2011 Engineers Without Borders Challenge

Report on the response of 2011_T73
Prepared by 2011T73:
Dan Nguyen
James McLeod
Lucinda Bright
Lucinda Hirth
Weiyi Shi

On 17 October 2011

Royal Melbourne Institute of Technology,
School of Civil, Environmental and Chemical Engineering
CIVE 1186 Engineering Practice 2, 2011T7

GPO Box 2476
Melbourne, Victoria 3001
Australia
1 Executive summary

As a result of India’s increasing population and ongoing poverty, the village of Devikulam is faced with many issues. One major issue was selected in particular for the pivot of the Engineers Without Borders challenge: water supply and sanitation. As the village’s current water supply becomes progressively saline, a new method to purify their water source is needed. Working in conjunction with the EWB objectives and criteria, group T73 have proposed a working design for the remedy of Devikulam’s lack of clean water supply.

The suggested design consists of an on ground solar still, which efficiently provides a clean supply of water to the people of Devikulam. The still functions as a closed system containing air and water. It uses the sun’s energy to desalinate water through the humidification-dehumidification process. Alongside effectively cleaning the water, the design is also simple and easy to maintain.

The cost of the proposal was kept to a minimum and aimed to optimise effectiveness at a reasonable price. The initial cost of the design is relatively high, but in juxtaposition, has low ongoing costs. The total cost of a still amounted to $730 AUD, which includes the cost of materials. Labour and maintenance can be done independently by villagers, hence saving costs.

There are no major concerns impacting the environment associated with this proposal. There may need to be removal of some vegetation in order to place stills, but they can be replanted in different areas. There will be 3.7 litres of concentrated waste produced each day, but this will be effectively disposed of through a sump under the still. An environmental effects statement will be drawn up in order to consider all the environmental impacts associated with the design.

Through the use of this effective design, the village will have clean water available as it desalinates the water. The community will have a constant water source that is easily accessible. The design is built from natural materials and doesn’t detract from the natural surroundings, and it is also sensitive to local culture and customs.
2 Team reflection

The Engineers Without Borders challenge provided a great opportunity to apply the skills we are learning as part of our course to a real world project with a tangible benefit.

The challenge was not without its obstacles that had to be overcome and in particular, we found the following to be the largest.

- The lack of availability of specific information about the area and the people made it challenging to form a detailed image of the township.
- Not being able to visit the site and talk to the people was another disadvantage and also restricted our image of the township.
- The very low budget was another obstacle that restricted our possibilities and made some aspects of the design hard.

As well as the obstacles that were present in this challenge there were many things that we enjoyed, these include:

- The tangible benefit that could be seen coming from this project was a good source of motivation and was something that we enjoyed. Often with engineering projects at university they are to demonstrate skills, however with this project it was to help people.
- The budget constraints as well as providing an obstacle was also a source of enjoyment as it required creative thinking and also helped us to use materials that we would have otherwise not considered, such as bamboo.
- While there was little information about the people of Devikulam the opportunity to learn about a new culture and its people was also something that we enjoyed about this project.

Working in a team was very important to this project as it provided a good forum to introduce new ideas, assess their suitability and then develop them into a feasible design and where one person may have a good idea, the team environment offers many perspectives and ultimately a more considered design.

If we could redo this project or expand more we would look into the following areas:

- We would look further into the waste disposal of this design.
- We would also expand more on the environmental and other impacts that this design would have.

In the end we feel as though we have developed a good design to tackle the issues we set out to address. Ultimately the design is limited by the lack of knowledge about Devikulam and its people so it was difficult to tailor a solution specifically for them. However this is also the greatest strength of this design, it means that it has worldwide applications and this one design could potentially benefit people all around the world.
3 Table of Contents

1 EXECUTIVE SUMMARY 3

2 TEAM REFLECTION 4

3 TABLE OF CONTENTS 5

3.1 LIST OF FIGURES 6
3.2 LIST OF TABLES 6

4 INTRODUCTION 7

4.1 PROBLEM BRIEF: 7
4.2 PRIMARY PROJECT OBJECTIVES 7
4.3 DESIGN REQUIREMENTS: 8

5 SUMMARY OF DESIGN PROPOSALS 9

5.1 REVERSE OSMOSIS 9
5.2 CERAMIC FILTERS 9
5.3 SOLAR STILL, ON-GROUND 10
5.4 SOLAR STILL, ON-ROOF 10
5.5 ‘DO NOTHING’ 11
5.6 EVALUATION CRITERIA 12
5.7 EVALUATION MATRIX 13
5.8 SELECTED DESIGN 14

6 DESIGN 15

6.1 SUMMARY 15
6.2 OPERATIONAL FLOW CHART 16
6.3 PROCESS 17
6.4 THERMODYNAMIC ANALYSIS 18
6.5 DETAILED DESIGN 19

7 IMPLEMENTATION 27

7.1 LOCATION/SITE 27
7.2 MATERIAL SOURCING 27
7.3 EDUCATION & COMMUNICATION 30
7.4 COSTS 31
7.5 FUNDING 31
7.6 MAINTENANCE PLAN 32

8 REVIEW 33

8.1 EXPECTED RESULTS 33
8.2 IMPACTS 33
8.3 LIFESPAN 34
8.4 POPULATION GROWTH 35
8.5 STRENGTHS 36
8.6 WEAKNESSES 37
8.7 FUTURE WORK 38

2011 Engineers Without Borders Challenge 5
9 CONCLUSION

10 BIBLIOGRAPHY

11 APPENDIXES

11.1 APPENDIX A, THERMODYNAMIC ANALYSIS
11.2 APPENDIX B, SOLAR DATA
11.3 APPENDIX C, WIND DATA
11.4 APPENDIX D, MATERIALS & COSTING
11.5 APPENDIX E, LAYOUT OF SOLAR STILL, ON GROUND
11.6 APPENDIX F, SOLAR STILL CONSTRUCTION INSTRUCTIONS

3.1 List of Figures
Figure 6.1, Solar Still On Ground 15
Figure 6.2, Operational Flow Chart 16
Figure 6.5.1, Design Dimensions 20
Figure 6.5.2, Water Dispersal Dimensions 21
Figure 6.5.3, Apron Attachment 22

3.2 List of Tables
Table 5.7, Evaluation Matrix 13
Table 7.4, Costs 33
4 Introduction

4.1 Problem brief:
The 2011 Engineers Without Borders challenge is to improve the quality of life for the small township of Devikulam in southern India. The booming population growth and the modernisation of India has caused many problems for the people of Devikulam and after consulting with Pitchandikulum Forest, Engineers Without Borders have outlined eight key issues affecting the township that may be addressed for this challenge.

This group, T7-3, has chosen to address the issue of water supply and sanitation, with a particular focus on the salinisation of the ground water caused by salt water intrusion, which has been triggered due to the over extraction of ground water. The salinisation has affected the colony's water supply, making it unsuitable for drinking and hence reduces overall access and places pressure on the other water resources in the village. There is also evidence that the village's water supply will eventually suffer the same fate in the future (EWB website 2011).

Our aim is to post-treat the saline water (rather than attempt recharge of the saline well) with a low-tech system, and to harness rainwater via collection and storage.

4.2 Primary project objectives

- Provide a sustainable treatment solution to the colony's water supply, giving them constant access to safe and clean drinking water

- Respect the religious and cultural beliefs of the people of Devikulam in any design proposed

- To work within the parameters of budget, and constraints of location, technology and need to be relatively 'self-sufficient' in terms on maintenance

4.2.1 Secondary project objectives

- Educate the people of Devikulam about water saving initiatives as well as developing good maintenance plans to reduce the amount of water extracted
4.3 **Design Requirements:**
When designing a solution, the following issues have been identified and should be considered as a priority.

The proposal should:

- Have a low start-up and maintenance cost (because the community does not have the ability to spend too much money on maintenance, and EWB and Pitchandikulum Forest have limited budgets)
- Build upon skills that people in the community already have- thus no complex, foreign technology that cannot be replicated or maintained locally
- Be eco-friendly by avoiding contamination of the local environment, or unfairly drawing upon community resources
- Be appropriate to the social, environmental and cultural context of Devikulam;

*Social:* identify who is responsible for water collection/use and design a system that reflects their needs and relationship to water.

*Environmental:* humidity, temperature and rainfall, available land and resources. These factors affect materials selection and hence lifespan, size and location of designs.

*Cultural:* consideration of the caste system and its limitations for short-term change and how caste affects access to water.

The implementation of the proposed design should also:

- Provide details of the conceptual and final design, including specifications and instructions
- Identify schedules, construction and maintenance costs associated with construction and completion of the design
- Discuss ethics, long-term sustainability and maintenance of the engineering work that would be completed as a consequence of the design
5 Summary of design proposals

5.1 Reverse osmosis

A small-scale reverse osmosis (RO) desalination facility would be constructed at the presently saline well. RO technology filters water with the use of a membrane, removing large molecules and ions from solutions by applying pressure from one side of a membrane. The result is that the solute is retained on the pressurised side of the membrane and the desalinated water is allowed to pass to the other side.

Other Considerations

RO systems are normally used to treat only drinking and cooking water supplies so may not be preferred where larger supplies are being treated. RO systems are not appropriate for treating water supplies that are contaminated by coliform bacteria.

The technology makes minimal use of chemicals.

There is a risk of bacterial contamination of the membranes; while bacteria are retained in the brine stream, bacterial growth on the membrane itself can introduce tastes and odours into the product water.

It is low maintenance, as it only requires cleaning of the membrane.

5.2 Ceramic filters

Ceramic water filters (CWF) are an inexpensive form of water filtration, which uses the small pore space of ceramic material to filter debris such as dirt and bacteria from contaminated water supplies. For improving the water supply for the villagers of Devikulam the CWF ‘clay pot’ style is what we have considered. The basic function of a CWF is similar to other filtration methods in which a contaminated water supply is steadily introduced to one side of the filter in which the pore size is suitable for water molecules to pass through. Specifically to CWF, the filter is made of porous piece of ceramic, which sits on top of a ceramic base. As water is poured in the clean water passes through the porous ceramic, this ‘clean’ water is then collected in the basin and the contaminant’s is collected in the filter.

Other Considerations

The production of ceramic filters is simple and few materials and production energy is required. The major disqualifier for this form of technology is that the ceramic water filters does not remove dissolved solids from the water supply. As salinity is the main issue that we aim to rectify, the CWF’s will not be successful in improving the water quality due to is inability to remove salts.
5.3 Solar still, on-ground
Solar energy is used to heat a closed system containing air and water. The closed system, a still, is to be constructed to harness the sun's energy in order to desalinate water through a humidification-dehumidification process. The design is effectively an isosceles triangle prism frame constructed out of bamboo with the largest rectangular face parallel to the ground and lined with black plastic. Clear plastic then lines the other 4 faces creating a closed system. Gutters are put inside along the bottom edges of the two clear rectangular faces. Water then sits on top of the black plastic and using the sun's energy then evaporates. Energy is then lost to the surroundings and the water vapour condenses and runs down into the gutter. By arranging the prism so that one end is higher than the other, the condensed water will flow along the gutter to the lower end where it can be collected.

Other Considerations
In addition to the primary purpose of this design of distilling saline water, the impermeable collection surface also provides the opportunity with some minor modifications of rainwater harvesting to supplement the water supply. Ensuring that even on overcast rainy days there is sufficient water to use. The process as well as removing dissolved salts, the process also removes human pathogens such as E. Coli and other bacteria as well as viruses.

5.4 Solar still, on-roof
This is a hybrid design of a flat plate collector, a common solar water heater applied to roofs in Australia and a solar still. This proposal is an alternative to design 3 above. The same principles are used to create a similar solar still though on the roof. The design would replace conventional roofs by having a timber frame the size of the required roof with a black impermeable surface on the bottom, i.e. between the frame and the house and a clear impermeable surface on the top approximately 15-20cm above the bottom surface. Water would then flow over the bottom surface and be evaporated by the sun. To ensure maximum efficiency of the system, thermal insulation would be put below the bottom surface. Thus meaning the majority of heat transfer from the system would occur from the upper surface producing the maximum amount of clean water. The condensed water on the upper surface would then flow down due to the slope of the roof and be collected by a gutter on the lower inside edge.

Other Considerations
In addition to the primary purpose of this design of distilling saline water, the impermeable collection surface also provides the opportunity with some minor modifications of rainwater harvesting to supplement the water supply. Ensuring that even on overcast rainy days there is sufficient water to use.
The process as well as removing dissolved salts the process also removes human pathogens such as E. Coli and other bacteria as well as viruses.

As is understood the colony has its own water distribution network so that each house has its own tap. This design would rely on this network and there being sufficient pressure to raise the water to the level of the roof and supply the design with a constant flow of water. Should there be insufficient pressure another method of manually supplying water would need to be put into place. Another concern is the addition of the weight of the design to the existing structure. Because of the additional weight of the design over a conventional roof some buildings may not be able to support this design because of risk of failure of the structure.

5.5 ‘Do nothing’

The ‘do nothing’ option would result in potential side effects. It would not immediately impact on several sensitive areas of consideration like environment and culture, though in the long term will cause deterioration in these areas as the water will continue to be saline and therefore place greater pressure on other water resources and affect the health of the community.

The ‘do nothing’ option is obviously best in terms of cost and also maintains the status quo in terms of social relations and access to water. In the long term, however, lack of action would ultimately be worse.
5.6 Evaluation criteria

5.6.1 Effectiveness- amount of water treated
Quantitative measurement of litres of water treated per day. This measurement is of primary importance in the selection of the chosen design as the project is centred on improved water access and treatment. The amount of water treated needs to meet current demand for water by residents, and if possible exceed current demands to improve access to better health and livelihood.

5.6.2 Cost- both establishment and ongoing costs
Consideration of all aspects of the design, implementation and operation costs. High establishment costs may be justified if the need for ongoing maintenance is low. Maintenance costs need to be within the financial means of the Devikulam community. The nature of EWB work (not-for-profit) and the setting of the Challenge (rural India) are constricted by a limited budget. The start-up cost of a project and its ongoing maintenance needs to be within the available budget.

5.6.3 Sustainability- environmental impact, maintenance, waste, energy
Because of sustainability principles and the limited natural resources of Devikulam designs need to have minimal impact on the local environment, if not enhance it. Local materials and technologies should be adopted where possible- with direct benefit to the community by encouraging cultivation of available resources (labour, natural resource production and management). Consideration of available energy supplies- design cannot be energy intensive. Design should be as low maintenance as possible. By ensuring the proposal is as sustainable as possible means there is less maintenance (and therefore less cost), a culture of conservation and resourcefulness encouraged, and long-term viability of the design is favourable.

5.6.4 Resources/Technology/Materials
Devikulam is relatively isolated due to location and seasonal access to roads, and is a comparatively poor village. Because of this technology and materials cannot be expensive and foreign. Long-distance transport is not viable due to cost. Local and regional materials need to be adopted. Materials need to blend in with current building standards and preferences. Consideration of climate for both choice and longevity of materials, and comfort of residents (e.g. Roofs and ventilation).

5.6.5 Cultural/Social impacts
Devikulam community is a part of the caste system and Hindu religion. Both these factors need to be considered in the design. The design for the construction, use and maintenance needs to be sensitive to the caste system and Hindu beliefs. Fail to do this could potentially mean failure for the project. The
proposal also needs to consider gender, and the different roles of men and women in the community and their relationship to water provision.

5.7 Evaluation Matrix

<table>
<thead>
<tr>
<th></th>
<th>Reverse Osmosis</th>
<th>Ceramic Water Filter</th>
<th>Solar Still, On Ground</th>
<th>Solar Still, Roof top</th>
<th>No Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Cost</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Sustainability</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Materials, Technology &amp; Materials</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Cultural &amp; Social impacts</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>16</strong></td>
<td><strong>21</strong></td>
<td><strong>21</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

Table 5.7, Evaluation Matrix
5.8 Selected Design

The selected proposal is the on-ground solar still. It out-performed the other proposals in important categories like performance and cost. Whilst the on-roof solar still had the obvious advantage of providing waterproofing to the buildings, its cost and applicability has made it prohibitive at present.

However, as the same basic principles of the on-ground solar still are in the on-roof still, in the future it may be incorporated in new constructions if tested for structural stability, improving on the application and use of the on-ground still.

The ceramic filters were ultimately not considered, as they did not meet the basic requirement of removing salt from the water. Reverse osmosis was unviable likewise due to its very high cost and complex technology. The ‘do nothing’ option, while at no-cost and no-impact, did not improve the health prospects of the community and did not address the ongoing issue of saltwater intrusion.
6 Design

6.1 Summary

As mentioned previously in section 5.3, solar energy is used to heat a closed system containing air and water. The closed system, a still, is to be constructed to harness the sun's energy in order to desalinate water through a humidification-dehumidification process. The design is effectively an isosceles triangle prism frame constructed out of bamboo with the largest rectangular face parallel to the ground and lined with black plastic. Clear plastic then lines the other 4 faces creating a closed system. Gutters are put inside along the bottom edges of the two clear rectangular faces. Water then sits on top of the black plastic and using the sun's energy then evaporates. Energy is then lost to the surroundings and the water vapour condenses and runs down into the gutter. By arranging the prism so that one end is higher than the other, the condensed water will flow along the gutter to the lower end where it can be collected.

Figure 6.1, Solar Still, On Ground. For more images see Appendix E
6.2 Operational Flow Chart

![Operational Flow Chart diagram]

- System at initial conditions
- Sun's energy in
- Saline water in
- Temperature of the system increases, water evaporates and air becomes saturated with water vapour
- Steady State Operation
- Concentrated brine waste
- System connected to colonies water supply
- Temperature gradient formed, system loses thermal energy
- Water condenses at heat transfer boundary
- Condensed water is collected and stored to be used as drinking water

Figure 6.2, Operational Flow Chart
6.3 Process

The simplest representation of a solar still is a half full water bottle left outside on a sunny day. It effectively uses the same natural process that creates the clouds and the rain, and works on the principal that the amount of water that can exist as vapour is dependent on temperature and for any given temperature at constant pressure there is a maximum amount of water that can exist as vapour. The formula that governs the relationship between vapour pressure and temperature is known as the Clausius–Clapeyron relation:

$$\ln \left( \frac{P_2}{P_1} \right) = -\frac{\Delta H_{\text{vap}}}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

Where:
- Conditions 1 and 2 are the partial pressures of water vapour at given temperatures
- $R$ is the universal gas constant
- $\Delta H_{\text{vap}}$ is the latent heat of vaporisation.

So if a volume of warm air is cooled from $T_1$ to $T_2$ at constant pressure, the maximum partial pressure of water vapour must reduce from $P_1$ to $P_2$. If the current partial pressure is greater than $P_2$ any excess water vapour must condense back into a liquid until the current water vapour partial pressure equals $P_2$.

So in the water bottle the sun’s energy heats the water in the bottom, which in turn evaporates saturating the air and also heats the air causing it to rise to the neck of the bottle. Because the heating effect from the warm water in the bottom of the bottle is less the saturated air begins to cool as it loses heat to the surroundings. This means that the current water vapour partial pressure is above the maximum and water begins to condense at the heat transfer boundary.

The same process takes place in a solar still only on a much larger scale. By collecting the condensed water at the heat transfer boundary you have a source of pure clean water and in theory completely free from all dissolved solids, bacteria and viruses.
6.4 Thermodynamic Analysis

As part of the design process a qualitative thermodynamic analysis was carried out to determine how best increase the efficiency as well as ensuring that assumptions made about the design were valid and correct.

The following conclusions were made based upon this analysis on how to best increase the efficiency of the design

- **The collection efficiency should be maximised. This can be achieved by**
  - Having the Transmittance of the clear collection panels as close to unity as possible
  - Convection surfaces should be sufficiently sloped so that condensate quickly runs down minimising the condensate adsorbing energy and revaporising
  - Having the collection area absorptivity as close to unity as possible.

- **Conductive heat losses should be minimised.**
  - This can be achieved by putting the thermal insulation between the bottom surface and the ground
  - Or remove contact between the bottom surface and the ground.

- **Convection should be maximised on the surfaces with condensate collection,**
  - This can be achieved by maximising wetted surface area

- **Convection should be minimised on surfaces without condensate collection,**
  - This can be achieved by bringing $T_{surf}$ as close to $T_{op}$ to minimise the heat transfer

- **Minimise the temperature difference water entering the system and the water leaving the system.**
  - This can be achieved by raising the temperature of the water entering the system before it enters

- **To maximise the amount of condensate produced the difference between $T_{op}$ and $T_{surf}$ should be as large as possible.**

- **The heat capacity of the system should be as low as possible.**
  - This can be achieved by using less material and materials with low density low and specific heat

These conclusions were then incorporated into the design where practical. To see the full analysis see Appendix A.
6.5 Detailed Design

6.5.1 Sizing
Research into this project found that after community consultation about the possibility of installing community toilets would not work because “it is expected there will be ongoing problems with maintenance (it is unlikely that anyone will take responsibility for cleaning the common toilet).” So based on this it was seen that the same problem would occur if a community desalination solution were to be installed, so instead the design would be built for individual households to work around this problem.

So based on the World Health Organisation recommendations of 5L of clean water per person per day for drinking, cooking and cleaning (WHO 2011) and with the average household population in Devikulam of 5 people (Gramap n.d.), each still would be required to produce 25L/day. By using the expected output estimate of 2.3L/m² (Practical Action 2006) it meant that the solar collection area of the still would need to be approximately 12m² to give the minimum amount of water required. However to take into account periods with lower solar insolation and give a safety margin the solar adsorption area was expanded to 14m².

6.5.2 Frame

Description: The frame is made out of two isosceles triangle profiles joined together at each corresponding corner to form the triangular prism. It forms the base of the design too, which all other components are attached to.

Material: Bamboo was chosen due to its easy access for the villagers of Devikulam, its status as a ‘sustainable’ building material and its quality as a building material such as high tensile strength, high elasticity and a very low weight. It is assumed that the process will already be known to the villagers of Devikulam and there are guidelines and specific methods to ensure the production of high quality bamboo during and after construction.

Design: The conclusions from the thermodynamic analysis suggested that to maximise the efficiency the weight of the design should be kept to a minimum to reduce the overall heat capacity of the system. This means that the greatest loading on the structure comes not from the weight but instead the external loading from the wind. So to keep this value as low as possible the vertical profile would need to be as low as possible, this would be achieved by reducing the overall height of the design.

For the ease of construction and the scaling of the design, the isosceles triangle profile would be made up of two right angled triangles back to back with the ratio of 3 units vertical: 4 units horizontal: 5 units along the hypotenuse. The length of one unit was selected based upon the clear polycarbonate that lies along the hypotenuse. The smallest standard length of the polycarbonate is
2100mm; so one unit was chosen to be 40mm. Thus giving the isosceles triangle a height of 1200mm and a width of 3200mm.

Another advantage to having the height low was that it would save on materials thus lowering the overall cost. This meant that with a width of 3.2m the length required to meet the required solar adsorption area was 4.38m, which was expanded to 4.5m for ease of construction. This gave a final geometry of 4.5m length, 3.2m width and 1.2m height.

![Figure 6.5.1, Design Dimensions](Image)

**Joining:** The largest source of wear on the system would come from the daily expansion and contraction caused by thermal expansion as the system heated up and cooled down. Therefore in order to reduce wear on the system, the joints that held the frame together needed to be flexible enough to allow this movement, eliminating the potential large stresses and strains on the joints, while maintaining their strength so the frame could withstand its internal and external loadings. Due to the nature of bamboo it could not be joined together using traditional Western construction methods such as nails and screws. The method to join the frame together was to use traditional bamboo joining methods where an incision was made into one of the members in between two of the nodes in the bamboo and then put the end of the other member into the incision and lash the two together (See Appendix F for a diagram). This system would provide the strength and flexibility required for the design.
6.5.3 Evaporation Surface

**Description:** The evaporation surface is the lower face of the frame and is where the sun’s energy is adsorbed and transferred to the water that flows over the top of the surface. The adsorbed energy is used to evaporate water and subsequently saturate the air within the system with water vapour.

**Materials:** Black pond liner was chosen primarily due to its high absorptivity, low weight, low cost and long life span.

**Design:** Based on the conclusions from the thermodynamic analysis in order to improve efficiency, conductive losses from the evaporation surface to the ground needed to be minimised. In this design it was achieved by raising the evaporation surface off the ground by raising the whole frame off the ground by approximately 20cm and therefore insulating it from the ground, Due to the arrangement of the hot and cold surfaces convection losses would be negligible for this arrangement.

In addition to raising the evaporation surface off the ground corrugations will be added to increase the surface area where evaporation can occur, further increasing the efficiency. To achieve this the three water supply hoses will be suspended above the bottom of the frame the black pond liner will be then draped over the hoses and then attached to the frame. Water will then flow out of holes in the top of the hose and over the evaporation surface. See figure 6.5.2.

![Figure 6.5.2, Water Dispersal Dimensions (measurements in mm)](image)

6.5.4 Apron

**Description:** In order the keep the design as a closed system, the gap now created by raising the frame off the ground to minimise conductive losses needs to be closed.
**Materials:** Black pond liner would be used to close this gap because of the aforementioned properties as well as the fact it has already been used in the design.

**Design:** The pond liner would be secured to the frame using glue and then extended down to the ground to close the gap. See figure 6.5.3

![Figure 6.5.3, Apron Attachment](image)

### 6.5.5 Solar Collection area

**Description:** The upper two rectangular surfaces are clear impermeable surfaces to allow the sun’s energy in, while maintaining a closed system

**Materials:** In order the transfer as much of the sun’s energy to the still as possible the material used for the solar collection area needs to have a high transmittance, and after considering several materials clear polycarbonate was selected. As well as the good transmittance and long life span another bonus is the corrugations, they effectively increase the surface area where convection can take place increasing the rate of heat transfer at the surface, which increases the temperature difference, producing more condensate.

### 6.5.6 End Sections

**Description:** these are the two triangle profiles at either end of the design and in order to keep the system closed they need to be covered with an impermeable covering.

**Design:** Condensate is produced at the four upper surfaces, and because the end sections only have a combined total area of 3.8m², when compared to the main solar collection total area of 18m² it was seen as unnecessary to collect the condensate forming on these areas. Because the condensate was not being collected from these areas it was decided to reduce the amount of convection occurring at this surface by reducing the temperature difference between the surface temperature and the operating temperature within the still.

**Materials:** To achieve this the ends would be covered with black pond liner, which would adsorb the sun’s energy rather than transferring it, thus raising the surface temperature closer to the operating temperature.
6.5.7 Condensed water collection

Description: Due to the pitch of the solar collection surface, the surface tension of water and the effect of gravity, the condensate produced on the solar collection surface would then run down to the base of the still. So by placing a gutter along the inside edge of the solar collection and placing the whole system on a slight pitch the water would then flow to and then through the gutter and into a storage tank.

Materials: PVC pipe was selected for the material to construct the water collection system based on its long life span, workability and the relative ease of access.

Design: As mentioned previously the isosceles triangle profile would have a width of 3200mm and height of 1200mm, giving the pitch for the solar collection surface a value of approximately thirty-six degrees. It was assumed that this value would provide enough gradient so that the water would run down the surface and not simply form large drops and fall back onto the evaporation surface.

Another important factor in the pitch of the solar collection surface is that the condensed water on the surface would reduce the transmittance of the solar collection surface. So it would be important to ensure that the condensed water quickly ran down the surface to maximise the energy reaching the evaporation surface and hence increase the overall efficiency of the system.

6.5.8 Rain water collection

Description: The impermeable solar collection surface provides excellent opportunities to integrate rainwater harvesting into this design. It would also mean that on days with rain and little insolation due to clouds etc. the design could still provide enough potable water to the users.

Design: Using a gutter similar to the condensed water collection gutter along the outside lower edge of the solar collection surface and then integrating it into the condensed water collection the rainwater could be harvested.

Due to the rural setting it was assumed that the rainwater would have very low levels of dissolved solids and other pollutants and when combined with the weekly cleaning of the collection surface it was thought unnecessary to add any water treatment to the collected rain water. However this assumption would need to be reviewed before the design was constructed.

Materials: PVC pipe and fittings would also be used to ease integration into the condensed water collection as well as the other favourable properties

6.5.9 Water storage

Description: the collected water would be stored is a small buried tank at the lower end of the design and then extracted using a pump as the water was
required. A removable bung in the top of the tank would be used to give access to
determine the volume of water using a dipstick.

**Design:** The storage tank would not to be large because the design is capable of
consistently producing clean drinking water in both sunny and rainy conditions,
so therefore a large storage volume is not required.
Secondly because there is no persistent form of water treatment for human
pathogens or other contaminates, it means having a small volume with a high
turnover rate would reduce the risk of microbe growth and there would not be
sufficient time for insects to develop. Also should the storage become
contaminated only a small volume of water would be spoilt.
It should be noted that while there are no forms of persistent water treatment,
measures have been taken to reduce the risk of growth and contamination.
These include the fact the water has been distilled and theoretically has no
dissolved solids or other biological contaminants present. This means that there
are no nutrients for microbes to feed on and also the water would be stored in
the absence of light so photosynthetic microbes could not survive.

**Materials:** A recycled food grade 44-gallon drum (approximately 200L) was
selected as the storage tank. The drum was selected for several reasons. The first
was that because the drum would have been recycled it would lower the cost and
reduce the environmental impact by lowering the embodied energy. And
secondly the 200L satisfied the required storage volume.
For the pump a manual diaphragm pump similar to the pumps used in small
marine craft bilge systems was selected. The pump was selected because of its
long life span, minimal moving parts, low technology level, low cost, low
maintenance requirements and its ability to provide sufficient head to extract
the water.

6.5.10 Waste

**Description:** The only by-product of the desalinisation process was concentrated
brine solution and the potential damage to the flora from this waste made the
effective and appropriate disposal of the waste an important priority.

**Design:** It was decided that it would be easier to deal with a small volume of very
concentrated saline solution rather than a large volume of mildly concentrated
saline solution. So to control the amount of waste produced the flow rate into the
design would be restricted, so that for every litre of saline water that entered the
still 0.9 litres of clean water would be produced. This would mean that a total of
3.7 litres of concentrated waste would be produced per day.
Initially methods of changing the waste into a source of income were looked at,
however because the composition of the brine was not known and the limited
technology of Devikulam this notion was dismissed.
Next due to the low volume of waste produced the design looked to collect the
waste and then divert it into a small shallow evaporation basin and periodically
removing the remaining crystalline salts. It was however decided to scrap this idea because of the high risk of spills during heavy rain events. The alternative that was reached was to return the concentrated brine back into the water table by constructing a sump under the still. A hole would be dug under the still and back filled with a porous material such as course sand. All the salts in the concentrated brine already existed in the current ground water and by controlling how they re-entered the ground water it was seen that this solution would not negatively impact the environment but simply restrict the use of the land area after the design was decommissioned to shallow rooted flora, construction, paths or roads. This solution also restricted the placement so that it could not be constructed within close proximity to current or proposed wells.

6.5.11 Orientation
To ensure maximum amount of insolation collection the design would be orientated so that the longest edge ran from north to south, i.e. the two triangular profiles would be on the north and south ends of the design. Also because the intended destination of the design is in the northern hemisphere the overall pitch of the design would go from north to south, i.e. the highest end would be on the northern end of the design.
7 Implementation

7.1 Location/site
The area required does not necessarily need to be flat, but it needs to be in a space where there is little shade, to ensure maximum sunlight for the system. Devikulam is quite densely vegetated with many tall trees, which provide shade and will reduce the efficiency of the design. This means that the implementation of the new system may require removal of some trees and replanting of these trees in different locations. The terrain of Devikulam is mostly relatively flat, and there are numerous open spaces where the system could be placed, whilst still within close range of the colony.

As it is unknown who currently owns the land, there is no indication of the use of the land or what may already exist there if anything. A list of site selection criteria will be developed in conjunction with Pitchandikulam Forest and will cover the current uses of the land, topography, vegetation, future developments and ownership over the land. This will then be used to select the optimum sites for each of the stills.

7.2 Material Sourcing
The majority of the materials required for the development of the ‘on ground’ solar still are easily accessible and financially convenient for the villagers of Devikulam.

The design of the solar still consists of 7 main materials:
- Clear Polycarbonate (Roofing)
- PVC pipe (Condensation and Rainwater Collection)
- Black Pond Liner (Water Distribution/Concentrated Salt Solution Storage)
- Bamboo (Framing)
- Wood (Framing)
- 44 Gallon Drum (200L) (Storage)
- Manual Diaphragm pump (Water Transport)

As well as the more substantial structural elements mentioned above, other building necessities include cable ties and pipe end caps. To see a full list of materials see Appendix D.

7.2.1 Bamboo and Wood
Bamboo and wood provide the structural frame for our project, the production of one standard Solar Still will require:
- 4x frame supports (500mmxØ100mm) Wood
- 1x frame supports (1500mmxØ150mm) Wood
- 3x X components (4500mmxØ50mm) Bamboo
• 2x Y components (3200mmxØ50mm) Bamboo
• 4x Z Components (2000mmxØ50mm) Bamboo
• 4x X Supports (2400mmxØ50mm) Bamboo

While undertaking limitations in high amounts of harvesting (due to the issue of negative environmental impacts by over-production) and selling of wild bamboo is legal and in some cases encouraged especially for the benefit for communities in isolation and in close proximity to forests in India.

As with the collection of bamboo for our proposed project the collection of wood for the structural foundation can also be easily sought out via the nearby forest, however both permission and perhaps supervision would be required by Pitchandikulam Forest. In the instance of the implementation of our solar still trees will need to be removed from the dense vegetation surrounding Devikulam to create an area with optimal sunlight exposure, if stable and non-deteriorated wood is cut then this can be used in the structure of the Solar Still. However if this is not possible due to animal infestation or other reasons than suitable amounts of wood can be imported from the nearby city of Pondicherry which offers over 10 suppliers of wooden building materials.

7.2.2 PVC Piping

The nearby city of Pondicherry has multiple stores and distributors of PVC piping and other necessities such as pipe end caps and cable ties. For the production of one standard Solar Still the following is required;

• 4500mmxØ100mm PVC pipe (split lengthways)
• 4300mmxØ100mm PVC pipe (split lengthways)
• 2x 1200mm xØ100mm PVC pipe
• 2x 135mm xØ100mm PVC pipe
• 2x 50mm xØ100mm PVC pipe
• 4x Ø100 PVC pipe end caps
• 6x Ø100 PVC pipe 90° joins
• 3x Ø100 PVC T pipe sections

7.2.3 Clear Polycarbonate

The clear polycarbonate is used as the roof of our structure. Unfortunately (as with PVC piping) this cannot be sourced naturally and therefore must be purchased from one of the multiple stores and warehouses in the nearby city of Pondicherry. For one standard ‘on ground’ required;

• 12x (760mmx2100mm) Clear Polycarbonate roofing
• 4x 4500mm polycarbonate profiled infill

7.2.4 Black Pond Liner

The black pond liner is used within the Solar Still to both hold the water during the evaporation process but also to create increase the heat of the water sample.
As with other process and/or manufactured materials these will need to be purchased from the nearby city if Pondicherry. For one standard ‘on ground’ solar still we require:

- 3x (1000mmx4500mm) black pond liner
- 15mx500mm black pond liner

7.2.5 44 Gallon Drum
The main product of our designed ‘on ground’ solar still is water and for the storage of this we have chosen a 44 Gallon Drum to be partially submerged in close proximity to the solar still. While any closed water carrying objects would be applicable to store the water product of the solar still, some are vulnerable to deterioration and some may not withstand the volumes of water collected during monsoon season. Additional storage drums can be easily added to expand storage capacity. A standard drum (or any other materials of equal qualities) can be purchased from the nearby city of Pondicherry. For one standard ‘on ground’ solar still we require:

- 1x 44 Gallon Drum

7.2.6 Manual Diaphragm Pumps
In transporting the water from the storage 44 Gallon Drum to new container we have chosen to use standard manual diaphragm pump. This avoids cross contamination between the clean water and external objects i.e. buckets while also reducing the amount of manual labour needed to be performed daily for the people of Devikulam. Research online show these pumps approximately cost $10. If bought locally and in bulk, in nearby Pondicherry, the cost would be lower. For one standard ‘on ground’ solar still we require:

- 1x Manual Diaphragm Pump

7.2.7 Surplus Materials
With all maintenance projects and structures there is a possibility that materials might fail or that alternations may be required in the future. In this sense we suggest that a 10%-20% surplus of all objects to be bought in preparation. Some materials (such as wood or bamboo) cannot be stored effectively without being exposed to deterioration and therefore reducing its structural ability, therefore products such as PVC pipe (and all its related products), clear polycarbonate, manual diaphragm pumps, pond liner and cable ties should be purchased in surplus and stored in Devikulam. Bamboo and wood can be stored in small amounts as they would for general community use.

7.2.8 Logistics and Transport
As demonstrated in the survey undertaken in the village of Devikulam transport options are incredibly limited, especially during monsoon season when roads between Devikulam and Pondicherry and rerouted my raising water levels. The
transport methods are reduced to 2 wheel vehicles such as motorbikes and one tractor. Therefore the transport of materials from the city of Pondicherry will require a 4 wheel vehicle capable of carrying large amounts of materials. The city of Pondicherry offers oversized vehicles for hire which while carrying the large amount of materials can also navigate the difficult roads between Devikulam and Pondicherry. Alternately, if available, the suppliers may be able to deliver the materials directly with their own transport.

7.3 Education & Communication
The education plan broadly covers all aspects of implementation, from the introduction to the village of the solar still design as a concept to the construction and maintenance of the unit to the education of water management of bore water.

7.3.1 Introduction of technology
As the colony has already identified saline groundwater as an issue for them our proposed design will hopefully be welcomed as a possible solution to one of their problems. Due to the language barrier and the preference for familiar people, it is proposed that Pitchandikulam Forest would spearhead the introduction of the solar still.

Along with the appropriate village elders, Pitchandikulam Forest could discuss the introduction and use of the solar still in a community meeting setting. If any foreign personnel were to be involved a local translator would be adopted. Visual aids would be used rather than text to convey the benefits of the solar still purification (McDonald, 2006). Allowing a time for questions and answers will help stimulate curiosity and remove resistance to the design that comes from lack of knowledge. Rather than importing a new technology and infrastructure without consultation, it is hoped through good communication and community meetings that the solar still will be adopted and embraced.

7.3.2 Training in construction and maintenance
As this design is easily constructed, local residents can be given minimal training to erect their own solar stills. This not only reduces the cost of the construction but also means that locals will feel capable of repairs in the future, having originally constructed the still.

Instructions have been developed with step-by-step graphics of the construction. There is minimal use of words as this takes into consideration issues of both literacy and dialect. The written part of the instructions would be translated to the local dialect. For those that cannot read, oral instructions will be given at the time of training.
7.4 Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Approximate cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>$0.00 (If sourced naturally)</td>
</tr>
<tr>
<td>Plumbing</td>
<td>$273.84</td>
</tr>
<tr>
<td>Lining</td>
<td>$74.52</td>
</tr>
<tr>
<td>Solar Collection</td>
<td>$224.60</td>
</tr>
<tr>
<td>Incidentals</td>
<td>$30.00</td>
</tr>
<tr>
<td>Additional Materials</td>
<td>$60.30</td>
</tr>
<tr>
<td>Logistics &amp; Transport</td>
<td>$66.33</td>
</tr>
<tr>
<td>Labour</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

**Total Cost Per Solar Still = **$730.00 AUD (₹35,750 INR)

*Table 7.4, Costs. For detailed costing see Appendix D*

7.5 Funding

To help reduce the cost of this design there are many organisations that can help with funding for the project. These include:

- Red Cross
- People in Action
- Rotary
- Water Can
- Apex

The funding from organisations will only be used to subsidise the costs so that they were within a feasible amount for the people of Devikulam to afford. We feel that if the people of Devikulam feel ownership for the project it will encourage them to continue proper maintenance procedures and care for the structure. Funding can be established through a business partnership with an organisation that is willing to help. Some organisations will raise money for projects through club fundraisers and other types of philanthropic support. Information regarding the project and the health and cultural benefits it would entail could be sent to local, national and even international companies for support. Furthermore a copy of the finalised design and plan would be sent to such organisations to further encourage their support.
7.6 Maintenance plan

The maintenance of the solar still is very important to its working order. Cleaning improves both the heat conduction and health outcomes, and general maintenance checks are important to ensure small amounts of damage or deterioration are not ignored thereby minimising the possibility of large repairs, thus reducing overall costs.

7.6.1 Weekly Clean

The polycarbonate sheeting on the outside of the still needs to be wiped clean. The amount of heat conducted (and thus the production capacity of the still) depends on cleanliness of the polycarbonate. Cleaning to be done with old rags and some water. Due to the height of the roof pitch, a long object like a broom handle will need to be used to help clean the top of the roof.

In monsoon season, cleaning of the outside of the polycarbonate may not be required due to heavy rainfall making it ‘self-cleaning’.

7.6.2 Monthly Dry Days and Structural checks

Each month the still needs to allow to dry. No water is to be added to the system for distilling and the still is to remain as open as possible to promote drying. Preferably, this will be done on the hottest, driest day available.

In order to continue producing distilled water, neighbours could take turns drying their still and assist one another with sharing their distilled water whilst the other dries their still.

At the same as drying the still, the physical structure should be checked over for any damage or deterioration. These checks should include: joints, leaks in both underside from the membrane and in the roof sheeting allowing escape of vapour, pipe and pipe connections, and checking the sump is draining properly and there is no organic build-up or pooling water that could attract mosquitoes.

7.6.3 Biannual herbicide and greasing

The still needs to be cleaned and flushed 1-2 times a year with a disinfectant like chlorine. This will kill any build-up of bacteria or algae inside the still.

At the same time the hinges on the pumps need to be greased.
8 Review

8.1 Expected Results

Based on the solar collection area being 14.4m² (4500mmx3200mm) and the expected effectiveness of 2.3L/m²/day for a typical solar still with insolation of 5kWhr/day (Practical Action 2006), the expected treated water output would be 33L/day.

Using the World Health Organisations recommendations for people in developing countries 5L per person per day for cooking, cleaning as well as drinking water (WHO 2011), the still could provide enough clean water for 5-6 people.

If the use of the water produced was restricted to only be used as drinking water the number of people that the still could provide for could be extended to 10-15. However the WHO developed this recommendation based upon their expertise and while this outcome is better than the current situation it is not the most desirable. Another issue with this is that it doesn't provide any contingency for the growing population, as the still is supporting the maximum number of people possible.

A third way would be to use the distilled water to dilute the saline water being extracted so that the total dissolved solids (TDS) fell back into the acceptable levels. This could potentially increase the number of people served dramatically. However this plan is also not without its own issues. Due to the current defecation practices and complete absence of any form of sanitation the village's water supply already shows signs of faecal coliform contamination and the current Indian standard for Characteristics for Drinking Water (IS: 10500 - 1991) have a zero tolerance on faecal coliform levels. It is assumed that due to the proximity the colony's water supply would also have the same chances of being contaminated. This means that no level of dilution would lower the faecal coliform levels to zero.

8.2 Impacts

The main impacts that could be experiences from the introduction of our design in the village of Devikulam can be placed into 4 main categories: Environmental, Financial, Social and Cultural. All of these factors must be taken into consideration when planning the implementation of our proposal.

8.2.1 Environmental

Firstly the concentrated brine solution waste (that has been estimated to be approximately 3.7L a day) poses a threat to the on ground vegetation, as a large
majority of the Devikulam rely on farming and agriculture as a source of income. It is important to us that the levels of salt do not increase in the soil used for farming. This is where the sump has been developed to return the brine solution back into the groundwater. This however restricts the land used for the solar stills to be used for development purposes in the future. Secondly as the solar still requires sunlight for the humidification of water and more than 14m² of land per solar still, there is a possibility that vegetation will need to be cleared in an area close to Devikulam village. Finally the disposal of manufactured materials such as the PVC pipe and Polycarbonate pipe must be undertaken ethically and sustainability as not to anaesthetically damage or environmentally disadvantage the surrounding area.

8.2.2 Financial
The proposed solar still design has little ongoing costs, however the initial installation costs are high. It comes to an estimated amount of approximately $730 Australian per still or 35,750 Rupees. This is mainly due to the high costs and amount of polycarbonate sheets required, however this was deemed necessary due to the Polycarbonates thermal properties and its qualities such as low weight. The only two foreseen ongoing costs are the replacement of materials such as PVC pipe, polycarbonate sheets and pumps (which have a long lifespan so replacements would be infrequent) and the purchase of disinfectant for the biannual cleaning.

8.2.3 Social
Due to the allocation of solar stills based on households and the assumption that on an average household contains approximately five people some social issues that could arise are allocation of tasks, disagreements with ownership and the issue that arises in expansion of families.

8.2.4 Cultural
Our research indicates that no cultural impacts will be made with our proposal.

8.3 Lifespan
Ultimately the lifespan of any engineering project is limited by the usefulness of the design, construction method or the materials used to build it. This issue of salinisation of the ground water is predicted to only get worse in the future. The current standard solution to salt water intrusion is impractical for the people of Devikulam and is predicted to remain that way for the near future. It is therefore seen that this design will remain effective and necessary for many years to come.
This means that the materials it is made from limit the lifespan. The synthetic materials such as the polycarbonate roofing and PVC piping were selected in part for their long lifespans and it is predicted that they will last and remain effective for between 20-25 years (Palram n.d.). This means that the weak link in the chain will be the bamboo used for the frame and the way it is put together.

The cyclic expansion and contraction due to thermal expansion was incorporated into the design but eventually it will still cause damage to the system, which will inevitably cause it to fail. The bamboo is the other limiting factor in the lifespan of the design. Depending on the treatment applied to the bamboo during harvesting it will limit how long until the bamboo begins to break down and no longer function for its intended purpose.

Due to the environmental conditions of high humidity and high temperature will effective treatment during harvesting the bamboo and joins should last for up to 5 years before it fails. This is far less than the lifespan of the synthetic materials so it is proposed that once a frame begins to fail it is deconstructed carefully and the synthetic materials are recycled and a new frame built. This will greatly extend the lifespan and help to reduce the overall costs.

8.4 Population Growth

With any design it is important to consider future changes that would affect its effectiveness in preforming its intended role. As the population grows in the colony it means that more clean water is required. Due to the high initial capital cost of this design it is prohibitive to regularly build more stills. There is however a contingency built into this design to accommodate the growth of households. As previously mentioned in section 8.1 by limiting the use of the water to only be used for drinking water it can expand the number of people the design will provide water for.

This solution only covers the growth of households however. Eventually more houses will be built and it will not be optimal for house hold to begin to share stills for the previously mentioned issues with maintenance. However because the members of the colony built the stills in the first place it means they have the knowledge to build more with no external assistance. Materials can be sourced from the surplus materials for maintenance and the growth of new house holds can be accommodated.

This could create conflict between the members of the colony as to who decides who gets new materials, so an appropriate person would be assigned when the design was initially implemented.
8.5 Strengths

9.2.1 Low ongoing cost
The still requires no continual supply of gas, electricity or chemicals to maintain the production of safe drinking water. Only allocated ongoing costs are towards the purchase of disinfectant and chemicals for the biannual treatment and the replacement materials such as PVC pipe and polycarbonate sheets.

8.5.2 Low technology levels
No additional technological materials such as generators are required as the humidification and dehumidification process is natural and dictated by sunlight.

8.5.3 Broad application potential
The solar still can be applied in any area with adequate sunlight and space.

8.5.4 Low maintenance
Other than the weekly, monthly, biannual cleaning and structural checks the solar still requires no other forms of maintenance. All maintenance processes are incredibly simple and time effective.

8.5.5 Consistent water production
Taking into consideration that under minor modification the solar still can be used for rainwater harvesting, it is possible for continual safe water collection in both monsoon season and days with large amount of sunlight.

8.5.6 Produces high quality potable water, regardless of feed water quality
No matter the degree of infestation capable of the bore water in the village of the Devikulam, the product after undertaking the humidification and dehumidification process will be safe water for consumption.

8.5.7 Long lasting
If structural checks and maintenance are continued, the solar still has the possibility to be effective for over 20 years.

8.5.8 No electrical power required
No external power sources are required.

8.5.9 Independent of environmental conditions, such as pressure, temperature and humidity
As long as sunlight is available and there is a closed system of air and water, the process will continue void of outside conditions.
8.6 Weaknesses

8.6.1 High initial cost
While materials such as bamboo and wood can be sourced naturally, the purchase of materials such as PVC pipe, polycarbonate sheets, pumps, storage tanks and pond liner, alongside their transport from the city of Pondicherry, will cost approximately $730 Australian Dollars or 35,750 Rupees. The polycarbonate sheets are the most expensive item but have high thermodynamic properties and have a life span of approximately 20 years.

8.6.2 Bamboo has short life span in relation to other materials used
While polycarbonate sheets have a life span of 20 years the bamboo used for structural purposes have a life span of approximate 5 years if they have undergone preparation such as waxing. This life span is also reduced due to the high operating temperature and the high levels of water and humidity exposure.

8.6.3 Concentrated saline waste produced
Approximately 10% (3.7L a day) of the water treated will be a concentrated brine solution, consisting of dissolved solids and other particles present in the bore water. The disposal methods for this concentrated brine was limited, therefore the concentrated waste is returned to the groundwater in the designated area where the stills are located.

8.6.4 Potential for problems with mould
Due to the levels of heat and moisture there is an increased chance that mould and algae could grow within the still. This is to be rectified through monthly ‘drying out’ maintenance and the biannual disinfectant spray.

8.6.5 Does not treat the source of the problem
While the solar still provides the continual supply of clean drinking water for the Colony in the village of Devikulam, it does nothing to address the current issue with salt-water intrusion in the current village water supply.

8.6.6 Has only limited additional uses
Other than the use of rainwater harvesting and the collection of water vapour as a drinking source, the solar still had no other addition purposes to benefit the people of Devikulam.
8.7 Future work
In order to secure the success of our proposal it is suggested that further work be undertaken, it is also necessary to improve and or expand our design.

8.7.1 Quantitative thermodynamic analysis
To ensure that our estimations are correct, a quantitative thermodynamic analysis based upon the qualitative analysis should be undertaken.

8.7.2 Development of education plan
Alongside Pitchandikulum Forest we aim to establish and distribute an education plan that would aim to educate the villagers on the importance of water management and the health risks associated with unclean drinking water.

8.7.3 Development of the site selection criteria
As well as the education plan there would need to be consultation with Pitchandikulum Forest to develop the site selection criteria to ensure that the design is located responsibly and has the best outcomes for the people of the colony.

8.7.4 Development of the on roof design for future buildings
The solar still ‘on ground’ design in which we have proposed is also applicable on the roof of housing buildings, however this alternate design was not chosen for our final design due to the poor infrastructure of the village of Devikulam. Continual consideration and design would be undertaken to perfect the ‘on roof’ version, which has the characteristics of improving the roof and infrastructure of the current poor levels of housing in Devikulam.

8.7.5 Identify uses for concentrated saline waste
The concentrated saline waste (which is estimated to be approximately 3.7L a day per solar still) poses the most severe environmental impact for the implementation of this design. Further research in disposal methods are requested to sustainably and effectively remove this waste from the area surrounding the village of Devikulam. Also if possible create a benefit to the disposal methods of the concentrated brine waste.
9 Conclusion

The village of Deivkulam’s current water supply is predicted to become highly saline as a result of saltwater intrusion. The proposed design aims to resolve this issue through the use of a simple design. Clean water will be easily accessible to villagers without the hassle of travelling long distances or using costly methods of water cleansing. The environmental impacts associated with the design are minimal and effectively resolved through simple methods. The design does not pose as a threat to either local flora or fauna, making it extremely environmentally sustainable.

The design satisfies all principle objectives in terms of being efficient in desalinating water, respecting the religious and cultural customs of the people, and works within the constraints of a reasonable budget, good location and technology sufficient. As well as improving the village’s health by providing clean drinking water it also places less pressure on the groundwater, thus stopping further intrusion.
It is effective in its purpose yet works at an appropriate cost, proving to be an advantageous addition into the lives of the people of Devikulam.
10 Bibliography


India Meteorological department. PUDUCHERRY CLIMATOLOGICAL TABLE. http://www.imd.gov.in/section/climate/pondicherry2.htm (accessed 08 05, 2011).


11 Appendixes

11.1 Appendix A, Thermodynamic Analysis 42
11.2 Appendix B, Solar Data 47
11.3 Appendix C, Wind Data 48
11.4 Appendix D, Materials & Costing 49
11.5 Appendix E, Layout of Solar Still, On Ground 51
11.6 Appendix F, Solar Still Construction Instructions 53
11.1 Appendix A, Thermodynamic analysis

This is a qualitative analysis of a solar still to determine what aspects are important to ensure maximum efficiency in its operation.

Assumptions:

- The system operates in a steady state
- The whole system is at operating temperature ($T_{op}$)
- The whole surface is at temperature ($T_{sur}$)

As mentioned previously, solar stills are effectively closed systems. So by using the first law of thermodynamics it is evident that;

$$\sum E_{in} = \sum E_{out} + \Delta U + W$$

Where:

- $\sum E_{in}$ is the energy put into the system.
- $\sum E_{out}$ is the energy lost from the system.
- $\Delta U$ is the change in internal energy of the system.
- $W$ is the work done by the system.

Energy is supplied to the system by the sun, and is equal to

$$\sum E_{in} = Insolation \times A_{coll} \times \eta_{collection}$$

Insolation is the amount of energy emitted by the sun per square metre at the surface of the earth and averaged over the day. For Devikulam the average is $(5.5 \pm 0.5 \, kWH/m^2/day)$, as can be seen in Appendix B.

- $A_{coll}$ is the collection area ($m^2$)
- $\eta_{collection}$ is how effectively the solar still collects the sun’s energy (%).

Energy is lost from the system in two principal ways

The first is through heat transfer. Due to the fact the solar still is operating at a higher temperature than its surroundings a thermal gradient exists between the still and the surroundings. This causes energy in the form of heat to flow from the system into the surrounding environment, with the heat transfer occurring through three mechanisms.

The first heat transfer mechanism is conduction, and it occurs where a surface of the system is in contact with a solid. In this case it occurs between the bottom of the system and the ground. Fourie’s law is used to predict the amount of energy lost.

$$Q_{cond} = -kA\Delta T$$
Where:
\( \dot{Q}_{\text{cond}} \) is the amount of energy lost per second (W)
\( k \) is the thermal conductivity (Wm\(^{-1}\)K\(^{-1}\))
\( A \) is the cross-sectional area where the heat transfer takes place (m\(^2\)).
\( \Delta T \) is the difference in temperature of the system and the solid (°C).

The second heat transfer mechanism is Convection and it occurs where a surface is in contact with a fluid. In this case between the four upper surfaces and the surrounding air. Newton’s law of cooling can be used to predict the amount of energy lost.

\[
\dot{Q}_{\text{conv}} = -h A \Delta T
\]

Where:
\( \dot{Q}_{\text{conv}} \) is the amount of energy lost per second (W)
\( h \) is the heat transfer coefficient (Wm\(^{-2}\)K\(^{-1}\)).
\( A \) is the cross-sectional area where the heat transfer takes place (m\(^2\)).
\( \Delta T \) is the difference in temperature of the system and the fluid (°C).

The heat transfer coefficient is specific for each application and for air is typically between 5-10 000 Wm\(^{-2}\)K\(^{-1}\). The formula for the heat transfer coefficient is

\[
h = \frac{Nu \times k}{L}
\]

Where:
\( k \) is the thermal conductivity of the fluid (Wm\(^{-1}\)K\(^{-1}\)).
\( L \) is the characteristic length (m).
\( Nu \) is the Nusselt number and is determined by correlations between empirical data. For forced convection over a plate at uniform temperature it is given by

\[
Nu = 0.332(Pr)^{1/3}(Re)^{1/2}
\]

Where
\( Pr \) is the Prandtl number
\[
Pr = \frac{c_p \mu}{k}
\]
\( c_p \) is the specific heat of the fluid (Jkg\(^{-1}\)K\(^{-1}\)).
\( \mu \) is the dynamic viscosity (Nsm\(^{-2}\)).
\( k \) is the thermal conductivity of the fluid (Wm\(^{-1}\)K\(^{-1}\)).

\( Re \) is the Reynolds number

\[
Re = \frac{\rho UL}{\mu}
\]
\( \rho \) is the density of the fluid (Kgm\(^{-3}\))
\( U \) is the velocity of the flow (ms\(^{-1}\)).
\( L \) is the characteristic length (m).
\( \mu \) is the dynamic viscosity (Nsm\(^{-2}\)).
Note that the Nusselt number has been calculated for forced convection because it is assumed that the average wind speed of 5.4ms\(^{-1}\) (see appendix C) is sufficiently higher than the air speed caused by buoyancy of the warmer air.

The third heat transfer mechanism is radiation, which is electro magnetic radiation and occurs in all substances above absolute zero due to the agitation of each atom due to thermal energy. The amount of heat transfer can be predicted using the Stefan-Boltzmann Law

\[ Q_{rad} = \varepsilon \sigma A T^4 \]

Where:
\( \dot{Q} \) is the amount of energy lost per second (W)
\( \varepsilon \) is the emissivity of the material.
\( \sigma \) is the Stefan-Boltzmann constant (5.6703x10\(^{-8}\) Wm\(^{-2}\)T\(^{-4}\)).
\( A \) is the cross-sectional area where the heat transfer takes place (m\(^2\)).
\( T \) is the absolute temperature (K).

For the purposes of this analysis however the effect of radiation has been ignored because of the relative magnitude when compared to the other two mechanisms.

The second way energy is lost from the system is due to the difference in temperature in the water entering the system and the water leaving the system.

\[ \dot{Q}_w = c_w \dot{m} T_{exit} - c_w \dot{m} T_{enter} = c_w \dot{m} \Delta T_w \]

Where:
\( \dot{Q}_w \) is the amount of energy lost per second (W)
\( c_w \) is the specific heat of water (Jkg\(^{-1}\)K\(^{-1}\))
\( \dot{m} \) is the mass flow rate of water (\( \rho_w \times \text{flow rate} \)) (kgs\(^{-1}\))
\( T_{exit} \) is the temperature of the water leaving the system (\(^\circ\)C)
\( T_{enter} \) is the temperature of the water as it enters the system (\(^\circ\)C)
\( \Delta T_w = T_{exit} - T_{enter} \) (\(^\circ\)C)

**The change in internal energy** has two principal components

The first is the energy required to heat the system, which can be predicted by

\[ Q_{sys} = c_{sys} \Delta T \]

Where
\( Q \) is the energy required to heat the system (J)
\( c_{sys} \) is the heat capacity of the system (JK\(^{-1}\))
\( \Delta T \) is the change in temperature (K)
$c_{sys}$ can be determined by adding together the heat capacities of each of the components of the system i.e.

$$c_{sys} = \sum c_{comp} m_{comp}$$

Where:
- $c_{comp}$ is the specific heat of the component (J K$^{-1}$ Kg$^{-1}$)
- $m_{comp}$ is the mass of the component (Kg)

The second is the energy required for the phase change of the water as it goes from a liquid to a gas.

$$Q = m \Delta H_{vap}$$

Where:
- Q is the energy required (J)
- m is the mass of the liquid (Kg)
- $\Delta H_{vap}$ is the latent heat of vaporisation (J Kg$^{-1}$)

So initially the energy required

$$Q_i = m_i \Delta H_{vap}$$

Where:
- $m_i$ is the initial mass of water vapour required to saturate the air at operating conditions,
- $m_i$ is given by

$$m_i = V \times (\rho_{wop} - \rho_{wi})$$

Where:
- V is the volume of the air within the system (m$^3$)
- $\rho_{wop}$ is the density of the water vapour when the system is at operating temperature (Kg m$^{-3}$)
- $\rho_{wi}$ is the density of the initial water vapour when the system is at operating temperature (Kg m$^{-3}$)

The densities can be determined from their partial pressures by the relationship

$$(\rho_{wop} - \rho_{wi}) = \frac{0.0022(p_{wop} - p_{wi})}{T_{op}}$$

Where:
- $p_{wop}$ is the partial pressure of water vapour at normal operating conditions (Pa)
- $p_{wi}$ is the partial pressure of water vapour at initial conditions (Pa)
- $T_{op}$ is the operating temperature (°C)
The difference between the partial pressures can be determined from the operating temperature and the dew temperature at initial conditions

\[
(p_{wop} - p_{wi}) = e^{\frac{-\Delta H_{vap}}{R(T_{op} - T_{idew})}}
\]

Where:
R Is the universal gas constant 
\(T_{idew}\) Is the dew temperature at initial conditions (°C)

This also means that during operation some of the sun's energy will not go into heating up the system, but instead be used to vaporise the water. Because the system is closed the amount of water evaporating is equal to the amount of water condensing. Assuming the latent heat of vaporisation is constant for the system, the amount of energy required to vaporise the water is equal and opposite to the amount of energy released when the water condenses
i.e. \(\Sigma Q_{condensing} = -Q_{evaporation}\). This can be determined by using the operating temperature and the surface temperature where heat transfer occurs.

\[
(p_{wop} - p_{wsurf}) = e^{\frac{-H_{vap}}{R(T_{op} - T_{surf})}}
\]

Where
\(p_{wsurf}\) Is the partial pressure of water vapour at the surface temperature (Pa) 
\(T_{surf}\) Is the surface temperature (°C)

Then by determining \((p_{wop} - p_{wsurf})\) and approximating the thermal boundary volume and the time taken for the air at the boundary to go from \(T_{op}\) to \(T_{surf}\) it is possible to determine the mass rate of the water condensing at the boundary and using the mass rate determine the energy release rate at the boundary.

It is assumed that because the condensation happens at the boundary, which is sufficiently distant to the region where evaporation occurs the energy does not go towards the evaporation of water and is instead lost from the system.

**Work done by the system** is assumed to be minimal because, the system is assumed to behave as a spring so that any force applied by an increase in internal pressure will be reversed once the pressure reduces. And gravity is assumed to be a lossless system so that any gain in potential energy is one hundred per cent efficient.

Assuming that at this latitude there is an average of 12 hours of daylight, this gives an overall energy balance of

\[
E_{in} = (Q_{conv} + Q_{conv} + Q_{w} + + Q_{evap})43200s + Q_{sys} + Q_{i}
\]
Appendix B, Solar Data
11.4 Appendix D, Materials & Costing

11.4.1 Frame

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Line Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FA</td>
<td>4</td>
<td>(500mmxØ100mm) Wood</td>
<td>2000 mm</td>
<td>$0/1000mm</td>
<td>$-</td>
</tr>
<tr>
<td>FF</td>
<td>1</td>
<td>(1500mmxØ150mm) Wood</td>
<td>1500 mm</td>
<td>$0/1000mm</td>
<td>$-</td>
</tr>
<tr>
<td>FB</td>
<td>3</td>
<td>(4500mmxØ50mm) Bamboo</td>
<td>13500 mm</td>
<td>$0/1000mm</td>
<td>$-</td>
</tr>
<tr>
<td>FC</td>
<td>2</td>
<td>(3200mmxØ50mm) Bamboo</td>
<td>6400 mm</td>
<td>$0/1000mm</td>
<td>$-</td>
</tr>
<tr>
<td>FD</td>
<td>4</td>
<td>(2000mmxØ50mm) Bamboo</td>
<td>8000 mm</td>
<td>$0/1000mm</td>
<td>$-</td>
</tr>
<tr>
<td>FE</td>
<td>2</td>
<td>(2400mmxØ50mm) Bamboo</td>
<td>4800 mm</td>
<td>$0/1000mm</td>
<td>$-</td>
</tr>
</tbody>
</table>

**Subtotal** $-

11.4.2 Plumbing

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Line Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>2</td>
<td>2xPA - 4500mmxØ100mm PVC pipe (split lengthways)</td>
<td>4500 mm</td>
<td>$10/1000mm</td>
<td>$45.00</td>
</tr>
<tr>
<td>PB</td>
<td>2</td>
<td>2xPB - 4300mmxØ100mm PVC pipe (split lengthways)</td>
<td>4300 mm</td>
<td>$10/1000mm</td>
<td>$43.00</td>
</tr>
<tr>
<td>PC</td>
<td>2</td>
<td>(180mmxØ100mm) PVC pipe</td>
<td>360 mm</td>
<td>$10/1000mm</td>
<td>$3.60</td>
</tr>
<tr>
<td>PD</td>
<td>2</td>
<td>(50mmxØ100mm) PVC pipe</td>
<td>100 mm</td>
<td>$10/1000mm</td>
<td>$1.00</td>
</tr>
<tr>
<td>PE</td>
<td>2</td>
<td>(135mmxØ100mm) PVC pipe</td>
<td>270 mm</td>
<td>$10/1000mm</td>
<td>$2.70</td>
</tr>
<tr>
<td>PF</td>
<td>2</td>
<td>(1200mmxØ100mm) PVC pipe</td>
<td>2400 mm</td>
<td>$10/1000mm</td>
<td>$24.00</td>
</tr>
<tr>
<td>PG</td>
<td>4</td>
<td>Ø100mm PVC pipe end caps</td>
<td>4 Fittings</td>
<td>$5/Fitting</td>
<td>$20.00</td>
</tr>
<tr>
<td>PH</td>
<td>6</td>
<td>Ø100mm PVC pipe 90° joints</td>
<td>6 Fittings</td>
<td>$5/Fitting</td>
<td>$30.00</td>
</tr>
<tr>
<td>PI</td>
<td>3</td>
<td>Ø100mm PVC 'T' pipe sections</td>
<td>3 Fittings</td>
<td>$5/Fitting</td>
<td>$15.00</td>
</tr>
<tr>
<td>PJ</td>
<td>3</td>
<td>(4500mm x Ø18mm) Hose</td>
<td>13500 mm</td>
<td>$2/1000mm</td>
<td>$27.00</td>
</tr>
<tr>
<td>PK</td>
<td>3</td>
<td>(90mm x Ø18mm) Hose</td>
<td>270 mm</td>
<td>$2/1000mm</td>
<td>$0.54</td>
</tr>
<tr>
<td>PL</td>
<td>3</td>
<td>Ø18mm Hose ends</td>
<td>3 Fittings</td>
<td>$0.50/Fitting</td>
<td>$1.50</td>
</tr>
<tr>
<td>PM</td>
<td>3</td>
<td>Ø18mm 90° Hose joints</td>
<td>3 Fittings</td>
<td>$0.50/Fitting</td>
<td>$1.50</td>
</tr>
<tr>
<td>PN</td>
<td>1</td>
<td>Ø18mm ‘+’ Hose joints</td>
<td>1 Fittings</td>
<td>$0.50/Fitting</td>
<td>$0.50</td>
</tr>
<tr>
<td>PO</td>
<td>1</td>
<td>Recycled food grade 44 gallon (200L) Drum</td>
<td>1 Drum</td>
<td>$15/Drum</td>
<td>$15.00</td>
</tr>
<tr>
<td>PP</td>
<td>1</td>
<td>Manual diaphragm pump</td>
<td>1 Pump</td>
<td>$30/Pump</td>
<td>$30.00</td>
</tr>
<tr>
<td>PQ</td>
<td>1</td>
<td>(2000mm x Ø50mm) Hose</td>
<td>2000 mm</td>
<td>$3/1000mm</td>
<td>$6.00</td>
</tr>
<tr>
<td>PR</td>
<td>1</td>
<td>1xPR – Outside water tap</td>
<td>1 Tap</td>
<td>$7.50/Tap</td>
<td>$7.50</td>
</tr>
</tbody>
</table>

**Subtotal** $273.84

11.4.3 Lining

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Line Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>1</td>
<td>1xLA – 15mx500mm black pond liner</td>
<td>7.5 m²</td>
<td>$3/m²</td>
<td>$22.50</td>
</tr>
<tr>
<td>LB</td>
<td>2</td>
<td>2xLB - isosceles triangles (base 3200mm height 1200mm) black pond liner</td>
<td>3.84 m²</td>
<td>$3/m²</td>
<td>$11.52</td>
</tr>
<tr>
<td>LC</td>
<td>3</td>
<td>3xLC - (1000mmx4500mm) black pond liner</td>
<td>13.5 m²</td>
<td>$3/m²</td>
<td>$40.50</td>
</tr>
</tbody>
</table>

**Subtotal** $74.52

2011 Engineers Without Borders Challenge
### 11.4.4 Solar Collection

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Line Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>12</td>
<td>(760mmx2100mm) clear corrugated polycarbonate roofing</td>
<td>19</td>
<td>$10/m²</td>
<td>$190.00</td>
</tr>
<tr>
<td>SB</td>
<td>4</td>
<td>(4500mm) polycarbonate profiled infill</td>
<td>18000</td>
<td>$1/1000mm</td>
<td>$18.00</td>
</tr>
<tr>
<td>SC</td>
<td>4</td>
<td>(5mmx10mmx2000mm) foam strip</td>
<td>8000</td>
<td>$1/1000mm</td>
<td>$8.00</td>
</tr>
<tr>
<td>SD</td>
<td>2</td>
<td>(5mmx10mmx4300mm) foam strip</td>
<td>8600</td>
<td>$1/1000mm</td>
<td>$8.60</td>
</tr>
</tbody>
</table>

**Subtotal** $224.60

### 11.4.5 Incidental

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Line Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>16</td>
<td>Large cable tie</td>
<td>16</td>
<td>-</td>
<td>$-</td>
</tr>
<tr>
<td>IB</td>
<td>8</td>
<td>(65mmxØ8mm) Nut &amp; Bolt</td>
<td>8</td>
<td>-</td>
<td>$-</td>
</tr>
<tr>
<td>IC</td>
<td>1</td>
<td>Roll of gaffer tape</td>
<td>1</td>
<td>-</td>
<td>$-</td>
</tr>
<tr>
<td>ID</td>
<td>1</td>
<td>Glue</td>
<td>1</td>
<td>-</td>
<td>$-</td>
</tr>
<tr>
<td>IE</td>
<td>8</td>
<td>Nails</td>
<td>8</td>
<td>-</td>
<td>$-</td>
</tr>
<tr>
<td>IF</td>
<td>1</td>
<td>φ50mm Bung</td>
<td>1</td>
<td>-</td>
<td>$-</td>
</tr>
</tbody>
</table>

**Subtotal** $30.00

**Materials Total** $602.96

**Additional 10% For Maintenance** $60.30

**Logistics and Transport Assumed 10% of cost of materials** $66.33

**Labour** $-

**Total Overall Cost Per Still** $730.00 AUD

*, Where possible local costs were used however in the absence of data approximate Australian costs were used.
Solar Still Construction Instructions
Components

Frame:
- 4xF_A - (500mmxØ100mm) Wood
- 3xF_B - (4500mmxØ50mm) Bamboo
- 2xF_C - (3200mmxØ50mm) Bamboo
- 4xF_D - (2000mmxØ50mm) Bamboo
- 2xF_E - (2400mmxØ50mm) Bamboo
- 1xF_F - (1500mmxØ150mm) Wood

Plumbing:
- 2xP_A - 4500mmxØ100mm PVC pipe (split lengthways)
- 2xP_B - 4300mmxØ100mm PVC pipe (split lengthways)
- 2xP_C - 180mmxØ100mm PVC pipe
- 2xP_D - 50mmxØ100mm PVC pipe
- 2xP_E - 135mmxØ100mm PVC pipe
- 2xP_F - 1200mmxØ100mm PVC pipe
- 4xP_G - Ø100mm PVC pipe end caps
- 6xP_H - Ø100mm PVC pipe 90° joints
- 3xP_I - Ø100mm PVC 'T' pipe sections
- 3xP_J - (4500mm x Ø18mm) Hose
- 3xP_K - (90mm x Ø18mm) Hose
- 3xP_L - Ø18mm Hose ends
- 3xP_M - Ø18mm 90° Hose joints
- 1xP_N - Ø18mm ‘+’ Hose joints
- 1xP_O - Recycled food grade 44 gallon (200L) Drum
- 1xP_P - Manual diaphragm pump
- 1xP_Q - 2000mmxØ50mm Hose
- 1xP_R - Outside water tap

Lining:
- 1xL_A - 15mx500mm black pond liner
- 2xL_B - isosceles triangles (base 3200mm height 1200mm) black pond liner
- 3xL_C - (1000mmx4500mm) black pond liner

Solar Collection
- 12xS_A - (760mmx2100mm) clear corrugated polycarbonate roofing
- **4xSB** – (4500mm) polycarbonate profiled infill
- **4xSC** – (5mmx10mmx2000mm) foam strip
- **2xSD** – (5mmx10mmx4300mm) foam strip

**Incidentals:**
- **16xIA** – Large cable tie
- **8xIB** – (65mmxØ8mm) Nut & Bolt
- **1xIC** – Roll of gaffer tape
- **1xID** – Glue
- **8xIE** – Nails
- **1xIF -** Ø50mm Bung

**Tools**
- Shovel
- Drill
- Ø5 mm drill bit
- Ø8mm drill bit
- Ø18mm drill bit
- Measuring tape
- Wood saw
- Hammer
- Compass
- Adjustable spanner
- 2xWood working clamps
Frame Joining Instructions

I

• Make an incision in between two nodes perpendicular to the joining member

II

• Clean region around the two cuts
• Cover the end of the joining member in wood glue and insert the joining member into the hole now created

III

• Drill a \( \phi5\,mm \) hole into the joining member approximately 100\,mm from the end of the joining member
• Thread a cable tie through the hole and then around the other member and then tighten to secure the join.

• Side View
Step 1, Site preparation

<table>
<thead>
<tr>
<th>Components</th>
<th>• 1xPR – Outside water tap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>• NA</td>
</tr>
</tbody>
</table>
| Instructions | • Select the site according to the site selection criteria  
• Clear any vegetation to ensure maximum insolation  
• Extend colonies water supply network to the site so that water can be supplied to the still  
• At the end of the supply hose install a tap to regulate flow through the still |
Step 2, Frame Foundations & Sump Construction

<table>
<thead>
<tr>
<th>Components</th>
<th>• 4xF4A - (500mmxØ100mm) Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>• Shovel</td>
</tr>
<tr>
<td></td>
<td>• Measuring tape</td>
</tr>
<tr>
<td></td>
<td>• Compass</td>
</tr>
<tr>
<td>Instructions</td>
<td>• Dig one hole approximately 400mm deep and wide enough to fit the wooden member</td>
</tr>
<tr>
<td></td>
<td>• Dig another hole 400mm deep, 3200mm due east of the first hole</td>
</tr>
<tr>
<td></td>
<td>• Dig another two holes 200mm deep, 4500mm due north of the first and second holes</td>
</tr>
<tr>
<td></td>
<td>• Place one wooden member in the hole and then back fill each of the holes to secure the foundations for the frame.</td>
</tr>
<tr>
<td></td>
<td>• In the centre of the four frame foundations dig a hole 2000mm deep and 400mm wide and back fill with course sand so that concentrated saline waste was infiltrate back into the ground water.</td>
</tr>
</tbody>
</table>
### Step 3, Frame Base

<table>
<thead>
<tr>
<th>Components</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 2xFB - (4500mmxØ50mm) Bamboo</td>
<td>• Join the four components members together as per the instructions on pages 4 &amp; 5, (make the incisions into the longer members)</td>
</tr>
<tr>
<td>• 2xFC - (3200mmxØ50mm) Bamboo</td>
<td>• Place the constructed rectangle onto the frame foundations and then secure by drilling through the shorter members and then nailing the frame to the foundations</td>
</tr>
<tr>
<td>• 4xA - Large cable tie</td>
<td></td>
</tr>
<tr>
<td>• 1xID - Glue</td>
<td></td>
</tr>
<tr>
<td>• 4xIE - Nails</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Wood saw</td>
<td></td>
</tr>
<tr>
<td>• Measuring tape</td>
<td></td>
</tr>
<tr>
<td>• Drill</td>
<td></td>
</tr>
<tr>
<td>• Ø5mm drill bit</td>
<td></td>
</tr>
</tbody>
</table>
Step 4, Frame Vertical Profiles

| Components       | • 1xFE - (2400mmx∅50mm) Bamboo  
|                  | • 2xFD - (2000mmx∅50mm) Bamboo  
|                  | • 2xA – Large cable tie  
|                  | • 1xID – Glue               |

| Tools            | • Wood saw  
|                  | • Measuring tape  
|                  | • Drill  
|                  | • ∅5mm drill bit |

| Instructions     | • Join member FE to the two FD members as per the instructions on page 4&5, however do not tighten the cable tie fully so there is still some flexibility in the members  
|                  | • Repeat this process so that there are two of these components |
### Step 5, Attaching Vertical Profiles

**Components**
- 2x product of step 4
- 4x IA – Large cable tie
- 1x ID – Glue

**Tools**
- Wood saw
- Measuring tape
- Drill
- Ø5mm drill bit

**Instructions**
- Join the two components constructed in the previous step to the frame as per the instructions on page 4&5
### Step 6, Top member attachment

| Components       | • 1xFB - (4500mmxØ50mm) Bamboo  
|                  | • 4xA – Large cable tie  
|                  | • 1xCD – Glue  |
| Tools            | • Wood saw  
|                  | • Measuring tape  
|                  | • Drill  
|                  | • Ø5mm drill bit  |
| Instructions     | • Join the Member FB to the other components as per the instructions on page 4&5  
|                  | • Tighten the cable ties that were lose from step 4 and check the other joins to ensure the whole frame is secure  |
Step 7, Apron

<table>
<thead>
<tr>
<th>Components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1xLA – 15mx500mm black pond liner</td>
<td></td>
</tr>
<tr>
<td>1xIC – Roll of gaffer tape</td>
<td></td>
</tr>
<tr>
<td>1xID – Glue</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attach the pond liner to the frame, see next page for detailed instructions</td>
<td></td>
</tr>
<tr>
<td>Bury the un secured edge into the ground so there are no gaps</td>
<td></td>
</tr>
</tbody>
</table>
Step 7 continued, Apron

| Components | • 1xLA – 15mx500mm black pond liner  
• 1xIC – Roll of gaffer tape  
• 1xID – Glue |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>• NA</td>
</tr>
</tbody>
</table>
| Instructions | • 1, Put the glue along the top surface of the frame and then align the pond liner along the inside edge of the frame  
• 2, Start to fold the pond liner over the top of the frame  
• 3, Continue folding the pond liner.  
• 4, Secure the pond liner with tape so while the glue dries. |
### Step 8, Rainwater Gutter Preparation

<table>
<thead>
<tr>
<th>Components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• <strong>PA</strong></td>
<td>1xPA - 4500mmxØ100mm PVC pipe (split lengthways)</td>
</tr>
<tr>
<td>• <strong>PG</strong></td>
<td>1xØ100mm PVC pipe end caps</td>
</tr>
<tr>
<td>• <strong>PH</strong></td>
<td>1xØ100mm PVC pipe 90° joints</td>
</tr>
</tbody>
</table>

| Tools            | NA                                                               |

<table>
<thead>
<tr>
<th>Instructions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Join the three components together</td>
<td></td>
</tr>
<tr>
<td>• Create a mirror image to be used on the other side of the frame</td>
<td></td>
</tr>
</tbody>
</table>
Step 9, Condensed Water Gutter Preparation

| Components       | • 1xPB - 4300mmxØ100mm PVC pipe (split lengthways)
|                  | • 2xPH - Ø100mm PVC pipe 90° joints
|                  | • 1xPD – 50mmxØ100mm PVC pipe
|                  | • 1xPG - Ø100mm PVC pipe end caps
|                  | • 1xPE - 135mmxØ100mm PVC pipe

| Tools | • NA

| Instructions | • Join Components together in the sequence shown in the diagram
|             | • On the other end attach the end cap as shown in the previous step
|             | • Create a mirror image of this to be used on the other side of the frame
Step 10, Rainwater Gutter & Condensed Water Gutter Attachment

<table>
<thead>
<tr>
<th>Components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• All the products of step 8 &amp; 9</td>
</tr>
<tr>
<td></td>
<td>• 8xIB – (65mmxØ8mm) Nut &amp; Bolts</td>
</tr>
<tr>
<td></td>
<td>• 2xSD – (5mmx10mmx4300mm) foam strip</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Drill</td>
</tr>
<tr>
<td></td>
<td>• Ø8mm drill bit</td>
</tr>
<tr>
<td></td>
<td>• Spanner</td>
</tr>
<tr>
<td></td>
<td>• Clamps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Attach the water collection gutter and rain water gutter to the frame, see next page for detailed instructions</td>
</tr>
<tr>
<td></td>
<td>• For the condensate collection gutters rotate the 90° joint so that the top of PE is flush with the bottom of the frame.</td>
</tr>
<tr>
<td></td>
<td>• To get the end of PE through the apron, make two cuts where it needs to go through in a ‘+’ configuration and then push the end through, gluing the flaps to the pipe once it is through</td>
</tr>
</tbody>
</table>
Step 10 Continued, Rainwater Gutter & Condensed Water Gutter Attachment

| Components | All the products of step X & Y  
8xIB – (65mmxØ8mm) Nut & Bolts  
2xSD – (5mmx10mmx4300mm) foam strip |
| Tools | Drill  
Ø8mm drill bit  
Spanner  
Clamps |
| Instructions | 1, Align the two gutters and foam along the edge of the frame  
2, Clamp the two gutters and foam onto the frame and drill 8mm holes through the two gutters, frame and foam at 150mm, 1550mm, 1950mm and 4150mm from one of the ends  
3, Put the bolts through the drilled holes, ensuring that the thread side is on the outside edge of the frame, ie the rainwater gutter side. (This is to assist with maintenance latter on.  
4, Tighten the bolts ensuring that they are tight enough to secure the gutters but not too tight to split the bamboo. |
Step 11, Polycarbonate profiled infill attachment

<table>
<thead>
<tr>
<th>Components</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 4xSB – (4500mm) polycarbonate profiled infill</td>
<td>Glue the 4500mm polycarbonate profiled infill along the members of the frame that run north to south, with two along the upper member</td>
</tr>
<tr>
<td>• 4xSC – (5mmx10mmx2000mm) foam strip</td>
<td>• Glue the foam strips along the out side of the vertices of the triangle profile.</td>
</tr>
<tr>
<td>• 1xID – Glue</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• NA</td>
<td>Glue the 4500mm polycarbonate profiled infill along the members of the frame that run north to south, with two along the upper member</td>
</tr>
<tr>
<td></td>
<td>• Glue the foam strips along the out side of the vertices of the triangle profile.</td>
</tr>
</tbody>
</table>
Step 12, End sections attachment

| Components | • 2xLB - 2x isosceles triangles (base 3200mm height 1200mm) black pond liner  
• 1xID - Glue |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>• NA</td>
</tr>
<tr>
<td>Instructions</td>
<td>• Glue the triangle profiles to the inside of the frame at each end to close the system</td>
</tr>
</tbody>
</table>
Step 13, Saline Water Distribution

<table>
<thead>
<tr>
<th>Components</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 3xPJ - (4500mm x Ø18mm) Hose</td>
<td>• Drill holes through member FE as per the dimensions on the next page</td>
</tr>
<tr>
<td>• 3xPK - (90mm x Ø18mm) Hose</td>
<td>• For each of the three hoses in one end of the hose put the hose end and ensure a water tight seal</td>
</tr>
<tr>
<td>• 3xPL - Ø18mm Hose ends</td>
<td>• Then feed the other end of the hose through the hole drilled in the member FE</td>
</tr>
<tr>
<td>• 3xPM- Ø18mm 90° Hose joints</td>
<td>• For the two outside hoses secure the ends with the 90° hose joints and with the centre hose the ‘+’ Hose joint</td>
</tr>
<tr>
<td>• 1xPN - Ø18mm ‘+’ Hose joint</td>
<td>• Then join the 90° hose joints to the ‘+’ hose joint using the 90mm lengths of hose finally join the system to the water mains using the last remaining join on the ‘+’ joint</td>
</tr>
</tbody>
</table>

Tools
- Drill
- Ø18mm drill bit
Frame
Evaporation Surface
Water Hose

(Dimensions in mm)
Step 14, Evaporating Surface

<table>
<thead>
<tr>
<th>Components</th>
<th>3xLC - (1000mmx4500mm) black pond liner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>NA</td>
</tr>
<tr>
<td>Instructions</td>
<td>Starting with the middle hose, drape one of the black pond liners over the top of the hose and then fasten each of the corners to the frame to make an inverted 'V' shape.</td>
</tr>
<tr>
<td></td>
<td>In the top of the hose and pond liner then make small punctures every 30mm so that once the water is turned on water will flow out of these holes and then over the evaporation surface.</td>
</tr>
<tr>
<td></td>
<td>Turn water supply on to test the operation and make any adjustments to ensure correct operation of the water distribution network.</td>
</tr>
</tbody>
</table>
Step 15, Polycarbonate Attachment

| Components | • 12xSA – (760mmx2100mm) clear corrugated polycarbonate roofing  
• 1xID –Glue |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>• NA</td>
</tr>
</tbody>
</table>
| Instructions | • Put glue on top of the profiled polycarbonate infill and they lay the polycarbonate over the top, ensuring that there is two corrugations of over lap or as per the manufactures instructions to make a watertight seal.  
• Note, Make sure that all tools, rubbish and personal belongings are removed from inside the still before attaching the polycarbonate as it is difficult to access once the polycarbonate has been attached |
### Step 16, Water Storage Installation

<table>
<thead>
<tr>
<th>Components</th>
<th>• 1xPO – Recycled food grade 44 gallon (200L) Drum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>• Shovel</td>
</tr>
</tbody>
</table>
| Instructions     | • Dig a hole on the southern end of the still, roughly in the centre and as close to the still as possible.  
                  | • The hole needs to be large enough to fit the whole drum so that it fits nearly flush to the ground. |
Step 17, Water Collection Preparation

| Components | • 2xPC - 180mmØ100mm PVC pipe  
|            | • 3xPI - Ø100mm PVC ‘T’ pipe sections  
|            | • 2xPF - 1200mmØ100mm PVC pipe |
| Tools      | • NA |
| Instructions | • Assemble the components as shown in the diagram |
Step 18, Water Collection Attachment

<table>
<thead>
<tr>
<th>Components</th>
<th>• The product of step 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>• Drill</td>
</tr>
</tbody>
</table>
| Instructions | • Attach the product of step 17 to the water collection gutters attached to the frame  
• Once the water collection piping is in place, measure and cut a hole into the top of the water storage and put the water collection end into the water storage drum. |
Step 19, Water Storage Extraction

| Components      | • 1xFF - (1500mmxØ150mm) Wood  
|                 | • 1xPQ - 2000mmxØ50mm Hose      
|                 | • 1xIF - ø50mm Bung             |
| Tools           | • Shovel                        
|                 | • Drill                         |
| Instructions    | • At the southern end of the water tank dig a hole 500mm deep and wide enough to fit the component FF  
|                 | • Put the member FF into the hole and back fill to secure the stand for the pump  
|                 | • Cut two 50mm holes into the top of the drum, one close to the newly installed post and the other close to the centre of the lid  
|                 | • In the hole close to the post thread PQ into the drum ensuring that the end of the hose reaches the bottom of the drum  
|                 | • In the other hole in the centre of the lid put the ø50mm Bung for access later on to check the water level. |
## Step 20, Pump Installation

### Components
- 1xPP – Manual diaphragm pump
- 4xIE – Nails

### Tools
- Hammer

### Instructions
- Attach the manual diaphragm pump to the top of the post using the nails
- Then attach the free end of the hose from step 19 to the inlet of the pump
- To test the function of the pump put 20L of clean water into the drum via the bung hole and then pump the water out.
Step 21, Final Checks

<table>
<thead>
<tr>
<th>Components</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>NA</td>
</tr>
</tbody>
</table>
| Instructions | Preform the final checks on the design ensuring:  
  o All the frame joints are tight and secure  
  o All the water collection gutters are connected and have no obstructions  
  o The water supply to the design is functioning  
  o The system is completely sealed and there are no gaps or tears  
  o The polycarbonate is firmly attached and also clean  
  • The first two days of collected water should be discarded to account for dust and other contaminants introduced during construction  
  • Once all these checks and measures have been performed the system should be ready to function normally |