total fish survey populations for two lower Hekeao / Hinds River sites (Source: M. Webb, Central South Island Fish and Game)

3 Hekeao / Hinds MAR Sites

An overview of MAR site operations and monitoring is presented in the Introduction. In combination with the two NRR sites, the total recharged MAR volume in Year 6 was approximately 7.21 million m^3, with around 5 million m^3 being via the MAR sites. This was a 52% decrease on the previous year and a 46% utilisation of consented MAR supply water. The key reason for this decrease was the shutdowns for flooding repair and high groundwater levels. This is reflected in the lower number of weeks in operation compared to the previous year.

Examples of the type of operational MAR test site designs during Year 6 are presented in Figures 3-1 to 3-5. Of these designs, the original test site design (Figure 3-1) is the most sensitive to sediment clogging as the recharge basin (backfilled with cobbles) is comparatively small. For this reason, these sites are directly connected to an irrigation pond where possible. Using this configuration, MAR supply water can be pumped into the pond before it is used to recharge at the MAR sites, allowing time for sediment suspended in the water to settle out. Sites 3, 6, 8, and 16 still use this design as they await upgrade decisions. Table 3-1 shows that the maximum discharge rate for each is less than 20 l/s, with basin size and local geology expected to be the primary constraints on maximum recharge rate. The enlarged test site in Figure 3-2 (Site 13) has the same sediment clogging potential but a lower risk due to having twice the recharge basin volume. The initial test site at this location recharged less than 20 l/s. Table 3-1 shows that doubling the volume of the basin has increased the discharge rate to approximately 35 l/s.

In Figure 3-3, MAR 12 has replaced a test site at the same location which did not perform well, due to sediment (and *E. coli*) management challenges. The new site is fed by the same water race as the test site (left of Figure 3-4), with an open channel sediment forebay trench, connected to a soak hole and down-gradient buried perforated pipe. The perforated pipe extension is a recharge design used for treated wastewater recharge which has the advantage that it doesn't take land out of production. Another potential advantage of the perforated pipe extension is that the recharge water can be spread over a wider area, thus increasing the chance of intercepting open framework gravels with higher recharge flow potential. This enhancement has increased discharge rates at the site from <15 l/s to >50 l/s.

Figure 3-4 (MAR 07) shows an example of a large MAR basin. The other large basin site (MAR 01) uses a forebay for dropping out sediment. MAR 07 instead uses parallel bunds to slow the flow of water and progressively allow sediment to settle out. Higher turbidity water has been recharged at this site, as it is comparatively easy to clean if it becomes clogged. Discharge rates are currently limited (by consent conditions) to 100 l/s, but a 200 l/s discharge rate was successfully trialled this year under compliance discretion to support re-consenting assessments.

MAR 02 (similar to MAR 17b) is a lateral race site, where any unused water race is scraped to remove accumulated sediment before multiple boulder beds are inserted along with bunds. These type of MAR sites are also easy to clean, and due to their length increase the chance of connecting to higher permeability groundwater flow pathways (open framework gravels).

Figure 3-1: MAR 08: Timaru Track Rd. MAR test site (Source: M. Neutze)

Figure 3-2: MAR 13, Hinds Arundel Road. Enlarged MAR test site (Source: M. Neutze)

Figure 3-3: MAR 12, Maronan Ealing Road, up gradient (left) and down gradient (right). MAR test site enhanced with buried slotted pipe (Source: M. Neutze)

Figure 3-4: MAR 07, Corner Timaru Track and Maronan Valetta Roads. MAR basin (Source: B. Painter)

Figure 3-5: MAR 02, Timaru Track Rd. MAR lateral race (Source: B. Painter)

4 Hekeao / Hinds MAR Case Studies

All MAR sites are designed and operated to maximise their potential positive effects (improved groundwater quality and levels) while avoiding potential negative effects (localised flooding or transmission of pathogenic bacteria - indicated by *E. coli*) through the groundwater system. Consent conditions focus particularly on avoidance of potential negative effects. A portion of MAR sites were also chosen as case study sites for specific monitoring and analysis of positive impacts.

When assessing monitoring records for potential MAR effects, it is important to consider the available evidence for groundwater flow direction. The Hekeao Hinds Plains were formed by alluvial fans distributed by the Rangitata Glacier / River and Ashburton Glacier / River systems, with the larger Rangitata system dominating the smaller Ashburton system. The Hekeao / Hinds River system was much smaller again, with its primary purpose being to direct nearby (e.g., Surrey Hills) rainfall toward the lower catchment swamps / wetlands. Multiple groundwater level readings are used to create equipotential (equal level) lines, with groundwater assumed to travel in general at right angles to the equipotential lines. Most groundwater is assumed to follow paleo river channels, as they contain open framework gravels. Paleo channels are assumed to follow different pathways of different sizes and connections (horizontal and vertical) at different depths. An example containing Hekeao / Hinds Plains piezometric contours, surface paleo channels and MAR sites is presented in Figure 4-1.

For this status report, assessment of two of the MAR test sites are presented in more detail. MAR 01 (the Lagmhor Pilot Site) was the initial case study site to prove the single site MAR concept for the Hekeao / Hinds Plains. This required investment in new monitoring bores as well as the monitoring of groundwater levels and quality in existing bores in the area potentially impacted by the site. The second case study site is MAR 12.

4.1 MAR 01 - Lagmhor Pilot Site

The Lagmhor Pilot Site (MAR 01) is a 0.9 ha recharge basin, inland from Tinwald. The site is supplied by an open channel race, connected to Valetta Pond 3, owned by MHV Water (Figure 4-2). The relevant discharge consent is CRC210830. Pre-construction modelling and infiltration testing suggested potential infiltration / recharge rates of 300-500 l/s, with significant lateral as well as down-gradient influence. The actual infiltration rate achieved during the first two years was approximately 80-100 l/s, with the water quality influence following a path consistent with the piezometric contours and surface paleo-channels presented in Figure 4-1. During Year 3, potential improvements were trialled: a deep soakage system, removal of accumulated sediment from the recharge basins and up-gradient delivery channel, and a higher basin depth. Maximum recharge rates (including the recharge race) increased to 120-140 l/s following these enhancements. The most recent addition to this site has been the installation of an automated flow measurement and control gate.

Figure 4-3 presents recharge flows and local monitoring for Years 1-6. Discharge flows (in hundreds of litres per second) are shown in yellow, with a maximum instantaneous discharge of approximately 180 l/s (though as a weekly average the maximum was approximately 130 l/s), and significant periods in recent years of no discharge due to supply constraints or prioritisation of available flow to other sites. Measured nitrate-N concentrations (at a 29 m deep bore 1 km down-gradient from MAR 01) are shown in purple, with an in-situ continuous nitrate-N sensor (in green) providing detailed monitoring until late 2019. This record shows nitrate-N at 6-7 mg/l immediately pre-MAR, reducing to 1.2-3.5 mg/l with MAR. Concentrations exceed 3 mg/l after a period of no MAR and after significant rainfall events, but quickly drop back to below 3 mg/l once MAR resumes. Groundwater levels are presented in dark blue, with reasonably rapid level changes when MAR begins or stops.

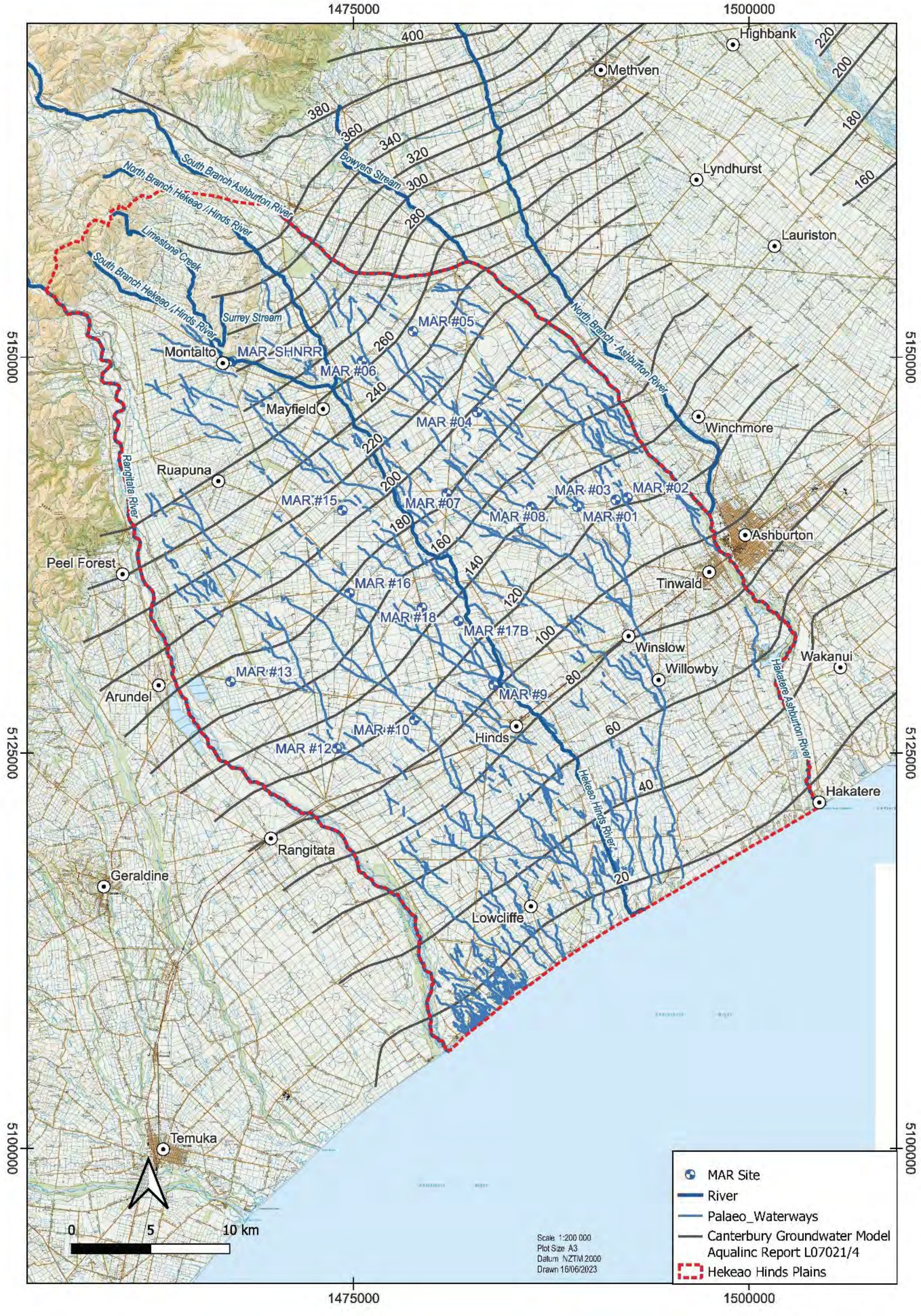

Figure 4-1: Hekeao / Hinds Plains piezometric contours, surface paleo channels and MAR sites (Source: MHV Water, Aqualinc Research, HHWET)

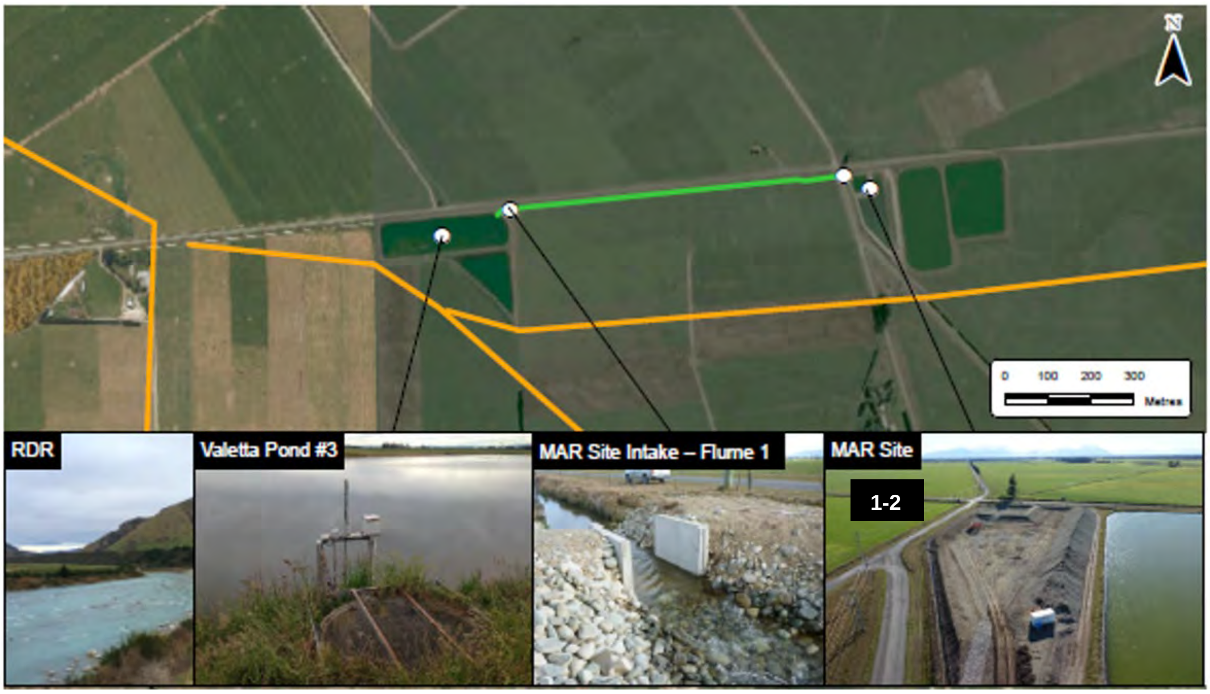

Figure 4-2: MAR 01 (Lagmhor Pilot Site) infrastructure (Source: MAR Year 1 report)

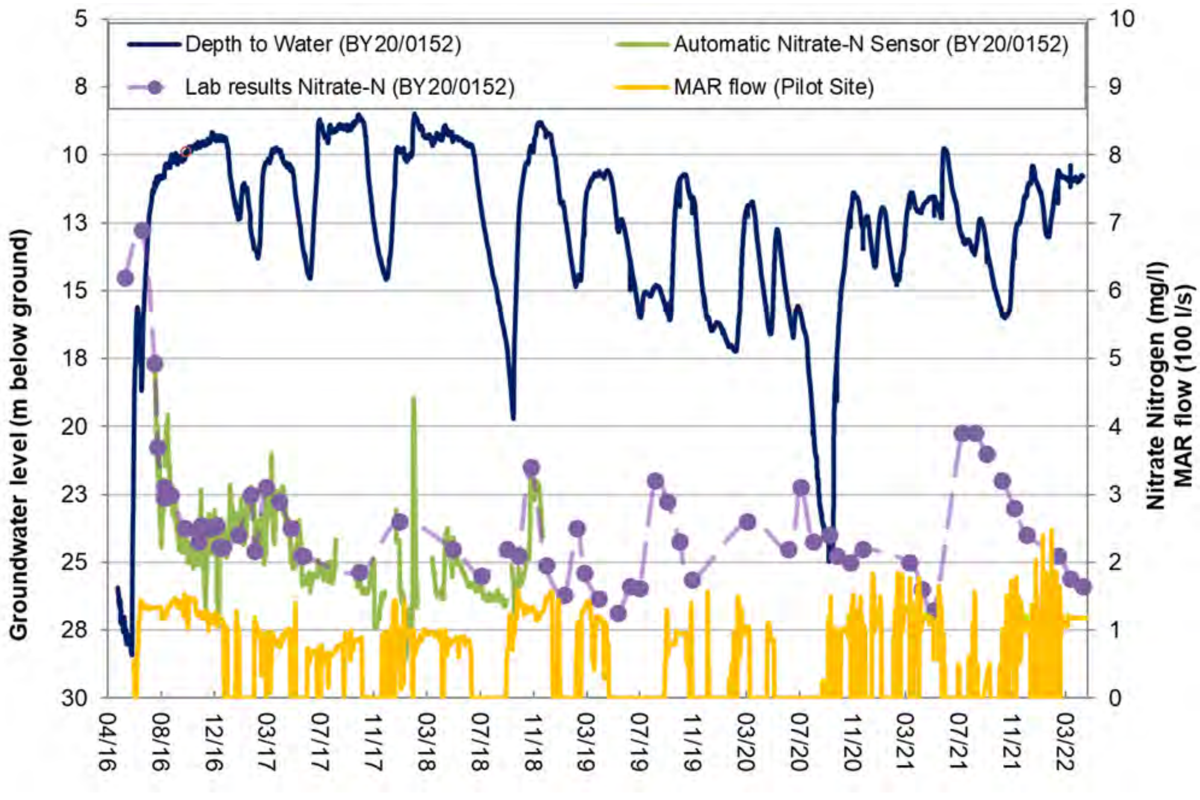

Figure 4-3: MAR 01 (Lagmhor Pilot Site) operational and key down-gradient monitoring

Discharge was required to cease due to consent conditions: once due to Hekeao/Hinds Plains rainfall and twice for *E. coli* exceedance during Year 6. The rainfall cessation was for the 29-31 May 2021 heavy rainfall event. Figure 4-3 shows that the greatest increase in nitrate-N concentration in BY20/0152 occurred after this rain event. Discharge then voluntarily ceased for more than half the period from June-October 2021 due to high groundwater levels. During this period the site was used to test recharge rates at different groundwater levels so that informed decisions could be made in regard to appropriate groundwater levels for re-starting MAR sites across the plains. Nitrate-N concentrations in BY20/0152 decreased in response to the site testing and resumption of operations. By the beginning of 2022, the nitrate-N concentration had returned to less than 2 mg/l.

In the Year 4 (2019/20) Annual Report, groundwater level and water quality monitoring down-gradient from MAR 01 was compared to conclusions from the 2019 Master of Water Resource Management Thesis titled “Quantification of the Probable Environmental Effects of the Hinds Managed Aquifer Recharge Trial using Mathematical Modelling and Advanced Uncertainty Techniques” by former Environment Canterbury scientist Patrick Durney. The relevant conclusion from this thesis was:

“the Hinds MAR trial will successfully raise groundwater levels across a large area and increase stream flows. Further, the trial will improve water quality in groundwater, though it will probably not influence surface water quality. Transport modelling suggests water quality improvements can be expected for several kilometres down-gradient of the trial site, though they are unlikely to propagate as far as the lowland streams.” (Durney, 2019)

A comparison of modelled and actual results to the end of Year 4 concurred with this conclusion, albeit with caveats regarding the challenge of distinguishing recharge effects from abstractive effects on groundwater levels, particularly with increasing distance away from MAR 01. Further updates were provided in the HHWET Year 5 report. No changes to these conclusions have been identified in Year 6.

Figure 4-4 presents Durney’s (2019) modelled groundwater quality changes after 5 years. Model results indicated that groundwater (in the identified depth range approximately 20-45 m below ground level) is comprised of approximately 80-100% MAR water immediately down-gradient from the Pilot Site (red), reducing to a 10-20% MAR groundwater component at the margins of MAR 01-influenced area (dark green). Numbers 1-13 have been added to Figure 4-4, at the location of bores with water quality monitoring information relevant to the MAR 01 analysis. These bores are also shown in Figure 4-8 in the MAR Year 2 report, with colour coding on the bores to show assessed MAR water quality influence as likely (green), possible (yellow) and unlikely (red).

The nitrate-N concentrations measured at these numbered bores are presented alongside MAR 01 inflow data in Figures 4-6 to 4-8 in this report. Bores with green dotted lines show evidence for changes in nitrate-N concentration (along with other water chemistry changes such as electrical conductivity, chloride, and hardness) and an initial lag time consistent with water particle travel time estimates in the Year 1&2 MAR reports. It was therefore concluded in the MAR Year 2 report that these wells are in the MAR 01 zone of water quality influence, although the decreasing MAR proportional contribution with increasing distance from the MAR site decreases confidence in these conclusions with increasing distance from the MAR site. Results to Year 6 do not change these conclusions. Bores with red coloured dotted lines do not show nitrate-N concentration changes consistent with expected water particle travel time, and it is concluded that these wells remain outside the MAR 01 zone of water quality influence. Bores with yellow dotted lines remain inconclusive. Most bores show an increase in nitrate concentration following the May 2021 rain event and subsequent cessation of MAR operations. However, the rates of concentration increase and then decrease were not consistent in monitored bores.

Bores close to MAR 01 (Fig. 4-6) show nitrate-N fluctuations of at least 50% between MAR 01 operational and non-operational periods. During operational periods, the nitrate-N concentrations are 80-90% lower than nearby bore BY20/0151. These results are consistent with Durney (2019) as presented in Figure 4-4. In the bores further down-gradient from MAR 01 (Figs 4-7 and 4-8), two additional bores have been added (numbered 14 and 15 in Fig. 4-4) for Year 6 analysis. Bore 10 on Figure 4-4 does not show any influence from MAR operations, Bore 6 remains unlikely to show MAR water quality influence, while Bores 7-9 do show water quality fluctuations (25-50%) and concentrations that suggest potential alignment with MAR 01 operations.

Bore 15 shows more significant nitrate concentration fluctuations than Bores 12 and 14. More detailed analysis of water quality in these bores is recommended. From this monitoring analysis, we can conclude that MAR 01 water inland from SH1 is more likely to be following the locally varying hydraulic gradient presented in Figure 4-5 (blue arrows, at right angles to the blue piezometric contours), than the modelled south easterly direction (Fig. 4-4).

Down-gradient from SH1 Bore 13 (BY21/0183) is in an area of shallow groundwater feeding the lowland waterways and springs. The monitoring to date, including a groundwater nitrate sensor installed for part of 2019, suggests that no measurable effect on water quality has occurred. The average flow rate from the first six years of MAR 01 operations is 50 l/s, however, the piezometric contours and paleo-channel analysis presented in Figure 4-1 (noting that paleo channel direction may be different at different depths) suggests that recharge from MAR 08 and MAR 07 (21 L/s on average) may also contribute to groundwater quality in the area surrounding Winslow as it heads towards the Parakanoi Drain. Durney (2019) concludes that no measurable water quality effect on potentially connected lowland waterways is likely even if an average of 110 l/s from contributing MAR sites is achieved, due to the higher nitrate water also feeding this area from catchments to the northeast and southwest of MAR 01-influenced groundwater. Monitoring will continue to be carried out, to understand both the individual and cumulative influences of MAR sites, as more become operational in this area.

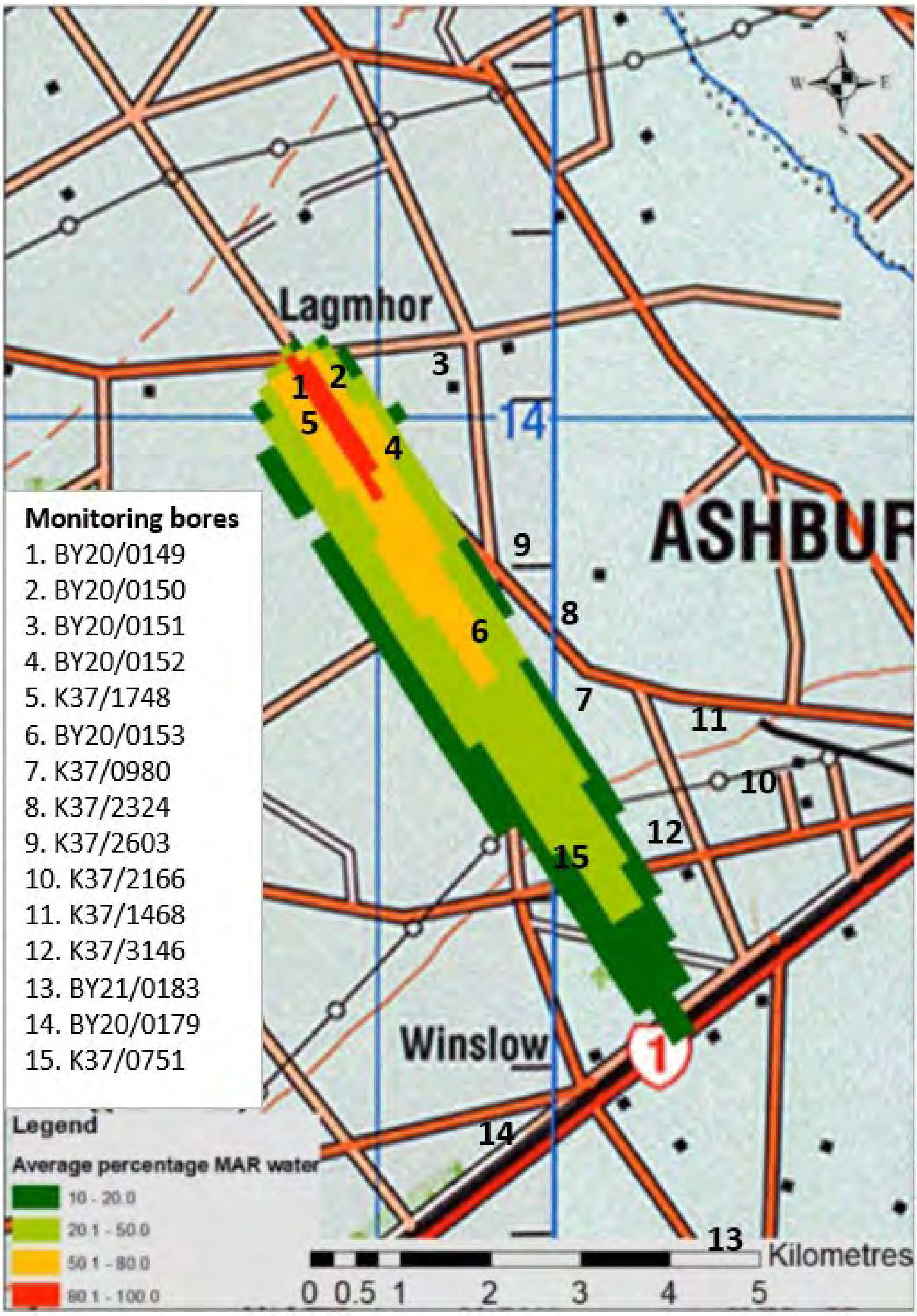

Figure 4-4: Modelled groundwater quality change after 5 years in response to the MAR trial (from Durney, 2019, Figure 5-23 MAR plume Layer 3)

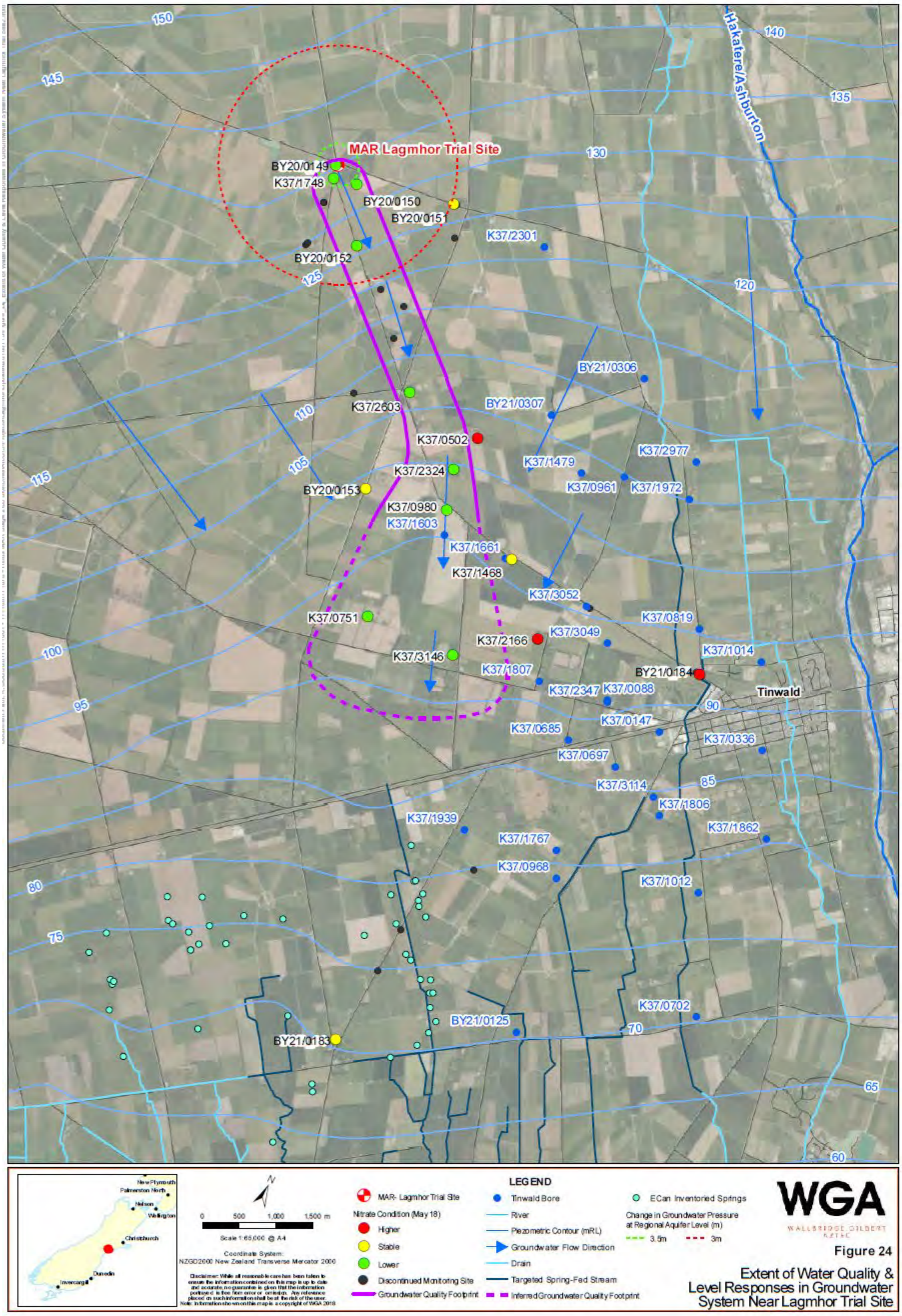

Figure 4-5: Figure 24 from Year 2 report (with updated bore names) showing assessed groundwater level and quality responses to MAR 01 operations

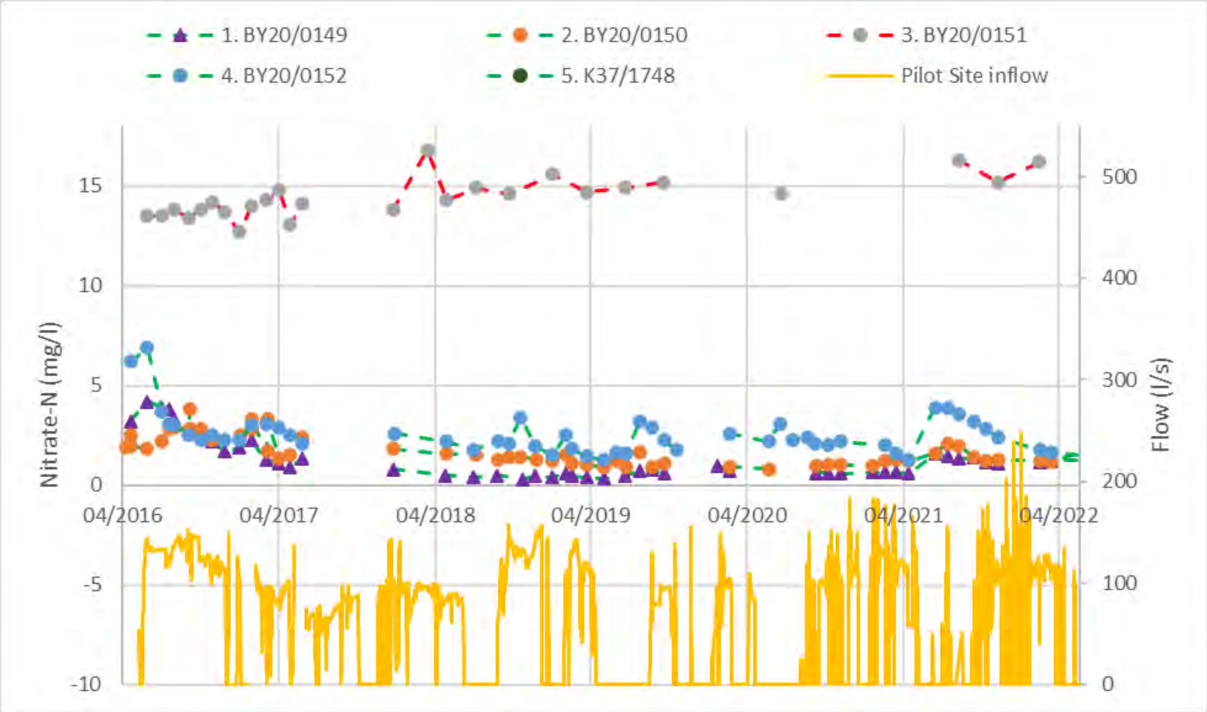

Figure 4-6: Nitrate-N measured concentrations for wells close to MAR 01 (Source: HHWET, CRC)

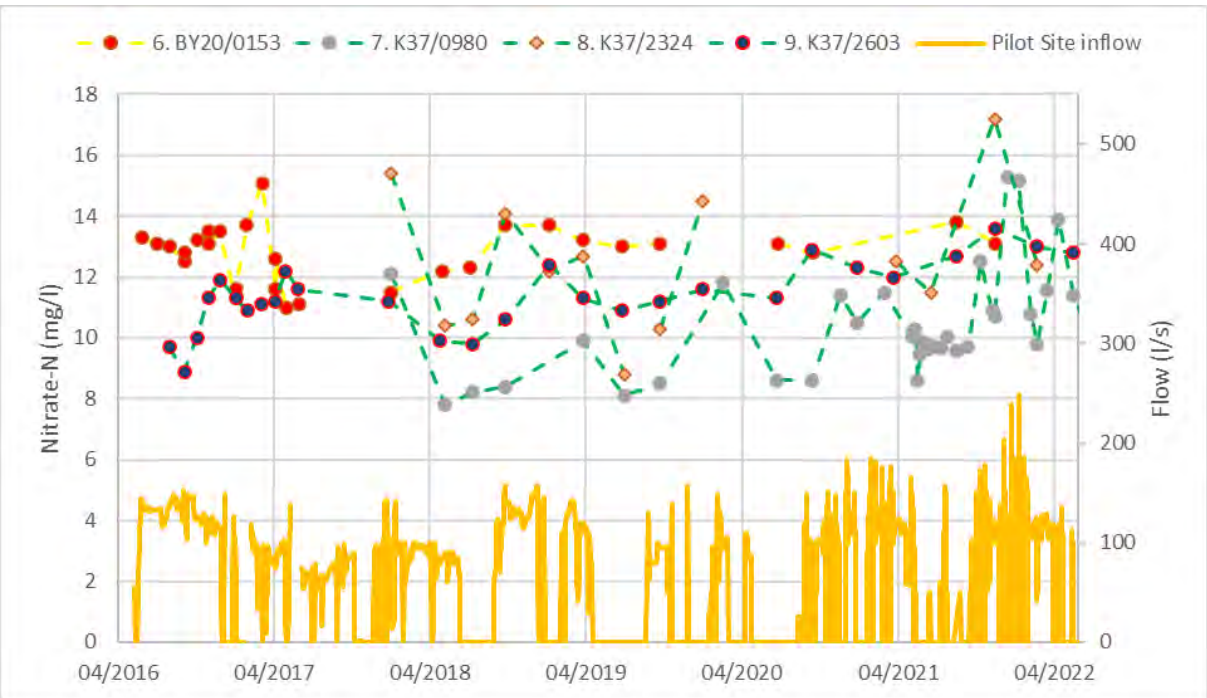

Figure 4-7: Nitrate-N measured concentrations for wells 3-5 km from MAR 01 (Source: HHWET, CRC)

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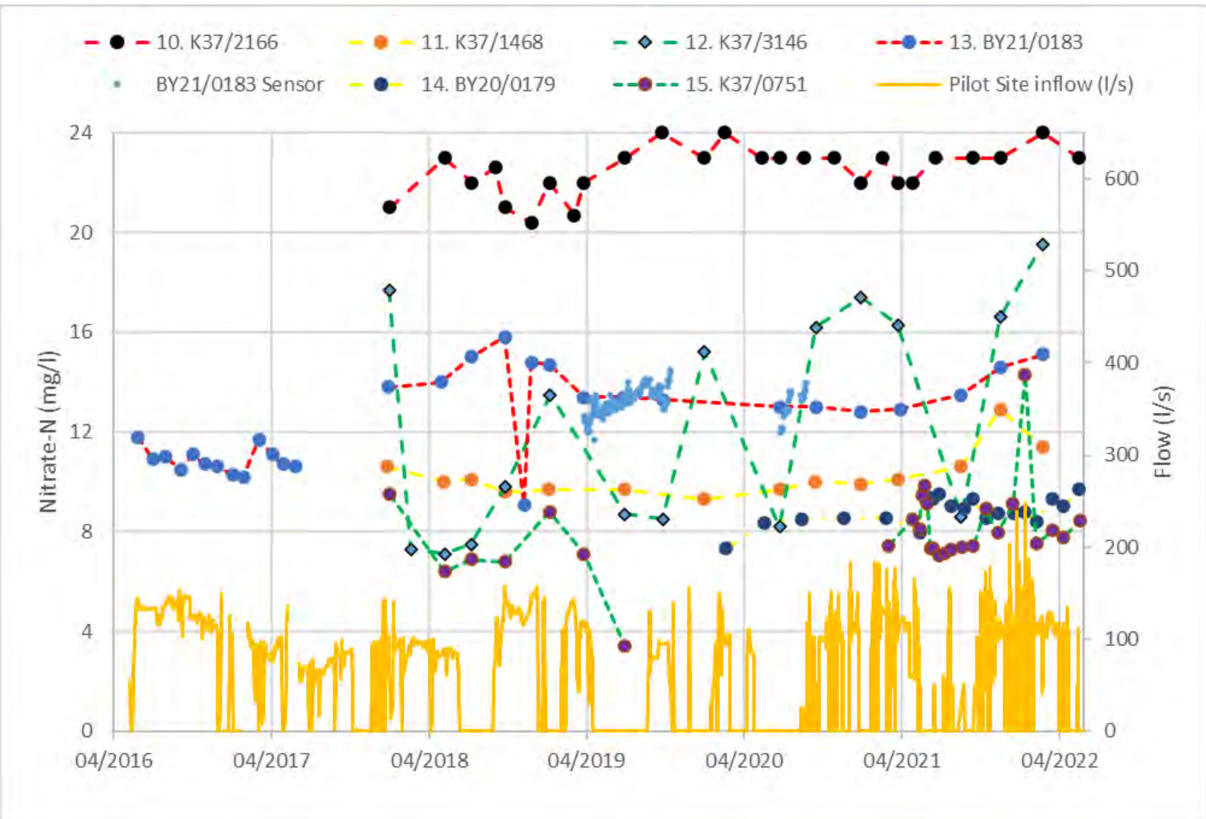

Figure 4-8: Nitrate-N measured concentrations for wells 6-12 km from MAR 01 (Source: HHWET, CRC)

4.2 MAR 12 - Maronan Ealing Road

As discussed in Chapter 3 of the HHWET 2020/21 (Year 5) report, MAR 12 has replaced a test site (at the same location on Maronan Ealing Rd) which did not perform well due to sediment and *E. coli* management challenges. The new site (which began operation in June 2020) is fed by the same water race as the previous test site, with the addition of an open channel sediment forebay trench, connected to a soak hole and down-gradient buried perforated pipe. This enhancement has increased recharge rates at the site from <15 l/s to >50 l/s. Figure 4-9 shows the location of MAR 12, two water quality monitoring bores and the anticipated groundwater flow direction (at right angles to the regional piezometric contours).

Figure 4-9 presents the MAR 12 recharge flow since construction plus nitrate-N concentrations at the two nearby bores (BY20/0148 and K37/0234). Both sites are monitored quarterly by CRC. BY20/0148 also has a groundwater nitrate sensor installed (see MAR Year 4 report). A groundwater nitrate sensor was also installed in K37/0234 but the presence of iron bacteria meant the bore was not appropriate for an optical sensor. CRC are planning to drill a new shallow bore (BY20/0253) beside K37/0234 as a replacement. Figure 4-10 shows nitrate-N concentrations following a similar, downward trend until the first monitoring round following the site upgrade in June 2020. From this point through to March 2021, nitrate-N concentrations continued to decrease at K37/0234 but increased at BY20/0148. After MAR 12 operations ceased in late April 2021 nitrate-N concentrations increased slightly at K37/0234. The changes in water quality are consistent with the flow direction predicted by the piezometric contours on Figure 4-9 which suggest BY20/0148 is likely to be cross-gradient and water quality is unlikely to be influenced by MAR 12 operations. In contrast K37/0234 appears to be more likely to be down-gradient and water quality could be influenced by MAR 12 operations.

Nitrate concentrations in BY20/0148 and K37/0234 in 2021/21 (Year 6) were clearly influenced by the high rainfall events. The quarterly monitoring of K37/0234 was not regular enough to compare the post-rainfall periods to assess potential MAR12 influence by comparing K37/0234 with BY20/0148. Monitoring regularity will be re-visited in 2022/23.

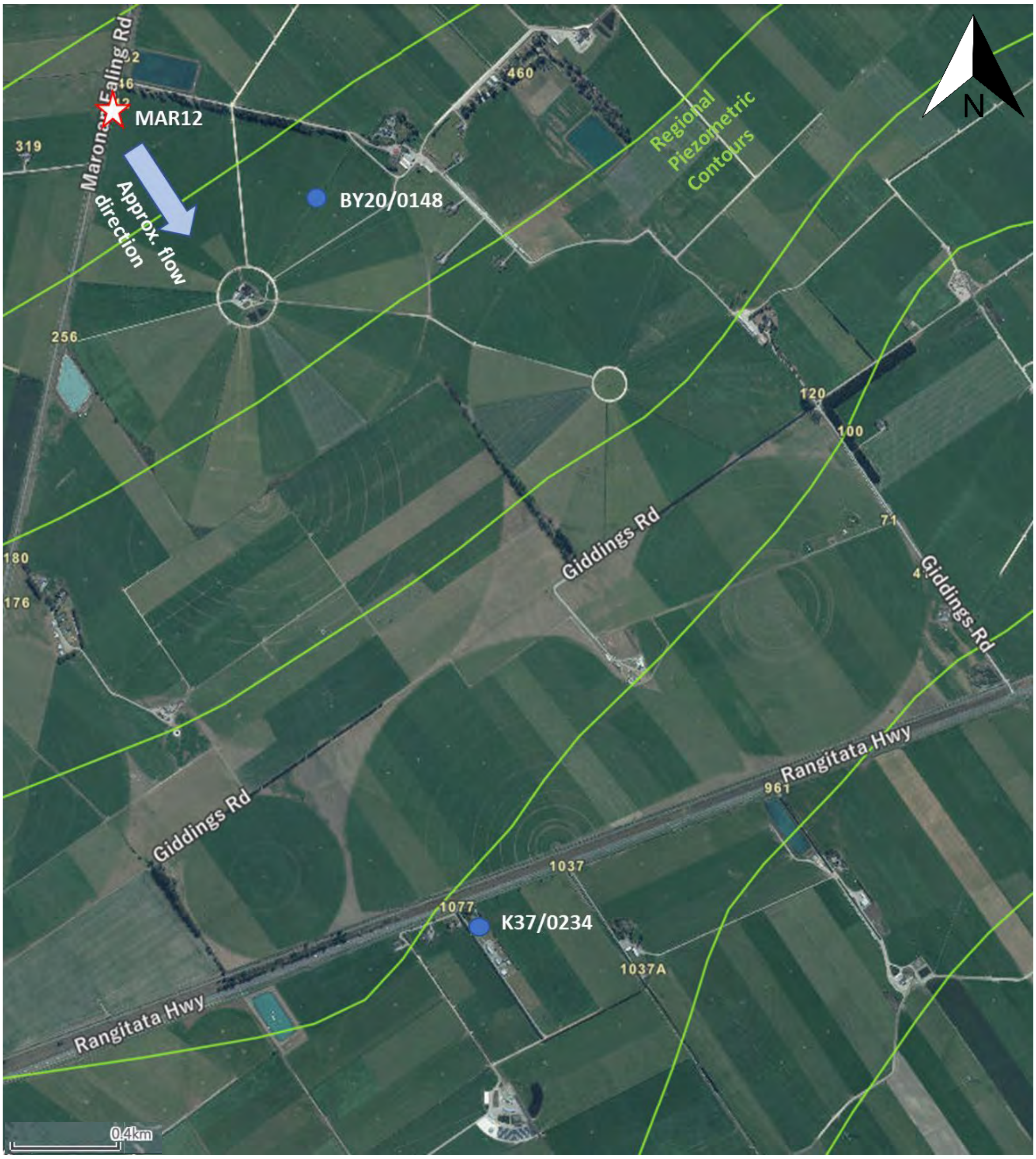

Figure 4-9: Location of MAR 12, regional piezometric contours and two bores of interest (Source: Canterbury Maps)

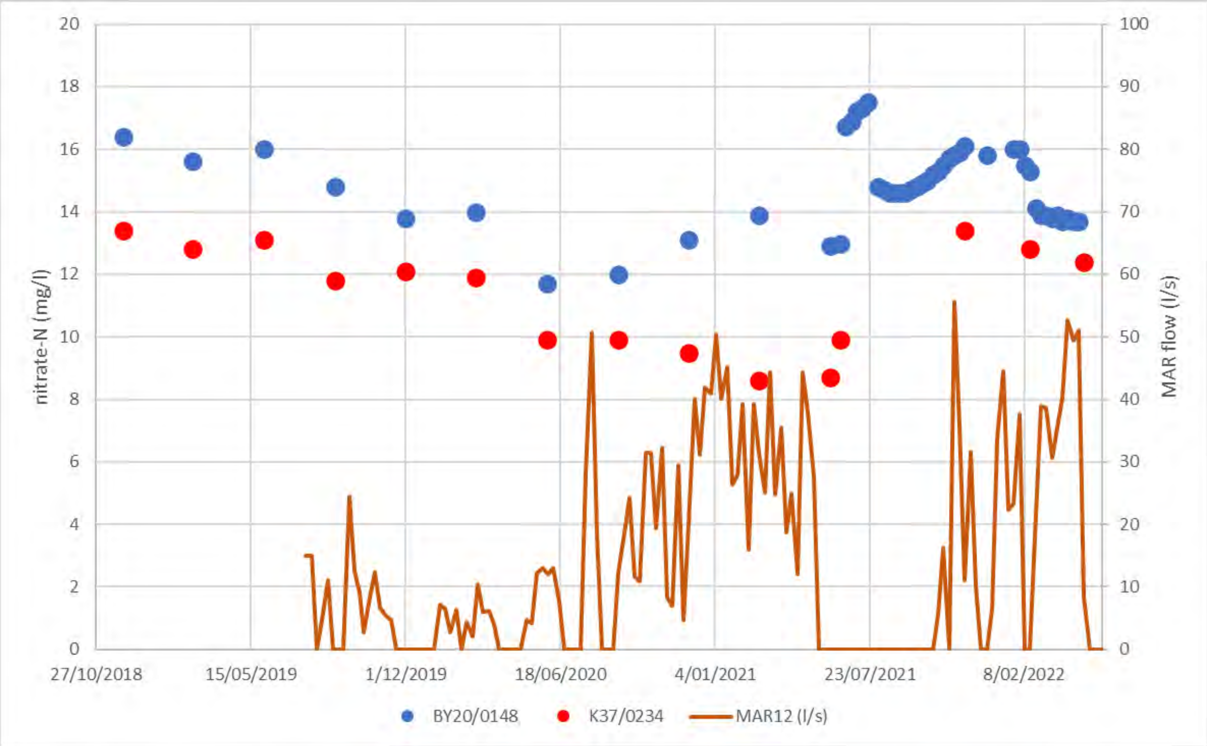

Figure 4-10: MAR 12 recharge flow, plus nitrate-N concentrations at two nearby bores (Source: CRC)

5 Hekeao / Hinds Groundwater and Northern Drains Water Quality

5.1 Hekeao / Hinds Plains Groundwater Quality

As noted in the Introduction, the groundwater nitrate-N PC2 monitoring update to 30 June 2022 (which is different from the MAR project reporting period to 31 May) in Figure 5-1 shows median nitrate-N concentrations in PC2-specified “shallow” wells across the Hekeao / Hinds Plains alongside annual Ashburton rainfall. Rainfall for the last two years is presented as a complete line (for measured rainfall) and a dotted line (where the 155 mm of rainfall that fell from 29-31 May 2021, is moved to the following year). The dotted line provides a more useful comparison with measured nitrate-N concentrations, as the heavy rain event resulted in significant movement of nutrients through the soil profile, groundwater and surface water systems which were measured throughout Year 6 (2021-22). Figure 5-1 shows the adjusted 2021-22 year as one of the four wettest years and one of the four highest years for median nitrate-N concentrations since 2006. Other years with high median nitrate-N concentrations in Figure 5-1 either occurred in the same year as high rainfall totals or in the following year. Catchment scale enhancements such as MAR and NRR are not currently expected to significantly improve groundwater quality during periods of high groundwater levels due to the amount of soil and legacy groundwater nutrients mobilised by the rainfall events.

Over time, as the concentrations of legacy nutrients reduce, the impact of catchment scale enhancements are expected to become more noticeable. Given the dominating influence of rainfall over other factors affecting surface and groundwater quality and quantity, at an annual timescale the rainfall variation influence can be reduced by only comparing annual water quality and quantity results between years with similar annual rainfall. Within these comparisons, rainfall intensity, regularity and initial groundwater conditions are still likely to contribute to concentration variance, but these contributions are expected to be less significant than that of total rainfall. For Figure 5-1, ‘wet’ year comparisons can be undertaken for 2018[3] and 2022 monitoring results, while ‘dry’ year comparisons can be undertaken for 2016 and 2021 results. There was no MAR or NRR prior to June 2016, and only one MAR site prior to scheme expansion in late 2018. The 2018/22 and 2016/21 equivalent annual rainfall comparisons are therefore the first ‘before’ and ‘during’ comparisons for MAR / NRR. Adjusted rainfall totals were <1% higher for 2022 compared with 2018. The annual median PC2 nitrate-N concentration was 2% higher in 2022. Adjusted rainfall totals were 4% lower in 2021 compared with 2016. The annual median PC2 nitrate-N concentration was 6% lower in 2021. These results suggest no significant change in median nitrate-N groundwater concentrations for the recent ‘wet’ and ‘dry’ year comparisons. Earlier comparisons (e.g., 2008, 2010, 2012) show increasing nitrate-N concentration for similar annual rainfall.

It will take many years of monitoring before enough similar annual rainfall total sets can be utilised for more in-depth trend analysis. Another analysis option is the moving average, which smooths out the rainfall influence by calculating the average of the annual median concentrations over a multi-year time period. As an example, the gold dotted line in Figure 5-1 shows the five-year moving average nitrate-N concentration increasing until 2015, then stabilising. Rainfall variation in five-year averages is still 40% for this dataset. This variation reduces to 10% for a ten-year moving average, but the analysis can then only begin in 2015. A moving median is an alternative to moving average for this dataset. The five-year moving median timeseries show greater variation than the equivalent moving average, while the ten-year moving medians and averages are similar.

[3] Hydrologic year to 30 June

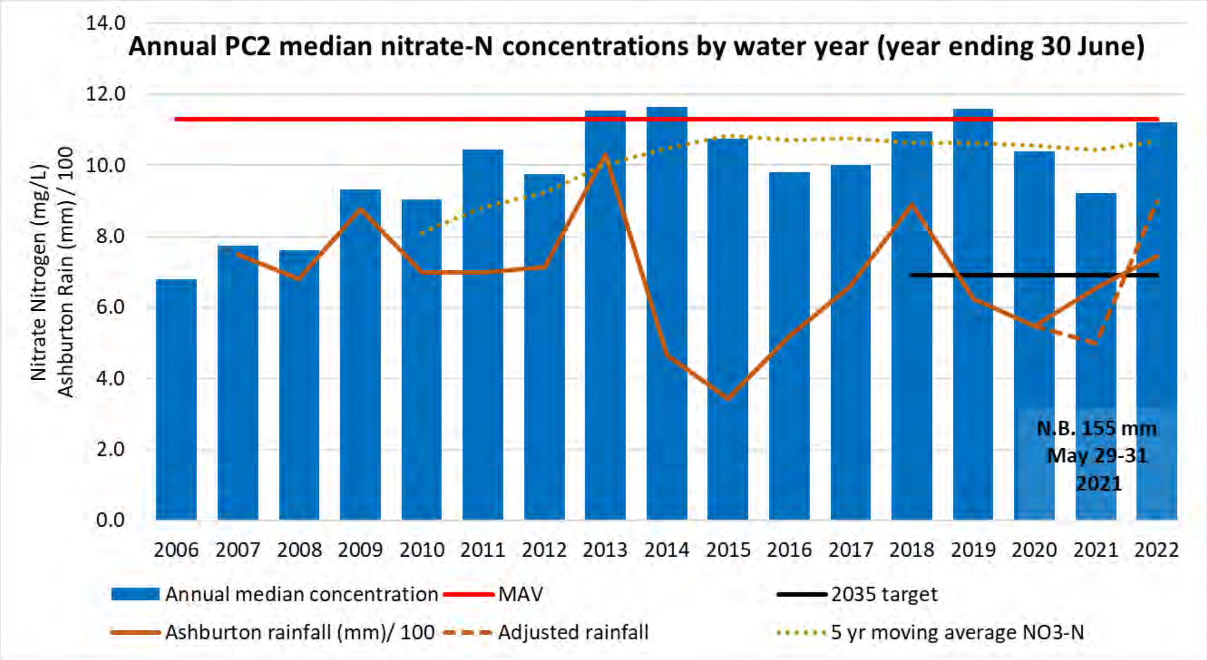

Figure 5-1: Plan Change 2 to Canterbury's Land and Water Regional Plan – Hekeao / Hinds Plains median annual nitrate-nitrogen concentrations plus Ashburton annual rainfall (Source: CRC)

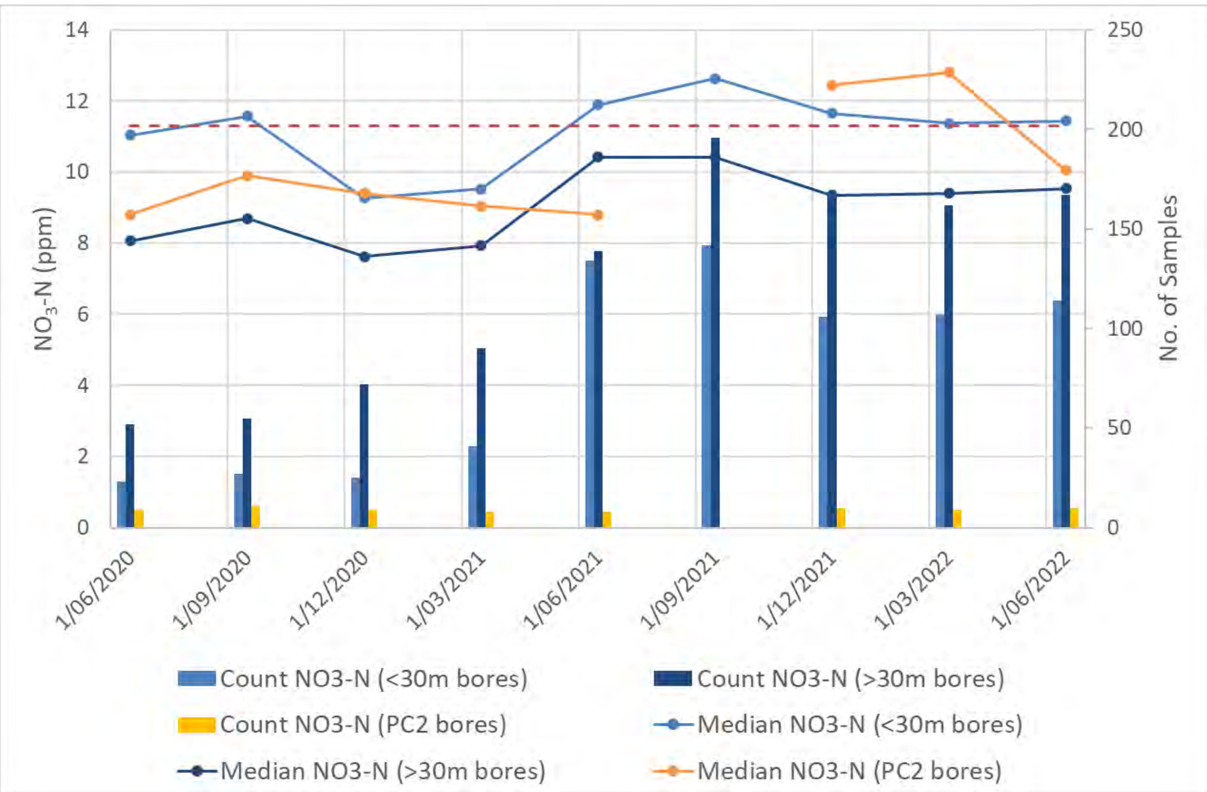

Figure 5-2: Year 6 Hekeao / Hinds groundwater nitrate-N monitoring (Source: MHV Water, CRC)

In order to assist with improved understanding of the catchment water quality along with improved targeting of concepts such as MAR to improve ecosystem health, MHV Water's Hekeao / Hinds Plains groundwater monitoring (on behalf of MHV Water and HHWET) has been underway since 2017. Results to 2020 are presented in the MAR Year 4 report. MHV Water monitoring coverage has increased significantly during Years 5 and 6. The vertical bars in Figure 5-2 show the number of MHV Water shallow (light blue), MHV Water deep (dark blue) and PC2 (orange) samples for each quarterly sampling round on the right axis. The number of PC2 bores stays the same throughout the year, but the total number of MHV Water bores increases to September 2021 then drops back slightly after the initial intensive monitoring following the May 2021 rain event. The ~150 bores in total monitored by MHV Water by the end of Year 5 cover the Hekeao / Hinds Plains, which will greatly assist analyses once a few years monitoring at this level of coverage is completed.

The median nitrate-N concentration is shown on the left axis for each set of bores and sampling round. Figure 5-2 shows that the Year 5 and 6 shallow MHV Water and PC2 bores only had similar (within 0.5 mg/l) median nitrate-N concentrations for two sampling rounds. The shallow MHV Water concentrations were higher than the PC2 result for four sampling rounds and lower for two sampling rounds. For each quarter the deep MHV Water bores show lower median nitrate-N concentrations than the shallow bore sets. All datasets show increased nitrate-N concentrations following the May 2021 rain event. No group showed median nitrate concentration reducing back to pre-rain event (March 2021) concentrations by the end of Year 6. More detailed analyses will be appropriate once a longer MHV Water dataset is available.

5.2 Hekeao / Hinds Northern Drains Water Quality

Consent conditions for MAR 01 (Lagmhor Pilot Site) discharge consents require water quality, quantity (flow) and ecology to be monitored in key Hekeao / Hinds drains. The piezometric contours and surface paleo channels presented in Figure 4-1 (noting that paleo channel direction may be different at different depths) suggests that recharge from MAR 01, MAR 07 and MAR 08 may contribute to the groundwater that provides spring-fed supply to the Flemington and Parakanoi Drains. However, the water quality assessment in Section 4-1 does not show measurable nitrate concentration decreases to date. As previously noted, Durney (2019) concludes that no measurable water quality effect on potentially connected lowland waterways is likely even if an average of 110 l/s from contributing MAR sites is achieved, due to the higher nitrate water also feeding this area from catchments to the northeast and southwest of MAR-influenced groundwater. The MAR volume delivered in Year 6 through these sites was 2.6 million cubic metres, equivalent to 83 l/s continuous recharge. The Hekeao / Hinds drains monitoring will therefore continue to be regarded as baseline monitoring until MAR volumes in this vicinity increase significantly.

Figure 5-3 presents the relevant monitoring sites for the Northern Drains. Figures 5-4 to 5-6 present the annual median NNN concentrations since the year ending June 2017 (which are used to assess whether the drains achieve the 6.9mg/l target), while Figures 5-7 to 5-9 present the monthly results. In general, Figures 5-4 to 5-9 show that water quality improves from the upgradient springs to the coast on the monitored drains. However, the only drain to meet the PC2 limits was the Windermere Drain Poplar Rd site in the 2021 year. Figure 5-7 shows that this was due to a significant period with low NNN concentrations during the irrigation season. The Windermere Drain below Boundary Road receives Targeted Stream Augmentation in addition to pumped irrigation supply (from the Eiffelton Community Group Irrigation Scheme). This augmentation influences water quality, particularly during periods of low natural spring flow and high irrigation demand, where this augmentation is sufficient to bring annual median NNN concentration below the PC2 target. Further assessment of this dataset shows that a missing sample in October 2020 was likely to be the reason why the Windermere Drain at Lower Beach Road didn't also achieve the annual PC2 target.

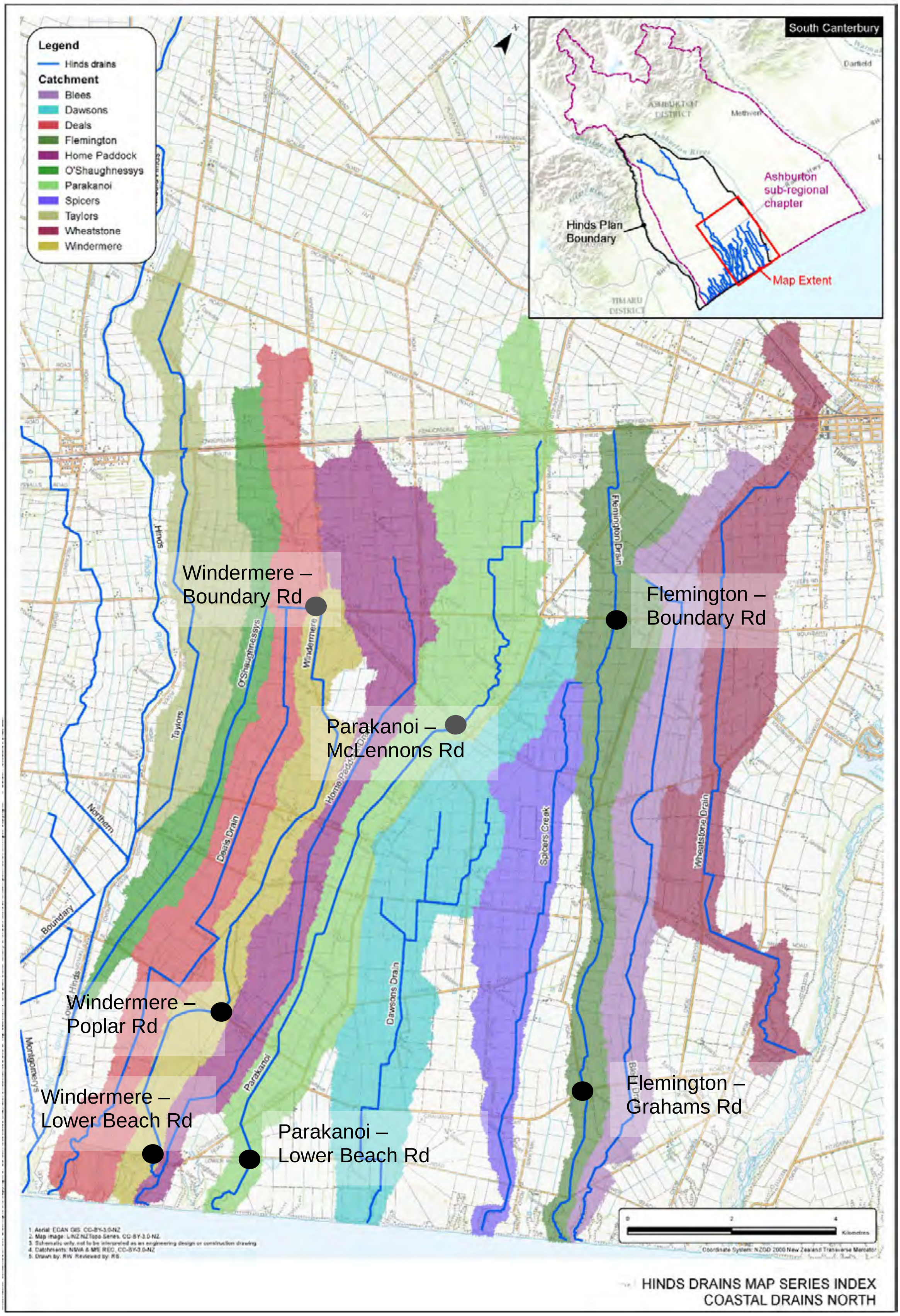

Figure 5-3: Hekeao / Hinds Northern Drains monitoring sites

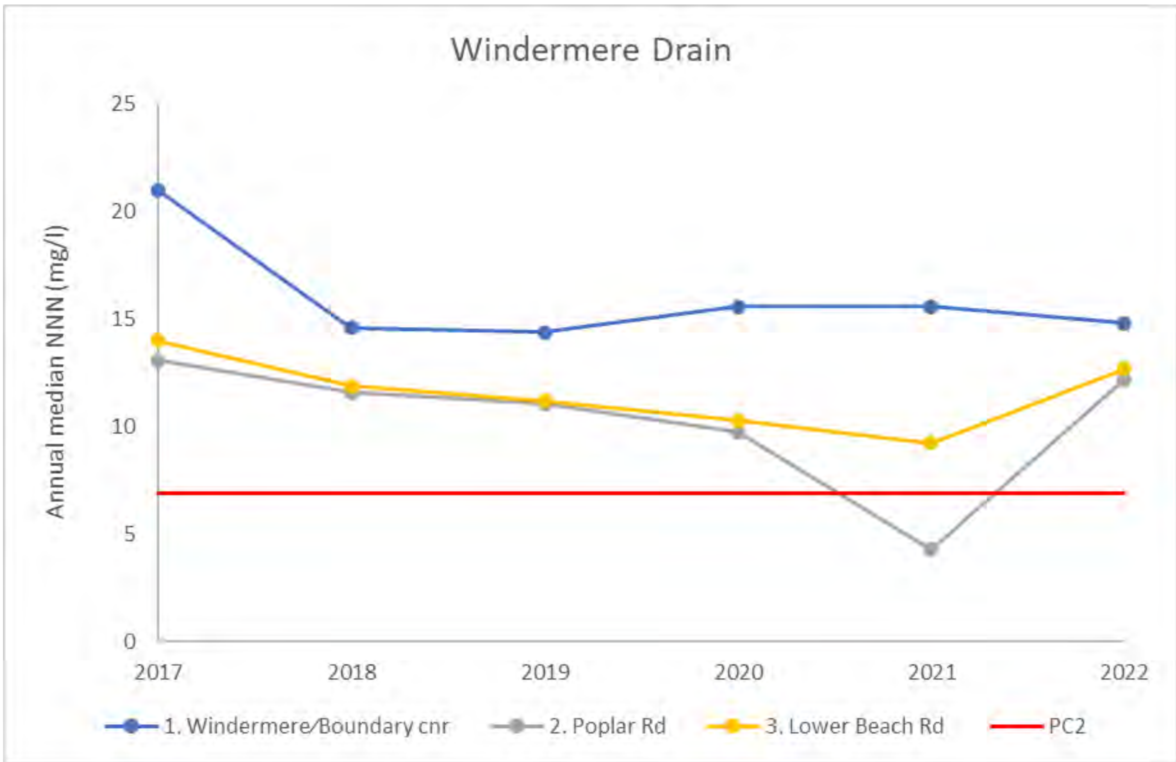

Figure 5-4: Windermere Drain annual median NNN monitoring (Source: CRC)

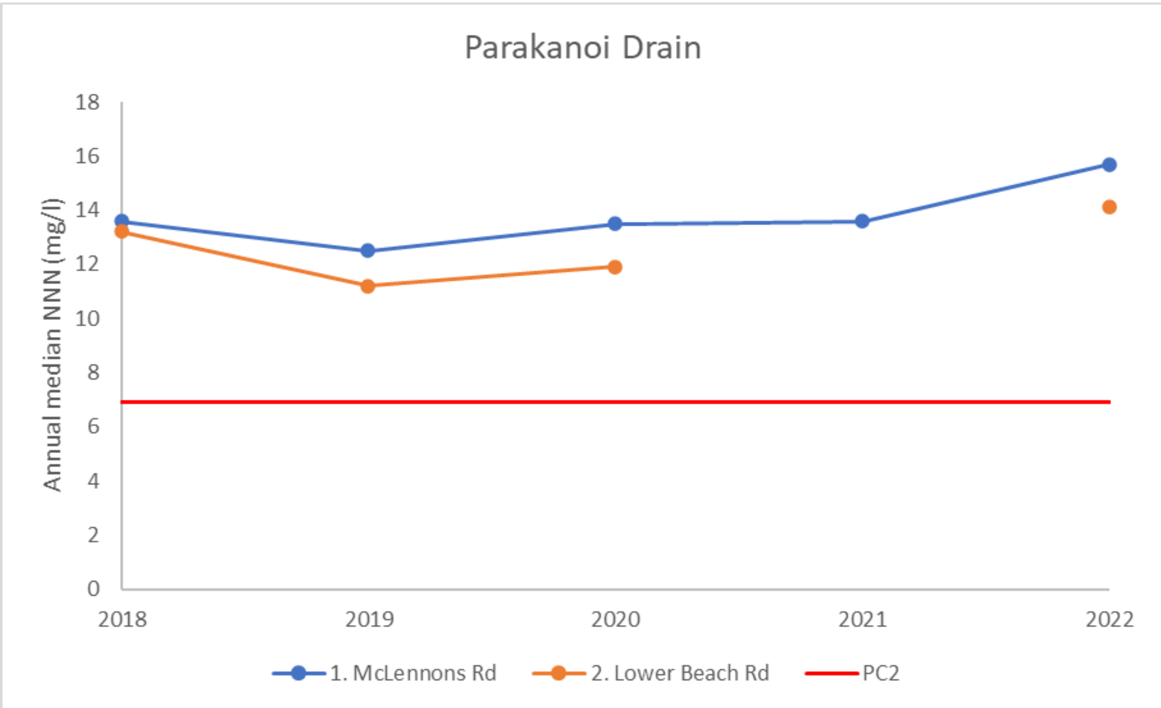

Figure 5-5: Parakanoi Drain annual median NNN monitoring (Source: CRC)

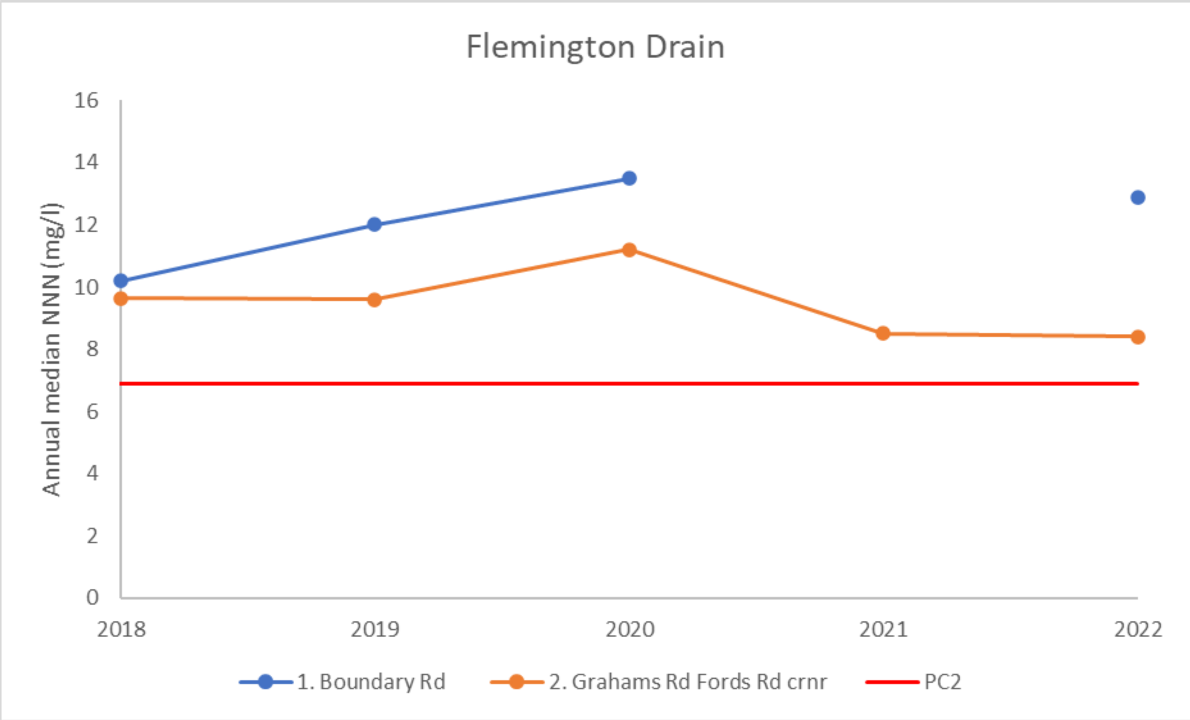

Figure 5-6: Flemington Drain annual median NNN monitoring (Source: CRC)

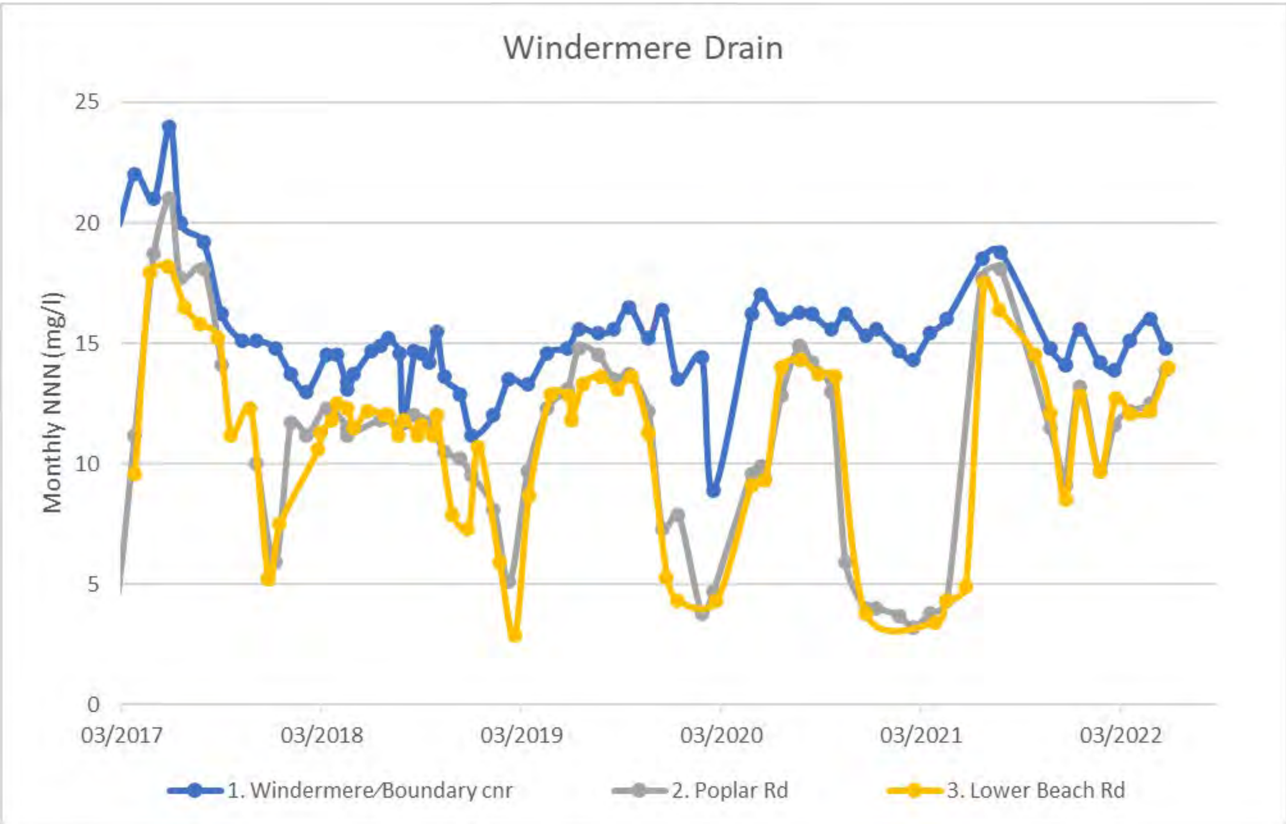

Figure 5-7: Windermere Drain monthly NNN monitoring (Source: CRC)

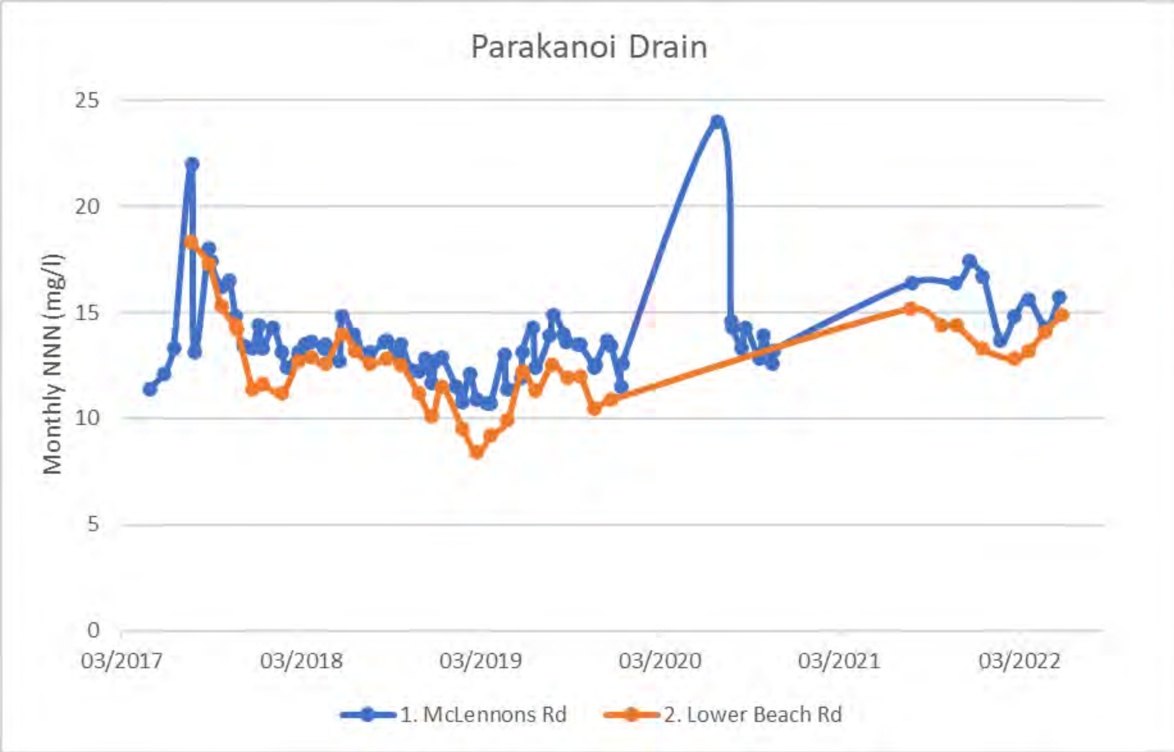

Figure 5-8: Parakanoi Drain monthly NNN monitoring (Source: CRC)

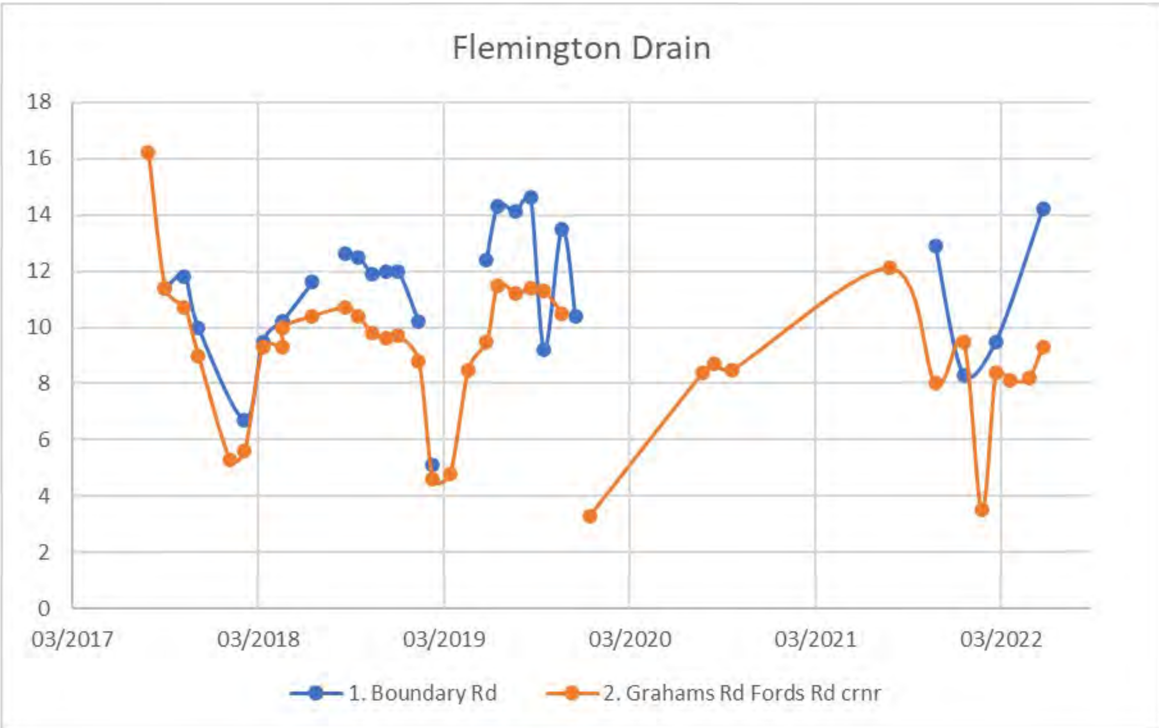

Figure 5-9: Flemington Drain monthly NNN monitoring (Source: CRC)

Figures 5-8 and 5-9 (for the Parakanoi and Flemington Drains) contain significant periods of missing data during 2020 and 2021. CRC records describe these periods as having low or no flow. Both drains have minimum flows measured at Lower Beach Rd for irrigation takes, with trigger levels of 100 l/s for the Parakanoi Drain and 25 l/s for the Flemington Drain. Parakanoi Drain nitrate concentrations vary by a factor of at least two while Flemington Drain nitrate concentrations vary by a factor of at least five. CRC records shows that significant decreases in Flemington Drain NNN concentrations usually occur in the summer months after a rainfall event, where surface rainfall runoff augments the low drain flow. Analysis and reporting at monthly as well as annual time frames will continue to assist understanding of this baseline data.

6 Irrigation Nutrient Recycling

The Irrigation Nutrient Recycling workstream is a catchment-wide HHWET initiative that focuses on supporting the incorporation of groundwater and drain irrigation water nutrients in on-farm fertiliser management. The need for this was established in Stewart & Aitchison-Earl (2020), who stated "The chemical concentrations of the groundwater are increased by recirculation of water already relatively high in chemicals {e.g., nitrate}. HHWET have worked with agribusiness consultants to develop case studies for pasture and mixed cropping situations. The concept and case studies have been shared through the HHWET website, HHWET Facebook page, groundwater irrigator meetings, MHV Water shareholders, and HHWET presentations. Irrigation New Zealand's Winter 2022 publication featured an article on this workstream to inform other irrigators and promote wider uptake.

Identified opportunities include:

- Lowering down-gradient surface and groundwater nutrient concentrations.
- Lowering the amount and cost of external fertiliser.

Identified challenges to improving outcomes in terms of groundwater and surface water quality include:

- Increased monitoring and analysis costs (not currently required through OVERSEER™).
- Irrigation using groundwater and drain water covers only part of the Hekeao Hinds Plains.
- There are a large number of independent irrigators, each with individual situations.

This workstream will be further developed in Year 7 (2022-23).

7 Next Steps

Year 6 highlights include measurable improvements in Hekeao Hinds River ecosystem health, MAR design and habitat enhancements, successful remediation and enhancement of NRR1 following the May 2021 floods, and evidence-based progression of the next stage of MAR / NRR Scheme development.

HHWET Ltd currently hold the following consents:

- CRC210832, which enables take and use of up to 500 l/s (supplementary to ADC consents CRC212909 and CRC169499) until December 2029.

- CRC210830, which enables discharge of up to 300 l/s at MAR01 until December 2029.

- CRC210704, which enables discharge of up to 210 l/s at NRR1 until September 2023.

- CRC210702, which enables discharge at up to 18 MAR test sites until January 2023.

With two consents expiring in 2023, a key focus for Year 7 (2022-23) is securing the following new consents, with duration until December 2029:

- Use of up to 3200 l/s, supplementary to RDRML consent CRC182542.

- Discharge of up to 610 l/s at 3 NRR sites (NRR1 plus two new NRR sites).
- Discharge of up to 3255 l/s at up to 34 MAR sites (including 14 of the current MAR sites).

Figure 7-1 presents the locations of current and potential MAR / NRR sites. Scheme development is part of an Integrated Catchment Management (ICM) approach that also includes analysis of on-farm improvements, potential future planning implications, changes to consented activities (e.g., consented takes from MAR / NRR influenced waterways), further analysis of sites influencing the Hekeao / Hinds River (currently the sites within the dark blue line), and the potential contribution of lower catchment enhancements such as Bioreactors, Constructed Wetlands and Targeted Stream Augmentation (see area labelled BW/TSA within green line).

New sites at the proposed locations will assist with the following objectives:

- Curtains of sites up-gradient from groundwater discharge points;
- Additional Hekeao / Hinds River augmentation via NRR; and
- Large upper catchment sites that are designed to be able to accept higher turbidity water.

Additional workstreams include communication (including social media and a website upgrade), water supply (via commercial arrangements), water distribution (including the trial of multi-use ADC water races), site access agreements, and collaboration with other agencies to minimise duplication and maximise use of available resources.

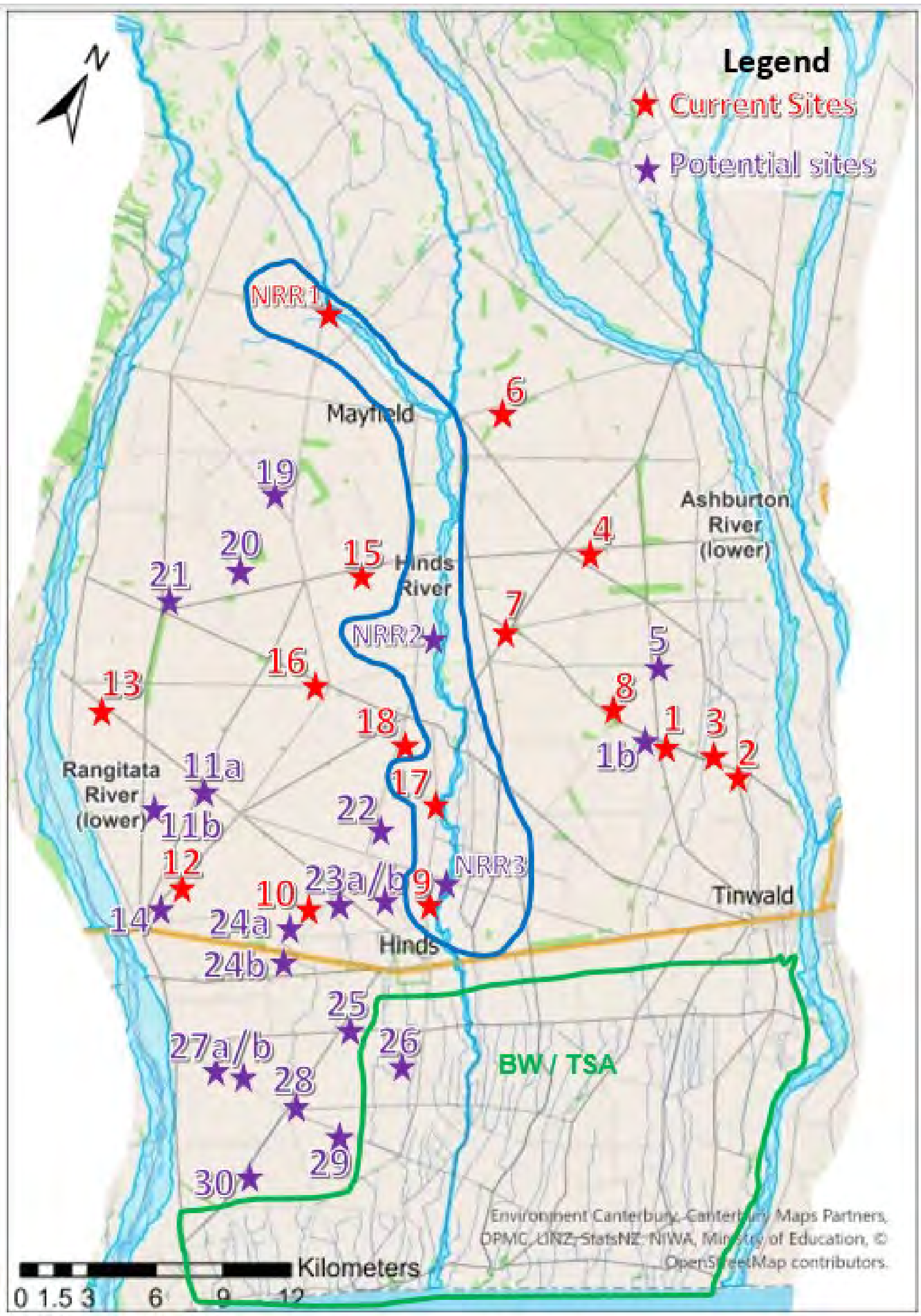

Figure 7-1: Hekeao / Hinds Plains enhancements, in addition to other catchment-wide improvements (e.g., on-farm nutrient management).

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