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PATTLE DELAMORE PARTNERS LTD

Biosolids Land Disposal Assessment

Alliance Group Limited – Lorneville Plant

***solutions** for your environment*

Biosolids Land Disposal Assessment

Prepared for

Alliance Group Limited – Lorneville Plant

October 2015

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Limitations:

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1.0 Introduction

Alliance Group Limited (AGL) operates a sheep and lamb processing plant at Lorneville (Alliance Lorneville). All wastewater generated from site processes is treated onsite prior to discharge to the Makarewa River.

AGL holds several resource consents granted by Southland Regional Council that are due to expire in 2016. In preparation for the new consent application AGL has investigated options for upgrading the existing wastewater treatment plant, with the preferred approach involving a high-rate biological nutrient removal (BNR) wastewater treatment system using a combination of aerobic and anoxic (activated sludge) treatment processes.

When wastewater is treated in an aerobic biological wastewater treatment plant, contaminants such as biochemical oxygen demand (BOD), nitrogen and phosphorus are consumed by microorganisms, and some of which are assimilated into microbial biomass. In order to maintain effluent quality, a portion of this biomass must be retained in the treatment system and a portion must be removed from the system. The aerobic treatment process produces a semisolid, nutrient-rich bacterial by-product known as biosolids. When treated and processed properly, biosolids can be recycled and applied to agricultural land to improve soil quality and productivity because of the nutrients and organic matter that they contain (Cheremisinoff, 2003).

The term “biosolids” is now generally used to emphasise the beneficial nature of the product resulting from downstream aerobic biological wastewater treatment processes. The key aspects that need to be considered for the management of biosolids for disposal onto land are the regulatory aspects. Biosolids generally require additional treatment at the wastewater treatment facility before they are disposed of in order to meet regulatory requirements that protect public health, manage handling and reduce costs.

Land disposal to AGL owned land is the preferred approach to manage biosolids generated from a new biological nitrogen removal wastewater treatment plant.

Dewatering of the biosolids prior to land disposal will be undertaken in order to mitigate against waterlogging, ponding and nutrient runoff. Minimising nitrogen leaching requires a sustainable biosolids loading rate, consistent with the agronomic uptake of the sheep grazed pasture system at the site.

This technical assessment of environmental effects has been prepared by Pattle Delamore Partners Limited (PDP) to accompany Alliance Lorneville’s application for resource consent to apply biosolids generated from the future upgraded aerobic wastewater treatment facilities plant to company owned land as a soil amendment.

2.0 Description of Proposal

Waste activated sludge (WAS, or biosolids) generated from the treatment of wastewater be dewatered (using a centrifuge and/or screw press) prior to deposition as soil amendment product.

The disposal of stockyard solids is currently authorised by separate Southland Regional Council Resource Consent No. 206363 expiring on 31 July 2034 and this consent will continue to have controls on the disposal of stockyard solids on the same farmland where the biosolids disposal is proposed.

For any land utilised for stockyards solids disposal within the area currently consented for the activity, there will be no biosolids onto the same land within any 12 month period.

2.1 Biosolids Characterisation

Characterisation of biosolids generated from an upgraded activated sludge wastewater treatment plant at Alliance Lorneville where biosolids will be continuously wasted from the system is not available. However, site processes at the Alliance Pukeuri meat processing site are similar (except no chromium is utilised at Alliance Lorneville fellmongery) to those at Alliance Lorneville, and the biological wastewater treatment process at Alliance Pukeuri is also similar to that which is proposed at Alliance Lorneville. On this basis the expected characteristics of Alliance Lorneville biosolids have been obtained from sampling and analysis of Alliance Pukeuri biosolids which are outlined in Table 1, and a full analytical laboratory report is included as Appendix A.

Table 1: Expected Dewatered Biosolids Characteristics

Parameter[1]	Unit	Concentration
Dry Solids Content (post dewatering)	(g DS/100g)	18
Total Nitrogen	(g/100g DS)	6.0
Ammoniacal-Nitrogen	(mg/kg DS)	2,300
Organic Nitrogen	(mg/kg DS)	57,700
Total Phosphorus	(mg/kg DS)	12,200
Total Sulphur	(mg/kg DS)	8,700
Total Potassium	(mg/kg DS)	8,100
Total Calcium	(mg/kg DS)	15,300
Total Magnesium	(mg/kg DS)	1,630
Total Sodium	(mg/kg DS)	39,800
Total Copper	(mg/kg DS)	37
Total Lead	(mg/kg DS)	5
Total Zinc	(mg/kg DS)	286
Total Nickel	(mg/kg DS)	5
Total Arsenic	(mg/kg DS)	6
Total Cadmium	(mg/kg DS)	0.3
Total Chromium	(mg/kg DS)	117
Sodium Absorption Ratio	-	11.4

Notes:

1. *Characteristics obtained from sampling and analysis of Alliance Pukeuri biosolids.*
2. *Chromium is not expected in the biosolids generated at Alliance Lorneville as chromium is not utilised at the fellmongery.*

Calcium, magnesium, potassium and sulphur are considered beneficial for plant growth. However, some can be regarded as contaminants if lost from the soil as runoff to waterways or leaching to groundwater. Nitrogen is the key element in this category, which in the form of nitrate (NO_3^-) is highly mobile and has a high potential for leaching.

As outlined in Table 1, the biosolids has nutrient value that has a ratio of N:P:K at approximately 7:1.5:1, and hence the loading rate is generally limited by the nitrogen load. To ensure an appropriate soil nutrient balance is maintained for pasture and animal health it is recommended that an annual review of biosolids characteristics and soil characteristics is undertaken, with addition of supplementary nutrients as required to maintain an optimal ratio of nutrients for pasture growth.

When assessing for the biosolids, reference is made to the "*Guidelines for the Safe Application of Biosolids in New Zealand*" (MfE,2003) [2003 Biosolids Guidelines] specifically for contaminant load application rate and receiving soil contaminant limit for metals. Biosolids heavy metal concentrations outlined in Table 1 are considered acceptable for biosolids application to land. Heavy metal concentrations are further discussed in Section 2.3.

Elevated sodium concentrations and a high sodium adsorption ratio (SAR) can affect soil properties, especially where soils are characterised by a low exchangeable sodium percentage (ESP). A SAR value of 11.4 is unlikely to cause soil permeability problems in the short-term, however, it is recommended that the SAR of the biosolids and soil ESP levels are monitored on an ongoing basis. If required at some point in the future, then land application of calcium (in the form of gypsum) would be used to displace sodium, lowering ESP levels and restoring soil properties.

In order to ensure that the biosolids generated from future Alliance Lorneville BNR plant is similar to that generated at Alliance Pukeuri, a full suite of biosolids characterisation, consistent with the requirements of 2003 Biosolids Guidelines will need to be undertaken to benchmark the actual contaminants subject to land disposal.

2.2 Solids Generation Rate and Disposal Area

The annual solid waste production rates as a result of the proposed treatment plant upgrade is estimated as follows:

i. Stockyard solids - 280 tonnes dry solids per year;

ii. Biosolids (waste activated sludge) – 700 tonnes dry solids per year.

Alliance Lorneville has identified a total of 272 ha of land that could be available for biosolids and currently consented stockyard solids disposal including the areas currently earmarked for wastewater irrigation. Each year up to 180 ha of land would be utilised for biosolids disposal. An additional 25 – 30 ha of land would be utilised for disposal of stockyard solids. The company owned land together with the soil types is shown in Figure 1.

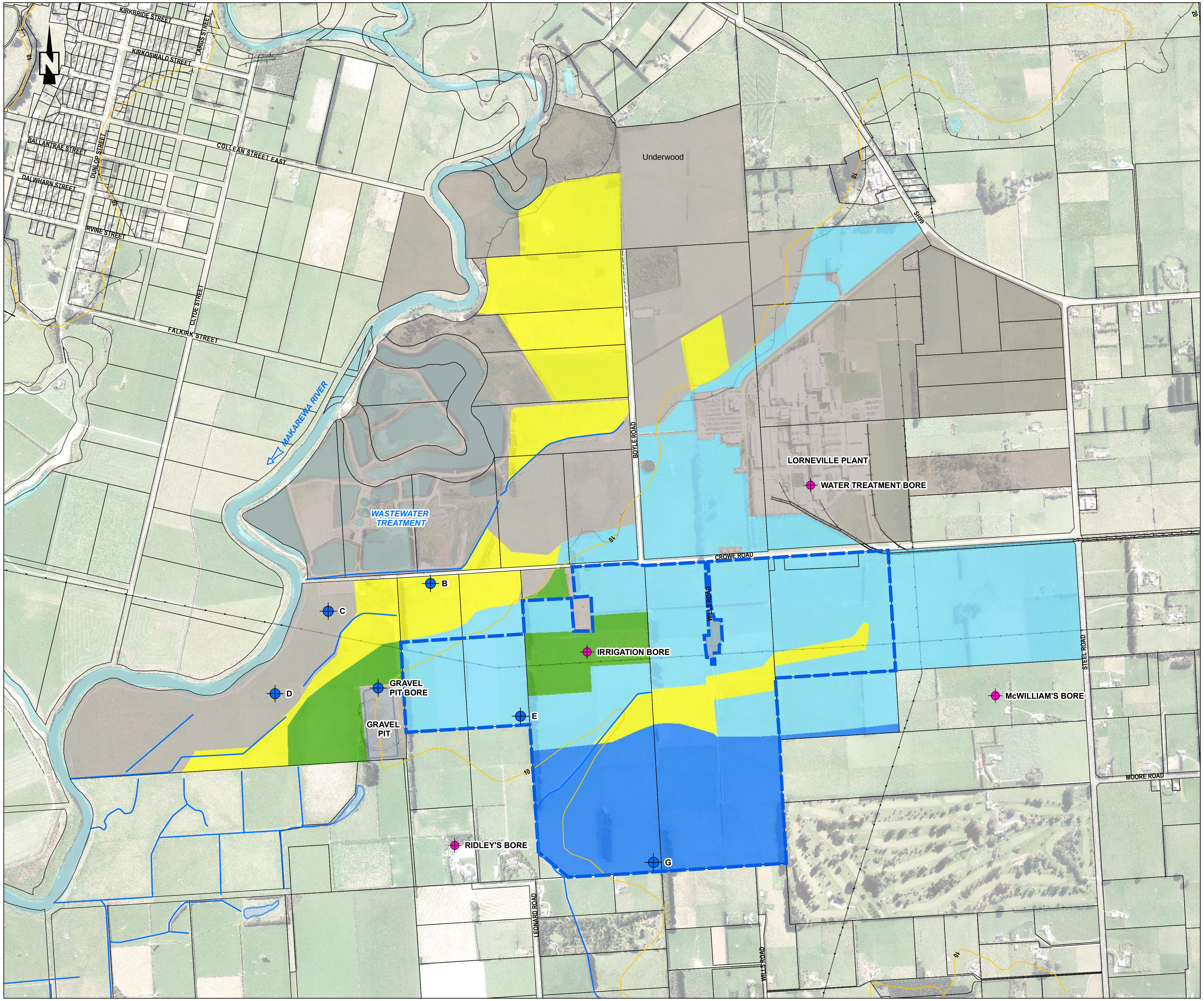
The disposal area will be managed as a grazed sheep pasture, with paddocks used for stock overflow when required to allow processing. The stock withholding period will be a minimum of 14 days. In the event the withholding period cannot be met, then the disposal of biosolids would be to a contingency monofill until the farm is released from the stock overflow management.

2.3 Comparison with NZ Biosolids Guidelines

In order to determine appropriate nitrogen loading rate, the default nitrogen loading limit of 200 kg total-N/ha/yr in the 2003 Biosolids Guideline (MfE, 2003) is considered conservative for land disposal of soil amendment material that has low nitrogen mineralisation rates and availability.

A site specific mass-balance assessment to support the proposed nitrogen loading rate of 250 kg total-N/ha/yr to the Alliance Lorneville sheep grazed system is considered in this assessment.

When checking against metal concentrations, the heavy metals outlined in Table 1 are all within acceptable levels for biosolids disposal to land under the 2003 Biosolids Guidelines, with the biosolids achieving a quality consistent with category '*grade a'* for all metal concentrations. Zinc concentrations could reach the *grade a* limit of 300 mg/kg DS, however, will be significantly less than the *grade b* limit of 1,500 mg/kg DS which is typically the established limit for land application when regular monitoring of biosolids characteristics is undertaken.



KEY :

- GROUNDWATER MONITORING BORE, MONITORED BY ALLIANCE LORNEVILLE (APPROX. LOCATION)
- ADDITIONAL GROUNDWATER MONITORING BORES (INSTALLED NOV 2014)

PROPOSED BIOSOLIDS DISPOSAL AREAS - SOIL TYPES:

ZONE 1

- 36ha of EDENDALE (WELL DRAINED)
- 118ha of WAIKIWI + WOODLANDS (WELL DRAINED AND MODERATELY DRAINED)
- 16ha of MOKOTUA (IMPERFECTLY DRAINED)

ZONE 2

- 56ha of TISBURY + DACRE + MAKAREWA (POORLY DRAINED)

- EXCLUDED AREA
- EXISTING WASTEWATER IRRIGATION AREA

SOURCE:
1. URBAN AERIAL IMAGES (FLOWN FEB 2011) SUPPLIED BY INVERCARGILL CITY COUNCIL.
2. SOIL TYPES DERIVED FROM SOIL WORK LTD. SOIL MAP DATED 25/02/2014.
3. CADASTRAL INFORMATION SUPPLIED BY LINZ 29/11/13.

NO.	REVISION	DATE	APP.
F	ISSUED FOR CONSENT	DEC 15	
A - E	ISSUED FOR REVIEW	MAR - NOV 14	

CLIENT : Alliance Group

PROJECT :

BIOSOLIDS LAND DISPOSAL ASSESSMENT

TITLE :

ALLIANCE LORNEVILLE PROPOSED BIOSOLIDS DISPOSAL AREA

pdp solutions for your environment

PATTLE DELAMORE PARTNERS LTD

Auckland Tauranga Wellington Christchurch

SCALE : 1:12,500 (A3)

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2.4 Estimate of Nitrogen Mineralisation

It is expected that nearly all of nitrogen present in the biosolids is initially in the form of organic nitrogen (organic-N), and is not available for plant uptake or leaching to groundwater immediately. Plant available nitrogen (PAN) comprises of ammoniacal nitrogen (NH_4-N) and nitrate/nitrite nitrogen (NO_3-N/NO_2-N). Organic-N is bound within bacterial cell walls, and must undergo mineralisation before it is released and available plant uptake.

In the absence of site-specific studies to determine the actual mineralisation rates for land application of biosolids from an upgraded wastewater treatment system, other field data from literature is relied upon. The USEPA (1995) guidelines for the land application of sewage sludge suggest that for anaerobically digested sludge, 20% mineralisation of organic-N occurs in the first year, which reduces to 10% in the second year, 5% in the third year, and less than 3% in the following years. After the third year, when the mineralisation rate is less than 3%, there is effectively no additional PAN other than that which would normally be obtained from the mineralisation of soil organic matter.

Henry *et al* (1999) suggests for that for lagooned biosolids the average mineralisation rate for the first year is between 10% and 30%. Evanylo (1999) suggests 30% mineralisation in the first year after application, 15% in the second, 8% in the third, with negligible mineralisation in subsequent years. Australia’s EPA NSW (1997) suggests 25% mineralisation in the first year for aerobically digested waste. For completely aerobically digested sludge, Australia’s EPA Victoria (2004) reports the first year nitrogen mineralisation rate to be approximately 25%.

For a high-rate biological nutrient removal activated sludge plant as proposed at Alliance Lorneville, a conservative approach has been taken to assume a rate of 40% mineralisation of the organic-N within the first year. Mineralisation rates of the order of 10% in the second year and 5% in the third year have been assumed. Thus for ongoing land application of biosolids to the Alliance Lorneville farm, it is assumed that approximately 55% of the organic-N content of the biosolids will become PAN.

2.5 Proposed Loading Rate

2.5.1 Proposed Biosolids Loading

Dewatered biosolids would be applied to land using specialised biosolids spreading equipment, such as a tractor hauled tandem axle computer controlled Strautmann VS 1204 – 2004 unit. This unit is capable of automatically adjusting the discharge as the speed of the tractor varies as it drives around a disposal site, allowing uniform biosolids application rate to be maintained.

The proposed nitrogen loading rate for application of dewatered biosolids to Alliance Lorneville land is 250 kg total-N/ha/yr. It is assessed that only 55% of the total nitrogen present will eventually become available for plant uptake, therefore, a loading rate of 250 kg total-N/ha/yr is equivalent to a PAN loading rate of 140 kg PAN/ha/yr.

Applying a biosolids total nitrogen composition of 6% of the dry weight, and assuming that the material will be dewatered to 18% dry solids, a total nitrogen load of 250 kg total-N/ha/yr equates to a gross bulk loading rate of 23 t/ha/yr.

When the above agronomic application for nitrogen is undertaken the heavy metals loading per hectare is likely to be no more than 153 grams for copper and 1.2 kg for zinc (based on results from biosolids testing). The annual loading rates permitted by USEPA (USEPA, 1999) are 75 kg/ha for copper and 140 kg/ha for zinc. Therefore the proposed heavy metals annual loading rates are very low.

2.5.2 Temporary Stock Overflow Faecal Load

The Alliance Lorneville farm is typically intensively stocked (up to 18,000 ewes) at the beginning of the production season from October to November, with numbers gradually reducing over the summer period, and with minimal stock onsite over the winter months.

Historical data shows that the average number of stock onsite over the course of the year is approximately 6,400 ewes, which equates to approximately 21 head/ha/yr over the 300 ha farm site (excluding the primary stock holding paddocks to the east of the plant). The faecal load from this stocking rate has been considered in the overall nitrogen load proposed for the land disposal area.

The historical stocking distribution at the site is indicated in Figure 2.

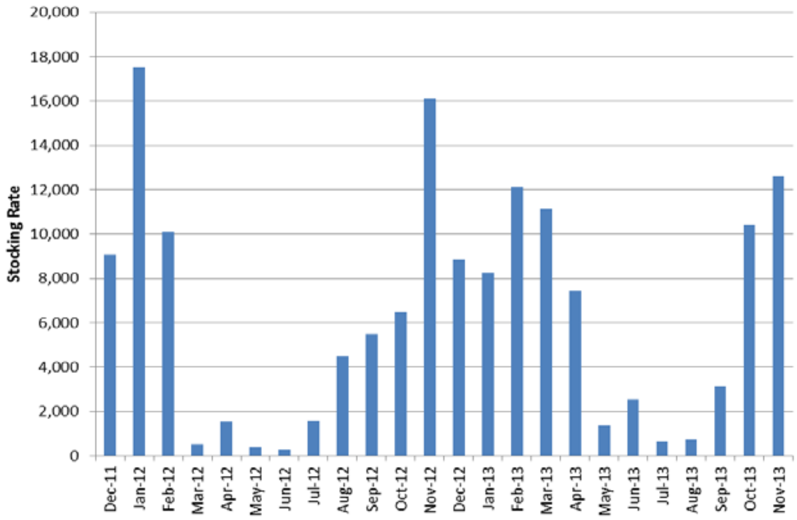

Figure 2: Historical Stocking Distribution

2.5.3 Nitrogen Loading from Wastewater Irrigation

Treated wastewater has been irrigated to a 100 ha area of well drained to imperfectly drained soils (Zone 1) on the Alliance Lorneville farm for the past 10 years under Southland Regional Council Resource Consent No. 20034. Monitoring is reported annually by SoilWork Ltd, and for 2013 as outlined in the report Lorneville Plant Wastewater Irrigation, Annual Monitoring and Performance (SoilWork, 2013a).

Wastewater irrigation has typically involved low nitrogen loading rates, with 89 kg/ha/yr and 236 kg N/ha/yr applied during the 2011-2012 and 2012-2013 seasons respectively (SoilWork, 2013a). While it is proposed that the existing wastewater irrigation would cease once the biosolids disposal commences following wastewater treatment plant upgrade, data from historical wastewater nitrogen loading and leaching monitoring has been used in the assessment of the predicted nitrogen with additional biosolids loading.

2.6 Alternative Options Considered

Apart from the disposal of biosolids to land, other alternatives can has also been considered but are not preferred.

The consideration of alternatives is assessed when the proposed activity may result in significant adverse environmental effects. There are no significant adverse effects expected from the proposed activity, however, Alliance Lorneville has considered alternative disposal options for the biosolids to ensure that the proposed activity is consistent with good practice. These included:

1. Biosolids dewatering with disposal to sanitary landfill;
2. Biosolids dewatering with disposal to monofill; and
3. Biosolids dewatering and composting for garden use.

2.6.1 Disposal to Sanitary Landfill

The use of biosolids for pasture growth is considered a more sustainable and environmentally friendly alternative to sanitary landfill disposal.

Based around 3,900 tonnes of dewatered solids, up to an additional 400 articulated truck movements would be required per year. The transportation and disposal at a landfill of material that can be used as a soil amendment is considered as a poor alternative.

2.6.2 Disposal to Monofill

Alliance Lorneville has proposed the use of a contingency monofill to temporarily store dewatered biosolids, such that continued use as a soil amendment can be promoted. In the event the biosolids cannot be disposed onto land for an extended period of time, the use of the monofill would also be relied upon.

It is expected that the use of the contingency monofill may result in up to 20% annual volume diverted to the monofill.

2.6.3 Composting for Garden Use

The ability of direct disposal of biosolids onto land can by-pass composting step when managed appropriately and provide flexibility to the site operations.

Composting does not offer any significant advantage over direct disposal to company owned farmland, and therefore this option has not been considered any further.

3.0 Description of Receiving Environment

3.1 Existing Land Use and Topography

The proposed biosolids disposal area is predominantly used for sheep grazing. Occasionally some areas are not grazed and crop harvested and exported from the farm. Dwellings in the area are associated with pastoral farming as well as residential housing, with the closest residential area being Underwood at SH99 on the north-eastern boundary of company owned land.

The proposed area of pasture to be used for biosolids disposal consists of generally flat to undulating topography. The site consists of two terraces, with the processing plant situated on the upper terrace above a lower river terrace. Both areas are generally flat with some undulations and hollows. Between the terraces there is a large area of moderately sloping ground utilised for pastoral grazing. There are a number of drains within the farm to direct surface water from low lying areas to the Makarewa River on the west of the farmland.

3.2 Climate

Mean monthly temperature, rainfall and potential evapotranspiration recorded by NIWA derived from various sites in the vicinity of the Lorneville plant is given in Table 2.

Table 2: Summary of Mean Monthly Climate Data

Month	Temperature (C°)	Rainfall (mm)	Pet (mm)
January	9.5 - 18.7	106.2	122.8
February	9.1 - 18.6	80.1	93.4
March	7.9 - 17.3	89.2	69.2
April	5.9 - 15.0	99.5	37.9
May	3.7 - 12.2	112.3	20.7
June	1.8 - 9.8	103.1	12.1
July	1.0 - 9.5	79.8	14.1
August	1.9 - 11.1	69.0	27.8
September	3.8 - 13.0	79.8	51.8
October	5.5 - 14.5	94.3	84.4
November	6.8 - 15.8	91.9	107.5
December	8.5 - 17.6	93.6	125.8
Annual Mean	**5.4 - 14.4**	**1,097**	**768**

Notes:

1. *PET is total Penman potential evapotranspiration.*
2. *Temperature values are associated with mean daily air temperature.*
3. *Data from NIWA for Lorneville site, Invercargill, January 1955 to October 2015.*
4. *The Latitude/Longitude value assumed for Lorneville is -46.35, 168.32.*
5. *Data sourced from the following stations in CliFlo: 11104, 12444, 5813 and 5814. These stations are located within 8km from the Lorneville plant.*

The predominant wind direction is from south-westerlies to westerlies for higher intensity winds. Low intensity winds generally tend be north to north-westerlies (Macara, 2013).

3.3 Soil Characteristics

A spatial analysis of soil characteristics of the Alliance Lorneville farm is illustrated in the soil map (soil mapping provided by SoilWork Ltd (SoilWork, 2013b)) in Figure 1. Areas currently receiving wastewater irrigation are identified, along with areas identified for potential biosolids land disposal.

The soils on the company owned land are grouped into 3 zones. Zone 1 areas contain Edendale, Waikiwi and Mokotua soils and are classified as “well drained to imperfectly drained”. These soils are considered to be suitable for biosolids disposal for an extended period of time. Zone 2 soils are “poorly drained” and could also receive biosolids during dry conditions to allow heavy mechanical equipment in these areas. Zone 3 areas contain “very poorly drained” soils which are considered unsuitable for biosolids disposal.

Key data from the spatial analysis of Alliance Lorneville farm soils is summarised in Table 3. Soil areas presented in Table 3 has made provision for buffer zones to water bodies, neighbouring properties and roads. Therefore, the areas available for biosolids disposal indicated in Table 3 are less than the total soils areas outlined in n Figure 1.

Table 3: Alliance Lorneville Farm Soil Characteristics

Soil Zone	Zone 1	Zone 2	Zone 3
Soil Classes	Edendale, Waikiwi and Mokotua soils	Makarewa, Dacre and Tisbury soils	Invercargill peaty soils
Permeability Category	Well drained to imperfectly drained	Poorly drained	Very poorly drained
Estimated Area (ha)	150	47	75

Notes:

1. *The area of Zone 1 soils presented in this table has been reduced by 3-5 ha to account for small unmapped relict stream channels that comprise of poorly drained Zone 2 soils, and which are not considered suitable for biosolids application;*
2. *Zone 2 soils are not considered suitable for wet biosolids disposal, and are considered suitable for dewatered biosolids disposal only during dry conditions;*
3. *Zone 3 soils are considered unsuitable for biosolids disposal;*
4. *Areas contained buildings, wastewater treatment lagoons and key paddocks for stock holding have been excluded, as well as allowance for buffer zones to water bodies, neighbouring properties and roads.*

3.4 Geology

The geology of the area comprises of Holocene age alluvium comprising unconsolidated sand and gravels which are overlain by loess in the flood plain of the Makarewa and Oreti Rivers. These Holocene deposits are reported as less than 12,000 years old and are likely to be stratified with some lateral variation in composition (Turnbull and Allibone, 2003).

3.5 Hydrogeology

The land disposal site is located within the lowland aquifers zones of Southland compromising of gently undulating topography with gravel surfaces formed by highly weathered glacial outwash. The groundwater zones are identified as Lower Oreti, Makarewa and Waihopai.

Similar subsurface geology is found within each of these groundwater zones, where relatively thin Quaternary gravel deposits overlay Tertiary Gore Lignite Measure Sediments.

Generally the groundwater system is considered to be an unconfined aquifer, although there are reported to be localised layers of low permeability strata in certain locations. The shallow gravel aquifer deposits vary in thickness, but are reported to be typically approximately 10 m thick in the Wallacetown area.

Groundwater recharge is principally from rainfall infiltration whereas discharge mostly occurs by local seepage into springs, streams and rivers.

Groundwater flow is from locations of higher groundwater elevation to lower groundwater elevation, often towards a river system. In general, aquifer permeability (hydraulic conductivity) is reported to be uniformly low across the area due to the highly weathered nature of the matrix material in the gravel deposits. The transmissivity is assessed at an average of 5.2 m^2/d and the hydraulic conductivity at 4 x 10^{-6} m/s. The groundwater flux is estimated to be around 0.25 m/yr.

Several monitoring wells are installed on the company owned farmland to monitor the shallow groundwater characteristics. The aquifer system is generally shallow and unconfined, and as a result, the quality of groundwater can be influenced by contaminants introduced at the surface level. Water quality of the groundwater measured at the Alliance Lorneville and the surrounding areas is shown in Table 4.

Table 4: Water Quality of Bores Within or Adjacent to Site

Parameter	McWilliam	Water Treatment	Irrigation	Ridley
Depth to Groundwater(m BGL)	NA	4.6	3.8	NA
NH_4-N (g/m^3)	0.07	0.07	0.4	0.03
NO_3-N (g/m^3)	1.8	4.5	1.8	4.7
Chloride (g/m^3)	31	64	57	44
Faecal Coliforms (cfu/100mL)	2.8	12	50	20
Conductivity (mS/m)	20	20	30	30
pH	6.4	6.4	6.9	6.2

Notes:

1. *NH_4-N=ammoniacal nitrogen, $N0_3$-N=nitrate nitrogen;*
2. *NA – data not available;*
3. *Water quality parameters reported here are average values (mean) from monthly sampling and analysis carried out from 2004 to 2014;*
4. *Based on the preliminary groundwater profile assessment McWilliams's bore and the Water Treatment bore are likely located upstream of the existing Alliance Lorneville WWTP and wastewater land disposal operation, the Irrigation bore is located within the existing wastewater irrigation area, and Ridley's bore is located downstream of the existing Alliance Lorneville WWTP and land disposal operation.*

The groundwater in the area is utilised for domestic purposes and stock water. The two domestic supply bores directly adjacent to the processing plant are monitored by Alliance Lorneville together with the bores on the farmland. Additional monitoring bores were installed in November 2014 and these bores could become part of future groundwater monitoring.

4.0 Assessment of Environmental Effects

The assessment of environmental effects has been prepared to consider the key environmental receptors and potential effects including:

a) Effects on soil;
b) Effects on groundwater, in particular nutrient leaching;
c) Effects on any surface water bodies, in particular ammoniacal nitrogen and nitrate nitrogen loading;
d) Effects on air quality.

4.1 Estimate of Current Nitrogen Leaching

For biosolids generated from meat processing wastewater treatment systems, nitrogen is considered to be the most significant constituent of the biosolids that may have the potential to have an effect on groundwater and surface waters. There is sufficient separation from water bodies being implemented to prevent any other contaminants reaching water bodies. Traditionally, nitrogen limitations are generally applied based on a total nitrogen limit with the assumption that all the nitrogen is available for uptake in the first year following application.

As discussed in Section 2.4, the majority of the nitrogen (95% approximately) is organic nitrogen (bound within bacterial cell wall) and must undergo reasonable mineralisation before it is released for plant uptake (plant available nitrogen). Therefore, the opportunity exists to manage the nitrogen application such that the rate of release of nitrogen from the biosolids is generally matched to the ability of nitrogen uptake by the pasture/crops where the disposal occurs.

Nitrogen losses are presently monitored at the Alliance Lorneville land treatment site using a series of lysimeters and by applying estimates of drainage obtained from a daily water balance model. Monthly lysimeter monitoring has been undertaken for a 10 year period. Monitoring is carried out at sites receiving wastewater and at sites not receiving wastewater, which include higher permeability Zone 1 soils and lower permeability Zone 2 soils.

The lysimeters are installed at approximately 1 m deep and consist of a ceramic cup (approximately 5 cm diameter and 6 cm long) which are attached to lengths of plastic pipe and contain pressure and vacuum tubes for extracting samples of leachate.

4.1.1 Non-Irrigated Area

During the last 10 years, the average nitrate leaching losses for Zone 1 soils not receiving wastewater irrigation was 2.7 kg N/ha/yr, and ranged from 0.5 to 11.5 kg N/ha/yr. Average leaching losses for Zone 2 soils not receiving wastewater was 11.3 kg N/ha/yr, and ranged from 0.1 to 40 kg N/ha/yr.

4.1.2 Wastewater Land Treatment Areas

During the last 10 years, the average nitrate leaching losses for Zone 1 soils receiving wastewater irrigation was 6.7 kg N/ha/yr, and ranged from 1.4 to 14.2 kg N/ha/yr. Average leaching losses for Zone 2 soils receiving wastewater was 11.4 kg N/ha/yr, and ranged from 1.6 to 38.6 kg N/ha/yr.

For the 2012/2013 season when the nitrogen loading rate was 236 kg N/ha/yr, average nitrate leaching losses for Zone 1 soils was 13.3 kg N/ha/yr and average leaching losses from Zone 2 soils was 10.6 kg N/ha/yr.

4.1.3 Effects of Stocking Rates

The average stocking rate on an annual basis for a conventional lowland Southland sheep farm is approximately 13.5 sheep/ha (Environment Southland, 2013). Therefore, the Alliance Lorneville farm stocking rate during peak times is approximately 1.6 times higher than an average lowland Southland sheep farm.

Typical annual nitrogen leaching losses for lowland sheep grazed pastures in New Zealand are of the order of 10 to 20 kg N/ha/yr (AgResearch, 2010a). Soil type influences the amount of nitrogen leaching from the soil profile, with greater losses observed for shallow stony soils, as compared to heavier-textured and/or poorly drained soils (such as the predominant soil type at Alliance Lorneville).

Nitrogen leaching rates to areas both receiving and not receiving wastewater irrigation are similar to those expected for a typical lowland Southland sheep farm at 10 to 20 kg N/ha/yr (AgResearch, 2010a).

Nitrate losses from stocking at the Alliance Lorneville farm are likely limited due to the peak stocking period coinciding with the period of peak spring grass growth, and due to the farm being largely free of stock over the winter period when the risk of nitrogen runoff/leaching is greatest. The moderately to poorly drained soils likely limits nitrogen leaching losses at the site.

While there is limited literature data on nitrogen leaching as a result of variable sheep stocking rates, Sprosen *et al* (2002) reported a trend for increased nitrogen leaching with decreased stocking rate in dairy farms with the same feed availability and attributed this to differences in patterns of nitrogen excretion and increased compaction and gaseous nitrogen losses with higher stocking rates. Sprosen *et al* suggested high stocking numbers do not necessarily result in increased losses in situations where additional feed is not brought to the site, as is the practice at the Alliance Lorneville farm. Therefore, the increased stocking rates at Alliance Lorneville farm may not necessarily impact on the nitrogen leaching losses.

4.2 Conceptual Nitrogen Leaching Estimation Model

A conceptual nitrogen balance model has been prepared for the Alliance Lorneville farm system (sheep grazed pasture). The key output from the model is the predicted nitrogen load leached to groundwater which is determined based on the applied nitrogen input and stocking rate.

4.2.1 Model Scenarios and Components

The nitrogen balance model has been validated against historical nitrogen applications and nitrogen leaching data from lysimeter monitoring. The following model scenarios have been developed:

- Model 1 - Existing grazed pasture system with no nitrogen addition (validation);
- Model 2 - Existing grazed pasture system with wastewater irrigation (validation);
- Model 3 - Proposed grazed pasture system with proposed biosolids application.

The following sections outline the basis of the nitrogen inputs and nitrogen pathways which have been utilised in the nitrogen balance models. Inputs and outputs for each model scenario are outlined in Figure 2 to Figure 4.

Nitrogen Input

The majority of the pasture grazing system receives no nitrogen addition (e.g. mineral fertiliser), however, a dedicated area has received nitrogen via treated wastewater irrigation.

The 2012-2013 nitrogen loading rate for the irrigated areas was 236 kg PAN/ha/yr and the 2011-2012 loading rate was 89 kg PAN/ha/yr (SoilWork, 2013a). For the validation model of wastewater irrigated pastures (Model 2), the average loading rate between the two periods of 163 kg PAN/ha/yr has been utilised. As the form of nitrogen within treated wastewater is predominantly oxidised nitrogen (NO_3-N and NO_2-N) and NH_4-N, the nitrogen loading rate is available for uptake by plants.

For the biosolids application model (Model 3) a PAN loading rate of 140 kg PAN/ha/yr has been utilised.

Nitrogen inputs through atmospheric clover fixation are discussed below.

Volatilisation of Nitrogen

A portion of nitrogen present in treated wastewater in the form of NH_4-N is lost to atmosphere via volatilisation. The fraction of total-nitrogen in the irrigated wastewater that was in the form of NH_4-N was on average 93% during 2011-2013.

Vanderholm (1984) reported volatilisation losses of 15 to 30% of total nitrogen for irrigated treated agricultural wastewater. The average of the range reported by Vanderholm of 23% has been assumed for this model. On this basis approximately 38 kg N/ha/yr of the 163 kg N/ha/yr load applied to the pasture is assumed to be volatilised.

Given that the fraction of total-nitrogen in the biosolids in the form of NH_4-N will be very low (estimated at 4% - refer Table 1), the biosolids model losses due to NH_4-N volatilisation are assumed to be negligible.

Plant Available Nitrogen within Soil

This represents the PAN available for uptake by pasture or microbial utilisation, including nitrification and denitrification by bacteria present within soils. The soil available nitrogen is the sum of all applied nitrogen such as biosolids or wastewater, as well as returned nitrogen from sheep manure and urine.

The return of nitrogen to the soil from pasture due to the process of senescence (dead pasture material) has been excluded, as pasture uptake has been determined based on the pasture consumed by sheep rather than pasture production rates.

Denitrification

Denitrification can be accomplished biologically under “anoxic” (without dissolved oxygen) conditions. Environmental factors which influence the denitrification process include the presence of oxygen, pH, and temperature.

Ledgard *et al* (1999) found nitrogen losses from pasture through denitrification of 2 to 10% of applied nitrogen. Losses through denitrification have been estimated conservatively at 2% for all nitrogen balance models.

Excess Soil Nitrogen

Soil available nitrogen that is not utilised by pasture or is not lost to atmosphere through denitrification will leach from the soil. Once it has progressed below the root zone of pastures, this nitrogen is no longer available for plant uptake and is eventually lost to groundwater.

Sheep Pasture Uptake

The uptake of nitrogen by sheep from pasture has been determined based on the dry weight mass of pasture consumed and the nitrogen content of the pasture.

The mass of pasture consumed by sheep has been based on the average monthly stocking rate for the Alliance Lorneville farm pastures, and typical monthly sheep feeding data provided by Beef and Lamb NZ (Beef and Lamb NZ, 2012). The resulting pasture consumption of 13,910 kg dry solids/ha/yr is consistent with pasture yield rates of 14,200 kg dry solids/ha/yr for the Winton area (Diary NZ, 2014).

With the lack of any herbage analysis data for pastures at Alliance Lorneville, the nitrogen content of consumed pasture has been based on typical values outlined in literature. The following literature was considered in order to estimate the expected nitrogen content of the pastures:

- 1.6% to 4.8% for pasture (Lambert and Litherland, 2000);
- 3.2% to 4.8% for pasture (Hill laboratories, 2014);
- 2.0% to 5.0% for ryegrass (Lamb *et al*, 2002);
- 4.0% to 4.5% for pasture (Bell *et al*, 2012).

For the nitrogen balance validation models, the nitrogen content of pasture has been set to achieve leaching values equivalent to the observed nitrogen leaching from lysimeter monitoring. As expected for a low input pasture system with no added fertiliser, the nitrogen content of pasture for Model 1 is 1.9%, which is at the lower end of the expected range. Thus the sheep pasture nitrogen uptake for Model 1 is estimated to be 260 kg N/ha/yr (1.9% of 13,909 kg dry solids/ha/yr).

The addition of fertilisers to pasture is often utilised to increase the nutritional content for stock consumption. The nitrogen content of pasture for Model 2 was determined to be 4.5%, at the upper end of the expected range for pastures. This is considered reasonable for pastures receiving nitrogen from treated wastewater. Thus the sheep pasture nitrogen uptake for Model 2 is estimated to be 630 kg N/ha/yr (4.5% of 13,909 kg dry solids/ha/yr).

The proposed addition of nitrogen in the form of biosolids is expected to increase the nitrogen content of pasture. Based on the nitrogen content of 1.9% for pastures for Model 1 (no nitrogen addition), and a nitrogen content of 4.5% for pastures receiving 126 kg PAN/ha/yr from treated wastewater irrigation (Model 2 - remaining PAN from average loading rate of 163 kg N/ha/yr for the 2011 to 2013 period after loss of 37 kg N/ha/year through volatilisation), the nitrogen content of pasture for the proposed biosolids disposal was proportionally estimated to be 4.8% for 140 kg PAN/ha/yr. This is at the higher end of the expected nitrogen content range for pasture (Lambert and Litherland, 2000). Thus the sheep pasture nitrogen uptake for Model 3 is estimated to be 674 kg N/ha/yr (4.8% of 13,910 kg dry solids/ha/yr).

Pasture Uptake from Clover Fixation

In addition to nitrogen contributions from fertiliser and animal excreta returns, nitrogen is also captured from the atmosphere through nitrogen fixation by clover within the pasture. Clover is reduced in pastures where higher levels of nitrogen are applied to pasture, as clover species are out competed by non-nitrogen fixing pasture species via clover suppression (Vanderholm, 1984).

Studies by Harris *et al* (1994) on clover cover and atmospheric nitrogen fixation by clover in pastures at nitrogen applications of 0, 200 and 400 kg N/ha/yr found decreasing clover cover and nitrogen fixation for increasing nitrogen application. Based on the results of studies by Harris *et al*, clover nitrogen fixation rates of 114 kg N/ha/yr, 85 kg N/ha/yr and 83 kg N/ha/yr have been assumed for Model 1, Model 2, and the biosolids model respectively.

Pasture Uptake from Soil Available Nitrogen

The pasture uptake from soil available nitrogen has been determined based on the nitrogen content of pasture where that nitrogen is not provided by clover fixation.

Sheep Nitrogen Retained and Returned

As the dietary uptake of nitrogen increases, the nitrogen content in animal urine increases to a greater extent than manure nitrogen content which stays relatively more constant (Diana *et al,* 2014) (AgResearch, 2010b).

The Ministry for Primary Industries (MPI) Technical Paper No. 2014/05 (AgResearch, 2010b) outlines the proportion of nitrogen uptake by sheep which is excreted in urine, excreted in manure and which is retained as animal matter for different nitrogen uptake rates. Based on this data, the proportion of nitrogen uptake by sheep which are returned to pasture as urine or manure, or retained by the animal have been estimated. Estimates which have been assumed in each model are presented in Table 5.

Table 5: Estimate of Nitrogen Uptake and Losses for Lorneville Farm

Model	Sheep Pasture Nitrogen Uptake	Urine-N	Dung-N	Retained-N
	kg N/ha/yr			
Model 1 – No Nitrogen	262	86	135	41
Model 2 – Wastewater	633	430	160	43
Model 3 – Biosolids	674	469	162	43

Notes:

1. *MPI Technical Paper No. 2014/05 (AgResearch, 2010b) outlines the proportion of nitrogen uptake by sheep which is excreted in urine, manure and which is retained as animal matter for different nitrogen uptake rates;*
2. *For a sheep pasture nitrogen uptake rate of 38 g N/sheep/d (291 kg N/ha/yr based on a stocking rate of 21 head/ha/yr) the conversion ratio is reported to be: urine 39% (114 kg N/ha/yr), dung 47% (137 kg N/ha/yr) and retained by the animal 14% (41 kg N/ha/yr);*
3. *For a sheep pasture nitrogen uptake rate of 94 g/sheep/d (720 kg N/ha/yr based on a stocking rate of 21 head/ha/yr) the conversion ratio is reported to be: urine 71% (512 kg N/ha/yr), dung 23% (166 kg N/ha/yr) and retained by the anima 6%l (43 kg N/ha/yr);*
4. *Intermediate sheep pasture nitrogen uptake conversion ratios for the various model scenarios have been determined on a proportional basis, based on the sheep pasture nitrogen uptake.*

Urine Nitrogen

The loss of nitrogen from urine to atmosphere occurs through volatilisation of ammonia. Volatilisation of ammonia from urine generally results in losses of 15 to 25% of urine nitrogen, although greater losses may occur under warm dry summer conditions (Russelle, 1996).

For each of the nitrogen balance models, volatilisation is assumed to be 20% of urine nitrogen.

The availability or recovery of urine nitrogen by pasture and soil has been found to range from 77 to 85% for sandy loam soils (Sorensen and Jensen, 1996). It is expected that recovery of urine nitrogen by Alliance Lorneville farm soils, which are generally silty loam, will be high due to expected lower infiltration rates compared to sandy loam soils. Therefore a value of 80% has been assumed for recovery of urine nitrogen. This nitrogen is available to soil for uptake by pasture.

Based on urine nitrogen recovery of 80% and urine nitrogen losses through volatilisation of urine ammonia of 20% urine nitrogen, the leachable fraction of urine nitrogen is zero. If a more conservative nitrogen recovery value of 75% is assumed, this results in deficit in available nitrogen within soil for Model 1 and therefore a value of 80% is considered to be reasonable.

Manure Nitrogen

The majority of nitrogen content within manure is Organic-N. Organic-N within manure must be mineralised before it becomes available for uptake by plants as PAN. The loss of NH_4-N within manure to atmosphere occurs through volatilisation, with the remaining NH_4-N being available for uptake by plants.

Based on an NH_4-N content for sheep manure of 28% of total manure nitrogen content, and a volatilisation rate of 75% of NH_4-N for manure (Barker *et al*, 2002), the loss of manure nitrogen through volatilisation has been determined to be 21% of total manure nitrogen. The volatilisation rate of NH_4-N is greater for manure than for urine, as manure remains on the surface of soil where it is exposed to air and sun for an extended period.

The organic-N content of manure is 72% (Barker *et al*, 2002), however, as outlined for biosolids, only a portion of this nitrogen is mineralised annually to become plant available.

Oregon State University (Sullivan, 2008) has provided mineralisation rates for estimation of manure PAN which are outlined as follows:

- 1st year 40%
- 2nd year 15%
- 3rd year 7%
- 4th year 3%
- 5th to 10th year 12% (cumulative)

Based on Sullivan (2008), for a system of ongoing pasture use, the total annual manure PAN will be 77% of Organic-N. Based on an Organic-N content of total manure nitrogen of 72%, the annual PAN will be approximately 55% of total manure nitrogen. Ketterings *et al* (2008) also reported that 55% of the total nitrogen component of sheep manure will eventually be released as PAN.

Leached Nitrogen Modelling

The leached nitrogen load for the Alliance Lorneville pasture system receiving no nitrogen application and pastures receiving treated wastewater irrigation has been based on the leached nitrogen loads for non-irrigated and irrigated pastures for the 2012-2013 seasons.

The model parameters outlined in the preceding sections have been configured to achieve the measured nitrogen leaching rates for Model 1 (pastures with no nitrogen application) and Model 2 (pastures with treated wastewater irrigation).

Results of each model are indicated in Figure 3 to Figure 5 and are discussed in Section 4.3.

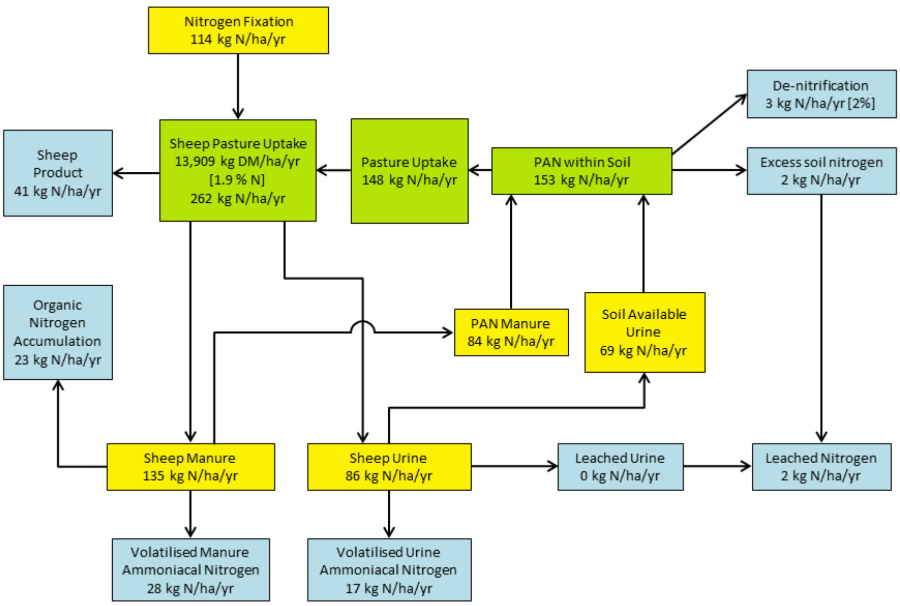

Figure 3: Model 1 - Existing System without Nitrogen Addition

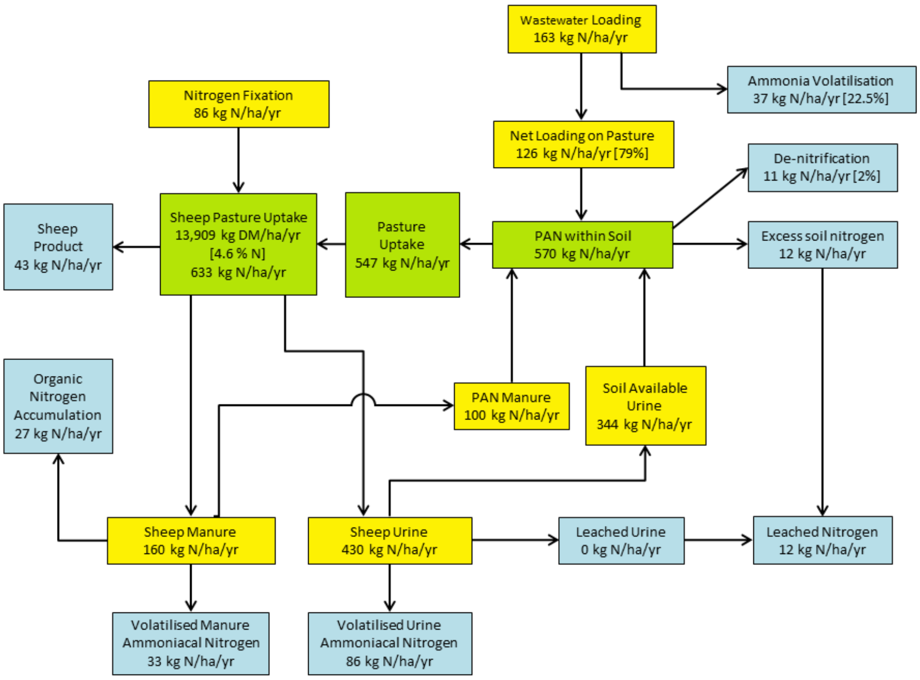

Figure 4: Model 2 - Existing System with Wastewater Irrigation

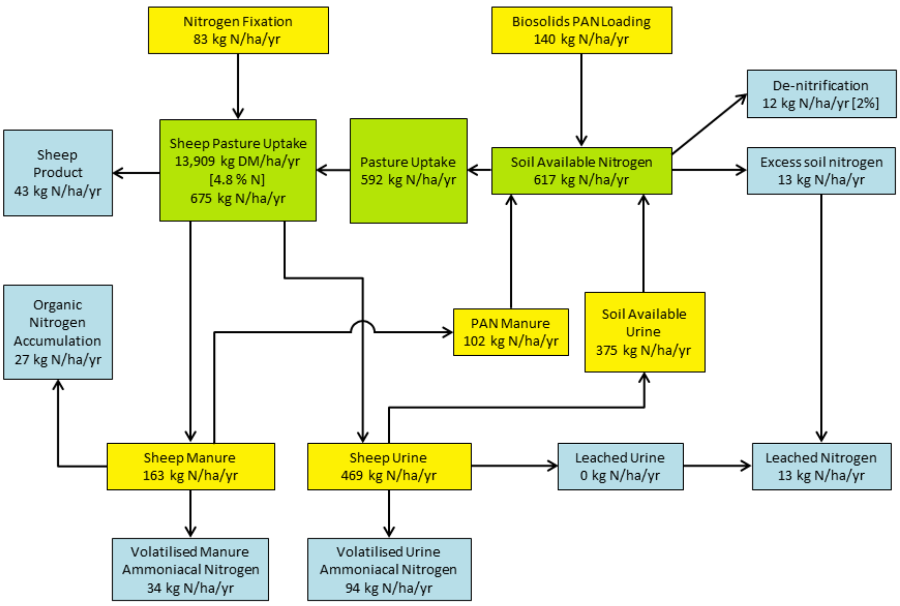

Figure 5: Model 3 - Proposed System with Biosolids Application

4.3 Leaching Estimation Model Results

Results for each of the nitrogen balance models are outlined as follows.

4.3.1 Model 1: Existing System without Nitrogen Addition

As indicated in Figure 3, the modelled nitrogen leaching rate for the existing sheep pasture system without nitrogen addition is 2 kg N/ha/yr. This is consistent with average monitored data, as expected given that this data has been used for model validation.

4.3.2 Model 2: Existing System with Wastewater Irrigation

As indicated in Figure 4, the modelled nitrogen leaching rate for the existing sheep pasture system with wastewater irrigated at a loading rate of 163 kg N/ha/yr is 12 kg N/ha/yr. This is consistent with average monitored data, as expected given that this data has been used for model validation.

4.3.3 Model 3: Existing System with Biosolids

As indicated in Figure 5, the modelled nitrogen leaching rate for the proposed sheep pasture system with a biosolids PAN loading rate of 140 kg PAN/ha/yr is 13 kg N/ha/yr.

This leaching rate is within the typical annual nitrate leaching losses for lowland sheep grazed pastures in New Zealand which are reported to be of the order of 10 to 20 kg N/ha/yr (AgResearch, 2010a).

4.4 Overseer Nutrient Budget Model

4.4.1 Model Description

Overseer® nutrient budget (Version 6.1.3 -2014) is an agricultural management tool used in New Zealand to develop nutrient budgets for various soil types and farm and cropping activities. Overseer® is typically used by farmers and agronomists to optimise production and fertiliser inputs, and can be used to estimate nutrient losses for assessment of environmental impacts. Overseer® has also been used to estimate leaching losses from wastewater and biosolids application activities.

The Overseer® tool has also been used to estimate leaching losses from the Alliance Lorneville pasture system for a biosolids loading rate of 140 kg PAN/ha/yr. The tool was used to estimate leaching losses for both the Waikiwi and Dacre soil types.

The following parameters were utilised for the Overseer® model:

- Stocking rates at the site were applied as outlined in Figure 2;
- Stocked animals were modelled as ewes and hoggets, sourced on farm at a starting weight of 60 kg and sold to works;

- Overseer® climate data for the coordinates of the Lorneville site was applied;
- Soil types Dacre and Waikiwi were utilised as included in Overseer®;
- It was assumed that rain water generally soaks into soils for both soil types rather than mostly running off or always soaking in;
- The specified nitrogen immobilisation potential for the model was set to “none” as this meant that the model would not assume certain levels of nitrogen are immobilised within soil rather than leaching to groundwater (conservative);
- The pasture selected for both soils was a ryegrass white clover mix;
- The biosolids application was modelled as a 100% inorganic-N (completely PAN) fertiliser as a single 140 kg PAN/ha/yr application in October.

4.5 Overseer® Model Results

For a biosolids nitrogen loading rate of 140 kg PAN/ha/yr and an average stocking rate of 21 ewes/ha/yr the Overseer® model estimated the nitrogen leaching losses from Waikiwi soils as 20 kg N/ha/yr and from Dacre soils as 9 kg N/ha/yr. Applying the soil areas available for biosolids disposal as outlined in Table 3, an area weighted average nitrogen leaching rate for the site is estimated to be 17 kg N/ha/yr.

This leaching rate is similar to that obtained from the conceptual model, indicating that an estimated leaching loss of 10 to 20 kg N/ha/yr is expected.

4.6 Heavy Metal Loading Effects

The key heavy metal contaminant for proposed biosolids application is zinc. However, the metal concentrations are well below the *grade b* maximum concentration limits suggested in 2003 Biosolids Guidelines for the disposal of biosolids.

It is considered that the effects of chromium and zinc loading onto land is no more than minor as the biosolids concentrations are well below the soil guideline limits.

4.7 Soils

Given the high organic matter content as well as the inherent nutrient properties of the biosolids and stockyard solids, the application is expected to improve the soil quality and hence is not expected to have any adverse effects on soil quality.

Potential for soil structure damage through compaction will be avoided through mitigation measures. Vehicle traffic (other than spreading trucks) will be avoided over the disposal areas until the biosolids have had time to dry through evaporation or soakage to such a degree that the soil profile is not saturated. For the dewatered biosolids, the hydraulic loading onto the land will be negligible. A stock withholding period of 14 days is proposed which will also ensure there is no potential for hoof (pugging) damage in paddocks.

4.8 Surface Water

There will be reasonable setback distances (buffer zones) maintained to avoid any potential for the mobilisation of the biosolids to any drains that will lead to Makarewa River.

The leachable fraction of nitrogen is at very low levels that are unlikely to result in nitrogen being discharged to surface water.

4.9 Landscape, Noise and Visual Effects

The surrounding environment is characteristic of a rural farm environment and as such the proposed activity, in respect to effects on the landscape, noise and visual environment, will be consistent with the land use of the surrounding area. The use of biosolids spreading trucks or irrigation equipment to apply the biosolids to land will be similar to other activities typical to farming (e.g. farm machinery and sheep mustering). Accordingly, it is considered that there will be no more than minor effects in terms of landscape, noise or visual amenity.

4.10 Effects on Air Quality

With appropriate management, the disposal of biosolids onto farmland is not expected to be odorous, and as such the effects of the proposed activity on air quality are considered to be less than minor.

4.11 Effects on Human Health

4.11.1 Potential Pathogens and Micro-organisms

The public health risk due to microbiological components of the biosolids is not considered significant. Public contact with the biosolids will be avoided through the operational management and the physical methods used for spreading. The use of appropriate setback distances and buffer zones is a key factor in minimising public contact with the applied biosolids, but additional management techniques such as ensuring disposal does not occur near a downwind boundary during windy conditions will further ensure that the public health risk is minimised.

Within the land disposal area itself, risk of exposure to microbial contaminants (both for workers on the site and for grazing animals in the short term) is minimised as the paddocks where disposal occurs will be subject to a 14 day stock withholding period (compared with only a 48 hour withholding period in the DoH (1992) guidelines for sewage sludge application) to ensure die-off of any potential microbial pathogens within the biosolids.

Microbial die-off in the irrigated/spread biosolids will occur primarily by desiccation (drying out) and ultraviolet light exposure. Both of these factors can be maximised by disposing in drier periods ensuring the ground is dry before stock access is resumed.

The setback distance between the disposal area and any occupied dwellings will be at least 100 m.

4.12 Effects on Landuse Activities

Alliance Lorneville proposes to apply a stock withholding period of 14 days for grazed pasture or stock food cropped areas.

The applied biosolids on the surface of the soil and pasture would normally dry out within a few days during which the microbial populations die-off as a result of desiccation and ultraviolet light exposure (from the sun).

5.0 Mitigation Measures

5.1 Mitigation Measures for Application Areas

One of the main mitigation controls would be to stop the biosolids disposal programme immediately in the unlikely event any adverse effects are experienced during the biosolids application programme and divert the material to the contingency monofill. This situation is considered unlikely, however, potential problems may include odour issues or run-off coinciding with non-forecasted heavy rain from application areas. Mitigation measures that may be implemented include:

Odour issues: Odours out of character with the surrounding environment are not expected to occur. However, in the unlikely event of an objectionable odour being experienced, it would be quickly remedied by the application of hydrated lime to the biosolids. Alliance Lorneville will have a supply of hydrated lime (available in stock at all times at the fellmongery) when biosolids disposal is undertaken.

Buffer Zones: Buffer zones or setback distances are proposed to limit potential adverse effects such as odour, spray drift on nearby residences and runoff to surface water bodies. Proposed buffer distances in which application of the biosolids will not occur are:

i. 100 m from residential dwellings (unless written consent of the occupier has been obtained to dispose closer);

ii. 50 m from any surface watercourse; and

iii. 20 m from any property boundary.

The application process using the disposal equipment will be managed with a high degree of care and attention to ensure that the activity does not cause adverse effects on the surrounding environment.

5.2 Monitoring Programme

Alliance Lorneville proposes field monitoring to be carried out during the biosolids disposal process to ensure that any undesirable effects are detected, if they occur. The observations will also take note of the evenness of the application and the uniformity of coverage.

The biosolids will be characterised for solids content, total nitrogen, inorganic nitrogen, phosphorus, potassium, calcium, magnesium and sodium on a monthly basis. Infrequent baseline monitoring of heavy metals (copper, lead, nickel, and zinc) and sulphur will also be undertaken.

The soils monitoring will be undertaken on a six-monthly basis for pH, exchangeable cations (calcium, magnesium, potassium and sodium), Olsen-P, total organic carbon and total nitrogen.

Further soil water leaching fraction will be monitored on a monthly basis using suction cup lysimeters.

The groundwater monitoring will be undertaken in the similar manner as undertaken for the existing wastewater irrigation activity on at least two monitoring bores on a three monthly basis and analyse for pH, electrical conductivity, selected cations (chloride), nitrogen (ammoniacal-N, nitrate-N) and *E. coli.*

5.3 Biosolids Management Plan

In order to ensure that the land disposal of biosolids is managed appropriately, Alliance Lorneville will develop a Biosolids Management Plan, which will allow for the day-to-day management of the stock movements and the appropriate disposal of the biosolids. As a minimum, the Biosolids Management Plan will include:

i. Health and safety, training and hygiene requirements in handling biosolids and stockyard solids;
ii. Machinery use and maintenance requirements to ensure adequate dewatering and controls on spreading of the solids;
iii. Biosolids characterisation for either every 300 tonnes of dewatered bulk solids generated or at least monthly to allow nutrient loadings to be determined;
iv. Biosolids generation rate on a day-to-day basis, dewatering and subsequent handling for direct disposal to land and/or disposal to contingency monofill;
v. Disposal management to address odour nuisance, wet weather conditions, noise, spill control and stock withholding;
vi. Monitoring of the gross biosolids on nominated parcels of land to assess actual loading, annual pasture/soils monitoring and groundwater monitoring;
vii. Monitoring of soils on an annual basis and the monitoring of the groundwater from the monitoring bores present on the farm at a minimum of six monthly basis;
viii. Additional nutrient monitoring of dry matter production if crop is removed from the site to determine export of nutrients from the site; and
ix. Controls on the diversion of the biosolids to the contingency monofill.

5.4 Contingency Disposal of Biosolids

If soil conditions become wetter due to extended period of rain, the risk of mobilisation of biosolids and pugging of soils through vehicles and mechanical equipment, then the biosolids and the stockyard solids will be diverted to a proposed monofill sited at the wastewater treatment plant.

Alliance Lorneville proposes to maintain an ability to dispose the biosolids onto land at a nitrogen loading that meets pastoral nitrogen requirements for as much time as possible, but also allowing contingency diversion to the monofill if/when required.

The utilisation of the company farmland for disposal of biosolids would become essential to maintaining an efficient future wastewater treatment plant whilst allowing reuse of nutrients from the solids generated at the site.

6.0 References

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Appendix A

Biosolids Analytical Laboratory Report

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

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ANALYSIS REPORT

Client:	Alliance Group - Pukeuri Plant	**Lab No:**	1323922 SPv1
Contact:	D Kan	**Date Registered:**	11-Sep-2014
	C/- Alliance Group - Pukeuri Plant	**Date Reported:**	22-Sep-2014
	Private Bag 50051	**Quote No:**	43082
	OAMARU 9444	**Order No:**	09732854
		Client Reference:	38443
		Submitted By:	D Kan

Sample Type: Sludge

	Sample Name:	WAS Biosolids 38443 10-Sep-2014 10:30 am				
	Lab Number:	1323922.1				
Escherichia coli	MPN / g	92,000	-	-	-	-

Sample Type: Aqueous

	Sample Name:	WAS Biosolids 38443 10-Sep-2014 10:30 am				
	Lab Number:	1323922.2				
Total Solids (TS)	g/m^3	19,600	-	-	-	-
Total Arsenic	g/m^3	< 0.11	-	-	-	-
Total Cadmium	g/m^3	< 0.0053	-	-	-	-
Total Calcium	g/m^3	300	-	-	-	-
Total Chromium	g/m^3	2.3	-	-	-	-
Total Copper	g/m^3	0.72	-	-	-	-
Total Lead	g/m^3	0.103	-	-	-	-
Total Magnesium	g/m^3	32	-	-	-	-
Total Nickel	g/m^3	0.102	-	-	-	-
Total Phosphorus	g/m^3	240	-	-	-	-
Total Potassium	g/m^3	159	-	-	-	-
Total Sodium	g/m^3	780	-	-	-	-
Total Sulphur	g/m^3	170	-	-	-	-
Total Zinc	g/m^3	5.6	-	-	-	-
Total Nitrogen	g/m^3	1,150	-	-	-	-
Total Ammoniacal-N	g/m^3	45	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	< 0.2 [#1]	-	-	-	-
Total Kjeldahl Nitrogen (TKN)	g/m^3	1,150	-	-	-	-

Analyst's Comments

[#1] Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NOxN analysis.

SUMMARY OF METHODS

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

Sample Type: Sludge

Test	Method Description	Default Detection Limit	Sample No
Escherichia coli	MPN count in LT Broth at 35°C for 48 hours, EC MUG Broth at 44.5°C for 24 hours Analysed at Hill Laboratories - Microbiology; 101c Waterloo Road, Hornby, Christchurch. APHA 9221 B, 9221 F 22nd ed. 2012.	2 MPN / g	1

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	2
Total Digestion	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	2
Total Digestion	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	2
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	2
Total Solids (TS)	Gravimetric. APHA 2540 B 22nd ed. 2012.	10 g/m^3	2
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.0011 g/m^3	2
Total Cadmium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.000053 g/m^3	2
Total Calcium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.053 g/m^3	2
Total Chromium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.00053 g/m^3	2
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.00053 g/m^3	2
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.00011 g/m^3	2
Total Magnesium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.021 g/m^3	2
Total Nickel	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.00053 g/m^3	2
Total Phosphorus	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.021 g/m^3	2
Total Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.053 g/m^3	2
Total Sodium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.021 g/m^3	2
Total Sulphur	Nitric acid digestion, ICP-OES (method may not fully account for H_2S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method.	0.5 g/m^3	2
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.0011 g/m^3	2
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	2
Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4+-N + NH_3-N). APHA 4500-NH_3 F (modified from manual analysis) 22nd ed. 2012.	0.010 g/m^3	2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	2
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D. (modified) 4500 NH_3 F (modified) 22nd ed. 2012.	0.10 g/m^3	2

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.

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