Christchurch Water Supplies

Water Safety Plan

Volume C: Christchurch/Lyttelton

Source Water Risk Management Plan

Christchurch City Council

Revision 1.0

May 2022

Christchurch City Council

Water safety plan requirements are provided in three parts. This volume (Volume C) covers information that is specific to the Christchurch/Lyttelton source water supply.

This information is to be read alongside Volume A which contains the water safety plan components that are common to all of the Council's water supplies (TRIM22/438283) and Volume B (TRIM22/438287)

Version Control

Revision Number	Year	Record Number	Revision	Prepared By
Revision 1	2022	TRIM 22/438290	Full revision	Judy Williamson

Internal Document Review and Approval

Revision Number	Year	Reviewed By	Approved By	Signature	Date
Revision 1.0	January 2022	Veronica Zefferino (CCC Team Leader Quality & Compliance)	Helen Beaumont Head of Three Waters		27/05/2022

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1 Source Risk Management Plans

1.1 Introduction

The Water Services Act requires that as part of the supplier's drinking water risk management plan that a source risk management plan must also be prepared.

A source risk management plan must:

- Identify any hazards that relate to the source water, including emerging or potential hazards
- Assess any risks that are associated with those hazards
- Identify how those risks will be managed, controlled, monitored, or eliminated and
- Have regard to any values identified by local authorities under the National Policy Statement for Freshwater Management that relate to a freshwater body that the supplier uses as a source of drinking water (section 43 WSA 2021).

"We will be unwavering in our advocacy and actions to minimise nitrate incursion (and other contaminants) into ground water sources used for our drinking water supply. The city will do all it can to protect its aquifers."

This is an extract from Christchurch City Council's Integrated Water Strategy ed Te Wai Ora o Tane Integrated Water Strategy which was adopted on 26th September 2019. This strategy was prepared by the Council to ensure that its water services, infrastructure and water taonga are managed in a manner that supports the environment, social, cultural and economic well-being of current and future generations. The vision of Te Wai Ora o Tane Integrated water strategy is "water is a valued taonga, in all that we do".

Christchurch has some of the best drinking water in the world, but no water supply is completely without risk. Bacteria, viruses, nitrate, metals and other chemicals can contaminate water. Some contaminants occur naturally, while others come from human activities. This document explores the risks of contamination to the sources of Christchurch's drinking water and how those risks are managed.

1.2 Assessment of the potential effects of catchment land-use on source water

The "Technical Guidelines for Drinking Water Source Protection Zones"[1] (PDP, 2018) was work commissioned as part of the review of the National Environmental Standards for Sources of Human Drinking Water; it outlines the method for assessing contamination risks to drinking water sources by assessing:

- the source of contamination
- the receptor that may be adversely affected by the contamination
- the pathway that allows the contaminant to reach the receptor.

For a risk to be present, all three components – source, pathway and receptor – must be present. The risk can be managed by eliminating one of these three components or to make the pathway between the source of contamination and receptor contain sufficient barriers so that the risk of an adverse effect on the drinking water supply is acceptable.

In the Christchurch/Lyttelton context, the receptor that may be adversely affected by contamination is the water supply wells. The sources of contamination that are present within the wider recharge area could introduce different types of contaminants to the wells and are described in TRIM

[1] PDP, 2018: Technical Guidelines for Drinking Water Source Protection Zones: https://www.mfe.govt.nz/publications/fresh-water/technical-guidelines-drinking-water-source-protection-zones

20/1427862 (Summary Table of Pump Station and Well Investigations) and are summarised in Table 1.

Table 1: Summary of potential contamination sources in the water supply catchment

Contamination Source	Types of Contaminants
Low intensity farming (outskirts of Christchurch)	Bacteria, Protozoa, Agrichemicals, Nitrate
Discharges – animal effluent	Bacteria, Protozoa, Nitrate
Reticulated wastewater network	Bacteria, Protozoa, Viruses
Residential/commercial/industrial on-site stormwater disposal	Bacteria, Chemicals
Historic landfills and contaminated sites	Bacteria, Chemicals
Roading infrastructure	Chemicals

According to the PDP guideline (detailed above) an effective barrier in the pathway between the contamination source and the receptor is attenuation of the contaminant between the source of contamination and the well.

Longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes:

- Dispersion and dilution
- Filtration and adsorption
- Bio-degradation and chemical transformation
- Pathogen die-off, mitigation

2 General Description of the Drinking Water Source

2.1 Overview

Christchurch City is situated on the flat alluvial Canterbury plains, bounded by the Port Hills to the south and the Pacific Ocean to the east. The city lies above the Christchurch West-Melton Aquifer System, which is part of the wider Canterbury Groundwater System. Figure 1 provides a 3D schematic of the Canterbury Plains and Figure 2 provides a simplified schematic of the Christchurch-West Melton Aquifer system. About three quarters of the aquifer system is recharged by seepage from the Waimakariri River and the remainder by infiltrating rainfall on the plains to the west and north of the city (see Figure 3). Groundwater modelling by GNS in 2018 found that an area north of the Waimakariri River could also contribute to Christchurch's aquifers[2].

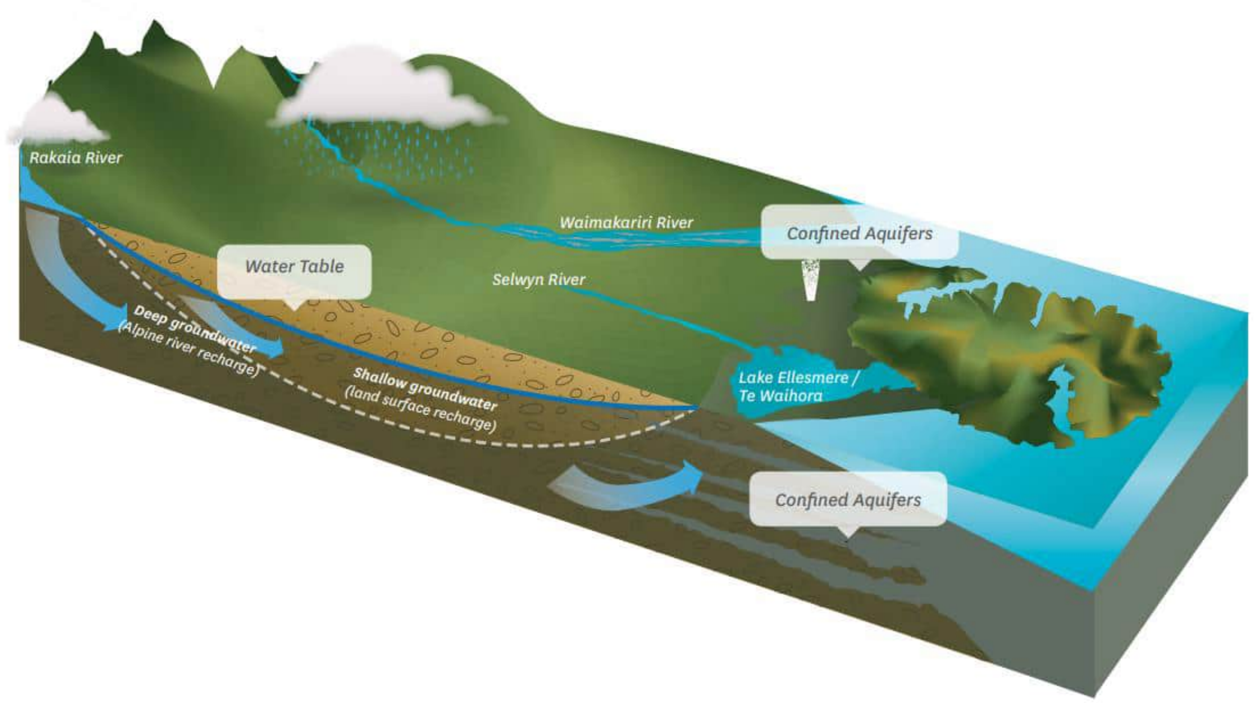

Figure 1: 3D Schematic of the Canterbury Plains

[2] Hemmings, B.J.C, Moore, C.R., Knowling, M.J (2018) Calibration constrained Monte Carlo uncertainty analysis of groundwater flow and contaminant transport models for the Waimakariri-Ashley region of the Canterbury Plains. Lower Hutt (NZ): GNS Science https://api.ecan.govt.nz/TrimPublicAPI/documents/download/3632774

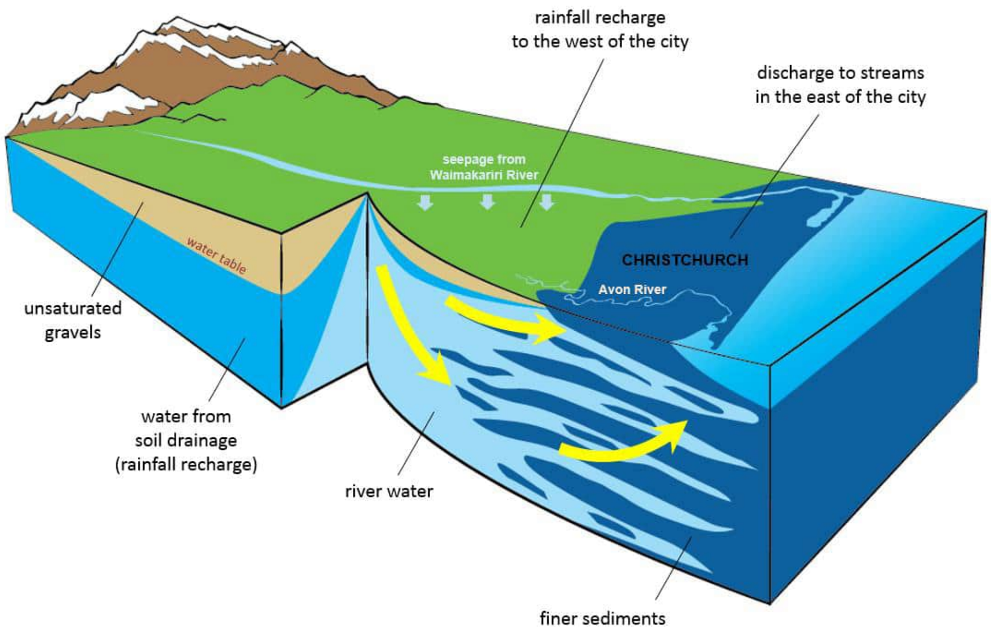

Figure 2: Schematic of the Christchurch-West Melton Groundwater System

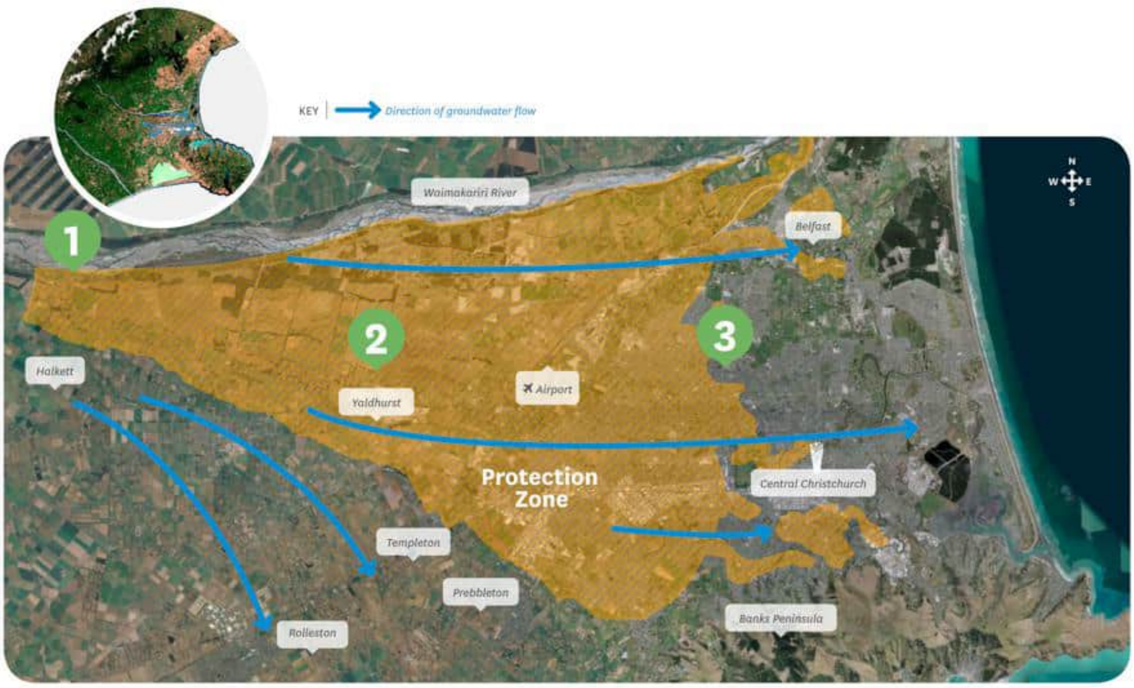

Figure 3: Where does Christchurch's water come from?

Notes accompanying Figure 3:

1: Downstream of this point, some of the water in the river begins to flow into the gravels of the plains, topping up the aquifers on which Christchurch depends for its drinking water.

2: Environment Canterbury owns a significant amount of land in this area. The land is managed to ensure it is used for appropriate purposes that will not have an adverse impact on Christchurch's groundwater.

3: Flow through the gravels is at about 25m a day, groundwater takes a few years to reach the zone from which Christchurch takes its drinking water.

2.2 Source catchment, well characteristics and source water risk management

2.2.1 Source catchment

The Christchurch City and Lyttelton Harbour Basin water supply is sourced entirely from the Christchurch-West Melton groundwater system. It comprises late Quarternary deposits of postglacial and interglacial fluvial gravels. Towards the coast, these gravels are interbedded with fine sand, silt, peat and clay deposits, together with marine, estuarine and lagoon sediments which accumulated during fluctuating climatic periods of the last 1 million years.

Figure 4 shows the sequence and nomenclature of the late-Quarternary deposits underlying Christchurch. Flowing artesian aquifers underlie the area from the coast extending inland to Papanui, Fendalton and Riccarton. Five known aquifers are present to a depth of over 200 metres.

Figure 5 illustrates the recharge sources of the upper aquifers of the Christchurch-West Melton groundwater system and shows the western limit of groundwater confinement in the first confined aquifer (Riccarton Gravel), indicated by the 3 metre isopach (thickness) line.

The principal aquifers are in outwash and reworked gravel deposits. The intervening silt, sand, and peat layers confine the groundwater.[3] The overlying confining sediments (Christchurch Formation) increase in thickness eastwards of 3 metre isopach line and are about 30 – 40 metres thick at the coast.

Recharge of the Christchurch-West Melton groundwater system occurs in the unconfined areas primarily from drainage from the Waimakariri River and rainfall on the plains. About three quarters of groundwater is recharged by Waimakariri River, with rainfall derived infiltration providing the remainder.

A contributing source of groundwater to the deep aquifers in the northeast part of the confined zone is deep flow beneath the Waimakariri riverbed from north of the Waimakariri River. This is based on groundwater modelling undertaken by GNS for Environment Canterbury and is described in the "Waimakariri Land and Water Solutions Programme – Options and Solutions Assessment – Nitrate Management" (Kreleger & Etheridge, 2019)[4]. The source area north of the Waimakariri River is shown in Figure 6**Error! Reference source not found.**. There is a risk that nitrate concentrations could increase in the Christchurch water supply in the future as a result of intensive land use north of the Waimakariri River. The Council made a submission and presented evidence on Plan Change 7 of Environment Canterbury's Land and Water Regional Plan (CLWRP) on this matter, advocating for more stringent controls on land use and an accelerated programme to reduce nitrate leaching from farms in this groundwater source area. The submission proposed a nitrate threshold of 1 milligram per litre of nitrate nitrogen (1mg/l NO_3-N) as the preferred option. Predicted levels of increase in nitrate are within maximum allowable values (MAVs) in the current DWSNZ (2018). Council submitted taking a precautionary approach based on the likelihood that the MAVs could reduce because of research that shows a link between lower nitrate concentrations and colorectal cancer.[5] This Danish based study has since lead to a NZ specific review of data

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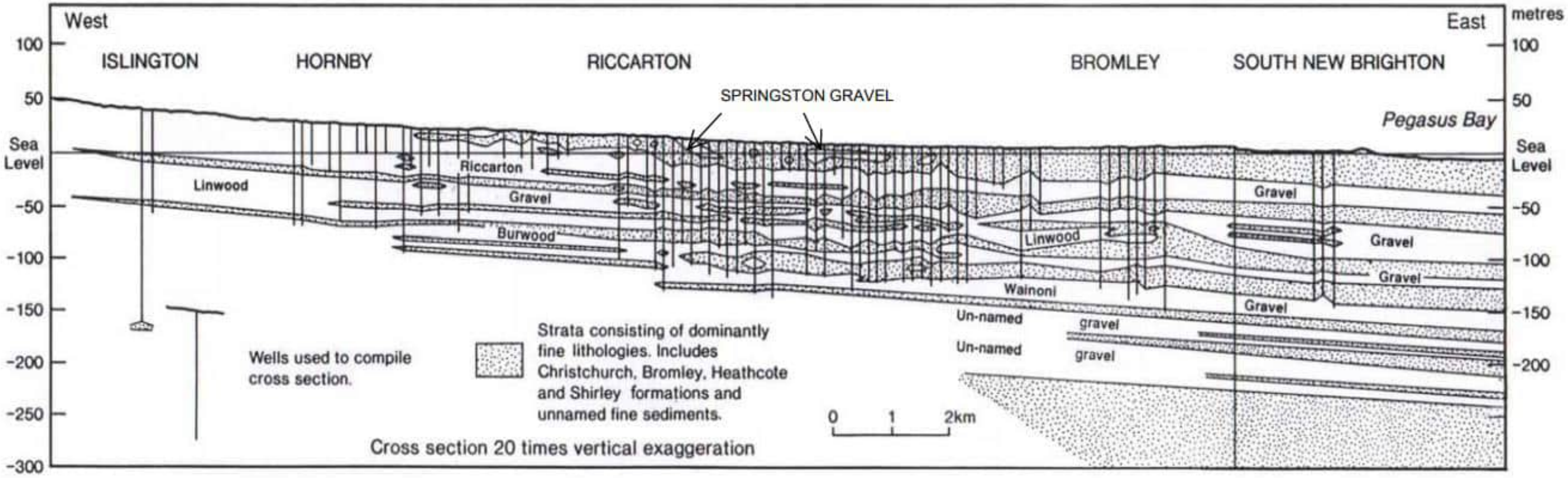
[3] S.A. Hayward, 2002. Christchurch-West Melton Groundwater Quality: a review of groundwater quality monitoring data from January 1986 to March 2002. Report No U02/47: https://api.ECan.govt.nz/TrimPublicAPI/documents/download/454603

[4] Kreleger & Etheridge, 2019: Waimakariri Land and Water Solutions Programme – Options and Solutions Assessment – Nitrate Management: https://api.ECan.govt.nz/TrimPublicAPI/documents/download/3626251 (Jorg Schullehner, 2018)

[5] Jorg Schullehner et al Nitrate in drinking-water and colorectal cancer risk: A Nation-wide population based cohort study Int J Cancer 2018 July1;143(1):73-79

which concluded that a substantial minority of New Zealanders are exposed to high or unknown levels of nitrates in their drinking water and given the international evidence showing the association between cancer and nitrate ingestion from drinking water that improvements to water management are justified.[6]

[6] Jayne Richards, Tim Chambers, Simon Hale etc al. Nitrate contamination in drinking water and colorectal cancer: Exposure assessment and estimated health burden in New Zealand. Environ Res 2022 March;204(Pt C):112322



Stratigraphy of the Christchurch – West Melton groundwater system (Brown and Weeber, 1992)

Riccarton gravel – Aquifer 1
Linwood gravel – Aquifer 2
Burwood gravel – Aquifer 3
Wainoni gravel – Aquifer 4
Un-named gravel – Aquifer 5

Figure 4: Stratigraphy of the Christchurch–West Melton Groundwater System

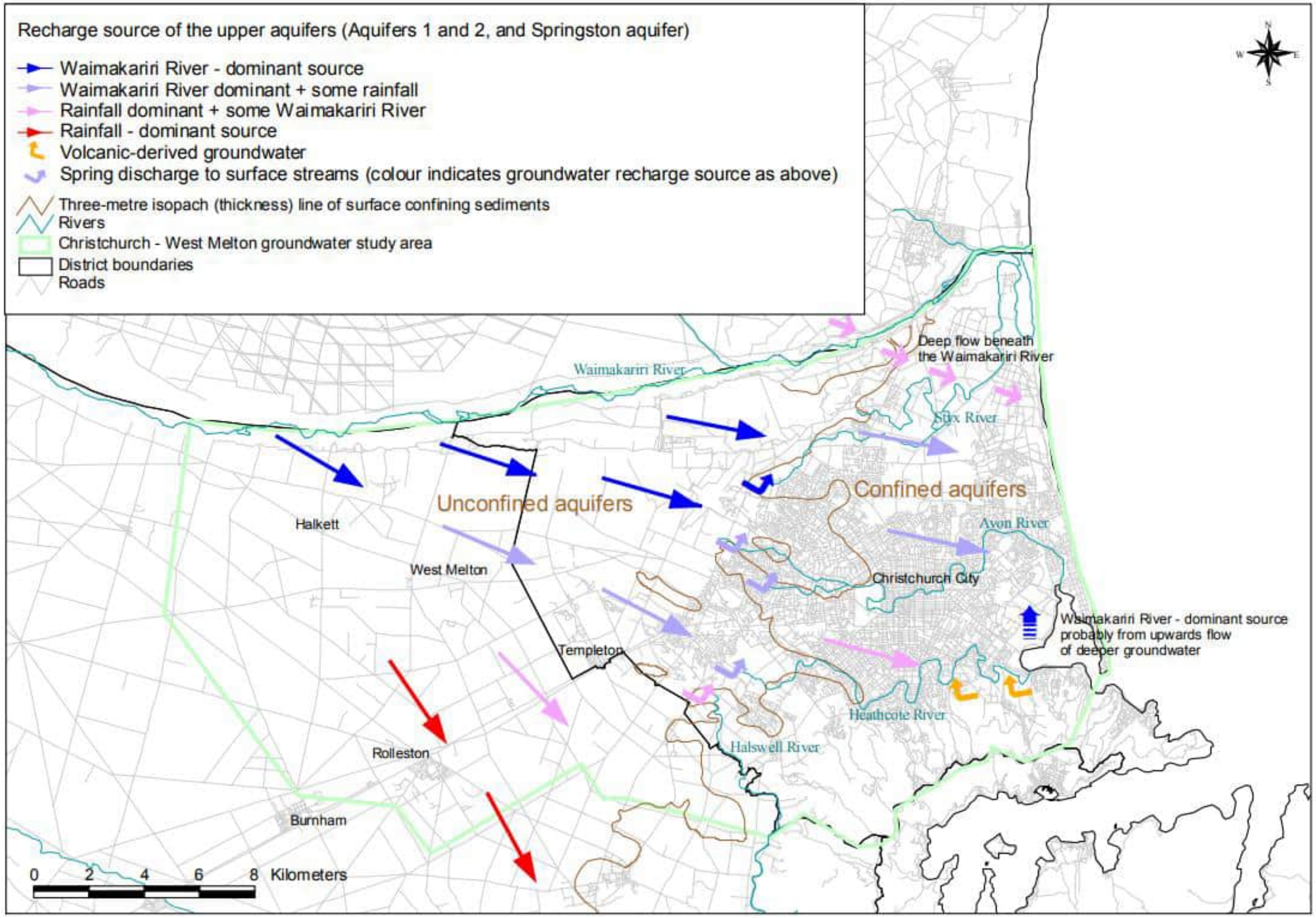


Figure 5: Recharge Sources of the Upper Aquifers of the Christchurch-West Melton Groundwater System

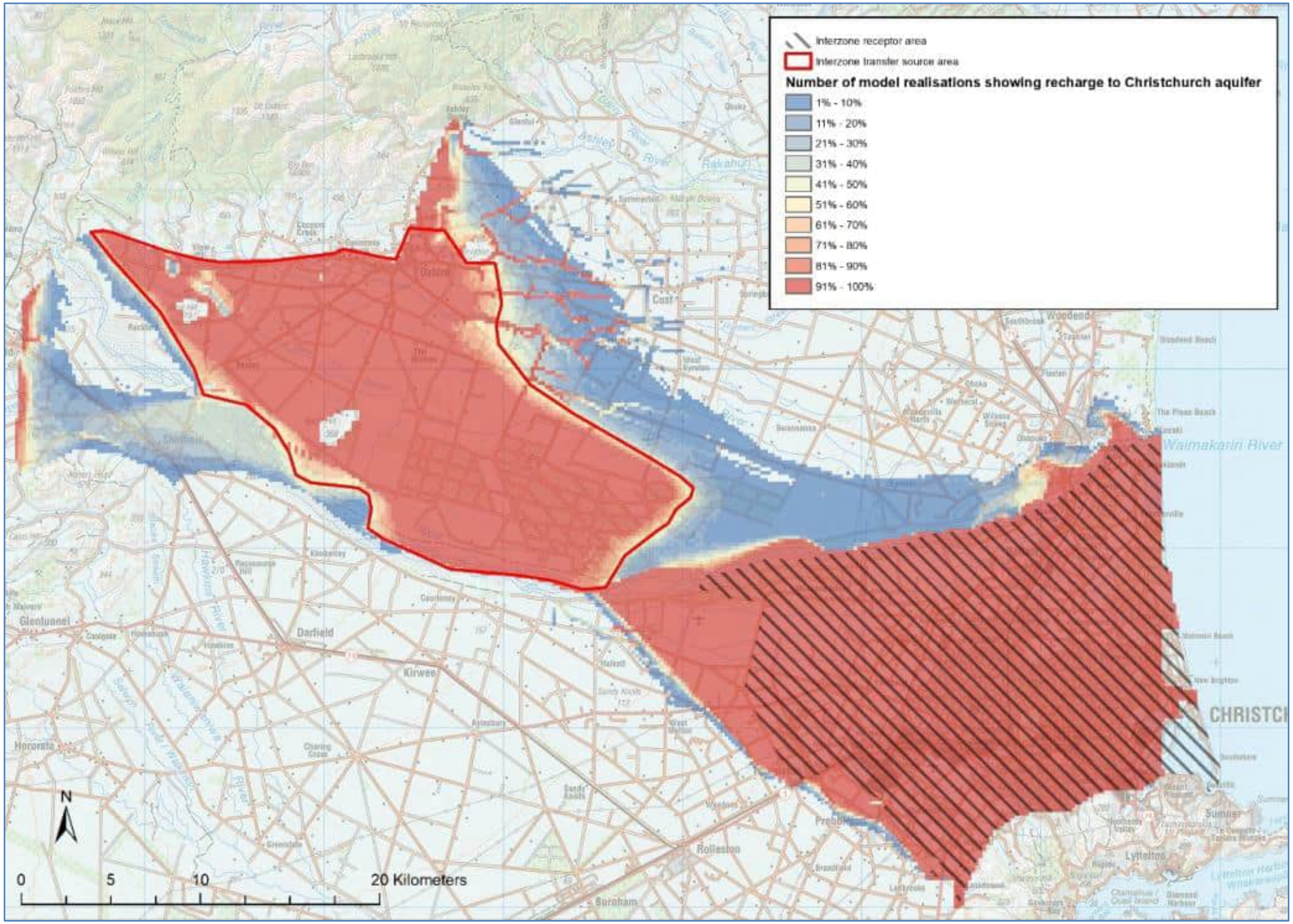


Figure 6: Waimakariri Recharge Sources of the Christchurch Groundwater System

The risk of surface or climatic influences on the aquifers is related to the thickness of the confining layer, the presence (or absence) of an upwards hydraulic gradient and the length of flow paths leading to any water supply well.

As illustrated in Figure 5 and Figure 6, Aquifer 1, the shallowest aquifer in the system, is protected from surface and climatic influences in the east of the city by a thick, low permeability layer. It has less protection in the west of the city where the confining layers are thinner, and in the Heathcote-Woolston area where the aquifers thin out and pinch adjacent to the low permeability volcanic rock. The extent of the 3-metre isopach (thickness) line of surface confining sediments is shown in Figure 4. Shallow wells located to the east of this line are considered unlikely to be affected by surface or climatic influences, and shallow wells located to the west of this line are considered more susceptible to surface or climatic influences.

Aquifers 2, 3, 4 and 5 are considered unlikely to be affected by surface or climatic influences at all locations throughout the city as groundwater modelling has shown that an upward hydraulic gradient exists in those deeper aquifers.

2.2.2 Community Drinking Water Protection Zones

Christchurch's groundwater supply is protected by the rules in the Canterbury Land and Water Regional Plan (CLWRP), which controls land–use within the recharge areas to minimise the risk of contamination. Much of the land is used for very low intensity stock grazing or recreational parks. Providing for community drinking-water supplies is seen as a first order priority along with safeguarding the life-supporting capacity of ecosystems, supporting customary uses and stock water. Schedule 1 of the CLWRP details provisional protection zones around sources of community drinking-water supplies. The dimensions of the specific protection zones have been determined using site specific information, including:

- Topography, geography and geology of the site
- Depth of well
- Construction of well
- Pumping rates
- Type of aquifer
- Potential risks to the water quality

The provisional protection zones are included in the Canterbury maps GIS layers, an example is shown in Figure 7 below. Any new or replacement permits to take water require an assessment of the specific protection zone required. The CLWRP has rules that exclude or restrict certain activities within the community drinking-water protection zones (e.g. discharge of wastewater from on-site treatment systems, discharge of vertebrate toxic agent or agrichemicals onto land).

Section 9 of the CLWRP covers the Christchurch-West Melton sub region, which includes the recognised recharge area for the Christchurch source aquifers and has additional policies around the protection of this important source water. An example is ensuring that the overlying confining layers above the aquifer are not removed or reduced as part of site construction or gravel or mineral extraction activities.

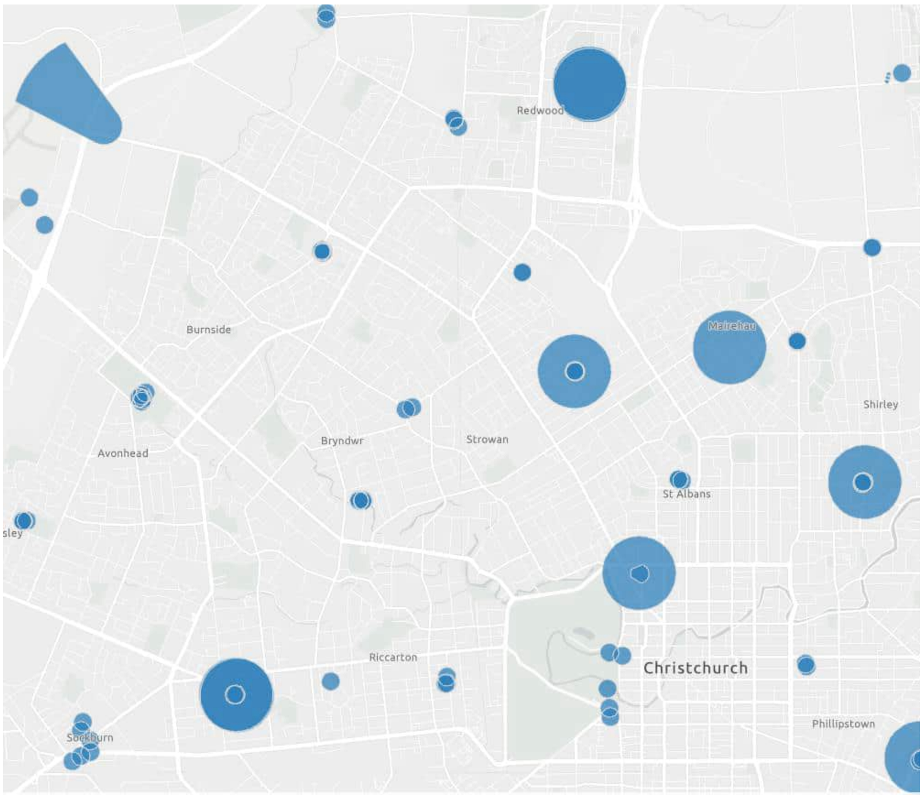


Figure 7: Canterbury Maps example of Community Drinking Water Protection zones

2.2.3 Water supply wells

There are 142 operational wells supplying water to Christchurch City and to Lyttelton Harbour Basin (see TRIM 18/422884 for information about each well). As described in section 1.2, the wells represent the 'receptor' in the model described by PDP in their source protection zone work.

Water is abstracted at 50 primary pump station sites under groundwater take consent CRC191331[7]. Appendix A – CRC191331 Schedule 1 – lists all wells currently included in this global consent.

At each of these sites there are between one and six wells. The wells are typically 200 and 300 mm in diameter and the wells are drilled to depths ranging from 28 m to 232 m. Wells are fully cased and screened in the last 5 to 10 m of the total well depth. All wells, except those indicated in 2, have above-ground well heads and have been grouted between the inner and outer casing.

The water supply demand base load is usually obtained from the deeper aquifer at each site, often free flowing into a suction tank if the wells are artesian. The supply is supplemented by the shallower aquifers and using submersible pumps during high demand periods. Suction tanks at some sites help balance the flow between wells in different aquifers, provide storage for short-term peaks, reduce surges on wells, and settle any sand that may come from the well.

The Council is reducing the amount of water drawn from Aquifer 1 by using the deeper wells at each pump station first and drilling deeper wells to replace shallow wells. In 2004/05, approximately 30% of Christchurch's water supply was drawn from Aquifer 1. This reduced to 11% in 2019/20. The percentage will reduce further as more Aquifer 1 wells are replaced with deeper wells.

[7] https://www.ECan.govt.nz/data/consent-search/consentdetails/CRC191331/CRC191331

As illustrated in Figure 5 and Figure 6, the Christchurch water supply is most vulnerable to contamination in the north-western parts of the city because the shallow Aquifer 1 in the north-west is protected by a thin confining layer. In 2004/05, approximately 60% of Northwest Christchurch's water supply was drawn from Aquifer 1. This reduced to 3% in 2018/19. This is due to the Council's well deepening programme in the Northwest zone which is almost complete. The remaining Aquifer 1 wells at Belfast and Redwood pump stations are no longer being used and deeper wells are being drilled to replace them.

Table 2 compares the total volume (cubic metres) from each aquifer for each supply zone for the period 1 July 2004 to 30 June 2005[8] with the period 1 July 2019 to 30 June 2020.

Table 3 presents a summary of the number of wells at each site and the aquifers that they source their water from.

Table 2: Total annual volume from Christchurch City aquifers (m^3)

	Aquifer 1	Aquifer 2	Aquifer 3	Aquifer 4	Aquifer 5	Total Flow
2004/5						
Brooklands / Kainga	0	526,101	0	0	0	**526,101**
Central	8,629,552	3,405,413	947,512	14,047,668	1,208,902	**28,239,047**
Northwest	6,059,958	198,596	0	0	3,863,059	**10,121,613**
Parklands	0	833,966	0	1,095,283	0	**1,929,249**
Riccarton	5,319	33,411	0	1,428,881	0	**1,467,611**
Rocky Point	315,813	0	0	0	0	**315,813**
West	0	6,864,392	1,154,690	0	0	**8,019,082**
Total Flows	**15,010,642**	**11,861,879**	**2,102,202**	**16,571,832**	**5,071,961**	**50,618,516**
Percentage	**30%**	**23%**	**4%**	**33%**	**10%**	
2019/20						
Brooklands / Kainga	0	272,185	0	0	0	**272,185**
Central	4,982,442	1,848,037	3,049,807	12,755,950	2,064,024	**24,700,260**
Ferrymead	1,151,183	0	0	2,427,411	742,844	**4,321,438**
Northwest	88,483	271,781	686,170	3,649,121	4,267,981	**8,963,536**
Parklands	0	124,437	350,284	430,787	1,353,143	**2,258,651**
Rawhiti	0	903,841	47,329	2,553,949	9,800	**3,514,919**
Riccarton	0	311,237	0	1,229,794	0	**1,541,031**
West	0	3,851,559	4,419,523	2,001,506	0	**10,272,587**
Total	**6,222,109**	**7,583,077**	**8,553,113**	**25,048,516**	**8,437,792**	**55,844,607**
Percentage	**11%**	**14%**	**15%**	**45%**	**15%**	

[8] Data from 'Report on "Secure" Status of Christchurch City Council Water Supply Wells', PDP, September 2005.

Table 3: Water supply zone, pump stations and wells – summary of information

Key

- Secure above ground well
- Well turned off, to be abandoned
- Below-ground well which meets DWSNZ secure bore water criterion 2 but will be replaced in the medium-term (new pump station)
- Well isolated, currently being replaced or on medium-term replacement programme
- Below-ground well which meets DWSNZ secure bore water criterion 2 but will be raised above ground in short-terr Completed
- Newly drilled well, not yet in service

Supply Zone	Station Name	PS Number	Number of wells in each aquifer					Total Wells	Comments	Artesian / Non-artesian	Suction Tank	Main Supply to reservoirs
			1	2	3	4	5					
Brooklands / Kainga	Brooklands	PS1066		1 1				1	Well 2 currently isolated	Non-artesian		
	Kainga	PS1067		1				1		Non-artesian		
Central	Addington	PS1001				2		2		Artesian		
	Aldwins	PS1002	1			2		3	Well 3 currently isolated	Artesian		
	Averill	PS1005	1	1		1		3	Well 2 (aquifer 1) not in use. Pump station will be replaced in the long-term	Artesian	Yes	
	Blighs	PS1007				1		1		Non-artesian	Yes	
	Grassmere	PS1014			2		1	3		Non-artesian	Yes	
	Hillmorton	PS1016				2		2	Well 1 abandoned	Non-artesian	Yes	
	Hills	PS1017			2	1		3		Artesian and non-artesian	Yes	
	Kerrs	PS1022				2		2		Artesian		
	Main Pumps	PS1024	6					6		Non-artesian	Yes	Yes

Supply Zone	Station Name	PS Number	Number of wells in each aquifer					Total Wells	Comments	Artesian / Non-artesian	Suction Tank	Main Supply to reservoirs
			1	2	3	4	5					
	Mays	PS1026		1		1		2		Artesian and non-artesian	Yes	
	Montreal	PS1027	1			1		2		Non-artesian		
	Palatine	PS1028	1					1		Non-artesian		
	Spreydon	PS1030	1	1	1	2		5		Artesian and non-artesian	Yes	
	Sydenham	PS1031		1		1	2	4		Artesian and non-artesian	Yes	
	Tanner	PS1095	2					2		Non-artesian		
	Trafalgar	PS1035				2	1	3		Artesian	Yes	
	Worcester	PS1037				2		2		Artesian		
Ferrymead	St Johns	PS1063				2	1	3		Artesian	Yes	Yes
	Woolston	PS1065	1			2		3		Artesian and non-artesian	Yes	Yes
Northwest	Auburn	PS1068		1			1	2	Well 3 isolated	Artesian	Yes	
	Avonhead	PS1068			1	1		2		Non-artesian		
	Belfast	PS1070	1		1	1		3		Artesian		
	Burnside	PS1071				3	3	6		Non-artesian		
	Crosbie	PS1072				2	1	3		Non-artesian		
	Farrington	PS1073			3	1	1	5		Non-artesian		
	Gardiners	PS1125				1	1	2		Non-artesian	Yes	
	Grampian	PS1074		1	1	1		3		Non-artesian	Yes	
	Jeffreys	PS1076			1		1	2	Wells 7 & 8 are drilled but not developed	Artesian and non-artesian	Yes	
	Redwood	PS1077	2					2	Wells 3 and 4 currently being drilled	Non-artesian		

Supply Zone	Station Name	PS Number	Number of wells in each aquifer					Total Wells	Comments	Artesian / Non-artesian	Suction Tank	Main Supply to reservoirs
			1	2	3	4	5					
	Thompsons	PS1078				2		2		Non-artesian		
	Wrights	PS1080			1	1		2		Non-artesian		
2	Burwood	PS1081				2		2		Artesian		
	Mairehau	PS1083				1		1		Artesian		
	Marshlands	PS1084				2		2		Artesian		
	Parklands	PS1085		2		1		3		Artesian		
	Prestons	PS1123		2	1	1		4		Artesian and non-artesian	Yes	
Rawhiti	Aston	PS1004		1		1		2		Artesian		
	Ben Rarere	PS1126				2		2	Under construction	Non-artesian		
	Carters	PS1008		1		3		4		Artesian and non-artesian	Yes	
	Effingham	PS1010		2		1		3		Artesian		
	Estuary	PS1012		1		1		2		Artesian and non-artesian	Yes	
	Keyes	PS1119		2		1		3		Artesian	Yes	
	Lake Terrace	PS1023			1	1	1	3		Artesian and non-artesian	Yes	
Riccarton	Picton	PS1088		1		2		3		Artesian		
	Tara	PS1089				1		1		Non-artesian		
West	Denton	PS1099		1	4			5		Non-artesian	Yes	
	Dunbars	PS1102		3		1		4		Non-artesian	Yes	Yes
	Sockburn	PS1109		6				6		Non-artesian	Yes	
	Wilmers	PS1117				2		2		Non-artesian	Yes	Yes

The groundwater is of good natural quality and has consistently complied with secure bore water criterion 3 (absence of E. coli), discussed further in Volume B section xxx. Until 22 December 2017 – with the exception of 22 shallow wells in unconfined aquifers in the Northwest zone – it met the secure bore water status of the DWSNZ, which meant that no treatment was required to comply with DWSNZ. In the more risk averse post-Havelock North environment, the routine well head security assessment of bores, by an independent expert, in late 2017 found that the well heads assessed were not secure, and so secure status was lost.

The loss of security, coupled with the finding of the Havelock North Inquiry Stage 2 that below ground wellheads should be prohibited lead to a wide programme across the city to raise bore heads. The upgrading of each well or commissioning of new wells is completed by an inspection and signoff from an independent expert, a report received to confirm that the wellhead meets the current DWSNZ criteria for a secure bore head. This reporting now includes additional minor requirements for a Sanitary Bore Head described in the Taumata Arowai document 'Draft Drinking Water Quality Assurance Rules (Oct 2021)'. Information about the wells is maintained in the document "Wellhead Security, Remediation and Well Renewals – Master Well List" TRIM18/422884. Wellhead inspections by an expert are currently repeated every five years.

2.2.4 Site-specific investigations

Over the years the Council has commissioned a significant number of site investigations which contribute to the improved understanding of site specific risks. Investigations include desktop based contamination pre-screening reports, preliminary site investigations and detailed site investigations for sites where further information was deemed necessary. In addition to contamination assessments, mapping of wastewater defects near water supply wells was undertaken. The Council has also commissioned city-wide groundwater modelling, described in section 3.2.2, and groundwater age dating, summarised in section 3.2.3.

The investigations have been summarised in TRIM 20/1427862 which provides a detailed breakdown of investigations undertaken at each pump station site and an overall assessment of the contamination risk to shallow groundwater and the contamination risk to the deeper aquifer(s) used for public water supply. While the contamination risk to shallow groundwater ranges between low and moderate-high, the contamination risk to the deeper aquifers used for public water supply has been assessed as low.

2.2.5 Site Specific Risk Management Plans

Each drinking water pump station has its own site specific risk management plan. These plans give the specifics of each contributing well, details of the pump station and site risks such as flooding potential and criticality of the pump station for the zone. Details of each site including the default source protection zone, details of potential contamination sources from the Listed Land Use Register, links to well head assessments, any contaminated site investigations, water quality results, wastewater pipeline assessments and maintenance records. Information from each of the Site Specific Risk Management Plans detailing risks and planned improvements is captured in TRIM 20/941794.

The Site Specific Risk Management Plans are routinely revised when changes occur and as a default are reviewed annually.

3 Microbiological Hazards and Risks

3.1 Bacterial risks

Council monitors bacterial compliance by taking samples from pump stations, storage reservoirs and private customer taps. Source monitoring is that undertaken at pump stations. Until 31 January 2018, each pump station was sampled at least once per month with the exception of the Northwest zone, which was sampled daily. This exceeded the DWSNZ requirement for monthly monitoring of secure groundwater. A new sampling programme was introduced on 1 February 2018, which covers more frequent sampling for non-secure groundwater supplies. All samples are enumerated for E. coli and total coliforms.

Although most wells have individual sampling taps, the sampling from pump stations tends to be from sampling taps on the surface pumps in the pump stations that transport the combined flows from the wells running at the time. These samples are considered to be 'Water Leaving the treatment plant'. Suction tanks are present at several pump stations, these sampling points are after suctions tanks. Suction tanks provide sand settlement and additional buffer storage, which allows for optimising potential flow capacity from the wells. Where suction tanks are present then the sampling point from the pump station is after these.

Routine compliance monitoring has therefore not generally targeted specific aquifers. The results of the last three years of 'Treatment plant' compliance monitoring are shown in Table 4. Note that, if temporary chlorination is undertaken at the pump station, this sampling is undertaken prior to the chlorination injection points. The chlorination injection points tends to be on the outgoing line(s) after the surface pumps.

Sampling is continuing to considerably exceed the minimum DWSNZ frequency requirements.

Table 4: Pump Station source monitoring (1st Jan 2019 – 28th Dec 2021)

TP / Aquifers		Year	Number of samples for E.Coli and total colifoms	Occurrence of total coliforms	Occurrence of E.Coli	Explanation
Central Aquifers 1,2,3,4+5	TP00179	2019	1559	5	1	SydenhamPS(2) – suction tank, currently being replaced 2021/22 Blighs PS – Well abandoned, replacement drilling Dec2021 – April 2022 Averill PS– suction tank Hills PS – suction tank Keyes PS – TC and transgression – suction tank
		2020	1399	7	0	Spreydon PS – suction tank Grassmere PS(5) – suction tank Sydenham PS– suction tank, currently being replaced 2021/22
		2021	901	1		Trafalgar PS– suction tank
Central – Main Pumps[2] Aquifer 1		2019				
		2020	105	0	0	
		2021	101	0	0	

Northwest Aquifers 1,2,3,4+5	TP00181	2019	1455	11	0	Gardiners PS Suction tank Grampian PS (10) Suction tank (considerable work undertaken 2021)
		2020	945	0	0	
		2021	893	2		Wrights PS Suction tank Grampian PS Suction tank
Parklands Aquifers 2,3+4	TP00182	2019	801	3	0	Parklands(3) PS (wells raised 2021)
		2020	787	0	0	
		2021	819	3	0	Prestons PS(3) Suction tank
Rocky Point[4] Aquifers 1,4+5	TP00184	2019	303	0	0	
		2020	526	0	0	
		2021		0	0	
Riccarton Aquifers 2+4	TP00185	2019	299	3	1	Picton PS (3 TCs and Transgression – potentially poor sampling tap) Tara PS (1)
		2020	569	1	0	Picton PS
		2021	843	0	0	
West Aquifers 2,3+4	TP00183	2019	935	22	1	Sockburn PS (3TCs + transgressions) Suction tank Denton PS(10) – Suction tank Dunbars PS(8) – suction tank Wilmers PS – Suction tank
		2020	925	11	2	Sockburn PS(3TCs + Transgression) Suction tank Dunbars PS (2) Suction tank Denton PS (8TCs+ 2 transgressions)
		2021	795	14		Wilmers PS(2) – Suction tank Dunbars PS(9) – Suction tank Sockburn PS(3) – Suction tank
Brooklands/Kainga Aquifer 2	TP00964	2019	266	1	0	
		2020	230	0	0	
		2021	229	0	0	
Rawhiti[3] Aquifers 2,3,4+5	TP04061	2019				
		2020	475	0	0	
		2021	887	6	0	Carters(5) Suction tank Aston – well heads raised late 2021
Ferrymead[1] Aquifers 1,4+5	TP04060	2019				
		2020	419			
		2021	857	1		Woolston – Suction tank

1 Existed from 1/7/20

2 –Existed from 5th April 2020

3 – Existed from 1st July 2020

4 – Ceased to exist 27th June 2020

From reviewing these results, a reasonably clear picture arises showing that suction tanks potentially present a risk to the source water (this risk is covered in Volume B of the WSP as it is a raw water storage risk rather than a source risk).

The WHISP programme has over the last few years replaced old shallow wells and raised the wellheads for other ones to above ground. Five pump stations currently have wells that have yet to be rehabilitated or replaced. When rainfall exceeds the set threshold there is a Wet Weather plan, which is put into action. The plan (detailed in TRIM20/650821) includes a number of measures:

- Isolating wells from use
- Inspections of well chambers
- Increasing FAC dosing rate
- Increased monitoring

3.2 Protozoa Risks

The Council undertook a comprehensive protozoa monitoring programme in 2018 and 2019. Fortnightly samples were taken from shallow wells and analysed for Cryptosporidium and Giardia. Samples were collected in accordance with DWSNZ requirements and covered different weather patterns. 184 samples were taken from shallower wells in Central, Northwest and Rocky Point zones. No protozoa were found in any of the samples.

The Council's protozoa monitoring results are well aligned with the results of the Ministry of Health's national baseline monitoring for protozoa in natural waters. The paper *Re-assessment of the Risks of Protozoa in New Zealand's Natural Waters*[9] shows that in eight years of protozoal monitoring none of the samples collected from shallow groundwater/spring sites have contained protozoa although 8% of samples contained E. coli. These sites were deliberately selected by the Ministry of Health because they were shallow or not secure, and had a history of occasionally containing E. coli.

3.2.1 Main Pumps Pump Station Sources and Protozoa Risk

At the Main Pumps pump station, there are six source wells which all access aquifer 1 via wells of less than 30 meters in depth. The wellheads for these six wells do not meet the current criteria 2 to enable them to be considered a 'secure' bore head under the current DWSNZ. Protozoa monitoring data from the wells at Main Pumps was used to confirm the Protozoa log credit treatment requirement for the UV treatment plant at Main pump station, which treats water from the six Aquifer 1 wells. The sampling results are saved in TRIM 19/1037925. The Draft Drinking Water Quality Assurance Rules (October 2021) list in section 10.8.1 the various classes and required protozoa treatment levels for each. Wells without a sanitary bore head required a minimum protozoa treatment barrier of 4 logs. This may be reduced to 3-log if the source water risk management plan for the supply provides evidence that the source water has a low risk of protozoa contamination. The discussions in sections above indicate that sources of protozoa are unlikely in the residential/commercial catchment. Between August 2018 and July 2019, twenty eight samples were taken from Main Pumps sources and tested for giardia. Results confirmed that under the current DWSNZ that three log credit treatment was required. The UV treatment was installed at Main Pumps in late 2019.

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9 https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=3362

Table 5: Main Pumps well information

Well No	Well Name	ECan well ID	Depth (m)	Aquifer	Year commissioned	Wellhead construction	Consented maximum weekly volume by aquifer (m^3)	Max tested yield	Non Artesian or Artesian	Last wellhead security assessment	Wellhead Secure (yes/no)
Well-01	Main Pumps Stn Well-01	M36/4591	29	1	1993	Below ground	212,688	80 L/s	Non-Artesian	15/834399	No
Well-02	Main Pumps Stn Well-02	M36/2828	29	1	1984	Below ground		68 L/s	Non-Artesian		No
Well-03	Main Pumps Stn Well-03	M36/1356	28	1	1924	Above ground		No info	Non-Artesian		No
Well-04	Main Pumps Stn Well-04	M36/1363	29	1	1966	Below ground		159 L/s	Non-Artesian		No
Well-05	Main Pumps Stn Well-05	M36/1195	29	1	1973	Below ground		116 L/s	Non-Artesian		No
Well-06	Main Pumps Stn Well-06	M36/0985	29	1	1975	Below ground		49 L/s	Non-Artesian		No

3.2.2 Wells no longer in service

CCC over the last few years have stopped using a number of water supply production wells. These may present a risk of direct contamination if they remain attached to our infrastructure and a potential conduit through to the aquifer. There are different situations where wells have been placed 'out of service' including individual wells servicing a particular pump station as well as complete water supply pump stations serviced by one or more wells. The Three Water's Master Well List (TRIM18/422884) identifies 69 wells in Christchurch and Banks Peninsula to be out of service. While Environment Canterbury's Regional Land and Water Plan has not specific requirements on how to decommission a well it does require that:

Abandoned or obsolete bores or galleries must be identified and decommissioned to prevent:

a) the entry of contaminants from the land surface; or

b) the exchange of water between aquifers, or water bearing layers in an aquifer, or between surface water and groundwater.

CCC have developed a comprehensive specification for decommissioning (TRIM21/678381). The list of wells has been reviewed, their decommission status confirmed and those that still require further work to be completed have been prioritised for decommissioning over the next three years based on an assessment of risk from/to each well.

3.2.3 Groundwater Modelling

The current DWSNZ includes in section 4.4.2.3 the option of using a verified model to establish bore water security criterion 1. This option was used by CCC for the groundwater source for Christchurch. The initial modelling was undertaken by PDP in 2005 and was accepted by the Ministry of Health as demonstrating the security of source water used for all but shallower wells in Northwest Christchurch.

Groundwater modelling is currently being undertaken by Aqualinc to investigate the source water for each well. Initially this work was commissioned with the intention that Christchurch would be able to regain its previous secure status under the DWSNZ (2018). These standards are intended to be replaced mid-2022 and the Draft Drinking water Quality Assurance Rules (October 2021) no longer have secure ground water as a compliance option. However, the work still provides extended knowledge of the behaviour of source water within the five aquifers. The modelling methodology has been developed with input from a technical panel of modelling experts. Initially in developing the model methodology several modelling scenarios with particle backward tracking were tested on two pump station sites: Effingham pump station, representing the eastern parts of Christchurch with artesian wells and thick confining layers; and Denton pump station, representing the western parts of Christchurch with non-artesian wells and non-homogenous confining layers:

- Baseline model representing the current best prediction of actual groundwater conditions based on the Weir (2018) model, with the modification that the higher 90 percentile flow rates are used rather than the long-term average flow rates which results in larger drawdowns in the pumped layers, which influences the vertical gradients between those layers and the surface.
- Locally punctured aquitards which may arise due to:
  - Fractures in the aquitard due to (say) seismic activity
  - Old lamp posts, building piles, rotting tree roots, extracted bores, etc.
  - Old river incisions
  - Areas of naturally thinning aquitards at a local scale that are too small to identify in bore logs.
- Leaky bores that could transmit water rapidly from the uppermost saturated layer through to the pumped layer due to:
  - Unsealed bores

- Multi-screened bores that hydraulically span shallow and deeper layers
- Gravel pits, building basements and other surface excavations.
- Reduced coastal confining layer extent with the inland extent of aquitards reduced by 2 km (i.e. moved closer to the coast).

This methodology was then applied to all the pump stations and their associated bore fields. For each pump station the report uses a range of information specific to the specific wells and from surrounding installations, as appropriate, to determine One Year travel time predictions. The work includes for each well field the scenarios of a local aquitard puncture or leaky bores within 1000m of the well field and modelling of a reduced coastal confining layer.

Modelling of wells at Denton (unconfined) and Effingham (confined) pump stations confirmed that no particles reach the bores within one year of entering shallow groundwater for any of these scenarios. These results provide confirmation that private bores near Council water supply wells are unlikely to provide a pathway for contamination and are therefore unlikely to affect water quality.

3.2.4 Groundwater residence time

Both the Council and Environment Canterbury take interest in groundwater residence time assessments as one of the tools that provide insight into water quality and potential changes. In 2017 Environment Canterbury and the Council undertook a joint project to study age tracers and isotopes in the Christchurch-West Melton aquifer system. The primary aim of this project was to better understand hydrogeological processes to allow for improved management of the system. Figure 8 shows the sampling locations and depth of wells tested. A total of 17 Council water supply wells were assessed for groundwater residence time. The GNS report is in TRIM 20/1605045 and the results are included in TRIM 19/1037931.

In 2018 the Council collected six samples from select wells in the urban Christchurch area for age tracer determination. In 2020 the Council collected 58 groundwater samples from different aquifers and locations in 5 'packages'. Results for Packages 1-4 have been received but Package 5 is still awaiting results from GNS. TRIM numbers for the four packages of results received to date are TRIM21/1224954, (package 4), TRIM21/622696 (Packages 2 and 3) and TRIM20/1336708 (package 1).

The results for wells, which are still operational, are summarised in Table 6. The data is also available in TRIM 19/1037931. The table shows that all wells tested that take water from Aquifer 2 and deeper met the existing DWSNZ Criterion 1 for secure bore water. Of the 12 wells tested that take water from Aquifer 1, nine met Criterion 1 and the results for three were unclear (Belfast well 1 and Redwood wells 1 and 2). The shallow Belfast well 1 was replaced with a deeper well in 2020. Redwood wells 1 and 2 are currently being replaced.

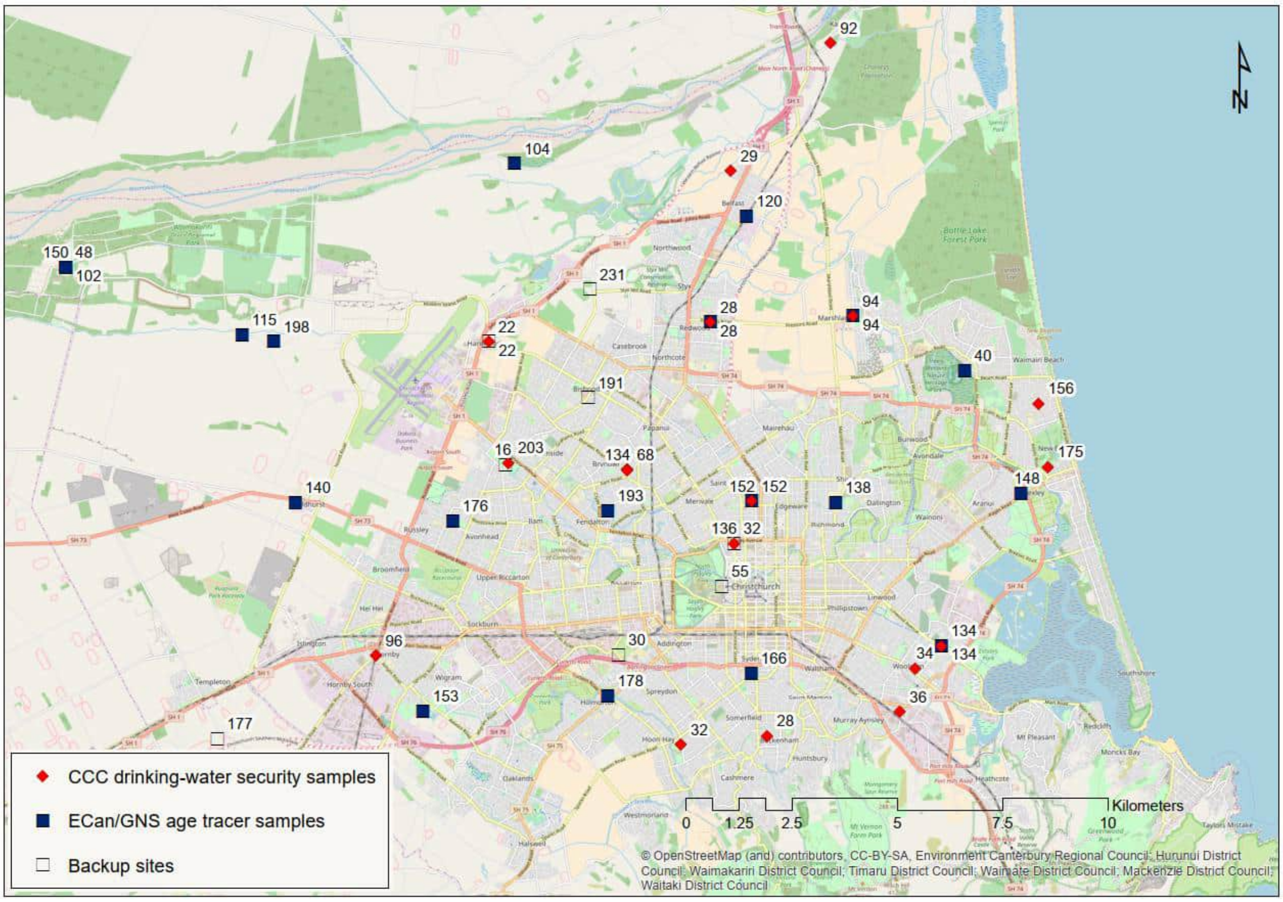


Figure 8: Wells selected for 2017 Environment Canterbury/Council age tracer project

Table 6: Summary of Council Groundwater Residence Time Assessments

Ecan Well ID	Name	Depth (m)	Aquifer	Sampling Date	Mean Residence Time MRT (years)	Minimum Residence Time (years)[1, 3]	Young Fraction <0.005% ?	Meets DWSNZ Criterion 1?	GNS Report Trim No.
M35/2587	Aldwins Well 1	130	4	20/10/2020	174 (169 - 180)	52	Yes	Yes	21/1224945
M35/7216	Aston Well 1	160	4	13/7/2020	183 (177-190)	55	Yes	Yes	21/622696
M35/7215	Aston Well 2	110	2	13/7/2020	>185	56	Yes	Yes	21/622696
M35/7600	Auburn Well 5	177	5	6/8/2020	>185	56	Yes	Yes	21/622696
M35/2403	Averill Well 3	86	2	20/10/2020	>185	56	Yes	Yes	21/1224945
M35/1870	Averill Well 4	138	4	20/10/2020	185 (182 - 205)[2]	70	Yes	Yes	21/1224945
BX23/0428	Avonhead Well5	132	3	30/06/2020	131 (118-143)	39	Yes	Yes	21/622696
BX23/0430	Avonhead Well 7	175	4	30/06/2020	185(179-197)	56	Yes	Yes	21/622696
BX24/0965	Blighs Well 4	134	4	12/09/2017	>175	52.5	Yes	Yes	19/113634
M35/7180	Brooklands Well 1	82	2	20/02/2020	182 (174-201)[2]	55	Yes	Yes	20/1336708
M35/9439	Burnside Well 5	205	5	12/09/2017	>175	52.5	Yes	Yes	19/113634
BX24/0187	Burnside Well 6	133	4	30/60/2020	182(176-189)	55	Yes	Yes	
M35/2789	Carters Well 1	145	4	10/03/2020	>185	56	Yes	Yes	20/1336708
M35/2790	Carters Well 2	95	2	10/03/2020	>185	56	Yes	Yes	20/1336708
M35/6040	Crosbie Well 2	176	5	15/07/2020	>185	56	Yes	Yes	21/622696
M35/18384	Crosbie Well 4	135	4	15/07/2020	164 (158-169)[2]	49	Yes	Yes	21/622696
M35/3547	Denton Well 1	96	3	20/02/2020	87 (79-96)[2]	28	Yes	Yes	20/1336708
M35/1864	Denton Well 5	73	2	1/03/1997	57	ND	Yes	Yes	ELEC07/5561
M35/1864	Denton Well 5	72.8	2	21/09/2017	99	31	Yes	Yes	19/113634
M36/4053	Dunbars Well 1	54	2	20/02/2020	130 (116-144)[2]	28	Yes	Yes	20/1336708
M36/8019	Dunbars Well 5	110	4	20/02/2020	147 (132-167)[2]	30	Yes	Yes	20/1336708
M35/1554	Effingham Well 1	156.4	4	14/09/2017	>175	52.5	Yes	Yes	19/113634
M35/1606	Effingham Well 2	97	2	4/08/2020	>185	56	Yes	Yes	21/622696
M35/2242	Estuary Well 2	48	1	1/04/1998	>78	ND	Yes	Yes	ELEC07/5561
BX24/1210	Estuary Well 5	147	4	20/02/2020	>185	56	Yes	Yes	20/1336708
M35/9440	Farrington Well 4	191	5	25/06/2020	>185	56	Yes	Yes	21/622696
BX24/0192	Farrington Well 5	108	3	25/06/2020	>185	56	Yes	Yes	21/622696
BX24/0195	Farrington Well 8	163	4	25/06/2020	>185	56	Yes	Yes	21/622696
BX24/1311	Gardiners Well 1	232	5	22/10/2018	>172	51.7	Yes	Yes	19/881791
BX24/1312	Gardiners Well 2	163	4	22/10/2018	171	51.5	Yes	Yes	19/881791
M35/8860	Grampian Well 5	72	2	23/07/2020	25 various	3.7 0.3-4	Yes ND		21/622696
BX24/1327	Grampian Well 6	113.5	3	30/06/2020	164 (158-170)[2]	49	Yes	Yes	21/622696
BX24/1328	Grampian Well 7	144	4	7/07/2020	172 (165-180)[2]	52	Yes	Yes	21/622696
M36/1058	Hillmorton Well 2	123	4	6/08/2020	172 (167-172)[2]	52	Yes	Yes	21/622696
BX24/0457	Hills Well 6	144	4	5/08/2020	187 (182-206)[2]	56	Yes	Yes	21/622696
BX24/0350	Hills Well 7	82	3	5/08/2020	>185	56	Yes	Yes	21/622696
M35/6667	Jeffreys Well 6	193	5	5/08/2020	>185	56	Yes	Yes	21/622696
BX24/0534	Jeffreys Well 9	103	3	5/08/2020	186 (180-198)[2]	56	Yes	Yes	21/622696
M35/6213	Kainga Well 1	92	2	19/09/2017	>175	52.5	Yes	Yes	19/113634
M35/2152	Kerrs Well 1	141	4	6/08/2020	>185	56	Yes	Yes	21/622696
M35/18733	Keyes Well 2	110	4	3/03/2020	184 (176-205)[2]	55	Yes	Yes	20/1336708
M35/18734	Keyes Well 3	106	2	16/09/2017	>175	52.5	Yes	Yes	19/113634
M35/2260	Lake Terrace Well 3	149	4	4/08/2020	>185	56	Yes	Yes	21/622696
M35/18398	Lake Terrace Well 4	183	5	4/08/2020	>185	56	Yes	Yes	21/622696
BX24/0993	Lake Terrace Well 5	120	3	20/10/2020	186(180 - 194)[2]	56	Yes	Yes	

Ecan Well ID	Name	Depth (m)	Aquifer	Sampling Date	Mean Residence Time MRT (years)	Minimum Residence Time (years)[1, 3]	Young Fraction <0.005% ?	Meets DWSNZ Criterion 1?	GNS Report Trim No.
M36/1356	Main Pumps Well 2	28.4	1	26/09/2017	107	32	Yes	Yes	19/113634
M35/7814	Marshlands Well 2	150	4	16/7/2020	182 (175-190) [2]	55	Yes	Yes	21/622696
M35/2243	Montreal Well 1	139	4	16/10/2018	>183	55	Yes	Yes	19/881791
M35/2325	Montreal Well 2	32	1	1/04/1998	17	ND	Yes	Yes	ELEC07/5561
M35/2325	Montreal Well 2	31.7	1	14/09/2017	155	47	Yes	Yes	19/113634
M35/2325	Montreal Well 2	32	1	16/10/2018	79	26	Yes	Yes	19/881791
M36/1197	Palatine Well 1	31	1	17/10/2018	>181	54.5	Yes	Yes	19/881791
M35/3128	Parklands Well 2	93	2	2/11/2020	>185	56	Yes	Yes	21/1224945
M35/3446	Parklands Well 1	157	4	2/11/2020	>185	56	Yes	Yes	21/1224945
M35/8897	Picton Well 1	126	4	6/8/2020	167 (161-172) [2]	50	Yes	Yes	21/622696
M35/8898	Picton Well 3	61	2	27/02/2020	204 (175-235)[2]	23	Yes	Yes	20/1336708
BX24/0624	Prestons Well 1	93.6	2	26/07/2017 2/11/2020	162 176(170-182)	48.5 53	Yes Yes	Yes Yes	19/113634 21/1224945
BX24/0625	Prestons Well 2	124	4	7/07/2020	70	174 (168-182) [2]	52	Yes	21/622696
BX24/0626	Prestons Well 3	156	4	2/11/2020	176 (170 - 182)[2]	53	Yes	Yes	21/1224945
M35/5251	Redwood Well 1	31	1	26/07/2017	21 20 - 40	2 0 - 3	ND	Unclear	19/113634
M35/5251	Redwood Well 1	31	1	17/10/2018	25 42 24-40	2.5 33 0.25-3	Yes Yes ND	Unclear	19/881791
M35/1859	Sockburn Well 1	81	2	20/02/2020	132 (115-145)[2]	20	Yes	Yes	20/1336708
M36/1225	Spreydon Well 2	32	1	1/05/1970	11	ND	Yes	Yes	ELEC07/5561
M36/1225	Spreydon Well 2	32.3	1	19/09/2017	67	40	Yes	Yes	19/113634
M36/1055	Spreydon Well 4	115	4	19/10/2020	186(180-196)	56	Yes	Yes	21/1224945
M36/8288	Spreydon Well 6	58	2	19/10/2020	121 120-150	29 12-16	Yes Yes	Yes Yes	21/1224945
M36/4565	Sydenham Well 6	166	5	19/10/2020	188 (183 - 210)[2]	57	Yes	Yes	21/1224945
M36/20670	Sydenham Well 7	65	2	19/10/2020	168 (163 - 174)[2]	50	Yes	Yes	21/1224945
M35/2805	St Johns Well 2	134.4	4	14/09/2017	>175	52.5	Yes	Yes	19/113634
M35/18432	St Johns Well 3	171	5	5/03/2020	185 (177-230)[2]	56	Yes	Yes	20/1336708
M36/1915	Tanner Well 2	36.4	1	14/09/2017	>175	52.5	Yes	Yes	19/113634
M35/6945	Tara Well 4	169	4	27/02/2020	>185	56	Yes	Yes	20/1336708
BX24/0153	Thompsons Well 3	171	4	23/07/2020	>185	56	Yes	Yes	21/622696
M35/2556	Trafalgar Well 5	143	4	22/09/2020	>185	56	Yes	Yes	21/622696
BX24/0348	Trafalgar Well 7	184	5	22/09/2020	>185	56	Yes	Yes	21/622696
M36/20556	Wilmers Well 1	150	4	20/02/2020	185 (178-250)[2]	56	Yes	Yes	20/1336708
M36/1045	Woolston Well 3	34	1	1/04/1998	24	ND	Yes	Yes	ELEC07/5561
M36/1045	Woolston Well 3	34.1	1	14/09/2017	128	12	Yes	Yes	19/113634
M36/1030	Woolston Well 4	129	4	5/03/2020	182 (174-201)[2]	55	Yes	Yes	20/1336708
M35/9289	Worcester Well 1	131.5	4	16/07/2020	>185	56	Yes	Yes	21/622696
BX24/1678	Wrights Well 5	126	3	22/07/2020	>185	56	Yes	Yes	21/622696
BX24/1679	Wrights Well 6	169	4	22/07/2020	172 (166-180) [2]	52	Yes	Yes	21/622696

Notes:

1	Minimum residence time is the modelled age of the youngest water present in the water sampled from the well outflow
2	BMM denotes a Binary Mixing Model with variable mixing parameters
3	ND denotes 'not determined'

3.3 Private wells

The Council works with Environment Canterbury to identify private bores that may provide pathways to contamination if not adequately decommissioned. A summary (Environment Canterbury) of private bores that are assumed to be in use, including their function and depth, is presented in Figure 9. A GIS app has been produced that allows a visual identification and assessment of private bores in the vicinity of Council water supply bores. An example map is provided in Figure 10.

		Well Depth (m)							
		<20	20<= x <50	50<= x < 100	100<= x < 140	140<= x <180	180<=		
Wells By Function	**Well Function**	**Shallow Unconfined**	**Aquifer 1**	**Aquifer 2**	**Aquifer 3**	**Aquifer 4**	**Aquifer 5**	**Unknown**	**Grand Total**
22.8%	Water Level Observation	1,342	217	23	9	2	-	37	**1,630**
16.6%	Geotechnical Investigation	846	308	4	2	3	-	28	**1,191**
12.0%	Domestic Supply	247	384	72	12	-	-	143	**858**
8.8%	Irrigation	186	370	37	10	-	1	23	**627**
3.8%	Domestic and Stockwater	50	174	30	1	-	1	13	**269**
3.5%	Commercial / Industrial	50	126	40	17	7	-	14	**254**
3.4%	Sewer Flushing	14	77	60	6	-	-	86	**243**
29.1%	Other	473	576	462	159	33	4	378	**2,085**
100.0%	**Grand Total**	**3,208**	**2,232**	**728**	**216**	**45**	**6**	**722**	**7,157**
	Wells By Aquifer	44.8%	31.2%	10.2%	3.0%	0.6%	0.1%	10.1%	100.0%

Figure 9: Private wells assumed to be in use

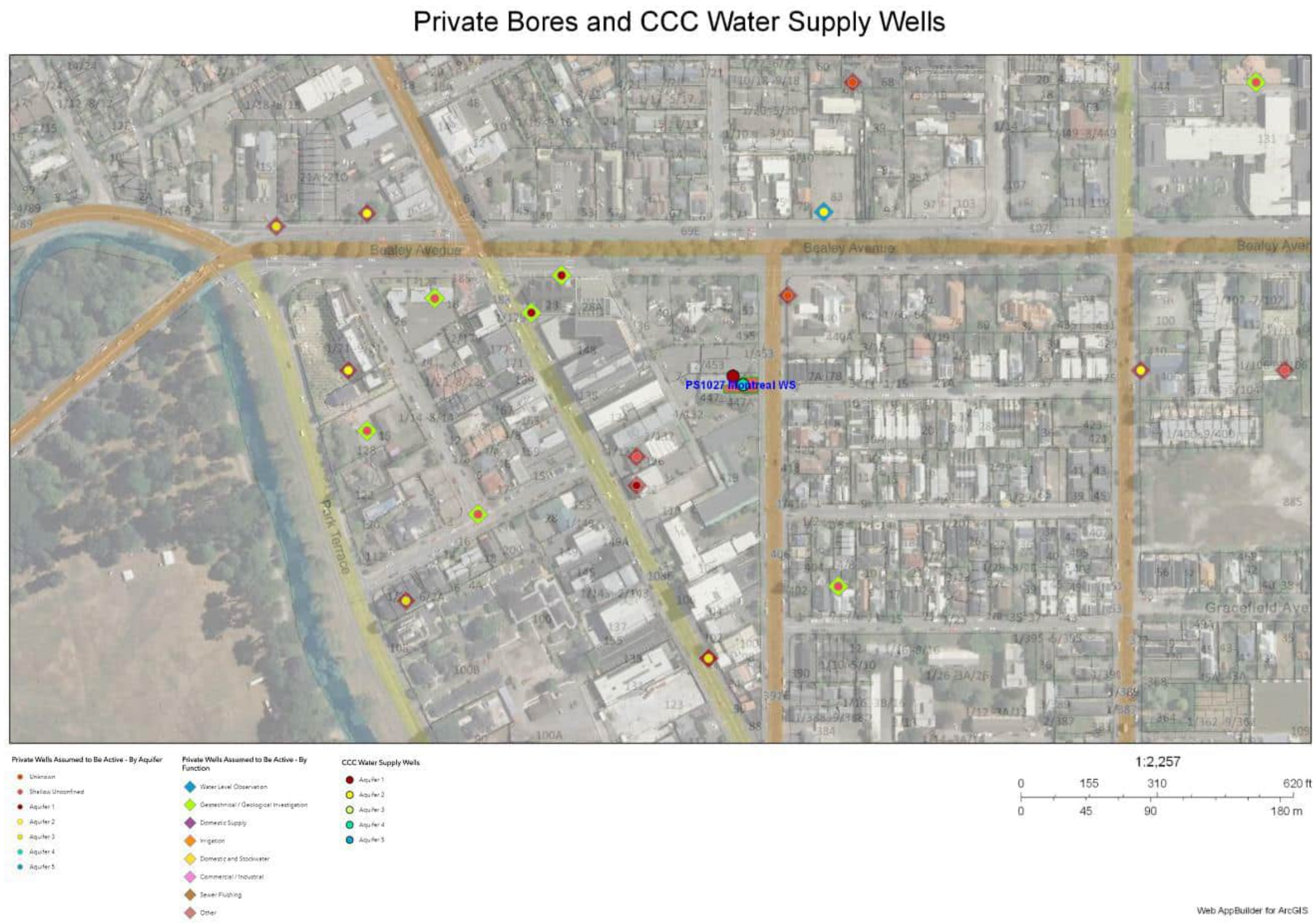


Figure 10: Example Map of Private Bores Near CCC Water Supply Wells

3.4 Viral Risk assessment

Pathogenic water-borne viruses are associated with human and animal effluent. Viruses are smaller than bacteria and protozoa and therefore more difficult to remove through natural filtration in the soil layer and vadose zone. Therefore it can be concluded that if appropriate virus attenuation is achieved then appropriate bacteria and protozoa attenuation is achieved as well.

Viruses can survive sewage treatment processes and be transported in water moving through the soil and the unsaturated material beneath and then laterally with groundwater flow. The concentration of viruses is reduced at each stage of the transportation process.

The Guidelines for Separation Distances Based on Virus Transport between On-site Domestic Wastewater Systems and Wells[10] (ESR, 2010) provides a methodology for estimating the reduction in virus concentrations in each of the four stages of the virus transport, which are illustrated in Figure 11. Reduction is dependent on separation distances between a land treatment area (contaminant source) and drinking water sources, and the soil conditions. While there are few domestic wastewater systems in the urban Christchurch and Lyttelton areas the same concept could apply to wastewater originating from broken wastewater pipes.

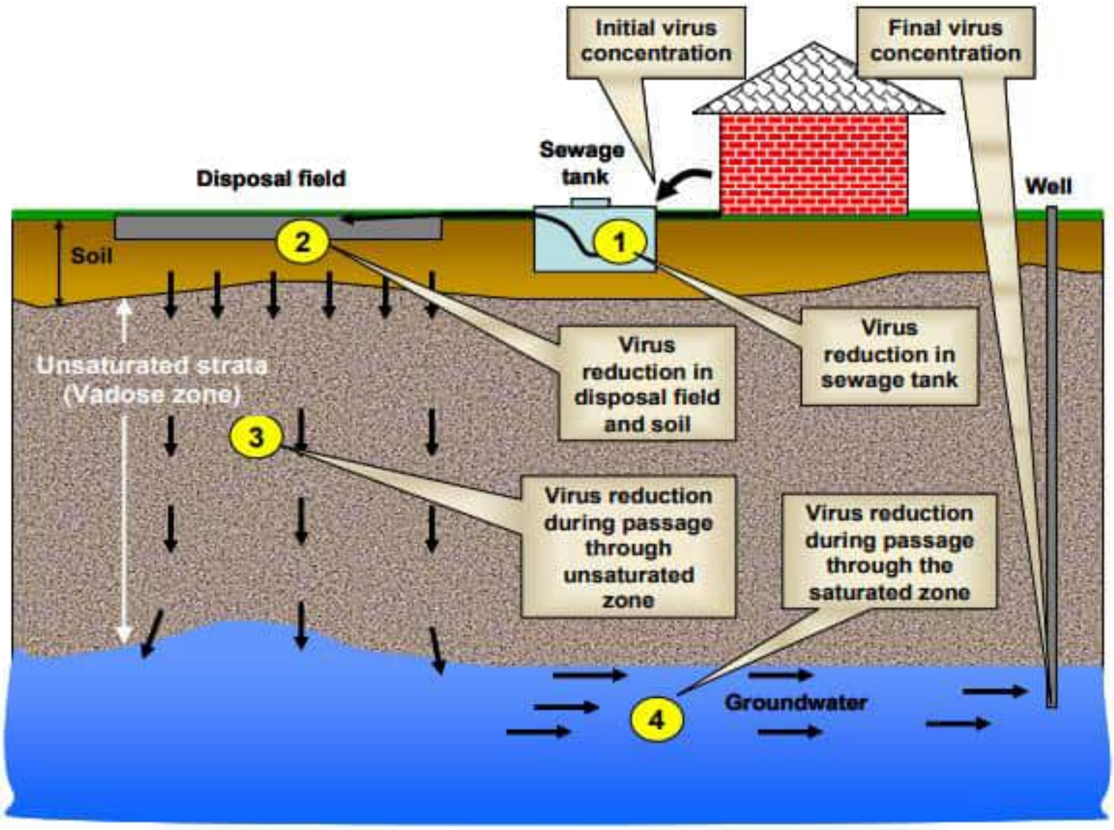


Figure 11: Components of virus removal between the sewage tank and abstraction point (ESR, 2010)

[10]ESR, 2010: Guidelines for separation distances based on virus transport between on-site domestic wastewater systems and wells: https://www.envirolink.govt.nz/assets/Envirolink/Guidelines-for-separation-distances-based-on-virus-transport-.pdf

Separation distance to nearest wastewater discharge is based on a 2019 report, which mapped wastewater pipe defects – established by CCTV inspections – in the vicinity of water supply pump stations and wells.

A potential source of contamination is wastewater pipes within the vicinity of the wells. In 2019 CCC engaged Beca to undertake a review of wastewater pipeline condition within a 400m radius around public supply well sites. Separation distance to nearest wastewater discharge is based on the 2019 report which mapped wastewater pipe defects – established by CCTV inspections – in the vicinity of water supply pump stations and wells.

Table 7A potential source of contamination is wastewater pipes within the vicinity of the wells. In 2019, CCC encaged Beca to undertook a review of wastewater pipeline condition within a 400m radius around public supply well sites. Separation distance to neares wastewater discharge is based on the 2019 report which mapped wastewater pipe defects – established by CCTV inspections – in the vicinity of water supply pump stations and wells.

Table 7 summarises the parameters used to estimate virus transport and log reduction. Two wells are presented as examples: a non-artesian shallow aquifer 1 well (Montreal well 2) representing the worst case scenario, and the shallowest aquifer 2 well (Dunbars well 3) which will be a representation of the most vulnerable well when all aquifer 1 wells have been replaced (except Main Pumps which have UV treatment). The bore logs shows a clay layer between 0.3m and 3m depth which potentially provides additional protection. However, the extent of these confining layers over the source protection zone is not known and therefore has not been considered in the assessment.

A potential source of contamination is wastewater pipes within the vicinity of the wells. In 2019 CCC engaged Beca to undertake a review of wastewater pipeline condition within a 400m radius around public supply well sites. Separation distance to nearest wastewater discharge is based on the 2019 report which mapped wastewater pipe defects – established by CCTV inspections – in the vicinity of water supply pump stations and wells.

Table 7: Parameters Used to Estimate Viral Log Reduction

Parameter	Montreal well 2 (M35/2325, 32m)	Dunbars well 3 (M36/4333, 53m)	Data Source
Soil material	Kaiapoiƒ mottled-weathered fluvial recent soil	Kaiapoiƒ mottled-weathered fluvial recent soil	• S-Map (Manaaki Whenua – Landcare Research)
Soil depth	1.2 m	No information	Well bore log
Aquifer type	Non-flowing artesian	Non-flowing artesian	Well bore log
Vadose zone material	Clay	Clay	Well bore log
Vadose zone thickness	1.1 m	1.3 m	ECan data / well bore log
Saturated zone material	Gravel, sand and clay	Gravel, pug	Well bore log
Depth to first groundwater	1.1 m	1.3 m	ECan data / well bore log
Separation distance to nearest up-gradient medium or high risk wastewater pipe	100 m	180 m	Beca Wastewater Pipeline Assessment (TRIM 20/21388)

Figure 12 from the ESR guideline provides the estimated virus log removal in relation to the separation distance to the nearest effluent disposal system for a gravel aquifer with gravel vadose zone. This table shows that:

- For Montreal well 2, with a 100 m separation distance to the nearest up-gradient medium or high risk wastewater pipe, virus removal in the vadose and saturated zone can be expected to be at least 1.9 log.
- For Dunbars well 3, with a 180 m separation distance to the nearest up-gradient medium or high risk wastewater pipe, virus removal in the vadose and saturated zone can be expected to be at least 2.2 log.

The above assessment represents the minimum expected log removal as it does not take into account any additional attenuation and protection due to confining layers which are present in the Christchurch/West Melton aquifer system. Protection due to confining layers is more accurately assessed by groundwater modelling which is discussed in section 3.2.2.

Log Reduction Table 1 **Vadose zone: Gravel - Saturated zone: Gravel**

		Separation Distance (m)													
		40	50	60	80	100	150	200	250	300	400	500	600	800	1000
Vadose Zone Thickness (m)	1	1.5	1.6	1.6	1.7	1.9	2.0	2.3	2.5	2.6	2.9	3.2	3.4	3.8	4.2
	2	1.7	1.8	1.8	2.0	2.1	2.3	2.6	2.7	2.9	3.2	3.5	3.7	4.1	4.5
	3	1.9	2.0	2.1	2.2	2.3	2.5	2.9	3.0	3.2	3.5	3.7	4.0	4.4	4.8
	4	2.1	2.2	2.2	2.4	2.5	2.7	3.1	3.2	3.4	3.7	4.0	4.2	4.7	5.1
	5	2.3	2.4	2.4	2.6	2.7	2.9	3.3	3.4	3.6	3.9	4.2	4.4	4.9	5.4
	6	2.4	2.5	2.6	2.8	2.9	3.1	3.5	3.6	3.8	4.1	4.5	4.7	5.2	5.6
	7	2.6	2.7	2.8	2.9	3.1	3.3	3.6	3.8	4.0	4.3	4.6	4.8	5.3	5.8
	8	2.8	2.8	2.9	3.0	3.2	3.4	3.8	4.0	4.2	4.5	4.8	5.0	5.6	6.1
	9	2.9	3.0	3.0	3.2	3.4	3.7	4.0	4.1	4.3	4.7	5.0	5.2	5.7	6.3
	10	3.1	3.2	3.2	3.4	3.5	3.8	4.2	4.3	4.5	4.8	5.2	5.5	6.0	6.4
	15	3.7	3.9	3.9	4.0	4.2	4.5	5.0	5.1	5.3	5.7	6.0	6.2	6.9	7.4
	20	4.5	4.6	4.6	4.8	4.9	5.3	5.7	5.9	6.1	6.6	6.9	7.2	7.8	8.3
	25	5.2	5.3	5.3	5.5	5.7	5.9	6.5	6.7	7.0	7.3	7.7	8.1	8.6	9.3
	30	5.9	5.9	6.1	6.3	6.4	6.8	7.3	7.4	7.8	8.1	8.5	8.8	9.6	10.1
	35	6.6	6.7	6.8	6.9	7.2	7.6	8.1	8.3	8.6	9.1	9.4	9.7	10.5	11.0
	40	7.4	7.6	7.7	7.9	8.0	8.4	8.9	9.0	9.4	9.9	10.4	10.7	11.3	12.1
	45	8.2	8.4	8.5	8.7	8.9	9.2	9.8	10.0	10.3	10.8	11.3	11.6	12.3	12.9
	50	9.1	9.1	9.2	9.4	9.6	10.1	10.7	10.8	11.1	11.6	12.1	12.4	13.0	14.0
	55	9.9	10.0	10.1	10.4	10.4	10.8	11.4	11.7	11.9	12.4	12.9	13.3	14.2	14.7
	60	10.7	10.9	10.8	11.0	11.2	11.6	12.3	12.4	12.9	13.3	13.5	14.5	15.0	15.7
	65	11.5	11.7	11.6	11.9	12.2	12.5	13.1	13.4	13.7	14.1	14.6	15.2	16.1	16.9
	70	12.4	12.4	12.5	12.8	13.0	13.3	14.2	14.3	14.6	15.2	15.6	16.0	17.0	17.8
	75	13.1	13.3	13.4	13.5	13.8	14.2	14.9	15.1	15.4	15.9	16.7	16.6	17.4	18.5
	80	13.9	14.1	14.1	14.2	14.5	14.9	15.7	15.9	16.3	16.6	17.2	17.5	18.5	19.3

Figure 12: Virus Log Removal Based on Separation Distance

3.5 Conclusion

Sections 3.1 to 3.2.3 provide information that the risk of contamination to the Christchurch supply source water (aquifers 1, 2, 3, 4 and 5) by pathogenic organisms is unlikely. This is evidenced by direct sampling, investigations, groundwater age dating and groundwater modelling across the entire city. The estimated viral log reduction presented in section 3.4 provides further assurance that the groundwater used for public water supply is protected from microbiological contamination.

4 Chemical determinands

4.1 Chemical monitoring - Review

The Council has routinely performed groundwater chemistry monitoring to better understand groundwater quality. The water from each aquifer at each pump station site is tested on a 5-year rolling programme. The Council has also established close working relationships with Environment Canterbury who is responsible for monitoring and safe guarding the general quality of Canterbury groundwater. Exchanges of water quality data take place on a regular basis.

In 2019 the Council commissioned a source water hydrochemistry assessment to determine geochemical variation across sites so that recharge sources could be better understood. The report (TRIM 19/1064915) confirmed that some bores that take water close to the foothills of Banks Peninsula (e.g. Palatine Well 1) have a geochemical 'finger print' of water emerging from the volcanic rocks whereas other bores showed similar geochemistry to bores located in the alluvial plains aquifer system.

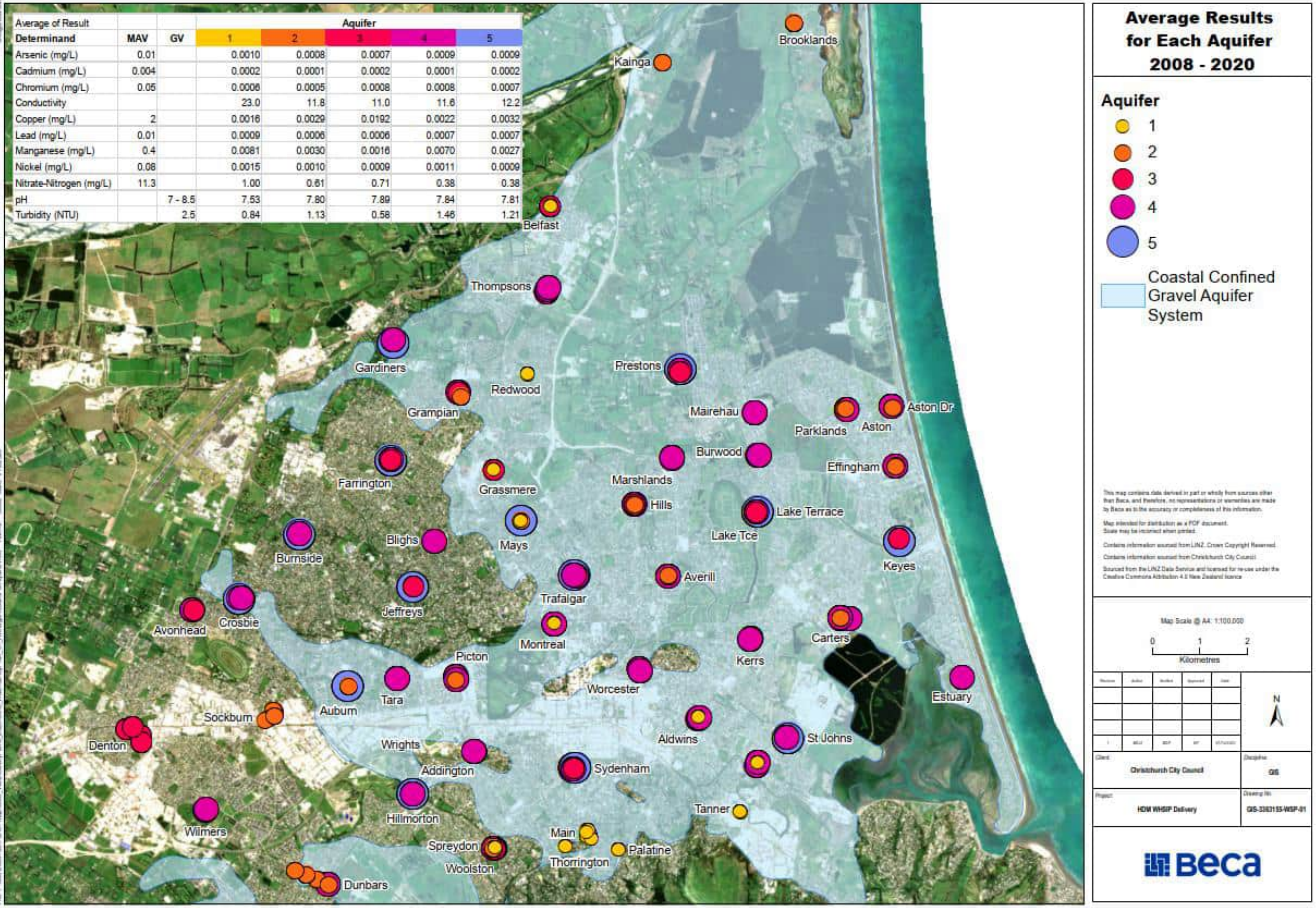
The Council has mapped the concentrations of key determinands in Christchurch's water supply wells. Figure 13, Figure 14 and Figure 15 provide example maps. More maps are provided in Appendix C.

A comprehensive summary of all chemistry data is saved in TRIM 19/1083022.

The following observations can be made:

- Cadmium: there were six cadmium results from 2009 where the chosen analytical detection limit (0.005 mg/L) was higher than the DWSNZ maximum acceptable value (MAV) (0.004 mg/L). More recent testing at those sites confirms that cadmium concentrations are below 50% MAV.
- Lead: there were two samples from wells at Spreydon pump station (0.051 mg/L in 2009) and Addington pump station (0.0066 mg/L in 2011) that were >50% MAV (0.005 mg/L). More recent testing at those sites confirms that lead concentrations are below 50% MAV.
- The chemistry data shows that all other results for tested parameters with a MAV were either below the detection limit or, where the result was above the detection limit, below 50% MAV.
- Turbidity: sites where elevated turbidity has been observed (usually during start-up of the well pump) have sand filters or suction tanks that help settle out particles.
- Turbidity: Also managed (often relevant for new wells) by introducing a minimum timeframe to have wells off line and a procedure for flushing wells after longer periods (because of work being undertaken at a pump station for example). TRIM 21/80158 summarises the exploratory work undertaken at some recent new wells.
- pH: there are several wells with pH greater than the DWSNZ guideline value (GV) of 8.5 (at Spreydon, Brooklands, Montreal, Picton, Tara, Mairehau and Parklands pump stations). There are also several wells with pH below the GV of 7.0 (Lake Terrace, Carters, Kerrs, Spreydon, Main Pumps, St Johns, Picton and Sockburn). At most sites, water from different wells (and depths) is mixed prior to distribution in the network which generally results in the pH falling within the DWSNZ guideline range of 7.0 – 8.5. The distribution system pH data is contained within TRIM 19/1083022.

- Nitrate-nitrogen: while all sample results are well below the MAV of 11.3 mg/L there is an emerging trend of rising concentrations across the district. This is illustrated in Figure 14 which shows the maximum concentrations of nitrate-nitrogen in Council water supply wells for 2008–2020 and mean nitrate-nitrogen concentrations in private wells, collected by Environment Canterbury between 1957 and 2020. The map clearly shows that these elevated concentrations are associated with dairy farming on the Canterbury Plains.



Average of Result			Aquifer				
Determinand	MAV	GV	1	2	3	4	5
Arsenic (mg/L)	0.01		0.0010	0.0008	0.0007	0.0009	0.0009
Cadmium (mg/L)	0.004		0.0002	0.0001	0.0002	0.0001	0.0002
Chromium (mg/L)	0.05		0.0006	0.0005	0.0008	0.0008	0.0007
Conductivity			23.0	11.8	11.0	11.6	12.2
Copper (mg/L)	2		0.0016	0.0029	0.0192	0.0022	0.0032
Lead (mg/L)	0.01		0.0009	0.0006	0.0006	0.0007	0.0007
Manganese (mg/L)	0.4		0.0081	0.0030	0.0016	0.0070	0.0027
Nickel (mg/L)	0.08		0.0015	0.0010	0.0009	0.0011	0.0009
Nitrate-Nitrogen (mg/L)	11.3		1.00	0.61	0.71	0.38	0.38
pH		7 - 8.5	7.53	7.80	7.89	7.84	7.81
Turbidity (NTU)		2.5	0.84	1.13	0.58	1.46	1.21

Figure 13: Average Concentrations of Select Chemical Determinands in Each Aquifer 2008 – 2020

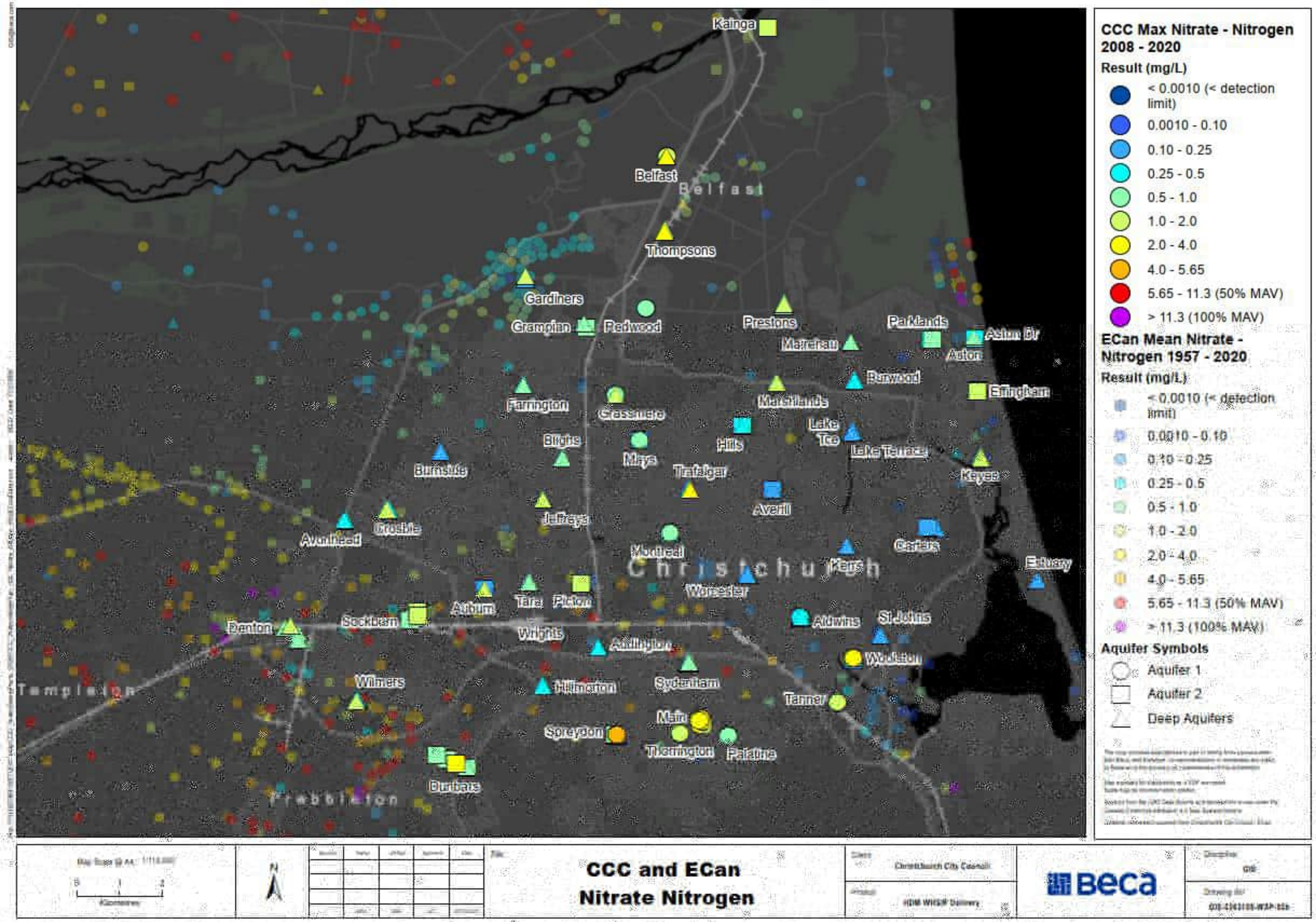


Figure 14: Nitrate-Nitrogen Concentrations – CCC Max 2008 – 2020 and Environment Canterbury Mean 1957 – 2020

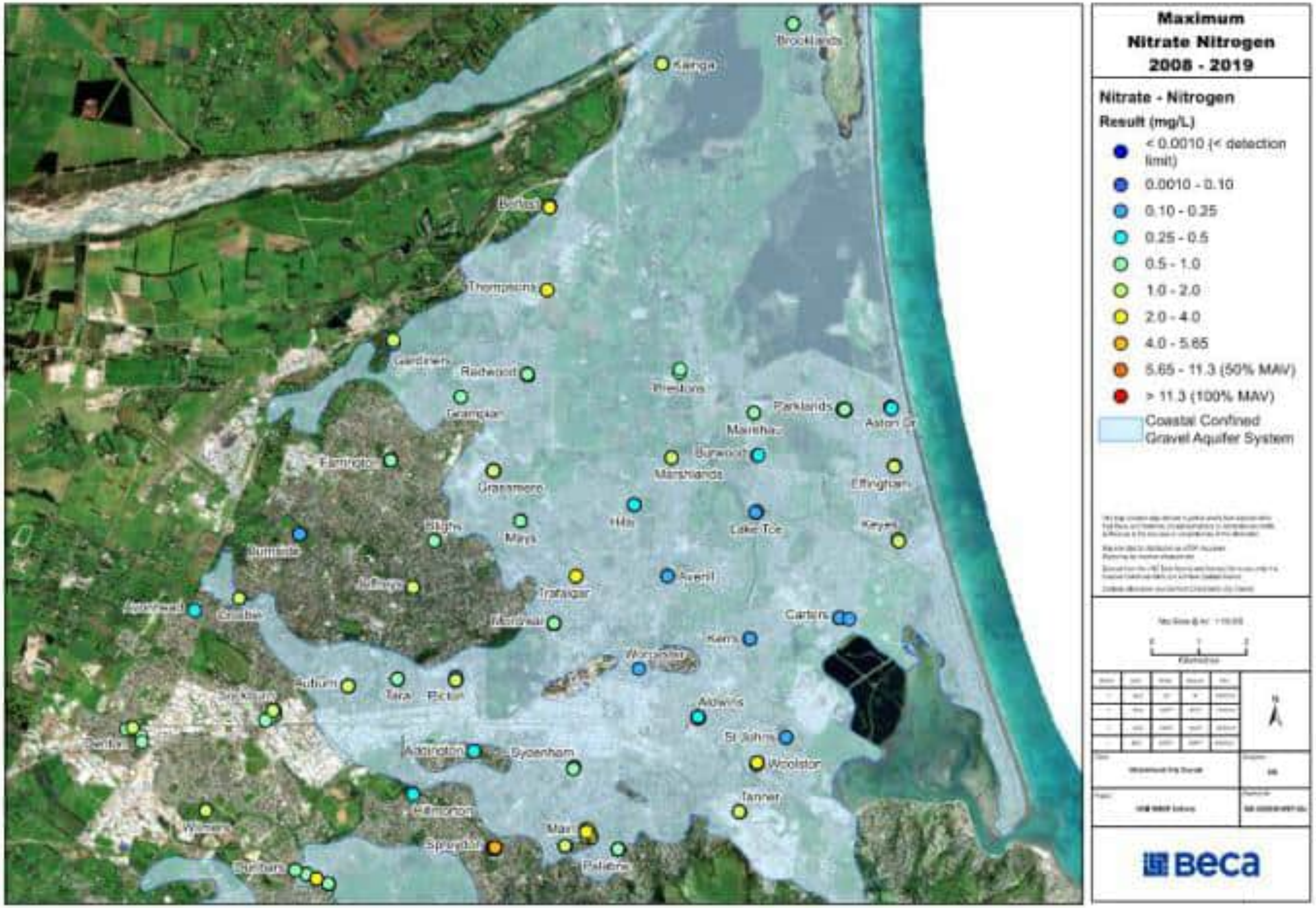


Figure 15: Map of maximum nitrate-nitrogen concentrations from Christchurch City Council bores

As part of the ongoing Well Head Security Improvement Programme (WHSIP) Christchurch City Council commissioned Beca Ltd to undertake a desk based preliminary site investigation of the area within a 400m radius of each pump station. The purpose of the assessment was to identify potential contamination risks to the wellheads from current or historical surface activities, and the vulnerability of the source aquifer at this location from the surface land uses within the 400m radius. This work included the following sources of information:

- Historical aerial photographs
- Environment Canterbury information (including discharge consent information, groundwater bore information, Listed Land Use Register (LLUR), HAIL sites)
- Christchurch City Council information
- Site walkover

These assessments were undertaken and reported in general accordance with Ministry for the Environment (MfE) Contaminated Land Management Guidelines No. 1 – Reporting on Contaminated Sites in New Zealand (2011) and MfE Contaminated Land Management Guidelines No. 5 – Site Investigation and Analysis (2011). Reports for each site presented historical aerial photographs with observations as land use changes were seen, a review of land uses giving details and an assessment of the readily leachable contaminant likelihood and the potential risk of migration through the shallow groundwater layer. A summary was provided of other bores within the 400m radius and consented activities from ECan information and an assessment made of the potential risk presented. A summary was included of any contaminants of potential concern and their potential exposure pathways.

At some pump stations, a more detailed site investigation was undertaken. One such example was Trafalgar pump station which is located at a historical landfill that was subject to uncontrolled land filling. The investigation at this site included assessing shallow groundwater and soil sampling with assessment against the requirements of the Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011

The information from these investigations is then used in the Sit specific Risk Management Plans that have been prepared for each pump station site .

4.2 Resource Consent Processes and Potential Chemical Contamination

Reviewing past land uses is important to determine historical contamination but current land uses can still present a risk. As described in Volume A, Council has good processes in place to work with Environment Canterbury across areas of shared interest. This includes the 'interested party' processes for resource consents where new or renewed consents have the potential to contaminate groundwater. CCC have adoption of UKWIR guidelines for assessment of contaminated land.

During 2021 CCC's responses to ECan as an interested party included: two separate applications looking at the impact of farming activities and resulting nitrate discharges in the Waimakariri sub region, an application for a clean fill site near Denton Park well field and a proposed ground source heat pump system in the vicinity of two CCC drinking water bores.

4.3 Chemical Monitoring – Planned Source Monitoring

Currently a project is underway that reviews all sources information pertinent to potential chemical risks to the source water (previous sampling including trend analysis, reviewing site specific risk management plans, site specific investigations, resource consent interests etc). From this information and the requirements that the new Drinking Water Quality Assurance

Rules will require of source water, a chemical sampling programme will be develop. This will, if warranted, contain site specific sampling and will otherwise identify a range of sampling across the 5 aquifers which will covered the required parameters and any additional monitoring to provide information about and track any potential chemical risks.

4.3.1 Monitoring of New Wells

New wells are sampled throughout their development. A list for determinands for sampling has been refined based on the Guidelines for Drinking Water Management document (Chapter 4.4.3/Table 4.5), the Draft Taumata Arowai Assurance Rules for source water and any site-specific information that is available regarding potential contaminants in the catchment. The list is included in Appendix B.

4.4 Online S-Scan Smart Water Monitoring Project

As part of the wider Smart Water goals and objects the Te Wai Ora o Tāne Integrated Water Strategy to improve the safety and performance of our water network, a pilot smart water network is being undertaken across the Rawhiti water supply zone. In November 2021, the continuous monitoring of source water quality aspect of this project was installed at Keyes Pump station in the Rawhiti zone. The S::CAN micro::station, a multi-parameter sensor instrument, continuously monitors temperature, conductivity, pH, turbidity, Oxidation Reduction Potential (ORP) and Dissolved Organic Carbon (DOC) of the source water leaving the pump station (untreated station). The objective is to provide accurate detection of changes in water quality, to provide an early warning of a contamination event.

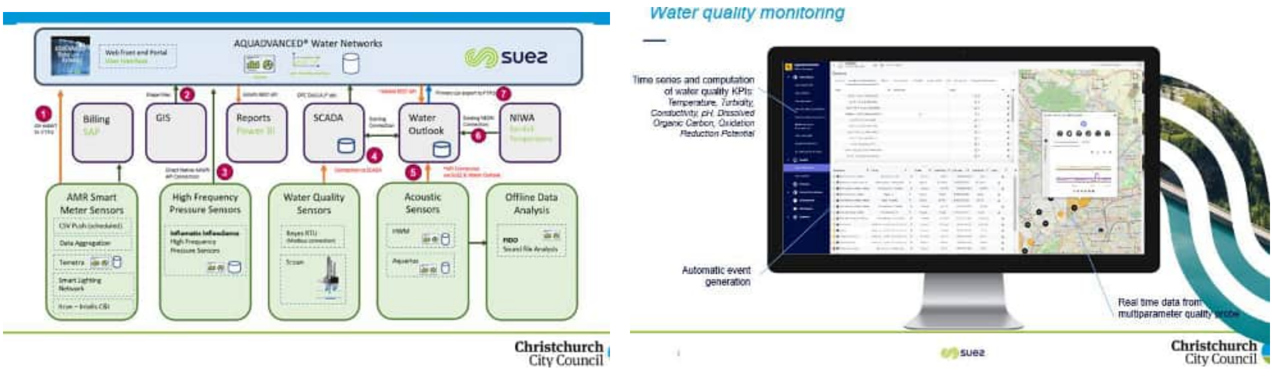


Figure 16: S-Scan smart water monitoring project

4.5 Radiological determinands

Drinking-water may contain radioactive substances (radionuclides) that could present a risk to human health. The Council tests groundwater from all five aquifers on an annual basis, in accordance with DWSNZ Section 9. Table 8 shows the 2020 sampling results. A full summary of results is saved in TRIM 19/1037907.

Table 8: Radiological Sampling Results

Pressure Zone	Pump Station	Well	Depth	Aquifer	Determinand	Result	Units	Date
Central	Montreal	Well 2	32	1	Radon-222	11.5 ± 1.5	Bq/L	13/10/2020
Central	Montreal	Well 2	32	1	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Central	Montreal	Well 2	32	1	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Ferrymead	Woolston	Well 3	34	1	Radon-222	23.8 ± 2.6	Bq/L	21/10/2020
Ferrymead	Woolston	Well 3	34	1	Total Alpha Concentration	0.047 ± 0.014	Bq/L	21/10/2020
Ferrymead	Woolston	Well 3	34	1	Total Beta Concentration	<0.15	Bq/L	21/10/2020
Rawhiti	Keyes	Well 1	97	2	Radon-222	17.7 ± 2.0	Bq/L	13/10/2020
Rawhiti	Keyes	Well 1	97	2	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Rawhiti	Keyes	Well 1	97	2	Total Beta Concentration	<0.15	Bq/L	13/10/2020
West	Sockburn	Well 5	76	2	Radon-222	30.9 ± 3.2	Bq/L	21/10/2020
West	Sockburn	Well 5	76	2	Total Alpha Concentration	0.062 ± 0.015	Bq/L	21/10/2020
West	Sockburn	Well 5	76	2	Total Beta Concentration	<0.15	Bq/L	21/10/2020
West	Sockburn	Well 5	76	2	Radon-222	29.4 ± 3.0	Bq/L	10/12/2020
West	Sockburn	Well 5	76	2	Total Alpha Concentration	<0.031	Bq/L	10/12/2020
West	Sockburn	Well 5	76	2	Total Beta Concentration	<0.15	Bq/L	10/12/2020
Central	Hills	Well 5	116	3	Radon-222	20.7 ± 2.3	Bq/L	13/10/2020
Central	Hills	Well 5	116	3	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Central	Hills	Well 5	116	3	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Northwest	Farrington	Well 7	107	3	Radon-222	25.7 ± 2.8	Bq/L	22/10/2020
Northwest	Farrington	Well 7	107	3	Total Alpha Concentration	<0.031	Bq/L	22/10/2020
Northwest	Farrington	Well 7	107	3	Total Beta Concentration	<0.15	Bq/L	22/10/2020
Northwest	Wrights	Well 5	126	3	Radon-222	19.2 ± 2.2	Bq/L	13/10/2020
Northwest	Wrights	Well 5	126	3	Total Alpha Concentration	0.023 ± 0.012	Bq/L	13/10/2020
Northwest	Wrights	Well 5	126	3	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Central	Hillmorton	Well 2	123	4	Radon-222	15.1 ± 1.8	Bq/L	13/10/2020
Central	Hillmorton	Well 2	123	4	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Central	Hillmorton	Well 2	123	4	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Parklands	Marshlands	Well 2	150	4	Radon-222	25.9 ± 2.8	Bq/L	21/10/2020
Parklands	Marshlands	Well 2	150	4	Total Alpha Concentration	0.055 ± 0.015	Bq/L	21/10/2020
Parklands	Marshlands	Well 2	150	4	Total Beta Concentration	<0.15	Bq/L	21/10/2020
Parklands	Marshlands	Well 2	150	4	Radon-222	24.1 ± 2.5	Bq/L	10/12/2020
Parklands	Marshlands	Well 2	150	4	Total Alpha Concentration	<0.031	Bq/L	10/12/2020
Parklands	Marshlands	Well 2	150	4	Total Beta Concentration	<0.15	Bq/L	10/12/2020
Rawhiti	Keyes	Well 2	151	4	Radon-222	16.8 ± 2.0	Bq/L	13/10/2020
Rawhiti	Keyes	Well 2	151	4	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Rawhiti	Keyes	Well 2	151	4	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Central	Sydenham	Well 6	166	5	Radon-222	24.4 ± 2.7	Bq/L	21/10/2020
Central	Sydenham	Well 6	166	5	Total Alpha Concentration	0.065 ± 0.016	Bq/L	21/10/2020
Central	Sydenham	Well 6	166	5	Total Beta Concentration	<0.15	Bq/L	21/10/2020
Central	Sydenham	Well 6	166	5	Radon-222	25.2 ± 2.6	Bq/L	10/12/2020
Central	Sydenham	Well 6	166	5	Total Alpha Concentration	<0.031	Bq/L	10/12/2020
Central	Sydenham	Well 6	166	5	Total Beta Concentration	<0.15	Bq/L	10/12/2020
Northwest	Burnside	Well 10	202	5	Radon-222	16.5 ± 1.9	Bq/L	13/10/2020
Northwest	Burnside	Well 10	202	5	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Northwest	Burnside	Well 10	202	5	Total Beta Concentration	<0.15	Bq/L	13/10/2020

The Total Alpha Concentration in three sample results was found to be greater than 50% MAV (0.05 Bg/L) with results between 0.055 and 0.065 (± 0.016) Bq/L. These results should be interpreted in the light of the World Health Organization 'Guidelines for Drinking-water Quality 4th Edition 2017'[11], which sets a screening value of 0.5 Bq/L for Total Alpha Activity, below which no further action is required. Furthermore, the WHO publication 'Management of Radioactivity in Drinking-water'[12] states that any health effects from radionuclides in drinking water are normally small, compared with the risks from microorganisms and chemicals, and will not be acute or immediate. Except in unusual circumstances, the radiation dose resulting from the ingestion of radionuclides in drinking-water is much lower than that received from other sources of radiation. Since the 2020 results are approximately 9 times lower than the WHO screening value it has been concluded that these concentrations pose no health risk. Repeat samples taken in December 2020 were all below 50% MAV.

4.6 Priority 2 determinands, disinfection by-products and other sampling

While not a specific source water contaminant, organic matter in source water can be responsible for the development of disinfection by products within the network. Disinfection by-product sampling was undertaken in June 2018 across the Christchurch and Lyttelton water supplies after temporary chlorination was introduced. There were no results that caused concerns. The data is stored in TRIM 18/916182. Another round was undertaken in 2021 and for 2022 the programme has been initiated to follow the requirements in the Draft Quality Assurance Rules (see TRIM 21/1390441). Within Christchurch results are well below the MAVs and indicate that the source water doesn't contain organic matter.

4.7 Source Risk Assessment

Below are the source risk assessment tables. These have been taken from the Volume B of the Christchurch Water Safety Plan. The completed risk assessment tables (including details of improvements) will remain in Volume B but are copied here to give completeness for the Source Risk Management Plan.

[11] https://www.who.int/publications/i/item/9789241549950

[12] https://www.who.int/publications/i/item/9789241513746

Source Risk Assessment Table

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals /	Disruption to	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of	Risk Acceptability	Improvement Plan Reference
Source - Groundwater	Source water (aquifer) receives chemical contamination	1.01	• Contaminated sites close enough to potentially affect groundwater quality • Consented activities, with non-conforming behaviour or poor consent conditions • Unconsented activities • Chemical/diesel spillage seeps into aquifer	☐	☐	☑	☐	Likely	Assumes: Unconfined aquifers, unsecure well heads, inadequate land use controls to protect aquifers from contamination, location and status of private wells unknown.	Major	Chronic harm to people (long-term exceedance of long-term chemical MAV). Most contaminants will appear over long period of time, contaminants appearing more suddenly likely to be hydrocarbons e.g. failed buried tank. Health impacts for hydrocarbons somewhat self-limiting due to taste and odour issues (people will avoid drinking very bad tasting or smelling water).	Extreme	• Routine inspection and maintenance of water supply assets • Building consent and HSNO processes and associated inspections • ECan groundwater quality monitoring reports • Well head security assessments • Pre-screening/ PSI/DSI Assessments • Site Specific Risk Management Plans • Water quality monitoring • Water supply connection application process • Customer complaints • Water quality monitoring • Listed Land Use Register (LLUR) of Hazardous Activities and Industries and	• Engagement with resource consent applications • Building consent and HSNO processes and associated inspections • Trade waste and stormwater audits • Liaison with ECan • Liaison with Council Contaminated Sites Officers • Programme to replace shallow wells with deep wells • CCC fuel tanks are all above ground • Well head security improvement programme • PSI/DSI Assessments • Monitoring known Council-owned assets that present a contamination risk • Controls under Land and Water Regional Plan and Christchurch District Plan • 3-yearly certification of fuel tanks	Unlikely	Depth to aquifer, and confining layers reduces influence from surface. Source aquifers have a significant depth of confining materials and often an upward artesian head. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation	Major	Rolling 5-yearly testing regime of all pump stations shows no history of chemical contamination in past 10 years. ECan's Land and Water Regional Plan (LWRP), Christchurch District Plan and other regulations manage activities to reduce risks to aquifers. Pre-screening for potential contamination undertaken for every pump station site in 2018 and 2019, and where required, followed up with preliminary site investigations and detailed site investigations including recommended remedial measures	Medium	Confident	Acceptable	CI03 PI14

													List (HAIL) sites • Groundwater modelling	• Mass balance checks on diesel volumes • Confined aquifer system • Dangerous goods legislation • Adoption of UKWIR guidelines for assessment of contaminated land • Maintain contamination monitoring, risk assessment and reactive processes				and shallow groundwater quality monitoring. Site-specific safety plan reviews include review of land use, and no contaminatin g activities identified in past 5 years. Majority of source aquifers believed to be too deep for contaminatio n by nearby sites. Not all abandoned wells are mapped by ECan.				
Source - Groundwater	Source water (aquifer) receives microbial contamination from untreated wastewater	1.0 2	• Broken or leaking wastewater pipes • Wastewater overflows • Septic tanks	☑	☑	☐	☐	Likely	Assumes: Poor condition wastewater network, frequent overflows and poor condition septic tanks in close proximity to water supply wells, unconfined aquifers, young water in wells, shallow unsecure drinking water supply wells	Catastrophic	Major microbial contamination , possibly deaths expected, that affects >5,000 people	Extreme	• Alert from CDHB about illness in the community • Customer complaints • Well head security assessments • Site Specific Risk Management Plans • Pre-screening/ PSI/DSI Assessments • Routine inspection and maintenance of water supply assets • Water quality monitoring • Groundwater modelling • Groundwater age dating • Wastewater	• Maintain contamination monitoring, risk assessment and reactive processes • Engagement with resource consent applications • Routine inspection and maintenance of water supply assets • Building consent process and associated inspections • Trade waste and stormwater audits • Liaison with ECan • Programme to replace shallow wells with deep wells • Well head security improvement	Rare	Depth to aquifer, and confining layers reduces influence from surface. Microbial monitoring history demonstrates DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of	Catastrophic		Medium	Reliable	Acceptable	CI0 3

													pipe defect mapping • Wastewater overflow monitoring and modelling	programme • PSI/DSI Assessments • Monitoring known Council-owned assets that present a contamination risk • Controls under Land and Water Regional Plan and Christchurch District Plan • Confined aquifer system • Reduced abstraction from shallow wells • Good asset records		a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off						
Source - Groundwater	Source water (aquifer) receives chemical or microbial contamination	1.03	Abandoned or improperly decommissioned private wells	☑	☑	☑	☐	Likely	Assumes: Poor condition private wells provide a direct contamination route to the aquifer, unconfined aquifers, no artesian pressure, young water in wells, shallow unsecure drinking water supply wells	Catastrophic	Major microbial contamination, possibly deaths expected, that affects >5,000 people	Extreme	• Alert from CDHB about illness in the community • Customer complaints • Well head security assessments • Site Specific Risk Management Plans • Pre-screening/ PSI/DSI Assessments • Routine inspection and maintenance of water supply assets • Water quality monitoring • Groundwater modelling • Groundwater age dating • Monitoring known Council-owned assets that present a contamination risk • ECan well data for private wells	• Maintain contamination monitoring, risk assessment and reactive processes • Engagement with resource consent applications • Routine inspection and maintenance of water supply assets • Liaison with ECan • Programme to replace shallow wells with deep wells • Well head security improvement programme • Controls under Land and Water Regional Plan • Confined aquifer system • Reduced abstraction from shallow wells • Good asset records	Rare	Depth to aquifer, and confining layers reduces influence from surface. Microbial monitoring history demonstrates DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells. Initial groundwater modelling with simulated aquifer punctures (e.g. private well contamination path) for Effingham and Denton wells concluded that no young water would reach the wells. Location of private wells in relation to CCC	Catastrophic		Medium	Reliable	Acceptable	CI03 CI04 PI16

																water supply wells has been mapped and is also considered during wellhead security assessments. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off						
Source - Groundwater	Source water (aquifer) receives discharge from domestic or industrial processes, either directly or indirectly (excluding septic tanks)	1.04	Ground-source heating and cooling systems not maintained and causing heat exchanger fluids to contaminate the source water.	□	□	☑	□	Possible		Major	Exceedance of the chemical MAV that affects <5,000 people	High	• Maintain contamination monitoring, risk assessment and reactive processes • Routine inspection and maintenance of water supply assets • Building consent process and associated inspections • Resource consent process and associated monitoring • Well head security assessments • Pre-screening/ PSI/DSI Assessments	• Maintain contamination monitoring, risk assessment and reactive processes • Engagement with Resource Consent applications • Building consent process and associated inspections • Liaison with ECan • Programme to replace shallow wells with deep wells • Well head security improvement programme • Pre-screening/PSI/DSI Assessments • Controls under Land and Water	Unlikely	Most ground source heating systems have been installed post-earthquakes and mostly in the Central city and are discharging into aquifer 1. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption	Major	Reduced abstraction from aquifer 1 for public water supply means less people potentially affected.	Medium	Reliable	Acceptable	

													• Site Specific Risk Management Plans • Water quality monitoring • Customer complaints	Regional Plan • Confined aquifer system • Double skinned heat exchangers prevent loss of heating/cooling fluid into aquifer		• Bio-degradation and chemical transformation						
Source - Groundwater	Water supply well receives water affected by microbial contamination from animals	1.05	Water abstracted from the well is less than 1 year old and animals are present in the 1-year source area	☑	☑	☐	☐	Likely	Assumes: Unrestricted land use in close proximity to water supply wells, unconfined aquifers, no artesian pressure, young water in wells, shallow unsecure drinking water supply wells.	Catastrophic	Major microbial contamination, possibly deaths expected, that affects >5,000 people	Extreme	• Well head security assessments • Site Specific Risk Management Plans • Water quality monitoring • Age dating of groundwater • Groundwater modelling • Routine inspection and maintenance of water supply assets	• Maintain contamination monitoring, risk assessment and reactive processes • Engagement with resource consent applications • Routine inspection and maintenance of water supply assets • Liaison with ECan • Programme to replace shallow wells with deep wells • Well head security improvement programme • Pre-screening/PSI/DSI Assessments • Controls under Land and Water Regional Plan and Christchurch District Plan • Confined aquifer system • Good asset records	Rare	Depth to aquifer, and confining layers reduces influence from surface Microbial monitoring history demonstrates DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells.	Catastrophic		Medium	Reliable	Acceptable	
Source - Groundwater	Water supply well receives water affected by agricultural land use and chemicals (e.g. nitrate)	1.06	• Application of fertiliser in the catchment or recharge zone • Land use intensification e.g. dairy conversions.	☐	☐	☑	☐	Possible	Assumes: Unrestricted land use in source water area	Major	Chronic harm to people (long-term exceedance of long-term chemical MAV).	High	• Groundwater modelling • Water quality monitoring • ECan groundwater quality modelling and monitoring reports	• Maintain contamination monitoring, risk assessment and reactive processes • Canterbury Water Management Strategy • Liaison with ECan • Controls under Land and Water	Unlikely	5-yearly chemical monitoring of wells shows low levels of nitrate. Majority of Christchurch groundwater is sourced from the Waimakariri River which has a very low nitrate	Major		Medium	Reliable	Acceptable	CI03 PI14

														Regional Plan • NES Freshwater 2020 limits land use intensification • Confined aquifer system • Submissions on Land and Water Regional Plan Changes		concentration. Groundwater modelling for ECan LWRP Plan Change 7 shows increasing nitrates from north of the Waimakariri river in the long term but still below MAV.						
Source - Groundwater	Groundwater nitrate concentrations much lower than the DWSNZ MAV may cause an increase in colorectal cancer rates	1.07	• Application of fertiliser in the catchment or recharge zone • Land use intensification e.g. dairy conversions.			☑		Rare	• Epidemiological studies have shown that nitrate may be a contributing factor to colorectal cancer at concentrations of less than 10% of the current MAV. • Groundwater modelling predicts increased nitrate concentrations from north of the Waimakariri river entering the deeper aquifers of the Christchurch West Melton groundwater system.	Major	Chronic harm to people	Low	• Water quality monitoring • Alert from CDHB about illness in the community • Epidemiological studies	• Maintain contamination monitoring, risk assessment and reactive processes • Canterbury Water Management Strategy • Liaison with ECan • Controls under Land and Water Regional Plan • NES Freshwater 2020 limits land use intensification • Confined aquifer system • Submissions on Land and Water Regional Plan Changes	Rare		Major		Low	Estimate	Acceptable	PI14 PI19 PI20
Source - Groundwater	Water supply well is affected by saline water intrusion	1.08	Shallow well near the coast could draw saline groundwater	☐	☐	☑	☐	Possible	Assumes: Shallow drinking water supply wells near the coast, unconfined aquifer, no alternative pump stations for supply	Major	Systems significantly compromised and abnormal operation	High	• Water quality monitoring • Customer complaints	• No shallow wells near coast • System redundancy	Unlikely	Shallow water supply wells near coast have been decommissioned and replaced with deeper wells. Monitoring data shows low conductivity and salinity	Minor		Low	Reliable	Acceptable	CI03 PI14
Source - G	Not enough source water available for abstraction	1.09	• Resource consent limitations: insufficient upper limit on	☐	☐	☐	☑	Possible	Assumes: Insufficient head room in Council's water take consent,	Catastrophi	Major disruption of service (over 24 hours and >500,000	High	• Groundwater take flow monitoring • Groundwater	• Sufficient headroom in Council's groundwater take consent	Rare	ECan data shows that there is sufficient water in the aquifers	Catastrophi		Medium	Confident	Acceptable	

			global water take consent • Water availability reduces over time due to more groundwater take consents issued to private well owners • Ground-source heating and cooling systems abstract too much water from deeper aquifers used for public water supply • Increased demand for water due to population growth, leakage and climate change						insufficient control on other groundwater takes, increasing demand due to population growth, climate change and increasing leakage due to deteriorating water supply pipe network		customer hours)		level monitoring • Water supply model for current and future demand scenarios	• Engagement with resource consent applications • Liaison with ECan • Controls under Land and Water Regional Plan • Annual water conservation campaign • Water restrictions if required • Masterplan for growth areas		and the only permissible consumptive use for new groundwater take consents is for community drinking water supplies. Infrastructure for growth is already provided for the next years with budget in the Long Term Plan and Infrastructure Strategy for water supply infrastructure for growth. Global groundwater consent is approx. 72 million m³ per year whereas current take is approx. 50 million m³ per year.						
Source - Groundwater	Not enough source water available for abstraction	1.10	Water abstraction / pumping exceeds recharge rates or causes well to collapse	☐	☐	☐	☑	Possible	Assumes: Over pumping of the well beyond its capacity, no alternative pump stations for supply	Moderate	Significant modification to normal operation but manageable (as only one well affected)	Medium	• SCADA alarms and associated maintenance • Groundwater level monitoring • Groundwater take flow monitoring • SCADA alarms	• Network Control staffing and processes • Step tests and sand tests undertaken during well development to determine the safe pumping rate for each well • Flow limiters on some wells • System redundancy	Unlikely		Moderate		Medium	Reliable	Acceptable	PI07
Source - Groundwater	Emerging contaminants affect drinking water supply wells	1.11	• PFOS and PFOA used in fire-retardant foams, particularly in Wigram and area around the airport • PFOS/PFOA found in shallow groundwater at [redacted]	☐	☐	☑	☐	Possible	Assumes: Use of PFOS and PFOA in source water catchments, unconfined aquifers, no artesian pressure, shallow unsecure drinking water supply wells.	Major	Exceedance of the chemical or radiological MAV that affects <5,000 people	High	• Test for PFOS and PFOA • PFAS Joint Agency Working Group	• Confined aquifer system • Programme to replace shallow wells with deep wells • Well head security improvement programme • Pre-screening/PSI/DSI Assessments	Rare	There are no water supply wells near Wigram and the airport. [redacted]	Major		Low	Estimate	Acceptable	PI14

			[redacted]													Testing in distribution system showed no presence of PFOS/PFOA Testing by Christchurch International Airport Ltd and FENZ has not found any contamination. Depth to aquifer, and confining layers reduces influence from surface. Source aquifers have a significant depth of confining materials and often an upward artesian head. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation						
Source - Groundwater	Radioactivity in the groundwater affects drinking water supply wells	1.12	Principally by: • leaching of radionuclides from rocks and soils into water • deposition of radionuclides from the atmosphere.	☐	☐	☑	☐	Unlikely	According to DWSNZ Guidelines chapter 9, naturally occurring radionuclides from both these sources account for almost the entire	Moderate	According to DWSNZ Guidelines chapter 9, in the radiological context, the MAV is intended to indicate a level above which the	Medium	• Water quality monitoring		Unlikely	Is naturally occurring radiation which cannot be prevented. Annual radiological sampling has not detected any concentrations exceeding the	Moderate		Medium	Reliable	Acceptable	

									radioactivity present in New Zealand drinking-waters. Concentrations are as variable as the nature of the soils and rocks themselves.		radioactive content of the water should be investigated further and an assessment of all relevant radiological issues undertaken. The MAV is thus more of a guideline than necessarily an absolute maximum. It is also intended to be clear however, that at levels below the MAV, there is no need for further assessment.					MAV (highest concentration was approx. 55-65% MAV for total alpha activity).						

Appendix A CRC204470: Authorised Water Take Bores and Rates of Take

CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m³)**	**Max. 150 Day Volume (m³)**	**Max. Annual Volume (m³)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
PS1001: Addington	Addington Stn Well-01	M35/2270	4	42,350			1568420	-5178474
	Addington Stn Well-02	M35/2787					1568414	-5178457
PS1002: Aldwins	Aldwins Stn Well-01	M35/2587	4	70,000			1573194	-5179193
	Aldwins Stn Well-02	M35/3813					1573165	-5179174
	Aldwins Stn Well-03	M35/8147	1	42,336			1573178	-5179203
PS1004: Aston Drive	Aston Stn Well-01	M35/7215	4	39,312			1577279	-5185757
	Aston Stn Well-02	M35/7216	2	39,312			1577258	-5185779
PS1068: Auburn	Auburn Stn Well-05	M35/7600	5	45,500	972,000		1565741	-5179851
PS1005: Averill	Averill Stn Well-02	M35/2159	1	7,623			1572555	-5182178
	Averill Stn Well-03	M35/2403	2	14,000			1572533	-5182178
	Averill Stn Well-01	M35/1976	4	28,000			1572545	-5182178
	Averill Stn Well-04	M35/1870					1572529	-5182166
PS1069: Avonhead	Avonhead Stn Well-05	BX23/0428	4	33250			1562480	-5181459
	Avonhead Stn Well-07	BX23/0430	5+	33250			1562453	-5181473
PS1070: Belfast	Belfast Stn Well-02	M35/10632	3	35,000			1570028	-5190029
	Belfast Stn Well-03	BX24/2762	4	44,150			1570035	-5190030
PS1006: Bexley Rd	Bexley Stn Well-01	M35/2266	4	45,500			1576927	-5182380
PS1007: Blighs	Blighs Stn Well-03	M35/6203	2	18,144			1567650	-5182963
	Blighs Stn Well-04	BX24/0965	3	28,000			1567578	-5182936
PS1066: Brooklands	Brooklands Stn Well-01	M35/7180	2	13,860			1575198	-5193914
	Brooklands Stn Well-02	M35/7291					1575139	-5193923
PS1071: Burnside	Burnside Stn Well-05	M35/9439	5	62,000			1564762	-5183107
	Burnside Stn Well-07	BX24/0188					1564735	-5183038
	Burnside Stn Well-10	BX24/0191					1564725	-5183010
	Burnside Stn Well-06	BX24/0187	4	44,000			1564718	-5183078
	Burnside Stn Well-08	BX24/0189					1564698	-5183051

CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m^3)**	**Max. 150 Day Volume (m^3)**	**Max. Annual Volume (m^3)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
	Burnside Stn Well-09	BX24/0190					1564699	-5183050
PS1081: Burwood	Burwood Stn Well-01	M35/3660	2	16,429			1574434	-5184750
	Burwood Stn Well-02	M35/4133	4				1574458	-5184757
	Burwood Stn Well-03	M35/1546					1574476	-5184770
PS1008: Carters	Carters Stn Well-01	M35/2789	4	76,020			1576180	-5181300
	Carters Stn Well-03	M35/2555					1576189	-5181294
	Carters Stn Well-05	M35/10928					1576383	-5181270
	Carters Stn Well-02	M35/2790	2	17,500			1576181	-5181309
PS1072: Crosbie	Crosbie Stn Well-02	M35/6040	5	25,200			1563443	-5181714
	Crosbie Stn Well-05	BX23/0227	5+	21,000			1563421	-5181729
	Crosbie Stn Well-04	M35/18384	4	49,980			1563481	-5181717
	Crosbie Stn Well-06	BX23/0228					1563437	-5181715
PS1100: Denton Park	Denton Main South Well-01	M35/1865	3	105,000			1561363	-5178795
	Denton Stn Well-02	M35/1866					1561046	-5178936
	Denton Stn Well-01	M35/3547					1561181	-5178980
	Denton Main South Well-02	M35/3546					1561370	-5178679
	Denton Amyes Well-01	M35/1864	2	13,104			1561619	-5178526
PS1102: Dunbars Rd	Dunbars Stn Well-01	M36/4053	2	133,000			1565342	-5175647
	Dunbars 56P Well-01(dunbars 3)	M36/4052					1565084	-5175757
	Dunbars 32P Well-01 (dunbars well 2)	M36/4333					1564862	-5175849
	Dunbars 85 Well-01(Dunbars well 4)	M36/3060					1564622	-5175939
	Dunbars Stn Well-05	M36/8019	4	37,800			1565311	-5175651
PS1010: Effingham	Effingham Stn Well-01	M35/1554	4	24,500			1577348	-5184510
	Effingham Stn Well-02	M35/1606	2	53,466			1577344	-5184524
	Effingham Stn Well-03	M35/2609	4				1577354	-5184523
PS1012: Estuary	Estuary Stn Well-04	BX24/0412	2	31,500			1578629	-5180019
	Estuary Stn Well-05	BX24/1210	4	10,500			1578760	-5180048

CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m^3)**	**Max. 150 Day Volume (m^3)**	**Max. Annual Volume (m^3)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
PS1073: Farrington	Farrington Stn Well-04	M35/9440	5	30,200			1566661	-5184646
	Farrington Stn Well-05	BX24/0192	3	51,400			1566673	-5184622
	Farrington Stn Well-06	BX24/0193					1566674	-5184625
	Farrington Stn Well-07	BX24/0194					1566689	-5184647
	Farrington Stn Well-08	BX24/0195	4	24,400			1566658	-5184645
PS1125: Gardiners	Gardiners Well-01	BX24/1311	5+	27,000			1566708	-5187208
	Gardiners Well-02	BX24/1312	4	23,000			1566701	-5187153
PS1074: Grampian	Grampian Stn Well-05	M35/8660	2	21,168			1568136	-5185992
	Grampian Stn Well-06	BX24/1327	3	48,000			1568088	-5186064
	Grampian Stn Well-07	BX24/1328					1568089	-5186084
PS1014: Grassmere	Grassmere Stn Well-01	M35/1476	1	28,000			1568832	-5184433
	Grassmere Stn Well-02	M35/1475	3	30,548			1568832	-5184426
	Grassmere Stn Well-03	M35/8087	4	45,360			1568839	-5184430
PS1016: Hillmorton	Hillmorton Stn Well-01	M36/0981	5	7,637			1567121	-5177567
	Hillmorton Stn Well-02	M36/1058	4	71,365			1567120	-5177568
	Hillmorton Stn Well-04	M36/4073					1567239	-5177644
PS1017: Hills Rd	Hills Stn Well-06	BX24/0457	4	28,000			1571817	-5183705
	Hills Stn Well-07	BX24/0350	2	21,000			1571819	-5183689
	Hills Stn Well-05	M35/10325	3	28,000			1571818	-5183696
PS1076: Jeffreys Rd	Jeffreys Stn Well-06	M35/6667	5	39,312			1567124	-5181957
	Jeffreys Stn Well-07	BX24/0533	4	18,000			1567080	-5181960
	Jeffreys Stn Well-08	BX24/0532	2	23,000			1567080	-5181950
	Jeffreys Stn Well-09	BX24/0534	3	18,718			1567120	-5181950
PS1067: Kainga	Kainga Stn Well-01	M35/6213	2	9,100			1572410	-5193067
PS1022: Kerrs Rd	Kerrs Stn Well-01	M35/2152	4	58,065			1574276	-5180860
	Kerrs Stn Well-02	M35/2241					1574287	-5180863
PS1119: Keyes	Keyes Stn Well-02	M35/18733	4	31,500			1577414	-5182970
	Keyes Stn Well-01	M35/18732	2	50,120			1577432	-5182927
	Keyes Stn Well-03	M35/18734					1577566	-5182999
PS1023: Lake Terrace	Lake Terrace Stn Well-03	M35/2260	4	66,752			1574392	-5183543
	Lake Terrace Stn Well-04	M35/18398	5	39,690			1574423	-5183561

CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m^3)**	**Max. 150 Day Volume (m^3)**	**Max. Annual Volume (m^3)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
	Lake Terrace Stn Well-05	BX24/0993	3	21,000			1574409	5183550
PS1529: Ly Dyers	LY Dyers Stn Well	M35/5135	4	41,204			1575622	-5178663
PS1024: Main Pumps	Main Pumps Stn Well-01	M36/4591	1	212,688			1570884	-5176731
	Main Pumps Stn Well-02	M36/2828					1570840	-5176812
	Main Pumps Stn Well-03	M36/1356					1570904	-5176629
	Main Pumps Stn Well-04	M36/1195					1570803	-5176810
	Main Pumps Stn Well-05	M36/0985					1570811	-5176673
	Main Pumps Stn Well-06	M36/1363					1570805	-5176753
PS1083: Mairehau	Mairehau Stn Well-01	M35/5830	4	45,360			1574361	-5185638
PS1084: Marshlands	Marshlands Stn Well-01	M35/7813	4	90,720			1572635	-5184704
	Marshlands Stn Well-02	M35/7814					1572622	-5184707
PS1026: Mays Rd	Mays Stn Well-04	M35/2494	2	76,202			1569403	-5183360
	Mays Stn Well-02	M35/1945					1569403	-5183362
	Mays Stn Well-03	M35/1944	1	45,360			1569403	-5183363
	Mays Stn Well-05	M35/7319	5	36,288			1569413	-5183358
PS1027: Montreal St	Montreal Stn Well-01	M35/2243	4	76,202			1570123	-5181177
	Montreal Stn Well-02	M35/2325	1				1570116	-5181183
PS1028: Palatine	Palatine Stn Well-01	M36/1197	1	14,000			1571483	-5176387
PS1085: Parklands	Parklands Stn Well-01	M35/3446	4	43,400			1576297	-5185725
	Parklands Stn Well-02	M35/3128	2	67,060			1576256	-5185733
	Parklands Stn Well-03	M35/7746					1576305	-5185714
PS1088: Picton Ave	Picton Stn Well-01	M35/8897	4	28,224			1568037	-5179984
	Picton Stn Well-02	M35/8896					1568040	-5180058
	Picton Stn Well-03	M35/8898	2	10,080			1568023	-5179980
PS1123: Prestons	Prestons Stn Well-01	BX24/0624	2	30,000			1572776	-5186506
	Prestons Stn Well-02	BX24/0625	3	23,000			1572781	-5186545
	Prestons Stn Well-03	BX24/0626	4	48,000			1572795	-5186582
	Prestons Stn Well-04	BX24/0627	2				1572942	-5186595
PS1077: Redwood	Redwood Stn Well-02	M35/5251	1	42,000			1569561	-5186447
	Redwood Stn Well-01	M35/5573					1569552	-5186469
PS1109: Sockburn	Sockburn Stn Well-01	M35/1859	2	182,000			1564187	-5179227

CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m^3)**	**Max. 150 Day Volume (m^3)**	**Max. Annual Volume (m^3)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
	Sockburn Stn Well-02	M35/1860					1564183	-5179350
	Sockburn Weaver Well-01	M35/2272					1564081	-5179452
	Sockburn Weaver Well-02	M35/2273					1564102	-5179548
	Sockburn Blenheim Well-01	M35/2274					1564080	-5179181
	Sockburn Blenheim Well-02	M35/2275					1563991	-5179124
PS1030: Spreydon	Spreydon Stn Well-02	M36/1225	1	21,000			1568860	-5176421
	Spreydon Stn Well-06	M36/8288	2	31,500	1,010,000		1568820	-5176409
	Spreydon Stn Well-03	M36/1210	4	46,900			1568852	-5176397
	Spreydon Stn Well-04	M36/1055					1568837	-5176407
	Spreydon Stn Well-05	M36/1619					1568855	-5176426
PS1063: St Johns	St Johns Stn Well-01	M35/2554	4	112,000			1575043	-5178769
	St Johns Stn Well-02	M35/2805					1575038	-5178766
	St Johns Stn Well-03	M35/18432	5				1575066	-5178758
PS1031: Sydenham	Sydenham Stn Well-05	M36/0967	4	27,800	2,245,000		1570548	-5178108
	Sydenham Stn Well-07	M36/20670	2	27,216			1570568	-5178118
	Sydenham Stn Well-06	M36/4565	5	84,672			1570527	-5178102
	Sydenham Stn Well-08	M36/20671					1570528	-5178127
PS1089: Tara	Tara Stn Well-04	M35/6945	4	29,484			1566784	-5180000
PS1095: Tanner	Tanner Stn Well-02	M36/1915	1	26,610		362,912	1574058	-5177188
	Tanner Stn Well-03	M36/20729				362,912	1574431	-5178228
PS1078: Thompsons Rd	Thompsons Stn Well-02	M35/8972	4	78,400	1,400,000		1569969	-5188255
	Thompsons Stn Well-03	BX24/0153	5				1569999	-5188293
PS1034: Thorrington	Thorrington Stn Well-01	M36/2195	1	14,000			1570359	-5176442
PS1035: Trafalgar	Trafalgar Stn Well-05	M35/2556	4	36,316	1,361,000		1570536	-5182198
	Trafalgar Stn Well-06	M35/8452					1570577	-5182184
	Trafalgar Stn Well-07	BX24/0348	5	27,384			1570539	-5182199
PS1037: Worcester	Worcester Stn Well-01	M35/9289	4	98,000			1571935	-5180186
	Worcester Stn Well-02	M35/9290					1571925	-5180216
PS1117: Wilmers Rd	Wilmers Stn Well-01	M36/20556	4	113,400			1562746	-5177258
	Wilmers Stn Well-02	M36/20557					1562731	-5177210

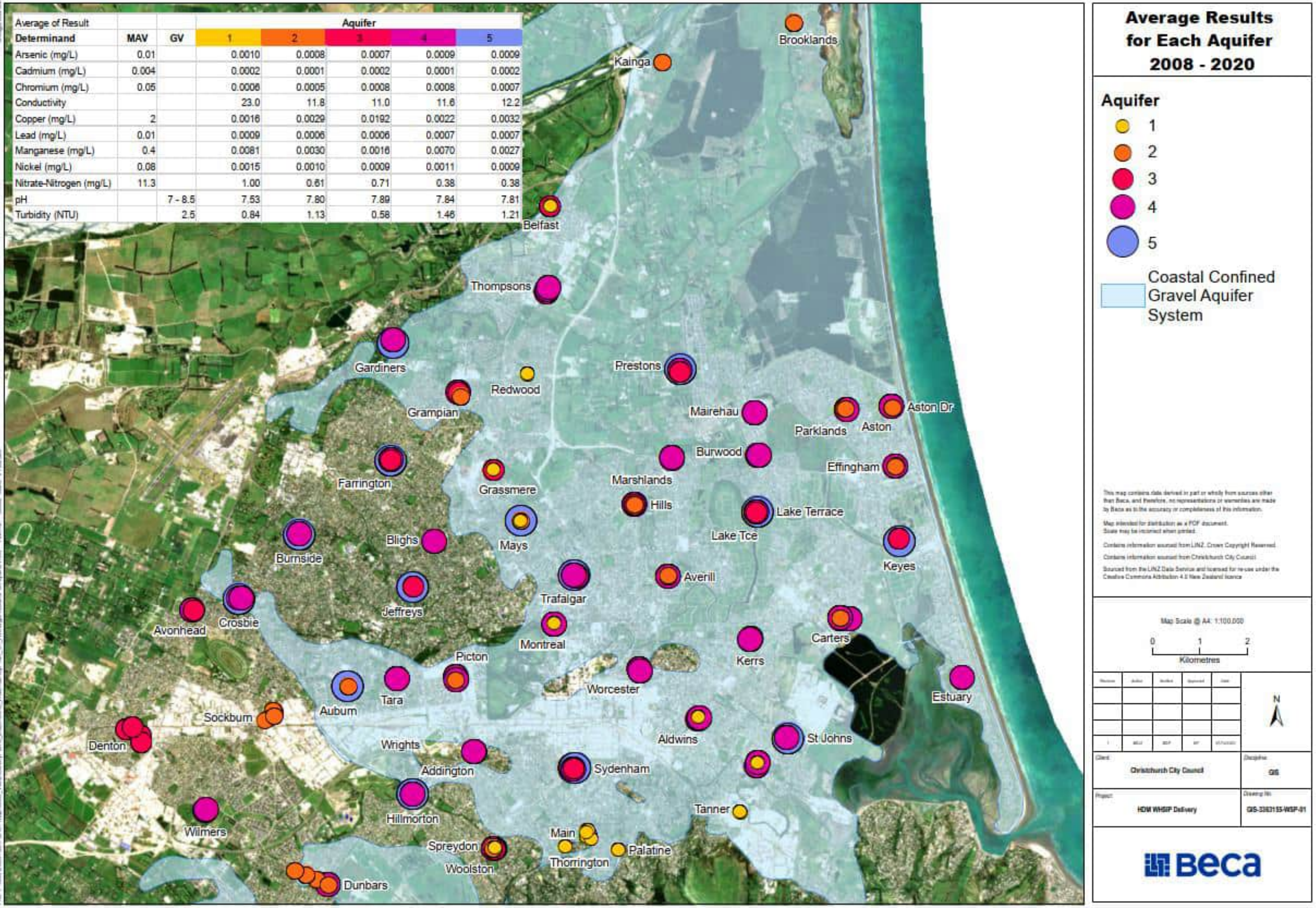
CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m^3)**	**Max. 150 Day Volume (m^3)**	**Max. Annual Volume (m^3)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
	Wilmers Stn Well-03	M36/20558					1562552	-5177159
	Wilmers Stn Well-04	M36/20559					1562542	-5177159
PS1065: Woolston	Woolston Stn Well-04	M36/1030	4	26,460			1574429	-5178236
	Woolston Stn Well-03	M36/1045	1	21,000		150,000	1574424	-5178232
	Woolston Stn Well-05	M36/5838	4	30,240			1574409	-5178186
Ruru Cemetery	Ruru Cemetery	BX24/0346		3,150		43,000	1574939	-5179549
PS1080: Wrights	Wrights Stn Well-05	BX24/1678	4	29,064			1567356	-5178607
	Wrights Stn Well-06	BX24/1679	5	30,744			1567377	-5178563
PS1126: Ben Rarere	Ben Rarere Stn Well-01	BX24/1710	4	42,336			1575521	-5182357
	Ben Rarere Stn Well-02	BX24/171	4	42,336			1575557	-5182356

Appendix B Determinands for Sampling of New Bores

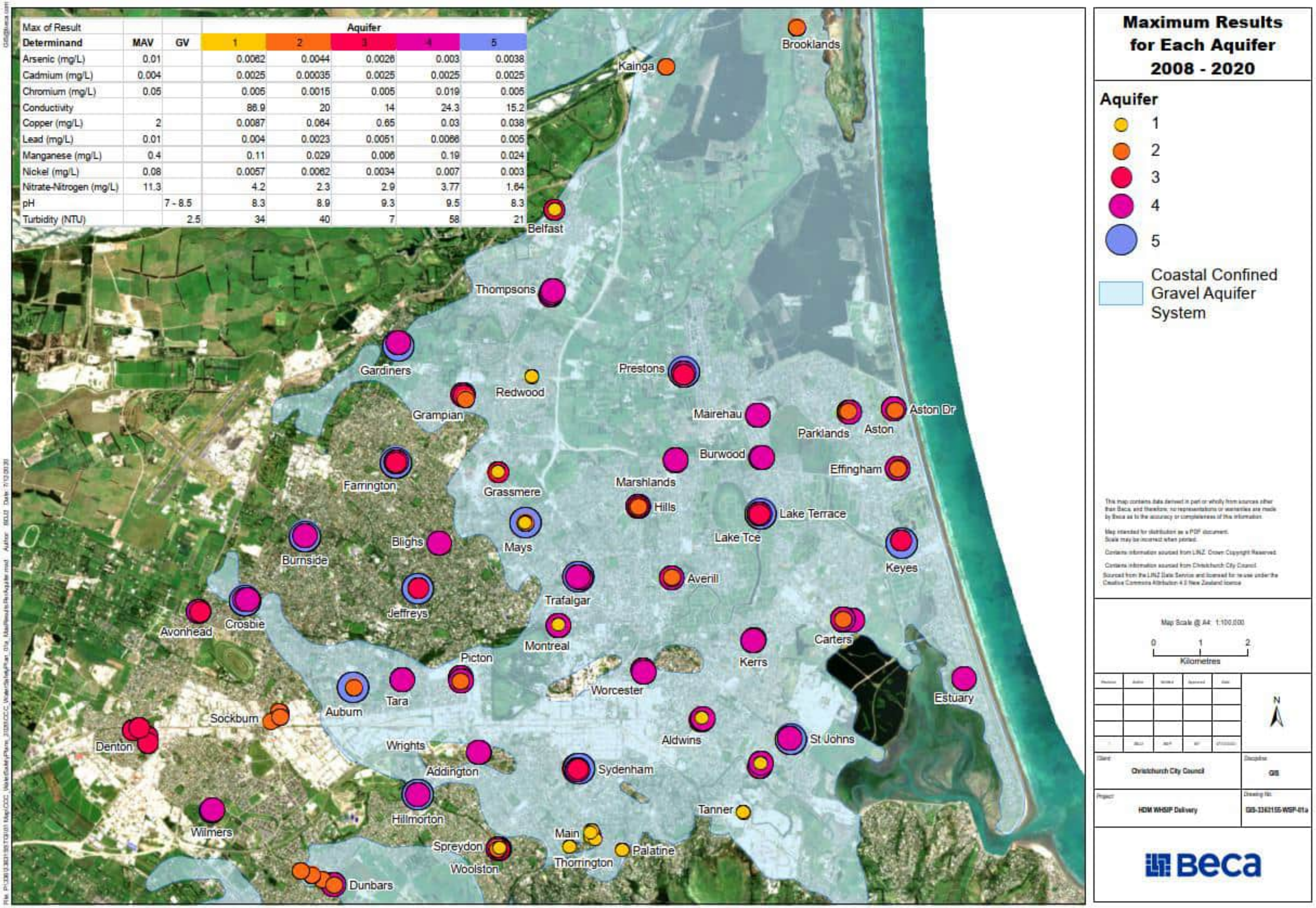
DETERMINAND	RATIONALE
E.Coli	S3 requirement
Total coliforms	S3 requirement
Turbidity	S3 requirement
pH	S3 requirement
Aluminium	VZ - Rock and soil leaching
Antimony	S3 requirement
Arsenic	S3 requirement
Barium	S3 requirement
Boron	S3 requirement
Cadmium	S3 requirement
Chlorite	No-DBP
Chromium	S3 requirement
Copper	S3 requirement
Fluoride	S3 requirement
Lead	S3 requirement
Manganese	S3 requirement
Mercury	S3 requirement
Nickel	S3 requirement
Nitrate	S3 requirement
Nitrite	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Alachlor	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Aldicarb	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Aldrin+Dieldrin	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Atrazine	VZ - Monitoring. Mostly used in North Island but still in use in NZ
Benzene	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Benzo(a)pyrene	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Bromodichloromethane	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Bromoform	No-DBP
Carbofuran	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Chlordane	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Chloroform	No-DBP
2,4-D	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
DDT+isomers	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5

1,2-Dibromo-3-chloropropane	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Dibromoacetonitrile	No-DBP
Dibromochloromethane	No-DBP
Dichloroacetic acid	No-DBP
Dichloroacetonitrile	No-DBP
Ethylbenzene	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Lindane	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
MCPA	VZ - Draft QA Rules (ocassionally found in bores)
Monochloroacetic acid	No-DBP
Pentachlorophenol	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
2,4,5-T	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Toluene	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Trichloroacetic acid	No-DBP
Xylenes (total)	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
1080	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Total alpha activity	S3 requirement
Total beta activity	S3 requirement
Ammonia	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Calcium	S3 requirement
Chloride	S3 requirement
2-Chlorophenol	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Colour	VZ - True colour
2,4-Dichlorophenol	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Hydrogen sulphide	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Iron	S3 requirement
Magnesium	S3 requirement
Sodium	S3 requirement
Sulphate	S3 requirement
Zinc	Guidelines for DW Management NZ - Chapter 4.4.3/ Table 4.5
Potassium	S3 requirement
Bromide	S3 requirement
TOC	S3 requirement
Conductivity	S3 requirement
Alkalinity	S3 requirement

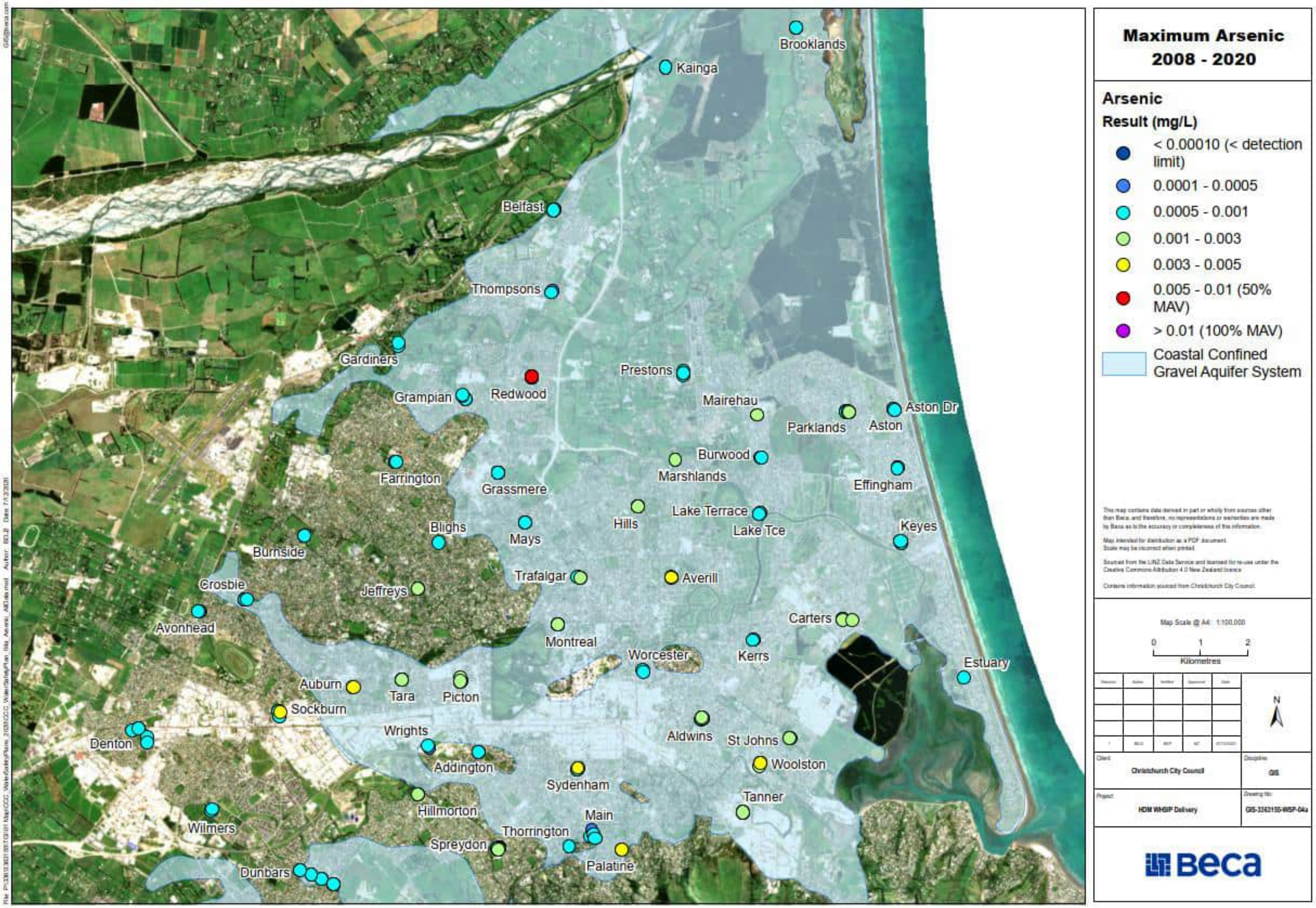
Appendix C Additional Chemical Sampling Result Maps



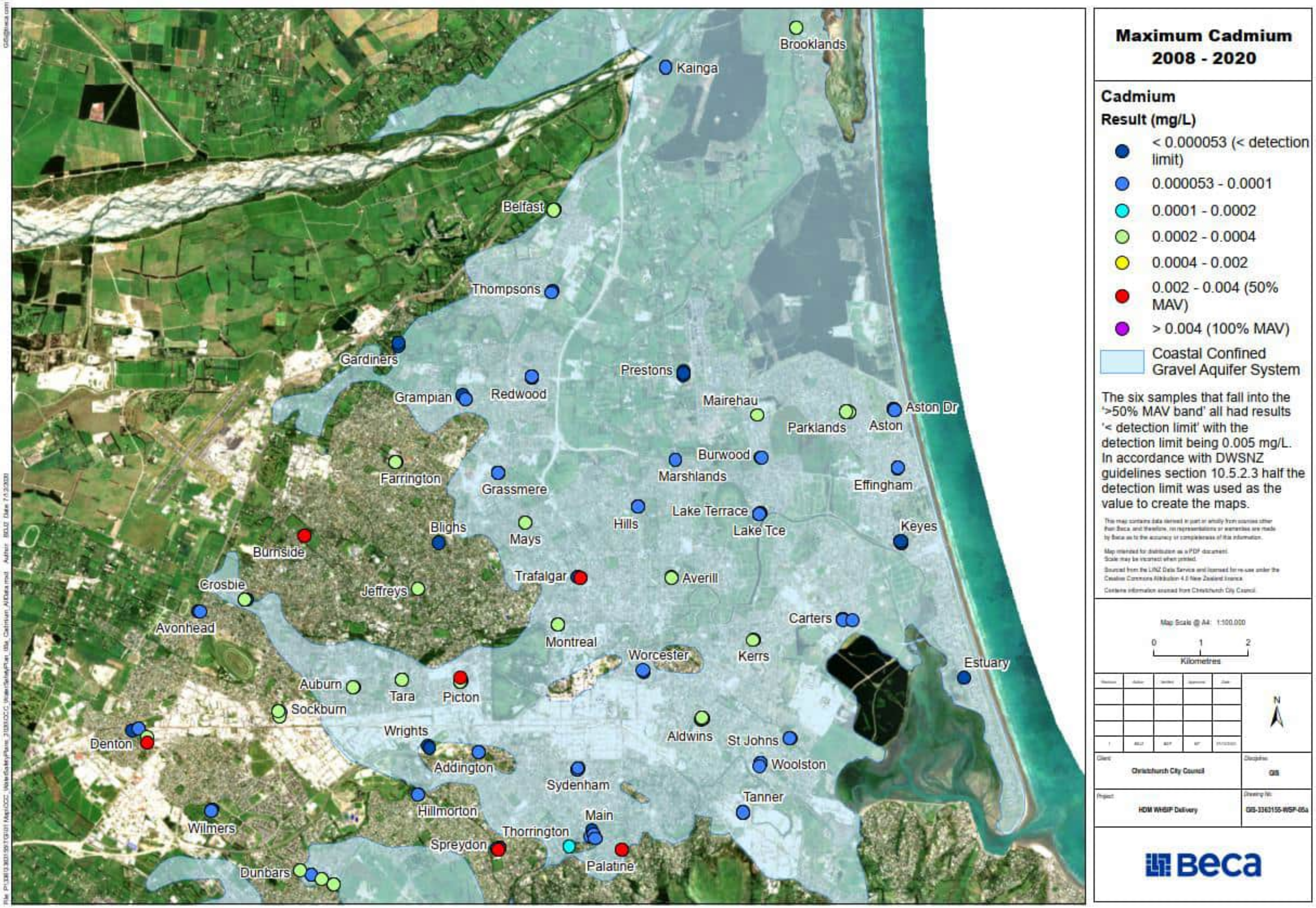
Average of Result			Aquifer				
Determinand	MAV	GV	1	2	3	4	5
Arsenic (mg/L)	0.01		0.0010	0.0008	0.0007	0.0009	0.0009
Cadmium (mg/L)	0.004		0.0002	0.0001	0.0002	0.0001	0.0002
Chromium (mg/L)	0.05		0.0006	0.0005	0.0008	0.0008	0.0007
Conductivity			23.0	11.8	11.0	11.6	12.2
Copper (mg/L)	2		0.0016	0.0029	0.0192	0.0022	0.0032
Lead (mg/L)	0.01		0.0009	0.0006	0.0006	0.0007	0.0007
Manganese (mg/L)	0.4		0.0081	0.0030	0.0016	0.0070	0.0027
Nickel (mg/L)	0.08		0.0015	0.0010	0.0009	0.0011	0.0009
Nitrate-Nitrogen (mg/L)	11.3		1.00	0.61	0.71	0.38	0.38
pH		7 - 8.5	7.53	7.80	7.89	7.84	7.81
Turbidity (NTU)		2.5	0.84	1.13	0.58	1.46	1.21



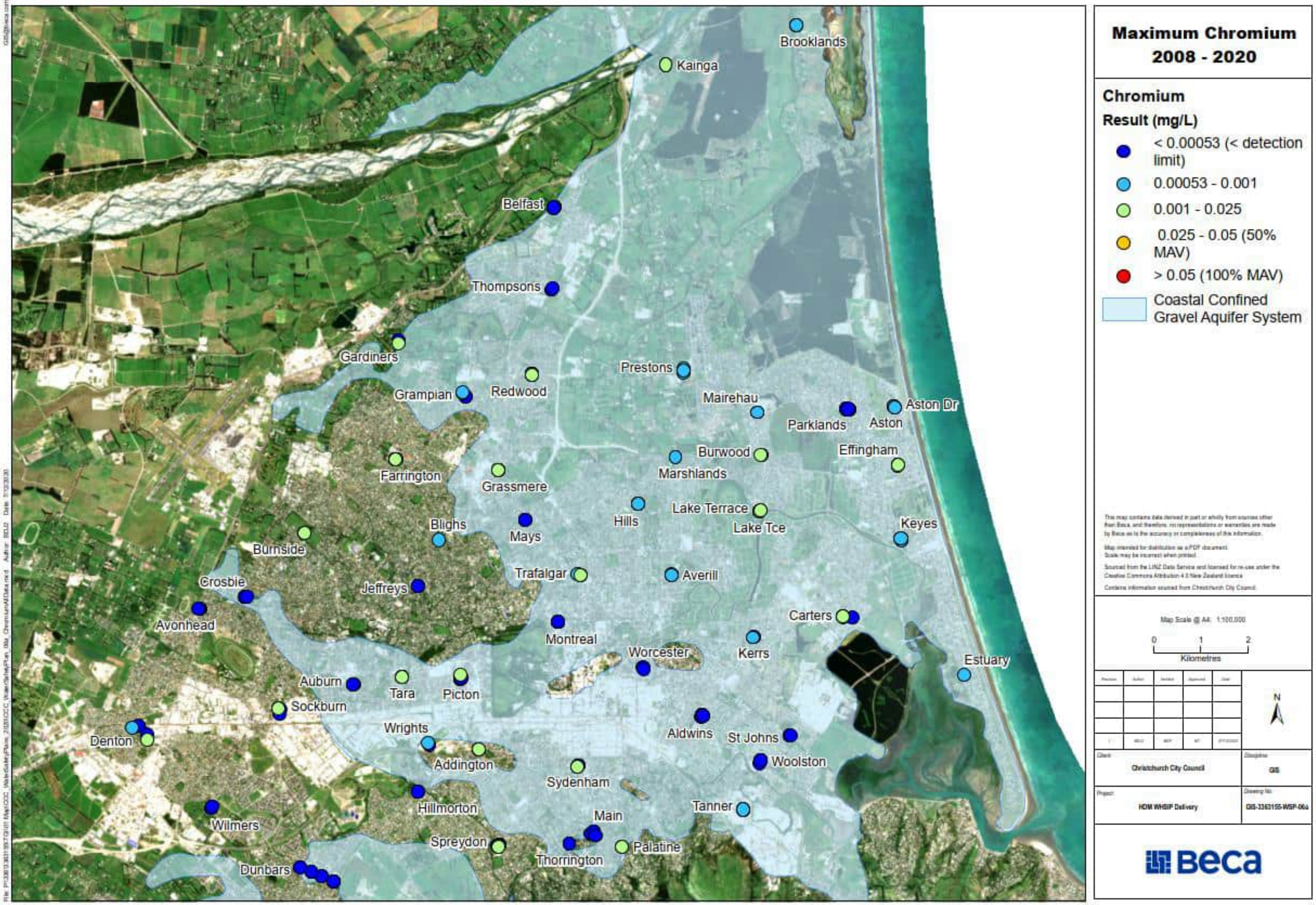
Max of Result			Aquifer				
Determinand	MAV	GV	1	2	3	4	5
Arsenic (mg/L)	0.01		0.0062	0.0044	0.0026	0.003	0.0038
Cadmium (mg/L)	0.004		0.0025	0.00035	0.0025	0.0025	0.0025
Chromium (mg/L)	0.05		0.005	0.0015	0.005	0.019	0.005
Conductivity			86.9	20	14	24.3	15.2
Copper (mg/L)	2		0.0087	0.064	0.65	0.03	0.038
Lead (mg/L)	0.01		0.004	0.0023	0.0051	0.0066	0.005
Manganese (mg/L)	0.4		0.11	0.029	0.006	0.19	0.024
Nickel (mg/L)	0.08		0.0057	0.0062	0.0034	0.007	0.003
Nitrate-Nitrogen (mg/L)	11.3		4.2	2.3	2.9	3.77	1.64
pH		7 - 8.5	8.3	8.9	9.3	9.5	8.3
Turbidity (NTU)		2.5	34	40	7	58	21



Maximum Arsenic
2008 - 2020
Arsenic
Result (mg/L)
< 0.00010 (< detection limit)
0.0001 - 0.0005
0.0005 - 0.001
0.001 - 0.003
0.003 - 0.005
0.005 - 0.01 (50% MAV)
> 0.01 (100% MAV)
Coastal Confined Gravel Aquifer System
Kilometres
0
1
2
N
Christchurch City Council
Beca
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Grampian
Redwood
Prestons
Mairehau
Parklands
Aston Dr
Aston
Burwood
Marshlands
Effingham
Farrington
Grassmere
Hills
Lake Terrace
Lake Tce
Keyes
Blighs
Mays
Burnside
Crosbie
Jeffreys
Trafalgar
Averill
Avonhead
Montreal
Carters
Worcester
Kerrs
Estuary
Auburn
Tara
Picton
Sockburn
Wrights
Aldwins
St Johns
Denton
Addington
Woolston
Sydenham
Tanner
Hillmorton
Main
Wilmers
Thorrington
Spreydon
Palatine
Dunbars



Maximum Cadmium 2008 - 2020
Cadmium
Result (mg/L)
< 0.000053 (< detection limit)
0.000053 - 0.0001
0.0001 - 0.0002
0.0002 - 0.0004
0.0004 - 0.002
0.002 - 0.004 (50% MAV)
> 0.004 (100% MAV)
Coastal Confined Gravel Aquifer System
The six samples that fall into the '>50% MAV band' all had results '< detection limit' with the detection limit being 0.005 mg/L. In accordance with DWSNZ guidelines section 10.5.2.3 half the detection limit was used as the value to create the maps.
Map Scale @ A4: 1:100,000
0
1
2
Kilometres
N
Christchurch City Council
Beca
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Prestons
Grampian
Redwood
Mairehau
Parklands
Aston
Aston Dr
Burwood
Marshlands
Effingham
Farrington
Grassmere
Lake Terrace
Lake Tce
Hills
Keyes
Blighs
Mays
Burnside
Trafalgar
Averill
Crosbie
Jeffreys
Avonhead
Carters
Montreal
Worcester
Kerrs
Estuary
Auburn
Tara
Picton
Sockburn
Wrights
Aldwins
St Johns
Denton
Addington
Woolston
Sydenham
Tanner
Hillmorton
Main
Wilmers
Thorrington
Spreydon
Palatine
Dunbars


Maximum Chromium 2008 - 2020
Chromium
Result (mg/L)
< 0.00053 (< detection limit)
0.00053 - 0.001
0.001 - 0.025
0.025 - 0.05 (50% MAV)
> 0.05 (100% MAV)
Coastal Confined Gravel Aquifer System
Map Scale @ A4: 1:100,000
0
1
2
Kilometres
N
Christchurch City Council
HDM WHSIP Delivery
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Prestons
Grampian
Redwood
Mairehau
Parklands
Aston Dr
Aston
Burwood
Effingham
Marshlands
Farrington
Grassmere
Lake Terrace
Lake Tce
Hills
Keyes
Blighs
Mays
Burnside
Trafalgar
Averill
Crosbie
Jeffreys
Avonhead
Carters
Montreal
Worcester
Kerrs
Estuary
Auburn
Tara
Picton
Sockburn
Wrights
Aldwins
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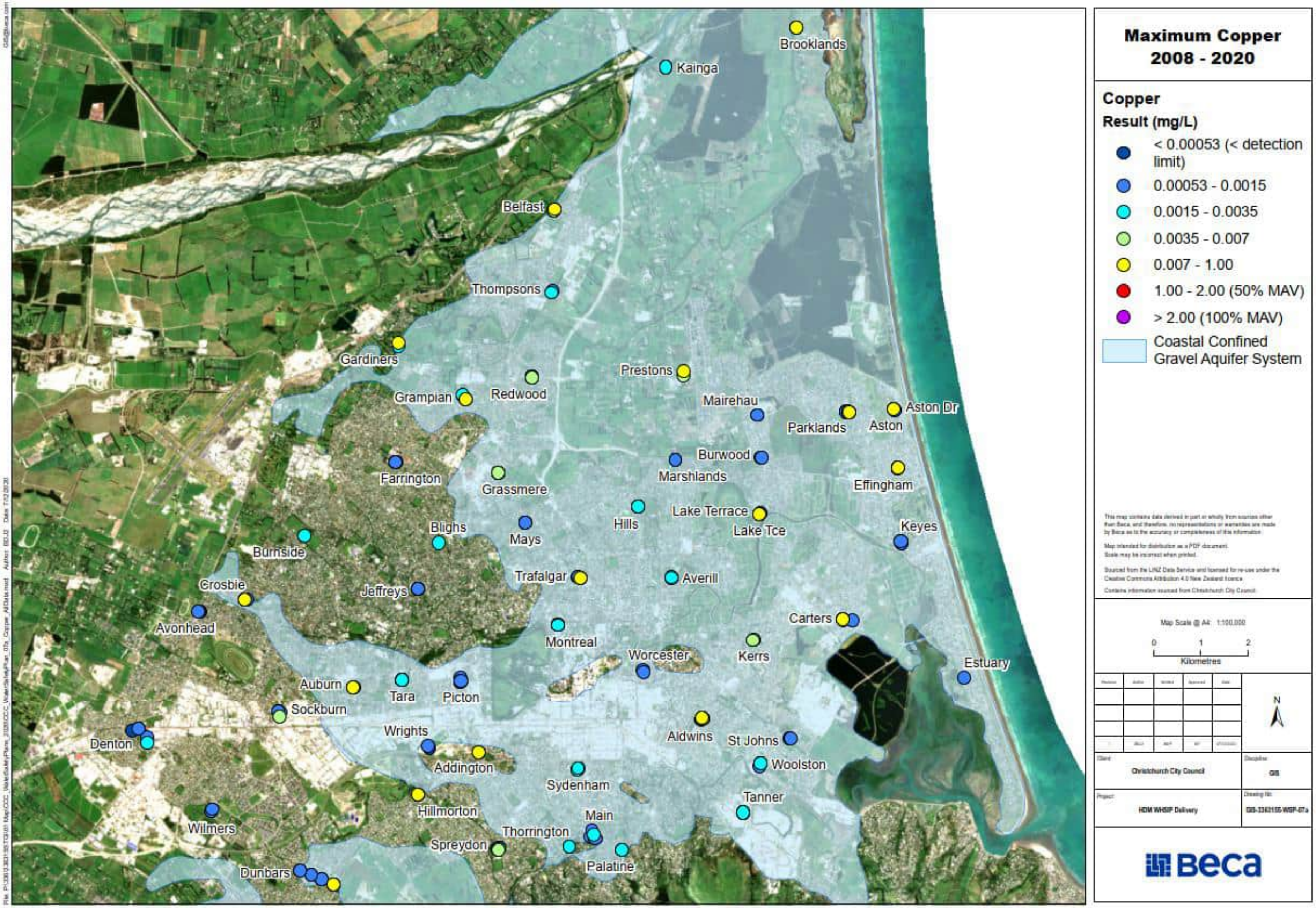
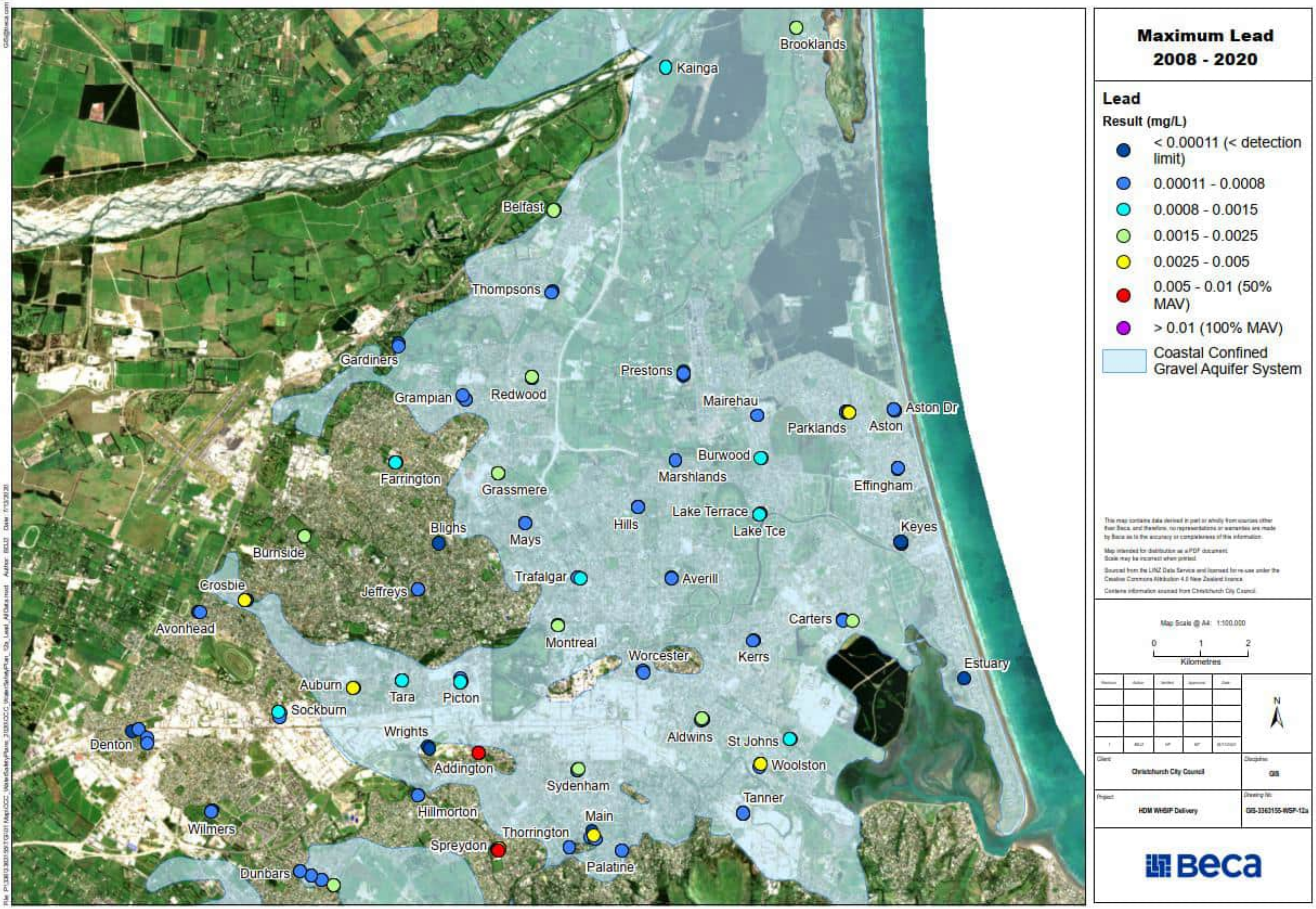
Denton
Addington
Woolston
Sydenham
Hillmorton
Tanner
Main
Wilmers
Spreydon
Palatine
Thorrington
Dunbars


Maximum Copper
2008 - 2020
Copper
Result (mg/L)
< 0.00053 (< detection limit)
0.00053 - 0.0015
0.0015 - 0.0035
0.0035 - 0.007
0.007 - 1.00
1.00 - 2.00 (50% MAV)
> 2.00 (100% MAV)
Coastal Confined Gravel Aquifer System
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Grampian
Redwood
Prestons
Mairehau
Parklands
Aston Dr
Aston
Burwood
Marshlands
Effingham
Farrington
Grassmere
Hills
Lake Terrace
Lake Tce
Keyes
Blighs
Mays
Burnside
Trafalgar
Averill
Crosbie
Jeffreys
Carters
Avonhead
Montreal
Worcester
Kerrs
Estuary
Auburn
Tara
Picton
Sockburn
Wrights
Aldwins
St Johns
Denton
Addington
Woolston
Sydenham
Tanner
Hillmorton
Main
Wilmers
Thorrington
Spreydon
Palatine
Dunbars
Kilometres
N
Christchurch City Council
HDM WHSIP Delivery
Beca


Maximum Lead
2008 - 2020
Lead
Result (mg/L)
< 0.00011 (< detection limit)
0.00011 - 0.0008
0.0008 - 0.0015
0.0015 - 0.0025
0.0025 - 0.005
0.005 - 0.01 (50% MAV)
> 0.01 (100% MAV)
Coastal Confined Gravel Aquifer System
Map Scale @ A4: 1:100,000
0 1 2
Kilometres
Christchurch City Council
HDM WHSIP Delivery
Beca
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Grampian
Redwood
Prestons
Mairehau
Parklands
Aston Dr
Aston
Burwood
Marshlands
Effingham
Farrington
Grassmere
Lake Terrace
Lake Tce
Hills
Blighs
Mays
Keyes
Burnside
Trafalgar
Averill
Crosbie
Jeffreys
Carters
Avonhead
Montreal
Worcester
Kerrs
Estuary
Auburn
Tara
Picton
Sockburn
Wrights
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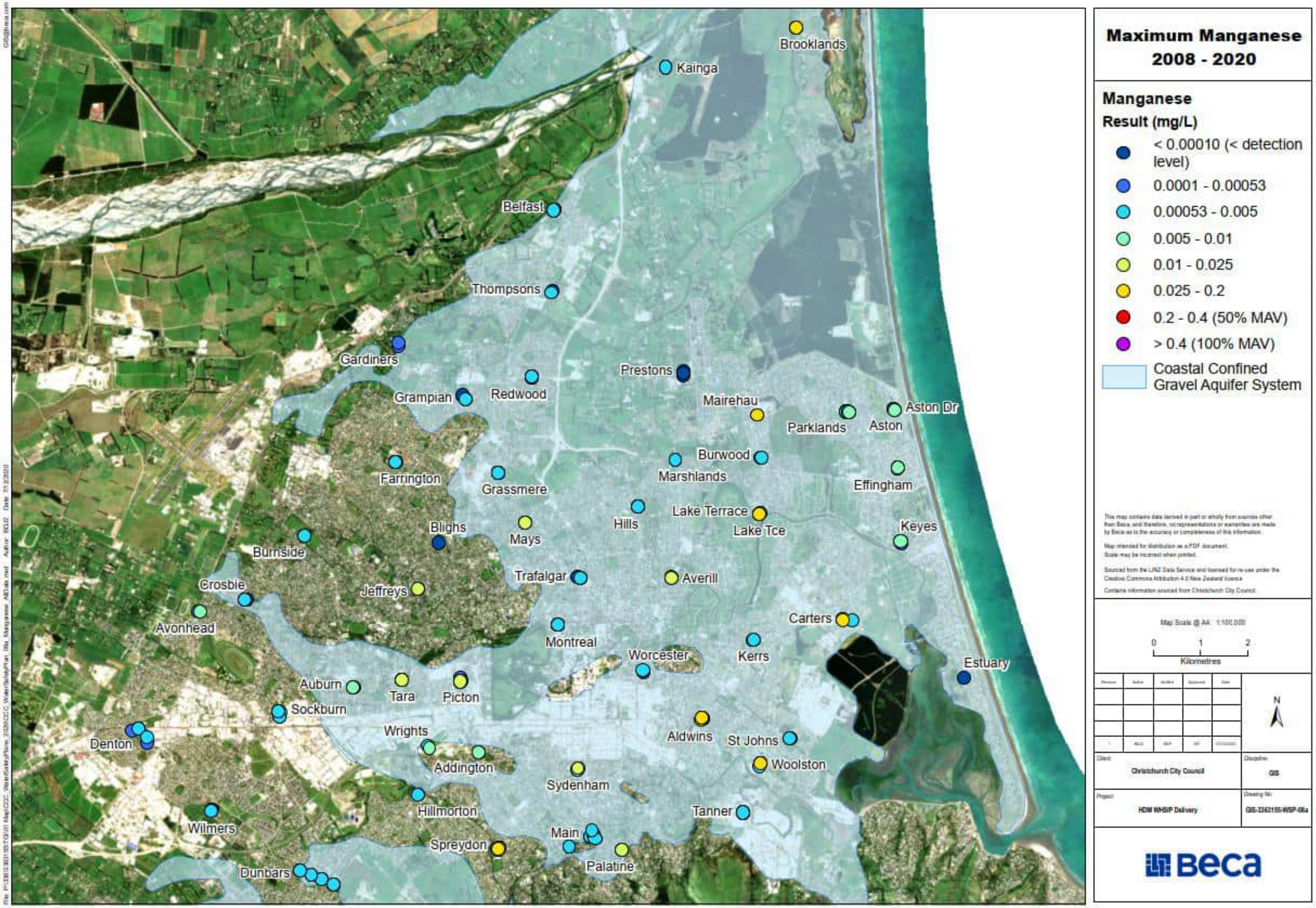
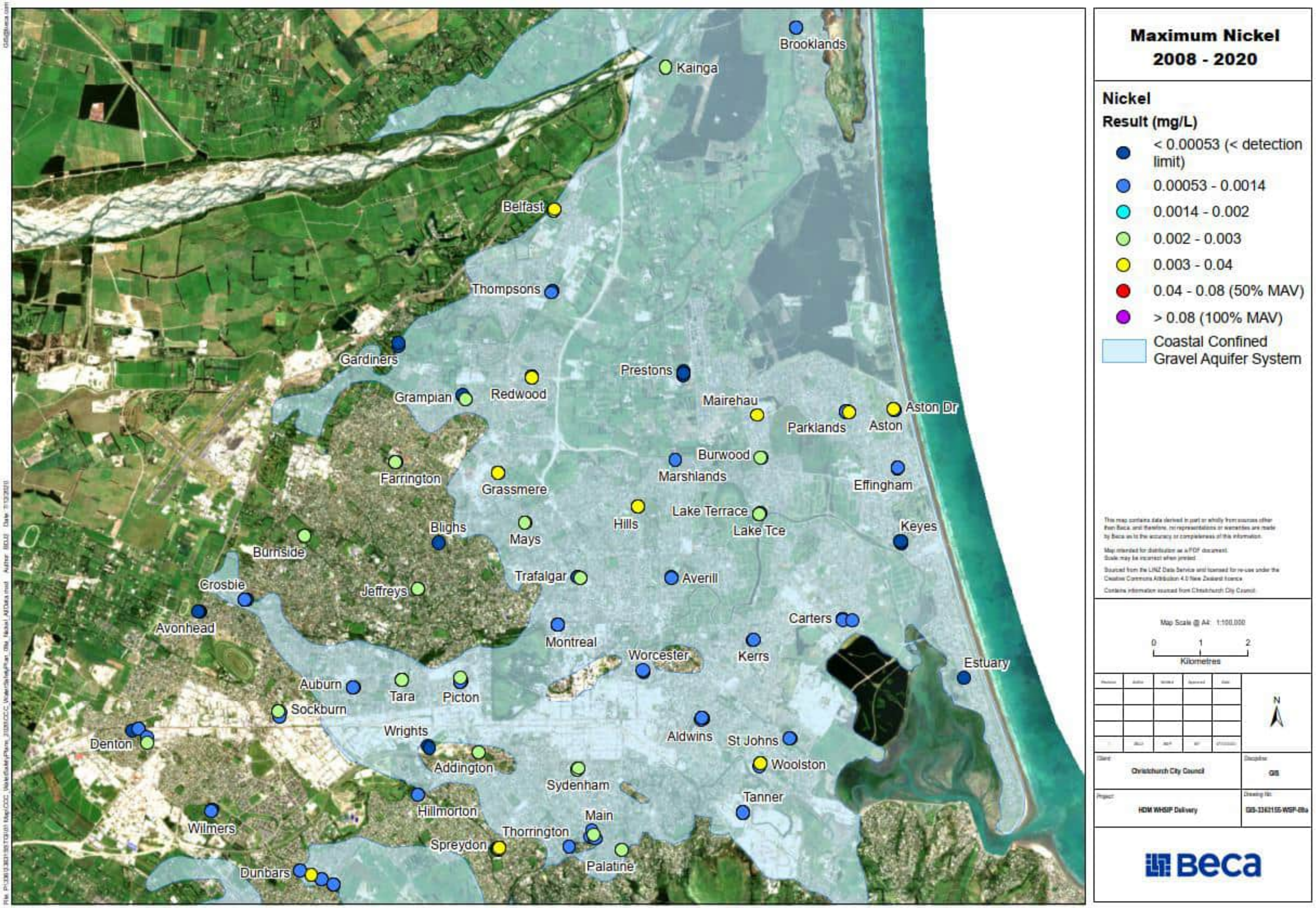
Thorrington
Spreydon
Palatine
Dunbars



Maximum Manganese
2008 - 2020
Manganese
Result (mg/L)
< 0.00010 (< detection level)
0.0001 - 0.00053
0.00053 - 0.005
0.005 - 0.01
0.01 - 0.025
0.025 - 0.2
0.2 - 0.4 (50% MAV)
> 0.4 (100% MAV)
Coastal Confined Gravel Aquifer System
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Grampian
Redwood
Prestons
Mairehau
Parklands
Aston
Aston Dr
Burwood
Marshlands
Effingham
Farrington
Grassmere
Hills
Lake Terrace
Lake Tce
Keyes
Blighs
Mays
Burnside
Crosbie
Jeffreys
Trafalgar
Averill
Avonhead
Montreal
Carters
Worcester
Kerrs
Estuary
Auburn
Tara
Picton
Sockburn
Denton
Wrights
Aldwins
St Johns
Addington
Woolston
Sydenham
Hillmorton
Tanner
Wilmers
Main
Spreydon
Palatine
Dunbars
Kilometres
Christchurch City Council
HDM WHSIP Delivery
Beca


Maximum Nickel
2008 - 2020
Nickel
Result (mg/L)
< 0.00053 (< detection limit)
0.00053 - 0.0014
0.0014 - 0.002
0.002 - 0.003
0.003 - 0.04
0.04 - 0.08 (50% MAV)
> 0.08 (100% MAV)
Coastal Confined Gravel Aquifer System
Map Scale @ A4: 1:100,000
0
1
2
Kilometres
N
Christchurch City Council
GIS
HDM WHSIP Delivery
Beca
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Prestons
Grampian
Redwood
Mairehau
Parklands
Aston
Aston Dr
Burwood
Marshlands
Effingham
Farrington
Grassmere
Lake Terrace
Lake Tce
Hills
Keyes
Blighs
Mays
Burnside
Crosbie
Trafalgar
Averill
Jeffreys
Avonhead
Montreal
Carters
Worcester
Kerrs
Estuary
Auburn
Tara
Picton
Sockburn
Wrights
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St Johns
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Tanner
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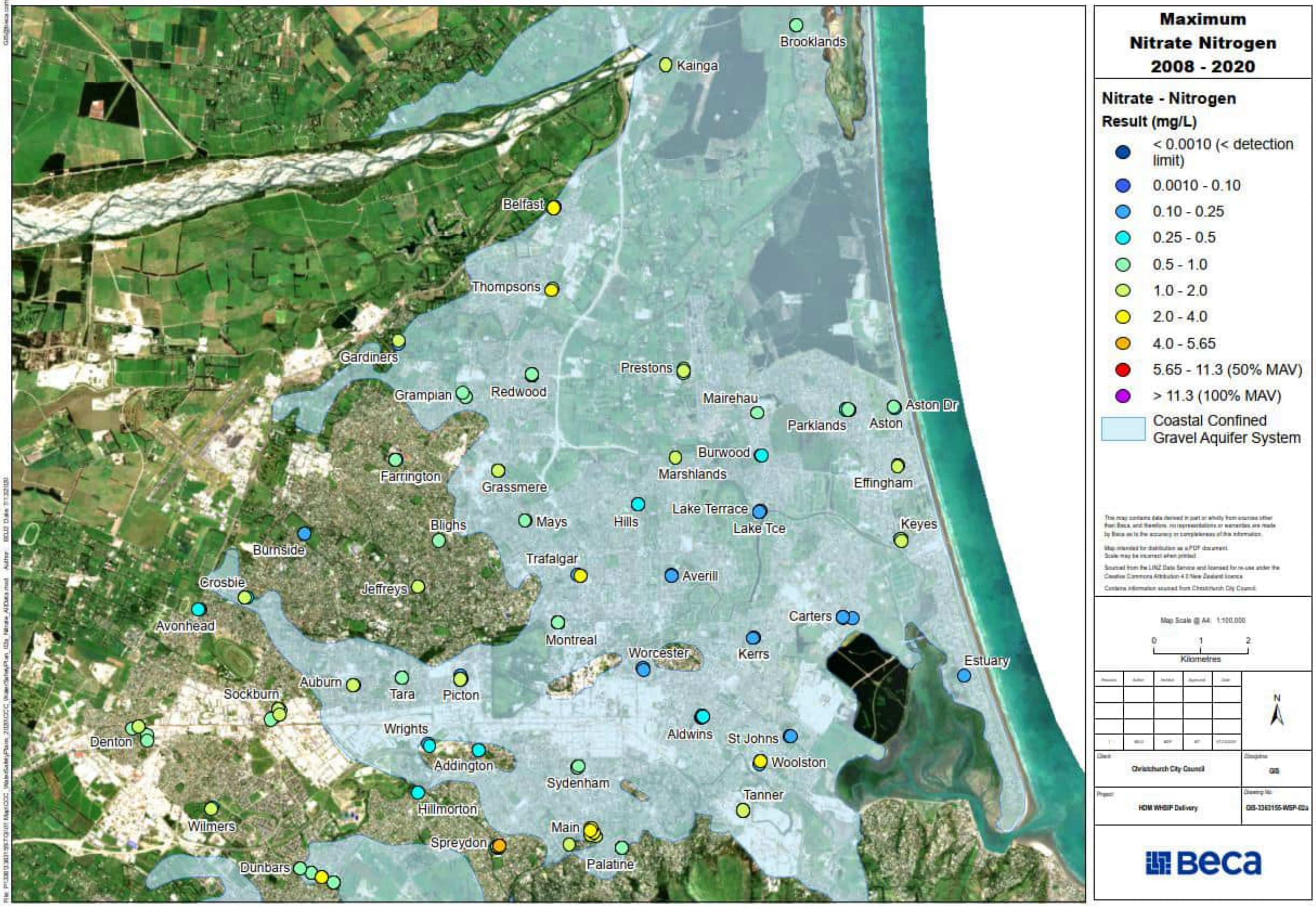
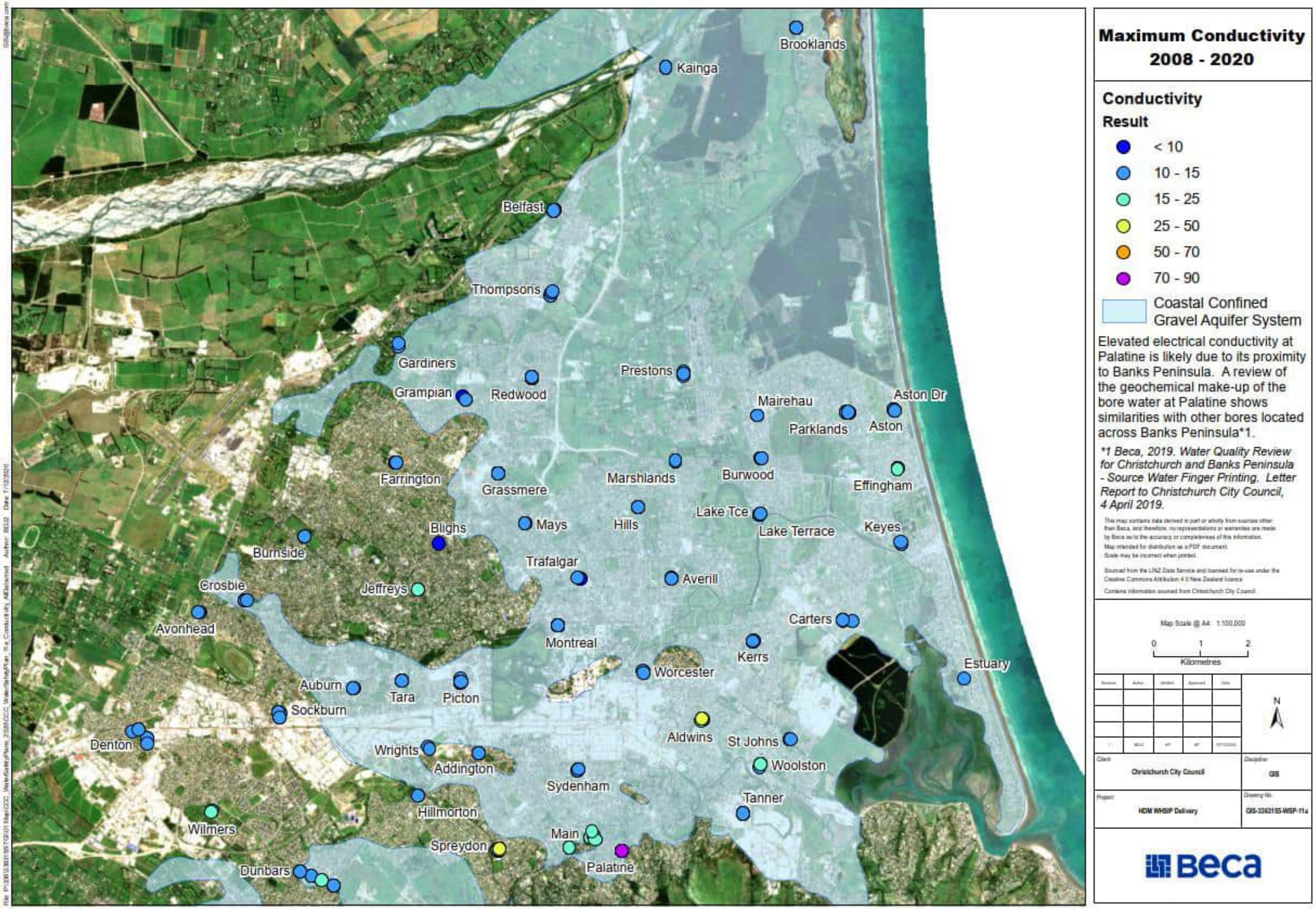
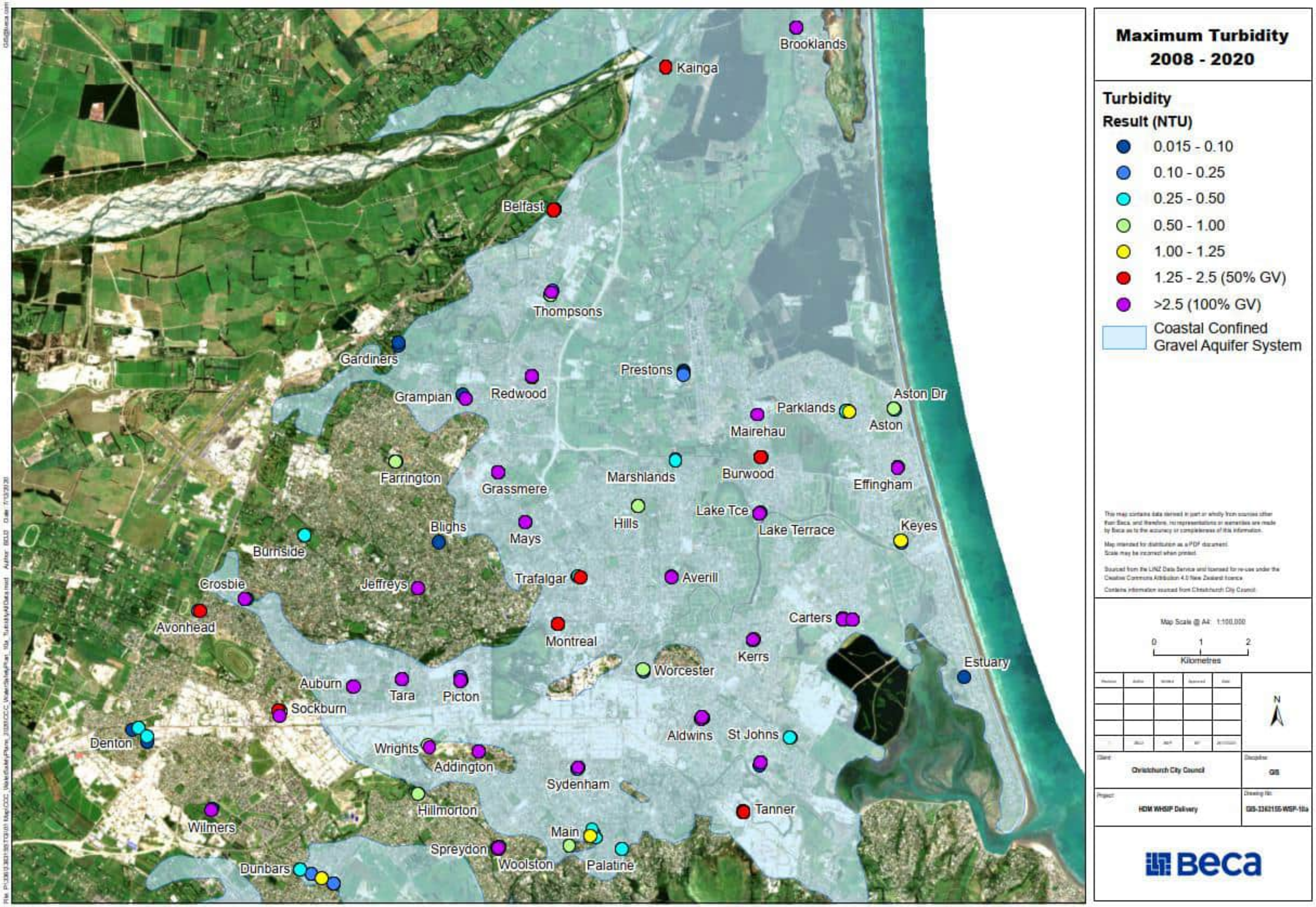
Main
Wilmers
Thorrington
Spreydon
Palatine
Dunbars


Maximum
Nitrate Nitrogen
2008 - 2020
Nitrate - Nitrogen
Result (mg/L)
< 0.0010 (< detection limit)
0.0010 - 0.10
0.10 - 0.25
0.25 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 4.0
4.0 - 5.65
5.65 - 11.3 (50% MAV)
> 11.3 (100% MAV)
Coastal Confined Gravel Aquifer System
Map Scale @ A4: 1:100,000
0
1
2
Kilometres
N
Christchurch City Council
GIS
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Grampian
Redwood
Prestons
Mairehau
Parklands
Aston
Aston Dr
Burwood
Marshlands
Farrington
Grassmere
Effingham
Lake Terrace
Lake Tce
Hills
Mays
Blighs
Keyes
Burnside
Trafalgar
Averill
Crosbie
Jeffreys
Avonhead
Montreal
Carters
Worcester
Kerrs
Estuary
Auburn
Tara
Picton
Sockburn
Wrights
Aldwins
St Johns
Denton
Addington
Woolston
Sydenham
Tanner
Hillmorton
Wilmers
Main
Spreydon
Palatine
Dunbars



Maximum Conductivity 2008 - 2020
Conductivity Result
< 10
10 - 15
15 - 25
25 - 50
50 - 70
70 - 90
Coastal Confined Gravel Aquifer System
Elevated electrical conductivity at Palatine is likely due to its proximity to Banks Peninsula. A review of the geochemical make-up of the bore water at Palatine shows similarities with other bores located across Banks Peninsula*1.
*1 Beca, 2019. Water Quality Review for Christchurch and Banks Peninsula - Source Water Finger Printing. Letter Report to Christchurch City Council, 4 April 2019.
Map Scale @ A4: 1:100,000
0
1
2
Kilometres
N
Christchurch City Council
HDM WHSIP Delivery
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Grampian
Redwood
Prestons
Mairehau
Parklands
Aston Dr
Aston
Farrington
Grassmere
Marshlands
Burwood
Effingham
Blighs
Mays
Hills
Lake Tce
Lake Terrace
Keyes
Burnside
Trafalgar
Averill
Crosbie
Jeffreys
Avonhead
Montreal
Carters
Kerrs
Estuary
Worcester
Auburn
Tara
Picton
Sockburn
Aldwins
St Johns
Denton
Wrights
Addington
Woolston
Sydenham
Tanner
Hillmorton
Wilmers
Main
Spreydon
Palatine
Dunbars


Maximum Turbidity
2008 - 2020
Turbidity
Result (NTU)
0.015 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 1.00
1.00 - 1.25
1.25 - 2.5 (50% GV)
>2.5 (100% GV)
Coastal Confined
Gravel Aquifer System
Brooklands
Kainga
Belfast
Thompsons
Gardiners
Prestons
Grampian
Redwood
Parklands
Aston Dr
Aston
Mairehau
Farrington
Grassmere
Marshlands
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Wrights
Addington
Sydenham
Hillmorton
Tanner
Wilmers
Main
Spreydon
Woolston
Palatine
Dunbars
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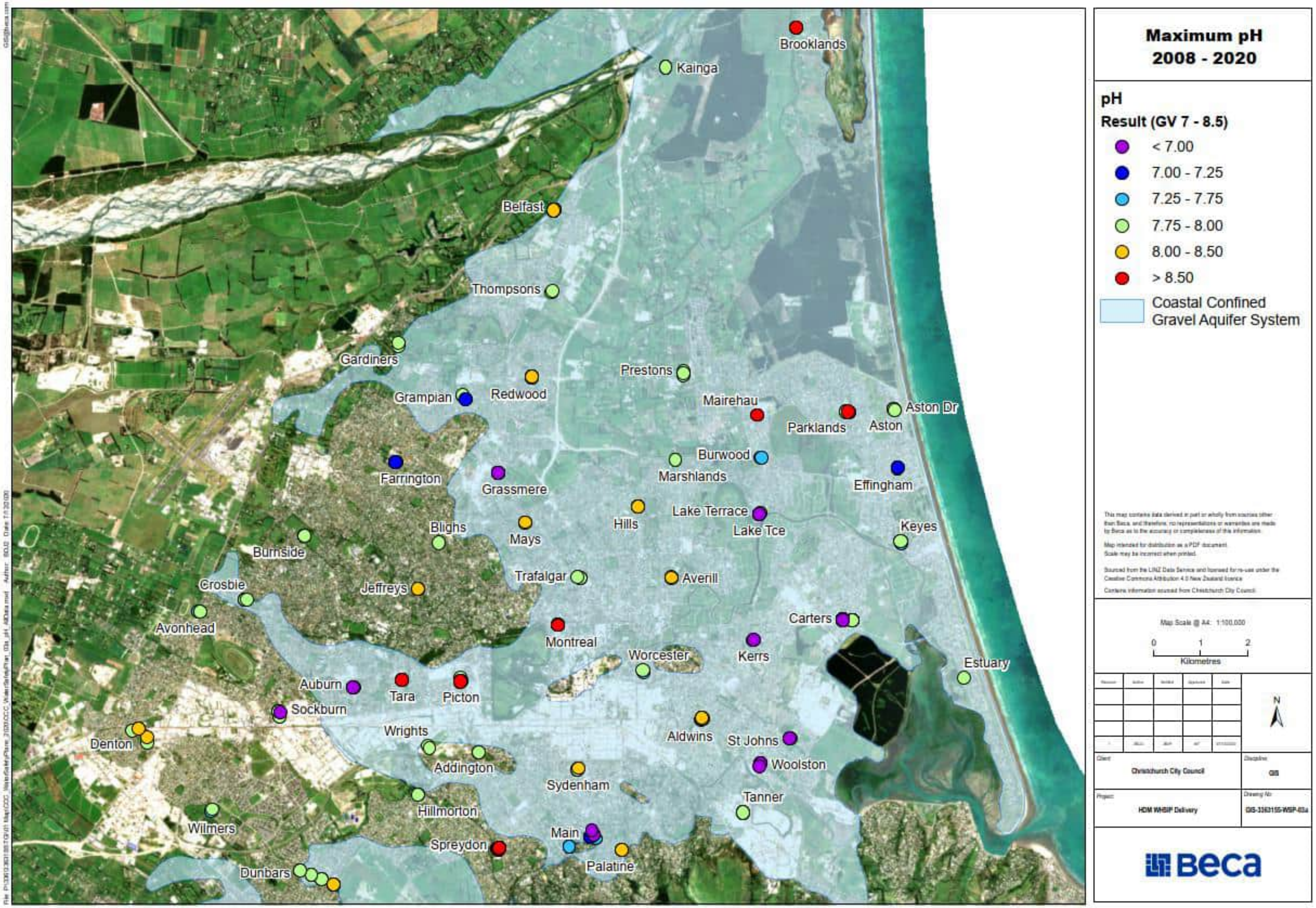
Contains information sourced from Christchurch City Council.
Map Scale @ A4: 1:100,000
0
1
2
Kilometres
N
Client:
Christchurch City Council
Discipline:
GIS
Project:
HDM WHSIP Delivery
Drawing No:
GIS-3362155-WSP-10a
Beca


Maximum pH
2008 - 2020
pH
Result (GV 7 - 8.5)
< 7.00
7.00 - 7.25
7.25 - 7.75
7.75 - 8.00
8.00 - 8.50
> 8.50
Coastal Confined Gravel Aquifer System
Map Scale @ A4: 1:100,000
0
1
2
Kilometres
N
Christchurch City Council
HDM WHSIP Delivery
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