final report

Project code: P.PIP.0730

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Date published: 19 January 2018

PUBLISHED BY
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Investigation into alternative wastewater treatment options for a large beef processing facility – Stage 1: Current State Investigation

This is an MLA Donor Company funded project.

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

Executive Summary

The Teys Naracoorte beef processing facility currently operates an open anaerobic lagoon and a downstream aerobic lagoon to biologically treat its wastewater. These two lagoons have treated the wastewater for a number of years, but recent wastewater samples out of the aerobic lagoon indicate that treatment performance may be falling in these ponds. At the same time, the facility has experienced a significant increase in the cost of electricity and natural gas. The purpose of this project was to evaluate the condition of the existing system and investigate the feasibility of a number of different wastewater treatment options and their potential for biogas generation and use for energy displacement.

A sludge survey of both the anaerobic and aerobic lagoons was undertaken by Johns Environmental. This revealed that the anaerobic lagoon has lost approximately 40% (9.3ML), and the aerobic lagoon 27% (54ML) of their working volume. The loss is due to a combination of a surface crust (especially in the anaerobic lagoon) and an accumulation of a sludge layer in both ponds.

In the anaerobic lagoon, the crust and sludge layers appear to comprise a combination of paunch solids and oil & grease. This suggests that the primary treatment system is not working properly to capture excess paunch solids. The conclusion of the sludge survey was that the anaerobic pond has a limited remaining lifetime, and if it is not replaced shortly even greater quantities of solids may be carried over into the aerobic pond, further reducing its remaining lifetime. It is recommended that the anaerobic lagoon be replaced as part of Stage 2 of this project.

A geotechnical survey was performed by FMG Engineering in June 2017 to determine the integrity of the existing walls of the anaerobic and aerobic lagoons as well as the suitability of the surrounding ground for the construction of a new anaerobic lagoon. This included investigation of soil conditions in two decommissioned lagoons to the east of the existing anaerobic lagoon and also in an area to the north of these lagoons ("new area").

The survey confirmed the surface geology of the two sites being considered for a new anaerobic lagoon. Essentially it found that there is an area of Gambier limestone in the east part of these sites adjacent to Parilla Sand to the west. No groundwater was observed in any of the test pits or boreholes, although this does not exclude the possibility of localised areas of perched watertable.

The geotechnical report contains additional test information concerning the properties of the soils and sub-soils in the areas investigated. A visual examination of the walls of the existing anaerobic lagoon suggested some damage of concern including tree root penetration, and erosion with particular damage to the northern wall.

A cost benefit analysis (CBA) was completed to calculate the feasibility of constructing a new, covered anaerobic lagoon (CAL) with and without biogas combustion in a cogeneration system for electricity production. The CBA also looked at whether it was beneficial to undertake such an upgrade now, or delay capital expenditure for a period of 5 years.

The CBA concluded that construction of a new CAL is advisable sooner rather than later (taken as 5 years' delay) due to the considerable cost to remove sludge discharged from the

existing anaerobic pond which is accumulating in the eastern deeper part of the aerobic dam where both inlet and outlet are located. It is probable that the sludge accumulation in the aerobic dam will contribute to non-compliant treated effluent and potentially odour if the quantity discharged from the anaerobic pond is not reduced.

The CBA also showed that construction of a CAL with cogeneration would displace electricity, repaying a portion (but not all) of the capital expenditure. However, considering that an upgrade to the wastewater treatment plant is necessary due to the diminishing lifetime of the existing lagoons, the displacement of mains electricity with biogas is still quite attractive. This is especially the case considering the uncertainty in the Australian energy market. South Australia has experienced a considerable rise in the cost of electricity and natural gas in the past 2 years. Having access to an on-site source of electricity also provides the facility with some security and reduced reliance on a potentially unreliable mains electricity network.

If Teys Australia are able to defray the capital cost of the cogeneration system through external funding, the project is financially more attractive than the construction of a new CAL without a cogeneration system.

Considering all of this as well as the cost of remedial works required if the upgrade were to be delayed 5 years from now as well as the implications of the time value of money, our recommendation is that it is best to commence the upgrade as soon as possible and that the combination of a new CAL with cogeneration provides the most economic outcome.

Table of Contents

1 Background

Teys Australia [Teys] have a large beef processing facility located in Naracoorte, SA. The wastewater treatment plant for this site currently consists of an open, anaerobic lagoon (lined with a 0.5 mm polypropylene liner on a compacted clay base) and a separate downstream unlined aerobic lagoon. These two lagoons have treated the wastewater from the meat processing facility for a number of years (the anaerobic pond is of the order of 17 years), but recent wastewater samples out of the aerobic lagoon indicate that treatment performance may be falling in these ponds.

At the same time, the facility has experienced a significant increase in the cost of electricity and natural gas. The purpose of this project is to evaluate the condition of the existing biological wastewater treatment system and investigate the feasibility of a number of different wastewater treatment options and their potential for biogas generation and use for energy displacement.

Stage 1 constitutes the pre-engineering for this project, which consists of three parts:

1. A sludge survey of the existing lagoons to determine remaining useful life,
2. A geotechnical survey of the integrity of the existing anaerobic lagoon and the potential sites for construction of a new lagoon, and
3. A cost benefit analysis to look at the economic feasibility of the construction of a new lagoon with biogas generation and use.

The overall objective of this work was to inform subsequent decision making as to the benefits or otherwise, of replacing the existing anaerobic lagoon with a new potentially covered anaerobic lagoon and indicate the most suitable timing of any such replacement.

This report is written as an overarching document which captures the main conclusions from the three components of the work. More detailed information and the specialist interpretations associated with it are found in the original reports (the sludge survey (by Johns Environmental) and the geotechnical investigations (by FMG Engineering)). Reference to these documents is essential before relying on the information contained in this document.

2 Projective Objectives

The objective of this stage of the project is to assess the current state of the current wastewater treatment system as a critical input to desktop modelling of any new or remedial development. This assessment will include:

- Determine volume, density and profile/stratification of sludge (bottoms solids) accumulation and distribution, and floating crust thickness and distribution to inform the 'free' water volume available for anaerobic treatment;
- Determine available hydraulic capacity, and therefore retention time of waste water, using wastewater flow data and volume calculations; and
- Determine the effectiveness of the current waste water treatment process.

3 Methodology

3.1 Sludge Survey

Sampling was conducted by Johns Environmental (JE) personnel on both the anaerobic and aerobic pond using a flat-bottomed punt over a two day period in March 2017. The punt was manoeuvred on crusted surfaces (the entire anaerobic pond and a portion of the aerobic pond) using a tractor and rope and with paddles on open water (most of the aerobic pond).

Safety is paramount for both JE and Teys Australia Naracoorte. JE completed the testing under a Safe Work Method Statement safety protocol assessed and approved by Teys Australia prior to work on-site beginning. JE staff also completed the Teys Site Conditions for Contractors.

3.1.1 Anaerobic Pond

The anaerobic pond sampling was conducted at 19 inspection sites in a grid as shown schematically on Figure 1. A handheld Garmin GPS unit identified the site location. The inlet end is on the eastern side and the outlet end on the western side.

At each site, a section of crust was removed using a long handled shovel. The thickness of the crust above and below the waterline was measured and the general description of the crust noted.

The sludge present in the water column at each site was measured using a Royce TSS meter to measure suspended solids. The suspended solids was recorded every 0.5m depth interval as the sensor bob was lowered through the pond. The depth was recorded where a step change in the Royce measurement exceeded the upper measureable limit of 10 g/L. A second depth was also recorded where the measurement bob detected a solid base.

The sludge from the base of the water column was sampled at six sites across the pond using an interval bomb sampler. Additional samples were also collected, one from within the water column and one of the anaerobic pond effluent. These samples were analysed for total solids, volatile solids, nitrogen and phosphorus concentrations.

3.1.2 Aerobic Pond

The aerobic pond sampling was conducted at 28 inspection sites at locations identified by the Garmin GPS handheld device as shown schematically on Figure 2. The inlet pipeline is at the south east corner and the pumped outlet is at the north east corner. At each site the pond depth was measured by gently lowering a metal rod until firm resistance occurred. This was assumed to measure the excavated pond depth.

The sludge present at 13 sites was measured using a Royce TSS meter to measure suspended solids. The suspended solids was recorded every 0.5m depth interval as described in Section 3.1.1.

Figure 1. Sampling Sites on Anaerobic Pond

Figure 2. Sampling Sites on Aerobic Pond

The sludge from the bottom of the pond was sampled at five sites across the pond using a bomb sampler. Additional samples of surface sludge were also collected at three sites close to the pond inlet. These samples were analysed for total solids, volatile solids, nitrogen and phosphorus concentrations.

The water chemistry in the aerobic pond was also analysed onsite using a Hydrolab MS5 minisonde that measured pH, EC, temperature, ORP and turbidity at 0.5 meter intervals as it was lowered through the water column.

3.2 Geotechnical Investigation

FMG Engineering were commissioned to conduct a geotechnical investigation of the site which included the old, decommissioned anaerobic lagoons (to east of existing one), the proposed site of a new anaerobic pond to the north and the materials search area. The work was performed on 19th – 21st June 2017.

The methodology involved drilling test boreholes to provide relatively continuous core samples of the ground and excavating test pits. Samples were tested for:

- Atterberg limit & particle size distribution and Emerson test (by FMG Engineering); and
- Permeability testing by Ground Science Laboratories (3 samples).

3.3 Cost Benefit Analysis

The cost benefit analysis for Stage 1 of the project involved looking at the Net Present Value (NPV) of two different scenarios. The two scenarios were the construction of a new, lined, covered anaerobic lagoon with no cogeneration and the construction of a new CAL with biogas being sent to a cogeneration system for electricity generation. Within these two scenarios, the CBA investigated the implications of either undertaking the project now, or waiting for a period of 5 years to undertake the project.

Both scenarios were prepared using standard cost benefit methodology with annual time-steps out to 20 years of operation (estimated project lifetime). Capital expenditure (CAPEX) for each scenario was spent over two years (the construction phase), before operation of the WWTP commences, resulting in positive revenue in the form of electricity savings as well as operational expenditure (OPEX) in the form of labour and maintenance. Savings due to hot water generation from the cogeneration system were not considered as part of the CBA. Additional costs were applied to the sub-scenarios in which the project is delayed 5 years to account for the desludging costs associated with the removal of accumulated material from the aerobic lagoon.

The savings and OPEX combine to form the Earnings Before Interest, Tax, Depreciation and Amortisation (EBITDA). Taxation, interest, depreciation and amortisation are not considered as part of this CBA. Strictly speaking, there are no actual ‘earnings’ associated with this project, but rather savings due to reduced electricity expenditure. Nevertheless, the term ‘EBITDA’ is used in this CBA.

Capital costs for the CAL were estimated using JE in-house knowledge and experience with the design and installation of a number of CALs for large meat processing facilities in Australia. Capital costs for the primary system (screw press) as well as the biogas cogeneration system were estimated using supplier quotes for a microturbine system. Allowances were made for project engineering and supervision, as well as expenditure required to obtain the necessary regulatory approvals. A contingency as a percentage of the raw equipment cost was also included.

A discount rate of 7% was used as per the MLA CBA Guidelines to account for the time value of money and opportunity cost of the investment. It was assumed that operating costs increase at the Reserve Bank of Australia’s target rate for inflation, 2.5%.

Dr Stewart McGlashan of Thixo Pty. Ltd. Provided electricity and natural gas pricing forecasts out to 2037 based on data from the Australian Energy Market Operator (AEMO).

4 Results

4.1 Sludge Survey

4.1.1 Anaerobic Pond

This section presents and discusses results from the sampling of the large anaerobic pond at Teys Naracoorte. This pond has a design volume of approximately 23.8 ML to top water level. The reader is referred to the cross sections provided in Appendix 7.1.1 which shows the relative distribution and depth of the various layers in the pond – crust, free water, active sludge and inactive solid sludge. The raw sampling data for the anaerobic pond is provided in Appendix 7.1.2

Crust

The anaerobic pond had the typical uneven crust layer across the entire surface. Vegetation was dense on the outer edges with the vegetated width being approximately equal to the wall batter on the pond base.

Photo 1. Anaerobic Pond Crust Sampling

The crust thickness at the inlet end transect (sites 1 to 4) was greater than the length of the shovel handle (1.5m) with the holes unable to penetrate to the free water volume at sites 2 and 4. The overall crust thickness decreased to 1m at the second transect and then averaged approximately 0.8m for the rest of the pond. Figure 3 shows a 3D schematic of the crust layer. Cross sections showing crust and other layers are also provided in Appendix 7.1.1.

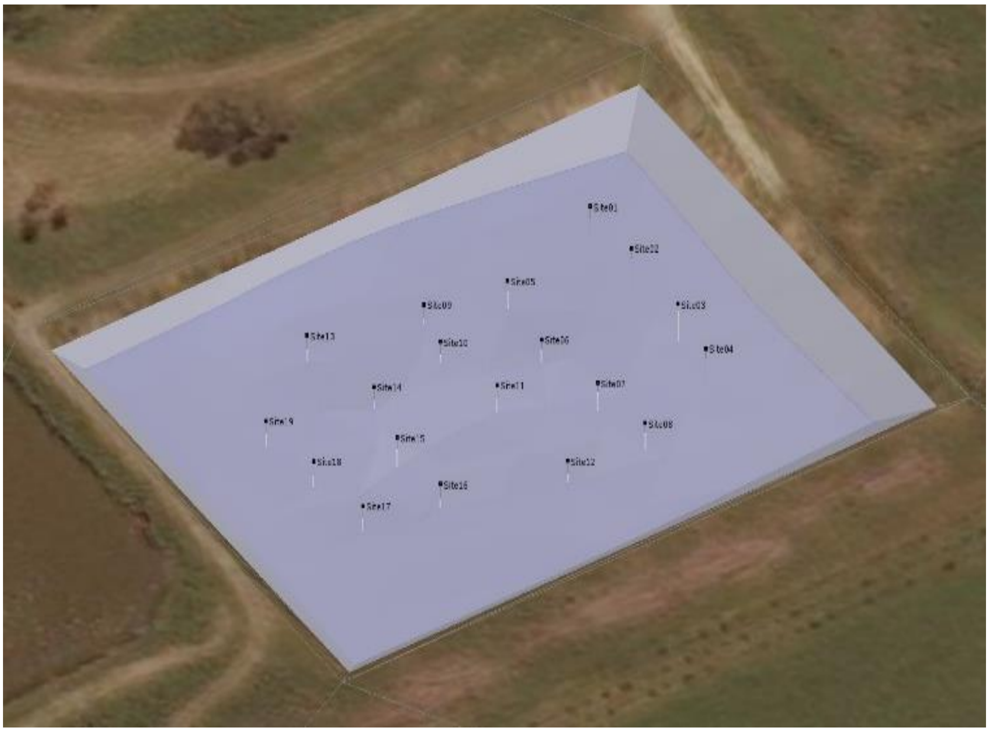

Figure 3. 3D schematic of surface crust on the anaerobic pond. Crust depth is indicated as the vertical difference between the curved dark purple surface and the top of the light purple area (only shown on outer banks).

Under the dry, grey crust surface, the majority of the subsurface crust had a yellow appearance and a firm to soft even texture (Photo 2). The crust increased in dryness and hardness towards the inlet end. There were some sites that had a black fatty surface crust layer and some where the crust was particularly odorous.

Photo 2. Typical Anaerobic crust

The approximate volume of the total crust layer is 7,400 m^3 with approximately 6,000 m^3 below the waterline displacing wastewater treatment volume.

Inactive Solid Sludge Layer

Accumulated sludge forming an inactive solid sludge layer was measured across the base of the anaerobic pond.

The thickness of the inactive solid sludge layer varied. It was calculated as the difference between the top of the layer (as measured by the depth at which the Royce bob could penetrate no deeper) and the design depth of the pond (5.0 m). The following general trends were observed:

- Thick deposits were found at the inlet end possibly due to heavy solids settling below the inlets.
- There was no solid sludge layer along the 2nd transect possibly due to the high anaerobic activity in the area.
- The depth of the inactive solid sludge layer increased from the 2nd transect towards the outlet end.

The approximate volume of the inactive solid sludge layer is 3,300 m^3 as estimated using Leapfrog software and displaces wastewater treatment volume. No samples could be retrieved for this sludge due to its thickness and challenge of getting samples through the crust. Nevertheless, the TS, TN and TP concentrations of this layer is probably at least that of the active sludge layer or more, since the sludge samples taken for the active sludge (see next section) were taken near the top of the inactive solid sludge layer.

Active Sludge Layer and Free Wastewater

An active sludge layer with suspended solids greater than 10 g/L (1% TS) was observed across the anaerobic pond at a relatively uniform depth of 1.8m ± 0.2m below the waterline as usually observed in other anaerobic ponds. The interface between this layer and the overlying free wastewater layer is sharp. It is probable that this interface is close to the depth of the outlet pipe and may result in large concentrations of solids exiting in the discharge from time to time. This layer is not considered to hinder the anaerobic capacity as it is fully engaged in the wastewater treatment process.

The results from the 7 samples of this active sludge layer are presented in Table 1 and depicted in Photo 3. The solids resemble paunch material and are not the characteristic black anaerobic sludge typically found at these depths in other anaerobic ponds. The total solids for the majority of the active sludge layer across pond is approximately 6%. The higher value at Site 3 is probably because of the inclusion of grit material settling at the inlet end. The volatile solids fraction was generally low and increased towards the discharge.

The sludge samples taken at the base of this layer are likely to be similar to the inactive solid sludge layer. They show total nitrogen and phosphorus contents of 2 – 4% and 0.9 – 4%, respectively.

The approximate volume of the active sludge layer is 9,000 m^3 and can be considered part of the active treatment volume.

Table 1. Laboratory Analysis of Sludge Samples in Anaerobic Pond

Parameter	Unit	Site 3	Site 8	Site 12	Site 13	Site 15	Site 15	Site 19
TS	%	13		5.7	6.0		6.5	
VS	% of TS	7.2		7.0	29.1	20.0	21.0	27.9
TN	mg/kg		42,800			21,900		23,400
TP	mg/kg		39,200			9,210		13,100

Photo 3: Typical sludge appearance from anaerobic pond

The free wastewater is the layer of wastewater in the pond under the crust and above the active sludge layer. The TSS concentrations in this layer was an average of 1.8 g/L in the more active zone along the 2nd transect (where no inactive solid sludge layer existed) but relatively uniform throughout the rest of the pond at 0.8 g/L. The free wastewater had an approximate volume of 5,500 m^3.

Anaerobic Summary

Figure 4 below shows a cross-section along the anaerobic pond. The various layers are:

- crust layer (green),
- free wastewater layer (blue),
- active sludge layer (cream) and
- inactive solid sludge layer (orange).

The most significant observations are:

- The very thick crust at the inlet end
- The generally flat top surface of the active sludge layer,
- The varying quantities of inactive solid sludge with higher depths at the inlet and outlet ends.

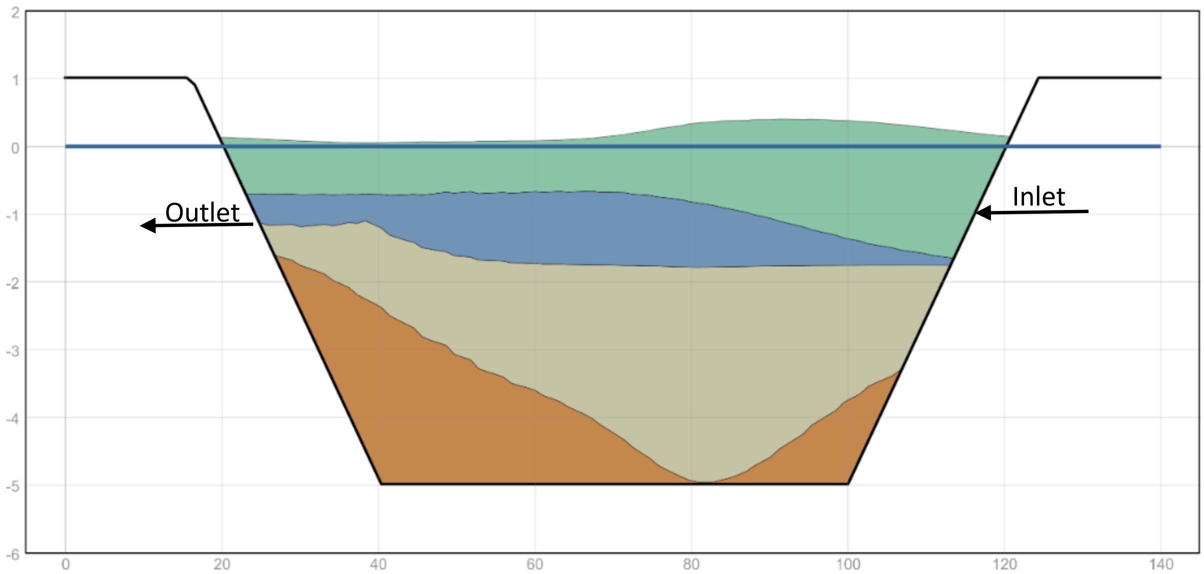

Figure 4. Anaerobic transect

Further cross sections are provided in Appendix 7.1.1 and the raw sampling data for the anaerobic pond is provided in Appendix 7.1.2

The overall anaerobic treatment volume is equivalent to the active sludge layer and the free wastewater layer of approximately 14,500 m^3, or 60% of design volume.

Table 2. Anaerobic pond volumes

Pond Parameter	Value
Design Volume	23.8 ML
Current Crust Volume	7.4 ML
	6.0 ML (below the waterline)
Current Solid Sludge Volume	3.3 ML
Current Treatment Capacity	14.5 ML

4.1.2 Aerobic Pond

This section presents and discusses results from the sampling of the large anaerobic pond at Teys Naracoorte. The reader is referred to the cross sections provided in Appendix 10.2.1 which shows the relative distribution and depth of the various layers in the pond – water and inactive settled sludge. The raw sampling data for the aerobic pond is provided in Appendix 10.2.2

Sludge accumulation

Considerable sludge accumulation was evident in the aerobic pond with sludge visible to the top water line over approximately a quarter of the surface. Photo 4 and Photo 5 show sludge accumulation at the inlet end and towards the pumped outlet respectively. The sludge at the inlet end is heavily vegetated and the surface has dried to form a solid crust with a very high solids content (69% by mass). Significant presence of paunch is evident in the surface sludge as seen in Photo 6.

Photo 4: Aerobic Pond sludge at Inlet point

A solid layer of accumulated sludge was measured below the water line across the entire pond. The thickness of the solid sludge layer increased towards the pond inlet.

The results from the 8 sludge samples are presented in Table 3 and depicted in Photo 7. The solids resemble paunch material. The total solids for the majority of the pond sludge is 8%, which is very dense. The total nitrogen content of the sludge is low (0.9 – 1.2%). The phosphorus content was extremely variable and enriched relative to nitrogen content.

Photo 5: Aerobic Pond Sludge towards pumped outlet

Photo 6: Aerobic Pond solid surface crust

Table 3. Laboratory Analysis of Sludge Samples from Aerobic Pond

Parameter	Unit	Site 1	Site 5	Site 14	Site 17	Site 19	Site 22	Site 25	Site 26
Depth	m	base	base	base	base	base	crust	crust	crust
TS	%		8.7		8.6	6.6	69.2	8.5	5.6
VS	%		3.8		7	8.9	32.6	14.5	6.5
Moisture Content	%		91.3		91.4	93.4	30.8	91.5	94.4
TN	mg/kg	9,230		12,800			12,500		
TP	mg/kg	4,030		88,700			12,500		

Photo 7: Aerobic Sludge Sample

The total sludge volume within the pond was estimated to be about 54,000 m^3.

The total water capacity in the aerobic pond has decreased from the design volume of approximately 200 ML to the current volume of approximately 146 ML. The difference is the estimated solid sludge volume of 54 ML.

Table 4. Aerobic pond volumes

Pond Parameter	Value
Design Volume	200 ML
Current Solid Sludge Volume	54 ML
Current Treatment Capacity	146 ML

Wastewater Properties

The wastewater properties measured at 12 different locations across the aerobic pond are listed in Appendix 7.2.2. General observations of the wastewater properties are as follows:

- pH varied between 6.7 and 8.2.
    - The lower pH was observed at the lowest depth near the pumped outlet where anaerobic conditions were likely.
    - pH increased towards the surface of each sampling site and as the sampling site moved away from the inlet.

- Conductivity was high with values ranging from 3.4 to 4.0 mS/cm. The high values are probably due to the considerable amount of evaporation from the large surface area.
- The temperature varied but this is likely to be affected by the ambient air temperature with the first 8 sites being approximately 22°C and the last site reaching 27°C when the air temperature was in the high 30°C's.
- The negative ORP measurement indicates anaerobic layers at all sampling sites. The most strongly anaerobic sites (Site 1 and 2) were in close proximity to the pumped outlet and were the only free water sites measured on the inlet/outlet side of the pond.

4.2 Geotechnical Investigation

The outcomes of the geotechnical investigation are laid out in the report by FMG Engineering Geotechnical Investigation Rev 1 issued 18 July 2017. Findings included:

- The near surface geology was as expected from regional studies – namely Parilla sand to the west of the site with a ridge of Gambier limestone to the east.

- The proposed site of a greenfield anaerobic lagoon (to the north of the presently decommissioned anaerobic ponds) is consistent with the near surface geology. Boreholes and test pits found some calcite/limestone rock as shallow as 0.7 m depth in the east but with none on the western half. Borehole logs are provided in the original report.

- There was no groundwater found during the investigation, despite it being conducted in early winter when rainfall is usually highest. This is positive for dam excavation. However, the authors note that perched water tables may exist and that groundwater is dependent on rainfall intensity and duration.

- The materials search found a shallow layer of clay suitable for lining future dams provided compaction is undertaken following geotechnical recommendations.

- The greenfield site was designated a Class P (problem) site due to the presence of fill.

- Finally, it was noted that there is considerable damage to the walls of the existing anaerobic lagoon, especially due to erosion of inner walls, root penetration and, in the case of the north wall, some tension cracking.

4.3 Cost Benefit Analysis

As outlined in the methodology, the CBA investigated 2 distinct scenarios. Scenario 1 is the construction of a new, lined, covered anaerobic lagoon with no cogeneration and Scenario 2 is the construction of a new CAL with biogas being sent to a cogeneration system for electricity generation. Within these two scenarios, the CBA investigated the implications of either undertaking the project now, or waiting for a period of 5 years to undertake the project.

Table 5. Cost Benefit Analysis Outcomes

		Scenario 1		Scenario 2	
Parameter	**Units**	**Now**	**Later**	**Now**	**Later**
Capital Expenditure	$	$4,400,000	$4,400,000	$6,680,000	$6,680,000
Savings	$/yr	$0	$0	$551,000	$551,000
	$/head	$0.00	$0.00	$2.85	$2.85
OPEX	$/yr	$71,000	$71,000	$204,000	$204,000
	$/head	$0.37	$0.37	$1.06	$1.06
Payback period	years	N/A	N/A	N/A	N/A
Annual net benefit (initial)	$/yr	-$71,000	-$71,000	$347,000	$347,000
Net Present Value (NPV) after 20 years	$	-$5,580,000	-$6,240,000	-$5,380,000	-$6,870,000

The capital and operating costs that have been prepared for this CBA are preliminary budget figures only, which use simple site factors to allow for the remoteness of the location, which can be expected to have a very sizeable impact on construction costs.

5 Discussion

5.1 Benefit of undertaking pre-engineering now

The primary benefits of performing the pre-engineering that has been undertaken as part of this project, rather than commencing detailed design immediately, is described below for each aspect.

- Sludge survey
    - Indicates the state of the existing infrastructure (ie. anaerobic and aerobic ponds).
    - Provides an indication of current treatment performance and whether this is adequate or not.
    - Allows for an estimation of the remaining useful life the ponds have, and when treatment performance can be expected to decline.
    - Indicates whether remediation of the existing anaerobic pond is feasible, or if a new pond is required.

  It is clear from the outcomes of this work that although the existing infrastructure may continue to provide a good degree of treatment into the medium term future, the downsides are considerable. The primary issue is the very high sludge load discharged from the anaerobic pond. This is resulting in a rapid accumulation of sludge in the east end of the downstream aerobic pond where both the inlet and outlet are located.

  The results of the survey show that this sludge discharge can be expected to increase with time and will increase the risk of odour emissions and nutrient feedback into the treated effluent sent to irrigation potentially resulting in non-compliant effluent.

  One option is to live with the existing anaerobic pond and regularly remove the accumulating sludge from the north end of the aerobic dam. Unfortunately, desludging ponds is time-consuming, expensive, especially when off-site disposal of the sludge is required and rarely effective. Extreme care is needed to avoid damage to existing dam liners otherwise contamination of groundwater is possible. This is discussed further below.

- Geotechnical investigation
    - Demonstrates whether the ground conditions at the site are suitable for the construction of a new pond or not.
    - Provides input into the design of a new pond (location, depths, batters etc.) which ultimately determine the footprint of the pond and the associated cost.

  This investigation found that there is an area of Gambier limestone in the east part of the sites being considered for a new anaerobic lagoon adjacent to Parilla Sand to the west. No groundwater was observed in any of the test pits or boreholes, although this does not exclude the possibility of localised areas of perched watertable.

The geotechnical report contains additional test information concerning the properties of the soils and sub-soils in the areas investigated.

A visual examination of the walls of the existing anaerobic lagoon suggested some damage of concern including tree root penetration, and erosion with particular damage to the northern wall. There is concern that this damage impairs the longevity of the existing dam and that care is taken in any new construction to ensure that the issues identified are not repeated.

- Cost Benefit Analysis
    - Indicates the economic feasibility of a particular option.
    - Provides insight into whether it is better to build a standalone CAL, or include a cogeneration system for electricity generation.
    - Demonstrates the expected savings from reduced expenditure on electricity, as well as the ongoing expenditure to operate the new WWTP.
    - Provides an understanding of whether it is of greatest benefit to implement the upgrade now, or to continue using the existing anaerobic pond for the remainder of its life and wait up to 5 years before upgrading it.

All of these components of the pre-engineering refine the scope for Stage 2 of the project, allowing funds to be allocated to further exploration of the options that have been deemed feasible by this report.

5.2 Implications of findings from pre-engineering for the scope of Stage 2

A number of options have been identified by Teys Australia for the Naracoorte site. These include:

- Remediate the existing anaerobic lagoon.
- Install a new, lined, open anaerobic lagoon.
- Install a new, lined, covered anaerobic lagoon with biogas to boiler.
- Install a new, lined, CAL with biogas to cogeneration.
- Install codigestion with biogas to boiler.
- Install codigestion with biogas to cogeneration

These are discussed below in the context of the findings from the pre-engineering studies.

5.2.1 Options 1 & 2: No Biogas Capture

Two options for Teys Australia at Naracoorte involve not capturing the biogas generated from treatment of the raw wastewater. These are discussed below.

<u>Option 1 – Remediate the existing anaerobic lagoon</u>

The pre-engineering studies indicate that the existing 17 year old anaerobic pond is at the end of its useful life. Several serious issues were identified. These include:

- The anaerobic pond has lost almost 40% of its working volume (9.3ML) to the surface crust layer and accumulated largely inactive sludge layer. Although treatment is still respectable, it is vulnerable to washout when inflows are high.
- The active sludge layer in the anaerobic pond is at the outlet pipe level. This is common in old anaerobic ponds and results in the carryover of very large quantities of sludge into the downstream aerobic pond.
- The impact of this discharge is seen clearly in the aerobic dam. This has lost 27% of its working volume to sludge accumulation (see Photo 4 and Photo 5). Most of this sludge is from the anaerobic lagoon. The concern for Teys Australia is that both the aerobic dam inlet and pump outlet are located on the north end of the dam and sludge appears to be close to the outlet point. As sludge comes closer to the outlet, effluent quality for irrigation will fall rapidly.
- The geotechnical work indicates that the integrity of the walls of the existing anaerobic pond are somewhat compromised.

Based on these key pre-engineering outcomes, it seems clear that remediation of the existing anaerobic pond is not a viable long-term solution for Teys Naracoorte. Removal of consolidated sludge from the base of anaerobic ponds not equipped with dedicated sludge removal piping systems is difficult and expensive and likely made more complex by the presence of a large quantity of tyres in the pond base. The poor state of the walls suggests work would also be required to repair these, especially if a cover was considered.

For this reason, the scope of options for Stage 2 should consider the construction of a new anaerobic lagoon to modern standard (preferably incorporating liner, cover and sludge removal) as the preferred solution.

In addition, it is clear that the construction of a new pond alone will not solve the problem of excess paunch accumulation in the ponds. The scope of works should expand to include upgrade of the primary wastewater treatment system to minimise the excess carryover of paunch and fat into any new lagoon.

<u>Option 2 – Install a new, lined, open anaerobic lagoon</u>

The most simple replacement anaerobic lagoon involves the traditional approach of an open lagoon without synthetic cover. Although feasible and capable of providing the degree of treatment required, this option has many disadvantages including:

- This technology is entirely a sunk cost. There is zero opportunity to recover value from it and although covering can be performed at a later date, it is inherently more challenging to do so once anaerobic activity has begun. The cover and biogas flare component represent a relatively small (~15%) of the total capital cost of a new CAL installation in Australia, suggesting that the financial benefit of not covering a new anaerobic lagoon is small relative to the potential negative impacts of not covering.

- There is little or no protection from odour emissions until the lagoon has formed a natural crust. The odour exposure of neighbouring sensitive receptors is a key determinant of whether EPA would accept this option.

- Construction of an open anaerobic lagoon without biogas capture would not result in any greenhouse gas emission reductions from the site. It is well accepted that a large component of Scope 1 emissions from a meat processing site arise from methane-rich biogas emitted off anaerobic treatment lagoons. Currently there is no specific regulatory penalty for carbon emissions, but the previous carbon pricing mechanism instituted by the Rudd government aggregated carbon emissions for multi-site companies like Teys Australia.

  To some extent, future risks associated with this matter can be mitigated by designing the open lagoon for subsequent cover installation if a carbon emissions scheme reappears.

Option 2 is viable but it is unlikely to be well received by EPA. Nearly all new anaerobic lagoons installed in meat processing plants over the last 7 years have been covered with biogas capture – including 4 Teys Australia sites. These have tended to be larger facilities, but community and EPA expectations have risen to expect employment of CAL technology wherever possible.

5.2.2 Options 3 – 6: Utilising value from capturing the biogas

High electricity and natural gas prices have become a major issue for the meat processing industry, especially in South Australia. Biogas produced through the anaerobic treatment of both wastewater and waste solids offers a means to realise some reduction in utility costs as shown in several Teys Australia facilities. This section discusses the suitability of four technical options.

<u>Option 3 – Install a new, lined, covered anaerobic lagoon with gas to boiler</u>

Based on the findings of the pre-engineering work, this option remains feasible and it is recommended that it is investigated further in Stage 2. Teys Australia has several sites running this technology option currently.

Natural gas costs at Teys Naracoorte have gone up substantially (approximately 30%) in the past year, so displacement of natural gas with biogas is likely to provide a good return on investment, provided that the Annual Contract Quantity (ACQ) agreement with AGL does not prevent reduced natural gas consumption from resulting in reduced costs and that existing infrastructure can handle biogas feed.

If the ACQ penalises use of biogas, then this option becomes much less viable unless contract negotiations are likely soon and the ACQ can be amended.

<u>Option 4 – Install a new, lined, covered anaerobic lagoon with gas to co-generation</u>

Based on the findings of the pre-engineering work, this option remains technically feasible and it is recommended that it is investigated further in Stage 2. Electricity costs at Teys Naracoorte have also gone up substantially (approximately 125%) in the past year, so displacement of electricity with biogas results in some recovery of the initial CAPEX required for this option (as indicated in Scenario 2 of the CBA).

Options 5 & 6 – Install co-digestion with biogas to boiler/ cogeneration

Biogas can be produced from both solid and liquid wastes produced in the abattoir. Co-digestion involves combining the wastewater and solid wastes in an anaerobic reactor (single or two-stage) and producing biogas, digested solids and nutrient-rich effluent (often highlighted for use as a liquid fertiliser). Despite the attractiveness of co-digestion, it is bedevilled by the fact that it far from straightforward to handle both a liquid and solid waste in the same reactor.

Fundamentally different mechanisms govern the rate of anaerobic treatment for each type of waste resulting in a large volume requirement compared to wastewater-only, or solid-only systems. Furthermore, for meat processing only a relatively small quantity of biogas (~ 10 - 15% of total) is generated from the solid waste compared to the wastewater fraction, yet the resulting nutrient feedback (from the digestion of solids) into the liquid complicates downstream treatment especially where nutrients are an issue such as for irrigation or sewer discharge. Use of the anaerobic co-digested liquid stream for fertiliser is far from simple unless it is preserved in some way (for example by pasteurisation) and/or there is a year-round market for fertiliser in the immediate vicinity.

For this reason co-digestion of solid and liquid fractions from meat process plants has yet to emerge as commercially viable anywhere. In some small studies, some dilution of solids with a portion of wastewater has been performed satisfactorily, but the majority of the wastewater must be separately treated. An example of this were the pilot trials by The University of Queensland at Teys Beenleigh.

This is in contrast to intensive livestock operations where co-digestion of manure and liquid wastes is commonplace, especially in Europe and North America. In these systems, the solid waste fraction makes up a far higher proportion of the total waste.

It is our view that co-digestion options are not yet commercially proven for meat processing plants and that the reasonably remote location of Naracoorte precludes it as a practical test site for emerging technologies.

5.2.3 Summary

Options 3 and 4 (CAL with biogas capture and use for boiler or cogeneration, respectively) represent the best options for Stage 2. This should also be associated with an upgrade of the primary wastewater treatment system to reduce green waste solids entering the CAL. The cost benefit analysis in Section 5.3 below assesses the economic outcomes of such an investment.

5.3 Cost Benefit Analysis

The cost benefit analysis for Stage 1 of the project involved looking at the Net Present Value (NPV) of two different scenarios. These were:

- Scenario 1: the construction of a new, lined, covered anaerobic lagoon with biogas capture and flaring only. No cogeneration is considered. This represents a baseline technology case and is commonly used by Australian meat processing plants.

- Scenario 2: the construction of a new CAL with biogas being sent to a cogeneration system for electricity generation. The cogeneration system modelled was a gas microturbine.

With both scenarios, the CBA investigated the implications of either undertaking the project now, or waiting for a period of 5 years to undertake the project to see if there was any benefit delaying the capital investment. Details of the methodology are explained in Section 3.3 and the results are given in Table 5.

5.3.1 Baseline Scenario 1

The graph below shows the Net Present Value (NPV) for the baseline Scenario 1 (installation of a new CAL with no cogeneration), investigating whether it is beneficial to construct it now or in 5 years time. The capital cost is $4.4 million and the analysis assumes a 2-year approval/construction period.

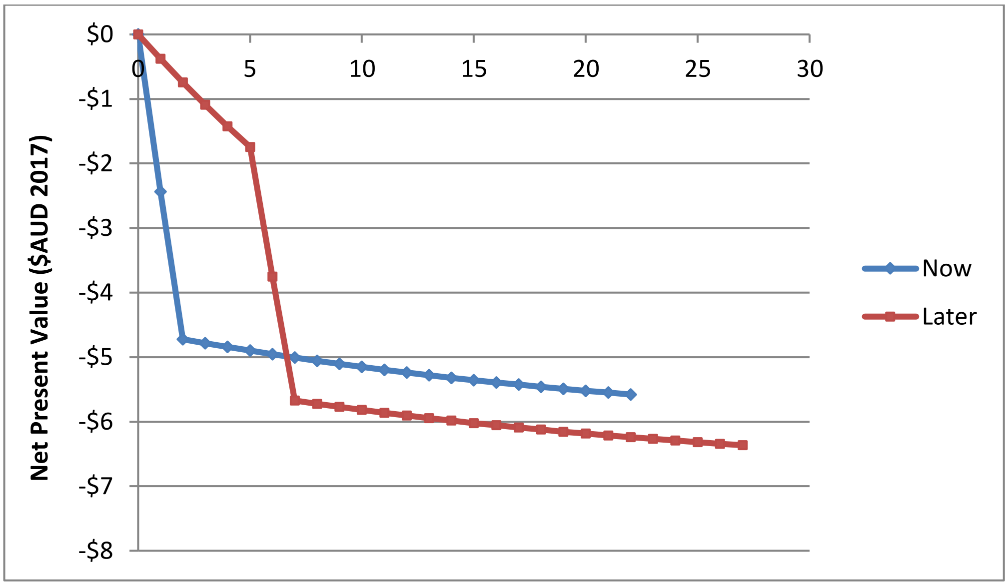

Figure 5. Scenario 1 Net Present Value Graph

From a financial point of view, it is better to commence construction immediately rather than delay it 5 years. This is primarily due to the fact that the remediation (desludging) costs are severe and necessary to stop the aerobic lagoon outlet from becoming sludged up during the 5-year delay to the point that water cannot be pumped from the lagoon any further. There is already evidence of short-circuiting in the aerobic lagoon, which will exacerbate the impact of sludge accumulation.

The analysis indicates that there is no return from the investment in Scenario 1, since there is no recovery and beneficial use of the biogas.

5.3.2 Scenario 2 – biogas recovery for cogeneration

The decision to recover the biogas and use it for cogeneration in a microturbine increases the capital cost to about $6.7 million. Most of this additional cost is associated with the cogeneration facility rather than the CAL cover. Despite the additional capital investment, this scenario has an improved, although still negative, NPV compared to the Scenario 1 baseline case due to the approximately $550,000 savings recovered from the green electricity generation.

The following graph shows the NPV output investigating whether it is beneficial to construct it now or in 5 years time. As for Scenario 1, construction of the system now rather than delaying it again saves significant cost in the form of ongoing remediation (desludging) of the aerobic lagoon, making it the more attractive option.

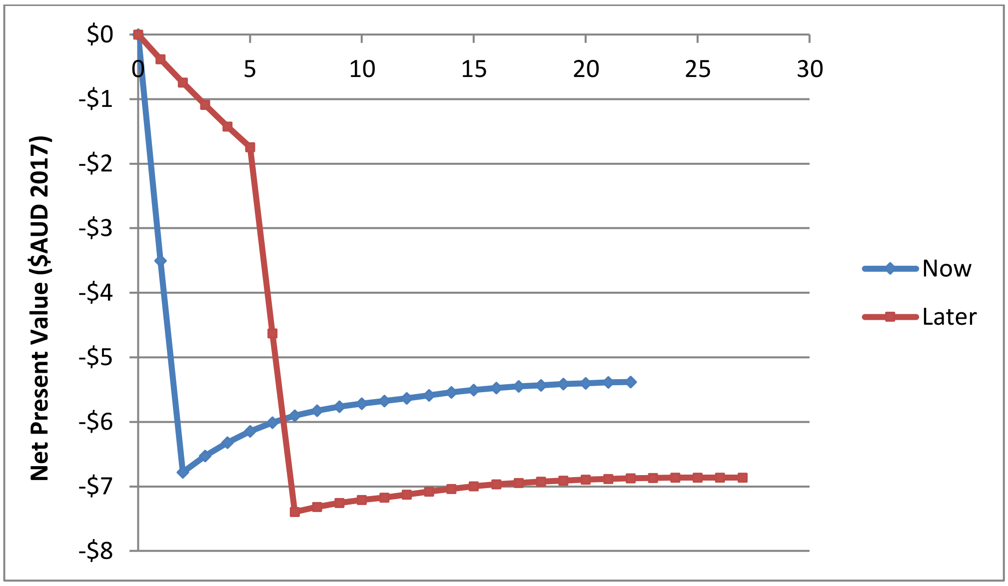

Figure 6. Scenario 2 Net Present Value Graph

Whilst investing a large amount of additional capital for a cogeneration system is expensive, displacing electricity through biogas generation results in significant savings, especially considering the high electricity prices that are currently paid by Teys Naracoorte. From 2016 to 2017, the unit price for electricity for the site went up approximately 125%.

In addition, the overall electricity savings for the ‘Now’ case are greater than for the ‘Later’ case. This is largely due to the fact that the ’Now’ case is displacing electricity while prices are relatively high. The AEMO predicts that electricity prices in SA will begin to fall from 2020 onwards, which impacts on the return from the ‘Later’ case. In addition, the 7%

discount rate to account for the time value of money means that savings in the distant future are not as valuable as savings made now.

In terms of whether it is of greater benefit to install a new CAL with (Scenario 2) or without (Scenario 1) a cogeneration system, the CBA indicates that for the ‘Now’ case, there is not a significant difference in NPV and the case is not convincingly strong on economic merits alone. However, there are a number of intangible benefits associated with the Scenario 2 case that are difficult to consider in the purely profit/loss sense of a CBA. These include:

- Improved reliability of the wastewater treatment system, leading to:
  - Reduced risk of non-compliance events.
  - Reduced risk of odour events.

- A degree of certainty and self-sufficiency with regards to power generation, especially considering the volatile situation in South Australia currently.

- Significantly reduced greenhouse gas emissions, which would be beneficial in the event of a reintroduction of the carbon tax. The reduction in emissions is higher for Scenario 2 compared to Scenario 1 due to displacement of fossil natural gas emissions by biogas rather than reductions due to combustion of biogas alone.

From a purely economic perspective, this wastewater treatment plant upgrade does not pay itself back and would not be considered financially attractive. However, the upgrade is necessary for ongoing treatment of the wastewater, so if it is to be implemented, it is important to investigate and select the solution that can recoup as much capital cost as possible, and provide Teys with the greatest possible operational flexibility and reliability.

In terms of whether it is of greater benefit to install a new CAL with or without a cogeneration system, the CBA indicates that for the ‘Now’ case, there is not a significant difference in NPV. However, this is based on the assumption that Teys Australia are fronting up the entire capital for the cogeneration system. If they were able to source capital to cover a significant portion of the CAPEX, it would certainly be more desirable to install an associated cogeneration system with the CAL rather than not.

5.4 Implications of doing nothing

Continued use of the anaerobic lagoon in its current state without any upgrade or remedial works will result in significant carryover of biological and inert solids into the aerobic lagoon. This process has already begun. The sludge survey indicates the extensive sludge accumulation in the eastern part of the dam.

The negative impacts of this process may include firstly a significant reduction in the treatment performance of the aerobic lagoon, as it loses working volume in which to treat the effluent. Eventually, the aerobic lagoon will not be able to effectively treat the wastewater and there will be ongoing non-compliance events. Secondly, where the sludge in the aerobic lagoon builds to the point where it breaches the surface of the water, there may be odour events which will be difficult to control. This would be detrimental to Teys Naracoorte’s relationships with neighbours and regulatory authorities. Finally, the carryover of sludge solids in the final effluent pumped to the irrigation area will result in higher than usual nutrient loadings on the property.

The aerobic lagoon is an important asset for Teys Naracoorte, and filling it with sludge degrades it, potentially rendering it worthless and requiring increased expenditure in the future to either construct a new aerobic lagoon, or perform extensive and expensive desludging of the existing lagoon.

5.5 Potential technology options for Stage 2

5.5.1 Anaerobic technologies

The primary technologies of interest have been discussed in Section 5.2. The proven technology for anaerobic treatment of meat processing wastewater is the Covered Anaerobic Lagoon (CAL). There are now over 18 such installations in the Australian red meat industry alone and many more treating wastewater in the chicken industry. Unlike the CALs in the intensive livestock industry, the CALs serving the red meat industry have proven robust and reliable in terms of treatment performance and biogas production, despite significant fluctuations in raw wastewater feed volumes and composition in many facilities.

Alternate anaerobic treatment concepts typically involve either co-digestion (as explained in Section 5.2.2), or more intensive, vessel-based anaerobic systems such as in-vessel digesters and anaerobic MBRs. These technologies have not yet been technically proven in full-scale operation for the red meat processing industry and their ability to cope with the full range of events including tallow/blood spills, equipment breakdown and variations in feed composition are yet to be evaluated. Australian costs for tankage, labour and materials such as concrete and steel are also much higher (in some cases double US values) than overseas, making simplistic country to country comparisons perilous and CALs a much cheaper option.

The Teys Australia Naracoorte facility is not severely space limited. In our view, a CAL is the most sensible option.

5.5.2 Biogas utilisation

Biogas utilisation involves primarily three main options:

- Flaring with no beneficial use of the biogas. This has been a common choice in Australian operations especially when the actual organic load being treated was uncertain (as is often the case) and there was little available information on biogas composition and flow from red meat industry CALs. This is less and less the case.

- Biogas as boiler fuel. This option has been probably the most popular choice for beneficial use of the biogas. Key issues with this option include the need for some conditioning of the biogas, care with boiler stack temperatures especially where economisers are present and the contractual problems associated with the Annual Contract Quantity conditions which are a part of existing gas contracts for sites.

- Biogas for electricity generation. This option has been much less frequently adopted for red meat CALs. Cogeneration with combined heat and power recovery offers the maximum return on biogas with an overall energy efficiency of up to 85%. Primarily gas engines are the preferred technology with heat exchangers on the gas exhaust and/or engine cooling jacket for heat recovery. This technology has become very efficient but has significant operating costs due to the need to condition the biogas to a higher degree than other uses especially with respect to hydrogen sulphide.

  The alternate technology is the microturbine approach which is regarded as being less sensitive to hydrogen sulphide in the feed biogas. We are unaware of any meat plant using this technology, but it is commercially proven and in widespread usage with natural gas feed in mining sites.

5.6 Summary

The specific objectives of this stage of the project were the assessment of the biological wastewater treatment plant at Naracoorte in relation to the following requirements:

1. A sludge survey of the existing lagoons to determine remaining useful life,

2. A geotechnical survey of the integrity of the existing anaerobic lagoon and the potential sites for construction of a new lagoon, and

3. A cost benefit analysis to look at the economic feasibility of the construction of a new lagoon with biogas generation and use.

Each of these objectives has been accomplished as discussed in this section of the report.

6 Conclusions/Recommendations

6.1 Conclusions

1. The primary treatment system at Naracoorte is allowing large quantities of paunch solids to flow through to the anaerobic pond, where it is settling out as sludge.
2. The existing anaerobic pond has lost almost 40% of its working volume (9.3ML) to a surface crust layer or a solidified, inactive sludge base layer.
3. The existing anaerobic pond's batters are compromised and are likely to deteriorate further with continued use and there are potential stability issues with one of the pond walls.
4. The downstream aerobic pond is filling with sludge and has lost about one quarter of its volume, particularly in the area between the inlet and the pumped outlet.
5. Geotechnical studies found little or no groundwater down to 10 m depth in sites investigated as potential sites for a new anaerobic pond.
6. Construction of a new, lined, covered anaerobic lagoon with biogas use should be done sooner rather than later to maximise savings and recoup as much of the capital cost as possible. Additionally, construction now prevents the flow of large quantities of solids from the anaerobic lagoon to the aerobic lagoon over the next few years, which risks making the treated effluent for irrigation of worse quality due to the accumulated sludge.
7. Construction of a new covered anaerobic lagoon with co-generation has a number of intangible benefits, such as improved wastewater treatment reliability, reduced risk of odour events, increased self-sufficiency with regards to power generation, and a significant reduction in greenhouse gas emissions.

6.2 Recommendations

1. Investigate improving primary treatment to reduce solids quantities, especially related to paunch processing, going to the existing and any new anaerobic lagoon. This may include a screw press or similar. This is critical to ensuring that a newly constructed anaerobic lagoon does not fill rapidly with paunch material, limiting their useful life.
2. Remove Options 1 (remediate existing anaerobic lagoon) and 2 (install a new, lined, open anaerobic lagoon) from the Stage 2 scope. The pre-engineering work has revealed that remediation is likely to be very challenging and expensive. A new lined, open anaerobic lagoon is likely to cost upwards of 85% of a CAL while sacrificing opportunities to recover value through capture of biogas and reductions in odour and carbon emissions. Strong resistance from EPA may also be incurred since regulatory expectations have risen to expect lagoon covers.

3. Remove Options 5 (Install co-digestion with biogas to boiler) and 6 (Install co-digestion with biogas to cogeneration) from the Stage 2 scope. Co-digestion remains unproven in meat processing facilities where the wastewater liquid to waste solids ratio is far in excess of the ratio for intensive livestock operations. This makes such technologies more expensive than existing options, especially when Australian costs for materials of construction and labour are factored in.

4. Proceed to Stage 2, focussing on Options 3 (Install a new, lined, covered anaerobic lagoon with biogas to boiler) and 4 (Install a new, lined, covered anaerobic lagoon with biogas to cogeneration). The preliminary cost benefit analysis performed indicates that these options are likely to be feasible for Naracoorte subject to other considerations (site-specific utility arrangements and factors) not part of the pre-engineering scope.

5. Consider the implication of the Annual Contract Quantity (ACQ) in Stage 2, which dictates that if Teys Naracoorte consume less than a certain quantity of natural gas each year, they must pay the difference to the utility company. This may mean that Option 3 is not economically feasible. The issue of ACQs in utility contracts remains a significant commercial impediment to green energy innovation in the red meat industry and should be targeted at an industry level since it applies to most facilities and companies.

7 Appendices

7.1 Anaerobic Pond

7.1.1 Cross Sections

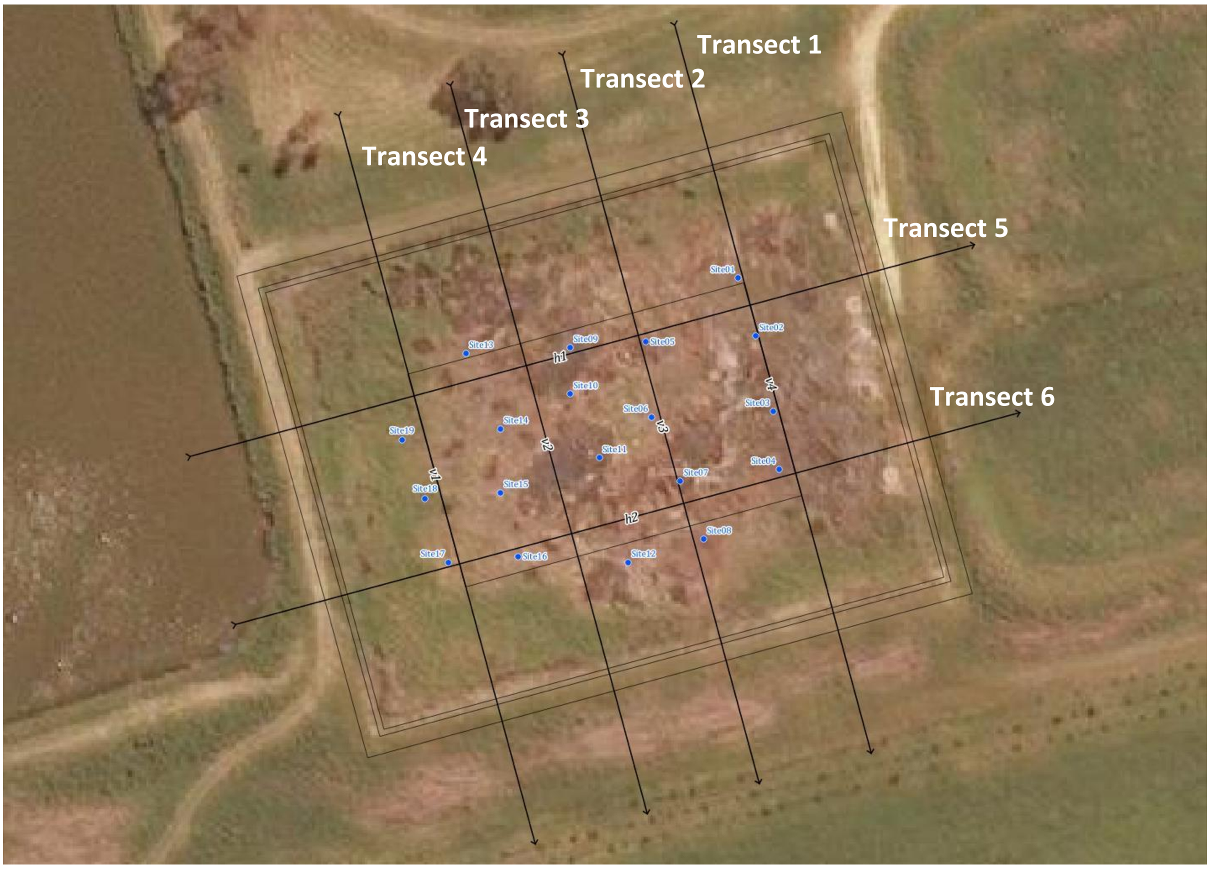

Figure 7: Anaerobic transect locations

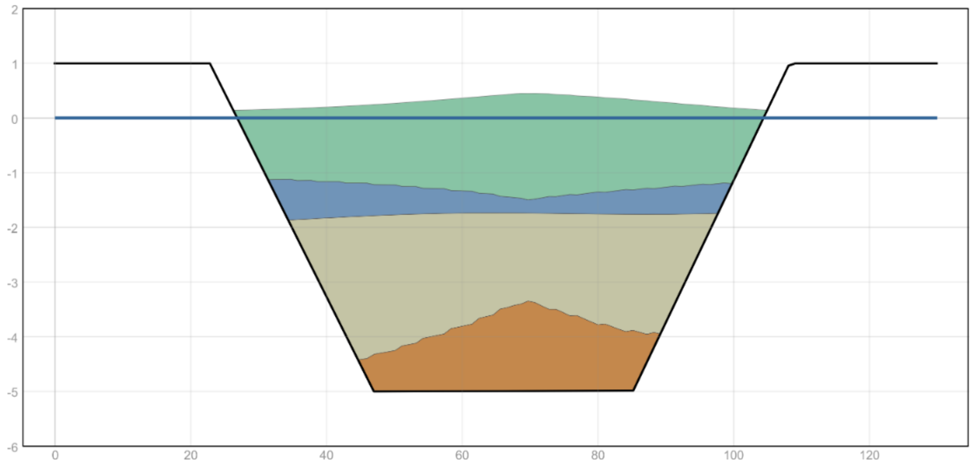

Figure 8: Anaerobic transect 1

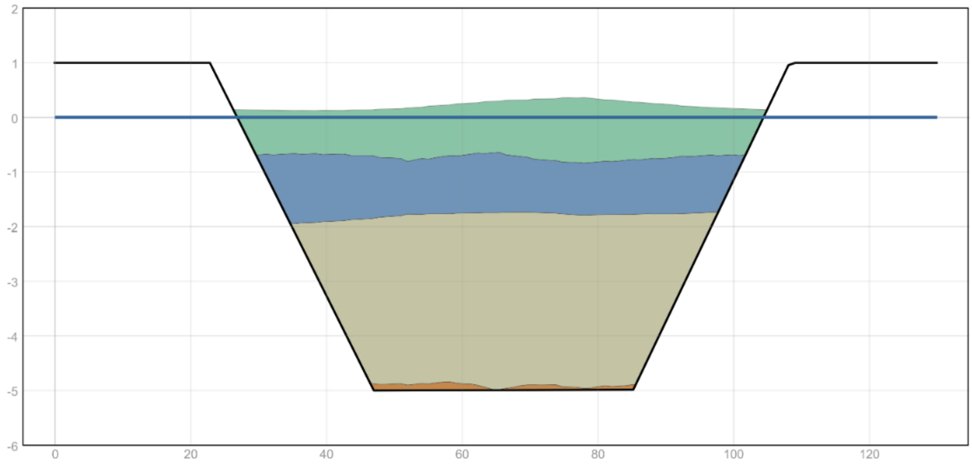

Figure 9: Anaerobic transect 2

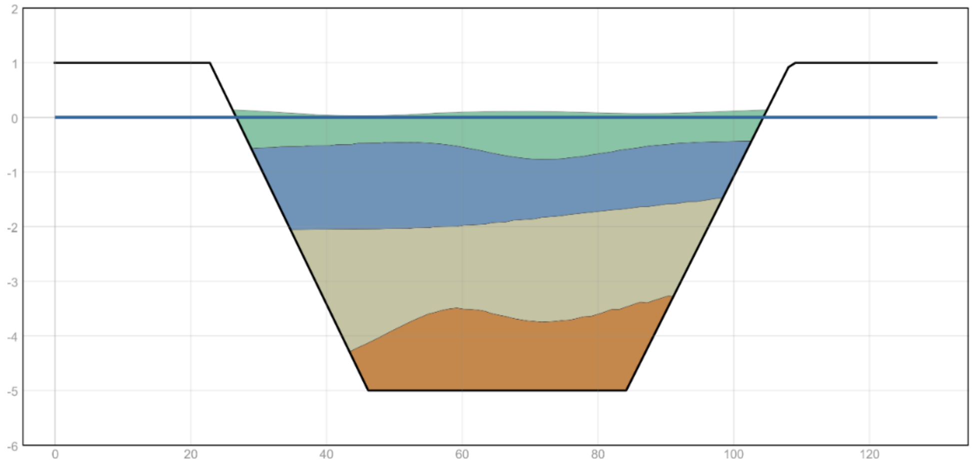

Figure 10: Anaerobic transect 3

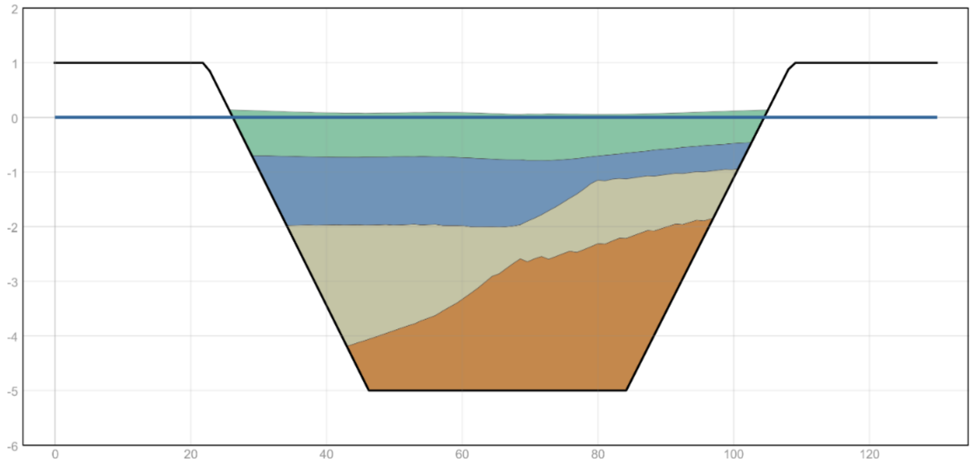

Figure 11: Anaerobic transect 4

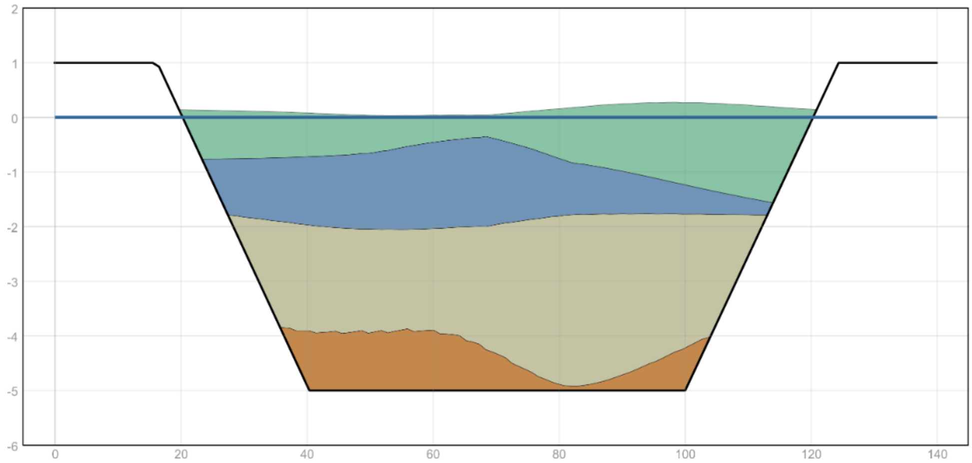

Figure 12: Anaerobic transect 5

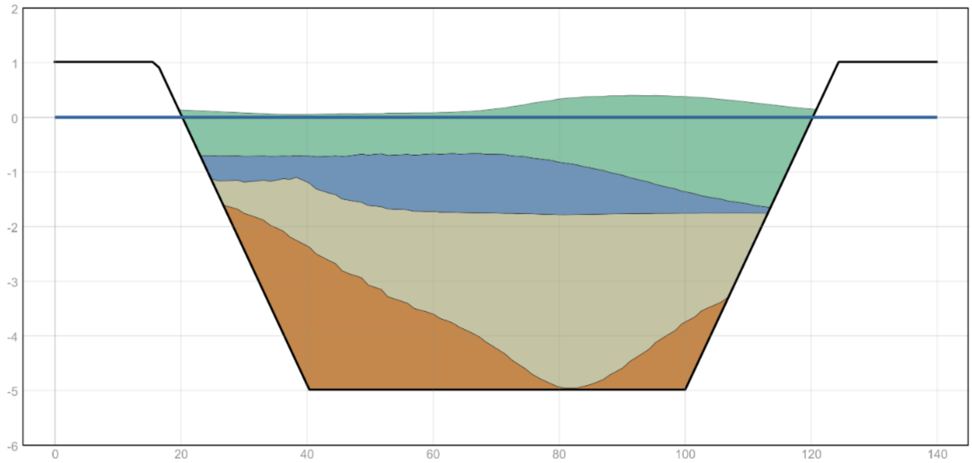

Figure 13: Anaerobic transect 6

7.1.2 Results and Observations

Site	Crust Description
Site 1	v hard & dry to 0.5m, base yellow & smelly
Site 2	0.1 - 0.2m dry crust, l brown crust thru, did not reach
Site 3	dry & crumbly ontop, soft l yellow on bottom
Site 4	v dry top 0.1m, d yellow, did not reach water
Site 5	Black soft top
Site 6	soft underneath, l brown colour, lot paunch
Site 7	firmer than s8, bit smelly, yellow colour
Site 8	0.05m dry, underneath soft yellow colour
Site 9	firm crust
Site 10	firm crust, 2nd crust below
Site 11	yellow thru, v odorous
Site 12	Soft, black
Site 13	d brown with black layer
Site 14	dry and d brown
Site 15	black surface, yellow beneath
Site 16	dead grass on top, moist ad black thru
Site 17	vegetated crust
Site 18	dry with bit dead vegetation
Site 19	dry, d brown. Dead vegetation

Table 6: Anaerobic Pond depth measurements

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19
Crust (above WL) (m)			0.5		0.2	0.3	0.4	0.3	0.05	0.15	0.1	0.1	0.05	0.1	0.2	0.05	0.1	0.1	0.15
Crust (below WL) (m)	-1.5	-1.5	-1.5	-1.5	-0.85	-0.6	-0.85	-0.8	-0.35	-0.45	-0.8	-0.45	-0.75	-0.5	-0.95	-0.6	-0.7	-0.75	-0.75
Total crust (m)	1.5	1.5	2	1.5	1.05	0.9	1.25	1.1	0.4	0.6	0.9	0.55	0.8	0.6	1.15	0.65	0.8	0.85	0.9
Top of sludge blanket (m)					-1.8	-1.8	-1.8	-1.8	-2.0	-1.9	-1.7	-1.8	-2.0	-2.1	-2.0	-1.6	-1.1	-2.0	-1.9
Total depth w royce (m)	-4.4		-3.35		-4.95	-5.25	-5.3	-5.25	-4.25	-3.7	-3.85	-3.9	-4.25	-3.25	-4	-2.9	-2.25	-2.35	-3.6

Table 7: Anaerobic Pond total solids measurements

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19
Royce Clear Water TS (g/L)																			
@ 0.5m									0.54	0.6		1.03					0.77		
@ 1.0m					1.69	1.91	1.07	2.5	0.65	0.66	0.56	1.05	0.7	0.73	0.89	0.55	6.3	0.82	1.4
@ 1.5m					2.17	1.63	0.99	2.3		0.72	0.61	1.23	0.72	0.78	0.83			0.7	1.2
average					1.93	1.77	1.03	2.40	0.60	0.66	0.59	1.10	0.71	0.76	0.86	0.55	0.77	0.76	1.30

Table 8: Anaerobic Pond laboratory analysis of sludge sample

Parameter	unit	Site 3	Site 8	Site 12	Site 13	Site 15	Site 15	Site 19	Effluent
TS	%	13		5.7	6		6.5		9.2
VS	%	7.2		7	29.1	20	21	27.9	
TN	mg/kg		42800			21900		23400	
TP	mg/kg		39200			9210		13100	

7.2 Aerobic Pond

7.2.1 Cross Sections

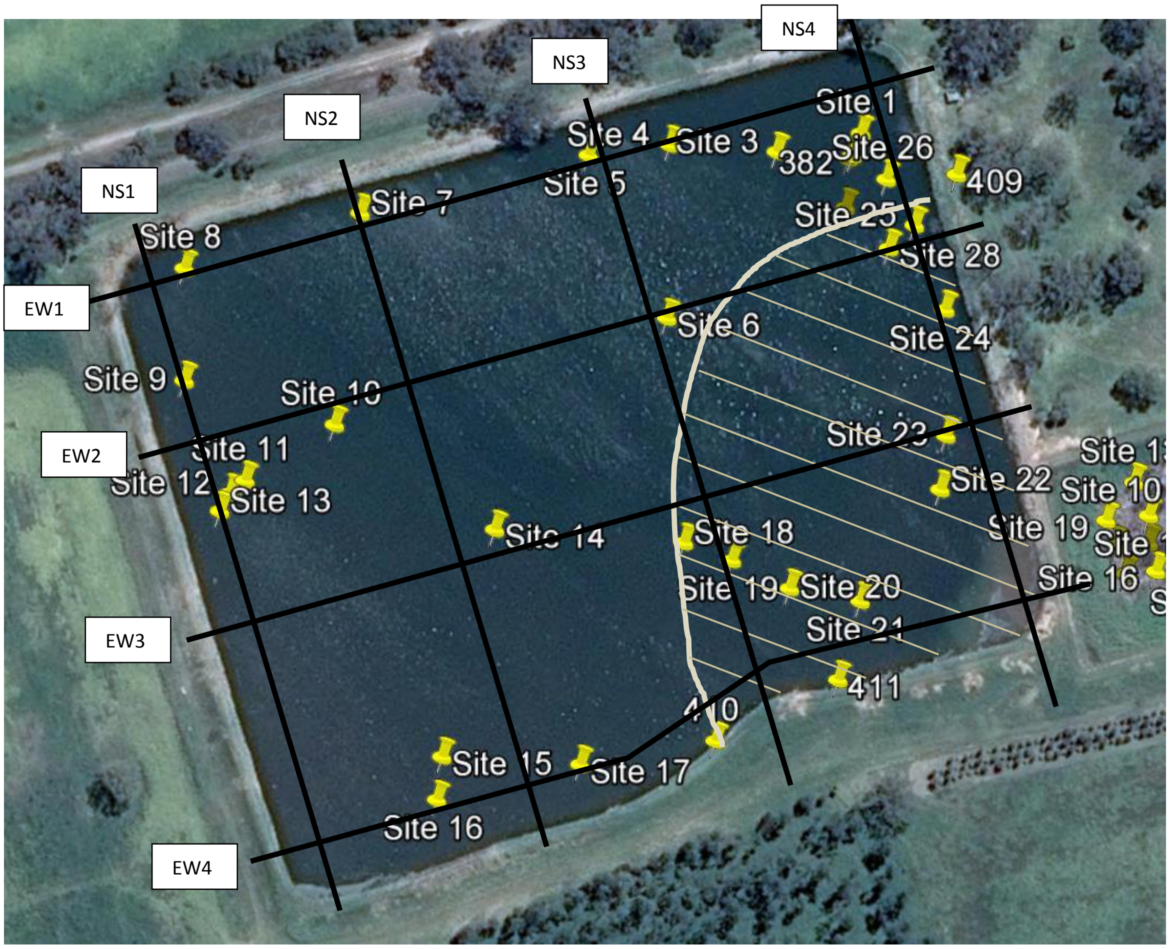

Figure 14: Aerobic Pond showing crust and transects for cross-sections below

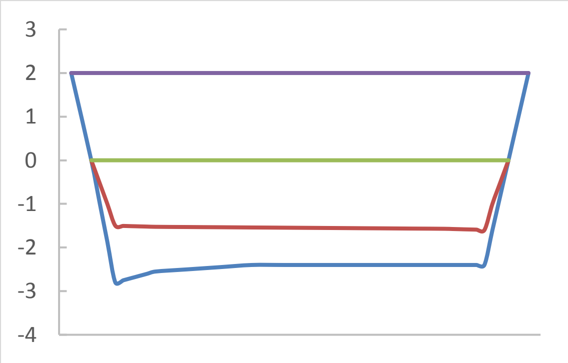

Figure 15: Aerobic Pond NS Transect 1

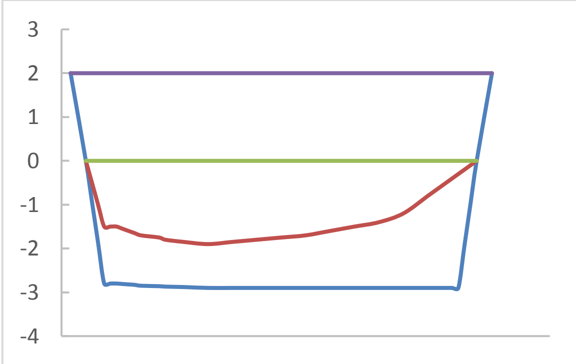

Figure 16: Aerobic Pond EW Transect 1

Figure 17: Aerobic Pond NS Transect 2

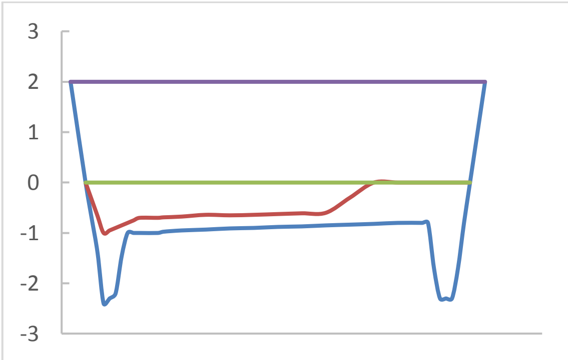

Figure 18: Aerobic Pond EW Transect 2

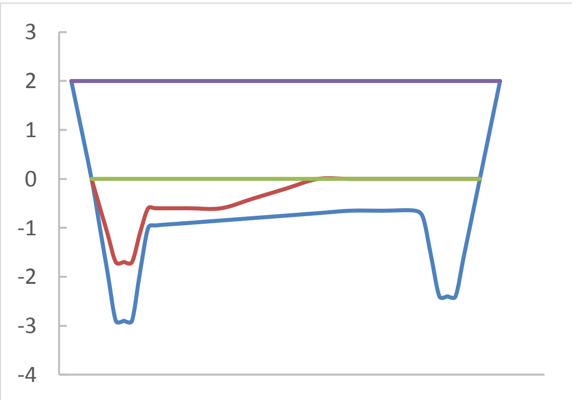

Figure 19: Aerobic Pond NS Transect 3

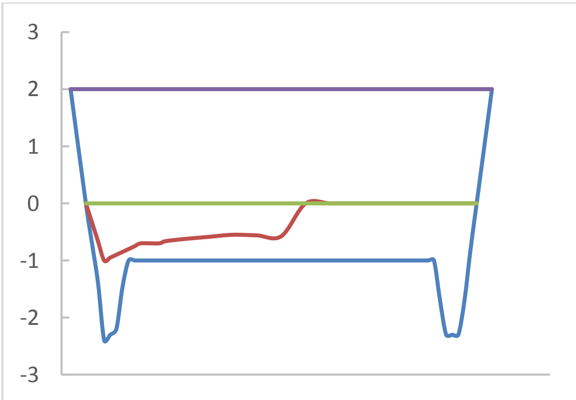

Figure 20: Aerobic Pond EW Transect 3

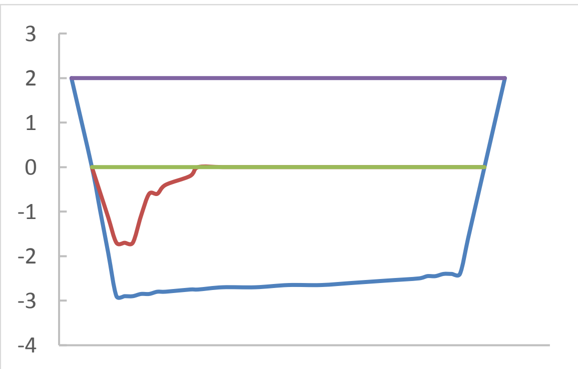

Figure 21: Aerobic Pond NS Transect 4

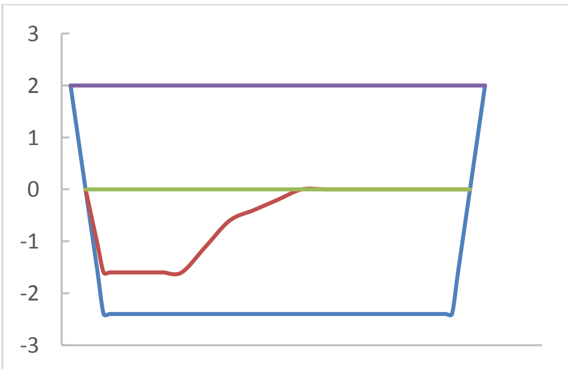

Figure 22: Aerobic Pond EW Transect 4

7.2.2 Results and Observations

Table 9: Aerobic Pond laboratory analysis of sludge sample

Parameter	unit	Site 1	Site 5	Site 14	Site 17	site 19	site 22	site 25	site 26
Depth	m	base	base	base	base	base	crust	crust	crust
TS	%		8.7		8.6	6.6	69.2	8.5	5.6
VS	%		3.8		7	8.9	32.6	14.5	6.5
Moisture Content	%		91.3		91.4	93.4	30.8	91.5	94.4
TN	mg/kg	9,230		12,800			12,500		
TP	mg/kg	4,030		88,700			12,500		

Table 10: Aerobic Pond onsite water quality analysis

Site	Depth	Hydrolab					Royce
		pH	EC	Temp	ORP	Turb	TSS
	m		µS	°C	mV	NTU	g/l
1	0.0	7.41	3604	22.6	51	2.3	0.28
	0.5	6.94	3416	22.6	-291	2.18	
	1.0	6.7	3525	22.4	-306	2.25	
2	0.0	7.5	3544	22.8	-108	2.25	
	0.5	7.4	3475	22.6	-61	2.22	
	1.0	7	3695	22.4	-178	2.34	
3	0.0	7.77	3600	22.6	14	2.3	
	0.5	7.6	3460	22.2	-133	2.21	
	0.58	base					
4	0.0						
5	0.0	7.92	3597	22.9	22	2	0.24
	0.5	7.88	3609	22.3	23	2.3	
	1.0	7.75	3621	21.9	-140	2.32	
	1.2	7.33	3605	21.6	-164	2.33	
6	0.0	7.9	3590	23.1	12	2.29	0.22
	0.6	7.8	3531	22.8	-94	2.15	
7	0.0	7.96	3590	23.2	12	2.3	0.33
	0.5	7.96	3601	22.7	16	2.3	0.32
	1.0	7.97	3605	22.3	19	2.31	0.31
	1.5	7.38	3824	20.9	-112	2.42	0.29
	1.8	??					
8	0.0	7.93	3585	23.3	14	2.29	0.24
	0.5	7.92	3504	23.1	17	2.3	0.29
	1.0	7.9	3600	22.9	19	2.3	0.29
	1.4	7.34	4040	21.3	-86	2.58	
9	0.0	8.16	3580	23.8	13	2.29	0.28
	0.5	7.6	3610	23.2	-85	2.27	0.44
	0.9	7.47	3500	22.5	-37	2.23	
10	0.0	7.94	3593	23.8	15	2.3	0.25
	0.5	7.85	3600	23.8	-63	2.26	0.36
14	0.0	8	3590	24.5	17	2.3	0.15
	0.3	8.05	3590	24.5	21	2.23	0.68
16	0.0	8.06	3599	25.5	28	2.3	0.34
	0.5	8.1	3595	24.4	29	2.31	0.63
	1.0	7.54	3584	22.5	-89	2.36	0.68
	1.2	7.25	3766	22.2	-142	2.43	
17	0.0	7.86	3621	27.21	8	2.33	0
	0.5	7.41	3240	24.4	-90	2	0.05
	1.0	7.3	3272	23.2	-130	2.1	

Table 11: Aerobic Pond observations

Site	Comment
1	
2	
3	
4	edge of moat. 1/2 here to bank
5	in moat
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	sludge to surface
19	thick sludge to surface
20	very thick dry sludge
21	very thick dry sludge
22	very hard crust
23	travelling more freely, over deeper
24	H_2S 5ppm, LEL >5%
25	anaerobic sludge alarms gas alert
26	
27	edge of slime
28	soft area crust

Table 12: Aerobic Pond depth measurements

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Depths (m)																												
Top sludge blanket	-0.3	-0.05	-0.25		-1.3	-0.5	-1.7	-1.4	-0.4	-0.6				-0.5		-1.35	-0.45											
Royce base	-0.6	-0.4	-0.5		-1.7	-0.6	-1.9	-1.5	-1	-0.7				-0.55		-1.6	-0.6									-0.5		
Rod base		-2.05	-1.2	-1.2	-2.9	-0.85	-2.9	-2.8	-2.6	-1	-2.2	-2.4	-1.4	-1	-1	-2.4	-2.4	-0.55	-0.65	-0.9	-1.2	-0.7	-2.6	-1.85	-1.7	-2.4		-2.3