H2O-2-GO

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0.0 Executive summary
The Engineers without Borders (EWB) 2011 Challenge formed the basis for a multidisciplinary subject available to students from all courses at the University of Melbourne. The challenge was centered around the development of a sustainable design solution as a means to improve the lives of the local citizens in Devikulam, a rural community in South-East India.

There were multiple options that groups could have chosen from to focus their report on; this report focuses on the area of water systems and providing a reliable source of potable water to the community. Sustainability and sustainable design played a key role in all aspects of this report, which is in line with the engineers without borders code of practice. The design proposed was multi-faceted by nature and approached the diverse areas of water treatment, distribution, storage and capture.

Water treatment was handled through a passive system called DEWATS- Decentralised Water Treatment System. This system was chosen due to its viability to be attached to the pond in a way that adds and blends to the natural scenery of the area. Water distribution throughout the community centred on the idea of keeping the tanks in the colony and village full at all times, even during blackouts, so that community members would have access to drinking water all day everyday, no matter where they were. This was achieved by proposing modifications to current systems such as rearranging pipes and adding back up power sources. Safe and sanitary water storage techniques were investigated and it was decided that ceramic pot filters be implemented at the household level, which means that any water source the community uses can be treated effectively and efficiently in homes, maximising convenience and ease of use. Traditional water harvesting methods have also been proposed in order to refill falling ground water tables and decrease salinity and contagion levels in bores.

A great deal was covered in this report, however all of these solutions are simple and proven to be effective, which means that the community can implement these ideas on their own in order to acquire the maximum benefits from them. The main aim of the report is to provide the EWB and other affiliated organisations with a range of ideas that they can develop upon and implement as they would desire. It was not an intention to propose a design that could solve Devikulam’s water issues perfectly. The results concluded that the overall design was effective, sustainable and would integrate well into the culture and way of life of the community of Devikulam.
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0.1 Team Reflection

Our team took a real world approach to this project as we believe that it should be approached as though we were actually engineers working on this, especially as the majority of us will be pursuing engineering studies. In this, we chose to divide the workload in such a way as to allow each team member to specialise in one area and essentially become an expert in their chosen field. In a way, this is how we believe typical engineering projects are undertaken in the real world; a group of specialist engineers uniting to a common cause where they commit all of their skills and experience in order to produce a viable solution to a given problem. Each team member adopted a role that they were interested in and if possible, was related to their chosen path of science/engineering.

Jesse Poulton took on the role of a water treatment expert, which relates to his passion for wanting to commit to humanitarian and development aid work alongside his Civil engineering studies. Sindre Seppola adopted the role of a water distribution expert, which is related to his desired course in Mechanical Engineering and will to bring improvements to people standards of living. Steven Tran was responsible for a household water storage and treatment solution, relating to his desire to improve people’s lives and pursuit to study Chemistry/Chemical Engineering. Tim Darby managed the area of water harvesting and use of natural resources in communities, which stemmed from his studies in Civil Engineering and Earth sciences as well as his desire to help preserve the Earth’s natural resources.

As a group we made a conscious decision that we would devise a strategy that could be implemented alongside the existing infrastructure to ensure that the community would be accepting of our ideas and that they would only benefit from our hard work. We felt that a system which improved and built upon their current way of life would be more beneficial then a system that introduced an unprecedented level of complexity. We feel that our system is simple enough that the community will understand the details and motivations behind it, which means that they are more likely to accept and enjoy our system whilst consciously making the decision to improve their quality of life, which is the overall aim of this challenge.
We thought that it was appropriate to take on a large scale project as this report was produced as the culmination of an entire subject. The subject, *Sustainability in developing communities*, was run by Dr Kaya Prpic, with support from other academic figures across the university. Our entire group believed that Dr Prpic did an excellent job in running the subject and always had plenty of input and ideas. Early in semester, tasks that helped us get to know each class member and find out who we would like to work with to produce a report. This was very beneficial as it gave us an opportunity to find out who we worked well with and who had similar motivations to our own. Eventually the time came to form a team, since we knew everyone in the class we were able to confidently form a group that we knew would work well together and produce a great report. All of us had similar motivations and goals for the subject which included; making a real contribution to people’s lives, improving the lives of those in developing communities, learning about sustainability, having fun and making new friends.

As the semester progressed, Dr Prpic taught us about learning and thought processes, design processes and visualization methods, among a myriad of other interesting and useful things that we could apply to our report. Of particular note was the time spent on sustainability and sustainable development which gave us new ideas about the world and how we can go about making it a better place for generations to come.

We were also set the task of utilising two visualization methods to evaluate our approach to the project which gave us multiple perspectives on what needed to be done; copies of these can be found in the appendices. Throughout the semester Dr Prpic organised guest lecturers who were experts in their respective fields, all relating to our projects.

Associate Professor Barbara Ozarska made a great presentation on natural building materials and how they can be used within communities to assist development. Not only can the natural building materials, such as bamboo, be incredibly effective, the excess can be used by individuals to produce items such as carvings which can be sold at local markets to begin a business and provide a family with an income. Our group took away the ideas that if the correct materials are used in efficient ways, the whole community can benefit immensely.
Dr Jim Black gave a fascinating lecture about health and the history surrounding medicine and heath. This gave all of us a wakeup call and showed us that the most successful new ideas throughout history have only succeeded because the entire community got involved and made things happen for themselves. We saw how successful new ideas are 99% people and 1% technology, however if that 1% is not implemented correctly everything falls apart. From that day we knew that we had to develop a proposal that the community of Devikulam could implement for themselves and take pride in their achievements.

During the project we found the biggest hurdle was finding information about the community itself, however the engineers without borders challenge forum was filled with excellent people who were willing and able to answer the majority of our questions about the community. It is hard to say what we would change if we redid the project, throughout the entire process we have had our mindsets and ideologies challenged which has transformed us as a group in a way that has had a unique and profound way that we would not want to change. For us, the most enjoyable part was the moment that we realised what we were doing could actually change this communities lives for the better.

In order to really get an idea for how well our team worked together, we thought it was a good idea to assess ourselves against the engineers Australia learning outcomes and professional attributes.

*Table 0.1: Team evaluation*

<table>
<thead>
<tr>
<th>Engineers Australia Graduate Attribute:</th>
<th>How we demonstrated the attribute:</th>
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<tbody>
<tr>
<td>Ability to utilise a systems approach to design and operational performance</td>
<td>We devised a full system strategy that is aligned with the community’s beliefs and way of life, thereby maximising potential success and operational performance.</td>
</tr>
<tr>
<td>Ability to undertake problem identification, formulation and solution.</td>
<td>We clearly found and defined what needed to be done and devised a strategy that would achieve our desired goals, whilst remaining conscious of the community and context of which it is servicing.</td>
</tr>
<tr>
<td>Ability to apply knowledge of basic science and engineering fundamentals</td>
<td>Wherever it was possible and appropriate we have included an overview of the underlying science and technology that demonstrates an understanding of our chosen processes.</td>
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<tr>
<td>Understanding of professional and ethical responsibilities and commitment to them.</td>
<td>Throughout our work we have made sure that all of our solutions are ethical and aligned to engineers Australia’s code of ethics, as well as keeping a firm grasp on the beliefs and ethics of the people of Devikulam.</td>
</tr>
<tr>
<td>Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development. Understanding of the principles of sustainable design and development</td>
<td>Throughout the entire design process our whole team has focused on strategies that would be sustainable and contribute positively to the sustainable development of the community. We have identified that it is very important for engineers to make sure that everything they do is sustainable in a social, cultural, global and environmental sense. We have also chosen solutions that will allow the community to get involved and take ownership of the system. We have also taken care to ensure that everything we recommend will not contribute negatively to the village of Devikulim in a physical or emotional sense. We also identified that the people of Devikulim have vastly different beliefs and cultures to our own and that we should not attempt to tamper with their culture.</td>
</tr>
<tr>
<td>Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member</td>
<td>Each team member was required to act as an expert, which gave them the ability to work individually, however we all had to bring our ideas together as a team and teach each other about our specific idea, which ensured that we had a very good idea of how it worked. We were all given leadership opportunities when it came to distributing tasks and interacting with professors and lecturers.</td>
</tr>
</tbody>
</table>
We have identified that our proposal may have some weaknesses in that we may have spread our resources too thin and focused on too many things which may have been excessive. However, in saying that, we also believe that since we had a reasonable amount of time to work on this project it was justified that we should cover so many aspects, which led to a solution that covered all bases and will integrate very well into the community. This essentially makes our biggest weakness our biggest strength, which is integral in successful engineering projects.

Our team began as a group of people who choose to work together because we thought that we would work well together. In the end it turned out that not only did we produce a great report together that met all of the recommended guidelines, we have become great friends from the project. We hope that the community of Devikulam will become more united from and enjoy the benefits of our proposed solution as much as we have enjoyed making it!

We would like to express our gratitude to all of the guest lecturers who gave us their time, as well as to Dr Prpic who has been very supportive and encouraging the whole way through.

0.2 Ethics

As the majority of our group are pursuing engineering studies, we felt that it was important that we kept the Engineers Australia code of ethics in mind. It was the general consensus that it was appropriate to behave as if we were practicing engineers in the real world. We must be willing to accept full responsibility for our recommendations, so they must be made in an ethical way so that we had something to back us up. We made sure that each aspect of our proposal was ethical in design and implementation. We did not want to be irresponsible by recommending a solution that would adversely affect the community of Devikulam in any way.

The main ethical concerns related to our proposal came from cultural acceptance and awareness. We had to be mindful of how different the culture of India is to our own, which was sometimes difficult, especially concerning the caste and class system that operates in India. We came to the decision that it was not our place, nor wise, to interfere with their cultural beliefs. This encouraged us to develop solutions that would be fair to the whole community. Many of the ethical concerns were raised and discussed in the report as they emerged during evaluation of ideas.
0.3 Defining Sustainability

Definition: ‘Satisfying the needs of the present generation without compromising the ability of future generations to satisfy their own needs’ (reference) the possibility that humans and other life flourish on earth forever. Sustainability by design - John Ehrenfeld. This definition presents sustainability as both a mindset and a vision. It is the ideal that we, as a group, have adopted in our thinking and is the cornerstone to which we have based our project upon.

Why it’s important: “As consumption increases and life-sustaining resources decline, we are faced with a growing crisis for the earth to sustain the demand for its resources.”

- Triple bottom line: The triple bottom line is an all-encompassing concept that underpins the relationship between the social, environmental and economic aspects of ‘sustainability’. It is necessary for all aspects of the triple bottom line to be met if one wishes to develop sustainable systems.

- Things to consider: ‘Sustainability’ in itself is not an outcome, but a process. For a design to be sustainable it must be able to exist in harmony with not just nature, but with the people it services for an extended period of time. Peoples needs change over time, and so any sustainable system must be able to adapt to fulfill these needs.

- Limitations: Sustainable practice in itself does not come without a price. Often times the development of any system requires consideration of the costs contrasted against the benefits and the outcomes. This is of no exception when one seeks to develop a ‘sustainable’ system. As such, there will be trade-offs in different aspects of the system and this will influence costs, outcomes, benefits and drawbacks accordingly.

The need for sustainability in India:
Today more than ever there is a need for sustainability in what is becoming an increasingly global society. Climate change, global warming, atmospheric temperature increase - call it what you will - our home is getting warmer and business as usual practices will only emphasis the rate of climate change and more to the point the effects it will have on humanity.
With her rapidly expanding economy (growth of 8.5% 2010-11 (IMF 2011)) and population the argument for sustainability in India is particularly poignant. While growing populations have long been since been considered the greatest challenge facing environmental security, a growing economy is more threatening in a variety of ways. India has both. In the future, India will not only have more people, but more people who consume more ‘stuff.’ The effects this will have on the environment cannot be overstated. There is simply no justification to think that Indians (and indeed the rest of the developing world) do not have a right to the privileged lifestyle we in the west enjoy. The Cities Alliance (2010) state that ‘no country has grown to middle-income status without industrialising and urbanising.’ Traditionally the industrialisation and urbanisation process has been environmentally damaging in every aspect and so the roots through which India’s development takes place must be addressed and turned sustainable so that when her people consume that which they are entitled to they do so in a way that will no threaten the future generations of planet earth.

The reason for tackling a rural area can be argued in terms of the sustainability of India economically, environmentally and medically. Increases in global temperature emphasises the challenges those living in rural regions face. Droughts will increase in frequency subsequently increasing the frequency with which crops, and peoples livelihoods fail. And as water becomes less accessible, people will be forced to risk everything to seek illusive opportunities in cities. This has (at least) a two fold effect. Firstly, Indian cities are not always pictures of supreme health and cramming these opportunity seekers in to a small space that lacks sanitation clearly leads to an increase in infection and spread of disease. Secondly the agricultural sector - India’s largest (Economic Survey 2009–10. Ministry of Finance, Government of India. pp. 294)— greatly suffers.

India, much like China, is a giant that is no longer asleep. After years of British oppression and third world living conditions she is now finding her feet and will no doubt be a key player in the world game in years to come. We must ensure that as she finds her feet and begins to run she is able to do so without treading on the future of her people.
- The current state of Sustainability in India:

Increasingly the world is shifting towards more environmentally sustainable practices and hence a sort of green revolution is taking place, but slowly. India for reasons discussed above has been identified as an integral hot-spot in which sustainable development simply must take place. The private, non-government and government sectors are all making genuine (and some not so genuine) attempts to guide this shift but what we must recognise is that India no longer wants to be a developing nation. She wants to be developed and, as we in the west did, wants to achieve this as quickly and as cost effectively as possible. Traditionally this has meant that the environment has been sacrificed on the road to development but programs from these three sectors are separating economic growth from environmental degradation. The programs are often based no solely on infrastructural changes but behavioural ones as well. Here is a snapshot of some of the initiatives that different sectors are taking.

- Non-Government Organisation

In Tamil Nadu alone there are 670 NGOs operating. A great portion of these focus their work on sustainable development. World Vision India, for example focuses its efforts on long term solutions, working with rural (and urban) communities to ensure that sustainable solutions are found to the problems such communities face in regards to access to water, sanitation, energy, farming and economic stimulation. Pitchandikulam Forest, on the other hand, works solely on preserving and restoring the tropical dry evergreen forest that is an undoubted microcosm of life and sustainability.

- Privates

While examples of large private companies branding themselves as ‘green’ for marketing purposes are semi prevalent, there are genuine attempts from the private sector to ensure India develops sustainably. The Coca-Cola company, an objective judgement of which aside, is implementing so brilliant programs across India. Their water usage program has 22 projects across India with ‘Community empowerment through water and sanitation’ in the south to drip Irrigation projects in the north. In private health sector, Jamkhed, a local medical clinic, has been empowering the community in every sense of the word. Dr Jim Black has referred to the Jamkhed facility as ‘the best example of health care I’ve ever seen’ more than once.
- Government

Whilst economic growth is the priority of the world's largest democracy, Indian government is implementing significant projects and programs to minimise their ecological footprint. The Ministry of New and Renewable energy is rolling out programs on both small and large scale around utilising solar and solar thermal, wind and watermills as well as biogas, to name a few. The government also works with or funds other organisations either in or outside the government that strives for sustainability in all aspects of Indian life, such as the ‘India Council for Sustainable Development’ who feed long term plans and policy directly to senior government ministers.
1.0 Problem Definition

1.1 Problem Scope:
There is currently insufficient access to clean water for all areas in the Devikulam community. The clean water that is available, is available in small quantities and at infrequent and possibly inconvenient times. There are concerns that current contamination issues will only get worse in the future if no intervention is made. While there it seems there is enough water for the community, not all members of the community are getting access to this water for numerous reasons.

1. The water is contaminated
2. The current water supply is not well enough distributed
3. During power outs there is no power to power the pump and hence no water for the community.
4. Water is not stored well enough in homes.
5. Currently, rain water its not captured

Our proposal will attempt to rectify each of these matters with sustainable solutions that the Devikluam community will embrace with gusto. Figure 1 below motivates the need for adequate water treatment in Devikulum, as the vast majority of India’s water supply is consumed untreated.

Fig 1.1. The state of water treatment in the world. See India; ‘Southern Asia’ in the figure (http://maps.grida.no/go/graphic/ratio-of-wastewater-treatment)
1.1.1 Design Requirements:

In order to evaluate the proposed ideas and solutions, it is necessary to have design requirements that clearly state what is expected of a successfully idea. This provides a clear cut way of comparing various ideas to find the most effective. All of the ideas that were considered were evaluated according to the following set of requirements.

A. Cultural acceptance/awareness: Any part of the proposed system must be accepted by the community and fall within the laws/ethics of the community. Similarly, the system must not cause any major upheaval of the community's way of life, unless absolutely necessary and only after careful consideration of the pros and cons.

B. Sustainable: The proposed solution must be available for generations to come. All facets of the technology must be easily implemented and maintained with little to no undesirable outcomes on the social, environmental and economical aspects of its context. Furthermore, it must maintain a constant standard of optimal functionality for the foreseeable future.

C. Cost-effectiveness: The proposed solution must not be economically stressful for the financial sponsor. We must be looking to maximise any investment into the proposed system to produce the maximum amount of benefit for the minimal amount of drawbacks for the community. Simply, the community must get maximum 'bang for their buck'.

D. Accessibility: We must consider accessibility of the people to the technology and the technology to the people. The community should be allowed minimal effort in accessing the products of the proposed system and likewise, there should be minimal effort for the construction and maintenance of the technology.
E. Safety: This aspect must encompass the entire process of the proposed solution. Simply, the technology itself must not pose a hazard to the health and safety of the community throughout its entire life span (e.g. during construction, use, maintenance etc.). Also, the products of the technology (e.g. wastewater from the process etc.) must not at any stage impact the context to which it is servicing (e.g. social/people, environmental etc.) in an undesirable way.

1.2 Technical Review

1.2.1 Water usage and supply

Members of the Devikulam community procure their water primarily from boreholes situated across the area. At present, it has been identified that the community is being serviced by three bores supplying water to the three main areas of Devikulam; the village, colony and Thoppu (EWB Innovations Water Report, 2011). Of these three bores, only the one in the village is currently capable of supplying clean drinking water to the members of the community. The colony bore has been reported by residents to be saline and so is only used for purposes other than for drinking such as cleaning and washing household items. Similarly, the Thoppu bore is currently unable to supply a consistent amount of water to the nearby community due to problems with their pumping systems. As such, the pump is observed to be under repair at present time (EWB, 2011) and so the bore itself is considered to be out-of-action until further notice.

There have also been reports of the village pond having once acted as a source of clean drinking water. However, in more recent years it has been used by members for bathing, washing cattle and swimming so it is no longer possible to obtain potable water from it (GRAMAP, 2010). On the other hand, given that the main occupations in Devikulam revolve around farming and agricultural labor, the bulk majority of water usage would be concentrated in those areas.

Due to India’s monsoonal climate, with an annual rainfall average of 970 mm in the state of Tamil Nadu where Devikulam resides, seasonal flooding is prevalent (TWAD board, 2011). In this, India is subject to two different monsoon seasons known as the ‘Advancing monsoon’ and ‘Retreating monsoon’. It is during the ‘Advancing monsoon’ where India receives the majority of its rainfall per year and this occurs
over the months of June, July, August and September. Similarly, the ‘Retreating monsoon’ occurs
directly afterwards with the state of Tamil Nadu in particular receiving steady rainfall all throughout the
months of September to November. Figure 1.2, below, shows India’s average rainfall, note that Tamil
Nadu receives some of the highest rainfall in India.

![India Annual Average Rainfall Map](http://en.wikipedia.org/wiki/File:India_annual_rainfall_map_en.svg)

*Fig 1.2. Average rainfall in India. ([http://en.wikipedia.org/wiki/File:India_annual_rainfall_map_en.svg](http://en.wikipedia.org/wiki/File:India_annual_rainfall_map_en.svg))*

The monsoonal nature of Devikulum’s rainfall means that the community is relatively dry for most of the
year, followed almost immediately by huge quantities of rainfall, creating flash floods and often
disrupting the life and well being of the people of Devikulum.
As evidence suggests, the community is not known to practice any form of rainwater collection and much of the rainwater is left to drain through the earth to hopefully replenish the groundwater in the bores. Although this method of replenishing the groundwater has proven effective thus far, a major concern is that with the monsoon the floods might cause contaminated water to drain into these bores and taint them. Furthermore, the constant use of the pumps to deliver groundwater from the bores to the storage tanks is slowly introducing saltwater intrusion which will increase the level of salinity in this supply over time (USGS, 2011). Similarly, it is inconclusive as to whether they collect any surface water nor do they refer to the use of bottled water as other sources for water consumption and usage. Currently, the assumption is that these practices are relatively non-existent.

**Details of water distribution**

The water distribution in Devikulam is not as bad as initially thought. From the information gathered it seems like most people have access to taps connected to the closest storage tank (EWB, 2011). This is a great convenience for this report, as it makes it very easy to distribute the water from the tanks using the existing system.

**Problems that will be addressed:**

1. The bore that fills the colony storage tank is saline, and can therefore not be used for drinking.
2. Frequent brownouts, rendering water pumping impossible.
   a. Brownouts usually last 3-4 hours.
   b. Blackouts of several days can occur.

The goal for the distribution section of the project is to provide the community with safe drinking water from their respective tanks, which will make it accessible from taps in their houses. Due to regular blackouts and brownouts, a system that makes water accessible 24 hours a day, without electricity must be designed. Adding to that, a system that can provide Devikulam with drinking water over sustained blackouts is imperative.
1.2.2 Water quality data

The two major water quality concerns within the Devikulam community are water borne diseases and the potential build-up of salinity. Water borne diseases are defined as bacteria, viruses and other parasites that can be contracted through consumption of water that is contaminated with these pathogens. Some of the possible adverse health affects from drinking contaminated water include diarrhea and the infectious and particularly lethal condition of gastroenteritis. Water borne diseases are known to be most commonly contracted via the faecal-oral pathway (Dr. Jim Black). *Escherichia coli,* or as it is more commonly referred to, ‘E. coli’, is a bacterium that is normally found in the lower intestine of warm-blooded organisms and is generally an indicator of contact with water that has been contaminated by feces. The World Health Organisation (WHO) Guidelines for Drinking Water Quality state that E. coli is able to provide conclusive evidence of faecal pollution and should not be present in water that is meant for human consumption. Furthermore, the presence of the bacterium generally is a sign of additional bacterial activity.

Figure 1.3, below, depicts the F diagram. The F diagram is a well known rhetoric that is used to assess the effectiveness of a plan to improve health and sanitation issues within a community. The blue circles indicate the areas which our report covers, which shows that our proposal shall be very effective by cutting the majority of the branches.

*Fig 1.3, The F diagram and what we have covered.*

(http://www.newint.org/features/2008/08/01/toilets-facts/)*
The parameters for drinking water quality can be qualitatively and quantitatively assessed via two methods: chemical/physical and microbiological. Chemical/physical parameters include heavy metals, total dissolved solids (TDS), turbidity and total suspended solids (TSS). Microbiological parameters would include coliform (indicator) bacteria, E. coli, and specific pathogenic species of bacteria, viruses and parasites.

Chemical parameters tend to pose more of a chronic health risk through build up of heavy metals and the like, although some compounds such as nitrates/nitrites along with arsenic can cause more of an immediate effect to health. Microbial pathogenic parameters however, are generally of greatest concern because of their immediate health risk and it is imperative that they be removed immediately once identified.

The community has voiced concerns regarding salinity of the colony’s water supply and that this may eventually occur across the entire range of their supplies. Whilst the water supplied to the village tank is currently safe to drink, the levels of salinity are slightly above the recommended average for potable water and this could look to increase in the future. However, in the case of the colony, the water they are collecting from their central tank has been identified as saline and far from suitable for human consumption. A more detailed investigation of the water quality is provided as data and can be found in the Appendix (specify section of appendix where ‘Water quality data’ is found).

1.3 Social scenario
1.3.1 Cultural values

Given the relatively small population of Devikulam which consists of 358 members of which there are 86 families and its seemingly isolate nature, there have been very few investigations conducted into the cultural values and behaviors of the members pertaining to water resources and sanitation. Sources have indicated that the village pond itself is a revered by the people and a central highlight of the village. This is further evidenced by the meaning behind the name of the community where “Devi” refers to ‘Goddess’ and “Kulam” means ‘pond’. Hence, the name of the village roughly translates to “Goddess of the pond” and it has also been stated that the village name can also be described locally as a “village blessed by God” (GRAMAP, 2010).
Similarly, it is widely known that in many parts of India cattle are revered and worshipped as religious entities (insert appropriate reference here). As such, it is known that the cattle in the community are generally washed in the pond itself. In so doing, this may be further tribute to the fact that the community places great respect for their pond.

The current state of the Devikulam’s sanitation practices is typical to many other developing communities like that of Africa and Kenya. Water that is collected is generally stored within simple clay or ceramic pots in households or any other container that is available in the community (“insert reference here?”). Similarly, it was initially expected that users would draw water from the household storage through simple methods of direct extraction from the opening of the container (e.g. scooping with a cup, pouring straight from the vessel etc.). Whilst there has been inconclusive evidence of how prevalent this practice is in Devikulam, what has been discovered is that the colony members do practice boiling of their water before consumption. This has yet to be validated for the rest of the community as to how prevalent this practice is.

1.3.2 Current systems

At present, the community is being serviced by three bores that are connected to a thorough distribution network supplying water to the major storage tanks found in each of the three main areas of Devikulam (EWB, 2011). Of the three storage tanks, the one in the village has been confirmed to be 30,000 liters in volume and is situated 10 meters in the air via wooden scaffolding. Similarly, it is a major assumption that the other two tanks in the colony and Thoppu area possess similar dimensions also (EWB FAQ, 2011) [Insert appropriate picture of tank]. The distribution system itself consists of a large network of piping that runs across the entire community and is supported by pumps that relay the water from the source to the storage tanks. These pumps are in turn, connected to the local power grid to maintain their continual operation. However, the grid has been reported as unreliable as overloading of the grid causes brownouts, and often times there is at least one power failure per day which can last up to around 3 - 4 hours. Similarly, adverse weather conditions such as that of the monsoon can cause even longer power outages (EWB FAQ, 2011). During these periods of power loss, the community has to rely solely upon the water available in the tanks and the amount that is accessible depends on how quickly they utilise it.
On the other hand, first-hand accounts by the EWB have confirmed that current systems of water storage in the household consist of simple clay pots and aluminum tins, roughly 15-20 liters in volume (EWB FAQ, 2011). Through use of these containers, it is assumed that they are exposed to open air and the basic method of extracting water from them is via pouring from the opening or scooping with a utensil.

1.3.3 Overseas/International programs

Whilst there have been no reported accounts of international programs committing to the aid of Devikulam specifically, there are however, an amiable number of non-government organisations (NGO) situated in India striving to provide development and sustainable aid to communities like Devikulam. As water contamination and access to potable water are major concerns all around the world, it is evident that the problems that Devikulam faces as of the present are not as uncommon as one would think. A multitude of solutions and designs have been already created and implemented with the sole aim of improving water quality and access to said water. In so doing, these examples are the cornerstones to which we are drawing the bulk of our ideas for our design. In consulting with technical experts in the appropriate fields and analyzing these examples, we have sought to improve the chances of the proposed design succeeding in its implementation. Similarly, the entire design will be centered around and abide by the self-proposed design requirements we have defined (see ‘Design requirements’) and the ethics as governed by Engineers Australia. As aspiring engineers, it is our responsibility to uphold the ethics and work within set parameters as to not cause any undesirable effects on the community we are seeking to service.

By conducting investigations into the successful designs in water resources and sanitation with the specific purpose of identifying how systems projects are effective, it is hoped that we will be able to emulate such processes to produce an efficient and successful solution ourselves. Many systems have failed due to complex production methods, high maintenance, high costs, insufficient flow rate, and/or reliance on materials unavailable in remote villages (Shrestha et. al. 2004).
In this, it is said that current systems projects tend to also have too much of an individualistic focus to a particular problem area and this results in ineffective solutions that are too complex to implement, operate or maintain. As such, we have sought to integrate the concept of a Multi-Barrier Approach (MBA) into our overall design to comply with this particular issue regarding systems projects.

Conversely, an example that we have derived from real-world applications pertains specifically to the area of household water treatment and storage (HWTS). A ceramic water filter design used by the Resource Development International Cambodian (RDIC) organisation was reported have an average flow rate of roughly 1 – 3 liters per hour. Whilst this seems like a substantial amount depending on the rate of usage of water, it may or may not be able to service large households if only one is installed. However, the insufficiency was tackled in a thesis (insert specific reference here) with the aim of increasing the flow rate whilst maintaining the exceptionally high performance of the filter in removing microbes and other contaminants.

1.4 Economic scenario

Given that Devikulam is largely still the process of developing as a community, it was not expected that the local economy would be as sophisticated as its first-world counterparts. Nonetheless, as provided by the EWB, a survey of the village was conducted on the number of households, the relevant occupations of the persons surveyed, average annual income of the families and number of technological devices (e.g. televisions, radios, mobile phones etc.) available (EWB Devikulam Survey, 2011). In so doing, it was roughly estimated that the average annual income in the Devikulam was approximately 38,000 rupees. This translates to roughly 760 AUD per year which is slightly less than the average Australian weekly earnings (ABS, 2011). Although annual incomes per household in the village have been shown to vary from 10,000 - 60,000 rupees. In the colony the range varies from 15,000 - 30,000 rupees.

The largest industry in Devikulam is the agricultural sector with most residents in the village having own their piece of land for the cultivation of crops such as rice, watermelon, tapioca, sugar cane and ground nuts. However, residents in the colony generally work as agri-coolis (labourers for other farms). This could be tied in with the fact that most villagers own a plot of land roughly 2 - 5 acres.
Conversely, only three households in the colony possesses land of around ¼ acre (EWB Devikulam Industry Report, 2011). Similarly, ownership of livestock, household items (e.g. TV, mobile phones) and access to private transport varies accordingly between the village and colony communities. In most cases, the villagers are reported to possess a greater percentage of ownership in contrast to the colony.

However, given that the local economy is so small (almost to point of being considered irrelevant by contrast to first-world standards) there is very little that could disturb the economical activity of Devikulam as a whole. Although this means that the community must be solely reliant upon their own industries and commodities to generate a stable and sufficient economy. Given the majority of occupations revolve around the agricultural sector, many workers are observed to tend to farms that are owned only by a select few in the community. Similarly, the Devikulam community also receives partial revenue from the local prawn industry in the area. However, this business has been met with negative responses given the environmental impact, bulk usage of groundwater and electrical supplies and contamination of the groundwater supplies which in turn affect local agricultural plots. Although this industry does create some employment opportunities for the local populace, most of the jobs tend to go to people outside the community (EWB Industry Development Report, 2011).

Despite the intention of producing sustainable designs that are light on the hip pocket nerve, it would seem that the initial start-up costs required to implement the most part of our designs would be simply too taxing for the community to fund out of their own pockets. RDI states that “The truly poor cannot afford to pay for any technology we provide without assistance” (RDIC, 2006). Rightly so we have taken into consideration this very factor from the beginning of our work phase. For the bulk majority of the proposed design, we have assumed that the EWB and other relevant financial sponsors will be funding the implementation and if applicable, the maintenance also. However, the maintenance costs could be covered by the community itself given aspects of the design incorporate the possibility of creating new industries with the introduction of new skills, education and jobs. This is an aim of the local development aid organisation Pitchandikulam Forest whose particular focus on Devikulam is to introduce greater employment opportunities to members in the community with the expansion of new industry. With this in mind, we have sought to integrate an eco-friendly and financially viable design that has the potential for industry creation in the local area (EWB Industry Development Report, 2011).
1.5 Why intervene at all?

The notion of doing nothing was also evaluated as a pseudo control type of option. This gave the team a better contrast of how much of an improvement the proposed options could produce. It inadvertently acted as a source of motivation for the team to work harder to find a suitable solution.

No intervention in the area of water treatment is a possibility due to lack of supporting evidence to show that significant heath issues, such as diarrhea, cholera and E.coli, are rampant in Devikulam. However, given that the drinking water they are currently sourcing from the bores is slowly being contaminated (by increasing salinity and bacterial levels), there is the possibility that not intervening could cost the community dearly in the coming future.

No intervention to the water distribution network in Devikulam would mean that the people have very limited access to water, however they may have gotten used to and accustomed to this. The idea of intervention in this area would be to provide the people with constant, easy access to water.

Given that the community currently faces no critical problems with their HWTS methods and sanitation practices, this could well be a possibility to take into consideration. This is further evidenced by the fact that there have been no reported accounts of illness or misfortune stemming from the absence of proper water treatment and storage methods.

No intervention with regards to rainwater capture would eventually end with the bores in the community drying up and their people losing their main source of water. There are no two ways about it, once all of the water in the water table dries up- and it will eventually- it will takes hundreds of years to fill up again. This looks like a bleak situation, and it is, all over India the same things are happening, frankly doing nothing with regards to water harvesting is unthinkable. However, if appropriate steps are taken now, things can go smoothly for generations to come. This issue mostly concerns future generations more so then the current generation, so the people of Devikulam must have, or be taught, the foresight and presence of mind to realise that they must act now, for their children’s futures.
A. Cultural awareness/acceptance – It could be an assumption that if we did not intervene, that the community would simply not mind at all. Given that their current water systems and practices are seemingly sufficient, any further external help, whilst possibly beneficial, might only serve to be redundant. Conversely, the community has been reported to express concerns around the future of their water resources and so intervention would be just as preferential as lack thereof. So any possible solutions that, if presented persuasively to be effective and only beneficial, could serve to preserve their quality of water would be perceived as a viable solution.

B. Sustainability – If we were to not intervene, then the community could eventually lose their current water systems due to lack of maintenance or suffer a substantial drop in their quality of water in the future. However, the simple perception would be that ‘nothing gained, is nothing lost’. Simply, if no intervention was preferred, then the community would have to rely upon what systems they have at present for the foreseeable future.

C. Cost-effectiveness – In terms of the economics, it is obvious that there would be no gain or loss if no intervention is chosen as the preferred solution to this aspect of the project.

D. Accessibility – Whilst intervention would provide new means of accessibility to potable drinking water, the opposite would only serve to hinder the community’s access to clean drinking water in the future. This is given by the reports of increased contamination of the water sources and possible increase in this taint over time. Whilst the community would still be serviced by a (relatively) reliable water system, there are simply too many possible areas for failure given events such as the monsoon and potential lack of maintenance to say the very least.

E. Safety – As no technology would be implemented in this scenario, this requirement is rather moot. Although, if no intervention was chosen in preference, then the safety of the community could be compromised in terms of health due to contaminated water further impacted by unsanitary practices. Similarly, if there truly is little to no maintenance in the current water system, then possible failure in the future could pose a potential hazard to the members of the community.

Doing nothing would essentially leave the community where they are right now, with no improvement to their way of life, which is the exact opposite of our mission statement.
Design

2.0 Overview of design

The proposed design consists of an entire process that encompasses each aspect that was to be targeted. These aspects and how they were met are covered table 2, below.

Table 2: The proposed system.

<table>
<thead>
<tr>
<th>The water is contaminated.</th>
<th>An effective treatment process and facility has been investigated and made ready for use in Devikulum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The current water supply is not well enough distributed.</td>
<td>A more reliable system for filling the current water tanks has been investigated and defined.</td>
</tr>
<tr>
<td>During power outs there is no power to power the pump and hence no water for the community.</td>
<td>A battery system for the current pump so that it can operate during blackouts was investigated and devised.</td>
</tr>
<tr>
<td>Water is not stored well enough in homes.</td>
<td>New, safer, cleaner household storage methods, namely ceramic pot filters, have been detailed.</td>
</tr>
<tr>
<td>Currently, rainwater is not captured.</td>
<td>Traditional rainwater capture methods were investigated and effective methods of recharging ground water have been investigated.</td>
</tr>
</tbody>
</table>

Each of the investigated options were compared and evaluated to the design requirements in a table that is presented preceding each section’s options. These tables feature a simple 5 point score in each aspect, one star being the lowest and 5 stars the highest. This allowed for easy and effective comparison of ideas and assisted in narrowing down the choices.
2.1 Using the pond as a source of treatable water:

It is possible to utilise the existing pond as a source for water to be fed into a treatment system. The pond is a large source of easily accessible water; however it is currently being used to wash cattle and clothing. There are a few considerations that must be taken into account when devising a strategy for using the pond’s water.

Contamination is a big issue; it is much easier to treat water that isn’t as badly contaminated. If treatment of the pond commenced it is advisable to reduce the amount of people washing cows in the pond, some kind of education system may need to be put in place. It is possible that alternative places for washing can be provided, and the saline bore water may prove useful for this.

Another major hurdle will come from the quantity of water drawn from the pond. It is essential that the pond is not drained by the system. If too much water is drawn the pond could be destroyed.

2.2 Options for water treatment

Table 3 presents a simple comparison of options.

<table>
<thead>
<tr>
<th>Proposed solution for treatment</th>
<th>Cost effectiveness</th>
<th>Cultural acceptance</th>
<th>Sustainability</th>
<th>Accessibility</th>
<th>Safety</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEWATS (from pond)</td>
<td>**</td>
<td>***</td>
<td>*****</td>
<td>***</td>
<td>****</td>
<td>17</td>
</tr>
<tr>
<td>Desalination (heat exchanger)</td>
<td>*</td>
<td>***</td>
<td>**</td>
<td>***</td>
<td>****</td>
<td>13</td>
</tr>
<tr>
<td>Sand filter/clay pot (at home)</td>
<td>****</td>
<td>***</td>
<td>****</td>
<td>***</td>
<td>****</td>
<td>18</td>
</tr>
<tr>
<td>Water cone desalination</td>
<td>*</td>
<td>***</td>
<td>*****</td>
<td>**</td>
<td>*****</td>
<td>16</td>
</tr>
<tr>
<td>No intervention</td>
<td>*****</td>
<td>***</td>
<td>*</td>
<td>N/A</td>
<td>N/A</td>
<td>9</td>
</tr>
</tbody>
</table>
**Water treatment in Devikulam**

Treating water is a tricky process. Generally this is a highly resource intensive procedure and if it is not, it is potentially ineffective and hence dangerous. In Devikulam a sustainable, reliable supply of clean fresh water is non-existent. Bore water, the near sole source drinking water in Devikulam is not regarded as sustainable. Pumping water from a bore is an arduous task when done by hand and given the non-constant power source in the village, electric pumps are unreliable. Similarly combustion pumps are out of the question given the high maintenance and upkeep costs as well as the inaccessibility of fuel. On top of this, the bores run the risk of becoming saline.

**2.2.1: Decentralised Waste Water Treatment Systems (DEWATS)**

Decentralised Waste Water Treatment Systems work on the premise that treating industrial waste water is far more difficult than treating domestic waste water. There are several different types of DEWATS but their common denominator is in how they work: they employ passive processes that require low to no maintenance or produced energy. They are decentralised which means they are able to be implemented on a small, medium or large scale and in some cases can add to an ecosystem. The flaw of the DEWATS is that it does not reliably treat water to a drinkable standard and hence purification would be required.

The proposed DEWATS system would utilize the natural flow of the pond. The system would allow the pond to be used to wash, bathe and generally enjoy as per usual, respecting the customs of the village. The proposed DEWATS system would be cost effective. Either way water directly from the DEWATS system has the potential also to fill agricultural voids given that, 80% of India’s freshwater is use for Agricultural purposes.

**A: Cultural Acceptance/Awareness** – The proposed DEWATS system will not cause any change of customs. It is integrated as a natural system and as far as the locals will be considered it will be a small scale infrastructure change that is more likely to add to the environment rather than detract from it.
B. Sustainable – Given that DEWATS are passive and hence require no electricity or fuel sustainability is at a maximum. On top of this there are no foreseen maintenance costs and given the simplicity of the system if something did go wrong, a highly skilled technician - who are hard to come by - would not need to be called in. On top of this it is likely to add life and vibrancy to the immediate ecosystem.

C. Cost effectiveness – While there will be some upfront costs of the project, the long term price and usefulness of the system will far outweigh those upfront costs. Again the fact that there is little to no maintenance cost comes in to play here as there will be little to no ongoing cost, as opposed to most alternate methods on this scale.

D. Accessibility – As previously stated, the ability of the local people to access the system ranks quite highly. This is mainly because the technology will be implemented without causing any real change in lifestyle. As for the accessibility of the materials required to implement it, a non-permeable layer, vegetation that can be altered to fit what is locally available and a piece of tubing through which water can flow are the key components, all of which are available if not immediately locally then within a reasonable distance from the town.

E. Safety – There is no safety issue with the DEWATS system, apart from the obvious one of drowning, given that it will be an open system in to the pond. However this is not an added safety hazard as it already exists in the village given the presence of the pond. The system is also passive so there are no fast moving components that would potentially be a hazard for locals.
2.2.2 Desalination Heat Exchanger

The Desalination Heat Exchanger was a device thought of by the group. While investigating different methods of treatment the idea that saline water could flow through an array of pipes that are heated to a point that steam would be generated, the steam is then collected and condensed into pure water. Similar technologies do exist; however, it was only after giving the exchanger deeper thought we realised that it may be quite difficult to construct with local materials, the lack of special tools and requires over-reliance on maintenance. An example of a Desalination Heat Exchanged can be seen in figure 2.1 below. While the prospect of an original idea was enticing, there were a number of problems some of which are detailed below.

![Desalination Heat Exchanger Diagram](http://www.sidem-desalination.com/en/process/MSF/)


A. Cultural acceptance/awareness – There didn’t seem many huge issues when analysing the heat exchanger with respects to this criteria. It wouldn’t impose a great deal on the Devikulam way of life apart from maintenance issues, which is a different problem. The main concern in this area was, depending on specifications of the unit, it could take up quite a lot of room and by somewhat of an eyesore which would have the potential to cause aversion in the community.
B. Sustainable – While particularly sustainable in terms of non-renewable energy use, there were a number of factors that contribute to the exchanger having a net unsustainable rating. The fact that it would be most likely made of a material that would not be available in the immediate area, coupled with the fact that it would likely need cleaning/replacement of parts due to excessive build up of salt/rust on a semi regular basis unfortunately made the heat exchanger unsustainable. This cleaning/replacement would need to be done by someone in the know and this would either require training a local or hiring a technician again making detracting from the products longevity.

C. Cost effectiveness – The cost effectiveness of the product would be difficult to calculate. From all research undertaken it seems to be quite an effective method of removing salt from water minus the cleaning. However the scale and hence cost of it was not thoroughly looked in to given that it was realised the product was not viable. It is likely that the product would be relatively cost effective as it would be made from black poly pipe however the ongoing upkeep costs obviously take away from the overall cost effectiveness somewhat.

D. Accessibility – The ability of locals to understand and use the product would be relatively high given that they would generally have no direct exposure to the technical aspects. The water would be pushed through the pump and stored as fresh water in a tank where they can turn on a tap to access it. There would be no real changes in lifestyle. The only problem is with maintenance issues and if it did break down it would be quite inaccessible to fix unless someone in the village was trained and even then there would be no guarantee. The components of the product, while not locally available are not difficult to find and so accessibility is reasonable in this sense, again the issue is with maintenance.

E. Safety – safety concerns are minimal at most with the desalination heat exchanger. The main threat is from the heat that it would be outputting which in itself would not be incredibly high. The other safety concern is to do with children. Potentially, it could look like a play area for children in the community so it must be contained in a way that will make this a non-issue.
2.2.3 Clay Pot Filter

The Clay Pot Filter is a product that employs passive flow with the help of gravity. It has been an effective method of water purification for decades. The clay pot water filter has been employed as not only water purification device but also a local market stimulus in Cambodia and it is on this premise that makes this filter a particularly attractive option. At its core the clay pot filter is essentially what it sounds like. A clay pot through which water flows and is cleaned in the process.

There are several different ways in which this technology could be used. Firstly it could be used in individual homes. This would require implementing a business that builds and repairs the filters and require houses purchasing them - a notably difficult process. The other option, which depends upon how the DEWATS is implemented is for the water from the DEWATS to be filtered through a large scale sand filter and then in to tanks. (If you recall this was on option for the DEWATS, the other was for the water to be diluted to a drinkable standard in which case no large scale clay pot filter would be necessary). Both of these options clearly have their pros and cons and if tangible, both methods could be implemented. For the following criteria, the in-house option will not be considered given that it has been explored further on in this report under section 2.3.2.

A. Cultural Acceptance/Awareness – This filter would essentially become part of the DEWATS system; wile still being a separate component. In this sense the cultural acceptance is similar to the DEWATS. It is highly unlikely that a filter such as this will cause cultural unrest. Essentially it would look like a tank and given that tanks are implemented throughout Devikulam it is expected to be a non-issue.
B. Sustainability – As far as energy consumption goes, this type of filter is highly sustainable. It is passive and hence requires little to no energy source. Maintenance would be required on a scheduled basis. After the sand and rocks in the filter have been exhausted they will eventually need replacing. This is where implementing both options would be highly beneficial as, having someone within the community who has the know how to tend to the filter as required is a far more sustainable option than employing a technician to do the work. The materials that the filter is made out of are long lasting and readily available, so no there is no issue of sustainability there.

C. Cost Effectiveness – Not unlike most treatment methods investigated, the clay pot/sand filter would have initial upfront costs but upkeep costs would be minimal. As far as value for money goes, the pot ranks quite highly. Given it essentially operates itself and can filter as much or as little water as necessary, the effectiveness or ‘bang for buck’ of this technology is quite high.

D. Accessibility – Accessibility of this technology is adequate. In one sense, the people of Devikulam will have no problems accessing it given they will have no significant interaction with it but on the other hand the semi regular upkeep will be necessary which is where an industry based approach would work particularly well.

E. Safety – There are no foreseen safety concerns with the product.

2.2.4 Watercone

The Watercone consists of two parts: a base on which an upside down cone sits. Around the perimeter of the cone is a rim that bends around, back towards the interior roof of the cone itself. At the tip of the cone there is a hole covered by a lid. The idea is that saline water is poured in to the base and the cone placed over the top. The Watercone is then left in the sun whereby the water eventually evaporates (leaving the salt behind), lifting off the base before it condensates over the cone. The condensation then runs down the walls of the cone in to a rim. The cone can then be picked up from the base, the lid removed and turned upside down with clean water coming out of it. If it were to be employed it would be done on an individual level where a household would use it as required.
A. Cultural Acceptance/Awareness – the Watercone, while a brilliant idea, would require some decent behavioral changes. Residents would have to get used to filling it up with saline water and emptying it into storage at the end of each day. Unlike simply turning on a tap, this process of acquiring clean water is much more difficult to achieve.

As far as going against any traditional customs, the Watercone should be fine but behavioral change is a flaw of the Watercone in this sense.

B. Sustainability – The product is sustainable. While made out of plastic it is proven to last for a long time. The problem is that if residents become dependent on the Watercone, (which is unlikely – see below) a high amount of plastic will be needed which is unsustainable as opposed to an organic, locally available material.

C. Cost Effectiveness – The Watercone is reasonably inexpensive in a western sense at $60-$100 depending on size. It must be recognised, however that Devikulam is an incredibly low socioeconomic area. If you were a family who relies so much on the little money you earn you’d want to see some serious results when spending $60-$100 on a water filter. Unfortunately the Watercone would not provide these serious results as it only has the capacity to collect 1.7L of water per unit per day. Overall cost effectiveness then is a major Achilles heal.

D. Accessibility – As far as the local people’s ability to use the water cone, accessibility is reasonably high. It is not highly technical and it is doubted any training would be required. But getting the product to the people is where it falls down. The product is only available online and needs to be shipped. The cost of this shipping would then be handed on to consumers in Devikulam and prices would be increased again. While there would be scope to set up an industry designing these products, there would no doubt be legal issues that would need to be overcome, not to mention that fact that designing and building a Watercone would be far more difficult than say, a clay pot filter.

E. Safety – Safety of the filter is first rate, there are no safety risks that plague the filter.
2.3 Options for distribution

Table 4 provides a quick comparison of the options.

<table>
<thead>
<tr>
<th>Proposed solution for distribution of clean water</th>
<th>Cost effectiveness</th>
<th>Cultural acceptance</th>
<th>Sustainability</th>
<th>Accessibility of the technology</th>
<th>Safety of technology</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use village supply as a central reservoir</td>
<td>***</td>
<td>****</td>
<td>***</td>
<td>****</td>
<td>****</td>
<td>18</td>
</tr>
<tr>
<td>Hydraulic ram pump</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
<td>****</td>
<td>15</td>
</tr>
<tr>
<td>Solar/battery operated pump</td>
<td>*</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>****</td>
<td>14</td>
</tr>
<tr>
<td>Windmill pump</td>
<td>*</td>
<td>**</td>
<td>***</td>
<td>**</td>
<td>***</td>
<td>11</td>
</tr>
<tr>
<td>No intervention</td>
<td>*****</td>
<td>**</td>
<td>*</td>
<td>N/A</td>
<td>N/A</td>
<td>8</td>
</tr>
</tbody>
</table>

Assumptions about infrastructure

As it was quite difficult to get detailed information about how the distribution network is set up, some assumptions have been made. Jennifer Turner on the EWB FAQ said “... water is piped from the village water tank to the colony area”, from this the assumption that there is a pipe that goes from the village tank to the colony, however it is not connected to the colony tank. On the same FAQ as mentioned, Jennifer Turner replied to one of our questions about the pump: “Unfortunately there is no extra information on the pump available. It does not require much maintenance”. Because of this we have made assumptions about all the details of the pump.
It is assumed to pump water from the village bore to the village over-head tank. From each of the tanks, Village and Colony, there is assumed to be a network that connects the tanks to the houses nearby, making the water in the tanks available in the houses. The Village over-head tank and the Colony tank are both assumed to be capable of storing 30 000L of water.

2.3.1 A central distribution hub in the Village

This project takes aim in creating a reliable water supply in Devikulam. This system will use different sources of water, and will have to distribute this to different parts of Devikulam. Because the water sources are going to be placed relatively close together in the Village, it is the most natural place to set up a hub. The requirements for the hub are that it has to be able to use several sources of water, pump the water to two different tanks and be able to function while there is not electricity in the grid.

A. Cultural acceptance/awareness - There should not be any difficulty installing such a system in Devikulam as it is mostly based on infrastructure that is already there. Therefore there should not be any problem for the community to accept this kind of system.

B. Sustainable - This system is fairly sustainable, by using infrastructure that is already in place, and durable pipes that will last a long time and require little maintenance will keep cost down. It will however use quite a bit of energy as the water will be pumped around 500m into the Colony tank. A 'green' energy source could be used, but it will have to be reliable enough to keep supplying the people of Devikulam all year around. Finally the source of the drinking water will have to be analyzed to see if it will run out of water by supplying both the Colony and the Village over a long period of time. It would not be acceptable if the bore that is currently used runs out of water and some other source of water will have to be created.

C. Cost-effectiveness - This part mainly depends on which method is used to pump the water from one place to another. What can be determined at this stage is that the pipes will not be expensive as it is very accessible and simple materials used in many sorts of pipe.

D. Accessibility - As mentioned before, pipes are very accessible.
2.3.2 Methods of pumping water from the village to the colony tank

2.3.2.1 Gravity

Using gravity is probably the most elegant way to do such a task. It uses no electricity, no moving parts. However this will probably not be possible because the distance from the Village to the Colony is about 500m and the height difference is just a couple of meters, making it a very small decline. The low flow rate is a problem, as it will possibly limit supply.

A. Cultural awareness/acceptance - There are already water pipes between the village and colony, so there should be no problems installing a pipe as described above.

B. Sustainability - Uses no source of energy to pump the water from tank to tank as it exploits the effects of gravity and pressure. To make the pipe less vulnerable, it should be dug into the ground so that people won’t accidentally drive or walk into it.

C. Cost-effectiveness - This is the cheapest way of doing such a system as it requires nothing but a pipe. Considering the effectiveness, it is not certain if this will be able to actually produce enough pressure to pump water 500 m. If it can, the pressure will not be great.

D. Accessibility - Pipes of different sorts are easily accessible in Devikulam.

E. Safety - The only thing we have to make sure is that the pipe does not start to leak or absorb bacteria from the ground. This could spread a disease through the entire community as most people will be drinking water from the tanks.


2.3.2.2 Hydraulic ram pump

A hydraulic ram pump uses valves and the kinetic energy of water 'falling' into the system to create a pressure surge. This effect is called a "Water Hammer", and is caused when a fluid in motion is forced to stop or change direction. A pressure surge is then created which makes it possible to pump water to a higher energy level. A hydraulic ram pump is, according to Lifewater (2011), "inexpensive, simple to build and operate and requires a minimum amount of maintenance". It keeps going as long as water is 'falling' into the pump, so it can pump water 24 hours a day without a drop of petrol, diesel or electricity.

Depending on the height the water 'falls' the pump can pump 1-20 % of the water that flows in to a height ten times greater than the intake. This means that most of the water that goes in, actually comes back out into the initial source. This makes it ideal when the water is sourced from a continuous stream of water, eg. raised springs, streams and waterfalls. In Devikulam however, the source of water is mainly bores, making this system inappropriate because of its ineffectiveness.

A. Cultural awareness/acceptance - The hydraulic ram pump is like a normal pump, the people in Devikulam will most likely be fine with this type of technology.

B. Sustainability - The hydraulic ram pump has some valves and is undergoing pressure changes as long as it is in operation. It is thought that it can break down because of wear on the valves, but as it is a simple design it will be possible to teach locals to build and repair these pumps.

C. Cost-effectiveness - Except for the initial price tag, and eventually the maintenance, there are no other expenses. However, as mentioned above, only 1-20 % of the water that enters the pump gets pumped to a higher level. That means 80-99 % of the water is wasted. Devikulam's water source is mainly a bore, so the water that is pumped up should not be wasted in any way. Seeing as the plan is to fill a 30,000 liter tank with water, the hydraulic ram pump will waste around three times that amount, which is unacceptable.
D. **Accessibility** - The materials are believed to be relatively easily accessible in Devikulam. Everything is fairly inexpensive and can be bought from one of many ram pump suppliers. Rife (2011) lists their hydraulic ram pumps in a range from $545 to $12,650 with many models to chose from.

**E. Safety** - Unless someone are planning on sticking their eyes into the end of the pipe where the water surge is going through, there are no safety issues.

### 2.3.2.3 Battery + Solar Energy

This system involves using a battery that is charged by the electrical grid when it is working. When the power goes out the battery will automatically power the pumps when necessary. To decide when it is necessary to pump water some level sensors will have to be installed. The reason for this is that the system needs to know if the tanks are full or not so it does not pump water and tries the fill a full tank. This wastes energy and puts unnecessary strain on the pumps. The battery is connected to a pump that is close to the source, and can switch between two pipes (one to each of the village and colony tanks) using a valve. If possible, using the pump that is already in place will keep cost down. By trying to keep the tanks as full as possible while the electricity is on, the water supply can last for a very long time without electricity, and even longer as the battery will allow the pump to pump more water when the grid is not working. Assuming that both tanks are 30 000L, we can store 60 000L of clean drinking water, and be able to refill some of it using the battery. Assuming that Devikulam uses 1000 liters of water, it will last 60 days before it is empty. The electrical grid is often overloaded, which causes brownouts of about 3-4 hours daily, or even longer during the monsoon. Therefore a system where the water pumping does not add to that load during peak hours will have to be created.

To support this system, solar panels can be installed to generate power which can be stored in the battery. This will allow the battery to be recharged during peak hours, and during brownouts. The energy used from this will be ‘greener’, and might save the community money over time as the power used to pump water will be locally generated. Initially the price of solar panels are huge, making this system less feasible, however there are government programs that supports the use of renewable energy in rural areas. A program like this, one of which was offered in India in 2010, covered 50-90 % of the costs of the solar panels (Indian Government, 2010).
The focus of this method is to provide as much clean water as possible, for as long as possible, to ensure that the people in Devikulam has constant access to clean drinking water. Currently there are pumps that pump water into the houses, making water available from the tap. This is not considered important, so the battery will only be used to pump water to the tanks. So the supply into their houses will be shut down when the electricity is out. Using the height of the tanks, water can be gravity fed to a shared access point in each of the Village and Colony from their respective tank.

**A. Cultural awareness/acceptance** - The people in Devikulam are not unfamiliar with the use of pumps and tanks, so the concept is not an issue. Depending on how used they are to having water in their houses, the fact that water will not be pumped into the taps in their home as long as the electricity is out will be the only possible problem. However, at the moment, when the electricity is out there are no pumps that are working, so they should be used to this from before.

**B. Sustainability** - The system does not have a lot of parts to it, but it requires some maintenance, most of which can be done by locals. Solar panels are the biggest maintenance task, as it will require regular cleaning to keep it as effective as possible. The pump and battery are quite long lasting and are expected to need a check up every two years or so.

**C. Cost-effectiveness** - The biggest expense in this system is the solar panel, which can range from $10,000 - $30,000 USD (http://www.trustyguides.com/solar-panels2.html) depending on how much energy the pump uses (Waiting for reply from EWB). The system does not require solar panels, it is a supporting feature to the system. So the solar panels are not necessary and can be taken away form the design to cut down the cost.

**D. Accessibility** - Solar panels, batteries and pumps are commonly used in India, and it is assumed to be easily accessible for Devikulam.

**E. Safety** - No safety concerns
2.3.2.4 Play Pump

A Play Pump is a merry-go-round type of device that uses the energy created by kids playing on it to power a pump that pumps water from a bore into an overhead tank (Water For People, 2011). Water For People indicates that the overhead tank is seven meters above ground, while not explained explicitly, the water is then gravity fed to the tap.

A. Cultural awareness/acceptance - As much as this seems like a really good idea, it is not known if this is going to be accepted by the people in Devikulam. We do not know how they are going to react to have kids working to supply them with water. However, the thought is that they will not mind as it is a toy for the kids.

B. Sustainability - Play Pump is according to STEP(2011) a sustainable option for a developing community. It uses the energy from kids, and provides a fun activity for the kids at the same time. Maintenance on the Play Pump is done by Roundabout Outdoor, who states in its FAQ that spare parts are free and readily available. Advertising is used to pay for the maintenance of the system.

C. Cost-effectiveness - The Play Pump costs $14,000 USD (Roundabout Water Solutions, 2011) making it very expensive. For that price it is capable of producing up to 1,400 liters of water per hour at 16 rounds per minute from 100m (Water For People, 2011). Roundabout Outdoor aims to hang billboards on the tanks, where two are for commercial advertising, the other two for health and educational messages. This pays for the maintenance of the system (Water For People, 2011).

D. Accessibility - STEP (2011) outlines that the materials used are easily accessible in rural areas, and only basic equipment is used to set it up.

E. Safety - The only safety concerns are overflowing the tank and contaminates in the water. Roundabout Outdoor (FAQ, 2011) explains that the system is closed to the outside, and the water in the borehole is analyzed to make sure it is fit for human consumption. The excess water produced will be pumped back down into the bore so that it is not wasted (Roundabout Outdoor, "How it works", 2011).
2.4 Options for water Storage

Table 5 provides a quick overview and assessment of the viability of the options.

<table>
<thead>
<tr>
<th>Proposed solution for storage of clean water</th>
<th>Cost</th>
<th>Cultural acceptance</th>
<th>Sustainability</th>
<th>Accessibility</th>
<th>Safety</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond (village)</td>
<td>*****</td>
<td>*</td>
<td>****</td>
<td>*****</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Current tanks</td>
<td>*****</td>
<td>*****</td>
<td>****</td>
<td>*****</td>
<td>****</td>
<td>23</td>
</tr>
<tr>
<td>New tanks</td>
<td>**</td>
<td>***</td>
<td>*</td>
<td>**</td>
<td>***</td>
<td>11</td>
</tr>
<tr>
<td>Household storage methods (include treatment)</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>20</td>
</tr>
<tr>
<td>No intervention</td>
<td>*****</td>
<td>***</td>
<td>*</td>
<td>N/A</td>
<td>N/A</td>
<td>9</td>
</tr>
</tbody>
</table>

“Access to safe water is a fundamental human need and, therefore, a basic human right (Kofi Annan, United Nations Secretary General)”. With approximately 97% of water on Earth consisting of saltwater, only the remaining 3% is fresh water. Of that 3%, two-thirds is locked away in glaciers and relatively inaccessible to us. Hence, less than 1% of water (or about 0.007% of all water on Earth) is readily accessible for human use. For humans, the access to clean water is crucial for life itself. Therefore, the need to not only derive greater amounts of water, but sustain what is currently available is paramount.

Often times, water that is stored in the home can become subject to recontamination, regardless of whether it was initially collected from a clean or non-clean source. This is generally attributed to the result of unsafe sanitary practices pertaining to household water treatment and storage (HWTS) methods. Simple containers used to store water in the homes of developing communities are often subject to relatively unhygienic conditions and are exposed to the open air, providing a range of contaminants access to the water within.
As such, this is generally the contributing factor as to the higher percentage of water-borne diseases prevalent in developing communities around the world. In this, Devikulam, despite there having been no reported accounts of illness related to water-borne diseases as of yet, is still of no exception.

The following options are those that we have considered for this particular aspect of the design solution, and whilst they might not have been chosen in the end, they were nonetheless subject to careful assessment and evaluation by the entire group.

### 2.4.1 Storage in pre-existing or new infrastructure

Given the context of the problem Devikulam faces with its water resources (and sanitation); there are a few possible solutions that could be implemented which would utilize the current infrastructure present in Devikulam. In this, all of the currently suggested options include use of the current or new tanks as an intermediate body for the storage of treated water after it has been subject to the treatment method as explained in more detail by Section 2.5.1. As such, this particular option of storing in existing infrastructure would tie in closely with the area of water treatment and to a further extent, distribution methods. This would involve treating the contaminated water in the pond through an appropriate technology (as proposed by the area of water treatment in Section 2.5.1) and storing the now potable water in a temporary storage vessel, before distributing this newly treated water across the community via a preferred method as proposed by the area of distribution in Section 2.5.2.

Similarly, it has been suggested that wastewater stemming from the industrial treatment process could be redirected into the pond, hence creating a cycle of ‘sustainable’ wastewater treatment and storage. In this, one question that would need to be clarified is whether it is truly possible to create an efficient, seemingly never-ending cycle of effective water treatment. Would the wastewater injected into the pond cause even greater contamination to the pond and reduce the efficiency of treatment over time? Also, the community does not seem to produce copious amounts of wastewater through their daily lives, so would it be feasible to introduce waste as a by-product of the treatment system? These aspects were thoroughly explored during evaluation and it was agreed that such a suggestion was impractical and unfeasible given that Devikulam would not be able to support it given the current systems they have in place.
The tanks are assumed to be in relatively good condition as the community has not raised any concerns of over the state of the tanks presently or for the future. As of recent discussions, it has been proposed that the central tanks in the village and colony could be used for a variety of purposes. Some of the suggestions have been to use them as a source for storing any treated water or rainwater given that it could be collected in some way. Similarly, it has been proposed also that we could install new tanks or storage vessels given the need of our finalized solution for any new systems to be implemented. As per the requirements of the EWB and the methodology to which we derived as a group to quantitatively assess each of our options, they are as follows:

A. Cultural awareness/acceptance - There seems to be little that could be attributed to the effects of altering the current tanks or introducing new ones in terms of cultural awareness or acceptance. In this, the community would surely not mind the use of the current infrastructure simply to store potable water. If it were the case where it was needed to construct and install new tanks, there might be some reluctance by the community depending on how they were to be implemented. Nevertheless, the community has voiced their opinion on accepting any form of aid by external organisations such as the EWB so long as it is obvious that the benefits are worth it. However, it might be wise at this point to reiterate an important consideration when it comes to the introduction of any form of technology into any society. That is, the overall physical form of the technology itself must not be overly grotesque nor cumbersome as this can severely impact upon the society’s, or in this case, the community’s will to accept such a solution.

B. Sustainability – Since the proposal of using the current tanks seems to touch upon the concept of sustainability only lightly, the key focus would mainly be on the ongoing maintenance of the tanks to ensure its continual life span. Any potential degradation of the current tanks could possibly cause contamination of the water within over time. However, in the case of installing new tanks, they will have to utilize minimal resources during construction and maintenance whilst maintaining minimal undesired effects on the environmental, social and economical aspect of things. Similarly, a strong maintenance program would have to be implemented alongside to ensure long-term growth and benefit of this technological solution to current and future generations to come.
C. Cost-effectiveness – Whilst the utilization of the current tanks would pose little to no cost at all and seemingly only benefit to the community, the opposite could be said if we had to construct and install new ones. If this is the case, then the implementation of the new tanks would serve for the assumed reasons of providing greater access to multiple storages for clean drinking water, reducing the effect of overall contamination if one storage is affected and increasing availability of water for times where this liquid of life is scarce. Similarly, the costs associated with acquiring materials, construction and maintenance of the new tanks would be relatively high. Though, the community could partake in the construction of the new tanks, hence equipping them with the necessary ability to maintain the technology. This would recognize the need for new jobs to be made available in the community and provide them with applicable skills after proper education of how to implement the technology. Whilst it is a possible consideration given that the EWB and other financial sponsors would be supporting the proposal, it was agreed that the use of the current tanks would be more preferred under this evaluation of cost-effectiveness.

D. Accessibility – An important factor to consider when implementing a potential large-scale solution such as that of a storage tank. Given if we were to use the current tanks for the storage of clean drinking water, then the accessibility would not even be a factor given that it is already accessible. However, the opposite would have to be said if the introduction of new tanks was required in preference. There would have to be considerations on how to ensure that the community can access and utilize this technological solution, as well as the practicality of acquiring all the necessary materials and labour required to bring this design to life.

E. Safety – As with any implementation of large-scale products, safety is a major factor in play. Measures will have to be derived during the potential exploration of this particular solution to ensure that the introduction of any tanks or the alterations of the current ones will pose no threat to the health and safety of the people of Devikulam. However, if the current tanks were utilized then there should be little to no threat to safety of the community members given they are considered to be safe at present time. This is of the opposite case if new tanks were to be installed. As such, proper guidelines would have to be followed to ensure safe design, installation and operation of the new tanks.
2.4.2 Introducing a household water treatment and storage program

Studies have been conducted by the World Health Organisation (WHO) on the implications of unsafe storage methods in the household. The study correlates the incidence of water contamination stored in the home with the practice of unsafe methods of storage which can be rectified through the introduction of proper health education or household water treatment and storage intervention program (insert appropriate reference here). Whilst there have been no accounts of waterborne diseases stemming from the community as of recent, there is a concern that with the slowly increasing levels of bacterial contamination at the source, this might become otherwise. Hence, the emphasis on safe HWTS practices is paramount. In this, two particular options were considered in the application of a HWTS program: the bio-sand filter and the cloth filtration method.

2.4.2.1 The bio-sand filter

The bio-sand filter works akin to that of the traditional sand filter, where contaminated water is treated to several layers of filter media (e.g. sand and gravel, diffusion plate and biological layer) before collecting at the bottom of the storage vessel where it is ready for consumption. However, the bio-sand filter is not a replica of the sand filter but rather a technological adaptation where substantial improvements have been made in contrast to its predecessor. In this, the bio-sand filter boasts greater flow rates to deliver larger quantities of potable water over a designed period of time in conjunction with a higher percentage of contaminant removal (especially with pathogenic microbes).

Generally, these filters are constructed using either concrete or plastic with sand and gravel layered inside the filter alongside a biological layer (known as ‘schmutzdecke’) and diffusion plate [Insert picture here]. Specifically, the schmutzdecke acts as the primary filter medium that removes the large majority of microbial contaminants and is itself composed of an array of biological organisms that are effective at this removal. The diffusion plate acts to even the flow of water that is poured onto the initial layers of the filter (schmutzdecke and sand) so that it does not harm the efficiency of the filtering process. As such, the sand and gravel layers act as the secondary media to which purify the water that is processed from the schmutzdecke even further. At the end of the filter, a PVC pipe is connected to the bottom and provides the extraction of the potable water when available.
Common models of the filter have been reported to produce up to 20 – 60 liters per hour of potable water, however fast flow rates do not necessarily contribute to the best quality of water obtained. Sometimes slower flow rates can allow greater filtration of the contaminated water and hence produce relatively cleaner water at the cost of quantity and time.

Overall, this design costs approximately $15 - $ 75 AUD without inclusion of start-up and upkeep costs and so is considered to be a relatively economically viable option. This is especially the case if it can be funded through a humanitarian grant or government subsidy. However, seeing as the aim is to service the entire, if not majority of households with the HWTS program, it might not be so feasible given the large maintenance requirement. In so doing, it may prove even more difficult to persuade the community to adopt this technological solution given the changes that they would have to adopt to operate and maintain it. Nonetheless, this solution was assessed in greater detail as per the design requirements and there are as given below:

**A. Cultural awareness/acceptance** – Given that the bio-sand filter has already been implemented in several other developing communities across the world, it seems that it has been met with generally positive views. As such, there is a chance that the community would likely see this proposal through to implementation if effective persuasion is made regarding this technology. However, there are always exceptions to the case. In this, we would have to take into consideration the fact that the HWTS program is not solely about the technological side of the solution (in this case, the bio-sand filter), but also of the educational process that comes along with it (health safety and sanitation practices). Effective measures will have to be undertaken to ensure that the people will understand the underlying facts about what the technology is and how it will benefit them with little to no misinterpretation.

The community will have to introduce a relatively new routine of HWTS might have a considerable effect on how effectively this solution would be implemented. Continual maintenance of the filter media involves cleaning and replacement as soon as it becomes contaminated. Similarly, the filter cannot be used immediately after it has been constructed or replaced given it requires roughly 1 – 2 weeks for the schmutzdecke to develop and grow. As such, they might be reluctant to change a way in life that is already considered effective and efficient given no problems currently stem from it. However, given information from the EWB on the community’s willingness to accept aid in many different forms, it seems likely that they could accept the proposition of a HWTS program.
**B. Cost-effectiveness** – Relative costs of constructing the filter range from $15 - $75 AUD and this would not include any initial or maintenance costs. This approximately translates to a range of 735 – 3,675 rupees. At a glance, it might not seem very much but seeing as the overall aim is to integrate this technology into the vast majority of households, the total costs would be rather substantial. This does not take into account any initial costs for the manufacturing and materials acquisition and does not include also the maintenance and operation costs. However, given that there is a need for new industries and jobs to be made available in Devikulam (as per the mission statement of the local development aid organisation, *Pitchandikulam Forest*) this filter could provide the necessary means to jump start the process. Similarly, the filter can be mainly constructed from local resources (e.g. sand, gravel, concrete, plastic) and labour.

Whilst highly effective in its job at removing contaminants from unclean water, the simple fact remains that the heavy maintenance of the filter could provide quite troublesome and conflict with the potential for this technology to operate at its optimal capacity. Seeing as the filter was initially designed for the primary purpose of servicing rural communities where naturally safe or treated water sources are not available, its purpose in Devikulam may hence be rather redundant. This is because Devikulam already has relatively good access to clean water through a somewhat reliable treatment and distribution system. As such, the need for an overly complicated HWTS program like this is unnecessary at best. Hence, any investment put forth into this solution would be questionable and filled with doubt, and we were not willing to commit to a solution that we were confident could not approach the community’s problems in the most effective manner possible.

**C. Safety** – As the filter is proposed to act on a small or individual-scale, the overall safety measures attributed to the technological side is relatively none. However, there is a drastic concern if the filter continues to operate beyond its regular use-by date. As the filter requires continual maintenance the moment signs of effective flow rate and quality of water decrease, there is an inherent threat to safety if users do not carefully handle the cleaning and replacing of individual parts of the filter. Aside from the obvious danger of unsafe physical handling of the filter components, the schmutzdecke poses a potential health risk to individuals given it is composed entirely of biological matter.
As the schmutzdecke ages, it could become host to a range of larger aquatic organisms such as snails, harmful microbes and annelid worms. This could pose a severe health risk to the individual maintaining the filter if they are not well practiced in safe sanitary practices.

Similarly, an evaluation of the application of this technology in Kenya has reported that many users tend to clean the filter out of desire and not because of a reduced flow rate or decreased quality of water. Also, in some projects it was observed that a majority of households will forget or ignore cleaning advice (Biosandfilter.org). This serves to disturb the biological layer even further and increases the potential for harmful microbes to house themselves in this layer or contaminate the water.

D. **Sustainability** – Despite that the technology would act on the small-scale, the filter would only last for so long as the community has access to the required materials and are willing to constantly apply proper maintenance to the system. Similarly, it has been stated that the filter is capable of operating for a life span of 8 years at optimal conditions (Samaritan’s Purse-Canada). However, this will heavily depend on the amount of maintenance administered by the user over a regular period of time. As briefly explained in the above aspect on safety, application projects of this filter have confirmed that many households will tend to forget or outright ignore proper maintenance procedures. In so doing, the ability for this technology to sustain itself into the long-term is relatively inconclusive. However, the filter was designed with the intention for emergency use in communities where no safe sources or water are present. It is not a 100% failsafe method of household water treatment despite its potential, but acts more effectively as a ‘better-than-nothing’ choice if the situation is dire.

E. **Accessibility** – As explained earlier, this design could be feasible given there was a humanitarian grant, government subsidy or other external financial sponsor willing to fund the implementation. The components of the filter mostly require materials and construction that could be achieved through local resources and labour. Conversely, the filter is designed to service at the individual-scale and so is relatively accessible to the user given appropriate education of use and sanitary practices beforehand.
2.4.2.2 The cloth filtration method

Given that reports have determined that Devikulam utilizes simple ceramic pots and aluminium tins for their household storage methods, the cloth filtration method proves to be an extremely cost-effective solution to the issue of unsafe HWTS. The design is very simple as it only consists of a clean cloth draped and tied over the top of the desired container to act as a physical filter against large contaminants and the majority of parasitic worms such as that of the guinea worm. As such, the cloth itself must be kept extremely clean and not be a source of other microbial contamination. As the design is horribly simple, there was little evaluation that could be made concerning the system. However, this suggestion was nonetheless considered as the group decided that there should be an equal focus on not only the high-tech solutions, but also that of the low-tech. It was agreed that this method would be more effective if integrated alongside another HWTS solution as a secondary measure.

A. Cultural awareness/acceptance: The consensus was that the cloth filtration method would be the most easily accepted option of all that we’ve considered so far for the area of water storage and household treatment. It seems quite unlikely that the community would reject this particular solution given that it requires no upheaval of their current way of life and routine pertaining to HWTS.

B. Cost-effectiveness: Given that filtration method requires only the use of a clean cloth, the costs are not adamant. However, it was estimated that costs could range from $0.10 - $1.00 AUD for the acquisition of the cloth from a local supplier for instance. Otherwise the community can easily make use of any cloth within the household or community so long as it is clean and remains to be for so long it is put into use.

C. Safety: There are no safety issues worth mentioning for the handling of the filter, or cloth in this case. However, to expand upon the point of safety, it is imperative that the cloth itself be kept pristine and extremely clean if it is to be used as a filter for processing contaminated water. In this, there is the fear that this solution could emulate what has happened with the bio-sand filter in terms of its maintenance procedures as governed by first-hand reports. Specifically, the community could easily forget or ignore that the cleaning or replacing of the cloth is critical for the design to work at all. Given that all the system consists of is the cloth itself, there are no failsafe alternatives or redundancies if the filter fails during the course of its action.
D. Sustainability: For so long as the filter is kept clean and maintained in good condition as to prevent tears or degradation of the material, the system should last for the foreseeable future.

E. Accessibility: The filter is relatively accessible given that locals could create their own or supply them from a local business that sells cloth of the desired type. Whilst it is extremely effective at removing drastically contaminated water (containing large, visible particles or contaminants larger than the pores in the seam of the cloth) to a certain extent, it does not address the problem of other forms of contaminants. As such, this design would only be most effective if combined with another HWTS system which would act as the primary treatment and storage method.

2.4.2.3 The Ceramic Pot Filter

As members only possess a basic health and sanitation education, it can be evidenced in their daily practice of HWTS that is far from effective in contrast to the first-world standards. Almost every person obtains household stored water from simply pouring out of containers that are also exposed to the open air. Similarly, only a small proportion of the community is known to practice boiling of their water before consumption (EWB FAQ, 2011). As it stands, there is very little protection of household water supplies from recontamination. To address this problem in detail, the ceramic pot filter was considered in earnest due to the high promise it presented in past studies and reports of the design. Having already been implemented in many other rural and developing communities across the world, the filter has been met with much appraise and success from reviewers of the technology. Given the components of the design are relatively simple to manufacture, operate and maintain, it seemed like the ideal option due to its long-term sustainability, affordability and simplicity.

A more detailed assessment of the design can be seen in Section 2.6.3. Below is a standard assessment and evaluation of this solution as per the design requirements:
A. Cultural awareness/acceptance: Given its application in other developing communities has been relatively successful, it is assumed that it will most likely be the case for Devikulam as well. This is further evidenced by the fact that the community has voiced their openness to the prospect of a health education program aligned with the implementation of a new household water treatment and storage method. As the filter can make use of pre-existing materials and items (receptacle container and lid/covering) in the household, it is smooth transition for the technology to be integrated into the home. Its simplicity, easy-to-use and ready-to-use nature may be further incentive for them to consider introducing the filter into their homes, and consequently, their daily routine.

B. Cost-effectiveness: The filter is relatively affordable and no doubt cost-effective, given that the pricing for ready-to-use filter units, including the pre-made receptacle tank, is usually $15-$25 AUD though it is largely governed by local production costs and other similar considerations that would need to be taken into account. Replacement filters can be supplied for roughly $4-$6 AUD and is quite affordable to the members of the community. Given that the filters can be procured from a local filter producer or manufacturing group in one of the nearby towns, the need for a local production facility in Devikulam should only be considered if the community has adapted well to the implementation initially. If a new industry can be developed, then the appropriate funding and capital will need to be generated.

The predicted cost-effectiveness of implementing a new filter production industry in Devikulam would be costly to start-up without external aid from beneficiaries, but very effective once it has been integrated into the community lifestyle. The introduction of new jobs, on-site production and maintenance will overall decrease the costs of implementing the filter by a significant amount in the long-term. For instance if local production is extremely successful its product output, then expansion could be made in the industry to begin exporting to the larger market in nearby towns.

C. Safety: As the filter is for personal-use and entirely customisable to the users needs, the considerations for safety are relatively minimal to say the least. The only notable safety considerations would be attributed to the proper handling of the design within the household and is explored further in depth in Section 4.3.4. However, if we take into account the safety associated with the implementation and operation of a local manufacturing industry, then much more can be expanded upon the aspect of safety.
Simply, the construction of the production facility would have to monitored carefully by on-site
construction personnel and workplace safety technicians. During operation, the workers (locally trained)
will have to be well taught in the practices of good occupational health and safety (OHS) to ensure
minimal chance for any accidents or injury in the workplace environment. This is due to the fact that
they will be operating potentially dangerous equipment to produce the filters on-site and can include
high temperatures (from the kiln), heavy machinery (hydraulic press) etc. Similarly, the community will
have to be educated in the proper safety measures attributed to living close to industrial equipment and
facilities.

Otherwise, the application of the filter into practice within the community is quite safe and should elicit
no problems whatsoever.

**D. Sustainability:** With a predicted lifespan of approximately 3 years in ideal conditions, the filter is
relatively sustainable in terms of its standard of performance throughout the 3 years. If users are
successfully able to commit to the proper maintenance procedures (see Section 4.3.4), then the filter in
essence will be an extremely sustainable option. Replacement for filters past their use-by date or out-of-
action can be made available on demand. This will rely somewhat on the efficiency of a supplier to
produce them on an as-need basis or if applicable, the local production facility’s ability to supply enough
filters dependant on demand at any time.

**E. Accessibility:** Given the filter can be procured from a local pottery producer or constructed locally
given the available resources, the community should be well placed to have access to the technology
whenever they need it. This in itself will be highly dependant on whether the right producer can be
found and is willing to service the community as part of the HWTS program, or if a local manufacturing
facility can be implemented.
2.5 Options for Rainwater capture

Table 6 ranks the options for quick, simple, visual comparison.

<table>
<thead>
<tr>
<th>Proposed solution for sourcing water</th>
<th>Cost effectiveness</th>
<th>Cultural acceptance</th>
<th>Sustainability</th>
<th>Accessibility</th>
<th>Safety</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talab</td>
<td>****</td>
<td>***</td>
<td>****</td>
<td>*****</td>
<td>***</td>
<td>19</td>
</tr>
<tr>
<td>Rooftop collection (lotus leaves)</td>
<td>****</td>
<td>***</td>
<td>****</td>
<td>****</td>
<td>*****</td>
<td>20</td>
</tr>
<tr>
<td>Run off from agriculture</td>
<td>***</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>14</td>
</tr>
<tr>
<td>Pond</td>
<td>****</td>
<td>***</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>18</td>
</tr>
<tr>
<td>Bores (old)</td>
<td>****</td>
<td>****</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>17</td>
</tr>
<tr>
<td>No intervention</td>
<td>*****</td>
<td>***</td>
<td>*</td>
<td>N/A</td>
<td>N/A</td>
<td>9</td>
</tr>
</tbody>
</table>

Rainwater collection/capture

All across India water tables are falling as the quantity of water being extracted is overwhelming the recharge from the monsoons, with some states receiving extremely low rainfall, enough to be called desert states. About 62 million people live in Tamil Nadu, the state surrounding Devikulam. In recent years, too much groundwater has been drawn from underground and even the country’s greatest monsoon falls cannot rectify the situation. Kuppannan Palanisami of Tamil Nadu Agricultural University says that “falling water tables have dried up 95 percent of the wells owned by small farmers, reducing the irrigated area in the state by half over the last decade”. (eoearth.org, 2011) This is happening in Devikulam, their wells are under strain and with one bore saline and another not working, intervention is critical.
Rainwater collection is becoming much more common around the world, nowhere more so then India. As part of new building codes, all new buildings in metropolitan India are now built with rainwater collection in mind, with rooftop collection being piped back into the ground water system. It is proposed that the people of Devikulam should also be given the opportunity to do their part and help get some of water back into the groundwater system. This will give them water for themselves, their family, and their future, allowing the community to grow and prosper.

Currently in Devikulam there is very little being done to utilise the vast quantity of good quality rainwater that falls during the monsoon season. An average of 1000mm of rain each season falls in Tamil Nadu, the state surrounding Devikulam. These solutions aim to change how water is collected by the community, in a way that gets the community involved and brings them joy.

Much effort has been expended to keep these solutions cheap and easy to maintain and implement as well as utilising methods that have are tried and tested in rural India. The focus is on traditional and natural methods as much as possible, in an attempt to make the people of Devikulam more likely to get involved believing that they are doing this for themselves and will be helping themselves. All methods will require some form of maintenance so steps must be taken to make it simple, however care has been taken to ensure that no particular skills are needed which means that the community will have no trouble with the implementation and use of these systems. Education and encouragement are crucial to the success of any new technology, it is necessary to show the community the benefits of these things and get them to join in and enjoy reaping the benefits of their hard work.

Each possible strategy/method was thoroughly investigated, the pros and cons weighed up against a set of requirements that were aligned to those set out in our mission statement.

### 2.5.1 Repair the existing wells water supplies by building/devising a strategy for recharging ground water supplies

This involves gathering the rainwater in areas around the wells, by digging suitable trenches in the ground around the wells, this system is a slightly modified Talab/Bandhis as it is known in India. This looks like a deep moat that surrounds about half of the well; this must be of sufficient dimension that it can be filled with a system of natural filtration consisting of sand, pebbles and large boulders.
As much water as possible is diverted or naturally runs into the Talab, the water will percolate into the groundwater table and recharge the well.

This strategy could also be supplemented by planting deep rooted trees nearby that will send roots down into the soil and help encourage the water to move into the water table. It is not advisable to put them too close or they may grow into the water filtration system; however they could also act as a natural fence to keep animals out. Also if there are too many trees people may see it as a nice private place to go to the toilet and everything falls apart, again education is the key to resolving this issue. The talab will require some maintenance, mostly in that the trenches need to be kept open and free from too much dirt/mud. The labour involved would not be too intensive and could be shared amongst the community.

There is also another option that utilises the same method- the water that is filtered in the Talab can potentially be piped directly into the well. This will help fill up the well, however it may not clean up the water as well as it is not fully percolated. It may also cause overflow if too much rainwater is sent in. This is potentially suitable for the saline well in the colony. It can become a recharge well which over time will again become a reliable source of clean drinking water as salinity issues are slowly resolved through natural water movement and percolation.

There are some problems with this method. Preventing people and animals from getting into the water is important, however this is not as big of an issue if water is encouraged to fully percolate and be naturally filtered. A possible solution is to cover it up- give it a thatched roof like a house, or educate the community not to use it for unsanitary practises. If it is covered it is necessary to make sure it is maintained.

Another method for storing rainwater would be to use traditional tankas. They are essentially an underground cistern, lined with lime mortar or cement. The tankas can be set up for the whole community and are used for collection of surface runoff and also for storage of water. Household tanks are possible, but they would potentially be too costly. Water is usually taken out with a special bucket; however a system where people can only get to water from a tap will prevent contamination. It is now pertinent to analyse recharging of groundwater in regards to each of the design criteria.
A. Cultural acceptance/awareness: Recharging groundwater through the use of modified a traditional Talab / Bandhis will be culturally acceptable as it does not negatively impact in any way on the community’s way of life. The system will not break any laws; it actually assists the community to follow laws set out for large cities. There is no reason as to why the community should not accept and appreciate the system as it is simple and effective and costs little time, effort and money to implement.

B. Sustainability: This system is not technologically advanced, thus it is more likely to be sustainable and last a long time. The system is easy to implement and will not cause any social, environmental or economical harm to the community. This system will provide large quantities of water to add into the groundwater system and provided it is maintained correctly, shall continue to function optimally for generations to come.

C. Cost-effectiveness: Because this system is built by the community, with tools and materials already available to the community it has an extremely low cost. The system will provide a great deal of water for close to no cost, the only cost comes from the time spent constructing and maintaining the system, which ensures that the community gets excellent value from their investment.

D. Accessibility: Due to the lack of advanced technology, the system becomes highly accessible to the people. The water generated from this system is directed into existing water sources which means that the community have to expend any more effort to acquire water. The system can be constructed using hand tools which the people already have, making it even more accessible.

E. Safety: This particular method of rainwater collection does have a couple of safety drawbacks; however, they can be overcome. The main safety concern comes from people or animals entering the water and getting stuck or contaminating it, suitable education about the system will be helpful here, as will physical barriers that prevent animals from getting into the water. If the water does become contaminated, the contaminants will not get into the groundwater, however they will be left in the layer of topsoil under the rocks in the filtration system. Any contaminants that get into the system will be killed and dealt with from UV radiation or other natural means. From this it can be seen that the system is actually quite safe, provided some basic usage rules are followed regarding contact with the system.
2.5.2 Harvesting water from roofs

In Devikulam, like much of rural India, the houses have thatched roofs. These roofs would get quite dirty over the year and may not be suitable to directly capture rainwater off. However, it would be wasteful to let so much harvestable water get away. A system that allows the roofs to be made clean and promote water runoff is necessary. Luckily the Indian population have such a method at their disposal!

The leaves of the lotus plant are quite large, larger than a dinner plate, and have a property called superhydrophobicity, meaning highly water repellent. This causes water to bead up and form droplets that easily run off. The lotus leaf also displays a self cleaning behaviour which is directly related to its superhydrophobicity. “The cause of the self-cleaning properties is the hydrophobic water-repellent double structure of the surface.” (http://aob.oxfordjournals.org/content/79/6/667 ). The double structure of the leaf is caused by the outermost layer of the leaf, called the cuticle, and the covering epicuticular waxes associated with it. The leaf’s epidermis is arranged in a structure of tiny papillae (smaller then, but similar to the bumps on your tongue) where the epicuticular wax superimposes in layers that are hydrophobic forming the second layer of the double structure.

Due to the microscopic structure of the leaf, as water droplets hit they are forced to form spherical droplets with less than 5% of their surface area in contact with the leaf. This prevents adhesion to the surface as nothing has the opportunity to stick to the surface. This also applies to dirt or contaminants which just run off straight away, keeping the leaves clean. This also protects the plant from pathogens like fungi or algae growth, which is imperative for harvesting good quality drinking water.

If roofs are covered with lotus leaves during the monsoon, the majority of the rainwater can be collected. The town of Devikulam was founded around a large lotus pond, which still today grows lotus plants, giving a great source of these wonderful leaves.
Any water that comes off the roofs the people in those houses want to have instant and direct access to, they do not want it taken away - so a solution must be found that incorporates suitable treatment methods for the rain water. The water that falls on the roofs must also be directed into the storage/treatment container by means a guttering system. This could potentially be constructed from local bamboo or other materials. It may also be possible to arrange the lotus leaves in a way that drains the water into a few central areas for collection. This method requires some work to set up, however it requires little upkeep provided the leaves are secured so that they do not get blown away by the wind. They will need to be taken down at the end of the monsoon season, and the used leaves can then be reused in traditional practices, or mulched for agriculture.

Problems can arise from the guttering not coping with the load or not being installed correctly and breaking. There is also concern over whether or not the locals will approve of using the sacred plant to put on their roofs, however, water is essential for life and it may be possible that they will see the lotus plant as giving them life. The biggest factor against this system is that it requires careful maintenance and has a fairly intricate setup procedure.

**A. Cultural acceptance/awareness** - Using lotus leaves for rooftop water harvesting should be culturally acceptable, as should the general concept of rooftop water harvesting. The people of India do see the lotus plant as a sacred plant, however, they have been using the plant for generations and it just makes their reverence grow stronger and is hopefully the case for rooftop water harvesting. The system will not cause a major upheaval of the communities way of life, they may have to grow a few more lotus plants but that could be considered a blessing not a chore to them.
B. Sustainability - Due to the natural materials involved in this method it is completely sustainable, provided enough lotus plants are grown in a sustainable and efficient method. The materials can be grown locally and indefinitely. There will also be no negative social, environmental and economical aspects involved provided the amount of lotus leaves used does not exceed those grown and that the growing of them does not destroy the pond. This system also has the ability to consistently provide a good amount of clean drinking water all through the wet season.

C. Cost-effectiveness - The planting and growing process of lotus plants is not an expensive endeavour, however much care needs to be taken in the early stages when they are extremely fragile. This could possibly add to the overall cost of the system as someone will need to spend some time geminating and tending to the plants. However, if multiple people take on this task it will be become a fun bonding experience. The initial investment for the plants will be low as the pond already has existing lotus plants that could be used to gather more bulbs from.

D. Accessibility - Because the lotus plant already grown within the town the materials and expertise required are already available. Again, this system does not require any advanced technology thus it is highly accessible to the people of Devikulam. This system will require some care to be taken during set up and dismantling, the leaves must be placed onto the roofs without being torn or damaged. There will need to be daily checks to ensure that the leaves have remained woven into the roof and are still capable of allowing water to flow.

E. Safety - This method is reasonably safe; however, the set up and deconstruction process must be undertaken with care to prevent injury from falling. The water collected by the lotus leaves will also be safe for consumption, especially after treatment. The used leaves may pose a health hazard if they are not disposed of correctly, they will make great fertiliser or mulch. Growing the lotus leaves poses no safety risks.
2.5.3 Treatment of collected water

The roof top water that is collected may be fit for drinking straight away, however there could be some contaminants found on the leaves or that have found their way onto the roofs. It is necessary to allow the first couple of day’s worth of monsoon rain to wash off the roof and clean it. The lotus leaves can then be secured to the roof by being partly woven at the edges into the rooftop. To purify the water from the rooftops clay pot filters with silver in the filter stage can be used. The pots on their own just filter contaminants, the silver kills bacteria. Another possible solution for household water treatment is to use plants for clarification and filtration. There are two main options, using the seeds from the moringa tree and using the roots from the ramachham plant.

2.5.4 Agricultural run off

Growing crops generally requires plenty of water for irrigation, this water has the potential to be reused and treated. In general, it is not recommended to use water that has been used for agricultural purposes for human consumption without significant treatment. The level of treatment required is too great and outweighs the potential for success. The best solution is to reuse the irrigated water again, or devise a way to prevent the irrigated water from running into the nearby river. The reason for this is twofold—allowing pesticides and chemicals into river systems is environmentally dangerous and unsustainable as the river will eventually become polluted, and water is better off being reintroduced back into the groundwater table as that is most likely where it has come from in the first place. A tried and trusted method is to simply build trenches and barriers at the downhill section of land which catches run off and holds it until it can percolate into the ground.

First and foremost an education system needs to be put in place that introduces new ideas of sustainable farming and efficient water use. Examples of this come from an India banana farmer who managed to turn infertile, alkali land into prime growing crop through wise planting and growing practices. He began by naturally fertilising the soil by sowing multiple seeds of plants that would germinate and be mulched back into the soil. He then began planting crops and each time they were harvested all of the excess and dead crop was re-purposed as fertiliser and he simply has to now plant and harvest his crops at an incredibly good gain.
People all over India are cottoning onto these ideas that through some smart, sustainable farming a lot can be achieved, it is important that the people of Devikulam are given the opportunity to lead the charge.

A. Cultural acceptance/awareness - Harvesting of agricultural runoff would potentially not be adverse to the cultural beliefs of the town. If it was undertaken in a way that shows the community that their crops would benefit from recycling agricultural runoff they may embrace the idea.

B. Sustainable - This system is potentially sustainable to a certain degree. There will come a point where the quantity of pesticide or contaminates found in the recycled water will become hazardous without excessive treatment. If done correctly, this method can be very sustainable as it encourages reuse of precious resources as well as instils an ideal of reuse into the community. If the treatment facility was to fail significant social, environmental and economical damage could ensue.

C. Cost-effectiveness - The treatment process for agricultural runoff could possible to great of a cost for the townspeople. However, if the run off was sent straight to groundwater it would potentially not need treatment, but would take more time for reuse.

D. Accessibility - The technology required for this system is not incredibly advanced, so it should be accessible to the community but may come at a price. The system would also require immense effort from the people during set up and maintenance, which they may not be prepared to do as their current system is working for them.

E. Safety - Reuse of agricultural water is fairly safe, provided that the treatment process is sufficient and people don’t come in contact with the contaminated water, which may pose a safety hazard in disposal. The system will only pose a safety hazard directly to the town if contaminated water contaminates the crops they eat. Otherwise the process is relatively safe.
2.6 Proposed selections

2.6.1 Recommendation for Treatment

The selected option for treatment for the overall system is a coupled Decentralised Waste Water Treatment System (DEWATS)/Clay Pot filter. As can be seen from the diagram below these two are the best in terms of the specified design criteria. Furthermore the two pieces of technology are best suited to work in a combination. Since the DEWATS do not consistently treat water to a drinkable standard, the clay pots will be employed to further purify the water so that it can be safely distributed in to the broader system.

2.6.2 Recommendation for distribution

The recommended system for distribution in Devikulam is a mix of the distribution systems mentioned before. By pumping water from the source to both the colony and the village tanks, it is possible to supply both with clean drinking water. As the tanks are already connected to a ‘local’ network of pipes connected to the houses, the simplest way to distribute the water is by using this network by filling the tanks (Devikulam Village Taps Map, 2011). The unreliable electricity grid is a problem, because when the electricity is not working, neither are the pumps. This makes the water inaccessible during brownouts. The suggested solution to this is to use gravity to feed the water to locally accessible taps connected to the closest tank, making the water in the tanks accessible all day. Because we are prioritising supplying enough water for the whole community, connecting the battery to a pump that pumps water to the individual houses would drain it too quickly as there would be frequent use of the pump. The important aspect is to get water into the tanks, which then makes it accessible for everyone. To be able to refill the tanks during a blackout, a battery will be connected to the pump so that it can pump water into a tank that is low on water. To accompany this, some level sensors will have to be installed in the tanks, making the system able to decide if it is necessary to start filling the tanks again. Because the source of water is both from the bore and the DEWATS, and the destination is two different tanks, valves that control the flow of water will have to be installed so that it is possible to choose where the water is sourced from and directed to.
2.6.3 Recommendation for household water storage

Whilst there are multiple examples, each with their own benefits and drawbacks, the selection of the appropriate technology and method was to be chosen in respect to the status quo of the community and as per the design requirements of this project. After careful consideration of each of the proposed options for household water treatment and storage (HWTS), it was decided that the best choice would come in the form a modified clay/ceramic pot which includes the addition of a basic ceramic pot filter. Alongside this, the implementation of an appropriate education scheme for health safety and sanitation practices would be included in the HWTS program. Furthermore, the scheme would include the proper training and education of constructing, operating and maintaining the technological aspect of this solution.

Despite that the current means of treating and storing household water are relatively unsanitary by first-world standards; it is assumed that the community members are nonetheless satisfied with their present routine of household water treatment and storage. This may be attributed to several factors of which include the lack of health education and minimal accounts of water borne diseases in the community. Also, it must be noted that the simple convenience of collecting water in a vessel and leaving it in the home for use whenever is a relatively easy routine to maintain. As such, there is the possibility that they might be somewhat reluctant in having to cope with the changes in daily routine by the HWTS program.

Given that community members are only taught the basic education required (confirm and reference this with appropriate information from EWB education section), it is highly likely that they would not be aware of the importance of maintaining proper sanitation practices when it comes utilizing, handling and consuming water. As explained by the Resource Development International Cambodian (RDIC) organisation, most people in the developing world would simply associate the sight of clear water with the assumption that it is clean and free of contaminants (insert reference here). This is of course, rarely the case when it comes to determining the quality of drinking water. Similarly, as there have been no reported accounts of illness stemming from the consumption of household supplies to date, it must be further speculated that they are oblivious to the connection between water borne disease and unsanitary HWTS practices.
As such, an effective health education plan will have to be implemented alongside the introduction of a ceramic pot filter to ensure that the community is well placed to understand the benefits of maintaining safe HWTS and sanitation practices in preventing the possibility of water borne disease. Seeing as the community is quite open to any suggestions that would only benefit them, this education plan could serve to further persuade members to consider the HWTS program in our favour. Conversely, the fact that the water filter can be manufactured locally with local resources and labour opens up the possibility for potential industry development in the community. In so doing, it would also allow members of the community access to the appropriate skills in filter construction which would translate to proper maintenance of the product itself. Similarly, they would gain skills in proper OHS, workplace and environmental management. All these little aspects of this chosen design would serve to cut costs and maximize the investment put forth into this solution.

Overall, the modified ceramic pot filter will serve as an effective means of reducing recontamination of potable water in the home, improving family health and educating the community in a wide array of practical skills and sanitation practices. These are the cornerstones to which this HWTS program is founded upon.

2.6.4: Recommendation for rainwater capture

It is recommended that modified Talabs be implemented, . This method, used in conjunction with the plant based treatment methods should provide a large quantity of water to the people of Devikulam both immediately and into the future.

Groundwater recharge, as is being proposed, is a sustainable way of managing water supplies. As the town already draws most of its water from underground it makes sense that as much water as possible needs to be allowed back in, ready for reuse. For thousands of years the Indian environment has regulated itself by means of natural water percolation during the monsoon to ensure a consistent groundwater supply for its ponds and plants. However, since extreme urbanisation has begun, surface water no longer gets sent into the water table, instead it gets directed into oceans and rivers. The people of India are now realising this and taking steps to repair their falling water supplies are there is no reason that the people of Devikulam cannot be a part of this movement and ensure adequate water supplies for their community now and into the future.
Treating water at the point of use in homes is typically thought of as cumbersome and ineffective, however the natural methods proposed here are safe, easy and proven to be effective, especially in developing countries. Using native plants ensure that the local people are more likely to know how to utilise them to their full potential and get maximum benefit, enjoyment and nourishment from them. This is also a sustainable practice as the community can replant these plants each year and they will be ready for use before the next monsoon.
3. **Design Description**

3.1 **Summary of the Design**

A multi-faceted approach is usually required in any successful engineering project, this challenge is no different. The proposed system incorporates the most highly recommended aspects of each of the four sections of the report; water treatment, distribution, capture and storage.

Currently the system in Devikulam is as follows; untreated water from depleting bores supplies tanks, one of which (in the colony) is saline and not fit for consumption. This water is then pumped into the tanks in the village and colony, however, the power to this pump is lost on a daily basis due to problems in the power grid. This means that the residents of the colony are unable to access water for extended periods unless they walk approximately 500m and carry water back home. The water in the tanks is supplied through recently repaired pipes into the houses. Currently at household level, nothing is being done to ensure stored water is kept sanitary; it is stored in open containers. Currently nothing in particular is being done to harvest rainwater; whatever naturally peculates underground replenishes bores.

*Fig 3.1: A visual interpretation of the current situation*
The proposed system from this report aims to improve each aspect of the communities’ water supply. Water from the pond will be run through a DEWATS filtration system which feeds into a sand filter and clay pot system. This water is then pumped directly into the main tank currently being used near the school to supplement the current water supply. The water from this tank is currently supplying the village; the proposed system will pipe water from this tank into the colony tank to provide them with clean water. The current pump will also be outfitted with a battery and solenoid system so that the battery remains charged from the power grid when available and can supply the pump at times of disconnection. This report proposes modifications to current household storage methods by means of enclosed containers and clay pot filters. Traditional water harvesting methods will be revived by means of capturing rain water in wells around the bores so that as much run off as possible can be directed underground to help recharge the falling water supplies. Other supplementary measures for sanitation in the form of native trees and plants will also be implemented.

It is clear to see that this report proposes a much improved water treatment and distribution system that is safer, cleaner and much more sustainable than current methods.

3.2 Detailed Description
3.2.1 Functional Block Diagram

Fig 3.2: A visualisation of the overview to our proposed solution
3.2.2 Functional Description

3.2.2.1 Detailed technical review of water treatment methods
The treatment method employed, as mentioned, employs basic principles. Figure... below shows an outline of the function of the treatment method. Passive, cost effective components make up both of the two main subsystems. These subsystems are A. DEWATS and B. Clay Pot filter. We will look at each sub-system separate while analysing their design.

A. DEWATS

There are many different types of DEWATS. The most effective type in this situation will be a Free Water Surface (FWS) Treatment system. (see figure 3.3) Constructed FWS systems mimic the hydrologic regime of a natural wetland. Wastewater, in this case water from the pond enters a settling tank where large solids are separated from the water. These solids breakdown which means two things. Firstly that the settling tank will not need to be cleaned and secondly there is an option to capture the gas that is excreted during this process.

Fig 3.3: A visual overview of the water treatment process.
From the settling tank water enters one end of a basin, flows through an area of emergent wetland plants and is collected and discharged at the opposite end. The surface of the water must remain above the rooting media and moves through the wetland at a slow velocity. The selection of plants can be altered to suit what is locally available.

To ensure that the pond is not drained, the inlet that will allow water to flow in to the settling tank will be 500mm below the maximum surface of the pond. Approximate calculations of the amount of water in the pond have been made based on the pond a 4m depth (see appendix B1). Based on these calculations it has been found that disallowing the pond to drop below the 500mm level will not only ensure the ponds ecosystem is sustained but there will be more than enough water for the community over the course of the year. In this sense we cannot see the system as one the merely drains the pond.

![Figure 3.3: a basic FWS Horizontal DEWATS](www.sozialstruktur.org/en/files/DEWATS05_09small.p)

**The Settling tank (Primary treatment)**

Before flowing in to the settling tank, water will flow through a meshing that will filter any major solids from entering the system. Once the water has flown through the mesh it will find itself in the settling tank. Here the next biggest solids will settle to the bottom and naturally decompose.

The settling tank needs to be made from concrete which -while not locally available- is the most viable solution, especially when we’re looking in the long term.
As mentioned there is potential for future projects to seal the settling tank and capture the gas that is excreted during the breakdown of these solids. This has been something we have chosen not to look into but leave the opportunity open for the future.

The Basin
The basin is the heart and sole of the system and is where the real beauty in the process takes place. Bacterial treatment will take place in the basin given that all remaining solids will have been removed from the water. The water flows from over the top of the settling tank and into the basin. The basin is lined firstly with an impermeable layer followed by an inorganic sediment layer and then a detritus layer. A dense network of emergent plants are planted in the detritus and sediment layer with the water flowing over the top these layers. The basin will be no more than 350mm deep at any time where plants are present, there will be 2 ‘deep zones’ that have no plants within them and are 1000mm in depth. These deep zones aid the distribution of flow throughout the FWS and further promote bacterial breakdown.

Plant selection
DEWATS would not be DEWATS without plants. Plants play an extremely important role in the FWS system. They shade the basin, provide surface area for bio-film growth and are integral in the cycling of nutrients and organic carbon. From the list of locally available plants made available via Engineers Without Borders, (appendix B2), the Cycas circinalis and Cyperus spp. have been recommended by the Water Environment Research Foundation (WERF, 2006). Instructions on correct procedure for planting these plants can be found in appendix B3.

On top of this the Moringa tree, also available in the immediate Devikulam area will be planted in the region surrounding the FWS DEWATS. The Moringa tree thrives in monsoonal conditions and is of incredible use. Not only can the trees leaves and seeds be used in traditional Indian dishes such as Sambar but the majority of the plant has a medicinal use while the seeds can be used as a fuel source. On top of this –and most relevant to this report- is the fact that it promotes soil regeneration when planted in an area around a pond or body of water. Its seeds, when crushed, can also be used as a flocculant in a low cost form of water treatment (which removes 90%-99% of bacteria).
**Design Specifications:**

**Settling Tank**

**Dimensions:**

- Width = 400mm
- Height = 320mm (at input end)
- Height = 308mm (at output end)
- Length = 1800mm

**Basin**

- ‘Lined’ with compact clay
- Plants used: Moringa Oleifera, Cycas Circinalis, Cyperus Spp.

**Dimensions:**

- Width = 2000mm
- Length = 5000mm
- Normal depth = 350mm
- Deep zone depth = 1000mm

**B. Clay Pot Filter**

The clay pot filter will be the final stage of purification. It is more a safety measure than anything else as, while DEWATS does not treat water to an entirely drinkable standard, by diluting the water from the DEWATS into the system with clean bore water the water would still be at a safe drinking level. However, to ensure that the water coming from the pond is entirely safe it is proposed that the water is filtered in a clay pot before distribution. The Clay Pot Filters’ ingenuity lies within its simplicity. Water is poured into a clay pot that is suspended on the inside of the top of the receptacle container (see fig. 3.4). The pores in the ceramic are designed to remove the vast majority of pathogenic microbes and allows only particles smaller than a water molecule through, hence purifying the water in the process.
The ceramic pot filter has a lifespan of roughly 3 years and is incredibly easy to replace.


The filter shown can filter, on average, 50L of water in a 12 hour period. An upscaled version of this filter has capacity far outside of this. This will be explored more thoroughly in the implementation plan.

### 3.2.2.2 Detailed technical review of water distribution methods

![Fig 3.5: The proposed water distribution system](#)
The cause of all the blackouts are attributed to overuse, not necessarily from Devikulam, however it is not ideal to adding to this overuse, so the system will be programmed to try to avoid pumping during the peak hours. And by calculating how much water is used on a daily basis it can make sure to have a couple of days worth of water stored, and let it drain during the day when the power is out. This is possible as there are water level sensors in each of the tanks, making it possible to record use and current levels.

The Village and the Colony uses 1100L of water each per day. To ensure that there is always enough water in the tanks, they will store about 15 000L each, supplying Devikulam with enough water for two weeks. If this was not enough, or the water supplies are running short and the conditions of the electricity grid is unsure, it will be possible to pump up more water from the bore and the DEWATS. This will firstly start to fill the Village tank, and move water from the Village tank to the Colony tank after this has been done.

The battery will have to be connected to two pumps, firstly the pump that is already installed, and a second one which has to be added to the system. The purpose of the second pump is to pump water from the Village tank to the Colony tank. This allows the water to be pumped through pipes that are already installed and into the Colony tank, making it accessible to everyone in the Colony.

For the system to decide when it is necessary to pump water, level sensors will have to be installed. The reason for this is that the system needs to know if the tanks are full or not so that it does not pump excessive water. The battery is connected to a pump that is close to the source, and can switch between two pipes (one to each of the village and colony tanks) using a valve. If possible, using the pump that is already in pace will keep cost down. By trying to keep the tanks as full as possible while the electricity is on, the water supply can last for a very long time without electricity, and even longer as the battery will allow the pump to pump more water when the grid is not working. Assuming that both tanks are 30 000L, we can store 60 000L of clean drinking water, and be able to refill some of it using the battery. Assuming that Devikulam uses 1000 liters of water, it will last 60 days before it is empty. The electrical grid is often overloaded, which causes brownouts of about 3-4 hours daily, or even longer during the monsoon. Therefore a system where the water pumping does not add to that load during peak hours will have to be created.
Initially the price of solar panels are huge, making this system less feasible, however there are government programmes that supports the use of renewable energy in rural areas. A programme like this, one of which was offered in India in 2010, covered 50-90% of the costs of the solar panels (Indian Government, 2010).

Figure 3.6, a flow chart depicting the water distribution.
3.2.2.3 Detailed technical review of household water storage

![Diagram: Water treatment process]

**Fig 3.6 The general idea behind the household water storage methods**

Ceramic/clay pot filters are simple in their design. They are capable of being manufactured or acquired locally with local materials, facilities and labour. The entire filter consists of four basic parts. The ceramic pot that comprises the filtering element is made of porous ceramic and is the most critical aspect of the design. The element itself can be modified as exemplified in multiple reports and studies through addition of specific materials during the ‘firing’ process of the clay. It is during this process where modification of the pot’s composition with the addition of certain organic materials can effectively increase the performance of the filter.

There is also the receptacle tank which is often, but not necessarily, a plastic bucket and the filter sits inside of it. In this, the appropriate dimensions of the container can vary and is entirely customisable to the needs of the user. Although, it is highly desirable that receptacle container be able to hold the maximum volume of water, be appropriate in weight according to the material used, easily accessible, maintained and disposable. Similarly, there is a lid to cover the filter and keep out contaminants from the open atmosphere. This might not necessarily have to be a lid as a clean piece of cloth could be used in substitution (this is explained in detail in Section 2.4.2.2).
There is also a **spigot** that is installed at the base of the receptacle through which filtered water is removed for use. In this, there have been studies conducted into the problems generally encountered in the installation of spigots on clay pots. Where the typically rounded surface of the pot inadvertently causes much difficulty with the choice of spigot or tap that has to be installed onto the receptacle. Problems include leakage, ineffective installation of the spigot that would require continual maintenance and non-standard sizing of the spigot. As such, it is recommended that the receptacle be cylindrical in shape instead of the rounded-shape that most ceramic pots are attributed to.

As water works its way through the pores naturally formed on the surface of the filter element during construction, sediment and pathogens become trapped in the pores. In so doing, the water that comes out on the other side is safe to drink.

In the ceramic water filter technology, the pore spaces in the porous ceramic filter element are small enough to prevent any particles larger than a water molecule from passing through. As such, this suggests effective removal of the vast majority of pathogenic microbes and other undesirable biological entities. All ceramic water filters work in the same manner, with some personal-size filters including a pump that helps force water through the pores to increase effective flow rate.

In addition to the mechanical trapping found in all ceramic water filters, it is also highly recommended that the filters themselves are treated with a colloidal silver solution. The silver, in essence, acts as a microbicide, capable of killing any pathogenic microbes that pass into the filter. Similarly, the addition of a filter media (e.g. sand, cloth, paper etc.) could increase the efficiency of contaminant removal in the system. However, there remains to be the question as to whether this would impact the effective flow rate and yield of the filter.
3.2.2.4 Detailed technical review of rainwater capture methods

The recommended solution for rainwater capture is to use modified talabs built around existing wells. The talab is constructed by digging a large moat/trench around approximately half of the existing bore well, it should be about 1.5m wide and 1.5m deep and as long as available. The talab must be dug a few meters away from the well so that it will not disrupt the well. Once the talab is dug it must be partially (approximately one third) filled with a series of progressively smaller rocks, starting with largeish boulders, then pebbles/small rocks, gravel and finally, sand.

This combination of rocks simulates the natural method of water filtration that occurs as water filters down to the water table. Water soaks into the soil as it lays on the surface, it then gradually works its way though the area between the rocks, the smaller this area the more filtration occurs, eventually the water reaches the water table below the surface. This simulation is necessary due to the high salinity present in the soil, providing the water with somewhere else to get into the soil that isn’t full of salt will help add nice clean water to the water table, lowering it below the saline layer and thus helping to clean up the groundwater. The talab can also act as a barrier that prevents any waste water or agricultural runoff from flowing into the water bores, which is a concern during the monsoon season.
Fig 3.8: How the modified talab works
A fair amount of manual labour will be necessary to construct the Talabs, the community must get involved and dig the trenches. Getting water into the system may be difficult, however the natural topography of the area could be an advantage as wells and bores are usually dug in areas of natural depression which encourage natural water flow. It should be possible to divert run off from nearby into the system, however agriculture runoff should not be diverted into this system as if it does overflow it could potentially end up in the well. This system will cost very little to implement, it depends on whether or not the rocks, pebbles, gravel and sand can be locally sourced. The Tamil Nadu Agricultural University has investigated the costs associated with these kinds of systems and the system outlined here may cost around Rs 650 (approximately $14 AUD) for the materials.
4 Implementation Plan

4.1 Treatment Implementation Plan

4.1.1 Overview

There is neither anything drastic nor surprising about the way in which the treatment aspect is proposed to be phased into operation. Given that is infrastructure, as opposed to a complex procedure or means of education it is considered that the treatment aspect of the proposal will be, in cultural terms, simple to implement.

Implementation of the DEWATS as a system will be completed and aimed to be in operation within two to three months. From here after occasional care will be needed to ensure the plants in the system are healthy a vibrant and that, in the rare instance of a blockage, that blockage can be removed. As for the Clay Pot Filtration component, it is not as straightforward as the DEWATS. While the Clay Pots, could be sourced from Pondicherry (see appendix B4.1 for details), the ideal goal is that the Clay Pot system will not only work as a means to filter the water but indeed, further down the track, as a market stimulus and opportunity for employment.

To come into affect the DEWATS will need external labour and expertise. Mainly this will be needed for the piping and fluid mechanical side of the operation.

4.1.2 Component List

We have made a significant effort to ensure that the majority of components are found in the immediate area and for those that cannot be found, they are at least are in Tamil Nadu. See Table 4.1 below
**Table 4.1: Component listing, price and source for DEWATS**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Description/ Use</th>
<th>Supplier</th>
<th>Estimated Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact Clay</td>
<td>As required</td>
<td>Permeable layer used to line Basin and Primary Settling Tank</td>
<td>Locally available</td>
<td>N/A</td>
</tr>
<tr>
<td>Plants - Cycas Cirinalis</td>
<td>6</td>
<td>Filtration component use in basin</td>
<td>Found locally</td>
<td>N/A</td>
</tr>
<tr>
<td>Plants - Cyperus Spp</td>
<td>15</td>
<td>Filtration component use in basin</td>
<td>Found Locally</td>
<td>N/A</td>
</tr>
<tr>
<td>Plants – Moringa Tree</td>
<td>5</td>
<td>Filtration component used around basin to refresh and encourage local ecosystem</td>
<td>Found locally</td>
<td>N/A</td>
</tr>
<tr>
<td>Piping 150mm Polypipe</td>
<td>6m+50m</td>
<td>Carry water from: Pond to Settling tank, settler tank to Basin, Basin to clay pots and clay pots to distribution</td>
<td>Sri Kaleeswarar Industries. 103, Salai Street, Olugaret, Pondicherry – 605 010. Visit: <a href="http://www.srikaleeswararindustries.com/">http://www.srikaleeswararindustries.com/</a> to order</td>
<td>$AU20.25/m</td>
</tr>
<tr>
<td>Item</td>
<td>Qty</td>
<td>Description</td>
<td>Address/Contact Information</td>
<td>Price</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
</tbody>
</table>
| Box Grate          | 1   | Wide separation: Filters large solids between pond and settling tank        | Sashti Metals’ Address
49, Ayyanar Koil Street Raja Nagar
Pondicherry Town
Pondicherry - 605001.
Phone: - 6501415 | $AU120.45 |
| Metal Grate        | 1   | Small separation: Filters smaller solids between settling pond and basin.   | As per above
Website: [http://pondicherry.magicpages.in/sashti-metals-pondicherry-town-pondicherry_contact-details.htm](http://pondicherry.magicpages.in/sashti-metals-pondicherry-town-pondicherry_contact-details.htm) | $AU48  |
| Clay Pot Filters   | 8   | Used for purification. Water flows through DEWATS and through clay pot filter. | Either locally made as per the manufacturing plan in appendix B5 or sourced externally from:
Nirmala Stanley
2/41 - VIP Nagar,
Vilankurichi Road,
Ponducherry - 641035,
Tamilnadu, India.
Phone: + 91 98430 90817 | $AU25ea |

### 4.1.3 Implementation Procedure

While we prefer to empower to the community by giving them a sense of ownership of the project by allowing and encouraging them to participate in the implementation of the water filtration system, it must be recognised that there are technical aspects to the project that simply cannot be undertaken by those without expertise.
With this in mind, however, we do wish to ensure that –where possible- locals have the opportunity to undertake the works they desire. We see that by being involved in the project and having the community members adopt a more hands-on approach should further persuade the people of Devikulam to understand the necessity for good sanitation practice. It is assumed that there is a slope leading up to the pond and it is on this slope that the following will be undertaken. It is important that the top of the pond sits above the top of the settling tank and that above the basin to ensure gravity driven flow.

1. Dig hole for Primary Settling Tank. See design requirements for specifications.

2. Dig hole for Basin. The majority of manual labour is done here. The dimensions of the dimensions as per the design requirements.

3. ‘Line’ basin and settling tank with compact clay. It is assumed that, at the depths required for both the basin and settling tank the lining should already be compact clay. It is advised, however, that livestock is made to walk over both the basin and settling tank for 45 minutes for 8 consecutive days to ensure that the clay is compacted and sealed. If livestock is appropriate in this respect and there is an obvious substitute, feel free to utilize that. After each day of either the livestock walking over the DEWATS or some alternative, the Basin and Settling Tank should be doused in water and left to dry, further helping in the compacting process. While some water is good in compacting the clay, we strongly recommend that step 3 is not undertaken in the monsoon season, as monsoonal storms or large quantities of water will be detrimental to the compacting process.

4. This step requires technical assistance. Piping will need to be run from the pond to the settling tank, settling tank to basin and basin to the several clay pot filters. From the filters the piping will need to be linked in to the main distribution board. The piping needs enter the pond no deeper than 500mm and around this entrance, the box grate must sit to filter out any solids. The metal grate must sit in front of the pipe that leads in to the basin. While piping will run between the clay pots filters and DEWATS, it is important that water is not initially hooked up to the clay pots. DEWATS need at least three weeks with water in them before the system is treating the water to an adequate level. After this week the pipe from the basin to the clay pots must be redirected so that the water is running in to the clay pots and being purified.
It is advised that when the technician comes to the community to construct the main piping system (leaving the basin-clay pot link blocked) he or she instructs someone in the community as to how they might unblock that link.

5. It is more than advisable to construct a small hut in which to house and protect the Clay Pot filters. Obviously this adds a certain amount of labour and cost. While this is the case it will significantly increase the lifespan of the filter given that the main source termination is damage from external sources. Clearly best methods of constructing huts are well known within the community and as such, no recommendations on this matter will be given, however we will say that the Clay Pot filters must not be raised and be sitting on the ground so they are in no risk of falling and being breaking.

6. It is important to ensure that there is water in the basin before this step is undertaken. The *Cycas Cirinali* and *Cyperus Spp* are plants that are easy to plant and are self sustaining. As such there is real technical skill involved with planting them, rather just some dirty hands. A small hole needs to be dug in the water in which the plants are placed. Dirt must cover the root system such that the plant will not float away. The *Cycas Cirinali* must be planted closer to the settling tank as is will do the bulk of the treatment. The *Cyperus Spp*, a smaller ‘purifying’ plant will proceed this. The Moringa Tree should be planted on the banks of the system to act not only as a sort of barrier but to promote the ecosystems biodiversity to grow. For a guide on correcting tree plant procedure, see appendix B3.

7. Once the DEWATS is up and running, it must be ensured that people do not enter and hence contaminate the Basin or settling tank. Signs will need to be constructed and put up around the perimeter of these parts of the system. For a guide as to what the sign may look like, see appendix B4.3

4.1.4 Additional Uses

The most notable additional use for this part of the system is in regards to the clay pots. There is a huge potential for the clay pots to be used as a market stimulus. This potential, due to a lack of expertise, has been excluded from this report.
While we have not planned a market stimulus, we have included operation guides on constructing the Clay Pot filters further in the report. In Cambodia the Clay Pot filter has been used to not only treat water and hence decrease water borne disease but kick start an economy. In this case study the area was urban, as opposed to rural and hence a larger audience to which they could sell their product. A report titled ‘Use of Ceramic Water Filters in Cambodia,’ (https://www.wsp.org/wsp/sites/wsp.org/files/publications/926200724252_eap_cambodia_filter.pdf) will be of great use but has been excluded from the appendices given its length. A summary of this report, however, showing the ease with which such a market could be set up, can be found in appendix B5.

4.2 Implementation procedure for distribution

4.2.1 Overview

The implementation of the distribution system is rather straight forward as it uses mostly infrastructure that is already in place. There are a couple of changes that has to be made to the current infrastructure, and some new parts to install. Firstly the pipe that goes from the Village tank to the Colony will have to be connected to the top of the Colony tank. Connecting the pipe to the top of the tank allows the tank to be filled completely without having to pump against pressure as the water level goes over the inflow pipe. This same pipe will have to be as straight as possible (avoiding turns on the way to the Colony as much as possible) to reduce the friction caused by such turns and extra lengths of pipe. Furthermore a pump that pumps the water between the tanks will have to be installed, which is best placed close to the Village tank, so it is near the other equipment. Finally, to be able to get the water out of the tanks when the power is out, pipes will have to be connected to the bottom of the tanks, which will allow the tanks to be emptied completely and create the greatest amount of pressure. The greater pressure, the easier it will be to feed it to the connected access point using gravity and the pressure caused by the water in the tanks. Each tank will have a access point which is relatively close to the tank, up to a couple of meters. This is so that the pressure will be big enough to fill buckets and such at a normal pace.
4.2.2 Component List

50 meters of 50mm diameter PVC pipe
1 x Pump
2 x Tap for access points
2 x water level sensors

*Table 4.2 materials for distribution.*

<table>
<thead>
<tr>
<th>Item:</th>
<th>Quantity</th>
<th>Description of use</th>
<th>Supplier</th>
<th>Estimated price</th>
</tr>
</thead>
<tbody>
<tr>
<td>150mm polypipe</td>
<td>50m</td>
<td>To transport water from the Village tank to the Colony tank. And from the tanks to the ‘access points’</td>
<td>Sri Kaleeswarar Industries. 103, Salai Street, Olugaret, Pondicherry – 605 010. Visit: [<a href="http://www.srikaleeswarar">http://www.srikaleeswarar</a> industries.com/](<a href="http://www.srikaleeswarar">http://www.srikaleeswarar</a> industries.com/) to order</td>
<td>AU $20.25</td>
</tr>
<tr>
<td>Taps</td>
<td>2</td>
<td>To close the flow of water from the tanks to the access points</td>
<td></td>
<td>No more than AU $100</td>
</tr>
</tbody>
</table>
It is not necessary to use the pump and battery in the table above as it is mostly used as a guide to how much it is going to cost.

4.3 Implementation plan for HWTS

4.3.1 Implementation overview

The filter itself has been designed with the intention of aiding developing communities in managing their household water and storage methods. As such, the design has been fine-tuned to address the need for a sustainable, efficient and cost-effective solution in these environments. The large majority of funds can be acquired from external parties, such as the government and other financial sponsors or beneficiaries. In so doing, Pitchandikulam Forest is one of the main organisations responsible for affairs related to industry expansion and sponsorship in Devikulam. The importing of skilled labour will need to be considered to oversee the initial stages of the filter’s implementation and integration into the community. The filters themselves can be obtained or manufactured according to one’s needs from a potter in one of the nearby towns. On the other hand, the community has voiced their willingness to accept the prospect of creating and operating a new industry in the area of ceramic pot filter-making. If the appropriate capital and demand can be generated, then it could be possible to develop a local manufacturing industry for these ceramic filters. In so doing, experts and skilled labour will need to be sourced from the appropriate external parties to monitor and aid in the start-up of the industry.

Furthermore, it is imperative that trial projects be introduced during the implementation process. This is to ensure that the filter will provide a continuously high standard of performance in delivering clean drinking water to its users. Similarly, it is to confirm whether the community is sufficient in their understanding of basic health and sanitation education in terms of HWTS. A small survey of households should be sufficient in providing the data to reasonably assess the filter’s operation, cultural acceptance and lifetime. Also, close attention will need to be made on the maintenance procedures of the filter on an ongoing basis. This testing will help to bolster the community’s awareness of the filter and the significant impact that good HWTS practice has on water quality.
In summary, the following HWTS implementation plan will focus primarily on the steps needed to introduce the initial stages of the design’s deployment, from introduction of the filters to the trial phase. It is assumed that the community will be sourcing the ceramic filters from an external supplier that manufactures these items for the initial trial phases. If the integration of the filters proves successful after testing, then it may then be possible to consider the implementation of a local manufacturing industry for the filters.

4.3.2 Human Capital

As the implementation of the filter will initially require skilled knowledge in its operation and maintenance, it is necessary to procure the appropriate technical expertise externally. Specifically, the expertise will come in a variety of different forms and they include, but are not limited to, field technicians, project administrators and liaisons and health trainers (specializing in HWTS and sanitation practices). As such, many of these roles may be integrated together during practice and constant communication between the different personnel is critical to ensuring that the project is successfully run.

Given that the design itself requires little complex skill to use, locals should be trained and educated in the appropriate knowledge of the filter’s operation and maintenance. Skilled staff (such as field technicians or health trainers) can be made available on-site through regular workshop and one-on-one tutorial sessions. It is an aim of the project to maximize the number of roles available for local citizens as per the desires of Pitchandikulam Forest’s vision statements. That is, “to improve the employment prospects of the local citizen” (EWB Industry Development Plan, 2011) and “to raise awareness of about appropriate water supply and sanitation facilities” (Pitchandikulam Forest, 2011).

The highlighted roles are defined in greater detail and are as follows:

**Field technician**: The role of the field technician is to assist with the introduction of the HWTS program through training of local users in the operation and maintenance of the filter itself. Similarly, they are capable of assisting with any start-up of a manufacturing facility through the analysis of available resources and labour in the community, as well as the training of potential workers.
It is expected of the field technician to possess a thorough knowledge of the local water quality issues, filter specifics, natural and local resources. In many cases, field technicians are usually volunteers for a specific development aid organisation such as that of the *Resource Development International* (RDI) and Potters’ for Peace (PFP) organisations.

**Administrator:** The administrator is responsible for the overall regulation of the project implementation and all the necessary data and documentation required for it. In so doing, they ensure that the project is running on schedule, effectively and without problems. They are the first point of contact for the liaison if any discrepancies should arise from any aspect of the project. Similarly, they are responsible for communicating to both on-site and off-site organisations and regulation bodies involved in the project itself.

**Liaison:** Liaisons act as on-site mediators between the different parties in the project to ensure that there is clear cut communication and contact between them all. Their duties include monitoring, regulation and constant updating of the project’s progress to the administrator. Any problems that occur will be addressed by the liaison and if it escalates out of control, will be forwarded to the administrator immediately for further action.

**Health trainers:** These personnel may include medical doctors, health and sanitation experts. They are expected to be knowledgeable in the area of HWTS methods alongside crucial sanitation practices. In so doing, trainers are responsible for the education of local users (and if applicable, workers) in the importance behind proper handling and maintenance of the filters. They must communicate their knowledge and expertise in a way such that there is little chance for misinterpretation of the information provided. Their primary aim will be to help the locals understand the importance behind good HWTS and the impact it has on water quality.
4.3.3 Education

Despite that the HWTS program seemingly relies heavily upon the technological aspect (filter), it is also highly dependant on the appropriate education to bring about its success. It is crucial that users be educated in the proper construction, operation and maintenance of the filter in order to maximize its performance. Similarly, it is desired that the community should gain an understanding into the importance of HWTS in preventing water borne disease and maintaining good water quality. As community members only possess a basic education in literacy and health and sanitation, it is critical to ensure that they do not misinterpret the facts and specifics of the HWTS program. In this, it is proposed that illustrated manuals, brochures and in-house posters are used to assist users with low literary capabilities. An example of these illustrations can be seen in Section 4.3.4. To further support the program, the trial projects will also be aimed to monitor (this can be done by the administrator or health trainer) how the education is put into practice by the community members and whether they will demonstrate perfect understanding of what they have been taught about HWTS.

Similarly, it has been identified that for the program to work effectively, some personnel will require education in the workings of the community before the commencement of the project and program.

**Education for field technicians:**

Aside from the knowledge that field technicians should be expected to have in ceramic pot filter construction, manufacture, operation and maintenance, it is necessary for them to understand the local culture and context of the community that are to service. Generally, an on-site visit of at least four weeks is required for the field technician to gather the appropriate data to evaluate the best means to service the community.
Table 4.3.1: Education outcomes for field technicians

<table>
<thead>
<tr>
<th>Education outcomes – Field technicians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should demonstrate:</td>
</tr>
<tr>
<td>• Knowledge of the culture of the community</td>
</tr>
<tr>
<td>• Knowledge of the status quo in regards to natural and acquired resources</td>
</tr>
<tr>
<td>• Understanding of the issues with water quality pertaining to bacterial and salinity presence</td>
</tr>
<tr>
<td>• Capability to design or construct the appropriate filter to meet the needs of the community</td>
</tr>
<tr>
<td>• Understanding of current HWTS methods</td>
</tr>
</tbody>
</table>

**Education for health trainers:**

Similarly, the health trainers, whilst experts in the area of health and sanitation practices, will require a basic education in the culture, education and lifestyle of the community. It is necessary for the trainers to understand the context of how Devikulam operates day-to-day from the individual perspective to the community as a whole. This is aimed to provide trainers with the appropriate data and information on how to best integrate the program into the lives of local citizens and educate them effectively in proper HWTS. It is crucial that the trainers aim to include and welcome as many individuals as possible to produce an effective education outcome in this program. Also, the trainers will need to be familiar with the operation and maintenance of the filter before the commencement of the project.
Table 4.3.2: Education outcomes for health trainers

<table>
<thead>
<tr>
<th>Education outcomes – Health trainers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should demonstrate:</td>
</tr>
<tr>
<td>• Knowledge of the culture of the community</td>
</tr>
<tr>
<td>• Understanding of the issues pertaining to water quality threatened by bacteria and salinity</td>
</tr>
<tr>
<td>• Ability to effectively communicate knowledge to the community in the best way</td>
</tr>
<tr>
<td>• Understanding of the specifics behind the ceramic pot filter’s operation and proper maintenance</td>
</tr>
<tr>
<td>• Be able to provide practical demonstrations of the filter’s operation and maintenance</td>
</tr>
<tr>
<td>• Understanding of the community’s education system</td>
</tr>
</tbody>
</table>

**Education for the users:**

Most importantly, the users themselves will require the bulk majority of education in regards to operating and maintaining the filter, as well as learning that not all water is potable. Water extracted from the household taps connected to the community storage tanks (and subsequently, the bores) are of the same quality throughout the entire distribution process. It is important that users understand that the filter is necessary for them to maintain a constant supply of clean drinking water. Much emphasis will be needed on the importance of maintaining the filter consistently after it has been integrated into the household. The education of the users can take place in a variety of innovative ways, all aimed to maximize interest and attention to the material being presented. These can include, but are not limited to, workshops, personal tutorials, community-wide forums, practical demonstrations and public meetings. It is imperative that the community members be made welcome and included in every aspect of the HWTS program to facilitate effective learning and adoption of the information.
**Table 4.3.3: Education outcomes for end users**

<table>
<thead>
<tr>
<th>Education outcomes - Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should demonstrate:</td>
</tr>
<tr>
<td>• Understanding of the need for good HWTS and sanitation practices (the impact on maintaining potable water)</td>
</tr>
<tr>
<td>• Knowledge of the filter’s operation and maintenance</td>
</tr>
<tr>
<td>• Ability to operate and maintain the filter independently</td>
</tr>
<tr>
<td>• Capability to teach each other in the use of the filter</td>
</tr>
<tr>
<td>• Understanding of current issues with the water quality and how it relates to the importance of HWTS</td>
</tr>
<tr>
<td>• Understanding of the importance of boiling any water before consumption</td>
</tr>
</tbody>
</table>
4.3.4 Implementation procedure

Operation and maintenance are simple and straight-forward making the filter an effective solution for point-of-use treatment and storage. Through use of the filter, it is expected that it will improve family health, reduce risk to health, and provide a cost-effective solution to the problem of contaminated water over the long-term.

1. **Take care to avoid cracks.** Handling of the ceramic pot and filter must be done carefully to avoid breaking or cracking it. Small invisible cracks may cause microorganisms to pass through the filter, reducing the overall effectiveness of the filter and making the water unsafe to drinking over an extended period of time. If the filter is full and takes less than (approximately) 3 hours to empty, the flow rate is too fast and it should be replaced immediately.

2. **Before using the filter for the first time.** Soak the ceramic pot in clear water (rainwater or borehole/well/ground water) for 12 hours. Fill the ceramic pot three times, allowing water to seep through, and then discard the filtered water.

Each one of the above steps will flush the smell of clay and colour from the pot. It is only required that one of the above steps be taken, it is not necessary to do both.

Lastly, clean the receptacle tank and spigot with soapy water.
Place the filter in a safe place where it will not get knocked over and secure it to a wall or a post if possible.

If the water source is observably very dirty, tie a piece of cloth over the top of the filter to strain out the dirt and debris.

The filter will flow faster when the ceramic pot is full, so fill it often. Although, this does not necessarily attribute to better filtration of the contaminants in the water.

Keep the lid closed at all times if possible, to prevent contamination from the open air from seeping in.
3. Cleaning the filter. The ceramic pot should be cleaned once per month or when the flow rate begins to slow down. Clean the inside of the lid with soapy water and allow it to dry. Place the lid on a level surface with the clean side facing up.

Carefully lift the ceramic filter out of the receptacle and set it on the lid. Touch only the rim when lifting the filter. Do not touch the outside of the ceramic filter with dirty hands and do not set it on an unclean surface. Scrub the inside of the ceramic filter with a cloth or soft brush and rinse with clean water.

Do not use soap to clean the filter. However, clean the receptacle tank and spigot with soapy water. Put the ceramic filter into the receptacle tank immediately after cleaning the latter to prevent recontamination. The filter does not need to be dried after cleaning.

Good hygiene. It is important to continually practice good hygiene along with good filter maintenance to ensure that the water leaving the system always stays clean. In this, do not touch the outside of the ceramic filter, the inside of the receptacle or the spigot opening with dirty hands.
Place the filter off the ground in a clean and tidy area.

Wash hands and drinking glasses often with soap and water.

NOTE: All images associated with Section 4.3.4 are the property of A Layman’s Guide to Clean Water (http://www.clean-water-for-laymen.com/water-filter-maintenance.html).

4.4 Rainwater capture

4.4.1 Implementation Plan

The modified talab system requires no special implementation process. The bulk of the work comes from physically digging and filling the trenches, which should not be difficult for a team of workers with basic tools and plenty of cooperation.
Strengths and weaknesses for each individual aspect of the system were outlined in the option selection section. Therefore this section details the strengths and weaknesses of the system as a whole.

The major strengths of this proposal is the sense of unity and community involvement it encompasses. The system builds upon existing technology and facilities that the people of Devikulam know and understand by adding new features and improvements that will make a profound difference to their lives. This ensures that the community will be accepting of what is being done. Each aspect of the proposal that has been chosen is designed to be implemented by the community on their own with minimal guidance (after initial training by skilled workers). This gives the community a sense of ownership, pride and a deep understanding of how everything works and how it will benefit them.

A major weakness with this proposal is that it may be too much to implement it all at once. It will most likely be necessary to implement each part in stages with appropriate monitoring throughout the entire process.
Next steps

This proposal will most likely have a profound affect on the community. The people of Devikulam will initially have some work to do to get the system in place. However, the beauty of this is that the people of Devikulam will have the opportunity to take charge and get a total understanding of the system. There will also be some minor ongoing maintenance, which may be shared among the community. The building, construction and maintenance of the system will provide the community with a sense of ownership of the project.

If everything goes well, the people of Devikulam will be able to access their taps and have access to clean drinking water twenty four hours a day. If a sick child needs a cool bath in the middle of the night, their mother will now be able to access as much water as needed without leaving her child's side. This will make the community members’ daily lives much easier and they should not have to worry about the possible contamination and reduction of their water supplies for the foreseeable future.
7 Evaluation

Now that all of the design information has been presented and discussed, the overall proposal can be evaluated with respect to the initial design requirements.

“A. Cultural acceptance/awareness: Any part of the proposed system must be accepted by the community and fall within the laws/ethics of the community. Similarly, the system must not cause any major upheaval of the community's way of life, unless absolutely necessary and only after careful consideration of the pros and cons.”

Each aspect of the chosen design has been researched and thoroughly thought out so that the community is as likely as possible to embrace the system. The system will not cause a major change to the community's way of life, but it will require a slight paradigm shift within the community. They will have a greater level of control and responsibility for their own water supply, which will hopefully empower the community.

“B. Sustainable: The proposed solution must be available for generations to come. All facets of the technology must be easily implemented and maintained with little to no undesirable outcomes on the social, environmental and economical aspects of its context. Furthermore, it must maintain a constant standard of optimal functionality for the foreseeable future.”

Because the entire design processes encompassed sustainable design practices, the system as a whole should be sustainable. It uses reasonably basic technology that is simple to implement, operate and repair, making it a system that can last a very long time. This is provided the proper maintenance is performed regularly.

“C. Cost-effectiveness: The proposed solution must not be economically stressful for the financial sponsor. We must be looking to maximise any investment into the proposed system to produce the maximum amount of benefit for the minimal amount of drawbacks for the community. Simply, the community must get maximum 'bang for their buck'.”
Much deliberation and conjecture was entered into over the costs of this project. We eventually came to the conclusion that we must focus on ideas that can potentially be funded by the EWB in conjunction with private investors. Therefore, we have kept solutions as cost effective as possible. The only real cost comes from materials required in the DEWATS and the batteries for the pump, which are all quite cheap given the tasks they can accomplish. This leads us to conclude that our choices are very cost conscious and effective.

“**D. Accessibility:** We must consider accessibility of the people to the technology and the technology to the people. The community should be allowed minimal effort in accessing the products of the proposed system and likewise, there should be minimal effort for the construction and maintenance of the technology.”

The proposed solution is strongly focused on providing seamless, constant access to clean, drinkable water which exactly fits our objectives. the technology involved is not overly complicated, thus the technology should be completely accessible to the people both physically and mentally. We have also chosen ideas that are easy to build and maintain, which is directly aligned with our design requirements.

“**E. Safety:** This aspect must encompass the entire process of the proposed solution. Simply, the technology itself must not pose a hazard to the health and safety of the community throughout its entire life span (e.g. during construction, use, maintenance etc.). Also, the products of the technology (e.g. waste water from the process etc.) must not at any stage impact the context to which it is servicing (e.g. social/people, environmental etc.) in an undesirable way.”

The final design is very safe as it introduces no significant new technology, buildings or facilities into the community. The DEWATS is essentially an extension of the pond which can be partially built into the pond so that it is completely safe. None of our proposals will produce any dangerous by products, thus bringing the safety factor up.

From the above, it can be seen that we have truly met all of our stated design requirements very well.
8  **Cost Analysis**

Cost of treatment: DEWATS: $450 ~ 23,600 INR, including labour

Clay Pot Filter: $200 ~ 10,500 INR

Cost of water transport: $7,300 ~ 382,810 INR

Cost of household storage: Clay pots $25/pot ~ 13,310 INR

Cost of rainwater capture: Possible materials, $14 ~ 734 INR.

It is plain to see that each aspect was kept as cost effective, and cheap as possible. The total cost to implement this system is approximately $8000 AUD, which is about 418,700 INR. The major cost comes from the battery for the pump, if a cheaper source can be found it is highly recommended that option is taken. External funding will be crucial to attaining a battery for the community. Everything else however, can be purchased by the community as a group. This is a very reasonable price that the community will most likely accept to pay for clean, safe drinkable water on demand.
Conclusion

Our proposed system of treating water from the pond with a DEWATS system, fed into a filter which is then directed into the existing storage tanks by means of a reliable, battery supplemented pump. This will greatly augment the existing water supply in Devikulam. Rainwater capture practices will also help replenish vital groundwater supplies in the area, helping to provide adequate bore water for generations to come.

We understand the proposed solution is broad and covers a numbers of areas. However this was a necessary part of the project as it was realised that the aspects of water we have looked at are very much interrelated. For example, if we supplied to village with treated water but their distribution system was faulty, they would have treated water, but no access to it.

Overall, a solution that can realistically be implemented into Devikulam has been proposed. It is a system that is sustainable, self reliant and requires little shift in terms of what community members will have to do to maintain it. Obviously we are confident the system will provide the community with constant access to a vast quantity of clean drinkable water and in this sense the quality of life in the community of Devikulam will be greatly increased. Water -after all- is one of mother natures great gifts and if this report is to be put in to action the people of Devikulam will at last have access to this precious and delicate resource.
References


Moringa tree image; http://www.treesforlife.org/our-work/our-initiatives/moringa, 16/10/11.


http://www.sapindusmukorossi.com/, (13/9/11).

http://www.treepeople.org/, (13/9/11).
http://www.treesforlife.org/our-work/our-initiatives/moringa
http://en.wikipedia.org/wiki/Moringa_oleifera


EWB Water Innovations Report: download from the EWB site

EWB FAQ: Provide links to the appropriate threads

EWB Devikulam Survey: download from the EWB site


USGS water science, Groundwater depletion: http://ga.water.usgs.gov/edu/gwdepletion.html

EWB Industry Development Report:

Resource Development International Cambodia (RDIC): http://www.rdic.org/

Maps of Devikulam;

Maps of India provided by the Indian Government. Includes annual rainfall and soils
http://www.surveyofindia.gov.in/soi_geo.html (24/10/11)


Wind Power in india http://en.wikipedia.org/wiki/Renewable_energy_in_India (24/10/11)

About bores, tanks and other infrastructure: http://www.ewb.org.au/discussions/988/10826 (24/10/11)

Where they currently get their water:
http://www.ewb.org.au/discussions/988/10836 (15/10/11)

About contaminates in lake (bottom)
http://www.ewb.org.au/discussions/988/10908 (15/10/11)

Bacteria Source: http://www.ewb.org.au/discussions/988/10846 (15/10/11)

DEWATS
http://indiasanitationportal.org/category/category/drinking-water


http://www.sozialstruktur.org/en/files/DEWATS05_09small.pdf (all (24/10/11))
Rainwater harvesting:
http://www.rainwater cambodia.org/index.html (24/10/11)

Monsoon season and climate in India: http://www.imd.gov.in/section/nhac/dynamic/weekra.htm (24/10/11)
http://www.mustseeindia.com/Devikulam-weather (24/10/11)
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The World Health Organisation (WHO):
http://www.who.int/water_sanitation_health/en/ (24/10/11)

WHO Guidelines for Drinking-Water quality:
http://www.who.int/water_sanitation_health/dwg/2edvol2p1.pdf (24/10/11)

Pure desalination seawater distilled for third-world communities: (24/10/11)


SODIS method: http://www.sodis.ch/methode/anwendung/index_EN (24/10/11)


The global water crisis:

Status of implementation, critical factors and challenges to scale-up of household water treatment and safe storage technologies: http://www.safewaterintl.org/HWTS%20Options.pdf (24/10/11)

Suzanne E. Young (Thesis):

Challenges in Implementing a Point-of-Use Water Quality Intervention in Rural Kenya:
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1446827/ (24/10/11)
Appendix A:

Team meeting log’s and reflection.

• Initial meeting, idea’s went on to an online program called ‘Prezi’. Thoughts of the group probably scattered.
• Visualisation methods used to get the groups progress underway, potential a non-useful exercise
• Loose team contract developed identifying teams strengths and weaknesses and the underlying values to which we want to work as a team
• Research done on general area’s
• Idea’s about what our system may look like developed; initial system with one pond, a solar driven pump and a gravity fed pump. Discussed potential for a two tank two pond system but concerns raised over whether that would emphasis a caste divide
• Problems identified with the system in place and more research needed to be done.
• A ‘what do we know/what solutions are available to us/what do we need to know’ chart drawn up.
• Conversation 8/9/11: It was discovered that water could be subject to contamination if stored in an open-aired container. Can’t expect people not to store water in their house, have to look at ways to make storage in their house safe and clean - part of the education campaign. Defined what we meant when we want to supply the community with water and sanitation. Decided we needed to start making some decisions around the actual project as the other parts of the project (i.e education campaign etc etc) may be more important. Looking at what we want to implement as far as toilets go.
• Identified the status quo of the community and what is currently available in regards to their water resources infrastructure. Investigated possible solutions and design proposals.
• 22/09/2011 - We met and presented all the possible solutions for every aspect of our system. We rated every suggestion from 1-5 to better be able to make a decision. We now have a proposed system that we are going to continue work on.
• 26/09/2011 - Revisited the design requirements, defined and discussed sustainability, discussed and defined where we are now and where we want to be by next Wednesday. Assigned tasks to make the report more uniform.
• 29/9/2011 - Brought all of our current work together and then realised that we had some overlap, so we went back and set out exactly who had to do what. We also looked at a possible design for our solution.
• 6/10/11 - this week we began to get close to starting the report, we found that we had some great stuff for a first draft, which we began making more polished. We fully fleshed out how our proposal will look and integrate together.
• 13/10/11 - We began coming things for the report. most of our proposals were ready, we knew what we wanted to implement for a solution. We revisited our proposal and found that we did in fact have a solution the fit our proposal, exactly as we had hoped, this was a great start. We also began breaking up tasks in the introduction and technical review section. the work really began to pick up now.
• 20/10/11 - this week we had a mini freak out. We found out that the finished report was due in just over a week- we did not expect this as no one was ever told when submissions were due. we got the technical review done and worked really hard to get the remainder of the report like the implementation plan and discussion ready.
• 25/10/11 - everything was written up. the conclusion, team reflection and executive summary was done during the week prior, many late nights were had by all. We got our presentation ready for the next day. we were were getting nervous, but also relieved that we were so close to done. just some minor polishing of the report was left.
• 27/10/11 - Relieved that we had gone so well in our presentation, the final report was formatted and made more professional and submitted. We all celebrated, but celebrations were cut short as we all had to return to study for our other subjects.
Appendix B

Appendix B1

Please note these calculations are a model and there is no way we can guarantee their absolute accuracy given the inconclusive information available to us.

Current water use per day:

1100L/day for the whole community

Therefore, given 386 people in the community:

2.84L/person/day

Desired level (per person per day);

25L/person/day

Desired level (for the community/day):

9650L/day

Plan to have bores to continue to supple 600L/day

Therefore the water to come from the pond

\[ P = 9650 - 600 \]

\[ = 9050 \text{L} \]

Obviously it must be considered whether or not this will be sustainable in terms of the lifespan of the pond.

It has been found through 3 different models of the pond, assuming it has a maximum depth of 4m and radius of 61.9m

\[ V(\text{pond}) = 32.9 \times 10^6 \text{L} \]

Hence the water available to us, without making the water level drop by any more than 500mm is

\[ V(\text{pond available}) = 8.8 \times 10^4 \text{m}^3 = 8 \times 10^6 \text{L} \]

If 25L of water per person per day is used, (9050L per day), the pond will last for:

\[ T = (8 \times 10^6 \text{L})/(9050) \]

\[ = 883 \text{ days} \]

This is more than sustainable
## Appendix B2: Native plants

<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Justicia pandanassa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrus precatorius</td>
<td>Koempferia galanga</td>
</tr>
<tr>
<td>Acalypha indica</td>
<td>Lawsonia inermis</td>
</tr>
<tr>
<td>Achyranthes aspera</td>
<td>Limonium acidissima</td>
</tr>
<tr>
<td>Acorus calamus</td>
<td>Michelia champaca</td>
</tr>
<tr>
<td>Aegle marmelos</td>
<td>Mimosa pudica</td>
</tr>
<tr>
<td>Aloe vera</td>
<td>Mimulus glomeratus</td>
</tr>
<tr>
<td>Alpinia galanga</td>
<td>Morinda rubescens</td>
</tr>
<tr>
<td>Andrographis paniculata</td>
<td>Nectandra arb-utris</td>
</tr>
<tr>
<td>Asparagus racemosus</td>
<td>Ormocarpum semideps</td>
</tr>
<tr>
<td>Azadirachta indica</td>
<td>Oxalis corniculata</td>
</tr>
<tr>
<td>Azima teracantha</td>
<td>Paecilozone ovata</td>
</tr>
<tr>
<td>Baleoperum montanum</td>
<td>Phyllanthus emblica</td>
</tr>
<tr>
<td>Barleria prionitis</td>
<td>Piper longum</td>
</tr>
<tr>
<td>Calotropis gigantea</td>
<td>Piper nigrum</td>
</tr>
<tr>
<td>Carludovia umbellata</td>
<td>Plumbago zeylanica</td>
</tr>
<tr>
<td>Catharanthus roseus</td>
<td>Premna serratifolia</td>
</tr>
<tr>
<td>Centella asiatica</td>
<td>Pentadactya vicieida</td>
</tr>
<tr>
<td>Cissus quadrangularis</td>
<td>Pierocarpus marzapin</td>
</tr>
<tr>
<td>Cissus segetosa</td>
<td>Punicia granatum</td>
</tr>
<tr>
<td>Coleus aromaticus</td>
<td>Bauhinia tetraphylla</td>
</tr>
<tr>
<td>Curculeg orthodes</td>
<td>Salacia chinensis</td>
</tr>
<tr>
<td>Curcuma longa</td>
<td>Sanserviera rosburghiana</td>
</tr>
<tr>
<td>Cynocephalus citrius</td>
<td>Sapindus emarginata</td>
</tr>
<tr>
<td>Dasycarpha ninosa</td>
<td>Saurauia androgynus</td>
</tr>
<tr>
<td>Eclipta prostrata</td>
<td>Solanum trifoliatum</td>
</tr>
<tr>
<td>Euphorbia antiquorum</td>
<td>Stachyphyla jamaicensis</td>
</tr>
<tr>
<td>Euphorbia nivalis</td>
<td>Syzygium cumini</td>
</tr>
<tr>
<td>Euphorbia tirucalli</td>
<td>Thebesia populnea</td>
</tr>
<tr>
<td>Glycosmis mauritianus</td>
<td>Trypomora cordifolia</td>
</tr>
<tr>
<td>Gymnema sylvestre</td>
<td>Tylophora indica</td>
</tr>
</tbody>
</table>
Appendix B3


The most common mistake when planting a tree is a digging hole which is both too deep and too narrow. Too deep and the roots don’t have access to sufficient oxygen to ensure proper growth. Too narrow and the root structure can’t expand sufficiently to nourish and properly anchor the tree. As a general rule, trees should be transplanted no deeper than the soil in which they were originally grown. The width of the hole should be at least 3 times the diameter of the root ball or container or the spread of the roots in the case of bare root trees. This will provide the tree with enough worked earth for its root structure to establish itself.

When digging in poorly drained clay soil, it is important to avoid ‘glazing’. Glazing occurs when the sides and bottom of a hole become smoothed forming a barrier, through which water has difficulty passing. To break up the glaze, use a fork to work the bottom and drag the points along the sides of the completed hole. Also, raising the centre bottom of the hole slightly higher than the surrounding area. This allows water to disperse, reducing the possibility of water pooling in the planting zone.

Planting Bare-Rooted Trees

Planting bare-rooted trees is a little different as there is no soil surrounding the roots. Most importantly, the time between purchase and planting is a more critical issue. Plant as soon as possible.

When purchasing bare-rooted trees, inspect the roots to ensure that they are moist and have numerous lengths of fine root hairs (healthy). Care should be taken to ensure that the roots are kept moist in the period between purchase and planting. Prune broken or damaged roots but save as much of the root structure as you can.

To plant, first build a cone of earth in the centre of the hole around which to splay the roots. Make sure that when properly seated on this cone the tree is planted so that the ‘trunk flare’ is clearly visible and the ‘crown’, where the roots and top meet, is about two inches above the soil level. This is to allow for natural settling.
Watering

Newly planted trees should be watered at the time of planting. In addition, during the first growing season, they should be watered at least once a week in the absence of rain, more often during the height of the summer. However, care should be taken not to overwater as this may result in oxygen deprivation.

If you are uncertain as to whether a tree needs watering, dig down 6-8 inches at the edge of the planting hole. If the soil at that depth feels powdery or crumbly, the tree needs water. Adequately moistened soil should form a ball when squeezed.

Regular deep soakings are better than frequent light wettings. Moisture should reach a depth of 12 to 18 inches below the soil surface to encourage ideal root growth.
Appendix B4

Appendix B4.1 - Contact details for Clay Pot manufacturer

Nirmala Stanley
2/41 - VIP Nagar,
Vilankurichi Road,
Ponducherry - 641035,
Tamilnadu,
India.
Phone: + 91 98430 90817
http://www.indianmirror.com/contact_us.php

Appendix B4.2 - Images of plants used


Moringa Tree [http://www.ilovemoringa.com/contact.html]
Appendix B4.3 - Warning Signs

Obviously some language changes will need to take place but take note of the images. Some warning messages that you would like to consider including can be found in table 1 below.

Table 1: English to Tamil translations of possible sign warnings

<table>
<thead>
<tr>
<th>English</th>
<th>Tamil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning! Keep out.</td>
<td>பாதகில்லை ! கிமு அப்ப டும் டும்</td>
</tr>
</tbody>
</table>
Appendix B5 - Manufacturing Plan for Ceramic Pot Filters

Please note that the manufacturing plan for the Ceramic Pot filters is not a step that we are proposing as part of this report, but rather an aspect that could be implemented if the people of Devikulam in conjunction a group or individual with experience in marketing and business see a need and benefit for it. This aspect will manifest itself into a business and hence will have livelihoods dependant on its success. Consequently we strongly advise against implementing this aspect unless relevant knowledgeable bodies see a need and benefit from it all the while having the project driven by the people of Devikulam

Please note that the contents in this appendix have been adapted from publications by Resource Development International – Cambodia (RDIC) and other resources mentioned in table 1.

1. Manufacturing Overview

While there are many reports that describe the production method involved in Ceramic Pot Filters, it has been identified that the ‘RDIC 10 Step Method’ is simplest and most proven. With that said there is a list of other relevant reports attached which may be useful given the failure of RDICs’ report. We do not wish to reproduce this report but rather bring light to its importance and viability. Our aim is that by reading this appendix, you will be more inclined to feel that this is an achievable goal. We have also assumed that relevant infrastructure and equipment is available for use. As while a great deal of work goes in to setting up this infrastructure initially, once this has been completed the manufacturing process is quite straight forward, in line with what we are attempting to illustrate.

Making the Ceramic Pot filters in not and overly arduous task and the majority of materials can be sourced locally. A list of inputs and outputs that are found in to the process can be found below.

Inputs
1. Clay material feedstock – unfired
2. Ground rice husks or other combustible organic material - added to clay material to produce the pores in the ceramic when burned in kiln
3. Water for mixing with the clay
4. Water for testing of fired pots (mostly internally recycled)
5. Plastic bags for the mechanical pressing process (2 per pot)
6. Silver solution as natural disinfectant in the finished pots
7. Plastic receptacle, tap (faucet), and scrubbing brush for use of filter
8. Physical labour

Outputs:
1. Ceramic water filter systems with an approximate lifespan of 3 years
2. Employment/wages for local community workforce
3. Clay powder from brick crushing and grinding
4. Plastic bags from mechanical pressing process
5. Faulty filters that do not meet quality control can be used for other purposes (turned into road fill etc)

The RDIC 10 Step Method is summarised below

Step 1 – Preparation of raw materials *
Step 2 – Mixing clay, combustible organic material and other components
Step 3 – Forming clay cubes for pressing
Step 4 – Pressing of clay cubes into ceramic filter form
Step 5 – Surface finishing and labelling of pressed filter
Step 6 – Drying of pressed filter elements #*
Step 7 – Firing of filter elements *
Step 8 – Flow rate testing of fired filter elements
Step 9 - Application of the colloidal silver solution on surface of filter element and quality control of filter dimensions ^
Step 10 – Packaging of filter systems and replacement parts ^

Key
Manual Labour required: *
Outsourced parts required: ^
Time lapse of greater than 1 week: #
2. Part Drawings

The real beauty of the Ceramic Pot filter is in its simplicity, as can be seen from Image 1 below. The dimensions of the filter are set by the mould but are generally 30-40cm in diameter at the top and 20-25cm at the bottom. In this, the dimensions are entirely customisable according to the needs of the users.

![Diagram of Ceramic Water Filter Components]

*Figure 1. Parts of the Ceramic Water Purifier*

4. Further Information

While setting up this industry in Devikulam would be fantastic not only for the proposed treatment system, the primary motive in doing so should be to bolster the local economy and improved livelihoods of not only those working at and running the business, but the whole community. It is our wish that if this is to be implemented that he or she who owns the business upholds moral values and ensures that the wider community benefits from the profits made.

The RDIC report that has been referred to throughout this appendix is entitled ‘Ceramic Water Filter Handbook’ (Version 1.1) and can be found online at the following domain:

Other resources can be found in table 2 below

<table>
<thead>
<tr>
<th>Name</th>
<th>What is it good for?</th>
<th>Where can it be found?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic Pot Filtration Construction</td>
<td>A solid and basic summary of the RDIC report</td>
<td>Online at <a href="http://www.clean-water-for-laymen.com/clay-pot-filter">www.clean-water-for-laymen.com/clay-pot-filter</a></td>
</tr>
<tr>
<td>Hydromission: ‘Water for the Thirsty in Jesus’ Name’</td>
<td>Introduces the potentially of utilising sand and rocks as further filtering the water</td>
<td>Online. Search for the title or follow this link directly: <a href="http://www.hydromissions.com/claypotfilt.pdf">http://www.hydromissions.com/claypotfilt.pdf</a></td>
</tr>
</tbody>
</table>

Table 2: Summary of useful resources for making Ceramic Pot filters

**Fin**