University of Southern Queensland
Faculty of Engineering and Surveying

Design of a Frame/Structure for a large wastewater treatment pond

A dissertation submitted by
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in fulfilment of the requirements of

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towards the degree of

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ABSTRACT

The aim of this project is to develop a conceptual structural solution to support the Churchill Abattoirs waste water pond cover. The wastewater treatment pond is anaerobic and the waste it collects is from an abattoir source.

Churchill Abattoirs engaged in a study of covering their ponds with a thin flexible membrane to control odour and to allow for the future capture of produced methane for electricity generation. This study identified a suitable membrane cover but also concluded that an effective support for the cover would be required to realise the full potential of the cover.

This project aims to:

1. Research existing commercially available frames/structures to support a large waste water treatment pond cover.
2. Critically evaluate existing designs including material use.
3. Analyse existing pond cover application and use.
4. Establish performance criteria for the structure.
5. Develop improvements/innovations to available proven designs and resolve whether suggested developments are applicable to the Churchill Abattoir situation.
6. Develop a conceptual structural design for the cover support at Churchill Abattoir waste water treatment pond.

The research methodology will consist of a literature review of available pond cover concepts and a critique of existing pond covers structures as well as any potential improvements. Finally conceptual designs will be developed and evaluated against a developed set of performance criteria.

The performance criteria will be developed from knowledge established during the literature review as well as documented suggestions from Churchill Abattoirs that were discovered during their field trials of the cover membrane.

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CANDIDATES CERTIFICATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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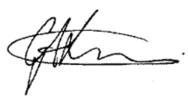

Signature

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Date

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I owe an immense sense of gratitude to my wife who with patience and understanding encouraged me to complete this research project and degree.

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NOMENCLATURE

ATV	-	All Terrain Vehicle
CA	-	Churchill Abattoirs Pty Ltd
CHS	-	Circular Hollow Section
EVA	-	Ethylene Vinyl Acetate
GHG	-	Green House Gases
GTI	-	Geomembrane Technologies Incorporated
HDPE	-	High Density Polyethylene
LDPE	-	Low Density Polyethylene
MDS	-	Marine Docking Systems
MLA	-	Meat and Livestock Australia
PP	-	Polypropylene
QLC	-	Quality Lining Company
uPVC	-	Un-Plasticised Poly Vinyl Chloride
USQ	-	University of Southern Queensland
WSAA	-	Water Services Association of Australia

1. INTRODUCTION

1.1. Outline of the Research Project

Churchill Abattoirs highlighted a need to design a feasible support structure for their in-house developed membrane to cover their anaerobic wastewater pond. The need for the cover is twofold. The cover controls and reduces the expelling of odour that the public may find offensive as well as enabling the capture of methane gas to be either flared off or used to generate electricity.

This project sets out to research existing structures used to support such covers, as well as critically evaluating them to ascertain their applicability to the CA context.

1.2. Introduction

Churchill Abattoirs Pty Ltd is a meat processing facility that provides meat to retail outlets in Queensland and Northern New South Wales. Its waste water is processed on-site by way of aerobic and anaerobic ponds to breakdown the organic waste that it contains. The organic constituents of the waste water contain traces of blood, fat and substances such as manure. The breakdown of these constituents involves the release of greenhouse gases and the creation of an odour of which is less than desirable to the general public. These issues were not truly appreciated during the original design and construction of the original waste water ponds.

CA engaged a redesign of their waste water treatment facility, in which six new ponds were constructed. The six new ponds are of a smaller size than the original existing ponds. On completion of the pond construction a study was engaged by CA to develop a pond cover. The intent was to cover the ponds with a thin flexible membrane to control odour and allow for the future of capture of the released methane for electricity generation.

Trials were conducted to find a suitable cover material for the ponds. Initially a review of the existing pond cover materials as well as site visits to similar facilities CA concluded that an in-house developed solution would be the best option. CA decided to use a propriety spray on product Liquid Rubber™ over a geo-textile membrane. Subsequent field trials with the cover were carried out. These initial trials also experimented with differing support structures to enable the placement of the cover over the wastewater treatment ponds. These experiments highlighted various issues with support requirements. This research project will seek to resolve these issues and develop conceptual design(s) for a suitable support structure for the wastewater treatment pond cover.

1.3. Research Objectives

There are three main objectives to be achieved for the research project. The first is the investigation of existing pond cover structures. Secondly to establish a knowledge base of the anaerobic wastewater pond environment, and finally, to source viable materials that can withstand this environment.

Investigations of existing pond cover structures allows for a greater appreciation of the type of structure that would be of benefit of CA, as well as aiding in the establishment of performance criteria for the structure. The information found will also provide inspiration and guidance on the development of conceptual design(s).

The pond environment is an important aspect for the conceptual design of the pond cover structure. The research of the primary influent and the resulting reactions will establish criteria for suitable types of materials that are able to withstand this environment. The environment of the pond will also establish what maintenance the pond requires during its design life and what functions the structure must accomplish to allow this ongoing maintenance to be achievable.

The research into materials is to establish a range of resources that can be used allow for a serviceable design. The type and the use of the materials chosen will have a bearing on the overall cost and function of the concept design. The materials used also have the greatest bearing on the durability of the structure and the amount of maintenance required to meet the required function of the structure.

1.4. Project Outcomes

The project outcomes follow from the successful completion of the research objectives. The outcomes from the project research will be to establish performance criteria for existing structure evaluation as well as a measure for the concept design. Further outcomes will include a suite of materials that can be used for the concept design, ideas for conceptual design development, areas of further research and a recommendation on which conceptual design to choose.

The performance criteria will be established by considering the issues raised by CA during their initial field trial of the development of the cover membrane. Conclusions reached from the development of existing structures will also aid in the creation of the performance criteria.

The material suite will be a comprehensive list of the chosen items with the mechanical properties as well as the serviceability features that will aid in a successful concept design.

1.5. Consequences and Implications

Tenet six of the Institute of Engineers Australia's code of ethics outlines that a member shall take reasonable steps to inform themselves, clients and employers of any consequential effect which may arise from their actions. The consequential effects are measured against four criteria of ethical, social, environmental and economic effect. The last three criteria are defined as the components of sustainability. Once the project is finished the ownership of the conceptual design developed has not. It is in the interest of the author as well as the general public that the final design is safe to construct and implement.

1.5.1. Ethical

During the search for information regarding pond covers and their associated support structures it became evident that the number of commercial options in Australia is limited. Only one company was found to produce a specialised anaerobic pond cover inclusive of methane gas capture. A search internationally, found one solution of stitched modules shows potential while gas capture ports embedded within the cover are still in development, both options were protected by patent. This situation raises the prospect of reproducing an existing design/idea and claiming it to be the authors work. This would be in breach of Tenet 2 of the Institute of Engineers Australia's code of ethics as well as meeting the University of Southern Queensland's (USQ) definition of Academic Misconduct. As such, a decision not to contact these suppliers directly for design information has been made, only data that is freely available to the public is used.

1.5.2. Safety

The final conceptual design must also be regarded as a safe to construct and use. Depending on the design and its intended use the owner of the facility must be aware of what can and cannot be done with the structure. Therefore the end user must be made aware of any assumptions used during the conceptual design phase.

1.5.3. Social

This project has the potential to contribute a positive effect on all three criteria due to the minimisation of the existing odour which will have a positive social effect. Zhang (1999) made the observation that a cover hides a pond from view therefore creating a perception that the odour is also eliminated. The potential capture and use of the bio gas to generate electricity also aids in the reduction of the reliance on non-renewable energies. This reduction may enable CA to reduce their energy costs by producing their own electricity.

1.5.4. Economic

The design intent is to enable the capture of methane gas for electricity generation. The economic benefit of doing so would reduce the company's cost of their electricity. The initial outlay for the construction of the support would be paid back over time as the electricity produced would be a reduction in the cost to the business therefore of direct economic benefit to the company.

1.5.5. Environmental

The concept of the design has the beneficial environmental effect of reducing odour and capturing methane which is considered a GHG. The capture of GHG will either be flared of producing carbon dioxide and water or used to generate electricity which reduces demand from other sources of electricity, the majority of which is sourced from coal. Equation 1 explains the chemical reaction of the combustion of methane (CH_4) to produce heat for electricity generation as well as producing odourless gases of carbon dioxide and water vapour.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \tag{1}$$

1.6. Methodology

The overall aim of the project is to develop a conceptual design for a pond cover support. The project methodology will therefore be of a theoretical nature as there will be no experimental work involved. The project methodology will be restricted to researching relevant designs and critically evaluating them against the CA requirements and the proposed CA concept of using an arch structure. Any improvements or innovations developed during the course of the project will also be required to undergo the same evaluation as the existing designs.

The literature review will summarise various types of pond cover structure designs. The critical evaluation of these existing designs enables any findings to be applied to the final concept. The evaluation of existing designs will be based, on the following criteria but not limited to:

- Practicality: Will the structure works in an abattoir context? Does it require specialist training of maintainers? How it will interact with other plant operations. Will it fulfil the requirements developed in the performance criteria?
- Durability: Are the materials that have been used, up to a meat industry anaerobic pond environment?
- Constructability: Is it easily constructed and transported from place of fabrication to service position?

The conceptual design will be based on the evaluation of existing designs. Any improvement of innovation to a design must be applicable to the Churchill Abattoir. Once a design concept is finalised the process of detailing, will proceed. The detailing will involve the discussion of the design in the dissertation against the established performance criteria as well as noting any new issues that may occur due to the concept.

1.7. Conclusions

CA treats their organic waste with the use of anaerobic ponds. The pond process produces GHG as well as odour. The initial design of the ponds did not account for these two situations. The anaerobic ponds started to deteriorate dramatically after five years of operation. The main driver for this deterioration was the lack of clean out and maintenance of the ponds. CA decided to construct six smaller ponds with the idea to rotate their service as each pond is cleaned out. CA also instigated a field trial to determine whether a viable cover is available for the ponds to both control odour and capture the GHG's.

After successfully developing a cover material, CA's attention turned to considering a support structure for the cover. Various trials were undertaken to determine the best approach to the design. This project is an extension of the initial trials into the investigation of the cover support structure.

The research project will investigate existing commercial designs that are currently available and develop a conceptual design(s) for the CA context based these existing designs. A set of performance criteria will be established to evaluate the concepts and a recommendation will be put forward on the most favourable approach.

2. LITERATURE REVIEW

2.1. Performance Criteria

The support structure for the pond cover must be able to meet a set of performance criteria to be deemed effective. The cover must be stable, have the required strength and meet certain serviceability requirements such as durability and allowable wind shear. Meat and Livestock Australia (Golder 2009) and CA (2010) also mention the potential for the cover to come under animal attack. Ongoing pond verge maintenance such as vegetation control is also be required.

The CA (2010) report also notes that the design of the pond cover itself is based on inter alia. This means that the pond cover does not have to encompass the entire surface, to be effective in minimising odour. This was detailed in an example of a pond cover at a piggery. The above suggests that the support structure does not have to enable 100% coverage of the pond.

The cover structure must also accommodate a variable pond surface to allow the cover to move with any surface fluctuation. The support for the cover can be designed to move with surface fluctuations or fixed in position, where the surface fluctuations will have no effect on the cover.

2.2. Available Structures

One commercial off the shelf structure specific to the needs of an anaerobic pond cover in Australia was discovered during the literature search. Fabtech SA Pty Ltd produce anaerobic pond covers incorporating an internal ring main that draws off the methane gas where it can be flared off or used to generate electricity. The Fabtech system uses closed cell polyethylene foam, wrapped in polypropylene which serves as a ring main that collects and conveys the methane gas to the external piping. The ring main also acts as floatation with the cover directly bonded to it. The cover is attached to a series of floats and weights to maintain a constant tension that removes any slack. The weights and floats are positioned in such a way that a gradient is formed to a sump that collects any rainwater which is then conveyed away with a submersible pump. Fabtech quote that their system has the following benefits:

1. Required retention time is dramatically reduced
2. The first lagoon of the anaerobic system is encapsulated; most odour problems do not exist.
3. Methane gas is collected and co-generated, providing a tangible pay-back period
4. Power is generated where it can be used or sold, dependent upon your needs.
5. The system ultimately pays for itself and contributes to profitability.

The Fabtech claim of reduced retention time is consistent with UNSW (1998) which reported that a covered anaerobic lagoon can be loaded up to six times compared to one that is uncovered. The Fabtech system is a similar design to that of the Reid Piggery design developed by Huebeck et al. (2009). In this design a flexible geomembrane cover is fixed to the pond embankment and rests on the pond surface. A weighted pipe is place centrally where water is collected at one end by an immersed pump stationed in a constructed sump.

A search of commercially available pond covers provided a differing alternative. The LemTEC^{TM} system from the United States uses a series of modules that are joined together by PVC coated cables. The modules have insulating floats which are sandwiched between flexible geo membranes. The stitching together of the modules allows for rainwater to pass through and the gases to escape (See figure 2-1). This option provides a possible alternative as it is easy to construct and solves the problems of gas entrapment and rainwater pooling. Disadvantages include the need to develop an external methane capture system and the requirement for double the amount of geo membrane required to create the cover. Similar systems by the Quality Lining Company (QLC), also from the United States, adopt a modular system. The QLC modules appear to be welded together to form an impervious cover.

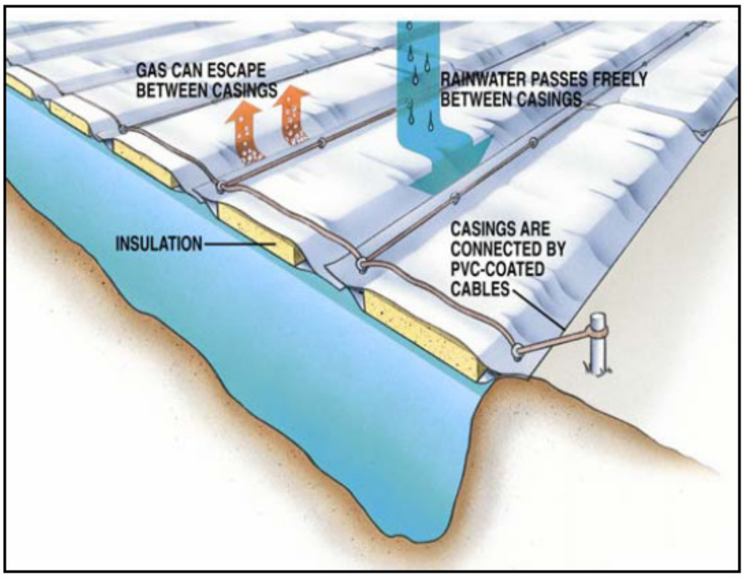


Figure 2-1 Example of an existing LemTEC^{TM} commercial design

Melbourne Water Corporation (MWC) developed a pond cover/structure for their anaerobic ponds in the late 1990's (De Garie et al. 2000). Their cover was designed by two Canadian companies, Geomembrane Technologies Inc. and ADI Limited. Both companies were experienced in the research of anaerobic pond covers in the North American climate where the winter time temperatures can reduce the biological activity thereby reducing the efficiency of the anaerobic pond. The pond cover was subsequently manufactured in North America in modules and transported to Melbourne. The modules were assembled on-site with the aid of local contractors. The MWC covers encompass two anaerobic ponds, each approximately 3.9ha in area. The cover structure is similar to the LemTEC design in that laminar modules were constructed using a HDPE bottom layer an insulation layer utilising 12.5mm ply poly-foam and a top layer consisting of a specialist Seaman XR-5 geomembrane. The HDPE layer rests on the water surface to prevent scum development. The insulation layer has thermal properties and is also the main form of buoyancy. The insulation is welded to the HDPE under cover. The XR-5 fabric has high UV resistance, high tensile strength and a low coefficient of thermal expansion which is ideal for use as the top layer. Huebeck (2009) considers the XR-5 is generally not required and recommends the use of PP or LDPE. Huebeck (2009) discuses further cover material and discourage the use of Butyl rubber covers due to the UV breakdown.

The MWC system design is fixed to the bank of the pond. The gas production permeates through the under layer and insulation through orifices placed at the cover edge. The XR-5 membrane captures and stores the produced gas for a collection system made up of perimeter conduits. The collection system can cause the gas to “bubble” at the edges before migrating to the centre. If the collection system is switched off or collection is less than the rate of gas production. This may cause surface runoff to be hindered at the cover edge. A review of the system by De Garie (2000) suggests this was not a problem experienced during in service use, due to the addition of a network of weights, floats and self-regulating gravity drains.

The Reid Piggery design by Huebeck (2009) is similar to the MWC as it is a floating cover fixed to the bank edge. Its dimensions are 25m by 84m, constructed of and of PP or LDPE rather than laminar modules. The water runoff is controlled by weighted water pipes while gas collection is achieved by fixed conduits on the bank edge. The Reid Piggery pond encountered a similar problem to that of CA during construction in that the water table was higher than expected and the initial cut depth was reduced as was the CA ponds. This was overcome by raising the banks of the pond to the maximum allowable height under local planning law. During the fabrication and construction of the Reid Piggery and the MWC design particular attention was paid to the welding of the seams of the cover to insure an impermeable joint. This was vital for both designs to ensure efficient gas collection and elimination of any atmospheric oxygen contamination.

Sludge management is a greater problem with the use of fixed covers as access to the sludge layer by earthmoving machinery is inhibited by the cover itself. The management of the ponds require periodic cleanout of the sludge, requiring the removal of the cover. De Garie (2000) highlights the extra difficulties of a fixed cover for sludge management through the discussion of the MWC design. Huebeck (2009) offers an alternative solution of installing suction ports. This is achieved by installing a number of flexible HDPE pipes from the intended sludge layer to an accessible point on the pond bank. This enables the sludge to be removed with the use of a vacuum truck or pump. Huebeck (2009) suggests that the most cost effective removal of excess sludge is by vacuum extraction.

Existing structures and materials that could be used for the development of a pond structure were also investigated. Traditional methods utilising steel frames or trusses that could be easily constructed by a local fabricator were researched. Structures over treatment ponds, as inspected at the Wetalla Water Treatment plant during a site visit (February 2010), were noted to be fabricated from Aluminium. Bowker et al. (1989) lists a series of materials that are acceptable for use in a wastewater treatment environment. Bowker suggests the use of Stainless steels, the WSSA (2000) suggest the use of austenitic stainless steels 304L of 316L dependant on the availability of halide ions (Fluoride, Chloride, and Bromide). 304L being used where halide ions are at low concentrations while 316L for the opposite. The use of the low carbon alloys of 304L and 316L are recommended to aid in welding. Bowker discusses the use of aluminium as a widely used material in wastewater treatment plants as it is not affected by Hydrogen Sulphide (H_2S), methane, carbon dioxide, or sulphur dioxide. Burchall et al (2008) describes the chemical process occurring in anaerobic ponds. Products produced include volatile acids such as acetic acid (vinegar); and these by products create a corrosive environment for steel. The acid reaction that occurs with aluminium forms a passive layer that inhibits any further corrosive action. It is prudent to use structural grade aluminium either welded into place or fixed using 316 stainless steel fasteners. The use of stainless steel with aluminium can lead to galvanic corrosion due to dissimilar metals coming into direct contact. This can be easily overcome with the use of plastic grommets between the parent metal and the fastener. The issue of galvanic corrosion between stainless steel and aluminium is addressed by both the WSAA and Bowker. WSAA suggest that galvanic corrosion between stainless steel fasteners and aluminium is not an issue unless the connection is present in a marine environment where instances of galvanic corrosion have occurred. Bowker takes the opposite view, suggesting that due care should be exercised when allowing physical contact between the two. Aluminium does require the use of gas shield welding for fabrication and repair which involves a greater cost of labour and equipment when compared with manual metal arc welding of steel. Beer et al (2006) and Hibbeler (2006) both develop the theory of the design of frames and trusses with either material while Australian Standards (AS4100:1998, AS1664.1:1997, AS4673:2001) detail the requirements for a complying structure under Australian conditions.

Koerner (1994) broadly categorises the types of reservoir covers into either fixed or floating. The edge of a fixed cover is held in place at the pond surrounds and the cover itself does not touch the pond surface. A floating cover rests on the pond surface and rises and falls with any change in surface level. Craggs et al (2008) further categorises fixed type structures into positive pressure and a negative pressure covers. A positive pressure structure has air pumped under the cover to create a balloon effect, while a negative pressure pond structure is the reverse with air sucked out and the cover is kept in direct contact with the lagoon surface. Both these types of cover can be deemed flexible, Craggs et al (2008) and Golder (2009) suggest that flexible pond covers are the most cost effective solution.

A further search was conducted into the use of plastics as an alternative support for the pond cover. Existing commercial materials discovered were a High Density Polyethylene (HDPE) modular float by MDS or readymade floating docks by Australasian Jetty's. Marine Docking Systems have a distribution warehouse in Brisbane, Queensland, while Australasian Jetty's are based on the Gold Coast. Discussions with MDS indicated that the HDPE modules are 500mm x 500mm x 400mm in size with a wall thickness of 5mm to 6mm and have a buoyancy capacity of 97.5kg each. Figure 2-2 shows how the modular system can be connected to form a stable platform.

Figure 2-2 Example of Marine Docking Systems modular floats

The use of proprietary floats incorporated into a feasible design requires the HDPE material to withstand an anaerobic environment. Golder (2009) conducted a study on the suitability of pond cover poly plastic materials. Material testing showed HDPE to meet all selection criteria with the exception of flexibility. CA (2010) question the suitability of HDPE as it reacts with the fats, oils and greases (FOG) of the meat industry. Huebeck (2009) are more concerned with the use of HDPE as a cover due to its high thermal expansion rate and being difficult to install. MDS suggest that the gases that are created or a combination of the gases, heat and chemicals created in turn degrade the HDPE over time by stripping out the additives placed during manufacture. Koerner (1994) indicates that HDPE generally provides good resistance to chemical attack apart from petroleum. Gabriel (2003) describes the process in which HDPE usually degrades in areas of tensile stress. This supports the CA (2010) observation of the degradation of HDPE pond covers by stretching (tensile stress) to approximately three times its original length. The use of HDPE floats are not under the same tensile stress as a HDPE cover. This is due to its increased thickness as well as the modular arrangement allowing a high degree of flexibility minimising any stress areas. The use of HDPE floats is suitable in an anaerobic pond containing meat industry waste.

2.3. Existing designs

The literature review covered varying types of existing pond cover structures. Theil (2001) and Zhang et al (1999) both describe the construction and development of a positive pressure pond cover. Theil (2001) uses a polypropylene membrane reinforced with wire cables. The wire cables carry the positive pressure forces to anchor ties. The determination of these cable forces is discussed in detail. Hibbeler (2006) also provide guidance on the calculations required for the forces in uniformly loaded cables. Both texts assume that the cable is flexible and will not elongate when the load is applied. These two texts provide a reference to this project with the CA (2010) report noting that a wire mesh frame support system showed some potential. The application of wire cables forming a mesh does use these same formulas. The inflated cover developed by Zhang differed with the cover supported only by a timber collar at the edges that is anchored in a backfilled trench. The cover itself withstands the tensile forces created by inflation without the need for cables.

Figure 2-3 Example of an inflated pond cover

Koerner (1994) also developed designs for both fixed and floating covers. The fixed design example is a cover over a small diameter tank where the cover is directly bonded to the edge of the tank with a level of clear air between the cover and the reservoir surface. The result is a parabolic shape with the lowest point at the centre of the reservoir. Koerner (1994) suggest the insertion of small diameter holes to allow rainwater drainage. The determination of the geo membrane forces are similar to the method discussed in Hibbeler (2006). Koerner (1994) also present different design methods for floating covers, these designs were reproduced by the MLA presentation discussing the Golder (2009) report. The floating design developed by Koerner (1994) use a system of floats and weights to control rainfall runoff in a similar way to that of Fabtech's description of their commercial system. Research suggests that the best way to eliminate rainfall pooling on the floating covers is to create a gradient with the combined use of weights and floats. The use of floats and weights are the main design features of both the Reid piggery design and the MWC design. The Reid piggery design used a central weighted water pipe with lateral weights at 12m centres. This causes the gas production to billow between the lateral weights forcing the rainwater to the lateral weight. The rainwater then drains to the centre where it is collected in a sump and pumped away. The optimum arrangement for the weights and floats to allow rainfall runoff cannot be determined from the given information. This knowledge gap can be closed with field trials.

Qasim (1985) present a range of designs for covers for anaerobic digesters. The designs are similarly separated into two categories of fixed and floating. The fixed covers are either flexible or rigid. The flexible covers are similar to the MWC and the Reid Piggery while the rigid covers are an enclosed tank or concrete lid. The floating designs discussed are the Wiggins type and the Downes design. The Wiggins is a pontoon arrangement where the cover is above the liquid level of the pond and spans the width of the pond. Floats (pontoons) are fixed along the full length on both sides. The Downes design has a fixed truss structure spanning the pond width with the cover over. Qasim does note the added requirements needed for an effective cover structure. The additional requirements are, sampling ports, access manholes, a liquid overflow system and a vacuum pressure release system inclusive of a flame trap. Qasim estimates that the gas pressure experienced under a cover can reach a maximum of 3.7kPa.

2.4. Proposed Pond Cover by Churchill Abattoirs

The proposed pond cover by CA is a composite membrane created by a spray on application of a proprietary product, Liquid Rubber™, onto a commercially available geo-textile. The proposed supporting structure developed by CA during field trials involved the construction of a "Raft" using 100mm PVC pipes as peripheral floatation with the cover spaning the pipes. These trials established the viability of the in-house developed material as pond cover that can be easily repaired and reused. CA considers a raft system to be more cost effective than that of a floating system where the sides are fixed to the pond bank (CA 2010). Both Heubeck (2009) and Qasim (1985), suggest that fixed cover designs are less expensive than the free floating (raft) designs. CA has also trialled a HDPE pipe support arch for the cover to rest on. The intention of the support is to create a gradient for rain water runoff and a sizable air gap allowing gas collection without bubbles forming at the cover. The conceptual design of a structure or frame to support the cover is the main objective of this research project.

The six new ponds constructed in late 2009 are approximately 20m wide and 100m long. The pond cover is expected to be of a size of 17m by 48m (CA 2010). A schematic of the wastewater treatment facility is shown in figure 2-4.

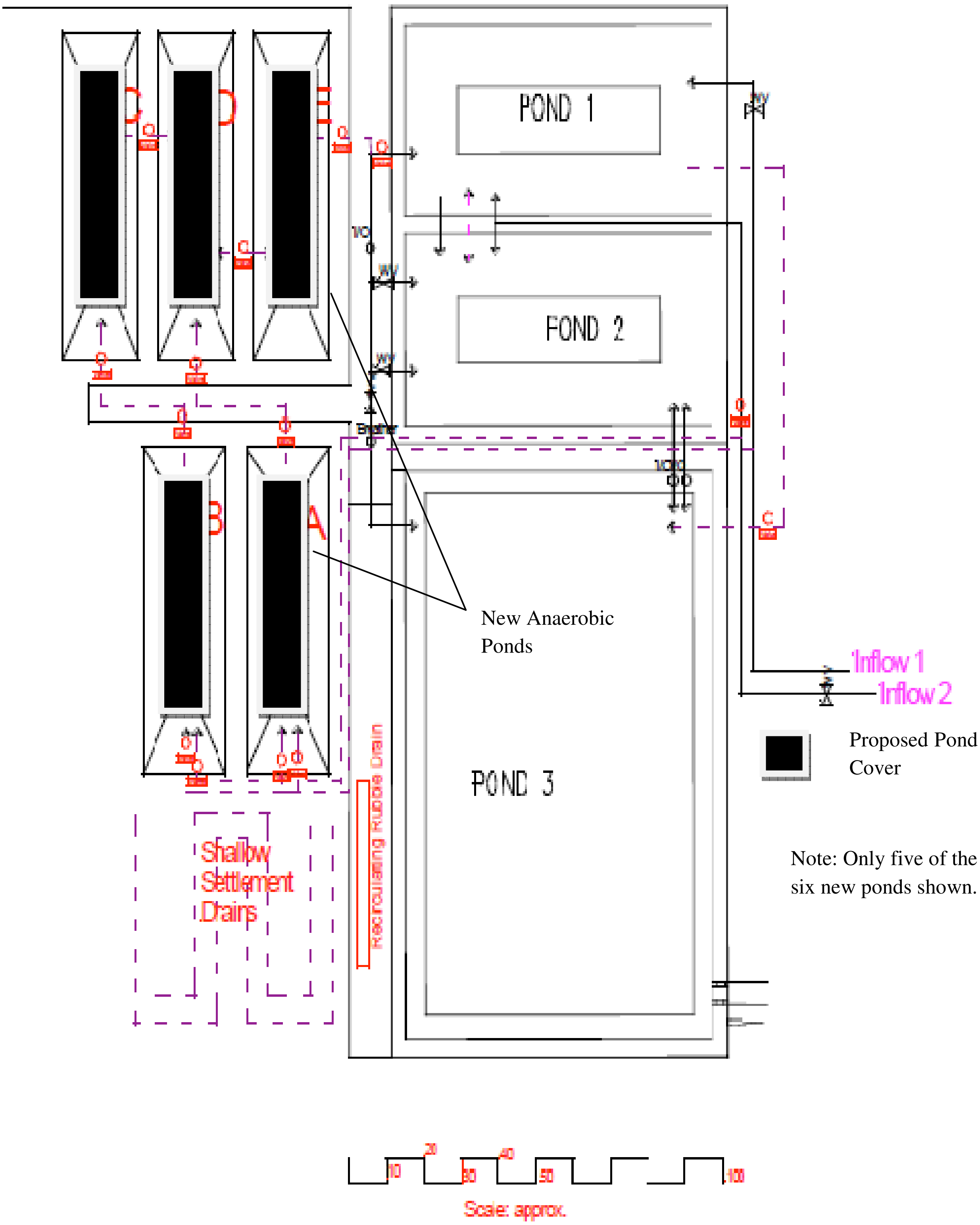


Figure 2-4 Schematic of Churchill Abattoir ponds (CA 2010)

3. RESEARCH METHODOLOGY

3.1. Introduction

The research methodology was bounded by the CA preference for a raft design. These set parameters influenced the direction in which the conceptual design and performance criteria would evolve. The preferences for a raft meant that the conceptual designs were restricted in that fixed systems to the pond edge were not considered. It did not mean that certain design aspects from fixed pond structure would not be employed in the conceptual design process.

The performance criteria is a measure against which the existing systems and the conceptual designs will be evaluated. The unhindered operation of the anaerobic pond gas collection and odour reduction are the main drivers for establishing a set of performance criteria.

3.2. Conceptual design

The conceptual design process started with the known parameters required by the end user (CA). CA's preference is to have a cover that is of a raft design. A raft design is one that floats on the pond surface without being fixed to the pond bank. This requires that the support structure to be wholly contained with the reaction forces being transmitted through the pond surface. CA specifies that a 17m by 48m cover is required with a height no greater than 1.5m above the water surface.

The concept design has two major serviceability considerations for it to be feasible. The first consideration is the fact that the structure has to Float. Provision must be made for suitable buoyancy aids to be attached or that the materials used for the structure are capable of floating. The second consideration is that the structure needs to have enough mass to ensure that it will not be picked up by the wind. This is critically important as CA's preference is for the pond cover not to be tethered to the pond bank.

3.3. Performance Criteria

The development of a pond cover structure is required to minimise the effect of odour and allow an easy capture of the resulting methane to flare off or for the use as a fuel for electricity production. CA produced a list of criteria for the pond cover; the supporting structure would also have to meet such requirements. The ideal pond cover criteria as developed by CA are listed as follows:

- Resistant to fats, oils and greases (for abattoir uses).

- Easily repairable in-situ.
- Wind and shear resistant.
- Can be removed and re-used.
- UV resistant.
- Does not collect rain. (Prevention of the “bubble” effect.)
- Covers the entire pond/lagoon.
- Allows inspection and/or sampling of the wastewater.
- Allows periodic clean out without detriment to the overall treatment processes.

The main issue to address is the conveyance of rain water while maintaining an impermeable cover that allows gas to be captured without the “bubble” effect. The” bubble” effect occurs when still water trapped on the pond surface forces the undercover gases to accumulate in concentrated areas, pushing the cover up into a bubble. Figure 3-1 shows an example of the “bubble” effect.

Figure 3-1 Existing pond cover with water and gas concentrations

MWC created a scope for their pond cover design. MWC had experience with floating cover designs before they commissioned their latest design in 1998. Their experience was used as a guide to create a cover design that would:

- Be installed when lagoons were in-service.
- Provide strength and stability.
- Require low maintenance.
- Facilitate maintenance.
- Allow for lagoon water level to fluctuate.
- Self draining for precipitation.
- Have a long design life.
- Have structural integrity to withstand pressures caused by scum development.

- Allow for increasing the length of the cover.
- Maximize biogas collection and minimize infiltration.
- Facilitate biogas migration/collection.
- Be used to store biogas for use during peak power demand periods.
- Have a biogas control system that would protect the cover and allow maximum usage of biogas.

Based on the experience of CA, MWC and the literature review the following table outlines the performance criteria that will be used to critically evaluate the concept designs.

Table 3-1 Pond Structure Performance Criteria

PERFORMANCE CRITERIA	ASSESSMENT CRITERIA
FUNCTIONALITY	
• Gas Capture	Is gas captured? Is there allowance for peak production or breakdown storage? How is the gas controlled?
• Water Shedding	Does rainwater pool? Is there a path for the rainfall to go?
• Maintenance	Can the cover be maintained? Is access to the pond acceptable?
• Operational Demands	Can pond sampling occur? Is the removal of sludge accounted for? Does influent have to be controlled?
STRUCTURAL SYSTEM	
• Load Path	How are design loads transferred? Uplift accounted for?
• Cover Connection	How is the cover connected to the structure? Can the connection be reused? Can the cover be reused if detached?
• Floatation	Is there sufficient buoyancy capacity? Is the required floatation excessive?
MATERIALS	
• Durability	Are the materials sufficient to withstand intended environment? What is the likely maintenance period?
• Availability	Are the materials readily available? Can spares be acquired?
• Repair	Can the in-service repairs occur on the structure? The length of time required for repair? Do plant owners require specialists training?
COMPONENT DESIGN	
• Fabrication	Are the components easy to fabricate?
• Transport	Is there a need for transport to site? Can the design be transported to site?
• Construction	Is there specialist equipment needed? Is the structure easy to handle?

The assessment of the conceptual designs will be a subjective one. The advantages and disadvantages of each design will be compared to each other using the above outline. A recommendation on a conceptual design will be based on Table 3-1 guidelines which will be given during the discussion chapter of this research dissertation.

3.4. Design

The conceptual designs developed during this project reference the appropriate Australian standards to ensure that a feasible concept is developed. Detailed evaluation against every clause was not considered, but an overview of the principles has been made to allow for a design concept to be developed and be workable in a real world context.

The first design action considered for the design of the structure was the effect wind would have on the structure. The areas of assessment were uplift in combination of any positive gas pressure created from gas production of the structure and any increase in any down force therefore requiring extra buoyancy. It was initially thought was to treat each structure as a free roof with blocked conditions under appendix D of AS1170.2:2002. The height to depth ratio was outside the suggested limits and it was therefore it was decided to treat the structure as a normal roof without side walls. It was also assumed that the cover material over the structure would provide for a situation where the assessment of internal pressures would be to have all exposed surfaces equally permeable. The worst case of uplift and downward pressure was determined to account for the worst case situations where extra buoyancy is required or self weight to counter both criteria. Assumptions and design criteria are available in Appendix B. Table 3-2 details the two worst case wind pressure situations.

Table 3-2 Wind and Gas Pressures

	Load Case	Wind Pressure
Uplift Pressure	1. Cross Wind	-0.49kPa (U), -0.21kPa (D)
	2. Gas Production	-3.7kPa
Down Pressure	3. Cross Wind	+0.05kPa (U&D)
	4. Gas Production	± 0kPa

It soon became apparent that if the design were to span the required 17m above the water surface that the use of a stiff material would be required. The use of steel, stainless steel or aluminium would fit these criteria with the requirement that some form of welding or bolted connection between the structural members would also be required. It was decided early on that if one of these material were to be used the choice would be aluminium due to its oxide layer preventing corrosion as well as it being relatively light weight when compared to steel. Aluminium also has the required strength capacities. Further research into the use of aluminium as a structural element, found a multitude or cast and wrought alloys and tempers available for use. The decision was to use readily available aluminium alloys and tempers from Australian suppliers such as Capral and One Steel and using the mechanical properties listed in AS1664.1:1997 "Aluminium Structures-Limit State Design, as well as ensuring differing alloys can be welded together with AS1665:2004 - Welding of Aluminium Structures

3.4.1. Materials

A material list was collated that would provide the necessary resources to develop the concept designs. The materials chosen were selected from proven materials used in existing designs researched during the literature review as well as materials that had properties with potential to be used in an abattoir context. The thermoplastic properties were sourced from the ASM International 1992, Handbook, while aluminium alloys and tempers were collated from various Australian standards. Table 3-3 lists the chosen material resources:

Table 3-3 Material Listing

Material	kg/m³	f_y (MPa)	f_u (MPa)
Structural Grade Aluminium	2700	241-355	262-303
Ethylene Vinyl Acetate (EVA)	55	9-10	13-14
Polyethylene, high-density (HDPE)	960	20-30	110
Polyethylene, low-density (LDPE)	930	6-17	140-185
Polyvinyl chloride (PVC), rigid	1300	35-55	35-55

3.4.2. Floats

The preferred option by CA is to use 100mm uPVC storm water pipe as the method of providing buoyancy. Figure 11 from the CA (2010) report shows a 6m x 12m raft being floated using 100mm uPVC periphery floats. Assuming a 20mm vertical displacement the weight of the cover material can be determined by:

$$\rho g V = weight\ of\ displaced\ fluid \tag{2}$$

$$\rho = density\ of\ water\ (1000 kg/m^3)$$

$$g = 9.81 m/s^2$$

$$V = Volume\ of\ submerged\ body$$

The weight of the displaced fluid is equal to the weight of the cover. A conservative approach was taken where the weight of the floats was ignored. The mass of the cover material was ascertained to be 44kg for the 6m x 12m raft. Therefore the length of 100mm uPVC stormwater conduit required to support a 17m x 48m area is 50m at full depth displacement. If the stormwater conduit is constructed around the pond cover edge as per the trials there would be 130m of conduit, greater than the required 50m.

Figure 3-2 CA Trial raft cover.

3.5. Summary

The development of the concept design is bounded by design criteria specified by CA. These being a raft type structure that spans an estimated 17m for a length of 48m. Performance criteria were developed by reviewing the experiences of MWC during their implementation of an anaerobic cover as well as the CA's trials. The performance criteria were divided into four assessment areas being, functionality, the structural system, materials used and component design.

The weight of the cover was inferred by the photos and descriptions detailed in the CA (2010) report. The method assessed the amount of displacement occurring when a 6m by 12m metre raft was floated using the 100mm uPVC floats. The wind forces were assessed using the Australian standard for wind actions, with the structure having equally permeable surfaces. The added effect of gas production causing an additional buoyancy effect was also considered.

4. CONCEPTUAL DESIGNS

4.1. "The Truss"

4.1.1. Introduction

The truss concept is an idealised design inspired by CA's trial and preference for an arch structure to support the cover. It incorporates nine truss structures at 6m centres spanning the required 17m at 6m centres giving a total length of 48 metres. The point at which the top and bottom chords terminate is where a lateral brace is fixed along with peripheral floats.

The concept was developed from the initial idea by CA during their trials, whereby a HDPE pipe was used to span the breadth of the cover by way of an arch. Various attempts were made to stiffen the HDPE pipe to ensure that it would have the capacity to withstand its weight and the weight of the cover. The draw backs of the intended system were the lack of inherent stiffness in the HDPE pipe as well as the necessary welding required to fit support struts under the arch itself. Attempts were also made to stiffen the structure as well as aid in its floatation by filling the core with expansive foam. Figure 4-1 shows the CA trials developing a HDPE arch support.

Figure 4-1 CA Cover support trial

4.1.2. Structural System

The structural system differs from that of the CA trial. The first improvement is the use of aluminium to overcome the HDPE pipe weakness due to lack of stiffness. With a truss the inclusion of a bottom chord insures that all the self weight and pond cover forces resist the natural reaction of the top spanning member to collapse flat. Lateral bracing runs from both the apex of the truss and the top and bottom chord intersection to the same position on the adjacent truss structure. Cross bracing in opposite directions at each end span provides a load path for wind shear to the pond surface. Cables or wires can span each truss structure to aid the support of the cover. Figure 4-2 shows an idealised section view of the Truss concept.

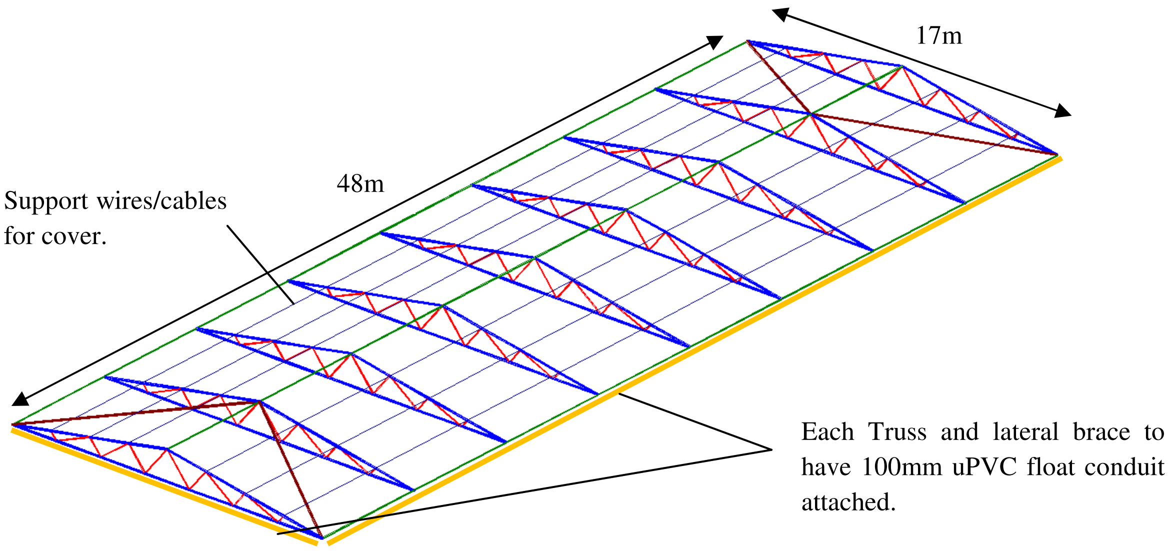


Figure 4-2 Idealised design for 17m x 48m Truss concept

The concept of the truss consists of a 17m span over the breadth of the pond connected onto 100mm diameter uPVC conduit floats. The connection of the truss to the floats will be achieved by a fabricated collar from the lateral brace connected directly to the uPVC conduit.

The initial trials by CA found that the use of the uPVC floats meant that large lengths could not be readily lifted due to the large deflections that conduit would endure under its own self weight. To counter this, the conceptual design allows for the uPVC conduit to connect directly to the lateral brace which is then bolted directly to the truss. This system allows for a truss module consisting of two truss components with connected braces to be lifted and placed into the pond without any forces being transmitted through the 100mm uPVC float.

The cover will rest on the top chord of the truss with strained cables or wire spanning between each truss. The level of tension required in each cable or wire needs only to be sufficient to resist any sag caused by the weight of the cover and allow unimpeded flow of water to the edge. The cables/wires do not contribute to the structural integrity of the support structure. The cover can either be welded to the uPVC float at the top and bottom chord interface or attached directly to the lateral brace and top chord by being pressed between the CHS section and section a of profiled plate running the length of the member and then fixed by self tapping aluminium fasteners.

Each truss will consist of two welded frames connected at the apex of the top chord and mid span of the bottom chord by an end plate and bolts. This design concept has been considered as it allows the truss to be easily transported on a flat bed truck in 8.5m x 1.5m sections. Both the lateral and cross bracing will also be attached by bolted connections. The brace will have a slotted cleat through the centre with a sealed cap to exclude any water ingress inside the CHS. The ends of all structural members will also be sealed to eliminate this problem.

The overall weight of the structure (excluding the cover material) will be approximately 2000kg (see appendix B); with the cover material, downward wind pressure the total mass of the structure would be in the order of 2800kg. The intended use of the 100mm uPVC stormwater pipe would have to provide the buoyancy to withstand this mass. The intention is to run the conduit down both sides of the 48m length giving a minimum total length of conduit of 96m. The minimum length required to account for 2800kg is 280m (Refer Appendix B). Provided each truss had a conduit attached to each side of the bottom chord as well as the conduits positioned at the lateral brace the total length is 402m which is greater than what is required. The benefit of the mass of the structure is that it counters any uplift forces from wind.

4.1.3. Design and Materials

The conceptual design will use structural grade aluminium for the chords and web diagonals to account for the lack of stiffness of the HDPE pipe. Aluminium has been selected for its light weight and substantial corrosion resistant properties, which are due to the passive oxide layer.

The mechanical properties and sections used for the design vary depending on the structural component. The top and bottom chord of the truss are the larger sections as well as having the greater mechanical properties Table 4-1 details the aluminium mechanical properties and sections proposed for the truss design.

Table 4-1 Aluminium Sections: Mechanical Properties

Section Size	Structural Component	Alloy and Temper		f_u (MPa)	f_y (MPa)
88.9 x 5.33 CHS	Top & Bottom Chord	6082	T5	295	255
50.0 x 4.0 CHS	Web Diagonals	6005	T5	262	241
63.5 x 6.35 CHS	Lateral & Cross Bracing	6061	T6	290	241
6mm plate	Collar/gussets/cover press	5083	H116	303	241

CA requires that the pond be available for periodic clean out and regular sampling. The clean out will be achieved by removing enough of the truss members to expose half of the pond. The exposed half of the pond will be cleaned then the pond cover moved to the cleaned section, providing access to the uncleaned half. Sampling of the pond can occur at each end of the truss structure at an opening of the cover at CA's discretion.

The truss members are designed for an even span length along the 48m structure. This means that the standard 6m length of conduit can be placed without extending or shortening it, therefore reducing construction effort. This also means there will be little waste of the purchased conduit.

4.1.4. Fabrication and Construction

The truss and brace components will be fabricated off site in workshop conditions. This allows for controlled welding conditions as well as providing access for inspection of fabrication. The welding of the different alloys and tempers is achieved by using the correct filler material as detailed in AS1665: 2004.

On-site the two truss modules will be constructed with the interconnecting braces and wires, followed with attaching the floats then laying the cover over the structure. The cover will be fastened by welding onto the peripheral floats and pressing it between two aluminium sections.

4.1.5. Ongoing Maintenance

Ongoing maintenance of the truss structure should be minimal as long as an acceptable standard or workmanship is achieved during fabrication. In service, the highest potential for damage on the structure will be during construction and when they are removed for cleaning. Periodic inspection of the fasteners connecting the cover to the structure will be required to ensure they remain secure and are not loosened by wind loading. In situ repairs of the cover will require the use of a platform that rest on the lateral braces and wires to ensure any point loading is distributed over a larger area. If the cover is found to have the capacity to withstand the force of a maintainer with tools this provision can be waivered.

4.1.6. Summary

The Truss design meets the preferred dimensions as stated in the CA report discussing the field trial testing of the intended cover structure. The use of 100mm uPVC conduit as a floatation aid will require that every truss module has at least one conduit attached to be sufficient to keep the structure above water level. The truss will be fabricated from aluminium sections and welded in a workshop environment. Aluminium will provide a durable and stiff support structure for the cover and will be of low maintenance. Access to the cover for in service repairs would however be difficult as maintainers would not be able to walk over the cover unless it can support the weight of a person over a 6m span. The truss modules would be transported to site and bolted together. The connection would be placed at the apex of the truss and mid span of the bottom chord therefore the maximum size of the transportation pieces would be 8.5m by 1.5m.

4.2. "The Raft Mat"

4.2.1. Introduction

The "Raft Mat" is a conceptual design based on the description of the MWC system which includes elements of the LemTEC system. Unlike the MWC system the edges are not fixed to the bank and the collection system will occur at the centre of the pond as opposed to the periphery. The design concept consists of a sandwich composite raft which floats directly on the pond surface. The intention of the design is that the gas collection conduit will serve as central spine at a higher elevation than that of the peripheral edge which will be weighed down with a collar. Rain will shed to the edge while gas produced will collect to the central area. The rainfall control is similar to Craggs (2007) design whereby a central 200L drum was used as a float and support for the cover but also provided a gradient for the rain to shed. The design will replace the drum in the Craggs (2007) design with the collection conduit.

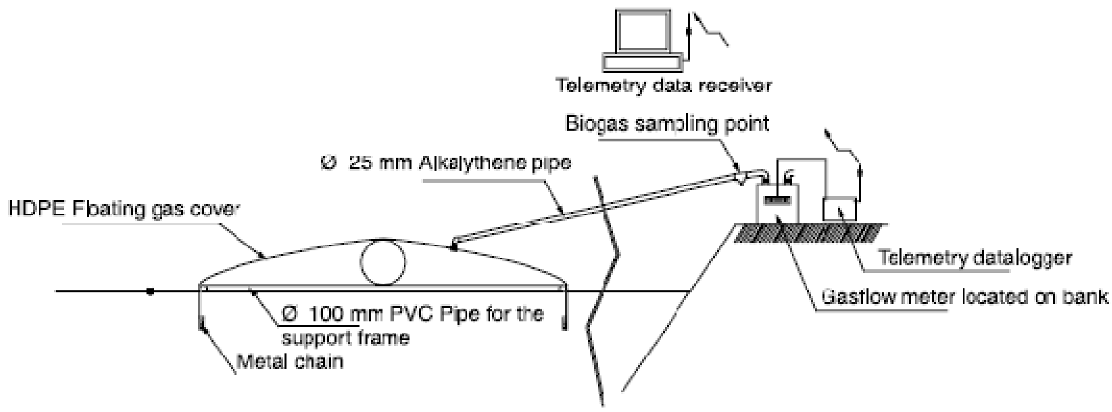


Figure 4-3 Craggs (2007) trial design

4.2.2. Structural System

The raft mat conceptual design is a composite laminar system. It involves the fabrication of modules that then connected on-site. The laminar module is constructed from two plies of the CA membrane with a relatively thick insulating "biscuit" in between. The insulating "biscuit" acts as a floatation device and also has the flexibility to move with the changing pond level.

The structure will rest on the pond surface and allow personnel to walk on the raft while in service. This design consideration has previously been achieved by MWC. This is demonstrated by the MWC design where an ATV and service personnel have worked directly on the cover while still on the pond (see figure 4-4). This design aspect needs to be tested as the MWC design had the edges fixed to the pond bank this meant that the edges did not sink into the pond when load was applied. The Raft Mat will need extra floatation and stiffness at the edge to support applied loads at the edge. The extra stiffness can be provided by incorporating the weighted collar as a structural member.

The raft mat system transfers all loads directly through the mat to the water surface. This direct load transfer removes the need to design a rigid structure that provides a load path to the water surface. It also eliminates the problem of using brittle materials such as the uPVC floats and low stiffness material such as the suggested HDPE pipe as a support structure.

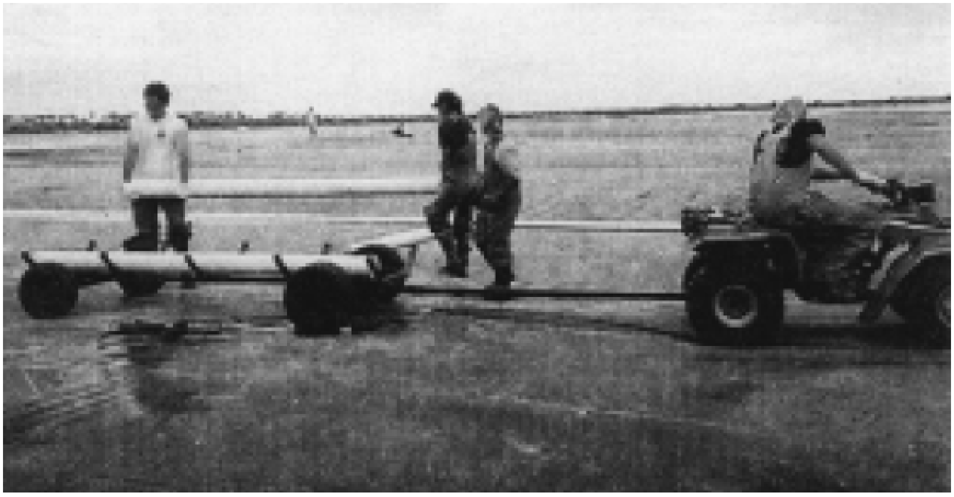


Figure 4-4 MWC pond cover with ATV and Maintainers.

The total mass of the system is approximately 2060kg as detailed in table 4-2 which is less than the Truss concept without the cover. The EVA provides approximately 15000kg of net buoyancy, which is more than adequate for workmen to travel on top of the cover structure. Uplift wind pressure at the edge can be eliminated by using AS1170-2:2002 as guidance and adopting the local cladding factor for edge areas (in this case the wind pressure would be increased by two). An appropriate weighted collar designed to counter this localised wind effect will be attached.

Table 4-2 Mass of Raft Mat Concept

Material	kg/m²	Area (m²)	Mass (kg)
Cover	0.61	1640	1000
EVA 20mm thick.	1.1	820	902
uPVC conduit	7.5	0.41	3
Aluminium Collar 6mm PL.	16.2	9.6	155
		Σ	2060

4.2.3. Design and Materials

The design of the Raft Mat involves the material selection for the insulating “biscuit” as well as establishing sound connections to the weighted collar and between the raft modules. The raft modules will be designed for standard sheets of EVA or LDPE to be used for the “biscuit”. These materials will also give buoyancy to the raft along with providing an insulating layer. Research (UNSW 1998) conducted has shown that elevated temperatures enhance the efficiency of the anaerobic pond as well as maintaining biological activity in colder environments.

The main area for the entrapment of the methane gas is around the central collection conduit. To ensure that the gas is conveyed to this area the bottom of the insulation can be profiled with channels that direct the gas to the centre. Emergency storage of the gas is accounted for by having orifices drilled through the insulation to between the insulation and top cover layer. These orifices will provide the capacity to store gas in the case of a breakdown of the collection asset or during periods of low electricity demand. The gas can only pass through the orifices under positive pressure, i.e. when there is not enough storage room under the bottom cover layer. The orifices will be placed near the centre but lower than the intake holes to the main collection pipe. This placement allows for the gas to remain concentrated at the centre of the mat and the gas to be stored between the top layer and insulation. The gas will concentrate at the peak of the mat therefore negating any potential of “bubbling” and still allowing rain to shed to the edges.

The uplift caused by wind shear will be overcome by placing weights on the top of the surface or by attaching weights to the underside of the cover structure. The fabrication of the modules must ensure that the internal area between the top layer and the insulation is sealed with the only access being by positive pressure through the orifices from the gas production. The edges will be weighed down with two sections of aluminium flat bar. The cover edge will be pressed between the two flats and fasteners will be passed through to hold the flats and cover in place. Due to the flat bar not performing any structural function but rather acting as ballast the choice of alloy and temper can be of a non structural grade.

4.2.4. Fabrication and Construction

The Raft Mat will be made into modules and assembled on-site. Subject to the Liquid Rubber geo-textile membrane the modules will be welded together as per the MWC design or have a detachable connection similar to the stitching of the LemTEC design. In lieu of stitching, a heavy duty zip will be easier to construct on-site; however the fabricator must create a tight seal at the seam to ensure maximum gas capture and minimise leakage. The seam will be smooth on the exposed side to allow a clear path for rainwater. The smooth seal requires the creation of having a tongue that covers the zip connection and is welded onto the adjoining module. Floats were incorporated at the seam connection areas in the MWC design. This will also be a design feature of the Raft Mat system whereby each seam edge is welded to a 100mm uPVC conduit the full length of the seam from the collection pipe to the edge. This feature will also increase the buoyancy of the raft as well as causing a slight parabolic shape laterally along each module. This in turn would create a drainage path for any rainwater.

The EVA insulation will be welded to the bottom layer with another layer of the geo-textile membrane over the top. The top geo-textile will be separate from the insulation too provide emergency storage capacity if the collection device, flare or electricity generator failed or demand was low. These modules will be fabricated to suit the largest available EVA sheet or compiled to fit the standard tray of a transport vehicle while still maintaining ease of handling.

4.2.5. Ongoing Maintenance

A cover structure design allows for access to the cover while in service. Maintenance personnel will be able to walk on the cover as was the case with the MWC cover. This allows direct access for ease of repair to the cover if holes or worn areas are found. The edge areas will have to be treated with caution as any load applied could cause the area to sink into the pond water. The smooth surface area also ensures that water drains freely and does not pond causing increased wear on the cover or the possibility of areas of cover being pushed into the pond itself.

MWC have discovered some areas where this type of cover structure does not perform as expected. Prevailing winds have pushed some areas of the pond structure into the water producing pools of water. While the influent area is causing the cover to lift over time, this problem was overcome by periodically moving the source inlet to different areas of the pond. MWC also discovered sludge management and clean out of the ponds was harder to achieve. This is due to their system of welded modules meaning that the cover could not be readily separated to allow for machinery access to the pond.

Sampling of the pond water will be achieved by inspection ports through the cover or sampling from the pond bank at the water edge. Sludge management and clean out would have increased difficulties if the mat modules are welded together. This would necessitate the removal of the whole raft to access the pond. The connection design of the modules will have a heavy duty plastic zip inclusive of a weak welded flap top and bottom of the join. The tongues will easily peal back, exposing the zip to allow the modules to be disconnected. This design concept will obviate the need for the whole cover to be removed. The join design is such that all tension forces will be through the zip while the sealed flaps are to prevent GHG egress and atmospheric oxygen ingress. The modules will then be separated individually allowing an easier process for accessing the pond. This design requires that only one module has to be removed as the remaining sections are structurally independent of each other and self buoyant. Another solution to the problem of cover interference with sludge cleanout is the suggestion by Huebeck (2009) to install suction ports to the sludge layer so no cover can be removed.

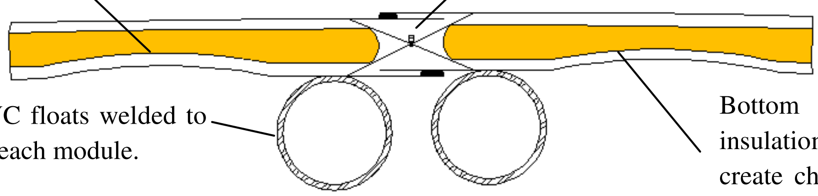


Figure 4-5 Idealised design of Raft Mat concept join

4.2.6. Summary

The Raft Mat concept is a hybrid of the MWC, Reid Piggery, and the LemTEC systems. The idea of using zips to connect the modules is derived from the LemTEC which used stitching. The concept of allowing direct access to the top of the pond cover is derived for MWC. The cover structure consists of a laminar module, where a bottom layer of the rubber cover is fused to an insulating EVA layer that also acts as the buoyancy aid. The top is a second layer of the rubber cover that is separated from the insulation. This allows for emergency storage capacity for times of low demand and collection breakdown.

The collection of the gas is through a conduit located along the central spine running the 48m length of the structure. The edge of cover is weighed down to provide fall for the rain to the cover edge. The underside of the insulation has profiled channels so the produced gas is directed to the centre where it is collected or stored temporarily between the top rubber cover layer and the insulation.

Maintenance of the cover is enhanced by direct access to the top of the cover but caution must be applied at the edges where there is no restraint to prevent the pond edge sinking into the pond. Access to the ponds for required periodic cleanout will be achieved simply by using a stitched or heavy zip system with cover flaps to allow for the separation of the required amount of modules.

4.3. "The Float"

4.3.1. Introduction

The "Float" makes use of the proprietary floats from Marine Docking Systems (MDS). The floats make up a large portion of the structure. The design is similar to the Raft Mat but there does not have piecemeal modules to be connected on-site. The CA cover rests directly onto the floats and gas collection conduit.

4.3.2. Structural System

The design makes use of the proprietary product from MDS. A series of marine floats are arranged in a grid pattern with a central collection conduit running along the full 48m down the spine of the arrangement. The central conduit is fixed in place by aluminium straps running perpendicular to it. The cover rests directly onto the central conduit and fixing straps. As with the Raft Mat the central conduit creates a high point for rain water to shed to the edges.

Gas storage capacity is provided by areas of voids at the centre under the collection conduit where the gas can be stored. In this case the whole cover footprint is not covered with the float modules.

The interlocking floats will be arranged so they have the capacity to withstand any wind uplift or differential movement from one corner to the opposite corner. Each individual float has the capacity to maintain buoyancy of up to 97.5kg.

4.3.3. Design and Materials

The floats are constructed of 6mm thick HDPE. This wall thickness allows for fasteners to be directly attached to the wall. The design requires the central gas collection conduit to be strapped down onto the floats. This is done using aluminium flat bar perpendicular over the conduit and spanning on an angle down towards the structure edge. The cover rests on top of the straps and central conduit creating an apex at centre for the rain to shed to the edge. The cover is fixed to the straps by an aluminium battens and self tapping aluminium fasteners.

The floats will be arranged in a way that the structure retains buoyancy and leaves sufficient voids so that gas capture is available. (See figure 4-6).

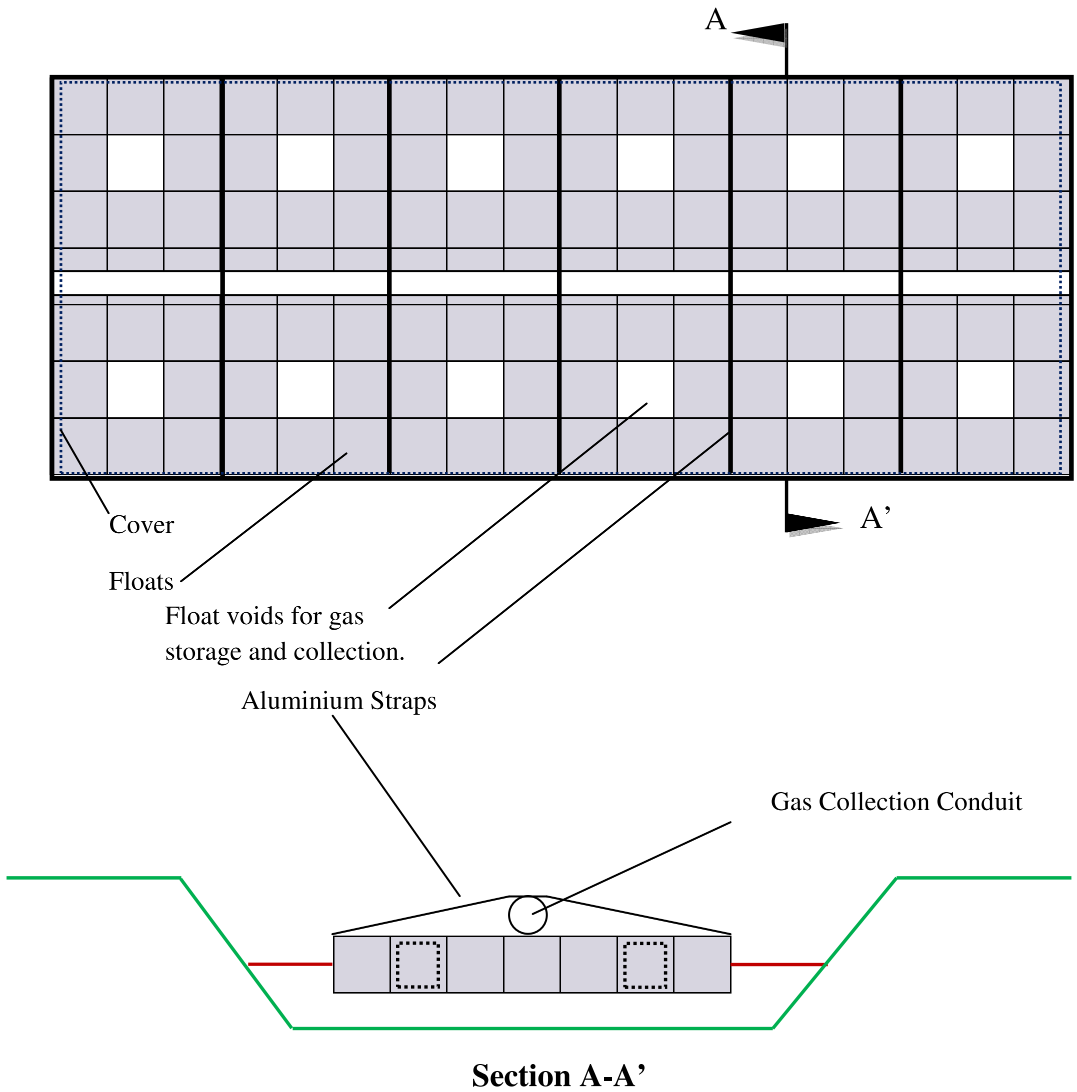


Figure 4-6 Idealised Float concept

4.3.4. Fabrication and Construction

There is very little fabrication involved in this design concept. All material items such as the floats the aluminium straps and fasteners can be purchased "off the shelf" and assembled together on-site. The modules will be systematically connected on-site in a predetermined pattern. The collection conduit will be fixed to the floats with the aluminium straps and the cover applied. The float structure will be progressively launched onto the pond water.

The fastening of the pond cover to the straps is by self tapping fastening where the fastener bears down on the cover ply or pressed between the straps and a length of aluminium flat bar. Connection to the floats at the water edge is by direct welding or pressing the fabric between the float and a length of flat bar.

4.3.5. Ongoing Maintenance

Inspection of the fasteners and the connection points as part of a regular maintenance schedule is required to ensure that the cover is adequately fixed to the support straps. Fasteners will be replaced on an as required basis.

The service life of float modules produced by MDS is unknown in an anaerobic wastewater pond environment. MDS suggested the volatiles produced by the pond can strip the hardening additives from the HDPE float. The use of HDPE material for pipe material and as floats on existing pond cover structures however suggest that it should not cause any maintenance problems. A trial of one of the MDS float modules in the abattoir pond environment will give the necessary performance guide of the float. Regular inspection and recording of in service performance will also capture the asset material behaviour allowing for the development of a maintenance schedule for the floats.

4.3.6. Summary

The Float concept design is the simple use of commercially available floats. The floats chosen are a modular block 500mm x 500mm x 400mm in dimension, which have the buoyancy capacity of 97.5kg. The design concept arranges the floats to form a platform for the gas collection conduit and the restraining straps.

The gas collection conduit combined with the straps provides the support structure for the CA cover to rest upon. The gas collection conduit is positioned in the centre of the 17m span and run the full 48m length. The conduit provides a ridge line at the centre to create a fall to the cover edge to allow the conveyance of rainwater.

The floats are constructed of HDPE and can be connected together on-site. The hold down straps are lengths of aluminium flat bar. The cover is attached directly to the straps with the use of stainless steel fasteners, and to the float edge by welding the fabric directly onto the floats.

5. CRITICAL EVALUATION

5.1. Functionality

5.1.1. Gas Capture

All three design concepts allows for gas capture. The Truss and the Float design both have a fixed storage capacity while the Raft Mat does have provision to expand during peak production or reduced collection. Each design has a gas storage capacity that is independent of the pond water level as is not the case with a fixed system, where the capacity storage is reduced by a higher pond level. The amount of gas the float design can store is dependent on the number of floats used. The more floats used the greater amount of space they occupy therefore reducing the gas storage capacity. The truss design has a fixed gas storage capacity which cannot be modified once it is in service.

The Float and Raft Mat designs control the flow of the gas to the centre of the structure. The Float design controls the gas by arranging the floats so that the main storage area is in the centre. The Raft Mat design controls the gas by only having the storage void at the centre and having profiled channels on the underside of the insulation to convey the gas to the centre under positive pressure of gas production. Further controls by the Raft Mat system are the orifices at the centre to allow for excess gas production and emergency storage. The Truss design has passive gas control, with no gas directed or channelled to certain areas the cover only traps the gas so the collection conduit can retrieve it.

5.1.2. Water Shedding

The three design concepts all have similar systems in controlling rainwater runoff. They each use a pitched roof structure to provide a slope for water to shed. The issue of “bubbling” that inhibits the correct water flow to the edge is resolved with each different concept design.

The Truss design allows for the cover to be installed relatively tight over the structure, reducing the chance for gas pressure bubbles to occur. If pressure bubbles cause a raised portion it will be at the apex of the truss aiding water flow to the edge. The “bubble” occurs at the ridge line due to the positive pressure of gas production would force it to the highest position. The truss design has no allowance to change the pitch of the runoff gradient without major structural redesign and fabrication.

The Raft Mat design has the least fall of the three designs. The fall is governed by the height of the internal collection conduit. Conduits placed at the seam joins will aid in water conveyance as the slight parabolic curve created results in water draining down to the edge on an angle towards the centre of each module. This also means that a the cover is separated into defined portions, meaning catchment areas are reduced so if a pool of water were to occur the water it would than collect would be limited to that area rather than the full surface area of the mat.

The Float design has a similar profile to that of the Raft Mat; however it has the advantage of raising the pitch of the cover to a steeper gradient if desired by raising the central collection conduit by the use of packing shims. The cover of the Float can also be fixed to the support structure relatively tight by adding more aluminium straps and fixing the cover to the straps at closer centres. Fixing the cover to the aluminium straps restricts the up force of the gas on the cover and reduces the effect of the "bubbles".

5.1.3. Maintenance

The maintenance of each structure is the first major variation of the three designs. The Truss concept is intended to be a low maintenance design, while the Raft Mat concept allows for in-situ repair if required. The Float concept allows for individual parts to be replaced.

The Truss concept is a low maintenance design. The structure being made from aluminium makes it highly durable in the anaerobic pond environment. Therefore it is envisaged that it would require very little maintenance. However the use of aluminium does have the disadvantage that if repairs are required, on-site welding can be difficult. This is due to the required use of gas shielding techniques; this technique can prove to be difficult in exposed wind conditions. The question of access would also be a disadvantage if repairs were to occur as the truss would have to be removed from service to allow the repair to occur.

The Raft Mat concept is designed to enable in-situ repair can occur on the structure. The structure has enough self weight and pressure distribution for maintenance personnel to walk over the cover while it is in service. The edge areas may require a bridging structure to allow access onto the mat due to the potential for the edge to sink under weight. The field trials by CA proved that the rubber geo-textile composite fabric can be repaired in situ while the EVA insulation layer can easily be replaced, but the method of welding a new section to the bottom layer may be problematic if it has to occur in service. Defects on the bottom layer should be repaired when the module is removed for sludge cleanout.

The Float concept offers probably the easiest of the three options to maintain. This is due to the floats being of a small dimension that they can be replaced easily if they were damaged. The cover repair could occur if the floats are arranged so that a maintainer could walk on a "path" of floats. The obvious problem with this scenario is that the maintainer would not be able to see the floats as they will be hidden from view by the pond cover. The capability of a maintainer to walk on the cover itself without the need for a float will depend on the tensile capacity of the cover material.

5.1.4. Operational Demands

The requirement for pond water sampling and periodic sludge cleanout are the main operational demands that the pond cover system has to consider, as well an appreciation of whether the influent position needs to be rotated from various points to stop any build up of waste material disturbing the cover.

Sampling of the pond can be achieved with all three designs simply by adding an access port at the edge of the pond structure. Samples from the centre of the pond or away from the edge can be obtained in the Raft Mat design. Such samples can be obtained in the Truss or Float concepts if the geomembrane developed by CA has the tensile capacity to enable personnel to walk over it.

Periodic sludge removal is the main operational demand having the most effect on the pond cover structure. All three concepts require the removal of whole or part of the structure to allow access to the pond to be achievable. This hindrance has been noted by all research on the subject matter. De Garie (2000) highlighted it as a problem with the MWC design while Huebeck (2009) suggested the installation of suction ports to obviate the need to remove the cover. The latter suggestion by Huebeck (2009) is a simple solution to the problem. However the cost of retrofitting the suction pipes may be prohibitive.

The Raft Mat design has the greatest risk of being inundated with influent if it is not controlled properly. This is due to its low profile and the fact it has the least capacity to shed a large volume of water quickly. Consideration must be given to insure that the influent port is below the water line of the pond the majority of the time. This ensures that the cover structure does not have a situation where the influent flow is on top of the cover. Flow control of the influent is required so that if the level of the pond reached a certain level no discharging into that pond can occur without precautions in place. The installation of a float switch with the capability of a manual override at the point of discharge allows for discharge to continue while operations personnel were present.

5.2. Structural System

5.2.1. Load Path

Each cover structure has differing load paths to distribute the self weight of the structure and the imposed loads of wind and gas production.

The Truss design transmits the weight of the cover structure from the top chord of the truss down to its dual floats at the bottom chord and lateral braces. The mass of the truss structure is greater than the other designs and easily accounts for any uplift forces. The effect of wind is greater on the Truss structure than the Float of raft design due to the greater pitch of the Truss concept. There is no load transfer is through the gas collection conduit.

The Raft Mat design distributes its load by applying any permanent or imposed action over a wide area, therefore reducing the deflection into the pond surface. The edge areas require caution as pressure applied at these points will cause localised sinking of the mat. It is prudent to tether the edges to the bank while allowing enough slack to account for the rise and fall of the pond surface. Extra 100mm uPVC stormwater conduit can added to the raft edge to increase edge stability when weight is applied. The cover edges are also a potential area for wind uplift which requires the addition of a weighted collar to minimise this.

The load path of the Float concept differs as the forces from the cover surface are transmitted through the restraining battens and the gas collection conduit. The forces then pass through the floats to the pond wastewater surface. The self weight of the structure accounts for the wind uplift forces.

5.2.2. Cover Connection

The concept designs developed have different connection details to the intended rubber cover. The connection to the cover must ensure that defects are not introduced to the cover that would allow gas flow between the pond surface and atmosphere. The connection must be reusable and not damage the cover if detached from the support structure.

The Truss design concept has two connection points between the structure and the cover material. The connection points are at the top chord of the truss and at the edge, either to the periphery floats or directly onto the lateral bracing. Connection to the top chord and the lateral bracing is achieved by direct fastening or clamping the cover by aluminium flat bar batten. These connection methods require the cover to be punctured by a fastener which introduces a potential point for gas ingress and egress. Eliminating any potential leaks by using fasteners will achieved by sealing around the fastener with a proprietary sealant. The clamping with a batten requires a flexible backing strip on its bearing surface to mould around the cover material sealing any puncture points. The removal of the connection requires careful repair to ensure all punctures created by the fasteners are sealed. The connection to the floats is achieved by direct welding similar to the CA trials, which requires the cover material to be cut from the float with the remnants left on the float discarded. There is no direct connection of the cover to the wires spanning from each truss structure. The wires prevent the cover from folding in on itself while any gas billowing will aid in water shedding.

The Raft Mat also has two connection design points to consider. They are the module to module connection, and the weighted collar connection. The module to module connection consist of three independent connection points firstly the zip connection the sealing of the over flaps and the direct bonding to the floats. The zip connection is a structural connection with no sealing properties about it. All tensile loads between each module will be transmitted through the zip allowing the weak seal to remain until it is required to be removed. The seal weld must be sufficient to maintain an airtight seal but weak enough to allow it to be peeled back when necessary. This design feature allows modules to be connected and separated easily without the need to puncture the material. The connection to the float is by direct welding. The weighted collar at the periphery edge of the float consists of two flat bar aluminium sections clamping the cover material with fasteners. This arrangement causes punctures through the cover material but does not have a detrimental effect on the seal of the cover as the weight immerses the join in the pond therefore eliminating any atmospheric contamination.

The Float concept uses the same connection details as the Truss design. The cover is attached to the aluminium straps and the floats at the edge. These similar connection details incur the same benefits and disadvantages as discussed with the Truss design.

5.2.3. Floatation

The buoyancy of each concept design is an integral part of the serviceability of the structure. The Truss and Float concepts use attached buoyancy aids to achieve floatation while the Raft Mat concept achieves floatation through the buoyancy properties of its internal EVA insulation.

The truss concept has a greater reliance its floatation aids, as its weight is far greater than that of the other two designs. CA's intention to use 100mm uPVC stormwater conduits as the main buoyancy aid should be sufficient for this relatively heavy structure. The addition of more floatation would be prudent as to increase the safety margin of sinking. The cost of acquiring extra flotation coupled with the fabrication costs of the aluminium trusses this design concept may be cost prohibitive. The floatation requirements for this concept are excessive when compared to the other two designs.

The need for added floatation in the Raft Mat concept is minimal as the laminar design incorporates a buoyant insulation layer. The added floatation that is included in the design concept is at the module joins which is used more to aid in rainwater flow over the surface than buoyancy.

The Float concept, as the name implies, is built upon the use of proprietary floats. The main critique of this design is the excessive use of the floats meaning there is more buoyancy than actually required. The floatation of this structure is excessive, but the floats do provide a stable platform in which to support the cover.

5.3. Materials

5.3.1. Durability

The Truss design is considered a durable design due to its use of commonly accepted materials in the wastewater industry that has proven to withstand an anaerobic environment in the wastewater industry. The durability issue with an aluminium structure such as this is the design is intended to be mobile. Due care is required to minimise the chances of damage by impact or other mechanical means. The preferred fasteners would be 316 Stainless Steel, which also have high durability properties in a potentially aggressive corrosion environment as an anaerobic pond.

The Raft Mat design also utilises materials proven in the wastewater industry. The thermoplastics selected demonstrate a broad resistance to corrosive environments. The main disadvantage of plastics is the loss of strength at high temperatures, however this will not be a problem as the temperature range will not vary from the expected ambient range.

5.3.2. Availability

The materials used in the design were chosen principally for their serviceability property of durability. Research confirmed that the materials used were readily available from the Brisbane region. The Truss concept uses structural grade aluminium. Standard member sections were chosen from the available charts from the One Steel Queensland aluminium catalogue with further reference to the Capral material list. Reserve sections lengths can be stored for use if required.

The Raft Mat concept uses the cover material developed by CA and EVA closed cell foam for the interior layer. The EVA is available in sheets ranging in thickness and size from most plastic retailers. MDS modules are used as the main material in the Float design. MDS head office is in Tasmania with a storage warehouse located in Brisbane. EVA sheets and MDS float modules can easily be stored as spares.

5.3.3. Repair

Different repair methods are required for each design due to the dissimilar materials used for each concept. The Truss concept is the most difficult of the three to repair, followed by the Raft Mat, while the Float concept is the least. Repairs required to the Truss must occur while it is not in service. This is a distinct disadvantage compared to the other two designs as accessibility and welding prove difficult while the Truss is in service.

Each truss must be removed before any remediation work on it can occur. Welding repairs may need to be carried out in a workshop environment if inhibited by factors such as gas shielding and weather conditions. Specialist equipment and training are required for these works. This repair is both time consuming and labour intensive. The fabrication of the truss modules to a required standard reduces the likelihood of structural repairs to low. Construction of an extra truss module is recommended to reduce down time during repairs.

The Raft Mat and the Float can be repaired in-situ. Repairs to the Float are simply an exchange of the damaged float module. This repair is quick and simple provided that spares are available. The underside and the top surface of the Raft Mat are both the CA cover requiring any ongoing maintenance to be on the cover itself. The CA trial proved that the cover could be repaired easily on-site. Patch repairs to the EVA sheet only require the damaged section to be removed and replaced with a similar size.

5.4. Component Design

5.4.1. Fabrication

The Truss concept requires a great deal of fabrication before site construction. Metal fabricating contractors must have the required skills in the fabrication of aluminium trusses. The correct welding quality of the welding of the aluminium member is vital. The service performance of the Truss concept depends largely upon a structurally sound weld. The welding of the aluminium truss requires that the correct filler material is used and this depends on the type of alloys being welded. Accurate welding documentation which includes the alloy welded and the filler material used is a necessary part of the fabrication of the trusses.

The Raft Mat design is best fabricated by a contractor experienced in sail making, plastic moulding or similar. A marine fabricator will have the necessary skills to construct the laminar modules. The fabrication require that the seam joints which incorporate the zip and seal flaps is of the highest quality as this area is the point of highest risk for failure or gas leakage.

The Float concept requires very little fabrication, with the majority or all of the work being conducted on-site. The MDS floats and aluminium flat bar can all be delivered to site without the need for offsite fabrication of components.

5.4.2. Transport

The Truss design has two bolted connections at the apex and at the mid span of the bottom chord. This allows for the truss to be broken down to a more manageable length of 8.5m which can be easily fitted onto a transport truck for delivery. The lateral CHS bracing is also bolted to the truss frames, with the longest at 10.5m length being the angled brace, which can also lie flat on a 12m truck bed.

The Raft Mat design also uses a modular system to enable transport from the fabrication workshop to on-site construction. The laminar modules will be constructed so they can be rolled up to aid in transport or be constructed to fit the width of the transport tray. The less the width in the delivery vehicle the more zip connections and seams is required. The reduced module size is a distinct disadvantage as additional zips and seams increase areas of gas escape and atmospheric infiltration.

The Float concept is easily delivered to site as the float modules are 500mm x 500mm x 400mm in dimension and able to tit on a variety of transport vehicles for delivery to site.

5.4.3. On-site Construction

The on-site construction of the cover must be simple so that it is easy to manoeuvre onto the pond and to keep any specialist equipment to a minimum. The Truss concept, once delivered to site requires the truss sections to be fitted and then the brace lengths to be added between them, with the support wires, and floats attached the cover can be attached. The Truss structure needs to be constructed in incremental stages. Two connected trusses with the cover attached are progressively pushed out onto the pond surface until the total 48m is built. This method only allows for two trusses to be handled at a time.

The Raft Mat design follows a similar method to that of the Truss concept. The use of a heat source is required to seal the zip joint and for direct welding of the cover material to the 100mm uPVC floats.

5.5. Summary

The three design concepts were evaluated against the performance criteria developed in Chapter 3. The criteria for which the concepts were evaluated were categorised into four main groups being Functionality, Structural System, Materials and Component Design.

The gas capture and water shedding capabilities were assessed under functionality. The three concepts had very similar systems to deal with these two criteria. The functionality criteria also investigated the maintenance and operational demands that the cover structure required as well as the pond and how the two systems interacted. The efficient and effective operation of the pond was seen to be the important factor when evaluating the three concepts. The criterion of maintenance was the first difference between the three designs. The Truss concept is considered a low maintenance design due to the durable nature of aluminium in an anaerobic pond environment. However if maintenance were to occur it would require greater effort than the other two concepts. The Operational demand of the pond requires periodic clean out and sampling. Sampling can easily be accommodated by providing sampling ports near the edge of each structure. The need for clean out highlighted the main problem for covered ponds, which is the restricted access. Removal of only a part of the structure to enable clean out is possible with all three designs. Huebeck (2009) and the MWC encountered the problem of partial structure removal with their designs. Huebeck (2009) suggested the installation of suction ports from the surface to the sludge layer to allow for pump removal without the need for cover removal.

The designs load distribution, connection to the cover as well as its floatation capability was assessed under the structural system category. The truss concept with its large self weight required more floatation than that of the other designs. The Float concept has the greatest buoyancy due to the use of floats as the main structural platform. The Truss concept is a more traditional system in transferring the load from imposed forces to the water surface than the other two concepts. The Float and Raft Mat systems distribute the imposed forces over a wider area, placing less demand on the buoyancy aids. The Raft Mat is designed to enable access by traversing the top. Further investigation is required to assess the viability of a maintainer to walk the edge of the Raft Mat without the edge becoming inundated. The connections between the cover material and the concepts were also assessed. The main concern is the provision an air tight seal at the connection for efficient gas capture. The connection details for the Truss and Float were direct welding, clamp and fasteners. The Raft Mat concept included an innovation on the stitched modular design by replacing the stitches with a zip and having tongue seals on both sides.

The materials chosen were assessed against the environment in which they are to perform. The criteria were durability, availability and repair. The materials used for the three concepts all used proven materials in used in the wastewater industry. The material schedule was developed during the Literature Review and Research Methodology. These schedules were transferred to the Design Concept stage; therefore by the time of evaluation the issue of durability had been reduced. Availability of the materials was the second consideration of each design concept. Research ensured that the materials were available in the Brisbane area. The Repair criteria assessed the repair method of each design concept along with required steps, timing and the need for specialist training.

The assessment of component design included the fabrication of each concept along with the transportation and cover construction at site. Fabrication of the Truss and Raft Mat is more intensive than the Float concept which can be sourced from individual parts and constructed on-site without the need for workshop fabrication.

6. DISCUSSION

6.1. Introduction

The critical evaluation of each design concept measured the design against the developed set of performance criteria. This following discussion will provide a basis to recommend the most appropriate design for CA. This chapter discusses the various design options available in the development of the concepts as well assessing each relative advantages and disadvantages of each concept design.

The concepts developed during the research project introduced elements from previously designed covers. The elements used were re worked to meet the required specifications of CA. The main design constraint was that a floating raft cover is the preferred design. Based on this preference, design concepts were developed to fit this criterion. A literature review of existing designs was completed to ascertain the types of cover structures available and the materials used. Buoyancy aids were also investigated to meet the CA requirement for a floating raft type. Further research was gathered on an anaerobic pond environment as well as the effective operation of an anaerobic pond. A set of performance criteria and materials were established to develop the raft design and measure its suitability to CA.

6.2. Design Options

The two types of design categories for pond covers are fixed and floating. The Periphery of fixed covers is anchored to the pond bank. It is usually above the pond surface and has limited vertical movement. The floating design has either a series of buoyancy aids maintaining clearance from the pond surface to the cover, or the cover rests directly on the pond surface. Both floating design methods allow for the cover structure to fluctuate with the rise and fall of the pond level.

The three concepts developed during the project have their origins from existing designs. The Truss concept is inspired by the efforts of CA with their arch support trials, it is also a combination of the Wiggins and Downes type as discussed by Qasim (1985). The Raft Mat concept uses elements from the LemTEC, MWC and Reid Piggery designs. The Float is an extension of the Wiggins design, with the concept of using the pontoons as the main support structure and not just the floatation aid.

The design concepts each have similar types of connections to the cover, with the main difference coming from the Raft Mat design. The Truss and Float have a connection to the cover either by direct fasteners or clamping the cover between aluminium battens. This connection detail has the potential to damage the cover and introduce imperfections into the cover that could allow gas transfer between the pond and the atmosphere, therefore reducing the gas capture efficiency. The Raft Mat concept uses a prefabricated connection of a heavy zip and two sealing overlays on the underside and top. This allows for an airtight seal to be developed while also accommodating any maintenance requirements for when the modules need removing. The Raft Mat has a distinct advantage over the two other concepts with regard to connection detailing.

The Truss concept has the least buoyancy, due to the weight of the structure being relatively high. The weight of the truss is beneficial when countering the uplift forces of the wind, but this concept adds to the problem of uplift as it has a higher pitched profile, therefore encountering a greater effect from any wind action. The Raft Mat and Float are lower in profile; with the Raft Mat resting on the pond surface reducing wind action to a minimum.

6.3. Material Use

The concepts developed use similar materials in their designs. The main difference is the amount of each differing material that is used. The Truss design is predominantly constructed of aluminium with only the floats providing a plastic component. During the critical evaluation it was considered that the Truss concept utilises the capacity of the floats more so than the other two. The addition of more floats to increase protection from sinking would be a sensible precaution. This extra cost incurred due the addition of extra floats may make the truss concept unfeasible. In comparison the Raft Mat concept is composed mainly of EVA and the CA cover material. The main disadvantage with this concept is that it will use twice as much cover material as it provides the bottom and top layers of the design. The use of EVA is an advantage with this concept as it provides both buoyancy and a structure for which the cover can rest on. The cover maintains its flexibility with the use of EVA making it better suited to covering a fluctuating pond. It also has the added feature of its thermal properties aiding in keeping a constant pond temperature. Materials required for each concept are all available in the greater Brisbane area.

The Float concept also provides a flexible platform. The use of modular marine floats that fit together in any configuration allows the optimum arrangement to be developed while in service. The design does rely on the floats for buoyancy and a structural foundation which is both an advantage and a disadvantage. The advantage is the same as the Raft Mat where one material is providing two functions in comparison with the Truss system where floats are added to the structure that is providing support. The disadvantage of the floats when compared to the Raft Mat is the doubt about their long term capacity to withstand the anaerobic environment. The purchase of numerous modules is required to create the foundation for the cover in the float concept. Similar modules on the market have a cost for a 100L float at $165. To cover the entire 17m x 48m area would require a cost in the order of $540,000, this could be prohibitive.

6.4. Pond Functionality

Sludge management is the main consideration not fully addressed by all three design concepts. The need for direct access to the pond to enable periodic cleanout of the ponds is inhibited by the covering of the ponds. The three concepts developed require that some part of the support structure be removed to allow access. The design that allows this to occur with the least amount of effort would obviously be the best option to have. If the removal of sludge is to be by vacuum extraction access ports can be incorporated into the surface of the cover. This would however create stress concentrations for the design concepts that have the cover suspended and under tension, mainly the Truss and Float concepts. The Raft Mat concept would be in the best design to allow for the access ports to be included. The reasons are that the cover is not under tension the access port can easily be sealed and the ports can be placed anywhere on the surface as they will be accessible as the concept design allows for direct access to the surface.

Water sampling is easily achieved with all three concept designs. The obvious point for sampling is at the pond bank between the pond and raft edge.

Maintenance of the three structures is vastly different between the concept designs. The Truss concept will require very little ongoing maintenance. The issue is if maintenance is required, the effort to do so is greater than the other two design concepts. The preference for workshop conditions and the need for specialist equipment for aluminium welding is a disadvantage of the truss design. The Raft Mat concept is also a low maintenance concept. A potential point of ongoing maintenance is if the zip connection fails. If the root cause of the failure is the seal, it would be easy to rectify by increasing the weld area. If the zip were to fail this would require more effort and cost to the operators as this type of repair would not be able to be conducted while the module is in service.

6.5. Recommendation

The cover concept recommended for the Churchill abattoir context is the Raft Mat. The reason for this decision is that the Raft Mat concept addresses most of the requirements of CA and best addresses the developed performance criteria as detailed in chapters five and six. Figure 6-1 details the preferred concept.

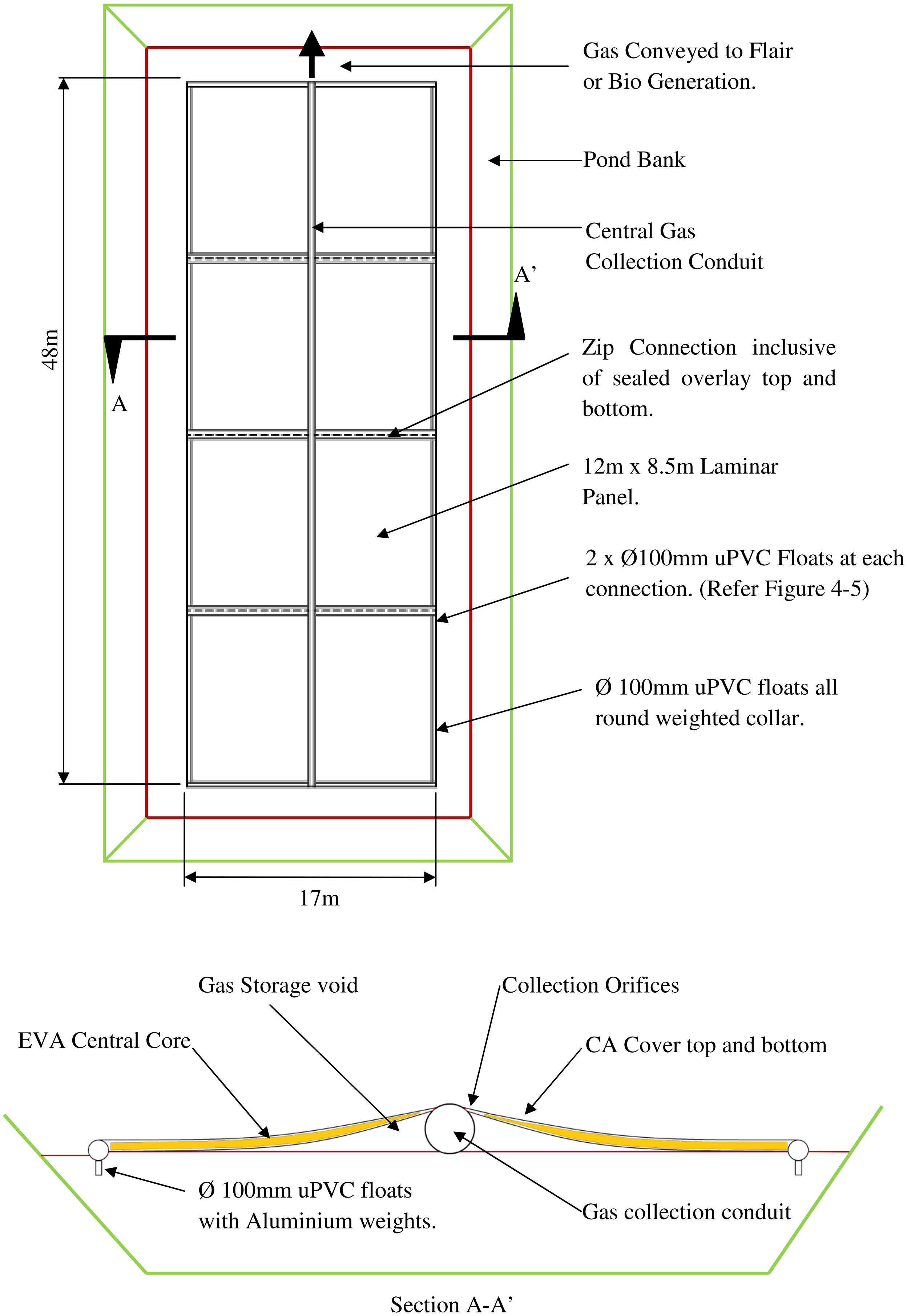


Figure 6-1 Pond Cover Structure Schematic

6.6. Summary

The Raft Mat is the recommended concept design for the CA anaerobic ponds. The concept design is based varying elements from exiting design concepts of from MWC, Reid Piggery and LemTEC. All three concept designs have been developed by addressing the core issues of gas collection, rainwater runoff and pond functionality. Pond Functionality in the end became the defining category for which concept deign was ultimately chosen.

The selection of the Raft Mat concept over the other two options is that the system has a greater number of advantages in pond functionality than the Truss and Float concepts. The advantages are:

1. The thermal properties of the EVA layer aids in the biological activity of the Pond.
2. Greater flexibility to access the structure as the buoyancy of the Raft Mat allows operators to traverse over the Mat.
3. Ease of access means the Raft Mat will be easier to maintain while the structure is in service.
4. The modular design and the connection concept allows for partial removal of the cover to enable sludge management of the pond easier than the other two options.
5. Stiffened edge conduits enabling lifting by crane.
6. The structure is composed mainly of the CA developed cover which has already been proven to be repairable and easy to connect to the uPVC floats.
7. No puncturing of the cover material needed to fasten the cover to the structure.
8. Lighter than the other to concepts.
9. Any gas “bubbles” occurring aid in rainwater shedding.

The main disadvantage of the Raft Mat is the unproven zip connection concept. Obtaining a heavy duty nylon zip that can be welded to the cover material should provide the required strength.

7. CONCLUSION

7.1. Introduction

The purpose of this research project was to develop a conceptual structural solution to support the CA's wastewater pond cover. The main objectives of the research were to research existing available designs, critically evaluate each design and the materials used and analyse existing pond cover applications. A set of performance criteria for the structure were established, and resolving whether any improvements or innovations to existing designs could be implemented by CA. The final objective was to develop a conceptual structural design for the wastewater pond at CA.

7.2. Further Research

During the course of this project various relevant topics of further research became evident. The first was the effect of the temperature profile on the anaerobic pond system. Raised temperatures were proven to increase the efficiency of the pond system to break down the waste. Further research on the optimum temperature for methane gas production would be of benefit in trying to improve fuel production capacity of anaerobic ponds.

Research is required to determine the mechanical properties of the developed cover material by CA. The tensile strength of the cover material would need to be established as it has significant applications to the viability of the cover structure concepts. If the cover is able to be suspended and have point loading applied, which is equivalent to a maintainer and tools the viability of the Truss and Float concepts is greatly enhanced. The reason is the cover will enable access to all parts of the structure similar to the intent of the Raft concept. The truss and float would then have a distinct advantage over the raft as they would have greater stability at the cover edge. Once the tensile strength of the cover material is established trials of the zip connection concept would also require research to determine the strength of the joint.

The cover material developed by CA is a composite geotextile with a rubber overlay. Trials of this material need to be conducted to verify its UV resistance, Craggs and Huebeck (2009) raised the possibility of reduced performance of rubber based covers due to UV degradation.

Research into an effective sludge management system without removing the covers would be of the most benefit for anaerobic pond covers. The need to remove or partially remove the cover in order to gain access for sludge removal is the main problem that existing designs and the concepts developed have been unable solve. The use of suction ports from an accessible position on the pond edge down to the sludge layer is one way of solving this problem.

7.3. Suggestions

The Raft Mat design concept is recommended to support the Churchill Abattoir anaerobic pond covers. The research into different designs of existing pond structures provided sufficient background knowledge into developing varying concept designs. The majority of the designs developed since the mid 1990's have used a cover fixed to the bank and floating directing on the pond surface. This type of design is endorsed by previous references (Qasim, 1985) as the most cost effective design. This is also reflected by Craggs and Huebeck (2009) development of trial pond covers from the floating raft type specified by CA before settling on a commercially viable design where the cover is fixed to the pond embankment. Serious consideration should be given to fixing the peripheral edges to the embankment and moving the gas collection conduit to the bank, similar to both the MWC and Huebeck (2009), if the Raft Mat concept is developed further. This approach would allow direct access to the cover surface anywhere on the pond. The conclusion by CA that the most cost effective solution is a raft type structure should also be reviewed considering the designs and conclusions by MWC, Huebeck (2009) and Fabtech.

The use of covers has increased the effort required for sludge management. All research has indicated that this is the main problem with covers over anaerobic ponds. The suggestion of installing suction ports into the pond bank down to the required sludge level is an innovation that should be investigated and implemented for use. If the effective use of suction ports is developed the issues raised with sludge management could be eliminated completely for pond cover design.

7.4. Summary

The research into a suitable frame structure for a large anaerobic pond cover produced a design concept that best meets the CA criteria and the performance criteria developed in this project. CA required the support structure for their covers to be of a raft type design that allowed for effective gas collection and free draining capabilities for rainwater. Rainwater entrapment was a significant issue to overcome as the pooling of concentrated surface water increased the wear on the pond cover as well as entrapping the gas into concentrated pockets halting the trapped gas to migrate to collection.

Pond Covers can be categorised into two design approaches, fixed cover design or floating. The fixed cover designs are usually rigid caps or positive pressure domes. The floating design cover floats directly on the surface or is held up off the surface by way of a floating structure. The cover can be fixed to the bank or free from the edges. The latter is the preferred design by CA.

8. APPENDIX A

8.1. Project Specification

FOR: **Glyn Alan LEWERS**

TOPIC: Design of a frame/structure to support large waste-treatment pond covers within the abattoir industry

SUPERVISOR: Steven Goh

SPONSERSHIP: Churchill Abattoir / Faculty of Engineering & Surveying

PROJECT AIM: Develop a conceptual structural solution to support the Churchill Abattoir's waste water pond cover.

PROGRAMME: (Revision 0, 18 March 2010)

1. Research existing commercially available frames/structures to support large waste water treatment pond covers.

2. Critically evaluate existing designs including material use.

3. Analyse existing pond cover application and use.

4. Establish performance criteria for the structure.

5. Develop improvements/innovations to available proven designs and resolve whether suggested developments are applicable to the Churchill Abattoir situation.

6. Develop a conceptual structural design for the cover support at Churchill Abattoir waste water treatment pond

7. Submit an academic dissertation on the research.

As time permits

8. Conduct a detailed structural analysis on the proposed conceptual design.

9. Produce detailed design sketches to enable drafting of construction drawings.

AGREED ______________ (student) ______________ (supervisor)

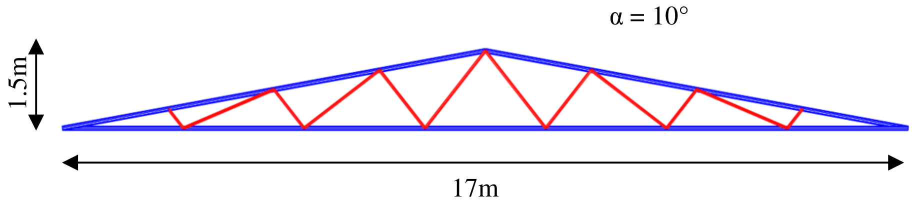
Date: 18/03/2010 Date: /03/2010

Examiner/Co-examiner: ______________

9. APPENDIX B

9.1. Wind Actions

Structure:



Given: Depth = 48m

Truss centres = 6m

Importance Level:2	(Assumption)	AS1170.0:2002
25 Year Design Life	(Assumption)	
R=1/50		AS1170.0:2002
Region: B		AS1170.2:2002 Fig. 3.1
$V_R = 44$m/s		AS1170.2:2002 Tab. 3.1
$M_d = 0.95$		AS1170.2:2002 cl.3.3.2
$M_{z\cdot cat} = 0.91$	(Assume Cat 2)	AS1170.2:2002 Tab. 4.1(A)
$M_s = 1.0$	(Assumption)	
$M_t = 1.0$	(Assumption)	
$V_{\theta,des} = 38$m/s	$V_{\theta,des} = V_R\ M_d\ (M_{z\cdot cat}\ M_s\ M_t)$	AS1170.2:2002 cl. 2.2
$P_{\theta,des} = 0.87$kPa	$P_{\theta,des} = 0.5(\rho_{air})(V_{\theta,des})^2/1000$	AS1170.2:2002 cl. 2.4.1
$C_{dyn} = 1.0$	(Assumption)	

$C_{fig} = C_{pn}K_aK_iK_pK_c$

$K_a = 0.8$		AS1170.2:2002 Tab. 5.4
$K_i = K_p = K_c = 1.0$	(Assumption)	AS1170.2:2002 cl.5.4.3

C_{pe}				
	U=	-0.7,-0.3		AS1170.2:2002 Tab. 5.3(B)
	D &R=	-0.3	(Assume	AS1170.2:2002 Tab. 5.3(C)
C_{pi}		-0.3,0.0	equally permeable)	AS1170.2:2002 Tab. 5.1(A)

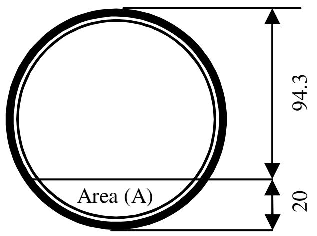
C_{fig}

U=	-0.26,-0.56
U=	0.06, -0.24
D & R=	0.06, -0.24

Wind Pressure (kPa): $C_{fig}(P_{\theta,des})$

Case #1	-0.23(U)	0.05(D)	
Case #2	-0.49(U)	-0.21(D)	Worst Case Uplift
Case #3	0.05(U)	0.05(D)	Worst Case Down force
Case #4	-0.21(U)	-0.21(D)	
Case #5	0.05(R)	-0.21(R)	

9.2. Buoyancy and Cover Mass



Assume Class 4.5 NB100mm Stormwater pipe.

Mean OD = 114.3mm

Mean ID = 109.3mm

Area (A) = 1206mm²

$L_{CONDUIT}$ = 2(12+6) = 36m (CA Trial Raft)

Volume = 36m x $1206/10^6$ = $0.0434m^3$

Mass = 43.4kg (ρ = $1000kg/m^3$)

Mass required for 48m x 17m Raft

(43.4 / (12 x 6)) x 48 x 17 = 492kg **say 500kg**

Conduit needed assuming full depth Immersion

$(\pi(0.1143)^2/4)L_{CONDUIT}$ = 500/1000

$L_{CONDUIT}$ = 48.7m **say 50m**

9.3. Truss Concept Mass

```
== I N P U T / A N A L Y S I S   R E P O R T ==

Title:  Research Project

Type:   Space frame
Date:   18 Aug 2010
Time:    1:24 PM

Nodes .............................    135
Members ...........................    319
Spring supports ...................      0
Sections ..........................      5
Materials .........................      1


== L I B R A R Y   S E C T I O N S ==

Section  Library       Name             Axis  Comment
     1   research      88.9x5.33CHS        Y  Chord
     2   research      50.0X4.0CHS         Y  Web Diagonals
     3   research      63.5X6.35CHS        Y  Ties
     4   research      ANALYSIS            Y  Cable
     5   research      63.5X6.35CHS        Y  Brace


== S E C T I O N   P R O P E R T I E S ==

Section         Ax         Ay         Az          J         Iy         Iz
                m2         m2         m2         m4         m4         m4
     1  1.399E-03  0.000E+00  0.000E+00  2.453E-06  1.227E-06  1.227E-06
     2  5.780E-04  0.000E+00  0.000E+00  3.081E-07  1.540E-07  1.540E-07
     3  1.140E-03  0.000E+00  0.000E+00  9.424E-07  4.712E-07  4.712E-07
     4  1.600E-09  0.000E+00  0.000E+00  0.000E+00  1.000E-18  1.000E-18
     5  1.140E-03  0.000E+00  0.000E+00  9.424E-07  4.712E-07  4.712E-07


== M A T E R I A L   P R O P E R T I E S ==

Material            E         u    Density        Alpha
                kN/m2                 t/m3       /deg C
     1      6.500E+07    0.3300  2.700E+00    2.100E-05   ALUMINIUM


== T A B L E   O F   Q U A N T I T I E S ==

MATERIAL      1   ALUMINIUM

Section  Name                 Length        Mass  Comment
                                   m       tonne
     1   88.9x5.33CHS        308.364       1.165  Chord
     2   50.0X4.0CHS         156.309       0.244  Web Diagonals
     3   63.5X6.35CHS        144.000       0.443  Ties
     4   ANALYSIS            288.000       0.000  Cable
     5   63.5X6.35CHS         42.048       0.129  Brace
                          ----------  ----------
                             938.721       1.982
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10. APPENDIX C

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