T:B.15 Evaluation of Soils Receiving Takapau Wastewater

Prepared for

Central Hawke's Bay District Council

Prepared by

Lowe Environmental Impact

December 2020

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TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

Central Hawke's Bay District Council ("CHBDC") are currently investigating options for the upgrade of the Takapau Wastewater Treatment Plant ("TWWTP") discharge. Incorporation of a land treatment system for part or all of the wastewater discharge from the TWWTP has been identified as an option for future discharge.

A neighbouring property to the TWWTP has been evaluated for its suitability to receive applied wastewater with site investigations taking place on the 8th and 9th of October 2020 by Lowe Environmental Impact ("LEI") staff. This management unit contains three property parcels with two of these identified as potential land to receive wastewater. These two parcels will collectively be referred to as the Drummond Farm and comprise 42.4 ha. This report presents the results, and discusses the key findings following these site investigations.

Investigations included:

- A site survey (both site walkover and drone flyover);
- Soil descriptions (desktop and on-site topsoil investigations);
- Hydraulic conductivity measurements; and
- Soil chemistry measurements.

The Drummond Farm is located on a river plain adjacent to the Makaretu River. The bulk of the site is located on an upper terrace. The area adjacent to the river is on a lower terrace around 4-5 m lower than the rest of the site. Six soil types were identified on-site being:

- Ashburton Sandy Loam (13 ha);
- Tikokino Shallow and Stony Silt Loam (10 ha);
- Ruataniwha Silt Loam (7 ha);
- Tikokino Silt Loam (7 ha);
- Takapau Silt Loam (4 ha); and
- Oronoko Silt Loam (2 ha)

A soil map is given in Appendix A.

Soil hydraulic conductivity is a measure of the rate water can enter and move through soil. Measured soil saturated hydraulic conductivity (K_{sat}) reflected the soil types identified and ranged between 26 mm/h and 119 mm/h. Measured unsaturated hydraulic conductivity ($K_{-40\ mm}$) reflected the current site management with rates in the order of 4 mm/h in pasture (uncultivated) and 9 mm/h in recently cultivated areas.

For long term discharge of low strength wastewater such as treated municipal wastewater a rate of up to 29 mm/d is considered sustainable for soil health of uncultivated land. It should be noted however, that the actual application depth on any day will be influenced by plant demand, the depth to groundwater and the sensitivity of groundwater at the site and may be less than the design irrigation rate of 29 mm/d.

Soil testing indicates that the Drummond farm has high fertility, likely due to the sites management history. The capacity to retain phosphorus is low to medium which may have implications for the amount of phosphorus that can be applied to the site to avoid losses from the soil profile. This may result in a lower application depth than can be supported by the soil hydraulic conductivity.

The total irrigable area of the site is considered to be approximately 37 ha, however it is likely that up to a maximum of 30 ha will be used due to conceptual irrigation layouts and accessibility for a centre pivot system. Under this maximum irrigable area of 30 ha and incorporating the uncultivated land irrigation rate of 29 mm/d for a daily maximum application event, the site is able to receive and assimilate ~8,640 m^3 of wastewater. It should be noted however, that the actual application depth on any day will be influenced by the depth to groundwater and sensitivity of groundwater on the site and may be less than the design irrigation rate of 29 mm/d for uncultivated land.

The number of days and actual rate of application is needed to determine the average, maximum (dry year) and minimum (wet year) volumes of wastewater to be applied to the site. Additional information is used to determine the annual volume specifically, daily wastewater flow records and daily climate data. This work is currently underway. If sufficient storage is available, and days suitable for discharge are high enough the site is likely to be sufficient to receive all of the TWWTP flows.

2 INTRODUCTION

2.1 Background

Central Hawke's Bay District Council ("CHBDC") are currently investigating options for the upgrade of the Takapau Wastewater Treatment Plant ("TWWTP") discharge. Incorporation of a land treatment system for part or all of the wastewater discharge from the TWWTP has been identified as an option for future discharge.

Currently, CHBDC hold resource consent (AUTH-109612-03) allowing the discharge of Takapau's wastewater from the TWWTP to the nearby Makaretu River, a tributary of the Tukituki River, via a wetland. This consent is scheduled to expire on the 31st of October 2021.

A neighbouring property to the TWWTP has been evaluated for its suitability for receiving wastewater. Site investigations took place on the 8th and 9th of October 2020 by LEI staff. This property contains three property parcels in total with two of these likely to receive wastewater. These two parcels will collectively be referred to as the Drummond Farm. This report presents the results of the site investigations and discusses the key findings following these site investigations.

2.2 Scope

This report gives the results of the site investigations for this nearby property. Information provided includes:

- A site description and location information;
- Details of the soil investigation methodology and results of these soil investigations;
- Soil hydraulic parameters measured for the site; and
- Soil chemistry parameters measured for the site.

3 SITE DESCRIPTION AND LOCATION

3.1 Site Description

The Takapau community is located in the Central Hawke's Bay region, ~35 km north-east of Dannevirke and 20 km west of Waipukurau along State Highway 2. The Takapau WWTP is located at 53 Burnside Road, approximately 1.5 km north-east of Takapau. Surrounding the WWTP to the west of Burnside Road, lies the Drummond Farm. This property encompasses a total of three land parcels. The parcel located on the corner of Burnside Road and SH2, extending to the Makaretu River is owned by the Drummond family. The remaining two parcels, also extending between SH2 and the Makaretu River are leased to the Drummonds. It is likely that with wastewater irrigation, only the two easterly parcels (one owned and one leased) will be utilised. No site investigations occurred on the western leased parcel.

This property has been identified to potentially receive Takapau's wastewater, primarily due to its proximity to the WWTP and likely suitable land use and soil conditions to assimilate applied wastewater. At the time of the investigation this farm was used for drystock farming and the growing of fodder crops such as barley and oats.

Details of the owned and eastern leased parcel are provided in Table 3.1. Figure 3.1 represents the location of the three parcels operated by the Drummond's. The township of Takapau is located directly to the south. The yellow parcel outline represents the owned parcel, with blue parcel outlines representing the two leased parcels.

Table 3.1: Drummond Farm Site Details

	Owned Parcel	Leased Eastern Parcel
Legal description	Part Lot 1 DP 15623	Lot 1 DP 16445
Property address	45 Burnside Road	4292 State Highway 2
Map ref, centre of site	1886370.7, 5565315.0	1885953.1, 5565134.3
Area (ha)	23.5	18.9
Distance to WWTP via road networks (km)	1.5	1.2

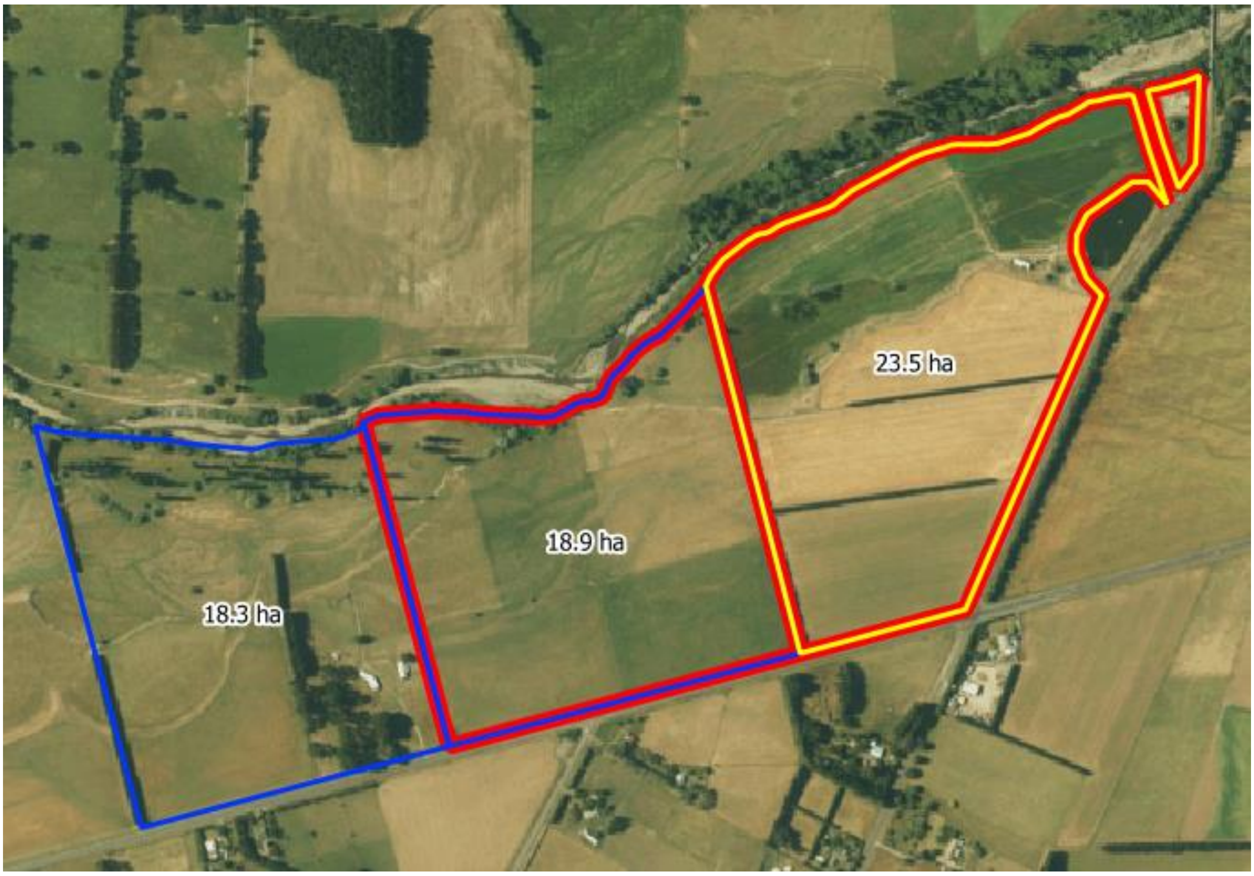

Figure 3.1: Drummond Farm Site – Blue = Leased, Yellow = Owned, Red = Proposed Application Site

3.2 Waterways and Topography

The Site is located across a series of river terraces formed by the nearby Makaretu River running along the property's northern extent. From elevation imagery taken during site investigations, there is evidence for at least four river terraces extending throughout the property (Section 4.2.2). Of these terraces, there appear to be two clear terraces, a lower terrace adjacent to the Makaretu River extending predominantly throughout the owned parcel's northern extent, as well as a higher terrace to which the remaining property overlies. Across this higher terrace, there appears to be three respective terraces with minor variations in elevation that can only be distinctively noticed with elevation imagery.

The variation in elevation between the lower terrace adjacent to the Makaretu, and the higher terrace, is in the order of 4-6 metres. Elevations across the site vary between 230-246 m.a.s.l.

3.3 Infrastructure in Locality

There are two dwellings within the western leased parcel which belong to the landowner for these leased parcels. The building near the wastewater pond within the owned parcel is a hayshed and does not house anyone and is simply for storage purposes. Outside of the property boundaries, a series of dwellings are located on the opposite side of SH2 roughly 40-50 m from the southern property boundary.

An enquiry was made to determine utilities within the Drummond Farm. The First Gas high pressure transmission pipeline extending from Palmerston North to Hastings runs through the property (First Gas, 2020). The positioning of this pipeline is well marked within the eastern leased parcel with this then running across the owned parcel, connecting along Burnside Road and over the Makaretu River bridge. Across the eastern leased parcel, this pipeline runs at a diagonal in a south-west to north-east direction before moving east over the owned parcel to connect with Burnside Road.

3.4 District Plan

The Site is located within the Rural Zone under the Central Hawke's Bay District Plan maps (Map 12).

3.5 Flooding Risk

According to HBRC (2020), the lower terrace mentioned within Section 3.2 is identified as being a *'flood risk area.'* This flood modelling is based on a 100 year return interval or a 1% annual exceedance probability. The rest of the site residing on the higher terrace is at minimal risk of flooding from the Makaretu River.

4 SOIL INSPECTION AND DESCRIPTION

4.1 General

An initial desktop assessment of land surrounding the Takapau WWTP was undertaken which identified the suitability of the neighbouring property (45 Burnside Road) to potentially receive Takapau's wastewater (Figure 1, Appendix A). Field investigations were undertaken where the property of interest was examined through:

- A site survey (both site walkover and drone flyover);
- Soil descriptions (desktop and on-site topsoil investigations);
- Hydraulic conductivity measurements; and
- Soil chemistry measurements.

Desktop soil descriptions as well as soil hydraulic conductivity and chemical analysis results are presented in the following sections.

4.2 Site Survey

4.2.1 Purpose

On site ground/aerial surveys are designed to give a better understanding of the designated application site prior to further work taking place. These investigations allow comparisons to be made between what has been identified through desktop site analysis and what is noted on site. This is important as it enables aspects that may be missed or not made aware of during a simple desktop analysis to be identified and examined. Furthermore, on site investigations enable parameters such as soil boundaries and conditions or elevations to be measured with higher accuracy than what may have been simply modelled through a desktop study.

Information gathered during the survey included:

- Current land uses;
- Identification of landforms within the investigation area;
- Land condition;
- Location and type of erosion/deposition features; and
- Assessment of similarities and disparities between testing sites.

4.2.2 Site Observations

Specific site and soil observations were undertaken at four sites across the farm. Here soil hydraulic conductivity was measured, alongside topsoil identification and site assessments. The site locations are shown in Figure 2, Appendix A. Site 1 was on the lower terrace, Site 2 adjacent to Burnside Road within a barley paddock, Site 3 on the poorly drained mapped soil within the leased parcel adjacent to the Makaretu River and Site 4 was near SH2 within the leased parcel. The following sub-sections describe key site characteristics:

Current Land Uses

The Drummond farm can be described as a low intensity sheep and cattle finishing block with rotational cropping on blocks nearest to Burnside Road. During Site investigations, there were a mixture of older (4) and younger (~20) (<1 year) finishing cattle, as well as a few older aged sheep present on Site. The total number of stock present on Site (sheep and cattle), would have been between 20-30 individuals, all grazing on the lower terrace.

In terms of vegetation cover, the farmer mentioned that much of the Site area had been cultivated and resown in either ryegrass or a barley crop over recent months. On the higher terrace of the owned block, the three paddocks between the two shelter belts adjacent to Burnside Road, were all recently (<2 months), been cultivated and resown in barley. There did not appear to be any significant variation in pasture growth across any of the paddocks, nor were there any signs of limited plant growth or crop failure.

For the land on the lower terrace of the owned parcel, this was covered in ryegrass, with no signs of any recent cultivation.

Within the leased parcel, much of these paddocks had been cultivated and resown in ryegrass over recent months. Southern land closest to SH2 appeared to have been cultivated and resown first (>6 months) with significant pasture cover established. Land within the central/northern extent of the leased parcel had also been cultivated, however over a more recent timeframe (<3 months). Land adjacent to the Makaretu River on the leased parcel predominantly on the lower terrace, had most recently been cultivated and resown in ryegrass for the entire farm (<1 month). Overall, across the farm there did not appear to be any indication of limited pasture growth or crop failure.

<u>Identification of Landforms within the Investigation Area</u>

The Site is situated on the Takapau Plains, a relatively flat series of alluvial river terraces with a gentle slope northwards towards the Makaretu River.

Across the property there appear to be the presence of four river terraces with two clear terraces distinguishable from elevation imagery (Figure 4.1). The lower terrace adjacent to the Makaretu River is clearly represented with this being elevated ~2 m above the river, with an elevation of between 230-236 m depending on location.

In Figure 4.1, blue regions represent lower lying elevations, with red/orange representing higher elevations.

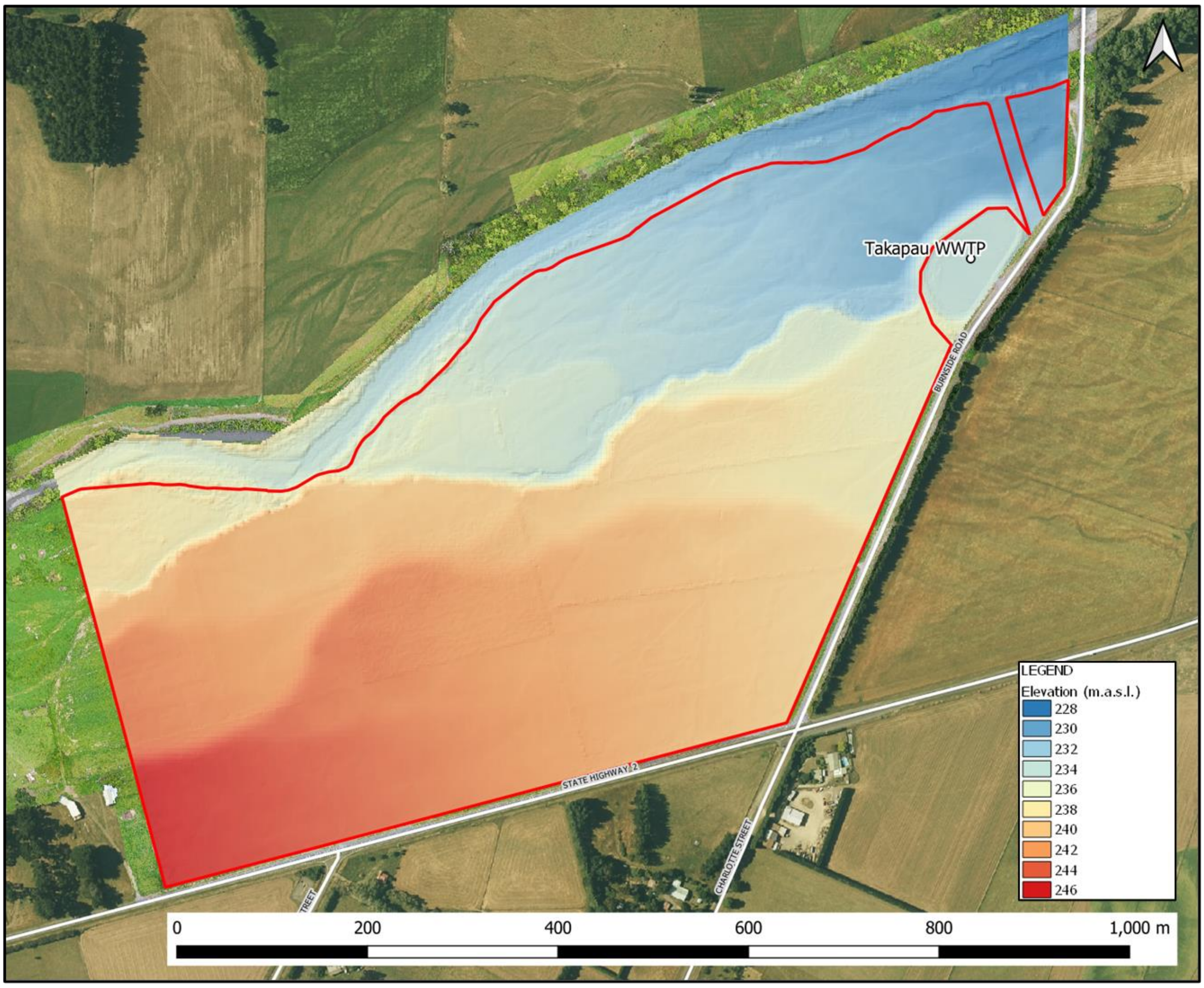

Figure 4.1: Elevation Map of the Drummond Farm

The higher river terrace is located at an elevation of 238-246 m.a.s.l depending on location. When viewing through an elevation map, there appear to be two smaller, less noticeable river terraces that form this larger higher terrace. These terraces are difficult to notice from both aerial imagery and site investigations and are <2 m above the main higher terrace. It is likely that these older terraces may have undergone erosion and subsequently seem to blend into the landscape of this higher terrace.

The difference between the main upper and lower terraces is in the order of 4-6 m, with this difference represented through a steep slope that acts as a paddock boundary.

Land Condition

Following site investigations, there did not appear to be any significant limitations of the Site to receiving wastewater. Due to recent cultivation across the majority of the Site, pasture growth of resown ryegrass/barley and variation of this growth across the Site is a fairly good indicator of land conditions with regards to soil. These variations are important as essentially, they will reflect potential limiting areas for pasture growth once wastewater is applied.

At the time of the site visit, soil conditions were far drier than what would be typical for spring conditions. Although the Central Hawke's Bay region is known for prolonged dry periods, soil conditions would be expected to be wetter, considering the wettest months of the year have just passed at the time of investigations.

Aside from dry soil conditions which can be improved through irrigation, the Site appeared to be what would be expected for a Central Hawke's Bay farm, adjacent to a river overlying alluvial soils.

Location and Type of Erosion/Deposition Features

Across the Site, the most significant erosional/depositional feature is the Makaretu River. Although this river does have the potential of eroding the site through either overland flow or bank erosion, it is likely more a source of deposition of alluvial material (silts, sands and gravels). As previously mentioned, the lower river terrace is referred to by HBRC as being a flood risk area due to its limited elevation above the active river channel. Site investigations confirmed that the lower terrace is a frequent deposition zone through the presence of river gravels at the soil surface. Aside from the Makaretu River, there is no other significant erosional or depositional feature.

4.2.3 Drone Flyover

As part of field investigations, aerial imagery for the owned and eastern leased parcels were captured using a drone. Captured imagery included photos, videos and a whole site flyover. Photos and videos were taken across the site to provide a better perspective of the site to what can be experienced on the ground. These photos and videos where also used to capture key features and supply visual resources to CHBDC. Figure 4.2 to Figure 4.5 shows the site from 80 m.

Figure 4.2: Drummond Farm - NE looking SW

Figure 4.3: Drummond Farm - N looking E

Figure 4.4: Drummond Farm - N looking S

Figure 4.5: Drummond Farm - E looking W

A whole site flyover was also undertaken for the Site where prior to flying, the drone is programmed to fly designated paths over the farm, capturing continuous vertical photos of the land surface. These photos can later be stitched together to form updated aerial imagery for the entire site. This flyover is valuable as it essentially provides updated imagery that can be used to make better decisions and gives a more realistic and updated view of the Site. Drone imagery is considered to be of a high quality and greater accuracy than published aerials can provide which can at times being severely outdated, of low resolution and up to tens of metres offset from reality.

This drone flyover was undertaken over a series of individual flights to map the total area due to both the larger area needing to be mapped and the requirement of being able to see the drone from the ground at all times. The drone was flown at a height of 80 m above the starting takeoff elevation.

4.3 Soil Description

On site test pits to identify soil conditions could not be undertaken at the Drummond Farm due to the unavailability of a digger operator at the time of investigations to prepare these. Pits were not hand dug at the request of the farmer to avoid damage to recently planted crops. To substitute on site soil descriptions, a desktop analysis of soil conditions and likely soil boundaries will be undertaken. Furthermore, on site analysis of the site topsoil will be included and commented on.

Estimated soil boundaries produced through a combination of desktop investigations as well as on site observations are provided within Figure 3, Appendix A.

4.3.1 Purpose

The purpose of soil profile description is to obtain information to assess the lateral continuity of subsurface features and identify any horizons which may impede the passage of water within the soil. Changes in soil morphology due to variations in the landform and land use across the site can be used to identify areas of preference for applying wastewater.

4.3.2 Soil Descriptions

Desktop soil descriptions for the Site can be summarised as follows:

Ashburton Silt Loam (Ashb_38a.1): These soils are located overlying the lower river terrace adjacent to the Makaretu River within the northern extent of the property. This soil contains a brown silty to sandy loam topsoil texture with a strong presence of rounded river gravels ranging between 1-10 cm. This soil appeared dry at the time of investigations with no clear presence of any underlying pans.

Oronoko Silt Loam (Orono_83a.1): This is a moderately deep, moderately well drained, silty loam textured soil residing on the slope surrounding the higher and lower terraces. This soil lacks the gravels noticed within the lower lying terrace soils.

Ruataniwha Silt Loam (Ruat_7a.1): These soils are classified as being poorly drained due an underlying pan at approximately 85-95 cm depth. Evidence for this underlying pan is represented within the soil hydraulic conductivity results within Section 5. This moderately deep soil contains a brown silty topsoil texture with a moderate over slow permeability status. The observed soil correlates completely the Smap description with the only difference being stone content. Smap notes that the Ruataniwha Silt Loam is a stoneless soil, however on site, this soil contains a moderate presence of smaller rounded river gravels. Despite the variation in stoniness, this soil is still considered to be the Ruataniwha Silt Loam.

Takapau Silt Loam (Tararu_6a.1): These soils are moderately deep, well drained, silty textured soils. They contain a rapid permeability profile, however, lack the presence of stones. These typic allophanic brown type of soils are extensive across the Takapau Plains region and contain high P retention statuses.

Tikokino Silt Loam: (Mand_22a.1): This soil extends throughout much of the property extent, particularly towards the south-east. These soils contain a silty topsoil texture with a moderately well drained drainage status. Compared to surrounding soils of the property, this soil lacks the gravels component as with the Ashburton Silt Loam, with no clear presence of any underlying pans. At the time of site investigations, this soil appeared to be drier than what would be expected and drier than surrounding soil types on the property.

Tikokino Shallow and Stony Loam (Mand_25a.1): This soil is very similar to its sibling the Tikokino Silt Loam described above. The only clear difference for this soil from the Silt Loam is the strong presence of river gravels ranging in size between 1-10 cm within the topsoil. This soil appears to extend throughout much of the centre of the leased parcel and within the western extent of the owned parcel on the higher terrace.

Factsheets for each of the soils listed are available at Smap (2020) by entering the bracketed name above into the 'soil name' category.

Assessment of Similarities/Disparities between Testing Sites

Between testing sites, all contained the same topsoil structure and texture with this being a brown silty loam. The lower terrace contained the greatest proportion of gravels within the topsoil with the majority being <5 cm, making up 40-50% of the soil matrix.

Lacking the stone proportion of Site 1, Site 2 contained ~10-20% stones, with these also typically being <5 cm. Soil moisture appeared to be drier for this site compared to other sites. Variations of this site with respect to stoniness and soil moisture may be a result of the recent cultivation and resowing of barley at the site.

Sites 3 and 4 were relatively similar to one another with the only significant difference between these being soil drainage and permeability. Site 3 contained a poor soil drainage status as shown in hydraulic conductivity results in Section 5. Site 3 contained a similar stone size and volume as Site 2, with Site 4 containing the same stone volume as Sites 2 and 3, however these were larger with many <10 cm.

4.4 Soil Descriptions: Summary and Implications for Land Treatment

Evidence for river gravels as well as an underlying pan at particular locations indicate that there may be limitations to wastewater irrigation on the site. Although the majority of the site is suitable for wastewater irrigation, these limiting regions will require appropriate management, particularly land overlying the soil pan on the leased parcel.

The present land use is not considered to be a limitation to irrigation on the site, however buffers will be required. These buffers will need to be from rivers and waterways, property boundaries and any nearby dwellings. Furthermore, in terms of current land use, there must be a designated area of a particular size that has the ability of receiving wastewater year round. This therefore means that pasture or a crop unlike barley will need to be grown, which has the ability of receiving wastewater as flows from the Takapau WWTP will be continuous and must be irrigated if storage or an alternative discharge is not available.

5 SOIL HYDRAULIC CONDUCTIVITY

5.1 General

Soil hydraulic conductivity (K) of the soil is a measure of the rate at which water is able to enter soil and move through the profile. K is dependent on multiple soil properties including, particle size, mineralogy, degree of packing, permeability, porosity, and pressure head. Direct measurements of soil hydraulic conductivity can be undertaken either within the field itself or through laboratory testing methods.

5.2 Purpose

Locations for site soil hydraulic measurements were selected to give a representative picture of various soil types, land management and landforms spanning the site. By undertaking hydraulic measurements on varying soil types and landforms, areas of a property that may be limited to receiving wastewater can be identified and an appropriate designated application volume can be calculated. The locations where measurements were undertaken are provided within Figure 2, Appendix A.

The measurement of K was undertaken to allow an assessment of the ability of the site to receive wastewater under varied application regimes being, rapid infiltration into coarse gravels, high rate application to surface soil for cropping and a low rate application to surface soils for cropping.

5.3 Testing Methodology

Two testing methodologies for soil hydraulic conductivities were used as follows:

5.3.1 Soil Saturated Hydraulic Conductivity by Double Ring Infiltrometer

For determination of the soils ability to receive wastewater to the soil surface at a high rate K_{sat} was measured using a double ring infiltrometer which is a preferred method for establishing K_{sat} near the soil surface. The double ring method measures vertical flow only, eliminating possible overestimation of infiltration due to lateral flow of water within the soil.

The rings are seated level in the soil, to a depth of several centimetres, then filled with water; the outside ring first, then the internal ring. Timed recording then measures the rate of water level fall in the inner ring over time to determine K_{sat}. A total of 2-4 replicates where undertaken for each site.

5.3.2 Soil Unsaturated Hydraulic Conductivity by Plate Permeameter

For determination of the soils ability to receive wastewater to the soil surface without affecting rapid drainage, soil unsaturated hydraulic conductivity ($K_{-40\ mm}$) at the site was measured using a CSIRO plate permeameter apparatus (Perroux and White, 1988). The permeameter method enables measurement of soil near-saturated hydraulic conductivity. Near-saturated soil conditions are favoured over saturated soil conditions in consideration of low rate application sites because:

- Near-saturated conditions more closely reflect typical soil conditions; and
- Saturated hydraulic conductivity may cause overestimation of infiltration due to the initiation of bypass flow under saturated conditions.

The goal of near-saturated hydraulic conductivity tests for wastewater irrigation is to determine the rate at which the soil has the capacity to draw water into the soil matrix whereby the potential for ponding, runoff, excessive wetness and preferential flow (excessive flow through the macro-pores) is reduced. Typically, it is desired in a land application system to avoid flow through the larger macro pores. Preferential flow is an issue as it reduces the time in which soil has to interact with applied wastewater, thus reducing the volume of applied nutrients within wastewater that can be adsorbed to soil surfaces or taken up by plants. The rate at which water can flow (be absorbed) into the soil avoiding macropores is often defined as the flow rate when the matrix potential is less than -40mm (i.e. $K_{-40\ mm}$) (Sparling et al, 2004).

The plate permeameter comprises a porous plate covered with a membrane. The plate is placed on a levelled soil surface which may have a thin layer of sand added to ensure a good contact between the plate and soil is achieved. Water is held under suction in water towers above the plate. A known suction is applied to the water. The ability of the soil to draw water from the plate reflects the rate at which the soils matrix potential can effectively and sustainably accept the applied water. The soil hydraulic conductivity is determined by a relationship between a measured drop in the water level in the water tower relative to the diameter of the plate.

Measurements of the drop in water level were taken at regular intervals and continued until the drop in water level reached a steady state for at least 3 readings. Three replicate tests were performed for each site.

The plate permeameter apparatus results in three dimensional flow of water under the plate (i.e. vertical and horizontal flow is measured). In order to avoid overestimation of soil hydraulic conductivity, the measured flow is converted to one dimensional flow (i.e. vertical flow only) using the Woodings (1968) equation. Data obtained from three levels of varying matrix potential (-100, -40 and -20 mm) are used to determine to $K_{-40\ mm}$ for vertical flow.

5.4 Results

A summary of the hydraulic conductivity results is provided below. The test locations are shown in Figure 2, Appendix A.

5.4.1 Double Ring Infiltrometer Results

The K_{sat} at the surface of each of the Sites was measured in quadruplicate where possible. The average results for each of the sites are represented within Table 5.1 below.

Table 5.1: Soil Saturated (K_{sat}) Results

Testing Location	Soil Saturated Hydraulic Conductivity K_{sat} (mm/h)	Smap Drainage Class
Site 1 – Lower Terrace	119 ± 55	Well Drained
Site 2 – Barley	65 ± 48	Moderately well drained
Site 3 – Makaretu River	26 ± 29	Poorly drained
Site 4 – SH2	50 ± 33	Moderately well drained
Whole Site Average	**65 ± 41**	**-**

Infiltrometer results appear to represent good correlation with currently identified soil drainage classes given in Smap descriptions. Sites on well to moderately well drained soils, appear to have greater hydraulic conductivities than those on poorly draining soils which is to be expected.

5.4.2 Plate Permeameter Results

The plate permeameter tests were conducted in triplicate. Plots of the $K_{-40\ mm}$ results for each of the four locations on the Drummond Farm Site are given below in Figure 5.1 through to Figure 5.4. The plot shows the soil hydraulic conductivity at the three matrix potentials as mentioned in Section 5.3.2 above.

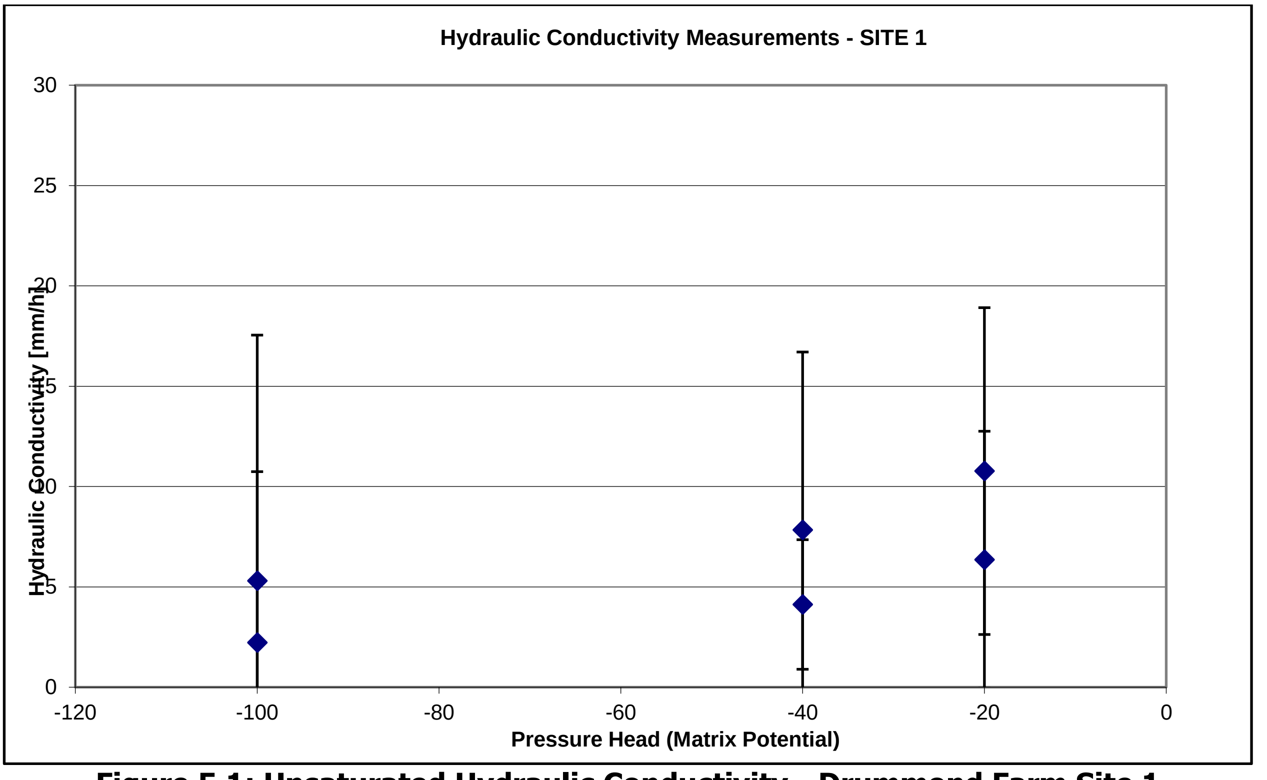

Figure 5.1: Unsaturated Hydraulic Conductivity - Drummond Farm Site 1

Site 2 below recorded the highest unsaturated hydraulic conductivity results due to the recent cultivation and sowing of the barley crop. This increase is to be expected and simply reflects the disturbance of the soil during cultivation, thus increasing the quantity of larger sized pores, thus increasing the conductivity shown below in comparison with other sites. It is likely that this value will reduce over time in no further cultivation occurs.

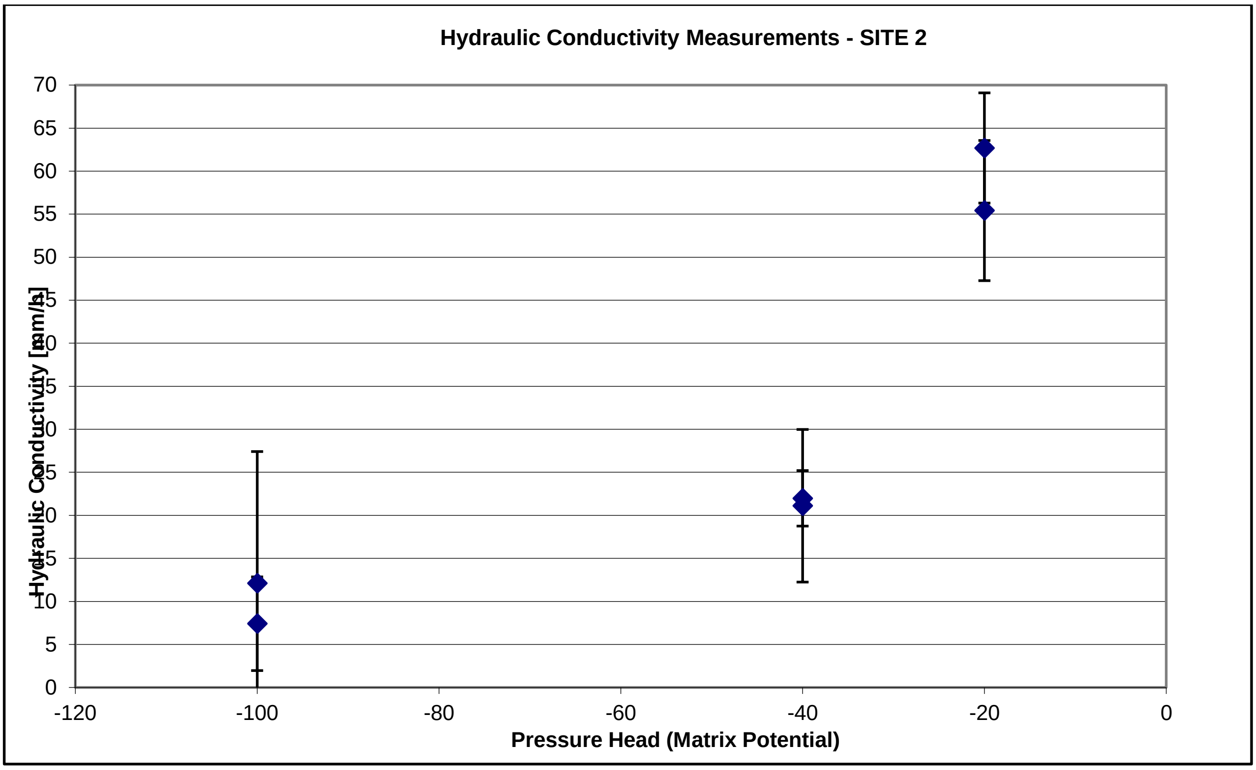

Figure 5.2: Unsaturated Hydraulic Conductivity - Drummond Farm Site 2

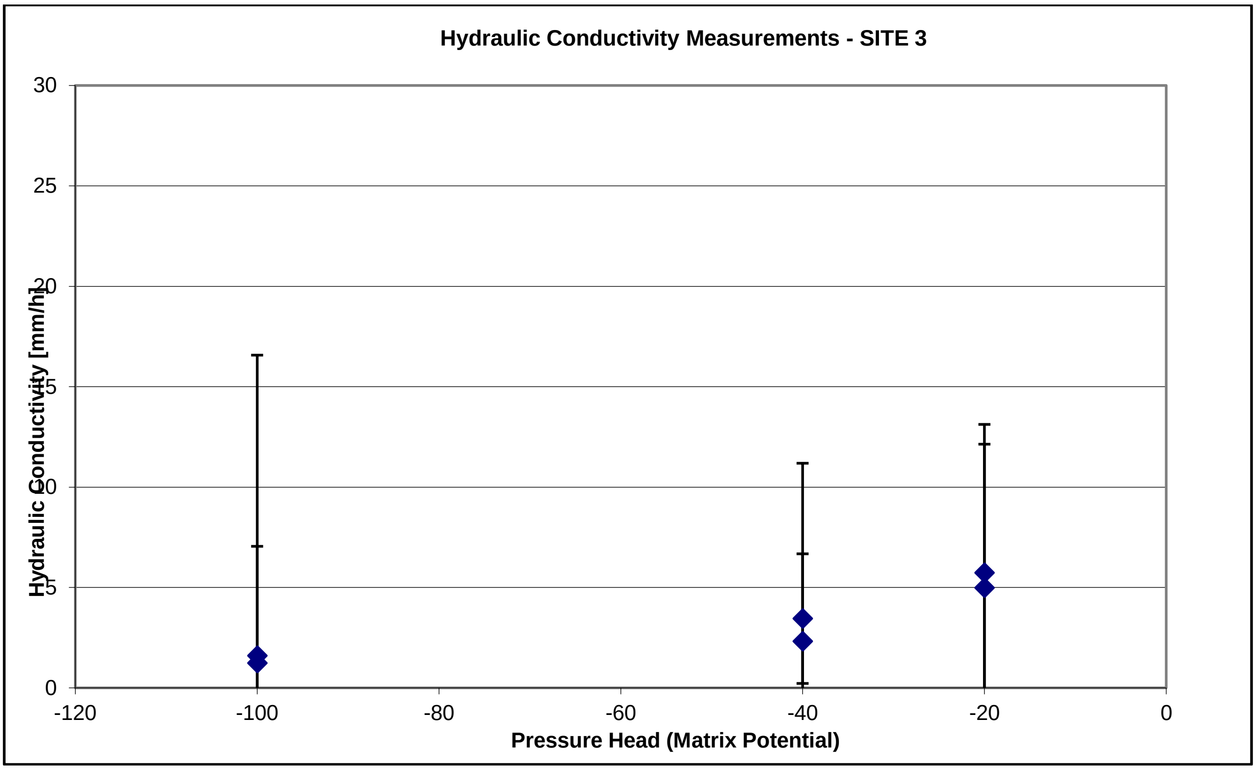

Figure 5.3: Unsaturated Hydraulic Conductivity Drummond Farm Site 3

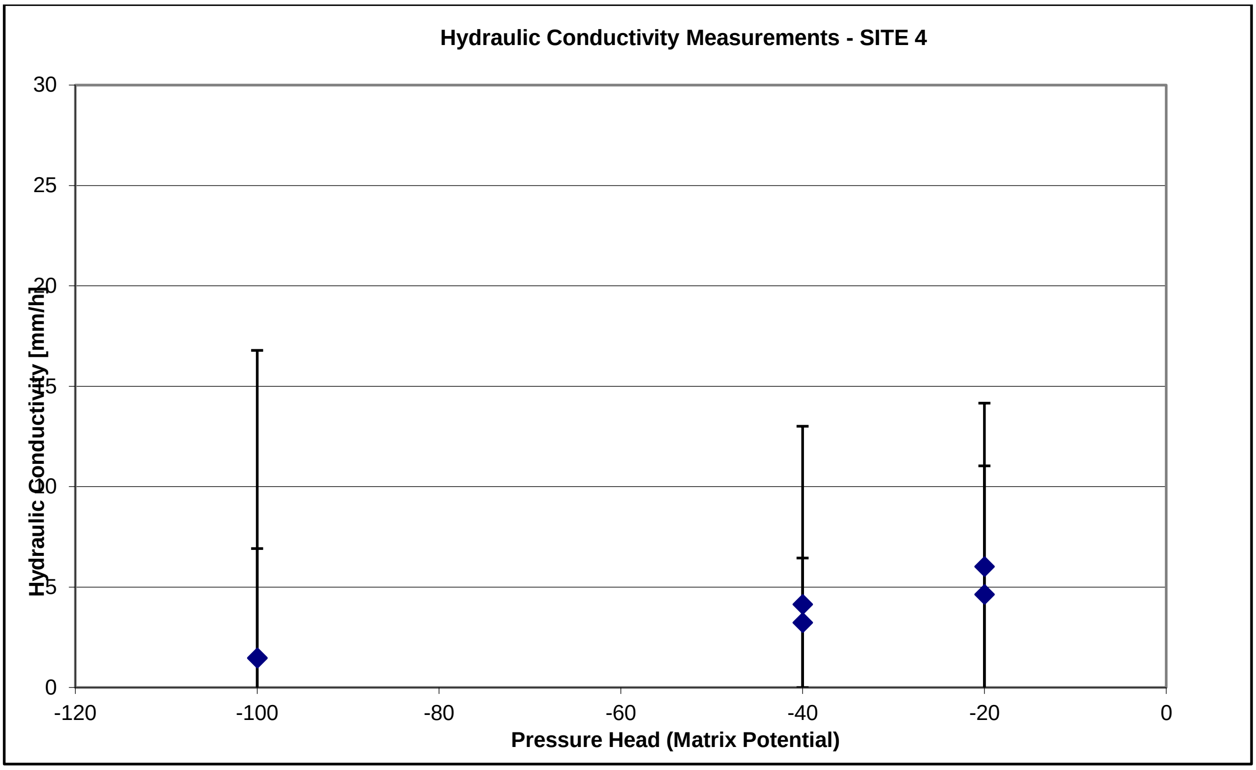

Figure 5.4: Unsaturated Hydraulic Conductivity Drummond Farm Site 4

Based on both on-site, alongside desktop observations, it is considered that the K_{-40mm} value that should be adopted for the areas currently under pasture or that have not been cultivated within the current growing season should be 4 mm. For areas that have been cultivated within the current growing season (Site 2), a K_{-40mm} of 9 mm should be adopted. Any irrigation applied to the site should be at a rate that does not exceed these respective volumes depending on the cultivation history.

5.5 Determination of Sustainable Hydraulic Loading Rate (Soil Protection)

In addition to allowing for the ability of water to enter the soil, consideration should be given to the effect of wastewater constituents, as opposed to clean water effects which are typically observed during field measurements. Organic material, solids and nutrients in the wastewater can allow the development of microbial growth commonly referred to as biofilm, which in turn can result in a 'clogging' effect of the soil pores, particularly near the soil surface. This in turn reduces the soil's infiltration capacity. In addition, the salt concentration will influence the soil wetting by altering the water tension.

There are limited empirical methods for developing an 'enriched' water rate from 'clean' water observations. This is because the rate is variable depending on the type of wastewater, nutrient and organic content, soil type, application method and application regime. A range in the order of 4 to 10 % is often used for 'clean' water to wastewater conversion (USEPA, 2006). The conversion rate implied in AS/NZS 1547:2000 ranges from 0.17 to 5 %. Both references mentioned above refer to a conversion between saturated hydraulic conductivity (not unsaturated conductivity) and wastewater application rates.

The need for 'clean' water to wastewater conversion is noted by Crites and Tchobanoglous (1998) who report an empirical method to determine a wastewater rate from a clean water measurement. The measured instantaneous rates can be translated into a daily hydraulic design irrigation rate using the following equation, which is modified from Crites and Tchobanoglous (1998):

$$P\ (\text{daily}) = K_{-40\ mm}\ (0.1\text{-}0.3)\ (24\ h/d)$$

Where:
P = the design irrigation rate
Is a function of 10-30% of the $K_{-40\ mm}$
Over 24 hours in the day.

The use of this equation and a conservative 30% function of the unsaturated (not saturated) infiltration rate at $K_{-40\ mm}$ provide a maximum hydraulic design irrigation rate of 29 mm/d (for uncultivated) and 65 mm/d (for cultivated). At this rate, the site is likely to be able to accept water without the generation of adverse effects on the immediate receiving environment and the soils itself. This is considered the maximum rate that can be accepted by the site however, consideration needs to be given to the resulting nutrient loading, land management practices and the site's attenuation ability, which may result in a reduction of the actual rate.

5.6 Soil Hydraulic Properties: Implications for Land Treatment

The average soil saturated hydraulic conductivity (K_{sat}) is 65 ± 41 mm/hr. The unsaturated hydraulic conductivity ($K_{-40\ mm}$) is 4 mm/hr for uncultivated land and 9 mm/hr for cultivated land within the current growing season. In order to avoid excessive loss of water, nutrients and other contaminants to adjacent surface water a rate more closely related to the $K_{-40\ mm}$ is recommended. For long term discharge with a short irrigation return time a rate of up to 29 mm/d (for uncultivated) and 65 mm/d (for cultivated) is recommended for the Drummond Farm Site.

It should be noted that these values reflect a rate that is considered sustainable for maintenance of soil health. Protection of groundwater and plant health may require a reduction in the irrigation rates.

6 SOIL CHEMISTRY

6.1 Soil Chemistry Sampling

Sampling of soil chemistry was undertaken using a foot corer of varying depths depending on whether the site was under pasture cover (75 mm) or barley (150 mm). Samples were collected within the proximity of the same sites where infiltration testing occurred. A composite sample of 20 cores was collected per site. Foot corer samples aim to give a representative overview of site soil conditions as they relate to soil productivity. Collected samples were from the same landform type, away from potentially influencing features such as gateways, fencelines, troughs, vehicle tracks etc. These samples were sent away to Hills Laboratories with the following parameters being analysed:

6.2 Soil Chemistry Results

6.3 Soil pH

A plot of soil pH results is represented within Figure 6.1. From this, it is evident that all four sites contain slightly acidic topsoils ranging between 5.5 to 6.1 pH units. Site 3 contains the most acidic topsoil at 5.5 pH units, with Site 2 (currently in barley) containing the least acidic topsoil at 6.1 pH units. The medium pH range for a sedimentary soil underlined by Hills Laboratories is between 5.8 and 6.2 pH units. As evident, Site 2 falls outside this range with the remaining three soils all being within this range.

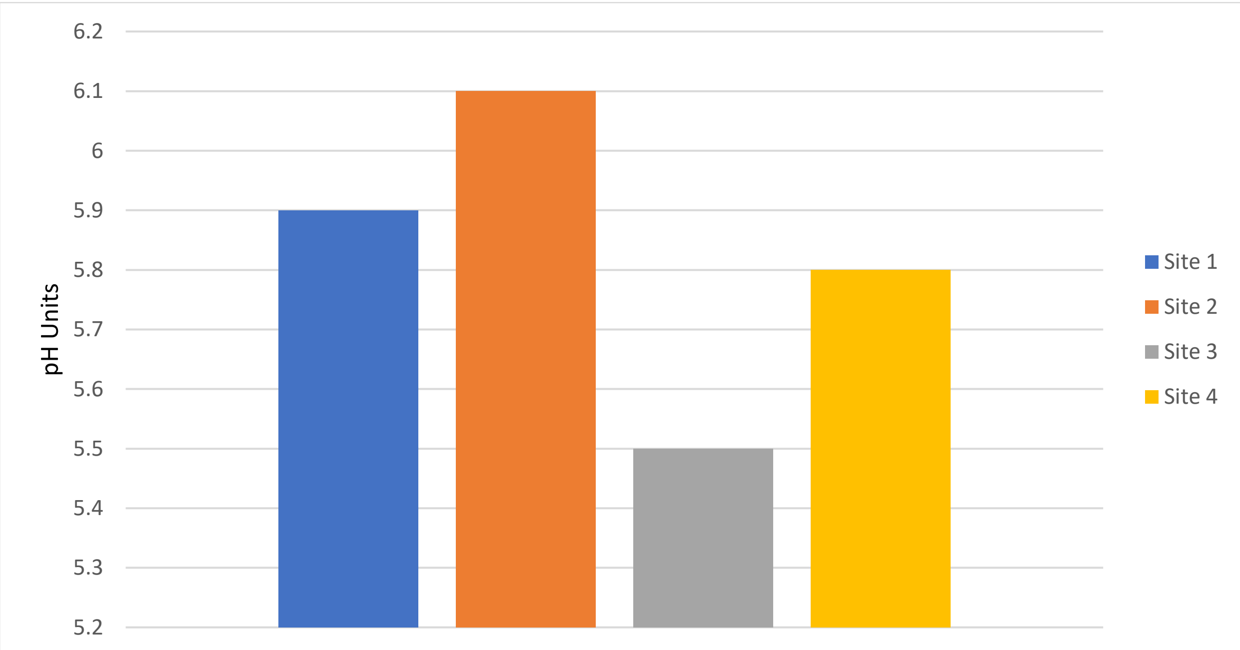

Figure 6.1: Soil pH Results

6.4 Soil Phosphorus & Anion Storage Capacity

A plot of Olsen P and Anion Storage Capacity ("ASC") results are represented within Figure 6.2 and Figure 6.3 respectively. For a sedimentary soil, the medium range for Olsen P is between 20-30 mg/L. From this figure, the lower terrace of Site 1 contains elevated concentrations of phosphorus at 65 mg/L, alongside Site 3 at 47 mg/L. Sites 2 and 4 are both within the medium range.

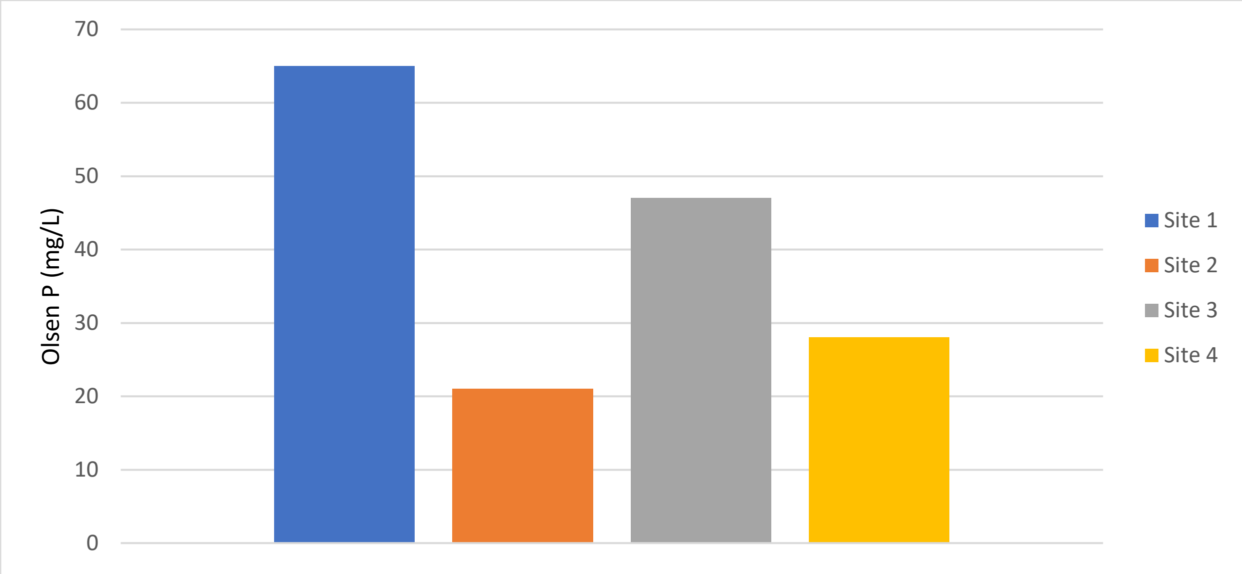

Figure 6.2: Soil Olsen P Results

From Figure 6.3, there is clear evidence that Sites 3 and 4 located on the leased Drummond property, contain higher ASC values than those on the owned Drummond parcel. For Sites 1 and 2, ASC values are classed as being low, with Sites 3 and 4 described as having medium ASC values according to Hill Laboratories typical levels (Hills Laboratories). Between these two figures, there does not appear to be a clear relationship between Olsen P and ASC. This can be represented through Site 1 for example where the site has an elevated Olsen P value, however it also has a low anion storage capacity of 16%. This is not unexpected since Olsen P is impacted by the fertiliser history of the site whereas the ASC is largely related to the soils mineralogy. The presence of allophane in the subsoil of the Takapau soils may result in higher ASC in the subsurface environment.

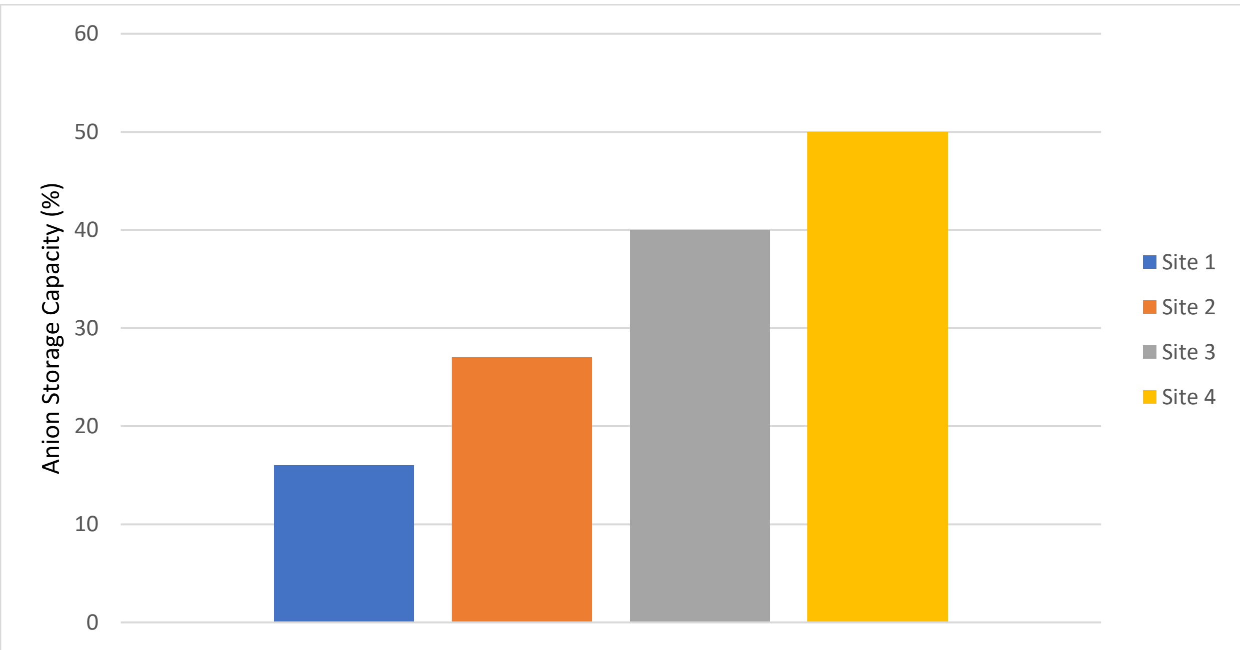

Figure 6.3: Anion Storage Capacity Results

6.5 Soil Sulphate

Sulphate-S results are represented within Figure 6.4 below. For all four sites, sulphate-S samples all fall outside of the medium range of 10-12 mg/kg for pastured sites and 10-15 mg/kg for cropped sites. From this, it is evident that Site 1 is below and Sites 3 and 4 are both slightly over the medium range for pasture. Site 2 contains elevated sulphate-S concentrations.

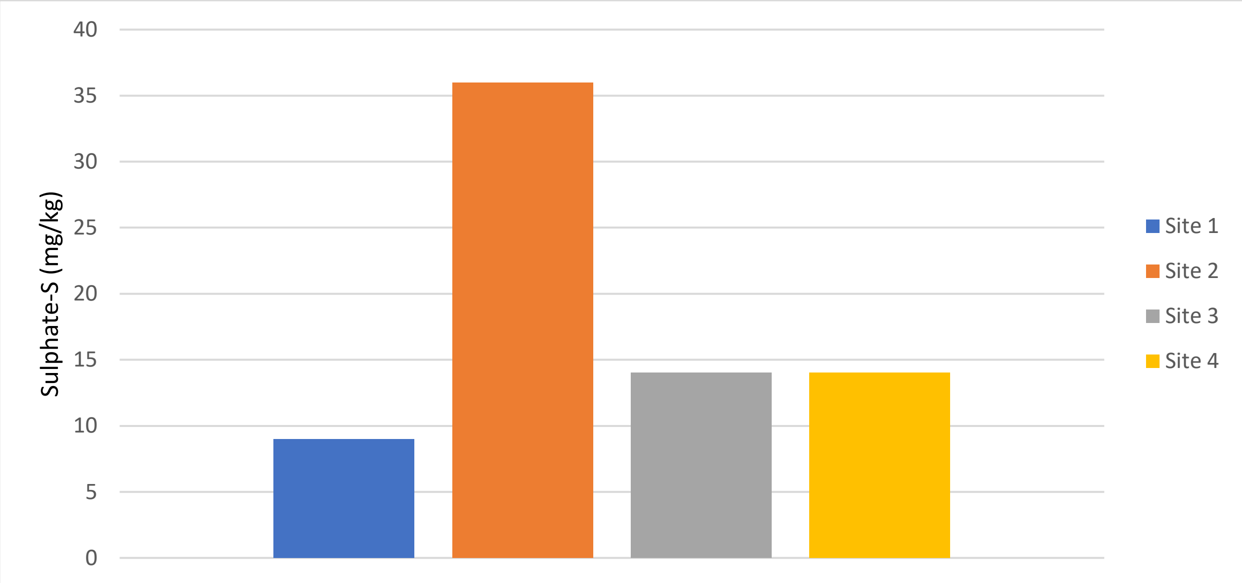

Figure 6.4: Sulphate-S Results

6.6 Carbon and Nitrogen Dynamics

Results for carbon and nitrogen concentrations are represented in Figure 6.5 through Figure 6.7. Figure 6.5 represents that soil carbon concentrations are all fairly similar for three of the four sites which fluctuate between 5.3% to 5.4%. As evident, Site 2 contains much lower total carbon concentrations at 3.4%. This is expected due to Site 2 recently being cultivated and the sowing of the barley crop occurring which reduces total soil carbon concentrations through the disturbance, mineralisation, and subsequent loss of soil carbon (Haddaway et al., 2017).

From Figure 6.6, soil nitrogen concentrations are all relatively similar throughout the site. These concentrations vary between 0.39% at Site 2, to 0.45% at Site 4. When comparing these values to those underlined by Hill Laboratories, these soil nitrogen concentrations are representative of a medium value within soil (0.2 - 0.5% Total Nitrogen) (Hills Laboratories, n.d.).

Figure 6.7 represents the C:N ratios for each of the sites. These values vary between 8.7 and Site 2, and 12.6 at both Sites 1 and 3. When comparing these values with those underlined by Hill Laboratories, it is evident that for Site 2, the C:N ratio is classed as low (8-10), and for Site 1, 3 and 4, this is classed as medium (10-15).

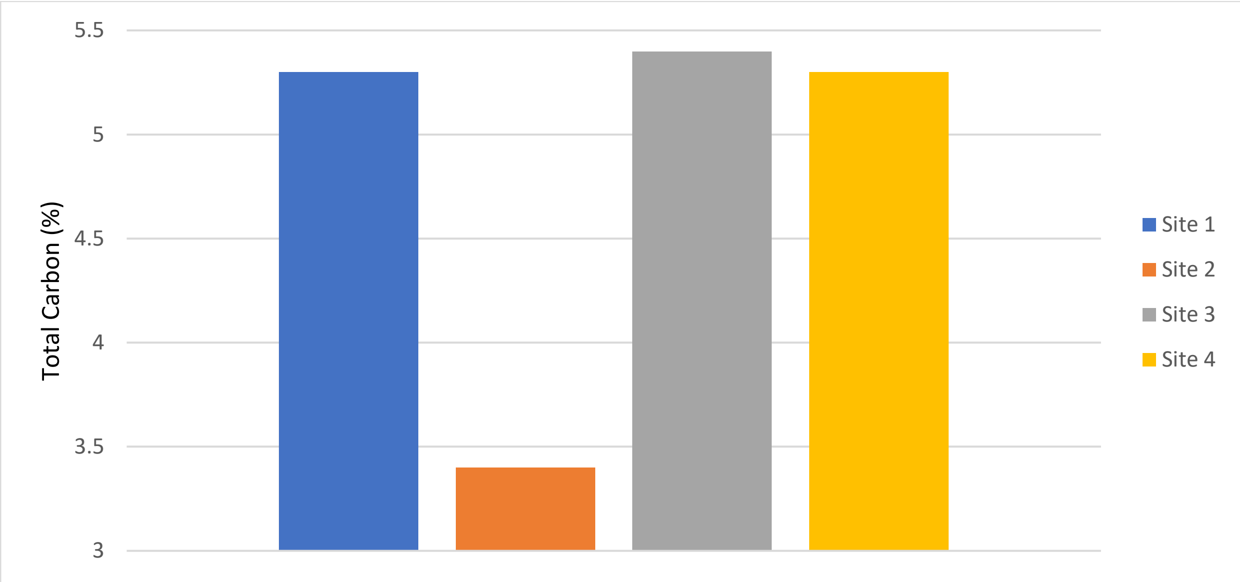

Figure 6.5: Total Carbon Results

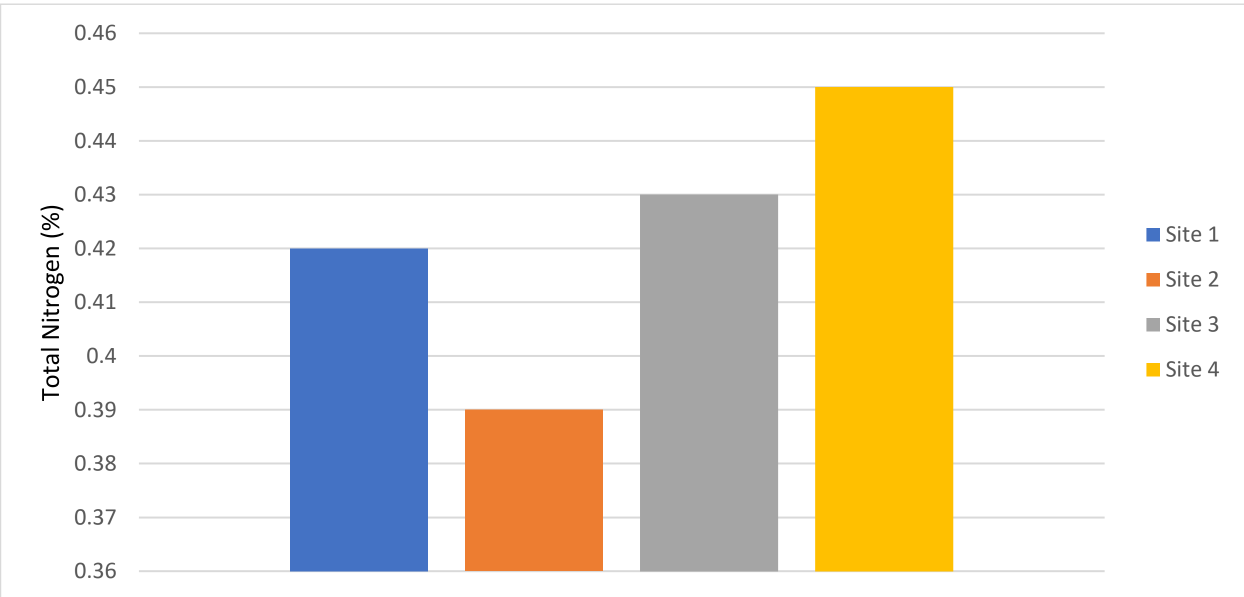

Figure 6.6: Total Nitrogen Results

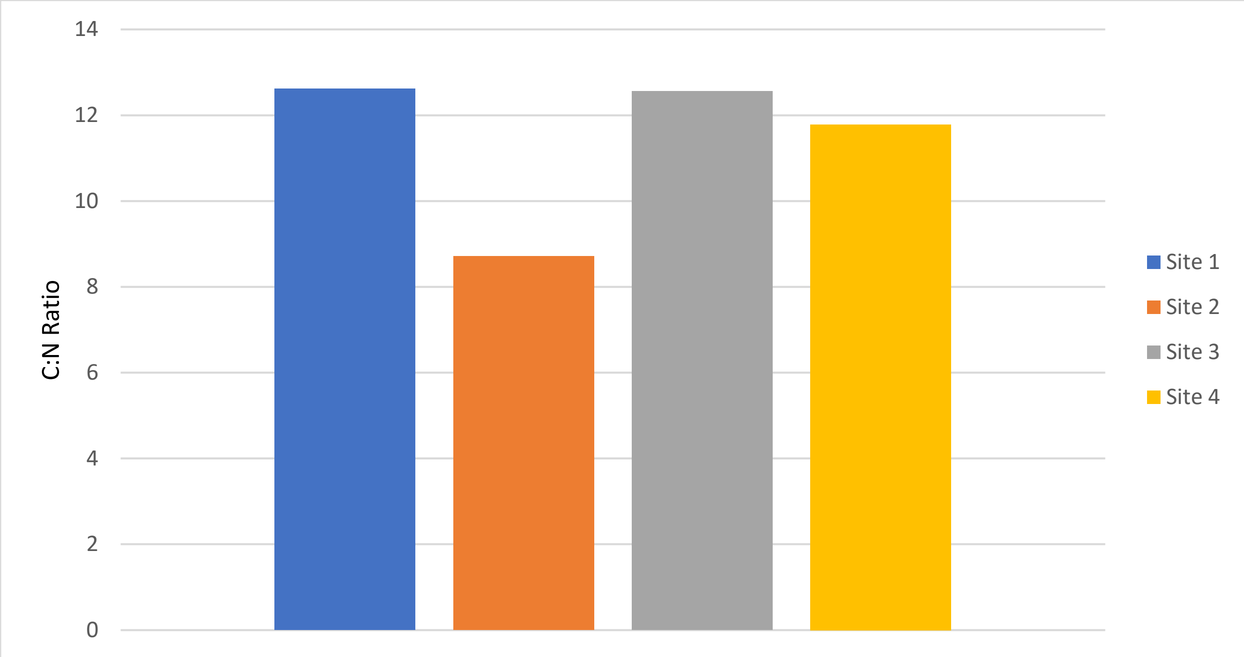

Figure 6.7: C:N Ratio Results

6.7 Cation Status and Cation Exchange Capacity

Figure 6.8 represents the variation in four key cations across the site; Potassium (K), Calcium (Ca), Magnesium (Mg) and Sodium (Na). Each of the four sites are represented moving from left to right (Site 1 = left, Site 4 = right).

For Potassium, exchangeable K is lowest at Site 4 (0.3 me/100 g), with this increasing to 0.94 me/100 g at Site 1. The medium range for exchangeable K is between 0.3-0.4 me/100 g for pasture and 0.3-0.6 me/100 g for cropping. Based on this, Site 4 concentrations reside within this range for pasture, with Site 2 being within this range for cropping practices. The remaining two sites are elevated above pasture medium ranges.

Calcium concentrations range between 6.3 me/100 g (Site 3) and 12.1 me/100 g (Site 2). In terms of medium ranges, for pasture, this is between 4.0-10.0, and between 5.0-12.0 for cropping. For pastured sites, all four sites are within the range described above. For Site 2, this site is 0.1 me/100 g above the upper limit of the medium range.

Magnesium concentrations range between 0.63 me/100 g (Site 4) and 1.5 me/100 g (Site 1). For medium ranges, these are between 0.4-0.6 me/100 g for pasture and between 0.6-1.2 me/100 g for cropping. For pastured sites, each of these three are above the Hills Laboratories range. Site 2 for cropping is between the designated medium range.

Sodium concentrations range between 0.08 me/100 g (Site 3) and 0.14 me/100 g (Site 2). There are no designated medium ranges for exchangeable sodium by Hill Laboratories however the current level are not considered to be an issue for plant growth and do not indicate any risk from irrigation of clean or enriched water.

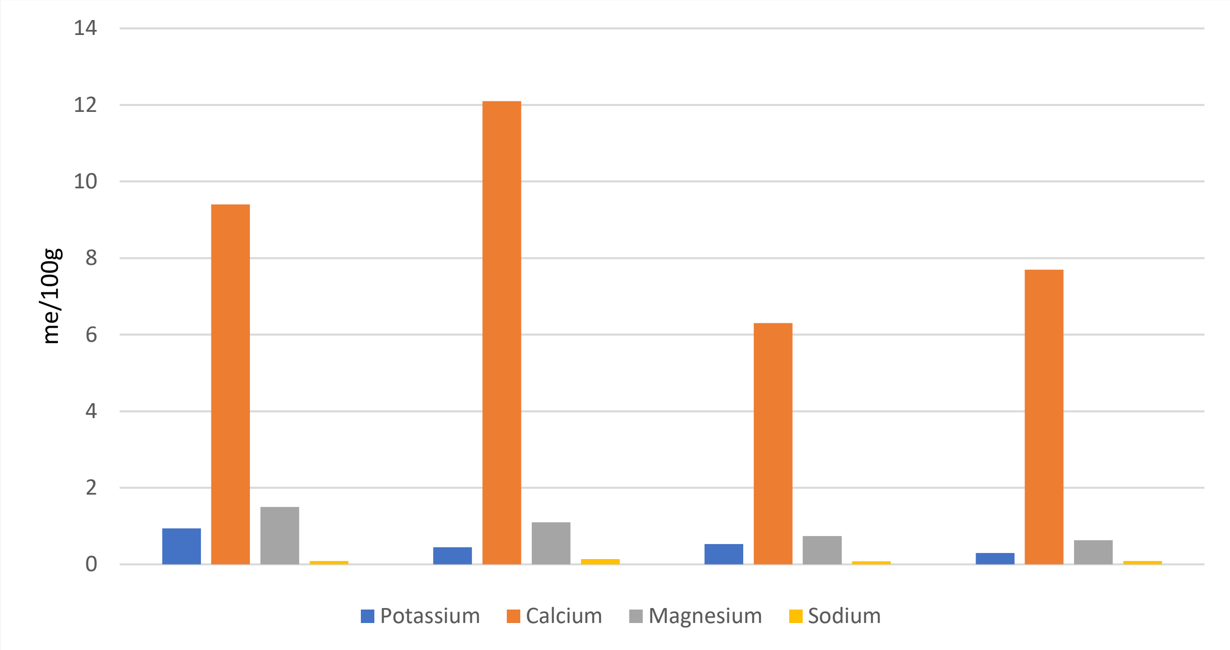

Figure 6.8: Exchangeable Cation Results

6.8 Summary of Soil Chemistry

The key implications of the soil chemical analysis results are:

- Sites within closer proximity to the Makaretu River (Sites 1 & 3) appear to have elevated Olsen P results. In contrast to this, sites located on the leased parcel (Sites 3 & 4) appear to have higher P retention (%) values (medium) than those on the owned parcel. The site on the lower terrace returned a low P retention of 16%. This may have potential implications to the volume of phosphorus that is absorbed by soil from wastewater depending on location.
- All four sites contain Sulphate-S concentrations outside of the medium range. Site 1 contains lower than medium Sulphate-S concentrations with Sites 2, 3 and 4 all containing elevated Sulphate-S concentrations.
- Site 2 contains reduced carbon concentrations than other sites which is to be expected following recent cultivation and sowing of barley, resulting in disturbance, mineralisation, and thus loss of soil carbon.
- Nitrogen concentrations are all fairly similar across the sites with C:N ratios also being fairly similar aside from Site 2 which is lower due to reduced carbon concentrations.
- For exchangeable cations, Sites 1 and 3 contain elevated potassium concentrations with all four sites being approximately within the range for calcium. For magnesium, only Site 2 is within this medium range. For all four sites, when values are not within the exchangeable cation medium ranges, these are elevated. No site contains a deficit of any of these cations (K, Ca and Mg). Medium ranges for exchangeable sulphur was not available through Hills Laboratories.

Soil chemistry results are represented with Table 6.1 below.

Table 6.1: Soil Chemistry Results

	Units	Testing Locations			
		Site 1 – Lower Terrace	Site 2 – Barley	Site 3 – Makaretu	Site 4 – SH2
Soil Sample Depth	mm	75 mm	150 mm	75 mm	75 mm
pH	pH Units	5.9	6.1	5.5	5.4
Olsen P	mg/L	65	21	47	28
Anion Storage Capacity	%	16	27	40	50
Sulphate Sulphur	mg/kg	9	36	14	14
Potassium	me/100g	0.94	0.45	0.53	0.3
Calcium	me/100g	9.4	12.1	6.3	7.7
Magnesium	me/100g	1.5	1.1	0.74	0.63
Sodium	me/100g	0.09	0.14	0.08	0.09
Total Carbon	%	5.3	3.4	5.4	5.3
Total Nitrogen	%	0.42	0.39	0.43	0.45
C:N Ratio	-	12.6	8.7	12.6	11.8
Cation Exchange Capacity	me/100g	17	18	17	17
Total Base Saturation	%	69	77	44	51
Volume Weight	g/mL	0.86	0.97	0.88	0.92

7 SITE ASSIMLATIVE CAPACTIY AND CONCLUSIONS

Site investigations have indicated that in general, the Drummond Farm soils are suitable to be used for the application of wastewater under appropriate management practices. The site is capable of assimilating up to 29 mm/d of Takapau's wastewater from an application event for land uncultivated within the past growing season and up to 65 mm/d for land cultivated within the past growing season (Site 2). At this rate of application, the applied water, nutrients and contaminants is expected to be assimilated by the soil under a regime which avoids the soils field capacity being exceeded.

The total irrigable area of the site is considered to be approximately 37 ha, however it is likely that up to a maximum of 30 ha will be used due to conceptual irrigation layouts and accessibility for a centre pivot system. Under this maximum irrigable area of 30 ha and incorporating the uncultivated land irrigation rate of 29 mm/d for a daily maximum application event, the site is able to receive and assimilate ~8,640 m^3 of wastewater. It should be noted however, that the actual application depth on any day will be influenced by the depth to groundwater on the site and may be less than the design irrigation rate of 29 mm/d for uncultivated land.

The number of days and actual rate of application is needed to determine the average, maximum (dry year) and minimum (wet year) volumes of wastewater to be applied to the site. Additional information is used to determine the annual volume specifically, daily wastewater flow records and daily climate data. This work is currently underway. If sufficient storage is available, and days suitable for discharge are high enough the site is likely to be sufficient to receive all of the TWWTP flows.

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9 APPENDICIES

Appendix A Figures

APPENDIX A

Figures