APPENDIX D

LEI Site Investigation Report

Site Investigation for Land Treatment Suitability

Prepared for

AFFCO NZ, Manawatu

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Site Investigation for Land Treatment Suitability

AFFCO NZ, Manawatu

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1 EXECUTIVE SUMMARY

AFFCO NZ, Manawatu (ANZ) is applying for renewal of a resource consent to authorise the application of wastewater to land from its meat processing plant at Feilding. The land presently receiving wastewater application is on the adjacent property owned by Byreburn Farm. The Byreburn land and additional land owned by Byreburn, ANZ and Dalcam Trust is being examined to determine suitability for wastewater application. All potential land application sites examined are referred to in this report as "the Investigation Area".

This report describes the results of an on-site investigation of the potential wastewater application sites on the 3 properties identified above. The investigation describes the characteristics of the land for its capability to assimilate discharges from the ANZ Wastewater Treatment ponds.

The results of the investigation identified that approximately 180 ha is available for irrigation within four irrigable zones that have the following characteristics:

- The predominantly flat grade of the land within the Investigation Areas is considered to be suitable for wastewater irrigation.

- Land Management Unit 1 includes Kairanga soils presently being irrigated on Byreburn Farm. All blocks within this unit have been extensively drained and are suited to receiving and transmitting irrigated wastewater within the allocated zones.

- Land Management Unit 2 includes Rangitikei soils located on Byreburn Farm adjacent to the Oroua River. This area has historically received MWE from ANZ. The area is predominantly free to excessively drained. The limitation on this LMU is avoidance of rapid drainage from the area which may result in poor nutrient removal from MWE.

- Land Management Unit 3 includes the Kairanga soils that are NOT extensively drained. Most areas are not being irrigated at present on Byreburn Farm. One block adjacent to the Byreburn milking shed is irrigated at present. With no drainage installed on these blocks, care is needed when applying wastewater to ensure the limitations of the soil are taken into account.

- Land Management Unit 4 includes a range of different soil types and management regimes. It is considered that these will most easily be managed with one single irrigation approach, being irrigation relative to the most limiting conditions. Soil types include Manawatu soils, Rangitikei soils, Parewanui/Rangitikei soils and Anthropic/Rangitikei-like soils. Management includes intensive stock holding yards, less intense stocking, organic application areas and amenity areas. The Manawatu soils are located on Dalcam Trust land and the river side of Byreburn Farm. The Rangitikei series soil types are located around the ANZ plant, and also adjacent to the Oroua River on a lower terrace adjacent to other parts of the farm. The Anthropic/Rangitikei-type soils will provide the greatest limitations for application, as they often have very stony topsoil and material under the topsoil that could be concrete and/or stones that allow rapid drainage. Irrigation application will need to be applied with care to avoid rapid infiltration that could quickly enter the ground water.

It is intended that the use of these four Land Management Units will be further refined in the development of the Conceptual Design, with buffer areas excluded and some blocks being changed to an irrigation regime different to that which has been historically used.

Additional considerations for the design of a wastewater application regime for the site include nutrient management, farm management practices and management of storage volume. Recommendations given in this report should be considered in light of these additional design issues.

2 INTRODUCTION

2.1 Background

ANZ Manawatu operates an export meat processing plant near Feilding. Applications for 11 resource consents which authorise various activities at the plant were lodged with Horizons Regional Council (HRC) in 2010 and 2011. The resource consent application relating to the discharge of treated wastewater from the ANZ plant to land has, to date, not been processed and granted. In the intervening period changes to the land area available have been proposed, including the addition of land previously not part of the irrigation scheme.

ANZ has engaged Lowe Environmental Impact (LEI) to undertake investigations to determine the capacity of the identified land to receive ANZ wastewater. The information collated will support the development of a wastewater application system and any accompanying resource consents that may be required.

The potential sites for irrigation include:

- Paddocks surrounding the ANZ Manawatu plant on Campbell Road, Feilding;
- Irrigation areas on the adjacent property at Byreburn Farm; and
- Two sites on property owned by Dalcam Trust, also adjacent to ANZ Manawatu.

These wastewater application sites are referred to as Investigation Areas for this report. Appendix A provides a Location figure to identify the Areas in the region and the Ownership figure to outline the three properties.

2.2 Scope

The scope of this report is to present information about the receiving environments over the Investigation Area and their ability to receive wastewater. The information is identified through on-site investigations with some desktop investigation to compare historical data collected from the Investigation Area.

The Sections for the report are identified and described below:

- Section 3: Site Location and Description;
- Section 4: Field Investigation, describes the methodologies used;
- Section 5: Soil Inspection and Description, presents the results from the field investigation;
- Section 6: Implications for the Investigation Area, compares the present site investigation with previous data collected for the sites; and
- Section 7: Conclusions and Recommendations.

3 SITE LOCATION AND DESCRIPTION

3.1 Site Location

ANZ Manawatu is located on the southern outskirts of the town of Feilding, around 13 km north of Palmerston North (Location Map, Appendix A). The ANZ wastewater treatment ponds are located toward the eastern boundary of the ANZ site at Lot 3 DP 89045 (Ownership Map, Appendix A). The land areas that have been identified for potential discharge of meatworks effluent are located near to the treatment ponds and are shown in the Figure titled Block Identification (Appendix A). The blue blocks identified as Byreburn Farm non-irrigated have not been included in this investigation. Details of the land areas investigated are given in Table 3.1 below. Approximate areas are provided when a land parcel is not fully incorporated into this investigation.

Table 3.1: Land Areas for Investigation

Legal Description	Owner	Cadastral Area (ha)
Part Section 225 Sbdn A Manchester DIST	Byreburn Limited	14.46
Lot 191 DP 100	Byreburn Limited	13.79
Section 5 Block XIV Oroua SD	Byreburn Limited	approx. 15
Lot 2 DP 89128	Byreburn Limited	39.97
Lot 1 DP 57580	Byreburn Limited	22.71
Lot 1 DP 89045	Byreburn Limited	19.27
Lot 2 DP 89045	Byreburn Limited	11.47
Lot 30 DP 2688	Byreburn Limited	0.61
Lot 31 DP 2688	Byreburn Limited	0.61
Lot 3 DP 89045	AFFCO New Zealand Limited	16.72
Sbdn 1 Sec 12 Block XIV Oroua SD	AFFCO New Zealand Limited	0.73
Part Section 13 Clock XIV Kairanga SD	AFFCO New Zealand Limited	18.32
Lot 28 DP 2688	AFFCO New Zealand Limited	0.67
Lot 24 DP 2688	AFFCO New Zealand Limited	0.59
Lot 23 DP 2688	AFFCO New Zealand Limited	0.6
Lot 22 DP 2688	AFFCO New Zealand Limited	0.6
Lot 21 DP 2688	AFFCO New Zealand Limited	0.6
Part Aorangi 1C Block	Dalcam Company Limited	approx. 4.09
Lot 19 DP 2688	Dalcam Company Limited	0.6
Lot 18 DP 2688	Dalcam Company Limited	0.81
TOTAL AREA		**182.49**

3.2 Site Description

The Investigation Area occupies the recent floodplain and an older terrace of the Oroua River. The Oroua River runs from north to south along the western boundary of the Site. The terrace areas (predominantly on Byreburn Farm) are flat to gently undulating and at an elevation of around 80 m above mean sea level (amsl). The floodplain areas are flat to gently rolling due to the presence of old stream channels and man-made disturbance over the areas. The floodplain areas vary in elevation from 70 to 78 m amsl.

The investigation sites are within the Rural and Industrial Zones under the operative district plan. The Oroua River separates the sites from the Residential Zone of Feilding township to the west.

4 FIELD INVESTIGATION

4.1 General

This section describes the objectives and methodology used for the site investigation. The Investigation Area is compartmentalised in order to identify representative areas to carry out testing. These compartments are numbered and presented in Appendix A Block Identification Map. The methodologies used for soil chemical tests and soil hydraulic tests are described.

At the time of the site investigation blocks 1.5 to 1.10 had not been included. These areas have been investigated in previous investigations (CPG 2010) and routine testing of soil hydraulic conductivity has been carried out to meet resource consent requirements at the site identified as Rangitikei 4 in Figure 4.1.

4.2 Investigation Objectives

The purpose of the site investigation was to obtain reliable information to enable the development of a land treatment regime for the areas available. In order to provide high quality information the objectives of the site investigations were to:

- Confirm soil types present over the sites and the extent of the soil types;
- Assess soil quality and nutrient status; and
- Measure soil hydraulic properties.

The information obtained enables the capacity of the sites to receive wastewater to be determined. Monitoring data for the existing irrigation areas to meet the requirements of the current consent has been gathered by Massey University over the course of the current consent. A soil survey has been undertaken for both the adjacent farmland (Byreburn) (CPG, 2011) and the areas in ANZ and Dalcam Trust ownership (Ross, 2013). This LEI report seeks to confirm previously identified soil boundaries and fill any information gaps.

4.3 Site Selection for Investigation and Sampling

Areas available for land treatment are shown in Appendix A Block Identification Map. These areas have been divided into blocks which are separated mainly by tracks, fences, waterways or property boundaries. As a result of tracks and other exclusions, the Investigation Area is less than the total property area given in Table 3.1 above.

The Investigation Area occupies different land ownership, management and soil types and this is reflected in the naming of the block IDs. Detail of each block is presented in Appendix B as Table 1: AFFCO Irrigation Area Descriptions and summarised below in Table 4.1.

The total area available for irrigation is included in Table 4.1, but land treatment design will require buffers from boundaries, waterways and dwellings to be subtracted and so the actual irrigable area will be less than the total available area. Further evaluation of this is beyond the scope of this report and will be adjusted in the Conceptual Design.

Table 4.1: Investigation Area Block Descriptions

Block ID	Ownership	Land Use	Irrigation	Soil Types	Total Area (ha)
1.1 to 1.10 2.1 to 2.9	Byreburn	dairying	irrigated & non irrigated	Kairanga Manawatu Rangitikei Parewanui - Rangitikei	129.93
4.1 to 4.13	AFFCO	organic enriched, amenity, stock yards, grazing	non irrigated	Manawatu Rangitikei Anthropic	15.15
24 and 25	Dalcam Trust	grazing	non irrigated	Manawatu	5.45
Total Area					**150.53**

Eight sites were selected for testing. The sites selected represent variations in land use, irrigation history and soil types across the sites. Sample site identification is given in Table 4.2 below. Where possible, existing sampling sites were revisited to enable comparison with historic testing results. Table 4.2 shows the relationship of the sampling sites to the annual monitoring sites and previously evaluated areas.

Sites sampled for this investigation include the historical sites Kairanga 1 and Manawatu 3 and 6 additional sites. Figure 4.1 shows the sampling locations. The lines represent the transects used for soil sampling and the squares are the soil hydraulic testing sites.

Table 4.2: Sampling Site Identification

Site ID	Massey University 1997-2013	CPG 2010	Irrigation History	Block ID
Kairanga 1	Kairanga 1	Kairanga equivalent to paddock 22,31,47	irrigated	1.4
Kairanga 2		Kairanga paddock 96	non irrigated	2.8
Manawatu 3	Manawatu 3	Manawatu paddock 51	irrigated	1.1
Manawatu 4		Manawatu paddock 58	non irrigated	2.1
Manawatu 5			non irrigated	4.6
Manawatu 6			non irrigated	3.2
	Rangitikei 4	Rangitikei paddock 61	irrigated	1.10
Rangitikei 5			non irrigated	4.5
Rangitikei 6			non irrigated	4.10

4.4 Soil and Waterway Survey

The topography and water features for the Investigation Area were described and identified on maps during the field investigation. Notes were recorded to determine features that could distinguish changes in soil types.

Sites for investigation were selected to compare representative soil profiles to the previous soil descriptions (CPG, 2010; Ross, 2013). These were located in blocks 3.2, 4.6 to represent Manawatu soils and 4.5 and 4.10 to represent Rangitikei soils.

For each soil profile description holes were dug or existing cuttings were used. Each layer of the profile was measured and described.

4.5 Soil Chemical Testing

Soil samples for chemical analysis were collected at 8 sites as identified in Figure 4.1 below, not including Rangitikei 4. Soil cores of 150 mm depth were taken every 10 to 20 m along transects of 100 to 200 m. The length of transect depended on the area available around the nominated site. The soil cores collected along each transect were mixed and placed into laboratory-supplied bags. The samples were packed in chilly bins and sent by courier to Hill Laboratories Ltd. for analysis.

The soil analyses requested included:

- pH
- Olsen P
- Sulphate S
- Potassium
- Calcium
- Magnesium
- Sodium
- Total nitrogen
- Available Nitrogen
- Anaerobically mineralisable nitrogen
- Anaerobically mineralisable nitrogen:Total nitrogen ratio
- Organic matter
- Carbon:Nitrogen ratio
- Total carbon
- Cation Exchange Capacity
- Total base saturation

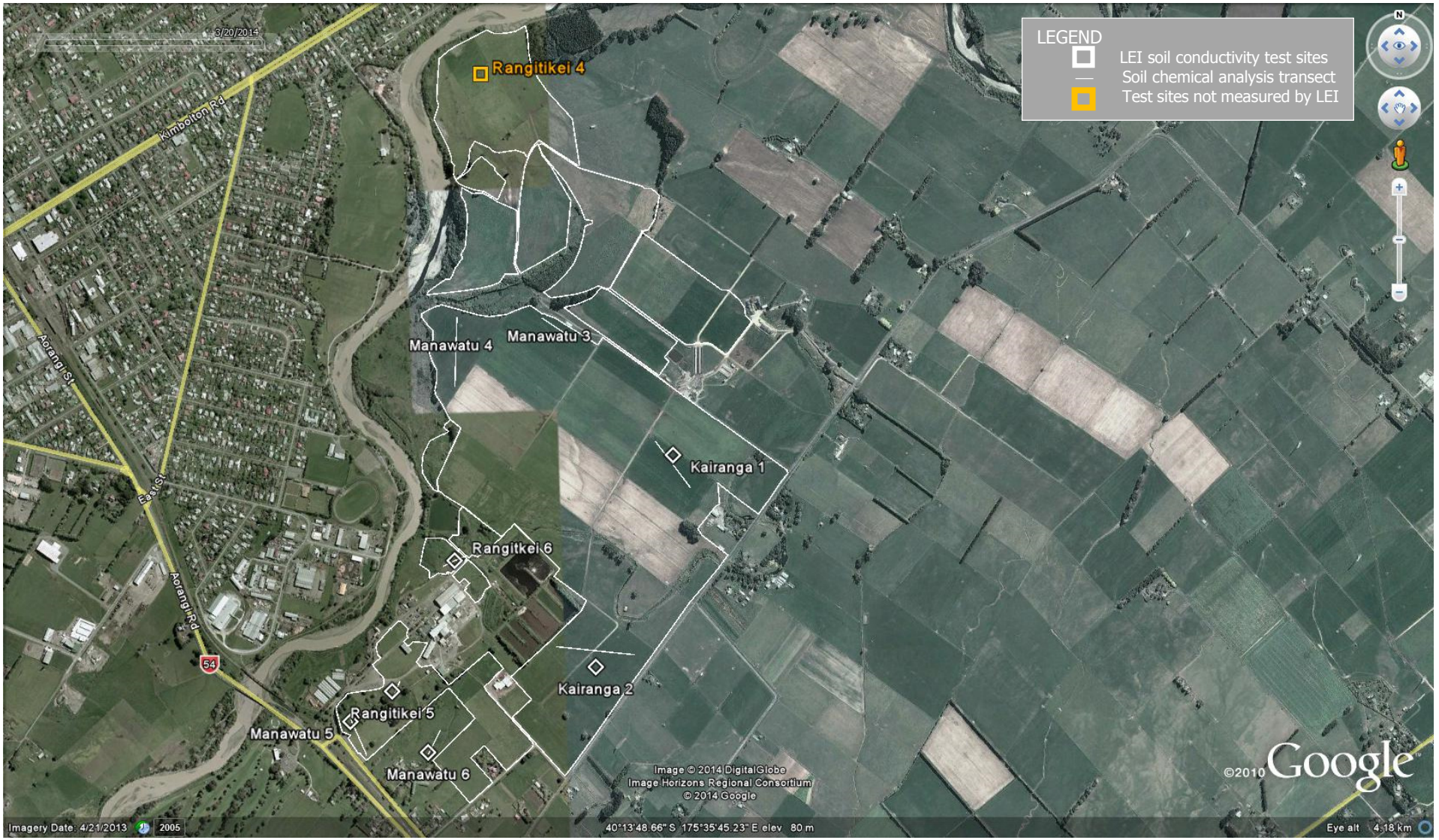

Figure 4.1: Sampling Site Location

4.6 Soil Hydraulic Testing

Soil hydraulic conductivity (K) is a measure of the rate at which water is able to enter soil and move through the profile. K is dependent on several properties, including particle size, mineralogy, degree of particle packing and pressure head of water applied. Direct measurement of hydraulic conductivity can be undertaken by the use of field or laboratory testing methods.

Locations for in-situ K measurement were chosen to represent a fair picture of the soil types and land use for the site and can be seen in Figure 4.1.

The measurement of K was undertaken to allow an assessment of the ability of the site to receive wastewater under varied application regimes.

Soil hydraulic conductivity measurements were performed on the 19th and 20th February 2014 by LEI staff.

Two testing methodologies were used as follows:

4.6.1 Soil Saturated Hydraulic Conductivity by Double Ring Infiltrometer

For determination of the ability of the soil to transmit water under saturated conditions (K_{sat}) a double ring infiltrometer was used. This is a preferred method for establishing K_{sat} near the soil surface. The double ring method measures vertical flow only, minimising possible overestimation of infiltration due to lateral flow in 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}. Measurements were continued until the drop in water level reached a steady state for at least 3 readings. Three replicate tests were undertaken at each site.

4.6.2 Soil Unsaturated Hydraulic Conductivity by Plate Permeameter

For determination of the rate of water movement under unsaturated conditions, unsaturated hydraulic conductivity was measured using a CSIRO plate permeameter apparatus (Perroux and White, 1988). The permeameter method enables measurement of soil near-saturated hydraulic conductivity. The use of testing results under near-saturated soil conditions are favoured over saturated soil conditions 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. 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 – 40 mm (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 K 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 undertaken at 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 K 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 INVESTIGATION RESULTS AND DISCUSSION

5.1 General

A field investigation was undertaken and site properties of interest were examined by:

- Site survey;
- Identification of water courses;
- Soil chemical analysis; and
- Hydraulic conductivity measurement.

Descriptions and results of the investigation are presented below.

5.2 Site Survey

5.2.1 Site Description

Byreburn Farm is a well-established farming property presently operating as a dairy unit. The pasture is predominantly ryegrass and clover. At the time of the investigation blocks 1, 1a and 5 had maize growing. The sites irrigated and with subsurface drainage are blocks 1.1, 1.2, 1.3 and 1.4. Sites irrigated without subsurface drainage are blocks 1.5 to 1.10.

The Dalcam Trust land is presently grazing cattle. The pasture was very dry at the time of the investigation (19-20 February 2014.)

The ANZ blocks have a number of large mature trees across the site with pasture underneath. Block 4.5 is used as stock holding pens for the processing plant. Other areas have sheep grazing and horses were grazing at the time of the investigation.

5.2.2 Waterways, Topography and Drainage

The Investigation Areas are predominantly flat, with water courses dividing the area. The land drops down to a lower terrace adjacent to the Oroua River where blocks 1.8 to 1.10 are located. Block 1.1 has a drop down towards the northern fence line that delineates the change in soil type from Manawatu to Kairanga soils. Blocks 4.12 and 4.13 are approximately 1 m lower in elevation than block 2.3; the elevation drops at the fence line between these two areas. Blocks 4.7 and 4.8 are higher than the adjacent block 4.5 which is likely due to the creation of the blocks with fill underneath. The area at the south end of block 1.10 has a raised area of land.

With reference to the figure Drainage in Appendix A, the following describes the water courses and bore locations. The Oroua River is the main waterway for the area and runs along the west boundary of the Investigation Area. An ephemeral stream is located on the east side of Byreburn Farm that crosses the back of the ANZ treatment ponds before it enters an artificial drain to the Oroua River. Block 4.9 has an open drain-like depression that has been filled to the surrounding land height at both ends. There is a depression that meanders across the ANZ land area. This appears to represent an old water course and was said to stay permanently dry (pers comm ANZ employees). It drops about 1 to 2 m below the surrounding land and is often around 5 m wide. One paddock on the west side of block 4.5 is below the other paddocks because it is mostly part of the water course. Soil examined within these old water courses reached stony material within 100 mm from the surface.

Two wet areas of approximately 3 to 5 m across were present in block 4.5.

The location of shallow bores within the Investigation Area and within a close proximity of the Investigation Area are identified on the Drainage map, Appendix A.

Blocks 1.1 to 1.4 and 2.1, on Byreburn Farm have been extensively drained, with some subsurface drainage on block 2.3. All other blocks do not have subsurface drainage.

5.3 Buildings in Locality

The rural location of the Investigation Area means there are no buildings within 20 m of the proposed irrigation areas. Neighbouring properties to the ANZ meat processing plant and to the Byreburn Farm buildings are listed in Table 5.1.

Table 5.1: Neighbouring properties to the Investigation Area

Identification	Land Use	Location	Legal Description	Building Distance to Investigation Area
Feilding Flowers	Glasshouse flower production	Entrance to AFFCO on Campbell Road	Lot 1 DP 86010	45 m
Dalcam Trust	Mental health unit	Campbell Road	Part Aorangi 1 1C Block	60 m
31 Matai St	Private dwelling	Matai St between St Dominic's & AFFCO land	Lot 20 DP 2688	30 m
Wallace Corporation	Slink processing plant	Ratanui St	Lot 27 DP 2688; Lot 28 DP 2688; Part Lot 29 2688 and Part Lot 29 2688(2)	30 m

5.4 Soil Description

The location of soil types are presented graphically in the figure Soil Types, Appendix A. The collected data has been compared to existing soil surveys (Ross 2013; CPG 2010) to establish the soil locations and types across the 3 properties. This is summarised as follows:

- Kairanga Soil and Parewanui-Rangitikei Soil
  Soil throughout Byreburn was not investigated due to extensive examination carried out by CPG in 2010. This work indicated the Kairanga Silt Loam examined had the following characteristics:
  - A horizon 200 mm. Grey brown silty loam. Moderately pedal. No indication of mottles. Fine polyhedral structure. Abundant fine roots.
  - B horizon to 700 mm. Silty loam. Moderately pedal. Grey matrix with 20% 2-4 mm reddish orange redox mottles. Medium to coarse prismatic breaking to medium polyhedral structure. Common fine roots.
  - C horizon to 1000 mm+. Loamy sand. Apedal single grains. Dark grey matrix with 15% 6-10 mm reddish redox mottles. No indication of roots.

- Manawatu Soil
  Soils investigated in blocks 4.6 and 3.2:
  - A horizon 150 and 240 mm. Brown sandy loam. Moderately pedal. No mottles. Coarse crumb structure, abundant root development.

- B horizon to 600 mm at block 4.6 sandy loam. Apedal. Loose. At block 3.2, sandy loam. Weakly pedal, fine angular. Below this layer is unaggregated sand.

- Rangitikei Soil
  Soils investigated in blocks 4.5 and 4.10. These are Anthropic soils.
  - A horizon 150 mm. Very dark grey, weakly pedal, sandy with stone to 10 mm size.
  - B horizon to 500 mm+. Sandy. Dark grey overlying abundant stones up to 20 mm size. Stones up to 50 mm size on the soil surface increased across block 4.5 towards the buildings.

5.5 Soil Analysis

Soil analysis was carried out and the results are tabulated below in Table 5.3 and Hill Laboratory reports are in Appendix C. The following characteristics can be identified and are summarised in Table 5.2:

- Kairanga 1 site recorded high Olsen P, Magnesium, Sodium and Sulphate Sulphur concentrations with other parameters having typical pastoral concentrations with no significantly low results.
- Kairanga 2 site recorded high Olsen P, Volume Weight, Sulphate Sulphur values with other parameters having typical pastoral concentrations with no significantly low results.
- Manawatu 5 site recorded particularly low results for all parameters, with only Calcium, Total Base Saturation, Volume Weight, Anaerobically Mineralisable Nitrogen: Total Nitrogen ratio being typical of pastoral soils.
- Manawatu 6 site recorded low values similar to Manawatu 5. Magnesium, Cation Exchange Capacity, Volume Weight, Total Nitrogen and Anaerobically Mineralisable Nitrogen: Total Nitrogen ratio recorded typical results. Sulphate Sulphur was very low and similar to the result at Rangitikei 5.
- Rangitikei 5 site recorded high Olsen P which is comparable to the high recordings historically at Manawatu 3 and Rangitikei 4. Potassium was also high at the site. Other parameters were typical of pastoral soils with only Sulphate Sulphur recording a low value.
- Rangitikei 6 site recorded high results for pH, Calcium, Total Base Saturation and Volume Weight and higher results to the other sites for Calcium (%BS), Total Base Saturation (%), Organic Matter, Carbon to Nitrogen ratio and Total Carbon. This reflects the high organic matter additions applied to this site. Low parameters measured for the site include Olsen P, Sulphate Sulphur and Available Nitrogen.

Table 5.2: Summary of Selected Soil Analysis Results

Soil Test Sites	Low	Medium/Typical	High
Kairanga 1			Olsen P, Mg, Na, SO_4-S
Kairanga 2			Olsen P, VW, SO_4-S
Manawatu 5		Ca, TBS, VW, AMN/TN	
Manawatu 6	SO_4-S	Mg, CEC, VW, TN, AMN/TN	
Rangitikei 5	SO_4-S		Olsen P, K
Rangitikei 6	Olsen P, SO_4-S, AN		pH, Ca, TBS, VW

Table 5.3: AFFCO Irrigation Sites Soil Analysis– March 2014

Sample Name:		Byre Kai Irr	Byre Kai Non	Byre Man Irr	Byre Man Non	Site 1 Affco	Site 3 Affco	Site 2 Affco	Site 4 Affco
Site Name		**Kairanga 1**	**Kairanga 2**	**Manawatu 3**	**Manawatu 4**	**Manawatu 5**	**Manawatu 6**	**Rangitikei 5**	**Rangitikei 6**
Date of Collection		20-Mar-14	20-Mar-14	20-Mar-14	20-Mar-14	19-Mar-14	19-Mar-2014	19-Mar-14	20-Mar-14
pH	pH Units	5.8	5.8	5.7	5.4	5.6	5.5	5.8	6.4
Olsen Phosphorus	mg/L	46	36	66	33	9	10	77	8
Sulphate Sulphur	mg/kg	14	13	9	18	1	2	3	3
Potassium	me/100g	0.53	0.57	0.31	0.56	0.27	0.34	0.97	0.47
Calcium	me/100g	7.2	7.5	4.9	8.6	4.8	6	5.5	13
Magnesium	me/100g	1.62	1.52	1.28	1.68	0.82	1.17	1.34	1.07
Sodium	me/100g	0.54	0.2	0.82	0.15	0.08	0.16	0.09	0.12
Available Nitrogen (15cm Depth)	kg/ha	113	133	110	121	123	148	147	70
Anaerobically Mineralisable N	µg/g	80	87	74	88	77	111	93	44
Anaerobically Mineralisable N/Total N Ratio	%	2.7	3.2	2.9	2.6	3.9	3.4	2.8	1.3
Organic Matter	%	5.1	4.8	4.6	5.6	3.1	4.9	5	10.8
C/N Ratio		9.7	10.1	10.6	9.9	9.2	8.9	8.8	17.9
Total Carbon	%	2.9	2.8	2.7	3.3	1.8	2.9	2.9	6.3
Total Nitrogen	%	0.3	0.27	0.25	0.33	0.2	0.32	0.33	0.35
CEC	me/100g	15	15	13	17	10	16	13	17
Total Base Saturation	%	65	67	55	65	58	49	63	89

5.6 Soil Hydraulic Testing

A summary of the hydraulic conductivity results is given Table 5.4. Detailed results are presented in Appendix D.

5.6.1 Double Ring Infiltrometer Results

The K_{sat} at the surface of each of the four sites were measured in triplicate. The average result for each site are presented in Table 5.4. These values correspond to rapid drainage which reflects the coarse sand and gravel composition of the topsoil.

Table 5.4: Summary Hydraulic Conductivity Tests March 2014

Analysis	Unit	Manawatu 5	Rangitikei 5	Manawatu 6	Rangitikei 6	Kairanga 2	Kairanga 1
		Sandy Manawatu	Anthropic - like Rangitikei	Sandy Manawatu	Organic Anthropic - like Rangitikei	Kairanga Silt Loam	Kairanga Silt Loam
		AFFCO Site 1	AFFCO Site 2	Dalcam Site 3	AFFCO Site 4	Byreburn unirrig	Byreburn irrig
		Block 4.6	Block 4.5	Block 4.5	Block 4.10	Block 2.8	Block 1.4
K_{-40mm}	mm/h	5.31	4.81	9.77	7.58	6.6	8.38
K_{-40mm} SD	mm/h	3.08	0.28	1.96	3.69	4.22	4.80
K_{sat}	mm/h	237	207	133	112		
K_{sat} SD	mm/h	65	87	5	51		

A large variability occurred between sites as well as large standard deviations (SD) at each site. The standard deviations show the variation between the tests at each site. Each site was very dry after little rain in the area for 2 months before the investigations. NZ Metservice recorded 33 mm for February and March 2014 in Palmerston North. This low rainfall can result in variability in the saturated hydraulic conductivity testing due to significant preferential flows paths developing as the soil dries out. The anthropic soil can be compacted on the surface when the overlying soil is used to cap material buried underneath. The buried material could also create preferential flows because of the potentially large gaps created, depending on its type. The Manawatu soils also have stony and sandy fractions through the profile. Ross (2013) described Manawatu 5 as a mosaic of Anthropic, Manawatu and Rangitikei soils. Examination of the site where the hydraulic conductivity measurement took place confirmed the Manawatu soil type, with a sandy unconsolidated layer at 150 mm.

5.6.2 Plate Permeameter Results

The plate permeameter tests were conducted in triplicate at each of the K_{sat} sites plus two additional sites on Byreburn Farm. Plots of the $K_{-40\ mm}$ results for each site are given in Table 5.4 above and shown in Figure 1, Appendix D. The plots show the K at three matrix potentials as mentioned in Section 4.6.2 above.

Sites 1 to 4 had similar results, despite the Rangitikei sites having stones up to 50 mm in size that may have created a faster permeability. The fastest permeability occurred on the Dalcam Trust land with a lower standard deviation (variability) compared to some of the other sites. Kairanga soils also resulted in similar results to the other soils tested. The faster rate of

permeability on Kairanga 1 compared to Kairanga 2 may be attributed to the cultivation for the maize crop being harvested at the time of testing.

6 IMPLICATIONS FOR INVESTIGATION AREA

6.1 General

In this section existing data is referred to as 'historical' and LEI's investigation presented in this report as 'this year'. The historical data and this year's data are compared.

6.2 Selection and Management of Land Areas for Irrigation

In addition to allowing for the ability of water to enter the soil, consideration should be given to:

- Rate of movement through the soil;
- Potential leaching;
- Level of nutrients in the soil that could become excessive if more nutrient from wastewater is applied;
- Sodium levels that could affect soil structure;
- Land use affecting nutrient levels; and
- Land use affecting water movement.

6.3 Determination of Sustainable Hydraulic Loading Rate

To allow 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 of the applied material 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):

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

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 10 % function of the unsaturated (not saturated) infiltration rate at $K_{-40\ mm}$ provides a maximum hydraulic design irrigation rate as listed in Table 6.1 below. At these rates the sites are likely to be able to accept water without the generation

of adverse effects on either the immediate receiving environment or the soils themselves. This is considered the maximum rate that can be accepted by the site. However, consideration needs to be given to the resulting nutrient loading and the site's attenuation ability, which may result in a reduction of the actual rate that may safely be applied.

Table 6.1: Design Irrigation Rate

Analysis	Unit	Manawatu 5	Rangitikei 5	Manawatu 6	Rangitikei 6	Kairanga 2	Kairanga 1
		Sandy Manawatu	Anthropic - like Rangitikei	Sandy Manawatu	Organic Anthropic - like Rangitikei	Kairanga Silt Loam	Kairanga Silt Loam
		AFFCO Site 1	AFFCO Site 2	St Dominics Site 3	AFFCO Site 4	Byreburn unirrig	Byreburn irrig
		Block 4.6	Block 4.5	Block 4.5	Block 4.10	Block 2.8	Block 1.4
DIR 10%	mm/d	12.74	11.54	23.45	18.19	15.84	20.11
DIR SD 10%	mm/d	7.39	0.67	4.70	8.86	10.13	11.52

6.4 Soil Hydraulic Properties: Implications for Land Treatment

The soil saturated hydraulic conductivity (K_{sat}) ranges between 112 to 237 mm/h at the four Investigation Areas. The unsaturated hydraulic conductivity ($K_{-40\ mm}$) is 5 to 9 mm/h at the same sites. The Byreburn Farm sites on Kairanga soils resulted in unsaturated hydraulic conductivity of 7 and 8 mm/h. In order to avoid excessive loss of water, nutrients and other contaminants to groundwater (and then to adjacent surface water) a rate more closely related to the $K_{-40\ mm}$ is recommended.

6.5 Changes to Soil Chemical Condition

Previous soil analysis carried out on Byreburn Farm occurred at sites Kairanga 1, Manawatu 3 and Rangitikei 4. They showed the following trends:

- All sites had consistently high phosphorus levels.
- Sodium levels at all sites were a medium level. They could become high with irrigation but this had not occurred to date.
- All sites had consistently low sulphate-sulphur with three isolated occasions at Kairanga 1 when sulphate-sulphur recorded a high level.
- Calcium often reached high levels at Kairanga 1.
- Magnesium was often high at all sites in the top 100 mm.

Results taken for this investigation were taken in March 2014 using 150 mm soil cores, by comparison to the 100 mm and 200 mm cores that were taken historically.

Comparison of the current results to the historical results showed the following:

- At Kairanga 1
    - Generally similar.
    - Sulphate-sulphur produced a high result as has occurred on isolated occasions previously.
    - Sodium was high but this has occurred occasionally at this site before.
    - Kairanga 2 results were similar to Kairanga 1 except sodium was down to a medium level similar to historical results.

- At Manawatu 3
    - Generally similar with the exception of sodium.
    - Sodium recorded 0.82 me/100 g compared to an average result at Manawatu 3 historically at 0.24 me/100 g.
    - Manawatu 4 results were similar to Manawatu 3 historical results with the exception of sulphate-sulphur.
    - Sulphate-sulphur at Manawatu 4 recorded 18 mg/kg compared to an average result at Manawatu 3 historically at 6 mg/kg.
    - Manawatu 5 and 6 produced significantly low levels of Olsen P and sulphate-sulphur.
- Rangitikei 5 and 6
    - Similar results compared to Rangitikei 4 historical results with the exception of Olsen P at Rangitikei 6.
    - Rangitikei 6 Olsen P recorded a low result of 6 µg/g compared to high results at other Rangitikei sites above 30 µg/g.

The addition of treated wastewater at these sites will need to:

- Avoid continued accumulation of phosphorus at previously irrigated sites; Byreburn Farm and intense stock areas at ANZ as Rangitikei 5 reflects.
- Avoid excess sulphate-sulphur accumulation.
- Avoid accumulation of calcium and magnesium.

6.6 Comparison to 'Historical' Soil Hydraulic data

Saturated hydraulic conductivity has been historically measured at sites Kairanga 1, Manawatu 3 and Rangitikei 4 on Byreburn Farm. The following characteristics emerged from this historical data:

- Mean results for the three sites show a wide variability over the years.
- Kairanga soils ranged between 12 and 177 mm/h.
- Laboratory determined saturated hydraulic conductivity tests carried out historically for Kairanga 1 ranged between <1 mm/h to 26 mm/h.
- The highest result at Manawatu 3 was 140 mm/h.

The results from the current investigation compared to the historical data showed:

- Manawatu soil results in this year's investigation were higher at 237 mm/h.
- The historical Rangitikei 4 soil results were similar to those recorded at the Anthropic Rangitikei sites analysed this year.
- Kairanga 1 unsaturated conductivity tests this year at 6.6 and 8.4 mm/h are similar to the laboratory saturated conductivity tests carried out historically.

Factors to take into consideration for irrigation design include:

- Kairanga hydraulic loading will require a lower rate compare to Manawatu and Rangitikei soils.
- Manawatu and Rangitikei soils drain rapidly and application rates will have to be limited to avoid leaching of nutrients.

6.7 Land Management Units

Based on the data collected the blocks can be grouped to be managed in a similar way. These groups become land management units that can contribute to the Conceptual Design and irrigation management decisions. The important part of these units is to distinguish the limiting factors as follows:

- Land Management Unit 1
    - Byreburn Farm previously irrigated blocks with high phosphorus.
    - Drained Kairanga soil.

- Land Management Unit 2
    - This area was identified subsequent to the site investigation and does not form part of the investigation above. It was evaluated by CPG (2011) as predominantly Rangitikei soils and has properties similar to the Rangitikei and anthropic soils described in this report. The limiting factor is the avoidance of excessive drainage of applied wastewater due to a likely high degree of connectivity with the Oroua River.

- Land Management Unit 3
    - Kairanga soil not drained that require limits to hydraulic loading.
    - Byreburn Farm Manawatu soil non-irrigated blocks with high phosphorus.

- Land Management Unit 4
    - Intense stock use on Rangitikei soil blocks producing high nitrogen and phosphorus levels.
    - Rapid drainage through Rangitikei and Manawatu soil blocks.

7 CONCLUSIONS AND RECOMMENDATIONS

All sites are predominantly flat and suitable for the application of wastewater. A total land area of approximately 180 ha is available but buffers will reduce this area for irrigation. Four distinct Land Management Units have been identified to assist irrigation management decisions. The irrigation design needs to take into account the most limiting soil characteristics from each zone.

- Land Management Unit 1 (Blocks 1.1 to 1.6) includes the Kairanga soils presently being irrigated on Byreburn Farm. All blocks have been extensively drained, with the exception of blocks 1.5 and 1.6).

- Land Management Unit 2 includes Rangitikei soils located on Byreburn Farm adjacent to the Oroua River. This area has historically received MWE from ANZ. The area is predominantly free to excessively drained. The limitation on this LMU is avoidance of rapid drainage from the area which may result in poor nutrient removal from MWE.

- Land Management Unit 3 (Blocks 2.1 to 2.9) includes the Kairanga soils presently not being irrigated on Byreburn Farm, with the exception of block 2.1 being irrigated. All blocks have NOT been extensively drained.

- Land Management Unit 4 includes a range of different soil types and management. It is considered that these will most easily be managed with one approach. Soil types include Manawatu soils, Rangitikei soils and Anthropic Rangitikei like soils. Management includes intensive stock holding yards, less intense stocking, organic application areas and amenity areas. The Manawatu soils are located on Dalcam Trust land and the Oroua side of Byreburn Farm. The Rangitikei and Anthropic Rangitikei-like soils are located around the ANZ plant and on the lower terrace adjacent to the Oroua River on the Byreburn Farm. These Anthropic Rangitikei-type soils will provide the greatest limitations for the rate of irrigation. They often have very stony topsoil and material under the topsoil that could be concrete and or stones that will create rapid drainage. Irrigation will need to be applied with care to avoid rapid infiltration that could quickly enter the ground water.

Interpretation of the results collected from the hydraulic testing needs to take into account the dry conditions at the time of testing that may have created some preferential flows and some variations may occur from the process of wetting the sites during the testing. The Rangitikei type soils and Kairanga soils results were similar to those collected historically but one Manawatu site resulted in significantly higher permeability than was shown in historical results.

The irrigation design also needs to consider the following characteristics of the sites:

- Sites owned by ANZ have large trees scattered across the site.
- Sites owned by ANZ and into Dalcam Trust have a wide old dry water course creating a significant drop in height across the area and its stony layer is much closer to the surface compared to the flat areas.
- Some sites owned by ANZ have very high organic material additions.

Additional considerations for the design of a wastewater application regime for the site include nutrient management, farm management practices and management of storage volume. Recommendations given in this report should be considered in light of these additional design issues.

8 REFERENCES

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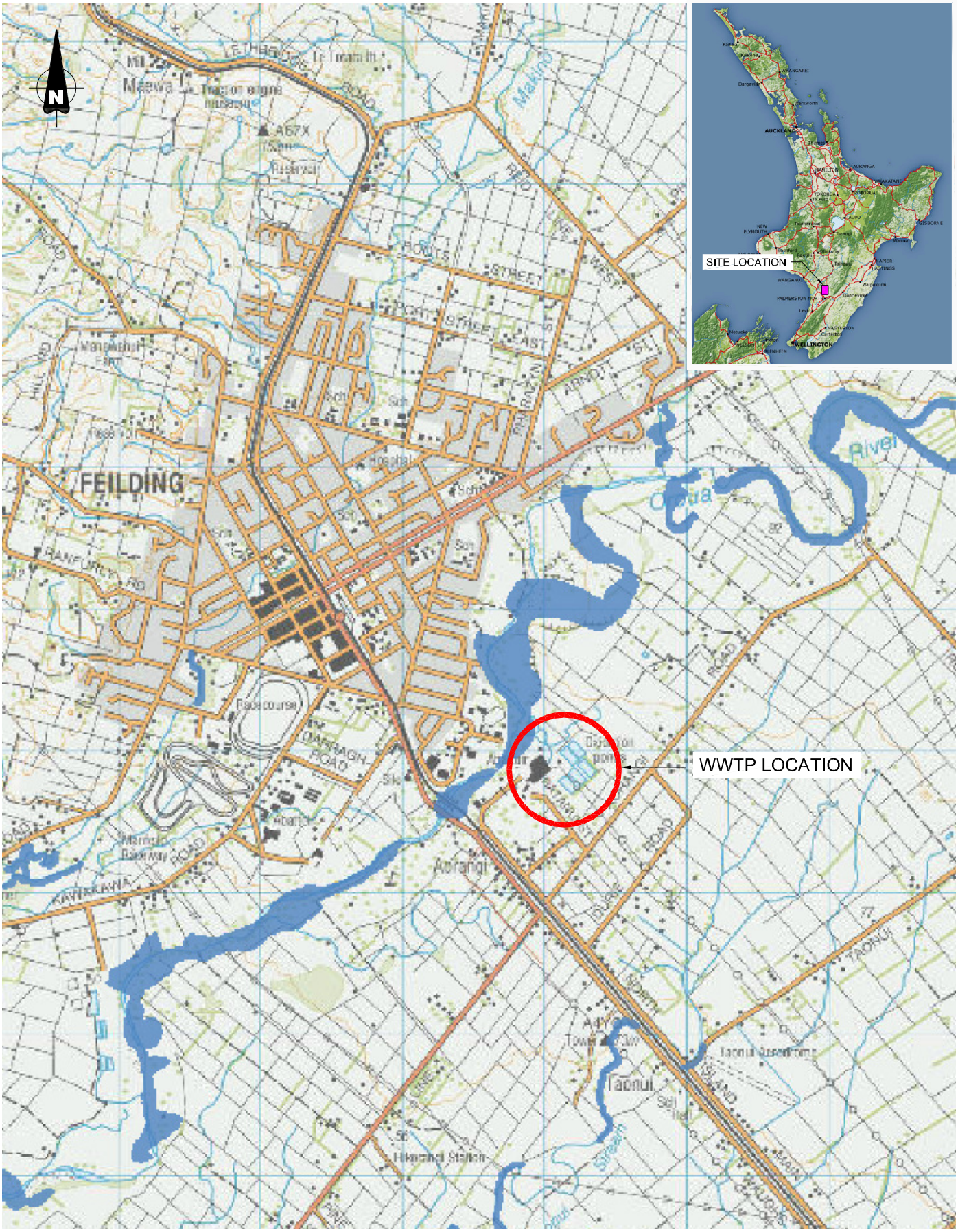
9 APPENDICES

Appendix A Figures: Location
Ownership
Block Identification
Drainage
Soil Types
Appendix B AFFCO Investigation Area Descriptions
Appendix C AFFCO Irrigation Sites Soil Analysis
Appendix D AFFCO Soil Hydraulic Conductivity Analysis

APPENDIX A

Figures

Location
Ownership
Block Identification
Drainage
Soil Types



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CLIENT

AFFCO Manawatu Limited

APPROVED	HL	15.03.13
CHECKED	–	–
DESIGNED	SC	15.03.13
DRAWN	PMJS	15.03.13

DRAWING TITLE

Location

PROJECT

AFFCO Manawatu Land Investigation

SCALE

NTS (A4)

DATE

30 Apr 2013

DRAWING No.

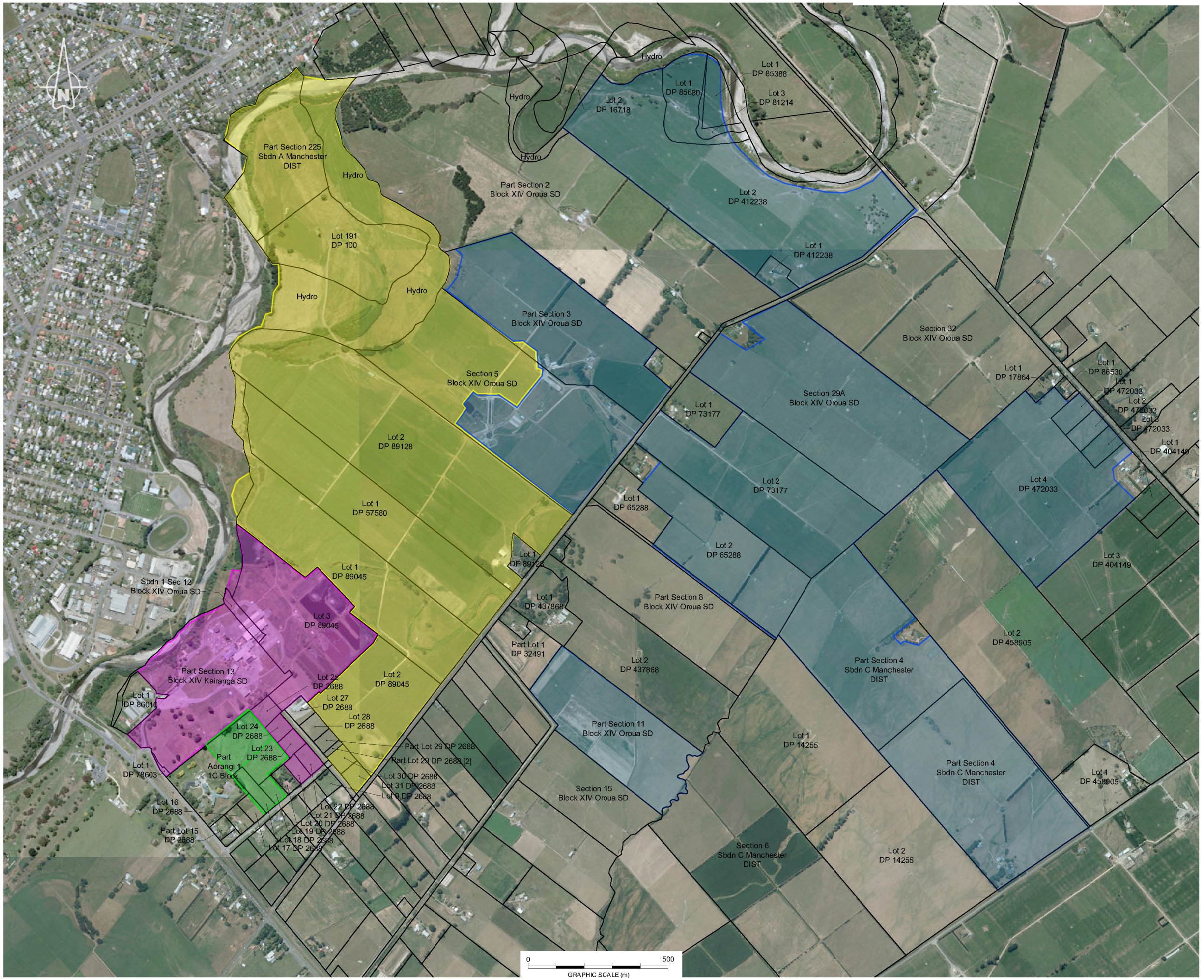
10146-01

DRAWING STATUS

Consenting

REVISION

-



NOTES

LEGEND

- BYREBURN FARM (IRRIGATED)
- BYREBURN FARM (NON-IRRIGATED)
- AFFCO
- ST. DOMINICS

REV.	DESCRIPTION	DATE
–	–	–

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APPROVED	HL	28.03.14
CHECKED	–	–
DESIGNED	SC	28.03.14
DRAWN	PMJS	28.03.14

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AFFCO Manawatu Land Investigation

DRAWING TITLE

Ownership

DRAWING STATUS

Conceptual Design

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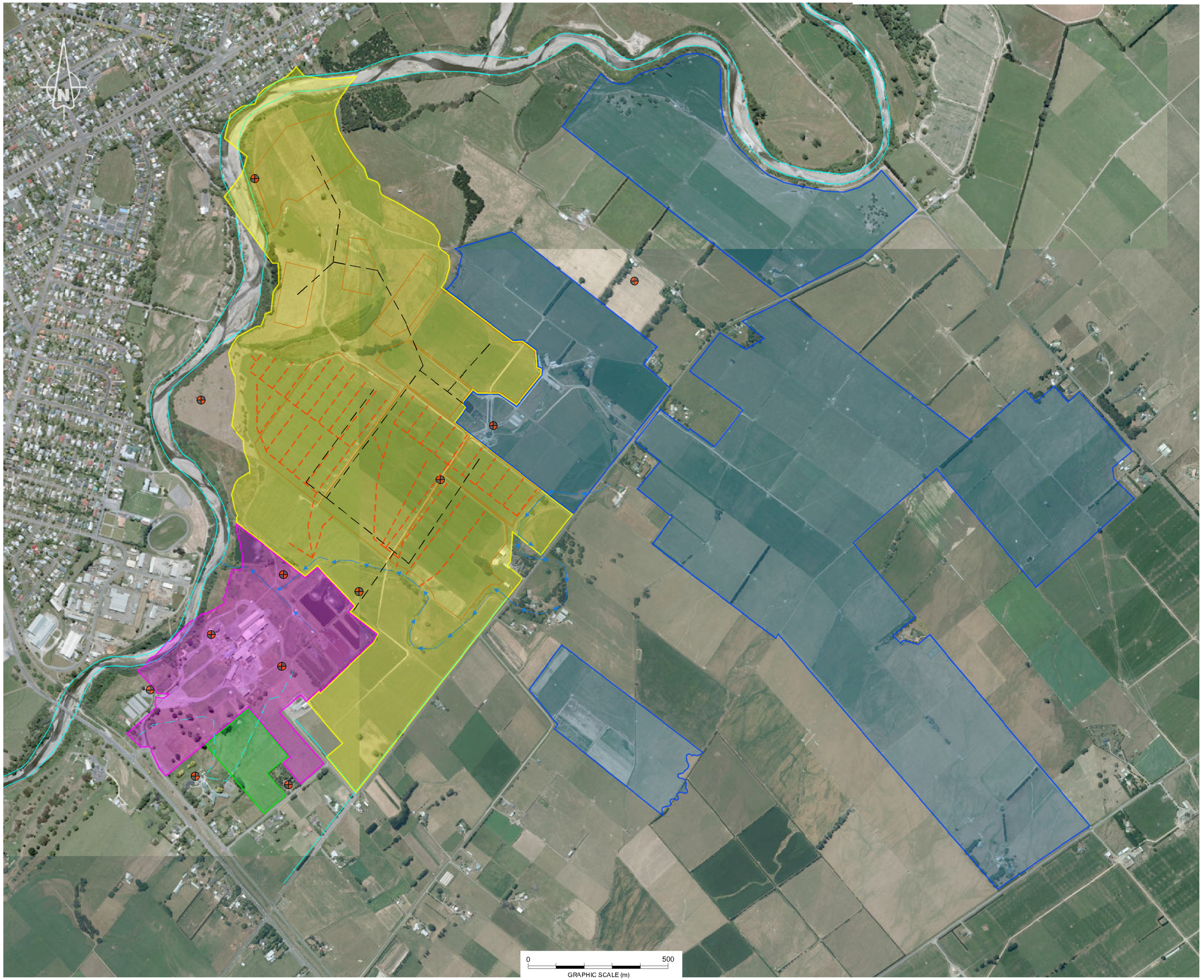

NOTES

LEGEND

- BYREBURN FARM (IRRIGATED)
- BYREBURN FARM (NON-IRRIGATED)
- AFFCO
- ST. DOMINICS
- CURRENTLY IRRIGATED
- OPEN WATER COURSES
- DRY WATER COURSES
- OPEN DRAIN
- IRRIGATION LINES
- SUBSURFACE DRAINAGE
- BORES

REV.	DESCRIPTION	DATE
–	–	–

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AFFCO Manawatu Limited

PROJECT

AFFCO Manawatu Land Investigation

DRAWING TITLE

Drainage

DRAWING STATUS

Conceptual Design

DATE	DRAWING No.
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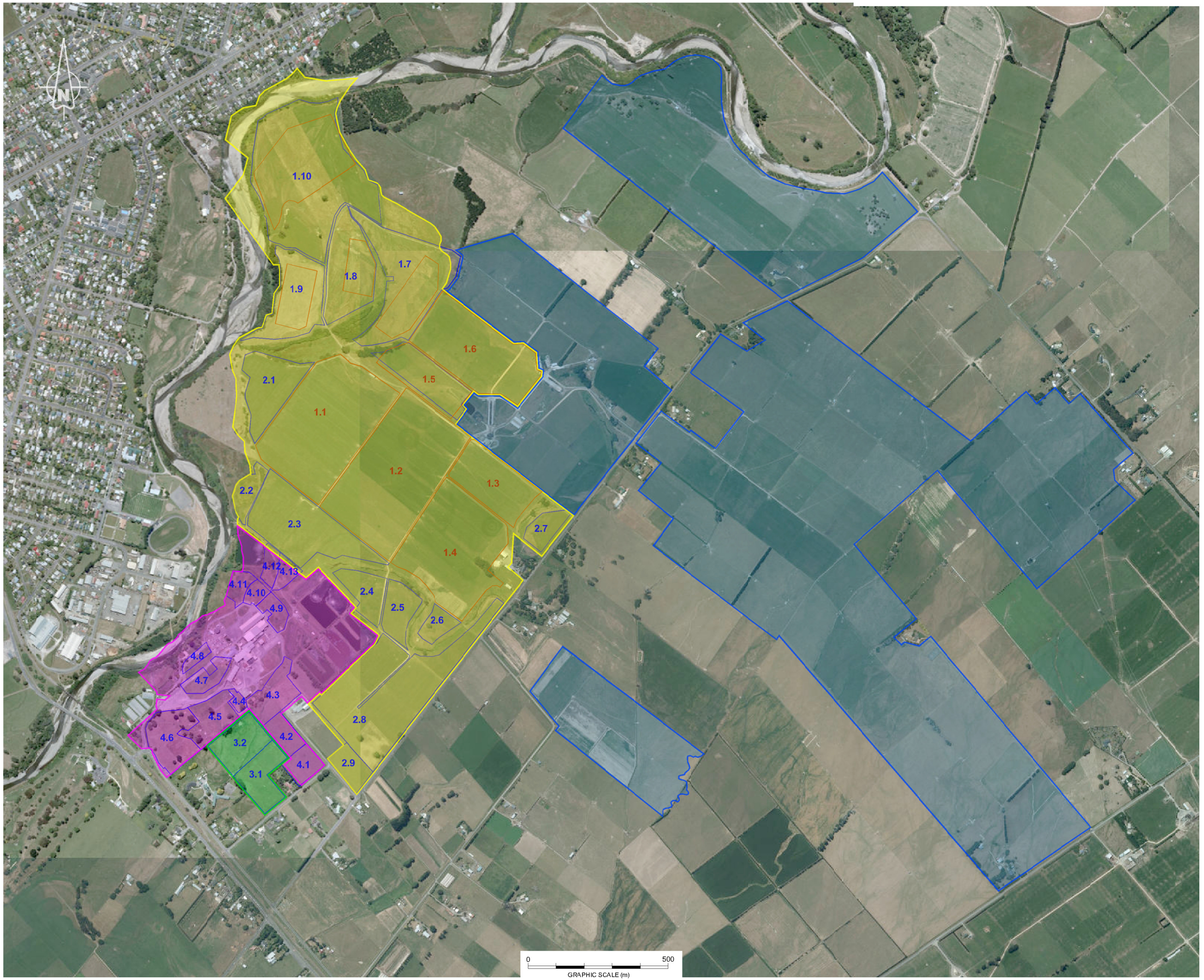

NOTES

LEGEND

- BYREBURN FARM (IRRIGATED)
- BYREBURN FARM (NON-IRRIGATED)
- AFFCO
- ST DOMINICS
- CURRENTLY IRRIGATED BLOCKS
- NEW IRRIGATION BLOCKS

REV.	DESCRIPTION	DATE
–	–	–

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AFFCO Manawatu Land Investigation

DRAWING TITLE

Block Identification

DRAWING STATUS

Conceptual Design

DATE	DRAWING No.
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SCALE	REVISION
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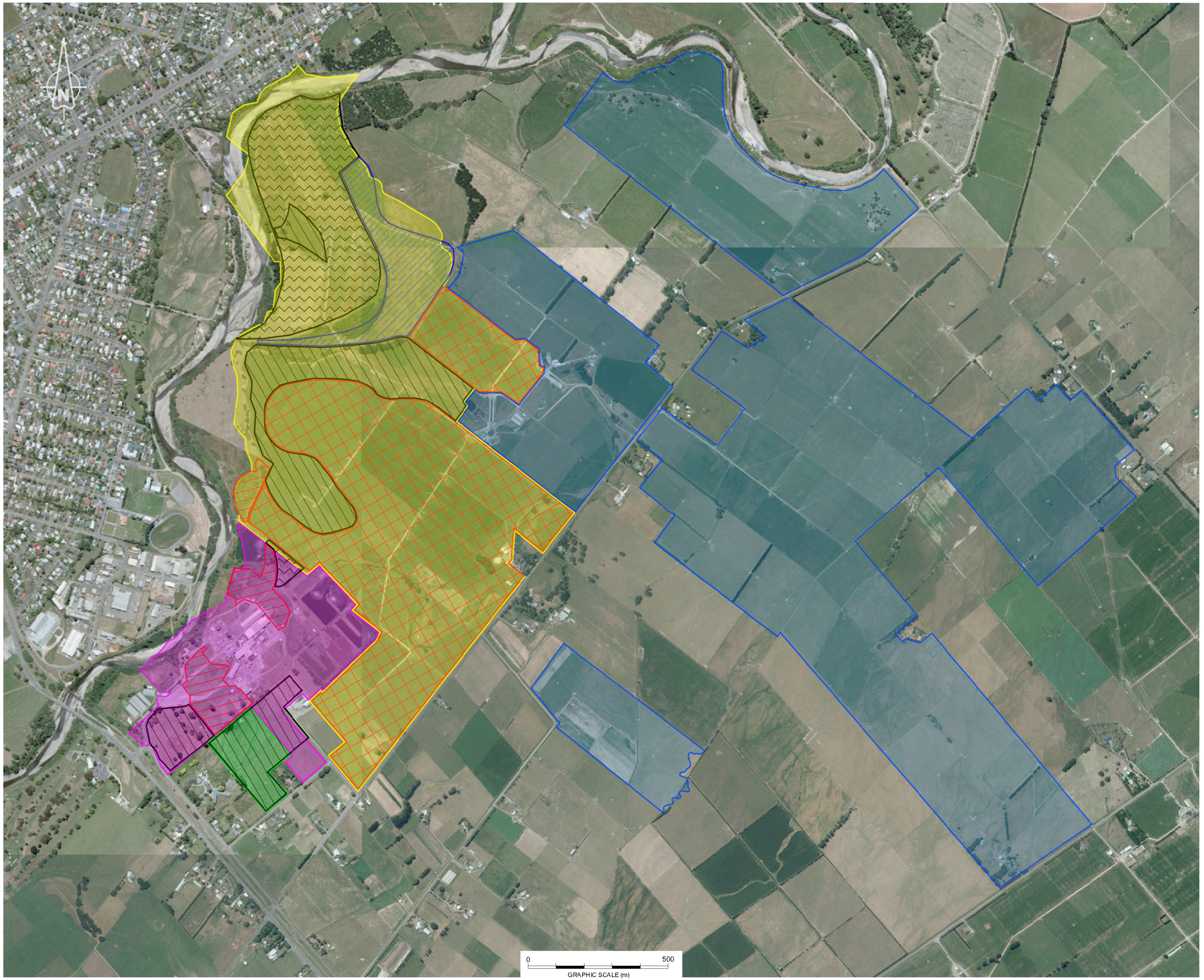

NOTES

LEGEND

- KAIRANGA SOIL
- ANTHROPIC SOIL
- RANGITIKEI SOIL
- MANAWATU SOIL
- PAREWANUI + RANGITIKEI SOIL
- BYREBURN FARM (IRRIGATED)
- BYREBURN FARM (NON-IRRIGATED)
- AFFCO
- ST DOMINICS

REV.	DESCRIPTION	DATE
–	–	–

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DESIGNED	SC	28.03.14
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CLIENT

AFFCO Manawatu Limited

PROJECT

AFFCO Manawatu Land Investigation

DRAWING TITLE

Soil Type

DRAWING STATUS

Conceptual Design

DATE	DRAWING No.
22 Apr 2014	10146-06
SCALE	REVISION
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APPENDIX B

AFFCO Investigation Area Descriptions

AFFCO Irrigation Area Descriptions

Block Name	Ownership	Land Use	Irrigation	Block Groups	Soil Type	Total Areas (ha)
1.1	Byreburn	Dairy	Irrigated	1	Manawatu & Kairanga silt loam	14.42
1.2	Byreburn	Dairy	Irrigated	1	Kairanga silt loam	15.98
1.3	Byreburn	Dairy	Irrigated	1	Kairanga silt loam	4.84
1.4	Byreburn	Dairy	Irrigated	1	Kairanga silt loam	11.75
1.5	Byreburn	Dairy	Irrigated	1	Kairanga silt loam	4.02
1.6	Byreburn	Dairy	Irrigated	1	Kairanga silt loam	9.31
1.7	Byreburn	Dairy	Irrigated	1	Parewanui Rangitikei	8.71
1.8	Byreburn	Dairy	Irrigated	1	Rangitikei	5.23
1.9	Byreburn	Dairy	Irrigated	1	Rangitikei	5.17
1.10	Byreburn	Dairy	Irrigated	1	Rangitikei	16.68
2.1	Byreburn	Dairy	Non irrigated	1	Manawatu silt loam	4.13
2.2	Byreburn	Dump non organic	Non irrigated	unsuitable	Anthropic - steel underneath	1.28
2.3	Byreburn	Dairy	Non irrigated	2	Manawatu & Kairanga silt loam	7.57
2.4	Byreburn	Dairy	Non irrigated	2	Kairanga silt loam	2.06
2.5	Byreburn	Dairy	Non irrigated	2	Kairanga silt loam	2.03
2.6	Byreburn	Dairy	Non irrigated	2	Kairanga silt loam	1.06
2.7	Byreburn	Dairy	Non irrigated	2	Kairanga silt loam	1.28
2.8	Byreburn	Dairy	Non irrigated	2	Kairanga silt loam	13.03
2.9	Byreburn	Dairy	Non irrigated	2	Kairanga silt loam	1.38
Sum Byreburn Area						**129.93**
4.1	AFFCO	Larger grazing paddock sheep	Non irrigated	3	Kairanga silt loam	1.2
4.2	AFFCO	Larger grazing	Non irrigated	3	Sandy and silty	1.18

		paddock sheep			Manawatu soils	
4.3	AFFCO	Human effluent application	Non irrigated	unsuitable	Sandy and silty Manawatu soils	2.16
4.4	AFFCO	Old air filtration	Non irrigated	3	Anthropic, high organic	0.31
4.5	AFFCO	Stock holding yards cattle	Non irrigated	3	Anthropic, behaves like Rangitikei shallow, sandy & stony	2.24
4.6	AFFCO	Larger grazing paddocks mixed livestock	Non irrigated	3	Anthropic, Manawatu, Rangitikei	2.97
4.7	AFFCO	Amenity	Non irrigated	3	Anthropic, concrete underneath	1.12
4.8	AFFCO	Amenity	Non irrigated	3	Anthropic, concrete underneath	0.42
4.9	AFFCO	Paunch & ears & heads	Non irrigated	3	Anthropic - organic	0.84
4.10	AFFCO	Larger grazing paddocks	Non irrigated	3	Anthropic - steel underneath	0.53
4.11	AFFCO	Mixed Dump organic non organic	Non irrigated	unsuitable	Anthropic	0.78
4.12	AFFCO	Paunch	Non irrigated	3	Anthropic - organic	0.72
4.13	AFFCO	Larger grazing paddocks sheep	Non irrigated	3	Sandy Rangitikei shallow soils	0.68
Sum AFFCO Areas						**15.15**
3.1	St Dominics	Larger grazing paddocks	Non irrigated	3	Sandy and silty Manawatu soils	2.64

3.2	St Dominics	Larger grazing paddocks	Non irrigated	3	Sandy and silty Manawatu soils	2.81
Sum St.Dom Areas						**5.45**
Total Area						**150.53**

APPENDIX C

AFFCO Irrigation Sites Soil Analysis

Hill Laboratory Reports

Hill Laboratories
BETTER TESTING BETTER RESULTS

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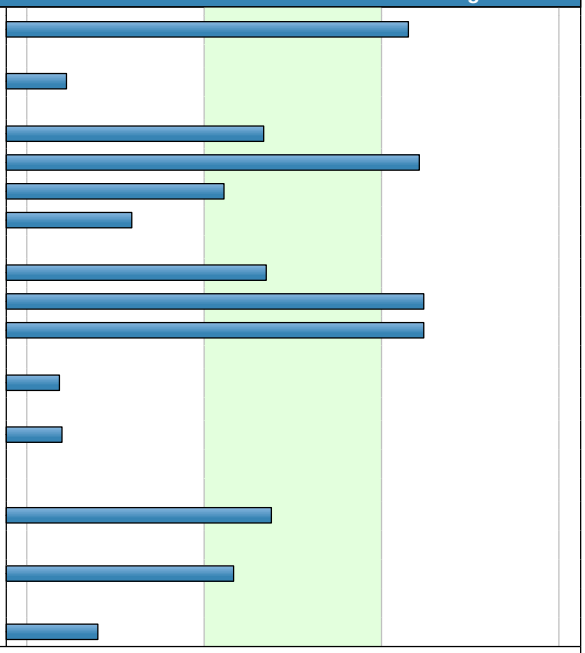
ANALYSIS REPORT

Client:	Lowe Environmental Impact Ltd	**Lab No:**	1251673	shpv1
Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014	
		Date Reported:	28-Mar-2014	
		Quote No:	60156	
		Order No:		
		Client Reference:		
Phone:	06 359 3099	**Submitted By:**	Sian Cass	

Sample Name: Site 4 Affco 20-Mar-2014 11:00 am **Lab Number:** 1251673.1
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.4	5.8 - 6.2
Olsen Phosphorus	mg/L	8	20 - 30
Potassium	me/100g	0.47	0.40 - 0.60
Calcium	me/100g	13.0	4.0 - 10.0
Magnesium	me/100g	1.07	1.00 - 1.60
Sodium	me/100g	0.12	0.20 - 0.50
CEC	me/100g	17	12 - 25
Total Base Saturation	%	89	50 - 85
Volume Weight	g/mL	1.06	0.60 - 1.00
Sulphate Sulphur	mg/kg	3	10 - 12
Available Nitrogen (15cm Depth)*	kg/ha	70	150 - 250
Anaerobically Mineralisable N*	µg/g	44	
Organic Matter*	%	10.8	7.0 - 17.0
Total Carbon	%	6.3	
Total Nitrogen	%	0.35	0.30 - 0.60
C/N Ratio*		17.9	
Anaerobically Mineralisable N/Total N Ratio*	%	1.3	3.0 - 5.0
Base Saturation %		K 2.8 Ca 79 Mg 6.4 Na 0.7	
MAF Units		K 10 Ca 17 Mg 25 Na 6	



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

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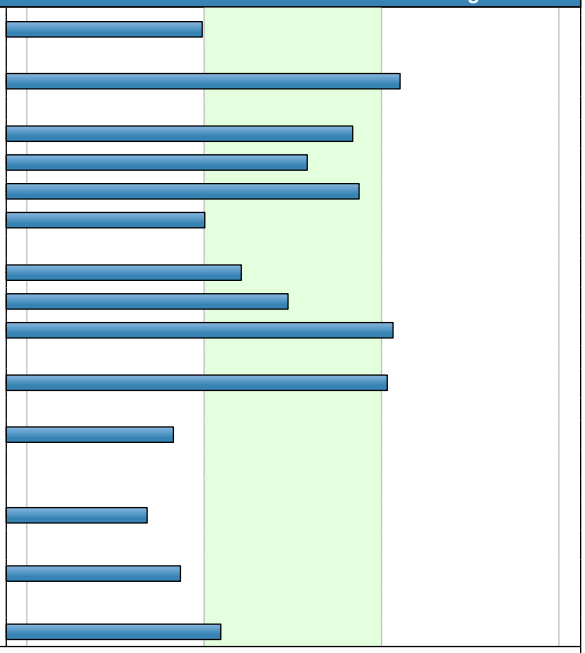
ANALYSIS REPORT

Client:	Lowe Environmental Impact Ltd	**Lab No:**	1251673 shpv1
Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014
		Date Reported:	28-Mar-2014
		Quote No:	60156
		Order No:	
		Client Reference:	
Phone:	06 359 3099	**Submitted By:**	Sian Cass

Sample Name: Byre Kai Non 20-Mar-2014 1:00 pm **Lab Number:** 1251673.2
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.2
Olsen Phosphorus	mg/L	36	20 - 30
Potassium	me/100g	0.57	0.40 - 0.60
Calcium	me/100g	7.5	4.0 - 10.0
Magnesium	me/100g	1.52	1.00 - 1.60
Sodium	me/100g	0.20	0.20 - 0.50
CEC	me/100g	15	12 - 25
Total Base Saturation	%	67	50 - 85
Volume Weight	g/mL	1.02	0.60 - 1.00
Sulphate Sulphur	mg/kg	13	10 - 12
Available Nitrogen (15cm Depth)*	kg/ha	133	150 - 250
Anaerobically Mineralisable N*	µg/g	87	
Organic Matter*	%	4.8	7.0 - 17.0
Total Carbon*	%	2.8	
Total Nitrogen*	%	0.27	0.30 - 0.60
C/N Ratio*		10.1	
Anaerobically Mineralisable N/Total N Ratio*	%	3.2	3.0 - 5.0
Base Saturation %		K 3.9	Ca 51 Mg 10.4 Na 1.4
MAF Units		K 12	Ca 10 Mg 35 Na 9



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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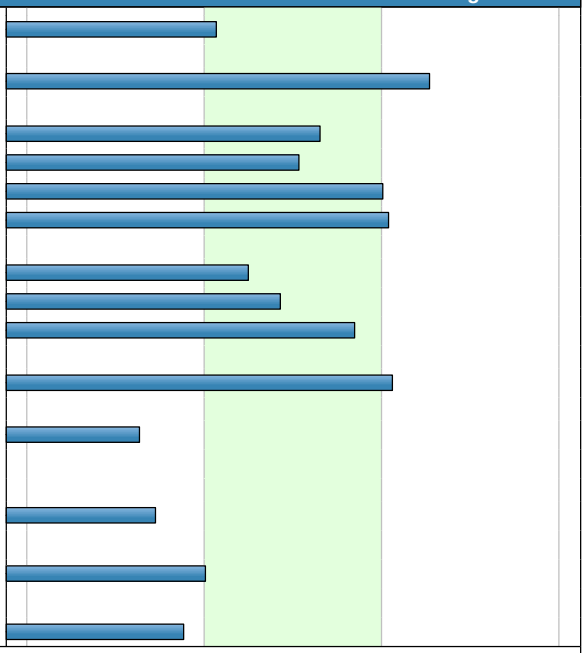
ANALYSIS REPORT

Client:	Lowe Environmental Impact Ltd	**Lab No:**	1251673 shpv1
Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014
		Date Reported:	28-Mar-2014
		Quote No:	60156
		Order No:	
		Client Reference:	
Phone:	06 359 3099	**Submitted By:**	Sian Cass

Sample Name: Byre Kai Irr 20-Mar-2014 2:00 pm **Lab Number:** 1251673.3
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.2
Olsen Phosphorus	mg/L	46	20 - 30
Potassium	me/100g	0.53	0.40 - 0.60
Calcium	me/100g	7.2	4.0 - 10.0
Magnesium	me/100g	1.62	1.00 - 1.60
Sodium	me/100g	0.54	0.20 - 0.50
CEC	me/100g	15	12 - 25
Total Base Saturation	%	65	50 - 85
Volume Weight	g/mL	0.94	0.60 - 1.00
Sulphate Sulphur	mg/kg	14	10 - 12
Available Nitrogen (15cm Depth)*	kg/ha	113	150 - 250
Anaerobically Mineralisable N*	µg/g	80	
Organic Matter*	%	5.1	7.0 - 17.0
Total Carbon*	%	2.9	
Total Nitrogen*	%	0.30	0.30 - 0.60
C/N Ratio*		9.7	
Anaerobically Mineralisable N/Total N Ratio*	%	2.7	3.0 - 5.0
Base Saturation %		K 3.5 Ca 47	Mg 10.6 Na 3.6
MAF Units		K 10 Ca 8	Mg 34 Na 23



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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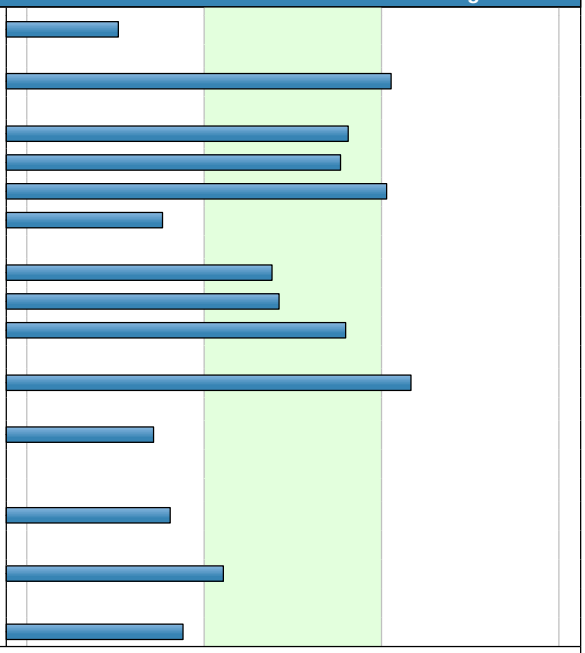
ANALYSIS REPORT

Client:	Lowe Environmental Impact Ltd	**Lab No:**	1251673 shpv1
Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014
		Date Reported:	28-Mar-2014
		Quote No:	60156
		Order No:	
		Client Reference:	
Phone:	06 359 3099	**Submitted By:**	Sian Cass

Sample Name: Byre Man Non 20-Mar-2014 3:00 pm **Lab Number:** 1251673.4
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.4	5.8 - 6.2
Olsen Phosphorus	mg/L	33	20 - 30
Potassium	me/100g	0.56	0.40 - 0.60
Calcium	me/100g	8.6	4.0 - 10.0
Magnesium	me/100g	1.68	1.00 - 1.60
Sodium	me/100g	0.15	0.20 - 0.50
CEC	me/100g	17	12 - 25
Total Base Saturation	%	65	50 - 85
Volume Weight	g/mL	0.92	0.60 - 1.00
Sulphate Sulphur	mg/kg	18	10 - 12
Available Nitrogen (15cm Depth)*	kg/ha	121	150 - 250
Anaerobically Mineralisable N*	µg/g	88	
Organic Matter*	%	5.6	7.0 - 17.0
Total Carbon*	%	3.3	
Total Nitrogen*	%	0.33	0.30 - 0.60
C/N Ratio*		9.9	
Anaerobically Mineralisable N/Total N Ratio*	%	2.6	3.0 - 5.0
Base Saturation %		K 3.3	Ca 51 Mg 9.9 Na 0.9
MAF Units		K 11	Ca 10 Mg 35 Na 6



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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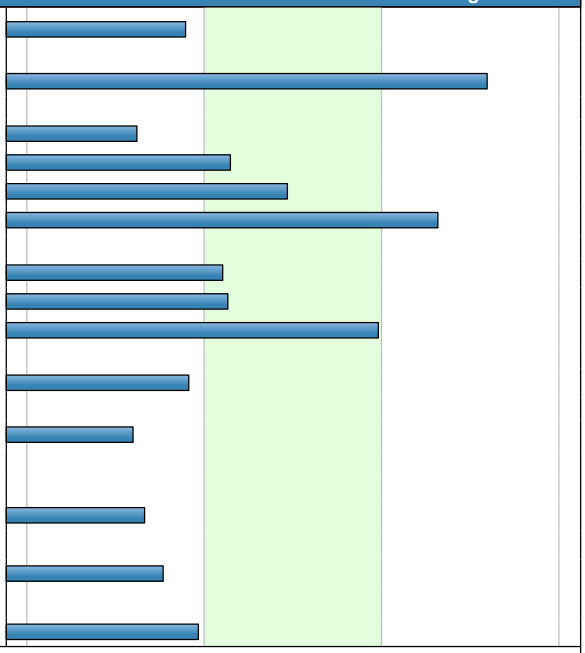
ANALYSIS REPORT

Client:	Lowe Environmental Impact Ltd	**Lab No:**	1251673 shpv1
Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014
		Date Reported:	28-Mar-2014
		Quote No:	60156
		Order No:	
		Client Reference:	
Phone:	06 359 3099	**Submitted By:**	Sian Cass

Sample Name: Byre Man Irr 20-Mar-2014 4:00 pm **Lab Number:** 1251673.5
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.7	5.8 - 6.2
Olsen Phosphorus	mg/L	66	20 - 30
Potassium	me/100g	0.31	0.40 - 0.60
Calcium	me/100g	4.9	4.0 - 10.0
Magnesium	me/100g	1.28	1.00 - 1.60
Sodium	me/100g	0.82	0.20 - 0.50
CEC	me/100g	13	12 - 25
Total Base Saturation	%	55	50 - 85
Volume Weight	g/mL	0.99	0.60 - 1.00
Sulphate Sulphur	mg/kg	9	10 - 12
Available Nitrogen (15cm Depth)*	kg/ha	110	150 - 250
Anaerobically Mineralisable N*	µg/g	74	
Organic Matter*	%	4.6	7.0 - 17.0
Total Carbon*	%	2.7	
Total Nitrogen*	%	0.25	0.30 - 0.60
C/N Ratio*		10.6	
Anaerobically Mineralisable N/Total N Ratio*	%	2.9	3.0 - 5.0
Base Saturation %		K 2.3 Ca 37	Mg 9.6 Na 6.2
MAF Units		K 6 Ca 6	Mg 29 Na 37



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014
		Date Reported:	28-Mar-2014
		Quote No:	60156
		Order No:	
		Client Reference:	
Phone:	06 359 3099	**Submitted By:**	Sian Cass

Analyst's Comments

Samples 1-5 Comment:
The medium range guidelines shown in the histogram report relate to sampling protocols as per Hill Laboratories' crop guides and are based on reference values where these are published. Results for samples collected to different depths than those described in the crop guide should be interpreted with caution.
For pastoral soils, the medium ranges are specific for a 75mm sample depth, but if a 150mm sampling depth is used the nutrient levels measured may appear low against these ranges, as nutrients are typically more concentrated in the top of the soil profile. These soil profile differences are altered upon cultivation or contouring.

Samples 1-5 Comment:
While soil Mg MAF levels of 8-10 are sufficient for pasture production, soil levels of 25-30 are required to ensure adequate Mg content in pasture for animal health (greater than 0.22%).

Samples 1-5 Comment:
The Available Nitrogen (kg/ha) test above assumes the sample is taken to a 15 cm depth. If the depth is 7.5 cm, then the result reported above should be divided by two.
To calculate Available Nitrogen (as kgN/ha) for other sample depths use the reported Anaerobic Mineralisable Nitrogen (AMN) result in the following equation:
AN (kg/ha) = AMN (µg/g) x VW (g/ml) x sample depth (cm) x 0.1
Note that the AN and AMN results reported include the readily available Mineral N (NH4-N and NO3-N) fraction, which is typically quite low.

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: Soil

Test	Method Description	Default Detection Limit	Sample No
Sample Registration*	Samples were registered according to instructions received.	-	1-5
Soil Prep (Dry & Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2mm screen.	-	1-5
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH.	0.1 pH Units	1-5
Olsen Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry.	1 mg/L	1-5
Sulphate Sulphur	0.02M Potassium phosphate extraction followed by Ion Chromatography.	1 mg/kg	1-5
Potassium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-5
Calcium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-5
Magnesium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-5
Sodium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	2 MAF units	1-5
Available Nitrogen*	Determined by NIR, calibration based on Available N by Anaerobic incubation followed by extraction using 2M KCl followed by Berthelot colorimetry. (Calculation based on 15cm depth sample).	1 mg/L	1-5
Anaerobically Mineralisable N*	As for Available Nitrogen but reported as µg/g.	5 µg/g	1-5
Organic Matter*	Organic Matter is 1.72 x Total Carbon.	0.2 %	1-5
Total Carbon	Dumas combustion.	0.1 %	1
Total Nitrogen	Dumas combustion.	0.04 %	1

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ANALYSIS REPORT

Client:	Lowe Environmental Impact Ltd	**Lab No:**	1251673 shpv1
Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014
		Date Reported:	28-Mar-2014
		Quote No:	60156
		Order No:	
		Client Reference:	
Phone:	06 359 3099	**Submitted By:**	Sian Cass

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Total Carbon*	Determined by NIR, calibration based on Total Carbon by Dumas combustion.	0.1 %	2-5
Total Nitrogen*	Determined by NIR, calibration based on Total N by Dumas combustion.	0.04 %	2-5
Potassium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.01 me/100g	1-5
Calcium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.5 me/100g	1-5
Magnesium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.04 me/100g	1-5
Sodium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.05 me/100g	1-5
Potassium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-5
Calcium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 %BS	1-5
Magnesium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.2 %BS	1-5
Sodium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-5
CEC	Summation of extractable cations (K, Ca, Mg, Na) and extractable acidity. May be overestimated if soil contains high levels of soluble salts or carbonates.	2 me/100g	1-5
Total Base Saturation	Calculated from Extractable Cations and Cation Exchange Capacity.	5 %	1-5
Volume Weight	The weight/volume ratio of dried, ground soil.	0.01 g/mL	1-5

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.

W.M.Homewood

Wendy Homewood
Operations Support - Agriculture Division

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ANALYSIS REPORT

Client:	Lowe Environmental Impact Ltd	**Lab No:**	1251760	svgpv1
Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014	
		Date Reported:	26-Mar-2014	
		Quote No:	60156	
		Order No:		
		Client Reference:		
Phone:	06 359 3099	**Submitted By:**	Sian Cass	

Soil Analysis Results

Sample Name:		Site 1 Affco 19-Mar-2014	Site 2 Affco 19-Mar-2014	Site 3 Affco 19-Mar-2014			
Lab Number:		1251760.1	1251760.2	1251760.3			
Sample Type:		SOIL Mixed Pasture	SOIL Mixed Pasture	SOIL Mixed Pasture			
Sample Type Code:		S1	S1	S1			
pH	pH Units	5.6	5.8	5.5	-	-	-
Olsen Phosphorus	mg/L	9	77	10	-	-	-
Potassium	me/100g	0.27	0.97	0.34	-	-	-
Potassium	%BS	2.6	7.7	2.2	-	-	-
Potassium	MAF units	6	21	6	-	-	-
Calcium	me/100g	4.8	5.5	6.0	-	-	-
Calcium	%BS	47	44	39	-	-	-
Calcium	MAF units	6	7	7	-	-	-
Magnesium	me/100g	0.82	1.34	1.17	-	-	-
Magnesium	%BS	8.0	10.6	7.6	-	-	-
Magnesium	MAF units	20	32	24	-	-	-
Sodium	me/100g	0.08	0.09	0.16	-	-	-
Sodium	%BS	0.8	0.7	1.0	-	-	-
Sodium	MAF units	4	4	6	-	-	-
CEC	me/100g	10	13	16	-	-	-
Total Base Saturation	%	58	63	49	-	-	-
Volume Weight	g/mL	1.06	1.06	0.89	-	-	-
Sulphate Sulphur	mg/kg	1	3	2	-	-	-
Available Nitrogen (15cm Depth)*	kg/ha	123	147	148	-	-	-
Anaerobically Mineralisable N*	µg/g	77	93	111	-	-	-
Organic Matter*	%	3.1	5.0	4.9	-	-	-
Total Carbon*	%	1.8	2.9	2.9	-	-	-
Total Nitrogen*	%	0.20	0.33	0.32	-	-	-
C/N Ratio*		9.2	8.8	8.9	-	-	-
Anaerobically Mineralisable N/Total N Ratio*	%	3.9	2.8	3.4	-	-	-

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ANALYSIS REPORT

Client:	Lowe Environmental Impact Ltd	**Lab No:**	1251760 svgpv1
Address:	PO Box 4667 PALMERSTON NORTH 4442	**Date Registered:**	21-Mar-2014
		Date Reported:	26-Mar-2014
		Quote No:	60156
		Order No:	
		Client Reference:	
Phone:	06 359 3099	**Submitted By:**	Sian Cass

Soil Analysis Results

Sample Name:	Site 1 Affco 19-Mar-2014	Site 2 Affco 19-Mar-2014	Site 3 Affco 19-Mar-2014			
Lab Number:	1251760.1	1251760.2	1251760.3			
Sample Type:	SOIL Mixed Pasture	SOIL Mixed Pasture	SOIL Mixed Pasture			
Sample Type Code:	S1	S1	S1			

Analyst's Comments

Sample 1 Comment:
The low CEC level found in this soil indicates that it can only retain cation nutrients (potassium, calcium, magnesium and sodium) at low levels. The normal ranges and the derived histograms are based on a typical soil with a CEC level between 12 and 25 me/100g. The % base saturation data for each element provides an alternative presentation that may be more appropriate for soils with atypical CEC values. Normal %BS levels, as a general guide, are: K 2%-5%, Ca 50%-75%, Mg 5%-15%, Na 1%-2%.

Samples 1-3 Comment:
The Available Nitrogen (kg/ha) test above assumes the sample is taken to a 15 cm depth. If the depth is 7.5 cm, then the result reported above should be divided by two.
To calculate Available Nitrogen (as kgN/ha) for other sample depths use the reported Anaerobic Mineralisable Nitrogen (AMN) result in the following equation:
AN (kg/ha) = AMN (µg/g) x VW (g/ml) x sample depth (cm) x 0.1
Note that the AN and AMN results reported include the readily available Mineral N (NH4-N and NO3-N) fraction, which is typically quite low.

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		Quote No:	60156
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		Client Reference:	
Phone:	06 359 3099	**Submitted By:**	Sian Cass

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: Soil

Test	Method Description	Default Detection Limit	Sample No
Sample Registration*	Samples were registered according to instructions received.	-	1-3
Soil Prep (Dry & Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2mm screen.	-	1-3
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH.	0.1 pH Units	1-3
Olsen Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry.	1 mg/L	1-3
Sulphate Sulphur	0.02M Potassium phosphate extraction followed by Ion Chromatography.	1 mg/kg	1-3
Potassium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-3
Calcium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-3
Magnesium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-3
Sodium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	2 MAF units	1-3
Available Nitrogen*	Determined by NIR, calibration based on Available N by Anaerobic incubation followed by extraction using 2M KCl followed by Berthelot colorimetry. (Calculation based on 15cm depth sample).	1 mg/L	1-3
Anaerobically Mineralisable N*	As for Available Nitrogen but reported as µg/g.	5 µg/g	1-3
Organic Matter*	Organic Matter is 1.72 x Total Carbon.	0.2 %	1-3
Total Carbon	Dumas combustion.	0.1 %	2
Total Nitrogen	Dumas combustion.	0.04 %	2
Total Carbon*	Determined by NIR, calibration based on Total Carbon by Dumas combustion.	0.1 %	1, 3
Total Nitrogen*	Determined by NIR, calibration based on Total N by Dumas combustion.	0.04 %	1, 3
Potassium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.01 me/100g	1-3
Calcium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.5 me/100g	1-3
Magnesium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.04 me/100g	1-3
Sodium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.05 me/100g	1-3
Potassium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-3
Calcium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 %BS	1-3
Magnesium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.2 %BS	1-3
Sodium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-3
CEC	Summation of extractable cations (K, Ca, Mg, Na) and extractable acidity. May be overestimated if soil contains high levels of soluble salts or carbonates.	2 me/100g	1-3
Total Base Saturation	Calculated from Extractable Cations and Cation Exchange Capacity.	5 %	1-3
Volume Weight	The weight/volume ratio of dried, ground soil.	0.01 g/mL	1-3

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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Fiona Calvert NZCS
Client Services Manager - Agriculture Division

APPENDIX D

AFFCO Soil Hydraulic Conductivity Analysis

Table 1: Soil Saturated Hydraulic Conductivity Results
Figure 1: Soil Unsaturated Hydraulic conductivity Results

Table 1: AFFCO Soil Saturated Hydraulic Conductivity Results

	Sandy Manawatu			Anthropic - like Rangitikei			Sandy Manawatu			Organic Anthropic - like Rangitikei		
	AFFCO Site 1			**AFFCO Site 2**			**AFFCO Site 3**			**AFFCO Site 4**		
Repetition	**Permeability**	**Average**	**Standard Deviation**	**Permeability**	**Average**	**Standard Deviation**	**Permeability**	**Average**	**Standard Deviation**	**Permeability**	**Average**	**Standard Deviation**
	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)	(mm/hr)
1	210			150			180			210		
	180			180			180			150		
	150			30			180			120		
	180			120			150			180		
		180	24		120	65		172.5	15		165	39
2	300			240			150			60		
	210			240			150			120		
	210			240			180			60		
	360			270			150			60		
		270	73		247.5	15		157.5	15		75	30
3	330			360			60			150		
	210			300			90			90		
	240			180			60			60		
	270			180			60			90		
		262	51		255	90		67.5	15		97	38
Site Average		**237**			**207**			**133**			**112**	
Site SD			**65**			**87**			**50**			**51**

Figure 1: AFFCO Soil Unsaturated Hydraulic Conductivity Results