Final report

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Paunch Value Adding: Energy, Nutrient Recovery and Reducing Carbon Exposure

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Abstract

Most abattoirs currently dispose their Paunch Waste (PW) via composting, land application or through use of landfills. Previous MLA and AMPC studies have indicated that energy and nutrient recovery from PW should improve economics and environmental outcomes for the industry. Specifically, improved PW dewatering systems were regarded as being a prime pre-requisite to permit improved energy and nutrient recovery operations. The dewatering technology assessment program identified that the Rotary Fan Press (RFP) was the “most promising new dewatering technology to trial in these studies. This study thus assessed, at pilot plant scale, the Rotary Fan Press. The results from the trials revealed that the technology did not improve cake solids levels but did provide improved solids capture. Thus this dewatering technology will not improve the economics of energy recovery from PW. Nutrient recovery via precipitation of struvite from the PW filtrates appears to be technically feasible but additional trialling of this technology is required to confirm the technicalities and economics of the process.

Executive Summary

Currently most abattoirs dispose of their paunch waste, after washing and screening, via either composting or land disposal. Recent studies report that there is potential for energy and nutrient recovery from paunch waste, however there are gaps in the industry knowledge base that Meat Livestock Australia (MLA) and Australian Meat Processor Corporation (AMPC) wish to address to enable a thorough evaluation of the economic viability of this management option. Specifically, improved PW dewatering systems were regarded as being a prime pre-requisite to permit improved energy and nutrient recovery operations. This current MLA/AMPC project is designed to fill this knowledge and technology gap with a review of suitable dewatering options followed by commercial demonstration and optimisation of the preferred dewatering option.

The specific objectives of this project are listed below:

1. Conduct an international literature review to examine Paunch Waste (PW) and Dissolved Air Flotation (DAF) sludge dewatering options and technologies alongside the impact of waste characteristics on dewatering performance.
2. Design a questionnaire to gather information from the red meat industry in relation to PW and DAF sludge treatment. Information from this questionnaire will be used as the basis of a review to quantify the variation in PW and DAF sludge amounts and quality and treatment processes applied across the Australian Industry. This will include a review of current MLA work relating to nutrient characterisation in waste streams at four abattoirs.
3. Conduct an international literature review of nutrient-rich filtrate management options.
4. Identify suitable PW dewatering technologies and demonstrate performance at commercial or pilot plant scale. Based on available data and information gained to date, the Rotary Fan Press appears to be the most effective dewatering technology for abattoir solid wastes. However, this will be confirmed during the international literature review among other alternatives, if available.
5. Undertake a cost benefit analysis of this management option for PW and potentially DAF sludge.

A thorough review of the published international literature revealed that there is very little valuable and relevant published information regarding the performance of PW dewatering systems. What publically available information exists is controlled by the commercial dewatering equipment vendors and is not published for open comparison nor is it independently verified. No peer-reviewed technical papers on PW dewatering system performance were identified during the literature review.

The only published and available information on the nutrient content of liquors generated from PW dewatering is in AMPC and MLA publications. These studies revealed that PW solids and filtrates do contain high levels of nutrients, particularly nitrogen, phosphorus and potassium. This data shows that about 90% of the TKN and TP in PW is transferred to the PW filtrate during the dewatering operation. This, together with the relatively high concentration of N and P in the PW liquors, makes them suitable candidates for nutrient recovery.

No data on nutrient recovery from PW liquors was found during the literature review. However, technologies such as ammonia stripping and struvite (Magnesium Ammonium Phosphate or MAP)

precipitation are used extensively to recover nitrogen and nitrogen plus phosphorus from other wastewaters high in N and P, notably liquors from sludge digestion. These technologies are likely the most suitable systems to use for nutrient recovery from PW liquors. However, trialling of these technologies on site will be essential before they can be considered for commercial use.

Results from a PW and DAF sludge survey sent to the red meat industry representatives indicated that the majority of abattoirs use screw presses for dewatering of their PW. In addition the survey revealed that 92% of the respondents land applied their PW and 8% sent the dewatered PW to landfill.

The dewatering technology assessment program identified that the RFP was the “most promising new dewatering technology to trial in this study The RFP dewatering technology was thus demonstrated at pilot plant scale, for PW dewatering, at a Beef Exports abattoir. The RFP pilot plant trials yielded the following information:

- The PW feed TSS was subjected to extreme variation ranging from 4,300 to 27,000 mg/L, with a grand average of 11,138 mg/L, which is considered to be normal for raw PW;
- The nutrient levels in the PW feed were much lower than those reported for other abattoirs;
- The cake solid achieved without polymer addition was 22.6%, compared to a value of 28.7% achieved by the commercial FAN screw press used by the trial site;
- The cake solids achieved with polymer addition were only marginally increased to 23.2%;
- Filtrate TSS averaged 2,450 mg/L without the use of polymer which decreased to 150 mg/L with polymer use. The FAN screw press filtrate TSS values averaged 7,850 mg/L, indicating significantly lower solids capture than that achieved with the RFP;
- Nutrient levels in the filtrate were significantly lower than those reported at other abattoirs.

Costs were developed for an integrated PW management system comprising RFP dewatering, nutrient recovery via struvite precipitation from the filtrate and energy recovery from the cake via co-combustion in the abattoir boiler. The economics of this proposed PW management system does not appear to be attractive, even for large abattoirs (1,600 head/day). The simple pay-back period for large abattoirs is estimated to be 7.4 years. These economics would possibly improve if higher cake solids could be achieved and the filtrate had higher nutrient concentrations.

Due to the uncertainties regarding nutrient recovery from PW filtrate, particularly the impact of potassium on the struvite precipitation process, it is recommended that MLA/AMPC consider conducting a pilot plant evaluation programme on the process. This will also allow the economics of the process to be better defined. However, this should only be conducted in association with a market review to analyse if a local market exists that would be willing to purchase the fertiliser. The latter point is important as many customers of the high quality fertiliser market require specific ratios of macro and micro nutrients that are not always provided by the struvite precipitation process.

This report is subject to, and must be read in conjunction with the assumptions and qualifications contained throughout the Report.

Definitions

PW	Paunch Waste
DAF	Dissolved Air Flotation
GHG	Greenhouse Gas
RFP	Rotary Fan Press
PFD	Process Flow Diagram
N	Nitrogen
P	Phosphorus
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TS	Total Solids
NH_3-N	Nitrogen present in the form of ammonia
TP_t	Total Phosphorus Unfiltered
TP_f	Total Phosphorus Filtered
TKN_t	Total Kjeldahl Nitrogen Unfiltered
TKN_f	Total Kjeldahl Nitrogen Filtered
VS	Volatile Solids
VSS	Volatile Suspended Solids
GCV	Gross Calorific Value
FPR	Filtered Reactive Phosphorus
pH	Potential of Hydrogen
$Mg(OH)_2$	Magnesium Hydroxide
MAP	Magnesium Ammonium Phosphate
CBA	Cost Benefit Analysis
HSCW	Hot Standard Carcase Weight
AIM	Affirmative Industrial Maintenance
PLC	Programmable logic controller
tpd	Tonnes per day
M&EB	Mass and Energy Balance
PFD	Process Flow Diagram
NCV	Net Calorific Value
CAPEX	Capital Expenditure
O&M	Operating and Maintenance Cost
NPV	Net Present Value

Contents

1. Introduction

1.1 Background

Currently most abattoirs dispose their paunch waste, after washing and screening, via either composting or land disposal. Typically the processed paunch waste has a Total Solids (TS) of about 20%, or a water content of 80%. These current disposal methods can incur disposal fees, particularly if landfilling is practiced. Both of the major current disposal options for paunch waste result in significant Greenhouse Gas (GHG) emissions. Recent studies report that there is potential for energy and nutrient recovery from paunch waste, however there are gaps in the industry knowledge base that Meat Livestock Australia (MLA) and Australian Meat Processor Corporation (AMPC) wish to address to enable a thorough evaluation of the economic viability of this management option. A previous MLA project[1] confirmed that if paunch waste can be mechanically dewatered to a TS of about 30% that it would combust autogenously in a boiler (that is, not require any external thermal energy for combustion). That study recommended full scale co-combustion trials be conducted to confirm the potential benefits offered via this waste disposal method. Consequently full-scale dewatered paunch waste co-combustion trials were conducted by MLA[2,3]. These projects verified the suitability of dewatered paunch waste co-combustion in boilers as a sustainable and environmentally sound management option. They also identified that improved dewatering performance would significantly increase the energy recovery potential via combustion.

The current MLA/AMPC project is designed to fill this knowledge and technology gap with a review of suitable dewatering options followed by commercial demonstration and optimisation of the preferred dewatering option. Successful demonstration of an optimised paunch waste dewatering process will allow the maximisation of energy and nutrient recovery from these wastes, with a reduction in the carbon footprint of abattoirs and a reduction in waste processing costs.

1.2 Project Objectives

The specific objectives of this project are listed below:

1. Conduct an international literature review to examine Paunch Waste (PW) and DAF sludge dewatering options and technologies alongside the impact of waste characteristics on dewatering performance.
2. Design a questionnaire to gather information from the red meat industry in relation to PW and DAF sludge treatment. Information from this questionnaire will be used as the basis of a review to quantify the variation in PW and DAF sludge amounts and quality and treatment processes applied across the Australian Industry. This will include a review of current MLA work relating to nutrient characterisation in waste streams at four abattoirs.
3. Conduct an international literature review of nutrient-rich filtrate management options.
4. Identify suitable PW dewatering technologies and demonstrate performance at commercial or pilot plant scale. Based on available data and information gained to date, the Canadian developed Rotary Fan Press appears to be the most effective dewatering technology for abattoir solid wastes. However, this will be confirmed

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[1] MLA, “Pilot Testing Pyrolysis Systems and Review of Solid Waste Use in Boilers”, Project A.ENV.0111, 2011.
[2] MLA, “Use of Paunch Waste as a Boiler Fuel”, Project A.ENV.0110, September, 2011.
[3] MLA, “Use of Paunch Waste and DAF Sludge as a Boiler Fuel”, Project A.ENV.0106, June 2012.

during the international literature review among other alternatives, if available. The Australian representative of the Canadian developed Rotary Fan Press technology has a suitable large-scale pilot plant which can be sourced from their Brisbane office.

5. Undertake a cost benefit analysis of this management option for PW and potentially DAF sludge.

1.3 Methodology

The international literature review on PW, DAF sludge dewatering technologies and nutrient rich PW filtrate management options were conducted using GHD's in-house data base from its global office network as well as online peer reviewed electronic journals/databases using appropriate keywords. A thorough review of Australian dewatering equipment vendor information was also conducted.

An industry questionnaire was developed in co-operation with AMPC. This questionnaire was designed to obtain the necessary PW and DAF sludge statistics required for this project. A copy of the questionnaire is shown in Appendix A. This questionnaire was made available on the AMPC website and AMPC/MLA members were encouraged to complete the questionnaire on-line.

The literature search and vendor information confirmed that the Rotary Fan Press (RFP) was a dewatering technology worthy of demonstrating on PW. Consequently agreement was reached with Affirmative Industrial Maintenance Water (AIM Water), the Australian agent for the press, to use their trailer-mounted RFP pilot plant for trialling at a Beef Export abattoir. This abattoir was chosen by AMPC/MLA for the site for the dewatering trial. A site visit was made to the abattoir to confirm that all the pilot plant operational requirements could be met by the trial site. Once this was confirmed, a date for the dewatering trial was agreed with AIM Water and the trial site. AMPC and MLA confirmed that the dewatering trials should be confined to PW alone. A dewatering test programme and protocol was agreed with AIM Water. A subcontract was developed with SGS Laboratories in Brisbane to conduct the required analyses.

A Cost Benefit Analysis (CBA) was also conducted using vendor-supplied costs for the dewatering equipment and estimated capital cost for the nutrient recovery process and operating costs and revenues from the integrated facilities.

2. Findings

2.1 PW dewatering and filtrate nutrient literature review

A thorough review of the published international literature revealed that there is very little valuable and relevant published information regarding the performance of PW dewatering systems. What publically available information exists is controlled by the commercial dewatering equipment vendors and is not published for open comparison nor is it independently verified. No peer-reviewed technical papers on PW dewatering system performance were identified during the literature review.

The international publicly available literature reveals that numerous systems are used to dewater PW around the world and the most often cited systems include:

- Screw presses;
- Belt filter presses;
- Centrifuges;
- Scraper and rotary screens;
- Rotary fan presses;
- DAF units and;
- Baleen screens.

Discussions with Australian PW dewatering system vendors revealed that many of them have recently conducted PW dewatering trials within the Australian red meat industry but this information has not been made publicly available.

Information from the Australian PW dewatering vendor websites indicates that the TS achievable from the various dewatering equipment, ranges from 20 to 35%. Similar data has also been obtained from Australian abattoirs. This survey (see Section 2.2) showed the cake TS obtained from screw presses ranged from 15 to 40% with an average value of 27% and one Belt filter Press achieved a cake solids of 30% while one Contrashear screen was reported to achieve a product TS of 25%.

The only published and available information on the nutrient content of liquors generated from PW dewatering is in AMPC and MLA publications. A 2005 MLA study measured the nutrient values in PW liquors generated during trials of a FAN screw press[4]. Two trials were done feeding a mix of PW, Save-all solids and DAF float and the results of these two trials are shown in Table 1.

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[4]MLA, December 2005, “Reduction in Fossil Fuel Derived Energy Demand in 5 Years at the AMH Dinmore Processing Facility”, Report PIP.104A

Table 1: *Liquor Nutrient Data, PW+ Save-all solids+ DAF float Feed*

Trial Number	PW in Feed (%)	Liquor TKN (mg/L)	Liquor TP (mg/L)
1	57	312	745
2	37	398	739

This data shows that PW liquor has relatively high nitrogen and phosphorus concentrations that may be worthy of recovery. A more comprehensive study of nutrients in PW solids and liquors was conducted by AMPC/MLA, at three abattoirs, during 2012[5]. A summary of these results is shown in Table 2.

Table 2: *PW Solids and Liquor Nutrient Analyses*

Parameter	Units	Site A	Site B	Site C
Abattoir type		Beef	Beef/sheep	Beef
Abattoir location		Qld	SA	NSW
Cattle processed	hd/d	800	800	400
Sheep processed	hd/d	0	9500	0
PW Liquor volume	kL/hd	0.388	0.0029[a]	0.5
PW Solids mass	t/hd	0.0236	0.00036[a]	0.0211
PW Liquor TKN	mg/L	517	233[a]	506
PW Liquor TP	mg/L	211	233[a]	256
PW Solids TKN	mg/L	1,185	2,185[a]	925
PW Solids TP	mg/L	350	427[a]	222
PW Solids K	mg/L	2,079	779[a]	1,128
Sheep PW[b]TKN	mg/L		1,805	
Sheep PW[b]TP	mg/L		1,805	
Beef PW[b]TKN	mg/L		640	
Beef PW[b]TP	mg/L		640	

Note: a) Sheep only data
b) Total PW data

The data generated by this AMPC/MLA study is somewhat different to that from the 2005 study. For beef abattoirs, this study showed PW liquor TKN values were much higher than that from the 2005 study, whereas TP values were much lower than the 2005 study. The difference between the 2012 study and the 2005 study is not known. It has however been reported that dry dumping of PW does result in a 4% reduction in TKN and 18 to 20% reduction in TP values in the PW liquor[6]. The PW solids TKN value is almost double that of the liquor whereas the TP values are only marginally higher. PW solids have a relatively high potassium value. Unfortunately no potassium values were reported in the liquors.

There is some difficulty in interpreting the information from Site B. Some of the Site B data is reported separately for sheep and cattle, creating difficulties in direct comparison. Furthermore the similarity of the TKN and TP values raises concerns over potentially questionable data.

Nutrient mass flows per head of cattle, for the two cattle abattoirs is shown in Table 3.

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[5]MLA, August 2012, "Energy and Nutrient Analysis on Individual Waste Streams", Report A.ENV.0131.
[6]MLA, February 2007, "Impact Review: Significant Stories of Impact", ISBN 1741910595.

Table 3: *Nutrient Mass Flows in PW Liquor and Solids (kg/hd cattle)*

Parameter	Site A	Site C		Average
PW Liquor TKN	0.2	0.253		0.226
PW Liquor TP	0.082	0.128		0.105
PW Solids TKN	0.0279	0.0195		0.0237
PW Solids TP	0.0083	0.0047		0.0065
PW Solids K	0.049	0.0238		0.0364

The data from Sites A and C shows that about 90% of the TKN and TP in PW is transferred to the PW liquor during the dewatering operation. This, together with the relatively high concentration of N and P in the PW liquors, makes them suitable candidates for nutrient recovery.

No data on nutrient recovery from PW liquors was found during the literature review. However, technologies such as ammonia stripping and struvite (Magnesium Ammonium Phosphate or MAP) precipitation are used extensively to recover nitrogen and nitrogen plus phosphorus from other wastewaters high in N and P, notably liquors from sludge digestion. These technologies are likely the most suitable systems to use for nutrient recovery from PW liquors. However, trialling of these technologies on site will be essential before they can be considered for commercial use.

2.2 Red meat industry PW and DAF sludge survey results

AMPC sent out the PW and DAF sludge questionnaire to the red meat industry representatives, via their website, in October 2012, to assist this project in obtaining information on current PW and DAF sludge management practises within the industry. A copy of the questionnaire is attached as Appendix A. The questionnaire was completed by 31 abattoirs from across Australia and these abattoirs processed either ‘cattle only’, ‘cattle and sheep’, or ‘sheep only’.

The PW processing and management options used by the industry, as generated by this survey, are summarised in Table 4.

Table 4: ***PW Management Practises***

Question	No of respondents	%
Is PW screened?	27	89% yes
Is PW dewatered?	27	56% yes
PW dewatering system used: Screw Press Belt Filter Press DAF unit Contrashear Screen Baleen Screen Other	 8 1 1 5 1 1	 47 6 6 29 6 6
PW disposal system: Land application Composting/Land app Drying/reuse Landfill	 5 16 1 2	 21 67 4 8
Is PW liquor analysed for N&P?	27	15% yes

The survey results indicate that 56% of abattoirs dewater their PW and that screw presses are the favoured dewatering device. All of the PW generated is either reused in agriculture (92%) or disposed via landfill (8%).

The DAF sludge processing and management options used by the industry, as generated by this survey, are summarised in Table 5. The results from this survey reveal that 54% of the industry dewaters its DAF sludge and that centrifuges are by far the most popular dewatering device used. Eighteen % of DAF sludge is reused in rendering operations with 76% reused via land application and composting. Only 6% is landfilled.

Table 5: *DAF Sludge Management Practises*

Question	Number of respondents	%
Is DAF sludge dewatered?	13	54% yes
DAF dewatering system used:		
Screw Press	1	11
Belt Filter Press	1	11
Centrifuge	5	56
Trailer-box with poly	1	11
Other	1	11
DAF disposal system:		
Rendering	3	18
Land application	6	35
Composting/Land app	6	35
Drying/reuse	1	6
Landfill	1	6

Statistical data from the survey is shown in Tables 6 to 9. The data has been grouped as ‘cattle only’, ‘sheep only’ and ‘cattle and sheep’ processing abattoirs. The ‘cattle only’ data is shown in Table 6.

Table 6: '*Cattle only' PW and DAF Data.*

	Cattle/d	tHSCW/d	PW Data			Dewatered PW Cake Data			PW	DAF Sludge Data		PW Disposal Cost
Abattoir Number			m^3/d	m^3/head	m^3/t	m^3/d	m^3/head	Cake TS	Disp cost ($/d)	m^3/d	m^3/head	$/$m^3$
1	530	137	200	0.38	1.46	16	0.03	40	0	20	0.038	0
11	800	277.5	25	0.03	0.09				0	1	0.001	0
13	1603	459						75	1,575			
14	1100	262	30	0.03	0.11	30	0.03		750			25
15	480	122	19	0.04	0.16					4	0.008	
16	1250	415	35	0.03	0.08	35	0.03	25	750	5	0.004	21.43
20	530	171	15	0.03	0.09							
22	900	250	100	0.11	0.4	28	0.03	50	500			17.86
23	1300	358	440	0.34	1.23			25		10	0.008	
25	830	224				15	0.02	15	450			30
26	400	100	9	0.02	0.09				0			0
Median Value	830	250	30	0.03	0.11	28	0.03	32.5	475	5	0.008	17.86
Average Value	884	252	97	0.11	0.41	25	0.03	38	503	8	0.012	13.47
Minimum Value	400	100	9	0.02	0.08	15	0.02	15	0	1	0.001	0.00
Maximum Value	1,603	459	440	0.38	1.46	35	0.03	75	1,575	20	0.038	30.00

Data was obtained from 11 ‘cattle only’ abattoirs and the median PW generation rate was 30 m^3/d, or 0.0313 m^3/hd. Expressed as per tonne of Hot Standard Carcase Weight (HSCW), the median value was 0.1145 m^3/t. It is very likely that many abattoirs reported their dewatered cake volumes as raw PW volumes which have resulted in significant errors in this statistic. The median TS of dewatered PW cake was 32.5%, with a range from 15 to 75%. The 75% value, which is for a mix of PW and DAF sludge, is suspect, as it is not considered feasible using a screw press. PW disposal charges varied from zero to $1,575 per day. The average PW disposal cost was $13.47/$m^3$. The median DAF sludge generation rate was 5 m^3/d or 0.0077 m^3/hd/d. This data indicates DAF sludge generation rates are about one-sixth of PW generation rates. This is consistent with typical PW and DAF sludge generation data from Australian beef abattoirs. Only two abattoirs reported DAF sludge disposal costs which were zero and $300/d, averaging $7.50/$m^3$. Only one dewatered DAF cake TS value was reported, with a TS of 40%.

Only three responses were received from ‘sheep only’ abattoirs and the data is shown in Table 7.

Table 7: ‘*Sheeponly’ PW and DAF Data.*

			PW Data			PW	DAF Sludge Data		PW disp. cost
Abattoir Number	Sheep/d	tHSCW/d	m^3/d	m^3/head	m^3/t	Disp. cost ($/d)	m^3/d	m^3/head	$/$m^3$
2	6000	140	15	0.0025	0.1071	1350			90
10	5500	100	40	0.0073	0.4	500	5	0.0008	12.5
18	4500		10	0.0022		0	100	0.0222	0
Median Value	5500	120	15	0.0025	0.2536	500	52.5	0.0115	12.5
Average Value	5,333	120	22	0.0040	0.2536	617	53	0.0115	34.17
Minimum Value	4,500	100	10	0.0022	0.1071	0	5	0.0008	0
Maximum Value	6,000	140	40	0.0073	0.4000	1350	100	0.0222	90

With such a small sample size the data is difficult to interpret correctly. It does however appear that PW and DAF sludge generation rates, on am^3/t HSCW basis, are higher for sheep than cattle. The average PW disposal cost was $34.17/$m^3$.

Data for abattoirs processing both cattle and sheep are shown in Tables 8 and 9. Table 8 shows the PW data and Table 9 the DAF sludge data obtained from 14 facilities.

Table 8: *Cattle and Sheep PW Data*

					PW Data			Dewatered PW Cake Data			PW	PW
Abattoir Number	Cattle/d	tHSCW/d	Sheep/d	tHSCW/d	m^3/d	m^3/head	m^3/t	m^3/d	m^3/head	Cake TS	Disp. cost ($/d)	Disposal Cost ($/$m^3$)
3	720	190	6,300	143				20	0.0028	20	150	7.5
4	275	100	1,300	20								
5	220	50.6	400	7.6	4	0.0065	0.0687	1	0.0016	50	0	0
9	50	11	1,000	22								
12	100	22	3,200	60.8	1	0.0003	0.0121	0.5	0.0002	50	0	0
17	792	211	4,640	104	22.7	0.0042	0.0721	22.7	0.0042	36		
19	120	30	650	16								
21	140	28	450	17	4	0.0068	0.0889					
24	800		6,000		20	0.0029						
27	150		600		3	0.004		3	0.004			
28	250		3,000									
29	700		3,500									
30	120	50	4,000	80	60	0.0146	0.4615				3,000	50
31	600		3,500					14	0.0034	30	2,380	170
Median Value	235	50	3,100	22	4	0.0042	0.0721	8.5	0.0031	36	150	7.5
Average Value	360	77	2,753	52	16	0.0056	0.1407	10	0.0027	37	1,106	45.5
Minimum Value	50	11	400	7.6	1	0.0003	0.0121	0.5	0.0002	20	0	0
Maximum Value	800	190	6,300	143	60	0.0146	0.4615	22.7	0.0034	50	3,000	170

Table 9: *Cattle and Sheep DAF Sludge Data*

					DAF Sludge Data		Dewatered DAF Cake data			Disposal cost	Disposal Cost
Abattoir Number	Cattle/d	tHSCW/d	Sheep/d	tHSCW/d	m^3/d	m^3/head	m^3/d	m^3/head	Cake TS	($/d)	$/m^3
3	720	190	6300	143	100	0.0142	5	0.0007	30	7,000	1,400
4	275	100	1300	20							
5	220	50.6	400	7.6							
9	50	11	1000	22							
12	100	22	3200	60.8	1	0.0003	0.5	0.0002	50		
17	792	211	4640	104							
19	120	30	650	16							
21	140	28	450	17	5	0.0085				50	10
24	800		6,000								
27	150		600								
28	250		3,000								
29	700		3,500								
30	120	50	4,000	80	30	0.0073				1200	40
31	600		3,500		30	0.0073	12	0.0029	30	2040	170
Median Value	235	50	3,100	22	30	0.0073	5	0.0007	30	1620	105
Average Value	360	77	2,753	52	33	0.0075	6	0.0013	37	2,573	405
Minimum Value	50	11	400	7.6	1	0.0003	0.5	0.0001	30	50	10
Maximum Value	800	190	6,300	143	100	0.142	12	0.0029	50	7,000	1,400

The PW and DAF sludge generation rates are difficult to interpret, other than on am^3/t HSCW basis. The median PW generation value of 0.072 m^3/t is lower than would be expected, since the value should be between the cattle and sheep only values of 0.115 and 0.254m^3/t respectively. This is probably due to large variability in reported results, a limited number of data sets for ‘sheep only’ and errors and inconsistencies in reporting. The average PW and DAF sludge disposal costs were $45.50/m^3 and $405/m^3 respectively.

2.3 PW Dewatering Technology Assessment

Information from dewatering vendors and results from the AMPC PW survey revealed that there are only a few technologies currently used to dewater PW in the Australian red meat industry with the screw press being the predominant technology. Internal GHD reviews, including input from the GHD US offices revealed that the RFP was gaining popularity in the US and Canada, mainly for sewage sludge dewatering. The consensus of GHD dewatering experts was that other dewatering technologies such as plate and frame filter presses, with and without membranes and electro dewatering devices would, at this time, not be regarded as suitable for PW dewatering. This is primarily due to their complexity, cost, operational requirements and the relatively large footprint required compared to screw presses and the RFP. For these reasons the RFP was selected for trialling in this study.

2.4 Dewatering trials

2.4.1 Site and pilot plant details

PW generated is currently dewatered using a FAN screw press at the ‘beef only ‘trail abattoir. The PW is wet-dumped on the kill floor and is conveyed via a chute to a PW tank outside the abattoir building. This tank has an active volume of about 4 m^3 and a picture of the tank is shown in Figure 1.

Figure 1: ***PW Tank at the trial site***

As illustrated in Figure 1, this PW feed bin is well mixed by the constant feed of material and some spray water. It was decided to feed the RFP pilot plant from this PW bin. A 50 mm nipple was attached to the drain line of the bin and the suction side of the RFP feed pump was attached to this connection. Currently PW from the feed bin is pumped to the existing FAN screw press for commercial dewatering. A picture of the current FAN screw press is shown in Figure 2. The dewatered cake drops directly into a truck for off-site disposal.

Figure 2: ***PW Dewatering System (Screw press)***

Due to the relatively poor solids capture obtained with the screw press the filtrate is screened using static inclined screens to capture additional solids. A picture of one of the two screens is shown in Figure 3.

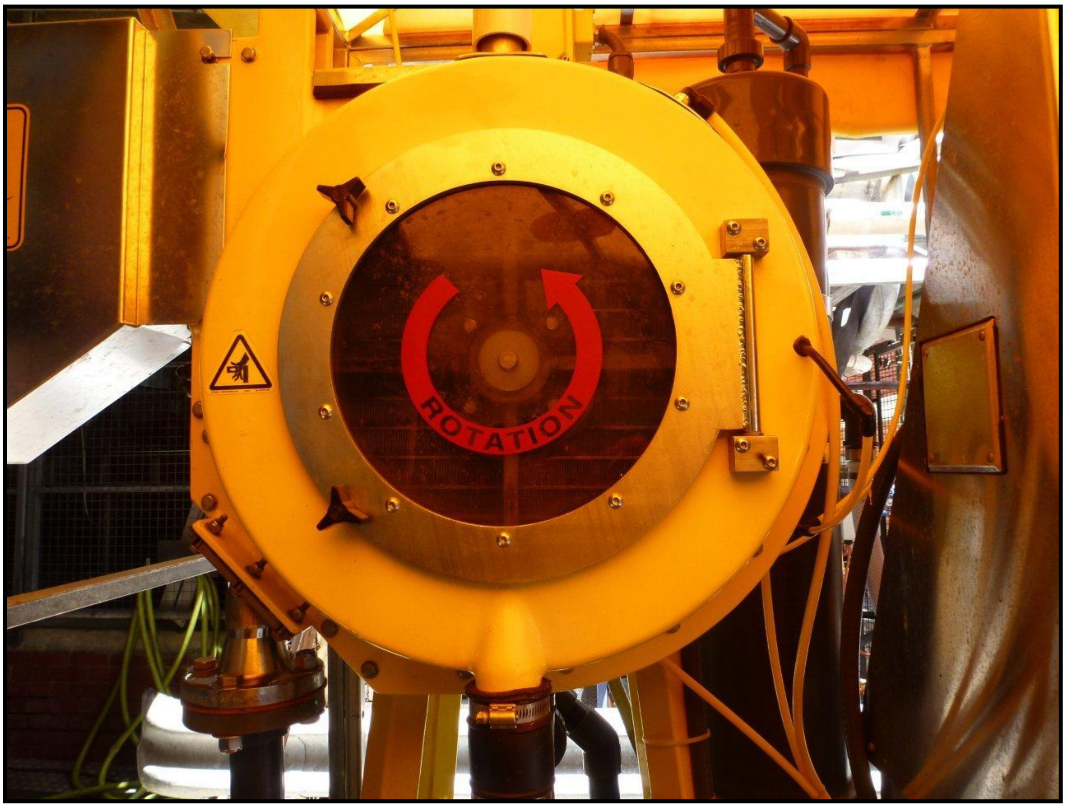
Figure 3: ***PW Filtrate Screening System***

The AIM Water RFP pilot plant is Model RFP-18S dewatering unit, with a nominal hydraulic capacity of 1.5 m^3/h. The pilot plant is an integrated dewatering system comprising a positive displacement feed pump, an in-line polymer feed and flocculation system, the RFP and a Programmable Logic Controller (PLC) for automated operation of the press. The entire system is trailer-mounted and a picture of the pilot plant is shown in Figure 4. The pilot plant trailer was located adjacent to the PW feed tank and a 50 mm poly line was used to connect the press feed pump to the PW feed tank. Power and water for press cleaning were also connected to the pilot plant.

Figure 4: ***RFP Pilot Plant***

A close-up of the press chamber is shown in Figure 5. The two stainless steel wedge-wire screens rotate at a maximum speed of 1 rpm and there are no bearings in the dewatering channel. The sludge enters at the bottom of press and the filtrate is extruded through the screens and discharges from each side of the press. There is a gradual increase in compaction as the sludge moves through the press and it is discharged at the top of the press.

Figure 5: ***Close-up of Press Chamber***



2.4.2 Pilot plant commissioning and testing protocol

The pilot plant was commissioned on 18th February 2013 and extensive polymer trials were conducted to confirm the optimal polymer to use to maximise solids capture. The polymer selected, based on these trials was SNF's high cationic charge polymer, with the product code of EM840 CT.

Based on the advice of AIM Water it was agreed to conduct four test runs the following day. Two runs were to be conducted without polymer and two with polymer. The PW feed rates to be used were a high rate and a lower rate. Again, based on AIM Water's experience the two selected feed rates were 1.38 and 0.78 m^3/h. Note that the nominal maximum capacity of the press is 1.5 m^3/h.

2.4.3 Pilot plant dewatering trials

The four PW dewatering trials were conducted on 19th February, 2013. GHD was informed by trial site personnel that on the 19th February only grass-fed cattle were to be slaughtered. There is anecdotal industry evidence that PW from grass-fed cattle is more difficult to dewater and produces lower cake TS values than that generated from grain-fed cattle. The dewatering trials commenced at 9:30 am and were completed by 12:10 pm. Two sets of samples of the PW feed, cake and filtrate were collected for each trial. These samples were analysed by SGS Laboratories in Sydney. It was soon discovered that the sample bottles provided by SGS for the PW feed were all narrow mouth (20 mm) polyethylene containers. It thus proved very difficult to obtain representative samples of the PW feed due to the high solids content and the very large fibrous nature of the solids. Pictures of the cake exiting the press and in the discharge bin are shown in Figure 6 and pictures of the centrate discharging the press are shown in Figure 7.

Figure 6: ***Cake from the Press***

As discharged   Cake in bin

Figure 7: ***Filtrate from the Press***

With polymer   Without polymer

The operating conditions for the four trials as well as timing of the sample collections is shown in Table 10.

Table 10: ***Dewatering trial operating conditions***

Test No	Feed rate	Solids Feed	Poly dose	Sample 1	Sample 2
	(m^3/h)	(kg/h)	(kg/t)	Local Time	Local Time
1	1.38	11.66	0	10:15	10:35
2	0.78	8.31	0	9:30	9:40
3	1.38	11.25	17.50	11:08	11:20
4	0.78	13.49	7.71	11:50	12:10

In addition to taking samples from the AIM Water pilot plant RFP, two sets of cake and filtrate samples were also taken from the full-scale operational FAN screw press at the trial site. This was done to allow a direct comparison in performance between the two dewatering devices. The back-pressure on the FAN press was set to the maximum value prior to taking these samples, to ensure maximum cake TS values would be obtained.

The analytical results from the testing of the RFP are shown in Tables 11 to 13 and the detailed SGS analytical reports can be found in Appendix B.

Table 11: ***PW feed analytical data (in mg/L except pH)***

Parameter	Test 1			Test 2			Test 3			Test 4			Grand
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	Average
TSS	8,200	8,700	8,450	17,000	4,300	10,650	7,800	8,500	8,150	7,600	27,000	17,300	11,138
VSS	7,900	9,200	8,550	16,000	4,100	10,050	7,800	7,800	7,800	6,800	23,000	14,900	10,325
VS	17,000	10,000	13,500	21,000	5,500	13,250	13,000	11,000	12,000	15,000	26,000	20,500	14,813
TKN_t	220	110	165	330	130	230	200	160	180	140	260	200	194
TKN_f	67	57	62	85	29	57	82	69	76	90	81	86	70
NH_3-N	46	29	38	59	12	36	60	53	57	49	90	70	50
TP_t	110	47	79	170	58	114	76	82	79	92	150	121	98
TP_f	120	52	86	190	51	121	74	86	80	100	160	130	104
K	71	69	70	100	31	66	96	100	98	82	110	96	82
pH	7.3	6.8	7.1	7.0	7.1	7.1	6.8	7.0	6.9	7.2	6.8	7.0	7

The PW feed data in Table 11 shows that the solids content varied significantly during the trial from a low of 4,300 mg/L to a high of 27,000 mg/L, with a grand average of 11,138 mg/L. As mentioned previously, due to the narrow-mouth sample bottles used, it was very difficult to obtain representative samples of the PW feed and this limitation may very well have contributed to the observed variability in feed TSS values. It is also possible that the feed TSS values were actually higher than that reported. It was however observed that due to the batch-dumping of paunch contents, there was significant variability in the TSS in the PW feed tank. The pH of the PW feed did not vary significantly and on average, was neutral. The nutrient data generated from this study is very different to that generated by previous MLA/AMPC studies[4,5]. It should also be noted that the variability in nutrient data is nowhere near as significant as that for the TSS values. The N, P and K values from this study are significantly lower than those generated by the previous MLA/AMPC studies. This may however be due to the fact that the samples taken were not representative, that is they could have been low in solids content. This data shows that essentially all of the phosphorus is in a soluble form whereas only about 36% of the nitrogen is in soluble form.

The cake and filtrate analytical results are shown in Tables 12 and 13 respectively.

Table 12: *Dewatered cake analytical data*

Parameter	Test 1			Test 2			Test 3			Test 4		
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average
TS (%)	21.5	24.6	23.1	21.7	22.7	22.2	21.9	22.3	22.1	25.4	23.2	24.3
VS (% of TS)	94.0	93.0	93.5	94.0	93.0	93.5	90.0	90.0	90.0	92.0	92.0	92.0
TKN (% of TS)	1.6	1.8	1.7	1.4	2.5	2.0	2.8	2.8	2.8	2.1	3.7	2.9
TP (% of TS)	0.31	0.28	0.30	0.27	0.41	0.34	0.44	0.35	0.40	0.30	0.23	0.27
K (% of TS)	0.12	0.11	0.12	0.11	0.14	0.13	0.19	0.17	0.18	0.12	0.11	0.12
GCV (GJ/dry t)	20.15	23.71	21.93	20.03	21.33	20.68	21.73	21.63	21.68	20.46	21.31	20.89
pH	6.8	5.4	6.1	6.9	6.0	6.5	5.6	5.8	5.7	5.9	6.0	6.0

Table 13: ***Press filtrate analytical data (all data in mg/L except pH)***

Parameter	Test 1			Test 2			Test 3			Test 4		
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average
TSS	1,700	4,700	3,200	2,300	1,100	1,700	71	140	106	100	290	195
CODt	3,100	8,000	5,550	3,300	2,000	2,650	760	1,300	1,030	620	880	750
CODf	510	940	725	410	230	320	640	1,000	820	480	410	445
TKNt	100	170	135	76	54	65	27	36	32	26	54	40
TKNf	43	92	68	36	23	30	23	37	30	22	33	28
NH_3-N	24	45	35	18	6	12	18	27	23	13	14	14
TP_t	87	69	78	92	45	69	52	88	70	67	87	77
FRP	84	74	79	110	37	74	53	85	69	71	62	67
K	81	98	90	66	36	51	88	110	99	57	98	78
pH	7.5	6.8	7.2	7.5	7.2	7.4	7.3	7.3	7.3	7.5	7.3	7.4

As can be seen from Table 12, the cake TS values were lower than expected, ranging from 21.5 to 25.4% TS. It was anticipated that cake TS values would be above 30%. There were not significant changes in cake TS values as a function of press throughput or the impact of polymer addition. It is interesting to note, that based on feed TS values, the actual solids loadings for tests 1 and 2 and 3 and 4 were almost the same even though the feedrate for tests 1 and 3 were almost double those for tests 2 and 4. The cake TS values achieved on the FAN screw press during the same time period were 25.9 and 31.5 %, with an average value of 28.7%, which was higher than that achieved on the RFP without the use of polymer (22.6%). There were not sufficient samples generated from this study to conduct statistical analysis on cake TS values but it does seem certain that the RFP produced a lower cake TS than the screw press which was sampled during the same time frame as the RFP. The cake VS ranged from 90 to 94% with a gross calorific value (GCV) ranging from 20.03 to 23.71 GJ/dry tonne. The associated inherent moisture from the GCV samples at 105 degrees Celsius suggests that a large portion of the moisture is essentially locked away within the PW.

The RFP filtrate data shown in Table 13 reveals that the filtrate is low in suspended solids and that the addition of polymer significantly increased solids capture, with filtrate TSS values decreasing 10 to 20 fold. Again, nutrient levels are much lower than those reported in previous MLA/AMPC studies[4,5]. This is particularly true for TKN in the trials done with polymer addition, due to the very high solids capture achieved, which reduced particulate TKN in the filtrate. The FAN screw press filtrate TSS values measured were 7,300 and 8,400 mg/L for an average value of 7,850 mg/L. This is three times higher than the average filtrate TSS value achieved with the RFP without the use of polymer. While there is insufficient data available from this study to conduct statistical analysis on filtrate TSS values, it is clear that the RFP achieves significantly higher solids capture values than the FAN screw press. Note that solids capture is the percentage of the feed solids that are captured in the dewatered cake and thus the lower the filtrate TSS the higher the solids capture. In abattoirs any solids not captured in PW dewatering pass onto downstream wastewater treatment processes and then incur added costs for removal via these treatment processes. For example, at the trial site there are static screens downstream of the screw press to capture additional solids not captured in the screw press.

Solids balances around the RFP were conducted for the four trials to allow the calculation of solids capture in the cake for each test run. A summary of the calculated solids capture data is shown in Table 14.

Table 14: *Solids capture data*

Parameter	Test 1	Test 2	Test 3	Test 4
Feed rate (m^3/h)	1.38	0.78	1.38	0.78
Solids loading (kg/h)	11.66	8.31	11.25	13.49
Polymer dose (kg/t)	0	0	17.5	7.71
Solids capture (%)	63	84.7	98.52	99.18

The calculated solids capture data in Table 14 is considered as being reasonable, except for Test 1. With a fibrous sludge such as PW, one would expect a RFP to achieve solids captures of at least 80 % without the use of polymer and above 95% with the use of polymer. This solids capture data again suggests that the feed TSS value during Test 1 was much higher than that reported by the measured feed TSS value.

Nutrient balances for the four tests were also conducted, based on the mass partitioning data (cake mass and filtrate volume) calculated via the solids balances. A summary of this data is shown in Table 15.

Table 15: *Nutrient balance data*

Parameter	Test 1	Test 2	Test 3	Test 4
% TKN in cake	54.8	76.5	124.9	248.7
% TP in cake	20.0	26.9	40.1	37.6
% K in cake	8.7	17.2	14.7	20.5
% TKN in filtrate	79.9	27.1	16.9	18.6
% TP in filtrate	97.1	57.6	85.4	59.3
% K in filtrate	124.9	74.7	97.3	75.3
% TKN in cake+filtrate	134.8	103.6	141.8	267.4
% TP in cake+filtrate	117.1	84.5	125.5	96.9
% K in cake+filtrate	133.6	91.9	112.1	95.8

The nutrient balance data for the four tests showed significant variability across the four tests and in some cases significant errors, with calculated combined nutrient recovery in the cake and filtrate exceeding 100% by a significant margin. This is particularly true for TKN recovery in the cake for Tests 3 and 4 and K recovery in the filtrate for Test 1. This suggests that some of the analytical data is in error. For example the TKN cake values for Tests 3 and 4 are significantly higher than those for Tests 1 and 2. The source of this error for the phosphorus measurements is likely to be compounds that present similar optical properties to the Filtered Reactive Phosphorus (FRP), a term often generically referred to as "matrix interference". Due to the highly oxidative measurement conditions of the TP tests, this is interference is not expected to be as significant. Additionally, since the FRP and TP values are often very similar, it is reasonable to assume that the primary form of TP is FRP.

It is however clear that on average about 75% of the P and 85% of the K in the PW is transferred to the filtrate during dewatering. The N data is more difficult to interpret but suggests that when polymer is used most of the N remains in the cake and possibly only about 50% of the N is transferred to the filtrate when no polymer is used. This data is in contrast to that generated by a previous MLA/AMPC study[4] which showed that about 90% of both the N and P in PW is transferred to the filtrate during dewatering operations.

2.5 Proposed Integrated PW Management System

The proposed integrated PW management system to be used for the Cost Benefit Analysis (CBA) comprises RFP dewatering, nutrient recovery from the filtrate via a struvite precipitation system and co-combustion of the PW cake in the abattoir boiler for steam generation. To develop the basis of design for these facilities, PW generation data from a previous MLA study has been used[4]. The average raw PW volumes generated from the 'beef only' abattoirs surveyed in that MLA study have been used for this design case. This data is deemed as being more reliable and defensible than that generated by the AMPC survey reported in Section 2.2 of this report. The data from the previous MLA report revealed that the average raw PW volume is 0.444 m^3/head, compared to the average value of 0.11 m^3/head from the AMPC survey reported in Section 2.2 of this report. Dewatered cake data has been obtained from unpublished survey results from a beef-only abattoir in NSW. This abattoir has a FAN screw press for PW dewatering and the survey results showed that the solids capture rate in the press was 83.7%. The dewatered PW cake data generation rate was 0.0045 dry t/head, and this was based on the reported solids capture rate of 83.7%. The use of a RFP, with polymer addition has a design solids capture rate of 99% and thus the PW cake generation rate increases to 0.0053 dry t/head for use in this CBA. Since nutrient recovery is an integral component of the management system, the RFP with polymer addition is chosen to minimise the solids loading to the struvite precipitator since high suspended solids would negatively impact struvite precipitation, thus the quality of the struvite generated.

Two cases are considered in the CBA, namely integrated PW management systems for nominal 800 head/day and 1,600 head/day abattoirs. That is the design cases are dry PW generation rates of 4.26 and 8.52 tpd. The basis of design for these PW management systems is shown in Table 16.

Table 16: ***Basis of Design for PW Management Systems***

Parameter	Units	Small abattoir	Large abattoir
Raw PW volume	m^3/d	355	710
PW cake mass	Dry tpd	4.26	8.52
PW Nutrient data		Feed value	Transferred to filtrate
NH_3-N	mg/L	50	100%
Soluble P	mg/L	100	75%
K	mg/L	80	85%

The PW nutrient data in Table 16 is that generated from this study. It has however been assumed that all of the ammonia in the feed is transferred to the filtrate, which is a reasonable assumption. Ammonia is used since this is what reacts with the soluble phosphorus and the added magnesium to precipitate magnesium ammonium phosphate (MAP) in the struvite precipitator.

Equipment process design parameters for the major components of the PW management system are shown in Table 17.

Table 17: ***Equipment Process Design Parameters***

Parameter	Units	Design Value
RFP polymer dose	kg/t	5
RFP cake TS	%	24
RFP solids capture	%	99
Cake NCV	GJ/dry t	20.3
RFP operations	hrs/day	10
Effluent P from precipitator	mg/L	1
Boiler thermal efficiency	%	70.82
Boiler operations	hrs/day	12
Steam requirements for small abattoir	tph	7.5
Steam requirements for large abattoir	tph	15
Steam enthalpy at 600 kPa	GJ/t	2.75

The RFP data shown in Table 17 is that generated by the pilot plant trials reported in Section 2.3 of this report and the RFP is designed to operate only while PW is being generated, or 10 hours per day. The struvite precipitator is designed to achieve an effluent P value of 1 mg/L, which is typical for commercial units processing other nutrient streams, notably digester supernatant streams from sewage treatment plants. The removal of ammonia and the magnesium requirements for the precipitation process are based on MAP stoichiometric parameters. It is not known whether the potassium in the filtrate will be co-precipitated with the MAP, which indicates that further research should be conducted on this process. The boiler process design data is taken from a previous MLA study which conducted full-scale PW co-combustion trials in the boiler[2]. This study was done using wood waste as the primary fuel and dewatered PW cake as the auxiliary fuel.

Based on the process design parameters shown in Tables 16 and 17, Process Flow Diagrams (PFDs) with Mass and Energy Balance (M&EB) data were developed for the two design cases. The PFD for the large abattoir is shown in Figure 8. In developing the M&EB for the boiler, the thermal properties of the wood waste used to fuel the existing boiler has been used, namely a TS content of 60% and a Net Calorific Value (NCV) of 15 GJ/dry t. In addition, only the available energy in the dewatered PW cake has been used in the M&EB. That is, the energy required to vaporise the water in the cake and raise the temperature to 800 ^{0}C, has been subtracted from the NCV of the cake. For these calculations the NCV for water (2.2 GJ/t) and its average Specific Heat to 800 ^{0}C (2.09 kJ/kg/^{0}C) have been used. Based on these PFDs and M&EBs the major process inputs and outputs for the two design cases are shown in Table 18. Note that the volume of avoided PW to disposal in Table 18 is calculated on the assumption that the abattoir has a screen which produces PW TS of about 10%, rather than the raw PW TS value of 1.45%.

Figure 8: *PFD for Large Abattoir*

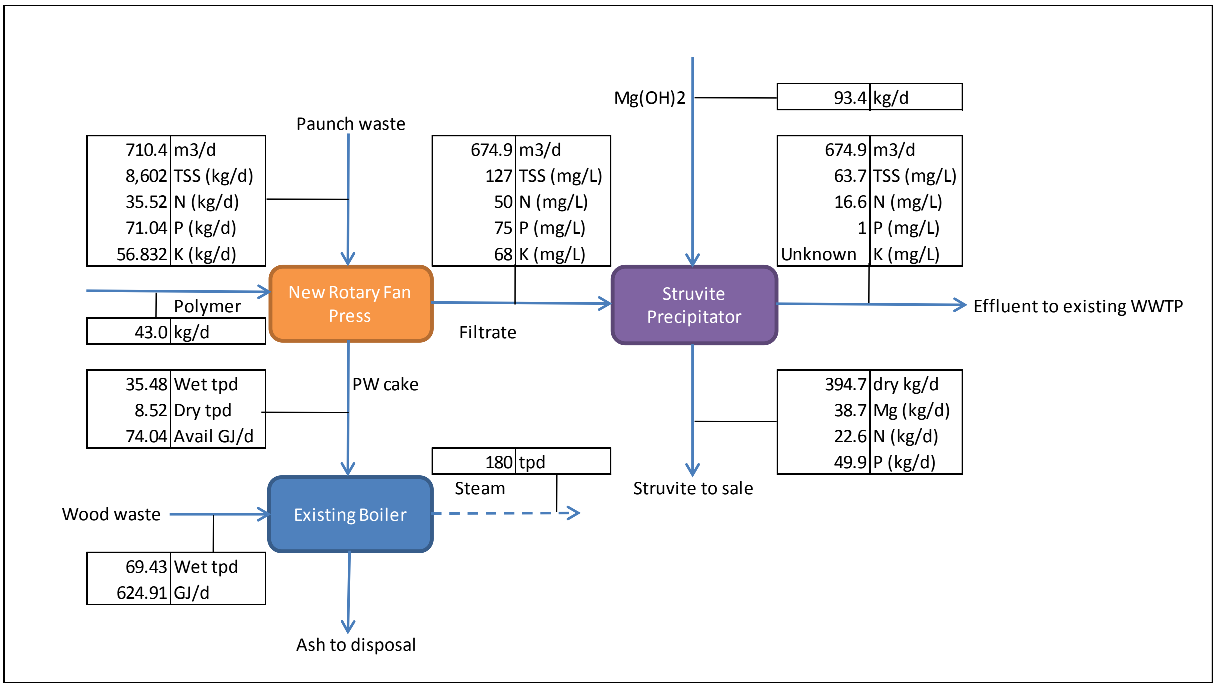


Table 18: *Process Inputs and Outputs for the Two Design Cases*

Parameter	Units	Small abattoir	Large abattoir
Raw PW volume input	m^3/d	355	710
Polymer use	kg/d	21.5	43
$Mg(OH)_2$ use	kg/d	46.7	93.4
Struvite output	kg/d	197.4	394.7
Wood waste reduction	wet tpd	4.11	8.23
Avoided PW disposal	m^3/d	51.5	103

2.6 Cost Benefit Analysis

Capital costs for the integrated PW management systems for the two design cases were developed based on quoted prices for the RFPs from AIM Water and GHD estimates of capital costs for the struvite precipitation package and other minor equipment items such as conveyors and hoppers. It should be emphasised that the RFP costs are for skid-mounted integrated complete packages, inclusive of feed pumps, RFP, polymer dosing system, instrumentation and a PLC based control system. The struvite package also provides a complete integrated system. Standard engineering cost factors are then used for items such as piping and valves, electrics, civil works etc. Table 19 provides a summary of these capital costs for the two design cases.

It is expected that the accuracy of the estimates be no better than ±40% for the items described in this report. The cost estimates may need to be reviewed and revised if any of the assumptions made by GHD in the report change. A functional design is recommended for budget setting purposes.

Table 19: *Capital Cost Estimates for the Two Design Cases*

Major Equipment Items	Cost Factor	Small abattoir ($)	Large abattoir ($)
RFP package		555,000	729,000
Struvite precipitator package		330,000	523,000
Conveyors/hoppers		50,000	75,000
Subtotal		**-935,000**	**-1,327,000**
Piping and valves (%)	5	47,000	66,000
Electrics (%)	10	94,000	133,000
Instruments and control (%)	5	47,000	66,000
Civils (%)	10	94,000	133,000
Mech installation (%)	5	47,000	66,000
Equipment Subtotal		**-1,263,000**	**-1,791,000**
Engineering design (%)	5	63,000	90,000
Project management (%)	5	63,000	90,000
Subtotal		**-1,390,000**	**-1,971,000**
Overheads/risk (%)	5	70,000	99,000
Profit margin (%)	5	70,000	99,000
Contingency (%)	10	139,000	197,000
TOTAL		**-1,669,000**	**-2,366,000**

Relatively low percentages have been allowed for items such as piping and valves, instruments and controls, installation, engineering design and project management, due to the complete package supply approach for the RFP and struvite precipitator. It has been assumed that the abattoir already has a boiler which is capable of co-combusting PW cake with their primary fuel and thus no additional capital costs are required, other than for a PW cake feeding and storage system. The total capital cost for the integrated PW management systems have been estimated to be $1.67million for the small abattoir and $2.37 million for the large abattoir.

Operating and Maintenance (O&M) costs have been estimated based on the requirements as identified in the relevant PFDs and in Table 18. In addition, it has been estimated that the power draw for the two design cases is 20 and 25 kW respectively. The utility costs and revenues used in this CBA are displayed Table 20. These figures also include the ± 40% accuracy similar to CAPEX. There will be some variance in cost associated with chemicals in particular, which will vary depending on actual requirements and available storage.

Table 20: Operational Cost Estimates

Utility or Material	Price ($/unit)
Power	$180/MWh
Polymer	$10/kg
Operator Salary	$60,000 per person per year
Magnesium hydroxide	$250/dry tonne
Wood waste	$35/wet tonne
Struvite	$700/tonne
PW cake disposal	$15/m^3

Based on the above, the estimated O&M cost for the two design cases is shown in Table 21.

Table 21: *O&M Cost Estimates for the Two Design Cases*

Cost Component	No.	Unit cost Factor	Small abattoir	Large abattoir
Operating staff	0.5	60,000	30,000	30,000
Electricity	-	180	9,000	11,250
Maintenance	3	% of equip	37,920	53,730
Polymer	-	10	53,763	107,527
$Mg(OH)_2$	-	250	2,920	5,840
Total costs			**-133,604**	**-208,347**
Woodwaste credit	-	35	35,992	71,985
Struvite sales	-	700	34,538	69,075
PW disposal credit	-	15	193,670	386,280
Total credits			**263,670**	**527,340**
Net O&M Cost			**130,067**	**318,993**

As can be seen from Table 21 the revenues exceed the operating costs for both design cases. Thus annual net revenues of $130,067 and $318,993 are realised for the two design cases.

The overall economics of this CBA are based on both a Net Present Value (NPV) and a simple payback period basis. The NPV is calculated on a 20-year period with a 7% discount rate. The Microsoft Office Excel “NPV function” was used to calculate the NPV values. This protocol calculates a “discount factor”, based on the criteria used (a 20 year period and 7% discount rate in this analysis). To calculate the NPV, the capital costs are added to the operating costs multiplied by the discount factor, which is calculated at 10.59 in this analysis. A positive NPV indicates that over the life of the project revenue is generated while negative NPVs indicate the total cost of the system over the life of the project. A summary of this data is shown in Table 22.

Table 22: ***Overall Economics for the Two Design Cases***

Financial Parameter	Small abattoir	Large abattoir
20 year NPV ($)	-291,073	1,013,417
Payback Period (years)	12.8	7.4

The overall economics for the proposed integrated PW management systems do not look attractive based on this analysis. Over a 20 year period, these PW management systems are estimated to incur additional costs of $291,073 for the small abattoir option and total revenue of $1,013,417 for the large abattoir option. The simple non-discounted pay-back period for the two design cases are 12.8 and 7.4 years respectively. This is significantly in excess of the typical industry threshold of 3 years.

It should be noted that in this CBA, the benefit of struvite recovery versus the industry normal practice of no nutrient recovery hasn’t been considered. The standard industry practise is utilising the nutrients via irrigating of abattoir effluent on pasture or some other cropping scenario. It is however fair to say that for most abattoirs, irrigation is limited by the high nutrient levels in the effluent, particularly nitrogen. It is thus believed that nutrient recovery via struvite precipitation will allow abattoirs to better manage their irrigation practises and reduce costs for irrigation, by reducing land requirements.

3. Discussion and Conclusion

This study has revealed that there is very limited publicly available information on PW dewatering systems and nutrient recovery options from PW liquors. The limited available information is published by MLA and AMPC. The dewatering technology assessment program identified that the RFP was the “most promising” new dewatering technology to trial in these studies. Pilot trialling of a RFP for PW dewatering indicated no improvement in PW cake solids could be achieved in comparison to the abattoir’s existing fan press. However the press did provide significantly higher solids capture than that achieved by generic screw presses.

The economics developed for a proposed PW management system comprising RFP dewatering, nutrient recovery from the filtrate and energy recovery from the cake, via co-combustion in boilers, does not look attractive. It must however be stated that these economics may be biased by the following factors:

- The cake TS used in this analysis is lower than that achieved by many existing PW dewatering systems, which transfers profound negative impacts to the economic projections of energy recovery;
- The capital cost of the RFP is probably significantly higher than that of alternate dewatering systems;
- The concentration of nutrients in the filtrate from this study is much lower than that reported for many other abattoirs, subsequently also negatively impacting the economics of nutrient recovery.

Based on the outcomes of this study the following specific conclusions are drawn:

1. No information was identified in the literature review on the performance of PW dewatering systems or on the impact of PW characteristics on dewatering performance. Limited data is available from dewatering vendors but this is not regarded to be truly independent or reliable.
2. The only publicly available literature on nutrients in PW liquors is that recently published by MLA and AMPC. No information on nutrient recovery systems was identified in the publicly available open literature.
3. Analysis of the AMPC PW questionnaire results indicates a very high variability in PW and DAF sludge data. It is very likely that many respondents did not complete the questionnaire accurately. For example, it appears that many responses on PW volumes are actually that for dewatered PW volumes.
4. Trialling of the RFP pilot plant for PW dewatering was successfully completed at the Beef Exports abattoir. During this trial only grass-fed cattle were being slaughtered. The RFP pilot plant trials yielded the following information:

    - The PW feed TSS was very variable ranging from 4,300 to 27,000 mg/L, with a grand average of 11,138 mg/L, which is considered to be normal for raw PW;
    - The nutrient levels in the PW feed were much lower than those reported for other abattoirs;
    - The GCV results indicate a large amount of water trapped within the PW fibrous matrix;

- The cake solid achieved without polymer addition was 22.6%, compared to a value of 28.7% achieved by the commercial FAN screw press used by the trial site;
- The cake solids achieved when polymer was added increased, only marginally, to 23.2%;
- Filtrate TSS averaged 2,450 mg/L without the use of polymer which decreased to 150 mg/L with polymer use. The FAN screw press filtrate TSS values averaged 7,850 mg/L, indicating significantly lower solids capture than that achieved with the RFP;
- Nutrient levels in the filtrate were significantly lower than those reported at other abattoirs.

5. Costs were developed for an integrated PW management system comprising RFP dewatering, nutrient recovery via struvite precipitation from the filtrate and energy recovery from the cake via co-combustion in the abattoir boiler.
6. The economics of this proposed PW management system does not appear to be attractive, even for large abattoirs. The simple pay-back period for large abattoirs is estimated to be 7.4 years. These economics would possibly improve if higher cake solids could be achieved and the filtrate had higher nutrient concentrations.

4. Recommendations

Due to the similar performance of the RFP to the trial site's existing screw press, it is not recommended that further trials or analysis be conducted at this point in time.

Due to the uncertainties regarding nutrient recovery from PW filtrate, particularly the impact of potassium on the struvite precipitation process, it is recommended that MLA/AMPC consider conducting a pilot plant evaluation programme on the process. This will also allow the economics of the process to be better defined. However, this should only be conducted in association with a market review to analyse if markets exist that would be willing to purchase the fertiliser. The latter point is important as many customers of the high quality fertiliser market require specific ratios of macro and micro nutrients that are not always provided by struvite.

The large fraction of water contained within the fibrous matrix of the PW material suggests a possible limitation to the dewatering abilities of the screw and fan presses in this context. It may be possible that chemical or thermal technologies could be utilised to separate the water from the PW through evaporation or osmotic pressure. The latter suggest that by utilising inorganic flocculent rather than an organic chemical, water could be theoretically be drawn out of the fibrous matrix through passive transport due to the concentration differential.

Appendices

Appendix A - (Questionnaire)

The following are the questions presented to the 31 abattoirs:

1. Please provide your business details and information about your role in the company. We may contact you to further explore your survey responses or obtain additional information.

2. Please enter details of the throughput of cattle or sheep through your processing facility. Please enter '0' where the question does not apply to your site.

3. Please enter 'n/a' where the details requested below cannot be provided.

4. If PW is dewatered, what system is used?

5. How are PW solids disposed?

6. Please enter 'n/a' where the details requested below cannot be provided.

7. If DAF sludge is dewatered, what system is used?

8. How are DAF sludge solids disposed?

9. Are you considering PW or DAF sludge dewatering?

10. If you are considering dewatering, what dewatering system are you considering?

11. Are you considering co-dewatering PW and DAF sludge?

Appendix B - (Laboratory Results)

Below are the SGS laboratory results:

Parameter	Units	LOR	Sample Number: SE115812.001 Sample Matrix: Soil Sample Date: 19 Feb 2013 Sample Name: T1-1C	SE115812.002 Soil 19 Feb 2013 T1-2C	SE115812.003 Soil 19 Feb 2013 T2-1C	SE115812.004 Soil 19 Feb 2013 T2-2C
Total and Volatile Solids in Soil Method: AN113						
Total Solids Dried at 105°C	%	1	20	24	22	23
Volatile Solids Ignited at 550°C	%	1	94	93	94	93
TKN Kjeldahl Digestion by Discrete Analyser in Soil Method: AN292						
Total Kjeldahl Nitrogen	mg/kg	40	16000	18000	14000	25000
pH in soil (1:5) Method: AN101						
pH	pH Units	-	6.8	5.4	6.9	6.0
Total Recoverable Metals in Soil by ICPOES from EPA 200.8 Digest Method: AN040/AN320						
Phosphorus, P	mg/kg	5	3100	2800	2700	4100
Potassium, K	mg/kg	10	1200	1100	1100	1400
Moisture Content Method: AN002						
% Moisture	%	0.5	78.5	75.4	78.3	77.3
Total and Volatile Solids for Water Method: AN113						
Volatile Solids Ignited at 550°C	mg/L	10	-	-	-	-
Filterable Reactive Phosphorus (FRP) Method: AN278						
Filterable Reactive Phosphorus	mg/L	0.002	-	-	-	-
Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293						
Total Phosphorus (Kjeldahl Digestion)	mg/L	0.05	-	-	-	-
TKN Kjeldahl Digestion by Discrete Analyser Method: AN281/AN292						
Total Kjeldahl Nitrogen	mg/L	0.05	-	-	-	-

Parameter	Units	LOR	Sample Number: SE115812.001 Sample Matrix: Soil Sample Date: 19 Feb 2013 Sample Name: T1-1C	SE115812.002 Soil 19 Feb 2013 T1-2C	SE115812.003 Soil 19 Feb 2013 T2-1C	SE115812.004 Soil 19 Feb 2013 T2-2C
Soluble TKN Kjeldahl Digestion by Discrete Analyser Method: AN281						
Soluble Total Kjeldahl Nitrogen	mg/L	0.05	-	-	-	-
Ammonia Nitrogen by Discrete Analyser (Aquakem) Method: AN291						
Ammonia Nitrogen, NH_3 as N^*	mg/L	0.01	-	-	-	-
pH in water Method: AN101						
pH	pH Units	-	-	-	-	-
COD in Water Method: AN179/AN181						
Chemical Oxygen Demand	mg/L	5	-	-	-	-
Soluble COD in Water Method: AN179/AN181						
Chemical Oxygen Demand (Soluble)	mg/L	5	-	-	-	-
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114						
Total Suspended Solids Dried at 105°C	mg/L	5	-	-	-	-
Metals in Water (Total) by ICPOES Method: AN022/AN320/AN321						
Total Potassium	mg/L	0.2	-	-	-	-

Parameter	Units	LOR	Sample Number: SE115812.005	SE115812.006	SE115812.007	SE115812.008
		Sample Matrix	Soil	Soil	Soil	Soil
		Sample Date	19 Feb 2013	19 Feb 2013	19 Feb 2013	19 Feb 2013
		Sample Name	T3-1C	T3-2C	T4-1C	T4-2C

Total and Volatile Solids in Soil   Method: AN113

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Total Solids Dried at 105°C	%	1	23	22	27	23
Volatile Solids Ignited at 550°C	%	1	90	90	92	92

TKN Kjeldahl Digestion by Discrete Analyser in Soil   Method: AN292

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Total Kjeldahl Nitrogen	mg/kg	40	28000	28000	21000	37000

pH in soil (1:5)   Method: AN101

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
pH	pH Units	-	5.6	5.8	5.9	6.0

Total Recoverable Metals in Soil by ICPOES from EPA 200.8 Digest   Method: AN040/AN320

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Phosphorus, P	mg/kg	5	4400	3500	3000	2300
Potassium, K	mg/kg	10	1900	1700	1200	1100

Moisture Content   Method: AN002

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
% Moisture	%	0.5	78.1	77.7	74.6	76.8

Total and Volatile Solids for Water   Method: AN113

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Volatile Solids Ignited at 550°C	mg/L	10	-	-	-	-

Filterable Reactive Phosphorus (FRP)   Method: AN278

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Filterable Reactive Phosphorus	mg/L	0.002	-	-	-	-

Total Phosphorus by Kjeldahl Digestion DA in Water   Method: AN279/AN293

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Total Phosphorus (Kjeldahl Digestion)	mg/L	0.05	-	-	-	-

TKN Kjeldahl Digestion by Discrete Analyser   Method: AN281/AN292

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Total Kjeldahl Nitrogen	mg/L	0.05	-	-	-	-

Parameter	Units	LOR	Sample Number: SE115812.005	SE115812.006	SE115812.007	SE115812.008
		Sample Matrix	Soil	Soil	Soil	Soil
		Sample Date	19 Feb 2013	19 Feb 2013	19 Feb 2013	19 Feb 2013
		Sample Name	T3-1C	T3-2C	T4-1C	T4-2C

Soluble TKN Kjeldahl Digestion by Discrete Analyser   Method: AN281

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Soluble Total Kjeldahl Nitrogen	mg/L	0.05	-	-	-	-

Ammonia Nitrogen by Discrete Analyser (Aquakem)   Method: AN291

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Ammonia Nitrogen, NH_3 as N*	mg/L	0.01	-	-	-	-

pH in water   Method: AN101

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
pH	pH Units	-	-	-	-	-

COD in Water   Method: AN179/AN181

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Chemical Oxygen Demand	mg/L	5	-	-	-	-

Soluble COD in Water   Method: AN179/AN181

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Chemical Oxygen Demand (Soluble)	mg/L	5	-	-	-	-

Total and Volatile Suspended Solids (TSS / VSS)   Method: AN114

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Total Suspended Solids Dried at 105°C	mg/L	5	-	-	-	-

Metals in Water (Total) by ICPOES   Method: AN022/AN320/AN321

Parameter	Units	LOR	T3-1C	T3-2C	T4-1C	T4-2C
Total Potassium	mg/L	0.2	-	-	-	-

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	SE115812.009 Soil 19 Feb 2013 T6-1C	SE115812.010 Soil 19 Feb 2013 T6-2C	SE115812.011 Water 19 Feb 2013 T1-1F	SE115812.012 Water 19 Feb 2013 T1-2F
Total and Volatile Solids in Soil Method: AN113							
Total Solids Dried at 105°C	%	1		17	46	-	-
Volatile Solids Ignited at 550°C	%	1		-	-	-	-
TKN Kjeldahl Digestion by Discrete Analyser in Soil Method: AN292							
Total Kjeldahl Nitrogen	mg/kg	40		-	-	-	-
pH in soil (1:5) Method: AN101							
pH	pH Units	-		-	-	-	-
Total Recoverable Metals in Soil by ICPOES from EPA 200.8 Digest Method: AN040/AN320							
Phosphorus, P	mg/kg	5		-	-	-	-
Potassium, K	mg/kg	10		-	-	-	-
Moisture Content Method: AN002							
% Moisture	%	0.5		74.1	68.5	-	-
Total and Volatile Solids for Water Method: AN113							
Volatile Solids Ignited at 550°C	mg/L	10		-	-	17000	10000
Filterable Reactive Phosphorus (FRP) Method: AN278							
Filterable Reactive Phosphorus	mg/L	0.002		-	-	120	52
Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293							
Total Phosphorus (Kjeldahl Digestion)	mg/L	0.05		-	-	110	47
TKN Kjeldahl Digestion by Discrete Analyser Method: AN281/AN292							
Total Kjeldahl Nitrogen	mg/L	0.05		-	-	220	100

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	SE115812.009 Soil 19 Feb 2013 T6-1C	SE115812.010 Soil 19 Feb 2013 T6-2C	SE115812.011 Water 19 Feb 2013 T1-1F	SE115812.012 Water 19 Feb 2013 T1-2F
Soluble TKN Kjeldahl Digestion by Discrete Analyser Method: AN281							
Soluble Total Kjeldahl Nitrogen	mg/L	0.05		-	-	67	57
Ammonia Nitrogen by Discrete Analyser (Aquakem) Method: AN291							
Ammonia Nitrogen, NH_3 as N*	mg/L	0.01		-	-	46	29
pH in water Method: AN101							
pH	pH Units	-		-	-	7.3	6.8
COD in Water Method: AN179/AN181							
Chemical Oxygen Demand	mg/L	5		-	-	-	-
Soluble COD in Water Method: AN179/AN181							
Chemical Oxygen Demand (Soluble)	mg/L	5		-	-	-	-
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114							
Total Suspended Solids Dried at 105°C	mg/L	5		-	-	6800	5500
Metals in Water (Total) by ICPOES Method: AN022/AN320/AN321							
Total Potassium	mg/L	0.2		-	-	71	69

Parameter	Units	LOR	Sample Number: SE115812.013 Sample Matrix: Water Sample Date: 19 Feb 2013 Sample Name: T2-1F	SE115812.014 Water 19 Feb 2013 T2-2F	SE115812.015 Water 19 Feb 2013 T3-1F	SE115812.016 Water 19 Feb 2013 T3-2F
Total and Volatile Solids in Soil Method: AN113						
Total Solids Dried at 105°C	%	1	-	-	-	-
Volatile Solids Ignited at 550°C	%	1	-	-	-	-
TKN Kjeldahl Digestion by Discrete Analyser in Soil Method: AN292						
Total Kjeldahl Nitrogen	mg/kg	40	-	-	-	-
pH in soil (1:5) Method: AN101						
pH	pH Units	-	-	-	-	-
Total Recoverable Metals in Soil by ICPOES from EPA 200.8 Digest Method: AN040/AN320						
Phosphorus, P	mg/kg	5	-	-	-	-
Potassium, K	mg/kg	10	-	-	-	-
Moisture Content Method: AN002						
% Moisture	%	0.5	-	-	-	-
Total and Volatile Solids for Water Method: AN113						
Volatile Solids Ignited at 550°C	mg/L	10	21000	5500	13000	11000
Filterable Reactive Phosphorus (FRP) Method: AN278						
Filterable Reactive Phosphorus	mg/L	0.002	190	51	74	88
Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293						
Total Phosphorus (Kjeldahl Digestion)	mg/L	0.05	170	58	78	82
TKN Kjeldahl Digestion by Discrete Analyser Method: AN281/AN292						
Total Kjeldahl Nitrogen	mg/L	0.05	330	130	200	160

Parameter	Units	LOR	Sample Number: SE115812.013 Sample Matrix: Water Sample Date: 19 Feb 2013 Sample Name: T2-1F	SE115812.014 Water 19 Feb 2013 T2-2F	SE115812.015 Water 19 Feb 2013 T3-1F	SE115812.016 Water 19 Feb 2013 T3-2F
Soluble TKN Kjeldahl Digestion by Discrete Analyser Method: AN281						
Soluble Total Kjeldahl Nitrogen	mg/L	0.05	85	29	82	69
Ammonia Nitrogen by Discrete Analyser (Aquakem) Method: AN291						
Ammonia Nitrogen, NH_3 as N*	mg/L	0.01	59	12	60	53
pH in water Method: AN101						
pH	pH Units	-	7.0	7.1	6.8	7.0
COD in Water Method: AN179/AN181						
Chemical Oxygen Demand	mg/L	5	-	-	-	-
Soluble COD in Water Method: AN179/AN181						
Chemical Oxygen Demand (Soluble)	mg/L	5	-	-	-	-
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114						
Total Suspended Solids Dried at 105°C	mg/L	5	16000	3600	7000	11000
Metals in Water (Total) by ICPOES Method: AN022/AN320/AN321						
Total Potassium	mg/L	0.2	100	31	96	100

Parameter	Units	LOR	Sample Number: SE115812.017 Sample Matrix: Water Sample Date: 19 Feb 2013 Sample Name: T4-1F	SE115812.018 Water 19 Feb 2013 T4-2F	SE115812.019 Water 19 Feb 2013 T1-1L	SE115812.020 Water 19 Feb 2013 T1-2L
Total and Volatile Solids in Soil Method: AN113						
Total Solids Dried at 105°C	%	1	-	-	-	-
Volatile Solids Ignited at 550°C	%	1	-	-	-	-
TKN Kjeldahl Digestion by Discrete Analyser in Soil Method: AN292						
Total Kjeldahl Nitrogen	mg/kg	40	-	-	-	-
pH in soil (1:5) Method: AN101						
pH	pH Units	-	-	-	-	-
Total Recoverable Metals in Soil by ICPOES from EPA 200.8 Digest Method: AN040/AN320						
Phosphorus, P	mg/kg	5	-	-	-	-
Potassium, K	mg/kg	10	-	-	-	-
Moisture Content Method: AN002						
% Moisture	%	0.5	-	-	-	-
Total and Volatile Solids for Water Method: AN113						
Volatile Solids Ignited at 550°C	mg/L	10	15000	26000	-	-
Filterable Reactive Phosphorus (FRP) Method: AN278						
Filterable Reactive Phosphorus	mg/L	0.002	100	160	84	74
Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293						
Total Phosphorus (Kjeldahl Digestion)	mg/L	0.05	92	150	87	69
TKN Kjeldahl Digestion by Discrete Analyser Method: AN281/AN292						
Total Kjeldahl Nitrogen	mg/L	0.05	140	260	100	170

Parameter	Units	LOR	Sample Number: SE115812.017 Sample Matrix: Water Sample Date: 19 Feb 2013 Sample Name: T4-1F	SE115812.018 Water 19 Feb 2013 T4-2F	SE115812.019 Water 19 Feb 2013 T1-1L	SE115812.020 Water 19 Feb 2013 T1-2L
Soluble TKN Kjeldahl Digestion by Discrete Analyser Method: AN281						
Soluble Total Kjeldahl Nitrogen	mg/L	0.05	90	81	43	92
Ammonia Nitrogen by Discrete Analyser (Aquakem) Method: AN291						
Ammonia Nitrogen, NH_3 as N*	mg/L	0.01	49	90	24	45
pH in water Method: AN101						
pH	pH Units	-	7.2	6.8	7.5	6.8
COD in Water Method: AN179/AN181						
Chemical Oxygen Demand	mg/L	5	-	-	3100	8000
Soluble COD in Water Method: AN179/AN181						
Chemical Oxygen Demand (Soluble)	mg/L	5	-	-	510	940
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114						
Total Suspended Solids Dried at 105°C	mg/L	5	7200	28000	1700	4700
Metals in Water (Total) by ICPOES Method: AN022/AN320/AN321						
Total Potassium	mg/L	0.2	82	110	81	98

Parameter	Units	LOR	Sample Number: SE115812.021 Sample Matrix: Water Sample Date: 19 Feb 2013 Sample Name: T2-1L	SE115812.022 Water 19 Feb 2013 T2-2L	SE115812.023 Water 19 Feb 2013 T3-1L	SE115812.024 Water 19 Feb 2013 T3-2L
Total and Volatile Solids in Soil Method: AN113						
Total Solids Dried at 105°C	%	1	-	-	-	-
Volatile Solids Ignited at 550°C	%	1	-	-	-	-
TKN Kjeldahl Digestion by Discrete Analyser in Soil Method: AN292						
Total Kjeldahl Nitrogen	mg/kg	40	-	-	-	-
pH in soil (1:5) Method: AN101						
pH	pH Units	-	-	-	-	-
Total Recoverable Metals in Soil by ICPOES from EPA 200.8 Digest Method: AN040/AN320						
Phosphorus, P	mg/kg	5	-	-	-	-
Potassium, K	mg/kg	10	-	-	-	-
Moisture Content Method: AN002						
% Moisture	%	0.5	-	-	-	-
Total and Volatile Solids for Water Method: AN113						
Volatile Solids Ignited at 550°C	mg/L	10	-	-	-	-
Filterable Reactive Phosphorus (FRP) Method: AN278						
Filterable Reactive Phosphorus	mg/L	0.002	110	37	53	85
Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293						
Total Phosphorus (Kjeldahl Digestion)	mg/L	0.05	92	45	52	88
TKN Kjeldahl Digestion by Discrete Analyser Method: AN281/AN292						
Total Kjeldahl Nitrogen	mg/L	0.05	76	54	27	36

Parameter	Units	LOR	Sample Number: SE115812.021 Sample Matrix: Water Sample Date: 19 Feb 2013 Sample Name: T2-1L	SE115812.022 Water 19 Feb 2013 T2-2L	SE115812.023 Water 19 Feb 2013 T3-1L	SE115812.024 Water 19 Feb 2013 T3-2L
Soluble TKN Kjeldahl Digestion by Discrete Analyser Method: AN281						
Soluble Total Kjeldahl Nitrogen	mg/L	0.05	36	23	23	37
Ammonia Nitrogen by Discrete Analyser (Aquakem) Method: AN291						
Ammonia Nitrogen, NH_3 as N*	mg/L	0.01	18	6.1	18	27
pH in water Method: AN101						
pH	pH Units	-	7.5	7.2	7.3	7.3
COD in Water Method: AN179/AN181						
Chemical Oxygen Demand	mg/L	5	3300	2000	760	1300
Soluble COD in Water Method: AN179/AN181						
Chemical Oxygen Demand (Soluble)	mg/L	5	410	230	640	1000
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114						
Total Suspended Solids Dried at 105°C	mg/L	5	2300	1100	71	140
Metals in Water (Total) by ICPOES Method: AN022/AN320/AN321						
Total Potassium	mg/L	0.2	66	36	88	110

		Sample Number	SE115812.025	SE115812.026	SE115812.027	SE115812.028
		Sample Matrix	Water	Water	Water	Water
		Sample Date	19 Feb 2013	19 Feb 2013	19 Feb 2013	19 Feb 2013
		Sample Name	T4-1L	T4-2L	T5-1L	T5-2L
Parameter	**Units**	**LOR**				

Total and Volatile Solids in Soil Method: AN113

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Total Solids Dried at 105°C	%	1	-	-	-	-
Volatile Solids Ignited at 550°C	%	1	-	-	-	-

TKN Kjeldahl Digestion by Discrete Analyser in Soil Method: AN292

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Total Kjeldahl Nitrogen	mg/kg	40	-	-	-	-

pH in soil (1:5) Method: AN101

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
pH	pH Units	-	-	-	-	-

Total Recoverable Metals in Soil by ICPOES from EPA 200.8 Digest Method: AN040/AN320

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Phosphorus, P	mg/kg	5	-	-	-	-
Potassium, K	mg/kg	10	-	-	-	-

Moisture Content Method: AN002

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
% Moisture	%	0.5	-	-	-	-

Total and Volatile Solids for Water Method: AN113

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Volatile Solids Ignited at 550°C	mg/L	10	-	-	-	-

Filterable Reactive Phosphorus (FRP) Method: AN278

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Filterable Reactive Phosphorus	mg/L	0.002	71	62	-	-

Total Phosphorus by Kjeldahl Digestion DA in Water Method: AN279/AN293

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Total Phosphorus (Kjeldahl Digestion)	mg/L	0.05	67	87	-	-

TKN Kjeldahl Digestion by Discrete Analyser Method: AN281/AN292

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Total Kjeldahl Nitrogen	mg/L	0.05	28	54	-	-

		Sample Number	SE115812.025	SE115812.026	SE115812.027	SE115812.028
		Sample Matrix	Water	Water	Water	Water
		Sample Date	19 Feb 2013	19 Feb 2013	19 Feb 2013	19 Feb 2013
		Sample Name	T4-1L	T4-2L	T5-1L	T5-2L
Parameter	**Units**	**LOR**				

Soluble TKN Kjeldahl Digestion by Discrete Analyser Method: AN281

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Soluble Total Kjeldahl Nitrogen	mg/L	0.05	22	33	-	-

Ammonia Nitrogen by Discrete Analyser (Aquakem) Method: AN291

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Ammonia Nitrogen, NH_3 as N*	mg/L	0.01	13	14	-	-

pH in water Method: AN101

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
pH	pH Units	-	7.5	7.3	-	-

COD in Water Method: AN179/AN181

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Chemical Oxygen Demand	mg/L	5	620	880	-	-

Soluble COD in Water Method: AN179/AN181

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Chemical Oxygen Demand (Soluble)	mg/L	5	480	410	-	-

Total and Volatile Suspended Solids (TSS / VSS) Method: AN114

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Total Suspended Solids Dried at 105°C	mg/L	5	100	290	7300	8400

Metals in Water (Total) by ICPOES Method: AN022/AN320/AN321

Parameter	Units	LOR	T4-1L	T4-2L	T5-1L	T5-2L
Total Potassium	mg/L	0.2	57	98	-	-

Ammonia Nitrogen by Discrete Analyser (Aquakem) Method: ME-(AU)-[ENV]AN291

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Ammonia Nitrogen, NH_3 as N*	LB034335	mg/L	0.01	<0.01	1 - 2%	100%

COD in Water Method: ME-(AU)-[ENV]AN178/AN181

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chemical Oxygen Demand	LB034456	mg/L	5	<5	0 - 7%	112%

Filterable Reactive Phosphorus (FRP) Method: ME-(AU)-[ENV]AN278

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Filterable Reactive Phosphorus	LB034334	mg/L	0.002	0.003	0 - 3%	95%

Metals in Water (Total) by ICPOES Method: ME-(AU)-[ENV]AN022/AN320/AN321

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Potassium	LB034367	mg/L	0.2	<0.2	0 - 2%	94%
	LB034584	mg/L	0.2	<0.2	0%	95%

pH in soil (1:5) Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	DUP %RPD	LCS %Recovery
pH	LB034527	pH Units	-	7%	99%

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	DUP %RPD	LCS %Recovery
pH	LB034484	pH Units	-	0%	99%

		Sample Number	SE116812A.011	SE116812A.012
		Sample Matrix	Water	Water
		Sample Date	19 Feb 2013	19 Feb 2013
		Sample Name	T1-1F	T1-2F
Parameter	Units	LOR		
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114				
Total Suspended Solids Dried at 105°C	mg/L	5	8200	8700
Volatile Suspended Solids Ignited at 550°C	mg/L	5	7900	9200

		Sample Number	SE116812A.013	SE116812A.014	SE116812A.015	SE116812A.016
		Sample Matrix	Water	Water	Water	Water
		Sample Date	19 Feb 2013	19 Feb 2013	19 Feb 2013	19 Feb 2013
		Sample Name	T2-1F	T2-2F	T3-1F	T3-2F
Parameter	Units	LOR				
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114						
Total Suspended Solids Dried at 105°C	mg/L	5	17000	4300	7800	8500
Volatile Suspended Solids Ignited at 550°C	mg/L	5	16000	4100	7800	7800

		Sample Number	SE116812A.017	SE116812A.018
		Sample Matrix	Water	Water
		Sample Date	19 Feb 2013	19 Feb 2013
		Sample Name	T4-1F	T4-2F
Parameter	Units	LOR		
Total and Volatile Suspended Solids (TSS / VSS) Method: AN114				
Total Suspended Solids Dried at 105°C	mg/L	5	7600	27000
Volatile Suspended Solids Ignited at 550°C	mg/L	5	6800	23000

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula: *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Total and Volatile Suspended Solids (TSS / VSS) Method: ME-(AU)-[ENV]AN114

Parameter	QC Reference	Units	LOR	MB	DUP %RPD
Total Suspended Solids Dried at 105°C	LB035270	mg/L	5	<5	5%
Volatile Suspended Solids Ignited at 550°C	LB035270	mg/L	5	<5	2%

Attention: SG ENVIRONMENTAL

SGS Reference: NM01308

Sample description: T1-1C-T4-2C

Date reported: 5 March 2013

Analysis Results

	Inherent Moisture % (air dried basis)	Gross Calorific Value (MJ/kg) (air dried basis)
T1-1C 001	11.1	17.92
T1-2C 002	9.1	21.79
T2-1C 003	11.6	17.71
T2-2C 004	11.1	18.96
T3-1C 005	11.2	19.30
T3-2C 006	12.7	18.88
T4-1C 007	12.8	17.86
T4-2C 008	11.5	18.86

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3	T. Bridle	Konstantinos Athanasiadis		Konstantinos Athanasiadis		2/05/2013
4	T. Bridle	Konstantinos Athanasiadis		Konstantinos Athanasiadis		27/05/2013

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