

Ground and Surface Water Monitoring Programme

2024-25 Annual Report

October 2025

Sustainable solutions for our community,
now and into the future



Justin Legg B.Sc. (Hons), MIWM; MAIG (R.P. Geo), HSNZ, NZFSS
Senior Hydrogeologist
Kaimātai Wainuku Matua



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Author(s) Justin Legg

Position Senior Hydrogeologist - *Kaimātai Wainuku Matua*



Reviewed By

Name	Organisation	Position	Role
Dr Helen Rutter	Lincoln Agritech	Principal Hydrogeologist	Independent Technical Review
Dr Brett Painter	HHWET	Executive Director	Internal Technical Review
Andrew Mockford	MHV Water	CEO	MHV Review
Nicole Matheson	MHV Water	Environmental Manager	MHV Review

Approved By Andrew Mockford

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Distribution	Organisation	Person	Role
	MHV	Andrew Mockford	CEO
	BCI	Nick Daniels	CEO
	HHWET	Peter Lowe	Chairman
	AEC	Ally Crane	General Manager
	ECan		

Executive Summary

Background

This report outlines and documents the ground and surface water monitoring programme conducted by MHV Water Ltd (MHV) during the period of January 2024 to June 2025 (2024/5). This work programme was undertaken to meet the following objectives for both ground and surface waters:

- i. complete routine ground and surface water monitoring of Nitrate-Nitrogen ($\text{NO}_3\text{-N}$) levels within the MHV irrigation area; as well as,
- ii. provide input data and observations for future work and research programmes.

MHV commenced routine ground and surface water monitoring of $\text{NO}_3\text{-N}$ levels within the MHV scheme area in September 2016. The programme's objective is to understand the changes in $\text{NO}_3\text{-N}$ in groundwater for the Hekeao Hinds Plains (HHP).

The 2024/5 Survey

In 2024/5, groundwater survey sizes ranged between 163 to 164 bores representing a spatial footprint of $\approx 111,000$ ha (Figure 1).

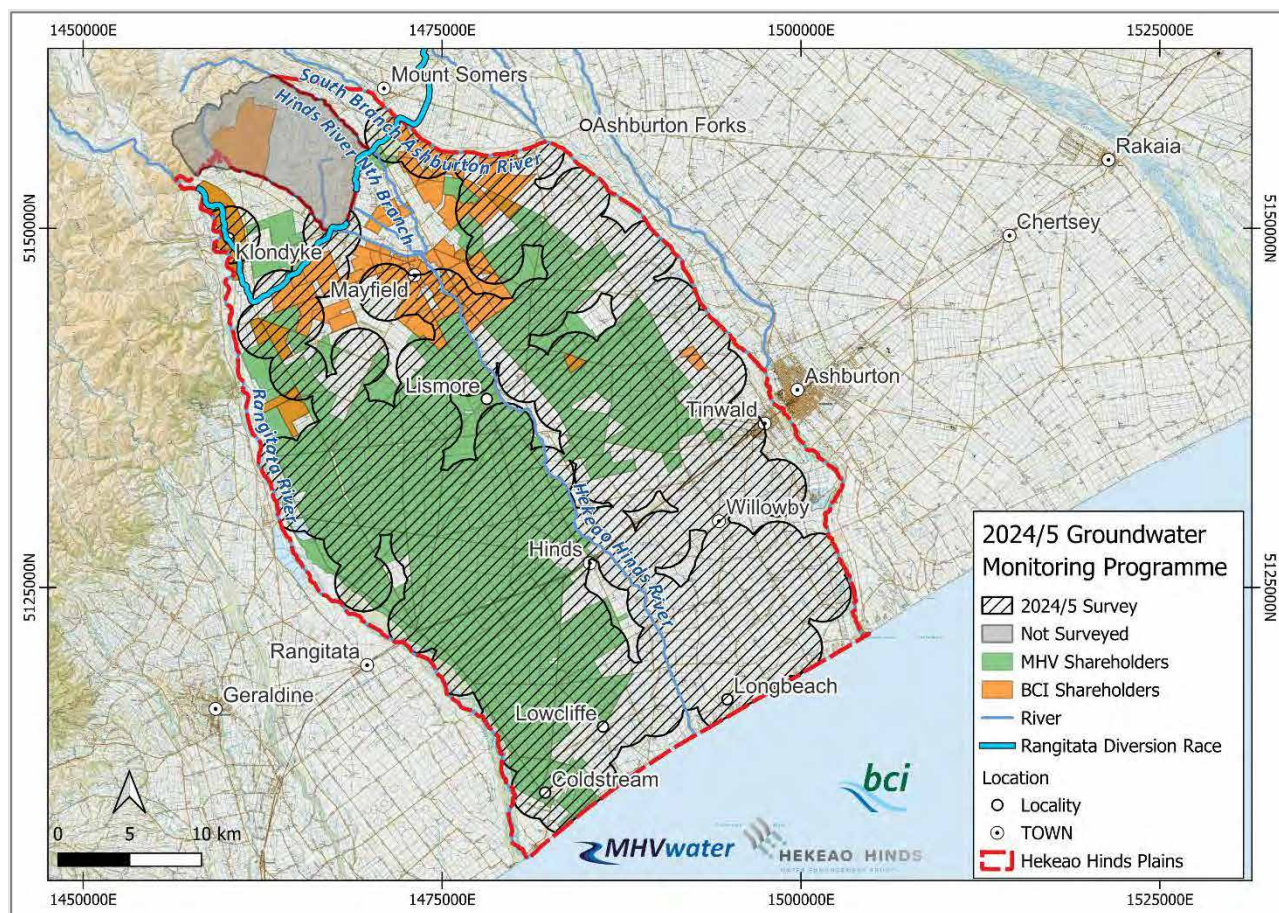


Figure 1 Survey coverage of the 2024/5 groundwater monitoring programme

During this period, MHV collected some 1200 samples from 101 surface water locations - the majority of locations (65) were at public road culverts or bridges (Figure 2).

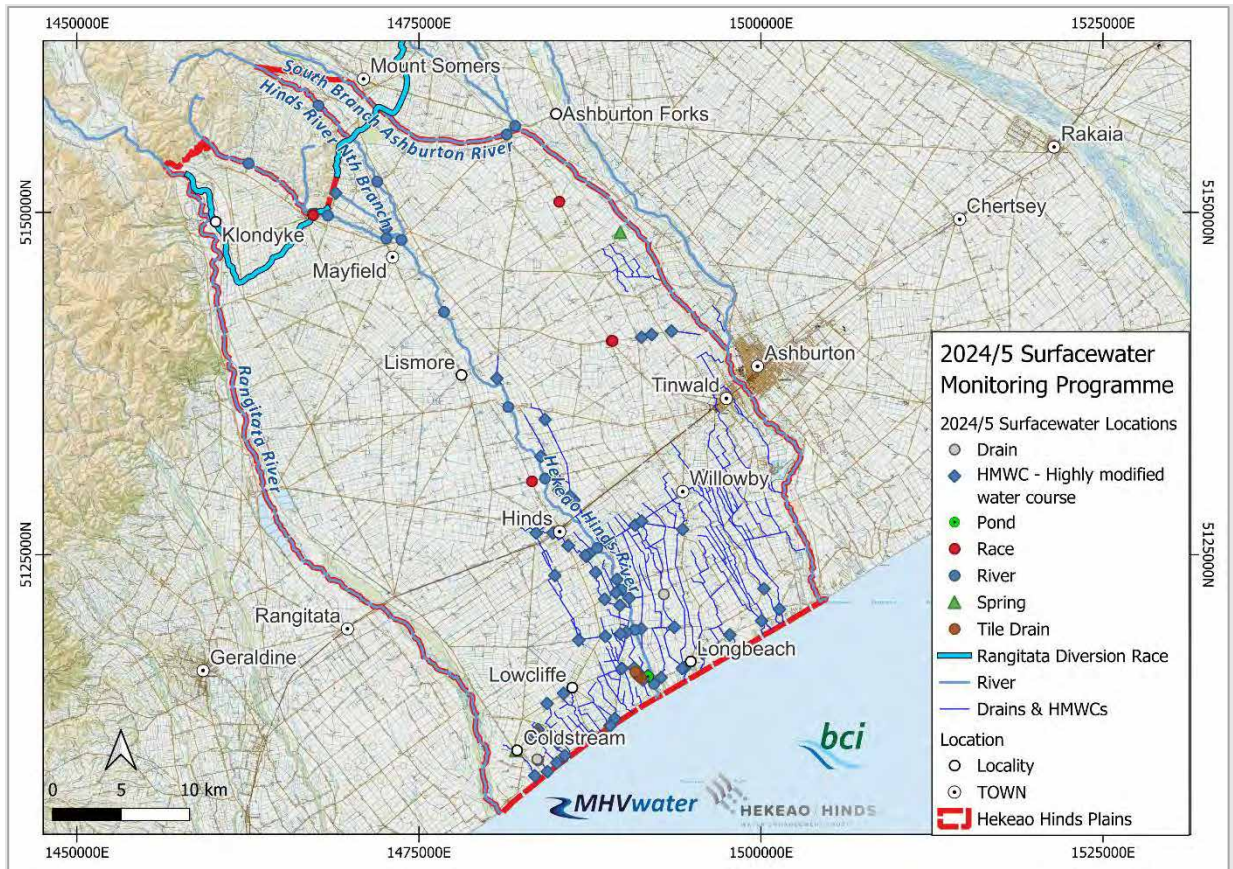


Figure 2 Location of 2024/5 surface water sampling sites

2024/5 Groundwater Results

During the 2024/5 reporting period, the Hekeao Hinds Plains received 1320 mm of rainfall – approximately 20% more than the long-term average of 774 mm, with 1045 mm being received in the six-month period from January to June 2025. This has resulted in an increase in $\text{NO}_3\text{-N}$ concentrations in groundwater at all depths.

An Inverse Distance (ID2) interpolation of the relative median changes in groundwater $\text{NO}_3\text{-N}$ for June 2024 and June 2025 are presented in Figure 5 and Figure 6.

NOTE The ID2 interpolation utilised the median $\text{NO}_3\text{-N}$ data only and did not consider factors such as (but not limited to) the influence of rivers, streams, soil type, preferential flow pathways, etc. Hence, by interpolating bores of that are close to each other, but vary significantly in depth, the results may appear ‘blotchy’.

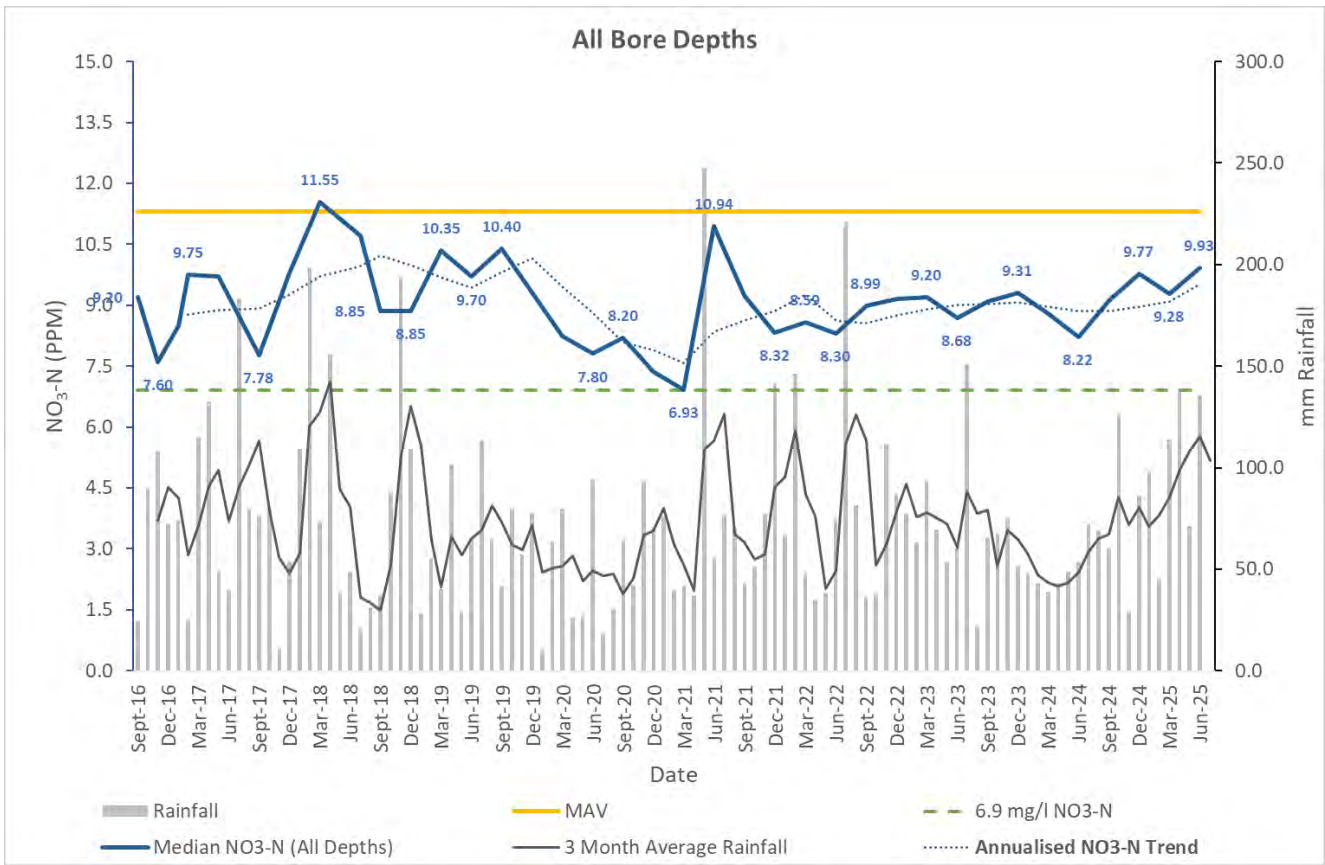


Figure 3 Long term NO₃-N results for the MHV groundwater monitoring programme (All bore depths)

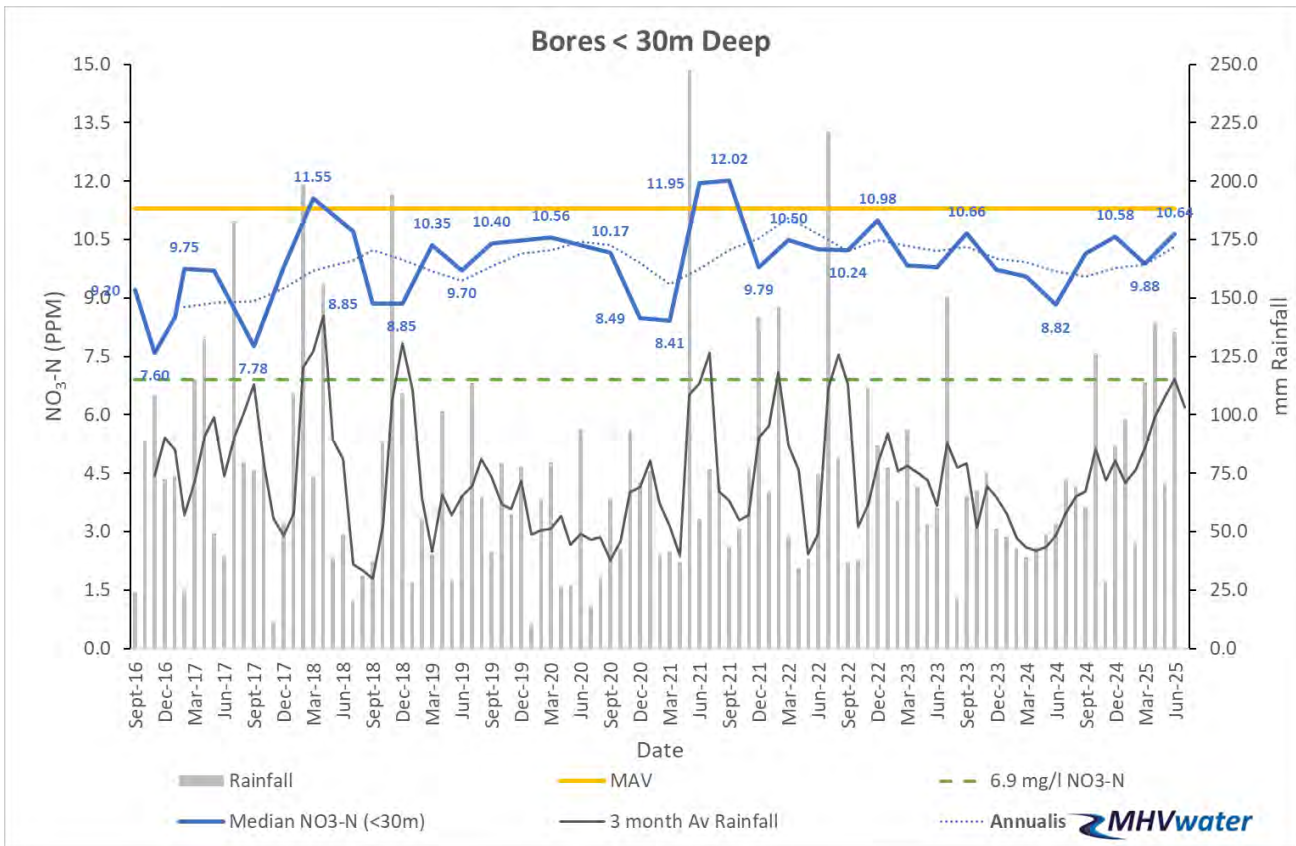


Figure 4 Long term NO₃-N results for the MHV groundwater monitoring programme (Bores <30m deep)

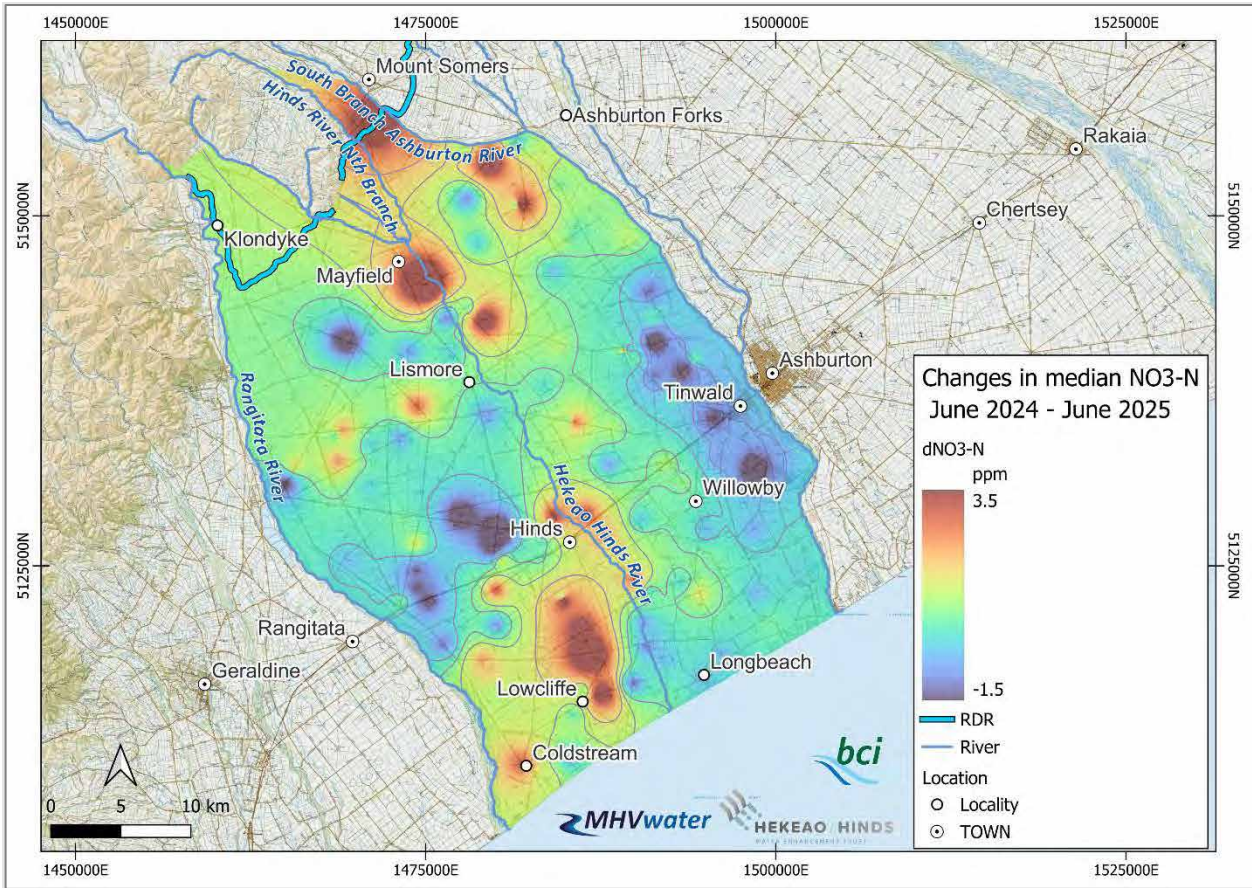


Figure 5 ID2 interpolation the difference between June 2024 and June 2025 NO₃-N median for all bores

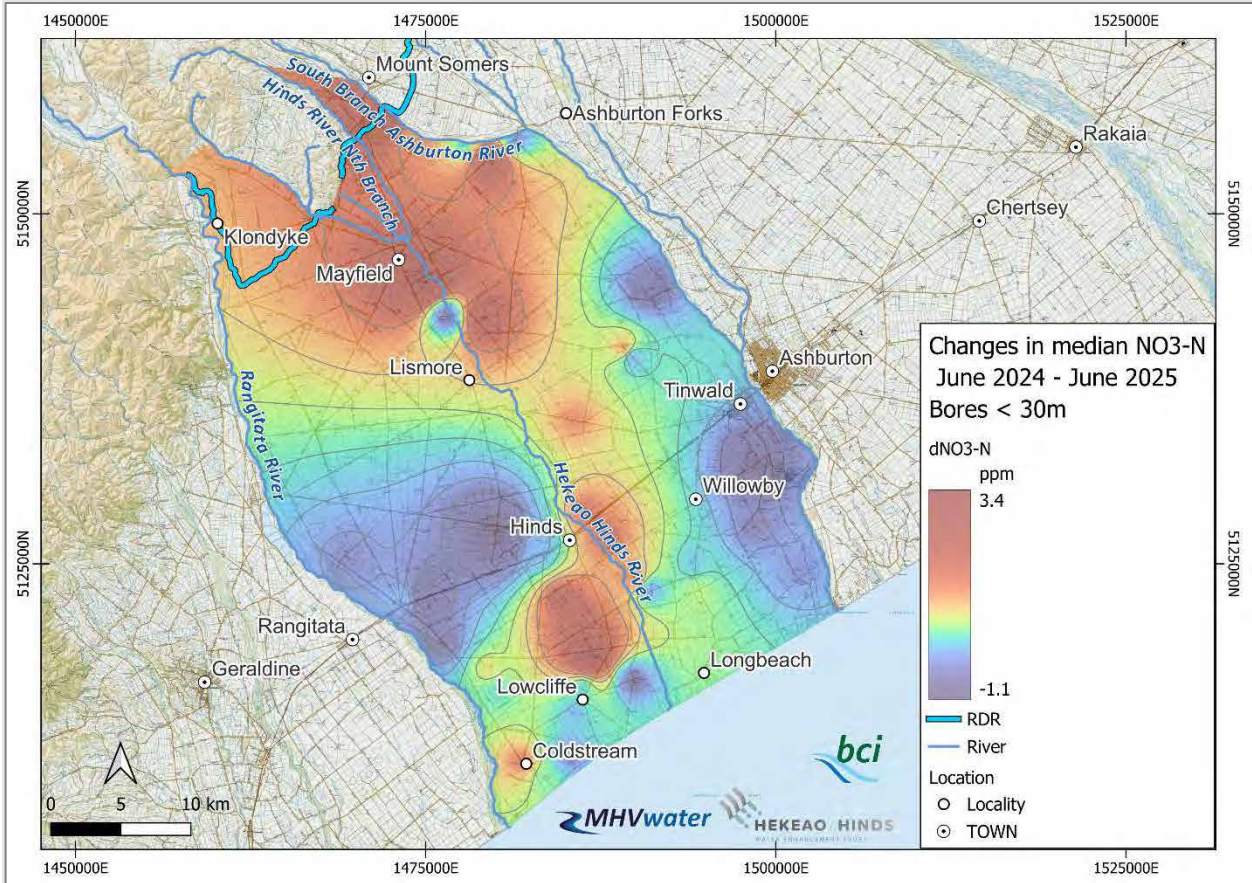


Figure 6 ID2 interpolation the difference between June 2024 and June 2025 NO₃-N median for bores < 30m deep

2024/5 Surface Water Results

The 2024/5 reporting period saw a higher-than-expected degree of volatility in both the Hekeao Hinds River as well as Highly Modified Water Courses – largely due to rainfall (Figure 7).

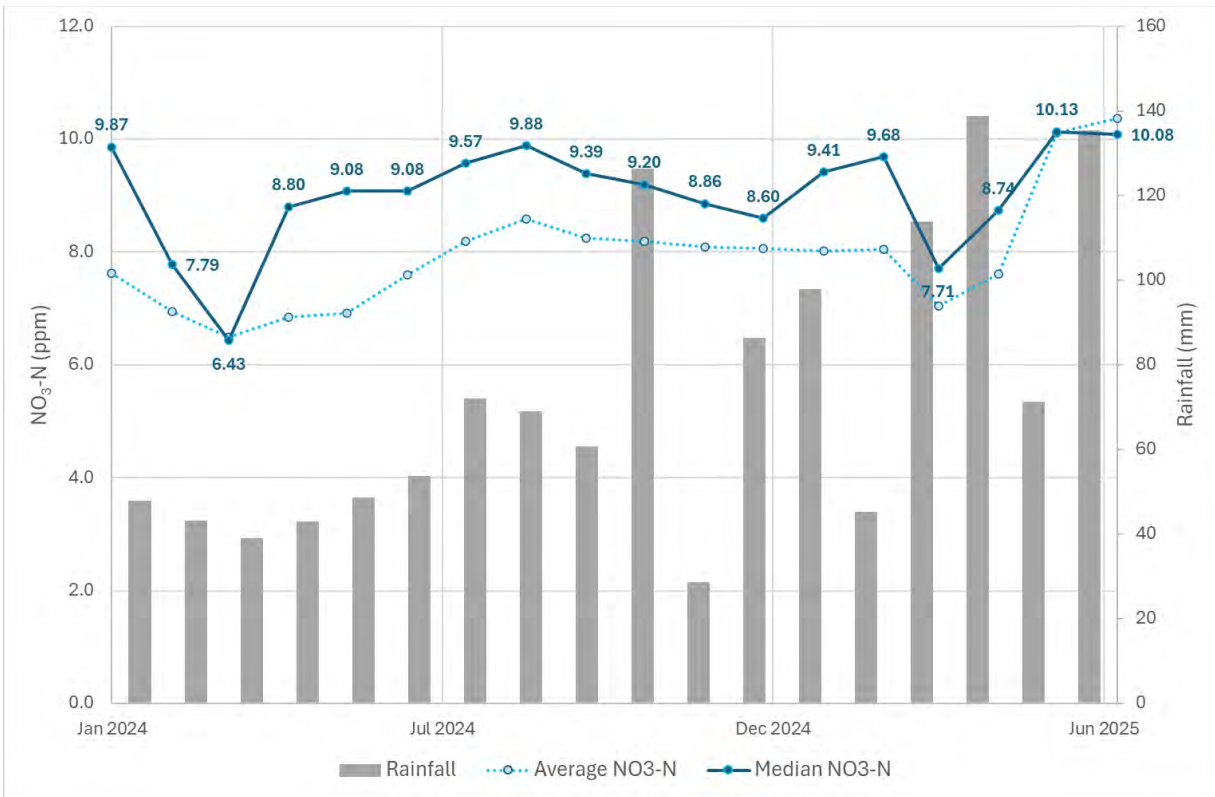


Figure 7 NO₃-N concentrations in Highly Modified Courses (HMWC's) for the 2024/5 reporting period

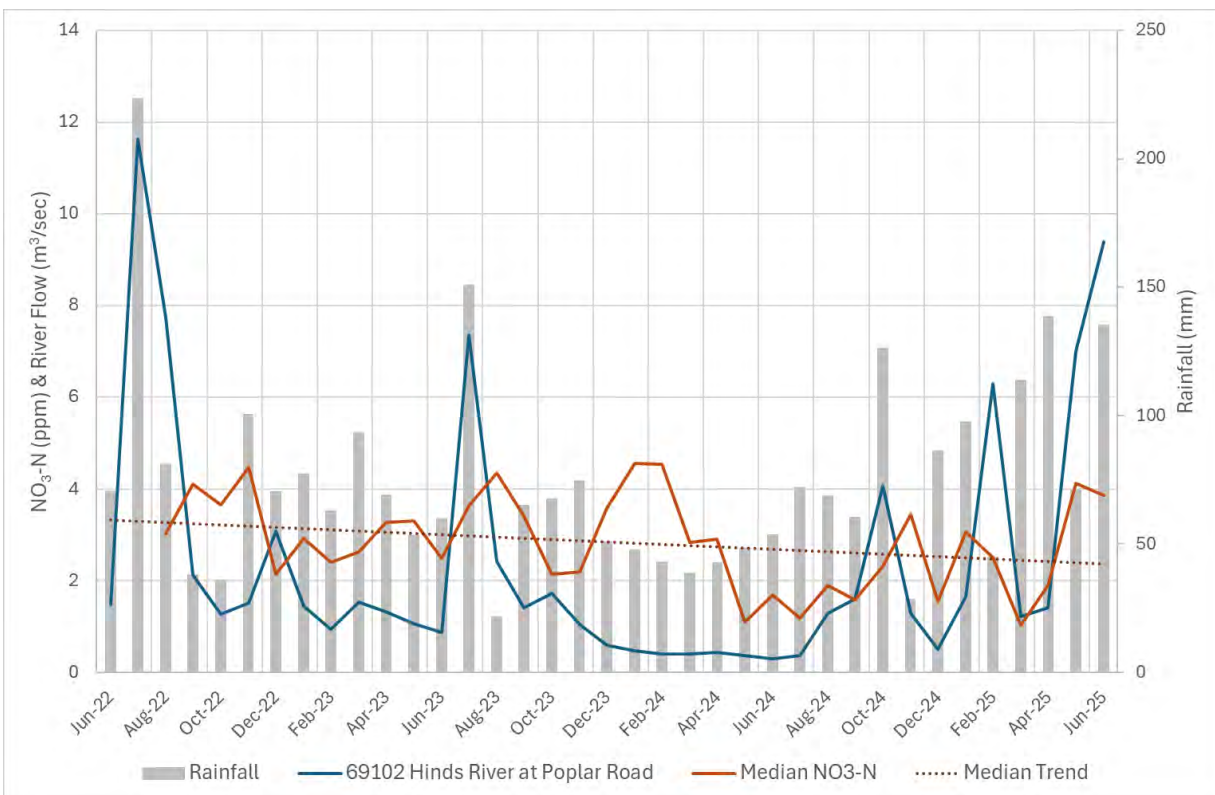


Figure 8 NO₃-N concentrations for the Hekeao Hinds River for the 2024/5 reporting period with rainfall & river flow at Poplar Rd

Nitrogen naming & unit convention

Nitrate-Nitrogen (NO₃-N)

When a laboratory directly reports the concentration of nitrate, it is referring specifically to the nitrate compound, which is designated chemically as NO₃. The drinking-water Standards for New Zealand 2005 (Revised 2018) currently define the Maximum Acceptable Level (MAV) for NO₃-N in potable water as 50 mg/L [1].

However, nitrate (NO₃) is one-part Nitrogen (N) plus three parts oxygen (O), so, nitrogen only makes up about 22.6% of the nitrate compound by weight (nitrogen weighs 14u, oxygen weighs 16u). Hence it can also be reported as the concentration of nitrogen (N) in the form of NO₃ (denoted as NO₃-N), as opposed to the amount of nitrogen in the form of NO₂, NH₄, NH₃, N₂ etc. which may also be present in a water sample.

Hence the following conversion is often applied:

$$\text{Nitrate-Nitrogen (NO}_3\text{-N)} = \text{Nitrate (NO}_3\text{)} \times 0.226$$

Or conversely

$$\text{Nitrate (NO}_3\text{)} = \text{Nitrate-Nitrogen (NO}_3\text{-N)} \times 4.43$$

So, **50 mg/L NO₃** = **11.3 mg/L NO₃-N**

As the 2020 National Policy Statement for Freshwater Management (NPS-FM 2020), the Ashburton Zone Committee and others refer to nitrate concentrations in terms of NO₃-N, all references to nitrates in this report will be with respect to NO₃-N.

Additionally, concentrations of NO₃-N can be reported as:

- milligrams per litre (mg/L),
- parts per million (ppm) and/ or
- grams per metre cubed (g/m³).

All of which are different volumetric expressions of 1 g solute per 1,000,000 g solution (i.e. they are the same).

To avoid all ambiguity, NO₃-N will be reported in this document in terms of ppm (e.g. NO₃-N MAV = 11.3 ppm).

Maximum Acceptable Level (MAV) for NO₃-N

The Ministry of Health defines Maximum Acceptable Level (MAV) for NO₃-N as follows.

“The MAV of a chemical determinant is the concentration of that determinant which does not result in any significant risk to the health of a 70 kg consumer over a lifetime of consumption of two litres of the water a day.

For genotoxic carcinogens the MAV represents an excess lifetime cancer risk, usually amounting to one extra incidence of cancer per 100,000 people drinking water containing the determinant in question at the MAV for 70 years (i.e. an assessed risk of 10⁻⁵)” [1], [2]

Abbreviations

ADC	Ashburton District Council	ha	10,000 square metres (2.471 acres)
ADZC	Ashburton District Zone Committee	HAB	Harmful Algal Bloom
AEC	Aoraki Environmental Consultancy Ltd	HDWP	Hinds Drains Working Party
AEP	Annual Exceedance Probability	HHP	Hekeao Hinds Plains
ARI	Annual Recurrence Interval	HHSCG	Hekeao Hinds Science Collaboration Group
BCI	Barrhill Chertsey Irrigation	HHWET	Hekeao Hinds Water Enhancement Trust
°C	Degrees Celsius	HMWC	Highly modified water course
CHI	Cultural Health Indicators	ID2	Inverse Distance Squared
CRM	Certified Reference Material	IEEE	Institute for Electrical & Electronics Engineers
Cumec	Cubic Meters per Second (m ³ /s)	IWM	Integrated Water Management
CV	Coefficient of Variation	JSEA	Job Safety & Environment Analysis
CWMS	Canterbury Water Management Strategy	K	Hydraulic Conductivity
CLWRP	Canterbury Land & Water Regional Plan	kL	Kilo Litre (1,000 Litres or 1m ³)
DIN	Dissolved organic nitrogen: comprised of nitrate plus nitrite and ammonium	l	Litre: a metric unit of capacity equal to 1,000cm ³ (0.264 gallons)
DO	Dissolved Oxygen	LSR	Land Surface Recharge
DOC	Dissolved Organic Carbon	LWRP	Land and Water Regional Plan
DON	Dissolved Organic Nitrogen	MAR	Managed Aquifer Recharge
DRP	Dissolved Reactive Phosphorus	MAV	Maximum Acceptable Level
DTM	Digital Terrain Model	m bgl	Met res below ground level
ECan	Canterbury Regional Council. It uses the promotional name Environment Canterbury, frequently abbreviated to ECan.	MCCC	Mid Canterbury Catchment Collective
<i>E. coli</i>	<i>Escherichia coli</i> , a microbe used to indicate the potential for faecal contamination.	mg/ L/ p.a.	milligrams per litre per annum
FEP	Farm Environment Plan	ML	Mega Litre (1,000,000 litres)
FHCG	Foothills Catchment Group	mm	Millimetres
GL	Giga Litre (1,000,000,000 Litres)	ml	millilitres
GNS	Geological and Nuclear Sciences	N	Nitrogen
GMP	Good Management Practices	NEMS	National Environmental Monitoring Standards
GWL	Groundwater Level	NH ₃	Ammonia
		NH ₄ ⁺	Ammonium
		NO ₂ -N	Nitrite-Nitrogen. The concentration of nitrogen (N) present in the form of the nitrite (NO ₂)

NO ₃ -N	Nitrate – Nitrogen. The concentration of nitrogen (N) present in the form of the nitrate (NO ₃)	REDOX	Reduction–Oxidation
		SOP	Standard Operating Procedures
		SPC	Specific Conductance
NPS-FM 2020	National Policy Statement for Freshwater Management 2020	T	Hydraulic Transmissivity
OFG	Open Framework Gravels	TDN	Total dissolved nitrogen. DIN+DON
p.a.	per annum (for each year)	TDR	Time Domain Reflectometry
PAW	Profile available water	t/ ha/ yr	Tonnes per hectare per year
PC2	Plan Change 2 of the Canterbury Land & Water Regional Plan	TKN	Total Kjeldahl Nitrogen.
PCE	Parliamentary Commissioner for the Environment		The sum of NH ₃ -N + organically bound nitrogen only
pH	a numeric scale used to specify the acidity or alkalinity of an aqueous solution.	TN	Total Nitrogen.
			The sum of NO ₃ -N + NO ₂ -N + NH ₃ -N and organically bonded nitrogen
QCMi	Quantitative Macroinvertebrate Community Index	QAQC	Quality Assurance & Quality Control
RDR	Rangitata Diversion Race	VMS	Vadose Monitoring System
		ZIP	Zone Implementation Programme

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1. Introduction

1.1.MHV Water Ltd

MHV is a farmer owned co-operative that has been delivering water for irrigation to the Hekeao Hinds Plains (HHP) since 1947. On 1 June 2017 Mayfield Hinds Irrigation Limited merged with Valetta Irrigation Limited to form MHV Water Limited. MHV now stores and delivers water for the purpose of irrigation to over 200 shareholders via ~320km of open race and ~100km of piped infrastructure over an area of ~58,000 ha. As part of this delivery, MHV manages the environmental compliance for its shareholders.

1.2.Purpose

This report documents the groundwater sampling programme conducted by MHV Water Ltd (MHV) during the period of 1st January 2024 to June 31st, 2025. Previous MHV reports had reported on a calendar year interval, with the change in reporting period being ascribed to the need for all reporting to be aligned with the government's fiscal reporting year of 1 July to 30 June; subsequently this report represents an 18-month period.

This work programme was undertaken to meet the following objectives for both ground and surface waters:

- a) complete routine groundwater monitoring of Nitrate-Nitrogen ($\text{NO}_3\text{-N}$)¹ levels within the MHV irrigation area²;
- b) provide input data and observations for future work and research programmes.

It also informs ongoing research as part of a PhD Research programme being undertaken by the author at the University of Otago.

1.3.Background of the monitoring programme

MHV commenced routine groundwater monitoring of $\text{NO}_3\text{-N}$ within the MHV scheme area in September 2016, with an initial survey of 29 bores. The programme's initial objective was to understand the changes in $\text{NO}_3\text{-N}$ in the groundwater of the HHP, because of ongoing and/or changing land use activities within the area.

As the focus of the monitoring programme has evolved over time, so too has the design of the programme. This evolutionary progression has resulted in survey sizes ranging from 13 to 41 boreholes. In early 2020 the programme was reviewed and extended in consultation with:

Te Arowhenua Rūnanga	Hekeao Hinds Water Enhancement Trust (HHWET)
Hinds Drains Working Party (HDWP)	Fish and Game
Environment Canterbury (ECan)	Aqualinc Research Ltd

The outcome was a collaboration between MHV, HHWET, and BCI to expand the survey to cover the entirety of the HHP such that the average catchment scale survey is now ~160 bores representing an area of over 110,000 ha.

¹ Nitrate-nitrogen ($\text{NO}_3\text{-N}$) is the concentration of nitrogen present in the form of the nitrate ion. Nitrate is a water-soluble molecule made up of nitrogen and oxygen with the chemical formula NO_3^- .

² The MHV irrigation area is constrained within the Rangitata, Coldstream, Hekeao Hinds and Westerfield Plains catchment areas

1.4. Why are we doing it?

The ground and surface water monitoring programme are a tangible expression of MHV's mission statement "To Provide Sustainable Solutions for our community, now and in the future". By monitoring NO₃-N in groundwater and surface waters across the scheme, MHV intends to provide data and complementary information that will enable evidence-based decision making, that leads to continuous improvement of sustainable water, nutrient management, and overarching environmental practices.

1.5. Scope

This report is intended to be a transparent account of MHV's ground and surface water monitoring programme for the period 1st January 2024 to 30th June 2025. It presents the results of sampling selected boreholes as well as surface water sites within the MHV scheme and surrounding areas by MHV staff – see Appendix 1 for statement of qualifications.

MHV is collaborating with other stakeholders who are also monitoring water quality in the HHP, such as:

Environment Canterbury (ECan)	Hekeao Hinds Science Collaboration Group
Mid Canterbury Catchment Collective	Hekeao Hinds Water Enhancement Trust (HHWET)
Lowlands Catchment Group	Barrhill Chertsey Irrigation Limited (BCI)

Whilst the Managed Aquifer Recharge (MAR) programme is recognised in this report, it is not considered the focus of this study.

This report does not seek nor intend to quantitatively reconcile the results with:

- current and/ or historical land use practices or nutrient allocation budgets;
- boreholes and/ or well logs; or
- numerical models.

1.6. National Policy Statement for Freshwater Management 2020

MHV has operated under Plan Change 2 (PC2) of the (Canterbury) Land and Water Regional Plan (LWRP) since 2018.

The plan requires that 'Hill-fed Lower' and 'Spring-fed Plains' surface waterbodies of the Lower Hekeao Hinds Plains have an annual median NO₃-N concentration of 3.8 and 6.9 ppm, respectively, by 2035 [3]. This target is to be determined by the results from the Canterbury Regional Council's monthly surface waterbodies monitoring sites³.

The plan also requires that shallow groundwater NO₃-N concentrations have an annual median concentration less than 6.9 ppm. This target will be determined by the results from up to 16 ECan nominated shallow⁴ (bores screened <30 m below ground level) monitoring bores that are tested on a quarterly basis.

NB depending on operating conditions, not all 16 bores may be sampled at any one time.

In May 2020, the New Zealand Central Government released the *Action for Healthy Waterways* Package, including the National Policy Statement for Freshwater Management 2020 (NPS-FM 2020) which came into force in September 2020. This package includes the strengthening of the bottom lines for NO₃-N and ammonia toxicity, to provide protection from nitrogen toxicity for 95% of freshwater species, up from 80% under the former NPS-FM 2017. This effectively reduces the NO₃-N limit from 6.9 to 2.4 ppm.

³ Refer to 13.7.3, Table 13(g) of the LWRP

⁴ Refer to s13.4.14 and s13.7.3, Table 13(i) of the LWRP

As the implementation of the new policy is yet to be confirmed, this report will refer to both the PC2 and NPS-FM 2020 NO₃-N limits of 6.9 ppm and 2.4 ppm respectively (see for Appendix 2 for details).

1.7. Map Projections

All maps are presented in New Zealand Transverse Mercator 2000 (NZTM2000) projection based on the NZGD2000 datum using the GRS80 reference ellipsoid – see Appendix 3.

1.8. Referencing and citations

For ease of reading, this document uses the Institute for Electrical and Electronics Engineers (IEEE) referencing system, a numeric style, where citations are numbered [1] in the order of appearance. Once a source has been cited, the same number is re-used for all subsequent citations to the same source.

Foot notes will be specified by a superscript numerical annotation such as ¹.

2. Engagement & Collaboration

Throughout the year MHV engaged with several stakeholders within the community as part of its value commitments, namely:

Intergenerational Focus

Responsible Stewards

Community Minded

Co-operative Spirit

Enable Innovation

The following highlights of 2024 - 2025 are presented below.

2.1. Ngāi Tahu Intern Scheme

Jemma Te Whaiti (Ngāti Porou, Ngāi Tāhu) from the University of Canterbury worked at MHV over the 2024/2025 summer as part of MHV's collaboration with Te Rūnanga o Ngāi Tahu. Jemma is a graduate geologist who was involved in water sampling, irrigation testing and MHV's research programme.



2.2. Radiometric Soil Survey

Understanding soil properties and their distribution on farms is critical for effective farm and environmental management. To quantify the potential differences between Manaaki Whenua – Landcare Research soil maps at farm scale, MHV working with HHWET and MCCC engaged Dr Clint Rissman from Land and Water Science to conduct a radiometric soil survey over three areas representing a survey size of 694 ha. The survey was conducted between 10th and 15th March (Figure 9) and targeted:

- 241.9 ha at Ealing assessing the uniformity of the Lismore (Lism_2a.1) and Balmoral soils (Balm_10a.1)
- 221.4 ha at Lagmhor targeting lateral changes in Lismore (Lism_1a.1), Darnley (Darn_1a.1), and Mayfield (Mayf_2a.1) soils; and
- 230.7 ha at Lowcliffe mapping the changes from the lighter Lismore (Lism_2a.1) and Lowcliffe (Lowc_1a.1) soils to the heavier Waimairi (Ymaj_18a.2) and Utuhina (Utuh_8a.1) soils.

At the time of writing, follow-up ground truthing had been delayed until spring 2025 due to persistent rainfall.

By measuring changes in the natural background of radiation from uranium, thorium, potassium and caesium in soils, the survey hopes to quantify potential variability of soils at the farm scale via a comparatively fast, cost-effective, low-impact method which will also feed into MHV's broader research programme.

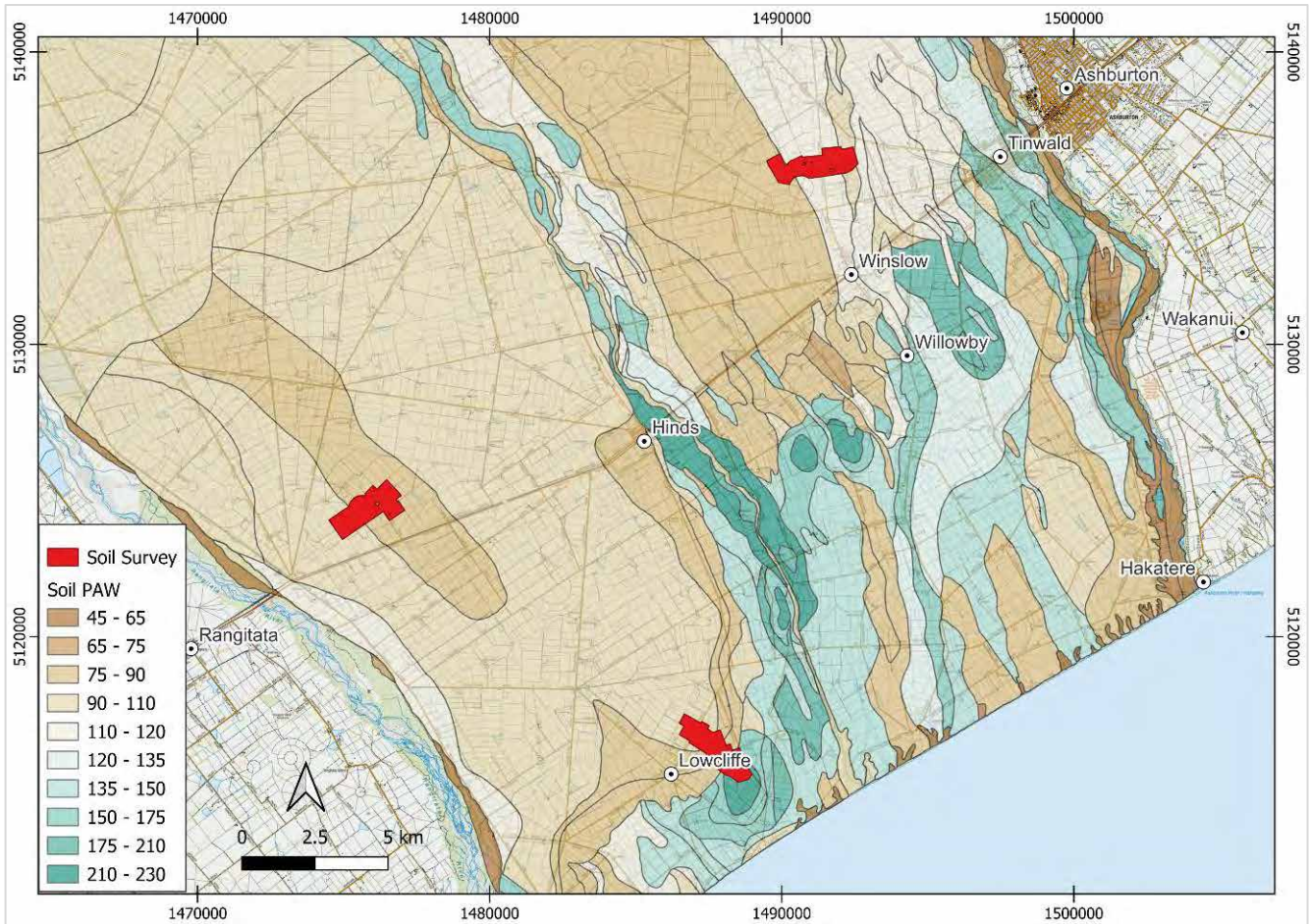


Figure 9 Locations of Radiometric Soil Surveys

2.3. Vadose Zone Monitoring System

In the first half of 2024, the Hekeao Hinds Science Collaboration Group (HHSCG) in collaboration with a steering group chaired by Rhys Roberts (CEO Align Farms), developed a White Paper regarding the applicability of a Vadose Zone Monitoring System (VMS); an *in situ* system that can detect and/ or characterize changes in the zone between the unsaturated phreatic zone and the water table in real time [4]. The VMS consists of a flexible PVC sleeve which hosts several water-content sensors and samplers- such as [5]:

- time domain reflectometry (TDR) soil moister sensor at regular intervals (nominally at 0.3m) along its length;
- a vadose-zone sampling port (VSP) for frequent sampling of the percolating leachates and pore water from the unsaturated sediment.

The VMS is installed into an un-cased inclined bore hole, thus allowing data recordings to be obtained from different depths at a single location in real time (see Figure 10) [6].

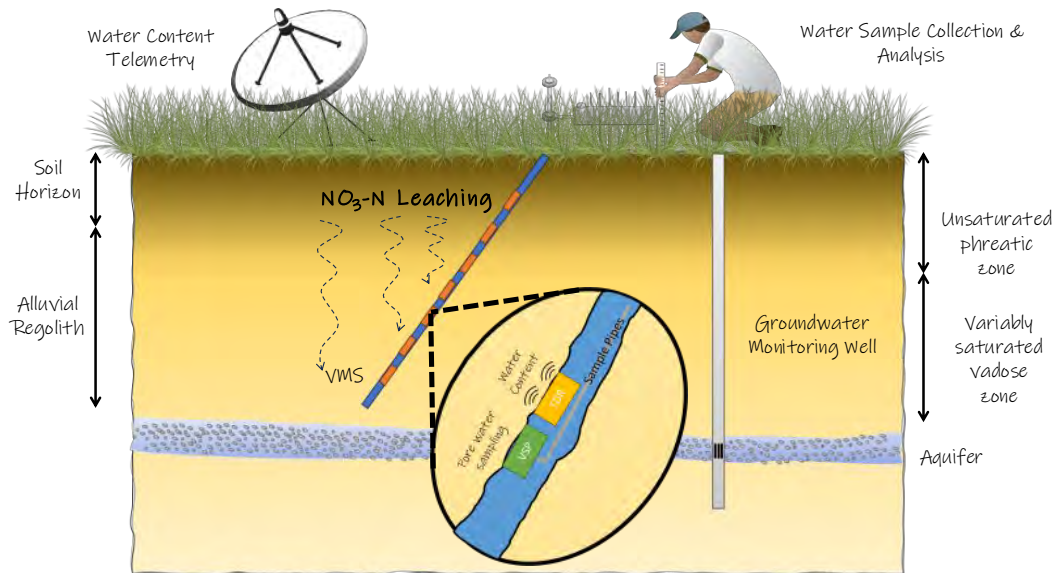


Figure 10 Schematic of a VMS Installation

A subsequent funding application to the Ministry for Primary Industries (MPI) through the Primary Sector Growth Fund, was approved in June 2025.

2.4. University Engagement

Throughout the reporting period, MHV supported a number of research projects.

2.4.1. Sidinei Teixeira Masters Student

Sidinei Teixeira submitted her master's thesis: *"Impact of managed aquifer recharge on nitrate concentration changes in an alluvial aquifer"* in late 2024.

Sidinei's research confirmed that in areas where MAR operates, the flux of recharge water with low nitrate content is sufficient to induce dilution of nitrate within the aquifer.

However, her research did not conclude that irrigating with low nitrate concentration water will result in a decrease nitrate in groundwater, concluding that leaching of nitrate from interaction of water with the land surface (soil) overwhelmed any initial differences in irrigation water nitrate concentration.

2.4.2. Madeline Inglis Masters Student

In early 2025, Madeline Inglis from the University of Canterbury submitted her master's titled: *"Assessing microbial pathogen transport in groundwater from the Hekeao Hinds Managed Aquifer Recharge (MAR) scheme"*. Her findings were consistent with previous literature for similar aquifers and supported previous calculations of *E. coli* transport undertaken for HHWET's MAR projects.

2.4.3. Jade Collins Masters Student

Jade Collins commenced a Master of Applied Science in Environmental Management at the University of Otago, in April 2025. Her research sought to assess potential carbon sequestration of shelterbelts as well as above ground carbon storage based on shelterbelt type.

The results found that shelterbelts were highly effectual in sequestering carbon. Across the HHP, the above ground carbon was 258,190 CO₂, with an annual sequestration rate of 1005 t CO₂/yr.

The results emphasised the importance of small-scale sequestration and showed how farmers could utilise the potential requalification of shelterbelts in future carbon accounting.

2.4.4. University of Canterbury GEOG309 - Research for Resilient Environments & Communities.

MHV, along with HHWET, the Lowlands Catchment Group and MCCC acted as a collective community partner with the University of Canterbury to support students studying GEOG309. This third-year problem-based learning exercise investigates initiatives that develop, support, and enhance resilient environments and communities. Based on a short field trip, occasional lectures and regular project group meetings, the students - Makayla Dyson, Ngaire Ferriss, Max Gerling, Ruby Gill-Clifford and Todd Storey- sought to evaluate if small-scale community-developed wetlands could be an effective tool for improving water quality.

Using the Montgomery Drain Community Wetland as a test case, the students concluded:

- the constructed wetland is successfully removing nitrates from the water;
- the wetland was successful in keeping within a budget and involving the community in a meaningful project; and that,
- community aspirations align and provide direction for the enhancement of the wetlands' value.

3. MHV Research Programme

In Q2 2023, MHV agreed to sponsor a “PhD thesis by publication” project at the University of Otago to be undertaken by Justin Legg (MHV Senior Hydrogeologist); to characterise, quantify and define the key drivers of Nitrate-Nitrogen (NO₃-N) sources, migration, and retention across the HHP with the intention of defining solutions for the co-existence of improving water quality practices and farming communities.

In addition to the aforementioned collaborative workstreams, the results of this work to date are outlined below:

3.1. Publications

In March 2025, Justin published a paper in ‘The Journal of Hydrology’, an internationally recognised and highly respected peer reviewed scientific journal that is currently ranked 8th worldwide for scientific content and rigour. The paper:

“Nitrate-nitrogen (NO₃-N) response domains following a large-scale rainfall event on the Hekeao Hinds Plains of Mid-Canterbury, New Zealand”

examined the changes in NO₃-N across the Hekeao after the 2021 rain event for a period of 12 months. The results indicate that there were seven different types of temporal responses to NO₃-N concentrations that were influenced by soil type, geological faulting, distance from rivers and groundwater levels (Figure 11).

The paper is available at: <https://doi.org/10.1016/j.jhydrol.2025.133123>

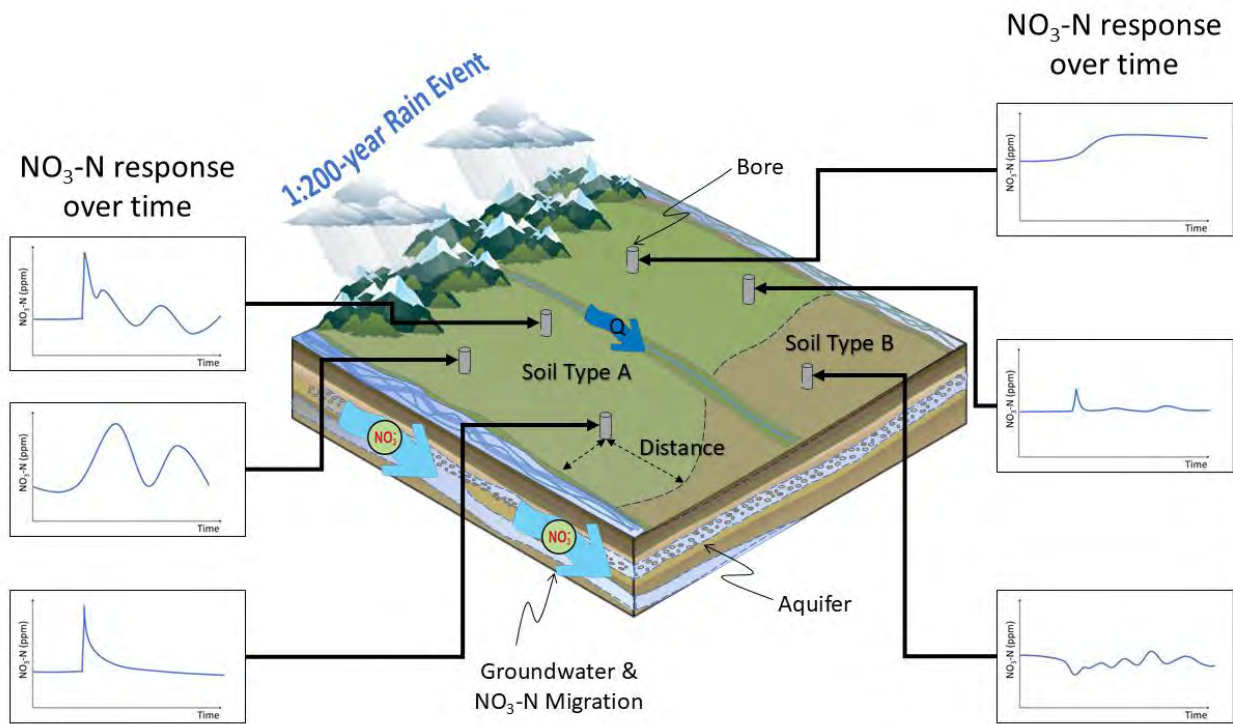


Figure 11 A conceptual model of different the $\text{NO}_3\text{-N}$ response domains across the Hekeao Hinds Plains.

Additionally, MHV submitted a second paper

“Protocol for the use of an Optical Nitrate Nitrogen ($\text{NO}_3\text{-N}$) sensor for measuring ground and surface water $\text{NO}_3\text{-N}$ concentrations”

to Methods X, another internationally recognised and respected peer reviewed journal. Essentially a how-to-guide, the paper outlined MHV’s learnings from using the Hydrometrics GW50 Optical Nitrate Probe over the last 5 years.

It is available at <https://doi.org/10.1016/j.mex.2025.103286>

3.2. Water Chemistry

As part of MHV’s research programme, samples collected between June 2024 and June 2025 (≈1500 samples) were sent to the University of Otago for multi element geochemical analysis, specifically:

- Flow Injection Analysis (N, P, Si)
- Ion Chromatography (F, Cl, NO_3 , SO_4 , PO_4) and
- Inductively Coupled Plasma Spectroscopy (major and minor cations)

The results are due in late 2025 and are expected to increase our understanding of ground and surface water interactions and migration.

3.3. Real time monitoring

During the reporting period three Hydrometric GW50 Optical Nitrate probes were installed into bores at Ealing, Carew and Maronan. Additionally, 2 water level loggers were installed into the Harris and Oakdale Drains respectively to provide real time monitoring data.

4. Background

4.1. Location

The HHP is an area of some 1,465 km² (146,500 ha) located within the larger Ashburton District of Canterbury in the South Island of New Zealand, approximately 85km northeast from Ōtautahi Christchurch. The plains are bounded by the Hakatere Ashburton and Rangitata Rivers and stretches from the Moorhouse Range to the coast.

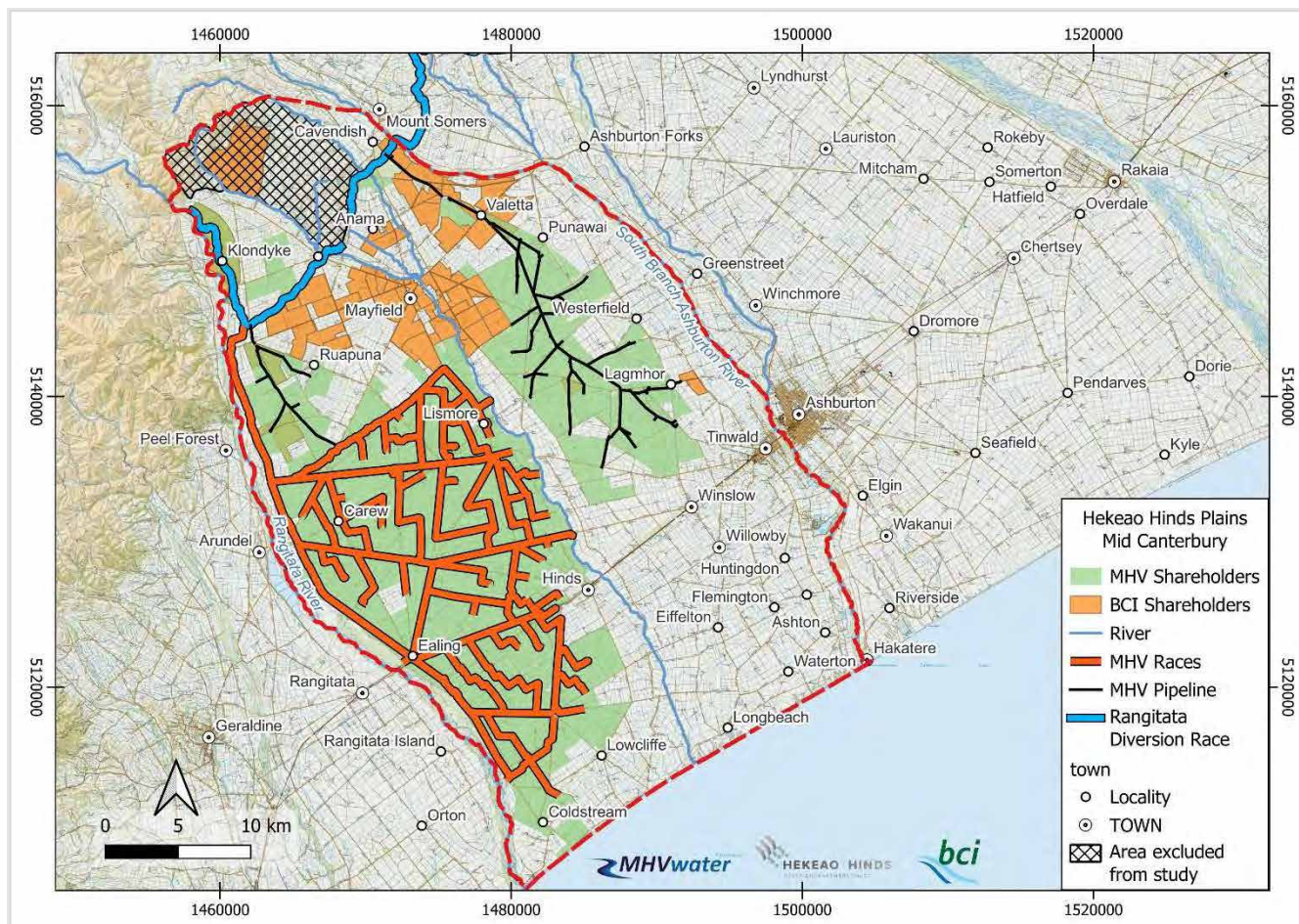


Figure 12 Locality map of the Hekeao Hinds Plains with MHV and BCI irrigation schemes and infrastructure

Following the establishment of the Ashburton District Council in 1876, irrigation was first trialed at the Ashburton Irrigation Farm near Elgin in 1887 [7], [8], although its potential was not fully realised until the construction of the Rangitata Diversion Race (RDR) in the late 1930's. The RDR was primarily built to provide irrigation water to the farmlands of Ashburton County; the 67 km race diverted water from the Rangitata River at Klondyke to the Rakaia River near Methven, servicing approximately 66,000 ha. It resulted in a significant increase in farming production as well as diversification from sheep to arable cropping across the HHP [7], [9], [10], [11].

In 2025 the Ashburton District alone contributed almost 1% of Aotearoa New Zealand's GDP, driven largely by its agriculture industry which makes up 29.4% of the local economy (the national average is 5.8%) [12].

4.1.1. Climate and Rainfall (after [13])

The HHP has a cool temperate climate (Köppen climate classification Cfb), that is prone to drought, with a mean annual rainfall of 774 mm, which ranges from 600 mm at the coast to approximately 980 mm at the foothills near the top of the plains [14], [15] (Figure 13 and Figure 14).

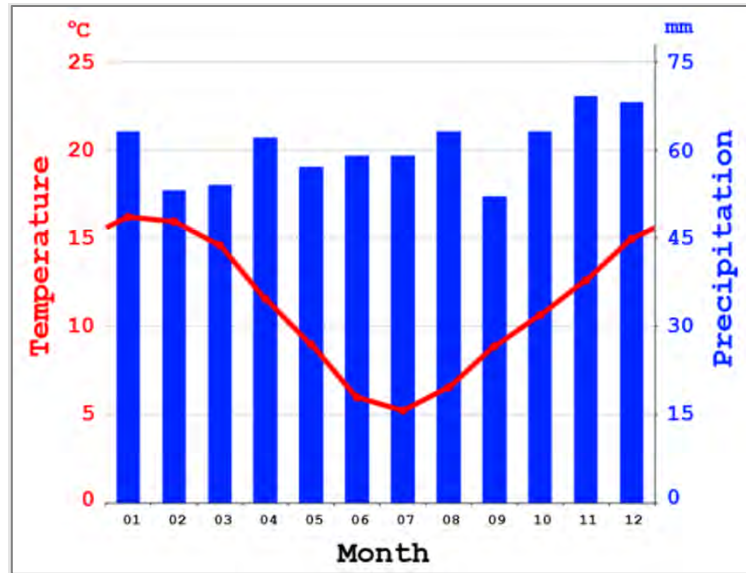


Figure 13 Ashburton Climate⁵

Mean evaporation across the catchment is considered uniform, varying seasonally between 1.6 mm d⁻¹ and 3.4 mm d⁻¹ [16], [15]. Regular snow does not make up a large proportion of the total precipitation in the catchment since only a small area of the catchment lies above 500 m [14].

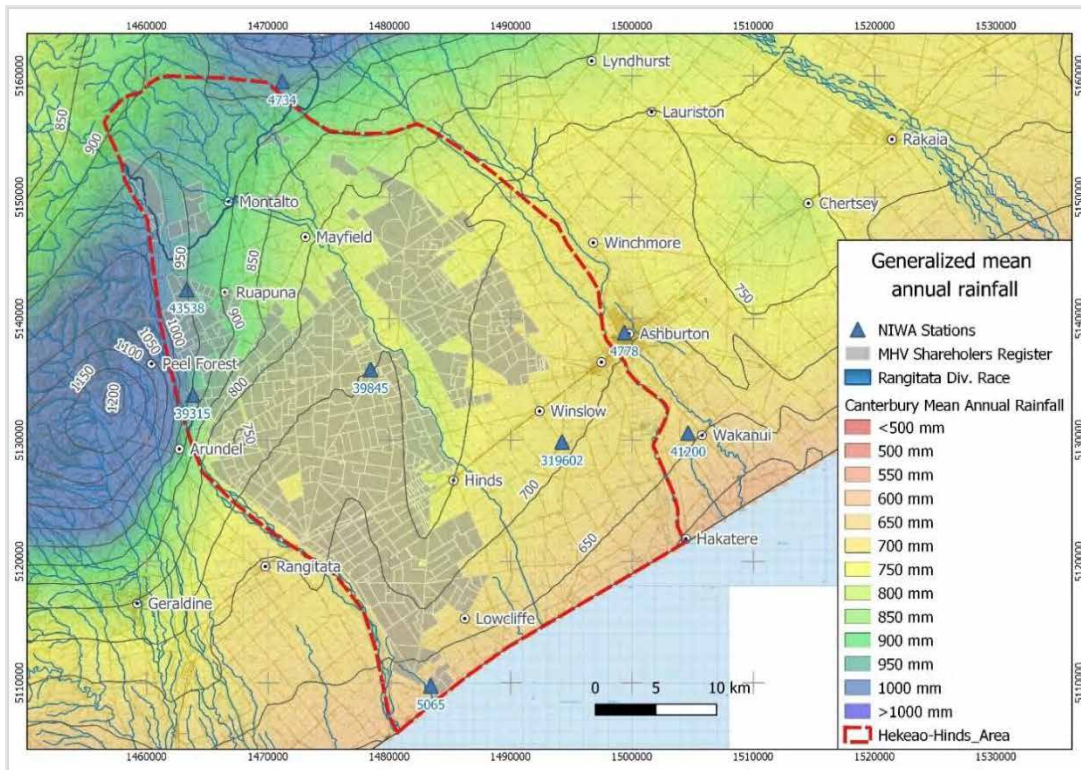


Figure 14 Generalised mean annual rainfall distribution across the Hekeao Hinds Plains

⁵ <https://en.climate-data.org/oceania/new-zealand/canterbury/ashburton-26549/>

4.2. Catchment Characteristics

4.2.1. Soils (after [13])

Approximately 40% of the catchment is covered in a thin (<0.3 m), stony (>50%), free-draining loess pallic soil (Lismore Soils), with a moderate to low water holding capacity or profile available water (PAW) of <90–110 mm [17] (Figure 15). Proximal to Hekeao Hinds and Ashburton Rivers, these pallic soils tend to be deeper (≤ 0.5 m) and more varied; characterised as deep silt loam soils with a higher PAW value (145–165 mm), being derived from swamp deposits [18], [19], [20], [21]. The lower catchment is bisected longitudinally with alternating bands of differing types of argillic orthic gley soils [17].

The heavier *Longbeach* soils are poorly drained, stoneless, deep silt loams (PAW > 130 mm) and have reduced oxidation states; these are interspersed with lighter *Waterton* stony silt loams (PAW \approx 90 mm) [22], [23], [17]. Notably, a stony pallic soil with a low PAW (<75 – 90 mm) bisects the catchment laterally, immediately below the well-drained *Lismore* Soils and above the heavier moderate to poorly drained *Longbeach* and *Waterton* soils.

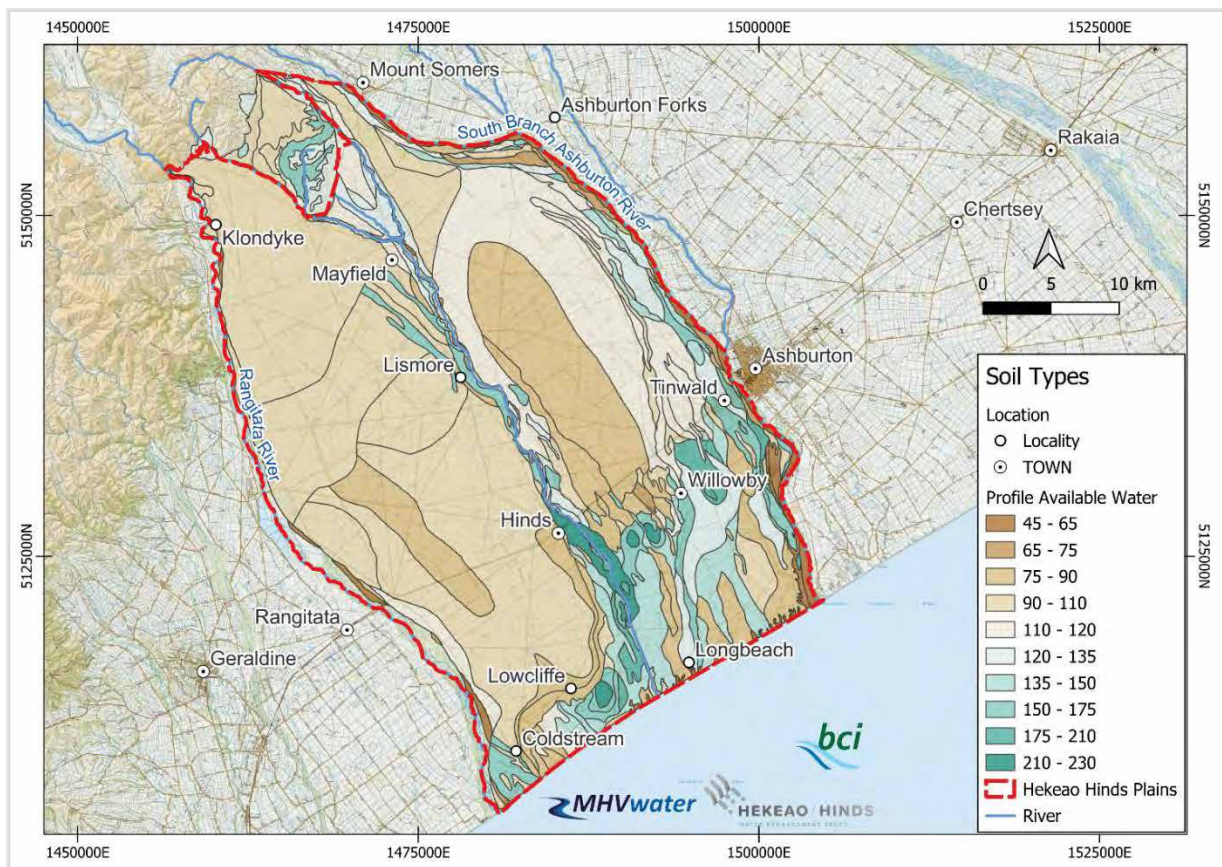


Figure 15 Soils of the Hekeao Hinds Plains

1.1.1. Geology (after [13])

Deep (>600 m) Quaternary aged anisotropic and heterogeneous glacial outwash alluvial gravel fans immediately underlie these soils [19], [24]. The gravels are composed of greywacke gravel clasts, in a matrix of sandy fine gravel and silt with minimal clay and are heterogeneous in structure.

Groundwater flow is principally through high permeability lenses of well-sorted gravels with minimal fine material, referred to as open framework gravels (OFGs) (refer to section 1.2.3), that can have [25]hydraulic conductivities (K) up to two orders of magnitude greater than the surrounding material [26], [27] and subsequently influence preferential flow pathways that infer horizontal anisotropy [25]

These Quaternary sediments are underlain by Tertiary sediments and Cretaceous greywacke basement of the Torlesse Group [18].

1.2. Hydrology

1.2.1. River Flows

River flows in the HHP almost mirror the seasonal rainfall, with river flows in all three rivers having lower flows over periods of lower rainfall (such as between 2019 and 2020) and responding to the much higher rainfall accumulations since mid-2021.

Monthly rainfall and river flows for the Hakatere Ashburton, Hekeao Hinds and Rangitata Rivers are shown in Figure 16 and Table 1.

Table 1 Average daily flow rates (m³/ second) for the rivers in the survey area between 2015 - 2024

	Hakatere Ashburton River at SH1	Hekeao Hinds River at Poplar Rd	Rangitata River at Klondyke
2015	13.3	0.36	86.9
2016	14.5	0.39	90.6
2017	29.4	2.99	86.1
2018	40.8	3.24	91.2
2019	25.0	1.54	105.7
2020	11.6	0.33	82.6
2021	34.3	2.35	106.7
2022	37.4	3.34	109.3
2023	25.3	1.89	92.7
2024	15.33	0.96	93.1

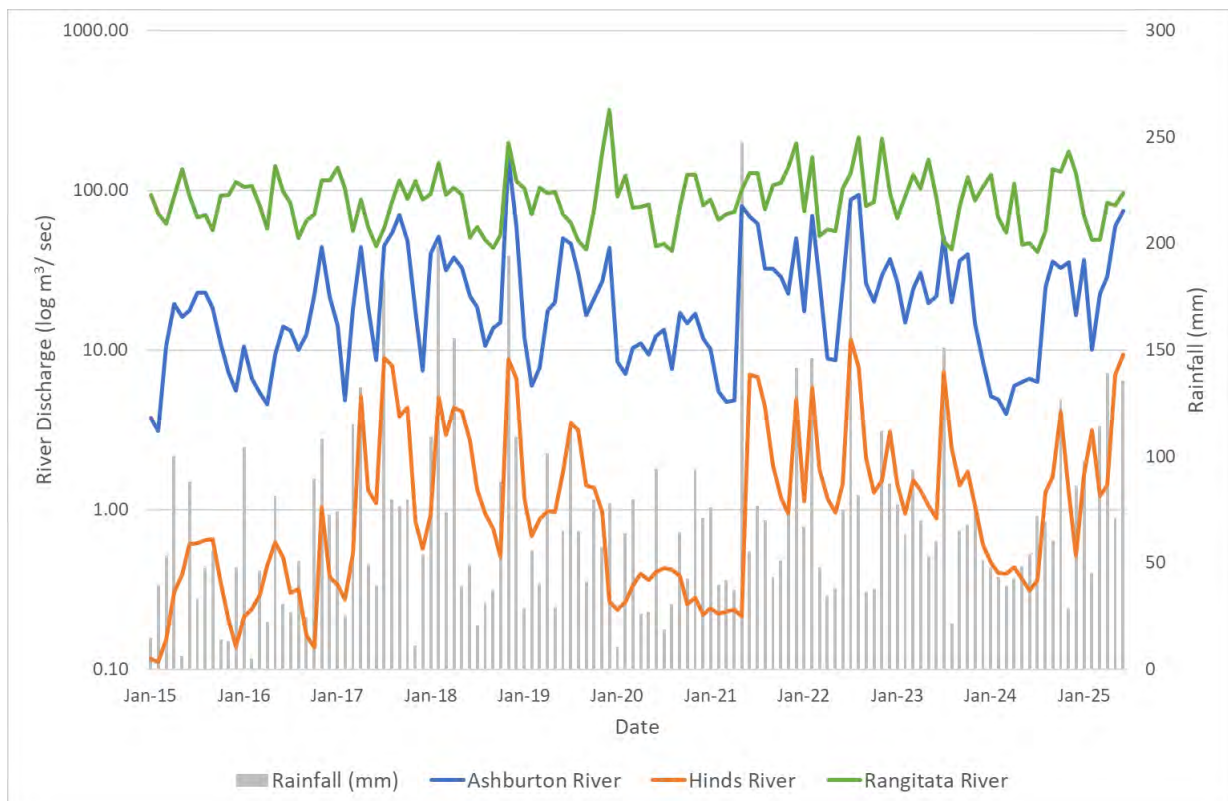


Figure 16 Rainfall and river flow data for the period 2015 to 2025

1.2.2. Catchment Scale

The HHP are serviced by three rivers: the Hakatere, Ashburton, Rangitata, and Hekeao Hinds. The Hakatere Ashburton, and Hekeao Hinds Rivers are considered foothill rivers, whereas the Rangitata is an alpine river. All these rivers have variable flow rates and are confined to terraced alluvial fans.

Both mātauranga māori and local farm knowledge attest that the regional shallow hydraulic gradient runs obliquely across the Hekeao Hinds from Tarahaoa Mt Peel towards the mouth of the Hakatere Ashburton River. A high-level interpretation of the 1 m LiDAR⁶ digital terrain model (DTM) supports this assertion, whereby the observable lineation of the data⁷ were digitised (Figure 18). These lineations are interpreted to be ‘paleo drainage channels’, associated with the migration of HHP rivers over time, and may represent near-surface preferential ephemeral flow paths and/or indicators of open framework gravels (see section 1.2.3).

These near-surface preferential ephemeral flow paths (or paleo channels) are variable in size and direction, with a mean direction of 135° (Figure 17) which is concordant with existing piezometric contours [28].

NB: Note that flow direction is perpendicular to piezometric contours

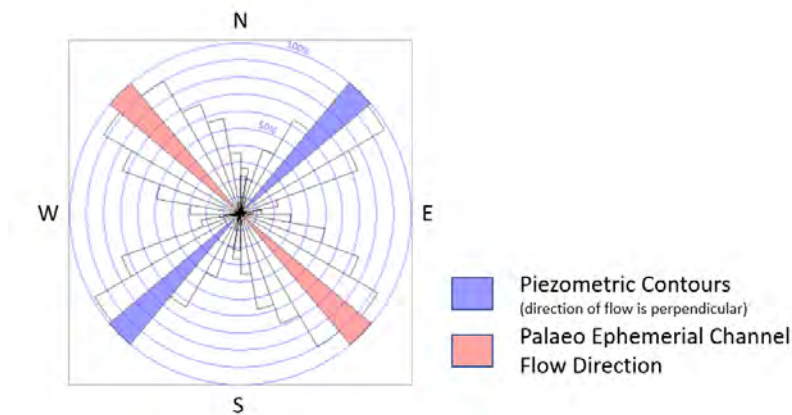


Figure 17 Rose diagram illustrating preferential ephemeral flow direction (red) with 2007 piezometric contours (blue)

These data sets are presented in Figure 18.

⁶Light detection and ranging

⁷ The LIDAR data was not manipulated via differential methods such as a 1st vertical derivative (1VD) as part of this process

- i. They are formed under high flow conditions when finer materials are suspended in the water column and separated from the bedload gravel; with later lower flow regimes depositing finer-grained, matrix-filled strata above them.
- ii. They are formed under variable flow rates (e.g. glacial melt-water streams) resulting in a bi-modal gravel with the finer sediment being winnowed from the gravelly bed at low flow stage to leave an open-framework deposit.
- iii. They are formed via migration of 'minor bedforms' in the river resulting in differential deposition of materials.

Notably, based on work in the Burnham area, it has been suggested that >95% of groundwater flow occurs through OFG's gravels; however, their lengths and interconnectedness at a broader scale is not well understood.

These gravel lenses can [18], [26], [32]:

- be planar-stratified or cross-stratified,
- vary in thickness from centimetres to decimetres,
- be variable in their spacing between lenses,
- can extend from metres to tens of metres, and,
- account for approximately 1% of braided river sedimentary systems in the Canterbury Plains.

The gravels within the lenses are characterised as [31], [33]:

- well sorted (possessing a unimodal grain size distribution) with a mean grain size ≥ 2 mm,
- negligible sand and/ or clay matrix,
- having hydraulic conductivities (K) of up to 5×10^{-1} m/ sec (i.e., up to two orders of magnitude greater than for sandy gravel, and up to four orders of magnitude greater than for sand), and,
- having Mn or Fe staining of the clasts

An example is presented in Figure 19.



Figure 19 Examples of open framework gravel lens

OFGs are important as they contribute significantly to flow within, and transport of solutes through, the Canterbury gravel aquifer systems. Their exact role, in terms of $\text{NO}_3\text{-N}$ transport, is not yet fully understood.

1.3. Localised surface hydrology

The HHP possess several different types of water courses (Figure 20). These include:

- **Highly modified water courses (HMWC)** - often lowland surface water bodies that have been straightened or incorporated into larger, extensive drainage and flood protection works [34], [35]. There are over 150 HMWC's within the catchment representing ≈430 km of waterways. Of these, < 10% (35.3 km) are within the MHV shareholding area.
- **Drains** - extensive drainage and flood protection works, including channelisation and man-made drains [34], it is estimated that there are ≈2,300km of council stock water races in the catchment.
- **Races** – Primary water delivery canals.
- **Springs**- a natural discharge point of subterranean water at the surface of the ground or directly into the bed of a stream.
- **Rivers** – i.e., the Hakatere Ashburton, Hekeao Hinds and Rangitata Rivers.

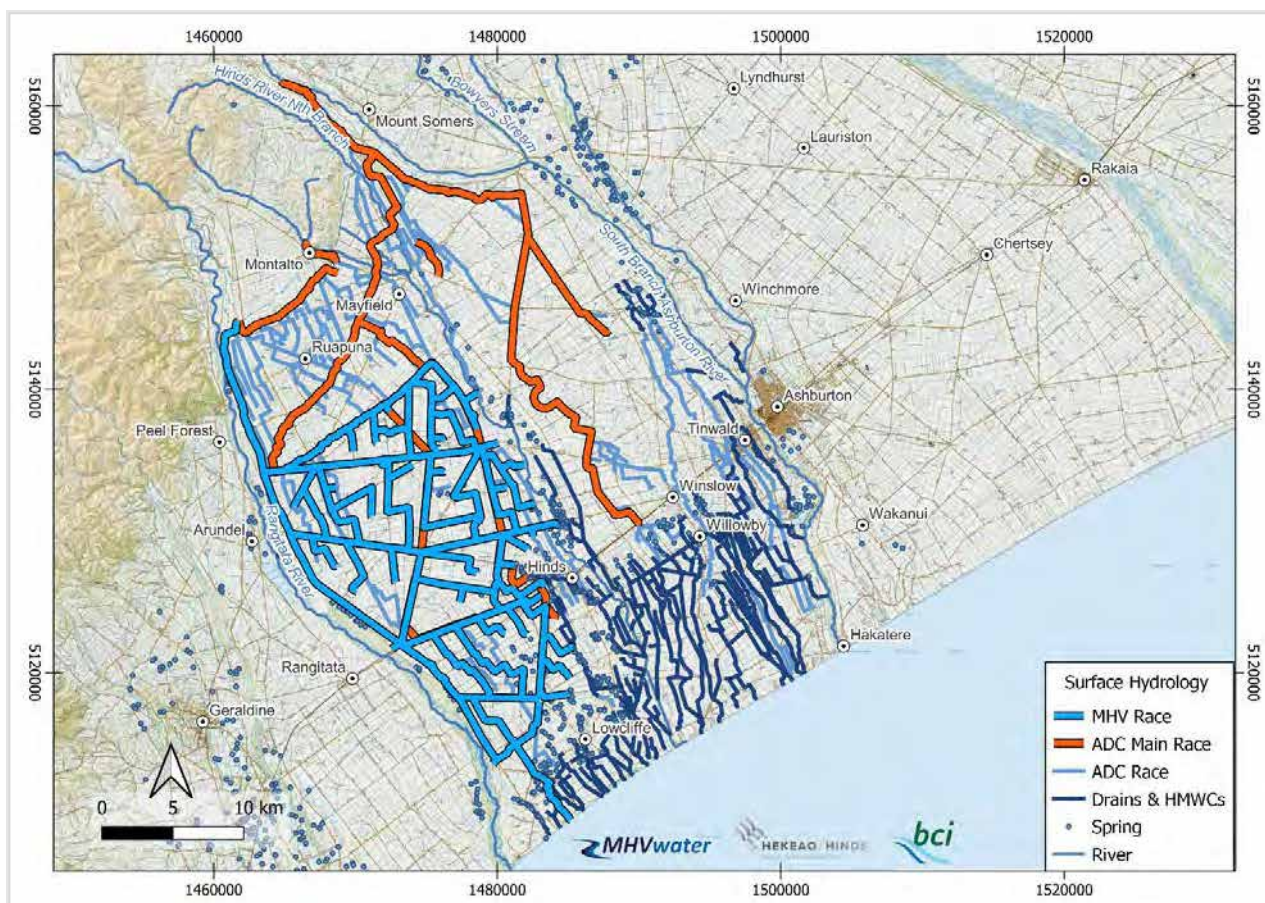


Figure 20 Surface waterways on the Hekeao Hinds Plains

1.4. Nitrate

1.4.1. Sources

Nitrate (reported as Nitrate -Nitrogen or NO₃-N) is a stable, plant-available form of oxygenated nitrogen formed through various chemical and biological processes. In the Hekeao Hinds catchment, NO₃-N is mostly derived from several sources, including [18], [20], [36]:

Point sources such as

- septic tanks (human effluent)⁹,
- dairy and other animal effluent discharges,
- stormwater and contaminated water,
- industrial water such as factory washdown water and gravel processing,
- Offal pits
- Soak holes
- Silage pits
- refuse dumps,
- animal feedlots,

Diffuse sources such as:

- Urbanisation and construction,
- stormwater runoff and urban drainage,
- Decaying plant debris,
- Agricultural fertilisers,
- Land use practices, ploughing, drainage, land clearing and other agricultural practices can cause acceleration of soil organic N mineralisation and oxidation and result in large amounts of leachable NO₃-N,– primarily pulses following recharge events but also potentially as baseflow recharge.

Some of these sources and impacts on groundwater have been quantified in Table 2 [37].

Table 2 Quantification of non-agricultural sources of NO₃-N

Source	Loading	Effluent concentration	Contribution to nearby groundwater
	kg N/ ha/ yr	ppm	ppm
Leaky Sewers	123	2	4 - 10
Leaky Mains	19		5 - 10
Septic tanks	100	25 - 68	10 – 30
Landfill	300 - 5700	2.0 – 2.5	6 - 70
River–aquifer interaction			1.8 to 5 in < 1 week
Highways and roads	3.2 – 8.7	0.4 – 3.3	1 – 3
Construction sites	59	48 – 303	
Urban Environ		0.0 – 2.70	

Nitrate is one component of a broader natural cycle known as the Nitrogen Cycle (Figure 21). In simple terms:

- Nitrogen enters the soil via fertilisers, animal effluent (dung and urine), fixated from the atmosphere or soil organic matter.
- It is then first converted into ammonium (NH₄⁺) via a process known as *mineralisation*.
- The ammonium then undergoes *nitrification* that oxidises it to form nitrite (NO₂⁻) and the more stable nitrate (NO₃⁻).
- The nitrate is then consumed by plants and bacteria in the soil profile; what is remaining is returned to the atmosphere via *denitrification* or is transported as a soluble leachate into the hydrosphere.

⁹ In Canterbury, septic tanks are estimated to contribute a load of 9 kg of nitrogen (a concentration of 55 mg/L) per dwelling per year for those installed pre-2006, and 3 kg (a concentration of 20 mg/L) post-2006 (Aitchison-Earl, 2019).

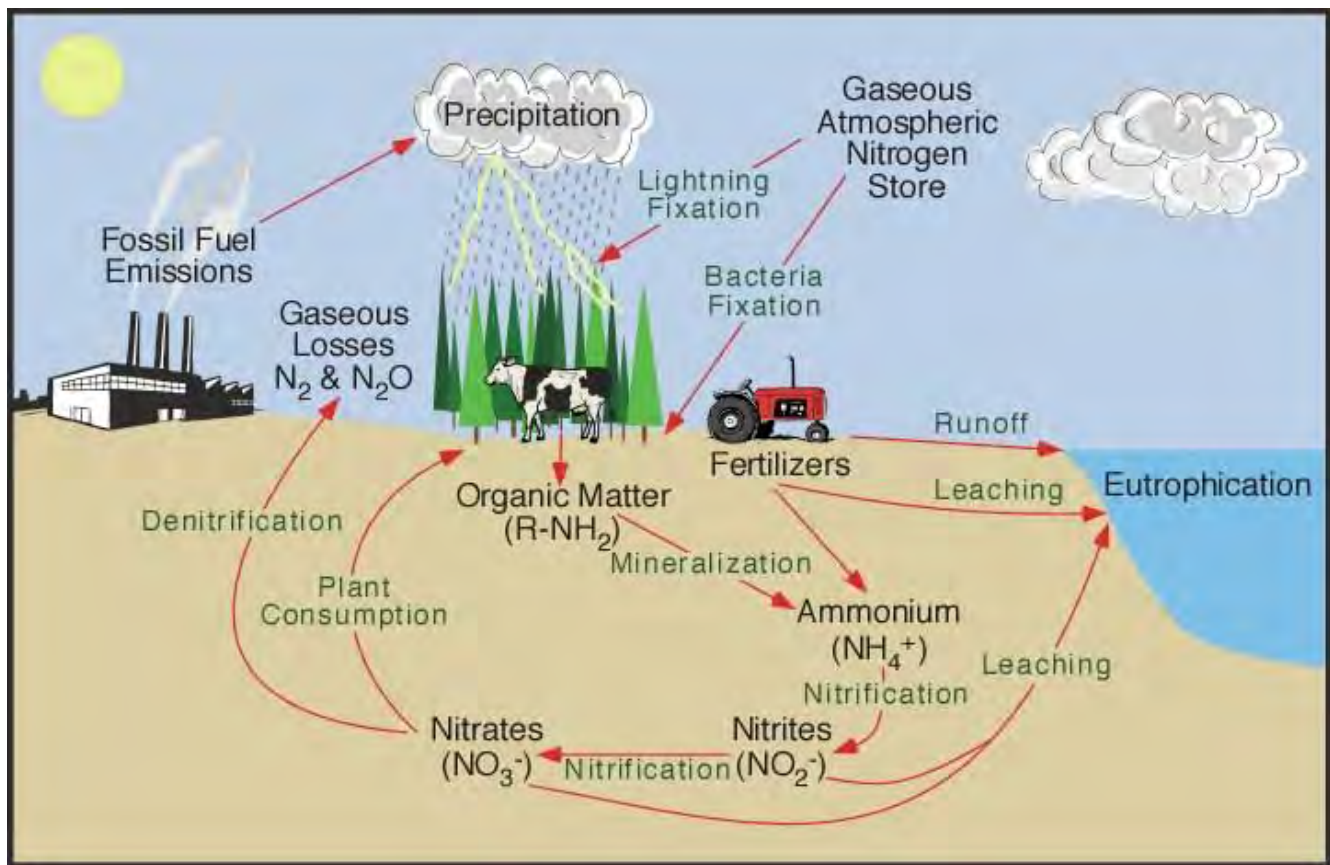


Figure 21 The nitrogen cycle¹⁰

It is important to note that depending on hydrological conditions, it may take years (and potentially decades) for $\text{NO}_3\text{-N}$ to move from the original source and through the groundwater system, so current and historical sources for $\text{NO}_3\text{-N}$ must be considered when trying to account for $\text{NO}_3\text{-N}$ concentrations in groundwater and surface water.

1.4.2. Nitrate Distribution

Work undertaken by ECan has revealed variable nitrate distribution across the HHP in response to different soil types (refer to section 4.2.1). In summary [18], [20]:

- Higher $\text{NO}_3\text{-N}$ concentrations were found in the middle and upper parts of the HHP (Hinds to Ruapuna) with free-draining loess and Lismore-type soils and well-oxygenated groundwater.
- Lower $\text{NO}_3\text{-N}$ concentrations were found in groundwater near the coast. This area was formerly covered by swamp and is characterised by heavy Waterton gley soils and low-permeability Wakanui loam silts.
- The highest $\text{NO}_3\text{-N}$ concentrations, including those in the Tinwald area, were found near the transition zone between high-permeability sediments beneath the upper plain and the lower-permeability sediments near the coast.

Due to the confluence of the soil type(s), the interconnectivity of surface and groundwater, as well as numerous $\text{NO}_3\text{-N}$ sources, it is important to recognise that $\text{NO}_3\text{-N}$ levels in shallow bores in the HHP can fluctuate significantly with rainfall and over short periods of time.

¹⁰ <http://www.physicalgeography.net/fundamentals/9s.html>

2. Groundwater Sampling Program

2.1. Groundwater Monitoring Program Development

The groundwater monitoring programme was initiated in late 2016, with an initial survey of 29 bores. As the focus of the monitoring programme has evolved over time, so too has the design of the programme. In 2024/5, survey sizes ranged between 163 and 164 bores (Figure 22) representing a spatial footprint of ≈110,00 ha- refer to section 2.3.

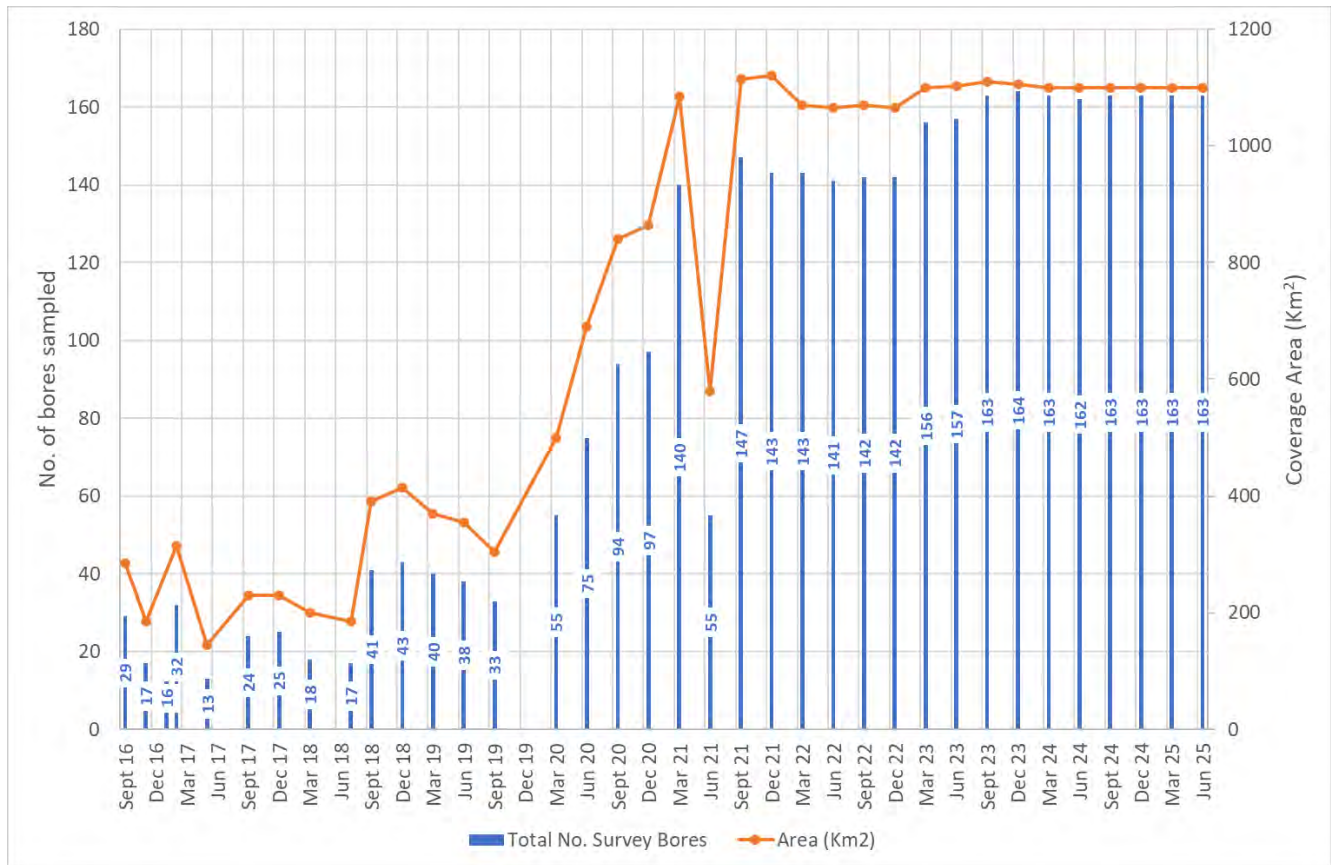


Figure 22 Frequency histogram of survey size changes over time

2.2. Bore Depths and Types

2.2.1. Bore Type

A wide variety of bore types was tested during 2024/5 to avoid sampling bias (i.e., sampling only type X bore, or depth Y bore) as well as for logistical/ practical considerations. Figure 23 presents a breakdown of the types of bores tested based on their designation in the ECan database¹¹.

¹¹ <https://www.ecan.govt.nz/data/well-search/>

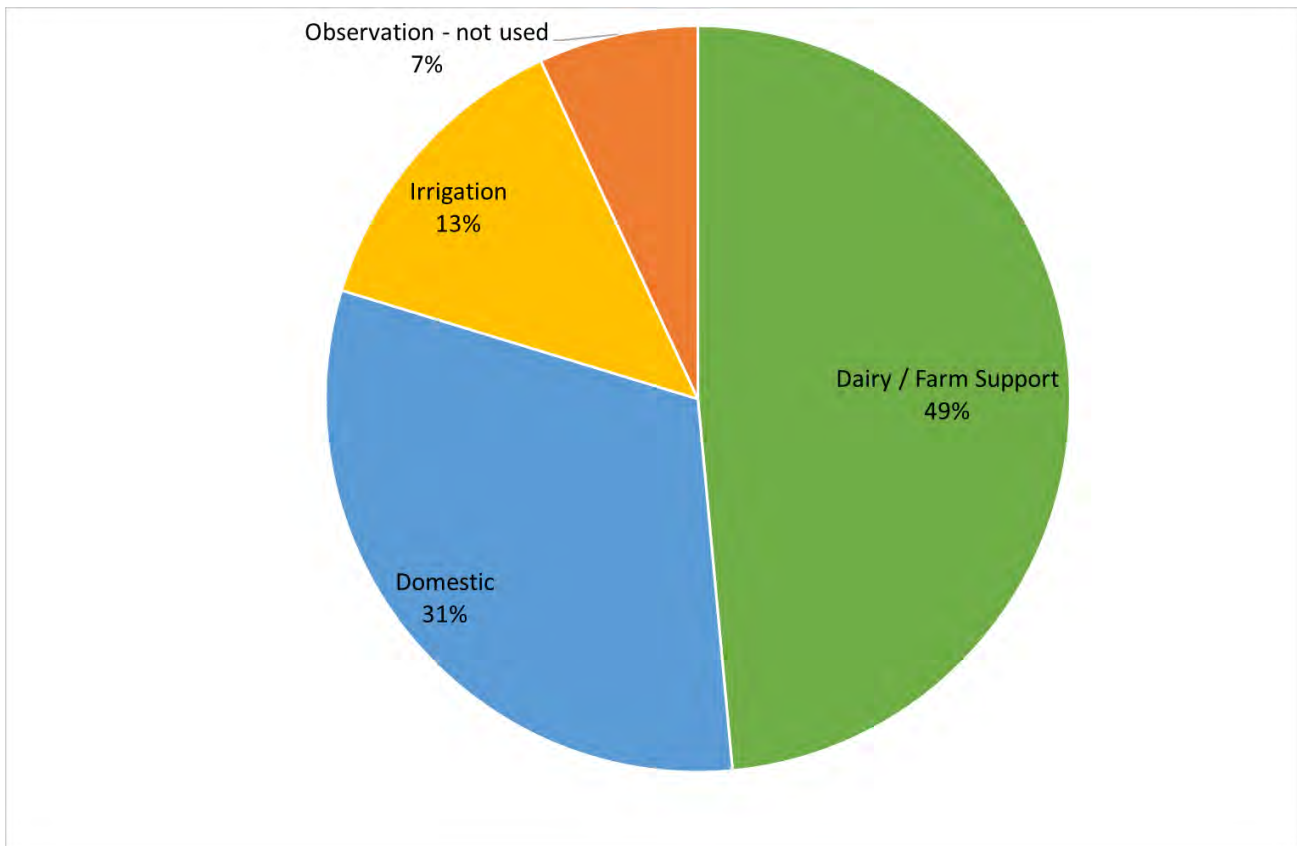


Figure 23 Bore types tested during 2024/5 as per the ECan database.

2.2.2. Bore Depths

Bore depths are categorised in keeping with the LWRP¹² [3], and are split into:

- **Shallow bores:** Groundwater bores screened <30 m below ground level (m bgl)
- **Intermediate bores:** Groundwater bores screened between 30 and 80 m bgl.
- **Deep bores:** Groundwater bores that abstract from depths ≥ 80 m bgl

Figure 24 and Figure 25 presents a frequency histogram of the depths of bores tested and number of samples collected by their respective depth in 2024/5.

¹² Refer to s13.7.3 Water Quality Limits and Targets - Canterbury Land and Water Regional Plan (Environment Canterbury, 2019)

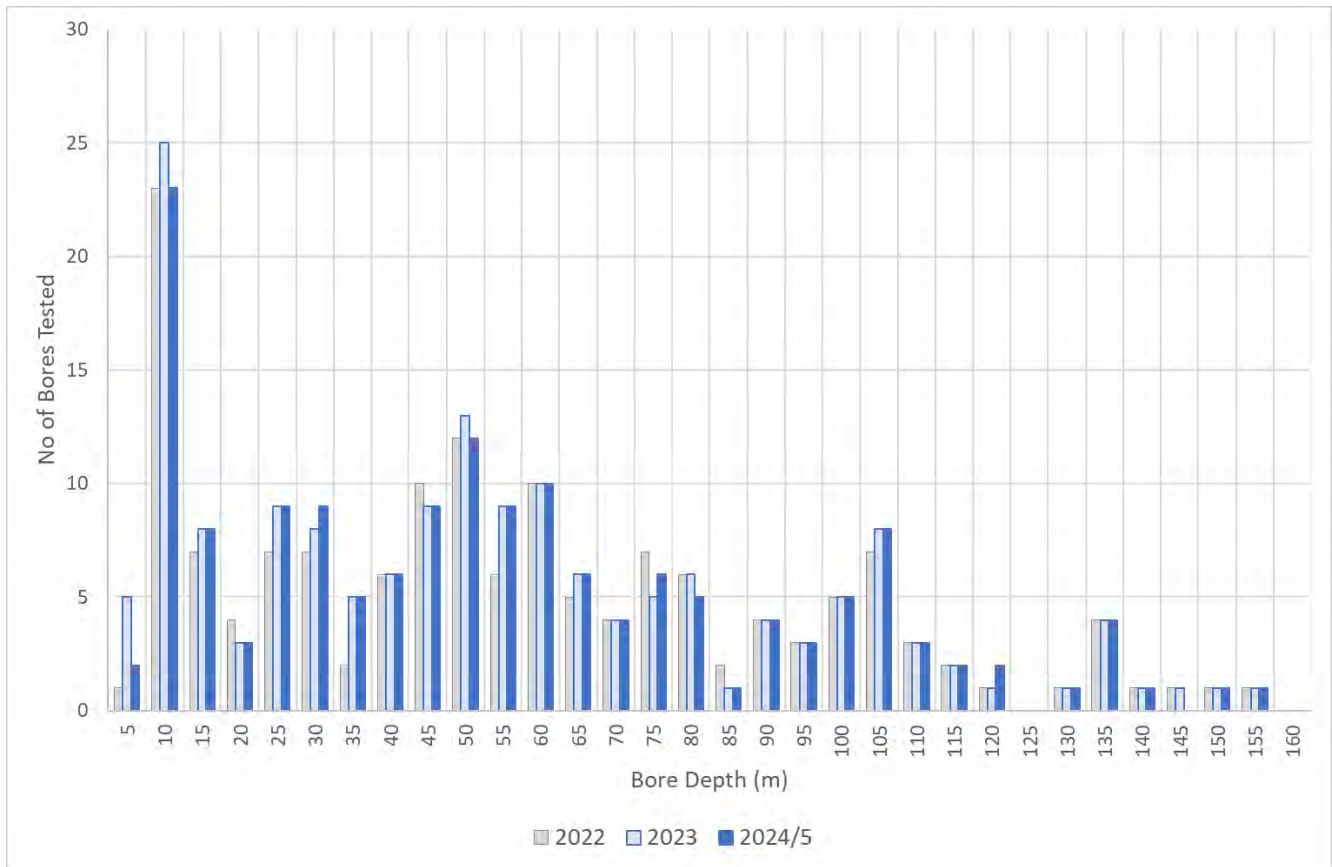


Figure 24 Number of bores tested by bore depth between 2022 and 2024

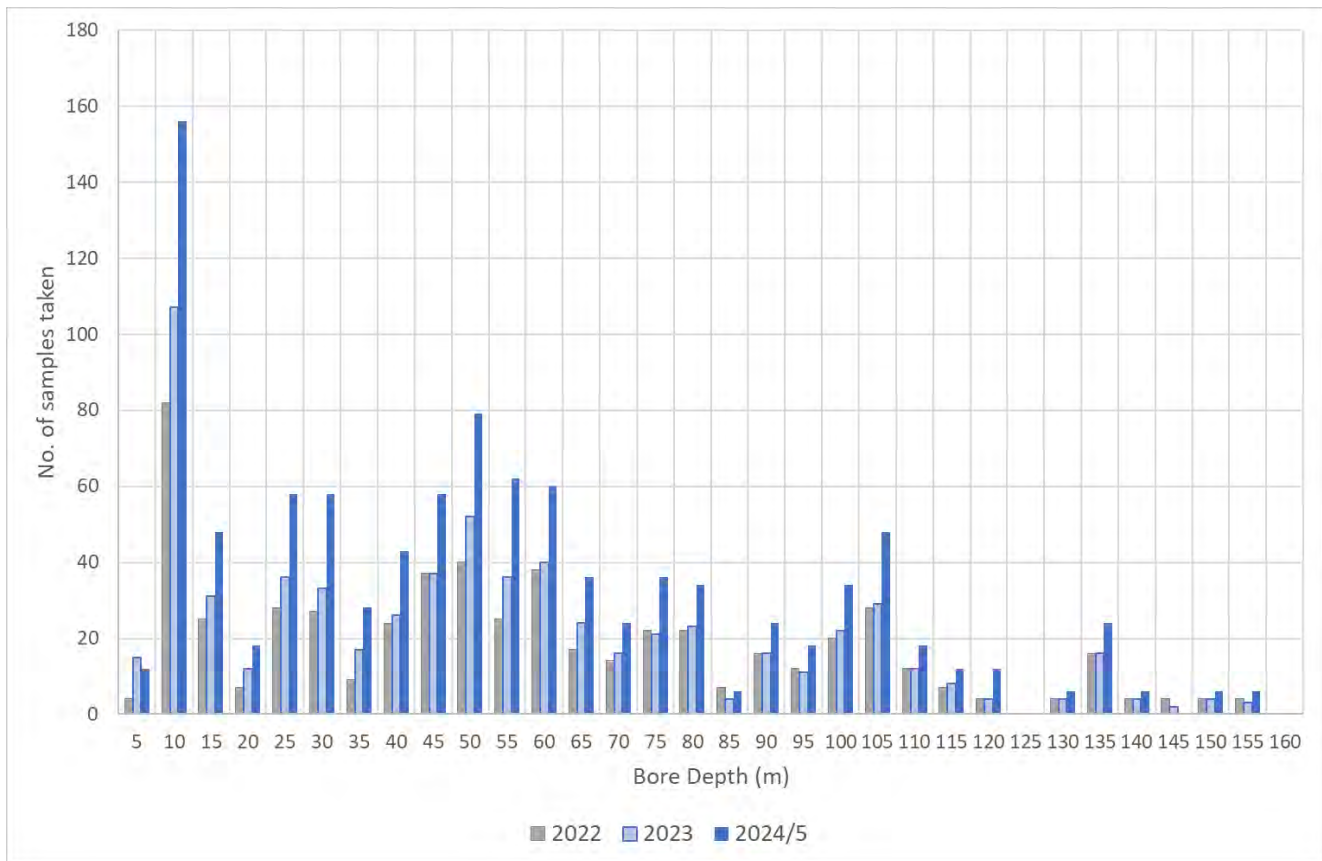


Figure 25 Number of samples collected by bore depth between 2021 and 2024.

A breakdown of bore depth and the number of samples taken during 2023 is presented in Table 3 and Figure 26.

Table 3 Breakdown of bore depth and the number of samples for 2024.

Year	Month	Bores <30 m	Bores 30 - 80m	Bores > 80m
2024	January	2	0	0
	February	47	60	34
	March	7	13	2
	April	2	0	0
	May	45	62	35
	June	7	12	1
	July	2	0	0
	August	13	20	20
	September	42	54	16
	October	2	0	0
	November	35	52	30
	December	12	17	5
2025	January	9	2	1
	February	35	48	27
	March	21	24	9
	April	3	0	0
	May	41	70	31
	June	25	26	9
Total		350	460	220

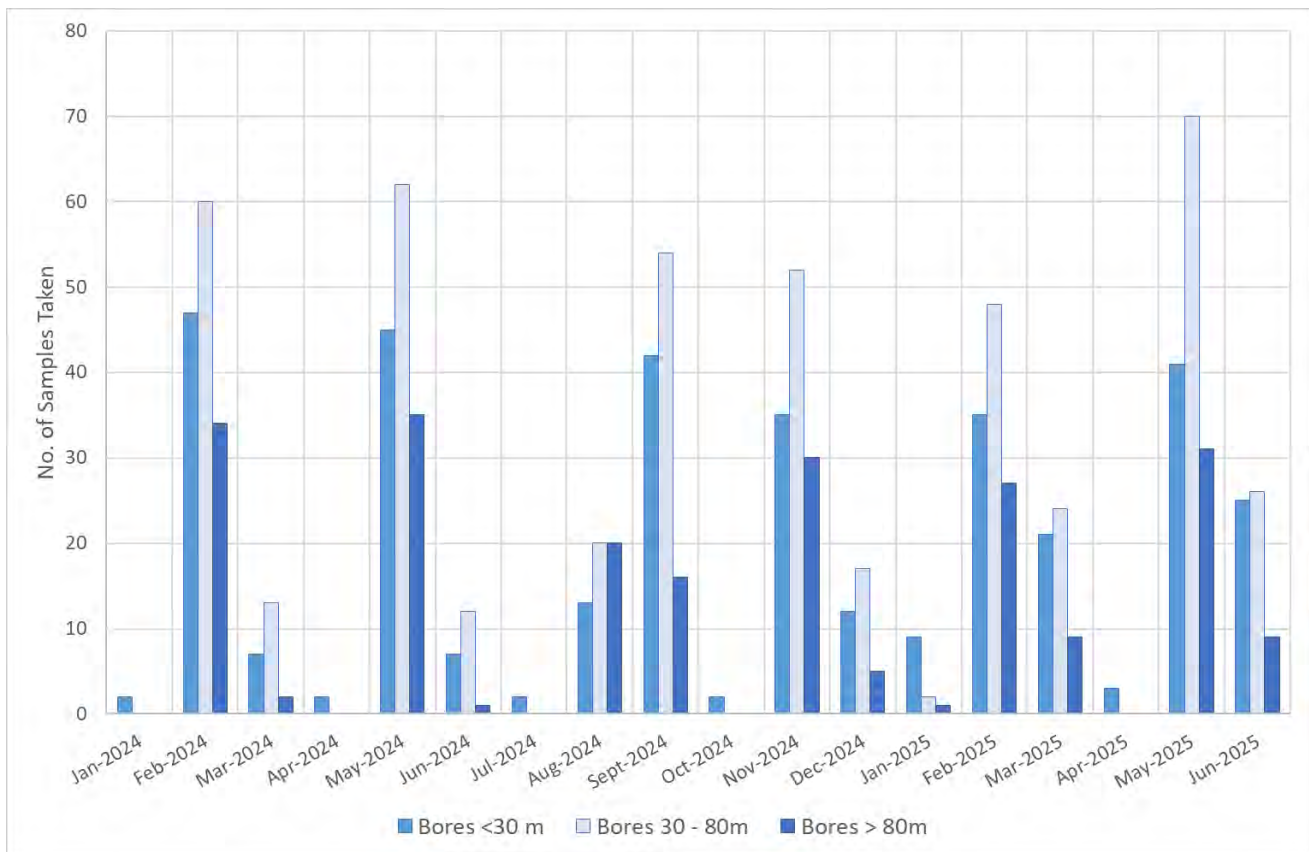


Figure 26 Sample frequency during 2024/5.

2.3. Survey Spatial Coverage

The current groundwater abstraction guidelines for ECan require a 2 km buffer zone from a bore [38], [39] for a WQN 10 assessment to assess interference effects from abstraction. On this basis, as well as the nominal spacing of the bores tested in pre 2020 surveys, a 2 km buffer around each bore was used as a measure of spatial coverage. Figure 27 presents the groundwater survey area for 2024/5. The average distance between bores sampled in 2024/5 was 2.15km (range 5.4m to 6.7km), see Table 4 for descriptive statistics.

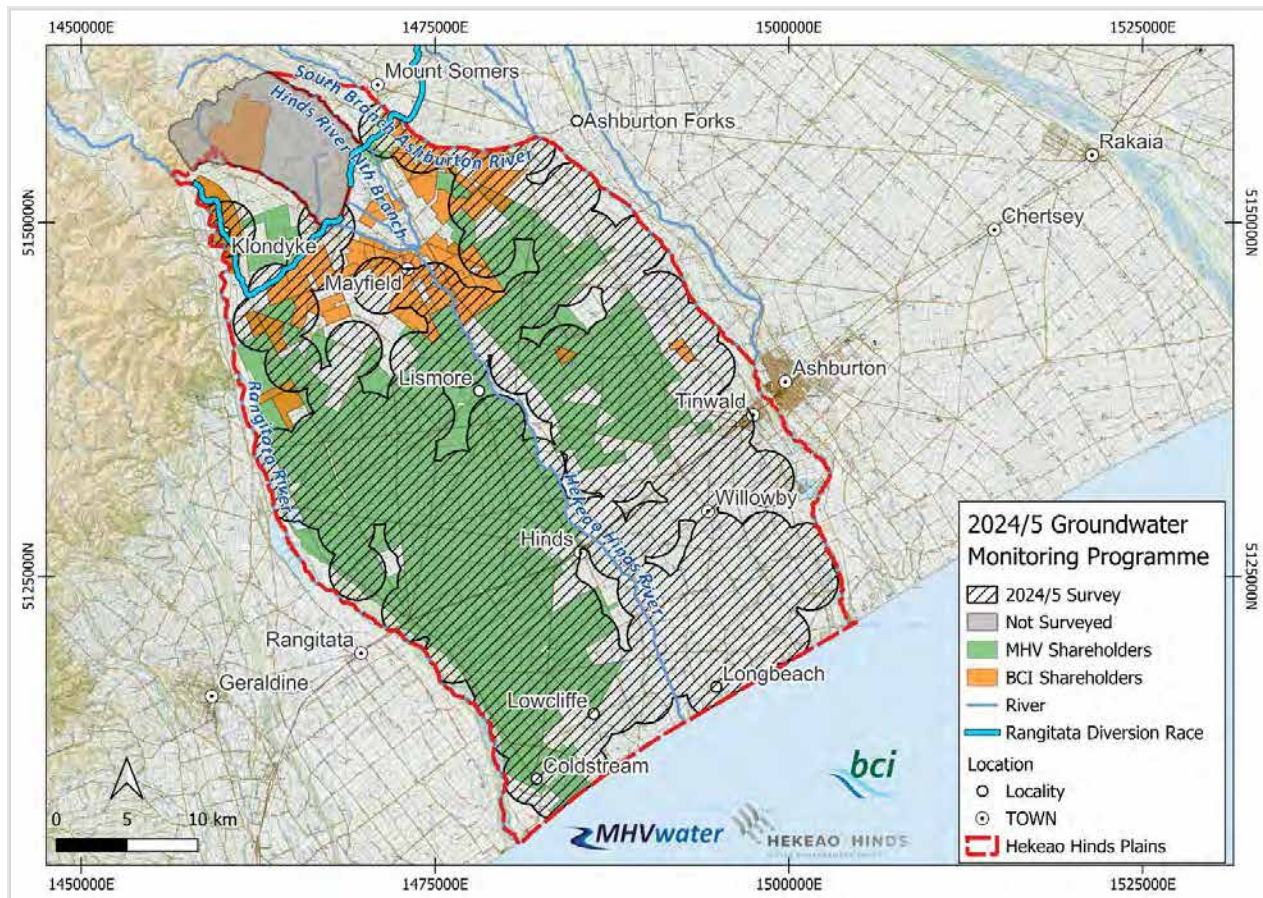


Figure 27 2024/5 Groundwater survey area

Table 4 Descriptive statistics for bore spacing for the 2024/5 Groundwater Monitoring Programme

Statistic	Distance (km)	Statistic	Distance (km)
Minimum	0.005	95th Percentile	4.7
Maximum	6.7	75th Percentile	2.8
Average	2.1	50th Percentile	2.0
Mode	2.6	25th Percentile	1.2
Standard Deviation	1.3	5th Percentile	0.2

2.4. Wellhead Security

Section 5.103 of the Canterbury Land and Water Regional Plan requires that all wellheads are secure, such that their construction prevents contaminants or surface water from entering the top of the bore or gallery or underlying groundwater. Whilst not necessarily relevant to nutrient sampling, non-secure well heads could present an opportunity for localised, point source contamination to occur. Therefore, as part of the monitoring programme, visual inspections of well head security were completed based on the following criteria (Figure 28):

- Collared:** Does the bore have a portion of the gallery pipe extending above the surface that is >200m in height and is in reasonable condition?
- Capped:** Does the bore have a robust, permanent, and weatherproof cap on the collar?
- Pad:** Is the collar of the bore encased in a single concrete pad of at least 0.3 m radius and 0.1 m thickness which is contoured to slope away from the bore or pipe?
- Proximity:** Is the bore <20 m from a potential pollution source? e.g., a dairy track to the milking shed.
- Secure:** Is the bore in a secure location – is the bore confined to a shed or a small-fenced area?

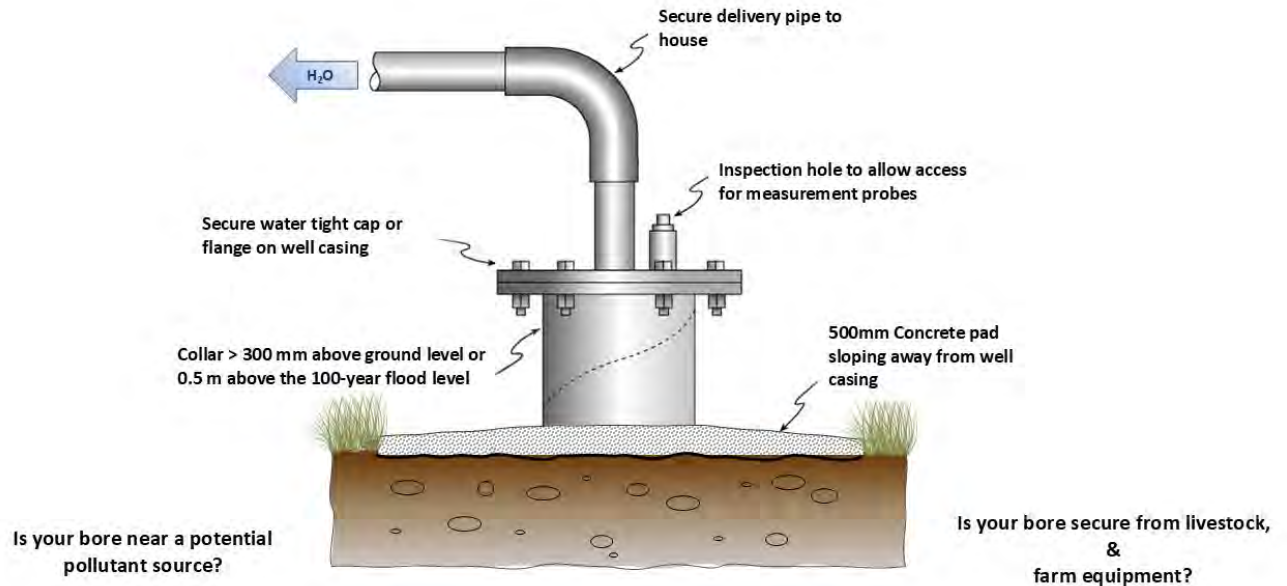


Figure 28 Schematic of wellhead security

NB: It should be noted that this inspection did not consider “Meaning of drinking water supplier” as per section 8 of the Water Services Act 2021 or section 4 of the Local Government (Water Services) Act 2024.

The results of an audit in December 2024 are presented in Table 5.

Table 5 Summary of well head security inspections of 165 bores December 2024/5

Aspect	Number	Percentage
A collar >250mm	113	68%
A concrete pad	86	52%
A secure steel cap	77	47%
Protection from damage	98	59%
Protection from pollution	102	62%

3. Surface Water Sampling Program

3.1. Surface-water Monitoring Program Development

During 2024/5, MHV monitored 98 locations averaging 55 samples per month - the majority of which were collected at public road culverts or bridges (Figure 29 & Table 6). Following higher than usual rainfall in May 2025, this was increased to 100 samples per month.

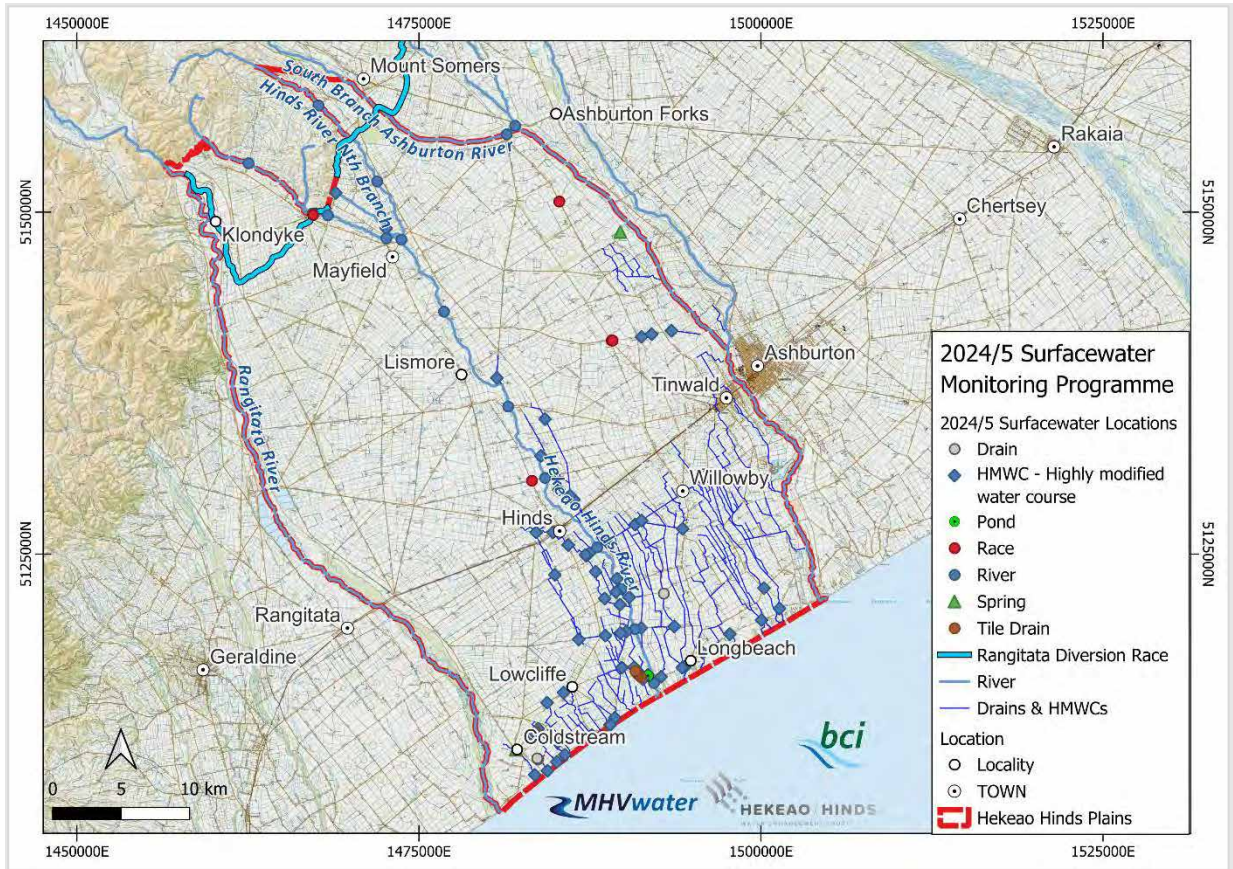


Figure 29 Location of 2024/5 surface water sampling sites

Table 6 Breakdown of 2024/5 surface water sampling sites

Location Type	No. of Sites	No of Samples collected
HMWC - Highly modified water course	59	835
Race	6	55
River	15	216
Spring	2	26
Tile Drains	8	24
Pond	3	30
Drain	5	20
Total	98	1206

Figure 30 presents the evolution of the surface water monitoring program since 2016; Table 7 presents a breakdown of samples collected during 2024/5.

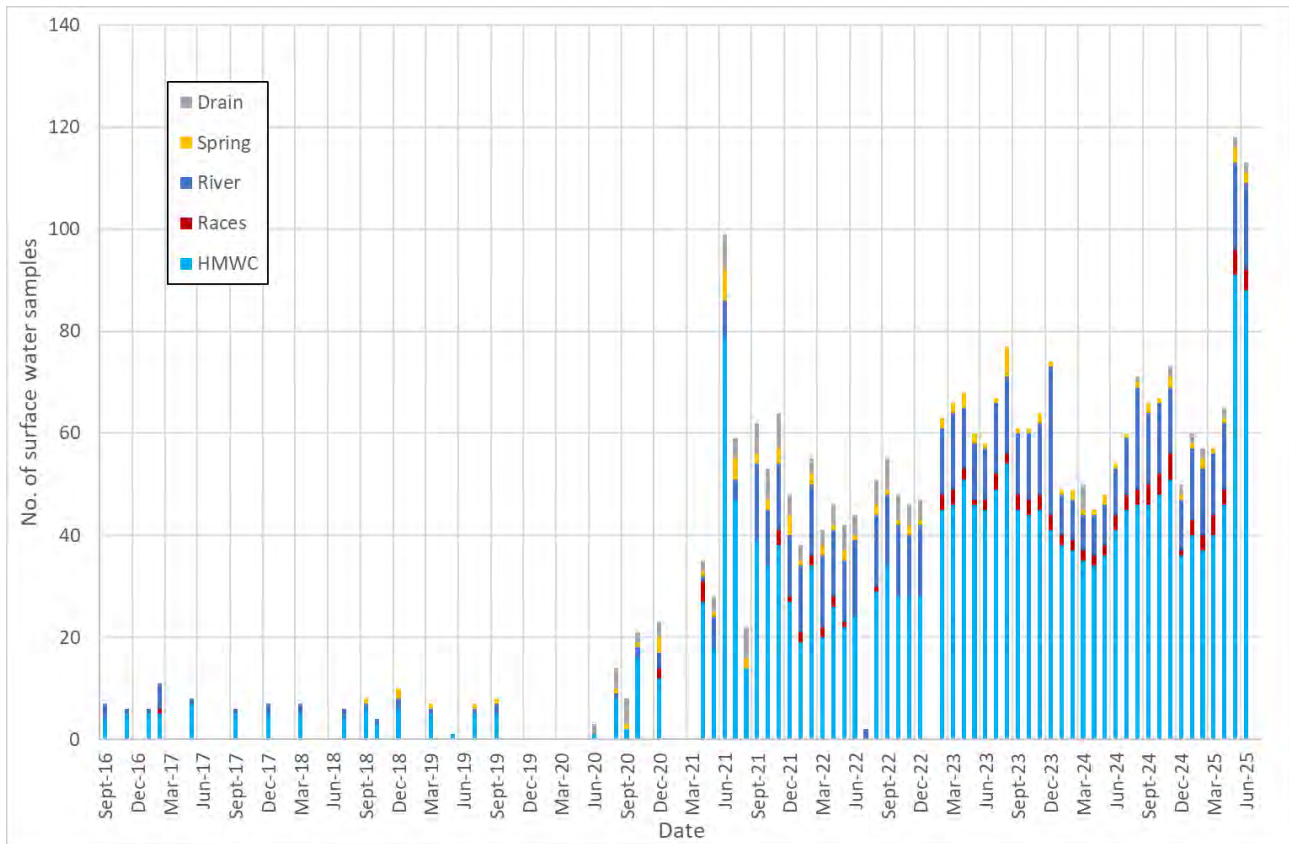


Figure 30 Changes in surface water survey design 09/2016 – 06/2025

Table 7 Summary of 2024/5 surface water sampling program

	Drain	HMWC	Pond	Race	River	Spring	Tile Drain	Total
Jan 2024		38		2	8	1		49
Feb 2024		37		2	8	2		49
Mar 2024	5	35		2	7	1		50
Apr 2024		34	1	2	8	1		46
May 2024		36		2	8	2		48
Jun 2024		41		3	9	1		54
Jul 2024		45		3	11	1		60
Aug 2024	1	46		3	20	1	8	79
Sept 2024		46		4	14	2		66
Oct 2024		48	3	4	14	1		70
Nov 2024	2	51	6	5	13	2	2	81
Dec 2024	2	36	1	1	10	1	2	53
Total 2024	10	493	11	33	130	16	12	705
Jan 2025	2	40	3	3	14	1	2	65
Feb 2025	2	37	4	3	13	2	2	63
Mar 2025		40	3	4	12	1	2	62
Apr 2025	2	46	3	3	13	1	2	70
May 2025	2	91	3	5	17	3	2	123
Jun 2025	2	88	3	4	17	2	2	118
Total 2025	8	254	16	18	69	8	10	383

4. QAQC

Samples were obtained using Standard Operating Procedures (SOP's) that are based on, and, in keeping with the National Environmental Monitoring Standards (NEMS) for Water Quality – Parts 1 & 2. A summary is presented in Appendix 4.

4.1. Water Quality and NO₃-N Measurements

Water quality data was obtained via a YSI Plus ProPlus portable water quality meter to measure:

- Dissolved Oxygen (% and mg/l),
- pH,
- Conductivity,
- Specific Conductance (SPC),
- Oxidation Reduction Potential (ORP),
- Turbidity (Nephelometric Turbidity Units – NTU), and;
- Water temperature (degrees Celsius).

NO₃-N concentrations for all samples collected in 2024 were measured in house via a HydroMetrics Nitrate GW50 Groundwater Optical NO₃-N Sensor. These in-house samples were analysed a minimum of 5 times with at least two sub-samples (i.e., 2 x 10ml samples from the site sample). An arithmetic mean was then calculated from the readings and used for reporting purposes.

4.2. Water Quality QAQC

Approximately 10% of the samples were analysed at Hill Laboratories (Middleton) throughout the year for Nitrite-N (NO₂-N) and Nitrate-N (NO₃-N) via Automated Azo dye colourimetry, with a flow injection analyser [40] to confirm the validity of the HydroMetrics Nitrate GW50 Groundwater Optical Nitrate Sensor and quantify and characterise the difference in reported results from both analytical methods. It also enabled a simple cross-check of the results. The approximate locations and depths of the 2024 QAQC samples are shown in Figure 31.

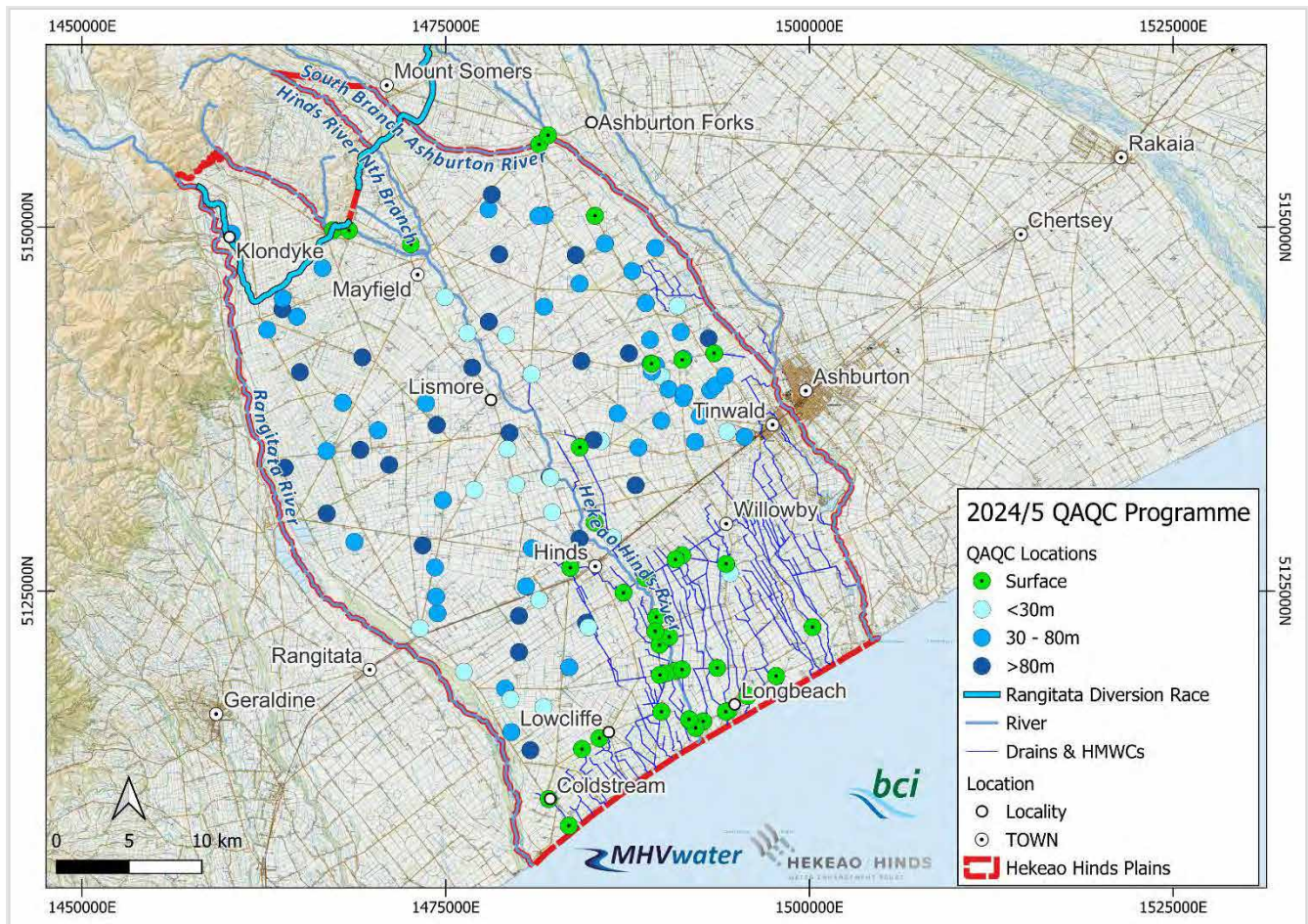


Figure 31 Location of and depth of QAQC samples sent to Hill Laboratories

As reported in 2022, routine calibration and maintenance of the GW50 affected the acceptable bias between the laboratory and instrument results from +7% to -8%. Whilst this bias is within the acceptable precision tolerance of $\pm 12\%$ as noted by Hill Laboratories, it did create a step change in the results. Subsequently, the data is now normalised¹³ with respect to the Hill Laboratory data via linear regression.

The following QAQC charts are presented for the reporting period:

Period	No. of Samples	Raw R ²	Adjust R ²	Adjusted R ²
01/2024 – 06/2024	171	0.9907	y = 1.065x - 0.42	0.9908
07/2024 – 03/2025	249	0.9888	y = 0.995x - 0.32	0.9889
03/2025 – 06/2025	93	0.9899	y = 0.985x	0.9899
Total	513			

These are presented in Figure 32 to Figure 34.

¹³ Normalisation means adjusting values measured on different scales to a notionally common scale. In this case the raw data is shifted via a linear regression equation so that the normalized values are directly comparable to the corresponding Hill Laboratory values, thus eliminating the effects of gross influences – such as calibration.

Figure 32 Regression analysis and normalisation factor for samples collected between January 2024 and June 2024 (n=171)

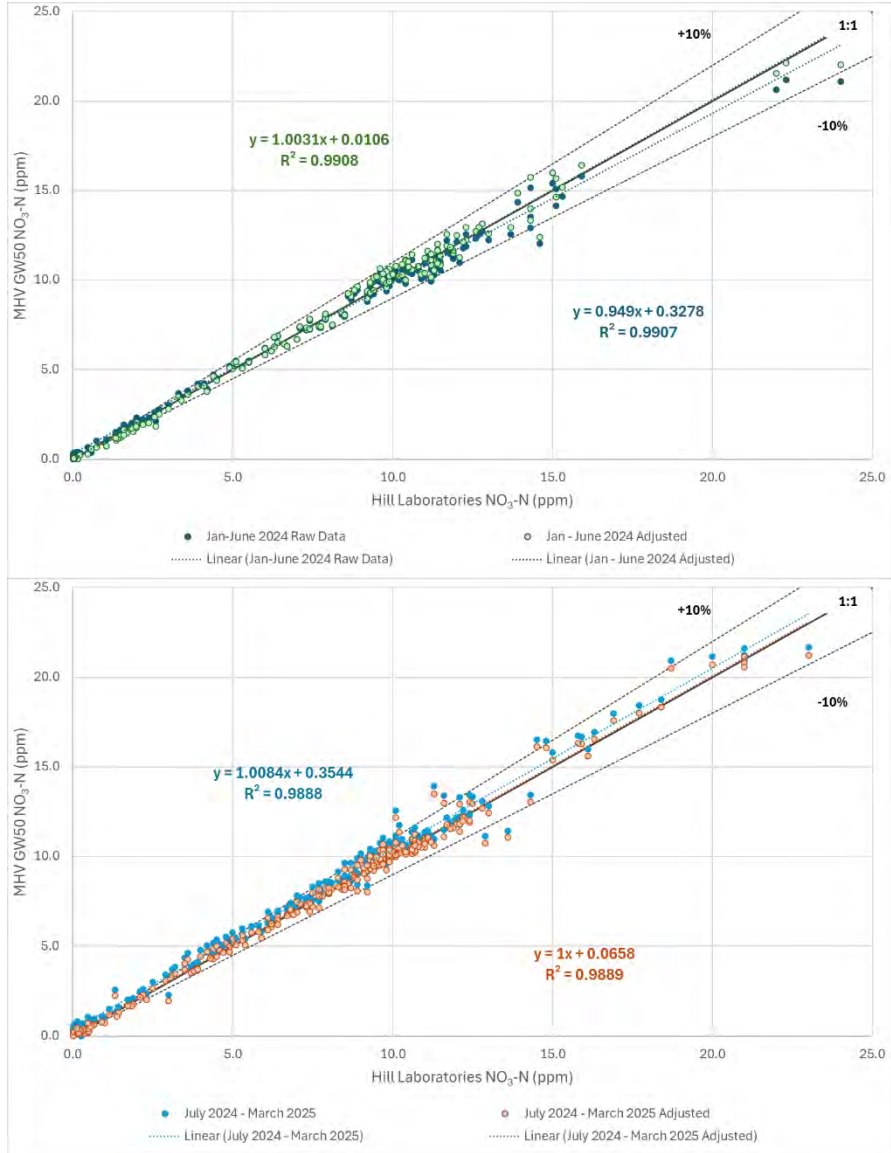


Figure 33 Regression analysis and normalisation factor for samples collected between July 2024 and March 2025 (n=249)

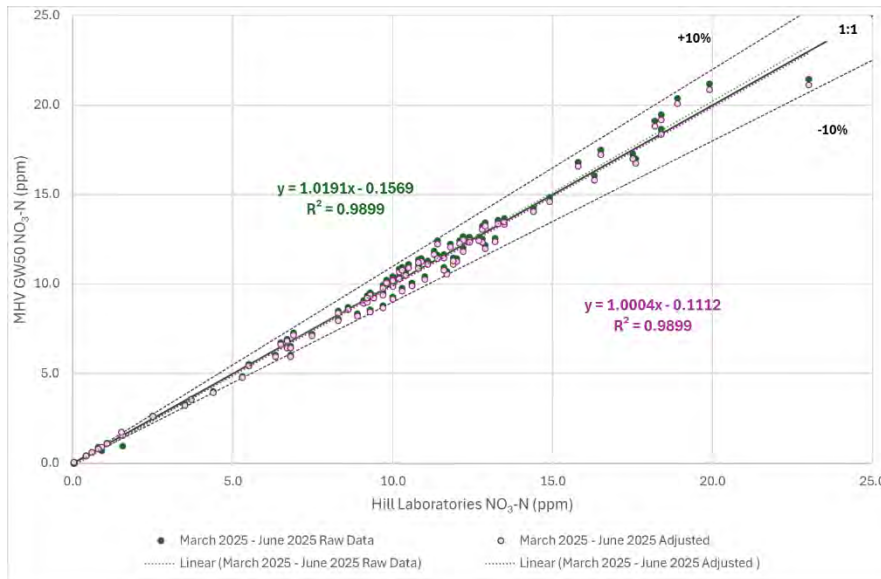


Figure 34 Regression analysis and normalisation factor for samples collected between March and June 2025 (n=93)

5. Groundwater Monitoring Results

5.1. Annualised groundwater NO₃-N results

A summary of the descriptive statistics for the 2024/5 results is presented in Table 8 and as a frequency histogram in Figure 35.

The median of the NO₃-N results for the reporting period is presented in Figure 36 to Figure 37.

Table 8 Descriptive statistics for the 2024/5 NO₃-N results

Bore Depth	Count	Min	Max	Median	Average	95th Percentile	Std. Dev	CV ¹⁴
<30 m	350	0.02	22.04	8.41	9.62	14.86	4.88	0.58
30-80 m	460	0.04	22.55	9.29	9.92	15.82	4.14	0.45
>80 m	220	1.36	13.72	6.69	6.64	11.59	2.70	0.40
All Bores	1030	0.02	22.55	8.44	9.08	14.87	4.27	0.51

¹⁴ The coefficient of variation (CV) is the ratio of the standard deviation to the mean. The higher the coefficient of variation, the greater the level of dispersion around the mean.

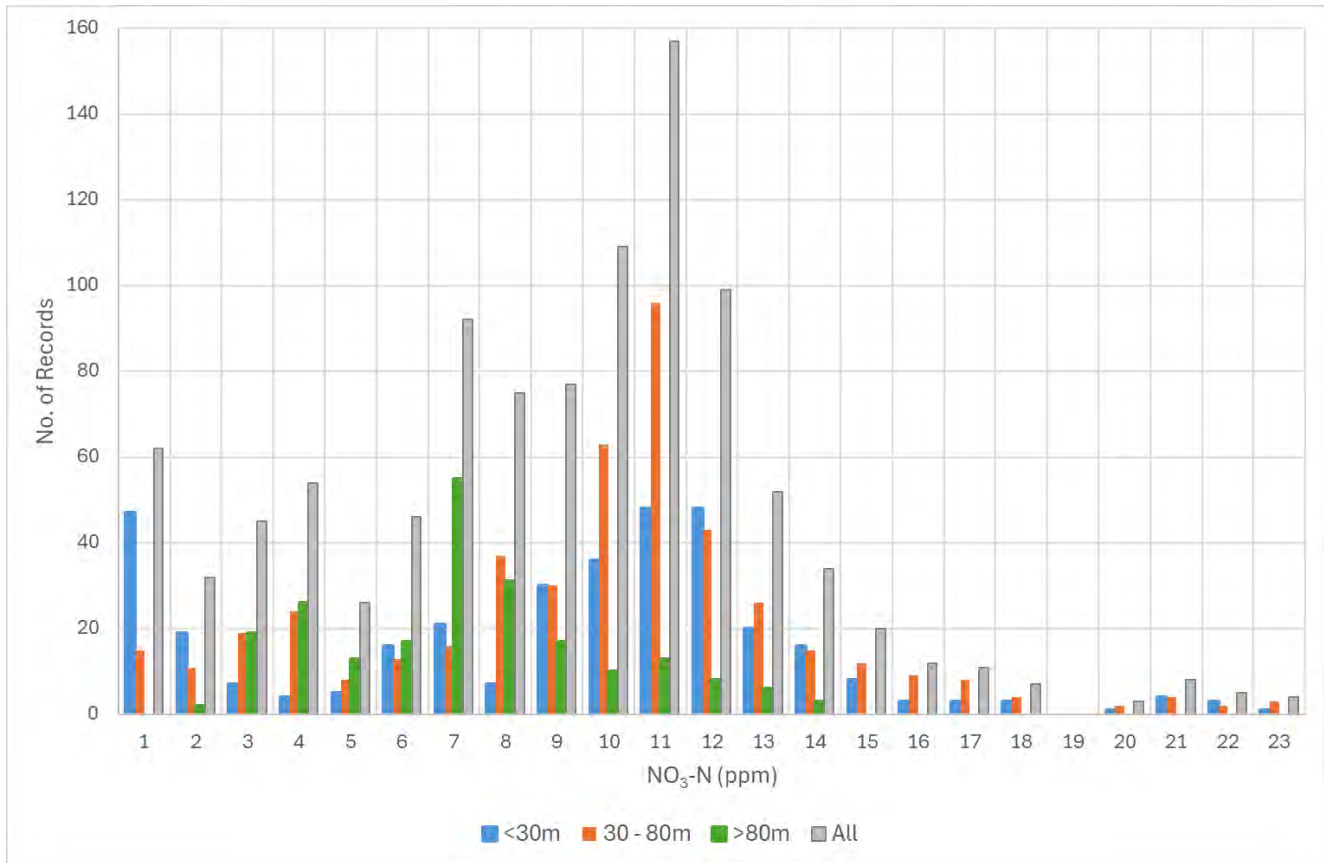


Figure 35 Frequency histogram for the 2024/5 NO₃-N results

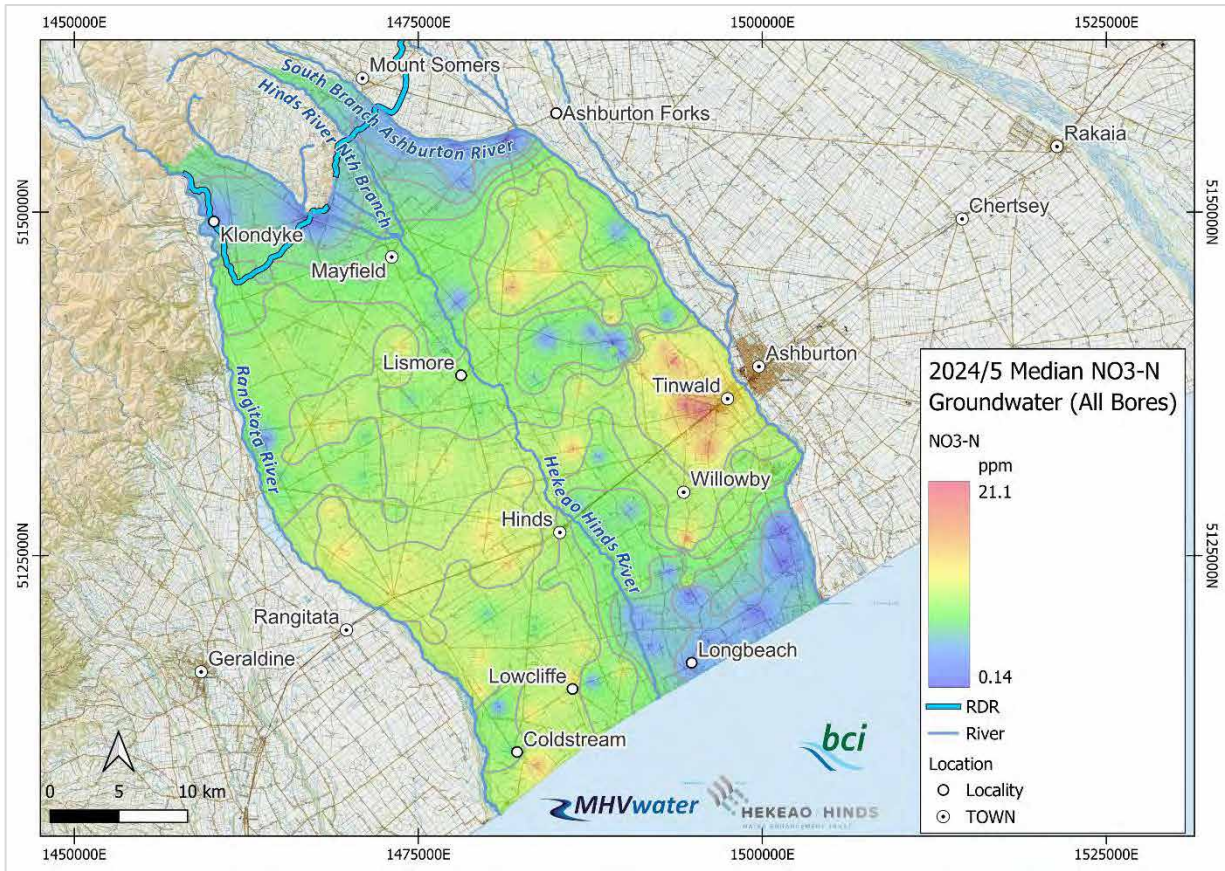


Figure 36 Median of the NO₃-N results for the reporting period for all bore depths

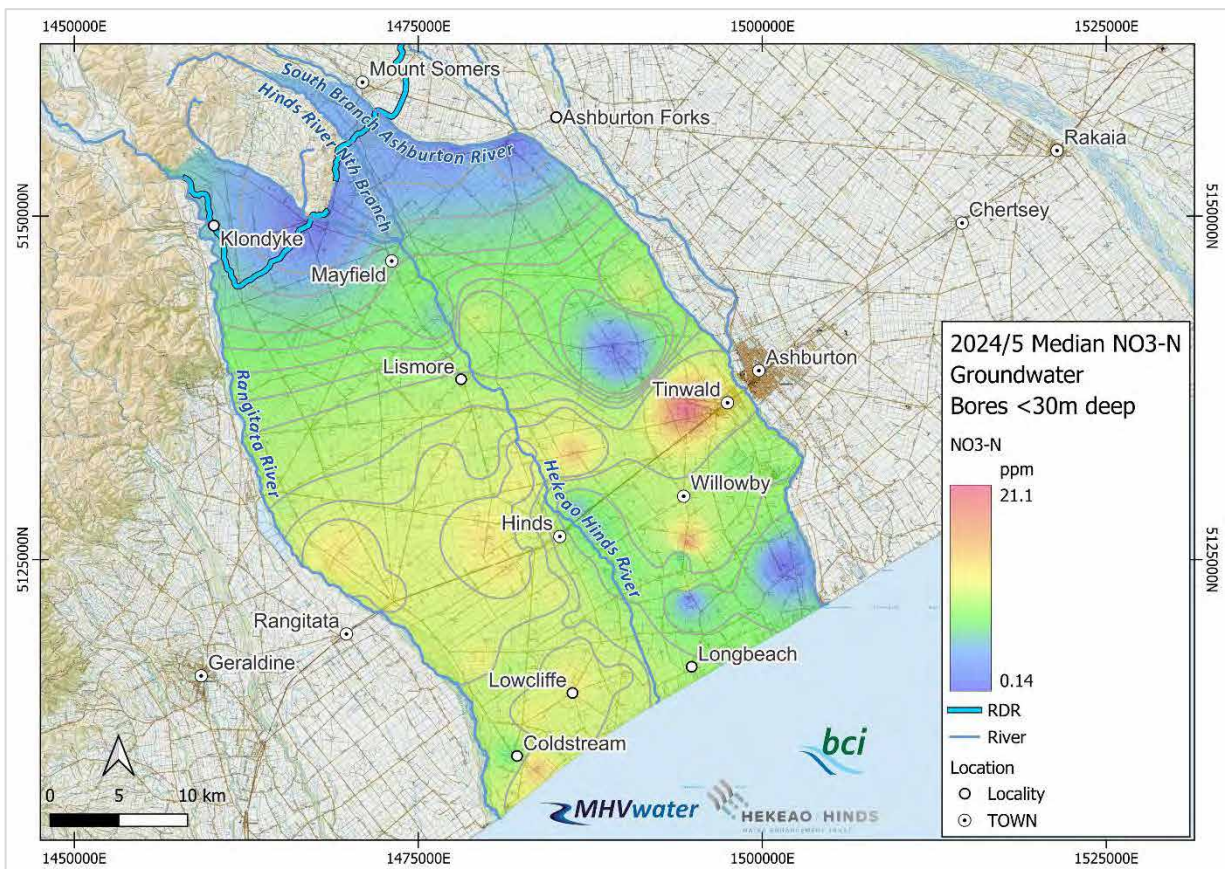


Figure 37 Median of the NO₃-N results for the reporting period for bores <30m deep

5.2. Groundwater Levels

MHV took 379 Ground Water Level (GWL) soundings from 59 bores across the HHP during the reporting period. The median GWL and sounding locations are presented in Figure 38; Table 9 presents a summary of the results.

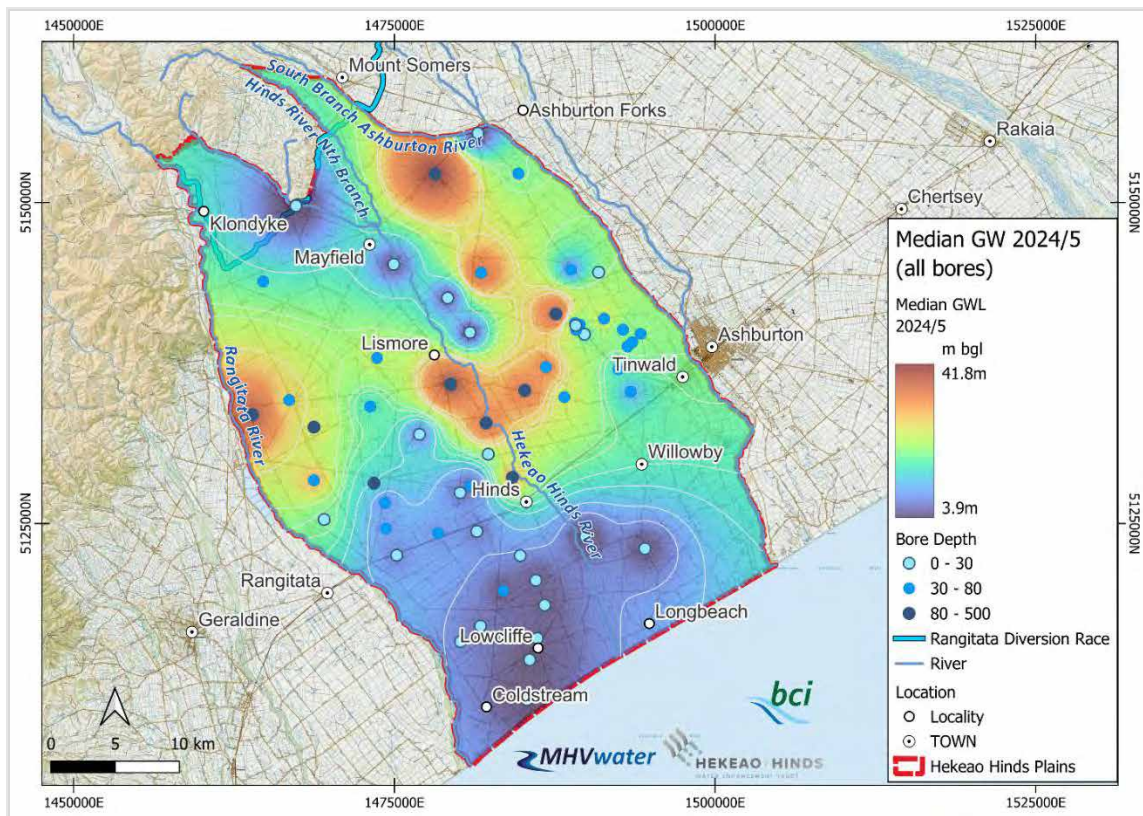


Figure 38 Median groundwater level (m bgl) for 2024/5 with sounding locations by depth

Table 9 Summary statistics of groundwater level soundings

Month	Month	Count	Minimum (m bgl)	Maximum (m bgl)	Average (m bgl)	Median (m bgl)
2024	Feb	38	1.15	62.80	21.26	12.60
	Mar	18	2.36	68.79	20.61	17.13
	Apr	2	2.12	2.45	2.29	2.29
	May	39	1.05	66.00	17.98	11.26
	Jun	17	1.64	70.65	19.59	14.42
	Jul	2	2.22	2.54	2.38	2.38
	Aug	13	2.00	61.36	22.75	16.54
	Sep	44	0.93	70.77	15.11	10.26
	Oct	2	2.14	2.43	2.29	2.29
	Nov	31	0.93	64.10	20.66	16.64
	Dec	13	2.14	73.38	21.21	15.30
2025	Jan	7	1.36	19.00	5.28	2.39
	Feb	32	1.11	65.89	18.55	11.28
	Mar	25	1.52	71.00	16.26	13.36
	Apr	2	1.74	1.92	1.83	1.83
	May	74	0.60	69.72	17.32	8.56
	Jun	20	0.77	66.48	14.37	11.41

GWL data for 2023 and 2024/5 was interpolated via an Inverse Distance Squares (ID2)¹⁵ estimation technique in QGIS© software. The resultant interpolations were then compared to each other to provide an indication of the relative changes in GWL between successive reporting periods in a spatial context. The results presented in Figure 39 indicate that GWL's reduced across the catchment, with the greatest drops observed in the deeper bores in the middle of the HHP.

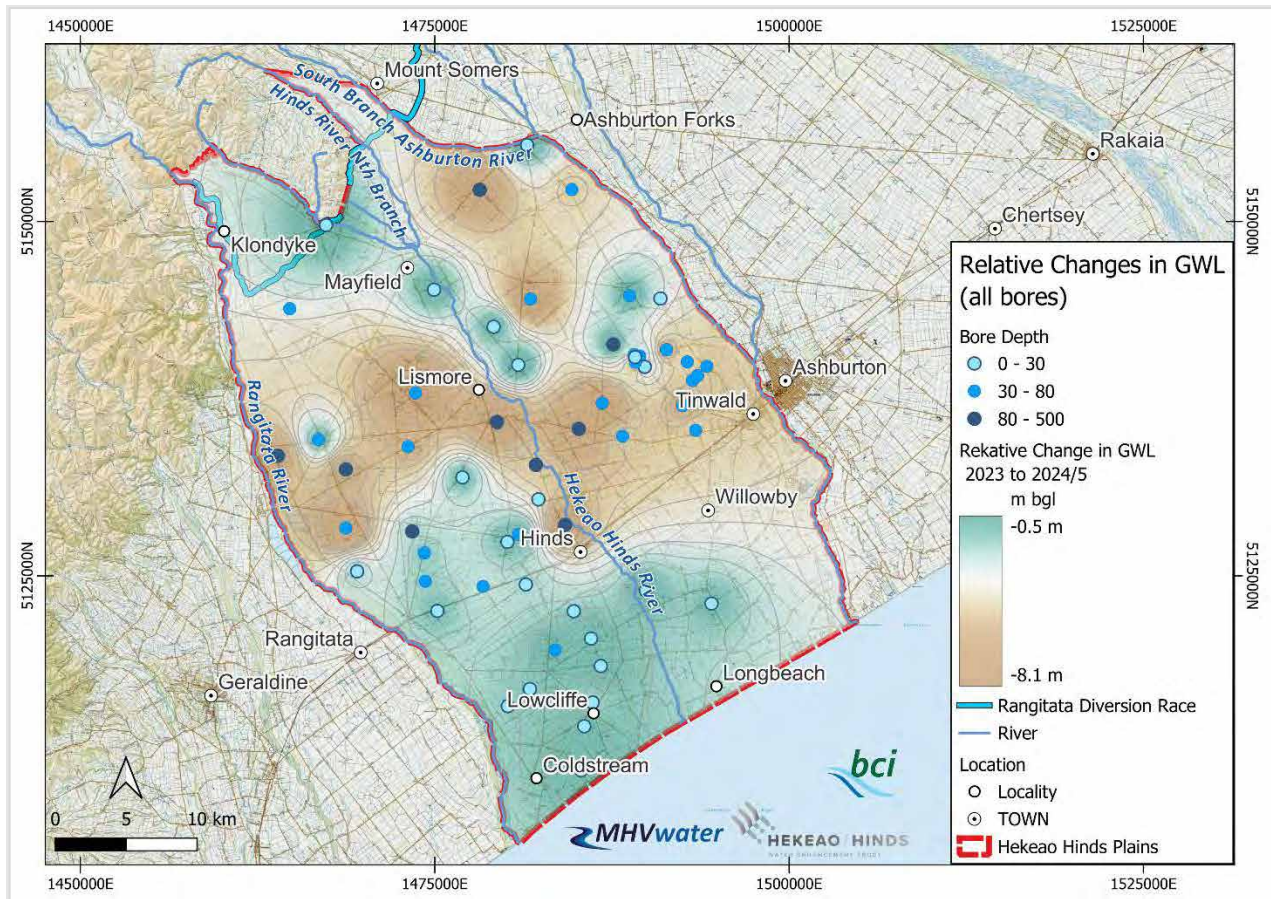


Figure 39 Relative changes in annual median GWL from 2023 and 2024/5.

A hydrograph of the different bore depths (see section 2.2.2) indicates that GWL's increased after increased rainfall after September 2024 in both shallow and intermediate bores, but that GWL's in deeper bores dropped regardless (Figure 40).

¹⁵ Inverse Distance Weighting (IDW) interpolation assumes closer values are more related than those values further away. Interpolated points are estimated based on their distance from known cell values. Points that are closer to known values will be more influenced than points that are farther away. Increasing the exponent of the interpolation (i.e. from 1 to 2 – designated ID2) increases the influence of a known value.

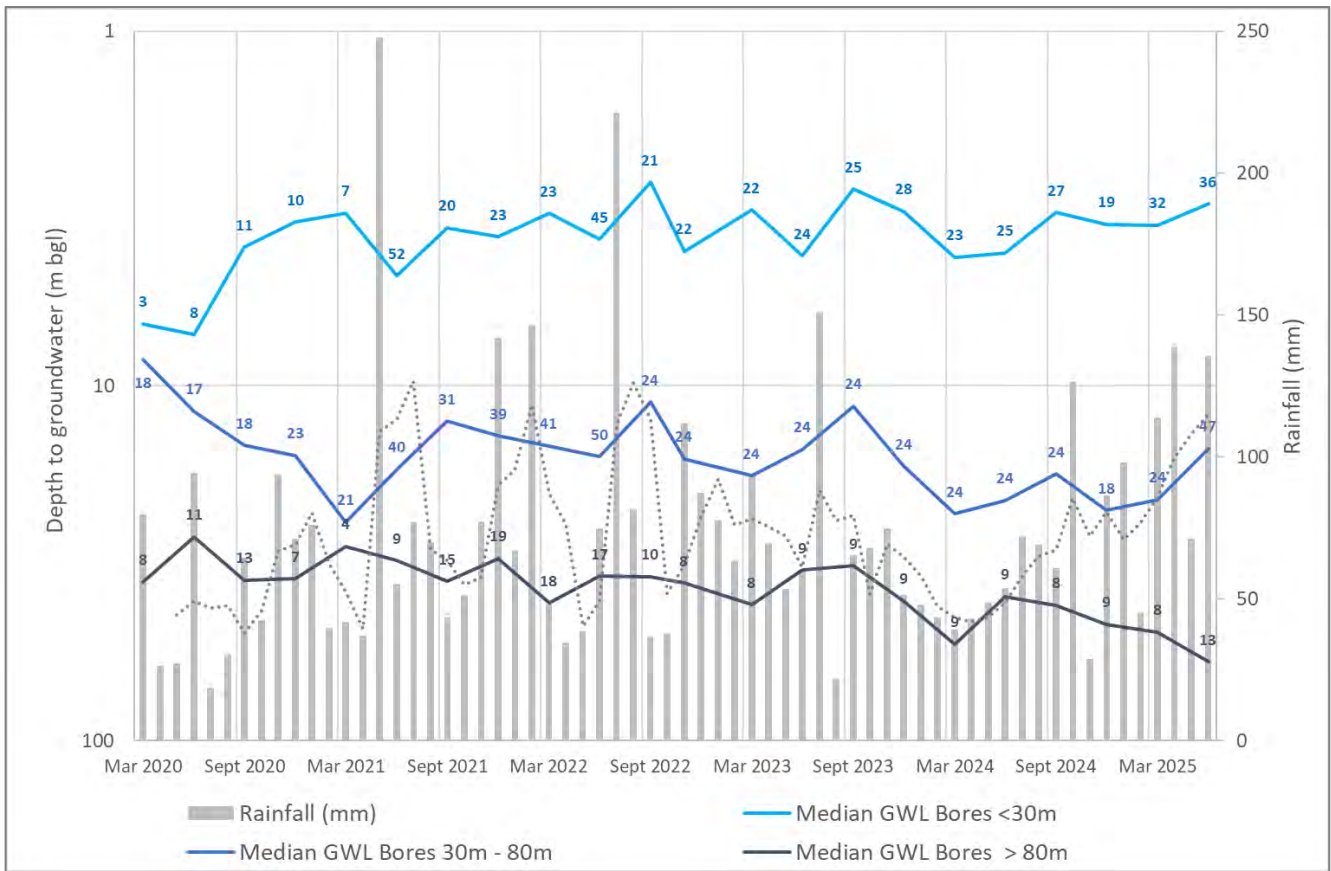


Figure 40 Median GWL for the period 2020 - 2025 year by depth bracket. Numerical annotation indicates the number of soundings

GWL's are generally at their highest in the winter months in response to winter recharge rainfall and the absence of abstraction. Figure 40 presents MHV observations for 01/2024 – 06/2025 whilst Figure 41 presents ECan data for the same period. The ECan results confer with MHV's observations but do show a slight increase in K37/0689 (91.5m). As bores >80m make up a minority of bores on the HHP (~ 15% of active bores) there is likely to be considerable variation in the >80m bore data.

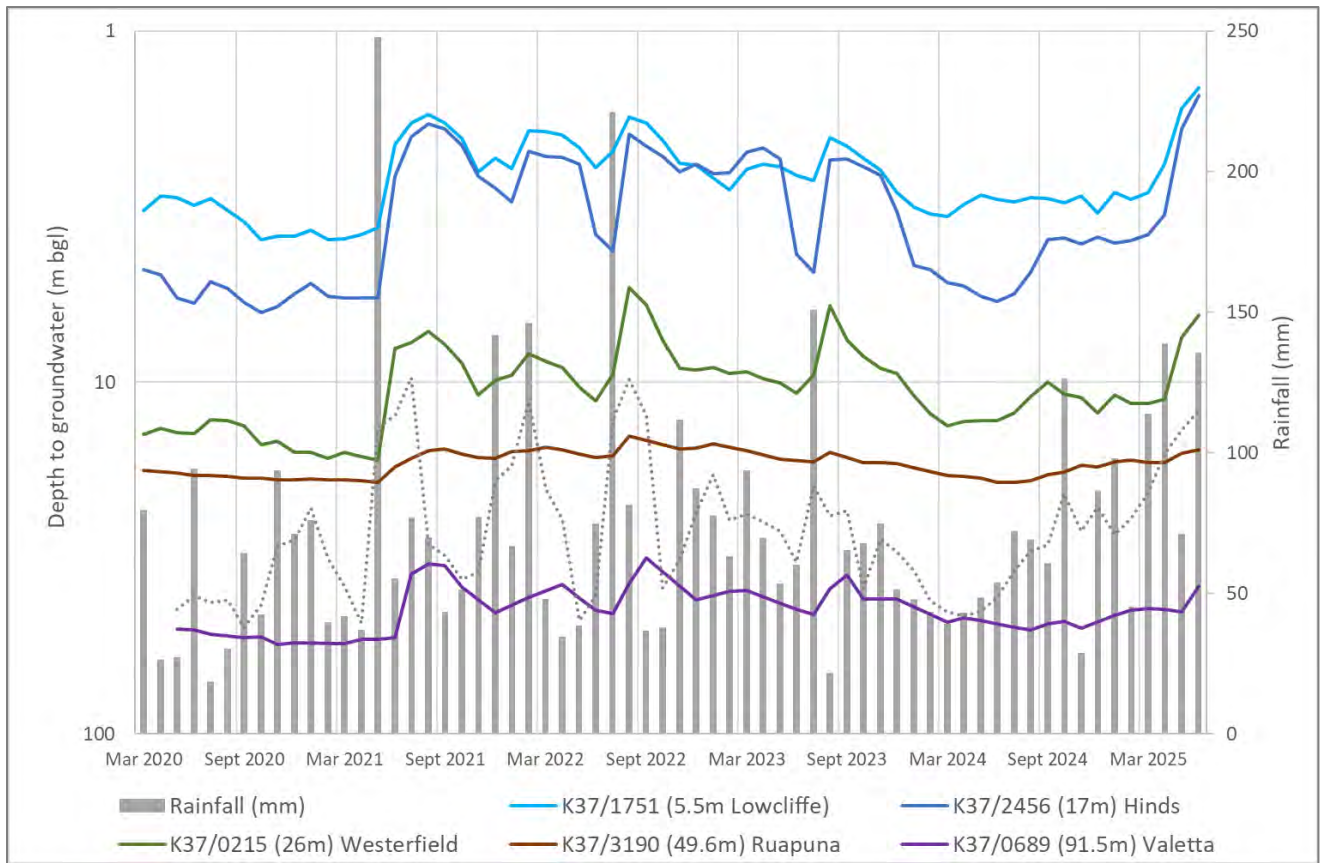


Figure 41 Groundwater levels from ECan bores across the Hekeao Hinds Plains with rainfall between January 2020 & June 2025

6. Surface Water Results

6.1. Disclaimer

The 2024/5 surface water results presented here need to be considered in the context that there are innumerable intersections between farm drains, council stock water races, irrigation races and highly modified water courses (HMWC) as shown in Figure 42.

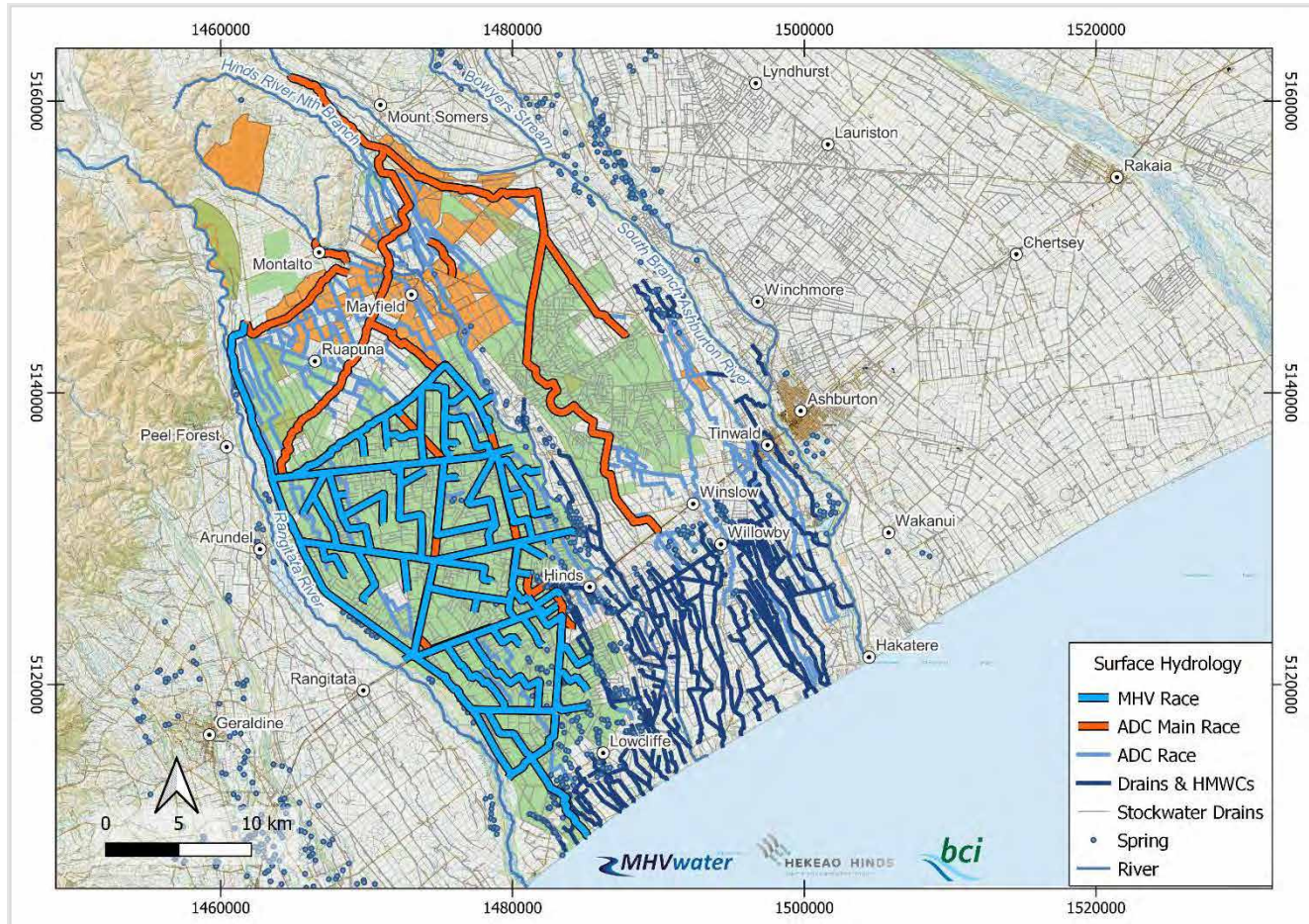


Figure 42 A map of known intersections between farm drains, council stock water races and highly modified waterways

Under normal conditions, water in the HMWC’s may be derived from one or more of the following sources:

- Springs,
- Ashburton District Council (ADC) stock water races – which is in turn is sourced from the Hakatere Ashburton or Rangitata Rivers,
- Farm drains,
- Surface run off;
- Tile drains and/ or,
- Irrigation races which are sourced from the Rangitata River via the RDR.

Additionally, factors such as proximal groundwater and/ or surface water abstraction, prevailing weather conditions and soil / geology can have a significant influence on flow rates.

Additionally, the HHP has received unusually high¹⁶ (>1045mm) rainfall since January 2025 due to an increase in the Southern Oscillation Index indicative of La Niña conditions (see section 7). This has increased shallow groundwater levels which are likely to increase the contribution from sources such as septic tanks and leaky sewers, urban impermeable surfaces, waste pits and landfill, and agricultural land. Therefore, the surface water data collected is considered to be somewhat heterogeneous and needs to be considered on a case-by-case basis.

For example, Moffatt’s Drain is a spring fed HMWC that is augmented with ADC stock water races (which are derived from the Hakatere Ashburton or Rangitata Rivers) resulting in significant decreases in NO₃-N concentrations in the short term (Figure 43). In comparison, the Parakanoi Drain, is a spring fed drain, which is not augmented with additional water and therefore has more consistent NO₃-N results.

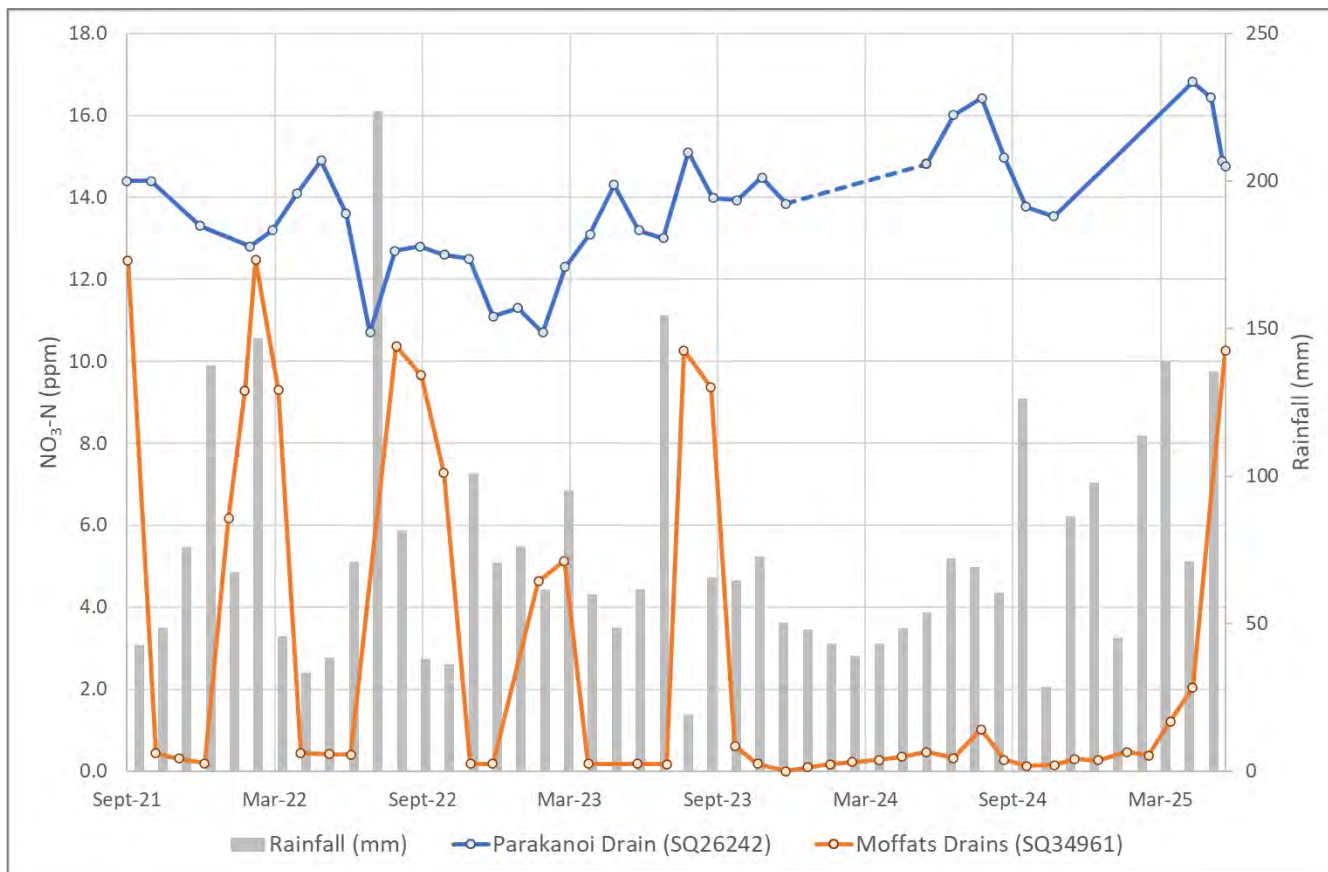


Figure 43 Changes in NO₃-N concentration for the Moffatts and Parakanoi Drains

¹⁶ Greater than the long term 95th percentile or 175mm a month

6.2.Results

Whilst MHV collected surface water samples from a wide variety of locations and waterbodies (Table 10), this report will focus on the Hekeao Hinds River and HMWC's.

Table 10 Summary of samples collected

Surface water type	Number of samples collected
Drain	20
HMWC - Highly modified water course	835
Pond	30
Race	55
River	216
Spring	26
Tile Drain	24
Total	1206

6.2.1. Hekeao Hinds River Results

The flow rates for the Hekeao Hinds River at Poplar Road (ECan station 69102) demonstrates that the Hekeao Hinds River is very responsive to rainfall (Table 11 and Figure 44).

Table 11 Descriptive statistics of daily flow rates (m3/ sec) for the Hekeao Hinds River at Poplar Road for the 2024/5 year

Count	Daily Min (m ³ /s)	Daily Max (m ³ /s)	Daily Av. (m ³ /s)	Daily Median (m ³ /s)	95th Percentile (m ³ /s)
345	0.20	101.50†	1.35	0.46	3.29

† Elevated flows between 23/07/2023 and 6/8/2023.

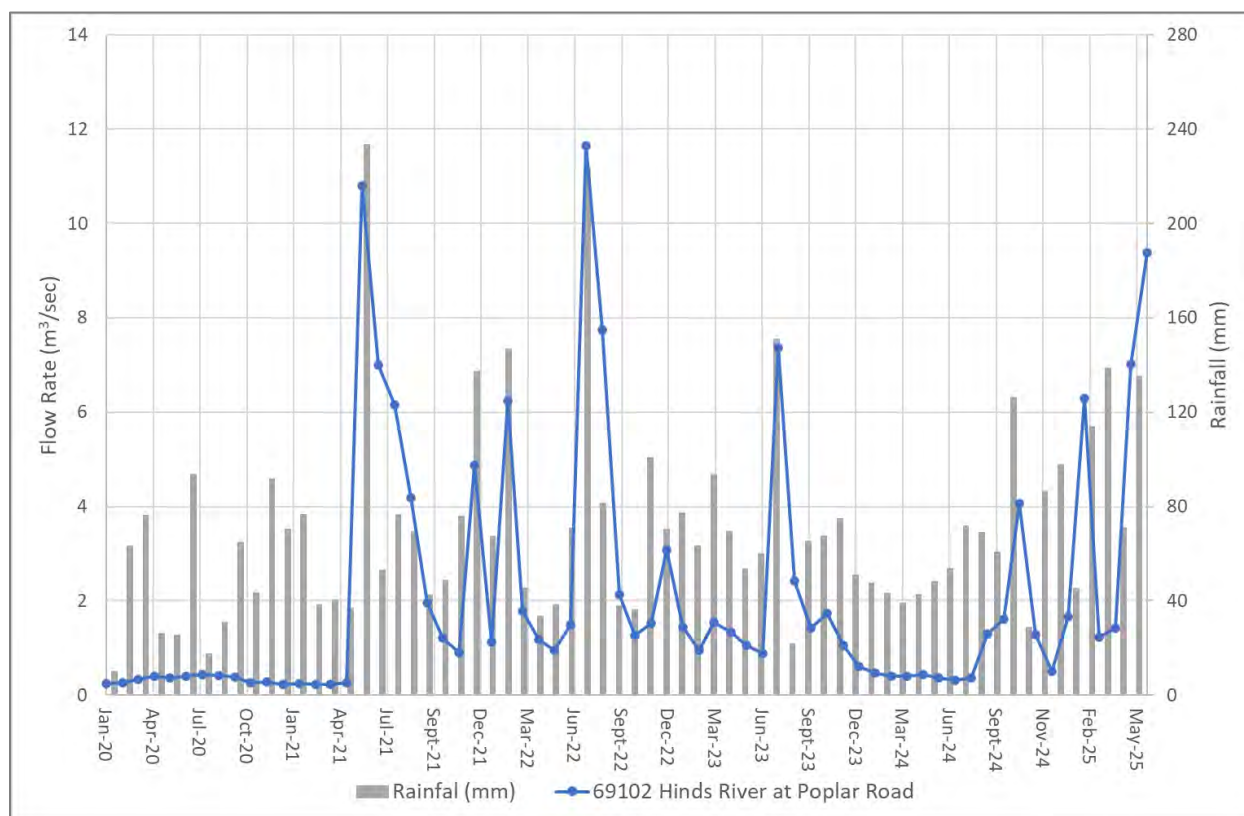


Figure 44 Monthly flow and rainfall for the Hekeao Hinds River

The NO₃-N results for the Hekeao Hinds River from Mayfield to Lower Beach presented in Figure 45 indicate:

- that there is an increase in NO₃-N as the river progresses down the catchment, and
- that NO₃-N concentrations appear to increase some 3 months after periods of rainfall and elevated river flows (Table 12 and Figure 46).

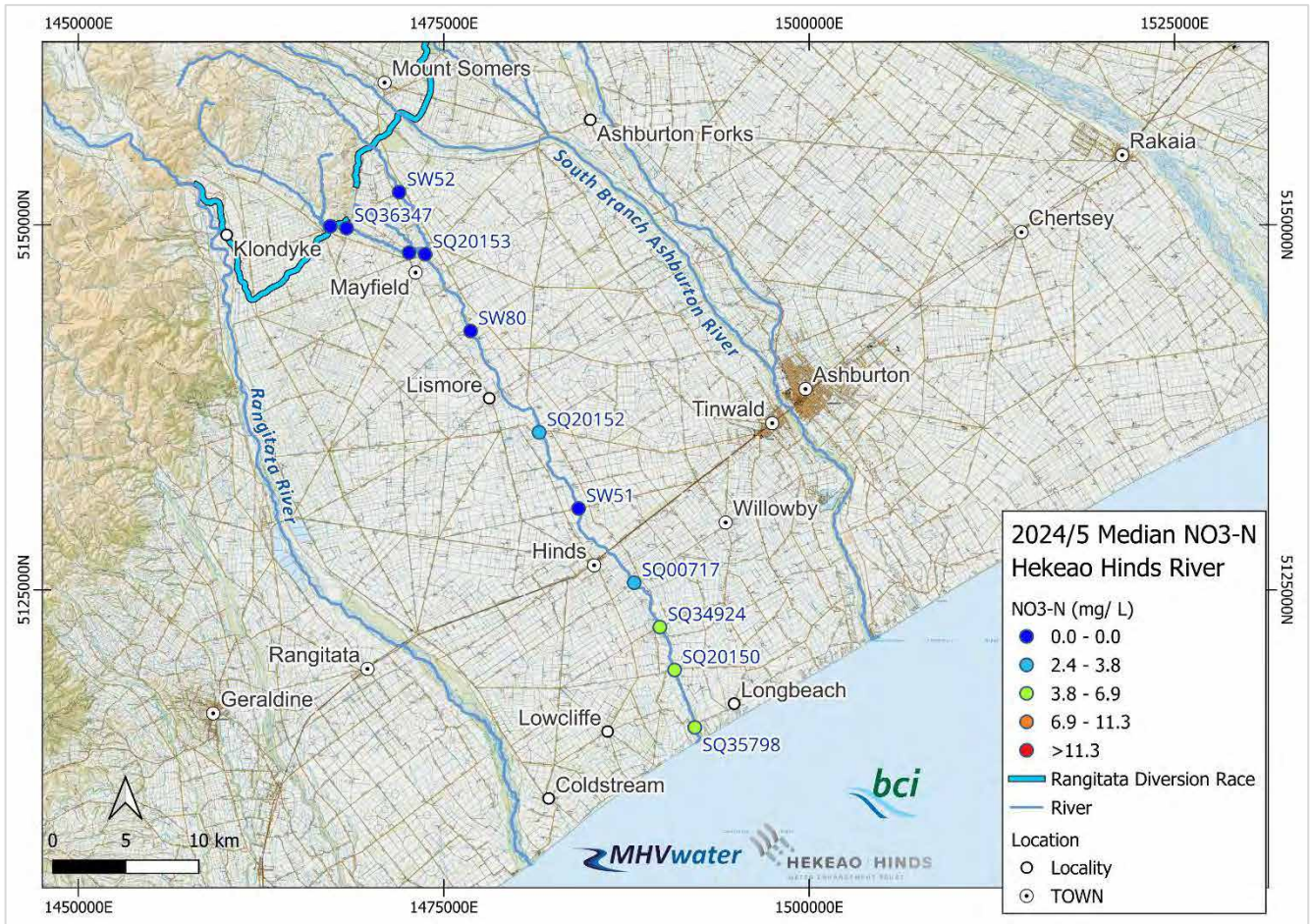


Figure 45 Sample locations along the Hekeao Hinds River, coloured by median NO₃-N concentrations

Table 12 NO₃-N Results for the Hekeao Hinds River from Mayfield to Lower Beach with rainfall

Sample Locations	No.	Min	Max	Average	Median	95th Percentile
SQ00717: Boundary Rd	10	2.22	4.86	2.81	2.49	4.10
SQ20150: Hinds River Rd	22	3.29	7.18	5.79	6.32	7.13
SQ20152: Maronan Rd	12	1.21	4.13	2.59	2.51	3.62
SQ20153: Arundel Rakaia Gorge Rd	20	0.60	4.69	1.95	1.62	3.93
SQ34924: Surveyors Rd	21	2.32	5.34	3.98	4.44	5.30
SQ35798: Lower Beach Rd	22	3.60	7.72	5.75	6.14	7.43
SQ35799: RDR	17	0.03	1.71	0.57	0.59	1.27
SQ36347: 656 Lower Downs Rd	18	0.03	1.75	0.55	0.51	1.59
SW51: Winslow Rd	11	1.02	3.95	1.90	1.54	3.36
SW52: Anama Station Rd	13	0.05	1.15	0.56	0.54	0.94
SW78: Alma Settlement Rd	9	0.49	2.08	0.91	0.76	1.67
SW80: Hackthorne Rd	11	0.83	4.12	1.80	1.49	3.31
Hinds River (All Samples)	186	0.03	7.72	2.75	2.24	6.74

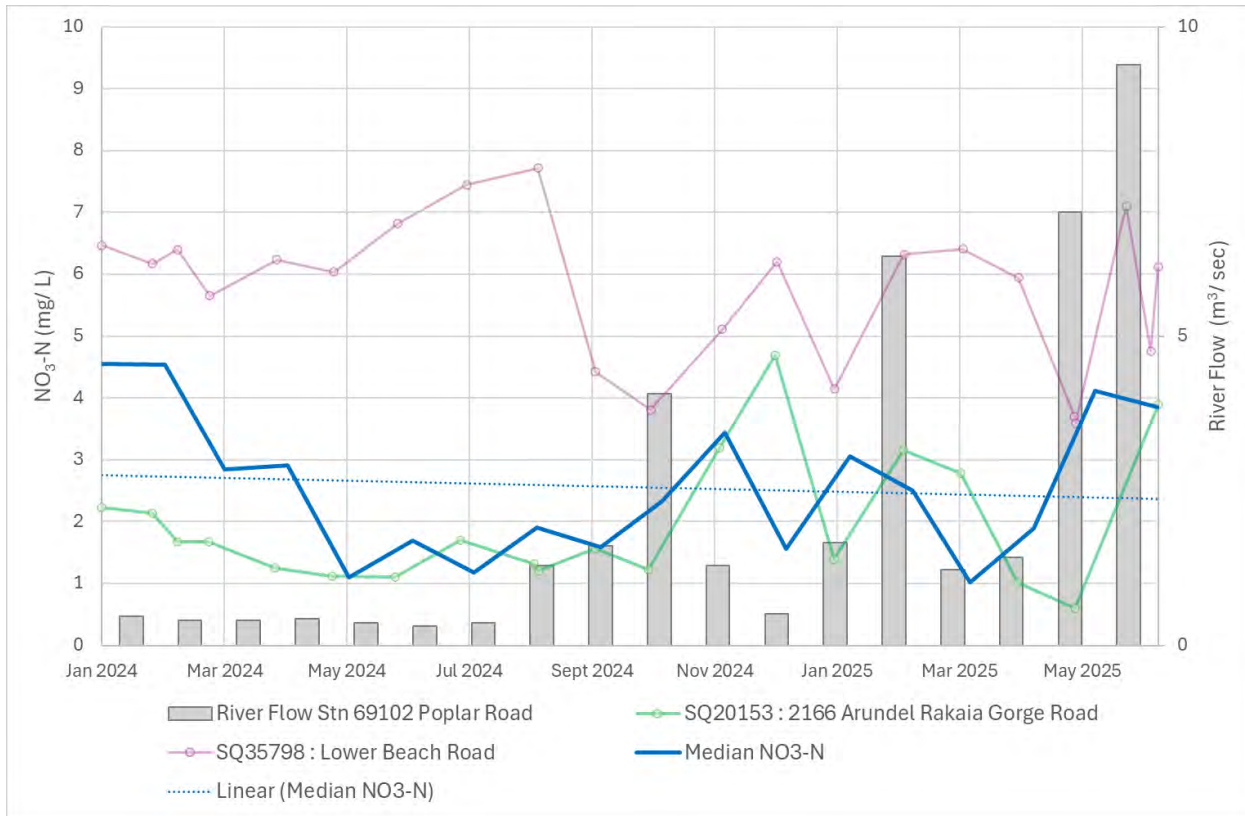


Figure 46 Median NO₃-N Results for the Hekeao Hinds River 2024/5

6.2.2. Highly Modified Water Course Results

During the reporting period 36 HMWC's were monitored, with 818 samples collected from 50 locations. The results are presented in Figure 47 and Table 13.

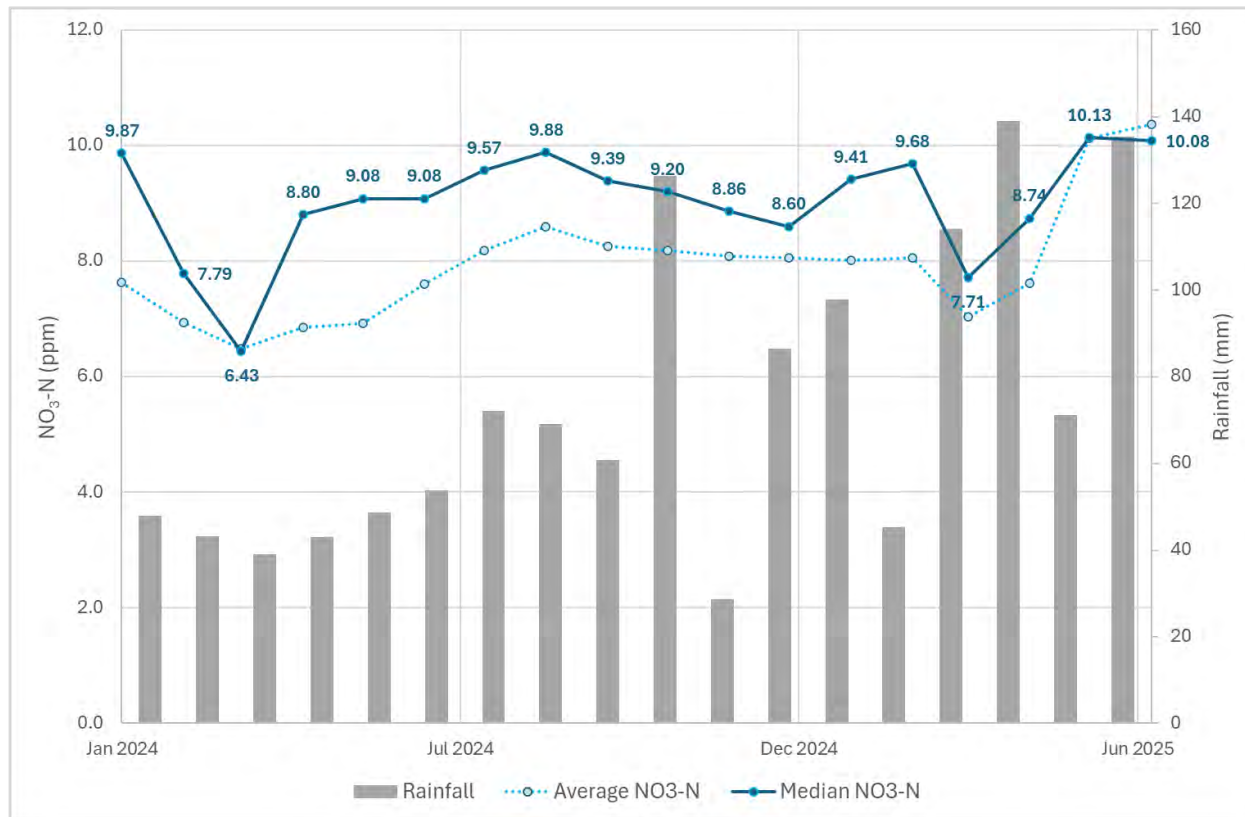


Figure 47 Monthly median and average NO₃-N for HMWC's with rainfall

Table 13 Summary statistics for NO₃-N concentration in HMWC's

Year	Month	Count	Min	Max	Average	Median
2024	Jan	38	0.09	15.10	7.63	9.87
	Feb	37	0.10	15.17	6.94	7.79
	Mar	34	0.18	11.53	6.49	6.43
	Apr	34	0.09	11.56	6.84	8.80
	May	36	0.33	15.81	6.92	9.08
	Jun	41	0.31	15.43	7.60	9.08
	Jul	42	0.28	16.69	8.19	9.57
	Aug	42	0.67	17.99	8.59	9.88
	Sept	46	0.17	16.46	8.25	9.39
	Oct	48	0.08	16.53	8.19	9.20
	Nov	49	0.07	16.95	8.09	8.86
	Dec	36	0.20	18.78	8.06	8.60
2025	Jan	39	0.27	18.42	8.02	9.41
	Feb	36	0.42	13.23	8.05	9.68
	Mar	38	0.38	12.65	7.04	7.71
	Apr	45	0.32	17.01	7.61	8.74
	May	90	0.32	19.11	10.12	10.13
	Jun	87	4.36	17.46	10.37	10.08

Notably, 4 different NO₃-N responses were noted within the HMWC data. This is illustrated in Figure 48 where the data has been normalised to its maxima (i.e. each value is expressed as a percentage of the maximum value for each sampling location). Summary statistics for the different response types is presented in Table 14 and spatially in Figure 49.

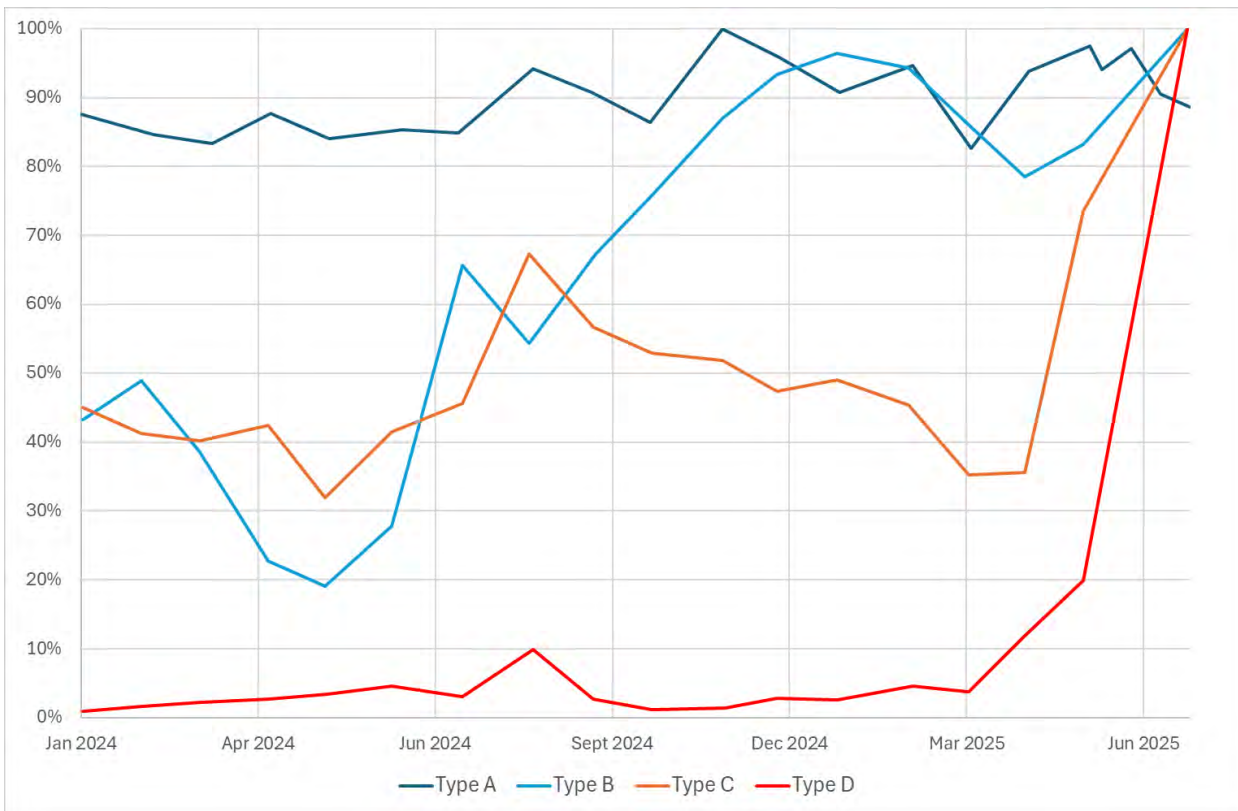


Figure 48 Normalised NO₃-N data indicating 4 different response types in HMWC's for the reporting period

Summary statistics for the different response types are presented in Table 14

Table 14 Summary statistics for different response types in HMWC's for the reporting period

Type	Count	Min	Max	Average	Median	95 th Percentile
A	328	3.90	19.11	10.91	10.43	15.03
B	278	1.11	14.83	7.75	8.19	14.32
C	154	1.30	13.94	6.02	5.05	12.28
D	58	0.07	10.27	1.56	0.32	7.56

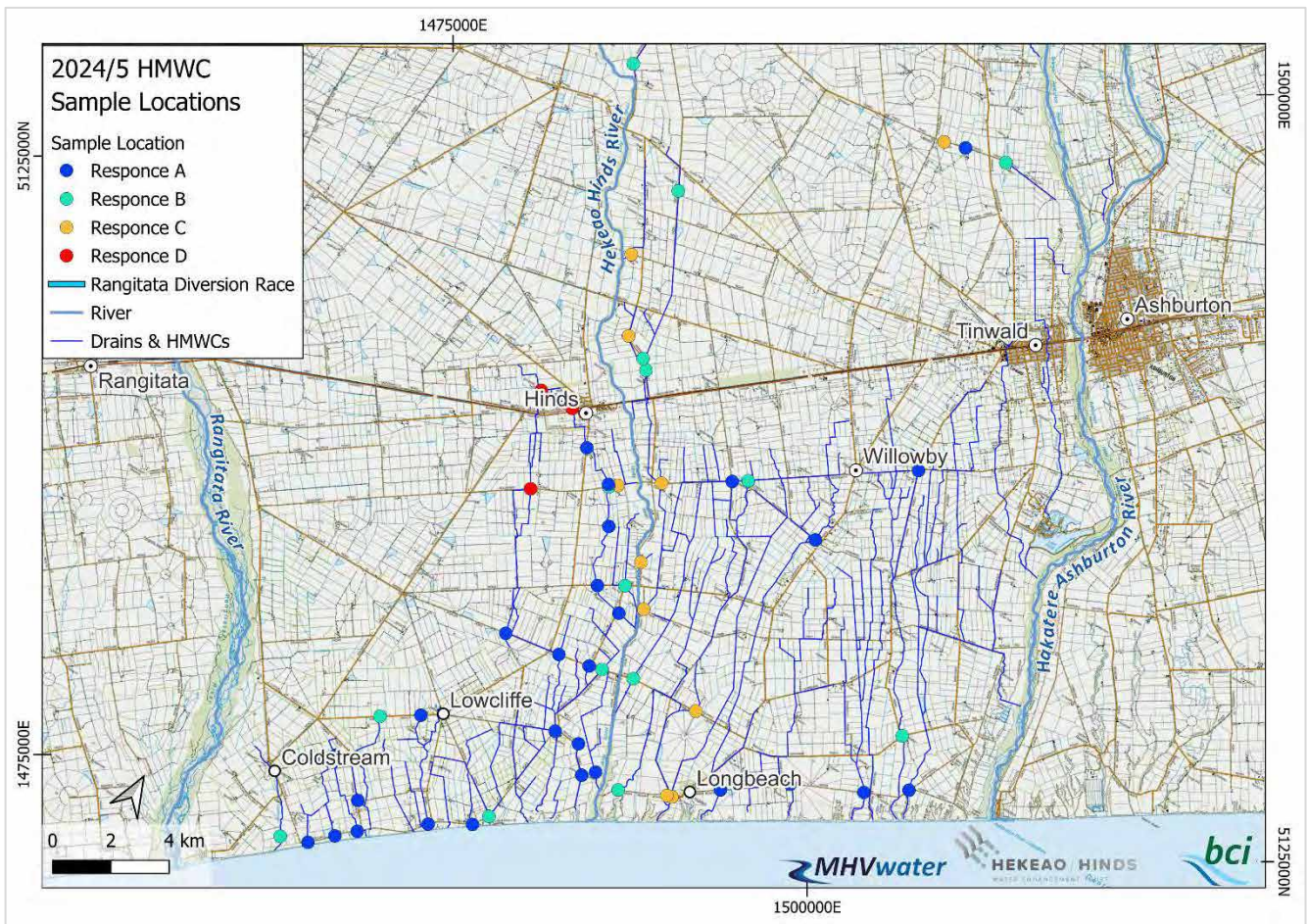


Figure 49 Locations of HMWC's sample locations coloured by NO₃-N response type

7. Discussion

In the reporting period, the HHP received 1320 mm of rainfall – approximately 20% more than the long-term annual average of 774 mm, with 1045 mm being received in the six-month period from January to June 2025. Since late 2023, the Southern Oscillation Index (SOI) has progressively increased, and though it has only peaked above +7 intermittently (indicating a La Niña event) it has resulted in higher-than-average rainfall in 2025 (Figure 50), with wet conditions expected to persist until the end of 2025 [41], [42].

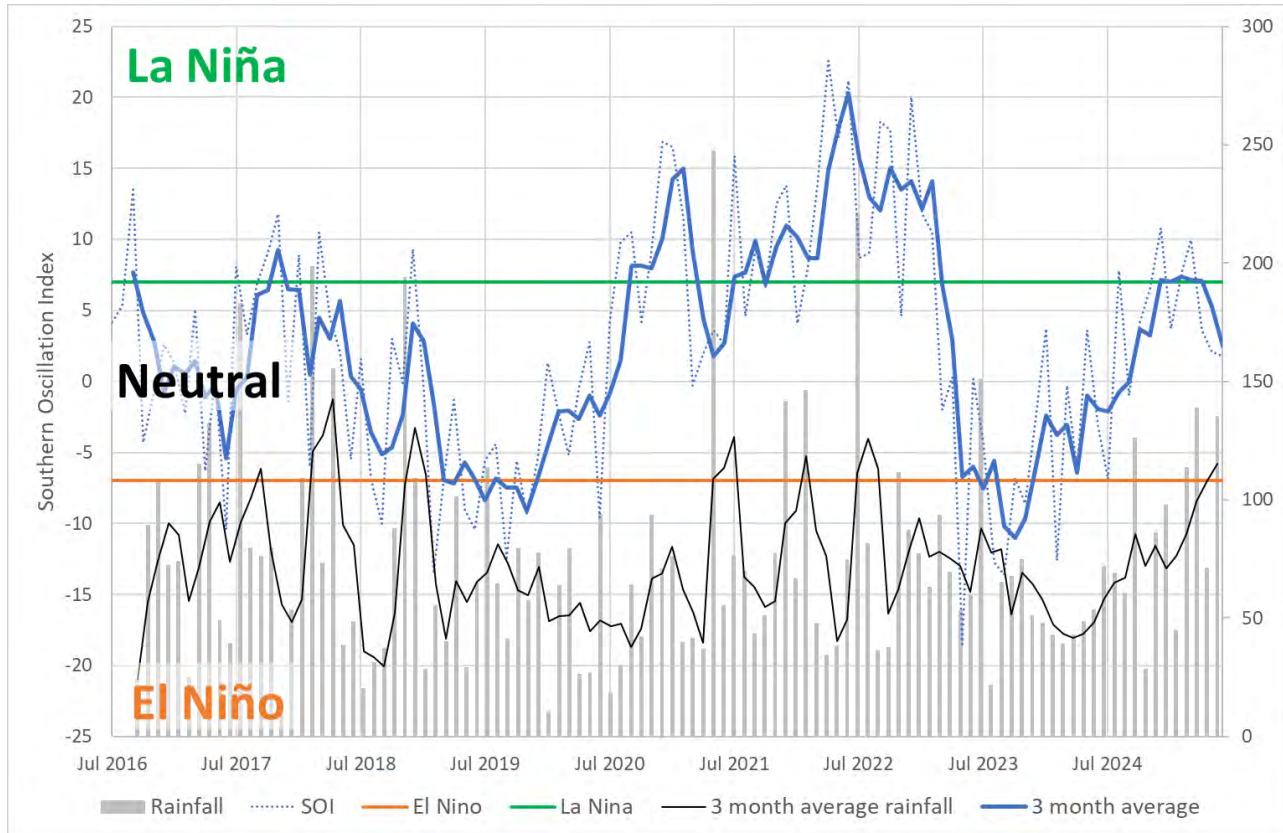


Figure 50 Southern Oscillation Index data 2015 – 2025

7.1. Groundwater

Given the higher-than-average rainfall, there has been a corresponding increase in NO₃-N concentrations in groundwater as shown in Figure 51 to Figure 53, with summary statistics presented in Table 15.

Table 15 Summary statistics for changes in groundwater NO₃-N (January 2024 to June 2025)

Bore Depth	Minimum	Maximum	Median	Average	95 th Percentile	5 th Percentile
All depths	-4.36	8.68	0.33	0.61	4.88	-2.00
<30m	-4.36	8.68	0.74	1.42	5.55	-2.50
>30m	-3.12	4.93	0.05	0.19	2.89	-1.80

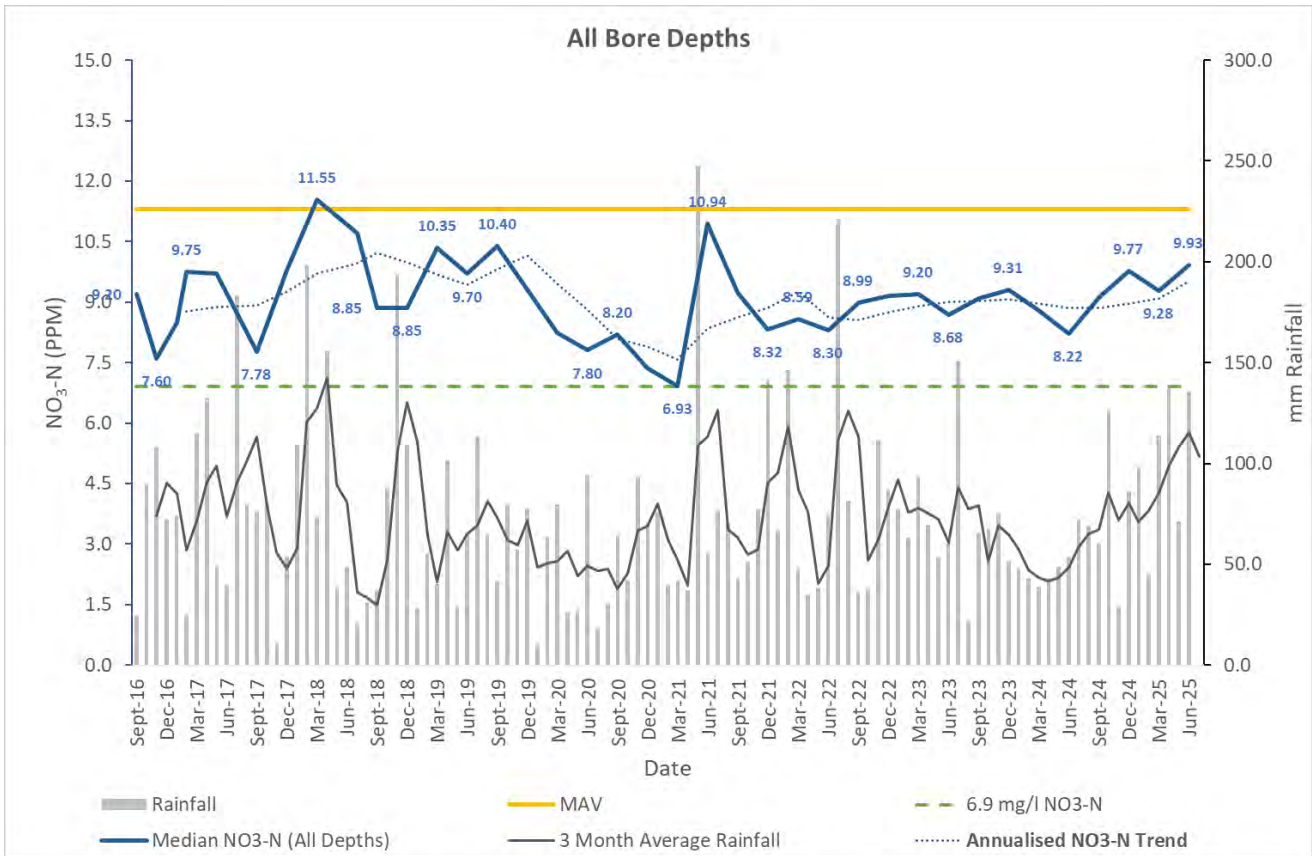


Figure 51 Long term NO₃-N data for all bores

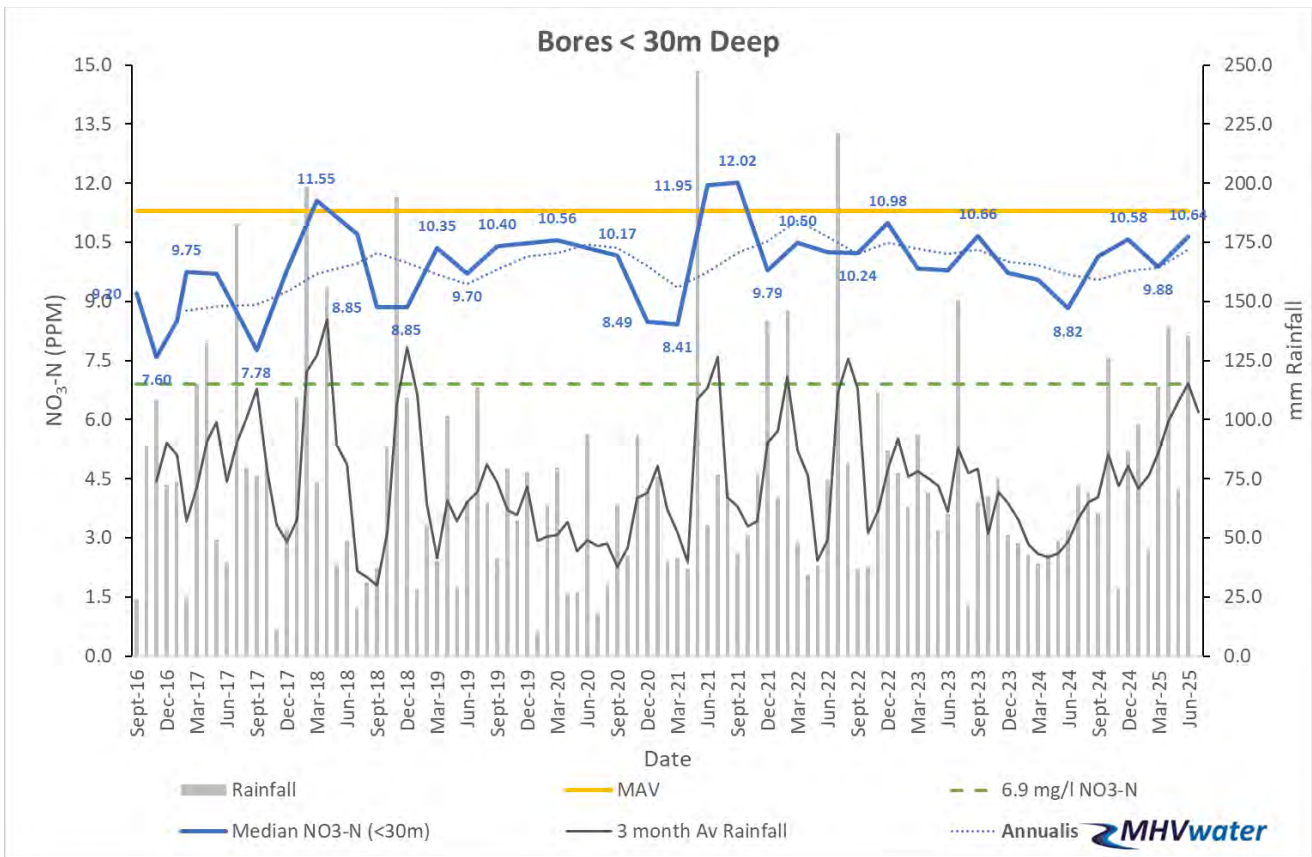


Figure 52 Long term NO₃-N data for bores <30m deep

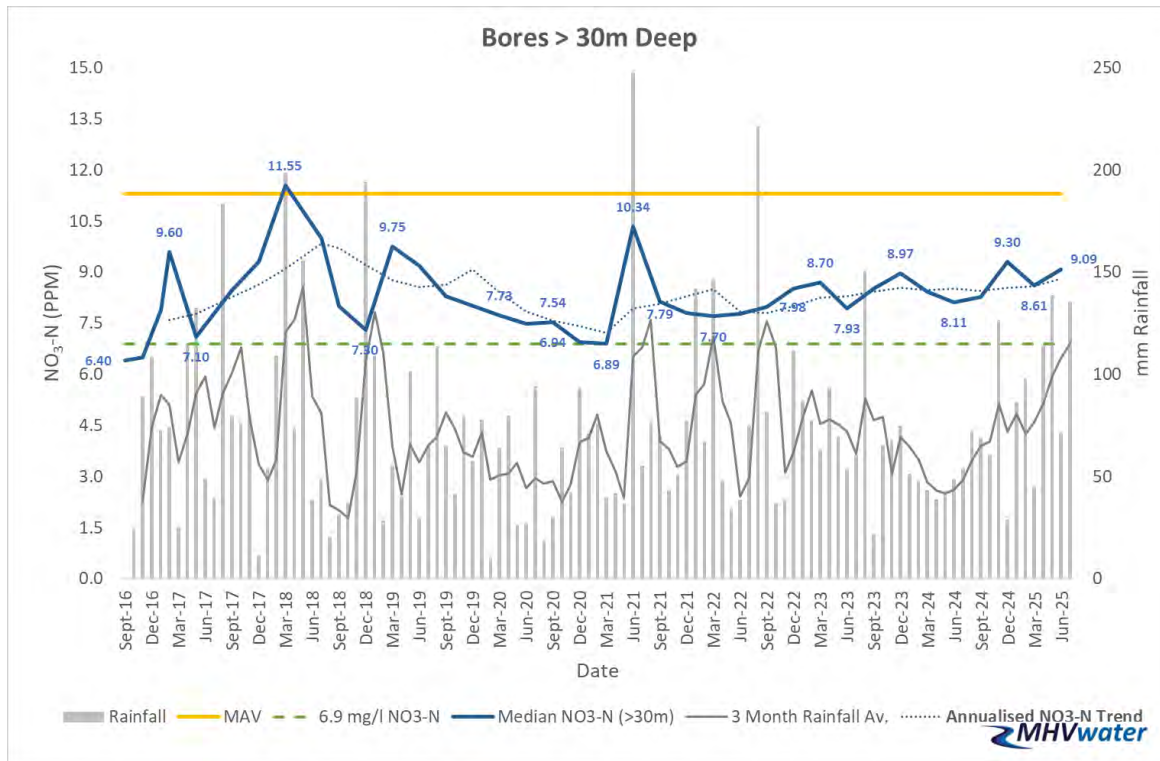


Figure 53 Long term NO₃-N data for bores >30m deep

When these changes are considered spatially, the changes in NO₃-N are associated with the confluence of the Hekeao Hinds River near Mayfield as well as the changes in soil types near Lowcliffe and areas where GWL's dropped by >5m during the reporting period.

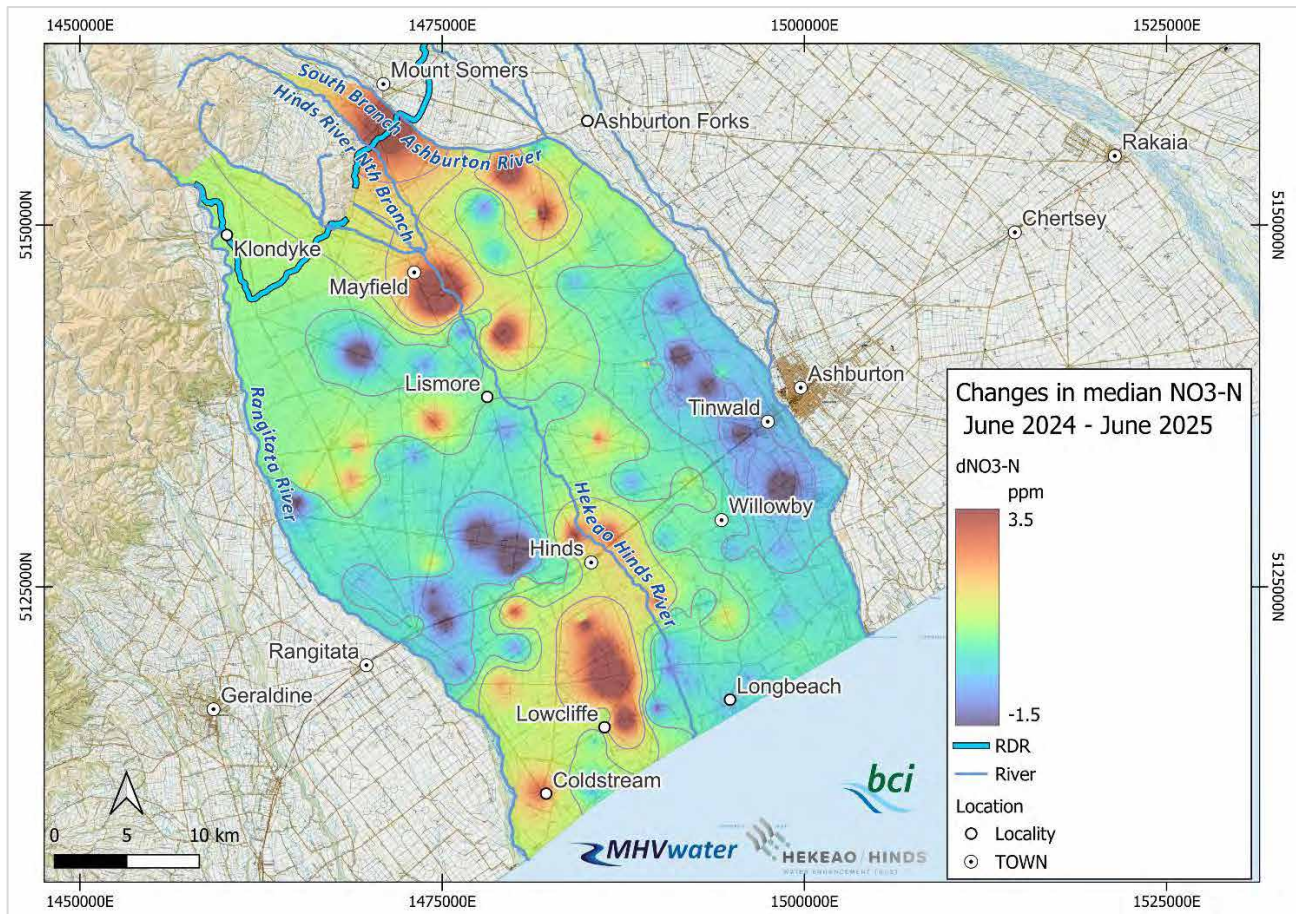


Figure 54 Changes in median NO₃-N between June 2024 and June 2025 for all bores

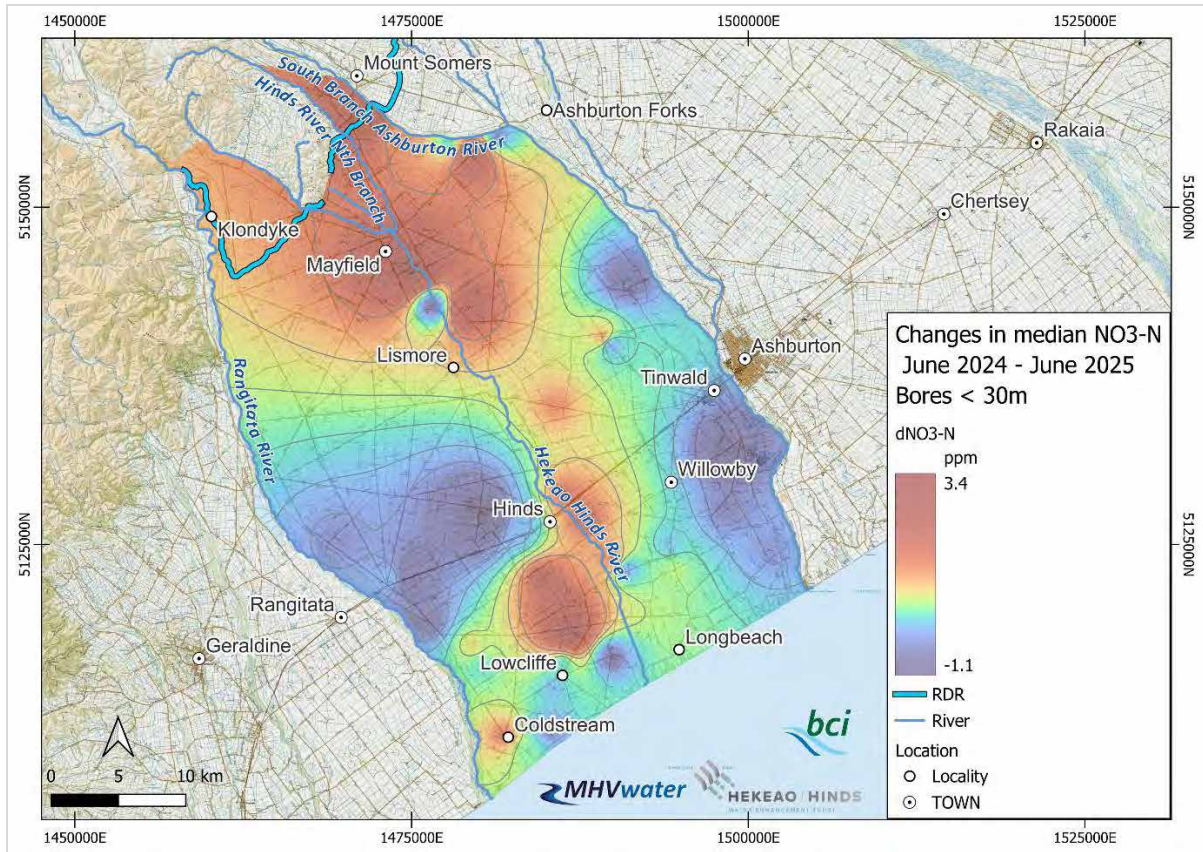


Figure 55 Changes in median NO₃-N between June 2024 and June 2025 for bores <30m deep

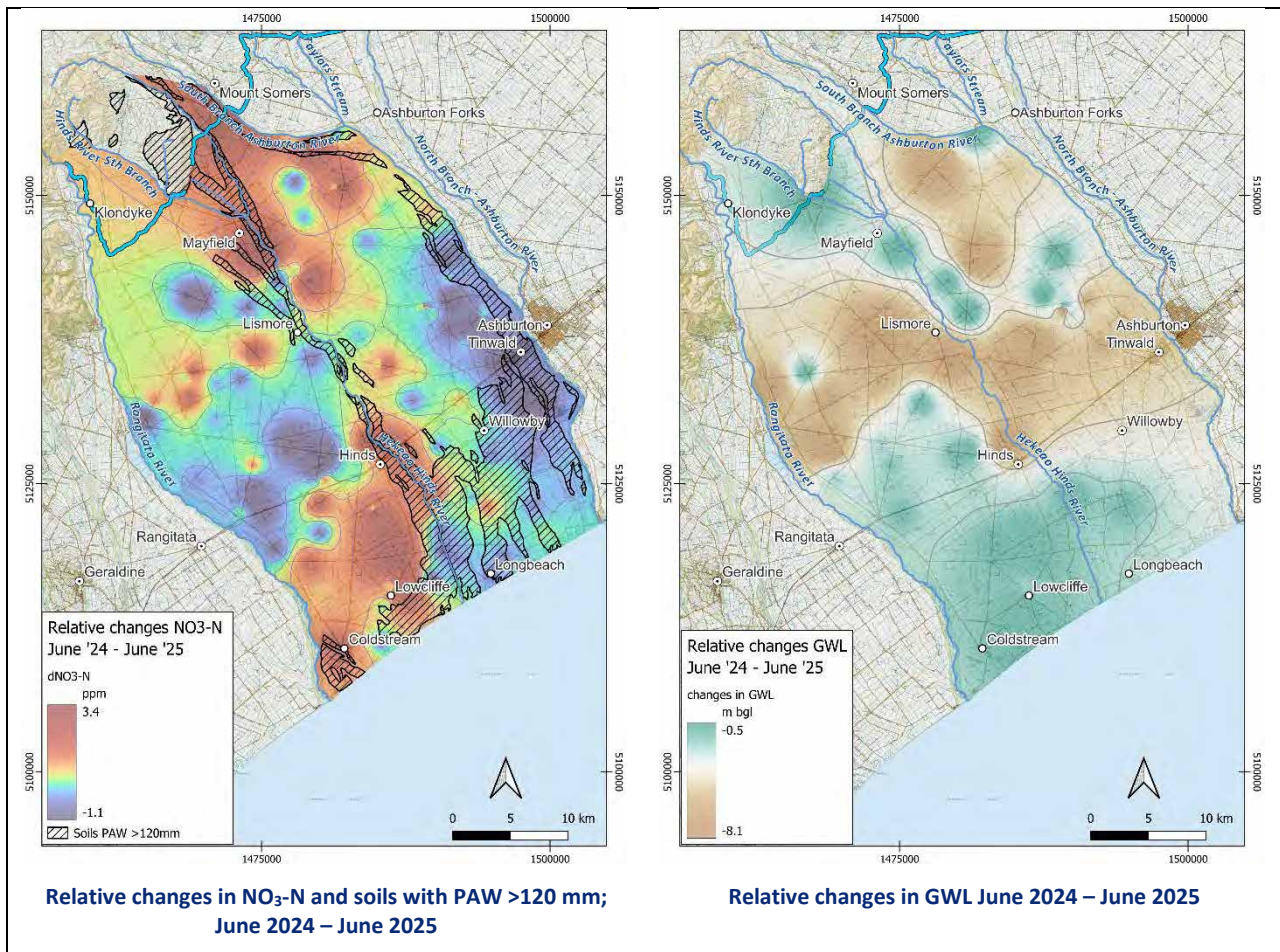


Figure 56 Changes in NO₃-N (June 2024 – June 2025) with heavy soils & changes in GWL

7.2.Hekeao Hinds River

As discussed in section 6.2.1, the Hekeao Hinds River responds quickly to rainfall, which in turn affects NO₃-N concentrations as shown in Figure 57 – albeit with a lag of approximately 1-2 months. Despite these variations, the gross trend since June 2022 is a slight decrease in NO₃-N concentrations in the Hekeao Hinds River.

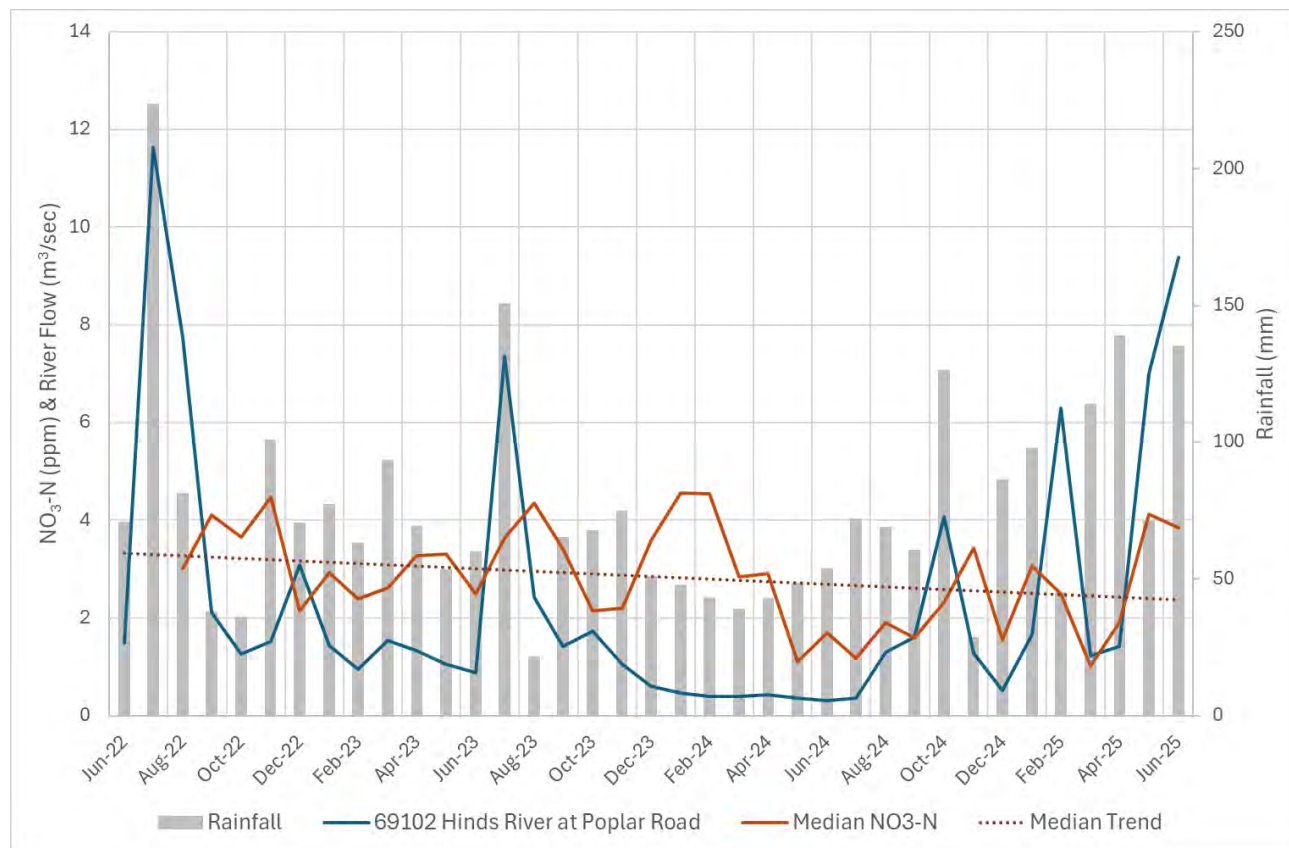


Figure 57 Median NO₃-N concentrations for the Hekeao Hinds River with Rainfall (mm) and Flow (m³/ sec)

7.3.Highly Modified Water Courses

As noted in section 6.2.2, 4 different NO₃-N response types were noted in the HMWC’s, with type C generally being in HMWC’s that drain into the Hekeao Hinds River from the north (true left bank).

A high-level reconciliation with rainfall and the Hekeao Hinds River flow suggests that:

- Type A** Base flow with minor variations in NO₃-N concentrations (<±20% variance) – suggesting a primarily shallower groundwater source with shorter lag time nutrient pulses from rain/recharge events.
- Type B** NO₃-N concentrations may be affected by rainfall, suggesting changes in concentrations are influenced by surface run off, or groundwater sources with longer lag times and cumulative response to rain/recharge events.
- Type C** NO₃-N concentrations may be affected by changes in groundwater levels suggesting that changes are driven by a hydrological gradient, such as dilution from river recharge.
- Type D** Affected by a combination of rainfall, river flow and groundwater levels, resulting in dormant springs becoming activated.

These relationships are presented in Figure 58.

Overall, the long-term trend for NO₃-N in HMWC's remains static with a reduction from 14.5 after the 2021 floods to 10.1 in June 2025, as shown in Figure 59.

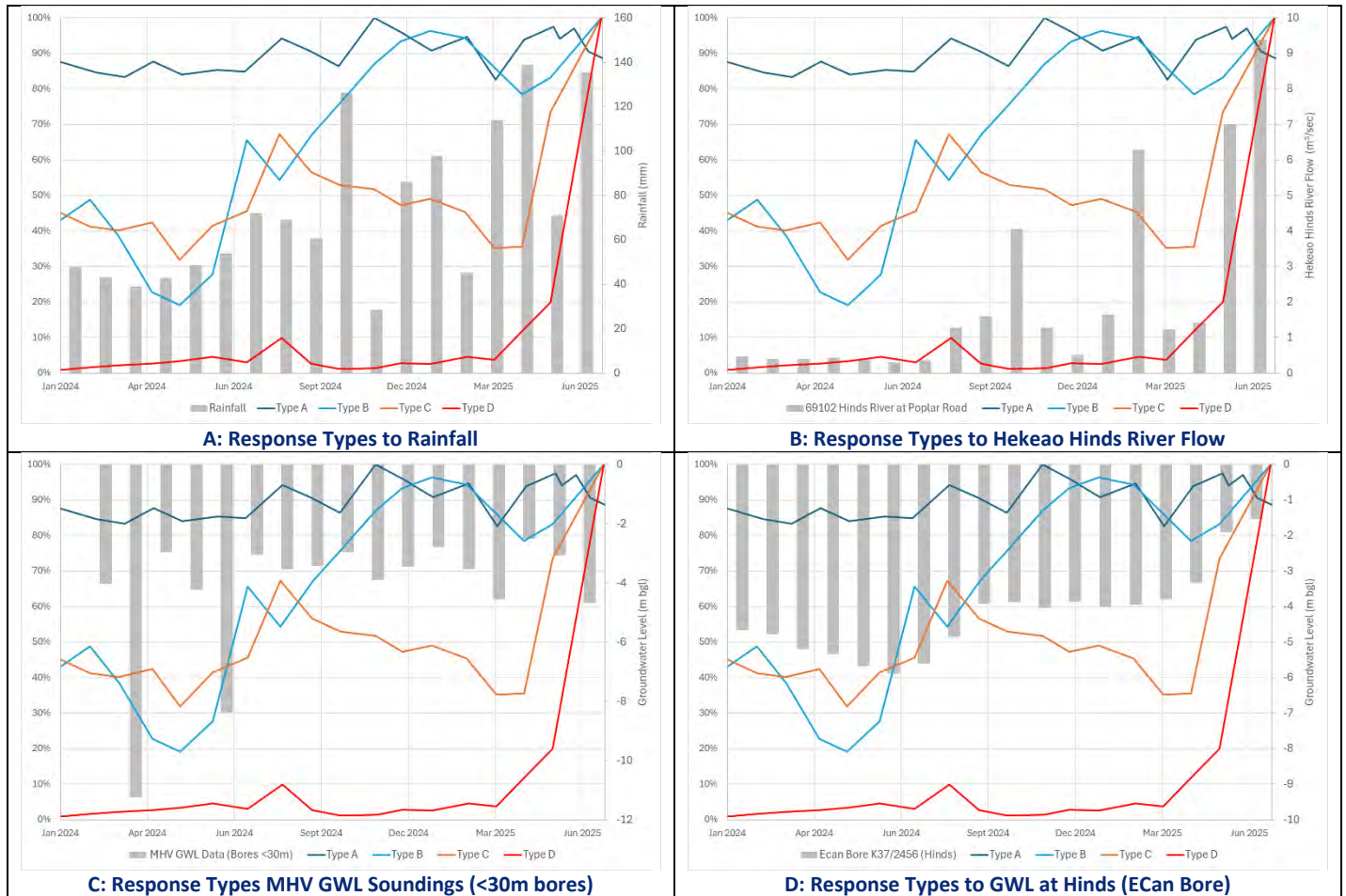


Figure 58 Different NO₃-N response types in HMWC's with respect to rainfall, GWL and river flow

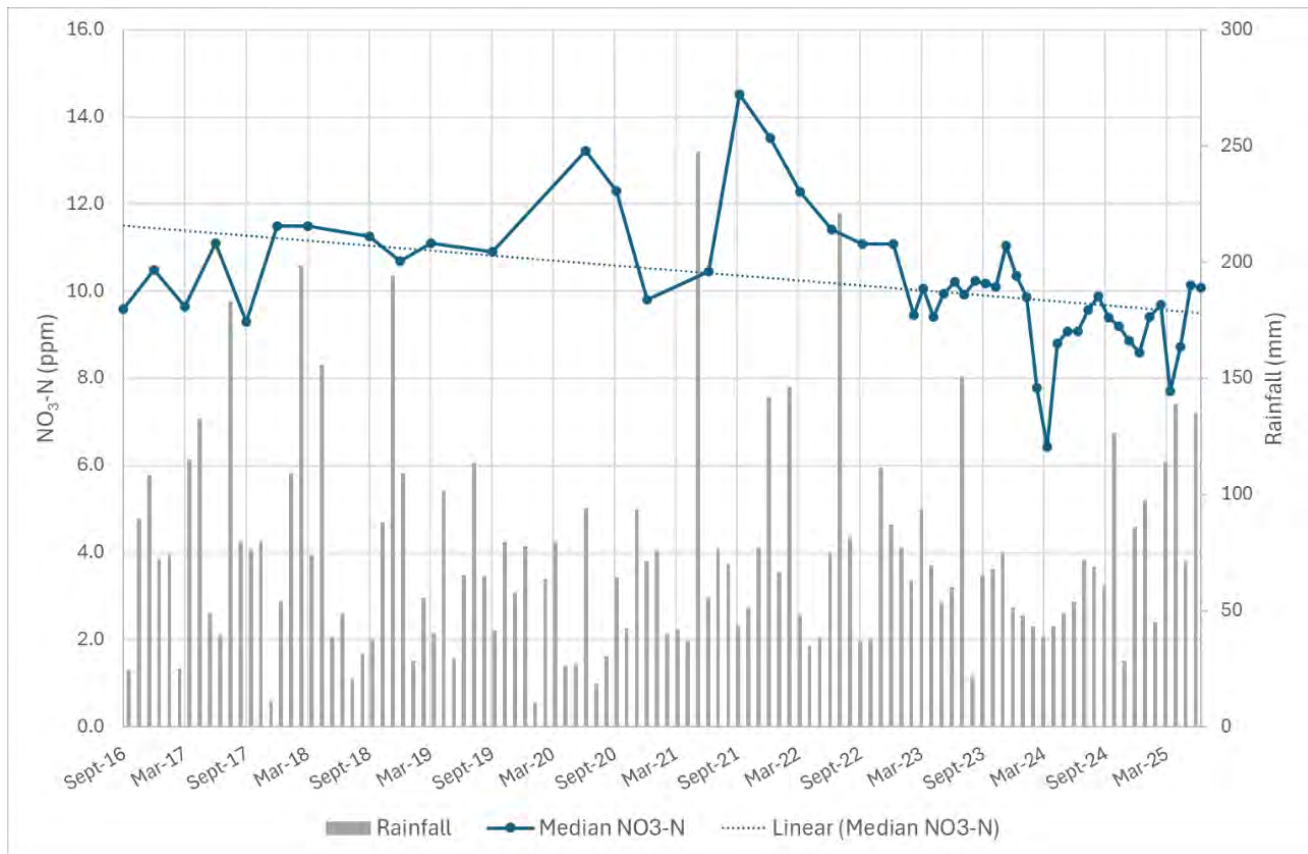


Figure 59 Longterm median trend of NO₃-N for HMWC's

8. Conclusions

Persistent and ongoing rainfall since the latter half of 2024 has seen NO₃-N concentration increases in groundwater at all depths, as well as HMWC's. Unfortunately, with average to above-average rainfall expected until the end of the 2025 calendar year, it is unlikely that NO₃-N concentrations will reduce in the short term.

The increased sampling frequency of HMWC's has enabled 4 different NO₃-N response types to be identified, although further work is required to confirm these preliminary ideas.

The results presented here also support previously identified observations, such as:

- NO₃-N migration is controlled by rainfall and river flow across the catchment.
- There appears to be a relationship with soil type and NO₃-N response to recharge events.
- Lateral flow of water via mechanisms such as open framework gravels appears to be the more dominant mechanism for subsurface NO₃-N migration. This contributes to significant variation across the catchment in nutrient concentration responses to recharge events.

Appendix 1

Statement of Qualifications

1. My name is Justin Legg.
2. I have been a full-time salaried employee of MHV Water Limited, where I hold the position of Senior Hydrogeologist since January 2020.
3. I hold the following qualifications:
 - a. Bachelor of Science (Geology) from the Australian National University, Canberra (1997);
 - b. Bachelor of Science with honours majoring in exploration geology and geochemistry from the University of Tasmania (2001);
 - c. Master of Integrated Water Management majoring in Catchment Management from the University of Queensland (2017).
4. MHV is sponsoring my PhD research at the University of Otago, which directly relates to my role at MHV.
5. I am a current member of the following professional organisations:
 - a. The Australian Institute of Geoscientists
 - b. The Hydrological Society of New Zealand.
 - c. The International Association of Hydrogeologists
6. I have worked exclusively as a geologist on a full-time basis since 1997 and a hydrogeologist on an exclusive full-time basis since 2017.
7. I am a Registered Geologist (R.P. Geo No. 10076) in the fields of Exploration (2008), Mining (2015), and Hydrogeology (2022) in accordance with the Australian Institute of Geoscientists 1996 guidelines.
8. I am considered a *Competent Person* for Public Reporting of Exploration Targets, Exploration Results, and Mineral Resources as defined in the 2012 Edition of the '*Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves*'.
9. I declare that to the best of my knowledge, the information contained herein is accurate, and all third-party information sources have been cited where practically possible.
10. I declare that I have no external financial relationships, social or political affiliations and/ or cultural or religious proclivities that may constitute a conflict of interest.

Appendix 2

Summary of Nitrogen Limits for the National Objectives Framework

Guideline Type	NO ₃ -N mg/l	NH ₄ -N mg/l	Total Phosphorus mg / m ³	Description of Management Class
A – Excellent High conservation value systems (99% protection)	1.0	<0.03	<10	Pristine environment with high biodiversity and conservation values. Lake ecological communities are healthy and resilient, similar to natural reference conditions
B – Good Slightly to moderately disturbed systems (95% protection)	2.4	0.03- 0.24	50 - 120	Environments which are subject to a range of disturbances from human activities, but with minor effects. Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions
Highly disturbed systems (90% protection)	3.8			Environments which have naturally seasonally elevated concentrations for significant periods of the year (1-3 months).
C - Fair Highly disturbed systems (80% protection)	6.9	0.24- 0.54	20 - 50	Environment which are measurably degraded, and which have seasonally elevated concentrations for significant periods of the year (1-3 months). Elevated concentrations from point source discharges or diffuse organic inputs noted. Potential for marked diurnal temperature and pH variability associated with excessive macrophyte, river periphyton and lake phytoplankton growths. Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions
D Acute	20	3.9	>50	Environments which are significantly degraded. Probable chronic effects on multiple species. Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes
Method of comparison	Annual median	Annual median		

Appendix 3

Map Projections

NZTM2000 is formally defined in the LINZ standard LINZS25002 (Standard for New Zealand Geodetic Datum 2000 Projections). The key parameters from this standard are summarised below:

Name:	New Zealand Transverse Mercator 2000
Abbreviation:	NZTM2000
Projection type:	Transverse Mercator
Reference ellipsoid:	GRS80
Datum:	NZGD2000
Origin latitude:	0° 00' 00" South
Origin longitude / central meridian:	173° 00' 00" East
False Northing:	10,000,000 metres North
False Easting:	1,600,000 metres East
Central meridian scale factor:	0.9996

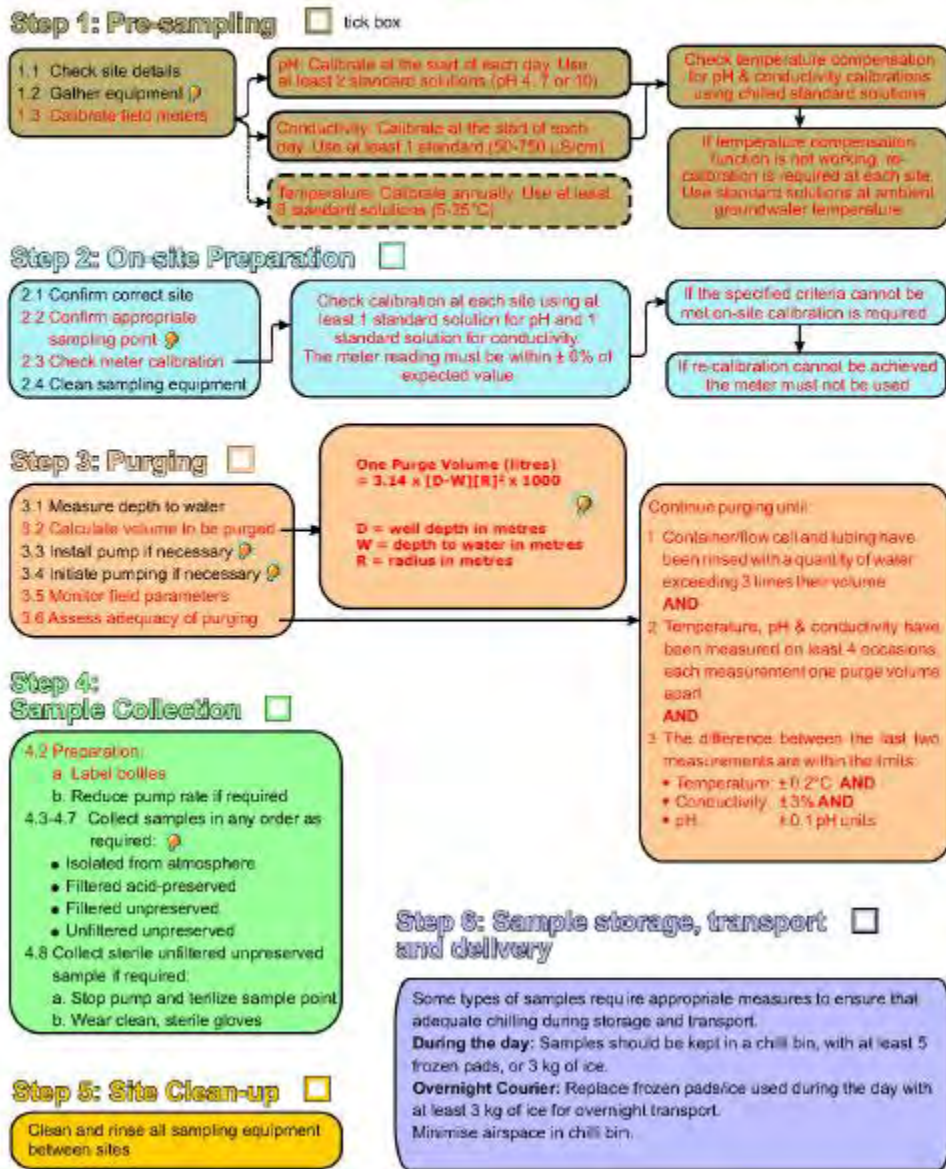
Appendix 4

Nationally Standardised Protocol for State of the Environment Groundwater Sampling in New Zealand

Nationally Standardised Protocol for State of the Environment Groundwater Sampling in New Zealand – Flow Chart

Instructions in **RED** must be done

See over for further explanations



Nationally Standardised Protocol for State of the Environment Groundwater Sampling in New Zealand

- 1.2 A preservative is required for some types of sample, (e.g. an acid preservative for samples to be analysed for cations). Be prepared to chill samples (e.g. for nutrients) to 1-4°C immediately after collection and for the duration of transport to the laboratory.
- 2.2 An appropriate sampling point is one that minimises the purging time (see Step 3) and minimises the potential for contamination or alteration of the sample. It is acceptable to collect samples from a short length of clean hose attached to the tap or wellhead.
- 3.2 For calculation of purge volume:
 - Well depth, depth to water, and well radius must be expressed in meters in order to derive the purge volume in litres.
 - If the depth to water under ambient (non-pumping) conditions cannot be determined for any reason, assume "depth to water" = 0.
 - Well depth can be obtained from the drilling log or through the use of the dip tape.
 - Well radius refers to the casing dimension and not to the dimension of the bore.
 - If it is not possible to determine depth to water and if the well depth is unknown, then purge volume cannot be calculated. In this case, any samples collected from the well will not comply with this protocol.
- 3.3 The pump should be installed so that its intake is positioned at least 1 m below the static water level and a minimum distance above the top of the screened/open interval of 10 times the well diameter (for example, 1500mm for a 150mm well diameter). This will ensure that the sample is representative of the entire screened or open interval of the well.
- 3.4 A suitable pumping rate produces a continuous stream of water from the pump outlet or sample point without turbulence, entrainment of air or pump cavitation. Compliance with this protocol requires determination of the pumping rate during purging.
- 3.6 For assessment of adequacy of purging, note that:
 - The purging operation requires extraction of *at least three times* the calculated purge volume and may require extraction of many more than three times the calculated purge volume.
 - The field values of temperature, conductivity and pH must be measured on at least four separate occasions, each measurement at least one purge volume apart.
 - The differences between the last two sets of field measurements must be the same within the following limits:
 - Temperature: $\pm 0.2^{\circ}\text{C}$, AND
 - Conductivity: $\pm 3\%$ ($\pm 5\%$ if $< 100 \mu\text{S/cm}$ at 25°C), AND
 - pH: ± 0.1 pH unit
- 4.3-4.7 All samples must be collected sequentially from the sample point or from a short length of clean tubing attached to the sample point. The filtered acid-preserved, filtered unpreserved, unfiltered unpreserved samples and the samples collected in isolation from the atmosphere can be collected in any order.
- 4.8 Sterile samples must be collected after all other samples. This is because the requirements for sterilisation could potentially influence the chemistry of samples collected afterwards. Note that sterilisation of the sample point requires the pump to be turned off briefly.



Refer to Groundwater Sampling Protocol for further detailed explanations when required



Standing Water Level measurements



Standing Water Levels (SWL) were obtained for background information, as well as to estimate the purge volumes required. Due to the potential for water monitoring equipment to become jammed and subsequently damaged (and/ or lost completely) within the within the wellhead infrastructure, or fouled amongst pump service cables, measurement of water levels was restricted to bores with an alkathene conduit down the bore, as shown in Figure 60.

Standing Water Level is the ambient water level of an active bore that is not being pumped at the time of the observation.

Static Water Level is the ambient water level of an abandoned bore that has not been pumped for a considerable period of time.

Figure 60 Well head with alkathene conduit

Water Column Purging and Sampling

Sampling was restricted to domestic and irrigation bores with pumps installed.

Locations of bores were confirmed via a Garmin eTrex 10 Handheld GPS. All sampled bores had a field sheet written up, indicating:

- Physical address
- Location on farm
- Pump and bore configuration
- On farm contacts

Where possible, samples were collected in accordance with New Zealand standard protocols (Daughney et al., 2006, refer to Appendix 2 with purge times amended for practicality as shown in Table 16.

Table 16 Water bore purging protocols for sampling

Bore Type	Assumption	MHV purge time
Domestic	Bore will be regularly purged	Minimum of 1x water column volume purged If occupants not home, then 3x water column purged
Farm Support	<ul style="list-style-type: none"> i. If used for domestic purposes, bore will be regularly purged. ii. If bore is running, then the bore has been purged. iii. If the farm has been / is milking, then the bore has been purged. 	Purge time 15 minutes if (i) to (iii) else bore purged 3x water column
Irrigation	Bore will be purged already if running. If not – purge required	Purge time 10 minutes if the pump running, else bore purged 3x water column volume. If the bore is offline (i.e. off season) – no sample taken
Domestic Tank	Purge unavailable, sample taken from the domestic tank	None – but noted as tank sample
Dairy Tank	Purge unavailable, sample taken from the low flow tap next to milk filter in dairy shed (Figure 61)	None – but noted as tank sample



Figure 61 Example of a low flow tap next to milk filter in dairy shed

Appendix 5

NIWA Stations

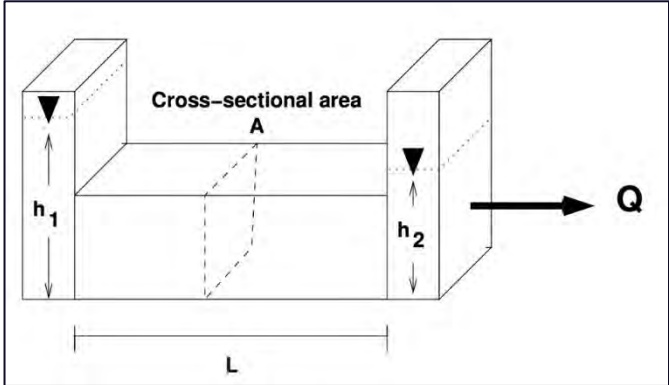
Name	Agent No.	Network No.	Latitude	Longitude	NZTM (mE)	NZTM (mN)	Height (m)	Observing Authority
Mt Somers, Somer Downs	18394	H31641	-43.674	171.413	1472069	5163110	372	N/A
Ashburton Aero AWS	26170	H31983	-43.903	171.804	1503965	5138172	88	Metservice
Orari Estate EWS	35704	H41132	-44.125	171.311	1464854	5112878	81	NIWA
Methven CWS	36645	H31665	-43.640	171.652	1491282	5167249	313	NIWA
Methven, Three Springs CWS	37920	H31656	-43.678	171.588	1486216	5162955	305	NIWA
Dorie CWS Riverstone	38866	H32805	-43.832	172.094	1527182	5146376	55	N/A
Arundel Simla	39315	H31824	-43.937	171.303	1463801	5133724	237	N/A
Chertsey CWS	39661	H31793	-43.794	171.961	1516388	5150492	108	NIWA
Lismore Racemans House CWS	39845	H31944	-43.921	171.486	1478423	5135819	168	NIWA
Wakanui 2 CWS	41200	H31986	-43.972	171.811	1504628	5130583	53	NIWA
Winchmore 2 EWS	42899	H31772	-43.789	171.790	1502671	5150806	164	NIWA
Mayfield At Ruapuna Forecast	43538	H31827	-43.859	171.299	1463333	5142392	325	NIWA
Springburn	4711	H31643	-43.690	171.483	1477776	5161461	312	N/A
Rakaia, Greenfields	4720	H31671	-43.609	171.733	1497722	5170817	305	N/A
Mt Somers	4734	H31736	-43.706	171.401	1471170	5159537	383	N/A
Lyndhurst Limewood Farm	4740	H31771	-43.703	171.717	1496625	5160313	243	N/A
Orari Gorge	4771	H31926	-43.976	171.196	1455307	5129210	259	N/A
Peel Forest	4772	H31927	-43.907	171.259	1460198	5137027	286	N/A
Ashburton Council	4778	H31971	-43.897	171.747	1499384	5138848	101	N/A
Kakahu Bush	5053	H41111	-44.159	171.096	1447757	5108704	122	N/A
Orari Estate	5061	H41131	-44.127	171.308	1464635	5112629	81	N/A
Coldstream No 3	5065	H41153	-44.156	171.542	1483413	5109766	12	N/A
Timaru Aero Aws	5086	H41325	-44.305	171.221	1458135	5092689	27	Metservice

Glossary

Taken from *Water quality in New Zealand: Understanding the science* [44] and other sources where cited

Aerobic	A condition of water where the oxygen level is high enough to support oxygen using bacteria.
Algae	A class of simple aquatic plants, including microscopic species known as periphyton and phytoplankton. Larger algae like seaweeds and charophytes are known as macrophytes. Almost all algae can use photosynthesis but are dependent on nutrients including nitrogen and phosphorus.
Algal bloom	Dense growths of microscopic algae or cyanobacteria in response to high nutrient levels and warm temperatures. Often makes water discolored and turbid, sometimes including scum on the surface of the water.
Ammonia	A highly soluble nitrogen compound, chemical formula NH_3 , characteristically found in manure, sewage and anaerobic conditions.
Anaerobic	A condition of water where the oxygen level is too low to support any kind of oxygen-breathing life.
Anoxic	Without any oxygen.
Aquifer	A geological layer of sand, gravel, or fractured rock that contains groundwater. Confined aquifers are underneath impermeable layers of silt or clay (aquitards) so they do not receive water and dissolved pollutants from land directly overlying them. Unconfined aquifers lack aquitards, so pollutants can leach directly into them.
Benthic	Living on the bottom of a water body.
Biochemical oxygen demand (BOD)	The amount of dissolved oxygen needed by micro-organisms to break down organic matter in the water. It is a measure of organic pollution, usually from wastewater.
Blue-green algae	See Cyanobacteria
Campylobacter	A type of bacteria living in the guts of humans and animals, which may cause gastroenteritis.
Catchment	A catchment is the area of land feeding a river system. All the precipitation within the catchment combines and flows down to form a single interconnected network of water bodies, including streams, rivers, lakes, wetlands, and aquifers.
Chlorophyll	A pigment used by plants, algae, and cyanobacteria to harvest energy from light as part of photosynthesis.
Cryptosporidium	A type of protozoan pathogen, living in the guts of humans and animals.
Cyanobacteria	A group of bacteria that can use photosynthesis, like true algae. Some species are periphyton and others are phytoplankton. Unlike freshwater algae, some species of cyanobacteria produce toxins and some are able to extract nitrogen directly from the air.
Darcy's Law	Developed by Henry Darcy in 1856, the law describes the flow of a fluid through a porous medium such as an aquifer.

	<p>Darcy's Law states that <i>Total Flow (Q)</i> is proportional to the change in <i>Head Pressure (h)</i> (or hydraulic gradient) due to friction relative to the <i>Cross Sectional Area of Flow (A)</i>, which is proportional to the flow distance or <i>Length (L)</i> (Hiscock & Bense 2014). This is presented schematically in below(Brikowski 2013).</p> <p>The <i>Permeability (K)</i> of the material is derived from the 'Kozeny-Carman Equation' $K = Cd^2$ where C is the tortuosity (grain size distribution) of the medium and d is the mean grain diameter (a proxy for the mean pore diameter) (Brikowski 2013).</p> <p>Hence Darcy's Law is expressed as: $Q = -KA (h_1-h_2)/L$</p>
Denitrification	A bacterial process removing nitrate from soil, air, or water, requiring anaerobic conditions and usually forming nitrogen gas.
Deposited sediment	Layers of fine sand, silt, and clay that have settled on the bottom of a waterway.
Diffuse source pollutants	Pollutants that do not come from a single end-of-pipe source, but from many small sources or from a wide area of leaching, runoff, erosion, etc.
Dissolved Oxygen	A relative measure of the amount of oxygen (O ₂) dissolved in water.
Escherichia coli	(abbr. E. coli) A type of bacteria that live in the guts of humans and other animals. Although usually harmless themselves, high levels of E. coli indicate that other pathogens are present.
Flow regime	Typical behavior of a stream or river, including how much water it carries, how fast it flows, how often it floods, and how big its flood peaks are.
Freshwater	Water of salinity less than 1,000 mg/L
Gastroenteritis	General term for gut disease involving inflammation of the stomach and intestines.
Giardia	A type of protozoan pathogen, living in the guts of humans and animals. Notoriously associated with trampers and possums, occasionally found in poorly treated drinking water supplies.
Hydraulic conductivity (K) (coefficient of permeability)	A measure of how easily water can pass through soil or rock. High values indicate a permeable material through which water can pass easily; low values indicate that the material is less permeable. Ranges of intrinsic permeability, k, and hydraulic conductivity, K, values. The alternating colours are used to make the chart easier to read [45].
Hypoxic	Of water with low levels of oxygen, low enough to kill fish.
Invertebrates	Types of animals without a backbone, such as insects, worms, and snails.
Leaching	Process by which pollutants in and on soil are dissolved by rain or irrigation water and carried down into groundwater.



Leptospirosis	An infectious bacterial disease of rats, dogs, pigs, and other animals, which can be transmitted to humans.
Macrophytes	Large water plants and algae that are visible to the naked eye, as opposed to the microscopic periphyton and phytoplankton.
Meteoric water	Water derived from rain, snow, streams, and other bodies of surface water that percolates in rocks and displaces interstitial water that may have been connate, meteoric, or of any other origin.
Mole-and-tile drainage	Drainage systems to remove excess water from heavy clay soils, formed by tunnelling through the soil (mole drains) or by laying down pipework (tile drains).
Nitrate	A highly soluble compound of nitrogen and oxygen with the chemical formula NO_3
Nitrification	A process, usually bacterial, forming nitrate from other forms of nitrogen.
Nitrogen	A chemical element, symbol N. Common forms of nitrogen in water include ammonia and nitrate. 'Nitrogen gas' N_2 , also makes up about 78 percent of the Earth's atmosphere. All life needs nitrogen for molecules such as proteins and DNA.
Non-point source pollution	Diffuse source pollution.
NTU	'Nephelometric turbidity units'; arbitrary units in which turbidity is measured.
Nutrient	A substance, element, or compound that organisms need to live and grow.
Nutrient budget	A calculation comparing nutrients brought onto a farm in fertilizer, feed, and new stock, with nutrients lost in produce, leaching, runoff, and into the atmosphere as gas.
Nutrient management plan	A written plan that documents how the major plant nutrients on a farm will be managed to maximize production or productivity while minimizing any adverse effects.
Organic matter	Any solid, liquid, or gaseous substance that contains carbon. It is generally taken to mean substances that have been produced by a plant or animal.
Pathogens	Disease-causing micro-organisms, including many bacteria, protozoa, and viruses.
Periphyton	Microscopic algae, cyanobacteria, and bacteria living in fresh water but attached to objects such as submerged rocks, wood, or macrophytes.
Phosphorus	A chemical element, symbol P. The most common form of phosphorus is (ortho)phosphate PO_4^{3-} which is only slightly soluble in water. Phosphates are constituents of bone and of molecules like DNA.
Photosynthesis	A biochemical process by which green plants and some other organisms use sunlight to help them make organic matter from carbon dioxide gas. Photosynthesis generally involves the green pigment chlorophyll. Oxygen is generated as a by-product.
Phytoplankton	Microscopic algae and cyanobacteria drifting or floating in water.
Plankton	Organisms drifting or floating in water, including some algae, some cyanobacteria, waterborne pathogens, and microscopic invertebrates.

Point sources	Pollutants from local, stationary sources such as factories or mines, which discharge wastewater through pipes or channels.
Porosity	The proportion of solids to voids in a sedimentary formation.
Precipitation	Water deposited on the ground; dew, rain, snow, etc.
Profile available water (PAW)	The amount of water potentially available to plant growth that can be stored in the soil to 100 cm depth. PAW takes into account variations in soil horizons and is expressed in units of millimetres of water, i.e. in the same way as rainfall. A PAW of 100 mm implies that 10% of the soil volume is water available to plants. Low PAW is <60 mm, moderate is between 60 and 150 mm, and high is ≥150 mm.
Protozoa	A class of simple, one-celled micro-organisms that do not photosynthesize, instead preying on bacteria, algae and other microscopic organisms. They include pathogens like Giardia and Cryptosporidium.
REDOX Reduction / Oxidation.	A chemical reaction that takes place between an oxidizing substance and a reducing substance. The oxidizing substance loses electrons in the reaction, and the reducing substance gains electrons.
Respiration	The process whereby animals, plants, algae, and some bacteria use oxygen to break down carbohydrates to generate energy. Respiration reduces dissolved oxygen.
Riparian	Relating to the banks of a river or wetland; a riparian strip is a buffer zone covered with plants and trees between surrounding land and a waterway.
Run-off	Water moving overland, carrying fine sediment and dissolved pollutants.
Salmonella	A family of bacterial pathogens that live in the guts of humans and other animals. In humans they can cause diarrhoea and vomiting; in cattle and sheep the symptoms are similar but often fatal.
Sediment	Material transported by the water. Sediment is generally inorganic material, but can include organic material such as plant fragments, and dead algae.
Sedimentation	Settling or depositing of sediment within waterways.
Sewage fungus	A form of periphyton made up of masses of bacteria, growing in water polluted by organic matter.
Stratification	Formation of two distinct layers within a lake over summer; a bright, warm upper layer or 'epilimnion' and a denser, cooler lower layer or 'hypolimnion'.
Suspended sediment	Particles of silt, clay, or organic matter floating in water.
Transmissivity	The rate of flow under a unit hydraulic gradient through a unit width of aquifer of given saturated thickness. It is measured in m ² per-day
Turbidity	Murkiness or cloudiness of water due to suspended sediment and/or other material, including phytoplankton.
Typhoid	A disease affecting people only, caused by the bacteria Salmonella enterica Typhi, transmitted in food or water. Typhoid causes fever, gastroenteritis, and potentially death.
Wash load	Suspended sediment carried by a stream or river.
Watershed	The boundary dividing one catchment from its neighbours.

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