PATTLE DELAMORE PARTNERS LTD

Alliance Lorneville – Summary Report on Alternatives and Proposed Upgrading of Wastewater Treatment Plant

Alliance Group Limited – Lorneville Plant

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Prepared for

Alliance Group Limited – Lorneville Plant

October 2015 (Version 2)

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Limitations:

This report has been prepared on the basis of information provided by Alliance Group Limited and others (not directly contracted by PDP for the work)], including Aquatic Sciences Limited and Freshwater Solutions Limited. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information. This report has been prepared by PDP on the specific instructions of Alliance Group Limited for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

Executive Summary

Alliance Group Limited owns and operates its flagship meat processing plant at Lorneville (Alliance Lorneville). The site operates a lamb, sheep and bobby calf processing plant with additional by-products processing including fellmongery and rendering operations.

The site holds several resource consents, granted by the Southland Regional Council, that are due to expire in 2016, including Resource Consent No. 92195 for discharge of treated wastewater to the Makarewa River.

In preparing for the new consent application, Alliance Lorneville has undertaken comprehensive environmental investigations, including assessing options and constraints to establish the best practicable option for the progressive upgrading of wastewater treatment technology at the plant.

This summary report has been prepared by Pattle Delamore Partners Limited to provide an outline of the investigations work carried out by Alliance Lorneville and the selection of the preferred upgrade route for the current wastewater treatment plant in order to meet proposed receiving environment constraints. This report has been prepared to inform and complement an assessment of the effects of the discharge on the Makarewa River undertaken jointly by Freshwater Solutions Limited and Aquatic Environmental Sciences Limited.

Based on identification of nitrogen, specifically ammoniacal nitrogen, as the key constraint for the continued discharges to the Makarewa River, a number of treatment and disposal options were considered. These included land treatment and a range of on-site wastewater treatment processes. Additional primary treatment for several waste streams has been identified which are common to all on-site options.

The preferred option for further consideration is the flow separation of nitrogenous waste streams contributing to around 25% of the plant wastewater volume, but contributing to in excess of 75% of the nitrogen load.

A parallel wastewater treatment plant that would include fully covered anaerobic reactor with biogas management, biological nitrogen removal reactor operated as activated sludge plant and a clarifier for solids separation. Options for phosphorus removal and microbial disinfection are also outlined. Biosolids management and disposal to land and/or landfilling has also been discussed. The progressive implementation of this upgrade is considered the best practicable option for the site.

The separable and non-separable domestic effluent is also assessed for dedicated treatment. Given the very low contribution that domestic effluent makes to the overall discharge load, it has been concluded that the existing management approach of combined treatment is the best practicable option.

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1.0 Introduction

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This report follows from a comprehensive investigation of wastewater treatment upgrade options and an assessment of water quality and ecological effects within the Makarewa River receiving environment.

1.1 Scope of Report

This report prepared by Pattle Delamore Partners Limited (PDP) provides a summary of the technical solutions available to Alliance Lorneville to mitigate the effects of the discharge of treated wastewater to the Makarewa River.

The approach adopted by Alliance Lorneville has been to investigate a range of wastewater treatment upgrading options in order to understand the best practicable treatment option for nitrogen removal which will be progressively implemented during the term of the consent sought.

A range of upgrade options have been investigated previously, including feasibility studies on land treatment and minimising the requirements to discharge to the Makarewa River.

An outline of the matters addressed in this report is as follows:

i. Description of the plant processes and the waste generation from various sources;
ii. History of the existing wastewater treatment plant, and description of the existing treatment facilities;
iii. Rationale for improved discharge and the requirements for the upgrade of wastewater treatment facilities;
iv. Assessment of waste minimisation approach and the likely future loads from the processing plant;
v. Assessing the requirements for domestic effluent separation and treatment;

vi. Assessing alternatives for wastewater treatment and/or disposal and developing the preferred option for treatment and continued discharge to the Makarewa River;

vii. Assessing the requirements to manage residuals from the wastewater treatment processes, namely biosolids and gaseous emissions; and

viii. Outlining the wastewater treatment plant roadmap.

2.0 Site Processes and Wastewater Management

2.1 Site Processes

Processing of lambs, sheep and bobby calves at the site includes stock washing, slaughtering and further processing, tripe recovery, casings, rendering (tallow, meat and bone meal, blood meal) and fellmongery operations.

Prior to 2001, processing capability changed from a six chain single shifted operation to a four chain double shifted operation.

In 2014 the processing pattern changed from the previous seasonal operation with an extended winter period to include a low level of winter sheep and lamb processing and seasonal bobby calf processing.

The site operates its own onsite water treatment plant and onsite wastewater treatment plant. Key plant processes are briefly described below.

2.1.1 Stockyards

Stock delivered to the site are unloaded at the yards where they are washed and remain until the plant is ready to process them.

2.1.2 Slaughtering and Further Processing

The site operates up to four chains over two shifts undertaking slaughtering and carcass preparation operations. These operations include sticking, bleeding, skinning, evisceration and trimming processes. Each carcass then undergoes further processing (boning) into various cuts of meat.

2.1.3 Rendering and Offal Processing

The site utilises a number of offal processes for product recovery which include tripe recovery, casings, blood drying, soup-stock manufacture and offal rendering via a new low temperature rendering plant to produce meal and tallow by-products.

2.1.4 Fellmongery

The fellmongery processes pelts ready to be sent off-site for further processing into leather products. These operations include washing, removing fleshings, and applying a solution containing lime and sulphide prior to the wool being mechanically pulled off from the skins. The de-haired skins are then washed with a lime solution and pickled.

2.2 Wastewater Treatment Plant History

2.2.1 Historical System

A wastewater treatment facility was built consisting of four 25 m diameter by 9 m deep circular tanks and two 14.5 m diameter clarifiers (shown in Figure 1) at the time when the Lorneville plant was opened in 1960. At this time, the plant had a processing capacity of 1 million sheep per annum and 200 cattle per day. Beef processing stopped in the 2001 season.

Three of the tanks were used as mixed cold anaerobic digesters. The digested wastewater then passed to the remaining tank that was used as a secondary sedimentation tank. The supernatant from the sedimentation tanks flowed to the clarifiers. The underflow sludge from the sedimentation tank and clarifier was returned and mixed with raw wastewater flow. The clarified wastewater was discharged to the Makarewa River. There was no provision for solids management.

As a result of solids overloading, it was decided in late 1960's to establish anaerobic lagoons. The mixers in the digester tanks were decommissioned and the three digesters were operated as unmixed anaerobic reactors. The discharge from the sedimentation tank was directed to the anaerobic lagoon and the final discharge passed through the clarifiers.

By 1968, annual production had increased to approximately 2 million sheep. At around this time, the then Catchment Board straightened the Makarewa River in the vicinity of the plant. Alliance Group Limited purchased a redundant section of the river bed. The section of the riverbed and adjacent land was converted to a facultative lagoon to treat the discharge from the clarifier prior to discharge to the Makarewa River. The pond was called the "Loop". Further maturation ponds were formed in series in the mid-1970's to improve effluent quality.

In 1983, one of the concrete tanks was converted to an Upflow Anaerobic Sludge Blanket (UASB) reactor utilised to recover biogas. Some of the diverted solid wastes were put back into the UASB reactor significantly increasing the loading to the wastewater treatment plant.

A milli-screening plant and dissolved air flotation (DAF) tank were installed upstream of the raw wastewater pump house in 1985. The new plant separated out fat and gross solids, which were pumped to one of the concrete tanks converted to a solids digester, with discharge back into the wastewater treatment system. The UASB process generated biogas that was piped back to the fellmongery for utilisation as a feed stock for the wool driers. It is understood that this system operated for approximately 2 years before being shut-down due to on-going operating issues. Issues included significant odour generation, problems with the combustion of the biogas, significant volumes of sludge production and high operating costs (Beca & NIWA, 2010).

In the 1991-92 processing season, a 35 kW aeration system was installed at the outlet of the Loop to improve wastewater quality.

2.2.2 Treatment Plant Changes to Manage Odour

Between 1995 and 1997 the site had received a considerable number of odour complaints from the neighbours and a substantial upgrade of the wastewater treatment system was planned to reduce odour emissions.

Between 1997 and 1999, considerable changes to the wastewater treatment plant included:

i. Decommissioning of the DAF tank and balance ponds 1-4;
ii. Conversion of the solids digester to an anaerobic clarifier;
iii. Waste minimisation and pre-treatment systems for the rendering plant and fellmongery;
iv. Desludging of the Loop;
v. Installation of 315 kW of mechanical aeration into the Loop;
vi. Segregation of sulphide liquors and commissioning of sulphide oxidation plant; and
vii. Diversion of sulphide laden waste streams to the Loop pond.

2.2.3 Decommissioned Plant

In early 2000, the balance pond 5, anaerobic pond 2, the concrete DAF units, settling tanks and the clarifiers were decommissioned as part of the treatment plant re-configuration. The sulphide oxidation system was decommissioned around this time to mitigate against uncontrolled odours associated with this process.

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IMAGE:

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PROJECT: LORNEVILLE PLANT WASTEWATER - SUMMARY REPORT ON ALTERNATIVES AND PROPOSED UPGRADING OF WASTEWATER TREATMENT PLANT

TITLE: WASTEWATER TREATMENT PLANT SYSTEM LAYOUT

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2.3 Wastewater Sources and Characteristics

2.3.1 Production Distribution

The wastewater flows and loads generated from the processing site are directly related to the plant production rate. The main production season typically begins in late November and continues through to June or July. A low level of winter kill was introduced in 2014 and this is likely to be continued. Weekly processing tallies for the 2012-2013 processing season are shown in Figure 2.

The total annual production for the 2012-2013 season was 3 million lamb equivalents (LE) over a 36 week period, whereas total production for the 2011-2012 season was 2.4 million LE. For the 2014 season, the annual kill was 3 million LE. Alliance Lorneville considers that an annualised 3 million LE is typical processing levels at the site, however, if stock number supply increases, there is potential for an extended season resulting in higher annual kill numbers.

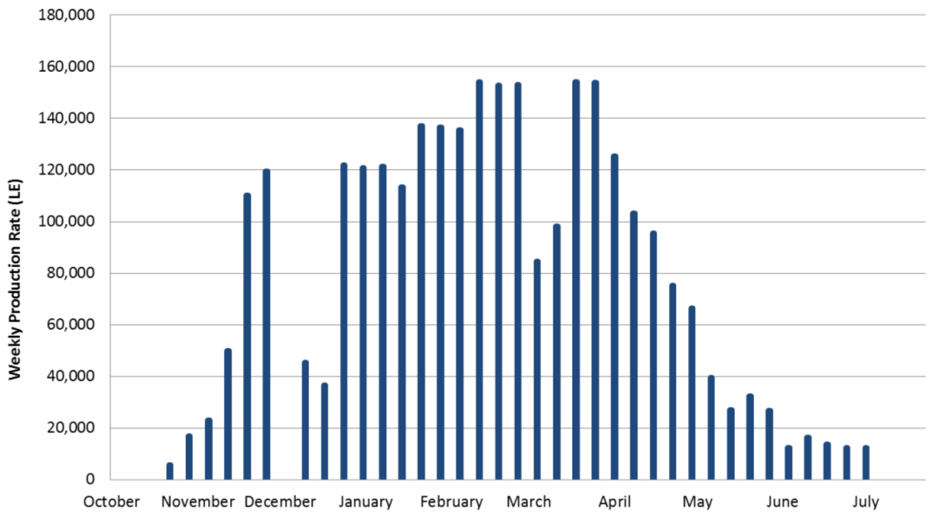

Figure 2: Plant Production Distribution

A normal peak kill tally of the plant is approximately 24,500 LE per day. This processing rate is the full-production capacity based on the normal shift length and with 7 chains operating each day made up of 4-chains during the day shift and 3-chains during the night-time shift.

When required, the duration of the day and night-time shifts can be increased to increase the full-production capacity to approximately 28,000 LE (extended peak) per day.

Therefore, the peak processing of 28,000 LE per day has been utilised for the determination of the production of wastewater and consideration of treatment technologies.

2.3.2 Wastewater Surveys

An extensive wastewater characterisation and flow survey was undertaken in February 2013 (PDP, 2013a). In this waste survey, the newly established low temperature rendering plant was undergoing commissioning and there was stickwater (waste by-product from tallow separation process) lost to the drains rather than being evaporated and recovered in the rendering plant waste heat evaporator (WHE). This additional discharge of stickwater contributed to considerable organic and nutrient loading.

A validation survey was carried out in February 2014 (PDP, 2014c) and this confirmed that the rendering plant WHE was operating well and there was a reduction of load from the rendering plant. However, the casings processing started at the site provided an additional load to the 2013 survey so it was difficult to compare the two surveys.

Key wastewater streams were identified and monitored during both surveys. The total plant flow and load was determined as well as the relative contaminant load contribution of each stream.

The waste surveys were undertaken to establish the design loadings from the plant.

2.3.3 Wastewater Sources

There are seven main waste generation sources. These are:

i. Edible processes in slaughter room and further processing (sticking bay, evisceration area, equipment and floor washes);
ii. Edible by-products processing (soupstock and tripe/casings);
iii. Non-edible by-products for rendering (stickwater, condensates, raw material bin leachate);
iv. Fellmongery (skin wash, salting area, lime wash, pickling liquors, floor washes);
v. Stockyards and truckwash (faecal material and urine);
vi. Water treatment plant backwash; and
vii. Domestic sewage.

Some specific processes within these areas contribute to large contaminant loads (namely nitrogen) and the waste survey targeted these specific waste generation sources to identify how waste separation and minimisation in future could occur to rationalise wastewater treatment upgrades for targeted treatment.

2.3.4 Raw Wastewater Flow

The raw wastewater flows to the treatment plant are not expected to deviate considerably from the existing peak processing period. The waste survey characterisation established the flows and the various contaminant loads.

The normal peak processing wastewater volume is assessed at 17,100 m^3/d, with extended peak processing increasing to 19,800 m^3/d. Allowing for an additional 10% water use, the peak design flow is assessed at 21,780 m^3/d. The site holds a resource consent to discharge treated wastewater at a maximum discharge volume of 22,730 m^3/d. This includes sewage from site and Wallacetown and accounts for attenuated rainfall inputs into the lagoon based treatment system.

PDP recommends that the current consent discharge volume is retained.

2.3.5 Contaminant Loads

The total design wastewater contaminant loads have been determined by considering both the monitored total discharge, as well as the sum of the monitored individual streams during the 2013 and 2014 waste surveys. In each instance, the maximum contaminant loads have been applied with allowance for a margin of safety. This accounts for the greater load typically determined via individual waste stream monitoring, which captured intermittent high-strength loads such as batch operations in the fellmongery.

The loads for the different contaminants are shown in Figure 3 and 4 (see Table 1 for labels).

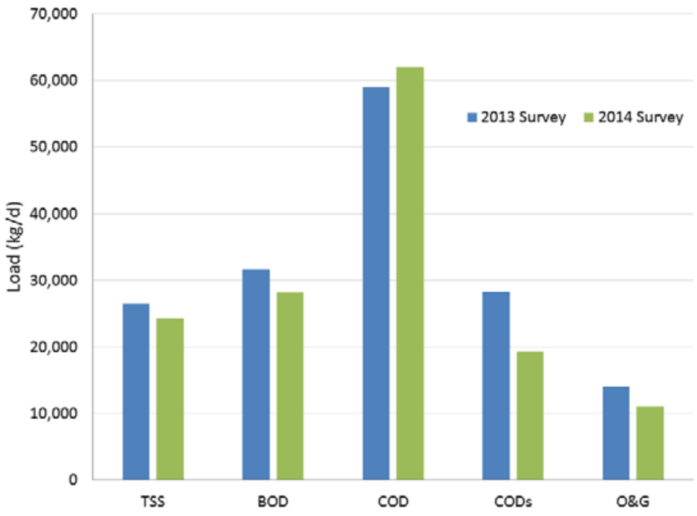

Figure 3: Monitored Solids and Organic Loads during Survey

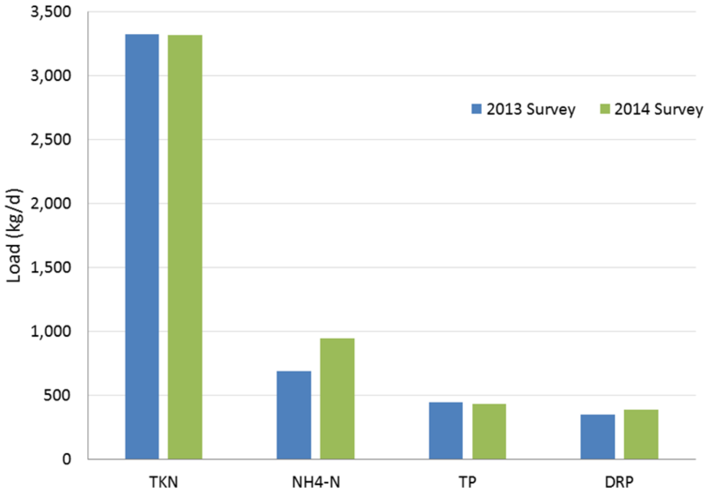

Figure 4: Monitored Nutrient Loads during Survey

Sulphide loads were not monitored during the first survey from specific waste streams, but were undertaken in the second waste survey. The total sulphide and sulphate loads expected out of the plant during peak processing are 610 kg/d sulphide and 1,650 kg/d sulphate.

On the basis of the waste surveys undertaken in 2013 and 2014 and allowing for a safety margin or operational buffer (10%), the contaminant loadings in the raw wastewater for assessing design loadings are given in Table 1.

Table 1: Raw Wastewater Characteristics for Design

Parameter	Typical Conc. (g/m^3)	Design Peak Load (kg/d)
Biochemical oxygen demand ($cBOD_5$)	1,760	34,900
Chemical oxygen demand (COD)	3,450	68,100
Soluble chemical oxygen demand (CODs)	1,580	31,100
Total suspended solids (TSS)	1,480	29,200
Total Kjeldahl nitrogen (TKN)	190	3,660
Ammoniacal nitrogen (NH_4-N)	50	1,040
Total Phosphorus (TP)	25	485
Dissolved reactive phosphorus (DRP)	20	420
Oil & Grease (O&G)	800	15,500
Total Sulphide	30	670

Notes:

1. *The design processing wastewater flow is based on 21,780 m^3/d and excludes stormwater and sewage.*

2.4 Existing Wastewater Treatment Plant Description

The existing treatment plant is shown in Figure 1. The north and south drains run in parallel and convey effluent via gravity to the inlet works of the disused DAF plant. From the inlet works, the combined flow is conveyed via gravity to a lagoon based wastewater treatment plant.

The existing treatment process comprises of a series of seven lagoons constructed on land adjacent to the banks of the Makarewa River, covering a total area of approximately 25 ha. These include an anaerobic lagoon, an aerobic lagoon aerated via mechanical aerators also referred to as the “Loop”, followed by 5 maturation ponds. Each of these lagoons is connected in series.

The majority of the treated wastewater is discharged to the Makarewa River, however, a small portion is discharged to land on occasions via an irrigation system. The irrigation area comprises approximately 100 ha of pasture within the Lorneville farm site. An additional area within the Lorneville plant site is consented for disposal of sheep yard solids which is currently undertaken on a limited basis.

The wastewater treatment system requires a low level of operator input and has a low energy demand in the form of electricity to operate the aerobic lagoon aerators. Further details of the existing treatment processes are provided below.

2.4.1 Preliminary and Primary Treatment

Within the Lorneville processing plant, solid material is extracted from a number of high-concentrated waste streams by mechanical milli-screening units, prior to being conveyed to a non-chemically assisted dissolved air flotation unit.

A disused saveall structure at the fellmongery was once utilised for primary solids separation, however, this has since been bypassed in order to reduce localised odour issues.

2.4.2 Anaerobic Lagoon

Further removal of solids is provided by Anaerobic Lagoon 1 covering an area of approximately 1.9 ha with an average depth of approximately 2.5 m.

Wastewater enters Anaerobic Lagoon 1 through a channelised section approximately 50 m long and 15 m wide, which collects a significant quantity of fat and floatable material. Material is removed from this section of the lagoon by a mechanical excavator at the end of each processing season.

Within the anaerobic lagoon, floatable material has developed a crust that has built up over some years. Non-biodegradable material accumulates in the remainder of the lagoon volume, reducing its treatment capacity and therefore this must also be removed on a regular basis.

Accounting for some sludge accumulation in the lagoon and the crust volume, the hydraulic residence time (HRT) in the lagoon is estimated to be approximately 2 - 3 days.

Historical sampling and analysis has shown that removal efficiencies through the anaerobic lagoon include up to 95% removal of carbonaceous 5-day biochemical oxygen demand ($cBOD_5$), 85% removal of total suspended solids (TSS) and conversion of proteinaceous organic nitrogen to ammoniacal nitrogen (NH_4-N). The crust cover of the lagoon means that there is no-collection of biogas for flaring or energy recovery.

A second smaller anaerobic pond (Anaerobic Lagoon 2) is situated adjacent to Anaerobic Lagoon 1 and covers an area of approximately 1.0 ha, but is currently not operational.

2.4.3 Aerated Lagoon

Effluent from Anaerobic Lagoon 1 is conveyed to a large shallow aerated lagoon. The total surface area of this lagoon is approximately 9.4 ha and the average depth is understood to be approximately 1.2 m, for a total volume of approximately 110,000 m^3, for an HRT in the order of 5 - 7 days. The aerated lagoon was formed from the remnant of a realigned a section of the Makarewa River and is often referred to as the “Loop”.

The aerated lagoon is installed with floating mechanical axial flow type aerators with a combined capacity of 315 kW, although only 175 - 190 kW of aeration is typically utilised.

The aerated lagoon provides for further $cBOD_5$ removal; but with minimal oxidation of nitrogen. This is expected given the limited aeration/mixing energy provided to the extent of the lagoon, with the result that biological nitrogen utilising bacteria (nitrifying bacteria) will not be kept in suspension and will instead settle to the bottom of the lagoon where their growth cannot be maintained. There is also no separation of solids from the aerated lagoon effluent to maintain populations of nitrifying bacteria.

The groundwater investigation shows that there is a minimal impact on the groundwater from the wastewater treatment system, suggesting that the Loop bed is well sealed even with potential for some bed disturbance by mechanical aerators.

2.4.4 Maturation Ponds

Effluent from the aerobic lagoon passes through a series of 5 maturation ponds with a combined surface area of approximately 13.4 ha.

These ponds rely on natural processes for the diffusion of air via the water surface wave action, and also algal growth to provide oxygen via photosynthesis. The performances of these natural processes are highly vulnerable to climatic variables such as temperature, sunshine hours and wind velocity.

These ponds assists with some further microbial reduction, however, historical sampling and analysis has shown little improvement in NH_4-N and suspended solids concentrations in the effluent quality between the aerobic lagoon and downstream of the maturation ponds. It is likely that the maturation ponds have a negative impact on suspended solids concentrations and *E. coli* levels at certain times of year due to algal growth and the presence of water fowl. The water level in these ponds can be varied to provide storage when conditions in the Makarewa River limit discharge of treated wastewater.

3.0 Rationale for Improved Discharge

3.1 Receiving Environment Criteria

Alliance Lorneville has been undertaking comprehensive investigations as part of the re-consenting programme to assess the effects of the discharge from the wastewater treatment plant on the water quality of the Makarewa and Oreti Rivers and the New River Estuary, and the ecology of these water bodies (FWS & AES, 2014).

Freshwater Solutions Ltd (FWS) and Aquatic Environmental Services Ltd (AES) have identified that the actual and potential effects of the current discharges include:

i. Increased risk of toxicity as a result of ammoniacal nitrogen discharges;
ii. Increased downstream nutrient (nitrogen and phosphorus) concentrations;
iii. Increase in microbial contaminants downstream of the discharge;
iv. Reduction in dissolved oxygen concentrations;
v. Altered colour and clarity downstream of the discharge point;
vi. Generation of foams and scums at the point of discharge;
vii. Development of nuisance algal growths;
viii. Altered benthic invertebrate and fish communities; and
ix. Potentially reduced recreational values downstream of the discharge point.

FWS & AES reported that the existing discharge does not adversely affect pH, temperature, dissolved oxygen and turbidity. However, there is some elevation of microbial levels on occasions and reduction of water clarity.

The key contaminants that may result in adverse effect are ammoniacal nitrogen in relation to toxicity, nutrients (nitrogen and phosphorus) with respect to nuisance growths in the river/estuarine system and increases in microbial contamination in lower Makarewa River.

FWS & AES have recommended the following improvements in the contaminant levels in the wastewater discharge to the Makarewa River.

i. A 75% reduction in ammoniacal nitrogen from 2012/13 season levels;
ii. Reductions in phosphorus commensurate with catchment targets; and
iii. Long term improvement in microbial quality of the discharged treated wastewater as part of catchment-wide plans to reduce levels of microbial contaminants; and
iv. Reducing risk of scums and foams at the point of discharge.

3.2 Contaminants of Concern

The current Southland Regional Council Resource Consent No. 92195 requires Alliance Lorneville to monitor the final discharge for pH, electrical conductivity, total suspended solids (TSS) and carbonaceous 5-day biochemical oxygen demand (cBOD$_5$), ammoniacal nitrogen (NH$_4$-N), total oxidised nitrogen (TON), total nitrogen (TN), total phosphorus (TP), dissolved reactive phosphorus (DRP) and faecal coliform (FC). In addition, in-stream total ammonia nitrogen concentrations limits are to be met downstream of the discharge point.

FWS and AES have confirmed that the key contaminants of concern from the discharge are nitrogen, specifically ammoniacal nitrogen, but also total nitrogen, phosphorus and *Escherichia coli* (*E. coli*).

3.3 Wastewater Treatment Design Criteria

3.3.1 Current Final Discharge Quality

Alliance Lorneville undertakes regular compliance monitoring of the final discharge from the existing wastewater treatment plant. The site is also required to meet in-stream total ammonia levels to ensure that ammoniacal nitrogen discharged is within compliance limits.

A summary of the final discharge characteristics for the 2013 processing season is given in Figure 5.

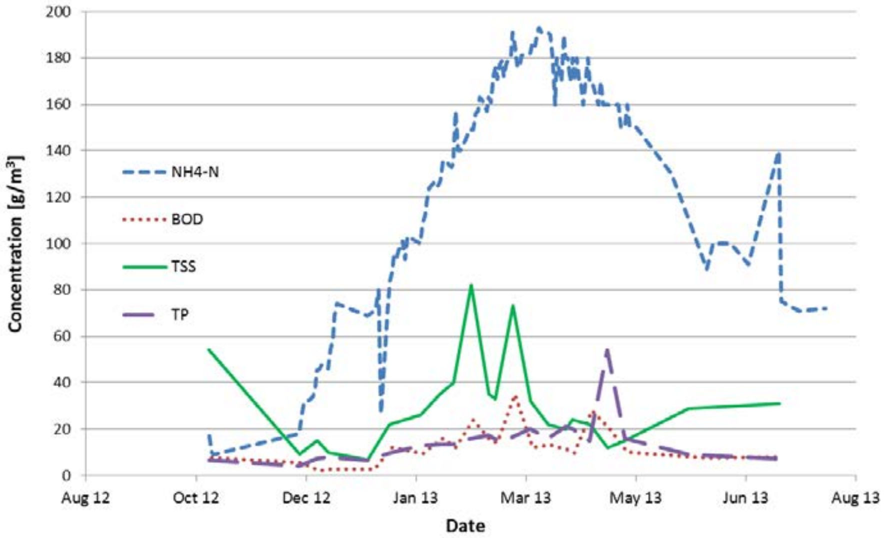

Figure 5: Final Discharge Treated Wastewater Quality

Historically, consent limits for the treated wastewater $cBOD_5$ and TSS concentrations have been consistently met. Alliance Lorneville has been able to manage the requirements to maintain the current in-river total ammonia limits by utilising available storage capacity and reducing the volume of discharge when the river flows are low. However, storage capacity may become limited during extended dry summer seasons.

During the 2013 processing season, high production rates, combined with commissioning issues with the new rendering plant resulted in higher than usual contaminant loads conveyed to the wastewater treatment plant. Although the 2014 ammoniacal nitrogen concentrations in the discharge were generally lower than 2013 season, the treatment options analysis is based on 2013 dataset.

Analysis of effluent monitoring data for 2013 season has shown that the average and 95th percentile concentration for NH_4-N in the final discharge reached as high as 137 g/m^3 and 189 g/m^3 respectively. Analysis has also shown that approximately 25% of the total nitrogen is removed from the wastewater via the existing wastewater treatment system as determined as the difference between the average anaerobic pond total nitrogen (TN) concentration and the average Pond 6 TN concentration.

3.3.2 Post Upgrade Final Discharge Quality

In order to establish the requirements for the wastewater treatment upgrade, the key criterion is to achieve a reduction of 75% of ammoniacal nitrogen from 2012/13 season peak loads, based on the assessment by FWS & AES (2014). This would mean that the ammoniacal nitrogen in the final discharge would need to be below 55 g/m^3 during peak discharge.

As a result of any wastewater treatment system upgrade, there is a likely consequential reduction of other contaminants, namely total suspended solids (TSS), carbonaceous biochemical oxygen demand ($cBOD_5$) and dissolved reactive phosphorus (DRP). The reduction of microbial contaminants requires dedicated disinfection technologies.

3.4 Environmental Investigations Undertaken

Alliance Lorneville has undertaken a number of investigations and studies in relation to the wastewater treatment system as production increases have occurred. A number of investigations were also related to the management of odour from the wastewater treatment plant.

A comprehensive number of investigations have been carried out as part of the re-consenting programme.

3.4.1 Previous Investigations

The specific investigations related to wastewater treatment system improvements are as follows:

i. June 2002 – Lorneville Wastewater Treatment Plant Review, Stage 1 Report undertaken by Harrison Grierson. This investigation examined the issues related to wastewater treatment system odour and the recommendations on odour reduction.

ii. December 2002 – Lorneville Wastewater Treatment Plant Options Study undertaken by Harrison Grierson. This investigation examined the issues and options for the wastewater treatment system improvements to meet future consent limits. The options investigated included conventional activated sludge treatment, sequencing batch reactors, membrane bioreactors, trickling filters and submerged aerated filters. As a result of the recommendations, pilot plant trials using activated sludge plant operated as sequencing batch reactor (SBR) were established in 2004 for the treatment of the anaerobic effluent. The main outcome of the pilot plant trials was poor maintenance of steady state conditions resulting in unreliable operation and no further progress was made.

iii. December 2004 – Review of Options for Treatment & Disposal of Human Waste (Sewage) undertaken by MWH. This investigation related to examination of options for the domestic effluent generated at the site as well as the management of Wallacetown sewage

iv. August 2006 – Anaerobic Wastewater Treatment – Issues and Options undertaken by Pattle Delamore Partners Ltd. This investigation addressed the sludge accumulation in the site's anaerobic lagoon and the management of sludge. It also examined the options for the covering of the anaerobic lagoon and the management of the biogas.

v. 2010 – High Rate Algal Pond (HRAP) Trial undertaken by NIWA. This investigation was establishing two adjoining 1,000 m^2 trial ponds to determine the suitability of HRAP for wastewater treatment.

3.4.2 2015 Re-Consenting Project Investigations

As part of 2015 re-consenting programme, a substantial number of investigations have been carried out by Alliance Lorneville. The specific investigations related to management of wastewater include:

i. **Lorneville Plant Wastewater Generation – Baseline Survey (PDP, 2013a)**. A comprehensive wastewater survey including flow monitoring and characterisation of 15 separate waste streams from specific processing areas was undertaken in February 2013. In addition, this survey undertook validation sampling of the combined waste streams. This work allowed identification of the sources of key contaminants, namely solids, organic material, oil & grease, nitrogen and phosphorus. The sulphide load assessment was not undertaken during this survey but was identified as a key waste stream that needed further investigation. During this survey, the newly established low temperature rendering plant was being commissioned and the load discharged from the rendering plant were not consistent, as a result of poor waste heat evaporator performance.

ii. **Lorneville Plant Wastewater Treatment – Issues and Options (PDP, 2013b)**. Following on from the baseline survey, Alliance Lorneville progressed to determining the issues and the options related to the wastewater generated from the site. This investigation detailed the wastewater treatment technologies and the shortlisted options to allow flow separation that would target overall nitrogen removal for high strength nitrogenous waste streams. In addition, the options for phosphorus reduction and microbial disinfection were examined. Also, the domestic effluent (sewage) separation and segregated treatment options were investigated. The solids management options as a result of improved wastewater treatment was also considered as part of this assessment. Rough order capital costs and operating costs for the shortlisted options were determined. The options investigation is detailed further in Section 3.7.

iii. **Primary Wastewater Treatment Upgrade – Design Basis and Technical Specifications (PDP, 2014a)**. Waste surveys identified two waste streams as significant nitrogen load contributors contained within relatively small volumes. Bench-scale testing in February 2014 confirmed that high rates of nitrogen removal could be achieved using an acid–DAF process, and the expected chemical dosing rates and nitrogen removal performance was determined. Preliminary design and equipment specifications were subsequently developed for an upgrade of the primary wastewater treatment system, which included installation of a new screen, DAF plant and reconfiguration of the existing solids dewatering system. Using this preliminary design, the Alliance Lorneville Engineering team then developed the detailed design and procured the upgrade works, which were commissioned in late 2014.

iv. **Lorneville Plant Wastewater – Land Treatment and Disposal Pre-Feasibility Study (PDP, 2014b)**. The feasibility of a land disposal system to accommodate all wastewater generated from the Alliance Lorneville site was investigated. The study considered discharging treated effluent from the existing wastewater treatment plant, as well from an upgraded treatment plant, with contaminant loads evaluated for each scenario. Soil characteristics within a 10 km radius of the site were investigated, and areas containing soils potentially suitable for wastewater disposal were identified, along with recommended hydraulic loading rates and irrigation infrastructure. Feasible nutrient loading rates were also evaluated for a grazed pasture system. Land disposal system sizing for the two options was determined to be 2,000 ha and 1,000 ha respectively, and capital cost estimates were $115M and $80M respectively, indicating that a land disposal system is unlikely to be financially viable approach for the site.

v. **Lorneville Plant Wastewater Generation – Waste Survey February 2014 (PDP, 2014c)**. Following processing changes at the site in 2013 (namely commissioning of the new rendering plant and introduction of casings processing), a second waste survey was undertaken during peak processing in February 2014. Additional sulphide waste stream characterisation was also undertaken.

vi. **Lorneville Plant Biosolids Management Options (PDP, 2014d)**. Options for managing significant quantities of waste activated sludge (WAS) generated from an upgraded biological nutrient removal (BNR) wastewater treatment plant were investigated. Six shortlisted options for solids management were investigated, with four options involving land disposal to the Alliance Lorneville farm and adjacent grazed pastoral sites. A multi-criteria assessment was undertaken for the options, with the preferred biosolids management as disposal to the Alliance Lorneville land, supplemented with a composting and/or monofill contingency operation.

vii. **Biosolids Land Disposal Assessment (PDP, 2014e)**. A comprehensive assessment of environmental effects for biosolids disposal to the Alliance Lorneville farm was undertaken. This assessment concluded that a biosolids loading rate of 250 kg N/ha/yr to the Alliance Lorneville grazed pasture system would likely result in a nitrogen leaching rate comparable to a Southland sheep farm, and was therefore considered to be acceptable.

viii. **Sulphide Removal from Wastewater – Feasibility Investigations (PDP, 2014f)**. The feasibility of removing sulphide from a high-sulphide waste stream from the fellmongery prior to discharging to the biological wastewater treatment process was investigated. Various sulphide removal technologies were investigated together with estimated capital/operating costs. Catalytic oxidation is considered to be the most economic option for the site. Further investigations would be required to determine the suitability and extent of such treatment option for Alliance Lorneville.

ix. **Groundwater and Surface Water Monitoring (PDP, 2015)**. A comprehensive field investigation for the groundwater and surface water in the vicinity of the existing wastewater treatment plant was undertaken to determine any effects on groundwater arising from the wastewater treatment lagoons. At the time of the sampling surveys in December 2014 and March 2015, there was no obvious effect from the leakage of treated wastewater from the wastewater treatment lagoon on the surrounding groundwater.

3.5 Waste Minimisation Targeted Approach

3.5.1 Targeting Nitrogen Sources

One of the key issues for the discharge is management of nitrogen, especially ammoniacal nitrogen once passed through the wastewater treatment plant. In order to reduce the nitrogen at the end-of-pipe, Alliance Lorneville has investigated the sources of the nitrogen in the waste streams generated from its processing operations.

Figure 6 shows the general contribution of nitrogen from various processing areas. In general terms the waste streams from casings, stockyards, lime wash, soupstock and the raw material bins contribute to 34% of the total daily volume of the discharge, but contribute to 75% of the nitrogen load. Within these waste streams, there is an opportunity to divert some clean water to reduce the volume.

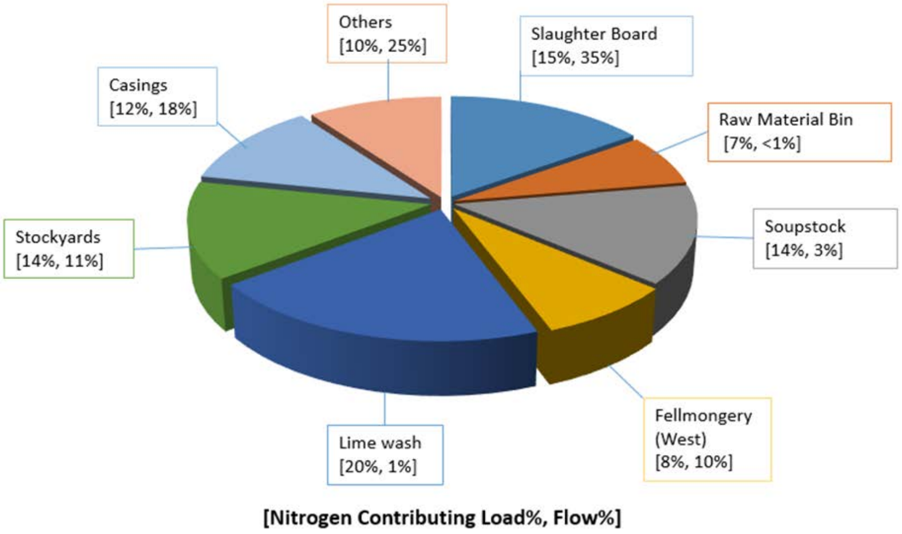

Figure 6: Waste Streams Contribution to Plant Nitrogen Load

3.5.2 Sulphide Management

The lime wash and pickle liquors from the fellmongery contribute to the largest sulphur based load from the processing operations. Alliance Lorneville is investigating the feasibility of options to separate these waste streams and to employ chemically assisted sulphide removal.

3.5.3 Preliminary Treatment from Specific Waste Streams

Following the waste surveys, it was recognised that some additional performance could be achieved from existing dissolved air flotation (DAF) plant. In addition some waste streams were identified that could be treated using another DAF unit. Alliance Lorneville has already started implementing some of these upgrades. This has included separation of some of the high strength sources and treating through a separate chemical assisted DAF unit.

The estimated nitrogen reduction from improvements in the primary treatment as part of this upgrade is expected to be between 10 – 20%.

3.6 Separable and Non-Separable Domestic Effluent

The plant wastewater collection system also collects domestic effluent (sewage) from various areas within the Alliance Lorneville plant site.

Alliance Lorneville has undertaken investigations to determine the feasibility of separation of the site’s domestic effluent from the meat processing wastewater to dedicated treatment and disposal.

3.6.1 Separable Effluent

Domestic effluent from Wallacetown is also transferred to the Alliance Lorneville wastewater treatment system via a pressure main installed in 2007 which currently services approximately 600 people. The peak wet weather flow from Wallacetown is expected to be 300 m^3/d.

3.6.2 Non-Separable Effluent

Based on peak site staff occupancy of approximately 2,000 employees, the estimated daily volume of domestic effluent is 220 m^3/d.

The domestic effluent is collected from various areas spread widely across the site. Any upgrade of the site's collection system will require separation at each generation point and either connected through a new gravity system or alternatively through a pressure sewer system.

3.6.3 Alternate Treatment and Disposal

The most cost effective option for treating domestic effluent would likely involve converting one of the disused lagoons to a dedicated treatment pond for treating the separated domestic effluent. In this case, a single facultative pond could achieve bulk removal of TSS, $cBOD_5$ and some nutrients. For disposal to land, a tertiary filter system would likely be required, and a UV disinfection system would likely be required if discharge to land via spray irrigation, but may not be needed if a drip-line irrigation system was utilised.

The minimum amount of land area required to manage the safe disposal of treated domestic effluent will be around 17 ha.

3.6.4 Continued Management of Domestic Effluent

Given that the site's domestic effluent contributes to 1% hydraulic load and a minute contribution to wastewater contaminant loading, the benefit derived from separation is assessed to be comparatively low, with a high attendant cost of implementation.

In particular, the capital cost for the separation of the domestic effluent at the Lorneville plant including Wallacetown sewage and dedicated treatment in one of the lagoons is estimated at around $1.7M. Of this Wallacetown sewage separation works from existing Alliance Lorneville wastewater treatment plant to new plant is likely to incur $400K.

Given the very low contribution that domestic effluent makes to the overall discharge load, it has been concluded that the existing management approach, coupled with the progressive upgrading which is set out within Section 4.0 below is the best practicable option.

It is acknowledged that this is a key matter for tangata whenua. Further consultation about this matter will be undertaken with tangata whenua.

3.7 Alternatives for Wastewater Treatment

3.7.1 Wastewater Treatment Technologies

A comprehensive assessment of wastewater treatment technologies that would enable the reduction of the key contaminants, namely nitrogen, phosphorus and *E. coli* is summarised in this section. A complete description of technologies examined and details of how they could be applied at the Alliance Lorneville site has been included as Appendix A.

The technologies assessed include the proven technologies in use by Alliance Group Limited on several of its plants as well as some new technologies.

A summary of the treatment technologies considered, the target contaminant removal, advantages and disadvantages are given in Table 2.

Table 2: Wastewater Treatment Technologies Comparison

Treatment Method	Contaminants Targeted	Advantages	Disadvantages
Primary Treatment	Solids, fats oil & grease, proteins	Bolt on solutions to existing waste streams, allowing for some product recovery	Additional chemical use for protein recovery
Anaerobic	$cBOD_5$, solids	Substantial solids and organic load reduction, minimises sludge generation, biogas generation for potential energy recovery	No nitrogen removal, management of hydrogen sulphide required in the biogas by-product stream, odour management required
Aerobic – Biological Nitrogen Removal	$cBOD_5$, nitrogen, phosphorus (minor)	Treated wastewater in aerobic state allowing for surface water discharge. Very low level of odour during treatment	High energy use for mechanical aeration and biosolids generation requiring solids management
Ammonia Stripping	Nitrogen	Small footprint, by-product can be utilised as fertiliser	High chemical usage
Chemical Phosphorus Removal	Phosphorus	Bolt-on solution for phosphorus removal to high levels	High chemical usage and solids management required
Sulphide Chemical Treatment	Sulphide	Bolt-on for sulphide removal	Moderate chemical usage
UV Disinfection	*E. coli*	Bolt-on solution to manage microbial contaminants	Requires very high clarity and transmittance to be effective
Land Treatment	Nitrogen	Utilise wastewater for resource reuse	Land area can be significant and depends on hydraulic and/or nutrient limits. May require high degree of treatment to minimise odour effects.

3.7.2 Primary Treatment

The primary treatment involves use of screens to remove gross solids, and dissolved air flotation (DAF) for further solids, fats, oil & grease removal. Chemically assisted DAF treatment can also assist in considerable reduction of proteins as well as improved solids and organic load removal. When appropriate chemicals are utilised, some phosphorus can also be removed.

Alliance Lorneville has a wide range of screening units utilised in various processing areas. DAF plant is utilised for the management of fats, oil & grease recovery. The recovered material from the DAF system form part of the renderable raw material.

Continued waste stream separation and targeted primary treatment has also been considered for Alliance Lorneville.

3.7.3 Anaerobic Lagoon

Anaerobic lagoons provide simple, robust and cost effective removal of degradable solids and organic matter. The by-product from anaerobic treatment is biogas (mixture of methane, carbon dioxide and other gases). Other odorous gases like hydrogen sulphide (H_2S) are also produced.

Typically anaerobic lagoons for this type of application are designed for a lagoon hydraulic retention time of 4-5 days and a depth of 4-5 m. Newly constructed anaerobic lagoons generally also have artificial covers for the collection of the biogas.

Alliance Lorneville has a large anaerobic lagoon with natural crust cover, however, no biogas management system is in place.

Further assessment of high strength waste separation and anaerobic treatment has been undertaken.

3.7.4 Aerobic Systems for Nitrogen Removal

Nitrogen removal can be undertaken in activated sludge systems with provision for biological nitrogen removal (BNR). The key process is enabling the biological nitrification (ammoniacal nitrogen oxidation) and denitrification (oxidised nitrogen reduction) with the by-product of nitrogen gas discharged to atmosphere.

BNR activated sludge process options typically comprise of suspended growth treatment processes utilising tank or lagoon based reactors, which can be operated on a continuous or batch basis (sequencing batch reactors).

Membrane bioreactor (MBR) processes are a form of suspended growth activated sludge process utilising a fine membrane to separate treated effluent from the biomass, allowing for high biomass concentrations for smaller reactor sizing. In these systems the membrane modules replace the secondary clarifier in a conventional activated sludge system.

The simplest and most robust suspended growth BNR processes is the simultaneous nitrification de-nitrification process (SND) involving maintaining an acceptable pH range, dissolved oxygen concentration and appropriate ratio of carbon to nitrogen constituents within the reactor. This process has been successfully implemented at many meat processing facilities in New Zealand including Alliance Pukeuri.

Further examination of the biological nitrogen removal options has been undertaken for Alliance Lorneville.

3.7.5 Land Treatment Systems for Nitrogen Management

Land treatment of wastewater involves the controlled application of effluent to land at a rate that allows organic constituents and nutrients to be assimilated by vegetation and by micro-organisms within the soil biomass. Application rates for land treatment are generally based on the hydraulic loading capacity of the soil, as well as on the nitrogen loading rate which is dependent on the land use.

The wastewater from meat and by-products processing plant generally contains a large amount of nitrogen and this becomes the key constraint to land based application of effluent. However, for Alliance Lorneville, the soils in vicinity of the plant also have a considerable hydraulic loading capacity constraint.

A pre-feasibility assessment of the land treatment requirements for wastewater from the existing wastewater treatment plant has been undertaken. Up to 2,000 ha of land will be required if nitrogen loading is at level of 150 kg N/ha/yr (PDP, 2014b). The procurement of land and establishment of a new land treatment system is likely to cost in excess of $115M, with the land purchase estimated at $70M.

If the wastewater treatment plant is upgraded to significantly reduce nitrogen and then the treated wastewater is disposed to land, the amount of land area required reduces to 1,100 ha. The procurement of land and establishment of a new land treatment system is likely to cost in excess of $82M, with land purchase estimated at $39M.

Although a land treatment system is technically feasible, with sufficient areas of suitable land within 5 km radius of the site, the difficulties in land procurement and/or access mean that this option is not practicable. Further, the capital costs associated with land treatment at around $45M is considerably higher than full treatment and continued discharge to the Makarewa River (as detailed in Section 4.0).

If land purchase is not feasible, but access to non-company land in the vicinity of the Alliance Lorneville plant is agreed by other land owners, then the application of treated wastewater to land for summer peak processing period (assuming pastoral water augmentation using treated wastewater is welcomed by the farmers) would require access to a several farms. The required land area needs to be based on the ability to dispose at a recommended application depth of 120 mm/yr because much of the soils in the vicinity of the processing plant are hydraulically limited. If the application depth is at 120 mm/yr, then an estimated 2,000,000 cubic metres of wastewater generated during this period would require access to at least 1,600 ha of well drained farmland (Zone 1 soils).

Additionally, once the wastewater treatment to reduce nitrogen concentrations is implemented, there is a corresponding increase in the generation of bacterial solids (waste activated sludge referred to as biosolids) and this will need to be managed appropriately. Alliance Lorneville has proposed that the biosolids will need to be managed through a land disposal system on land owned by the company. In the land disposal assessment provided for Alliance Lorneville up to 180 ha of company owned land would then be fully utilised for biosolids disposal. An additional 25 – 30 ha will be required for stockyards solids requiring access to around 200 ha every year of the 300 ha grazed farmland owned by the company. The estimated costs for development of irrigation system to allow for land treatment onto other land would be around $28M (excludes any costs associated access rights).

A further assessment of the separation of the high strength waste streams and land treatment for this waste stream was considered not feasible, because the land area of around 400 ha is required to manage the hydraulic loading resulting in consequential nitrogen loading in excess of 600 kg N/ha/yr, higher than what would be acceptable for a zero-grazed (cut & carry) system. The application of such wastewater would not be acceptable as the nitrogen concentration would be around 530 mg/L (generally in ammoniacal-N form) and this could result in pasture burn, poor uptake by pasture, and could promote leaching. In order to ensure optimum crop yield, the nitrogen concentration of the irrigated wastewater needs to be low. Even if a zero grazed option were to be feasible, a substantial undertaking in terms of access to market for up to 8,400 tonnes per year of dry matter production would be required.

Given that Alliance Lorneville does not have access to other land, it is very difficult to plan around a discharge regime that utilises land treatment that would have zero grazing option. For the land that Alliance Group Limited owns, the proposal requires around 210 ha of land available for the management of biosolids and stockyard solids. This land cannot be converted into a zero grazing option as the land is required for stock overflow and holding purposes to manage processing at the plant.

3.7.6 Ammonia Stripping for Nitrogen Removal

Conventional ammonia stripping involves shifting the pH of the wastewater to favour dissolved ammonia (NH_3) over soluble ammonium ions (NH_4^+), and then transfer of NH_3 from the liquid phase to the gas phase by contacting the wastewater with air. This is usually carried out in a packed-bed tower in which the wastewater is sprayed over the packing media at the top of the tower, with air entering via the bottom of the tower. Disposal of NH_3 gas can be by dispersal to the atmosphere, or by a second closed loop reabsorption tower utilising sulphuric acid and recovery of ammonium salts.

For Lorneville, the ammonia gas would need to be recovered in a closed loop system to minimise discharges to air. The use of an ammonia stripper tower would be a new technology for Alliance Lorneville and this requires substantial waste separation, dedicated anaerobic treatment and filtration for this waste stream prior to implementation. Estimated capital costs for establishing such a system would be around $11M with annual operating costs of $1.5M. Further pilot testing and quantifying the risks would be required if this alternative is considered further.

3.7.7 Phosphorus Removal

There are two main methods to remove phosphorus from wastewater. These are enhanced biological phosphorus removal (EBPR) and chemical precipitation.

EPBR can prevail under certain conditions in activated sludge systems, but can be difficult to manage and EBPR performance is generally at the expense of BNR. For this reason, biological treatment systems often focus on BNR and utilise chemical precipitation to supplement removal of phosphorus.

Chemical phosphorus removal includes precipitation with metal salts such as ferric chloride, aluminium sulphate, or lime, as well as via the physio-chemical DAF-in-series system. Solids removal following chemical precipitation is most often via primary or secondary clarification or DAF.

The DAF-in-series system utilises acid and lime dosing to release and subsequently precipitate phosphorus, which can be more cost effective than utilising metal salts or lime alone, however would involve construction of significant additional infrastructure at the site. Alliance Mataura operate a DAF-in-series system for the high phosphorus laden waste stream.

For phosphorus removal the main costs are the operational costs associated with chemical use and the likely costs are between $200- $500K per year. Alliance Lorneville may consider the requirements for bolt-on chemical phosphorus removal system in future.

3.7.8 Sulphide Removal

Some of the processes at the fellmongery utilise sulphur-based chemicals that result in the discharge of sulphate as well as sulphides. High sulphide concentrations in wastewater can inhibit biological processes, and can also generate odour nuisance under anaerobic treatment conditions.

Oxidation of sulphides to sulphates can be achieved via aeration in the presence of a metal catalyst, or using chemical oxidisers such as hydrogen peroxide. Iron salts can also be used for chemical precipitation of sulphide to form insoluble iron sulphide salts.

Sulphide can be converted to H_2S gas under anaerobic conditions which then requires gas phase treatment to avoid odour generation and air emissions problems. Treatment of H_2S can be achieved via conventional wet-scrubbing systems, biological scrubbing systems, biological filter or activated carbon filtering. Combustion of biogas oxidises H_2S into sulphide dioxide and this needs to be managed appropriately.

Alliance Lorneville is further assessing appropriate treatment solutions for the waste streams that have high sulphur loads (PDP, 2014f).

3.7.9 Disinfection

There are a number of available microbial disinfection technologies, however, Alliance Lorneville has determined that if it was to consider reductions of microbial contaminants in the longer term as part of catchment wide plan then ultraviolet (UV) disinfection is the most suitable method of disinfection after the successful implementation of this system at Alliance Pukeuri.

UV disinfection is the most common wastewater disinfection method in New Zealand as it is a relatively simple technology to install and operate. It also results in no harmful chemical by-products.

The downside of UV disinfection system is that the effectiveness is highly dependent on the level of TSS in the wastewater. Solids in the wastewater can shield microbial contaminants from UV light, reducing the rate of disinfection. To overcome suspended solids issues, filtration systems can be installed prior to the UV plant, or alternatively, an increased level of UV intensity can be provided.

Once Alliance Lorneville have upgraded the treatment plant, then a filtration system may not be required. It is still unclear that once the high strength waste streams are separated, whether there will be any requirement to disinfect the wastewater passing through the existing system because the microbial load could be very low and that the existing treatment plant may be able to manage the disinfection via natural sunlight disinfection and through use of maturation ponds. If disinfection is required in future for the final discharge from the existing lagoons, then filtration or a dissolved air flotation system would need to be implemented to improve the transmittance of the final discharge. The likely capital costs for implementation of disinfection systems for the site could be around $4.4M.

Alliance Lorneville proposes to undertake an assessment to determine if disinfection will be beneficial once the BNR treatment systems have been implemented.

3.8 Residuals Management

The residuals management includes management of primary treatment system solids, stockyard solids, biological solids (biosolids) wasted from a BNR system and biogas from any new anaerobic lagoons.

3.8.1 Primary Treatment System Solids

Significantly more primary solids will be generated from the upgraded primary wastewater treatment system. Solids recovered from site processes will be assessed for suitability for inclusion in rendering plant for product recovery. Unsuitable primary solids would be dewatered and disposed of to landfill.

3.8.2 Stockyard Solids

The stockyard solids may require separate management and disposal onto land or disposed to monofill either at the site or disposed off-site. Alternative may also include composting if suitable downstream market is always available.

3.8.3 Biosolids

The biosolids generated from any upgraded biological treatment system will be disposed of onto land, and will require dewatering prior to disposal to areas of lower permeable soils. In the event dewatered solids cannot be disposed of onto land then it could be monofilled in either one of the sludge management lagoons within the existing wastewater treatment system or within a new dedicated monofill.

For biosolids disposal onto land, the plant available nitrogen loading will be the key constraint. Alliance Lorneville has undertaken an extensive options assessment for the disposal of biosolids (PDP, 2014d) as well as an assessment of environmental effects for biosolids application to land (PDP, 2014e). The nitrogen loading of biosolids onto land is based on 250 kg N/ha/yr providing a plant available nitrogen (PAN) of 140 kg N/ha/yr.

3.8.4 Biogas

Biogas is a by-product of the anaerobic digestion process and it can be combusted using a flare to reduce its explosiveness, toxicity and odour potential. However, biogas also has the potential to be utilised as an energy source, such as a boiler fuel or via cogeneration to produce electricity. Energy savings would be in addition to the energy conservation offered by the reduced aeration demand in subsequent aerobic wastewater treatment.

For any new anaerobic lagoon established at Alliance Lorneville, the site is proposing to capture the biogas and combust it using a flare unit as a minimum. Further assessment of the biogas and its utilisation will be considered once biogas characterisation is completed.

4.0 Proposed Approach for Upgrades

Prior to the completion of the ecological studies (FWS & AES, 2014) and the development of the relevant criteria in terms of managing the ammoniacal nitrogen discharged to the Makarewa River, Alliance Lorneville investigated the wastewater treatment plant upgrade options (PDP, 2013b) to meet certain nitrogen targets in the final discharge.

4.1 Options Shortlisted for Nitrogen Reduction

The options include a complete wastewater treatment plant replacement as well as separating higher strength effluent streams for targeted treatment and blending back into the existing wastewater treatment plant. The shortlisted options identified were as follows:

1. **Primary Treatment System Upgrade**. In this option there is separation of high strength nitrogenous waste streams. It also includes a front-end retrofit involving upgrading the existing DAF plant and installing a new decommissioned DAF plant from Alliance Mataura (PDP, 2014a). Since this upgrade requirement was common to all other options, Alliance Lorneville commenced the implementation of this upgrade during the non-processing season in 2014 (June 2014). It is expected that the total nitrogen reduction from the site as a result of this primary treatment system upgrade will be between 10 – 20%.

2. **High Strength Flow Separation –Ammonia Stripping**. This option includes the upgrade to the primary treatment system, as well as separating high-strength effluent streams for targeted nitrogen removal. Treatment of the separated stream includes anaerobic treatment, filtration, and ammonia (NH_3) stripping before discharge to the existing wastewater treatment plant after the anaerobic lagoon. The overall nitrogen removal from high strength flow separation, anaerobic treatment of this waste stream and implementation of ammonia stripping is likely to result in approximately 60% reduction of nitrogen from current levels. The estimated capital costs for implementation of this option (including solids management) is $11M with the likely annual operating costs of $1.5M.

3. **Medium Strength Flow Separation – New BNR Plant.** This option includes the upgrade to the primary treatment system, as well as separating high and medium-strength effluent streams for targeted nitrogen removal. Treatment of this stream includes anaerobic treatment, aerobic treatment via a BNR reactor, secondary clarification, and discharge of treated effluent back into the existing wastewater treatment system after the anaerobic lagoon. An assessment indicated that the overall nitrogen load to the existing wastewater treatment plant could be reduced by approximately 75% from 2012/13 season levels.

Assuming a further nitrogen removal rate of 25% through the existing wastewater treatment plant, implementing this option could reduce the final discharge ammoniacal nitrogen concentration to approximately 50 g/m^3. The estimated capital costs for implementation of this option including biosolids management is $16M. The operating costs are estimated at $1M per year.

4. **Half Flow Separation – New BNR Plant.** This option includes the upgrade to the primary treatment system, as well as separating the higher concentrated stream making up approximately half of the total discharge. Treatment would include anaerobic treatment, aerobic treatment via a BNR reactor, secondary clarification, and discharge of treated effluent back to the existing wastewater treatment plant. This option indicates that the overall nitrogen load to the existing wastewater treatment plant could be reduced by approximately 82%. Assuming a nitrogen removal rate of 25% through the existing wastewater treatment plant, implementing this option could reduce the final discharge ammoniacal nitrogen concentration to approximately 30 g/m^3. The estimated capital costs for implementation of this option including biosolids management is $18M, with annual operating costs of $1M.

5. **Complete Replacement – New BNR Treatment Plant.** This option incorporates a complete wastewater treatment plant replacement targeting nitrogen removal for the full flow and load generated from the processing plant. The upgrade would include the primary treatment system, followed by anaerobic treatment, aerobic treatment via two BNR reactors, secondary clarification, and the discharge of treated effluent direct to the river bypassing the existing wastewater treatment plant. This option allows for approximately 90% nitrogen removal from existing levels and the final discharge is expected to have ammoniacal nitrogen concentration of the order of 15 g/m^3 under peak loading conditions. The estimated capital costs for implementation of this option including biosolids management is $22M with annual operating costs of $1M.

4.2 Other Contaminants Reduction

Additional bolt-on treatment units for the removal of sulphide, phosphorus and microbial disinfection are described in this section.

4.2.1 Sulphide Removal

For sulphide removal the options are catalytic oxidation of sulphide, oxidation using hydrogen peroxide or precipitation using metal salts. Based on a separate investigation (PDP, 2014f), the catalytic sulphide oxidation is the preferred option. Further investigations and refinement of the preferred option would be required to determine the cost implication. However, the preliminary estimates suggest the capital costs of $1M with annual operating costs of $80K.

4.2.2 Phosphorus Removal

For phosphorus reduction, there is an expectation that as a result of improved biological treatment, some phosphorus removal will occur as a result of biological phosphorus removal.

A chemical phosphorus removal system can be added onto the biological process train to enable further reduction of phosphorus.

4.2.3 Microbial Disinfection

For microbial disinfection the combination of filtration and UV disinfection is the preferred approach prior to final discharge.

4.3 Preferred Option

Following from the outcomes of the ecological assessment (FWS & AES, 2014), the final discharge requires a reduction in existing ammoniacal nitrogen concentrations by around 75% to ensure that the continued discharge to the Makarewa River can occur under site specific ammonia limits.

This would mean that the preferred option for nitrogen removal would be Medium Strength Flow Separation – New BNR Plant.

Wastewater streams separated for treatment under this option make up approximately 25% of the total flow from the plant by selecting the higher nitrogen loaded streams. Key influent wastewater characteristics of the combined medium and high-strength stream are shown in Table 3.

A process flow diagram showing the proposed medium strength waste stream flow separation and the requirements for the new parallel wastewater treatment plant to treat this wastewater is set out in Figure 7.

Table 3: Preferred Option – Estimate of Loads and Removal Rates

Parameter	Raw Influent	Post Primary Treatment	Medium Strength Flow Separation + New BNR Plant Option				To Existing WWTP	Future Discharge	Existing Discharge	Overall Reduction
			Influent		Effluent					
	[kg/d]	[kg/d]	[kg/d]	[%] Raw	[g/m^3]	[kg/d]	[kg/d]	[g/m^3]	[g/m^3]	[%]
Flow [m^3/d]	21,780	-	7,400	34	-	6,900	21,780	22,730	22,730	-
TSS	29,200	20,100	11,500	58	<50	250	8,850	<80	80	-
cBOD$_5$	34,900	25,000	18,400	53	<30	150	6,750	<30	30	-
TN	3,660	3,300	2,700	76	<60	300	900	<50	210	76
TP	485	440	360	76	<30	150	230	<15	22	45

Notes:

1. *All units as stated except flow in m^3/d.*
2. *TSS = total suspended solids, cBOD$_5$ = carbonaceous biochemical oxygen demand, TN – total nitrogen, TP = total phosphorus.*
3. *The design raw influent flow is based on 21,780 m^3/d and excludes stormwater and domestic effluent.*
4. *Domestic effluent at site is expected to be 220 m^3/d with an additional peak flow of 300 m^3/d from Wallacetown.*
5. *Preferred Option is the Medium Strength Flow Separation – New BNR Plant for the separated wastewater.*
6. *Raw Effluent is based on peak design load allowing for 10% factor of safety on extended peak load assessed for the processing of 28,000 lamb equivalents.*
7. *Medium strength flow separation shows the estimated proportion of the loads to the raw influent as kg/d and percentage. The effluent volume takes into account the biosolids (1% solids) removal of around 500 m^3/d.*
8. *To existing WWTP – This shows the wastewater diverted to existing wastewater treatment system once the separated waste stream is treated in a new dedicated treatment plant. The volume also takes into account of additional domestic effluent volume of 520 m^3/d.*
9. *The existing discharge and future discharge volume is based on the current consent limit of 22,730 m^3/d.*
10. *The existing discharge concentration is based on 90-percentile value of the 2013 season final discharge dataset. The actual 90-percentile value for TSS = 76 g/m^3, cBOD5 = 27 g/m^3, TN = 210 g/m^3 and TP = 22 g/m^3. Minor adjustments to TSS and cBOD$_5$ have been applied to show no change in TSS and cBOD$_5$ from current to future for the preferred option.*
11. *The final discharge nitrogen concentrations are assessed as ammoniacal nitrogen. Some oxidised nitrogen may be expected from the discharge on occasions but has not been quantified.*
12. *The phosphorus removal through the primary system is assumed to be at 10% removal rate.*

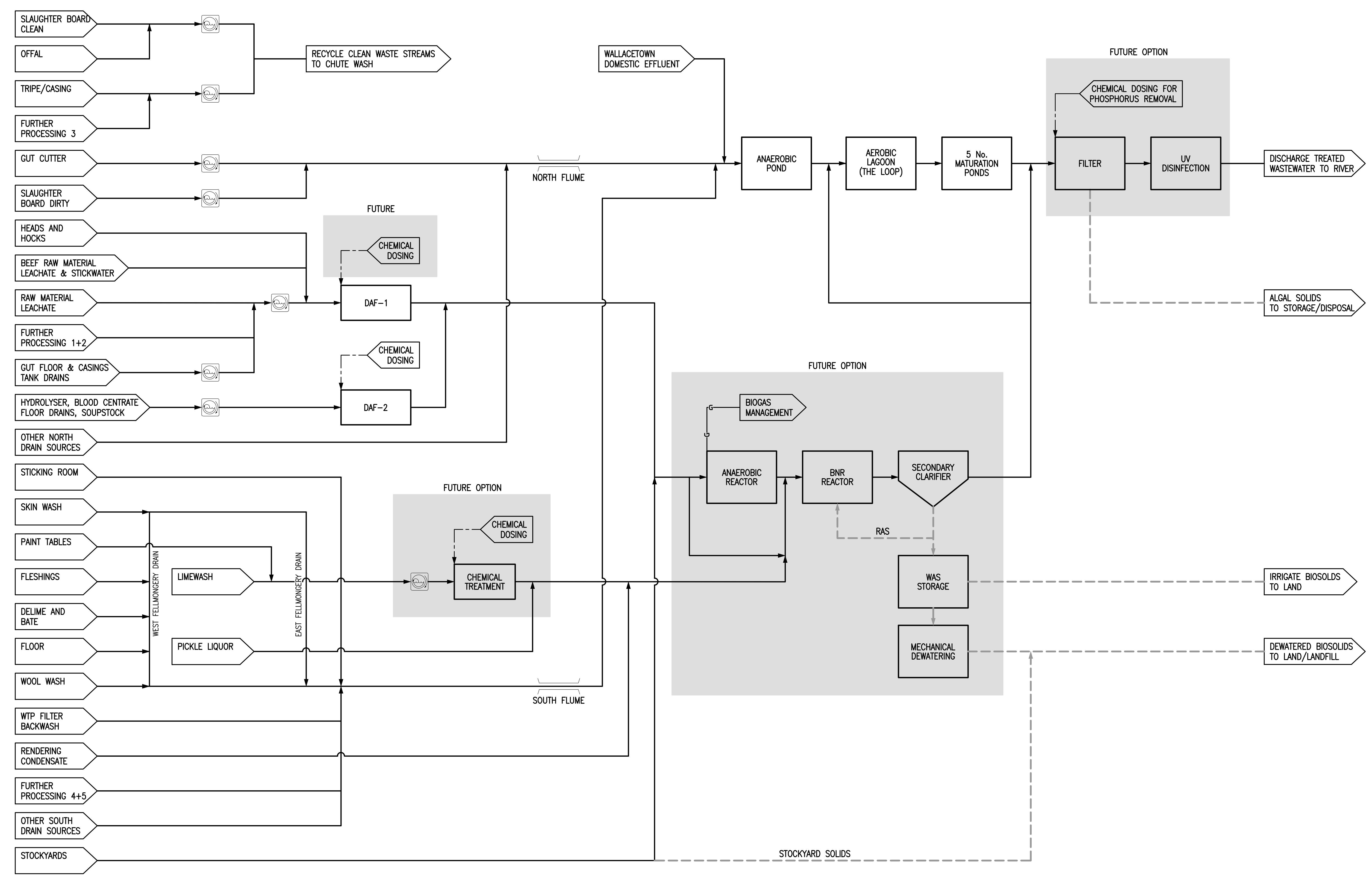

IMAGE:

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KEY :

⊜	MECHANICAL SCREEN
———	WASTEWATER STREAM
– – – –	SOLIDS STREAM
——G——	GAS STREAM
— - — - —	CHEMICAL DOSING

NO.	REVISION	DATE	APP.
B	ISSUED FOR CONSENT	DEC 14	
A	ISSUED FOR REVIEW	NOV 14	

	BY	CHECKED	DATE
DESIGNED	D.G.	A.K.	NOV 14
DRAWN	D.R.	D.G.	NOV 14
APPROVED ISSUE FOR :			
APPROVED :			

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CLIENT: Alliance Group

PROJECT: LORNEVILLE PLANT WASTEWATER - SUMMARY REPORT ON ALTERNATIVES AND PROPOSED UPGRADING OF WASTEWATER TREATMENT PLANT

TITLE: MEDIUM STRENGTH FLOW SEPARATION - NEW BNR PLANT

PROJECT NO. : A01856214

SCALE NTS (A3)

SHEET : -
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FIGURE NO. : 7

REV : B

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4.4 Recommended Upgrade Methodology

The upgrade of the wastewater treatment plant to meet the future requirements is a substantial capital undertaking and will need to be undertaken in a staged manner to ensure that flow separation is successful with the capture of as much high strength nitrogenous waste streams as possible.

It is envisaged that the upgrade will occur in the following manner:

1. Establishment of the primary treatment upgrades as required for the waste streams that require better management of solids, oil & grease and protein recovery. Some of the upgrades have already been undertaken by Alliance Lorneville during 2014;
2. Targeted chemical treatment of fellmongery wastewater containing a large sulphide load;
3. Separation of the waste streams from existing common north and south drains into a separate pump station to allow the diversion of the high strength waste streams to a new treatment facility;
4. Confirmation of the waste streams and corresponding loads to ensure that the required level of nitrogen removal can be achieved with the development of a parallel treatment plant;
5. Separation of the stockyard solids wastes and diverting to direct land disposal and/or composting;
6. Establishment of a new covered anaerobic reactor for the reduction of the organic load and mineralisation of organic nitrogen into ammoniacal nitrogen;
7. Management of the biogas generated from the new covered anaerobic reactor through flaring and future energy recovery. If required, management of hydrogen sulphide in the biogas stream prior to combustion;
8. Establishment of an activated sludge system with biological nutrient removal (BNR) capability and clarifier for solids separation;
9. Diversion of high strength rendering plant condensates into the BNR to assist with nitrogen removal;
10. Diversion of treated wastewater from the new BNR plant into the aerobic part of existing treatment plant;
11. Establishment of biosolids management system and solids dewatering facility for land disposal and/or landfilling;
12. If required, start investigations to determine the extent of further chemical phosphorus removal;

13. If required, determine the requirements for disinfection from existing and/or the upgraded treatment plant; and
14. Once the new treatment plant is established and operating for at least one processing season and, if required, investigating additional waste streams that contribute to high nitrogen loads to be diverted to the new BNR plant for treatment to meet future limits.

5.0 Conclusions and Recommendations

5.1 Technical Solution

The range of technical solutions investigated by PDP on behalf of Alliance Lorneville will achieve various levels of nitrogen reduction. Additional treatment processes, if required, would address the reduction of phosphorus and microbial contaminants. Specific treatment for sulphide waste streams would reduce the potential for hydrogen sulphide generation from the anaerobic and aerobic treatment processes.

The separation of the medium strength flow streams and establishment of a new modern wastewater treatment plant will achieve up to 75% reduction in nitrogen from 2012/13 season levels.

5.2 Recommendations

In order to progress the wastewater treatment upgrade, the following recommendations have been made:

i. Confirm the acceptance of the relevant site-specific limits derived for ammoniacal nitrogen through the resource consenting process;
ii. Start relevant investigations to refine the upgrade approach and confirm the flows and contaminant loadings after the completion of primary treatment system upgrades and flow separation;
iii. Carry out site investigations to determine the geotechnical suitability of nominated site(s) for the new parallel wastewater treatment plant; and
iv. Investigate capital cost implications for a modular BNR upgrade approach, for future progression from the preferred option through to full BNR replacement plant;
v. Undertake risk assessment for various elements of the preferred option and how the diversion will affect existing infrastructure; and
vi. Undertake preliminary design to establish more refined costs of the upgraded treatment plant.

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Appendix A

Wastewater Treatment Technologies

Appendix A: Wastewater Treatment Technologies

Treatment technologies which could potentially be implemented at Alliance Lorneville are outlined in the following sections. For the purpose of this assessment, treatment technologies have been grouped into preliminary treatment operations, primary treatment processes and technologies focussing on removal of nitrogen, phosphorus and sulphides. Wastewater disinfection technologies are also outlined.

1.0 Preliminary Treatment

Preliminary treatment involves removal of gross solids from wastewater. Preliminary treatment typically utilises mechanical milliscreen units. The aperture size of the existing screens is 1 mm. Given the high oil and grease (O&G) load attributed to these streams, installation of finer aperture screening is unlikely to be feasible.

2.0 Primary Treatment

Primary treatment uses physical operations to remove O&G, suspended solids and organic matter from wastewater. Existing primary treatment devices at the site include the existing DAF unit and the existing anaerobic lagoon.

2.1 Dissolved Air Flotation

DAF involves dissolving air in wastewater under pressure and then releasing it at atmospheric pressure inside a flotation tank to form tiny bubbles which adhere to the suspended matter causing it to float to the surface where it can be removed by a skimming device.

Much of the protein in meat processing effluents is either colloidal or soluble and therefore is not recovered by simple DAF treatment alone. DAF performance can be significant improved by adjusting the pH to precipitate and coagulate proteins, and further contaminant removal can be achieved by dosing specific polyelectrolytes to aid flocculation. Adjustment of effluent pH to a value of 4-5 can remove a large proportion of the soluble proteins from the effluent.

An efficient DAF system, using pH adjustment and polyelectrolyte dosing, can typically achieve total suspended solids (TSS), carbonaceous biochemical oxygen demand ($cBOD_5$) and oil & grease (O&G) removal efficiencies of the order of 50-60% and total Kjeldahl nitrogen (TKN) removal efficiencies of up to 40-50%. Removed solids can often be utilised in rendering to produce low grade rendering products to off-set operating costs.

2.2 Anaerobic Treatment

An anaerobic lagoon is the simplest, most robust and most cost effective anaerobic treatment process. Anaerobic lagoons provide for settling of influent solids, which are then consumed by anaerobic bacteria near the base of the pond, converting organic carbon, fats and carbohydrates into a mixture of methane (CH_4) and carbon dioxide (CO_2) which is referred to as biogas. BOD and TSS removal efficiencies in the existing anaerobic lagoon have been shown to be as high as 95% and 83% respectively.

Although anaerobic treatment processes do not remove nitrogen (other than a small amount for cell synthesis), reducing the BOD and TSS load ahead of an activated sludge system can significantly reduce aeration and solids management requirements in the activated sludge system.

Although the majority of the influent BOD and TSS is bio-degradable and is released from the anaerobic lagoon as biogas (CH_4 and CO_2), a proportion of non-biodegradable material accumulates at the base of anaerobic lagoons overtime. For this reason, anaerobic lagoons require periodic desludging.

Key design parameters for an anaerobic lagoon are the hydraulic retention time (HRT) and temperature. Experience has shown that for high strength proteinaceous wastewater from meat processing facilities operating under typical summertime temperatures, a HRT of the order of 4-5 days typically allows for efficient anaerobic lagoon performance. For larger systems such as would be required at Alliance Lorneville, a typical lagoon depth would be 4 - 5m.

As well as CH_4 and CO_2, hydrogen sulphide (H_2S) is also released under anaerobic conditions, which can cause significant odour nuisance. For this reason, anaerobic lagoons are typically covered in order to collect biogas for removal of H_2S prior to release to atmosphere. If significant volumes of biogas are collected, CH_4 can be used to generate electricity to off-set demands at the site, or possibly as boiler feed stock. Biogas utilisation in a gas engine or boiler generally requires biogas treatment. Gas phase biogas treatment technologies are discussed later.

3.0 Nitrogen Removal

3.1 Biological Nitrogen Removal

Biological nutrient removal (BNR) in wastewater treatment system occurs by biomass synthesis (nitrogen assimilation) and sludge wasting, as well as by biological nitrification and de-nitrification.

Treatment options for nitrification and/or nitrogen removal can be classified as either:

- Suspended treatment processes, either utilising tank or lagoon based reactors, and include aerated lagoons, continuous or batch activated sludge based processes, and membrane bioreactor processes; and,
- Fixed growth processes, including trickling filtration or submerged biological contactors.

The advantage of fixed growth processes is that they do not require mechanical aeration, as air is supplied for biological processes via natural convection. However these systems require large reactor volumes, and can achieve only very limited nitrogen removal via de-nitrification. Preliminary calculations based on peak loads from the site indicate that a trickling filter capacity to achieve BOD removal and nitrification would be of the order of 60,000 m^3, which is not considered to be feasible.

The simplest and most robust suspended growth BNR process used successfully at meat processing plants in New Zealand is the simultaneous nitrification de-nitrification process (SND). This process involves maintaining low DO levels in the reactor (below 1 g/m^3), which prevents DO penetrating the entire floc depth and allows for nitrification on the exterior portions of the floc and de-nitrification in the anoxic, interior portion. This removes the need for separate reactors or zones. The large reactor volume also allows for effective buffering capacity in the event of processing changes which are characteristic of meat processing sites. Treated effluent can be separated from the biomass in a clarifier, with some recycling of solids back to the reactor, and wasting (removal) of sludge to maintain biomass concentrations.

A sequencing batch reactor (SBR) process involves repeated fill, react, settle and decant cycles carried out all in the same reactor. This system removes the need for a separate clarifier; however, generally requires balancing lagoons or multiple reactors to regulate discharge rates. This approach requires a sophisticated control system, and large pumping capacity for large scale systems, and therefore SBR systems are best suited for smaller wastewater treatment systems.

A membrane bioreactor (MBR) system utilises a membrane media (typically with a pore size of 0.07 to 2.0 µm) to separate solids and maintain high concentrations of biomass in a smaller reactor volume. The membrane system effectively replaces the clarifier in a conventional system. MBR systems are capable of achieving a very low TSS concentrations, however, require high operating costs associated with aeration requirement to scour the membranes surfaces (in addition to the biological process requirements), high pressure pumping and for regular membrane replacement (typically every 6-8 years).

3.2 Ammonia Gas Stripping

Soluble ammonium ions (NH_4^+) in wastewater exist in equilibrium with dissolved ammonia (NH_3), and as the pH and temperature of the wastewater are increased, the equilibrium shifts in favour of NH_3. Conventional NH_3 stripping of wastewater involves the transfer of NH_3 from the liquid phase to the gas phase, by contacting the wastewater with air. This is usually carried out in a tower in which wastewater is distributed over an internal packing media at the top of the tower, and air enters at the bottom of the tower. Once NH_3 is removed from the wastewater as NH_3 gas, disposal options include air dispersal, or dissolving back into solution as ammonium sulphate using sulphuric acid and a second absorber tower. Salt recovered via this “closed loop” system can potentially be used as an agricultural fertiliser product.

Typically these systems involve modest capital investment, but can involve significant operating costs in the form of chemical requirements for pH adjustment. Capital costs associated with constructing packed-bed stripping towers can become prohibitive for large wastewater flows, therefore NH_3 stripping is likely only to be feasible for treating relatively low-volume streams. Prior to an NH_3 stripper, organic nitrogen must be converted to NH_4-N (inorganic nitrogen) via an anaerobic treatment process. An anaerobic lagoon could serve this purpose.

This option would need to consider the high sulphide concentration in this stream and removal options are discussed later 5.0. High calcium loads in the limewash stream may impact negatively on ammonia stripping systems.

4.0 Phosphorus Removal

4.1 Biological Phosphorus Removal

High-rate activated sludge treatment processes such as the SND process outlined earlier will remove some phosphorus by biomass synthesis (phosphorus assimilation) and sludge wasting.

Enhanced biological phosphorus removal (EBPR) relies on conditions existing in the biological reactors which encourage certain micro-organisms to take up excess phosphorus. These conditions prevail when sufficient carbon (BOD) is readily available, and there is an absence of oxygen and nitrates. These conditions are typically created by cycling aerobic and anaerobic conditions. Phosphorus is removed from the process by removing a percentage of the mixed liquor suspended solids at the end of the aerobic phase.

EBPR typically produces varied results and is difficult to manage and operate to achieve consistently high removal rates. Results vary from plant to plant, and it is difficult to predict what phosphorus removal rate will be achieved. For this reason many EBPR plants also have facilities for chemical dosing to assist phosphorus removal when the biological process is not achieving the required result. Designing a system for EBPR is also generally at the expense of nitrogen removal.

For these reasons, it is assumed that any biological system would be better designed for BNR rather than EBPR, and if additional phosphorus removal is required in excess of that provided by the BNR process, then this could be managed by chemical phosphorus removal.

4.2 Chemical Phosphorus Removal

Chemical phosphorus removal includes precipitation with metal salts or lime. Chemical phosphorus removal can only remove the dissolved reactive phosphorus (DRP) component of total phosphorus (TP), which in the case of the Alliance Lorneville site, makes up approximately 80% of TP in the effluent. Solids/sludge removal following chemical precipitation is most often via primary or secondary clarification or DAF.

- **Precipitation with Metal Salts:** Chemical precipitation using metal salts is widely used to remove DRP from wastewater to concentrations below 1.0 g/m^3. Metal salts can be added at primary, secondary or tertiary treatment stages. The most commonly used metal salts for phosphorus precipitation are ferric chloride ($FeCl_3$) and aluminium sulphate (alum - $Al_2(SO_4)_3$), both of which are available in New Zealand.
- **Precipitation with Lime:** When lime is added to wastewater, it initially reacts with bicarbonate alkalinity to form calcium carbonate ($CaC0_3$). As the pH increase to more than 9, excess calcium ions will react with phosphorus to precipitate hydroxylapatite $Ca_{10}(PO_4)_6(OH)_2$. Because lime reacts first with alkalinity; the dose is often independent of influent phosphorus concentrations.

4.3 DAF-in-Series System

The DAF-in-series system is a physico-chemical treatment process targeting removal of soluble phosphorus. One such process has been patented by PDP after its first application at the Alliance – Mataura meat processing plant in 2007. For separated high phosphorus loaded streams, this system has been shown to have less operating costs than metal precipitation for phosphorus removal.

The DAF-in-series process incorporate an initial acid dosing phase to lower the pH to less than 4.5, with breakdown of proteins and harvesting of precipitated solids via the first DAF unit. Subsequent to this, alkaline addition raises the pH to approximately pH 9.5 to remove DRP as protein-calcium phosphate aggregates via harvesting in a second DAF unit.

A significant upgrade would be required for a DAF in-series system to treat all phosphorus loads from the site. Based on previous studies, as sufficient land is available at the site for biological treatment, a biological upgrade to target nitrogen removal, with some associated phosphorus removal, is likely to be more cost effective than constructing a new DAF-in-series system for phosphorus removal only.

5.0 Sulphide Removal

If not removed, the sulphide load could inhibit downstream biological treatment processes, including methane producing bacteria (in the anaerobic system) and nitrifying and denitrifying bacteria (in the aerobic system). If not removed, hydrogen sulphide gas (H_2S) release from the wastewater conveyance system and downstream wastewater treatment processes can also generate nuisance odours.

Sodium sulphide (Na_2S) is added at the paint tables in the fellmongery to assist with the separation of wool from the skins. High sulphide concentrations are subsequently washed-out in the limewash waste stream. Review of the fellmongery operators “recipe” and wastewater survey in February 2014 has shown that sulphide concentrations in the limewash waste stream are approximately 2,000 g/m^3.

In a BNR reactor with sufficiently diluted sulphide concentration, sulphide oxidising bacteria can convert sulphide to oxidised sulphur species. Aeration requirements must allow for the additional aeration load associated for sulphide oxidation, which will be of the order of 45 kW for sulphide load in the limewash waste stream at Alliance Lorneville.

However, in order to minimise the risk of sulphide toxicity in the BNR system, and also to minimise the risk of odour generation in the conveyance system and biological treatment system, sulphide removal upstream of the biological process should be considered. Possible sulphide removal options are outlined in the following sections.

5.1 Liquid Phase Oxidation Treatment

Air oxidation with a manganese catalyst or oxidation via hydrogen peroxide dosing are common methods to oxidise separated high sulphide waste streams from tanneries and fellmongery operations.

For neutral or slightly acidic conditions, elemental sulphur is predominantly produced, which can be subsequently removed by chemical flocculation and sedimentation or filtration. Given the high pH (>12) and high buffering capacity of the limewash effluent, soluble thiosulphates ($S_2O_3^{2-}$), sulphites (SO_3^{2-})and sulphate (SO_4^{2-}) are the reaction product. Downstream anaerobic conditions must be avoided to prevent oxidised sulphur species from being reduced back to sulphides.

5.2 Liquid Phase Treatment via Chemical Precipitation

Chemical precipitation of sulphide typically uses iron salts, forming ferrous sulphide (FeS) as an end product. This reaction is favoured by high pH, indicating that it could be feasibly applied to the limewash effluent although operating costs would be significant. Phosphorus precipitation can be a competing reaction with the addition of iron salts.

5.3 Gas Phase Treatment

Gas phase treatment of H_2S gas includes the following possible options:

- Conventional chemical wet-scrubber utilising a packed-bed tower with a scrubbing solution of NaOH or H_2O_2 and typically requires sophisticated online sulphide analysis to control chemical dosing rates;
- Biological scrubbing, such as the Thiopaq® process which utilises an alkaline wash water, bioreactor and sulphur settler.

Alternatively, high sulphide loaded biogas can be combusted via a flare without prior sulphide removal, however this producers high sulphur dioxide emissions which can exceed ambient air quality limits.

6.0 Disinfection

E. coli bacteria and faecal coliform bacteria originate from the intestinal tract of warm blooded animals and are often used as indicators of pathogenic organisms. The existing pond based wastewater treatment system achieves some disinfection via natural UV radiation, however is unlikely to meet future tightening of *E. coli* limits. Common wastewater disinfection processes include:

- Disinfection using chemical agents, most commonly using chorine and its compounds or ozone; and,
- Disinfection with UV radiation.

Disinfection using chlorine based compounds generally results in residual chlorine being discharged to the receiving environment which is often not permitted by regional authorities. De-chlorination systems are available but carry significant cost, as do ozone disinfection systems.

UV reactor systems have become a popular disinfection method, and have been shown to be more cost effective than chemical disinfection options at many sites. UV reactor systems impart no residual contaminants to the effluent, and require minimal operator input. Key effluent quality design criteria for UV systems include:

- UV dose rate, as a function of flow, UV intensity and exposure time;
- Total suspended solids; and,

- UV transmittance.

To maintain the final effluent quality, all upgrade options other than a complete wastewater treatment plant replacement will be required to utilise the existing pond-based wastewater treatment plant, with disinfection of the final pond effluent. Algal growth in pond based systems can be a significant source of TSS which generally must be removed prior to UV disinfection. The TSS concentration in the final effluent (Pond 6) for the 2012-2013 processing season has been shown to range between 10 g/m^3 and 80 g/m^3.

Based on this data filtration of pond effluent may be required prior to the UV unit. Filtration of algae generally requires a three dimensional type filter such as a sand filter for reliable separation of algae. Alternatively a DAF system can be implemented for algal removal.