final report

Project code: P.PIP.0141

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Date submitted: April 2006

PUBLISHED BY
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Churchill Abattoir (CA) large scale demonstration wastewater recycling plant

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

Churchill Abattoir embarked on a water re-use strategy centred on an updated slow sand filter (SSF) to replace potable water with recycled water from the 'Pond 3' aerobic treatment lagoon for use in non-food sensitive areas. The purpose of the current project is a demonstration of a low-cost recycling system at the Churchill Abattoir therefore enabling the replacement of potable supplies of water with lesser quality water thus reducing costs, wastewater treatment, and allowing redistribution of redundant supply.

The project will achieve the purpose by employing a novel slow sand filter that has been employed. The project has been operating since January 2006 but has been limited by extrinsic factors not known at the commencement of the project.

In summary, Churchill Abattoir undertook the project based on operating parameters at that time. At the time of completion of the SSF, water quality parameters changed that led to limits being placed on the operation of the SSF. However, Churchill Abattoir has achieved a reduction in potable water use of about 11 ML/annum between January 2006 and June 2007 that can be attributed to replacing potable water with recycled water.

Enclosure 1 contains a full discussion of the technical aspects and limiting factors of the project.

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1 Overview

Churchill Abattoir Management Pty Ltd (CA) had investigated several wastewater recovery options over the past few years to minimise potable water use. The QLD Dept. of State Development identified and recommended a Gold Coast company that had achieved success with a 'slow sand filter' system. CA investigated the system and found that it was an improved, modified version of extant 'sand filter' technology.

Simplistically, the slow sand filter uses a gravel sand layer mix to provide the 'bed' for an active sludge layer. The innovation is the layer arrangement and mix of sand types/grading that minimise the sludge build-up common to traditional sand filter technologies. It also means that backwashing is not required allowing the bacteria to operate on a continuous basis.

CA sought a quotation to provide a 10 year design life and a minimum of 3 L/s flow to replace potable water in the boiler, condensers, and wash areas. The essential elements of the system are: sand filter, storage, secondary carbon filter, disinfection, pumping, and delivery systems.

Preliminary work has been undertaken by CA in preparation for this project.

This includes:

1. An investigation and the design of a suitable slow sand filter for CA; and
2. Installation of the slow sand filter including earth works, pump and gravity feed from pond, wells, power board, and filter media. In addition, an electronic flow meter on the feed supply has been installed.

2 Project Description

The aim of the project is to replace potable water with recycled water using a slow sand filter (SSF).

There are three prime objectives of the project:

1. Install a slow sand filter treatment system that delivers usable recycled water from Pond 3;
2. Install a recycled water reticulation system; and
3. Use recycled water to replace potable water in the boiler, condensers, gut wash, truck wash, yard wash, cattle wash, belly wash, and other areas as the opportunity arises to a volume of 60ML/year

Figure A-1 (Appendix A) represents Churchill Abattoir's waste management system and shows a three pond system with all liquid wastes to irrigation/cropping. The plan was to install a Slow Sand Filter (SSF) after the 3rd pond as shown in Figure A-2 (Appendix A).

There are four Milestones to this project as follows:

Milestone 1: Design and Installation - comprising:

a) **Project Design and Supervision**. Install pump, reticulation system to key areas: includes all pipework, connectors, general non-return valves, terminals, ball valves. Recondition existing 100 kL DAF tank to water storage, connect to reticulation.

b) Supply and install 2-way automatic, non-return valve to condensers.

c) **Install and commission Flow Meters**.
d) Install PLC, controls, cabling, clean room, connect to SCADA.

Milestone2: Monitoring

Monitor quantity and quality from filter system and monitor boilers and condenser operation. Pond 3 feed water is to be monitored by grab sample at least three times during this period. Filtered water is to be sampled (composite daily) on a fortnightly basis.

Milestone 3: Draft Final Report

Generate a draft final project report. The report will summarise the actual flow rate experienced by the filter, a description of filter performance during the project, methodology and results of testing.

Milestone 4: Final Report

Produce final report and other deliverables.

3 Project Implementation

3.1 Preliminary Work

The purpose of the project is to trial a low-cost recycling system at Churchill Abattoir. Churchill Abattoir undertook pre-requisite preliminary work that included the sand filter; primary waste/recycled water delivery, and storage. Figures 1 show the installation process of a SSF approximately 20 x 10 x 2m. The SSF is a plastic sheet sealed unit with a gravel base containing perforated pipe connected to a sump at either end (raw inlet –treated outlet), geofabric forms a top and bottom layer to contain the sand with gravel and pipes in the top layer as shown. The whole unit is designed to contain and treat all raw water and exclude seepage into and out of the filter.

Figure 1: Slow Sand Filter

The 2-way valve allows the water to be directed to the storage tanks or returned to the Pond 3 lagoon. The filter was supplied using 2 x 50mm suction lines: 1 x siphon, and 1 x pumped. The pump was used to maintain a flow of approximately 4 L/s.
A single 20,000L storage tank was installed as part of the contract. Churchill Abattoir then undertook to install another 4 tanks to increase the storage capacity to 100,000L. The supply line to the tanks consists of 2 x 50mm poly and 1 x 75mm poly as a spare line. The optic fibre cable was laid at the same time as the poly and the trench backfilled and is connected to the filter and pump power board to allow remote flow control.

The Carbon Filter was installed prior to the treated wastewater entering the storage tanks. The Carbon Filter has a capacity of approximately 3000L and contains activated carbon. The role of the Carbon Filter was to remove any fine particles remaining.

3.2 Milestone 1: Design and Installation

There are four components to the first Milestone and are discussed individually.

1a. Project Design and Supervision. Install pump, reticulation system to key areas: includes all pipework, connectors, general non-return valves, terminals, ball valves. Recondition existing 100 kL DAF tank to water storage, connect to reticulation.

The preliminary work fell short of providing reticulation to all areas and also fell short in providing adequate storage and volume/pressure delivery. To this end an extensive reticulation system was installed as part of the project. Pipework is painted purple as standard purple pipe was not available. Over 200m of reticulated pipework was installed in the plant. An additional task involved disconnecting existing water supply pipe form the potable supply and connecting to the recycled mains (this also included painting the galvanised pipe purple).

Churchill Abattoir had an existing 100 000L DAF tank that was no longer operable. Although CA had added an extra 90 000L storage, additional storage was required. The existing DAF tank was ideally located and took up less space than adding additional smaller tanks. The old DAF tank was cleaned out, treated for rust and epoxy coated internally. A pump was purchased to provide the volume and pressure required for the additional uses and locations for the recycled water.

While Milestone 1a has effectively been achieved; however, additional work beyond that specified in the Milestone is still being done to accommodate changes in the design.

1b. Supply and install 2-way automatic, non-return valve to condensers.
This valve to the condensers has yet to be installed. One valve has been installed to the boiler feed line.

Milestone 1b is yet to be achieved.

1c. Install and commission Flow Meters.
A flow meter (2” ABB) was purchased and installed on the outflow of the SSF and measured approximately 4L/s over a period of several weeks. The meter was located on the return outflow pipe to Pond 3.

Milestone 1c has bee partially achieved.

1d. Install PLC, controls, cabling, clean room, and connect to SCADA.
Fibre Optic cable was laid in the ancillary line from the SSF to the primary storage tanks, thence to the main hub and 'clean room'. The cable and facilities are installed but the cables have yet to be terminated. CA is awaiting advice on a PLC make and associated software.

Fibre optic cable was laid to the SSF, Tank Power Board and was terminated at the plant workshop. The concept was to link into an existing PLC to allow operation of pumps remotely. Circumstances prevented the final connection to allow remote control and is discussed later.

Milestone 1d has been partially achieved. Final connection is part of a larger control system and is partially complete.

4 What was Achieved

The Performance Indicators for the project are essentially:

a. Infrastructure;
b. Water Savings, and
c. Water Quality

4.1 Infrastructure

All the essential system elements for Milestone 1 identified in the project proposal, apart from the final computer connection for the remote control of pumps, and a two-way valve, have been installed. While we have one flow meter, additional flow meters are to be installed when the SSF is back on line and a decision on the best monitoring locations is decided. The QLD WEMP project will have an influence on this decision.

The SSF achieved the design flow rate of approximately 4L/s measured using an ABB Flow meter.

4.2 Water Savings

Comparing the periods 1 Jul 2005 – 30 Jun 2006 and 1 Jul 2006 – 30 Jun 2007, water usage dropped about 11 ML during the 06/07 financial year. The pressure to implement water savings arising from the Government WEMP initiative did not impact until about May 2007. While the full range of water savings originally envisaged was less than expected, 11 ML remains substantial.

Figures 10 and 11 show the reductive trend in water use commencing Jan 2006 when the SSF effectively came on line. Apr and May 2007 delineate the introduction of a concerted effort to meet WEMP targets. Larger water savings are envisaged when the boiler and condensing towers come on line. However, 11 ML is still a substantial saving due to the SSF.

Figure 10 – Water Reduction Charts (kL/t HSCW

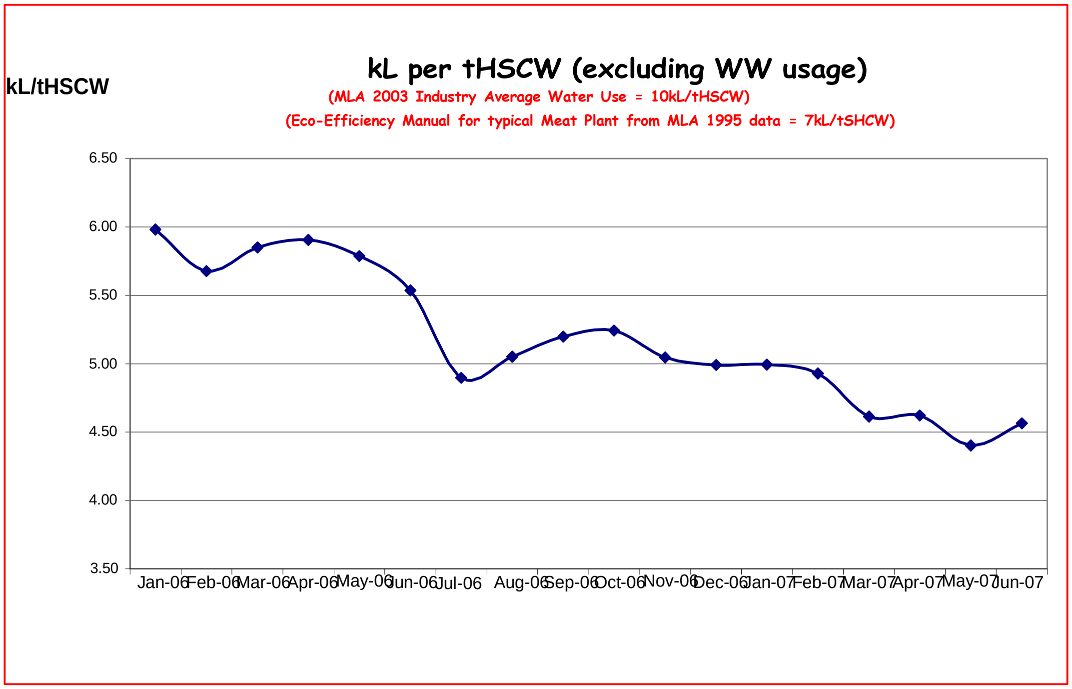
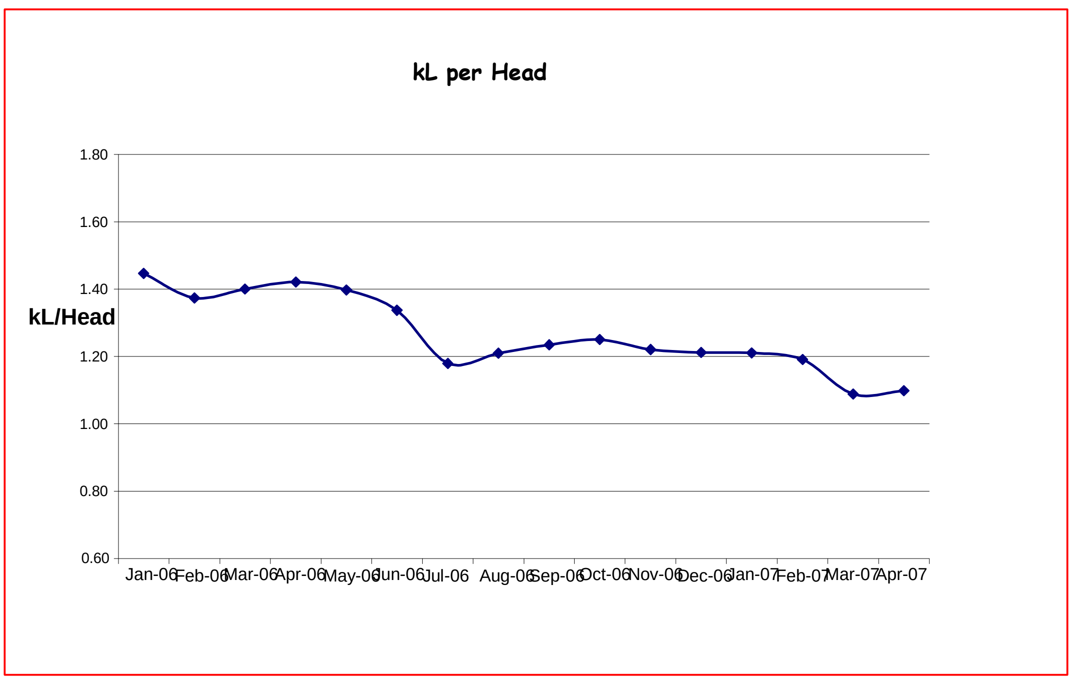


Figure 11 – Water Reduction Charts (kL/Head)



4.3 Water Quality

Table 1 shows analytical results undertaken by Buckman Laboratories in late July 2005 when the SSF had been in operation for a about one month. Churchill Abattoir was advised that the filter would only become effective after 3 – 6 months continuous operation. However, it was apparent that the SSF removed Oil and Grease and a percentage of Suspended Solids (200 – 157 mg/L). While Turbidity was reduced, pH, and EC remained relatively constant as expected. It was believed that Total N should have been significantly reduced but this did not occur.

Table 1: Initial Trial Data

Sample ID **Units**	**pH**	**Cond** **(*u*S/cm)**	**Turbidity** **NTU**	**Total N** **(mg/L)**	**SS** **(mg/L)**	**Oil and Grease** **(mg/L)**
3rd pond (influent)	7.7	3720	458	394	200	20
SSF Effluent	7.5	3660	270	296	157	<2

Figure 12 is a visual comparison of water quality in July 2005 of pre- and post-SSF. Both samples have been shaken to enable the visual characteristics to be identified. The discolouration in both samples is due to Green Algae (Chlorophytes) and Blue-Green Algae (Cyanophytes). It is evident that the post-SSF sample is much clearer than the 'Raw' sample although the post-SSF sample still shows discolouration.

Figure 12 – Initial Visual Quality Comparison

A total algal count was performed by Queensland Health (QHSS) in September 2005; the results are as follows (Table 2):

Table 2: Total Algal Count QHSS (QLD Health)

	Raw (Pond 3) SSF Input	SSF Output
Chlorophytes (cell/mL)		
Monoraphidium spp.	3750	
Unicellular green algae	3096357	
Scenedesmus spp.	170	
Cyanophytes (cells/mL)		
Merismopedia spp.	804528	
Total (*Chroococcales*)	805000	
Total Cells per mL	3920000	4730000
Chlorophyll a (*u*g/L)	1900	1800

The Total Algal Count included Chlorophytes and Cyanophytes as shown in Table 2. The Cyanophytes were reported as non-toxic. Further algal counts and quality testing was discontinued as ‘Raw’ water quality continued to deteriorate. This is discussed in the following section. Separate species counts were not done on the SSF output but it is concluded that the Cyanophytes and unicellular algae were not trapped in the SSF.

The data shows that the SSF achieved a good reduction in oils and greases and a reasonable reduction in Turbidity as shown in Table 1. This data was prior to a Carbon Filter being installed in Jan 2006. The water quality was good enough for boiler and condenser use except for Turbidity as these will affect boiler and condenser performance. On advice, it was believed that the ‘algae’ would be removed by an activated carbon filter. The carbon filter was sized accordingly but only achieved partial success as it quickly became overloaded.

Since January 2006, the concentration of ‘algae’ has increased by several magnitudes, overloading the carbon filter, and has meant that we could not use the recycled water in the boiler or condensers. The algal bloom was caused by Ponds 1 and 2 being highly overloaded thus resulting in higher levels of nutrients moving into Pond 3. This aspect of the whole system was not recognised by the proponents of the SSF.

5 What affected the results

After investigation and on professional advice, the original concept of using a SSF to treat wastewater was sound and, in the absence of any industry specific data, was implemented. However, several issues arose that affected the operation of the SSF and are discussed below.

5.1 Algae

Algae has been discussed above and is a significant factor in where the recycled water can be used. Professional advice was that a carbon filter would remove algae but the mass of algae was too great for the carbon filter. A carbon filter larger by at least a factor of ten would be required. This was not an option. At January 2005 the algae had started to increase with the build up of organics in the first two primary ponds. This allowed more nutrients and hence algae to increase.

5.2 SSF Collapse

In November 2005 an inexplicable event occurred where flow out of the SSF reduced to a trickle. Normal flow was about 3 – 4 L/s. It is unresolved as to the 'how' and 'what' happened but the result was that the top layer of the SSF became clogged with what appears to be clay minerals as shown in Figure 13; note the algal discolouration of the 'Raw' influent. The SSF was cleaned by removing the top layer and re-applying the geotextile layer and gravel. The SSF was repaired and re-commenced operation in February 2006.

5.3 Pond Overloading

With a change in staff in early 2006 the algal issue was recognised and plans to remediate the treatment ponds were put in place. A permanent dredge ('Sludge Rat' ™) was purchased to desludge Ponds 1 and 2 thereby reducing nutrients reaching Pond 3. Pond 2 was finished in about November 2006 with Pond 1 finalised in May 2007. Figure 14 shows the 'Sludge Rat' in operation in Pond 2.

The sludge was pumped into a series of trenches (Figure 15) approximately 1 km long by 3 m wide and 1 m deep. This system worked well with the sludge settling into the trenches and the desludged supernatant being collected in a sump and pumped back into the pond. The sludge was allowed to dry and eventually removed.

Since the 'algae' has been well established, re-conditioning Ponds 1 and 2 was insufficient by itself. Algal control measures are also required. The options include chemical and/or mechanical intervention. These measures are currently being investigated.

While algal control is being investigated, the quality of Pond 3 SSF feedwater has deteriorated. It will take some time to return Pond 3 back to a well maintained aerobic state at which time it is expected that algal blooms will again occur.

5.4 Struvite

Struvite is a crystal of magnesium, ammonia, and phosphorus. Figure 16 shows the crystalline formation in a siphon line to the SSF. It has not been substantively established that the crystals are Struvite but observation from other industries suggests that it is more than likely Struvite. Regardless of its naming, the crystals have formed in pipes, pumps, and all other surfaces. This has meant that the SSF has been suspended until a solution to remedy the situation has been found. The Struvite crystals have seized the irrigation and other pumps. It is believed it is not prudent to continue at this time.

Experience from other sites where Struvite is an issue suggests that it is found where wastewater is recycled from treatment ponds; e.g., flushing of pig sheds. Whether this is the case in this instance is yet to be proven. A plan to resolve the issue is discussed later.

Crystalline 'Struvite' Build-up

6 What have we learnt?

There are several major lessons to be learnt from this project.

6.1 Project Development

The project came highly recommended and previous Churchill Abattoir staff investigated the technology that proved to be highly successful in the domestic sewage treatment arena. Data previously provided shows that the treated water is effectively pathogen free to drinking water standards.

What were not taken into account were a. the level of algae in the water, and b. the effect of mineral concentration after recycling. Another issue was the variability in pond operation. It is still unproven how the SSF would perform if the algal and Struvite issues did not exist. Pond 3 has become less effective due to the extra loading when Ponds 1 and 2 were out of commission but there has not been the opportunity to test the SSF hypothesis while the pumps and lines are blocked with Struvite and/or algae remains in Pond 3.

A bench test would have been preferable prior to the demonstration project.

6.2 Abattoir Pond Sludge

While there probably exists industry experience in the properties of pond sludge, local plant experience was in piggery, cattle, and sewage sludge properties. It was believed that Pond 1 was overloaded (and there was sufficient evidence that this was the case), and consequently Pond 2 was also overloaded. This resulted in excess nutrients moving into Pond 3 and creating odours from ponds 1 and 2. From a commissioned survey of Ponds 1 and 2, it was shown that the sludge layer was close to the surface in Ponds 1 and 2.

Pond 2 was desludged using a ‘Sludge Rat’™. The operation was successful using trenches. It was noticed that the sludge was colloidal when pumped and in some instances formed small balls of sludge. The sludge settled to the bottom of the trenches separating from the supernatant that was reasonably clarified. The supernatant was collected in a sump and pumped back into the ponds. The sludge had no odour. A side effect was that it did stir up the pond and some sludge escaped into Pond 3. SSF operations were halted during this period. The ‘Sludge Rat’ ™ and the trench system proved very successful.

Pond 1 was desludged next. It was believed that Pond 1 would have a substantial compacted sludge layer. Additionally, the organic filter layer on Pond 1 consisted of thick layers of straw, fat, and other material to form a crust to filter pond odour. For these reasons Pond 1 was isolated and the ‘loose’ sludge pumped into the trenches prior to de-water the pond; the concept being to excavate the ‘hard’ sludge. It was found that the ‘hard’ layer was minimal. As much sludge as possible was pumped out and the pond reinstated as at July 2007.

6.3 Fats and Clays

We found that both unprocessed (i.e., raw tallow) fat, and clay minerals will disrupt the functioning of the SSF. It is imperative that the fat and other material be monitored to avoid clogging the SSF. Domestic situations are different from industrial applications such as an abattoir. Thus, raw effluent must be pre-treated prior to SSF treatment to break down fats; and clay minerals must be kept away from the SSF such as fixing the height of foot valves.

6.4 Struvite

Struvite has disrupted the use of wastewater from Pond 3. It is likely that the SSF may be compromised by Struvite. Churchill Abattoir is embarking on a pre-treatment system to extract Struvite from Pond 3 prior to SSF treatment. Construction of this system has recently commenced.

Pump cleaning with six types of acid was trialled. Formic Acid from Buckman Laboratories proved to be successful in softening the Struvite. The difficulty is that long supply pipes are difficult to treat in this way. Some success was had by high pressure pumping of the lines. Where small nozzles are used in various applications the Struvite particles clog the apertures that require constant cleaning.

6.5 Algae

Algae have no effect, *per se*, on the SSF and the SSF has no effect on most algae (notably cyanobacteria). Algae limit the use to which the wastewater can be put. Churchill Abattoir has recently commenced a project to minimise algal growth in line with Struvite minimisation.

6.6 Carbon Filter

The Carbon Filter did not perform as expected. The algal load was far too much for the filter to be effective. The algal population must be reduced prior to the SSF but chemical means are contraindicated as chemicals would likely harm the effectiveness of the SSF organisms.

6.7 DAF Tank Reconstruction

The old DAF Tank had about 1 – 2m of partially composted tallow and other solid waste material compacted in the bottom of the tank with large fatty deposits on the walls. The entire internal wall area was significantly rusted.

Removal of the tallow was labour intensive as the opening to the tank was small. Once emptied and all excess tallow removed, the internal walls and floor were treated with Phosphoric Acid followed by Tannic Acid. Both products are readily available at most meat plants. Rust conversion had to be investigated and advice was received from Buckman Laboratories. It was found that there are many rust treatment solutions offering varying results. The Phosphoric Acid penetrates the deeper rust deposits aggressively but the Tannic Acid provides a final 'conversion' of the rust. The treatment worked exceptionally well.

The tank was then painted with a food grade epoxy resin. The tank was then covered to exclude birds and other foreign material.

7 How could we do it better?

The major lessons of Struvite and Algae indicate that either the wastewater for SSF treatment must be limited in these elements or the wastewater should be fed directly from, in our case, Pond 2. This may not necessarily be sound, as the recycling of the wastewater may increase the concentrations of metallic ions and phosphorus.

Mechanical removal of Struvite and aeration to remove or limit algal growth is indicated.

8 What are we going to do?

Work has commenced on an algal aeration and mechanical Struvite reduction system that is due for completion in about mid- to late September. Once this system is in place monitoring of the performance of the SSF can recommence.

Investigation into an appropriate PLC and software has commenced and CA is awaiting technical advice prior to connection of the optic fibre cables.

9 Conclusion

We believe that the MLA partnered project is an important development at Churchill Abattoir. While this report could be entitled ‘a series of unfortunate events’, there have been a number of important discoveries concerning wastewater, pond management, and water re-use that had not been known or easily recognisable as available prior to the project commencing. It is believed that this project has focused attention on the holistic operation of the wastewater treatment system rather than individual components.

Smooth introduction of the SSF has been hampered by a suite of extrinsic factors, primarily algal loads and Struvite, not known at the time the project commenced. While recycled water is being used, the full results are yet to be realised. Plans are in place and have commenced to remedy the issues holding back full use of the recycled water.

Recycling water has an immense impact on the viability of not only this abattoir but industry in general. The project has focused attention on our primary water usage but has delivered water savings in excess of 10 ML/year. Churchill Abattoir will continue with the project to remedy the inhibitors to fully achieve the project outcomes.