



PATTLE DELAMORE PARTNERS LTD

# Groundwater and Surface Water Monitoring at Alliance Lorneville

Alliance Group Limited - Lorneville



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✦ Prepared for

Alliance Group Limited - Lorneville

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## Executive Summary

Five new groundwater monitoring bores have been installed in the general vicinity of the wastewater treatment lagoons at the Alliance Group Limited Lorneville Plant and monitoring of groundwater and surface water has been undertaken to determine any effects on groundwater arising from the wastewater treatment lagoons. The strata underlying the area comprises surface soils, silts and clay underlain by predominately gravel and sand with minor amounts of silt. The depth to groundwater in these boreholes was measured at around 0.8 – 1.4 m below ground level in bores near the Makarewa River and 2.0 – 4.1 m below ground level in bores occurring at higher elevations and /or greater depth. Slug tests indicate the gravelly strata is reasonably permeable with hydraulic conductivity values estimated to range from 4-33 m/day.

Water level monitoring shows tidal fluctuations occur in the Makarewa River and lower reaches of Boiler Ditch (during the higher part of the tidal cycle). This in turn induces a subdued tidal response in the adjacent groundwater levels. Despite these fluctuations groundwater levels decline in a general south-westerly and westerly direction away from the main processing plant, due to drainage effects from Boiler Ditch, Bateman's Drain and the Makarewa River all of which receive discharge from the groundwater system. The groundwater levels in the vicinity of the wastewater treatment ponds are all lower than the level of wastewater in those ponds.

Groundwater samples show generally similar characteristics with some localised variations in particular parameters. Samples from Bateman's Drain and Boiler Ditch (above the wastewater discharge) show similar chemical characteristics to the eastern groundwater samples and indicates a more aerobic groundwater environment, due to the greater occurrence of nitrate-N relative to ammoniacal-N. The absence of elevated concentrations in boreholes BHB and BHC, immediately to the south of the wastewater treatment lagoons, indicates that no obvious groundwater effects were occurring at the time of the sampling. One groundwater sample, from BHD, located further south of the treatment ponds and close to the Makarewa River, tends to have higher concentrations of several chemical species. However the chemical signature at BHD does not fully match the oxidation pond discharge and it seems most likely that the elevated concentrations in BHD are primarily due to naturally occurring hydrogeologic conditions. The primary cause of the change in chemistry is a change to a less oxidised groundwater environment towards the Makarewa River as indicated by the occurrence of ammoniacal-N and an absence of nitrate-N and may be due to higher groundwater levels extending in to the surface silty strata causing confined groundwater conditions.



Therefore, at the time of the sampling surveys in December 2014 and March 2015, groundwater elevations were sufficiently high so as not to indicate any obvious effect from the wastewater discharge on the surrounding groundwater.

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## 1.0 Introduction

Wastewater from the Alliance Group Limited (AGL) sheep and lamb processing plant at Lorneville is treated in an onsite lagoon-based wastewater treatment plant (WWTP) prior to discharge to the Makarewa River. There is uncertainty about the extent of any seepage from the ponds and the potential migration of that seepage through the groundwater system. In order to provide some understanding of that potential issue, AGL have engaged Pattle Delamore Partners Ltd (PDP) to investigate groundwater conditions to the south of the WWTP and the interaction between groundwater and surface water bodies.

This report has been prepared by PDP to describe the results of that investigation which includes:

- ∴ drilling of five monitoring bores;
- ∴ measurement of groundwater levels and surface water levels to a common datum to define the direction of groundwater movement;
- ∴ groundwater quality analyses;
- ∴ Slug tests to indicate the hydraulic conductivity of the strata.

This information is used to describe the hydrogeologic characteristics of the area and the interaction between groundwater and surface water in the vicinity.

## 2.0 Hydrogeologic Setting

The AGL plant is located on gently undulating topography formed by highly weathered fluvio-glacial outwash. The Quaternary aged fluvio-glacial outwash deposits comprise quartz gravels within a weathered clay matrix with varying proportions of silts and sands. The thickness of the strata varies from less than 5 m up to around 30 m, with the greatest thicknesses typically occurring underneath ridges in the undulating topography (Environment Southland, 2014).

Underlying the Quaternary deposits are the older, Tertiary Gore Lignite Measures which were deposited between 65 million and 2 million years ago. Higher sea levels between 65 million and 2 million years ago resulted in deltaic deposits, which included extensive mudstone (i.e. marine sediments) and lignite (compressed vegetation) sequences that occur across much of Southland. Thus, the Gore Lignite Measures are typically comprised of lignite seams, carbonaceous and non-carbonaceous mudstones, sandstone and conglomerates which dip very gently at around 2° to the southwest. They are part of the East Southland Group, which are up to 8 km thick (Turnbull and Allibone, 2003).

Groundwater levels in the shallow Quaternary sediments can be close to the surface near streams and rivers but are known to occur at greater depths below the intervening ridges in the undulating topography. That pattern results in a groundwater table surface that generally follows the topographic surface

although local variations can occur, for example close to pumping bores and/or close to surface waterways and drainage channels.

Recharge to the shallow strata is almost exclusively the result of rainfall infiltration, with recharge estimates of around 436 mm/yr (Environment Southland, 2014). However, much of the shallow strata is covered by a network of tile drains and other artificial drainage channels. As a result a significant proportion of the rainfall that infiltrates into the soil may be intercepted and discharged into surface water courses before it reaches the underlying groundwater table. Notwithstanding that interception, many small streams in the area are fed by groundwater where they occur at a lower elevation compared to the local groundwater table.

Groundwater resources are also present in the underlying Gore Lignite Measures, although they are poorly defined and are typically low yielding. Likewise, Environment Southland report poor yields from bores within the shallower Quaternary Gravels (Environment Southland, 2014). Figures 1a and 1b present the location of bores within 3 km of the site coloured according to their yield and use respectively. Most bores in the area are shallow (less than 20 m deep except for a few deeper bores used for geological investigation) and are used for domestic, stockwater and small scale irrigation, reflecting the low yields available from the shallow strata.

The AGL site is located within the Makarewa groundwater zone defined by Environment Southland. According to Environment Southland, the groundwater allocation status of the Makarewa zone is 'low' implying that there is groundwater available for allocation in that area.

### 3.0 Borehole Installation

To complement the existing monitoring bores in the area used by AGL, five additional groundwater monitoring bores were installed by McNeill Drilling under the supervision of PDP between 4 and 5 November 2014. The locations of these additional bores are displayed in Figure 2, along with other bores that are monitored by AGL. During the drilling and installation of the bores, the geology of each borehole was logged by PDP. The bore holes were drilled using a 3 inch (76 mm) diameter Sonic Samp drill rig. All five bores were installed to depths between 5.7 and 8.4 m bgl and consist of a 50 mm diameter PVC pipe and 100 mm diameter metal well cap at the ground surface. The screened section of each piezo was wrapped with a geosock and filter pack material consisting of Walton Park sand (grade 7/14) was placed around the screened section of the piezo with the filter pack extending at least 200 mm above the top of the screened section.

A bentonite seal of at least 500 mm thick was placed above the filter pack around the upper blank section of PVC casing to provide a seal between the filter pack and the ground surface to stop any ingress of surface water down the bore

annulus. Lastly, a concrete seal of at least 200 mm thick was placed on top of the bentonite seal at ground surface. The concrete seal was contoured away from the piezometer to ensure surface water would not pond around the casing of the bore. The details of the five new bores (BHA, BHB, BHC, BHD and BHE) installed at the Alliance Group Lorneville site (along with details of the existing monitoring bores) are provided in the table below and borelogs for the new boreholes borehole are provided in Appendix B. The work was originally intended to utilise an existing bore located at the gravel pit. However, this was found to be blocked and inaccessible.

Table 1: Monitoring Bore Details						
Bore ID	Depth (m bgl)	Diameter (mm)	Screened Interval (m bgl)	Depth to Water (m bgl)	Easting (NZTMX)	Northing (NZTMY)
BHA	7.32	50	1.0 – 7.32	1.4	1238660	4856242
BHB	8.40	50	2.0 – 8.4	1.3	1238365	4856204
BHC	5.80	50	1.0 – 5.8	1.3	1238046	4856124
BHD	5.76	50	1.0 – 5.76	0.88	1237894	4855853
BHE	7.12	50	1.0 – 7.12	2.0	1238690	4855725
Water Treatment Well	5.5	1000	-	3.2	1239563	4856494
Irrigation Bore	10.2	50	-	2.9	1238901	4856005
McWilliam Bore	14.5	100	-	3.1	1240346	4855733
Ridley Bore	12	150	-	4.1	1238440	4855313

*Notes: Depth to water levels were measured during a piezometric survey on 9 December 2014. BHA through to BHE established in November 2014. The Water Treatment Well is a large diameter open well with steel casing and steel plate covering the well opening. In following tables notes you will need to right click on the number and select 'restart at 1'*

Generally, the borelogs of the five new bores show more permeable alluvial gravels and sands with varying amounts of silt between approximately 3.8 and 5.3 m. These more permeable sediments are overlain by less permeable silts and clays up to 2 m thick which is capped by a layer of top soil layer between 0.2 and 0.8 m thick.

The purpose of the boreholes was to determine groundwater flow directions to the south and east of the wastewater treatment lagoons and to be used to collect water samples for water quality analysis. The information obtained from these boreholes provides a general picture of groundwater quality and movement relative to the wastewater treatment ponds.

Due to the location of the monitoring bores within active farm paddocks, the above ground metal casing of each bore was fenced off to keep animals away.

## 4.0 Groundwater Levels and Flow Direction

### 4.1 Piezometric Survey

Piezometric surveys of groundwater levels and surface water levels were undertaken by PDP in conjunction with Bonisch Environmental on 9 December 2014 and again by PDP on 19 March 2015. The purpose of the piezometric surveys was to determine the direction of shallow groundwater flow near the wastewater treatment lagoons and how the shallow groundwater system and the surface water ways, including the wastewater treatment lagoons in the area interact. The March 2015 survey was timed to target minimum groundwater and surface water levels in the area.

Groundwater levels were measured using a water level dipper and measured from the top of the well casing to groundwater level. The point on the top of the well casing from which the groundwater level measurement was taken from was surveyed so the depth to water level measurements could be converted to a water level elevation relative to sea level. Figure 3a (Appendix A) shows the measuring point of the one of the bores being surveyed by Bonisch Environmental.

Surface water level measurements were made from the top of a metal waratah to the water surface. The waratah was driven into the substrate of the surface waterway prior to measurements being undertaken. The top of the waratah was then surveyed so the water level measurements could be converted to a water level elevation. Figure 3b shows the measuring point of a waratah located in a surface waterway being surveyed. Water levels in a total of nine groundwater bores and twelve surface water way sites were measured and surveyed on 9 December 2014. The depth of bores for the survey varied between 5.5 to 14.5 m bgl. Of the twelve surface waterway sites, four of these were located in the wastewater treatment lagoons.

All water levels measured during the piezometric survey were converted to water level elevations relative to local mean sea level. The local mean sea level datum for the area is the Bluff 1955 datum. The spatial coordinates of each bore and surface water site were also recorded during surveying.

Appendix C provides details of the groundwater bores and surface waterway sites where water level elevations were measured during the surveys on 9 December 2014 and 19 March 2015. The water level elevations measured during the surveys are also provided in Appendix C. The spatial coordinates of each bore and surface water site are provided in the New Zealand Transverse Mercator 2000 coordinate system.

Indicative groundwater contours for each piezometric survey are presented in Figure 4a and 4b (Appendix A), based on the seven shallow boreholes shown in Table 1 (the two deeper boreholes at 12 m and 14.5 m may not necessarily represent water table elevations). The groundwater contours from both the December 2014 and March 2015 piezometric surveys show a general south-westerly flow direction from the processing plant (influenced by drainage of groundwater into Bateman's Drain). To the west of the Bateman's Drain, a more westerly groundwater flow component occurs (influenced by drainage of groundwater into Boiler Ditch and Makarewa River). Surface water levels in all those waterways are lower than the nearby shallow groundwater monitoring bores. The surface water levels at sites S1 and S2 also appear to create a localised drainage effect on the surrounding groundwater levels, although any groundwater flow into that depression may be impeded by the lower permeability silts within the top 2 m of strata.

Water levels were lower during the March 2015 survey compared with the water levels measured during the December 2014 survey with the range of fluctuations being greater with increasing distance from the rivers and streams. Water levels during the December 2014 piezometric survey were generally 0.5 m higher near the Makarewa River and around 1 m higher at the eastern extent of the survey area when compared to the March 2015 piezometric survey.

At all times, water levels in the wastewater ponds are higher than the surrounding groundwater levels and the water levels in the Boiler Ditch which flows between the groundwater monitoring bores and the waste water ponds. Consequently, there is always a hydraulic gradient from the wastewater ponds to the groundwater and boreholes BHB and BHC allow sampling of the groundwater closest to the ponds, other than the groundwater that drains directly from the ponds into the Makarewa River. Although, if any significant seepage losses were to be occurring it seems most likely that a portion of it would be intercepted by Boiler Ditch (due to its lower water level elevations), rather than passing through to the groundwater further south or east of the ponds.

#### 4.2 Effects from Tidal Fluctuations

The AGL Plant is located approximately 10 km north east from the coast. The Makarewa River flows in a south westerly direction past the wastewater treatment plant before flowing into the Oreti River. This section of the Oreti River and Makarewa River are tidally influenced and groundwater levels near the



rivers as well as surface water levels in the Makarewa River at the site and the Boiler Ditch near its confluence with the Makarewa River were monitored to determine the influence of the tidal fluctuations. This information compliments the piezometric survey data in regard to local groundwater levels south of the wastewater treatment plant.

Groundwater levels were measured in bores BHC and BHD, as they were the closest bores to the Makarewa River. Water levels in both of these bores were measured electronically using unvented pressure transducers and also with occasional depth to water level manual measurements. Manual water level measurements were measured from the ground surface down to water using a water level dipper. The transducers in these two bores measured changes in water pressures at 15 minute intervals between 8 December 2014 when they were installed and 11 December 2014 when they were removed.

Surface water levels were measured using unvented pressure transducers attached to a metal waratah standard driven into the substrate of the stream bed at sites MR1 in the Makarewa River and BD3 in the Boiler Ditch. The transducer was housed inside a perforated PVC tube to protect the transducers from debris. The transducers were installed on 9 December 2014 and measured changes in water pressure at 15 minute intervals until 11 December when the transducers were removed. Manual water levels were also measured at each of these sites to compliment the transducer data and were measured using a water level dipper from the top of the metal waratah. The monitoring sites are shown in Figure 5 and photos of the surface water level monitoring sites (MR1 and BD3) are displayed in Figures 6a and 6b respectively.

A dedicated barometric pressure transducer was used to measure changes in atmospheric pressure which was used to remove the atmospheric component of pressure recorded by the pressure transducers installed in bores and the surface water monitoring sites. The barometric pressure transducer recorded changes in atmospheric pressure every 15 minutes for the entire period of measurements between 8 December and 11 December 2014.

The water levels were measured manually and using the pressure transducers in BHC, BHD and surface water sites MR1 and BD3 are displayed in Figure 7 (Appendix A). Tidal data from Bluff is also displayed in this figure.

The Makarewa River shows the full pattern of tidal fluctuation with around half the amplitude that occurs at the sea. The Boiler Ditch maintains a base flow level at an elevation around 0.8 metres above mean sea level during the monitoring period, but rises above that for the higher part of the tidal cycle to match the levels in the Makarewa River when they rise above the 0.8 m elevation.

Boreholes BHC and BHD are located around 90 m from the Makarewa River and the groundwater level fluctuations show a subdued response to the tidal fluctuations in both the Makarewa River and Boiler Ditch, the ground water levels show a consistent

pattern of elevations with BHC at a higher elevation than BHD and both higher than the nearby surface water levels with the exception of a short period of time at the highest tidal peak recorded in the river. The main influence of the surface waterways on groundwater flow patterns will be the mean surface water levels and the data indicates groundwater levels that are higher than both the Boiler Ditch and the Makarewa River indicating that groundwater will flow towards those surface waterways.

At the time these measurements were made, flow in the Makarewa River, measured at Counsell Road (located approximately 7 km North East of the AGL site) was around 6-7 m<sup>3</sup>/s which is around a 57 percentile flow (i.e. the flow is greater than this value around 57 % of the time). The median flow is 7.7 m<sup>3</sup>/s and corresponds to an increase in stage height of around 0.05 m compared to the monitoring period. Therefore at times of median flow groundwater levels can still be expected to flow towards the Makarewa River. Also, at times of higher flow in the river the tidal peaks are reduced, which accounts for the lower surface water level peaks observed in the evening of 10 December and the morning of 11 December (Figure 7).

### 4.3 Flow Gauging

Flow gauging was undertaken by PDP in Bateman’s Drain at sites S3 and S4 (Figure 5, Appendix A) on 9 December 2014 to determine whether this section of drain gained or lost water to ground. Flow gauging was carried out using a Sontek/YSI FlowTracker in accordance with the open channel flow measurement procedures outlined in the Open Channel Flow Measurement procedure (NEMS, 2013). Bateman’s Drain is typically overgrown with weed which required clearing prior to gauging the drain at each site. Weed was also removed from both upstream and downstream of the gauging sites to reduce the potential for turbulence and interference generated by weed.

For each site, at least 22 verticals were used to determine the cross section of the drain and determine the velocity of the drain at each site. The results of the flow gauging at sites S3 and S4 in Bateman’s Drain are provided in Table 2 below.

Table 2: Flow Gauging Results from Bateman's Drain		
Site	Discharge (m <sup>3</sup> /s)	Discharge (L/s)
S3	0.0222	22.2
S4	0.0266	26.6
<i>Notes:</i> 1. : Both gaugings undertaken on 9 December 2014		

The flow gauging in Bateman's Drain indicated relatively low flows although site S4 had a slightly higher flow rate of 26.6 L/s compared to the lower flow of 22.2 L/s measured at site S3. Since S4 is located approximately 560 m downstream of S3 and the flow increased between the two sites, the flow gauging results indicate that the section of Bateman's Drain between the two flow gauging sites gains water from the shallow groundwater system.

## 5.0 Groundwater and Surface Water Quality

To determine the existing effect of the AGL wastewater treatment plant on the surrounding groundwater and surface water quality, samples were collected from five groundwater monitoring bores and five surface water sites (Figure 8). Groundwater samples and surface water samples were collected during a period of fine stable weather to ensure that groundwater and surface water levels would not be affected by rapid infiltration or surface runoff.

The sample collection methods and a discussion of the results are provided in the following sections.

### 5.1 Groundwater Sample Collection

Groundwater samples were collected by PDP from the five additional monitoring bores installed in November on 10 December 2014 and on 18 March 2015 when groundwater levels in the area were lowest.

During the sampling round on 10 December 2014, the five monitoring bores were purged using a bailer dedicated to each bore and at least three casing volumes of purge water removed as well as the stabilisation of at least three field measurements of pH, electrical conductivity and temperature prior to the collection of samples. This was to ensure that the groundwater being sampled was representative of the shallow groundwater system and not stagnant water in the casing. Samples were also collected using the bailer used to purge each bore and samples collected for dissolved metals analysis were filtered in the field to remove any suspended solids.

During the sampling round on 18 March 2015, the five monitoring bores were purged using a small submersible electric pump. A section of downhole tubing was dedicated to each bore and at least three casing volumes of purge water were removed. The purged water was passed through a flow cell and field measurements of pH, electrical conductivity, temperature, dissolved oxygen and oxidation/reduction potential (ORP) were measured during purging. In addition to the removal of three casing volumes of water, field measurements of pH, electrical conductivity and temperature were measured until at least three readings for each parameter had stabilised. The reason for using a small submersible pump during the March 2015 sampling round was to make sure that the abstracted purge water would not come into contact with oxygen, ensuring

that accurate measurements of dissolved oxygen and ORP could be made. Samples for dissolved metals were not filtered in the field and instead were filtered at Hill Laboratories. Iron and manganese were also analysed during the March 2015 sampling round.

After collection, the samples were chilled and couriered to Hill Laboratories in Christchurch within 48 hours of collection for analysis.

## 5.2 Surface Water Sample Collection

Surface water samples were collected by PDP from the five surface water monitoring sites on 10 December 2014 and 18 March 2015. The locations of these sites are shown in Figure 8. The surface water sample sites were selected to compare surface water quality with groundwater quality.

All five surface water samples were grab sampled from the edge of the surface water body. During the 10 December 2014 sampling round, samples collected for dissolved metals analysis were filtered in the field to remove any suspended solids in the sample. Field pH, electrical conductivity and temperature measurements were measured at the time of sample collection.

Samples collected for dissolved metals analysis during the 18 March 2015 sampling round were filtered in the laboratory. Field measurements of pH, electrical conductivity, temperature, dissolved oxygen and oxidation/reduction potential (ORP) were measured at the time of sample collection. Iron and manganese were also analysed during the March 2015 sampling round.

All surface water samples during both sampling rounds were collected around low tide to ensure that the samples would not be affected by elevated water levels due to high tide. During sampling of the Boiler Ditch at sites BDA and BD3 during both sampling rounds, treated wastewater was being discharged into the ditch from Pond 6.

All surface water samples collected were chilled and couriered to Hill Laboratories in Christchurch within 48 hours of collection for analysis.

## 5.3 Groundwater and Surface Water Quality Results

Water quality results from the groundwater sampling rounds on 10 December 2014 and 18 March 2015 are displayed in Tables 3 and 4 respectively. The surface water quality results for these two sampling rounds are provided in Tables 5 and 6. Full laboratory reports for both sampling rounds are provided in Appendix D.

The Boiler Ditch emerges from a pipe just to the west of Boyle Road. The origin of the water is thought to be a combination of stormwater runoff from around the plant, tile drains intercepting shallow groundwater in surrounding paddocks as well as natural groundwater inflow. This ditch flows past the southern edge of

the wastewater treatment lagoons before discharging into the Makarewa River. Treated water from the wastewater treatment lagoons is discharged into the Boiler Ditch from the two southernmost wastewater lagoons. Surface water monitoring site BDA is located near the head of the drain where groundwater enters the ditch and BD3 is located below both of the discharge points from the two southernmost wastewater treatment lagoons but up stream of the confluence of the Boiler Ditch with the Makarewa River. Treated wastewater was discharging into the Boiler Ditch during both sampling rounds at site BD3. The water quality results indicate that site BD3 generally has the highest concentrations of most parameters due to its location downstream of the treated wastewater discharge point during both sampling rounds. The water quality results from both sampling rounds indicate that concentrations of parameters at all sites were generally higher during the March 2015 sampling round compared to the December 2014 sampling round. This may be related to the lower water levels in the area at this time of year resulting in less dilution of the water quality parameters analysed during the two sampling rounds. The flow at the Counsell Road gauging station on the Makarewa River on 10 December 2014 was recorded at 6.6 m<sup>3</sup>/s whereas on 18 March 2015 it had dropped to 3.36 m<sup>3</sup>/s.

Total ammoniacal-N and TKN concentrations are significantly higher at BD3 (39 g/m<sup>3</sup> and 42 g/m<sup>3</sup> respectively – 10 December 2014, 131 g/m<sup>3</sup> and 139 g/m<sup>3</sup> respectively – 18 March 2015) than concentrations at BDA (0.22 g/m<sup>3</sup> and 1.01 g/m<sup>3</sup> - 10 December 2014, 0.74 g/m<sup>3</sup> and 3.2 g/m<sup>3</sup> - 18 March 2015). In contrast, nitrate-N concentrations at BD3 (0.42 g/m<sup>3</sup> - 10 December 2014, 0.47 g/m<sup>3</sup> - 18 March 2015) are lower than at BDA (2.0 g/m<sup>3</sup> - 10 December 2014 and 18 March 2015) which is likely due to the chemical environment within the wastewater treatment lagoons prior to discharge into the Boiler Ditch and the oxidising environment within the Boiler Ditch at site BDA

**Table 3: Groundwater Quality Sampling Results collected on 10 December 2014**

Site / Time of Sample Collection	BHA (14:20)	BHB (15:40)	BHC (16:50)	BHD (17:55)	BHE (10:25)	NZDWS GV	NZDWS MAV
Sum of Anions (meq/L)	3.1	1.76	2.1	3.4	1.85	-	-
Sum of Cations (meq/L)	3.3	2	2.3	3.7	1.9	-	-
pH – Laboratory Measurement	<b>6.7</b>	<b>6.6</b>	<b>6.5</b>	<b>6.8</b>	<b>5.9</b>	7.0 - 8.5	-
pH – Field Measurement	<b>5.66</b>	<b>6.22</b>	<b>5.6</b>	<b>6.06</b>	<b>5.13</b>	7.0 - 8.5	-
Total Alkalinity (g/m <sup>3</sup> as CaCO <sub>3</sub> )	38	37	49	83	3.8	-	-
Carbonate (g/m <sup>3</sup> as CaCO <sub>3</sub> )	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	-	-
Bicarbonate (g/m <sup>3</sup> at 25°C)	46	45	60	102	4.6	-	-
Total Hardness (g/m <sup>3</sup> as CaCO <sub>3</sub> )	69	48	50	100	52	200	-
Electrical Conductivity (EC) (mS/m)	34.8	19	21.6	34.4	21.5	-	-
Total Suspended Solids (g/m <sup>3</sup> )	8,600	4,400	3,000	7,400	6,100	-	-
Dissolved Calcium (g/m <sup>3</sup> )	13	9	8.3	18.6	8.6	-	-
Dissolved Magnesium (g/m <sup>3</sup> )	8.9	6.2	7	13	7.3	-	-
Dissolved Potassium (g/m <sup>3</sup> )	2.1	1.28	1.09	2.1	1.42	-	-
Dissolved Sodium (g/m <sup>3</sup> )	42	23	29	38	19	200	-
Chloride (g/m <sup>3</sup> )	60	25	29	34	45	250	-
Total Nitrogen (g/m <sup>3</sup> )	8.8	1.47	1.13	2.7	4.9	-	-
Total Ammoniacal-N (g/m <sup>3</sup> )	0.014	0.122	0.013	0.085	< 0.010	1.2	-
Nitrite-N (g/m <sup>3</sup> )	0.007	< 0.02	< 0.002	< 0.02	< 0.002	-	0.06 <sup>+</sup>
Nitrate-N (g/m <sup>3</sup> )	4.8	< 0.02	< 0.002	< 0.02	1.98	-	11.3
Nitrate-N + Nitrite-N (g/m <sup>3</sup> )	4.8	< 0.02	< 0.002	< 0.02	1.98	-	-
Total Kjeldahl Nitrogen (TKN) (g/m <sup>3</sup> )	4	1.47	1.13	2.7	2.9	-	-
Dissolved Reactive Phosphorus (g/m <sup>3</sup> )	< 0.004	0.004	< 0.004	< 0.004	< 0.004	-	-
Sulphate (g/m <sup>3</sup> )	13.3	15.6	14.6	37	17.5	250	-

Notes: New Zealand Drinking-water Standards (NZDWS) 2000 (Revised 2008) guideline value (GV) for aesthetic effects and maximum acceptable value (MAV) for the protection of human health. <sup>+</sup> More stringent long term MAV for Nitrite - N. Short term Nitrite - N MAV = 0.91 g/m<sup>3</sup>. **Bold** values indicate value outside of GV.

**Table 4: Groundwater Quality Sampling Results Collected on 18 March 2015**

Site	BHA (9:32)	BHB (11:51)	BHC (13:33)	BHD (12:43)	BHE (10:31)	NZDWS GV	NZDWS MAV
Sum of Anions (meq/L)	3.2	2.4	2.5	3.8	2	-	-
Sum of Cations (meq/L)	3.4	2.2	2.6	3.9	2.2	-	-
pH – Laboratory Measurement	<b>6.4</b>	<b>6.8</b>	<b>6.7</b>	<b>6.8</b>	<b>5.8</b>	7.0 - 8.5	-
pH – Field Measurement	<b>5.40</b>	<b>6.03</b>	<b>5.64</b>	<b>5.82</b>	<b>4.75</b>	7.0 - 8.5	-
ORP (mV) – Field Measurement	200.1	69.5	152.6	109.1	365.9	-	-
DO (mg/L) – Field Measurement	2.61	0.29	0.39	0.25	8.94	-	-
DO (% Sat.) – Field Measurement	24.3	2.8	3.9	2.3	83.1	-	-
Electrical Conductivity (mS/m) – Field Measurement	39.9	29.4	29.2	42.5	26.1		
Electrical Conductivity (mS/m) – Lab Measurement	36.8	25	26.3	38.6	24	-	-
Total Alkalinity (g/m <sup>3</sup> as CaCO <sub>3</sub> )	38	53	65	94	5	-	-
Bicarbonate (g/m <sup>3</sup> at 25°C)	47	64	79	114	6.2	-	-
Total Hardness (g/m <sup>3</sup> as CaCO <sub>3</sub> )	72	45	57	102	57	200	-
Total Suspended Solids (g/m <sup>3</sup> )	169	48	9	1,100	20	-	-
Dissolved Calcium (g/m <sup>3</sup> )	13.5	8	10	18.7	7.8	-	-
Dissolved Iron (g/m <sup>3</sup> )	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02		
Dissolved Magnesium (g/m <sup>3</sup> )	9.3	6.2	7.8	13.4	9.2	-	-
Dissolved Manganese (g/m <sup>3</sup> )	0.091	0.7	0.97	1.28	0.023		
Dissolved Potassium (g/m <sup>3</sup> )	1.87	1.16	1.32	2.2	1.82	-	-
Dissolved Sodium (g/m <sup>3</sup> )	44	27	32	41	22	200	-
Chloride (g/m <sup>3</sup> )	64	32	31	35	50	250	-
Total Nitrogen (g/m <sup>3</sup> )	5.3	0.3	< 0.3	0.9	2.4	-	-
Total Ammoniacal-N (g/m <sup>3</sup> )	0.01	0.116	0.029	0.1	< 0.010	1.2	-
Nitrite-N (g/m <sup>3</sup> )	0.002	< 0.2	< 0.2	< 0.2	< 0.002	-	0.06 <sup>+</sup>
Nitrate-N (g/m <sup>3</sup> )	5.2	< 0.2	< 0.2	< 0.2	2.3	-	11.3
Nitrate-N + Nitrite-N (g/m <sup>3</sup> )	5.2	< 0.2	< 0.2	< 0.2	2.3	-	-
Total Kjeldahl Nitrogen (TKN) (g/m <sup>3</sup> )	0.15	0.22	0.13	0.79	< 0.10	-	-
Dissolved Reactive Phosphorus (g/m <sup>3</sup> )	< 0.004	0.109	0.018	0.009	< 0.004	-	-
Sulphate (g/m <sup>3</sup> )	14.6	19.9	18	43	17.5	250	-

Notes: New Zealand Drinking-water Standards (NZDWS) 2000 (Revised 2008) guideline value (GV) for aesthetic effects and maximum acceptable value (MAV) for the protection of human health. <sup>+</sup> More stringent long term MAV for Nitrite - N. Short term Nitrite - N MAV = 0.91 g/m<sup>3</sup>. Bold values indicate value outside of GV. DO – Dissolved Oxygen and ORP – Oxidation/Reduction Potential

**Table 5: Surface Water Quality Sampling Results Collected on 10 December 2014**

Site / Time of Sample Collection	MR1 (11:50)	MR2 (11:30)	BD3 (12:15)	BDA (11:00)	S4 (8:50)
Sum of Anions (meq/L)	2.5	1.79	12.6	3.4	2.4
Sum of Cations (meq/L)	2.7	1.94	13.3	3.8	2.6
pH – Laboratory Measurement	7.8	7.7	8.1	7.1	7.3
pH – Field Measurement	6.58	6.66	7.43	6.11	6.12
Total Alkalinity (g/m <sup>3</sup> as CaCO <sub>3</sub> )	63	48	260	52	35
Carbonate (g/m <sup>3</sup> as CaCO <sub>3</sub> )	< 1.0	< 1.0	1.9	< 1.0	< 1.0
Bicarbonate (g/m <sup>3</sup> at 25°C)	76	58	320	63	43
Total Hardness (g/m <sup>3</sup> as CaCO <sub>3</sub> )	62	56	112	69	59
Electrical Conductivity (EC) (mS/m)	26.3	18.9	133.7	37.7	26.2
Total Suspended Solids (g/m <sup>3</sup> )	9	4	48	10	< 3
Dissolved Calcium (g/m <sup>3</sup> )	16.9	15	36	19.3	14
Dissolved Magnesium (g/m <sup>3</sup> )	4.8	4.6	5.7	5	5.8
Dissolved Potassium (g/m <sup>3</sup> )	3.1	1.69	25	2.5	2.8
Dissolved Sodium (g/m <sup>3</sup> )	27	17.5	175	53	30
Chloride (g/m <sup>3</sup> )	31	19.8	191	60	41
Total Nitrogen (g/m <sup>3</sup> )	4.4	1.39	43	3.1	4.2
Total Ammoniacal-N (g/m <sup>3</sup> )	2.6	0.066	39	0.22	0.88
Nitrite-N (g/m <sup>3</sup> )	0.02	0.016	0.081	0.03	0.067
Nitrate-N (g/m <sup>3</sup> )	0.87	0.9	0.42	2	2.7
Nitrate-N + Nitrite-N (g/m <sup>3</sup> )	0.89	0.91	0.5	2.1	2.8
Total Kjeldahl Nitrogen (TKN) (g/m <sup>3</sup> )	3.6	0.48	42	1.01	1.41
Dissolved Reactive Phosphorus (g/m <sup>3</sup> )	0.34	0.024	5.2	0.066	0.012
Sulphate (g/m <sup>3</sup> )	13.1	10	67	27	14.3



**Table 6: Surface Water Quality Sampling Results Collected on 18 March 2015**

Site	MR1 (14:45)	MR2 (14:25)	BD3 (15:05)	BDA (14:10)	S4 (11:00)
Sum of Anions (meq/L)	3.5	1.6	28	13	4.4
Sum of Cations (meq/L)	3.5	1.81	29	12.8	4.6
pH – Laboratory Measurements	7.9	7.8	8.3	7.1	7.2
pH – Field Measurements	7.45	7.23	8.12	6.39	5.68
Oxidation/Reduction Potential - ORP (mV)	136.9	110.6	123.6	86.5	266.9
DO (mg/L) – Field Measurement	8.58	9.68	9.98	3.45	4.14
DO (% Sat.) – Field Measurement	83.3	93.2	101.9	36.6	40.2
Electrical Conductivity (mS/m) – Field Measurement	40.9	20.1	342.4	169.9	53.3
Electrical Conductivity (mS/m) – Lab Measurement	36.8	17.5	283	146.2	50.2
Total Alkalinity (g/m <sup>3</sup> as CaCO <sub>3</sub> )	88	44	700	50	63
Bicarbonate (g/m <sup>3</sup> at 25°C)	107	53	840	60	77
Total Hardness (g/m <sup>3</sup> as CaCO <sub>3</sub> )	54	51	144	89	76
Total Suspended Solids (g/m <sup>3</sup> )	10	5	99	9	5
Dissolved Calcium (g/m <sup>3</sup> )	14.2	12.7	48	28	17.9
Dissolved Iron (g/m <sup>3</sup> )	0.26	0.32	0.13	0.58	0.07
Dissolved Magnesium (g/m <sup>3</sup> )	4.6	4.7	6	4.8	7.6
Dissolved Manganese (g/m <sup>3</sup> )	0.0012	0.0013	0.099	0.031	0.023
Dissolved Potassium (g/m <sup>3</sup> )	6.5	1.58	79	2.6	6
Dissolved Sodium (g/m <sup>3</sup> )	39	16.8	340	250	58
Chloride (g/m <sup>3</sup> )	43	18.9	360	360	83
Total Nitrogen (g/m <sup>3</sup> )	9.9	0.76	140	5.2	10.7
Total Ammoniacal-N (g/m <sup>3</sup> )	8.1	0.026	131	0.74	5.7
Nitrite-N (g/m <sup>3</sup> )	0.102	0.011	0.78	0.074	0.22
Nitrate-N (g/m <sup>3</sup> )	0.57	0.33	0.47	2	4.4
Nitrate-N + Nitrite-N (g/m <sup>3</sup> )	0.67	0.34	1.25	2.1	4.6
Total Kjeldahl Nitrogen (TKN) (g/m <sup>3</sup> )	9.2	0.42	139	3.2	6.1
Dissolved Reactive Phosphorus (g/m <sup>3</sup> )	0.97	0.03	14.7	0.43	0.184

The March 2015 sample from BDA shows some unusually elevated chloride and sodium concentrations which are of similar magnitude to sample BD3, which is affected by the wastewater discharge. This is an unexpected result that does not match the earlier sampling round in December 2014, although it does not impact on the interpretation of the groundwater results.

The Makarewa River sites (MR1 and MR2) also show the effect of the wastewater treatment pond discharge into the river via the Boiler Ditch during both sampling rounds. MR1 is located downstream of the confluence of the Boiler Ditch with the Makarewa River and has elevated concentrations of the same parameters that are elevated in the Boiler Ditch sample BD3. These same parameters are also elevated above the concentrations for MR2 which is located upstream of the wastewater treatment lagoons. Dissolved iron concentrations ranged between 0.07 (S4) and 0.58 (BDA) g/m<sup>3</sup> and dissolved manganese ranged between 0.0012 (MR1) and 0.099 (BD3) g/m<sup>3</sup> for the five surface water sites.

Site S4, located in Bateman's Drain recorded slightly lower concentrations than the other surface water sites, but had elevated concentrations of both ammoniacal-N (0.88 g/m<sup>3</sup>) and nitrate-N (2.7 g/m<sup>3</sup>) during the 10 December 2014 sampling round. During the 18 March 2015 sampling round, both of these parameters were elevated above the results from the December sampling round (5.7 g/m<sup>3</sup> and 4.4 g/m<sup>3</sup>). Batemans' Drain is located on a terrace elevated above the wastewater treatment lagoons and is surrounded by agricultural land. The drain receives groundwater inflow along its length and from a spring located approximately 240 m upstream of surface water level monitoring site S3. Bateman's Drain also receives subsurface drainage from a network of field tiles within the surrounding paddocks.

The field measurements of dissolved oxygen (DO) and ORP measured during the 18 March 2015 sampling round ranged between 40.2 (S4) and 101.9 (BD3) % for DO and between 86.5 (BDA) and 266.9 (S4) mV for ORP. Oxidising conditions generally have higher DO saturations and concentrations and also higher ORP readings. Reducing conditions generally have lower DO and negative ORP values.

The parameters analysed from the groundwater samples were generally below their respective maximum acceptable value (MAV) and guideline value (GV) in the NZ Drinking Water Standards, with the exception of both field and laboratory pH which were below the GV range of 7.0 to 8.5 in all five groundwater samples during both sampling rounds. This is not uncommon as many shallow groundwaters in New Zealand have low pH due to recharge from rainfall infiltration through soil. During the 10 December 2014 sampling round, all five groundwater samples had high total suspended solid concentrations ranging between 3,000 (BHC) and 8,600 (BHA) g/m<sup>3</sup>. The high total suspended solid concentration in all five bores is due to the nature of the bore screens relative to the fine particle sizes in the surrounding strata. Also, during sampling of BHA

iron flocculent was noted which may have attributed to the high total suspended solid concentration in this bore. During the 18 March 2015 sampling round, total suspended solid concentrations were significantly lower, ranging between 9 (BHC) and 1,100 (BHD) g/m<sup>3</sup>. The lower total suspended solids is likely to be due to a combination of the different purging methods used during each sampling round (a small pump provides a consistent abstraction as opposed to a bailer which causes a degree of disturbance in the bore when it is dropped down and pulled out) and the bores having a longer period of time settle after they were installed.

Dissolved iron concentrations were less than the detection limit of 0.02 g/m<sup>3</sup> in all five monitoring bores and dissolved manganese ranged between 0.023 (BHE) and 1.28 (BHD) g/m<sup>3</sup>.

Field measurements of DO and ORP measured during the 18 March 2015 sampling round ranged between 2.3 (BHD) and 83.1 (BHE) % for DO and between 69.5 (BHB) and 365.9 (BHE) mV for ORP. Bores BHB, BHC and BHE all recorded similar DO saturations that were less than 4.0 % saturation. These three bores also had the lowest ORP values which suggests that the groundwater environment around the bore locations is less oxidised than BHA or BHE.

The results from both sampling rounds indicate that the groundwater samples show similar composition, with the following exceptions:

- ❖ BHE has a lower bicarbonate concentration and low alkalinity;
- ❖ BHA has a higher concentration of chloride;
- ❖ BHD has higher concentrations of bicarbonate, calcium, magnesium (hardness), manganese and sulphate.

With regard to nitrogen species, ammoniacal-N was detected at low concentrations (<0.2 g/m<sup>3</sup>) in all bores with the exception of its non-detection in BHE. Nitrate-N was detected in BHA and BHE at concentrations of 4.8 and 1.98 g/m<sup>3</sup> (10 December 2014) and 5.2 and 2.3 g/m<sup>3</sup> (18 March 2015) respectively. In contrast, nitrate-N was not detected in BHB, BHC or BHD, which may be indicative of some degree of reducing conditions around those bore locations.

The nitrate-N concentration measured in BHA is similar to previous sampling results collected by AGL for the Wastewater Treatment Well (WTW) and the lower nitrate-N concentration in BHE is similar to previous sampling results from the Irrigation bore (IB).

### 5.3.1 Major Ionic Water Chemistry

The major ion data for the five groundwater and surface water samples collected during the 10 December 2014 and 18 March 2015 sampling rounds has been analysed using Stiff plots, equivalents analysis and spatial plots of major anions

and cations to provide a variety of representations of the water quality data and allow the identification of different water types.

Stiff plots are constructed by plotting major cation/anion pairs on their individual horizontal axes, with all major cations on one side and anions on the other. A vertical axis divides the anions from the cations and acts as zero for each horizontal axes. Data for each ionic concentration are plotted on the corresponding horizontal axis in units of milliequivalents per litre. The resulting points are then linked to produce a polygonal shape that will be indicative of that particular water sample. Stiff plots display the concentrations of an individual water sample visually, so it can be compared to other water samples. Water types of similar chemistry will have similar shapes. Stiff plots for the five groundwater samples and the five surface water samples collected during the 10 December 2014 and 18 March 2015 sampling rounds are displayed in Figures 9a and 9b respectively (Appendix A).

The Stiff plots displayed in Figures 9a and 9b are coloured depending on whether they are surface water or groundwater samples. The plots are arranged into groups based on their shape, given that the likely water source for the samples causes similar shaped Stiff plots. Based on these shapes, the samples have been divided into groups which are summarized in Table 7 below.

Table 7: Stiff Plot Groups Based on Shape		
Group	Bore Number/Surface Water Sample Site	Dominant Water Source
Group 1	BD3	Wastewater from treatment lagoons
Group 2	MR1 and MR2	Makarewa River
Group 3	BHA, BHE, BDA and S4	Shallow groundwater and surface water receiving significant input from that shallow groundwater
Group 4	BHB, BHC and BHD	Western shallow groundwater

The MR1, MR2 and BD3 Stiff plots fall into two distinct groups with BD3 (Group 1) dominated by elevated concentrations from the wastewater discharge. MR1 and MR2 (Group 2) are dominated by sodium, potassium, bicarbonate and carbonate, with a secondary component of calcium and chloride.

A third group consists of BHA, BHE, BDA and S4. These Stiff plots indicate that groundwater to the east and south east of the wastewater treatment lagoons is generally of similar major ionic chemistry and that the Boiler Ditch (above the wastewater treatment lagoons) and Bateman's Drain receive groundwater from the shallow groundwater system. BHE is slightly distinct by having a lower bicarbonate-carbonate composition.

Both BHA and BHE were the only two bores to have nitrate-N concentrations above the detection limit. Similarly, chloride concentrations in both bores were higher than chloride concentrations in the other three monitoring bores. Sodium concentrations in BHA were higher than BHE, although water quality data for surface water sites BDA and S4 display similar elevated concentrations of chloride, nitrogen and sodium. Suspended solids in BHA were elevated above the other monitoring bores during the December 2014 sampling round, although this is most likely due to nature of the bore screens relative to the fine particle size of the sediments in the surrounding strata. Furthermore, iron flocculent was noted in the bore which have been a cause of the elevated suspended solids in this bore. Based on data discussed above, the water chemistry of BHA is relatively similar to borehole BHE, and surface water sites BDA and S4, and any minor differences are likely to be related to changes in the strata and land use surrounding the bore. Consequently, the elevated concentrations in the water chemistry at BHA are not expected to be related to the waste water treatment ponds.

The final similar grouping based on the Stiff plot shape contains the groundwater samples from BHB, BHC and BHD which, when compared to the groundwater bores in Group 3, have less of a chloride component and in the case of BHD, has a greater sulphate deviation. However, none of these changes are obviously related to the patterns in the Boiler Ditch at BD3 or the Makarewa River. If those surface waterways (or the wastewater treatment lagoons) were having a strong and continuous influence on the groundwater, it would be expected to show elevated chloride and nitrogen concentrations.

The sum of cations and anions are generally higher than those measured during the December 2014 sampling ground. This is shown by the larger scale used for the March 2015 Stiff plots and is most obvious in the increased size of the Stiff plot for BDA from the March 2015 samples. While the size of the Stiff plot for BDA increased between the two sampling rounds, the shape has remained similar and it still falls in to Group 3. The increases in ionic concentration can also be seen when comparing Figure 10a (samples collected 10 December 2014) and 10b (samples collected 18 March 2015) which show the distribution of major cation and anions as well as conductivity.

There are differences in the chemistry of groundwater sampled from BHB, BHC and BHD, but this may simply reflect different geological conditions. In particular, the strata observed at BHB, BHC and BHD was distinct from BHA and

BHE as the strata at BHB, BHC and BHD typically appears to display predominantly grey to greyish brown strata generally indicative of reducing conditions. In contrast, the geology at BHA and BHE displays brownish orange coloured strata with iron staining on unconsolidated gravel clasts which is generally indicative of oxidising groundwater conditions. In addition to this, nitrate-N concentrations in BHA and BHE are elevated (4.8 and 1.98 g/m<sup>3</sup> respectively) above the lower nitrate-N concentrations in BHB, BHC and BHD (all <0.02 g/m<sup>3</sup>) which is also an indicator of oxidising groundwater conditions. Ammoniacal-N is the reduced species of nitrogen and concentrations of this parameter in BHB, BHC and BHD were generally elevated above the concentrations of ammoniacal-N in BHA and BHE. It is also worth noting that water levels in BHB, BHC and BHD were typically shallower than in BHA and BHE at the time of sampling and during the piezometric survey which may indicate a different proportional influence from the near surface silty strata on the water sample. The lower DO and ORP field measurements for BHB, BHC and BHD compared with BHA and BHE also support the suggestion that there is a less oxidised environment around the location of these three bores.

Hydrogeochemical facies can also be indicated by arranging the major cations and anions based on their equivalent weight (Rosen, 2001). The molecular weight of each major cation and anion is converted from milliequivalent per litre (meq/L) to percentages and the hydrogeochemical facies are described by listing the ions greater than 10% in decreasing order starting with the cations. The groupings using the equivalents method for the 10 December 2014 sampling round are outlined in Table 8.

Table 8: Stiff Plot Groups Using the Equivalents Method - 10 December 2014		
Group	Bore Number/Surface Water Sample Site	Hydrogeochemical Signature
Group 1	BD3	Na + K, NH <sub>4</sub> , Ca – Cl, HCO <sub>3</sub> , SO <sub>4</sub>
Group 2	MR1 and MR2	Na + K, Ca, Mg – HCO <sub>3</sub> , Cl, SO <sub>4</sub>
Group 3	BDA and S4	Na + K, Ca, Mg – Cl, HCO <sub>3</sub> , SO <sub>4</sub>
Group 4	BHB, BHC and BHD	Na + K, Mg, Ca – Cl, HCO <sub>3</sub> , SO <sub>4</sub>
Group 5	BHA	Na + K, Mg, Ca – Cl, HCO <sub>3</sub>
Group 6	BHE	Na + K, Mg, Ca – Cl, SO <sub>4</sub>

The equivalent method generally forms groups similar to the groups described using the method based on the shape of the Stiff plots with the exception of BHA and BHE which form groups of their own. Inspection of the hydrogeochemical signature for BHA and BHE in comparison with Group 4 on Table 8 indicates that BHA and BHE are missing an additional anion group (BHA –  $\text{SO}_4$ , BHE –  $\text{HCO}_3$ ) from their hydrogeochemical signature due to lower concentrations of this ion compared to the other major anions for each particular bore, but otherwise have a similar signature to the other groundwater bores in Group 4.

The equivalent method was also applied to the water quality data collected during the March 2015 sampling round. The March 2015 data produced similar hydrogeochemical signatures to the ones identified using the December 2014 data, although there were slight variations in the order of the major cations and anions for Groups 1, 2 and 3 and the addition of  $\text{NH}_4$  to MR1 and  $\text{SO}_4$  to BHA.

Additional figures (Figure 10a and 10b, Appendix A) display the relative concentrations of the major ionic species with the size of each pie chart proportional to the electrical conductivity of the sample from the two sampling rounds.

In summary, from major ionic chemistry analyses undertaken, the eastern bores BHA and BHE generally show similar chemistry to surface water (spring fed) samples BDA and S4. There are some variations with BHE showing low bicarbonate and alkalinity concentrations, and BHA having higher chloride and calcium concentrations.

BHB, BHC and BHD show variances in chemistry. Of the three bores, BHD in particular has the highest concentrations of bicarbonate, calcium, magnesium and sulphate and high alkalinity. However the absence of elevated concentrations of most parameters in BHB and BHC and the absence of elevated concentrations of chloride and nitrogen in BHD coupled with the higher concentration of magnesium indicates that the groundwater at the time of sampling was not affected in any obvious way by seepage from the wastewater treatment lagoons, or by the surface discharge from those lagoons. The differences in the chemistry of BHB, BHC and BHD most likely reflects changes in the natural hydrogeologic environment. In particular, the non-detections of nitrate-N in BHB, BHC and BHD, and the occurrence of ammoniacal-N indicates that some influence from a reducing environment may occur in the area of these bores, although this is not entirely consistent with the elevated sulphate in BHD.

## 6.0 Hydraulic Conductivity

### 6.1 Results from Slug Tests

Slugs test were undertaken in the five additional groundwater monitoring bores (BHA, BHB, BHC, BHD and BHE) on 11 December 2014 by PDP with the intention

of providing *in situ* estimates of the hydraulic conductivity of the strata surrounding the screened interval of each bore. Whilst slug tests provide aquifer parameters based on actual data, it is worth noting that they only test a very small area of strata and the results represent the aquifer parameters that occur locally around each bore.

Two rising head and falling head tests were undertaken in each bore. Dedicated pressure transducers were installed in each bore prior to testing and were set to record changes in water pressure at 1 second intervals. Figure 11 shows the water levels recorded in each bore during slug testing where a sharp increase in water level represents the introduction of a slug into the piezometer and the start of the falling head test, whilst a decrease in water level indicates the removal of the slug and the start of the rising head test. In general, the water level response in the bores was rapid, implying higher conductivities.

The slug test data from each piezometer was analysed using the Bouwer and Rice (1976) method to provide an estimate of hydraulic conductivity of the material surrounding the screened section of each bore. The results of the slug test analyses are provided in Table 9 below.

<b>Table 9: Hydraulic Conductivity Estimates from Slug Tests</b>				
<b>Bore</b>	<b>Screened interval (m bgl)</b>	<b>Static water level (m bgl)</b>	<b>Average hydraulic conductivity from falling head tests (m/d)</b>	<b>Average hydraulic conductivity from rising head tests (m/d)</b>
BHA	1.0 – 7.32	1.5	32.37	20.73
BHB	2.0 – 8.4	1.2	7.54	4.03
BHC	1.0 – 5.8	1.4	18.58	17.60
BHD	1.0 – 5.76	1.5	10.21	8.24
BHE	1.0 – 7.12	2.4	7.19	8.11

As Table 9 shows, in several cases the static water level in the bore is below the top of the screen (except in bore BHB). That lower groundwater level means that water introduced into the bores during the slug tests can alter the saturated thickness for water moving into or out of the bore. Consequently, the resulting pattern of water level change within the bore may include effects due to the hydraulic conductivity of the filter pack material as well as the surrounding



strata. That effect has been accounted for in the analysis of the results, although it does cause uncertainties.

The hydraulic conductivities provided in Table 9 indicate that the shallow strata are variable with a range of values from around 4 m/day to around 30 m/day. That variability is not unsurprising, given the depositional history the shallow strata and suggests that some of the bores intersect lenses of higher permeability material. The overall average hydraulic conductivity from all the bores is around 10 m/day, which would be consistent with sandy strata shown in the bore logs.

The slug tests results represent the strata outside the screened intervals of the bores, which are typically in the order of 6 m long. Therefore, the transmissivity of the strata tested may be in the order of 60 m<sup>2</sup>/day, which is relatively low.

## 7.0 Interaction with Surface Waterways

The monitoring data gathered to date, indicate that groundwater levels between the AGL plant and the Makarewa River decrease in a general westerly and south-westerly direction. This is likely driven by the drainage effect on the groundwater caused by the surface waterways, namely Boiler Ditch, Bateman's Drain and the Makarewa River. Boiler Ditch and Bateman's Drain are known to be spring fed and groundwater levels are higher than nearby surface water levels, as shown in Figure 4:

- ❖ BHE compared to S3
- ❖ BHA, BHB and BHC compared to BD2 and BD3

Flow gauging along Bateman's Drain have shown an increase in flow of 4.4 L/s along a 560 m long reach, caused by inflow of groundwater.

Similarly, water levels in monitoring bores BHC and BHD are higher than the Makarewa River (MR1) indicating that it too causes a drainage effect on the local groundwater environment.

Groundwater chemistry patterns indicate a generally similar chemistry between the eastern boreholes BHA and BHE and the nearby spring fed streams BDA and S4. All the groundwater bores are dominated by sodium, potassium, magnesium, calcium and chloride, although there are some specific differences:

- ❖ BHE is low in bicarbonate
- ❖ BHA is high in chloride
- ❖ BHD is high in bicarbonate, calcium, magnesium (hardness), manganese and sulphate, but low in chloride.

These differences could be due to localised effects from strata and/or nearby land use.

The characteristics of the Alliance Lorneville wastewater, as indicated by the sample from BD3, are elevated bicarbonate, calcium, potassium, sodium, chloride, nitrogen, phosphorus and sulphate.

The higher concentrations of many of these parameters in BHD are not obviously caused by a seepage discharge from the ponds or their discharge into Boiler Ditch and/or the Makarewa River. The lack of an obvious effect is evidenced by the absence of elevated chloride and nitrogen (and to a lesser extent sodium, potassium and phosphorus) and the elevated magnesium in BHD. These chemical patterns suggest that the differences in chemistry are due to local geological and land use effects rather than seepage effects from the wastewater treatment lagoons. This conclusion is supported by the grouping of the groundwater chemistry of BHB, BHC and BHD and the fact that BHB and BHC are not unusually elevated in the main cations and anions present in the BD3 sample.

Therefore, the information from both the groundwater levels and the groundwater chemistry suggests that at the time of the two piezometric surveys and sampling rounds, the wastewater discharge was primarily directed towards the Makarewa River.

## 8.0 Conclusions

The area to the south of the wastewater treatment lagoons is underlain by surface silty strata to depths of around 2 m, which in turn are underlain by more permeable gravelly strata. The depth to water has been measured to occur at 0.8 – 1.4 m on the low lying terrace near the Makarewa River and 2.0 – 4.1 m on the higher terrace to the east and in deeper boreholes.

Groundwater levels decrease from east to west due to drainage of groundwater into Boiler Ditch, Bateman's Drain and the Makarewa River.

Groundwater quality samples from the monitoring bores show similar characteristics, with some variations in particular parameters. The geological logs and analyses of nitrogen species indicate that the groundwater changes from more oxidised conditions in the east to a less oxidised environment in the west. Sampling from boreholes BHB and BHC show no significantly elevated concentrations that would suggest any adverse effects arising from the wastewater treatment lagoons or the discharge from those lagoons. The highest groundwater concentrations occur in BHD, which indicates a less oxidised environment and does not show a consistent chemistry with the wastewater ponds.

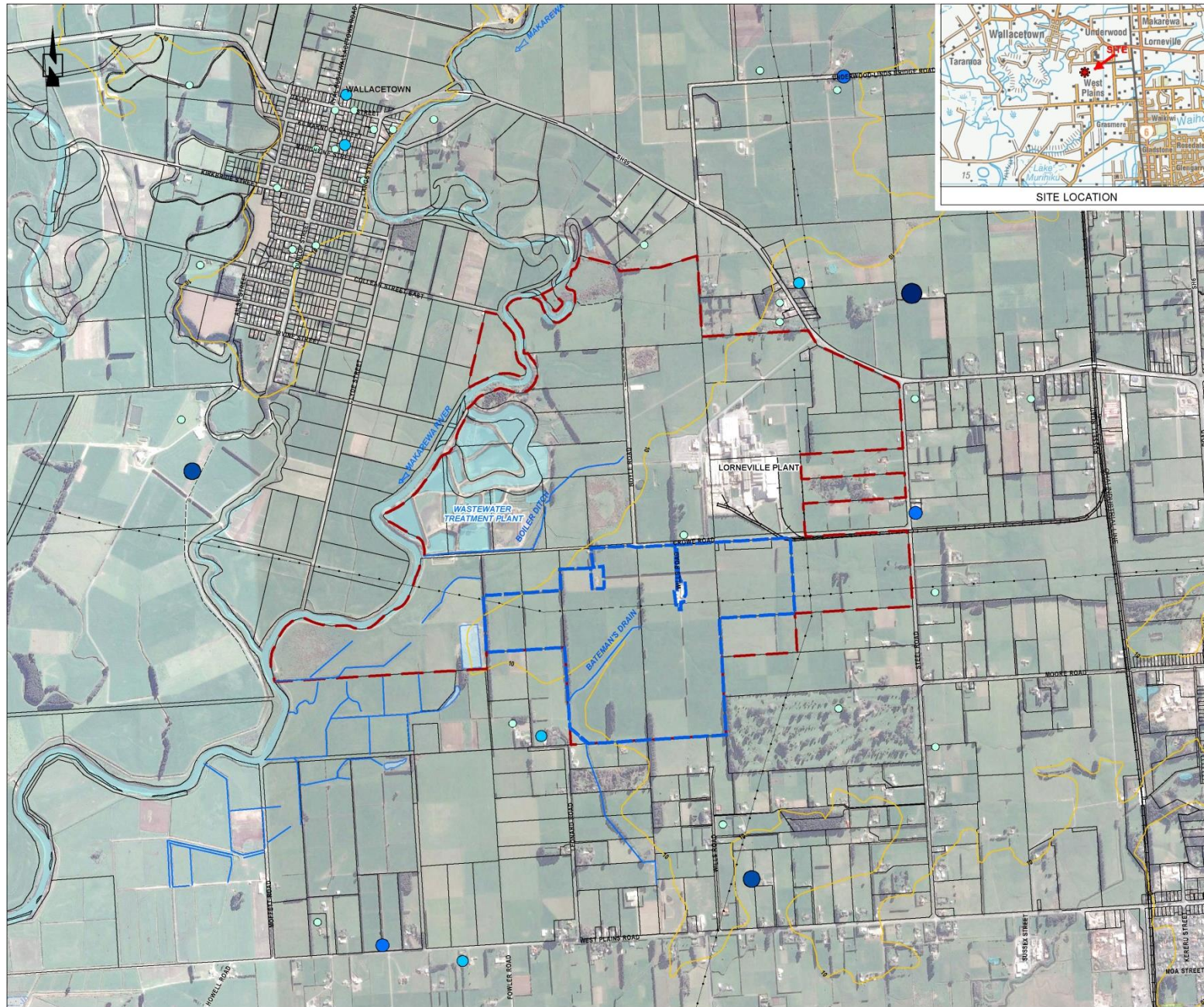
Because of these chemical patterns and the fact that the groundwater levels at the time of sampling were above the levels in the adjacent reaches of the Boiler Ditch and Makarewa River, it is concluded that discharges from the wastewater ponds were not affecting groundwater during the monitoring periods described in this report.

## 9.0 References

- Bouwer, H. and Rice, R.C. 1976. *A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells*, Water Resources, Res., 12(3), 423
- Environment Southland. 2014. *Makarewa Groundwater Zone Information Sheet*. Accessed (19 December 2014) from Environment Southland website <http://gis.es.govt.nz/groundwater/zones/makarewa.pdf>
- Kruseman, G.P. and de Ridder, N.A. 1990. *Analysis and Evaluation of Pumping Test Data* – ILRI Publication 47, The Netherlands, Int. Inst. for Land Reclamation and Improvement
- National Environmental Monitoring Standards (NEMS). 2013. *Open Channel Flow Measurement: Measurement, Processing and Archiving of Open Channel Flow Data*. Version 1.1. June 2013
- Rosen, M. R. 2001. *Hydrochemistry of New Zealand's aquifers*. In M. R. Rosen & P. A. White (Eds.), *Groundwaters of New Zealand*. New Zealand Hydrological Society Inc. Wellington. Pages 77-110.
- Turnbull, I. M. and Allibone, A. H. (compilers) 2003. *Geology of the Murihiku area*. Institute of Geological and Nuclear Sciences 1:250 000 geological map. 1 sheet and 74 p. Lower Hutt, New Zealand. Institute of Geological and Nuclear Sciences Limited.







**KEY :**

- EXISTING WASTEWATER IRRIGATION AREA
- SITE BOUNDARY

**Yield (L/s)**

- 0.0 - 0.5 L/s
- 0.5 - 1.0 L/s
- 1.0 - 1.5 L/s
- 1.5 - 2.0 L/s
- > 2.0 L/s

**NOTES AND SOURCE:**

1. GW MONITORING BORE LOCATIONS ARE APPROXIMATE ONLY, DERIVED FROM SIM REPORT ASSESSMENT OF EFFECTS OF APPLICATION OF WASTEWATER TO LAND (RD MAY 2000) FIGURE 6.7. LOCATION OF BORES ON NEIGHBOURING PROPERTY;
2. FROM AERIAL IMAGES (FLOWFEB 2011) SUPPLIED BY RIVERCROSSLAND CITY COUNCIL;
3. CADASTRAL INFORMATION SUPPLIED BY LINZ 28/11/13.

NO.	REVISION	DATE	APP.
A	ISSUED FOR REVIEW	JAN 15	

NO. REVISION DATE APP.

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**CLIENT :**

**PROJECT :**

**LORNEVILLE PLANT  
GROUNDWATER  
SITE INVESTIGATION**

**TITLE :**

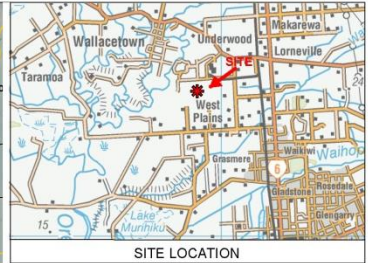
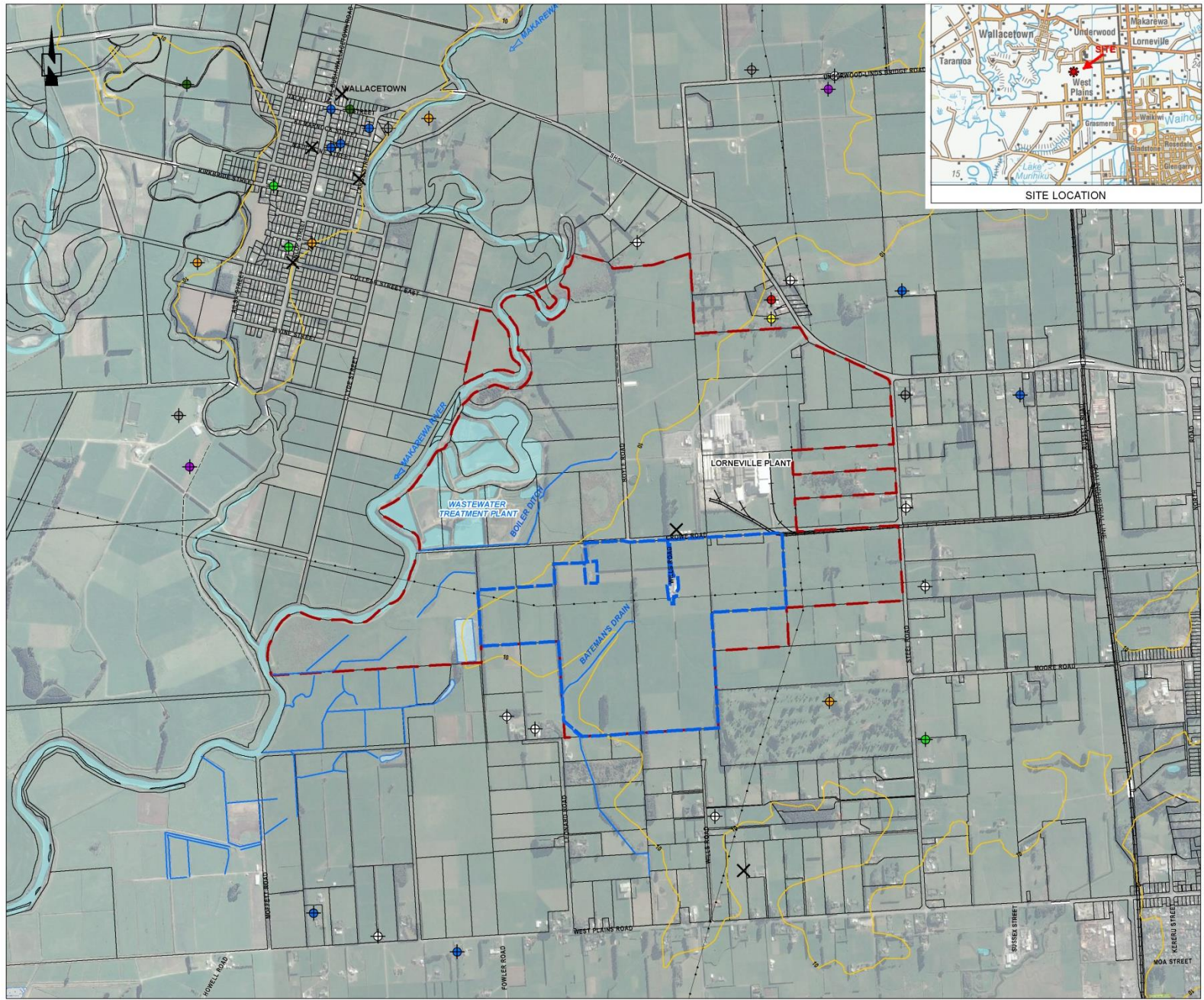
**LOCATION OF  
NEIGHBOURING BORES,  
INDICATING YIELDS**

**PATTLE DELAMORE PARTNERS LTD**  
Auckland Tauranga Wellington Christchurch

**SCALE : 1:20,000 (A3)**

PROJECT NO. : <b>A01856210</b>	FIGURE NO. : <b>1A</b>	REVISION : <b>A</b>
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**KEY :**

- EXISTING WASTEWATER IRRIGATION AREA
- SITE BOUNDARY

**USE OF BORES WITHIN 3KM**

- UNKNOWN
- COMMERCIAL
- DAIRY USE
- DOMESTIC SUPPLY
- GARDEN
- GEOLOGICAL RESEARCH
- INDUSTRIAL
- IRRIGATION
- MONITORING
- STOCK SUPPLY

**NOTES AND SOURCE:**

1. GW MONITORING BORE LOCATIONS ARE APPROXIMATE ONLY. DERIVED FROM ENVIRONMENTAL ASSESSMENT OF EFFECTS - IRRIGATION OF WASTEWATER TO LAND (RD MAY 2009) FIGURE 6.7 LOCATION OF BORES ON NEIGHBOURING PROPERTIES.
2. URBAN AERIAL IMAGES (FLOWER FEB 2011) SUPPLIED BY HIVERCROFT CITY COUNCIL.
3. CADASTRAL INFORMATION SUPPLIED BY LINZ (2011).

A	ISSUED FOR REVIEW	JAN 14	
NO.	REVISION	DATE	APP.

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**CLIENT :**

**PROJECT :**

**LORNEVILLE PLANT  
GROUNDWATER  
SITE INVESTIGATION**

**TITLE :**

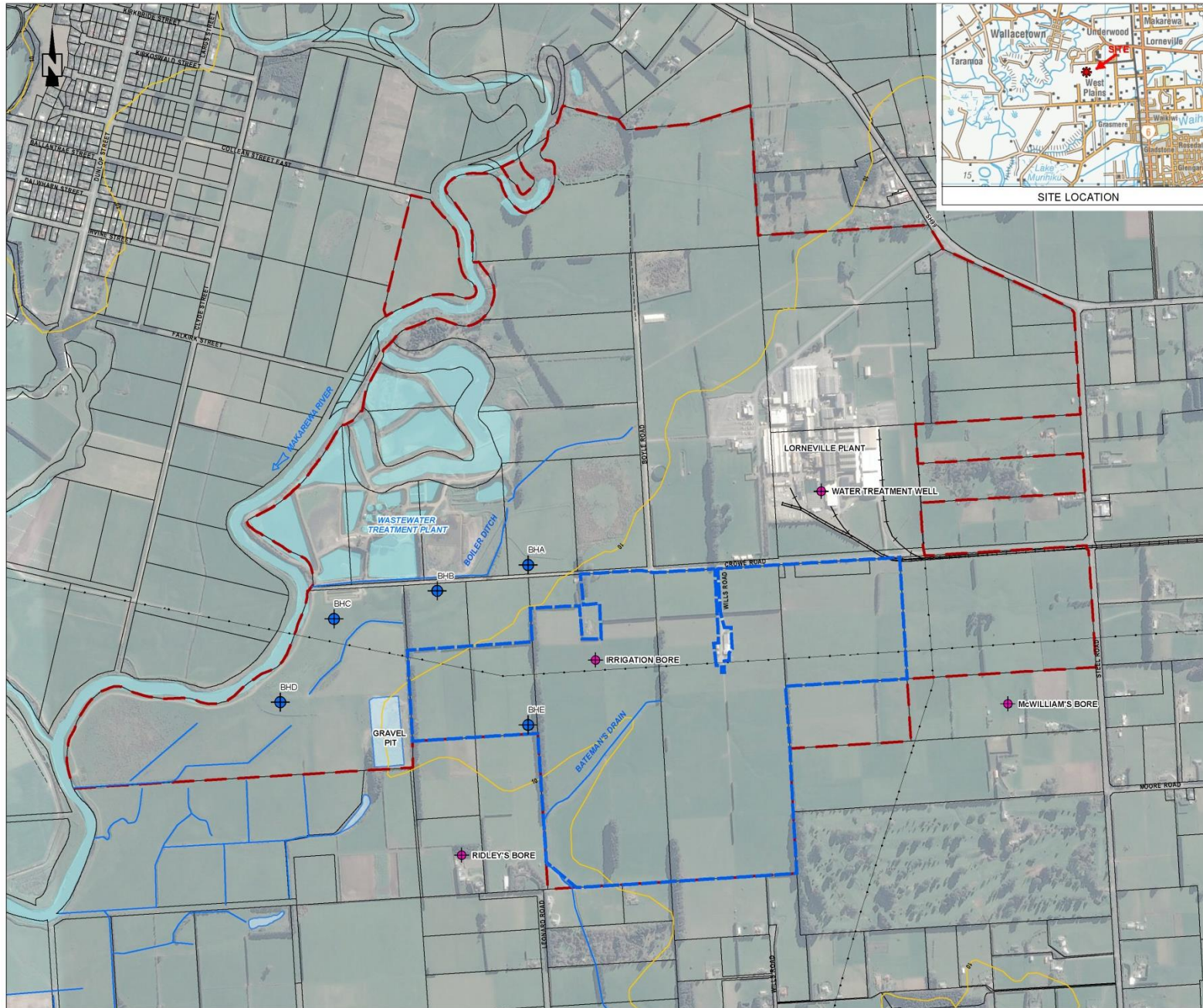
**USES OF BORES WITHIN  
3KM OF ALLIANCE GROUP  
LIMITED LORNEVILLE PLANT**

**PATTLE DELAMORE PARTNERS LTD**  
Auckland Tauranga Wellington Christchurch

**SCALE : 1:20,000 (A3)**

PROJECT NO. : <b>A01856210</b>	FIGURE NO. : <b>1B</b>	REVISION : <b>A</b>
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- KEY :**
- EXISTING WASTEWATER IRRIGATION AREA
  - SITE BOUNDARY
  - ADDITIONAL MONITORING BORES
  - EXISTING GROUNDWATER MONITORING BORE MONITORED BY ALLIANCE LORVILLE (APPROX. LOCATION)

**NOTES AND SOURCE:**  
 1. GROUNDWATER MONITORING BORE LOCATIONS ARE APPROXIMATE ONLY, DERIVED FROM DRAM REPORT ASSESSMENT OF EFFECTS - IRRIGATION OF WASTEWATER TO LAND (RD MAY 2008) FIGURE 5.7 LOCATION OF BORES ON DEVELOPING PROPERTIES  
 2. URBAN AERIAL IMAGES (FLOW FEB 2011) SUPPLIED BY INVERCARGILL CITY COUNCIL  
 3. CADASTRAL INFORMATION SUPPLIED BY LINZ 23/11/13

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NO.	REVISION	DATE	APP.

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**CLIENT :**

**PROJECT :**

**LORVILLE PLANT  
GROUNDWATER  
SITE INVESTIGATION**

**TITLE :**

**ADDITIONAL GROUNDWATER  
MONITORING BORES &  
EXISTING MONITORING BORES**

**PATTLE DELAMORE PARTNERS LTD**  
 Auckland Tauranga Wellington Christchurch

**SCALE : 1:12,500 (A3)**

PROJECT NO. : <b>A01856210</b>	FIGURE NO. : <b>2</b>	REVISION : <b>A</b>
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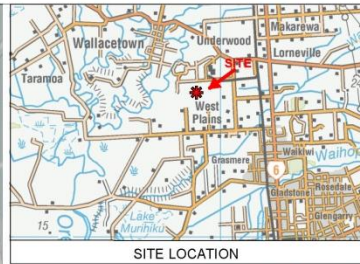
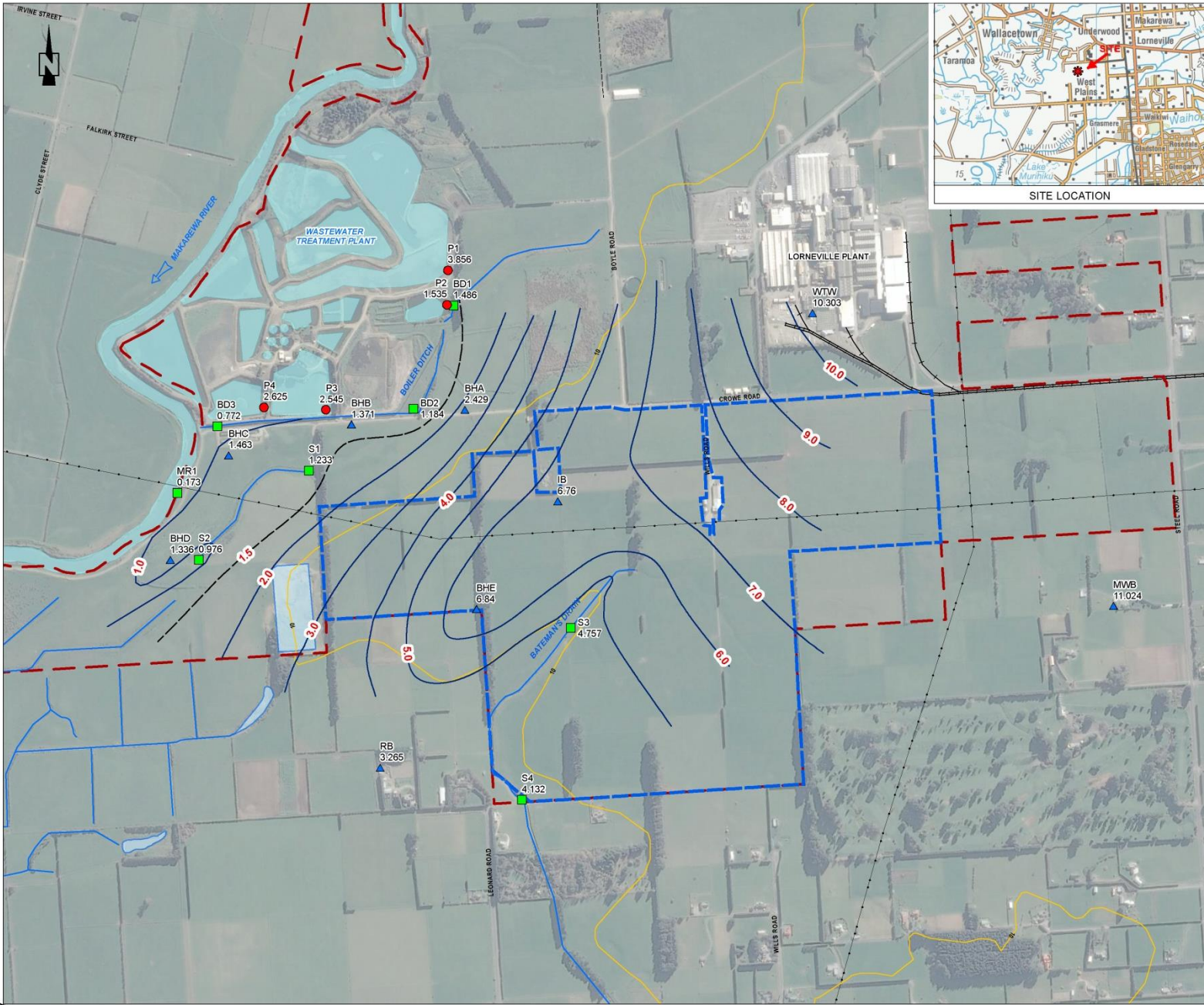


**Figure 3a: Surveying the rim of the metal casing of BHD.**



**Figure 3b: Surveying the metal waratah measuring point at site S1.**





- KEY :**
- EXISTING WASTEWATER IRRIGATION AREA
  - SITE BOUNDARY
  - ▲ GROUNDWATER - BORE (SITE ID WATER LEVEL (masl))
  - SURFACE WATER SITE
  - WASTE WATER SITE
  - GROUNDWATER AND SURFACE WATER LEVEL (masl)

**NOTES AND SOURCE:**  
 1. GROUNDWATER BORE LOCATIONS ARE APPROXIMATE ONLY, DERIVED FROM SIM REPORT ASSESSMENT OF EFFECTS - BRIGATION OF WASTEWATER TO LAND (FD MAY 2000 FIGURE 5.7) LOCATION OF BORES ON NEIGHBOURING PROPERTIES  
 2. URBAN AERIAL IMAGES (FLOWN FEB 2011) SUPPLIED BY INVERCARGILL CITY COUNCIL  
 3. CADASTRAL INFORMATION SUPPLIED BY LINZ (2011/12)

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**CLIENT :**

**PROJECT :**

**LORVEVILLE PLANT  
GROUNDWATER  
SITE INVESTIGATION**

**TITLE :**

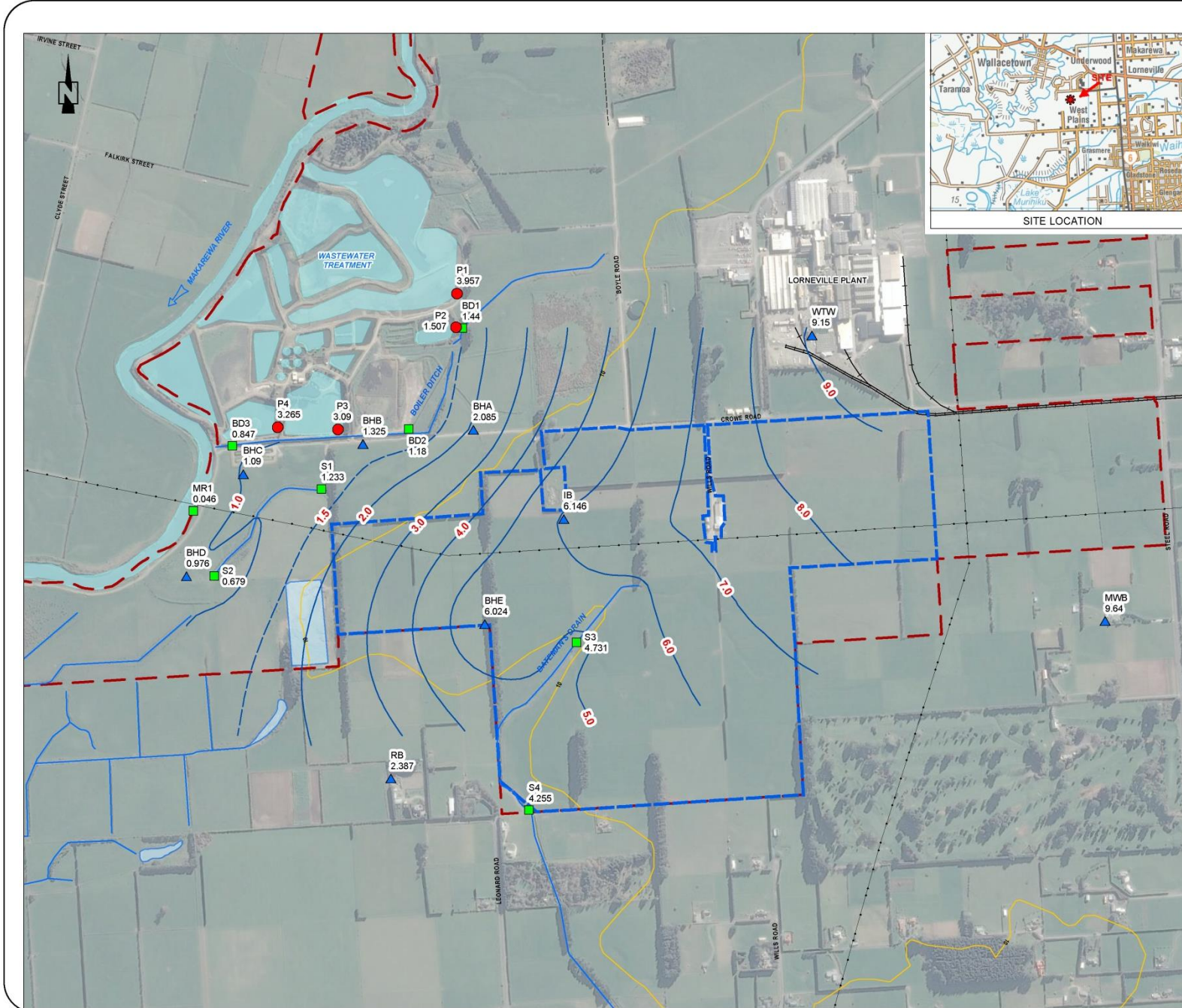
**WATER LEVELS FROM  
PIEZOMETRIC SURVEY ON 9  
DECEMBER 2014**

**PATTLE DELAMORE PARTNERS LTD**  
 Auckland Tauranga Wellington Christchurch



PROJECT NO. : <b>A01856210</b>	FIGURE NO. : <b>4A</b>	REVISION : <b>A</b>
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- KEY :**
- EXISTING WASTEWATER IRRIGATION AREA
  - SITE BOUNDARY
  - ▲ GROUNDWATER - BORE (SITE ID WATER LEVEL (m)ASPD)
  - SURFACE WATER SITE
  - WASTE WATER SITE
  - GROUNDWATER AND SURFACE WATER LEVEL

**NOTES AND SOURCE:**

1. GW MONITORING BORE LOCATIONS ARE APPROXIMATE ONLY, DERIVED FROM SWAMPFOOT ASSESSMENT OF EFFECTS: IRRIGATION OF WASTEWATER TO LAND (PD MAY 2000) FIGURE 5.7 LOCATION OF BORES ON NEIGHBOURING PROPERTIES;
2. URBAN AERIAL IMAGES (FLOWN FEB 2011) SUPPLIED BY INVERCARGILL CITY COUNCIL;
3. GEOLOGICAL INFORMATION SUPPLIED BY LINZ (2011/15).

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**CLIENT :**

**PROJECT :**

**LORNEVILLE PLANT  
GROUNDWATER  
SITE INVESTIGATION**

**TITLE :**

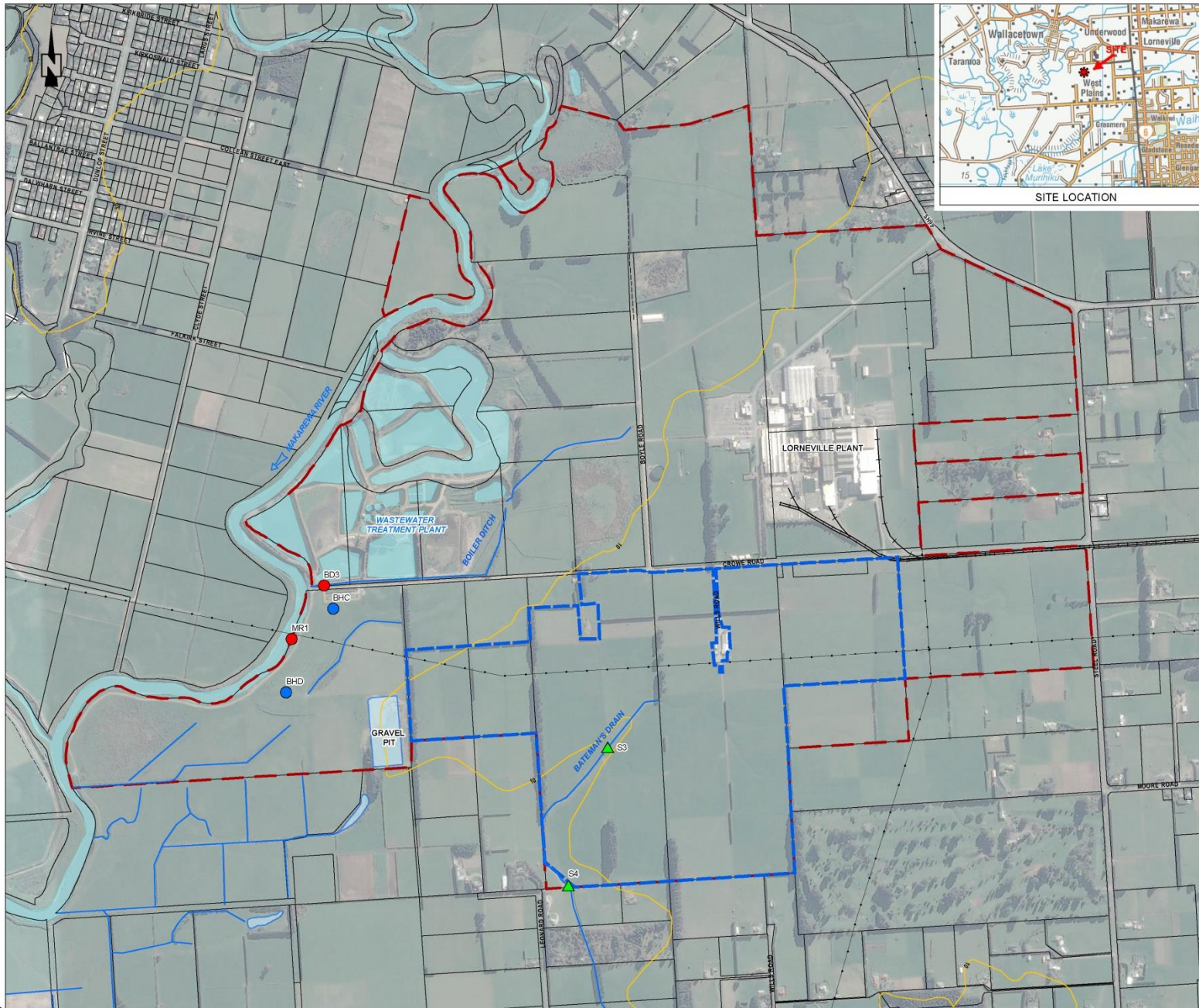
**WATER LEVELS FROM  
PIEZOMETRIC SURVEY ON  
19 MARCH 2015**

**PATTLE DELAMORE PARTNERS LTD**  
Auckland Tauranga Wellington Christchurch

**SCALE : 1:10,000 (A3)**

PROJECT NO. : <b>A01856210</b>	FIGURE NO. : <b>4B</b>	REVISION : <b>A</b>
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- KEY :**
- EXISTING WASTEWATER IRRIGATION AREA
  - SITE BOUNDARY
  - FLOW GAUGING SITES
  - WATER LEVEL MONITORING SITES**
  - BORE (GROUNDWATER)
  - SURFACE WATER

**NOTES AND SOURCE:**  
 1. GW MONITORING BORE LOCATIONS ARE APPROXIMATE ONLY, DERIVED FROM SNW REPORT ASSESSMENT OF EFFECTS - IRRIGATION OF WASTEWATER TO LAND (RD MAY 2009) FIGURE 5.7. LOCATION OF BORES ON NEIGHBOURING PROPERTIES.  
 2. URBAN AERIAL IMAGES (FLOW FEB 2011) SUPPLIED BY INVERCARGILL CITY COUNCIL.  
 3. CADASTRAL INFORMATION SUPPLIED BY LINZ (2011/11).

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A	ISSUED FOR REVIEW	JAN 15	
NO.	REVISION	DATE	APP.
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**CLIENT :**

**PROJECT :**  
**LORNEVILLE PLANT  
 GROUNDWATER  
 SITE INVESTIGATION**

**TITLE :**  
**WATER LEVEL MONITORING  
 SITES FOR ASSESSMENT OF  
 TIDAL FLUCTUATIONS AND  
 FLOW GAUGING SITES**

**PATTE DELAMORE PARTNERS LTD**  
 Auckland Tauranga Wellington Christchurch

**SCALE :** 1:12,500 (A3)

**PROJECT NO. :** A01856210    **FIGURE NO. :** 5    **REVISION :** A



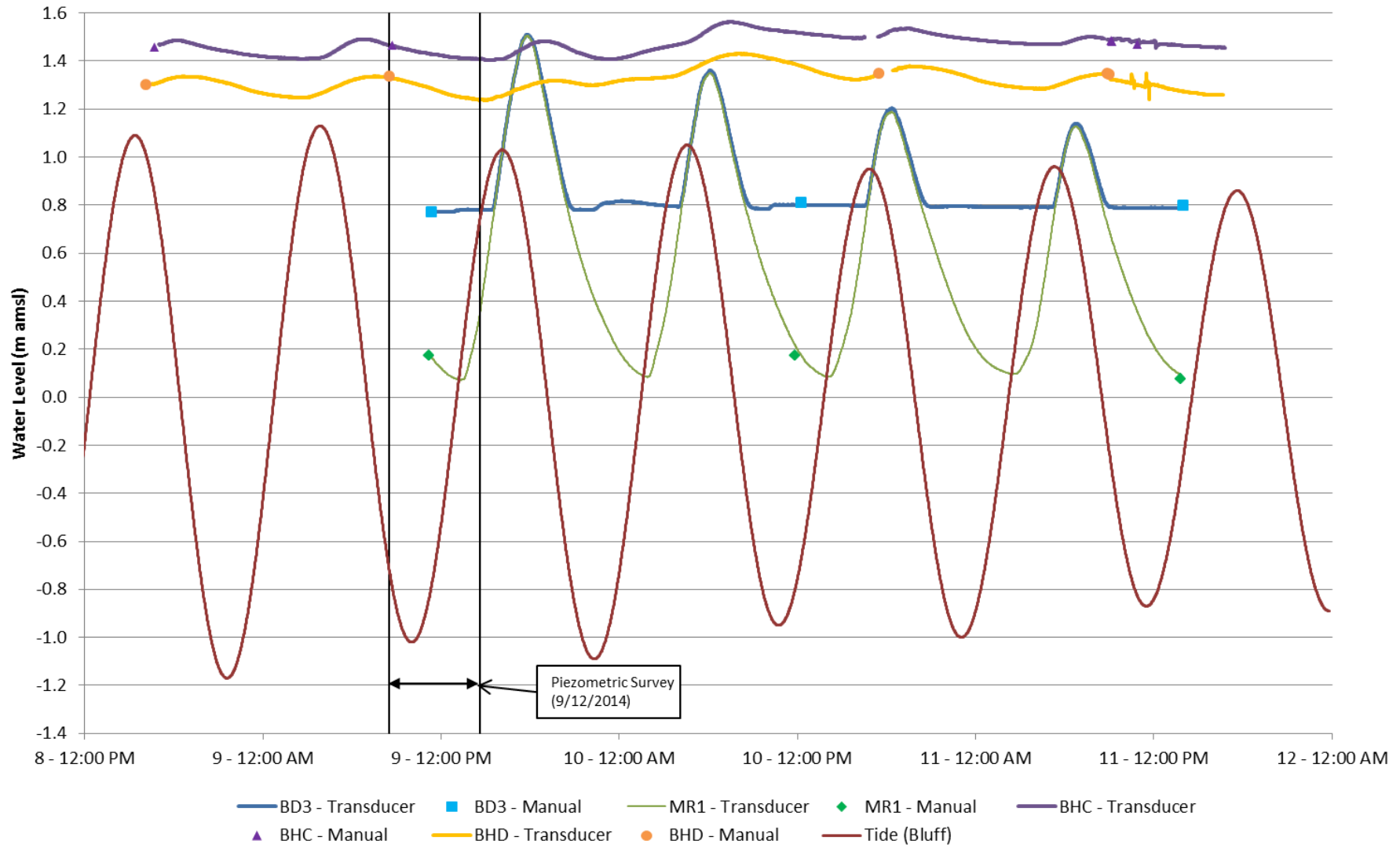


**Figure 6a: Water level measuring point at site MR1 in the Makarewa River.**



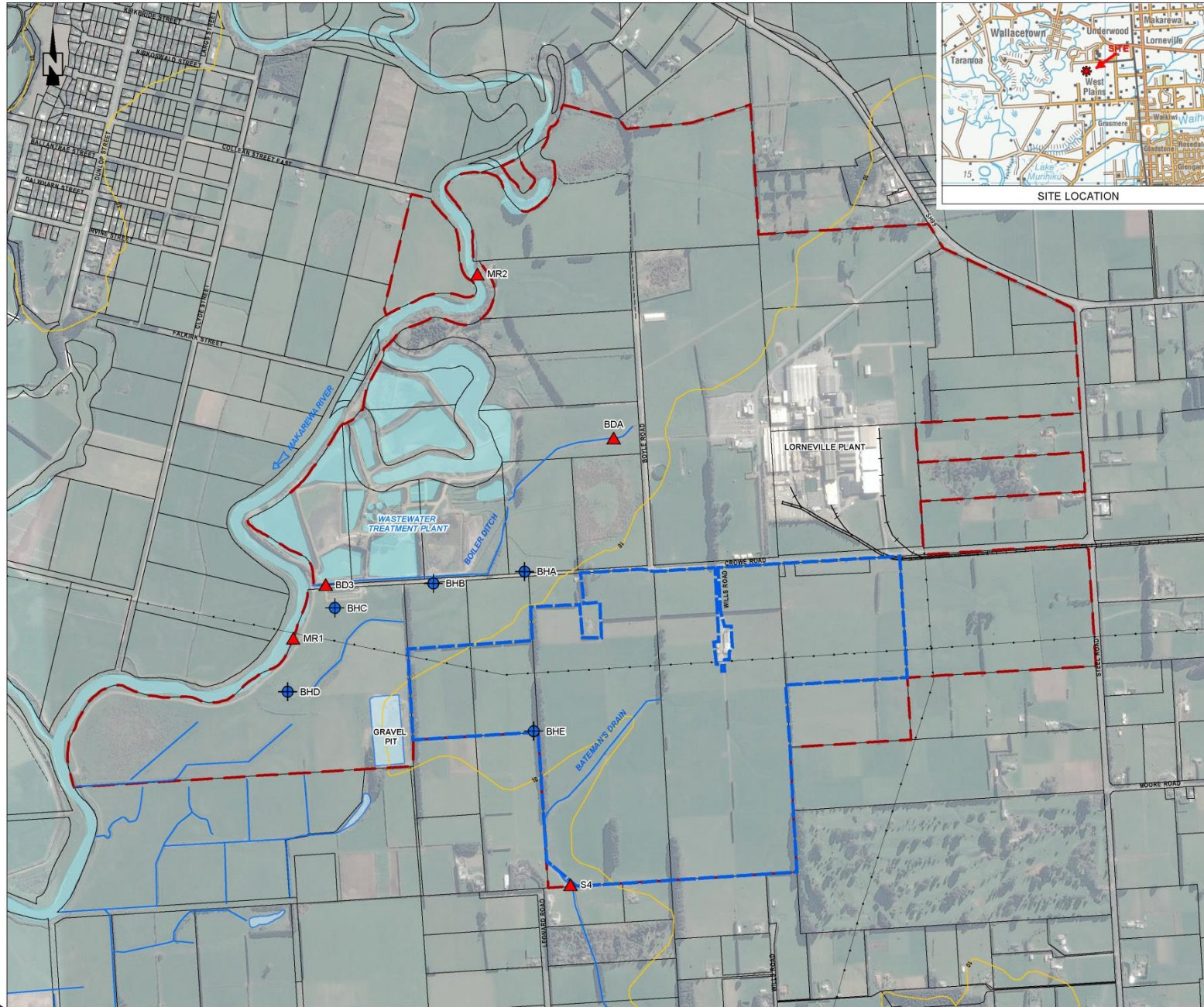
**Figure 6b: Water level measuring point at site BD3 in the Boiler Ditch.**

### December 2014



**Figure 7: Water levels at monitoring sites MR1 (Makarewa River), BD3 (Boiler Drain), bores BHC and BHD and tidal fluctuations.**





**KEY :**

- EXISTING WASTEWATER IRRIGATION AREA
- SITE BOUNDARY

**SAMPLING SITES**

- BORE (GROUNDWATER)
- ▲ SURFACE WATER

NOTES AND SOURCE:  
 1. GROUNDWATER BORE LOCATIONS ARE APPROXIMATE ONLY. DERIVED FROM  
 2. RISK REPORT ASSESSMENT OF EFFECTS - IRRIGATION OF WASTEWATER TO LAND 3RD  
 3. MAY 2000 FIGURE 57 LOCATION OF BORES ON NEIGHBOURING PROPERTIES  
 4. 2010 AERIAL IMAGES FROM FEB 2011 (SUPPLIED BY RIVERGULL CITY COUNCIL)  
 5. CADASTRAL INFORMATION SUPPLIED BY LINZ 29/11/13

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**CLIENT :**



**PROJECT :**

**LORNEVILLE PLANT  
GROUNDWATER  
SITE INVESTIGATION**


**TITLE :**

**GROUNDWATER AND  
SURFACE WATER QUALITY  
MONITORING SITES**

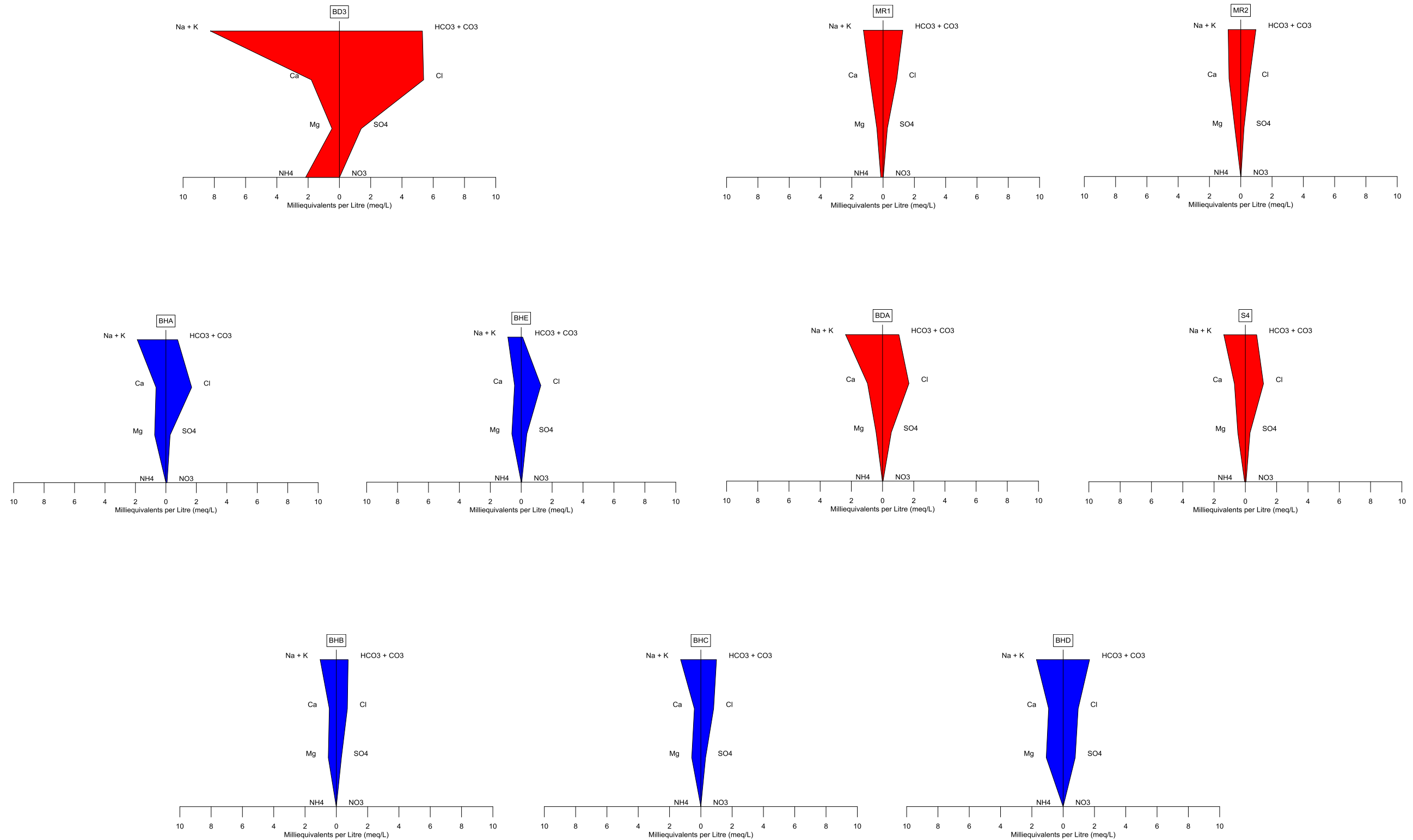


**PATTLE DELAMORE PARTNERS LTD**  
 Auckland Tauranga Wellington Christchurch

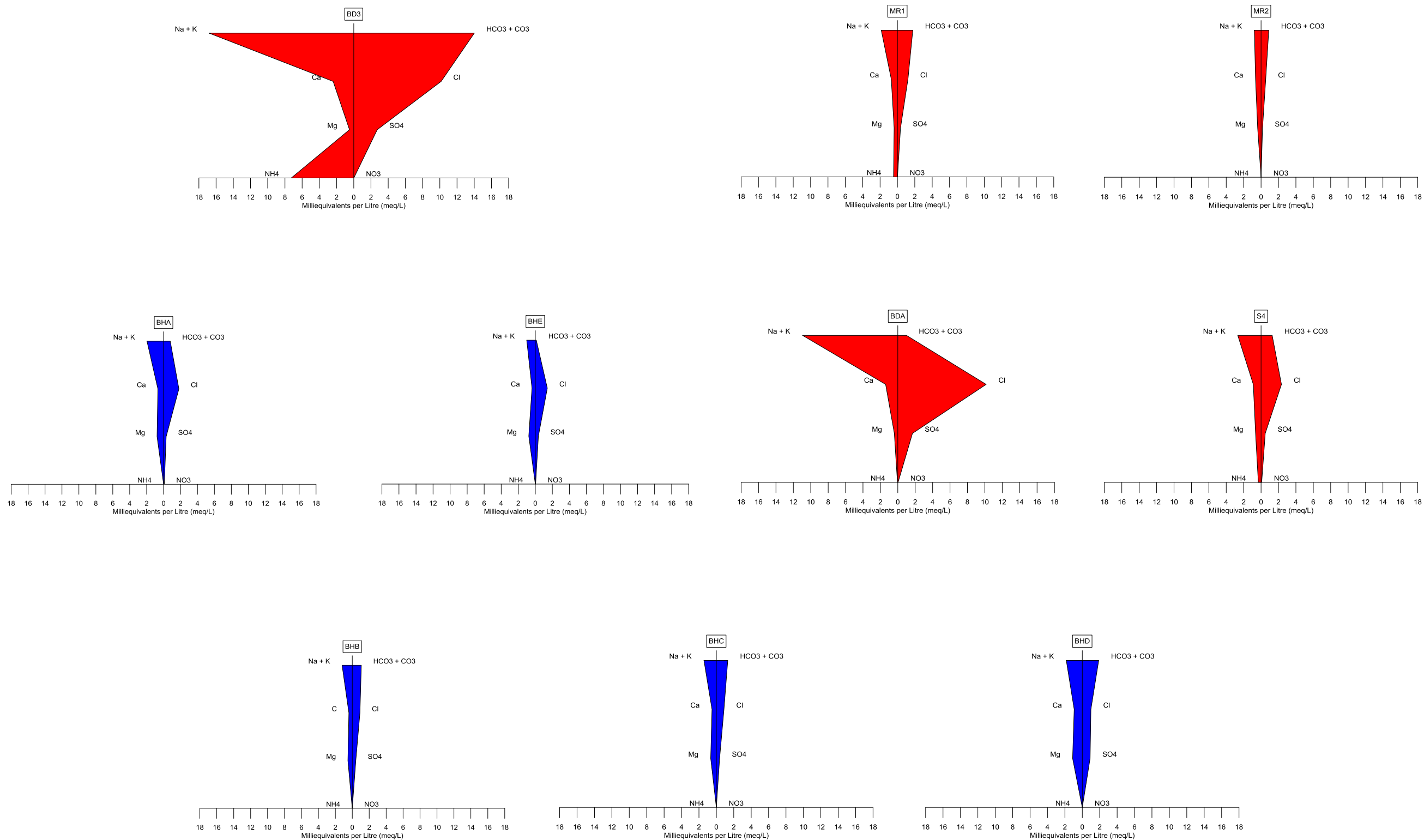
**SCALE :** 1:12,500 (A3)



PROJECT NO. :	FIGURE NO. :	REVISION :
A01856210	8	A

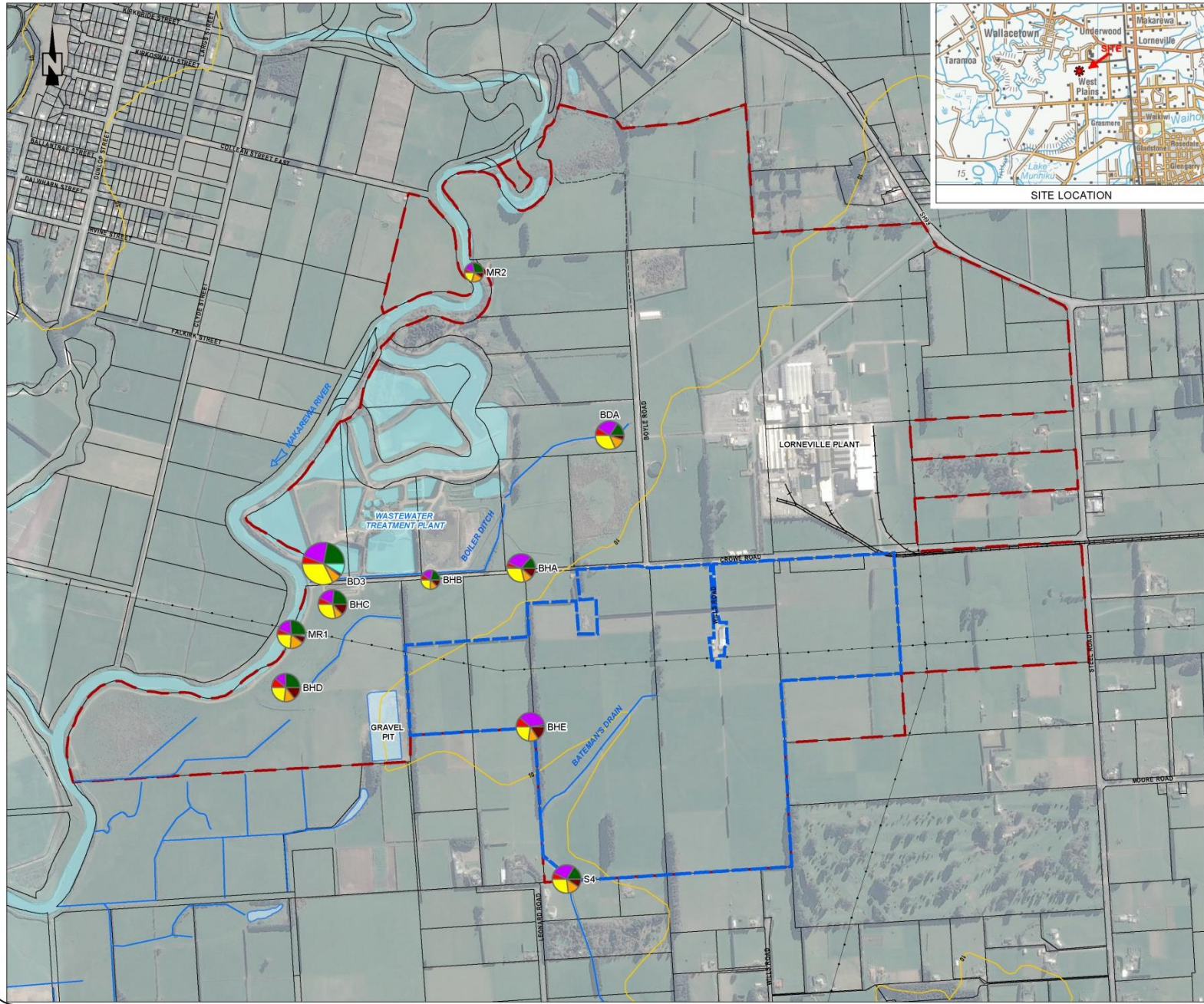


**Figure: 9a: Stiff plots of major cation and anion data from water samples collected on 10 December 2014. Groundwater samples from bores indicated by blue stiff plots and surface water samples indicated by red stiff plots.**



**Figure: 9b: Stiff plots of major cation and anion data from water samples collected on 18 March 2015. Groundwater samples from bores indicated by blue stiff plots and surface water samples indicated by red stiff plots.**





**KEY :**  
 EXISTING WASTEWATER IRRIGATION AREA  
 SITE BOUNDARY

**LABORATORY**

CONDUCTIVITY (mS/m)	MAJOR ANIONS AND CATIONS
0 - 20	HCO3 + CO3
21 - 50	Cl
50 - 100	SO4
> 100	NO3
	Na + K
	Ca
	Mg
	NH4 - N

NOTES AND SOURCE  
 1. SW MONITORING BORE LOCATIONS ARE APPROXIMATE ONLY, DERIVED FROM SWM REPORT ASSESSMENT OF EFFECTS - IRRIGATION OF WASTEWATER TO LAND (RD 184) 2007 (SHEETS 1) LOCATION OF BORES ON THE OTHER SIDE PROPERTIES;  
 2. URBAN AERIAL IMAGES (FL OWN FEB 2011) SUPPLIED BY INVERCARGILL CITY COUNCIL;  
 3. CADASTRAL INFORMATION SUPPLIED BY LINZ (2011/13).

A	ISSUED FOR REVIEW	JAN 15	
NO.	REVISION	DATE	APP.
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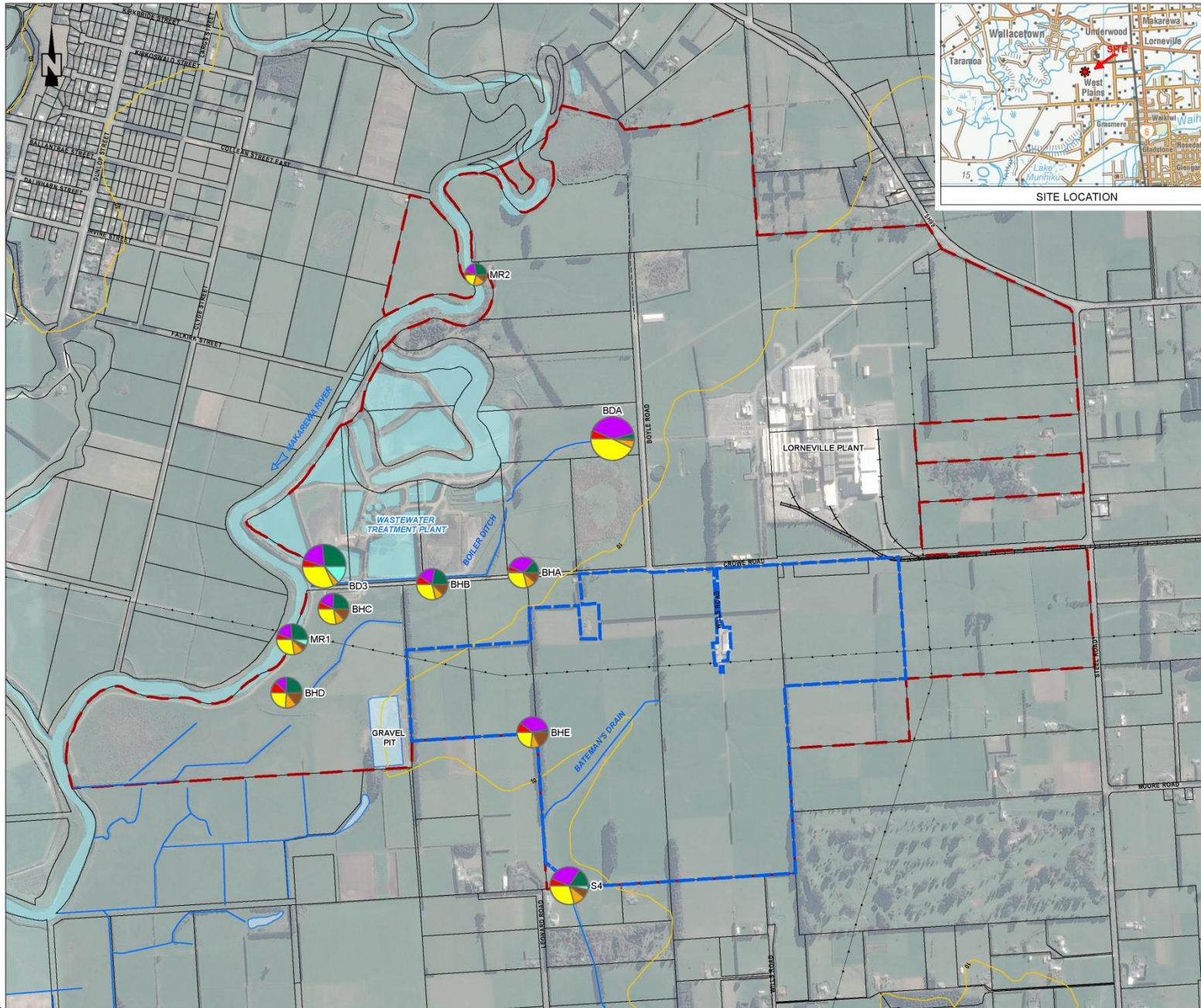
**CLIENT :**  
  
**PROJECT :**  
 LORNEVILLE PLANT  
 GROUNDWATER  
 SITE INVESTIGATION  
**TITLE :**  
 DISTRIBUTION OF MAJOR  
 ANIONS AND CATIONS  
 FROM 9 DECEMBER 2014  
 SAMPLING

solutions for your environment  
 PATTLE DELAMORE PARTNERS LTD  
 Auckland Tauranga Wellington Christchurch

**SCALE :** 1:12,500 (A3)

PROJECT NO. : A01856210	FIGURE NO. : 10A	REVISION : A
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**KEY :**

- EXISTING WASTEWATER IRRIGATION AREA
- SITE BOUNDARY

**LABORATORY**

<b>CONDUCTIVITY (mS/m)</b>	<b>MAJOR ANIONS AND CATIONS</b>
0 - 20	HCO <sub>3</sub> + CO <sub>3</sub>
21 - 50	Cl
50 - 100	SO <sub>4</sub>
> 100	NO <sub>3</sub>
	Na + K
	Ca
	Mg
	NH <sub>4</sub> - N

NOTES AND SOURCE:  
 1. OUR MONITORING BORE LOCATIONS ARE APPROXIMATE ONLY. DERIVED FROM SWM REPORT ASSESSMENT OF EFFECTS - IRRIGATION OF WASTEWATER TO LAND 3RD MAY 2000 (FIGURE 5.7 LOCATION OF BORES ON THE ADJACENT PROPERTIES);  
 2. FROM AERIAL IMAGES (LOW RES 2011) SUPPLIED BY WAIKAREINI CITY COUNCIL;  
 3. CADASTRAL INFORMATION SUPPLIED BY LINZ 28/1/13.

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NO.	REVISION	DATE	APP.
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**CLIENT :**

**PROJECT :**

**LORNEVILLE PLANT  
GROUNDWATER  
SITE INVESTIGATION**

**TITLE :**

**DISTRIBUTION OF MAJOR  
ANIONS AND CATIONS  
FROM 18 MARCH 2015  
SAMPLING**

**PATTLE DELAMORE PARTNERS LTD**  
 Auckland Tauranga Wellington Christchurch

**SCALE : 1:12,500 (A3)**

PROJECT NO. : <b>A01856210</b>	FIGURE NO. : <b>10B</b>	REVISION : <b>A</b>
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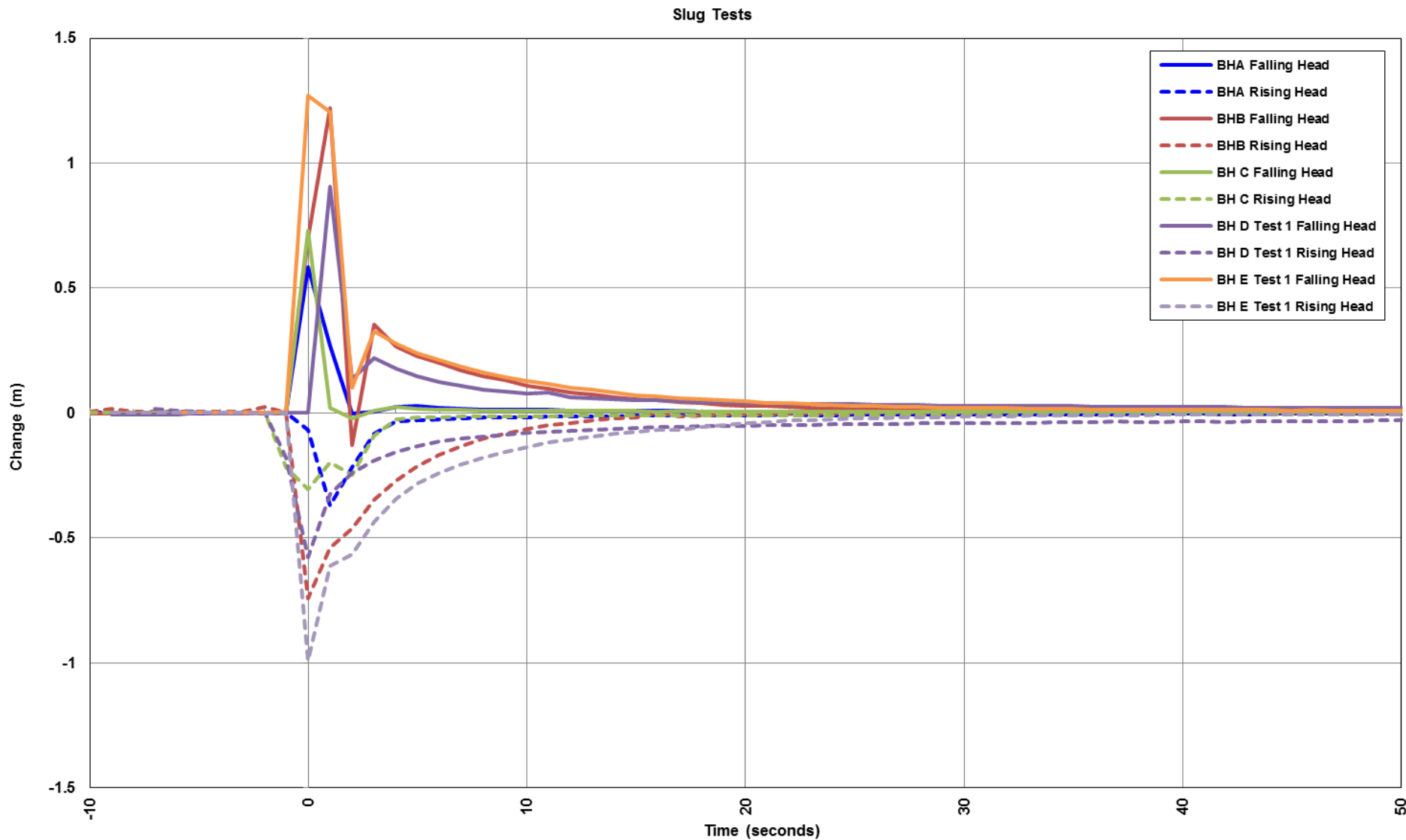


Figure 11: Slug test results

## Appendix B

Borelogs

CLIENT: Alliance Group Ltd LOCATION: Lorneville, Southland

START DATE: 4/11/2014 END DATE: 4/11/2014 COORDINATES: E1238660 N4856242 TOTAL DEPTH: 7.32 m LOGGED BY: RN(PDP) SHEET 1 OF 1

GROUND LEVEL: TOP OF CASING: 0.755 m above ground level

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT; dark brown. Soft, moist, slightly plastic, roots and organics present (TOP SOIL).		0.0	0				Concrete Toby box
	Silty CLAY; bluish brown. Soft, wet, highly plastic. Some lenses of dark brown slightly plastic silt near top of layer; orange mottling.		1.0	-1				Bentonite uPVC Casing
	CLAY with some sand; blue. Soft, wet, highly plastic.							
	Silty SAND; blue. Loosely packed, wet; sand, medium with some coarse sand grains.		2.0	-2		5/11/14 @ 9:55am		
	Sandy medium to coarse GRAVEL with some silt; Blue. Loosely packed, wet, well graded, sub rounded, slightly weathered sandstone and granitic gravel; sand, medium to coarse.		3.0	-3				uPVC Screen (0.5 mm slots) Geo Sock over screened uPVC
	Sandy fine to coarse GRAVEL with some silt and clay; brownish orange. Tightly packed, dry (top 1.0 m wet), well graded, moderately to highly weathered sandstone gravels with some extremely weathered clasts; sand, fine to coarse; silt and clay; firm to stiff, slightly plastic.		4.0	-4				
	Lense of fine sand between 5.5 m and 6.0 m		5.0	-5				Filter Pack (Walton Park Sand 7:14)
	SILT; Bluish grey. Firm, dry; some slightly weathered fine gravel and coarse sand at top of layer (0.1m thick).		6.0	-6				End Cap
			7.0	-7				

END OF BOREHOLE at 7.32 m bgl

Notes: Coordinates are in NZTM

- KEY**
- Groundwater Level
  - Water Gain
  - Water Loss
  - Grab sample

Drilled By: McNeill Drilling  
Diameter: 3 inch (Piezo 50 mm)  
Method: Sonic Samp  
Datum:  
Filename: A01856210BH-A

**LOG OF BOREHOLE**  
**Alliance Group - Lorneville**

HOLE NO. **BH-B**  
JOB NO: A01856210

CLIENT: Alliance Group Ltd LOCATION: Lorneville, Southland

START DATE: 4/11/2014 END DATE: 4/11/2014 COORDINATES: E1238365 N4856204 TOTAL DEPTH: 8.4 m LOGGED BY: RN(PDP) SHEET 1 OF 1

GROUND LEVEL: TOP OF CASING: 0.725 m above ground level

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT; dark brown. Soft, moist, organics and roots (TOP SOIL).		0.0	0				Concrete Toby box
	Clayey SILT with some sand; brownish grey. Firm, moist, slightly plastic, brown mottling; sand, fine to medium.							Bentonite
	Fine SAND with some silt; dark greyish brown. Loosely packed, wet, well graded, slightly weathered.		1.0	-1				uPVC Casing
	Gravelly medium to coarse SAND with minor clayey silt; dark greyish brown. Loosely packed, wet, uniformly graded; gravel, medium to coarse, uniformly graded, subangular; clay and silt, slightly plastic, lenses of clay up to 0.1 m thick.		2.0	-2				
	Gravelly SILT with some clay; dark bluish grey. Stiff, dry, slightly plastic; gravels, fine to coarse, subrounded to subangular, highly weathered sandstone and quartz gravels.		3.0	-3				uPVC Screen (0.5 mm slots) Geo Sock over screened uPVC
	Medium to coarse GRAVEL with some clayey silt and minor cobbles; dark bluish grey. Loosely packed, wet, subrounded, uniformly graded, moderately weathered sandstone gravels; silt and clay, stiff, brownish orange mottle between 3.2 m and 3.6 m.		4.0	-4				
	Clayey silt content increases towards base of layer.		5.0	-5				
	Medium SAND with some silt; greyish brown. Loosely packed, saturated, homogeneous; brown and orange mottle towards base of layer.		6.0	-6				Filter Pack (Walton Park Sand 7:14)
	Gravelly SILT; dark grey. Stiff, moist, slightly plastic; gravel, fine to coarse, subangular, moderately weathered sandstone clasts; gravel content increases towards base of borehole.		7.0	-7				
			8.0	-8				End Cap

5/11/14 @ 10:02am

END OF BOREHOLE at 8.4 m bgl

Notes: Coordinates are in NZTM

- KEY**
- Groundwater Level
  - Water Gain
  - Water Loss
  - Grab sample

Drilled By: McNeill Drilling  
Diameter: 3 inch (Piezo 50 mm)  
Method: Sonic Samp  
Datum:  
Filename: A01856210BH-B

CLIENT: Alliance Group Ltd LOCATION: Lorneville, Southland

START DATE: 5/11/2014 END DATE: 5/11/2014 COORDINATES: E1238046 N4856124 TOTAL DEPTH: 5.8 m LOGGED BY: RN(PDP) SHEET 1 OF 1

GROUND LEVEL: TOP OF CASING: 0.530 m above ground level

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT; grayish brown. Soft, moist, organics and roots, orange mottle (TOP SOIL).		0.0	0				Concrete Toby box
	Clayey SILT; brown. Soft, wet, highly plastic; some extremely weathered residual gravel clasts.							Bentonite
	SILT with some clay; grey. Soft, wet, slightly plastic, orange mottling.		1.0	-1				uPVC Casing
	Silty medium SAND; grey. Loosely packed, wet, poorly graded, slightly weathered; some coarse sand and fine to medium gravel at base of layer.		2.0	-2				
	Sandy fine to coarse GRAVEL with minor silt; brown. Loosely packed, saturated, subrounded to sub angular, moderately weathered quartz and sandstone gravel; sand, fine to medium, dark gray sand lenses up to 0.1 m thick; iron staining on gravel clasts.		3.0	-3				uPVC Screen (0.5 mm slots) Geo Sock over screened uPVC
	Sandy fine to coarse GRAVEL with minor silt; brownish grey. Loosely packed, saturated, subrounded to sub angular moderately weathered quartz and sandstone gravel; sand, fine to medium.		4.0	-4				Filter Pack (Walton Park Sand 7:14)
	Silty fine to coarse GRAVEL with some clay; brownish orange. Loosely packed, wet, well graded, moderately to highly weathered sandstone and mudstone; silt and clay, slightly plastic.		5.0	-5				
	SILT with some gravel and sand; grey. Firm, slightly plastic, moist; gravel, fine to medium; sand, coarse.		6.0	-6				End Cap
	SILT with minor clay; dark brownish purple. Stiff, moist, highly plastic, organics.							

5/11/2014  
(Estimate from Driller)

END OF BOREHOLE at 5.8 m bgl

Notes: Coordinates are in NZTM

**KEY**

- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: McNeill Drilling  
Diameter: 3 inch (Piezo 50 mm)  
Method: Sonic Samp  
Datum:  
Filename: A01856210BH-C

**LOG OF BOREHOLE**  
**Alliance Group - Lorneville**

HOLE NO. **BH-D**  
JOB NO: A01856210

CLIENT: Alliance Group Ltd LOCATION: Lorneville, Southland

START DATE: 5/11/2014 COORDINATES: E1237894 N4855853 TOTAL DEPTH: 5.76 m LOGGED BY: RN(PDP) SHEET 1 OF 1  
END DATE: 5/11/2014

GROUND LEVEL: TOP OF CASING: 0.410 m above ground level		GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)							
	SILT; brown. Moist, soft, slightly plastic; roots and organics (TOP SOIL).		0.0	0				Concrete Toby box
	Clayey SILT; greyish brown. Firm, moist, slightly plastic; orange mottle.		1.0	-1				Bentonite
	SILT; dark brown. Soft, wet, organics.							uPVC Casing
	Clayey SILT; grey. Soft, wet, highly plastic; some nodules of brown clayey silt.		2.0	-2				
	Silty fine to medium SAND; Loosely packed, saturated, poorly graded; quartz grains.							
	Sandy fine to coarse GRAVEL with some silt and cobbles; grey. Loosely packed, saturated, well graded, subrounded to subangular, slightly weathered gravel; sand, fine to medium.		3.0	-3				uPVC Screen (0.5 mm slots) Geo Sock over screened uPVC
	Silty fine to coarse GRAVEL; greyish brown with some sand. Tightly packed, dry, subrounded to subangular, moderately weathered gravels; sand fine; iron staining on gravel clasts, gravels moist near bottom of hole.		4.0	-4				Filter Pack (Walton Park Sand 7:14)
			5.0	-5				End Cap

5/11/2014  
(Estimate from Driller)

END OF BOREHOLE at 5.76 m bgl

Notes: Coordinates are in NZTM

<b>KEY</b>	Drilled By: McNeill Drilling
Groundwater Level	Diameter: 3 inch (Piezo 50 mm)
Water Gain	Method: Sonic Samp
Water Loss	Datum:
Grab sample	Filename: A01856210BH-D



**LOG OF BOREHOLE**  
**Alliance Group - Lorneville**

HOLE NO. **BH-E**  
JOB NO: A01856210

CLIENT: Alliance Group Ltd LOCATION: Lorneville, Southland

START DATE: 4/11/2014 COORDINATES: E1238690 N4855725 TOTAL DEPTH: 7.12 m LOGGED BY: RN(PDP) SHEET 1 OF 1  
END DATE: 4/11/2014

GROUND LEVEL:  
TOP OF CASING: 0.933 m above ground level

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
	SILT; dark brown. Soft, moist, roots and organics present (TOP SOIL).		0.0	0				Concrete Toby box
	SILT with some clay; brown. Soft, moist, slightly plastic; orange mottle, some extremely weathered residual gravel clasts near base of layer.		1.0	-1				Bentonite uPVC Casing
	Silty medium SAND; grey. Loosely packed, wet, poorly graded; orange sand lense approximately 0.2 m thick.		2.0	-2				
	SILT with some sand; light grey. Soft, moist; sand, fine.		3.0	-3				
	Silty medium SAND; brownish grey. Loosely packed, saturated, moderately weathered.		4.0	-4				
	Fine to medium GRAVEL with some clayey silt and sand; brownish orange. Loosely packed, saturated, subrounded, uniformly graded moderately weathered gravel; some coarse gravel clasts, some well graded medium sand lenses.		5.0	-5				uPVC Screen (0.5 mm slots) Geo Sock over screened uPVC
	Silty medium to coarse GRAVEL with some sand; brownish grey. Tightly packed, dry, subangular, well graded, moderately weathered gravel; silt, slightly plastic; sand, medium to coarse; some minor clay from extremely weathered residual gravel clasts		6.0	-6				Filter Pack (Walton Park Sand 7:14)
	Medium to coarse GRAVEL with some sand; brownish orange. Loosely packed, moist, subangular clasts, well graded, moderately to highly weathered gravel; sand, medium to coarse.		7.0	-7				End Cap
	SILT; greyish brown. Stiff, dry, slightly plastic; orange mottling and banding; gray silt nodules with organics, some extremely weathered residual gravel clasts.							

5/11/14 @ 11:18 am

END OF BOREHOLE at 7.12 m bgl

Notes: Coordinates are in NZTM

- KEY**
- Groundwater Level
  - Water Gain
  - Water Loss
  - Grab sample

Drilled By: McNeill Drilling  
Diameter: 3 inch (Piezo 50 mm)  
Method: Sonic Samp  
Datum:  
Filename: A01856210BH-E

## Appendix C

### Piezometric Survey Details

**Table C1: Water levels and details of water level monitoring sites used during the piezometric survey on 9 December 2014**

Site ID	Name	Type	Time of Measurement	DTW (m bMP)	MP Elevation (m amsl)	Water Level Elevation (m amsl)	Bore MP (m agl)	Bore Depth (m bMP)	Bore Depth (m bgl)	NZTMX	NZTMY	Site Description	MP Description
BHA	BHA	Groundwater - Bore	8:59	2.151	4.580	2.429	0.738	8.058	7.320	1238660	4856242	Monitoring bore	Inside edge of metal well cap
BHB	BHB	Groundwater - Bore	10:20	1.969	3.340	1.371	0.707	9.120	8.413	1238365	4856204	Monitoring bore	Inside edge of metal well cap
BHC	BHC	Groundwater - Bore	8:44	1.817	3.280	1.463	0.52	6.363	5.843	1238046	4856124	Monitoring bore	Inside edge of metal well cap
BHD	BHD	Groundwater - Bore	8:31	1.274	2.610	1.336	0.394	6.170	5.776	1237894	4855853	Monitoring bore	Inside edge of metal well cap
BHE	BHE	Groundwater - Bore	10:30	2.94	9.780	6.840	0.905	8.023	7.118	1238690	4855725	Monitoring bore	Inside edge of metal well cap
IB	Irrigation Bore	Groundwater - Bore	10:56	3.15	9.910	6.760	0.300	10.200	9.900	1238901	4856005	Ex-irrigation bore owned by Alliance Lorneville	Edge of metal casing
RB	Ridley Bore	Groundwater - Bore	14:23	4.555	7.820	3.265	0.463	12.463	12.000	1238440	4855313	Private bore used for stock water supply	Lowest point on metal casing
MWB	McWilliam Bore	Groundwater - Bore	14:37	3.486	14.510	11.024	0.353	14.853	14.500	1240346	4855733	Private bore used for stock water supply	Edge of metal casing
WTW	Water Treatment Well	Groundwater - Well	12:06	3.717	14.020	10.303	0.486	6.000	5.514	1239563	4856494	Alliance Lorneville bore at factory water treatment site	Lowest point on metal casing
MR1	MR1	Surface Water Site	11:10	0.457	0.630	0.173	-	-	-	1237912	4856026	Makarewa River - below Boiler Drain outlet	Top of metal waratah
S1	S1	Surface Water Site	8:51	0.477	1.710	1.233	-	-	-	1238254	4856084	Unnamed drainage ditch near farm track	Top of metal waratah
S2	S2	Surface Water Site	8:37	0.484	1.460	0.976	-	-	-	1237968	4855853	Unnamed drainage ditch near BHD	Top of metal waratah
S3	S3	Surface Water Site	10:47	0.353	5.110	4.757	-	-	-	1238935	4855676	Bateman's Drain near farm lane	Top of metal waratah
S4	S4	Surface Water Site	10:51	0.788	4.920	4.132	-	-	-	1238808	4855229	Bateman's Drain near Leonard road	Top of metal waratah
BD1	BD1	Surface Water Site	9:13	0.644	2.130	1.486	-	-	-	1238630	4856513	Boiler Drain - near waste water treatment ponds	Top of metal waratah
BD2	BD2	Surface Water Site	9:05	0.856	2.040	1.184	-	-	-	1238526	4856245	Boiler Drain - mid section of drain	Top of metal waratah
BD3	BD3	Surface Water Site	11:23	0.498	1.270	0.772	-	-	-	1238016	4856199	Boiler Drain - immediately above outlet	Top of metal waratah
P1	P1	Waste Water Pond	9:34	0.384	4.240	3.856	-	-	-	1238616	4856605	Waste water treatment pond	Top of metal waratah
P2	P2	Waste Water Pond	9:15	0.695	2.230	1.535	-	-	-	1238613	4856515	Waste water treatment pond	Top of metal waratah
P3	P3	Waste Water Pond	10:10	1.135	3.680	2.545	-	-	-	1238298	4856242	Waste water treatment pond	Top of left post on outlet structure
P4	P4	Waste Water Pond	10:14	0.645	3.270	2.625	-	-	-	1238137	4856248	Waste water treatment pond	Top of metal waratah

**NOTE:** All measurements made on 9/12/2014. DTW = depth to water level. MP = measuring point

**Table C2: Water levels and details of water level monitoring sites used during the piezometric survey on 19 March 2015**

Site ID	Name	Type	Time of Measurement	DTW (m BMP)	MP Elevation (m amsl)	Water Level Elevation (m amsl)	Bore MP (m agl)	Bore Depth (m BMP)	Bore Depth (m bgl)	NZTMX	NZTMY	Site Description	MP Description
BHA	BHA	Groundwater - Bore	9:39 a.m.	2.495	4.580	2.085	0.738	8.058	7.320	1238660	4856242	Monitoring bore	Inside edge of metal well cap
BHB	BHB	Groundwater - Bore	9:47 a.m.	2.015	3.340	1.325	0.707	9.120	8.413	1238365	4856204	Monitoring bore	Inside edge of metal well cap
BHC	BHC	Groundwater - Bore	8:54 a.m.	2.190	3.280	1.090	0.520	6.363	5.843	1238046	4856124	Monitoring bore	Inside edge of metal well cap
BHD	BHD	Groundwater - Bore	8:45 a.m.	1.634	2.610	0.976	0.394	6.170	5.776	1237894	4855853	Monitoring bore	Inside edge of metal well cap
BHE	BHE	Groundwater - Bore	9:10 a.m.	3.756	9.780	6.024	0.905	8.023	7.118	1238690	4855725	Monitoring bore	Inside edge of metal well cap
IB	Irrigation Bore	Groundwater - Bore	9:20 a.m.	3.764	9.910	6.146	0.300	10.200	9.900	1238901	4856005	Ex-irrigation bore owned by Alliance Lorneville	Edge of metal casing
RB	Ridley Bore	Groundwater - Bore	10:45 a.m.	5.433	7.820	2.387	0.463	12.463	12.000	1238440	4855313	Private bore used for stock water supply	lowest point on metal casing
MWB	McWilliam Bore	Groundwater - Bore	11:02 a.m.	4.870	14.510	9.640	0.353	14.853	14.500	1240346	4855733	Private bore used for stock water supply	Edge of metal casing
WTW	Water Treatment Well	Groundwater - Well	11:14 a.m.	4.870	14.020	9.150	0.486	6.000	5.514	1239563	4856494	Alliance Lorneville bore at factory water treatment site	lowest point on metal casing
S1	S1	Surface Water Site	9:02 a.m.	0.477	1.710	1.233	-	-	-	1238254	4856084	Unnamed drainage ditch near farm track	Top of metal waratah
S2	S2	Surface Water Site	8:48 a.m.	0.781	1.460	0.679	-	-	-	1237968	4855853	Unnamed drainage ditch near BHD	Top of metal waratah
S3	S3	Surface Water Site	9:24 a.m.	0.379	5.110	4.731	-	-	-	1238935	4855676	Bateman's Drain near farm lane	Top of metal waratah
S4	S4	Surface Water Site	9:30 a.m.	0.665	4.920	4.255	-	-	-	1238808	4855229	Bateman's Drain near Leonard road	Top of metal waratah
BD1	BD1	Surface Water Site	10:06 a.m.	0.690	2.130	1.440	-	-	-	1238630	4856513	Boiler Drain - near waste water treatment ponds	Top of metal waratah
BD2	BD2	Surface Water Site	9:43 a.m.	0.860	2.040	1.180	-	-	-	1238526	4856245	Boiler Drain - mid section of drain	Top of metal waratah
BD3	BD3	Surface Water Site	8:58 a.m.	0.423	1.270	0.847	-	-	-	1238016	4856199	Boiler Drain - immediately above outlet	Top of metal waratah
P1	P1	Surface Water Site	10:00 a.m.	0.283	4.240	3.957	-	-	-	1238616	4856605	Waste water treatment pond	Top of metal waratah
P2	P2	Surface Water Site	10:04 a.m.	0.723	2.230	1.507	-	-	-	1238613	4856515	Waste water treatment pond	Top of metal waratah
P3	P3	Surface Water Site	9:50 a.m.	0.590	3.680	3.090	-	-	-	1238298	4856242	Waste water treatment pond	Top of left post on outlet structure
P4	P4	Surface Water Site	9:55 a.m.	0.005	3.270	3.265	-	-	-	1238137	4856248	Waste water treatment pond	Top of metal waratah
MR1	MR1	Surface Water Site	7:43 a.m.	0.584	0.630	0.046	-	-	-	1237912	4856026	Makarewa River - below Boiler Drain outlet	Top of metal waratah

**NOTE:** All measurements made on 19/03/2015. DTW = depth to water level. MP = measuring point

**Table C1: Water levels and details of water level monitoring sites used during the piezometric survey on 9 December 2014**

Site ID	Name	Type	Time of Measurement	DTW (m bMP)	MP Elevation (m amsl)	Water Level Elevation (m amsl)	Bore MP (m agl)	Bore Depth (m bMP)	Bore Depth (m bgl)	NZTMX	NZTMY	Site Description	MP Description
BHA	BHA	Groundwater - Bore	8:59	2.151	4.580	2.429	0.738	8.058	7.320	1238660	4856242	Monitoring bore	Inside edge of metal well cap
BHB	BHB	Groundwater - Bore	10:20	1.969	3.340	1.371	0.707	9.120	8.413	1238365	4856204	Monitoring bore	Inside edge of metal well cap
BHC	BHC	Groundwater - Bore	8:44	1.817	3.280	1.463	0.52	6.363	5.843	1238046	4856124	Monitoring bore	Inside edge of metal well cap
BHD	BHD	Groundwater - Bore	8:31	1.274	2.610	1.336	0.394	6.170	5.776	1237894	4855853	Monitoring bore	Inside edge of metal well cap
BHE	BHE	Groundwater - Bore	10:30	2.94	9.780	6.840	0.905	8.023	7.118	1238690	4855725	Monitoring bore	Inside edge of metal well cap
IB	Irrigation Bore	Groundwater - Bore	10:56	3.15	9.910	6.760	0.300	10.200	9.900	1238901	4856005	Ex-irrigation bore owned by Alliance Lorneville	Edge of metal casing
RB	Ridley Bore	Groundwater - Bore	14:23	4.555	7.820	3.265	0.463	12.463	12.000	1238440	4855313	Private bore used for stock water supply	Lowest point on metal casing
MWB	McWilliam Bore	Groundwater - Bore	14:37	3.486	14.510	11.024	0.353	14.853	14.500	1240346	4855733	Private bore used for stock water supply	Edge of metal casing
WTW	Water Treatment Well	Groundwater - Well	12:06	3.717	14.020	10.303	0.486	6.000	5.514	1239563	4856494	Alliance Lorneville bore at factory water treatment site	Lowest point on metal casing
MR1	MR1	Surface Water Site	11:10	0.457	0.630	0.173	-	-	-	1237912	4856026	Makarewa River - below Boiler Drain outlet	Top of metal waratah
S1	S1	Surface Water Site	8:51	0.477	1.710	1.233	-	-	-	1238254	4856084	Unnamed drainage ditch near farm track	Top of metal waratah
S2	S2	Surface Water Site	8:37	0.484	1.460	0.976	-	-	-	1237968	4855853	Unnamed drainage ditch near BHD	Top of metal waratah
S3	S3	Surface Water Site	10:47	0.353	5.110	4.757	-	-	-	1238935	4855676	Bateman's Drain near farm lane	Top of metal waratah
S4	S4	Surface Water Site	10:51	0.788	4.920	4.132	-	-	-	1238808	4855229	Bateman's Drain near Leonard road	Top of metal waratah
BD1	BD1	Surface Water Site	9:13	0.644	2.130	1.486	-	-	-	1238630	4856513	Boiler Drain - near waste water treatment ponds	Top of metal waratah
BD2	BD2	Surface Water Site	9:05	0.856	2.040	1.184	-	-	-	1238526	4856245	Boiler Drain - mid section of drain	Top of metal waratah
BD3	BD3	Surface Water Site	11:23	0.498	1.270	0.772	-	-	-	1238016	4856199	Boiler Drain - immediately above outlet	Top of metal waratah
P1	P1	Waste Water Pond	9:34	0.384	4.240	3.856	-	-	-	1238616	4856605	Waste water treatment pond	Top of metal waratah
P2	P2	Waste Water Pond	9:15	0.695	2.230	1.535	-	-	-	1238613	4856515	Waste water treatment pond	Top of metal waratah
P3	P3	Waste Water Pond	10:10	1.135	3.680	2.545	-	-	-	1238298	4856242	Waste water treatment pond	Top of left post on outlet structure
P4	P4	Waste Water Pond	10:14	0.645	3.270	2.625	-	-	-	1238137	4856248	Waste water treatment pond	Top of metal waratah

**NOTE:** All measurements made on 9/12/2014. DTW = depth to water level. MP = measuring point

**Table C2: Water levels and details of water level monitoring sites used during the piezometric survey on 19 March 2015**

Site ID	Name	Type	Time of Measurement	DTW (m BMP)	MP Elevation (m amsl)	Water Level Elevation (m amsl)	Bore MP (m agl)	Bore Depth (m BMP)	Bore Depth (m bgl)	NZTMX	NZTMY	Site Description	MP Description
BHA	BHA	Groundwater - Bore	9:39 a.m.	2.495	4.580	2.085	0.738	8.058	7.320	1238660	4856242	Monitoring bore	Inside edge of metal well cap
BHB	BHB	Groundwater - Bore	9:47 a.m.	2.015	3.340	1.325	0.707	9.120	8.413	1238365	4856204	Monitoring bore	Inside edge of metal well cap
BHC	BHC	Groundwater - Bore	8:54 a.m.	2.190	3.280	1.090	0.520	6.363	5.843	1238046	4856124	Monitoring bore	Inside edge of metal well cap
BHD	BHD	Groundwater - Bore	8:45 a.m.	1.634	2.610	0.976	0.394	6.170	5.776	1237894	4855853	Monitoring bore	Inside edge of metal well cap
BHE	BHE	Groundwater - Bore	9:10 a.m.	3.756	9.780	6.024	0.905	8.023	7.118	1238690	4855725	Monitoring bore	Inside edge of metal well cap
IB	Irrigation Bore	Groundwater - Bore	9:20 a.m.	3.764	9.910	6.146	0.300	10.200	9.900	1238901	4856005	Ex-irrigation bore owned by Alliance Lorneville	Edge of metal casing
RB	Ridley Bore	Groundwater - Bore	10:45 a.m.	5.433	7.820	2.387	0.463	12.463	12.000	1238440	4855313	Private bore used for stock water supply	lowest point on metal casing
MWB	McWilliam Bore	Groundwater - Bore	11:02 a.m.	4.870	14.510	9.640	0.353	14.853	14.500	1240346	4855733	Private bore used for stock water supply	Edge of metal casing
WTW	Water Treatment Well	Groundwater - Well	11:14 a.m.	4.870	14.020	9.150	0.486	6.000	5.514	1239563	4856494	Alliance Lorneville bore at factory water treatment site	lowest point on metal casing
S1	S1	Surface Water Site	9:02 a.m.	0.477	1.710	1.233	-	-	-	1238254	4856084	Unnamed drainage ditch near farm track	Top of metal waratah
S2	S2	Surface Water Site	8:48 a.m.	0.781	1.460	0.679	-	-	-	1237968	4855853	Unnamed drainage ditch near BHD	Top of metal waratah
S3	S3	Surface Water Site	9:24 a.m.	0.379	5.110	4.731	-	-	-	1238935	4855676	Bateman's Drain near farm lane	Top of metal waratah
S4	S4	Surface Water Site	9:30 a.m.	0.665	4.920	4.255	-	-	-	1238808	4855229	Bateman's Drain near Leonard road	Top of metal waratah
BD1	BD1	Surface Water Site	10:06 a.m.	0.690	2.130	1.440	-	-	-	1238630	4856513	Boiler Drain - near waste water treatment ponds	Top of metal waratah
BD2	BD2	Surface Water Site	9:43 a.m.	0.860	2.040	1.180	-	-	-	1238526	4856245	Boiler Drain - mid section of drain	Top of metal waratah
BD3	BD3	Surface Water Site	8:58 a.m.	0.423	1.270	0.847	-	-	-	1238016	4856199	Boiler Drain - immediately above outlet	Top of metal waratah
P1	P1	Surface Water Site	10:00 a.m.	0.283	4.240	3.957	-	-	-	1238616	4856605	Waste water treatment pond	Top of metal waratah
P2	P2	Surface Water Site	10:04 a.m.	0.723	2.230	1.507	-	-	-	1238613	4856515	Waste water treatment pond	Top of metal waratah
P3	P3	Surface Water Site	9:50 a.m.	0.590	3.680	3.090	-	-	-	1238298	4856242	Waste water treatment pond	Top of left post on outlet structure
P4	P4	Surface Water Site	9:55 a.m.	0.005	3.270	3.265	-	-	-	1238137	4856248	Waste water treatment pond	Top of metal waratah
MR1	MR1	Surface Water Site	7:43 a.m.	0.584	0.630	0.046	-	-	-	1237912	4856026	Makarewa River - below Boiler Drain outlet	Top of metal waratah

**NOTE:** All measurements made on 19/03/2015. DTW = depth to water level. MP = measuring point

## Appendix D

WQ Results



## ANALYSIS REPORT

<b>Client:</b>	Pattle Delamore Partners Limited	<b>Lab No:</b>	1363897	SPV2
<b>Contact:</b>	R Nicol C/- Pattle Delamore Partners Limited PO Box 389 CHRISTCHURCH 8140	<b>Date Registered:</b>	12-Dec-2014	
		<b>Date Reported:</b>	07-Jan-2015	
		<b>Quote No:</b>	65140	
		<b>Order No:</b>		
		<b>Client Reference:</b>		
		<b>Submitted By:</b>	R Nicol	

### Amended Report

This report replaces an earlier report issued on the 22 Dec 2014 at 12:21 pm  
 The carbonate calculated results have been added.

#### Sample Type: Aqueous

Sample Name:	BD3 10-Dec-2014 12:15 pm	MR1 10-Dec-2014 11:50 am	MR2 10-Dec-2014 11:30 am	BDA 10-Dec-2014 11:00 am	S4 10-Dec-2014 8:50 am
Lab Number:	1363897.1	1363897.2	1363897.3	1363897.4	1363897.5
Sum of Anions meq/L	12.6	2.5	1.79	3.4	2.4
Sum of Cations meq/L	13.3	2.7	1.94	3.8	2.6
pH pH Units	8.1	7.8	7.7	7.1	7.3
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	260	63	48	52	35
Carbonate g/m <sup>3</sup> at 25°C	1.9	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	320	76	58	63	43
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	112	62	56	69	59
Electrical Conductivity (EC) mS/m	133.7	26.3	18.9	37.7	26.2
Total Suspended Solids g/m <sup>3</sup>	48	9	4	10	< 3
Dissolved Calcium g/m <sup>3</sup>	36	16.9	15.0	19.3	14.0
Dissolved Magnesium g/m <sup>3</sup>	5.7	4.8	4.6	5.0	5.8
Dissolved Potassium g/m <sup>3</sup>	25	3.1	1.69	2.5	2.8
Dissolved Sodium g/m <sup>3</sup>	175	27	17.5	53	30
Chloride g/m <sup>3</sup>	191	31	19.8	60	41
Total Nitrogen g/m <sup>3</sup>	43	4.4	1.39	3.1	4.2
Total Ammoniacal-N g/m <sup>3</sup>	39	2.6	0.066	0.22	0.88
Nitrite-N g/m <sup>3</sup>	0.081	0.020	0.016	0.030	0.067
Nitrate-N g/m <sup>3</sup>	0.42	0.87	0.90	2.0	2.7
Nitrate-N + Nitrite-N g/m <sup>3</sup>	0.50	0.89	0.91	2.1	2.8
Total Kjeldahl Nitrogen (TKN) g/m <sup>3</sup>	42	3.6	0.48	1.01	1.41
Dissolved Reactive Phosphorus g/m <sup>3</sup>	5.2	0.34	0.024	0.066	0.012
Sulphate g/m <sup>3</sup>	67	13.1	10.0	27	14.3

Sample Name:	BHA 10-Dec-2014 2:20 pm	BHB 10-Dec-2014 3:40 pm	BHC 10-Dec-2014 4:50 pm	BHD 10-Dec-2014 5:55 pm	BHE 10-Dec-2014 10:25 am
Lab Number:	1363897.6	1363897.7	1363897.8	1363897.9	1363897.10
Sum of Anions meq/L	3.1	1.76	2.1	3.4	1.85
Sum of Cations meq/L	3.3	2.0	2.3	3.7	1.90
pH pH Units	6.7	6.6	6.5	6.8	5.9
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	38	37	49	83	3.8
Carbonate g/m <sup>3</sup> at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	46	45	60	102	4.6
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	69	48	50	100	52
Electrical Conductivity (EC) mS/m	34.8	19.0	21.6	34.4	21.5
Total Suspended Solids g/m <sup>3</sup>	8,600	4,400	3,000	7,400	6,100
Dissolved Calcium g/m <sup>3</sup>	13.0	9.0	8.3	18.6	8.6
Dissolved Magnesium g/m <sup>3</sup>	8.9	6.2	7.0	13.0	7.3



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.

The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked \*, which are not accredited.



Sample Type: Aqueous						
Sample Name:	BHA 10-Dec-2014 2:20 pm	BHB 10-Dec-2014 3:40 pm	BHC 10-Dec-2014 4:50 pm	BHD 10-Dec-2014 5:55 pm	BHE 10-Dec-2014 10:25 am	
Lab Number:	1363897.6	1363897.7	1363897.8	1363897.9	1363897.10	
Dissolved Potassium	g/m <sup>3</sup>	2.1	1.28	1.09	2.1	1.42
Dissolved Sodium	g/m <sup>3</sup>	42	23	29	38	19.0
Chloride	g/m <sup>3</sup>	60	25	29	34	45
Total Nitrogen	g/m <sup>3</sup>	8.8	1.47	1.13	2.7	4.9
Total Ammoniacal-N	g/m <sup>3</sup>	0.014	0.122	0.013	0.085	< 0.010
Nitrite-N	g/m <sup>3</sup>	0.007	< 0.02	< 0.002	< 0.02	< 0.002
Nitrate-N	g/m <sup>3</sup>	4.8	< 0.02	< 0.002	< 0.02	1.98
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	4.8	< 0.02 #1	< 0.002	< 0.02 #1	1.98
Total Kjeldahl Nitrogen (TKN)	g/m <sup>3</sup>	4.0	1.47	1.13	2.7	2.9
Dissolved Reactive Phosphorus	g/m <sup>3</sup>	< 0.004	0.004	< 0.004	< 0.004	< 0.004
Sulphate	g/m <sup>3</sup>	13.3	15.6	14.6	37	17.5

### Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxN /NO2N analysis.

## SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-10
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	1-10
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1-10
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1-10
pH	pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-H+ B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1-10
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1-10
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D 22 <sup>nd</sup> ed. 2012.	3 g/m <sup>3</sup>	1-10
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Chloride	Filtered sample from Christchurch. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl <sup>-</sup> E (modified from continuous flow analysis) 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m <sup>3</sup> is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m <sup>3</sup> , the Default Detection Limit for Total Nitrogen will be 0.11 g/m <sup>3</sup> .	0.05 g/m <sup>3</sup>	1-10
Total Ammoniacal-N	Filtered sample from Christchurch. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH <sub>4</sub> -N = NH <sub>4</sub> <sup>+</sup> -N + NH <sub>3</sub> -N). APHA 4500-NH <sub>3</sub> F (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.010 g/m <sup>3</sup>	1-10
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>2</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N. In-House.	0.0010 g/m <sup>3</sup>	1-10
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO <sub>3</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N <sub>org</sub> D. (modified) 4500 NH <sub>3</sub> F (modified) 22 <sup>nd</sup> ed. 2012.	0.10 g/m <sup>3</sup>	1-10
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.004 g/m <sup>3</sup>	1-10
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Ara Heron BSc (Tech)  
Client Services Manager - Environmental Division



## ANALYSIS REPORT

<b>Client:</b>	Pattle Delamore Partners Limited	<b>Lab No:</b>	1399945	SPv2
<b>Contact:</b>	R Nicol C/- Pattle Delamore Partners Limited PO Box 389 CHRISTCHURCH 8140	<b>Date Registered:</b>	19-Mar-2015	
		<b>Date Reported:</b>	30-Mar-2015	
		<b>Quote No:</b>	66725	
		<b>Order No:</b>		
		<b>Client Reference:</b>		
		<b>Submitted By:</b>	R Nicol	

### Amended Report

This report replaces an earlier report issued on the 26 Mar 2015 at 3:07 pm  
 Carbonate results added at clients request.

#### Sample Type: Aqueous

Sample Name:	BHA 18-Mar-2015 9:32 am	BHB 18-Mar-2015 11:51 am	BHC 18-Mar-2015 1:33 pm	BHD 18-Mar-2015 12:43 pm	BHE 18-Mar-2015 10:31 am
Lab Number:	1399945.1	1399945.2	1399945.3	1399945.4	1399945.5
Sum of Anions meq/L	3.2	2.4	2.5	3.8	2.0
Sum of Cations meq/L	3.4	2.2	2.6	3.9	2.2
pH pH Units	6.4	6.8	6.7	6.8	5.8
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	38	53	65	94	5.0
Carbonate g/m <sup>3</sup> at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	47	64	79	114	6.2
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	72	45	57	102	57
Electrical Conductivity (EC) mS/m	36.8	25.0	26.3	38.6	24.0
Total Suspended Solids g/m <sup>3</sup>	169	48	9	1,100	20
Dissolved Calcium g/m <sup>3</sup>	13.5	8.0	10.0	18.7	7.8
Dissolved Iron g/m <sup>3</sup>	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Magnesium g/m <sup>3</sup>	9.3	6.2	7.8	13.4	9.2
Dissolved Manganese g/m <sup>3</sup>	0.091	0.70	0.97	1.28	0.023
Dissolved Potassium g/m <sup>3</sup>	1.87	1.16	1.32	2.2	1.82
Dissolved Sodium g/m <sup>3</sup>	44	27	32	41	22
Chloride g/m <sup>3</sup>	64	32	31	35	50
Total Nitrogen g/m <sup>3</sup>	5.3	0.3	< 0.3	0.9	2.4
Total Ammoniacal-N g/m <sup>3</sup>	0.010	0.116	0.029	0.100	< 0.010
Nitrite-N g/m <sup>3</sup>	0.002	< 0.2 #1	< 0.2 #1	< 0.2 #1	< 0.002
Nitrate-N g/m <sup>3</sup>	5.2	< 0.2	< 0.2	< 0.2	2.3
Nitrate-N + Nitrite-N g/m <sup>3</sup>	5.2	< 0.2 #1	< 0.2 #1	< 0.2 #1	2.3
Total Kjeldahl Nitrogen (TKN) g/m <sup>3</sup>	0.15	0.22	0.13	0.79	< 0.10
Dissolved Reactive Phosphorus g/m <sup>3</sup>	< 0.004	0.109	0.018	0.009	< 0.004
Sulphate g/m <sup>3</sup>	14.6	19.9	18.0	43	17.5

Sample Name:	MR1 18-Mar-2015 2:45 pm	MR2 18-Mar-2015 2:25 pm	BDA 18-Mar-2015 2:10 pm	BD3 18-Mar-2015 3:05 pm	S4 18-Mar-2015 11:00 am
Lab Number:	1399945.6	1399945.7	1399945.8	1399945.9	1399945.10
Sum of Anions meq/L	3.5	1.60	13.0	28	4.4
Sum of Cations meq/L	3.5	1.81	12.8	29	4.6
pH pH Units	7.9	7.8	7.1	8.3	7.2
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	88	44	50	700	63
Carbonate g/m <sup>3</sup> at 25°C	< 1.0	< 1.0	< 1.0	7.3	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	107	53	60	840	77
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	54	51	89	144	76
Electrical Conductivity (EC) mS/m	36.8	17.5	146.2	283	50.2
Total Suspended Solids g/m <sup>3</sup>	10	5	9	99	5



Sample Type: Aqueous						
Sample Name:	MR1 18-Mar-2015 2:45 pm	MR2 18-Mar-2015 2:25 pm	BDA 18-Mar-2015 2:10 pm	BD3 18-Mar-2015 3:05 pm	S4 18-Mar-2015 11:00 am	
Lab Number:	1399945.6	1399945.7	1399945.8	1399945.9	1399945.10	
Dissolved Calcium	g/m <sup>3</sup>	14.2	12.7	28	48	17.9
Dissolved Iron	g/m <sup>3</sup>	0.26	0.32	0.58	0.13	0.07
Dissolved Magnesium	g/m <sup>3</sup>	4.6	4.7	4.8	6.0	7.6
Dissolved Manganese	g/m <sup>3</sup>	0.0012	0.0013	0.031	0.099	0.023
Dissolved Potassium	g/m <sup>3</sup>	6.5	1.58	2.6	79	6.0
Dissolved Sodium	g/m <sup>3</sup>	39	16.8	250	340	58
Chloride	g/m <sup>3</sup>	43	18.9	360	360	83
Total Nitrogen	g/m <sup>3</sup>	9.9	0.76	5.2	140	10.7
Total Ammoniacal-N	g/m <sup>3</sup>	8.1	0.026	0.74	131	5.7
Nitrite-N	g/m <sup>3</sup>	0.102	0.011	0.074	0.78	0.22
Nitrate-N	g/m <sup>3</sup>	0.57	0.33	2.0	0.47	4.4
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	0.67	0.34	2.1	1.25	4.6
Total Kjeldahl Nitrogen (TKN)	g/m <sup>3</sup>	9.2	0.42	3.2	139	6.1
Dissolved Reactive Phosphorus	g/m <sup>3</sup>	0.97	0.030	0.43	14.7	0.184
Sulphate	g/m <sup>3</sup>	17.0	8.0	81	131	23

### Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NO<sub>2</sub>N, NO<sub>3</sub>N and NO<sub>x</sub>N analysis.

## SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-10
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	1-10
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22 <sup>nd</sup> ed. 2012.	0.07 meq/L	1-10
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H <sup>+</sup> ) also included in calculation if available. APHA 1030 E 22 <sup>nd</sup> ed. 2012.	0.05 meq/L	1-10
pH	pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-H <sup>+</sup> B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1-10
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1-10
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D 22 <sup>nd</sup> ed. 2012.	3 g/m <sup>3</sup>	1-10
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22 <sup>nd</sup> ed. 2012.	-	1-10
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0005 g/m <sup>3</sup>	1-10
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Chloride	Filtered sample from Christchurch. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl <sup>-</sup> E (modified from continuous flow analysis) 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m <sup>3</sup> is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m <sup>3</sup> , the Default Detection Limit for Total Nitrogen will be 0.11 g/m <sup>3</sup> .	0.05 g/m <sup>3</sup>	1-10
Total Ammoniacal-N	Filtered sample from Christchurch. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH <sub>4</sub> -N = NH <sub>4</sub> <sup>+</sup> -N + NH <sub>3</sub> -N). APHA 4500-NH <sub>3</sub> F (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.010 g/m <sup>3</sup>	1-10
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>2</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N. In-House.	0.0010 g/m <sup>3</sup>	1-10
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO <sub>3</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N <sub>org</sub> D. (modified) 4500 NH <sub>3</sub> F (modified) 22 <sup>nd</sup> ed. 2012.	0.10 g/m <sup>3</sup>	1-10
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.004 g/m <sup>3</sup>	1-10
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Martin Cowell - BSc  
Client Services Manager - Environmental Division



## ANALYSIS REPORT

<b>Client:</b>	Pattle Delamore Partners Limited	<b>Lab No:</b>	1363897	SPV2
<b>Contact:</b>	R Nicol C/- Pattle Delamore Partners Limited PO Box 389 CHRISTCHURCH 8140	<b>Date Registered:</b>	12-Dec-2014	
		<b>Date Reported:</b>	07-Jan-2015	
		<b>Quote No:</b>	65140	
		<b>Order No:</b>		
		<b>Client Reference:</b>		
		<b>Submitted By:</b>	R Nicol	

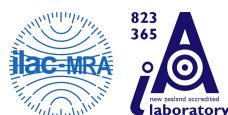
### Amended Report

This report replaces an earlier report issued on the 22 Dec 2014 at 12:21 pm  
 The carbonate calculated results have been added.

#### Sample Type: Aqueous

Sample Name:	BD3 10-Dec-2014 12:15 pm	MR1 10-Dec-2014 11:50 am	MR2 10-Dec-2014 11:30 am	BDA 10-Dec-2014 11:00 am	S4 10-Dec-2014 8:50 am
Lab Number:	1363897.1	1363897.2	1363897.3	1363897.4	1363897.5
Sum of Anions meq/L	12.6	2.5	1.79	3.4	2.4
Sum of Cations meq/L	13.3	2.7	1.94	3.8	2.6
pH pH Units	8.1	7.8	7.7	7.1	7.3
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	260	63	48	52	35
Carbonate g/m <sup>3</sup> at 25°C	1.9	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	320	76	58	63	43
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	112	62	56	69	59
Electrical Conductivity (EC) mS/m	133.7	26.3	18.9	37.7	26.2
Total Suspended Solids g/m <sup>3</sup>	48	9	4	10	< 3
Dissolved Calcium g/m <sup>3</sup>	36	16.9	15.0	19.3	14.0
Dissolved Magnesium g/m <sup>3</sup>	5.7	4.8	4.6	5.0	5.8
Dissolved Potassium g/m <sup>3</sup>	25	3.1	1.69	2.5	2.8
Dissolved Sodium g/m <sup>3</sup>	175	27	17.5	53	30
Chloride g/m <sup>3</sup>	191	31	19.8	60	41
Total Nitrogen g/m <sup>3</sup>	43	4.4	1.39	3.1	4.2
Total Ammoniacal-N g/m <sup>3</sup>	39	2.6	0.066	0.22	0.88
Nitrite-N g/m <sup>3</sup>	0.081	0.020	0.016	0.030	0.067
Nitrate-N g/m <sup>3</sup>	0.42	0.87	0.90	2.0	2.7
Nitrate-N + Nitrite-N g/m <sup>3</sup>	0.50	0.89	0.91	2.1	2.8
Total Kjeldahl Nitrogen (TKN) g/m <sup>3</sup>	42	3.6	0.48	1.01	1.41
Dissolved Reactive Phosphorus g/m <sup>3</sup>	5.2	0.34	0.024	0.066	0.012
Sulphate g/m <sup>3</sup>	67	13.1	10.0	27	14.3

Sample Name:	BHA 10-Dec-2014 2:20 pm	BHB 10-Dec-2014 3:40 pm	BHC 10-Dec-2014 4:50 pm	BHD 10-Dec-2014 5:55 pm	BHE 10-Dec-2014 10:25 am
Lab Number:	1363897.6	1363897.7	1363897.8	1363897.9	1363897.10
Sum of Anions meq/L	3.1	1.76	2.1	3.4	1.85
Sum of Cations meq/L	3.3	2.0	2.3	3.7	1.90
pH pH Units	6.7	6.6	6.5	6.8	5.9
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	38	37	49	83	3.8
Carbonate g/m <sup>3</sup> at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	46	45	60	102	4.6
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	69	48	50	100	52
Electrical Conductivity (EC) mS/m	34.8	19.0	21.6	34.4	21.5
Total Suspended Solids g/m <sup>3</sup>	8,600	4,400	3,000	7,400	6,100
Dissolved Calcium g/m <sup>3</sup>	13.0	9.0	8.3	18.6	8.6
Dissolved Magnesium g/m <sup>3</sup>	8.9	6.2	7.0	13.0	7.3



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.

The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked \*, which are not accredited.



Sample Type: Aqueous						
Sample Name:	BHA 10-Dec-2014 2:20 pm	BHB 10-Dec-2014 3:40 pm	BHC 10-Dec-2014 4:50 pm	BHD 10-Dec-2014 5:55 pm	BHE 10-Dec-2014 10:25 am	
Lab Number:	1363897.6	1363897.7	1363897.8	1363897.9	1363897.10	
Dissolved Potassium	g/m <sup>3</sup>	2.1	1.28	1.09	2.1	1.42
Dissolved Sodium	g/m <sup>3</sup>	42	23	29	38	19.0
Chloride	g/m <sup>3</sup>	60	25	29	34	45
Total Nitrogen	g/m <sup>3</sup>	8.8	1.47	1.13	2.7	4.9
Total Ammoniacal-N	g/m <sup>3</sup>	0.014	0.122	0.013	0.085	< 0.010
Nitrite-N	g/m <sup>3</sup>	0.007	< 0.02	< 0.002	< 0.02	< 0.002
Nitrate-N	g/m <sup>3</sup>	4.8	< 0.02	< 0.002	< 0.02	1.98
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	4.8	< 0.02 #1	< 0.002	< 0.02 #1	1.98
Total Kjeldahl Nitrogen (TKN)	g/m <sup>3</sup>	4.0	1.47	1.13	2.7	2.9
Dissolved Reactive Phosphorus	g/m <sup>3</sup>	< 0.004	0.004	< 0.004	< 0.004	< 0.004
Sulphate	g/m <sup>3</sup>	13.3	15.6	14.6	37	17.5

### Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxN /NO2N analysis.

## SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-10
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	1-10
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L.	0.07 meq/L	1-10
Total cations for anion/cation balance check	Calculation: sum of cations as mEq/L.	0.05 meq/L	1-10
pH	pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-H+ B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1-10
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1-10
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D 22 <sup>nd</sup> ed. 2012.	3 g/m <sup>3</sup>	1-10
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Chloride	Filtered sample from Christchurch. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl <sup>-</sup> E (modified from continuous flow analysis) 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m <sup>3</sup> is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m <sup>3</sup> , the Default Detection Limit for Total Nitrogen will be 0.11 g/m <sup>3</sup> .	0.05 g/m <sup>3</sup>	1-10
Total Ammoniacal-N	Filtered sample from Christchurch. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH <sub>4</sub> -N = NH <sub>4</sub> <sup>+</sup> -N + NH <sub>3</sub> -N). APHA 4500-NH <sub>3</sub> F (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.010 g/m <sup>3</sup>	1-10
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>2</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N. In-House.	0.0010 g/m <sup>3</sup>	1-10
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO <sub>3</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N <sub>org</sub> D. (modified) 4500 NH <sub>3</sub> F (modified) 22 <sup>nd</sup> ed. 2012.	0.10 g/m <sup>3</sup>	1-10
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.004 g/m <sup>3</sup>	1-10
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Ara Heron BSc (Tech)  
Client Services Manager - Environmental Division



## ANALYSIS REPORT

<b>Client:</b>	Pattle Delamore Partners Limited	<b>Lab No:</b>	1399945	SPv2
<b>Contact:</b>	R Nicol C/- Pattle Delamore Partners Limited PO Box 389 CHRISTCHURCH 8140	<b>Date Registered:</b>	19-Mar-2015	
		<b>Date Reported:</b>	30-Mar-2015	
		<b>Quote No:</b>	66725	
		<b>Order No:</b>		
		<b>Client Reference:</b>		
		<b>Submitted By:</b>	R Nicol	

### Amended Report

This report replaces an earlier report issued on the 26 Mar 2015 at 3:07 pm  
 Carbonate results added at clients request.

#### Sample Type: Aqueous

Sample Name:	BHA 18-Mar-2015 9:32 am	BHB 18-Mar-2015 11:51 am	BHC 18-Mar-2015 1:33 pm	BHD 18-Mar-2015 12:43 pm	BHE 18-Mar-2015 10:31 am
Lab Number:	1399945.1	1399945.2	1399945.3	1399945.4	1399945.5
Sum of Anions meq/L	3.2	2.4	2.5	3.8	2.0
Sum of Cations meq/L	3.4	2.2	2.6	3.9	2.2
pH pH Units	6.4	6.8	6.7	6.8	5.8
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	38	53	65	94	5.0
Carbonate g/m <sup>3</sup> at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	47	64	79	114	6.2
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	72	45	57	102	57
Electrical Conductivity (EC) mS/m	36.8	25.0	26.3	38.6	24.0
Total Suspended Solids g/m <sup>3</sup>	169	48	9	1,100	20
Dissolved Calcium g/m <sup>3</sup>	13.5	8.0	10.0	18.7	7.8
Dissolved Iron g/m <sup>3</sup>	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Magnesium g/m <sup>3</sup>	9.3	6.2	7.8	13.4	9.2
Dissolved Manganese g/m <sup>3</sup>	0.091	0.70	0.97	1.28	0.023
Dissolved Potassium g/m <sup>3</sup>	1.87	1.16	1.32	2.2	1.82
Dissolved Sodium g/m <sup>3</sup>	44	27	32	41	22
Chloride g/m <sup>3</sup>	64	32	31	35	50
Total Nitrogen g/m <sup>3</sup>	5.3	0.3	< 0.3	0.9	2.4
Total Ammoniacal-N g/m <sup>3</sup>	0.010	0.116	0.029	0.100	< 0.010
Nitrite-N g/m <sup>3</sup>	0.002	< 0.2 #1	< 0.2 #1	< 0.2 #1	< 0.002
Nitrate-N g/m <sup>3</sup>	5.2	< 0.2	< 0.2	< 0.2	2.3
Nitrate-N + Nitrite-N g/m <sup>3</sup>	5.2	< 0.2 #1	< 0.2 #1	< 0.2 #1	2.3
Total Kjeldahl Nitrogen (TKN) g/m <sup>3</sup>	0.15	0.22	0.13	0.79	< 0.10
Dissolved Reactive Phosphorus g/m <sup>3</sup>	< 0.004	0.109	0.018	0.009	< 0.004
Sulphate g/m <sup>3</sup>	14.6	19.9	18.0	43	17.5

Sample Name:	MR1 18-Mar-2015 2:45 pm	MR2 18-Mar-2015 2:25 pm	BDA 18-Mar-2015 2:10 pm	BD3 18-Mar-2015 3:05 pm	S4 18-Mar-2015 11:00 am
Lab Number:	1399945.6	1399945.7	1399945.8	1399945.9	1399945.10
Sum of Anions meq/L	3.5	1.60	13.0	28	4.4
Sum of Cations meq/L	3.5	1.81	12.8	29	4.6
pH pH Units	7.9	7.8	7.1	8.3	7.2
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	88	44	50	700	63
Carbonate g/m <sup>3</sup> at 25°C	< 1.0	< 1.0	< 1.0	7.3	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	107	53	60	840	77
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	54	51	89	144	76
Electrical Conductivity (EC) mS/m	36.8	17.5	146.2	283	50.2
Total Suspended Solids g/m <sup>3</sup>	10	5	9	99	5



Sample Type: Aqueous						
Sample Name:	MR1 18-Mar-2015 2:45 pm	MR2 18-Mar-2015 2:25 pm	BDA 18-Mar-2015 2:10 pm	BD3 18-Mar-2015 3:05 pm	S4 18-Mar-2015 11:00 am	
Lab Number:	1399945.6	1399945.7	1399945.8	1399945.9	1399945.10	
Dissolved Calcium	g/m <sup>3</sup>	14.2	12.7	28	48	17.9
Dissolved Iron	g/m <sup>3</sup>	0.26	0.32	0.58	0.13	0.07
Dissolved Magnesium	g/m <sup>3</sup>	4.6	4.7	4.8	6.0	7.6
Dissolved Manganese	g/m <sup>3</sup>	0.0012	0.0013	0.031	0.099	0.023
Dissolved Potassium	g/m <sup>3</sup>	6.5	1.58	2.6	79	6.0
Dissolved Sodium	g/m <sup>3</sup>	39	16.8	250	340	58
Chloride	g/m <sup>3</sup>	43	18.9	360	360	83
Total Nitrogen	g/m <sup>3</sup>	9.9	0.76	5.2	140	10.7
Total Ammoniacal-N	g/m <sup>3</sup>	8.1	0.026	0.74	131	5.7
Nitrite-N	g/m <sup>3</sup>	0.102	0.011	0.074	0.78	0.22
Nitrate-N	g/m <sup>3</sup>	0.57	0.33	2.0	0.47	4.4
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	0.67	0.34	2.1	1.25	4.6
Total Kjeldahl Nitrogen (TKN)	g/m <sup>3</sup>	9.2	0.42	3.2	139	6.1
Dissolved Reactive Phosphorus	g/m <sup>3</sup>	0.97	0.030	0.43	14.7	0.184
Sulphate	g/m <sup>3</sup>	17.0	8.0	81	131	23

### Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NO<sub>2</sub>N, NO<sub>3</sub>N and NO<sub>x</sub>N analysis.

## SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-10
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	1-10
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22 <sup>nd</sup> ed. 2012.	0.07 meq/L	1-10
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H <sup>+</sup> ) also included in calculation if available. APHA 1030 E 22 <sup>nd</sup> ed. 2012.	0.05 meq/L	1-10
pH	pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-H <sup>+</sup> B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1-10
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1-10
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D 22 <sup>nd</sup> ed. 2012.	3 g/m <sup>3</sup>	1-10
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22 <sup>nd</sup> ed. 2012.	-	1-10
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0005 g/m <sup>3</sup>	1-10
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Chloride	Filtered sample from Christchurch. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl <sup>-</sup> E (modified from continuous flow analysis) 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m <sup>3</sup> is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m <sup>3</sup> , the Default Detection Limit for Total Nitrogen will be 0.11 g/m <sup>3</sup> .	0.05 g/m <sup>3</sup>	1-10
Total Ammoniacal-N	Filtered sample from Christchurch. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH <sub>4</sub> -N = NH <sub>4</sub> <sup>+</sup> -N + NH <sub>3</sub> -N). APHA 4500-NH <sub>3</sub> F (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.010 g/m <sup>3</sup>	1-10
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>2</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N. In-House.	0.0010 g/m <sup>3</sup>	1-10
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO <sub>3</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N <sub>org</sub> D. (modified) 4500 NH <sub>3</sub> F (modified) 22 <sup>nd</sup> ed. 2012.	0.10 g/m <sup>3</sup>	1-10
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.004 g/m <sup>3</sup>	1-10
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Martin Cowell - BSc  
Client Services Manager - Environmental Division



## ANALYSIS REPORT

<b>Client:</b>	Pattle Delamore Partners Limited	<b>Lab No:</b>	1399945	SPv2
<b>Contact:</b>	R Nicol C/- Pattle Delamore Partners Limited PO Box 389 CHRISTCHURCH 8140	<b>Date Registered:</b>	19-Mar-2015	
		<b>Date Reported:</b>	30-Mar-2015	
		<b>Quote No:</b>	66725	
		<b>Order No:</b>		
		<b>Client Reference:</b>		
		<b>Submitted By:</b>	R Nicol	

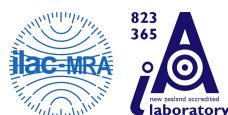
### Amended Report

This report replaces an earlier report issued on the 26 Mar 2015 at 3:07 pm  
 Carbonate results added at clients request.

#### Sample Type: Aqueous

Sample Name:	BHA 18-Mar-2015 9:32 am	BHB 18-Mar-2015 11:51 am	BHC 18-Mar-2015 1:33 pm	BHD 18-Mar-2015 12:43 pm	BHE 18-Mar-2015 10:31 am
Lab Number:	1399945.1	1399945.2	1399945.3	1399945.4	1399945.5
Sum of Anions meq/L	3.2	2.4	2.5	3.8	2.0
Sum of Cations meq/L	3.4	2.2	2.6	3.9	2.2
pH pH Units	6.4	6.8	6.7	6.8	5.8
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	38	53	65	94	5.0
Carbonate g/m <sup>3</sup> at 25°C	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	47	64	79	114	6.2
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	72	45	57	102	57
Electrical Conductivity (EC) mS/m	36.8	25.0	26.3	38.6	24.0
Total Suspended Solids g/m <sup>3</sup>	169	48	9	1,100	20
Dissolved Calcium g/m <sup>3</sup>	13.5	8.0	10.0	18.7	7.8
Dissolved Iron g/m <sup>3</sup>	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Magnesium g/m <sup>3</sup>	9.3	6.2	7.8	13.4	9.2
Dissolved Manganese g/m <sup>3</sup>	0.091	0.70	0.97	1.28	0.023
Dissolved Potassium g/m <sup>3</sup>	1.87	1.16	1.32	2.2	1.82
Dissolved Sodium g/m <sup>3</sup>	44	27	32	41	22
Chloride g/m <sup>3</sup>	64	32	31	35	50
Total Nitrogen g/m <sup>3</sup>	5.3	0.3	< 0.3	0.9	2.4
Total Ammoniacal-N g/m <sup>3</sup>	0.010	0.116	0.029	0.100	< 0.010
Nitrite-N g/m <sup>3</sup>	0.002	< 0.2 #1	< 0.2 #1	< 0.2 #1	< 0.002
Nitrate-N g/m <sup>3</sup>	5.2	< 0.2	< 0.2	< 0.2	2.3
Nitrate-N + Nitrite-N g/m <sup>3</sup>	5.2	< 0.2 #1	< 0.2 #1	< 0.2 #1	2.3
Total Kjeldahl Nitrogen (TKN) g/m <sup>3</sup>	0.15	0.22	0.13	0.79	< 0.10
Dissolved Reactive Phosphorus g/m <sup>3</sup>	< 0.004	0.109	0.018	0.009	< 0.004
Sulphate g/m <sup>3</sup>	14.6	19.9	18.0	43	17.5

Sample Name:	MR1 18-Mar-2015 2:45 pm	MR2 18-Mar-2015 2:25 pm	BDA 18-Mar-2015 2:10 pm	BD3 18-Mar-2015 3:05 pm	S4 18-Mar-2015 11:00 am
Lab Number:	1399945.6	1399945.7	1399945.8	1399945.9	1399945.10
Sum of Anions meq/L	3.5	1.60	13.0	28	4.4
Sum of Cations meq/L	3.5	1.81	12.8	29	4.6
pH pH Units	7.9	7.8	7.1	8.3	7.2
Total Alkalinity g/m <sup>3</sup> as CaCO <sub>3</sub>	88	44	50	700	63
Carbonate g/m <sup>3</sup> at 25°C	< 1.0	< 1.0	< 1.0	7.3	< 1.0
Bicarbonate g/m <sup>3</sup> at 25°C	107	53	60	840	77
Total Hardness g/m <sup>3</sup> as CaCO <sub>3</sub>	54	51	89	144	76
Electrical Conductivity (EC) mS/m	36.8	17.5	146.2	283	50.2
Total Suspended Solids g/m <sup>3</sup>	10	5	9	99	5





Sample Type: Aqueous						
Sample Name:	MR1 18-Mar-2015 2:45 pm	MR2 18-Mar-2015 2:25 pm	BDA 18-Mar-2015 2:10 pm	BD3 18-Mar-2015 3:05 pm	S4 18-Mar-2015 11:00 am	
Lab Number:	1399945.6	1399945.7	1399945.8	1399945.9	1399945.10	
Dissolved Calcium	g/m <sup>3</sup>	14.2	12.7	28	48	17.9
Dissolved Iron	g/m <sup>3</sup>	0.26	0.32	0.58	0.13	0.07
Dissolved Magnesium	g/m <sup>3</sup>	4.6	4.7	4.8	6.0	7.6
Dissolved Manganese	g/m <sup>3</sup>	0.0012	0.0013	0.031	0.099	0.023
Dissolved Potassium	g/m <sup>3</sup>	6.5	1.58	2.6	79	6.0
Dissolved Sodium	g/m <sup>3</sup>	39	16.8	250	340	58
Chloride	g/m <sup>3</sup>	43	18.9	360	360	83
Total Nitrogen	g/m <sup>3</sup>	9.9	0.76	5.2	140	10.7
Total Ammoniacal-N	g/m <sup>3</sup>	8.1	0.026	0.74	131	5.7
Nitrite-N	g/m <sup>3</sup>	0.102	0.011	0.074	0.78	0.22
Nitrate-N	g/m <sup>3</sup>	0.57	0.33	2.0	0.47	4.4
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	0.67	0.34	2.1	1.25	4.6
Total Kjeldahl Nitrogen (TKN)	g/m <sup>3</sup>	9.2	0.42	3.2	139	6.1
Dissolved Reactive Phosphorus	g/m <sup>3</sup>	0.97	0.030	0.43	14.7	0.184
Sulphate	g/m <sup>3</sup>	17.0	8.0	81	131	23

### Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NO<sub>2</sub>N, NO<sub>3</sub>N and NO<sub>x</sub>N analysis.

## SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-10
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	1-10
Total anions for anion/cation balance check	Calculation: sum of anions as mEq/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22 <sup>nd</sup> ed. 2012.	0.07 meq/L	1-10
Total cations for anion/cation balance check	Sum of cations as mEq/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H <sup>+</sup> ) also included in calculation if available. APHA 1030 E 22 <sup>nd</sup> ed. 2012.	0.05 meq/L	1-10
pH	pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-H <sup>+</sup> B 22 <sup>nd</sup> ed. 2012.	0.1 pH Units	1-10
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2320 B (Modified for alk <20) 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Carbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> at 25°C	1-10
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22 <sup>nd</sup> ed. 2012.	1.0 g/m <sup>3</sup> as CaCO <sub>3</sub>	1-10
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2510 B 22 <sup>nd</sup> ed. 2012.	0.1 mS/m	1-10
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D 22 <sup>nd</sup> ed. 2012.	3 g/m <sup>3</sup>	1-10
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22 <sup>nd</sup> ed. 2012.	-	1-10
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.0005 g/m <sup>3</sup>	1-10
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.05 g/m <sup>3</sup>	1-10
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 <sup>nd</sup> ed. 2012.	0.02 g/m <sup>3</sup>	1-10
Chloride	Filtered sample from Christchurch. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl <sup>-</sup> E (modified from continuous flow analysis) 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m <sup>3</sup> is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m <sup>3</sup> , the Default Detection Limit for Total Nitrogen will be 0.11 g/m <sup>3</sup> .	0.05 g/m <sup>3</sup>	1-10
Total Ammoniacal-N	Filtered sample from Christchurch. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH <sub>4</sub> -N = NH <sub>4</sub> <sup>+</sup> -N + NH <sub>3</sub> -N). APHA 4500-NH <sub>3</sub> F (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.010 g/m <sup>3</sup>	1-10
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>2</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO <sub>2</sub> N. In-House.	0.0010 g/m <sup>3</sup>	1-10
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO <sub>3</sub> <sup>-</sup> I 22 <sup>nd</sup> ed. 2012.	0.002 g/m <sup>3</sup>	1-10
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N <sub>org</sub> D. (modified) 4500 NH <sub>3</sub> F (modified) 22 <sup>nd</sup> ed. 2012.	0.10 g/m <sup>3</sup>	1-10
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22 <sup>nd</sup> ed. 2012.	0.004 g/m <sup>3</sup>	1-10
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B 22 <sup>nd</sup> ed. 2012.	0.5 g/m <sup>3</sup>	1-10

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

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Martin Cowell - BSc  
Client Services Manager - Environmental Division