final report

Project code: P.PIP.0460

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Date published: 2 February 2016

PUBLISHED BY
Meat and Livestock Australia Limited
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NORTH SYDNEY NSW 2059

Investigating potential benefits of biomass recirculation in a covered anaerobic lagoon

This is an MLA Donor Company funded project.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government and contributions from the Australian Meat Processor Corporation to support the research and development detailed in this publication.

Executive Summary

This project examined the effect of resuspending sludge in a CAL via sludge recycling on the overall treatment performance. An improved organic treatment would result in greater production of valuable biogas. Thomas Foods International Murray Bridge site provided a unique opportunity for this study with the installation of a versatile sludge withdrawal and recirculation system during the recent CAL construction.

Operating the sludge system in two distinctly different ways achieved two modes of sludge resuspension. The CAL influent and effluent wastewater, biogas and sludge were monitored over a 12 month period to assess the effect of these two modes.

The hypothesis of this project, that increasing sludge concentration in the upper volume of the CAL would increase the rate of organic removal and thus result in an overall increase in total organic load removal, was disproved. Results found insignificant improvement on the biogas production or organic treatment performance during both biomass recirculation modes despite success in sludge resuspension through the upper volume of the CAL.

It is likely that the overall organic load removal is already optimised in an established anaerobic pond such as those at TFI Murray Bridge. It is possible that sludge resuspension is beneficial during the start-up period of the CAL or in under-loaded CALs where natural gas mixing is limited.

The sludge recirculation system performance was successfully pumped sludge from the base of the CAL to the inlet pit. The peristaltic pump successfully pumped the anaerobic sludge over long periods but the rate steadily decreased over the weeks of operation due to pump damage. The sludge solids concentration from the base of the CAL did not reduce over a week’s pumping but remained at an approximately constant value of 37 g/L. The sludge layer on the CAL base self-levelled as the sludge was withdrawn.

The use of the peristaltic pump for circulating wastewater during Mode 2 was non-ideal.

The settled sludge at the base of each CAL increased over the 12 month monitoring period by 0.5m to 1.0m.

While this project indicated little to no benefit from running the sludge recirculation system, the cost benefit analysis found that only a small improvement in biogas production would justify the capital and operating expense. Increasing the quantity of sludge recirculation or operating during a different phase of the CAL life may have a positive outcome. At a 10% increase in biogas production the payback period is only 4 years.

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Abbreviations

BOD_5	=	Biochemical Oxygen Demand (after 5 days at 20°C) (mg/ℓ).
CAL	=	Covered Anaerobic Lagoon
CH_4	=	Methane
COD	=	Chemical Oxygen Demand (mg/ℓ)
DAF	=	Dissolved Air Flotation
EC	=	Electrical conductivity
JEPL	=	Johns Environmental Pty Ltd
HTR	=	High Temperature Rendering
H_2S	=	Hydrogen Sulphide
NH_3-N	=	Ammonia-nitrogen concentration (mg/ℓ)
NO_2-N	=	Nitrite-nitrogen concentration (mg/ℓ)
NO_3-N	=	Nitrate-nitrogen concentration (mg/ℓ)
O&G	=	Oil and Grease
OH&S	=	Occupational Health and Safety
PLEA	=	Probiotic Low Energy Aeration
SCADA	=	Supervisory Control and Data Acquisition
SP	=	Setpoint
SS	=	Suspended Solids concentration (mg/ℓ)
TA	=	Total Alkalinity (mg/ℓ)
TFI	=	Thomas Foods International
TKN	=	Total Kjeldahl nitrogen (mg/ℓ)
TN	=	Total Nitrogen concentration (mg/ℓ)
TP	=	Total Phosphorus concentration (mg/ℓ)
TSS	=	Total Suspended Solids (mg/ℓ)
VFA	=	Volatile Fatty Acids (mg/ℓ)
WWTP	=	Wastewater Treatment Plant

LIST of UNITS

kg	=	kilogram
kL/d	=	kilolitres (cubic metres) per day
L	=	litre
m	=	metre
mg/L	=	milligrams per litre = ppm.
ML	=	Megalitres (1,000 kL)
ML/wk	=	megalitres per week

1 Background

1.1 Previous research

This research project continues from PIP.0340 “Manipulation of the newly constructed Waste Water Treatment System at Murray Bridge to maximise bio-gas production” that studied the start-up of twin Covered Anaerobic Lagoons (CALs) and investigated the effect of the upstream Dissolved Air Flotation (DAF) unit operation on the biogas formation in the newly constructed CALs. The CALs operated successfully and biogas production was maximised when the DAF operation achieved oil and grease removal without polymer addition.

1.2 Introduction

Covered Anaerobic Lagoons (CALs) are large biological treatment units that use bacteria to convert wastewater organic loads to valuable biogas. Dense bacterial populations are referred to as ‘biomass’ or ‘sludge’ and are characterised by the Suspended Solids (SS) concentration. The sludge concentration is one of the primary factors determining the degree of organic load removal in the CAL.

Low bacterial population reduces organic load conversion rate. Low sludge concentration can occur during CAL commissioning when the bacterial population is developing or in the upper CAL layer during normal operation if the sludge has settled to the bottom of the CALs (which are often quite deep) and is not being resuspended. Dispersion of the sludge through the entire CAL volume may be beneficial to organic removal.

The purpose of this project is to examine two methods of resuspending sludge in a CAL and whether either of these methods have a significant effect on the overall treatment performance of the CAL. If sludge density is a limiting factor in the biological removal of organics in abattoir wastewater, its resuspension would improve the performance of the CAL. The benefits of this would be numerous.

1. Increased organic load removal in the CAL would produce a greater amount of valuable biogas. This would result in operational cost savings and reduced greenhouse emissions due to the increased offset of natural gas.

2. Greater organic load removal in the CAL results in reduced loading on downstream units. In systems with downstream aerobic treatment with mechanical aeration, units can be designed smaller and would require less aeration to deliver an appropriate oxygen supply. This offers both capital cost and long-term operational cost savings.

3. Reduced organic loading from the CAL also reduces the risk of offensive odours being emitted from downstream treatment units or during irrigation.

1.3 Site Description

Thomas Foods International is a mixed species facility located in Murray Bridge, South Australia. Figure 1 shows the site and location of the twin CALs commissioned in late 2012. The abattoir typically processes 11,000 lamb per day and 900 cattle per day operating on a 5 day per week, 250 day per year basis. There exists a full range of ancillary operations including rendering (HTR), boning and offal and intestine processing. Hides for the cattle and sheep are dry salted for offsite transport.

The twin CALs each have a 20ML capacity and are fed evenly via the central split pit. Biogas is collected under the covers and feeds the single biogas train to the flare and/or onsite boiler. The effluent spills over a weir at the discharge end of each CAL and flows to the effluent substation before being pumped to the offsite ponds for further treatment before irrigation.

Figure 1: Thomas Foods International Murray Bridge facility with twin CAL WWTP

A sludge withdrawal and recirculation system was installed during the CAL construction. The sludge system consists of four perforated pipes per CAL and a header pipe connecting to a peristaltic pumping system that is operated by the adjacent control board. Each of the sludge removal pipe can be isolated via manual valves (Photo 2). The pumping station includes a Kelair peristaltic pump, flowmeter, newly installed suspended solid meter, pressure meter, pressure relief valves and isolation valves. Figure 2 illustrates the sludge recirculation system and Photo 1 shows the pumping station.

The arrangement of the isolation valves in the pumping station determines the mode of operation. The sludge system has three modes of operation:

1. Withdrawal of sludge from one or more perforated pipes from one CAL and discharge to the belt filter press located in the DAF shed. This mode of operation is to be used for the removal of accumulated anaerobic sludge to prevent its discharge to the offsite PLEA pond system.

2. Withdrawal of sludge from one or more perforated pipes from one CAL and discharge to either CAL inlet pit. This mode of operation is to be used for the resuspension of settled sludge.

3. Withdrawal of wastewater from the CAL inlet pit and discharge into the bottom of the CAL through one or more perforated pipe. This mode of operation was provided for operational flexibility.

Photo 1: Pumping station for sludge removal and recirculation system at TFI Murray Bridge

Photo 2: Valve on sludge removal points

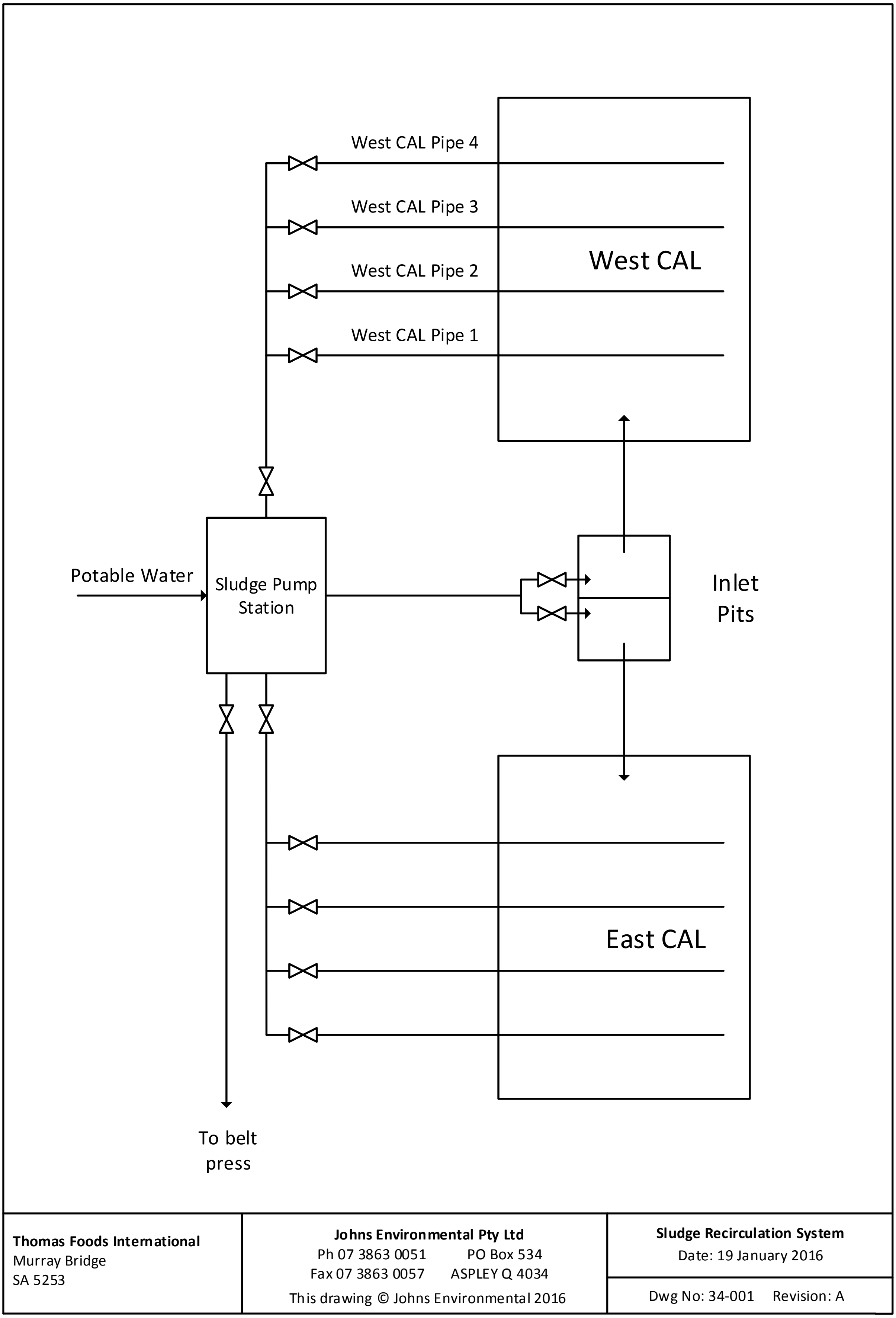

Figure 2: Sludge removal and recirculation system as installed at TFI Murray Bridge facility

2 Projective Objectives

The project objectives as stated in the original PIP project.

- Determine the impact of sludge recirculation on biogas production, quality and treatment performance.

- Assessment of the efficiency of biomass recovery by the sludge recirculation system through in-line TSS measurement and analysis. This is critical to understanding the usual range of solids content in the recovered sludge both with time & position and identifying the risks associated with “rat-holing” through the sludge bed, especially during prolonged biomass pumping regimes.

- Cost benefit analysis of operation of CAL sludge recirculation systems.

3 Methodology

The covered anaerobic lagoons (CALs) were monitored over 12 months as the sludge recirculation system was operated in two distinctly different modes:

1. Pumping sludge from perforated pipe 1 at the base of the west CAL and discharging to the west CAL inlet pit.
2. Pumping wastewater from the west CAL inlet pit and discharging through the perforated pipe 1 at the base of the west CAL.

Data collected during the investigation period includes;

- Wastewater laboratory and field data from weekly sampling of CAL inlet and east and west CAL outlet streams. No measurements were collected during shutdowns periods.
- Biogas flowrate and methane content from the SCADA system.
- Effluent flowrate data from the SCADA system.
- Sludge recirculation system flowrate from the SCADA system.
- Sludge recirculation system total suspended solids (TSS) from the SCADA system.
- Sludge analysis during site visits.

3.1 Project operational modes

3.1.1 Baseline operation

Monitoring of the CAL operation without the sludge recirculation system for four weeks provided typical values for the influent and effluent CAL wastewater prior to sludge recirculation in either CAL.

3.1.2 Mode 1 – Sludge recirculation

The sludge recirculation mode was monitored over 13 weeks. Mode 1 consisted of pumping sludge from the base of the West CAL to the feed pit of the West CAL. The East CAL remained in its normal mode of operation, to act as a ‘control’ set of results. The aim of this mode was to premix anaerobic bacteria with the CAL feed and investigate the resulting CAL treatment efficiency.

Sludge was withdrawn from the first of the four sludge pipes in the West CAL. The first sludge port is closest to the pump minimising head losses and maximising recirculated sludge flow rate.

The sludge was recirculated daily during Mode 1. For the first 3 weeks the sludge recirculation pump was operated for 8 hours a day from Monday to Friday. After this period passed without any issues, this was increased to pumping from 6am Monday morning to 2pm Friday afternoon each week. The pump was not operated on weekends due to limited supervision from the wastewater treatment plant operator. The peristaltic pump required flushing with potable water prior to turning off on Friday afternoon to prevent start-up issues caused by sludge settling.

3.1.3 Mode 2 – Partial wastewater feed through sludge system

Influent wastewater was pumped from the West CAL inlet pit and into the first perforated sludge pipe at the base of the West CAL over a total period of 13 weeks. Again, the East CAL remained in its normal mode of operation to act as a ‘control’. This operational mode aimed to resuspend the settled sludge at the base of the CAL through the upper layers and investigate the organic removal performance.

The wastewater was pumped Monday to Friday during daylight hours only in Mode 2. For the first 7 weeks the original peristaltic pump circulated the wastewater. However, after significant problems with the operation of the pump, it was taken offline for maintenance and found to have been severely damaged. A new peristaltic pump was purchased to perform this duty for the remaining 6 weeks of Mode 2. Wastewater sampling was suspended during the 3 week period taken to source and install the new pump (28/09/2015 to 20/10/2015).

3.2 Wastewater Monitoring

Wastewater monitoring of the CAL influent stream (i.e. DAF effluent stream) and east and west CAL effluent streams enabled characterization of individual stream flow and quality entering and leaving the CALs.

3.2.1 Wastewater Flow

Inline flowmeters connected to SCADA allowed both instantaneous and totalized flow recording at 15 minute intervals. Two flowmeters monitored the following streams:

- DAF effluent, and
- Combined CALs effluent. This flow was assumed to be split evenly between the East and West CAL.

TFI provided JEPL with the daily wastewater flows at each point along with daily production information.

3.2.2 Wastewater Characterization

A CAL influent sample (DAF effluent) was collected on Wednesdays by TFI personnel. An ISCO auto sampler was located at the DAF effluent sampling point and collected hourly samples that were composited into a large bottle. Analysis of this sample was conducted onsite and via an external laboratory.

- Onsite measurements by TFI personnel determined pH, temperature, and conductivity using a portable Hach HQ40d device supplied by JEPL.

- The DAF effluent samples were also bottled, chilled and sent to an offsite laboratory for analysis. Weekly analysis measured COD. Additional analysis of BOD_5, TSS and O&G was also included in the last four weeks of each mode.

CAL discharge samples from each discharge pit were collected weekly on Wednesday by TFI personnel. The samples were also both field and laboratory analysed:

- Field measurements of the effluent samples to determine pH, temperature, and conductivity were conducted by TFI personnel using a portable Hach HQ40d.

- Each CAL sample was also bottled individually and sent to an offsite laboratory. Laboratory analyses in the initial 9 weeks adjustment period of each set point determined COD, BOD, TSS, VFA and TA. Additional analysis in the final 4 weeks steady state period for each mode returned O&G, TKN, TP and NH_3 results.

Photo 3: CAL Discharge sample

3.3 Biogas Analysis

Biogas monitoring included biogas flowrate and methane concentration.

3.3.1 Biogas Flow

An inline Drager 400 biogas flowrate meter connected to SCADA provided cumulative biogas flowrate data at 15 minute intervals. This meter measured the total biogas flowrate to the flare and the biogas boiler.

3.3.2 Biogas Characterization

Biogas methane composition was measured using an inline Endress & Hauser Proline 200 biogas methane analyzer situated downstream of the biogas fan. Readings were linked to SCADA and control systems.

3.4 CAL Sludge Analysis

The depth of accumulated sludge and the upper TSS concentration in the CALs were measured at the beginning and end of each mode. Figure 3 is a schematic of the numbering system of the sampling ports on the east and west CALs. Measurement required the opening of the sampling ports on the CAL covers that, for OH&S requirements, was only performed if the cover was at water level to minimize biogas escape. A Royce 711 suspended solids meter was lowered through the water column (Photo 4). TSS readings were recorded at 0.5m intervals and the depth noted where the interface exceeded the maximum 10 g/L recorded.

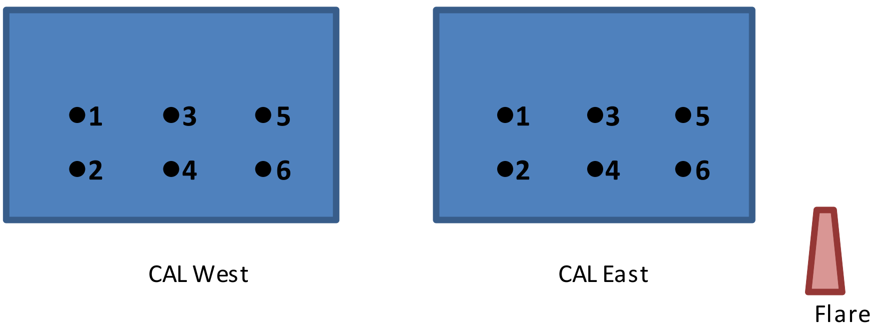

Figure 3 - CAL Inspection Port Locations

3.5 Sludge Recirculation System Analysis

Flowrate and total suspended solids (TSS) were measured with inline instruments linked to the site SCADA. The in-line WTW ViSolid 700 IQ TSS sensor installed on a manufactured mount monitored the solids content of the sludge during Mode 1 (Photo 5). The inline flowmeter (Photo 6) monitored the sludge or wastewater flowrate recirculated by the pump during Mode 1 and 2 respectively. TFI Murray Bridge provided Johns Environmental with SCADA information monthly.

Photo 4: Sludge depth and CAL water TSS measured with Royce Probe

Photo 5: Inline Total Solids Meter at Sludge Pumping Station

Photo 6: Flowmeter at Sludge Pumping Station

4 Results

4.1 Baseline Monitoring

4.1.1 Baseline - Wastewater Flows

Wastewater flow rates throughout the baseline monitoring period were fairly consistent, with a median weekly flow of 17.6 ML.

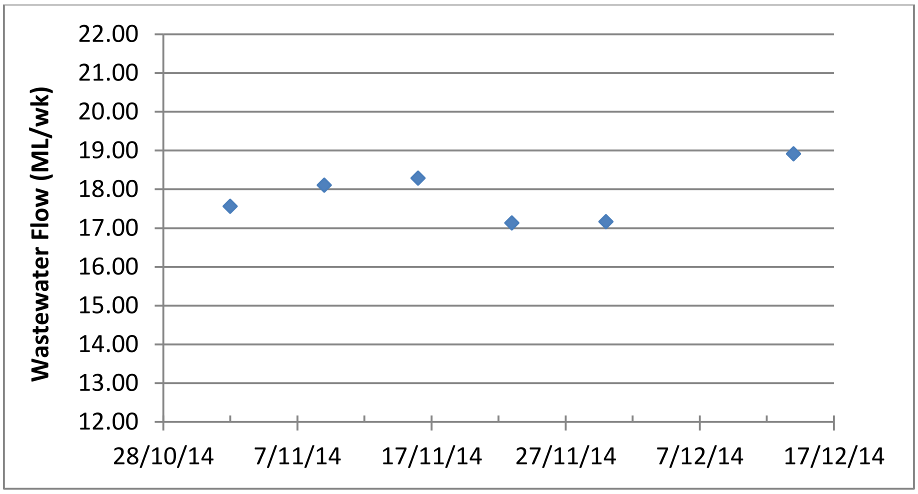

Figure 4 - Baseline Monitoring Weekly Wastewater Flows

4.1.2 Baseline - CAL Influent Wastewater Quality

COD entering the CAL was consistent throughout the baseline monitoring period. Influent COD had a median value of approximately 9,600 mg/L during the baseline monitoring period.

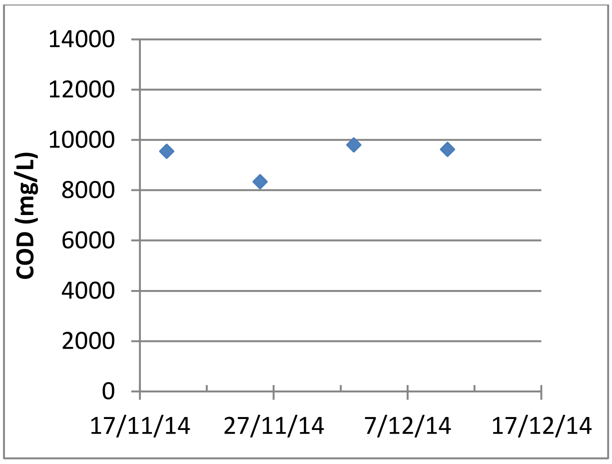

Figure 5 - CAL Influent COD Concentration

4.1.3 Baseline - CAL Effluent Wastewater Quality

The graphs below show that the COD, BOD, VFA/TA and TSS, the West and East CALs are not significantly different. The median COD and BOD concentrations were 1,340 mg/L and 370 mg/L respectively. The median TSS and O&G values were 380 mg/L and 34 mg/L respectively. The median COD removal rates in the East and West CALs were 85% and 84% respectively.

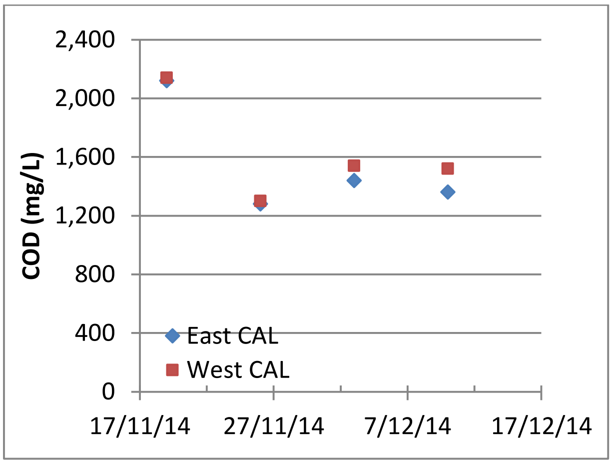

Figure 6 - CAL Effluent COD Concentration

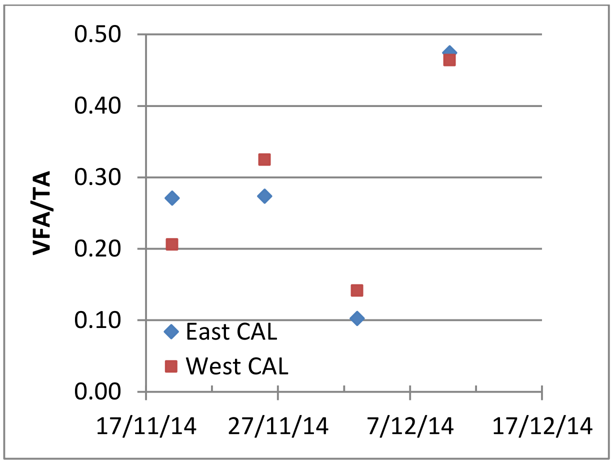

Figure 7 - CAL Effluent VFA/TA Ratio

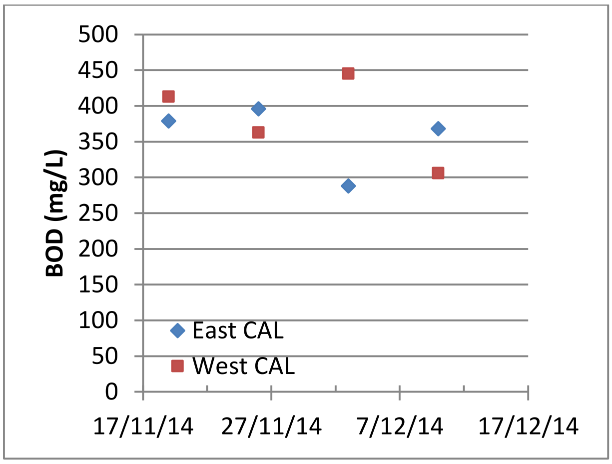

Figure 8 - CAL Effluent BOD Concentration

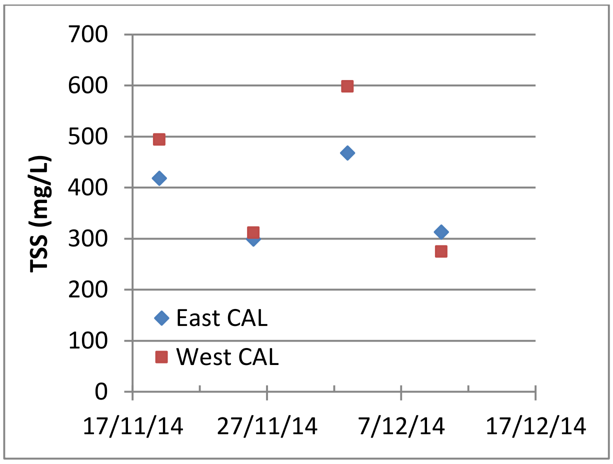

Figure 9 - CAL Effluent TSS Concentration

4.1.4 Baseline - Biogas Flow and Composition Data

Biogas flow and methane composition was consistent throughout the baseline monitoring period. The median weekly biogas flow was 74,000 m^3/wk and the median CH_4 percentage was 75%.

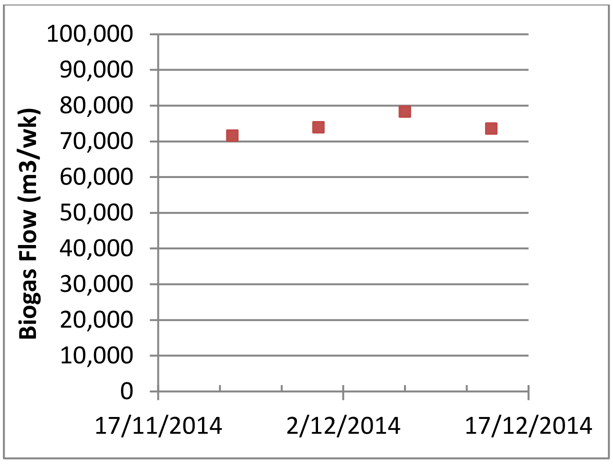

Figure 10 - Biogas Weekly Flows

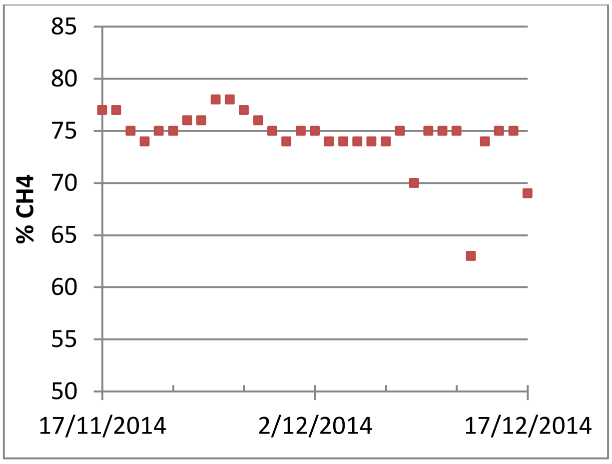

Figure 11 – Biogas Daily Median Methane Content

4.2 Mode 1 – Sludge recirculation

4.2.1 Mode 1 - Sludge System Data

The weekly flowrate and the median weekly TSS results of the sludge being pumped from the bottom of the west CAL to the inlet pit are shown in Figure 9 and Figure 10. Issues with connection to the SCADA system resulted in missing data early in Mode 1.

Initially, the sludge recirculation pump appeared to perform quite well, achieving weekly flows of almost 400 kL/wk. However, the pump got progressively worse with time, achieving lower flows each week. The median weekly sludge flow over Mode 1 was 275 kL/wk.

The median TSS of the recirculated sludge had little variation both over the short and long term as shown in Figure 11 and Figure 13. The average instantaneous sludge flowrate during the week of TSS data represented in Figure 14 was 0.82 L/s.

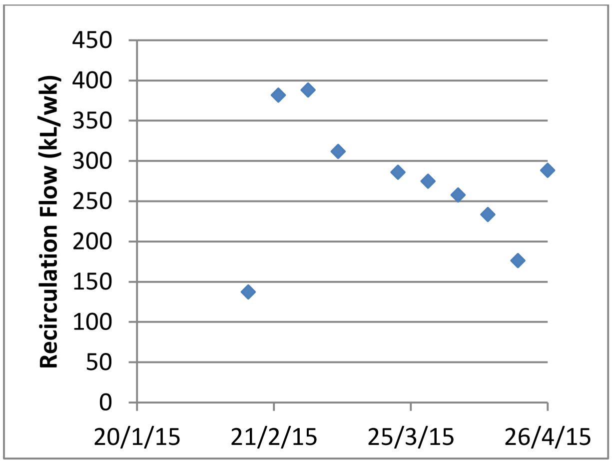

Figure 12 - Recirculated Sludge Weekly Flows

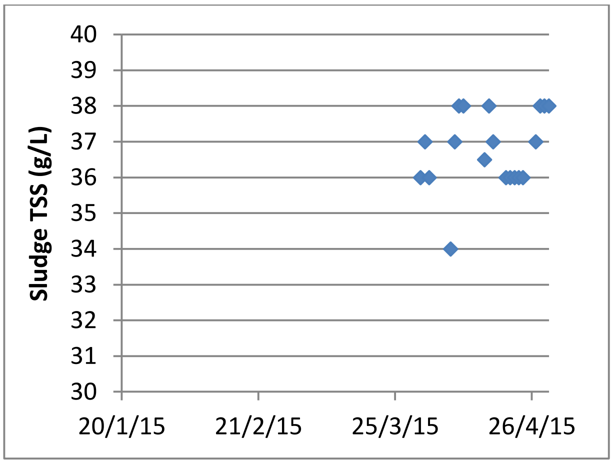

Figure 13 - Recirculated Sludge TSS

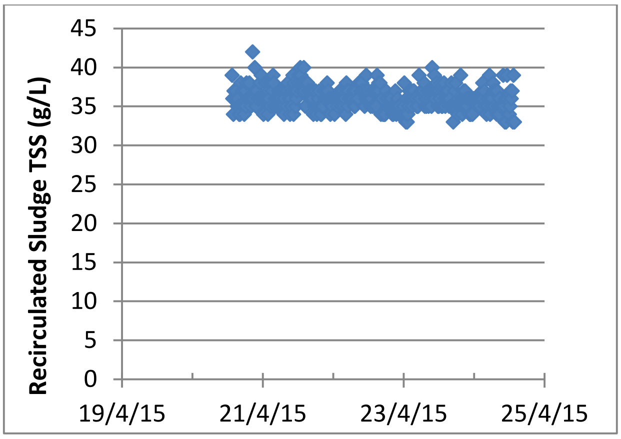

Figure 14 - Recirculated Sludge Weekly Flows

From this data and the wastewater flow data, the following table was generated.

Table 1 - Mode 1 Sludge Recirculation MLSS Summary and Calculations

Parameter	Units	Value
Average sludge flow rate	kL/wk	275
Average sludge total solids concentration	mg/L	37,000
Recirculated Sludge TSS Load	kg/wk	10,200
Sludge volatile fraction	%	72
Recirculated Sludge VSS Load	kg/wk	7,300
Total CAL influent flow rate	ML/wk	17.3
West CAL influent flow rate	ML/wk	8,6
Increase in west CAL influent TSS concentration	mg/L	1,100
Increase in west CAL influent VSS concentration	mg/L	800

4.2.2 Mode 1 - Wastewater Flows

The wastewater flowrate throughout Mode 1 was fairly consistent, as seen below in Figure 15. The hollowed out data points represent weeks with public holidays which resulted in reduced total flows. The median weekly flowrate for Mode 1 was 17.3 ML/wk.

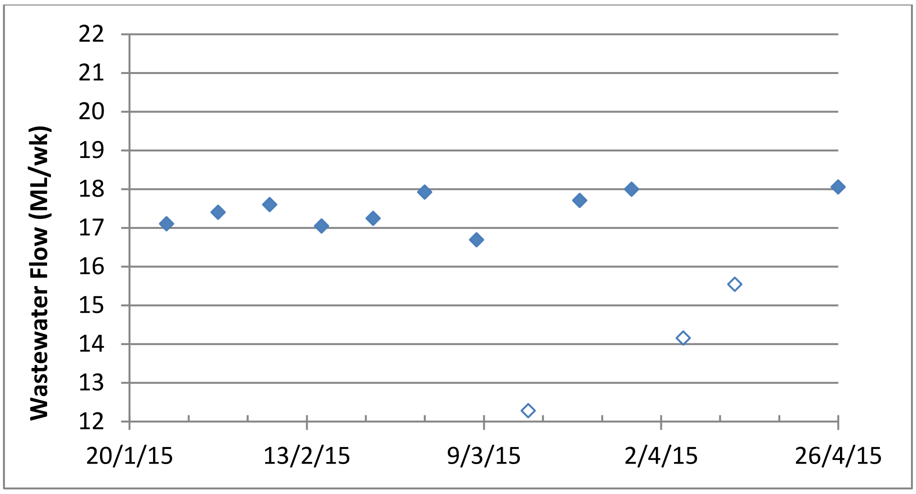

Figure 15 – Mode 1 Weekly Wastewater Flows

4.2.3 Mode 1 - CAL Influent Wastewater Quality

The influent wastewater to the CALs in Mode 1 had a median concentration of 10,400 mg/L during the Mode 1 monitoring period. This is greater than the median organic load measured during the baseline monitoring.

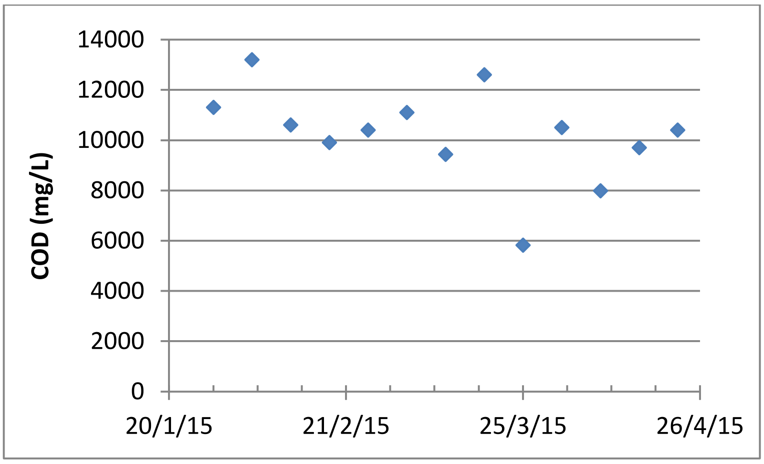

Figure 16 - Mode 1 CAL Influent Wastewater COD Concentrations

4.2.4 Mode 1 - CAL Effluent Wastewater Quality

The figures below show that the East and West CALs have similar organic removal. Median Mode 1 monitoring period results are meaningless due to the step change in early March that resulted in significantly reduced COD, BOD and TSS. The comparison between the east and west CAL provides the most useful information.

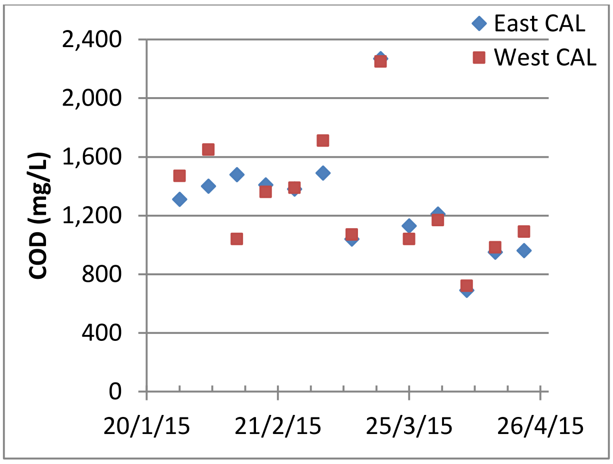

Figure 17 – Mode 1 CAL Effluent COD Concentrations

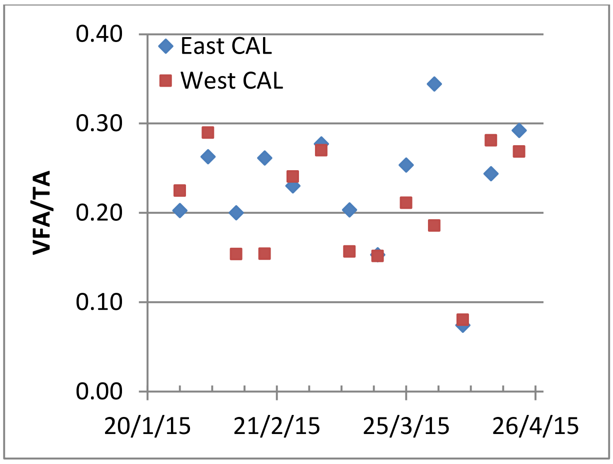

Figure 18 – Mode 1 CAL Effluent VFA/TA Ratios

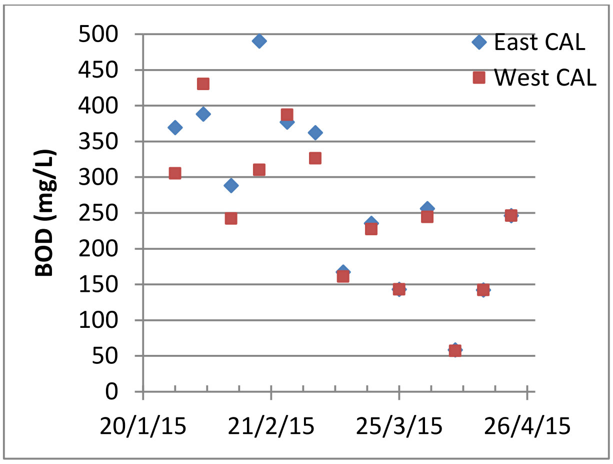

Figure 19 – Mode 1 CAL Effluent BOD Concentrations

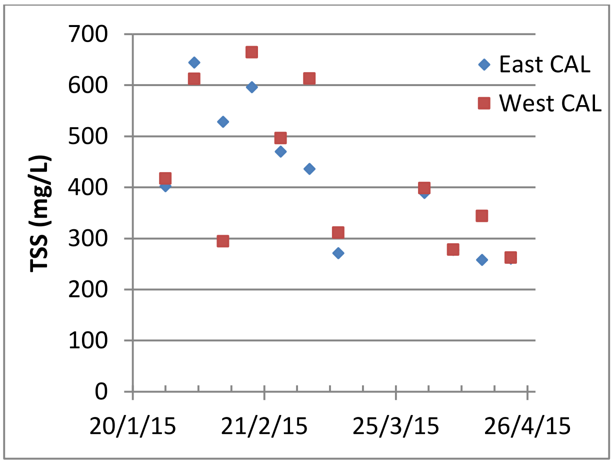

Figure 20 – Mode 1 CAL Effluent TSS Concentrations

4.2.5 Mode 1 - Biogas Flow and Composition Data

The biogas weekly flows were somewhat variable throughout Mode 1. However, the median weekly biogas flow in Mode 1 of 71,300 m^3/wk was similar to that found during baseline monitoring. The median CH_4 percentage of the biogas was 72%.

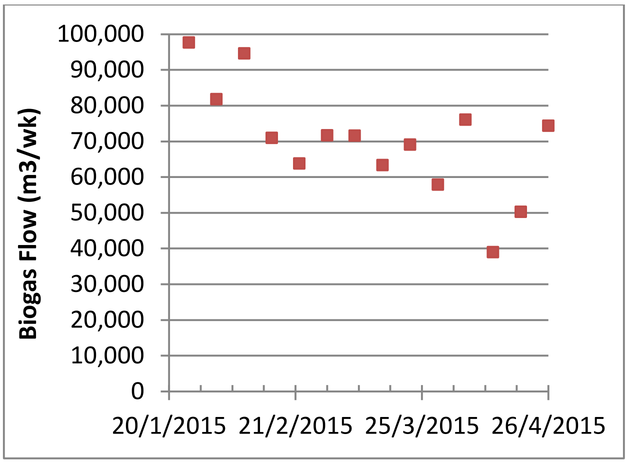

Figure 21 - Biogas Weekly Flow Data

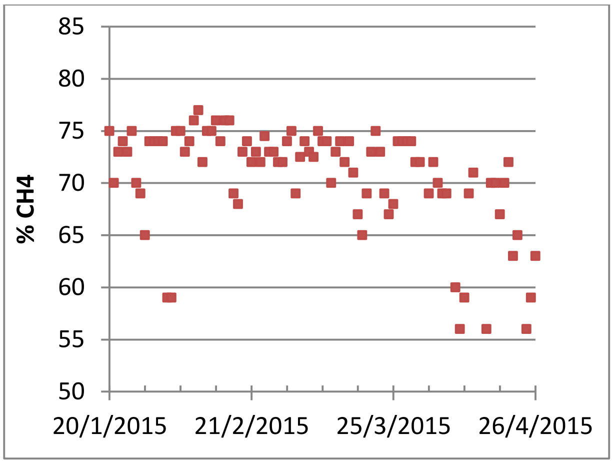

Figure 22 - Biogas Daily Median Methane Content

4.3 Mode 2 – Partial wastewater feed through the sludge system

4.3.1 Mode 2 – Sludge System Data

The weekly sludge system wastewater flowrate being pumped from the west CAL inlet pit to the bottom of the west CAL is shown in Figure 23. Results from the inline TSS meter were not recorded during this period.

The pump in the sludge system had issues during this mode. Originally, the same peristaltic pump from Mode 1 was reused for Mode 2 wastewater circulation. However, the pump began to operate poorly after a few weeks, achieving low flows of recirculated wastewater. The pump was taken offline at the beginning of October and a new pump was installed by the end of October. This pump initially performed well but it also suffered from the same issues and began to pump less wastewater over the time. The median wastewater flowrate through the sludge system during Mode 2 was 240 kL/wk.

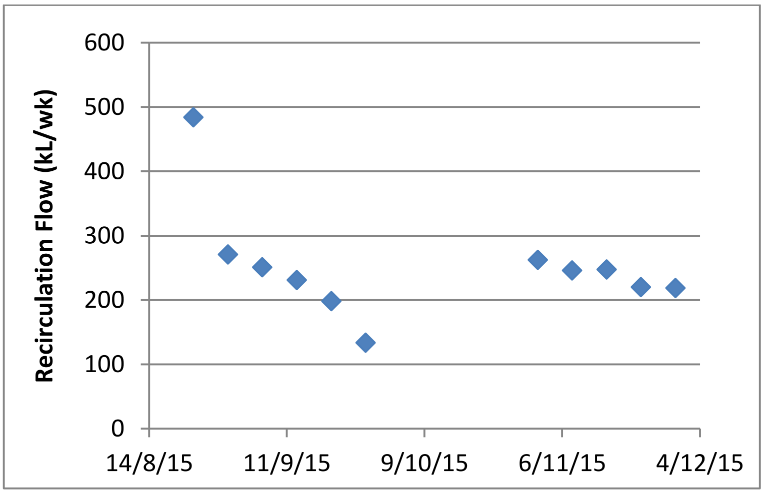

Figure 23 - Mode 2 Weekly Wastewater Recirculation Flows

4.3.2 Mode 2 - Wastewater Flows

The median weekly wastewater flow to the CALs in Mode 2 was 20.4 ML/wk. This is significantly greater than wastewater flows in both the baseline and Mode 1 monitoring periods. The wastewater production increase is attributed to the change to overflow sterilisers on the kill floors during Mode 2.

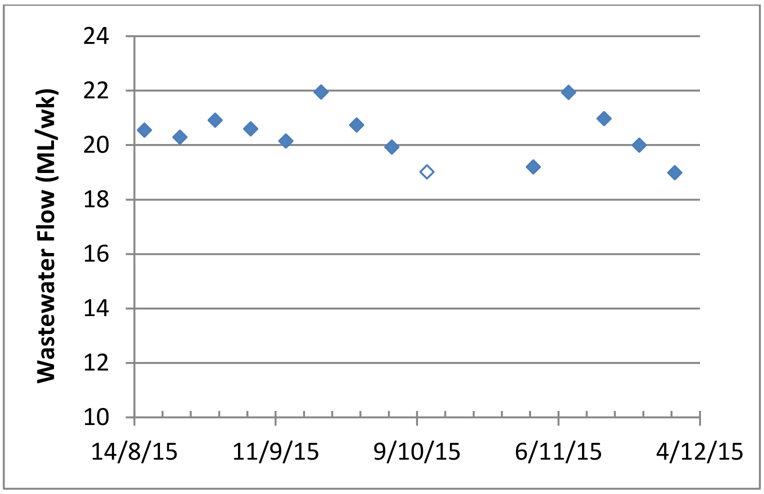

Figure 24 - Mode 2 Weekly Wastewater Flows

4.3.3 Mode 2 - CAL Influent Wastewater Quality

The CAL influent organic loading varied significantly throughout Mode 2. It appeared to have three distinct phases. For the first 4 weeks, the COD was approximately 7,500 mg/L, for the next 4 weeks it was approximately 9,500 mg/L and for the final 5 weeks it was 5,500 mg/L. This is largely due to adjustments in abattoir and rendering operational strategies, which adjusted the COD of the wastewater accordingly.

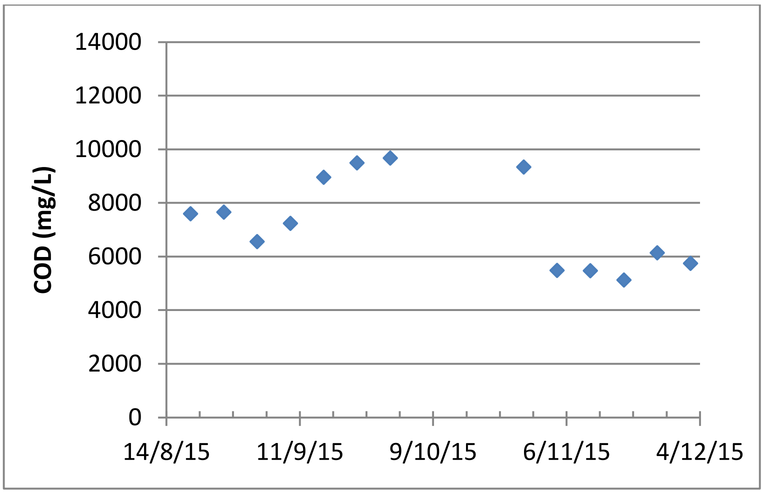

Figure 25 - Mode 2 CAL Influent Wastewater COD Concentrations

4.3.4 Mode 2 - CAL Effluent Wastewater Quality

The COD concentrations in the CAL effluent from both the East and West CALs were significantly lower in Mode 2 compared to the baseline monitoring or Mode 1. Over the Mode 2 monitoring period, the effluent COD concentrations increased slightly but started from a significantly lower value than observed in Mode 1. The median COD concentrations were 550 mg/L and 530 mg/L in the East and West CALs respectively. This is over 60% less than measured during baseline monitoring.

The VFA to TA ratio significantly reduced from the Mode 1 to the Mode 2 monitoring period.

The effluent TSS was also significantly lower, with a median concentration of about 130 mg/L in both CALs (67% less than baseline monitoring measurements).

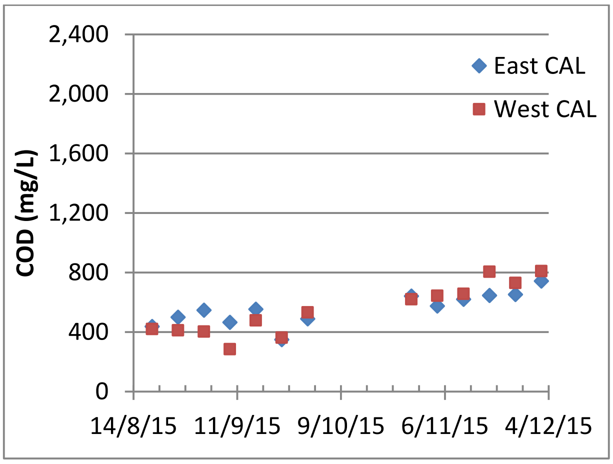

Figure 26 - Mode 2 CAL Effluent COD Concentrations

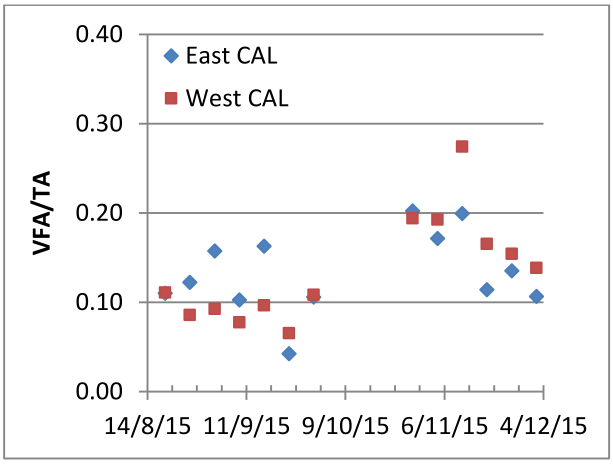

Figure 27 - Mode 2 CAL Effluent VFA/TA Ratios

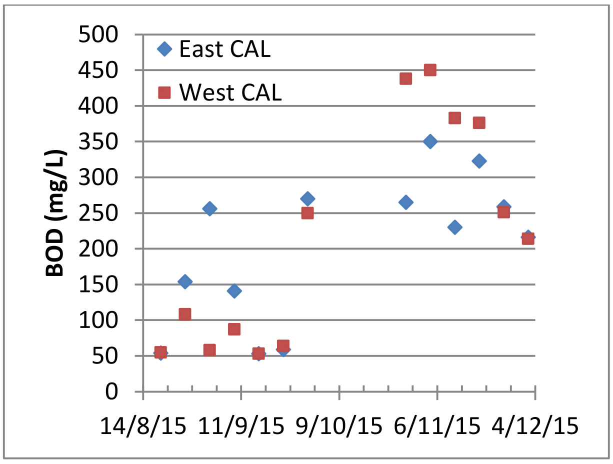

Figure 28 - Mode 2 CAL Effluent BOD Concentrations

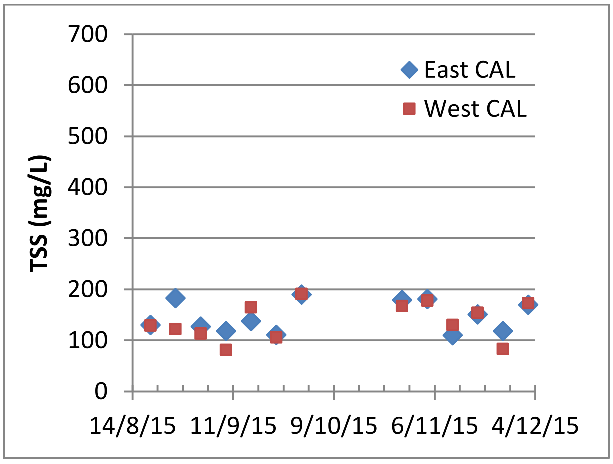

Figure 29 - Mode 2 CAL Effluent TSS Concentrations

4.3.5 Mode 2 - Biogas Flow and Composition Data

The median weekly biogas flow in Mode 2 was approximately 61,200 m^3/wk, which is lower than the previous monitoring periods. The median CH_4 composition of the biogas was 69%, which is also a reduction from previous monitoring periods.

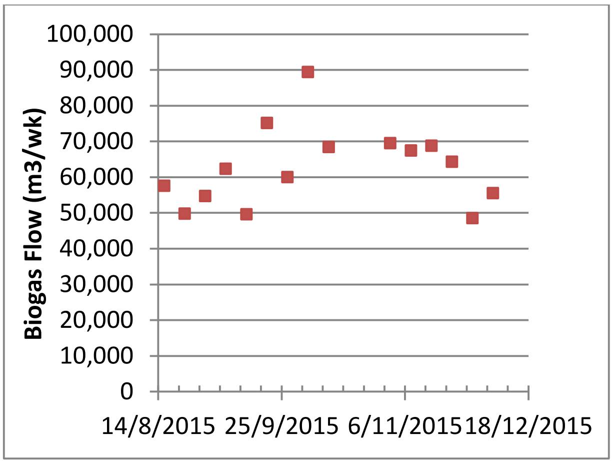

Figure 30 - Mode 2 Weekly Biogas Flows

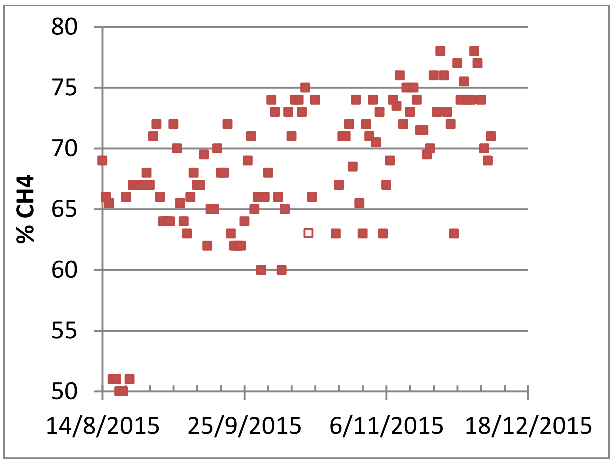

Figure 31 - Mode 2 Daily Median Methane Content

4.4 CAL Sludge Data

4.4.1 Sludge Accumulation

The graphs below show the sludge layer thickness the TSS in the upper water column of each CAL over the entire project.

In Figure 32 and Figure 33, the green section refers to the operation of Mode 1 recirculation and the purple section is the period during which Mode 2 recirculation was in operation. The yellow period in between was a staggered shutdown during which limited flow and organic loading entered the CALs. The bars shown indicate the range of results found in the 6 sampling ports across the CAL area.

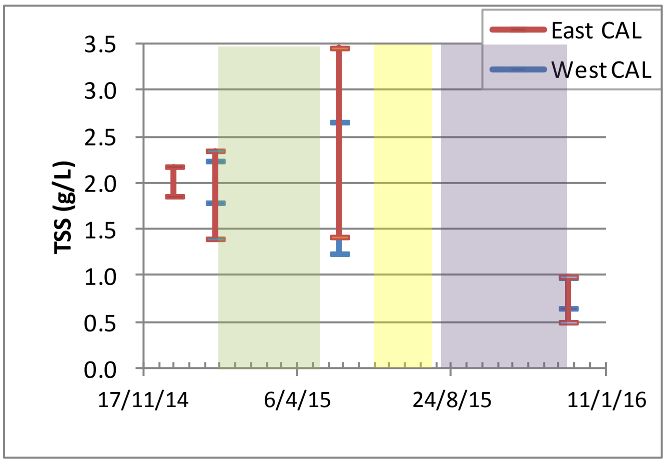

Figure 32 - CAL Water Column TSS Ranges

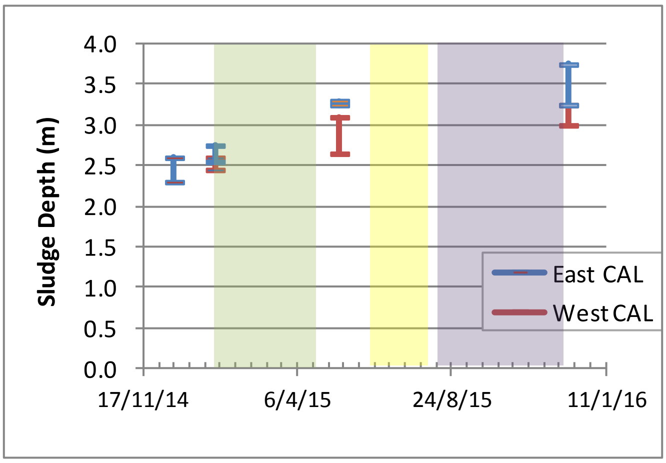

Figure 33 - CAL Sludge Depth

Figure 34 to Figure 39 show the TSS results found through the water column above the dense sludge layer within each CAL.

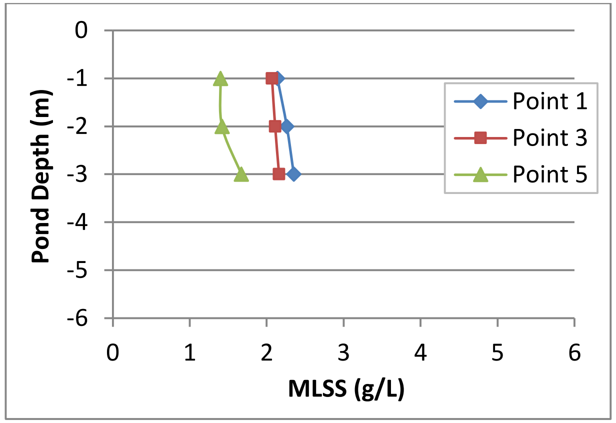

Figure 34 - Baseline Monitoring East CAL Water Column TSS Concentrations

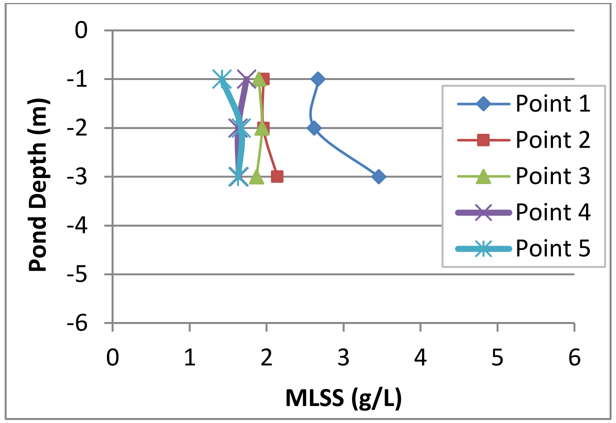

Figure 35 - Mode 1 East CAL Water Column TSS Concentrations

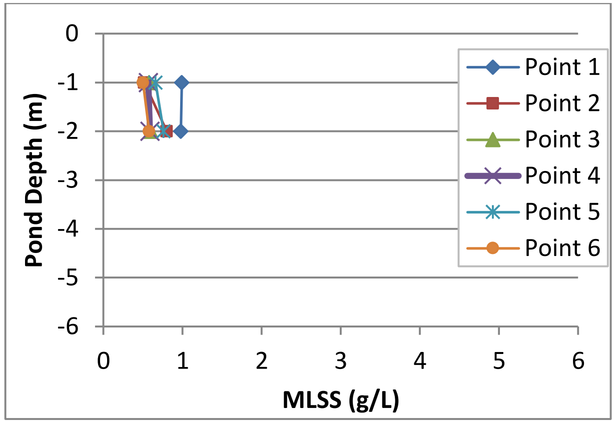

Figure 36 - Mode 2 East CAL Water Column TSS Concentrations

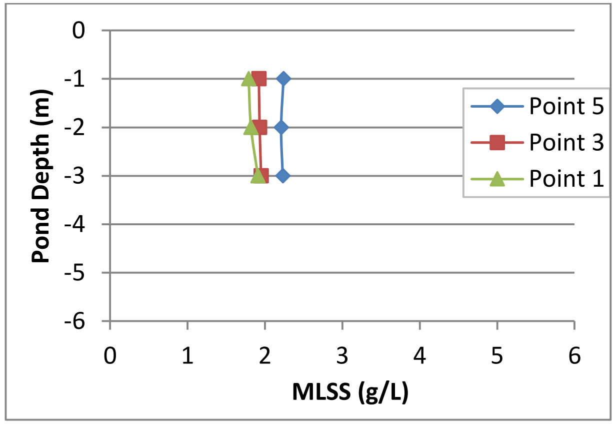

Figure 37 - Baseline Monitoring West CAL Water Column TSS Concentrations

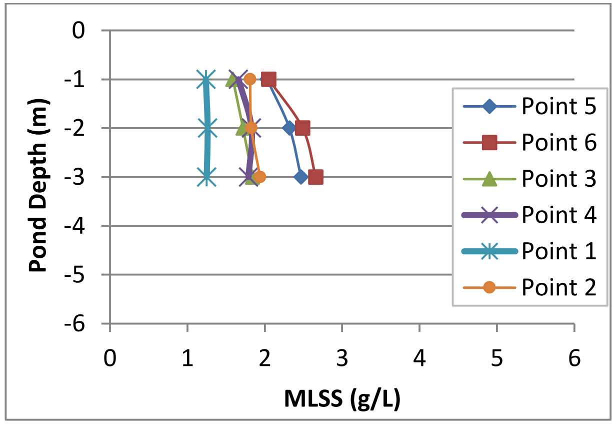

Figure 38 - Mode 1 West CAL Water Column TSS Concentrations

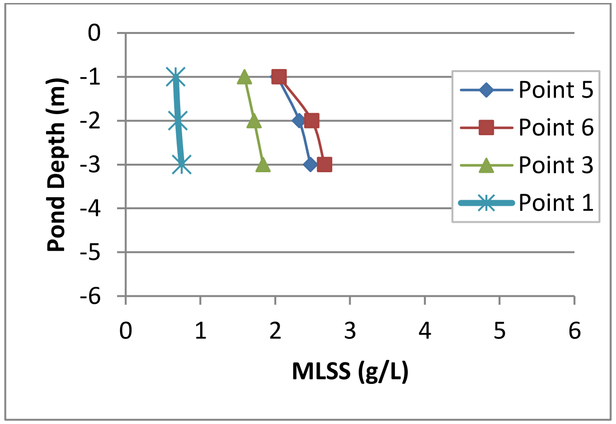

Figure 39 - Mode 2 West CAL Water Column TSS Concentrations

5 Discussion

5.1 Mode 1 – sludge recirculation

The aim of sludge recirculation operation in Mode 1 was to mix sludge containing anaerobic bacteria with the influent flow to improve the organic removal rate. While the resuspension of the sludge was successful there was no significant increase in the organic removal.

5.1.1 Mode 1 sludge resuspension

Sludge recirculation successfully increased anaerobic bacteria into the west CAL influent wastewater by 1,100 mg/L as shown in Table 1. This TSS increase is observed in Figure 41. The TSS in the water column was distinctly greater at the inlet end of the west CAL and also greater than the entire CAL during the baseline monitoring period (Figure 40). The TSS concentration also increased with depth at the inlet end of the west CAL to approximately 2,500 mg/L while the TSS in remainder of the pond was approximately 2,000 mg/L.

5.1.2 Mode 1 CAL performance

Sludge recirculation did not have a significant effect on the ability of the West CAL to remove organic loading from influent wastewater. COD removal rates during baseline monitoring were 85% and 84% in the East and West CALs respectively. During Mode 1 recirculation, the average removal rates were 86% and 88% in the East and West CALs respectively. This does not represent a significant change and is within the margin of error in the sampling and analysis. Sludge density does not appear to be a limiting factor for COD removal in these CALs.

Despite the elevated TSS at the west CAL inlet, there was insignificant increase in TSS in the effluent wastewater. The median effluent TSS concentrations from both the East and West CALs were 400 mg/L. This indicates that the TSS being introduced into the West CAL feed pit had sufficient time to settle out before it reached the outlet of the CAL

5.1.3 Mode 1 sludge system performance

Mode 1 tested the mechanical and physical operation of the sludge system. While the mechanical pumping of the sludge through a peristaltic pump was successful it did present challenges as this was the first time it was operated for long periods. The physical properties of the sludge being pumped over long periods surprisingly found little change.

Pumping anaerobic sludge is challenging due to its flow thickening and degassing properties. The original centrifugal pump failed pumping sludge after only a short period as discussed in PIP 0.340 “Manipulation of Wastewater Treatment System to maximise biogas production”. The new peristaltic pump successfully pumped sludge for long periods of up to a week. Unfortunately pump damage from the long term use cause the flowrate to slowly decrease throughout Mode 1 from approximately 400 kL/wk to 250 kL/wk. A second issue was difficulty priming the peristaltic pump after long periods of inactivity, most likely due to sludge settling in the pump tubing and the piping. This was resolved by flushing the pump with clean water prior to shutdown.

Despite the continuous pumping from Monday 6am to Friday 2pm of the sludge out of the first sludge removal port only, the sludge in the base of the CAL did not appear to 'rathole' but rather maintained a very consistent TSS concentration of 37 g/L as shown in Figure 13. This indicates that either the volume of sludge being pumped was insignificant in comparison to the inventory of sludge already existing in the CAL; or that the sludge blanket was self-levelling. Sludge blanket depth measurements indicated that the sludge self-levelling as the depth typically varied around 0.3 metres over an entire CAL despite the majority of activity at the inlet end.

5.2 Mode 2 – Partial wastewater feed through sludge system

The aim of the partial wastewater feed through the sludge system was to mix the sludge at the base of the CAL through the upper water column at the inlet end to improve organic removal rate. The mixing was aimed to be achieved via two mechanisms:

1. Hydraulic upflow of the wastewater through the dense sludge blanket.
2. Gas mixing as the organic content in the high strength wastewater converts to biogas in the sludge layer.

While there was evidence of sludge suspension at the inlet end, the west CAL organic removal did not significantly improve.

5.2.1 Mode 2 sludge suspension

Partial wastewater feed through the sludge system successfully suspended the sludge through the water column at the inlet end of the west CAL. Figure 39 shows much higher TSS in the west CAL water column at the inlet end than the downstream sampling sites. The TSS of the water column in this region was around 2-3 g/L, and was greater the lower in depth it was measured. In comparison, the TSS in the East CAL water column was very tightly grouped (approximately <1,000 mg/L TSS) both vertically and horizontally across the CAL as shown in Figure 36. This strongly indicates that even at the relatively low recirculation pumping flowrates that were seen in Mode 2, the sludge was suspended to a significant degree.

5.2.2 Mode 2 CAL performance

Partial feed recirculation through the sludge blanket did not appear to have any significant effect on the ability of the West CAL to remove organic loading from influent wastewater. While the effluent COD was significantly lower during this mode, there was insignificant difference between organic removal performance in the east and west CALs and seen in Figure 26 and Figure 28. Sludge density does not appear to be a limiting factor for COD removal in these CALs.

Partial feed recirculation in the West CAL did not have an impact on the TSS in the effluent wastewater. The median effluent TSS concentrations from both the East and West CALs were 140 and 130 mg/L respectively (Figure 29). This indicates that the TSS being suspended at the inlet end of the West CAL had sufficient time to settle out before it reached the outlet of the CAL.

Biogas production and methane percentage during Mode 2 was not significantly different than in Mode 1 or the baseline monitoring period. There were periods of lower biogas production rates that may be due to the immediately preceding shutdown.

5.2.3 Mode 2 sludge system performance

The peristaltic pump was found to be non-ideal for wastewater circulation. The flowrate of recirculated feed from the peristaltic pump dropped from 270 kL/wk to 130 kL/wk over the first few weeks of Mode 2 operation by which point the peristaltic pump was found to be quite damaged. A replacement peristaltic pump was used for the remainder of Mode 2. The second peristaltic pump also began at 260 kL/wk and dropped steadily to 220 kL/wk.

Pumping wastewater instead of sludge through the sludge system caused the pump and pipes to vibrate heavily. The resultant damage included the pumps internal tubing and bearings and the pipe and pump supports. A centrifugal pump may perform better for recirculating wastewater.

5.3 CAL Sludge accumulation over 12 month monitoring period

Figure 33 displays that the increasing thickness of the dense sludge blanket over the 12 month monitoring period by 0.5 to 1.0m. The rate of increase will slow as the CAL area increases with the sloped walls. This finding shows the importance of regular sludge blanket thickness analysis and the ability to remove sludge so as to prevent sludge release in the CAL effluent.

6 Cost Benefit Analysis of Recirculation

The results from operating Mode 1 and Mode 2 indicate that there is little to no benefit from running the sludge recirculation system in this manner. However, increasing the quantity of recirculated material or changing the recirculation regime may result in superior wastewater treatment and therefore greater biogas production. For this reason, a cost benefit analysis has been performed, examining two scenarios. In the first scenario, the biogas production increases by 5% relative to current levels, and in the second scenario, it increases by 10%.

The capital expense for this cost benefit analysis only considers the installation of recirculation system (piping, control board, sensors etc.) and the peristaltic pump. While the CAL and the sludge removal pipes are necessary for the recirculation of the sludge, they are primarily for the purposes of wastewater treatment and sludge removal and are presumed to already be existing prior to constructing a sludge recirculation system. The estimated capital expense of the TFI Murray Bridge sludge recirculation system is $117,000 (Table 2).

Table 2: Capital Expense Items required for Sludge Recirculation

Item	Capital Expense
Sludge Recirculation System (estimated)	~$100,000
Peristaltic Pump	$17,000
Total Capital Expense	**$117,000**

The operating expense of the sludge recirculation system will consider the electricity required to operate the peristaltic pump and maintenance on the pump. For the purpose of this calculation electricity is assumed to cost 10 cents/kWh. Maintenance costs will be assumed to be 10% of the capital cost.

The biogas produced allows displacement of natural gas consumption to the boilers. These calculations assume a natural gas value of $10/GJ. Table 3 summarizes the assumptions and values used to calculate the income due to an increase in biogas production (either 5% or 10% relative to baseline values). Table 4 outlines the calculations used to calculate the annual OPEX.

Table 3: Income Calculations

Parameter	Unit	Value
Increase in Biogas Flowrate (5% increase)	m^3/wk	3,500
Increase in Biogas Flowrate (10% increase)	m^3/wk	7,000
Methane Composition	%	70
Methane Energy Content	MJ/m^3	33.81
Biogas Energy Content	MJ/m^3	23.7
Natural Gas Price	$/GJ	10
Production Weeks	wk/yr	48
Natural Gas Saving (5% increase)	$/yr	$39,800
Natural Gas Saving (10% increase)	$/yr	$79,600

Table 4: Operating Cost Calculations

Parameter	Unit	Value
Electricity cost	$/kWh	0.10
Peristaltic pump power consumption	kW	7.5
Hours operated per wk	hrs	104
Electricity Cost	$/yr	$3,700
Maintenance Cost (10% of CAPEX)	$/yr	$11,700
TOTAL	**$/yr**	**$15,400**

Figure 40 summarises the cost benefit analysis below for a 10% increase in biogas production as a result of sludge recirculation. This was done using a 30% taxation rate and a 5% inflation rate.

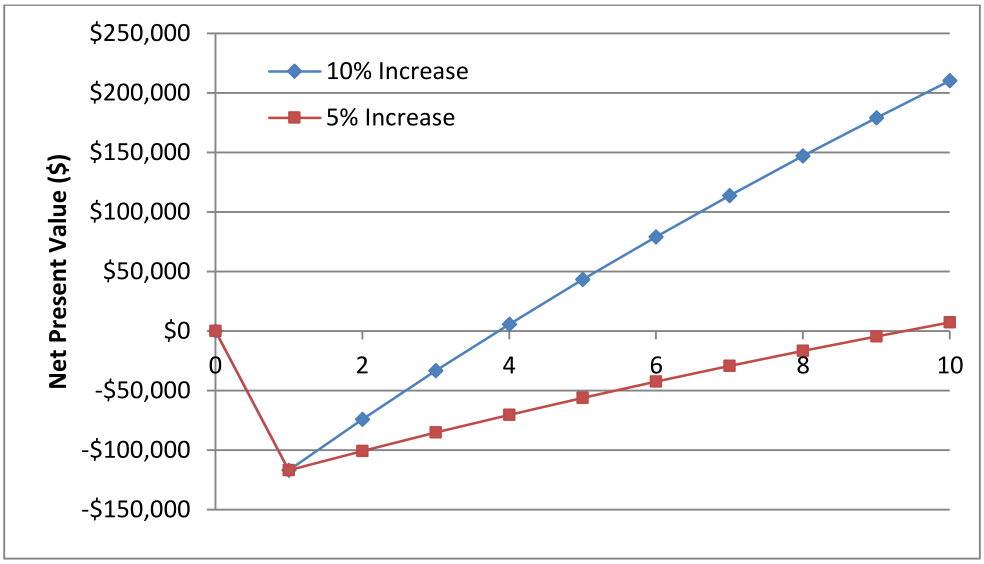

Figure 40 - Net Present Value of Sludge Recirculation

From this analysis, it is clear that the relative increase in biogas makes a substantial difference to the Net Present Value of the project over its lifetime. With a 5% increase in biogas production (3,500 m^3/wk), the project has a payback period of 9 years of operation whereas with a 10% increase (7,000 m^3/wk) the payback period is 3 years of operation. The Internal Rate of Return over 5 years of operation is 31% for the first scenario (10% additional biogas and is -10% for the second scenario (5% additional biogas). From this analysis it is clear that because the biogas is such a valuable resource, the economic viability of the project is largely dependent on the magnitude of this increase.

Due to the fact that the maintenance costs could be very high if an appropriate pump is not selected for the recirculation duty, a 5% increase in biogas production alone would not be sufficient incentive to run this project. However, a 10% increase appears to be quite viable.

Despite this, the results from this project indicate that there was no increase in biogas over the Mode 1 and Mode 2 recirculation periods. As such, this project is not economically viable.

7 Conclusions/Recommendations

The main conclusions drawn from this report are as follows.

- CAL performance measured by organic removal and biogas production was not significantly improved by the resuspension of sludge in either mode. It must be noted, however, that this CAL was already achieving significant removal rates of 85% COD removal and that sludge resuspension may be beneficial in other circumstances.

- The sludge pumping system successfully pumped sludge over long periods using a peristaltic pump. Future installations should consider a preventative maintenance schedule to reduce equipment failure likelihood and/or an alternative pump type.

- Little variation in the sludge TSS was observed over extended periods of pumping sludge from the base of the pond at a rate of up to 1.2L/s.

- The long term average TSS concentration of the sludge from the base of the CAL was 37,000 mg/L.

- Sludge resuspension by both modes of operation successfully increased the anaerobic TSS in the CAL water column.

- Despite increased TSS at the inlet end of the CAL, there was no significant increase in the effluent TSS indicating that there was sufficient hydraulic residence time in the CAL for the solids to naturally settle.

- CAL sludge accumulation increased by 0.5m to 1.0m over the 12 month monitoring period.

- The cost benefit analysis predicts that the installation and operation of a sludge recirculation system would be economically feasible with a 10% or greater increase in biogas production.

8 Key Messages

1. Resuspending sludge is not economically feasible and of no significant benefit at the flowrates rates investigated in this project for an established CAL. However, alternative applications of sludge resuspension, during commissioning periods for example, may still be of interest as only a small improvement in biogas production is needed to cover the capital and operating expenses.

2. Install a positive displacement pump, such as a peristaltic pump, to enable continuous anaerobic sludge pumping. Consideration of other pumping systems with lower wear items could be beneficial.

3. Consider sludge removal in Covered Anaerobic Pond design if downstream sludge accumulation is undesirable as anaerobic sludge will accumulate at a reasonable rate.