HEKEAO / HINDS
WATER ENHANCEMENT TRUST

Hekeao/Hinds Environmental Enhancement Projects

Year 7 Annual Report

(June 2022 – May 2023)

Dr Brett Painter (HHWET Executive Director)

	Name	**Date**
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Hekeao/South Hinds River NRR1 site in June 2023 (Source: HHWET)

Chairman's Foreword

It is my privilege to present this Chairman's Foreword on behalf of Hekeao Hinds Water Enhancement Trust.

The challenges our Hekeao Hinds Plains catchment face have not diminished. The first Environment Canterbury Plan Change 2 (Land and Water Regional Plan) nutrient reduction milestone occurs in 2025. The requirement for effective catchment wide nutrient mitigations that are complementary to the on-farm improvements are still as real as they were when PC2 was notified. The work of HHWET is and remains crucial to achieving the community decided environmental goals.

Our Year 7 work has been completed with our Managed Aquifer Recharge operations achieving a recharge volume of 9.7 M m3 for the year. This is a pleasing result, with an increase in recharge volume of 35% from the preceding year. This is despite sites MAR 02 to MAR 18 being unavailable for recharge since 31 May 2022 due to Environment Canterbury declining HHWET's consent continuance request.

HHWET workstreams undertaken this year that are complementary to Managed Aquifer Recharge and Near River Recharge include progressing Nutrient Recycling with groundwater irrigators, partnering with Mid Canterbury Catchment Collective in installation and consenting of two eClean Bioreactors sited on the Northern Drain, plus preliminary consent investigations for a large constructed wetland adjacent to the lower Hekeao Hinds River. In partnership with Eiffelton Community Group Irrigation Scheme (ECGIS), plans are advanced to trial Targeted Stream Augmentation to lower nutrient levels and enhance flows in the Windermere Drain.

These workstreams all fall under the umbrella of HHWET's Hekeao Hinds Environmental Enhancement Scheme.

Working with MHV Water and BCI, HHWET are contributing to the Hekeao Hinds Plains groundwater and surface water monitoring program. Monitoring is undertaken at approximately 150 sites, 4 times a year. This is the most comprehensive water sampling undertaken in any catchment in Canterbury.

Results to date are indicating stable to decreasing nitrate concentrations and are reported in the body of this report. These positive results are in part due to the steps taken by farms in the catchment to reduce on-farm nutrient leaching.

In December 2022 HHWET lodged a suit of consents to expand operations from targeted trial sites to catchment wide sites in line with Environment Canterbury's Plan Change 2 expectations.

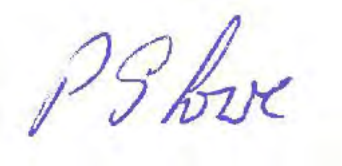
Environment Canterbury have been partners in this project with HHWET in the Hekeao Hinds Plains from the beginning, and their decision to not grant continuance to HHWETs existing consents on expiry this year is a major concern to HHWET. There is no doubt that the loser from this decision by Environment Canterbury is the Hekeao Hinds environment.

Also of serious concern to the Trust is Environment Canterbury's ongoing lack of prompt processing and decision making regarding HHWET's lodged consents. This will impact on HHWET's ability to assist with achieving Environment Canterbury's Plan Change 2 objectives.

In accordance with the HHWET / Environment Canterbury Agreement governing the Long Term Plan targeted rate funding, HHWET provide Environment Canterbury with quarterly reports and meet with Environment Canterbury staff at regular intervals to discuss these reports.

In a year frustrated by decisions made by Environment Canterbury staff I sincerely thank all HHWET Trustees for their time and dedication given to providing excellent governance. I would also like to thank retiring Trustees Sir Graeme Harrison and Richard Wilson, and welcome new Trustee Evan Chisnall representing RDRML. Dr Brett Painter and Murray Neutze (MHV Water), in their respective roles of Executive Director and Operations Lead, are extremely valuable to the progress of this project, and I thank them for their work this year. MHV Water hydrogeologist Justin Legg continues to provide support through the monitoring program and other areas; this is also appreciated.

Finaly I would like to express my gratitude for the support given by the Hekeao Hinds community, be it through access to sites, collaboration with the monitoring program, and ongoing support for the targeted rates that fund the Trust's activities.



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.

Hekeao Hinds Water Enhancement Trust (HHWET) are a community-led charitable trust established in 2019, currently governed by 11 Trustees representing Ashburton District Council (ADC), Environment Canterbury (ECan), Ashburton community, Hinds drainage district, Mid Canterbury Federated Farmers, Rangitata Diversion Race Management Ltd, and Ashburton District irrigation companies. A representative of Central South Island Fish and Game Council attends meetings and works closely with HHWET as an observer/advisor. Mid Canterbury Catchment Collective representatives also attend monthly meeting. HHWET employ an Executive Director and contract out other services.

The Challenge:

Increased farming intensity, climate change and other demands on our water resource have resulted in adverse environmental effects – namely reduced water quantity and 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. These efforts are focussed on achieving the following 2035 targets as detailed in Plan Change 2 to Canterbury's Land and Water Regional Plan (LWRP PC2, 2018):

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

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).

To achieve these goals, HHWET are contributing to an Integrated Catchment Management (ICM) approach for developing a Hekeao/Hinds Environmental Enhancement Scheme via four complementary

focus areas (as presented in Figure ES-1). This approach is co-ordinated through the Hekeao Hinds Science Collaboration Group, of which HHWET hold the primary oversight role.

To date, HHWET's key contribution to on-farm improvements has been via its leadership of the Irrigation Nutrient Recycling workstream. HHWET are contributing to groundwater and ecosystem health via the trialling and implementation of Managed Aquifer Recharge (MAR) and Near River Recharge (NRR) concepts. Additional biodiversity gains occur in the vicinity of MAR and NRR sites due to land retirement, native plantings, lizard, bird, and fish habitat. In addition to the MAR and NRR support for spring-fed ecosystems, HHWET are leading and/or supporting the trialling and implementation of Targeted Stream Augmentation (TSA), Bioreactors and Constructed Wetlands. The "managing allocation" focus area is about supporting sustainable water allocation and HHWET's contribution is to ensure that MAR, NRR and TSA activities are not covering for overuse or overallocation situations. For example, HHWET have confirmed that no surface water takes from the Hekeao Hinds River mainstem have occurred for ~10 years. HHWET will oppose any future surface water take consent applications from the Hekeao Hinds River, thus maximising the benefits of NRR. HHWET have also committed to only applying for supplementary / shadow take consents rather than applying for new take consents.

The reporting of progress towards these goals focusses on the contribution of the trialled tools to relevant PC2 Targets. 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. Consultation on the new integrated planning process (including the Canterbury Regional Policy Statement and targeted changes to the Canterbury Land and Water Regional Plan) began during the 2022-23 operational year and will continue through the 2023-24 operational year.

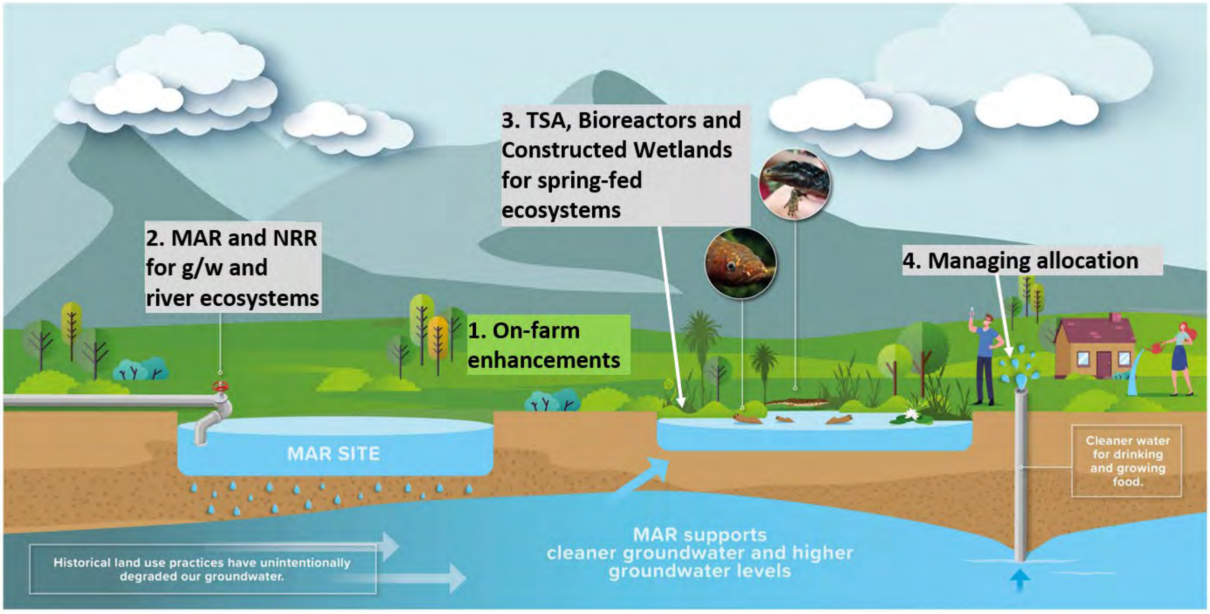


Figure ES-1: Hekeao/Hinds Integrated Catchment Management (ICM) approach.

2022-23 progress:

During Year 7 (2022-23), HHWET continued the project phase that began in 2021 which is funded by a Targeted Rate to Hekeao/Hinds Plains landowners, through Environment Canterbury's Long-Term Plan. Arrangements continued with project partners Ashburton District Council, Rangitata Diversion Race Management Ltd (RDRML), Central South Island Fish and Game, and MHV Water. HHWET thanked and farewelled Trustees Sir Graham Harrison (co-opted Trustee) and Richard Wilson (RDRML) and welcomed Trustee Evan Chisnall (RDRML). HHWET met monthly except for January with meetings focussed on agreements, arrangements, permissions and policies, financial accountability, external reporting, and progress toward 2022/23 objectives.

The primary technical focus for 2022-23 has been the development and consenting of the next stage of an Environmental Enhancement Scheme for the Hekeao Hinds Plains, which includes new MAR and NRR sites, and trials of bioreactor, constructed wetland and TSA concepts (Figure ES-2). This process has relied on the extensive monitoring and analysis to date. Target areas for Managed Aquifer Recharge (MAR), Near River Recharge (NRR), Targeted Stream Augmentation (TSA), Bioreactors and Constructed Wetlands (BW) have been defined and new MAR sites identified to trial. Potential water requirements have also been refined. Initial assessments for the Ashburton Zone Implementation Programme Addendum (Ashburton Zone Committee, 2014) which informed PC2 were for a maximum MAR flow of 5 m^3/s and an average of 3.8 m^3/s. Current and proposed MAR/NRR sites are expected to require a maximum combined MAR/NRR flow of 3.7 m^3/s, and an average of 2.4 m^3/s. An expansion of current TSA, plus successful bioreactor and constructed wetland contributions will be required to confirm the reduced MAR requirements. Consent applications have been lodged for the MAR, NRR and bioreactor components, with consenting investigations for TSA and initial constructed wetland trials underway. There have been significant delays in Canterbury Regional Council's processing of these applications. The ecosystem health benefits that will occur once the relevant activities are authorised are also therefore delayed.

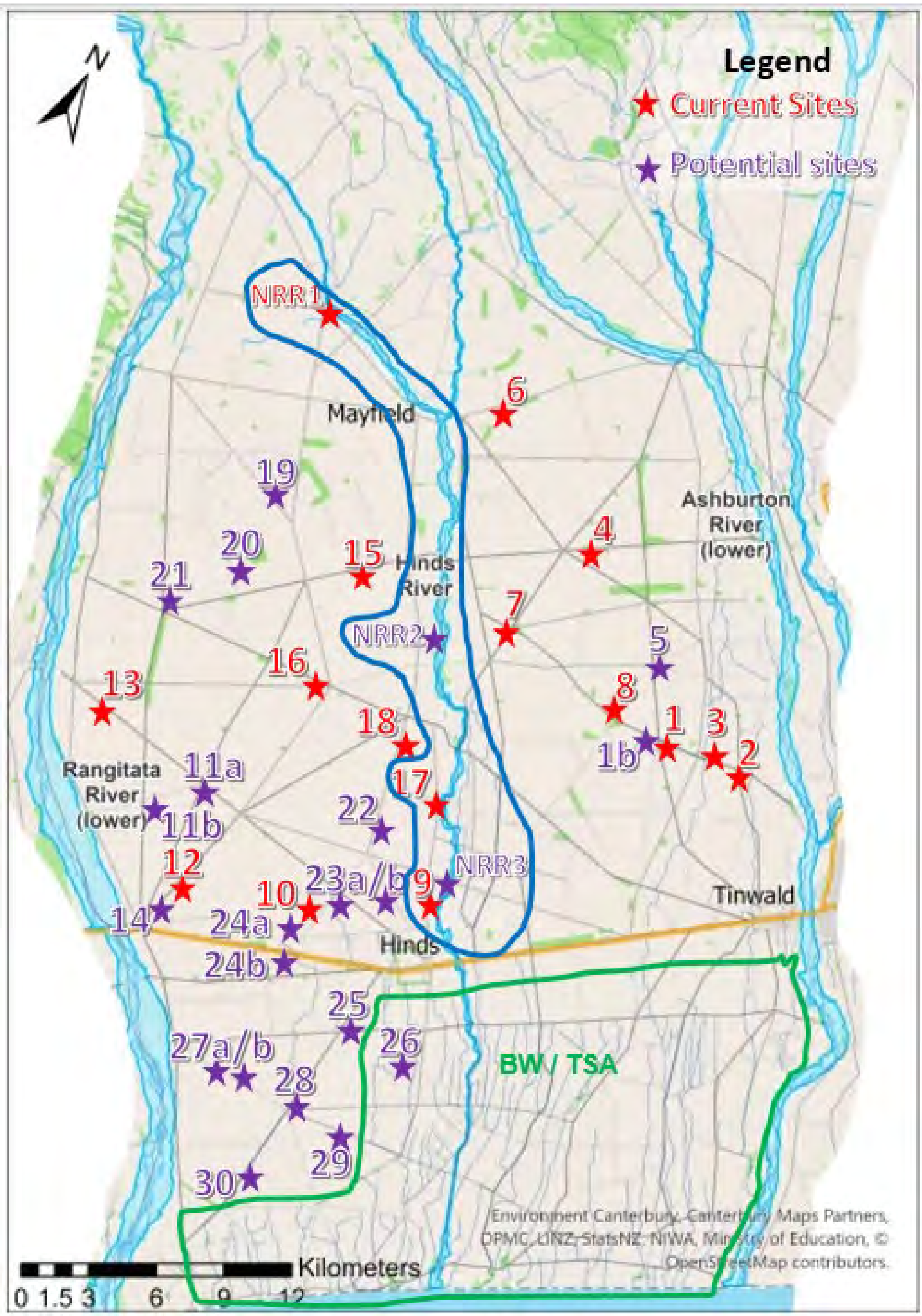


Figure ES-2: HHWET Environmental Enhancement Scheme 2022/23

What we learned:

Key learnings from Year 7 (2022-23) include:

- Analysis methods (equivalent rainfall year comparisons and moving average comparisons) have been found to be useful methods of presenting water quality and water quantity monitoring information, as they reduce the dominating influence of rainfall on annual statistics.
- 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 (just following rainfall fluctuations).
- When MHV Water/HHWET quarterly water quality data is added to the ~12 PC2 monitoring sites, analysis can be presented for a maximum of 84 shallow groundwater (PC2 definition) sites. Analysis of this dataset shows lower levels of seasonal and annual variation than the PC2 dataset. Due to the larger number of bores and their greater geographical coverage, this expanded dataset is a more accurate representation of catchment shallow water quality (as defined by PC2) than the PC2 dataset.
- Groundwater quality (as per the expanded dataset) shows a recent peak after the May 2021 rain event and reasonably consistent improvement since. By May 2023, median shallow nitrate-N concentrations for the Hekeao/Hinds Plains had returned to levels like Autumn 2021 (prior to the rain event). The annual (July 2022 – June 2023) rainfall total (789 mm) was not close enough to previous annual rainfall totals to provide a new equivalent rainfall year comparison (previously provided for 2015/16 vs 2020/21 and 2017/18 vs 2021/22).
- Groundwater monitoring in areas influenced by MAR sites continues to show significantly lower nitrate concentrations than pre-MAR and nearby bores at a similar depth. The key monitoring bore 1 km down-gradient from MAR01 (Lagmhor Pilot Site) reached ~4 mg/l nitrate-N after the May 2021 rain event, its highest concentration since MAR01 operations began. However, by June 2023 the nitrate-N was ~1 mg/l, its lowest concentration since MAR01 operations began.
- Likely MAR influence has also been identified in groundwater deeper than 100 m, in a bore down-gradient from MAR07. Monitoring of this groundwater will continue so the level of confidence in this analysis can be increased.
- Hekeao/Hinds River water monitoring and fish surveys show that NRR and MAR sites have supported increased length of flowing reaches, increased flow rates, and improved water quality, which are highly likely to have contributed to increased fish populations.

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 number of sites and length of datasets enable the other influences on water quality and quantity to be more visible in surface and groundwater monitoring. Potential influences will continue to be assessed.

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 gradually 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.

Learnings to date also suggest that environmental infrastructure can be scaled-up to assist on-farm improvements in achieving more challenging catchment targets and timeframes (as currently contemplated in NPS-FM 2020). However, there are environmental, economic, social, and cultural costs as well as benefits to consider. HHWET will continue to assist these considerations through evidence-based analysis.

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1 Introduction

Plan Change 2 (PC2) to Canterbury's Land and Water Regional Plan (LWRP) includes requirements to reduce on-farm nitrogen leaching by 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. Potential changes to the Canterbury Regional Policy Statement and LWRP are under consultation in response to the New Zealand Government's "Essential Freshwater" package. These changes may adjust targets and/or monitoring requirements at some point in the future, but PC2 remains active in the meantime.

Table 1-1 shows that the total recharged MAR volume in 2022/23 (Year 7) was approximately 9.7 million m^3, which is the second highest annual total to date. This was achieved despite high groundwater table shutdowns and Canterbury Regional Council's (CRC) decision to not exercise their discretion to allow continued operation of the MAR02 – MAR18 sites while their replacement discharge consents were being processed. Figure 1-1 shows that the low delivery periods (due to high groundwater levels) were in June, August, and September 2022.

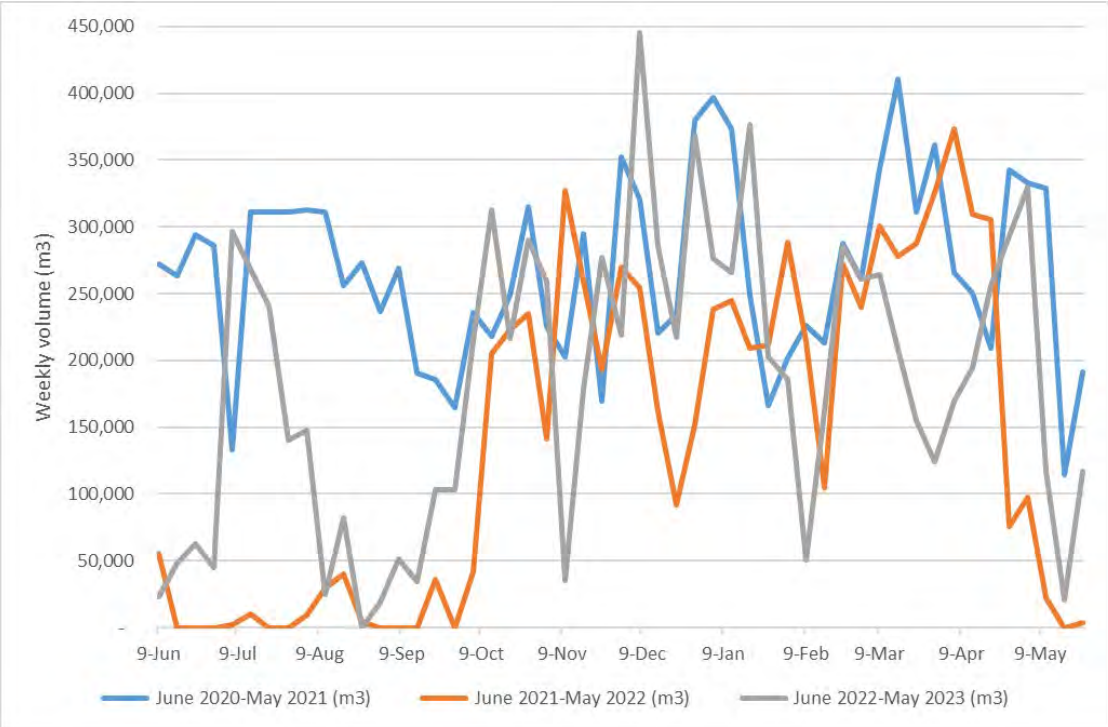

Figure 1-1: Total MAR/NRR weekly volume since June 2020. Source: HHWET.

Table 1-1: 2022-23 Hekeao/Hinds MAR/NRR recharge

	MAR volume (cubic metres)
Delivered to South Hinds NRR1 Site	3,529,366
Delivered to MAR Pilot Site MAR01	1,629,751
Delivered to MAR Sites MAR02-18	3,618,506
Distribution system recharge (race "losses")	746,842
New site testing (MAR27a)	139,104
Total 2022-23 recharged flow	**9,663,568**

The nitrate-N PC2 update to 30 June 2023 in Figure 1-2 shows median nitrate-N concentrations in PC2-specified "shallow" wells across the Hekeao/Hinds Plains alongside the larger MHV/HHWET/PC2 "shallow" wells dataset. Annual Ashburton rainfall is also provided. Rainfall for the 2020/21 and 2021/22 hydrologic 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 2021/22 and into the 2022/23 hydrologic years.

The MHV Water/HHWET/PC2 water quality "shallow" bore dataset is presented in this annual report (for the first time) for comparison with the PC2 (only) dataset. There are up to 12 PC2 bores monitored each year; the addition of MHV Water and HHWET "shallow" bores increases this dataset to a maximum of 84 sites. Acknowledging that the combined dataset is only three years long, initial analysis (presented in Section 5.1) suggests lower levels of quarterly and annual variation than the PC2 dataset and a higher level of confidence in the catchment-scale representativeness of summary statistics.

Nutrients in water are transported from the soil profile through the unsaturated zone and groundwater system; this can be measured in nearby wells within days (to weeks) of a rainfall event but can then take much longer (e.g., years to decades) to travel through the catchment to the ocean. Low nutrient recharged water from a MAR or NRR site travels to and through the groundwater system in a similar way, with recharge operations driving this process as well as rainfall events. The travel time is known as the lag time. The water sampled at a particular monitoring site will represent water that has taken many different pathways and hence will have numerous different lag times. Assessing the relative contributions of on-farm improvements, MAR/NRR, and rainfall for a set of monitoring bores is therefore challenging.

Various evidence shows that rainfall recharge is a strong driver of changes in nitrate concentrations in groundwater (e.g., Mourot et al., 2022, ECan, 2023). Figure 1-2 shows 2023[1] as a relatively high rainfall year with an annual median nitrate-N nitrate concentration that was only matched or exceeded in four years of the past 18. 2023 was also preceded by a year with high annual average rainfall. A comparison of changes in nitrate and rainfall statistics in Figure 1-2 suggests that there is a 1-2 year lag between rainfall changes and corresponding nitrate changes in shallow groundwater.

Given the dominating influence of rainfall recharge events over other factors affecting surface and groundwater quality and quantity, at an annual timescale a preferred analysis technique is to focus on comparing annual water quality and quantity results between years with similar annual rainfall. While rainfall intensity, rainfall timing and initial groundwater conditions will still contribute to concentration variance in these analyses, other factors affecting nitrate concentration will be clearer than a nitrate concentration comparison between years of significantly different rainfall. For Figure 1-2, 'wet' year comparisons were undertaken for 2018 and 2022 monitoring results, while 'dry' year comparisons were 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 2023 annual rainfall total is not close enough to previous annual rainfall totals for an equivalent rainfall year comparison. Acknowledging the multiple potential concentration influencers noted above, annual median nitrate-N comparisons for PC2 bores suggest no significant change in median nitrate-N groundwater concentrations for the recent 'wet' and 'dry' year comparisons. Comparisons of earlier years presented in Figure 1-2 (e.g., 2008, 2010, 2012) shows increasing nitrate-N concentration for similar annual rainfall.

Another option to assess the annual statistics 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.

[1] Hydrologic years, to the year ending 30 June, for example, "2023" represents the 2022/23 hydrologic year.

As an example, the blue dotted line in Figure 1-3 shows the five-year moving average nitrate-N concentration increasing until 2015, then stabilising. The gold dotted line in Figure 1-3 shows higher 5 year average annual rainfall until 2014 and then lower average annual rainfall from 2015 to 2021. The higher 5 year rainfalls from 2011 to 2015 had a greater influence on 5 year nitrate concentration variations during this period than during the 2015 to 2021 period, so the noted nitrate increases from 2011 to 2015 cannot be only attributed to other potential causes such as increasing land use intensity. The increasing rainfall statistics from 2018 to 2021 correspond with stable to decreasing nitrate statistics. As the rainfall statistics are lower than the 2011 to 2015 period and as the rainfall and nitrate statistics are moving in opposite directions, we can have more confidence that improved nutrient management is contributing to these nitrate statistics. Section 5.1 includes further analysis and discussion on this topic.

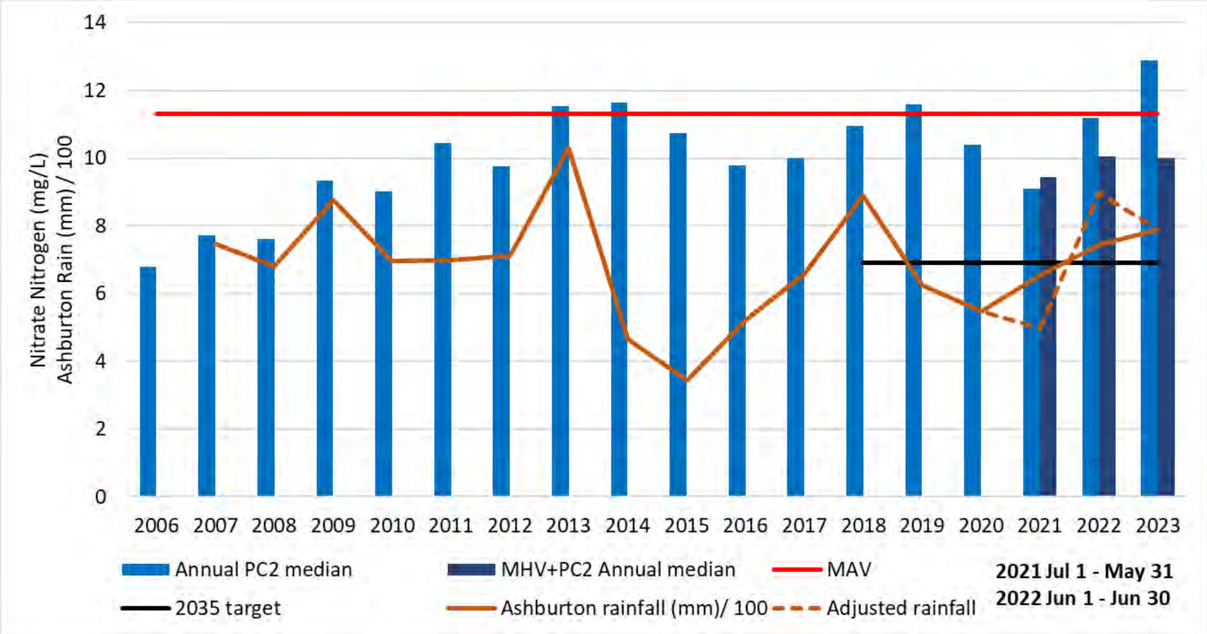

Figure 1-2: Plan Change 2 to Canterbury's Land and Water Regional Plan (PC2) – Hekeao/Hinds Plains median annual nitrate-nitrogen concentrations plus Ashburton annual rainfall (Source: MHV Water, HHWET, CRC)

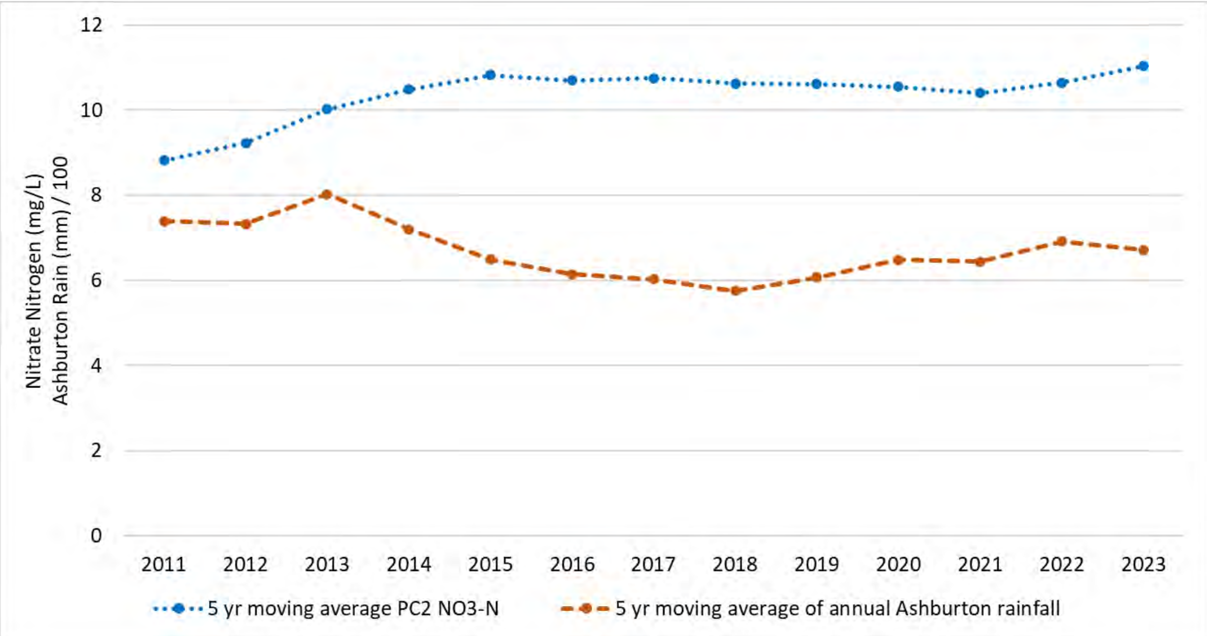

Figure 1-3: PC2 – 5 year moving average of Hekeao/Hinds Plains median annual nitrate-nitrogen concentrations plus Ashburton annual rainfall (Source: MHV Water, HHWET, CRC)

This report focusses on NRR and MAR operational updates, key monitoring information and analysis. Updates are also provided on the other catchment-scale enhancements HHWET are involved in, which are at an earlier stage of development. Consent compliance monitoring results are presented in the Annual Compliance Report (HHWET, 2023).

Figure 1-4 presents the NRR and MAR sites operational during 2022/23 and Table 1-2 presents their key performance indicators. Two MAR sites utilised in 2021/22 were not utilised in 2022/23 so that available flow could be targeted at the highest performing sites. Canterbury Regional Council's decision to not exercise their discretion to allow continued operation of the MAR02 – MAR18 sites while HHWET's replacement discharge consents were being processed meant that sites MAR02 - MAR18 were shut down in mid-January 2023, except for high flow testing purposes which continued until 31 May 2023. This had a significant impact on total recharge volume, weeks in operation, and resultant environmental benefits. The other significant supply constraint in 2022/23 was due to the MHV Water Valetta distribution being unavailable from 2 August – 27 September 2022 due to maintenance requirements.

Testing of MAR source water ensures that it is of high quality. Nitrate-N, suspended sediment and *E. coli* are the key source quality parameters (as indicators of water quality, recharge site 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 2022/23 monitoring, and turbidity was lower than 2021/22 (see Table 1-3, for example 60% of flow less than 60 NTU in 2022/23 and <50% of flow less than 60 NTU in 2021/22). 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 2022/23, however turbidity does reduce as the water travels through the distribution system (particularly in water storage ponds). MAR site shutdowns for *E. coli* exceedance totalled 17 (Table 1-2), down from 36 in the previous year, but occurring over fewer operational weeks than in 2021/22.

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 Rakitata/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. MAR10 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. 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 recharge site clogging risk as well as *E. coli* risk.

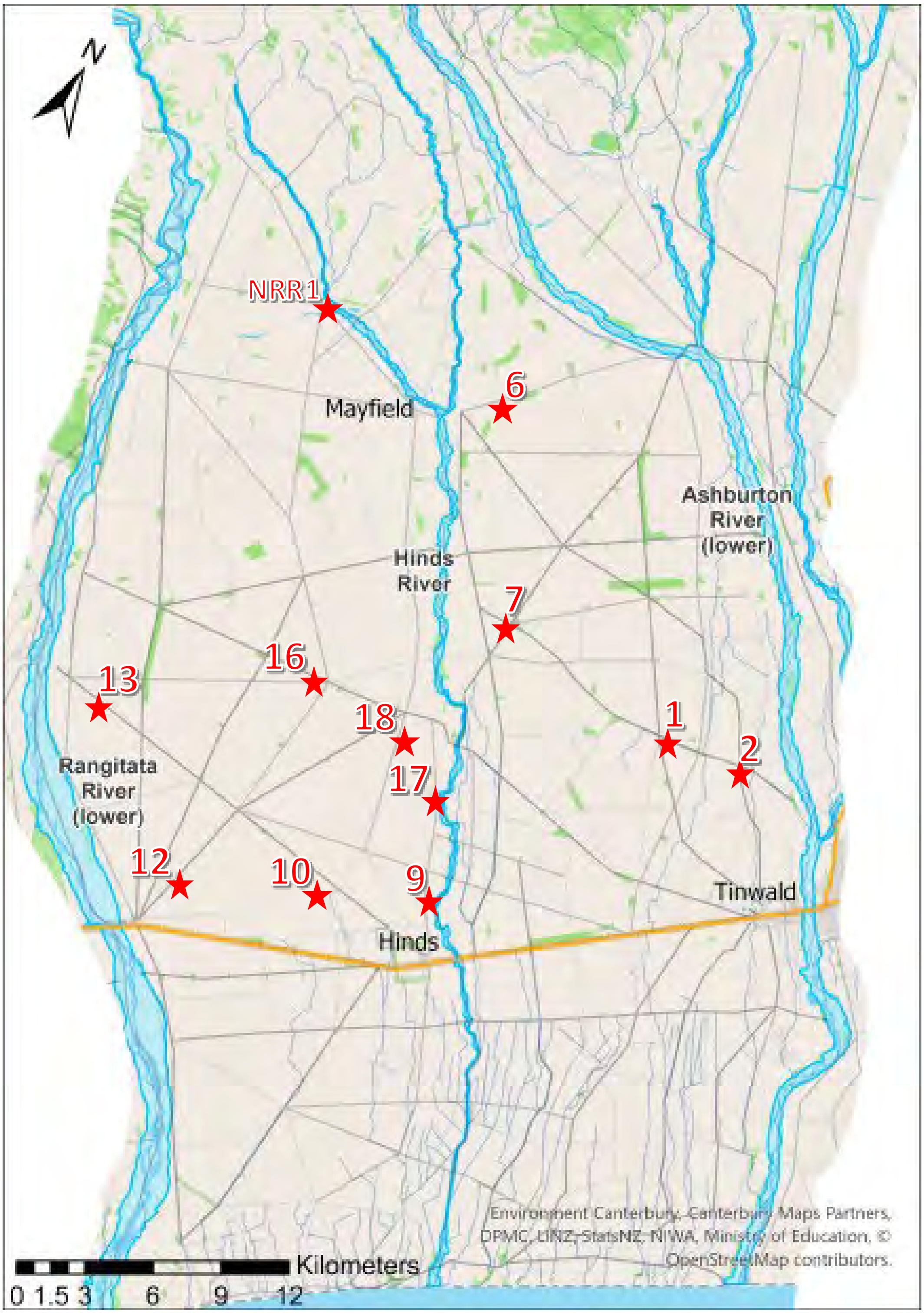

Figure 1-4: Hekeao/Hinds NRR/MAR sites operational during 2022/23

Table 1-2: MAR site performance information for June 2022 – May 2023 inclusive (Year 7)

June 2022-May 2023	Maximum weekly ave recharge rate (l/s)	Total recharge volume (m^3)	Weeks in operation	*E. coli* shutdowns	Notes
1 – Lagmhor Pilot	135	1,627,751	34		
2 – Timaru Track	114 (high flow trial)	532,614	18		
6 – BCI/Howden	15	125,567	16		Supply limited to ~25 l/s
7 - Lobblin	163 (high flow trial)	688,128	17		
9 – Riverbank	56	401,006	22		
10 - Foster	35	174,658	17	4	
12 - Slee	44	265,529	18	3	
13 – Hills view	33	217,186	22		
16 - Broadfields	18	210,970	22	1	
17b – Jones	190 (high flow trial)	856,028	23	3	
18 - McDougall	36	146,820	12	6	
27a - Proposed	77	139,104	4		Flow trial for proposed site
NRR1 - South Hinds	358 (high flow trial)	3,529,366	48		
MH race losses	222	746,842	8		

Table 1-3: RDR Intake turbidity distribution for 2021/22 and 2022/23 (percent of flow less than prescribed turbidity)

Percentile	2021/22 Turbidity (NTU)	2022/23 Turbidity (NTU)
10	28	28
20	33	31
30	38	33
40	46	38
50	62	47
60	90	60
70	138	84
80	223	138
90	691	345
100	2840	2833

2 Hekeao/Hinds River Project

Chapter 2 of the Year 5 (2020/21) HHWET report introduces the Hekeao/Hinds Plains hydrogeology and provides the reasoning behind the Hekeao/Hinds River Project (HHRP). The purpose of the HHRP is to trial complementary ecosystem enhancements for the purpose of improving the ecosystem health of the whole Hekeao/Hinds River system (in combination with relevant on-farm enhancements 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 upper catchment 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 and ensures that there is no risk of ecosystem harm by direct mixing of NRR water with river water. The shallow groundwater table around NRR sites is raised, which supports local wetlands and the establishment of native plants (aquatic and terrestrial). The aquatic life of supported wetlands and river reaches is therefore enhanced. Other biodiversity initiatives, such as protection of valued existing terrestrial plants and/or wildlife, can be progressed at NRR sites as added value.

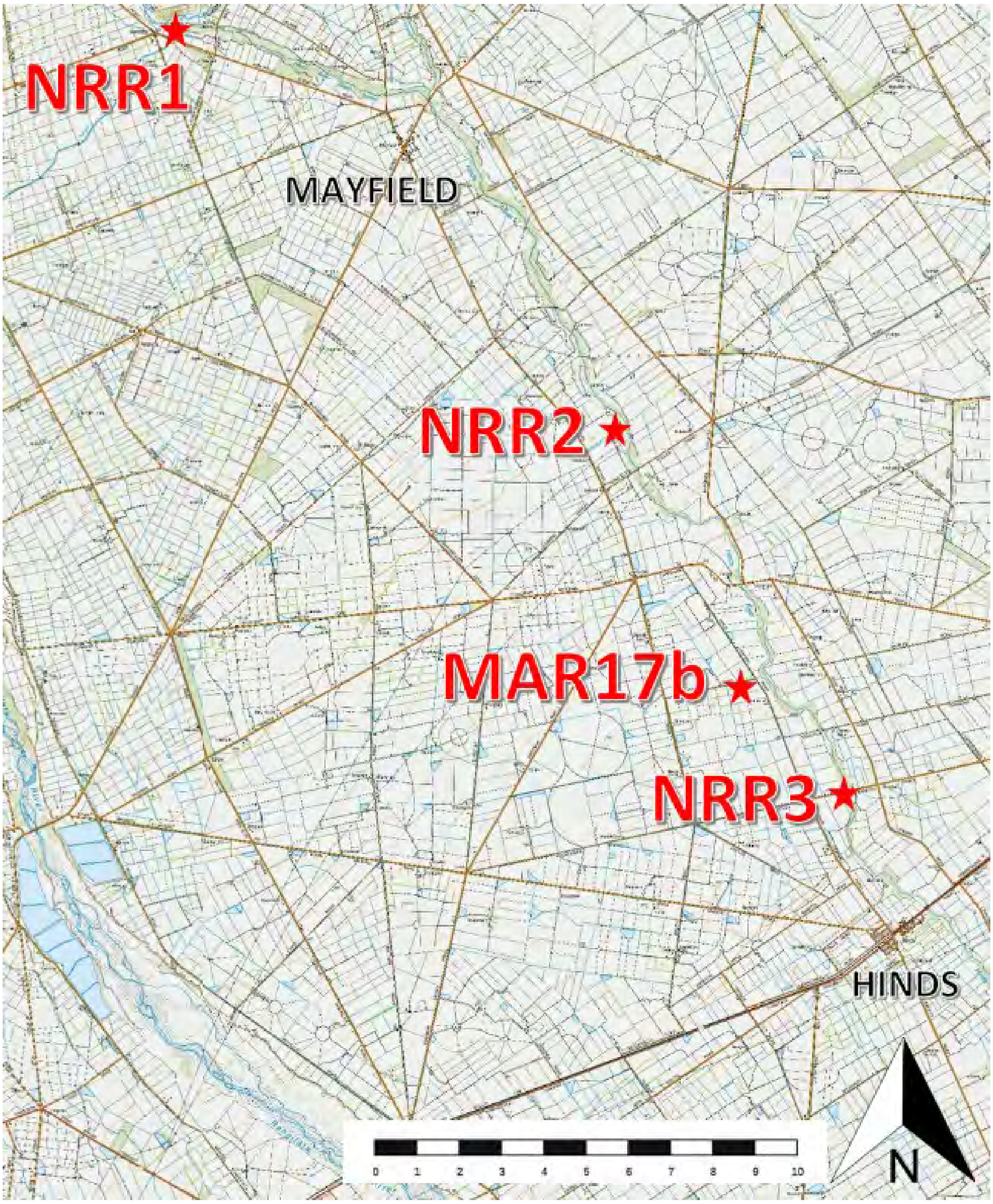

Figure 2-1: Current and potential HHRP sites

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 operations in June 2020. Assessment and preliminary design processes for NRR2 and NRR3 began in 2021 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 additional recharge basins in 2021 has enabled supply flow up to 400 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 has been rehabilitated and extended for native fish habitat. This wetland is supported by the raised local groundwater due to NRR. Since the site began operations in 2018, approximately 25 hectares of farmland has been fenced and retired in the vicinity of NRR1 and approximately 17,000 native plants (wetland and dryland) have been reintroduced (Figures 2-3 to 2-6). 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 Kōtuku/White Heron.

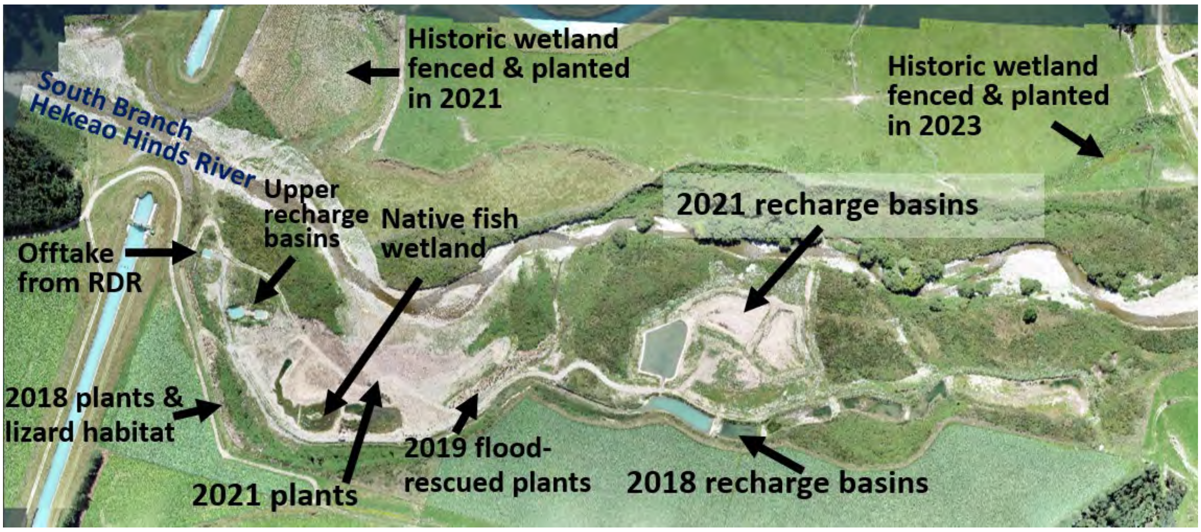

Figure 2-2: NRR1 site overview (2022/23)

Figure 2-3: NRR1 site native fish wetland and Spring 2021 plantings (Source: HHWET)

Figure 2-4: NRR1 2018 (right) & 2021 (left) recharge basins (Source: HHWET)

Figure 2-5: NRR1 upper tributary wetland, fenced and planted in Spring 2021 (Source: HHWET)

Figure 2-6: NRR1 lower tributary wetland, fenced and planted in Autumn 2023 (Source: HHWET)

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 (HHWET, 2023). 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 highly 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. Table 2-2 and Figure 2-8 present the turbidity and NRR1 flow analysis for 2022/23. Site shutdowns to date for high turbidity have occurred approximately 33% of the time, but only 22% during 2022/23. A comparison of Tables 1-3 and 2-2 shows that NRR1 intake turbidity is lower than RDR intake turbidity. This is because sediment drops out of suspension at the RDR Sandtrap and in the RDR canal before reaching the NRR1 intake. The NRR1 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 1.9% 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 1/6/2022 to 31/5/2023 (percent of flow less than prescribed turbidity)

Percentile	Turbidity, 1/6/2022 - 31/5/2023 (NTU)
10	8
20	10
30	16
40	21
50	27
60	36
70	50
80	85
90	193
100	1,189

Figure 2-7: NRR1 monitoring points (Source: HHWET, July 2021)

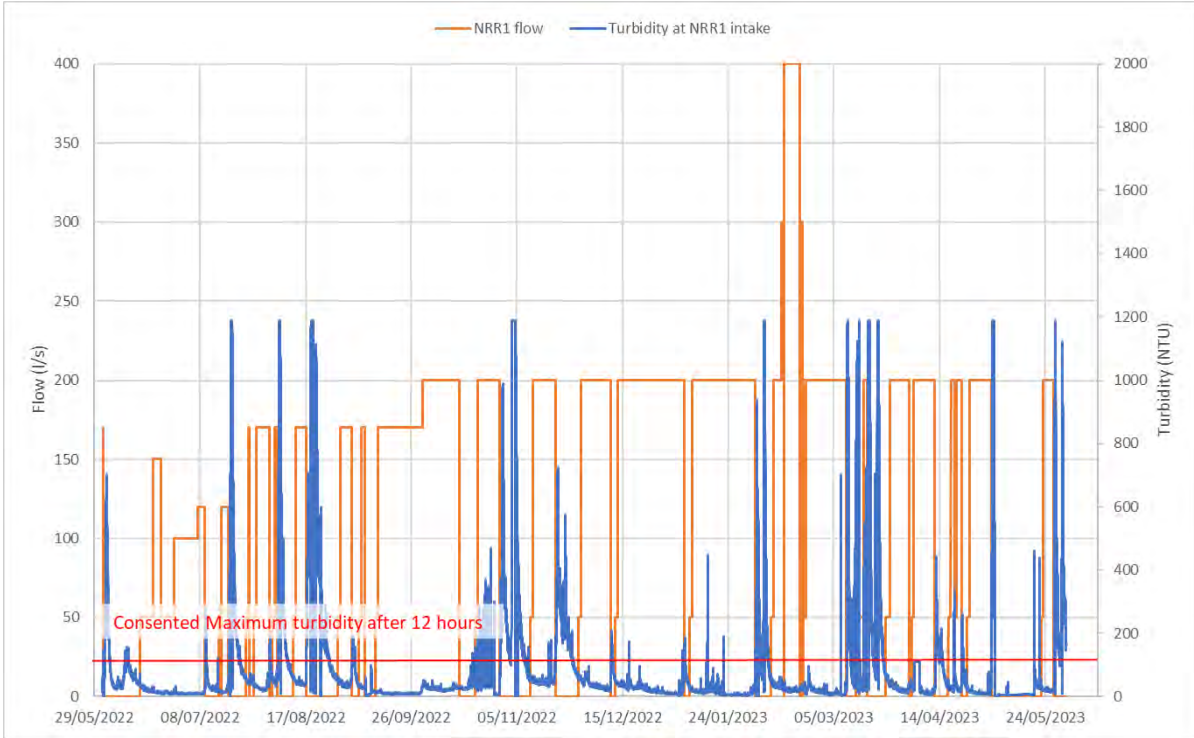

Figure 2-8: 2022/23 NRR1 intake turbidity and flow monitoring (Source: HHWET)

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). The #69106 record concludes in May 2021, when a flood destroyed the flow recorder. The flow recorder has not been re-established. 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 primarily 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 2018-21 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**. In 2022/23, flow at #69101 (RDR siphon) was less than 50 l/s for 14% of the year.

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 insufficient data collected for this project to assess 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. Changes in local groundwater conditions can also be expected to contribute to the variation in this recharge estimate.

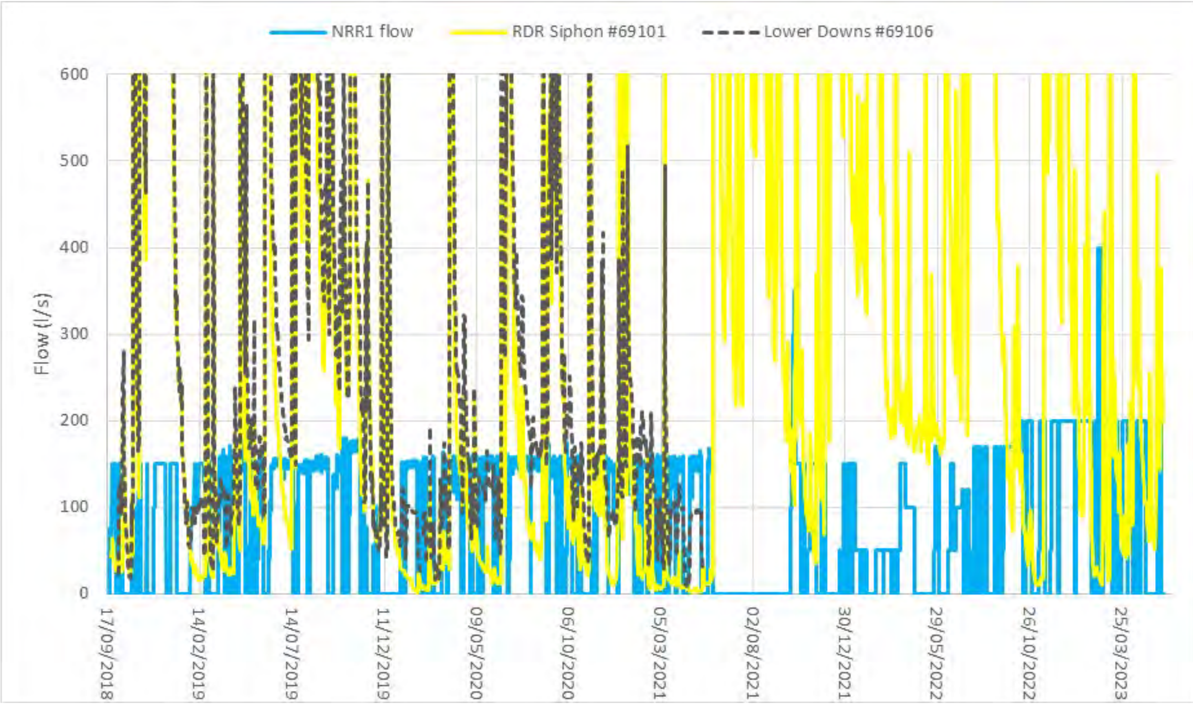

Figure 2-9: NRR1 and Hekeao/Hinds River flow (Source: HHWET, CRC)

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 expected to be 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.

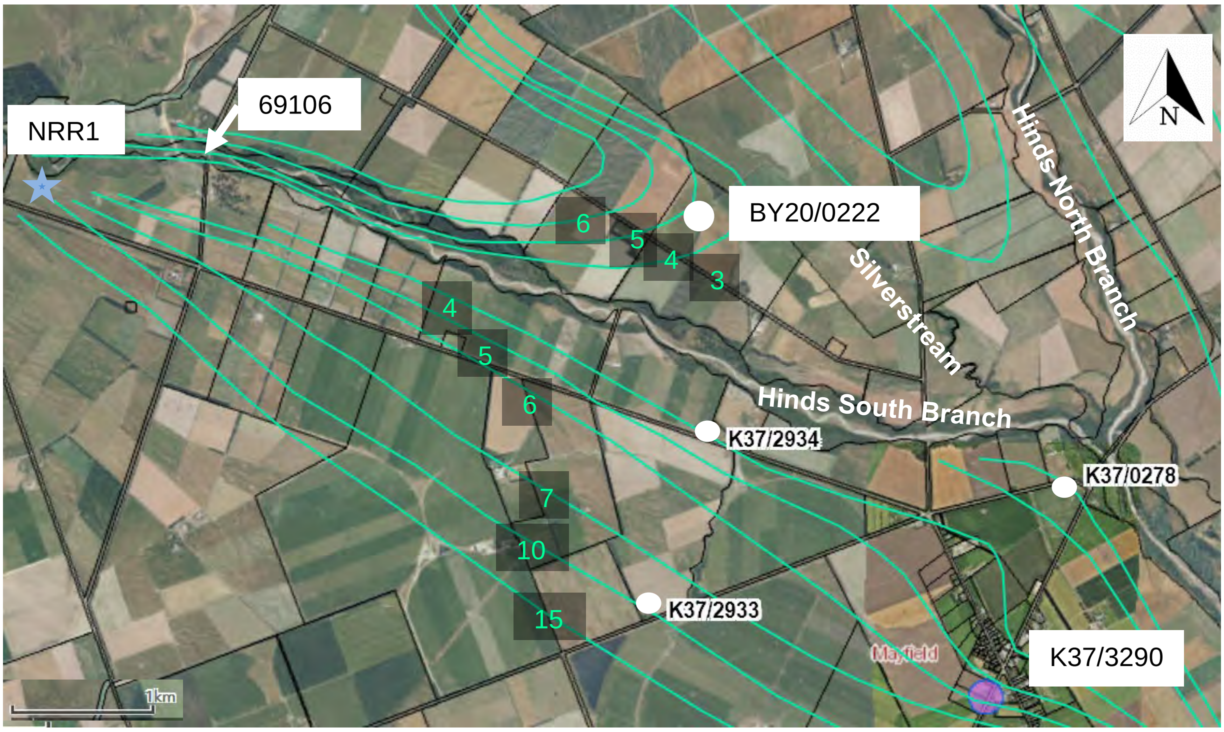

Figure 2-10: NRR1 down-gradient monitoring wells and minimum depth to groundwater contours (in m) (Source: Canterbury Maps)

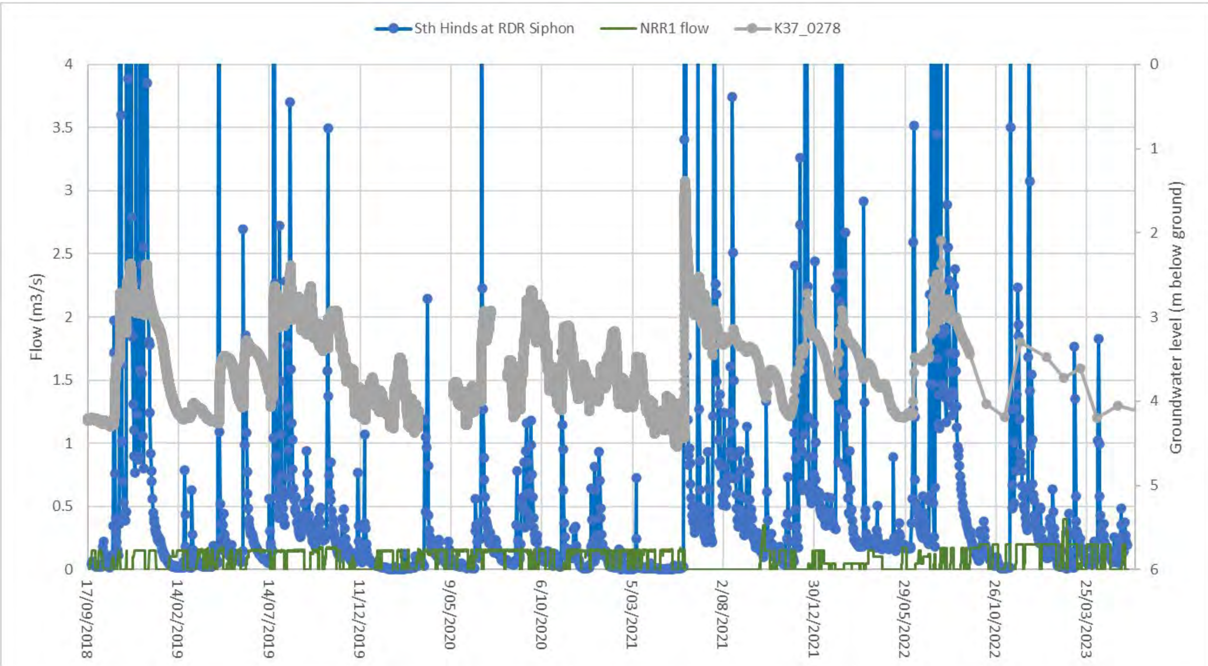

Figure 2-11: NRR1 flow, Hinds River flow and K37/0278 groundwater level (Source: HHWET, CRC)

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 (greater than 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 and sustained weather events and long-term weather patterns.

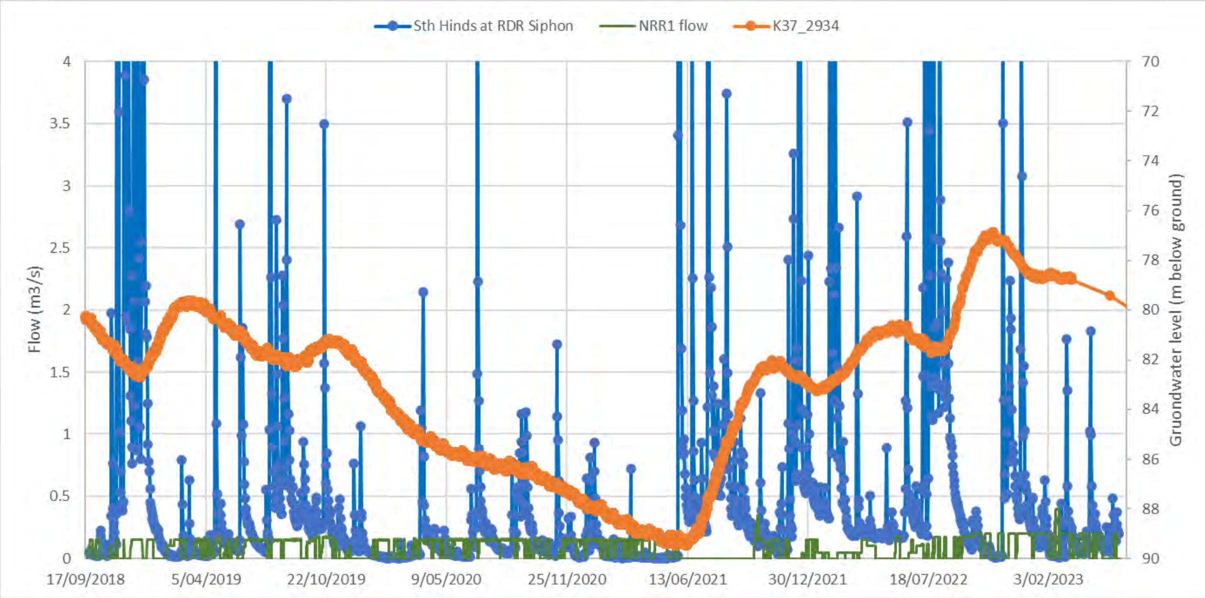

Figure 2-12: NRR1 flow, Hekeao/Hinds River flow and K37/2934 groundwater level (Source: HHWET, CRC)

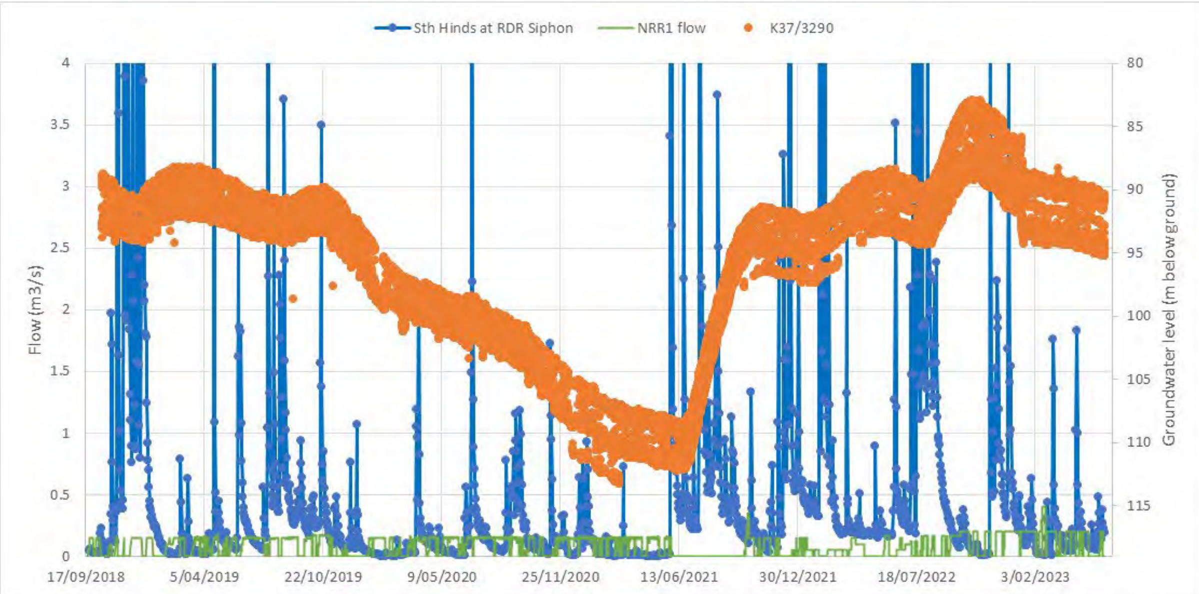

Figure 2-13: NRR1 flow, Hekeao/Hinds River flow and K37/3290 groundwater level (Source: HHWET, CRC, ADC)

2.1.2 Water quality monitoring

The key concerns 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 (2019/20) 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) has gradually increased from ~2 to ~3.3 mg/l since 2015. Year 4 (2019/20) 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 up-gradient river reach (as measured at RDR Siphon, at Site #69101), nitrate and *E. coli* was shown to increase after rain events. These increases could be due to overland recharge, local tributaries, and tributaries further up-river. 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 potential increases in contaminants, paddocks at the base of these tributaries have been fenced off, stock are excluded, and native plants introduced to filter sediment, uptake nutrients and reduce bacteria. 1.5 ha was planted in October 2021, with the remaining 1 ha planted in Autumn 2023.

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 (Carle-Strub method).

At the Hekeao/South Branch Hinds site only three fish species have been found during the annual surveys: Upland bully, Canterbury galaxias, and a single adult long finned eel. Figure 2-14 shows a step change in Upland bully and Canterbury galaxias populations since NNR1 began operations in late 2018. The December 2022 survey shows the highest Canterbury galaxias population to date but a lower number of Upland bullies than recent surveys. The lack of predators such as eels and trout (probably due to the low flows and lack of deep pools) combined with improved low flows due to NRR1 are likely to be key contributors to increased population levels for these native fish species since 2018.

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 50 m 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 assess habitat suitability for native species such as the Upland bully and Canterbury mudfish/Kōwaro. Telemetered equipment to monitor temperature, water level and dissolved oxygen in the primary and downstream wetlands was installed in Autumn 2022. A fish survey undertaken in Autumn 2023 by Canterbury Regional Council and Central South Island Fish and Game staff identified more than 2100 Upland Bullies in the three NRR1 wetlands.

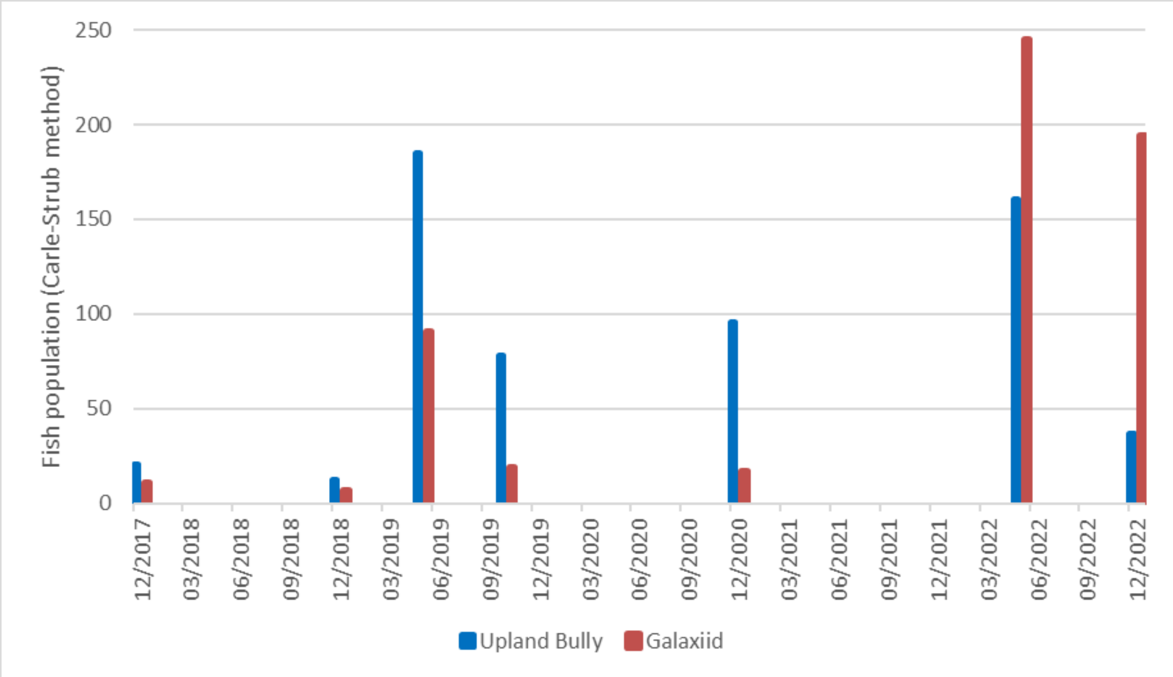

Figure 2-14: Hekeao/South Branch Hinds River at Lower Downs Rd Bridge, annual fish population estimates per 30 lineal metres, 2017 – 2023 (Source: Central South Island Fish and Game)

2.2 MAR17b – Lennies Road

A second active recharge site (MAR17b) is close to Lennies Road. This site began operations in June 2020 and has recharged approximately 3.38 million m^3 in its three years of operation. This makes it the second most productive MAR site after MAR01. 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 down-gradient surface river flow. An advantage of situating a MAR/NRR site close to, but outside, the immediate river 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. An increase in maximum discharge rate to 180 l/s is proposed for the replacement discharge consent in process.

Section 2.2 of the HHWET Year 5 (2020/21) Annual Report presents an analysis of the positive contribution of MAR17b to Hekeao/Hinds River flows during the 2020/21 summer period. Section 2.4 of the Year 6 (2021/22) Annual Report presented analysis of potential links between MAR17b operations and improved water quality in both Taylors Drain and the lower Hekeao/Hinds River. Following the May 2021 rain event, MHV Water began regular monitoring of surface water sites across the Hekeao/Hinds Plains. Sites of potential relevance to MAR17b are presented in Figure 2-17, with site SW83 situated on Dickson's Cut-off Drain, SW51 in the Hekeao/Hinds River at Winslow Road, and SW40 in the McLeans Swamp Drain (which feeds Taylors Drain). For the 2 years of available data, we can see that nitrate concentrations were highest at the beginning of the record (likely impacted by the May 2021 rain event) and lowest in the 2022/23 summer. Nitrate concentration in SW40 is usually closer to SW51 (Hekeao/Hinds River) than SW83, particularly after periods of low rainfall. This suggests that SW51 has a greater river recharge component than SW83, and as it is down-gradient from MAR17b, is likely to be influenced by MAR17b operations and therefore contributing to the Taylors Drain nitrate concentration decreases presented in Section 2.4 of the Year 6 (2021/22) Annual Report.

Figure 2-15: MAR17b in mid-2020, with Hekeao/Hinds River margins in the background (Source: M. Neutze)

Figure 2-16: End of MAR17b in mid-2023, looking back towards intake (Source: M. Neutze)

Figure 2-17: MAR17b and nearby MHV surface water monitoring sites (Source: MHV, HHWET, Canterbury Maps)

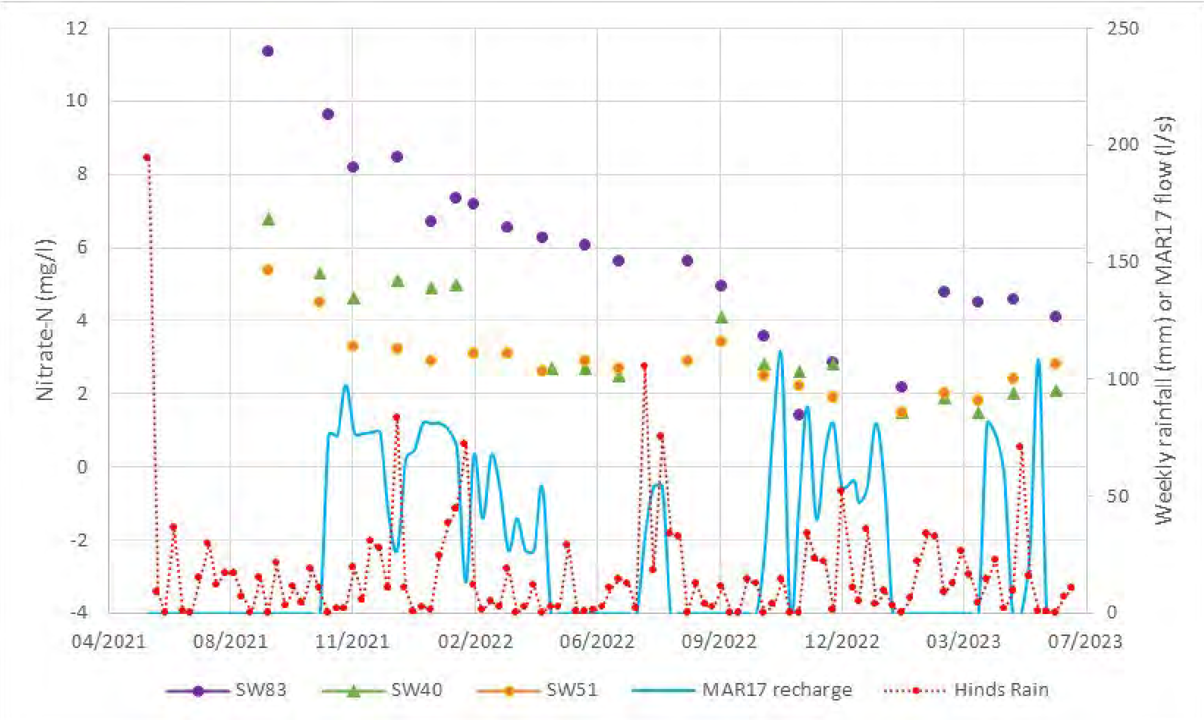

Figure 2-18: MAR17b, Hinds rainfall and surface water quality (Source: MHV, HHWET)

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 both sites is the presence of an existing MHV Water discharge race and available land for recharge basins.

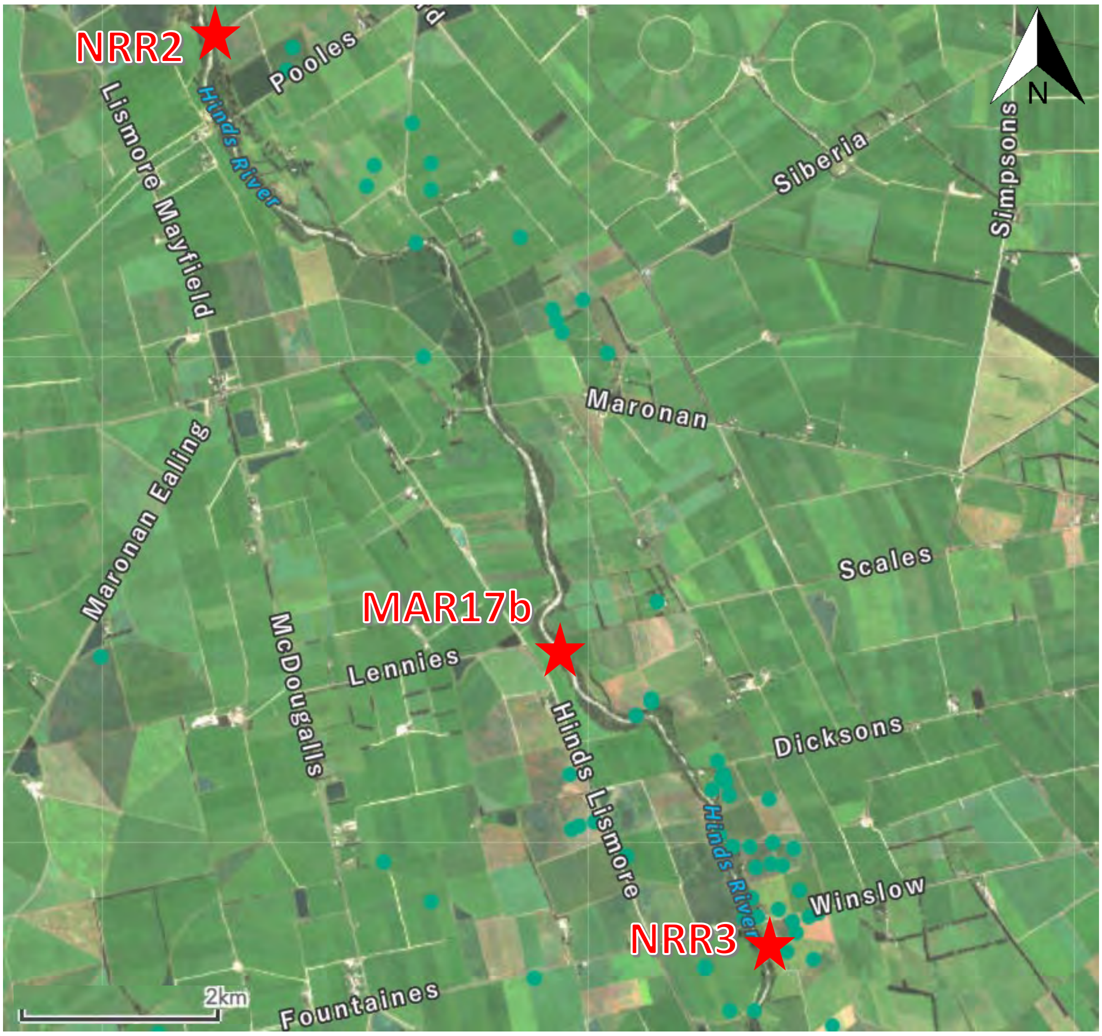

Figure 2-19: NRR sites and spring locations (Source: Canterbury Maps)

Figure 2-19 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 2-19, 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 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.

Preliminary design (e.g., Figure 2-20) and consenting assessments were completed for NRR2 and NRR3 between 2020 and 2022. A preliminary cultural assessment was also completed over the same time period for NRR3. Discharge and construction consent applications were lodged in December 2022.

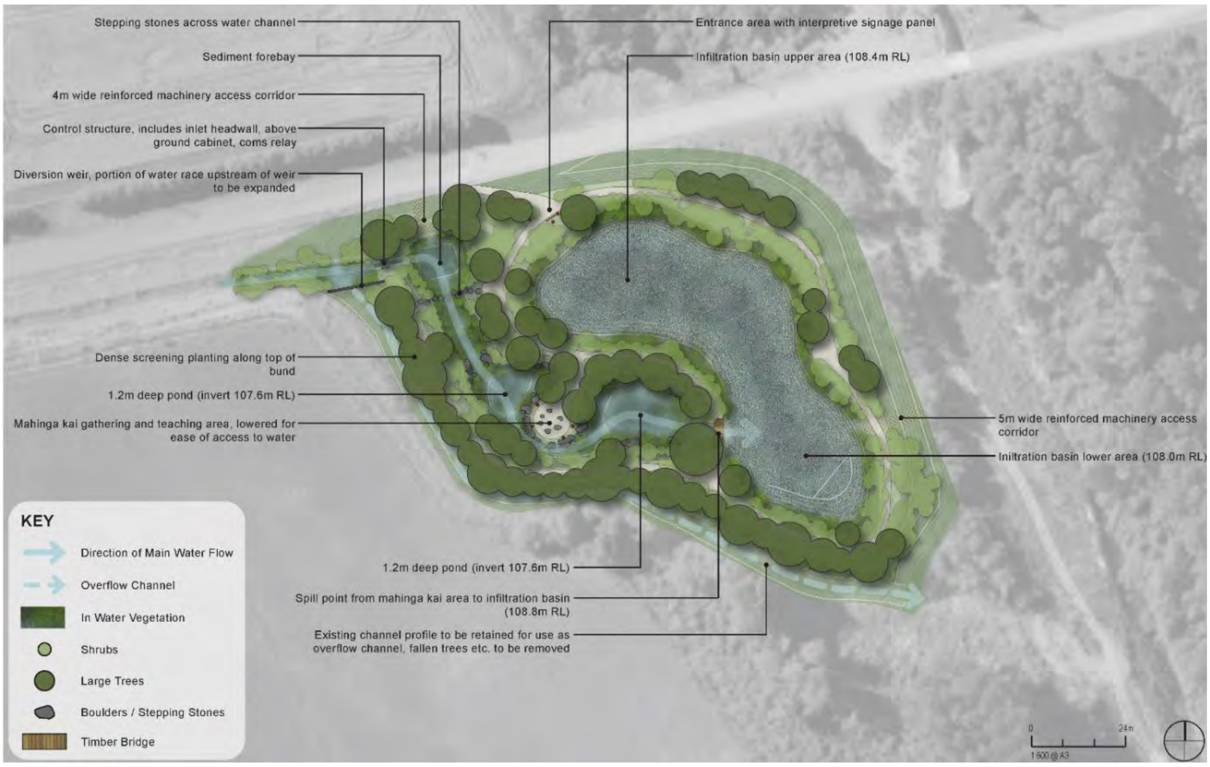

Figure 2-20: Draft concept for NRR3 site (Source: Boffa-Miskell)

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 its four groundwater-fed tributaries (Northern, Taylors, O'Shaughnessy's, and Montgomery's Drains – see Figure 2-21). 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 represents 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 (HDWP, 2016). In mid-2022 a 5-year summary of progress to date was prepared and discussed with the Hinds Drains Working Party (HDWP, 2022). Progress of relevance to HHWET activities are presented in Section 2.4 of the HHWET 2021/22 Annual Report.

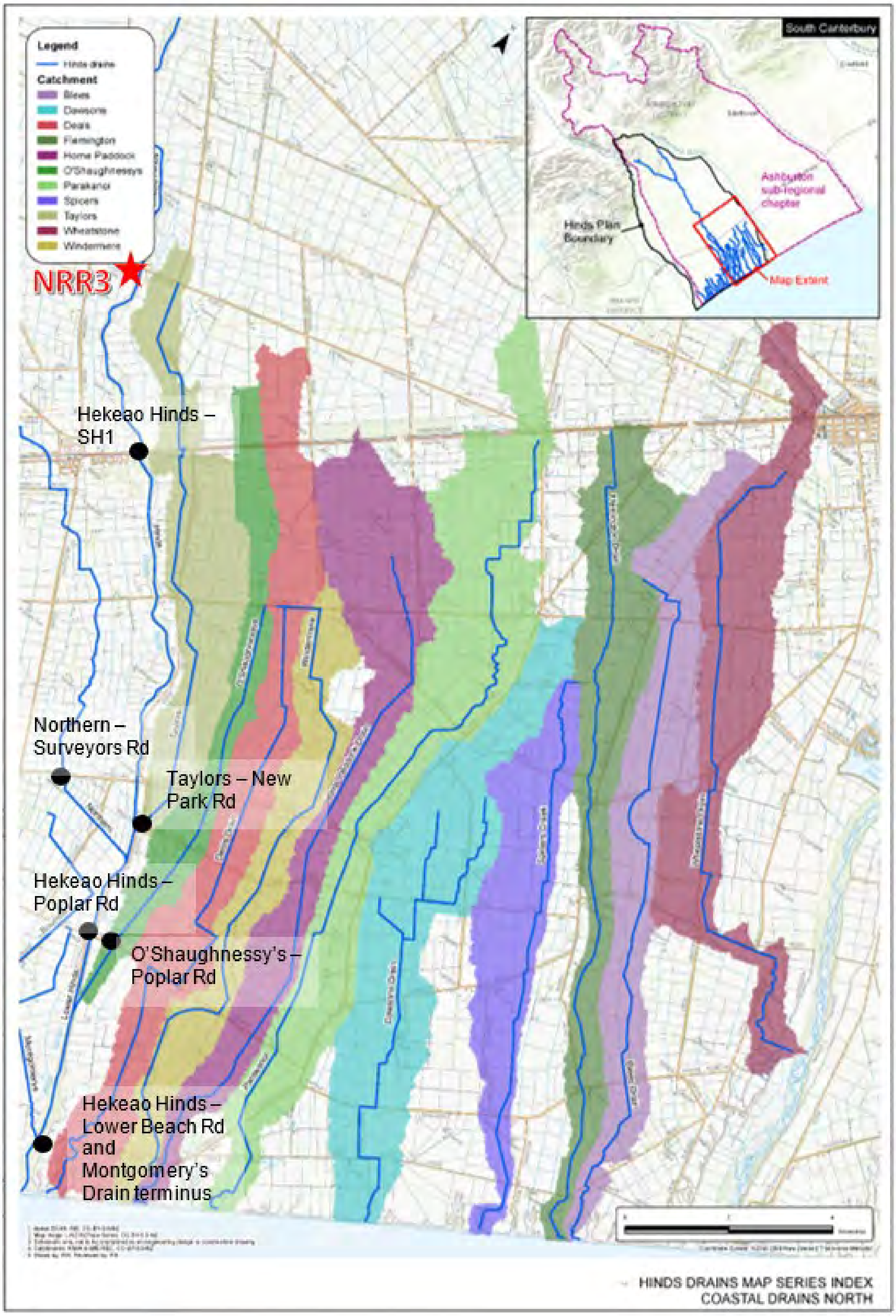

Figure 2-21: Hekeao/Hinds River monitoring sites (Source: HDWP)

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. 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 2-21, with Hekeao/Hinds River flow analysis presented on Figure 2-22 and water quality monitoring analysis presented on Figures 2-23 to 2-25.

As discussed for Figure 1-2, due to the dominating influence of rainfall recharge on water quality and quantity, a useful way of tracking progress towards 2035 targets is to compare years with similar annual rainfall. 'Wet' year comparisons can be undertaken between 2017/18 and 2021/22 monitoring results, while 'dry' year comparisons can be undertaken between 2015/16 and 2020/21 results. There was no NRR prior to September 2018, so these comparisons represent 'before' and 'after' potential influence from NRR. For the purposes of the following analysis, the 2021/22 hydrological year has been amended to start at the significant rainfall event beginning 31 May in order to keep it in the same hydrologic year as the resultant flow and water quality effects.

The flow comparisons for Hekeao/Hinds River at Poplar Road are presented in Figure 2-22. The average daily flow during the 31 May to 1 June 2021 flood is assumed to be ~200 m^3/s (the flow recorder did not operate during this period). With this flow added to the 2022 hydrological year dataset, the average daily flows for 2017/18 and 2021/22 are similar. The 112% increase in average flow for 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. Average daily flows at Poplar Road for the 2022-23 year were 2.85 m^3/s, more than 50% above the daily average since 2010. No equivalent rainfall year comparison was possible.

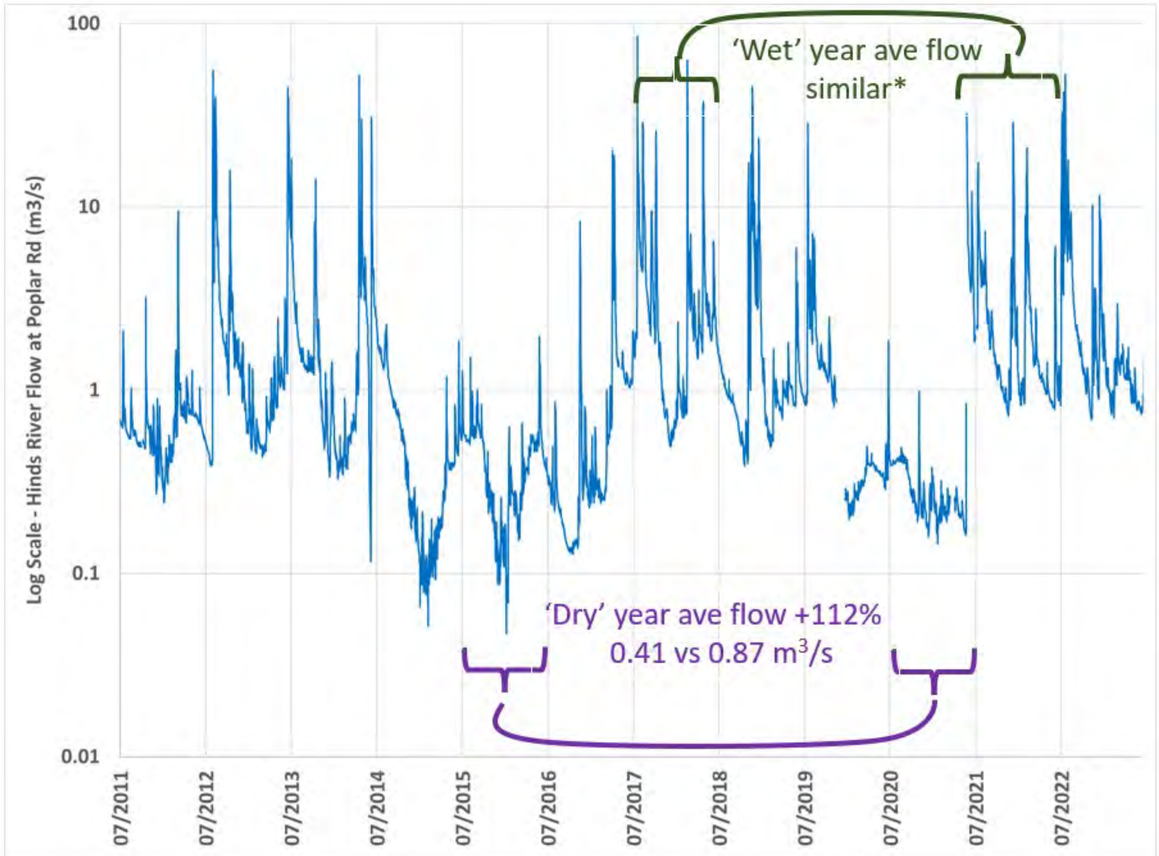

Figure 2-22: Hekeao/Hinds River flow at Poplar Rd (Source: CRC)

Hekeao/Hinds River water quality (nitrate-nitrite-N or NNN) monitoring data at Lower Beach Road is presented in Figure 2-23, with the 'wet' and 'dry' year comparisons showing improvements of 14% and 6% respectively. The two drains with long monitoring records are Taylors Drain and Northern Drain. Taylors Drain showed significant decreases in NNN for both the 'wet' and 'dry' year comparisons, while Northern Drain was similar for the wet year comparison and 16% higher for the 'dry' year comparison (see Sections 2.2 and 2.4 of the HHWET 2020/21 Annual Report for discussion regarding the positive influence of NRR on Taylors Drain water quality but not Northern Drain). Figure 2-24 compares annual median NNN for the three primary lower Hekeao/Hinds Drains with their 2035 PC2 target. Taylors Drain has met its target every year except 2018 and O'Shaughnessy's Drain is showing positive progress, albeit with limited data. In addition to on-farm improvements in the contributing catchment, further enhancements in Northern Drain water quality are the focus of the eClean Bioreactor project and proposed new MAR sites.

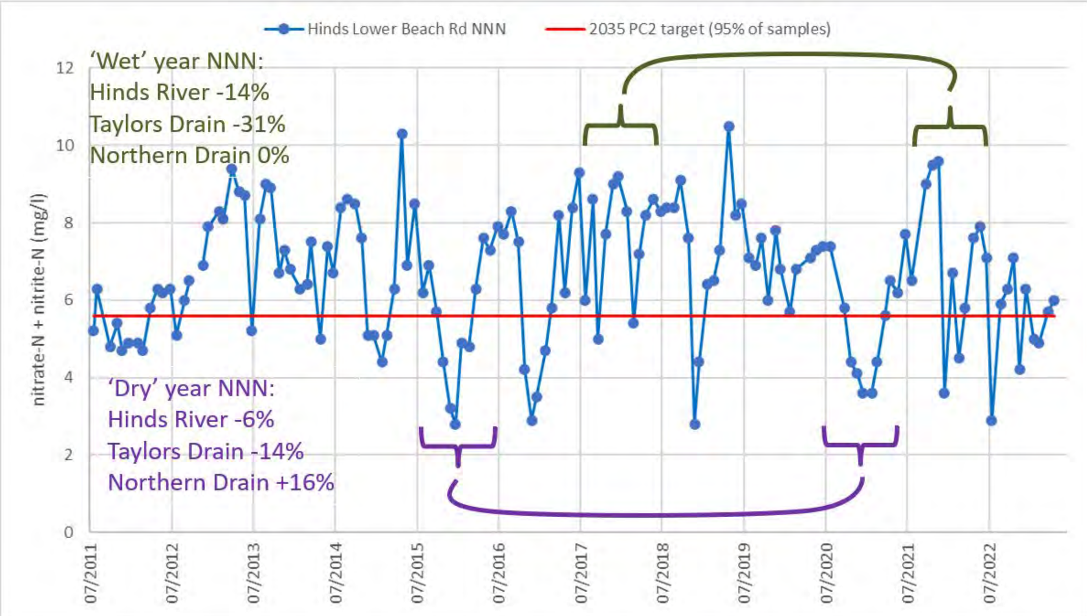

Figure 2-23: Hekeao/Hinds River water quality at Lower Beach Rd (Source: CRC)

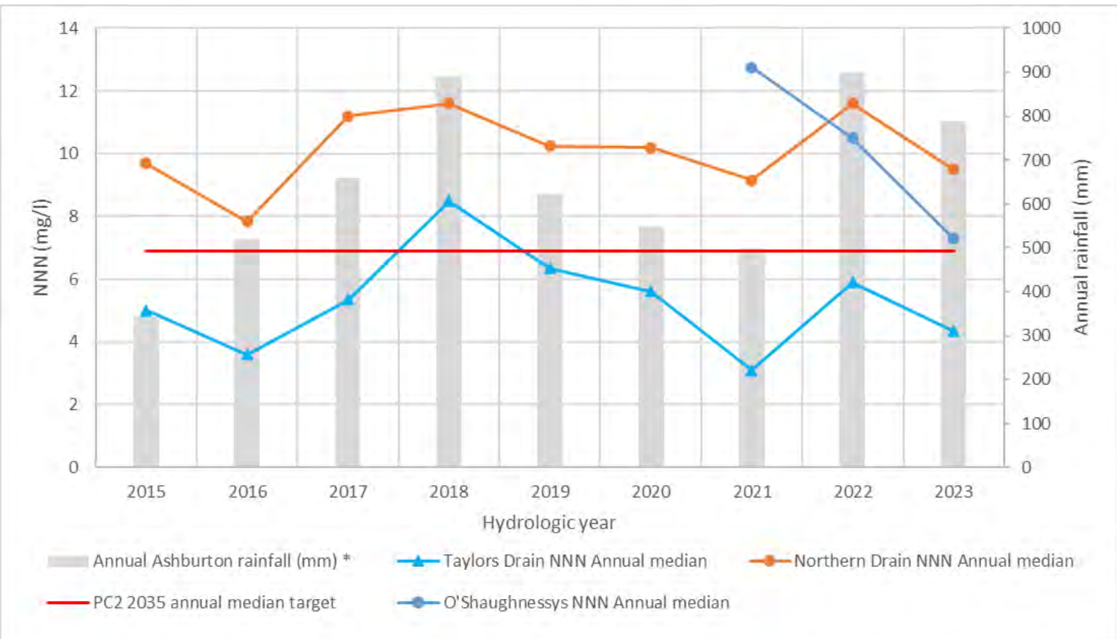

Figure 2-24: Lower Hekeao/Hinds River tributary NNN concentrations (Source: CRC)

Progress toward the 2035 PC2 water quality targets for the lower Hekeao/Hinds River are presented in Figure 2-25. Despite 2022/23 being the fourth wettest year on record, its median NNN was the second lowest on record and its 95[th] percentile NNN was the third lowest on record (even lower than the dry years from 2014–16). Further progress is required to reach the 2035 targets, but it appears that HHWET are on track to achieve their contribution to these targets.

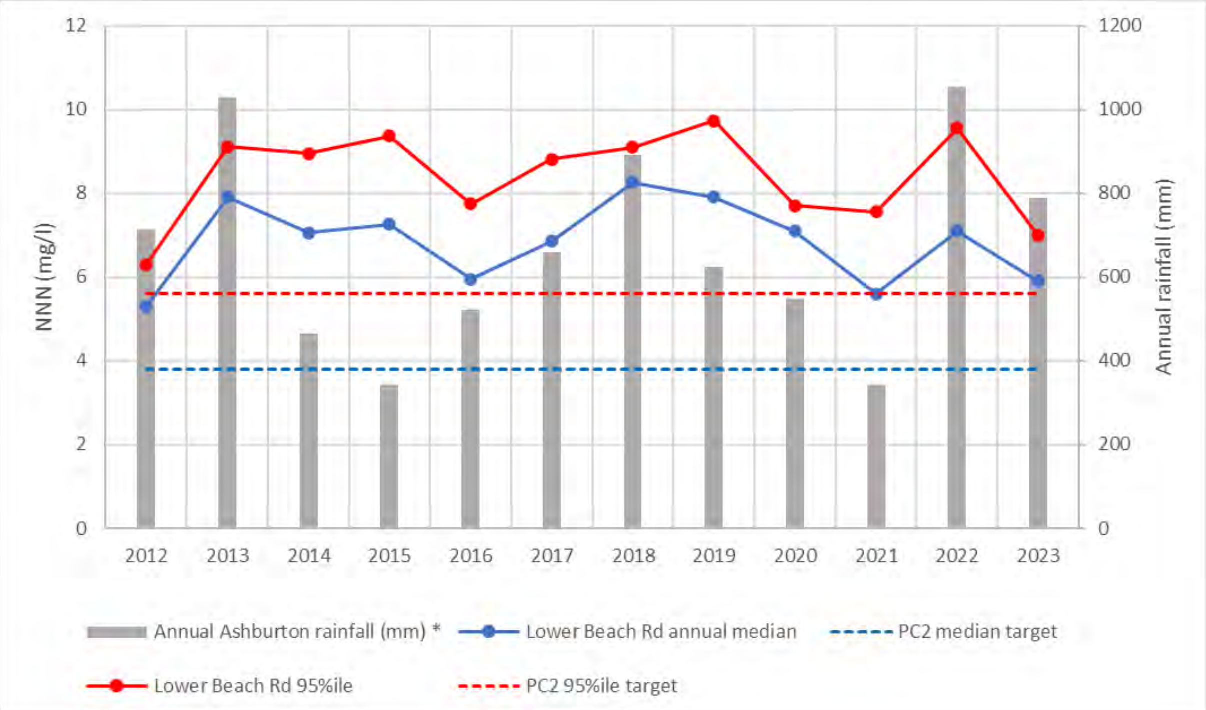

Figure 2-25: Annual (year ending 30 June) Ashburton rainfall and annual median Nitrate-Nitrite-Nitrogen concentrations for the Hekeao/Hinds River at Lower Beach Rd (Source: CRC)

The QMCI (Quantitative Macroinvertebrate Community Index) is based on the tolerance or sensitivity of species (taxa) to organic pollution and nutrient enrichment. Figure 2-26 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. In a below average rainfall year, the effect of NRR via Taylors Drain is expected 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 ‘dry’ year comparison for Hekeao/Hinds River at Poplar Road in Figure 2-26 supports this hypothesis, however increased NRR (as proposed in the two additional sites under consent application) are anticipated to be required for measurable improvements in dry year QMCI comparisons further down river at Lower Beach Road. The ‘wet’ year QMCI comparison shows similar QMCI at SH1, but significant improvements in QMCI at Poplar Rd and Lower Beach Rd. This suggests that improvements are coming from the tributary drains, however, further data and analysis are required to support this hypothesis as QMCI can also be affected by other external factors that are more variable in wetter years (e.g. river channel development status and bed sediment load). In 2022/23, the QMCI target was met at all three sites, for only the second time in the eleven years of record. The monitoring was undertaken in December 2022 while all MAR/NRR sites were operational.

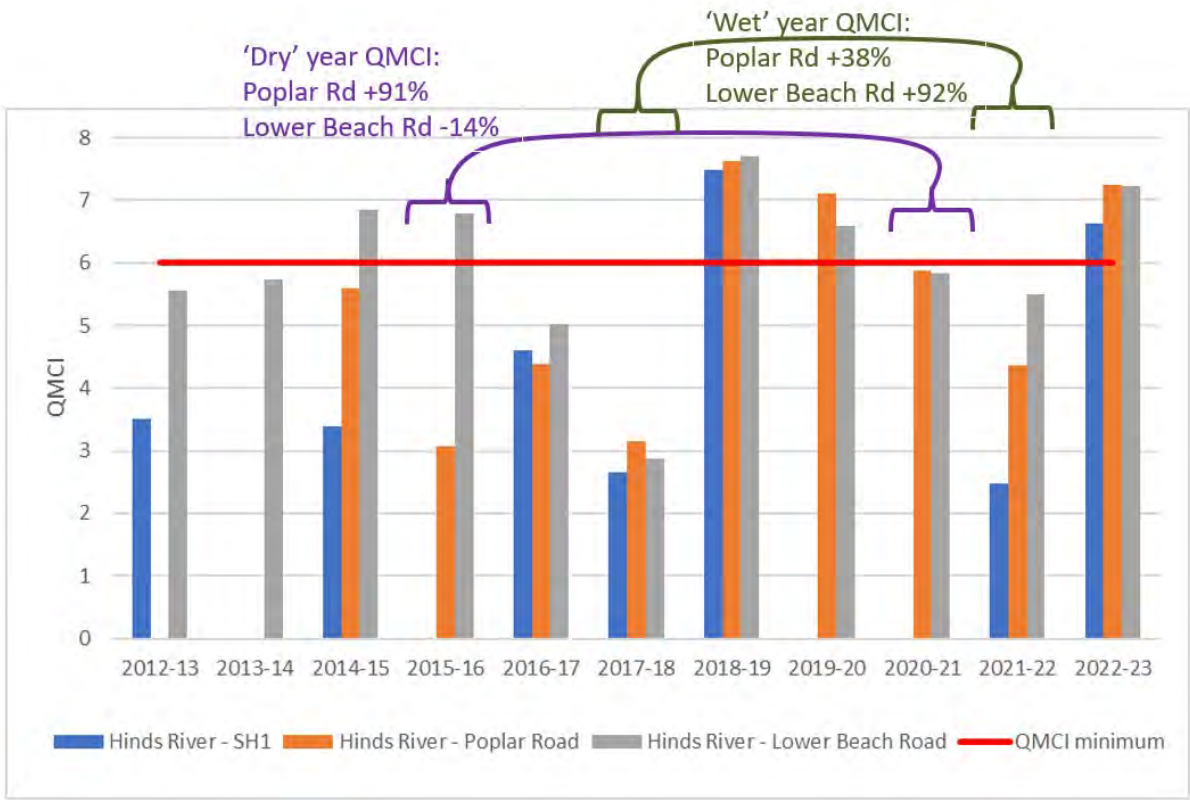

Figure 2-26: QMCI Scores for three lower Hekeao/Hinds River sites (Source: CRC[2])

Lower Hekeao/Hinds River 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 estimated population size (from three passes) is presented in Figure 2-27. The 2021 Above Lagoon population was dominated by 362 bluegilled bully and the 2022 population was dominated by 666 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 the presence of these migrant species suggests the Hekeao/Hinds River mouth was open frequently enough in these years to enable fish migration. The 2023 Above Lagoon population was dominated by 102 bluegilled bully with only one common smelt. While it is still the third best result to date, one explanation for this drop in total population is reduced fish migration through the river mouth compared with the previous two years. The 2023 Poplar Rd total population was also the third best to date and better than the previous three years. 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 annual NRR volume and estimates of 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.

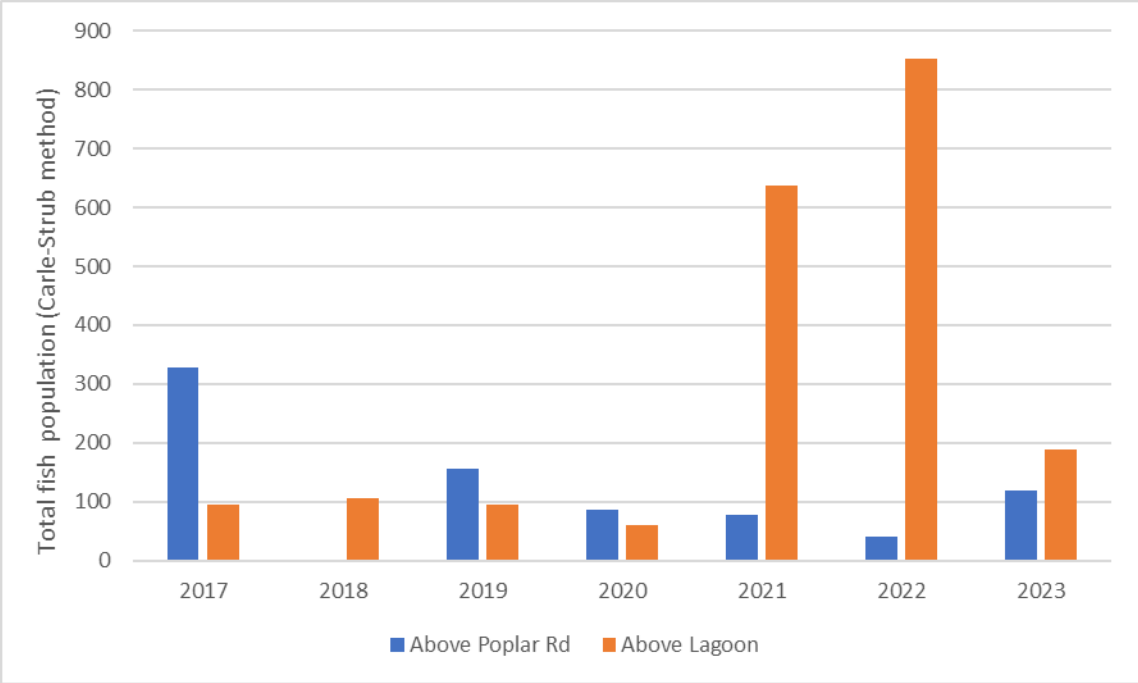

Figure 2-27: Total fish population estimates for two lower Hekeao/Hinds River sites (Source: M. Webb, Central South Island Fish and Game)

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 volume in 2022/23 was approximately 9.66 million m^3, with around 5.4 million m^3 being via the MAR sites. This was a 34% increase on the previous year and a 61% utilisation of consented MAR supply water. Table 1-2 shows that MAR01 operated for 34 weeks, while the remaining MAR sites operated for between 12 and 23 weeks. There were 17 site shutdowns for high *E. coli* counts. The key constraint on supply in 2022/23 (with resultant effects on operational weeks, total recharge, and utilisation of consented supply) was Canterbury Regional Council's decision to decline consent continuance for MAR02 – MAR18 from expiry of CRC210702 on 24 January 2023 until the completion of the new consenting process. This was a discretionary decision by Canterbury Regional Canterbury, which has resulted in a temporary halt on the environmental gains made in recent years resulting from operation of these sites. Compliance discretion was granted until 31 May 2023 for recharge trials at potential and expanded MAR sites. This discretion was appreciated by HHWET as it allowed for continued trials (such as the extended MAR07 trial at up to 200 l/s shown in Figures 3-1 and 3-2, and Section 4.2), which have provided higher confidence recharge estimates for the current consenting process. The other significant supply constraint in 2022/23 was due to the MHV Water Valetta distribution being unavailable from 2 August – 27 September 2022 due to maintenance requirements.

Examples of the type of operational MAR test site designs during 2022/23 are presented in the HHWET 2021/22 Annual Report (Figures 3-1 to 3-5). The only site upgrade undertaken in 2022/23 was MAR09 at Riverbank. This upgrade involved the first installation of a Rubicon Blademeter (to trial an alternative flow control and monitoring option), plus an additional recharge area (see Figures 3-3 to 3-5). The upgraded site was successfully trialled between 26 and 31 May 2023 at a maximum flow rate of 80 l/s. The previous maximum flowrate was approximately 45 l/s.

Figure 3-1: MAR 07: Start of high flow trial, February 2023 (Source: M. Neutze)

Figure 3-2: MAR 07: During high flow trial, February 2023 (Source: M. Neutze)

Figure 3-3: MAR09: New Rubicon 300 mm Rubicon Blademeter (Source: M. Neutze)

Figure 3-4: MAR09: New intake and flow control infrastructure (Source: M. Neutze)

Figure 3-5: MAR09: New recharge area (Source: M. Neutze)

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. Additional detailed focus on positive impacts is only conducted on a portion of MAR sites, as the additional monitoring and analysis can be expensive.

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 Rakitata/Rangitata Glacier and river system interacting with the Hakatere/Ashburton Glacier and River system, with the larger Rakitata/Rangitata system dominating the smaller Hakatere/ Ashburton system (Barrell et al., 1996). 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. Further information on the catchment hydrogeology is presented in Figure 4-1 of the HHWET 2021/22 Annual Report.

For this status report, assessment of two of the MAR test sites are presented in more detail. MAR01 (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 (see Figure 4-1). The second case study site for 2022/23 is MAR07.

4.1 MAR01 - Lagmhor Pilot Site

The Lagmhor Pilot Site (MAR01) is a 0.9 ha recharge basin, inland from Tinwald. 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 groundwater flow direction 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 approximately 180 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 4-2 presents recharge flows and local monitoring since just before operations began in mid-2016. Discharge flows (in hundreds of litres per second) are shown in yellow and in 100 l/s increments on the right axis. The discharge rate increase following site upgrades can be seen from September 2018. Measured nitrate-N concentrations (at a 29 m deep bore 1 km down-gradient from MAR01) are shown in purple and on the right axis, 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 – 3 mg/l with MAR. Concentrations exceed 3 mg/l after a period of no MAR and after significant rainfall events (such as May 2021), but quickly drop back to below 3 mg/l once MAR resumes (i.e., the nitrate increase is due to a combination of leaching caused by rainfall and the cessation of MAR due to the rainfall event). The lowest recorded nitrate-N concentrations of ~1 mg/l were recorded in the first half of 2023. Groundwater levels are presented in dark blue and on the left axis, with reasonably rapid level changes when MAR begins or stops.

Cessation of operations is required when the local groundwater level is measured at two metres or less below ground level, when the *E. coli* count in the source water exceeds 1,000 MPN/100mL, or when 30 millimetres or more of rainfall within any 24-hour period is measured at the Hinds Plains Rainfall Monitoring Site. No cessation for groundwater levels or *E. coli* were required in 2022/23, however daily rainfall exceeded 30 mm four times between 1 June 2022 and 31 May 2023. After the rainfall on 10 May 2023, the site was turned off for three days. The site was not running during the other three rain events.

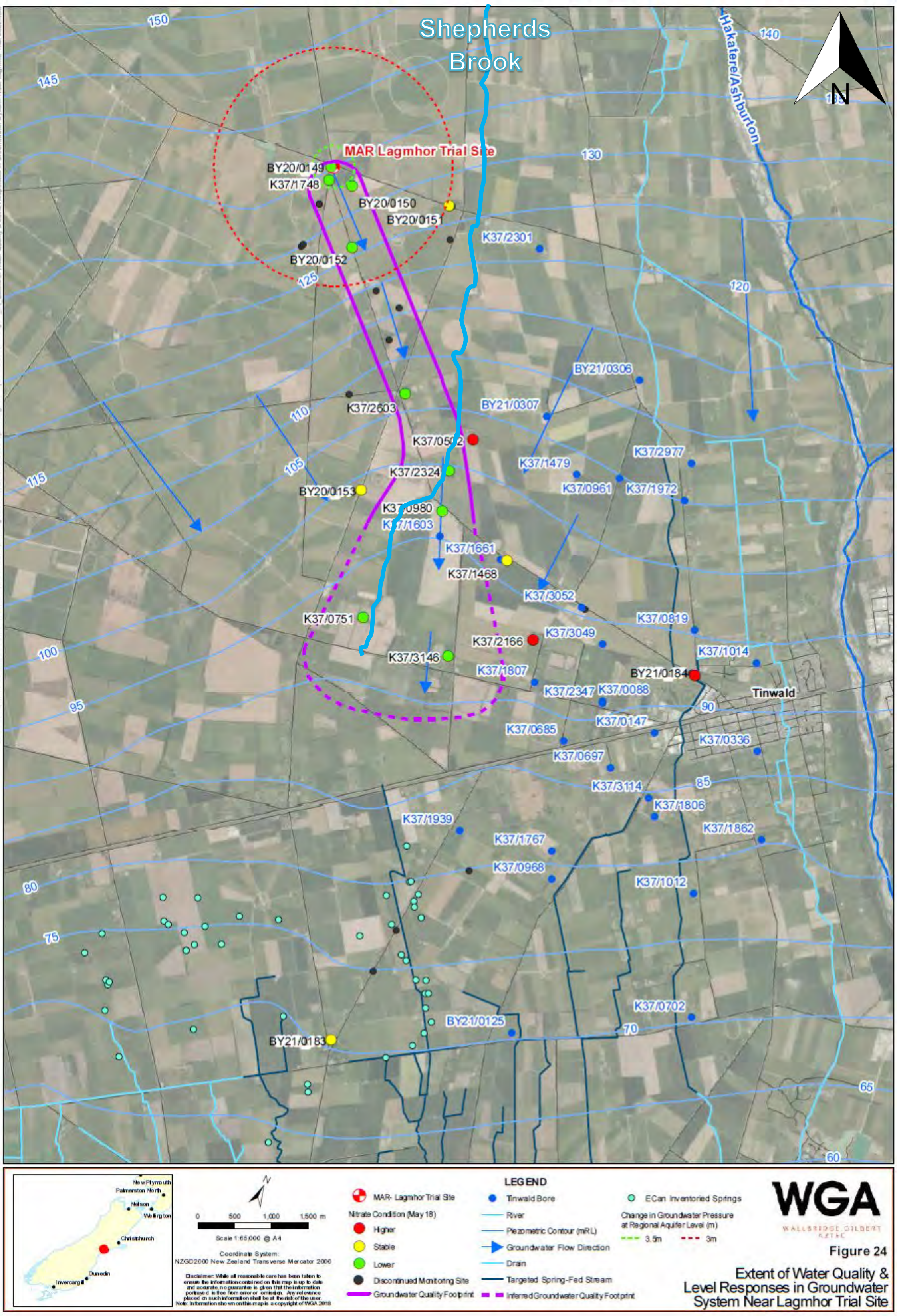

Figure 4-1: Figure 24 from Year 2 report (with updated bore names and an additional waterway – Shepherds Brook) showing assessed groundwater level and quality responses to MAR01 operations.

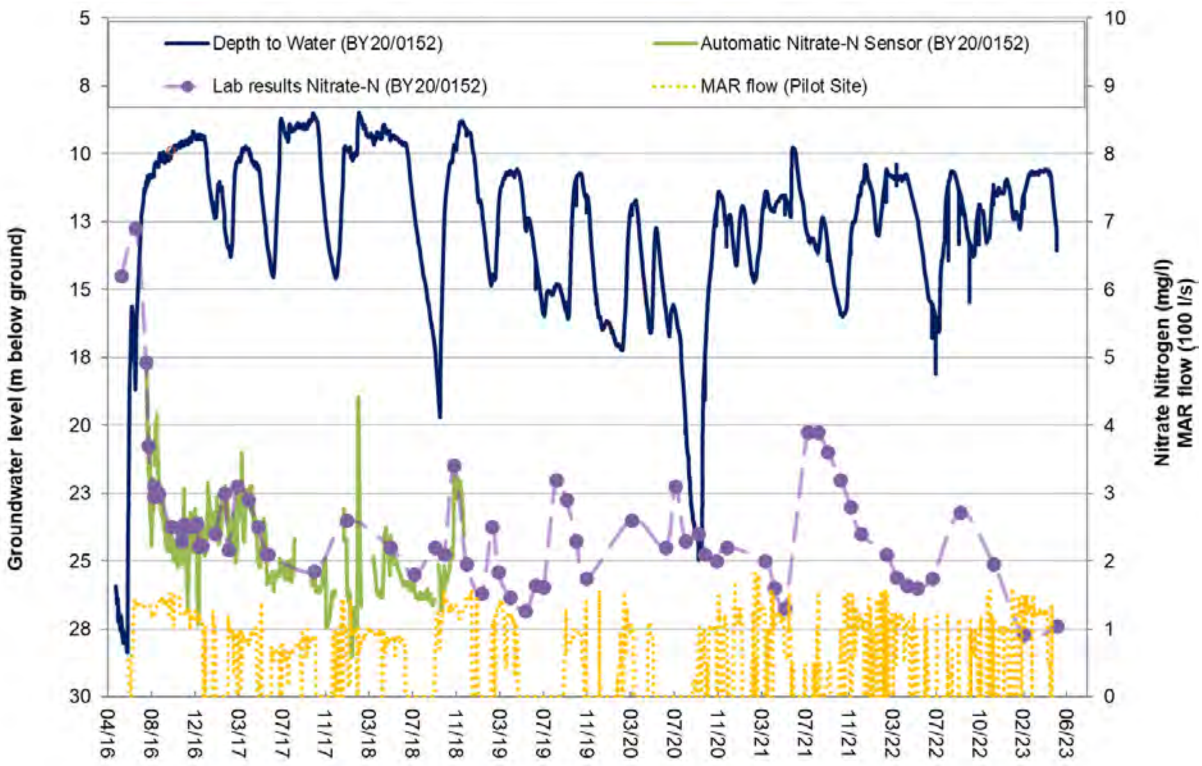

Figure 4-2: MAR 01 (Lagmhor Pilot Site) operational and key down-gradient monitoring

In the HHWET Annual Reports from 2019/20 through to 2021/22, groundwater level and water quality monitoring down-gradient from MAR01 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 Canterbury Regional Council 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 in these reports concurred with this conclusion. Key monitoring bores down-gradient from MAR01 are shown in Figure 4-1, with colour coding on the bores to show initial assessed MAR water quality influence as likely (green), possible (yellow) and unlikely (red). This potential influence was based on initial monitoring lag times that were consistent with water particle travel time estimates (1-1.5 years for bores up to 5 km downgradient and at least 2 years for bores greater than 6 km downgradient) along with other water chemistry changes such as electrical conductivity, chloride, and hardness.

Figure 4-3 shows that the nitrate-N concentrations in bores close to MAR01 are 80-90% lower than nearby bore BY20/0151 (cross-gradient from the site). These results are consistent with Durney (2019) as presented in Figure 4-4 of the 2021/22 HHWET Annual Report. BY20/0152 and K37/1748 also show increases following extended periods of no MAR01 recharge (some of which occur after a significant rain event).

As noted by Durney (2019), MAR water quality influence at a distance greater than a few kilometres down-gradient from MAR01 becomes increasingly challenging to distinguish with increasing distance due to the mixing with other recharge. Both bores in Figure 4-4 (which are 3-5 km down-gradient from MAR01) show concentration increase 1-1.5 years after extended periods of no MAR01 recharge. However, delayed nitrate increases following rainfall events (e.g., February 2018, December 2018 and May 2021) also appear to be occurring. In Figure 4-5, both presented bores are 6-8 km down-gradient from MAR01. These bores continue to show concentration changes that are difficult to match (in timing and magnitude) with extended periods of no MAR01 recharge. The colour of their connecting lines was green (likely influence from MAR01) in previous reports, but this has been changed to yellow (possible influence from MAR01) in this report.

Shepherds Brook (see Fig. 4-1) water quality at Timaru Track Road has been added to Figs 4-4 and 4-5 for this analysis. It is relatively high in nitrate and loses all flow (via recharge) in the reach presented in Figure 4-1. This suggests that it may be influencing groundwater quality in the MAR01 area of potential influence at least 4 km down-gradient from MAR01. Nitrate concentrations in Shepherds Brook increased after the two significant rain events in 2021-23 (the May and December 2021 events). Following these type of rainfall events, local land surface recharge will also be increasing nitrate concentrations in groundwater, so differentiating the Shepherds Brook recharge from other land surface recharge influences on the lagged increases in K37/0980 and K37/0751 nitrate concentrations is challenging. Nevertheless, the Shepherds Brook nitrate concentration range in the available monitoring data is consistent with it potentially contributing to the nitrate increases down-gradient from MAR01. In mid-2023, nitrate sensors that sample every 15 minutes were installed in K37/3146 and K37/0751. This increased monitoring intensity will inform additional analysis in future years.

Down-gradient from SH1 (approximately 9km downgradient from MAR01) is 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. 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.

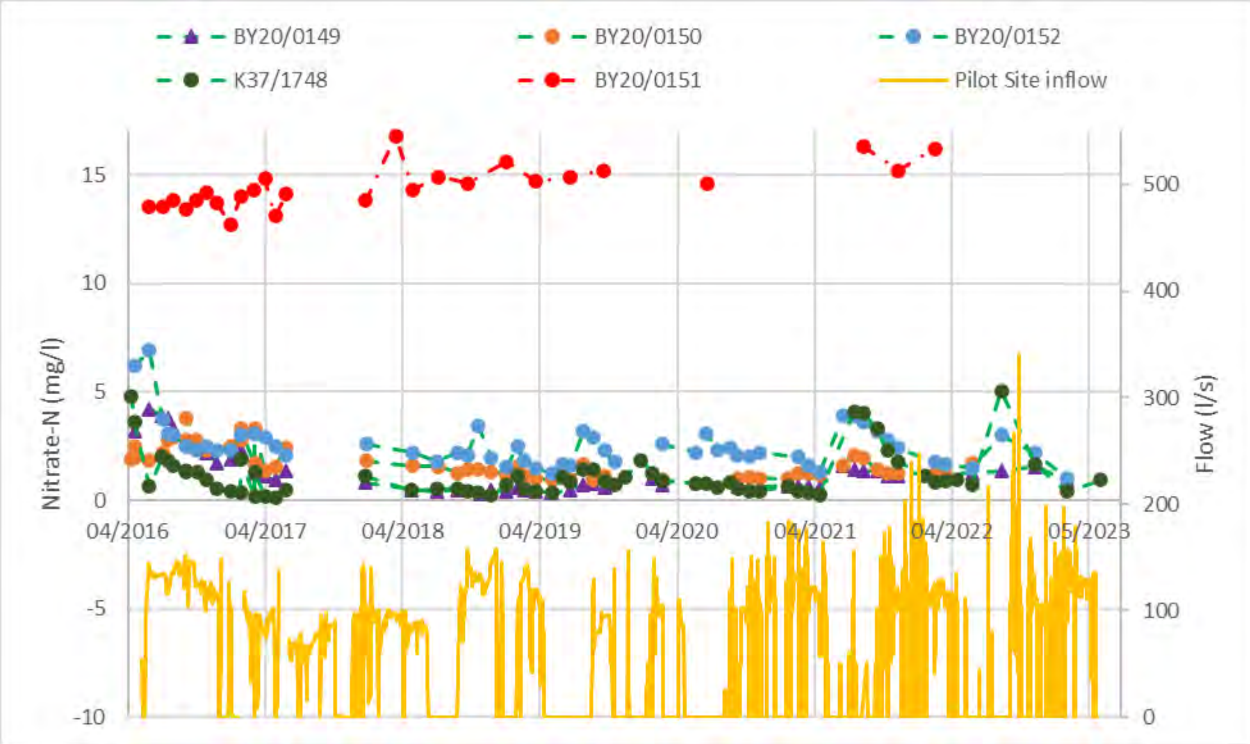

Figure 4-3: Nitrate-N concentrations for wells close to MAR01 (Source: HHWET, CRC)

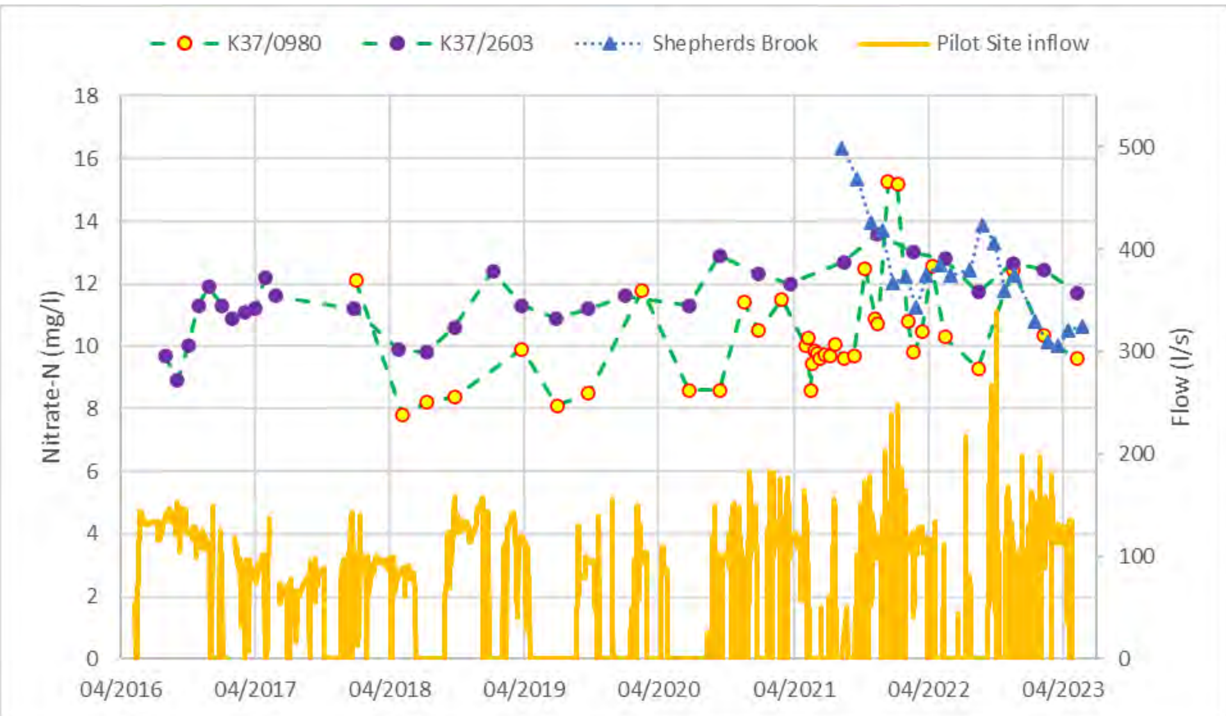

Figure 4-4: Nitrate-N concentrations for wells 3-5 km from MAR01 (Source: HHWET, CRC)

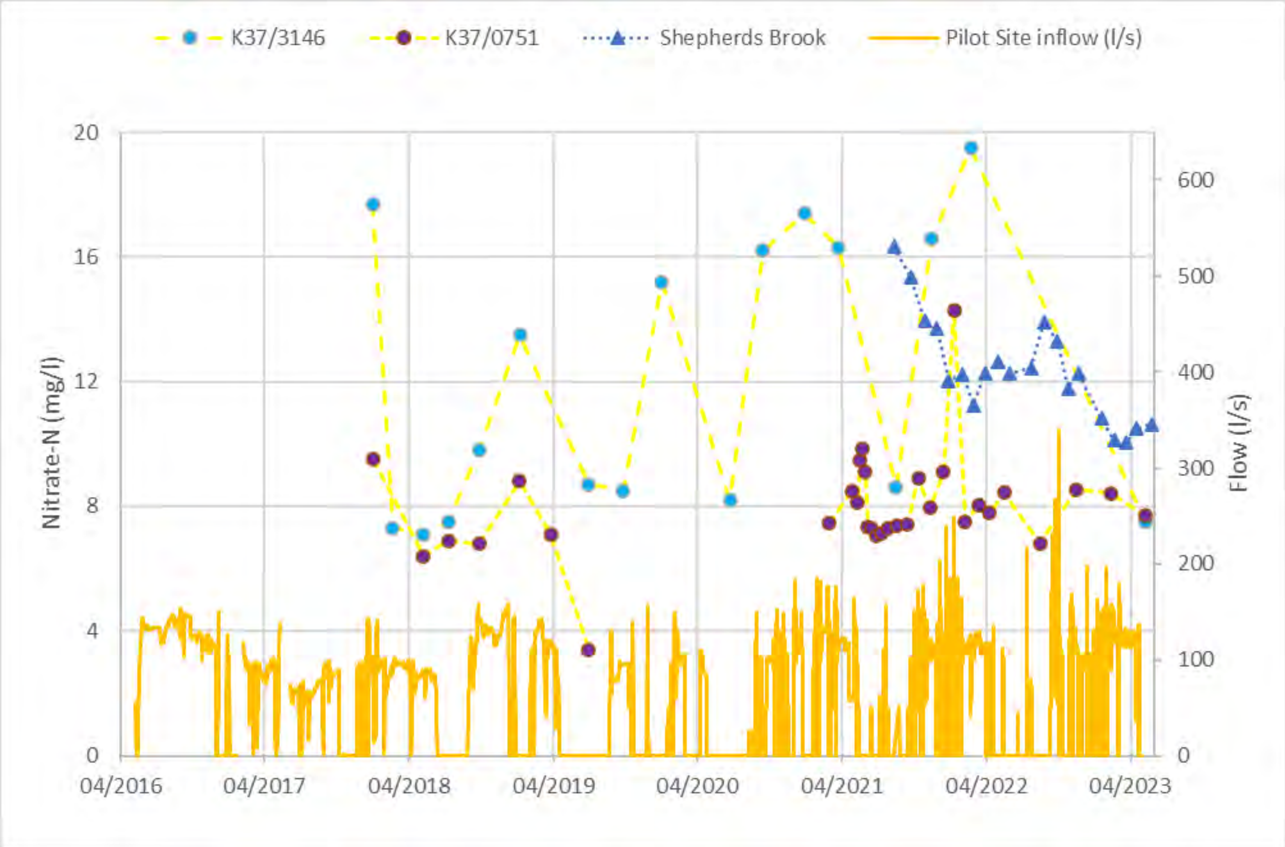

Figure 4-5: Nitrate-N concentrations for wells 6-8 km from MAR01 (Source: HHWET, CRC)

4.2 MAR07 – Timaru Track Road

MAR07 is a managed aquifer recharge basin constructed from an unlined former irrigation pond on the corner of Timaru Track and Maronan Valetta Roads (Figures 1-3, 3-1 and 3-2). The site has been fully operational since September 2020, with short periods of testing at the site in the two years prior. MHV Water began testing nearby groundwater bores for nitrate-N in September 2020, with additional bores added in the following six months. Bore names, locations and depths are presented along with the MAR07 location in Figure 4-6.

Figure 4-7 presents the MAR flow rate (compared with the right-hand axis) and the quarterly nitrate-N concentrations (left hand axis) at the four chosen monitoring bores. Available regional piezometric contours (e.g., Canterbury Groundwater Model – Aqualinc Research Ltd, 2007) suggest approximately a south-easterly groundwater flow direction in this area, although changes in flow direction with depth, groundwater abstraction and rainfall recharge are not uncommon.

BY20/0162 is up-gradient from MAR07 and close to the Hekeao Hinds River. Its low nitrate-N concentration throughout the monitoring period suggests that its primary recharge source is the Hekeao/Hinds River. K37/2986 is down-gradient from MAR07 in a SSE direction and shows no measurable change in nitrate-N concentrations with changes in MAR07 flow. The most significant change is an increase from May to September 2021, most likely due to the significant rain event around 31 May 2021. This suggests that land surface recharge is the primary contributor to K37/2986 water quality.

Nitrate-N concentrations in K37/2372 (133 m deep) were relatively high initially, suggesting that land surface recharge was its primary contributor water quality. Somewhere between December 2021 and

March 2022, the nitrate-N concentration at K37/2372 decreased from 6.3 mg/l to 2.8 mg/l and has remained low since. For MAR01 testing in 2016-17, initial lag time between start of operations and water quality changes in 23-48 m deep bores translated to groundwater velocities of ~8-10 m per day. MAR07 recharge producing groundwater velocities of ~8 m per day would be required to explain the late 2021 nitrate-N concentration changes at K37/2372. No other reason for this change in concentration has been identified to date. Hekeao/Hinds MAR influence has not previously been identified in bores deeper than 54 m.

As MAR07 has not operated since high flow testing in March 2023, the next step is to assess monitoring through to at least mid-2024 to see if the nitrate-N concentrations rise again. If so, then we can be more confident that MAR07 operations are influencing water quality in these bores and that a deep groundwater flow direction in this area is east of southeast.

Figure 4-6: MAR07 and nearby regular groundwater monitoring sites. (Source: Canterbury Maps)

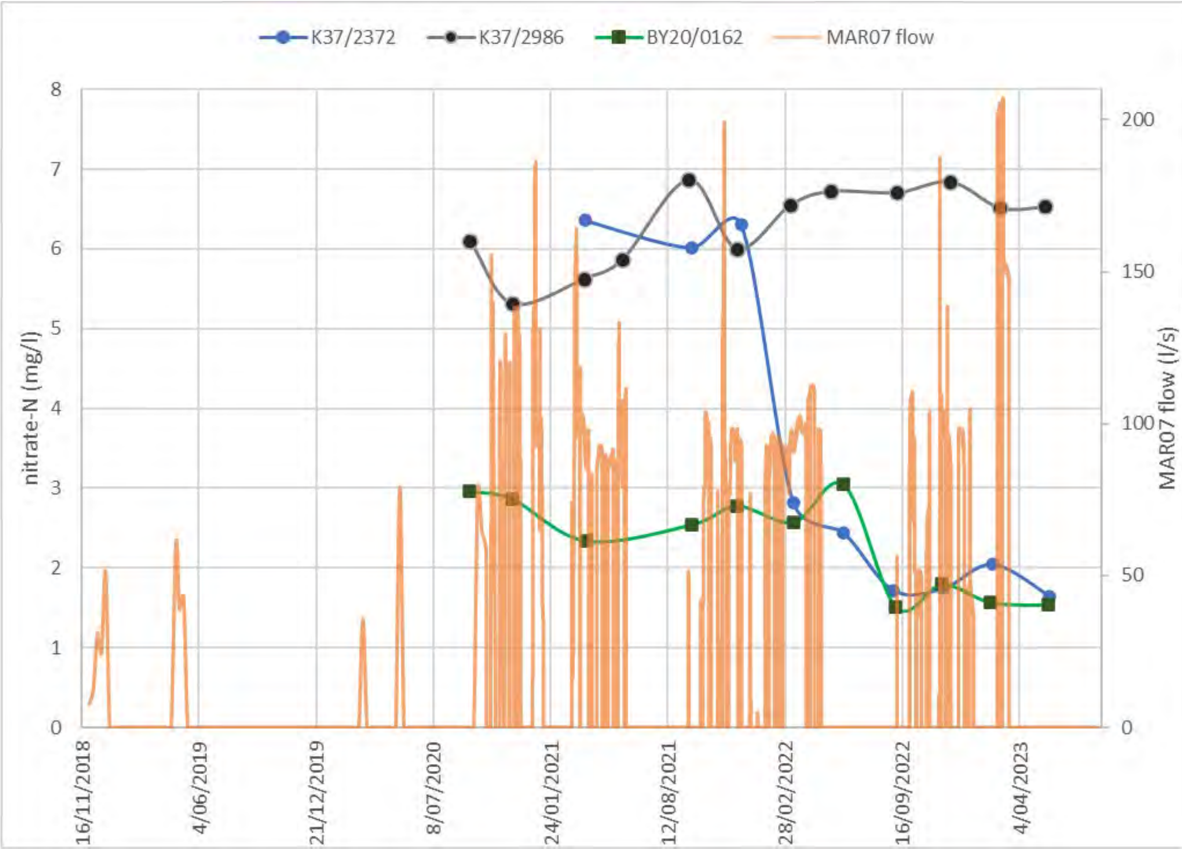

Figure 4-7: MAR07 flow and nearby groundwater nitrate-N concentrations. (Source: MHV Water, HHWET)

5 Hekeao/Hinds Groundwater and Northern Drains Surface Water Quality

5.1 Hekeao/Hinds Plains Groundwater Quality

As noted in the introduction, the groundwater nitrate-N PC2 monitoring update to 30 June 2023 (which is different from the MAR project reporting period to 31 May) in Figure 5-1 (also Figure 1-2) shows median nitrate-N concentrations in PC2-specified “shallow” wells across the Hekeao/Hinds Plains alongside MHV Water’s significantly larger dataset of similarly defined “shallow” bores, plus annual Ashburton rainfall. Rainfall for the years ending June 2021 and 2022 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 2022/23 year in the top 15% of annual rainfall and the highest year for median nitrate-N concentrations for PC2 wells since 2006. However, a closer examination of the data shows that the high result was primarily due to the addition of a new bore (BY21/0199) with the highest annual median value in the dataset (20.5 mg/l) and a jump in annual median value in another bore (K37/2314) from 6.5 to 17.3 mg/l. Further analysis of groundwater monitoring in the vicinity of K37/2314 suggests that the 2022/23 increases were primarily due to a lagged response to the May 2021 rain event, which resulted in peak nitrate concentrations around November 2022 and decreasing concentrations since. Without these two changes, the annual median of the medians for the PC2 bores would have decreased between the 2021/22 and 2022/23 years.

Figure 5-1 also presents the annual nitrate-N median of the site medians from a significantly larger dataset which includes the MHV Water, HHWET and PC2 bores. Figure 5-2 (which presents the median of all monitored sites for each quarterly monitoring round, as opposed to the median of the set of annual medians for each monitored site in Fig. 5-1) shows that between 44 and 79 samples have been collected quarterly compared with 0 to 12 samples for the PC2 set. For the 2021-23 hydrologic years the quarterly results from the PC2 bores shows median values vary between 8.8 and 13.8 mg/l, while the larger dataset only varies between 8.9 and 10.7 mg/l. The larger dataset shows higher median values in general for the lower rainfall year (2020/21) and lower median values for the higher rainfall years (2021/22 and 2022/23). Large dataset results since December 2021 give the highest confidence as to their representation of catchment shallow groundwater quality due to the greatest consistency of measured sites and highest number of monitored bores (>70). Given the importance of the PC2 monitoring results as a key indicator of progress towards ecosystem health targets, it is important that the results are representative of the catchment. The current number and choice of PC2 bores does not appear to be as representative of catchment water quality changes as the larger dataset. Both datasets will continue to be compared over the coming years and further analysis will be undertaken to identify an expanded PC2 dataset that is more representative of catchment water quality without adding significant cost or making so many changes to the set of bores that comparisons back to 2006 are no longer justifiable.

Section 5.1 of the HHWET 2021/22 Annual Report included equivalent annual rainfall comparisons as one method for tracking progress toward catchment groundwater quality targets. As noted in Section 2.4 of this report, no equivalent rainfall year is available for the 2022/23 results.

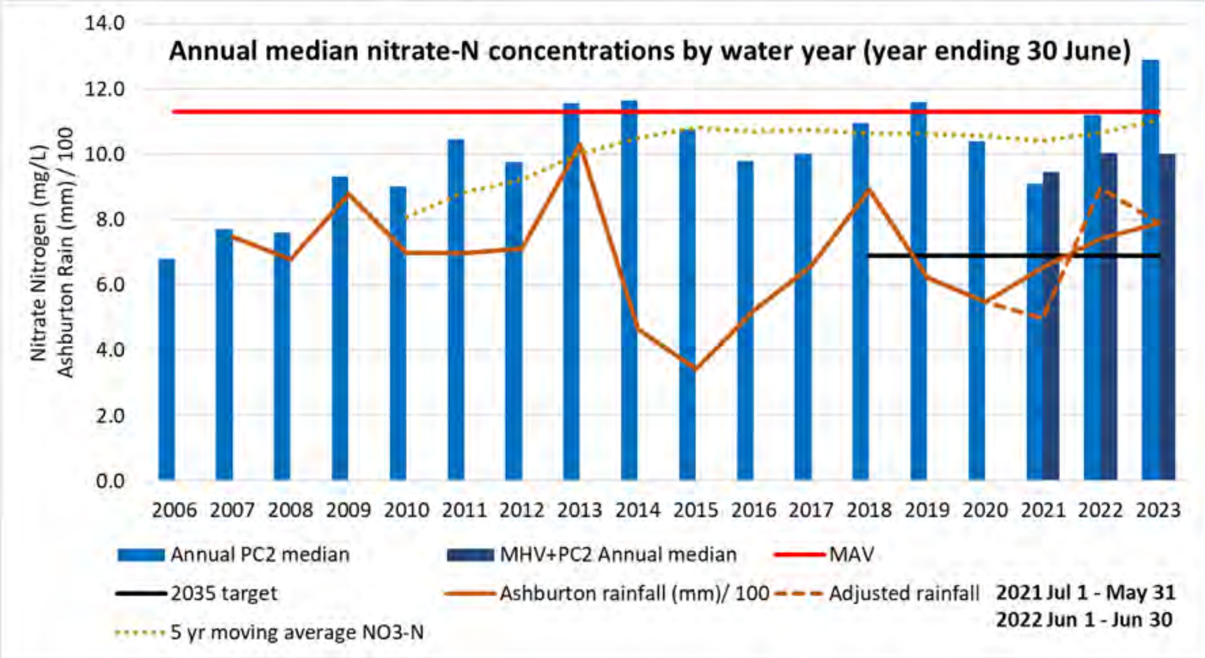

Figure 5-1: Hekeao/Hinds Plains PC2 and MHV Water + PC2 median annual nitrate-N concentrations, plus Ashburton annual rainfall (Source: CRC, MHV Water)

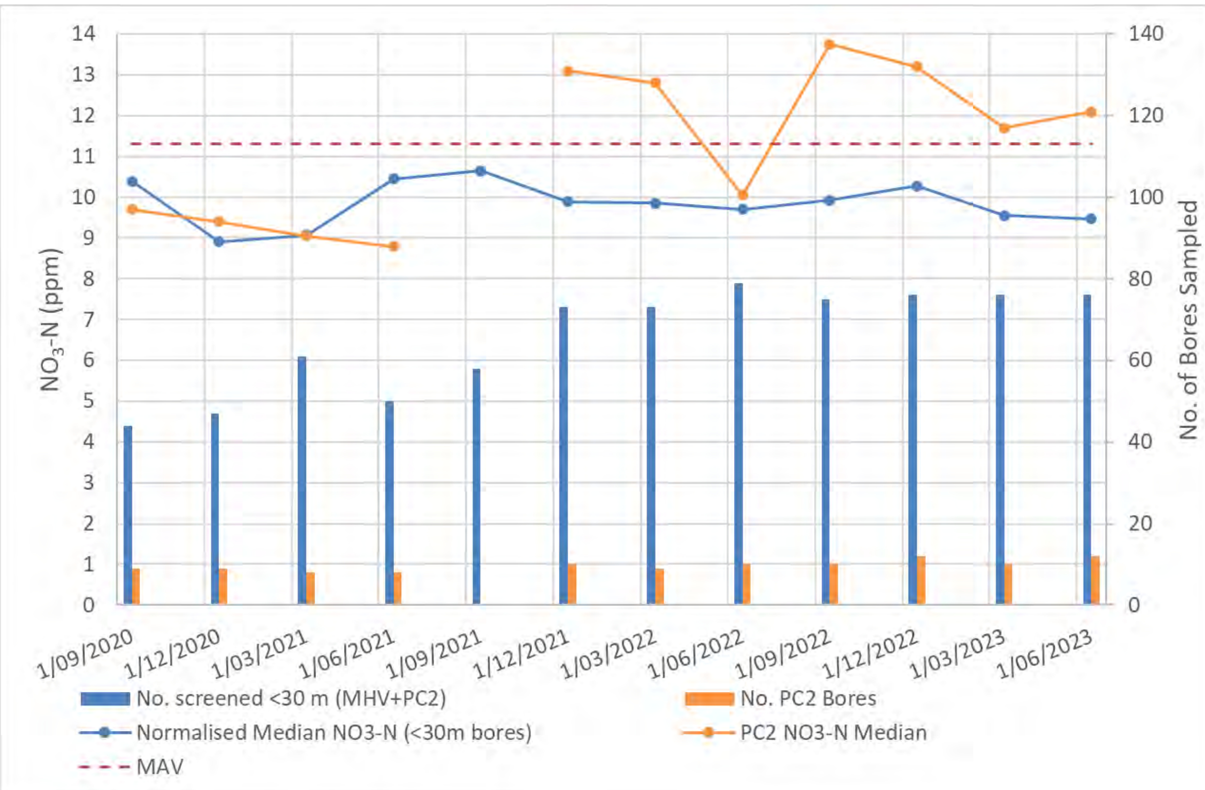

Figure 5-2: 2020-23 Hekeao/Hinds quarterly groundwater nitrate-N monitoring (Source: MHV Water, CRC)

5.2 Hekeao/Hinds Northern Drains Surface Water Quality

Consent conditions for MAR01 (Lagmhor Pilot Site) discharge consents require water quality, quantity (flow) and ecology to be monitored in key Hekeao/Hinds drains. The piezometric contours presented in Figure 4-1 (noting that groundwater flow direction may be different at different depths and at different times of year, due to pumping and recharge influences) suggests that recharge from MAR01, MAR07, and MAR08 (when reactivated) 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 2022/23 (Year 7) through these sites was 2.3 million cubic metres, equivalent to 73 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 6.9 mg/l target), while Figures 5-7 to 5-9 present the monthly results (with 95% of monthly samples required to be below the PC2 target by 2035). In general (but not in the lower Windermere Drain), 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 annual median PC2 target was the Windermere Drain Poplar Rd site in the 2021 year (Figure 5-4). Figure 5-7 shows that this was due to a significant period with low NNN concentrations during the irrigation season. However, the period of low NNN concentrations was not of sufficient duration to meet the 95%ile target as well.

The Windermere Drain below Boundary Road receives Targeted Stream Augmentation (TSA) in addition to pumped irrigation supply (from the Eiffelton Community Group Irrigation Scheme - ECGIS). Multiple ECGIS bores discharge into the drain and multiple offtakes supply ECGIS irrigators. The TSA component comprises additional water that is pumped into the drain by ECGIS to enhance fish habitat and fish passage. The combined augmentation influences water quality, particularly during periods of low natural spring flow and high irrigation demand. Figure 5-4 shows that this augmentation was sufficient to bring annual median NNN concentration below the PC2 target at Poplar Rd in the 2021 hydrologic year. Further assessment of the Windermere Drain 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 (though it would have still missed the 95%ile target).

Figures 5-8 and 5-9 (for the Parakanoi and Flemington Drains) contain significant periods of low or no flow during 2020 and 2021. This results in gaps in the water quality monitoring record. 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. Two nitrate concentration readings greater than 20 mg/l can be seen in the monthly Parakanoi Drain at McLennons Road dataset, though nitrate concentrations in both case return to normal in the next monitoring period. Both increases occur when drain flows increased suddenly from low or no flow, suggesting a "first flush" effect. Flemington Drain nitrate concentrations vary more significantly than Parakanoi Drain nitrate concentrations, with lower annual median nitrate concentrations and more missing records due to low or no flow. Environment Canterbury records shows that significant decreases in Flemington Drain NNN concentrations usually occur in the summer months after a rainfall event, where rainfall runoff augments the spring-fed drain flow. Further consideration of Targeted Stream Augmentation as well as other ways to reduce the spring-fed nutrient load will be progressed in 2023/24.

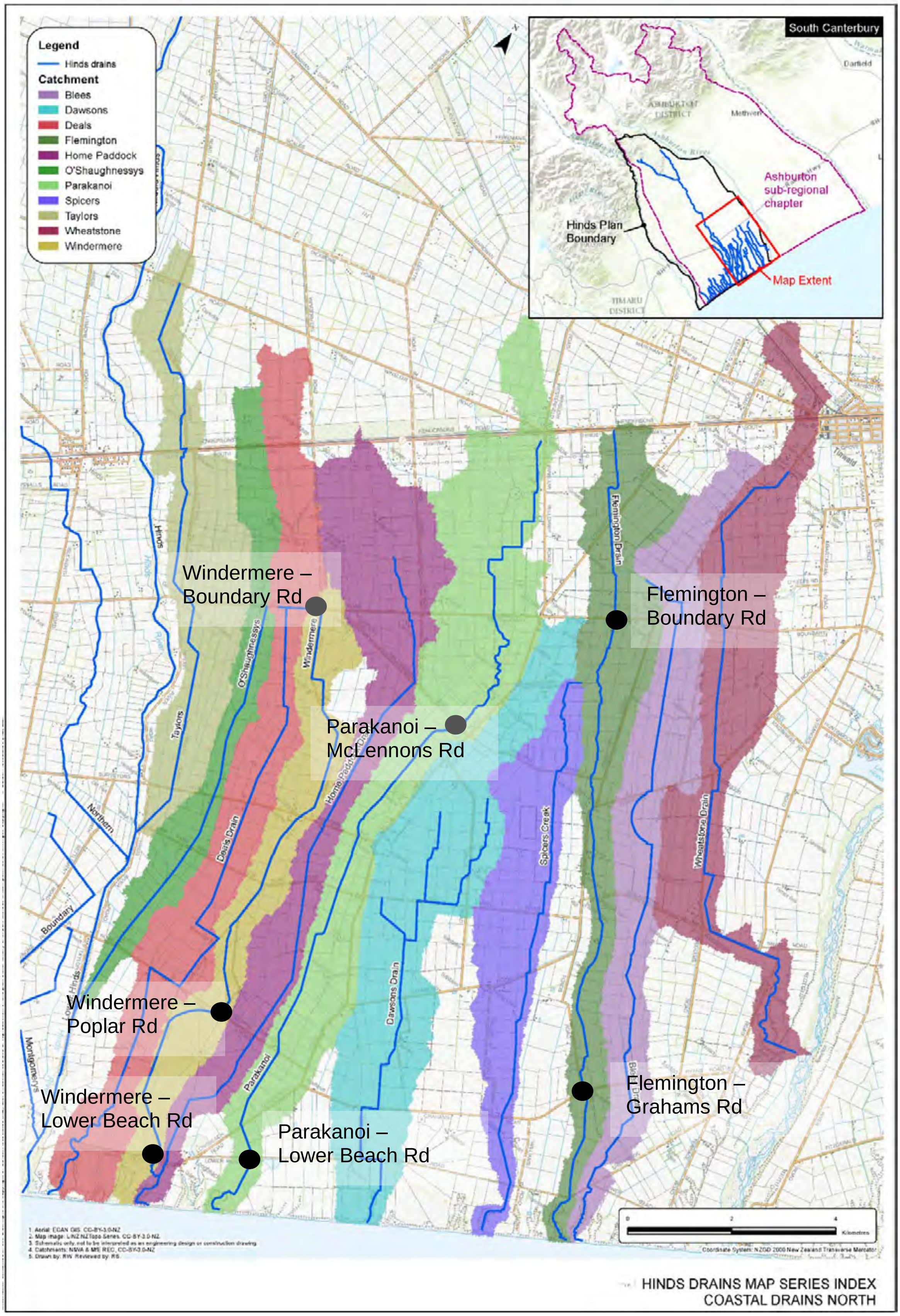

Figure 5-3: Hekeao/Hinds Northern Drains monitoring sites

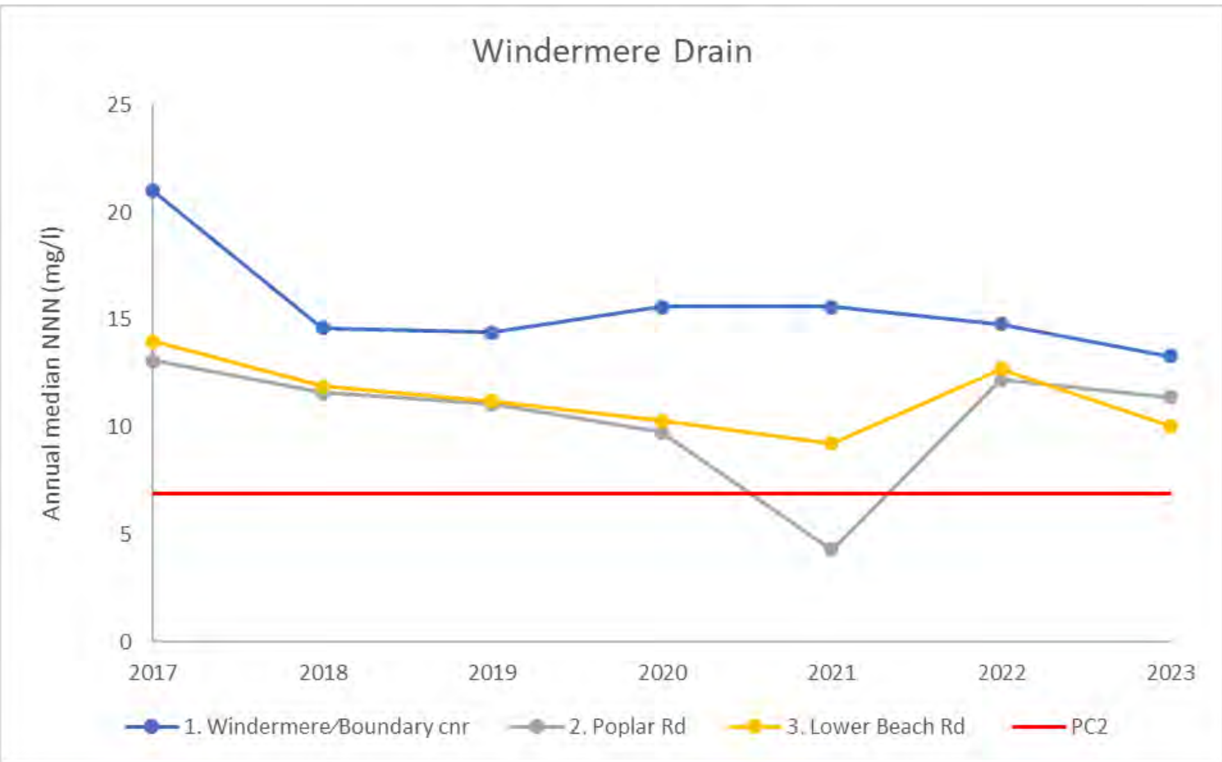

Figure 5-4: Windermere Drain annual median NNN monitoring (Source: CRC)

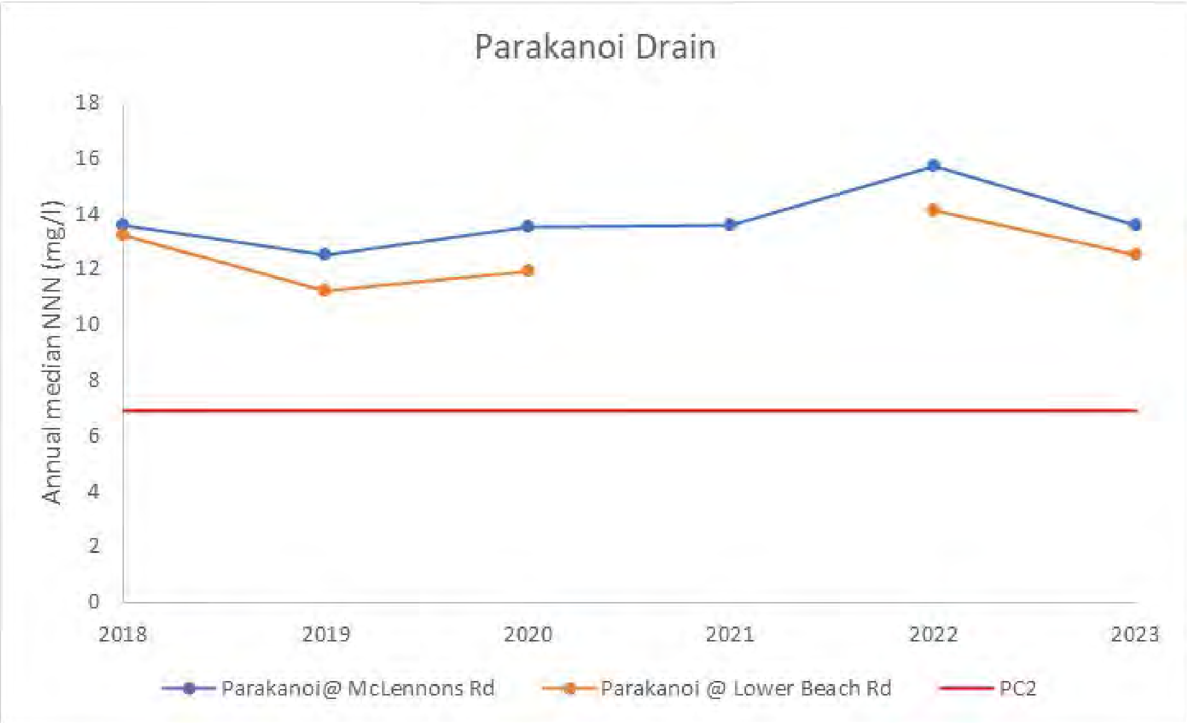

Figure 5-5: Parakanoi Drain annual median NNN monitoring (Source: CRC)

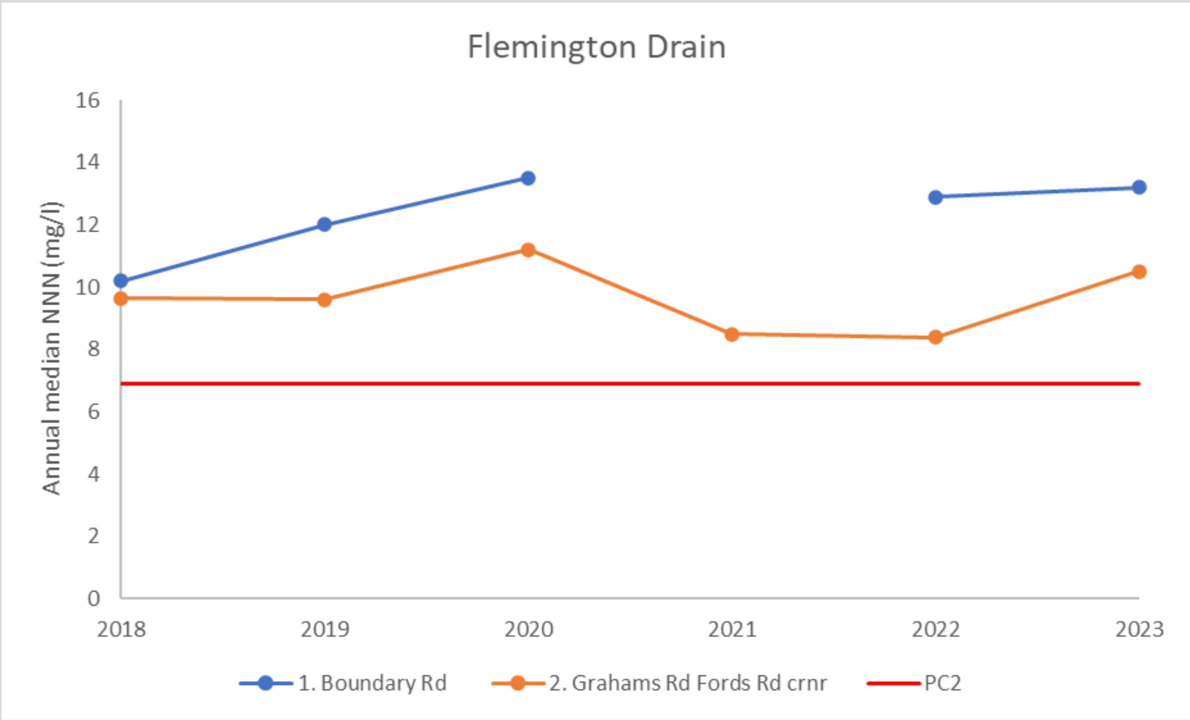

Figure 5-6: Flemington Drain annual median NNN monitoring (Source: CRC, MHV Water)

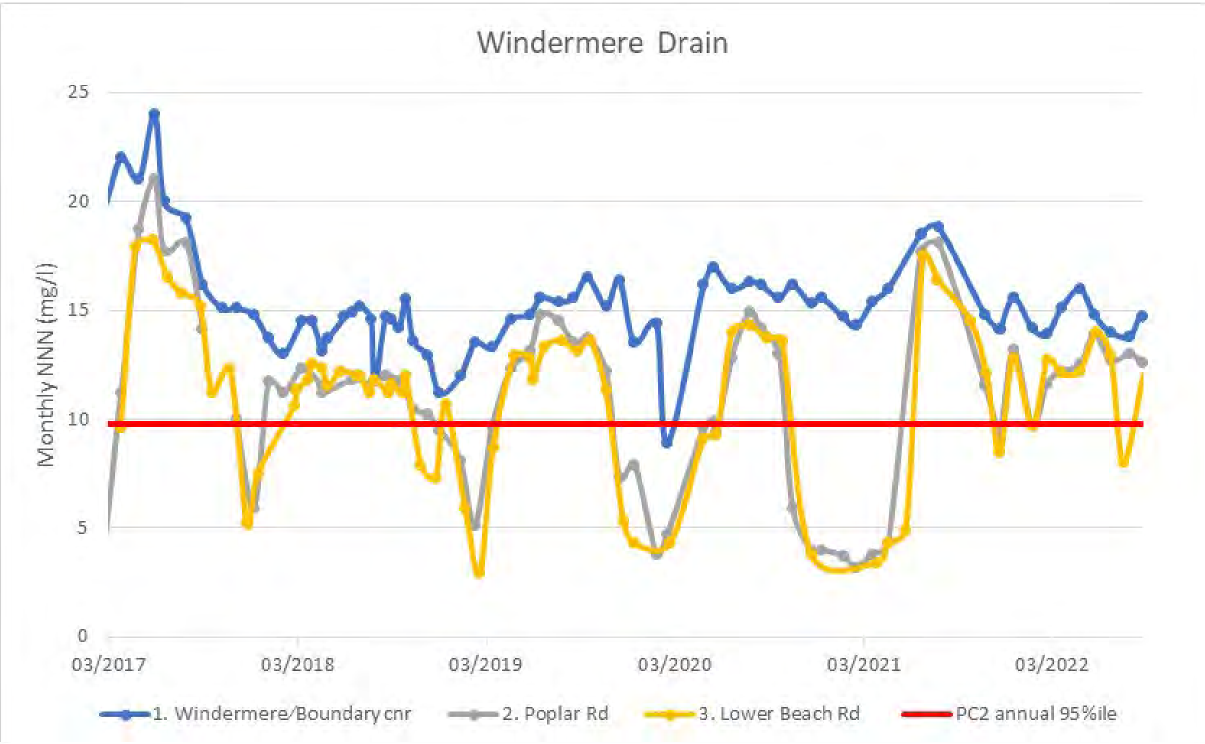

Figure 5-7: Windermere Drain monthly NNN monitoring (Source: CRC)

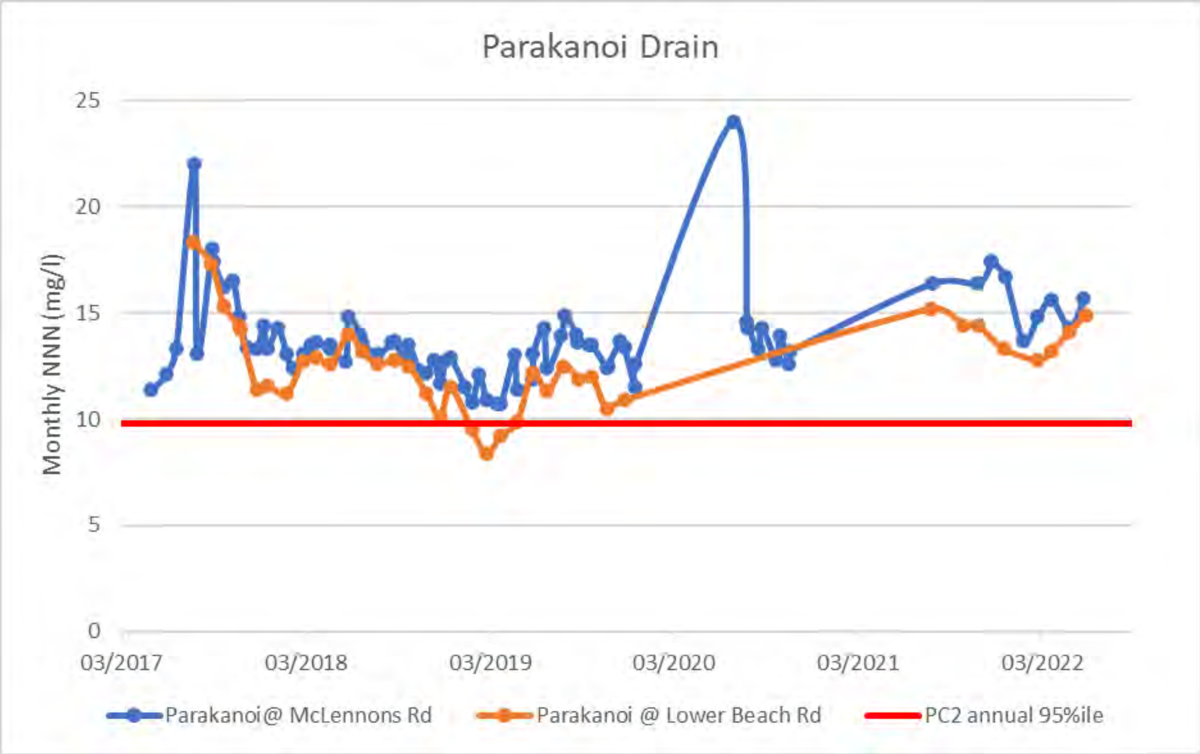

Figure 5-8: Parakanoi Drain monthly NNN monitoring (Source: CRC)

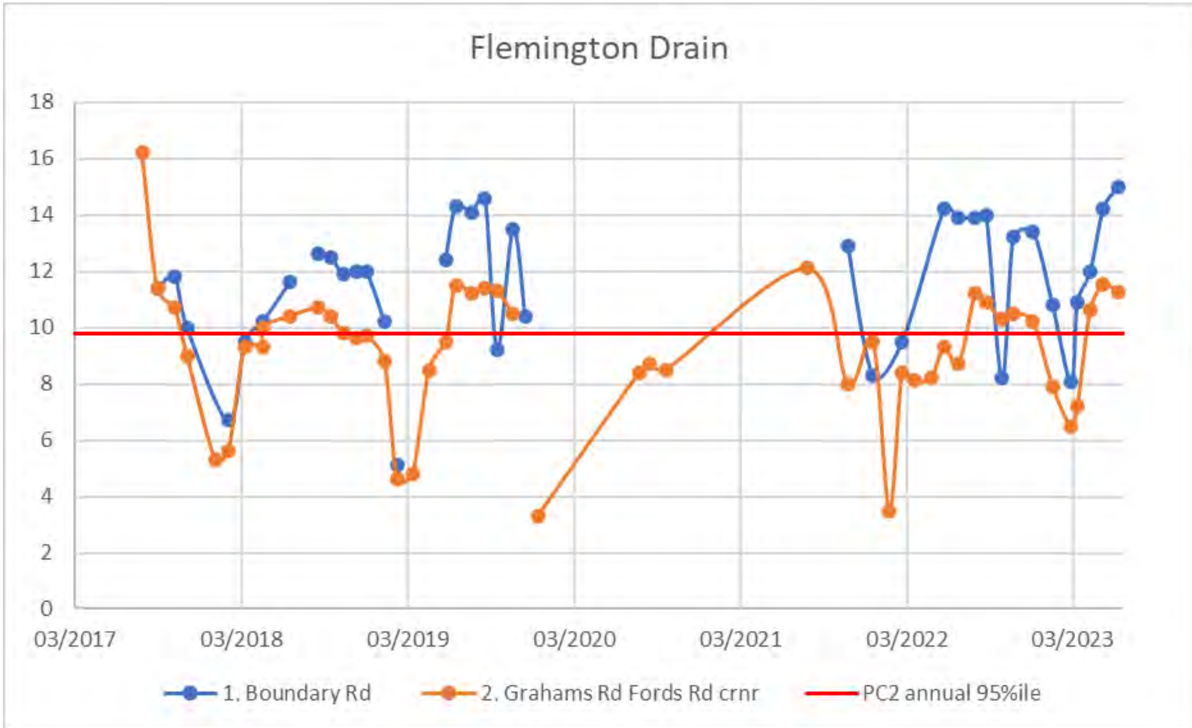

Figure 5-9: Flemington Drain monthly NNN monitoring (Source: CRC, MHV Water)

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.
- Irrigation using groundwater and drain water covers only part of the Hekeao/Hinds Plains.
- There are many independent irrigators, each with individual situations.

During 2022/23, this workstream has been discussed with groundwater users and farm advisors across the catchment, and the concept (including monitoring requirements) has been amended as a result of these discussions. Potential participants for an extended on-farm experiment have been identified and discussions begun with the objective of beginning the first experiment during 2023/24.

7 HHWET Objectives and Next Steps

HHWET objectives are set annually in five subject areas. HHWET 2022/23 objectives were met except for those influenced by consenting delays. Year 7 (2022/23) achievements are summarised as follows:

1. Governance
   - Monthly HHWET meetings (except January), attended by HHWET Trustees, a Central South Island Fish and Game Council observer/advisor, Mid Canterbury Catchment Collective representatives, the HHWET Executive Director and contracted minutes secretary.
   - Annual public meeting and Hekeao Hinds Science Collaboration Group meetings.
   - Farewells to departing Trustees Sir Graham Harrison (co-opted Trustee) and Richard Wilson (RDRML), and a welcome to new Trustee Evan Chisnall (RDRML).
   - An Access Agreement was finalised with Rangitata Diversion Race Management (RDRML).
   - HHWET Purposes and Objectives were reviewed and amended for the 2023/24 Business Plan.
   - Deeds of lease were agreed with ADC for 3 MAR sites (MAR01, MAR21 and MAR22).
   - A dual (stockwater/MAR) use water race trial was agreed with ADC.
2. Communications
   - The HHWET website (www.hhwet.org.nz) was redeveloped and reached an increasing number of people along with the HHWET Facebook page (@HekeaoHindsWET).
   - The Hekeao/Hinds Science Collaboration Communications Strategy was approved.
   - Wider communications were achieved through articles in the Rubicon Water newsletter, Irrigation Leader New Zealand magazine and in local media.
3. Enabling Regulatory Environment
   - CRC233041, for use of up to 3200 l/s surface water for MAR purposes, supplementary to RDRML consent CRC182542 was lodged on behalf of RDRML in December 2022.

- CRC233046, to discharge up to 3255 l/s at up to 34 Managed Aquifer Recharge (MAR) sites (including 14 of the current MAR test sites) was lodged in December 2022.
- CRC233851, to discharge up to 410 l/s at Near River Recharge Site #1 (NRR1) was lodged in March 2023.
- CRC233852, to undertake works in the bed of the Hekeao/Hinds River (for NRR site construction) was lodged in March 2023.
- CRC233853, to discharge up to 200 l/s in total at NRR2 and NRR3 was lodged in March 2023.
- CRC234782 and CRC234783 for eClean Bioreactor take, use and discharge was lodged on behalf of Ortongreen farm in May 2023.

4. Access to water
   - Final details for the RDRML Water Supply Agreements were confirmed.
5. Proof of concept
   - Hekeao/Hinds Environmental Enhancement Scheme size was reviewed to support consent applications and the Scheme Business Case.
   - HHWET are a project partner in the trialling of the eClean bioreactor in Hekeao/Hinds. During 2022/23, the required Flood Protection Bylaw Authority was approved, consents were lodged, and the site was prepared for bioreactor installation.
   - An MSc project investigating microbial pathogen risk from MAR was supported.
   - Potential lower catchment constructed wetland sites were confirmed and initial assessments completed. A pilot site was constructed at one of these sites under permitted activity conditions.
   - MAR09 was upgraded with additional recharge areas.
   - High flow testing was undertaken at potential new and expanded MAR/NRR sites to inform current discharge consent processes.
6. Collaboration
   - Oversight of the Hekeao Hinds Science Collaboration Group.
   - MSc supervision of Sidinei Teixeira (Hydrological drivers influencing nitrate nitrogen changes in an alluvial aquifer).
   - MSc support for Madeleine Inglis (Microbial pathogen risk from MAR).
   - Increase in new native plantings near MAR/NRR sites to 17,500, which have contributed to the arrival of Australasian Bittern, Marsh Crake, Bellbird, Kingfisher, and White Heron birds near NRR1.

HHWET's next steps were determined in May 2023 by confirming the following objectives through to 30 June 2024, along with a commitment to continue the ICM approach presented in Figure ES-1 for the achievement of the Hekeao/Hinds Environmental Enhancement Scheme presented in Figure ES-2:

1. <u>Governance</u>
   a. Long term agreements in place with Hekeao/Hinds Environmental Enhancement Scheme operators (monitoring and distribution), partners and landowners.
   b. HHWET Purposes and Functions reviewed on an annual basis.
   c. Business Case Addendum confirmed by 31 December 2023 as a support document for 2024 Long Term Plan funding processes.
   d. Annual report and annual accounts externally reviewed on an annual basis.
2. <u>Communications</u>
   a. Communications Plan reviewed and updated on an annual basis.
   b. Communication opportunities identified and actioned (including local organisations, educational institutions, tangata whenua, media, and conferences).

   c. Engage with and inform Essential Freshwater/Te Mana o te Wai processes where relevant.

3. Enabling Regulatory Environment

   a. Long term HHWET Ltd take, use and discharge consents confirmed for a combined MAR/NRR flowrate contribution to the Hekeao/Hinds Environmental Enhancement Scheme of at least 3700 l/s (equivalent to a maximum of 117 million m^3/year).

   b. Consents confirmed for Targeted Stream Augmentation, Constructed Wetland and Bioreactor concepts as required to support Hekeao/Hinds Environmental Enhancement Scheme implementation.

   c. Additional consents and approvals (e.g., construction consents and Flood Protection Bylaw Authorities) secured as required.

   d. Additional permissions (e.g., DOC) secured as required.

4. Access to water

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

5. Proof of concept

   a. 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).

   b. Hekeao/Hinds Environmental Enhancement Scheme size reviewed by 30 October 2023 for the purpose of updating long term Scheme size estimations and the Scheme Business Case.

   c. Monitoring Plan reviewed and updated on an annual basis.

   d. Methods of managing bacterial contamination and suspended sediment to reduce MAR/NRR supply shutdowns reviewed and updated on an annual basis.

   e. Hekeao/Hinds Environmental Enhancement Scheme infrastructure in place that provides compliant, safe, efficient, and reliable operation.

   f. Groundwater Irrigation Nutrient Recycling concept actively supported through development and implementation.

   g. Targeted Stream Augmentation concept actively supported through further development and implementation.

   h. Constructed wetland and bioreactor concepts actively supported through further development and implementation.

   i. Additional research and development concepts relevant to HHWET Purposes actively considered.

6. Collaboration

   a. Collaborative opportunities actively sought with potentially complementary groups.

   b. Actively engage with stakeholders to ensure strong relationships which foster a high level of trust and collaboration.

   c. Site co-benefits identified and actively implemented on a site-by-site basis, seeking external funding support where possible.

d. Support (including supervision) provided for tertiary and post-graduate students where their subject matter is relevant to Trust Purposes and Objectives.

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