The Reed Bed Sewage Treatment System

2009 EWB Challenge

2009 EWB Challenge

Charmian Wong	309200024
Eric Au	309244994
Harrison Truong	309222494
Jeffrey Quan	309254698
Jimmy Young	309218829
Sawan Kathriarachchi	309201950

Waste Busters

Executive Summary

In today's society, the phenomenon known as globalisation has brought about a variety of change to many countries across the world. On one end, globalisation has allowed for the growth of many developed countries, opening up international markets and allowing for a greater standard of living throughout these economies. On the other end, however, there are many developing countries that still do not have the luxury of shelter, food and clean water.

Cambodia is one such country that continues to deal with such humanitarian concerns. In the region of Tonle Sap, the regional lake provides a home to much of the population, with people living in close proximity to, or even on the lake. Despite this, the inhabitants of Tonle Sap region face immense physical hardships in everyday life, such as minimal access to electricity, poor transportation methods and waste mismanagement.

Technological development is the answer to these problems. As engineers, we must innovate and improve on technology so that such solutions can be devised. Even so, engineers must also remember that we do not always have to look towards newer, more complicated technology to solve problems, but can replicate and contextualize established solutions as well. While considering our proposal, we came across a variety of alternatives which proved to be too complicated and costly to implement in the Tonle Sap region. These included the creation and placement of a bio digester and a vast piping system used to transport waste from within the village.

For the EWB Challenge (2009), the group Waste Busters proposes a solution to deal directly with the issue of waste management and water treatment. We propose to implement a system of reed beds, and a new education syllabus at a school in an attempt to raise awareness and foster methods to achieve improved water quality.

Social, environmental, economical factors had to be considered in the implementation of our reed bed system. On a social level, we had to ensure minimal impacts on the community's culture and way of life. Hence, it was decided that the system would be introduced into a school environment. By doing so, the younger population will then be able to develop a firm foundation on the importance of waste management.

From an environmental standpoint, the reed bed system is quite ideal. The choice of materials used in its construction is quite flexible, and there is the advantage that the materials can be fashioned out of local resources. The reed species, *phragmites karka*, which we intend to use for this system are native to the Tonle Sap region and therefore will be easily obtained. The process of this water treatment system is natural, requiring no input of energy and releasing no output of waste. Thus, it affects the surrounding environmental minimally.

The reed bed system is also economically viable. Materials required for this system can be obtained locally, with no requirement to import any special products. The proposal to implement the project on a small scale, school by school, means that the project will be economically manageable.

This project agrees with the ethical responsibilities of engineers as set out by Engineers Australia Standard. It is important we adhere to the nine Tenets of the Code of Ethics as outlined by the Institution of Engineers, Australia. Our aim to maintain a healthy relationship between the Tonle Sap villagers and Live & Learn means that we are keen on avoiding the conflict that arises from imposition of a foreign values system onto the pre-existing Cambodian-Tonle-Sap culture. Our aim is purely to assist in a healthier way of managing the waste-disposal issue.

An essential objective of our project is the promotion of economic and environmental sustainability, and the longevity of the reed bed system in the Tonle Sap region. We hope that the immediate benefits reaped from the reed bed will be propagated into the Tonle Sap region in future

generations. An advantage of our system in regard to environmental sustainability is its utilisation of a natural process of decomposition that allows for the treatment of grey[i] and black[ii] water with minimal labour input for maintenance. The reeds will need to be harvested seasonally but such harvest can be used as an additional resource such as, the thatching of houses or even sold to reap financial gain.

In addition to the physical and practical advantages of the physical system, we believe strongly that the project requires an education component. Through careful consideration and design, a primary education syllabus has been devised in conjunction with the implementation of the reed bed system. It seeks to educate the Tonle Sap children on the need to be responsible stewards of the environment, to carefully dispose of waste and the maintenance of their reed bed systems.

In conclusion, we believe, through design and critical analysis of our proposed Reed Bed Sewage Treatment System, that it is an environmentally, economically, socially and ethically viable solutiont towards the issue of waste and water management of the Tonle Sap Region. The reed bed system is a solution that answers the vision of Engineers Without Borders. The system is a definite step towards achieving a world where each individual and community will have adequate access to the "resources, knowledge and technology necessary to meet their self identified human needs." (EWB, 2006) We hope our system will pave the way for an improved quality of life for the Tonle Sap population.

[i] *Greywater – "Domestic wastewater other than that containing human excrete. E.g. sink drainage, or bath water" (Queen's Printer for Ontario, 2009)*
[ii] *Blackwater – water containing faecal matter or urine*.

Team Reflection

Before we launched ourselves into the rigours of the EWB Challenge, we first had to overcome the barrier of being relative strangers to each other. Over time and many tutorial-bonding exercises we became tight-knit team of first year engineering students. Using all of our determination, innovation and creativity, we were directed to tackle a real life scenario in the real world.

The beginning of the course was a slow start. It took time for ideas to be collaborated, and such initial proposals to be born, discussed, discarded and appreciated. We came across many obstacles, with communication being the main issue. With two group meetings a week, it wasn't enough time to spur us on to complete and decide on our design.

Finally, however, we settled on our proposal of the Reed Bed System. We were all interested and excited in the idea, and all believed the proposal to have merit. A natural Reed Bed system requiring low to no maintenance, cheap, and flexible in design? The idea sounded like the most feasible idea in tackling the humanitarian concerns brought on by the EWB Challenge. We were finally moving forward.

Research followed. In true team spirit, we picked parts of the design we were most interested in, and promised each other to meet the deadlines we set. This was all done to great effect. The two meetings a week, evenly spaced between the five weekdays also helped us keep in contact with each other, so discussion and the development of insight and advice was not an issue. Many times, we were so caught up in perfecting our design, and delving into its economic, environmental and social implications that we ran over the given meeting times. Our group was coming together with great spirit and determination.

In undertaking the EWB Challenge, we would all agree that it has been rewarding and a valuable experience for all of us, allowing our development, both on an individual and team basis. Co-operation as a result of continuous team collaboration has definitely improved, whereas on an individual scale, the ability to complete responsibilities and meet deadlines has also strengthened our character.

-Waste Busters

An Expression of Thanks

The Waste Busters would like to thank the University of Sydney for the opportunity to partake in such a noble challenge. We especially thank our tutors, Peter Sistrom and Chak Yu for the invaluable support and advice they gave us.

Table of Contents

Waste Situation

The Current Environmental and Socioeconomic Climate

Environmental Situation

The environmental situation and the socioeconomic climate of the Tonle Sap region is one of poor standard in comparison with the rest of the world. The region suffers from a severely inadequate waste management system and poor ethics regarding waste disposal such as the dumping of waste into the Tonle Sap Lake. This consequently affects the sustainability of the Tonle Sap ecosystem but also encourages poor sanitation and hygiene. We propose to implement a solution that incorporates the sustainable management of sanitation, and also introduce an education system which will educate villagers on the need for a waste management system, hence fostering wider acceptance of the system across the region.

The current waste situation in the Tonle Sap region is adverse. The hygiene state is of primary concern as villagers drink and bathe in the lake which is frequently pumped with human and animal faeces. Of concern is the fact that the Tonle Sap villagers have no current efficient or sustainable way of managing their waste disposal. Villagers are constantly diagnosed with malnutrition or related diseases such as diarrhoea and skin infections.

Another important aspect of Tonle Sap that we hope to deal with is water quality and its availability. Despite their close proximity to the lake, villagers of Tonle Sap have limited access to the

fresh and clean water. Inhabitants of the area continue to defecate in the lake as well as continue to use the lake as a disposal site for much of their rubbish and other waste. The figures from the table below show that this problem is of pressing importance. Of all the regions in Cambodia, Tonle Sap has the highest rate of daily release of polluting substances to inland and ground water bodies.

Table 1: Daily release of polluting substances to inland and ground water bodies

Region	Faeces (Tonnes)	Urine (m3)	Grey water (m3)	BOD (Tonnes)
Phnom Penh	29	287	607	58
Plains	71	713	1777	196
Tonle Sap	77	765	3100	150
Coastal	26	257	1305	37
Plateau	31	314	1365	57
Total	234	2335	8154	497

(WSP) Water and Sanitation Program: Economic Impacts of Sanitation in Cambodia Summary, by the World Bank

Table 2: Selected water quality measurements in Cambodia

River (location) (Wet season)	Total Release; (faeces, urine, grey water)	Polluting Substances (BOD)
Tonle Sap River	120	3.4
Mekong River	175	5.5
Tonle Sap lake	661	6.5

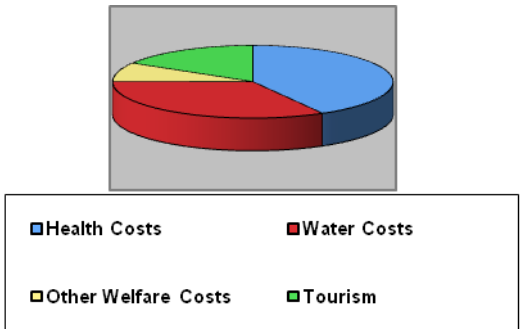
(WSP) Water and Sanitation Program: Economic Impacts of Sanitation in Cambodia Summary, World Bank

Table 2 compares the total water quality in the river regions across Cambodia. It can be seen that the Tonle Sap Lake has the worst, by a large margin, water quality compared to the two other rivers in the country.

Economic Situation

Like many developing countries, Cambodia is heavily reliant on the international market in order to attract funds into its economy. It is the 24th-highest recipient of aid out of the 129 economies (Rapid Intelligence, 2008) and their debt level is at one of the highest levels reported in the Asia region at a staggering value of $US3,890,000,000. "The major economic challenge for Cambodia over the next decade is to create an economic environment in which the private sector can create enough jobs to handle Cambodia's demographic imbalance" (World Bank WSP Report, 2008).

The problem with the economy despite the billions of dollars flowing into it is that the existing services, technologies and infrastructures fail to meet the boom in resources and tourism. To make the issue even more problematic, more than half of the population is less than 21 years old. In addition, the general population lacks education and productive skills, especially in the poverty-stricken country side. The region of Tonle Sap itself suffers from basic infrastructure and waste management and sanitation (World Bank WSP Report, 2008).


Health Costs
Water Costs
Other Welfare Costs
Tourism

Literature Review

This section of the report will assess the implementation of previous projects in similar scenarios of the Tonle Sap region.

In Cambodia, many methods of water treatment have been devised and an attempt has been made to implement each of them. One of our initial proposals, and a previous consideration for the Tonle Sap region was the construction of a water delivery system through a series of pipes and water treatment facility. However, for this to be viable, the requirements are “high capital investment, a concentrated population large enough to justify construction, a suitable raw water source of high quality or centralized treatment, and ongoing operation and maintenance costs requiring fees of users”[Brown, 2007]. Effectively considered however, the Tonle Sap region lacks the majority of these requirements; capital for a developing country is difficult to come by, the implications of cultural and social lifestyle change would be enormous if the lake was partly transformed into a treatment facility, and “ongoing maintenance and costs” would be drastically difficult for the inhabitants to pay for. Through this first consideration of using a water delivery system, many problems that make the Tonle Sap region difficult to provide clean and effective water treatment are highlighted as obstacles to be implemented in for any project hoping to address this issue.

The four factors listed below:

- Cost
- Cultural and Social changes
- Maintenance
- Effectiveness

must be considered and effectively compromised to achieve a project of sound prospects and effective implementation into the Tonle Sap Region.

Ceramic Water Purifier

One such is the idea of a ceramic filtration system, which allows for the treatment of unsanitary lake water into clean drinking water. Aptly and professionally termed the “ceramic water purifier”, the treatment consists of a particular ceramic pot which acts as a filter for the water to pass through. Subsequently, the water is treated at a physical microbial level.

The successful use of the ceramic water purifier was researched by Joseph Mark Brown, who observed “diarrheal diseases prevalence proportion in the intervention groups would be ≥20% less than in control households (without access to a filter)” [Brown, 2007]. It can thus be inferred that the ceramic water purifier is effective in the prevention of viral diseases. Continuing locally made ceramic water purifiers are “lightweight, portable, relatively inexpensive, and low-maintenance.” [Brown, 2007].

Cost

In terms of cost, the ceramic water purifier is “US$10 in 2007” [Brown, 2007]. Considering the low level income of locals in the Tonle Sap region, this is, although effective, a difficult and economically unviable alternative for water treatment. In another sense, however, the ceramic water purifier can be produced on a local scale, thus inferring lesser costs than to a comparative and consequent imported solution that must be specially made from other areas or countries.

Impact

Due to its small size and relative ease in use, the ceramic water purifier would have a small impact on the cultural and social aspect of the Tonle Sap region. In current Cambodia, this type of water treatment is known as Point-of-use water treatment. The Ceramic water purifier has had a positive influence on the water usage of the Tonle Sap region, and will continue to improve in impact as technological advancements are made. However, where the ceramic filtration system is relatively

effective, a reed bed system that we propose will also exert the positive stigma and externalities on the society of Tonle Sap.

Bio-digester

Another attempt to manage waste in the area of Cambodia is through the implementation of the bio-digester. The theory behind the bio-digester is the storage of wastes such as human excrement to create another source of fuel for the community. As such, the use of a bio-digester provides a variety of advantages to the community. [Bui Xuan An, 2007] Wastes that would be considered pollution can be "reused" as an extra source of fuel-to-fuel fires, consequently lessening the pressure of other more valuable resources such as electricity and fuel wood. Furthermore, the "waste" that is then collected from the bio-digester can be reused again as fertilizer [Bui Xuan An, 2007].

Effectiveness

As with any waste management solution however, there are a myriad of issues that must be solved before it can be deemed effective and economically viable. In an actual recorded attempt to evaluate the effectiveness of such a solution, a farmer's survey was polled by Bui Xuan An et al. in 1996. They identified that a lack of proper education and skills deteriorated the effectiveness of the bio-digester's implementation, with the resulting issue of "using too much or too little manure" [Bui Xuan An, 2006]. Furthermore, the geographical placement of the bio-digester was an issue, as it was either too far for easy access, or either too close, giving of a polluting odour. [Bui Xuan An, 2007] The bio-digester has been in implementation since 1986 and has been most effective in waste management in the farming areas of Cambodia. The benefit of its implementation further outweighs the losses and thus can be used in waste treatment.

Cost

Cost can also be evaluated to be acceptable, due to its low-cost materials such as polyethylene, which would be relatively cheap compared to other alternative solutions to waste management. Ultimately, the bio-digester has been capable of treating some issues of waste in the region of Tonle Sap, but of course, much more can be improved on for it to be more effective.

Compost toilets

Another project that has been implemented recently in the region of Tonle Sap has been organized by Lien Aid, headed by Mr. Sahari Ani. They planned to introduce a system of "floating toilets" which would "provide better sanitation options for the floating communities on the Tonle Sap [lake]" [Sahari Ani, 2009]. Coupled with an education program, they also have ambitions to build "a floating water treatment plant" and "a land-based composting unit and collection system…to manage the semi-composted feces" [Sahari Ani, 2009]. Simply put, the floating toilets are to prevent more human excreta from entering the lake, giving the villagers an alternative of disposing of their wastes without polluting the lake, in a natural, easy and relatively simple manner.

The current issue is the fact that the "majority of residents defecate directly into the lake and that's what we need to prevent." [Sahari Ani, 2009]. To tackle this, Lien Aid has proposed the urine diversion-dissecting (UDD) toilet, which in effect "separates the liquid stream from the solid portion of excreta" [Sahari Ani, 2009]. Similar to our proposal, the implementation of Lien Aid's project has been done with proper consideration with foremost factors including economic viability, "cultural acceptability and ease of use" [Sahari Ani, 2009].

Cost

Costs of the toilet are quite flexible, and like our reed bed system, is dependant on the availability of local resources rather than imported materials. It is quoted to be "between US$50 to 200,

depending on…" [Sahari Ani, 2009] the full extent of the toilet replacements, size of the toilet and whether businesses are capable of manufacturing on a local scale.

Education has also been a main goal for them. Already, Lien Aid claims to have "heightened the communities' awareness on proper sanitation". This would contribute to the ease of cultural acceptance and ease of use, as education in waste management and will stress its importance and increase initiative from the local villagers to improve the situation.

Comparison with Waste Buster Proposal

The proposal of UDD toilets by Lien Aid is very similar to our proposal of a reed bed system. Both proposals are initiatives to deal with the problems of sanitary management and thus must have similar considerations such as cost, impacts of culture, sustainability. Furthermore, both groups, Lien Aid and the Waste Busters, are collectively using education to more effectively implement our designs, without causing vast changes which may disrupt the cultural balance of the area.

Initial Proposals

After considering the issue of waste management of the Ton Le Sap Region, there were a variety of solutions, with both advantageous and disadvantageous aspects, we considered before we reached our final proposal. In regards to the issue of waste, and its management, there were many ideas which had potential but were rejected for social, environmental and economic reasons. Amongst these were the bio digester and piping systems, which we, the Waste Busters, deemed unsuitable in the context of the EWB Challenge project with the time and financial constraints.

The Bio-digester

On a basic level, bio-digesters consist of a tank used for the decomposition of waste, ranging from human waste to food scraps. The materials used in a bio-digester may vary, depending on the type of waste it treats, as well as the people using it and their local resources. The bio digester allows for such waste to decompose anaerobically (i.e. without oxygen), creating biogas. Despite the supposed flexibility in using bio-digester, there were various issues that would have been difficult to deal with, on both a practical and economical basis. (Rural Costa Rica, 2009)

Cost

The implementation of a single bio-digester in the Tonle Sap community would be extremely expensive, “a simple and most inexpensive design is located in Sante Fe but requires materials such as cement and costs around 300USD” (Rural Costa Rica, 2009). For a population whose majority that lives on less than $US1 a day, a $US300 piece of technology is very inexpensive and economically inappropriate for the region. Other materials used to construct the bio-digester include plastic sheets for the walls, curved tubes and cement, which is mixed with sand. These materials are not easily found and are quite costly to deliver to the Tonle Sap region in Cambodia.

Environment

The bio-digester does not harm the environment. Although, since the machine can only digest faeces, it is a high producer of CO2, thus releasing it in large proportions into the atmosphere, consequently, contributing to the increased rate of the greenhouse effect (Rural Costa Rica, 2009).

Social/Cultural:

The bio-digester requires constant input of water to keep the system running, which would be quite new to the community and may not be widely accepted. The aspect of placing the faeces into the machine may also be a hindrance to the society of Tonle Sap as many would find it hard to adapt to the new procedure.

Reasons against the Bio digester

Factors of economic viability, limited use in the community, its high maintenance, and its difficulty to construct influenced our decision not to adapt such technology into our design. We deemed a bio-digester, as seen in the diagram below, would be difficult to be culturally accepted by the Tonle Sape community.

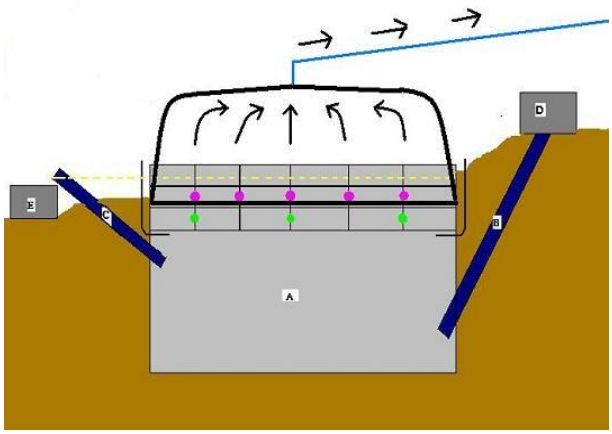


Figure 2: Implementation of a bio digester (Rural Costa Rica, 2009)

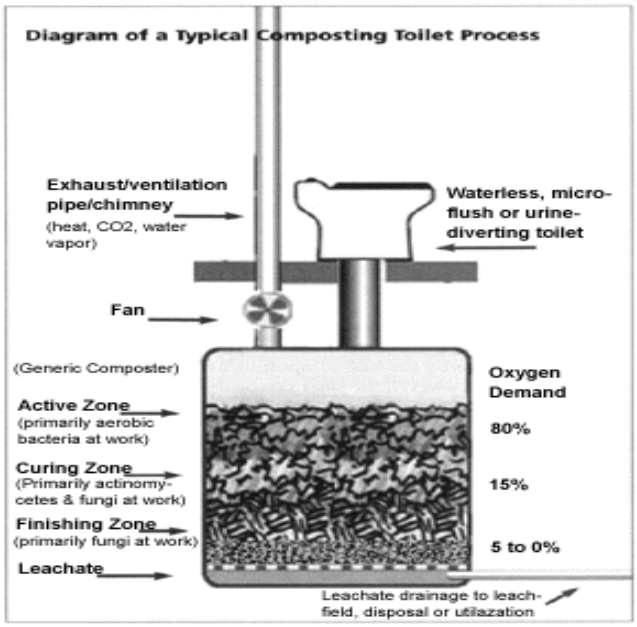
Piping

Piping System Proposal

The piping system consists of tubes made out of possibly PVC material and are attached to lavatories to extract faeces. It is also another alternative that can be introduced into the Tonle Sap region for waste management.

Reasons against the Piping System

Piping is a good idea to bring forth in many countries. However, for Tonle Sap, it would not be the best or most appropriate option. Housing components and public toilets (rare) are located in the middle of the lake in Tonle Sap. There is a major conflict in introducing piping into the Tonle Sap community as the construction of a piping system requires a lot of work and money; it is something too complicated to work and to remain sustainable in such an environment. Aesthetically, it could disrupt the aesthetics of the Tonle Sap Lake habitat.



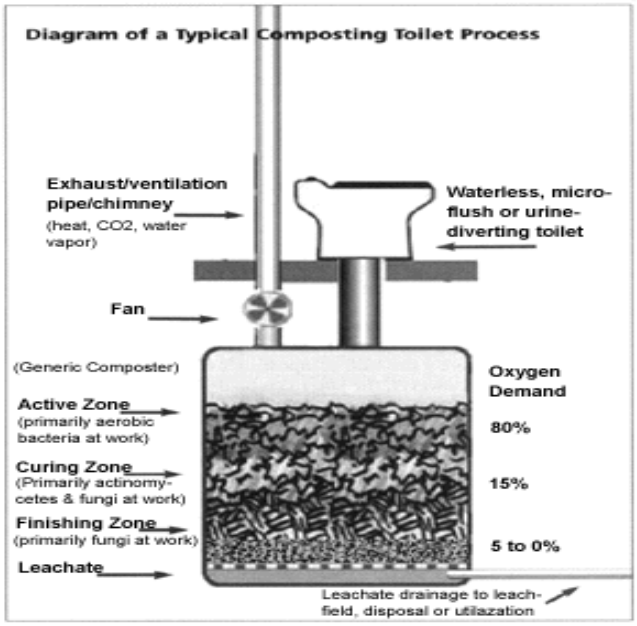


Figure 3: REUK, compost toilet design

Cost

On a small scale, the cost of the PVC materials would be affordable, however for large-scale production, piping for "12,000 square kilometres" (Asiaroom travel, 2009) would be quite costly. The primary concern and major money-consuming factor here is the underwater is a substantial task and heavy machinery is required to perform this task.

Environment:

The impact of introducing piping into the Tonle Sap region will not have a major effect on the environment. The only major concern, in placing pipes, is the potential leakage of pipes. Pollutants may enter the body of water and endanger the marine life, hence, reversing the benefits of the pipes.

Social/Cultural:

As a social and cultural aspect to piping, the end result of the faeces will have to be deposited in a certain location and this would cause large amounts of unwanted stench. Maintaining the pipes involves checking them for cracks. Should cracks appear, pipes may need to be replaced, which requires the locals to be trained. The villagers may refuse to work with faecal matter as it is considered a

demeaning task. This can be seen to be an adaptation issue and could have cultural conflicts in imposing such a concept.

The Reed Bed System

The reed bed system consists of reed beds designed in such a manner that they are able to filter out grey water (i.e. water used in washing, bathing and other domestic processes) and black water (i.e. water with human waste). The system's initial appeal was its flexibility in design, allowing the system to suit any landscape and be made of materials found in the surrounding environment. The filtered water is treated by a physical and chemical process which allows for its reuse in other domestic activities (e.g. washing of clothes, watering plants). Reed beds are environmentally friendly, cost-effective and overall, extremely efficient in its performance. The system works by first passing the grey or black water through a contained acting as the septic tank; sediments and large unwanted material are deposited. It is then followed by the process of evaporation, plant transpiration, and decantation within the reeds to clean out the water. This is a natural process that occurs in the presence of particular reeds and gravel, making it a very economically-viable solution. With it being a natural process, there is minimal to zero harm to the surround environment (Lismore City Council, 2003).

Cost

Firstly, cost and resources were the main factors affecting how and where to propose such a solution to the waste issue in Tonle Sap. The construction of a reed bed consists of cheap materials, such as pebbles, certain reeds (i.e. Phragmites Karka, commonly found within the Tonle Sap region), PVC piping and polyethylene. (Lismore City Council, 2003)

Environment

As the Tonle Sap region has already high levels of pollution due to the lifestyle of the villagers, i.e. disposing garbage into the lake, the system not only reduces the pollution level in Tonle Sap but also induces no other problematic harm to the environment. Another advantage of the system is that the

reed bed uses naturally-occurring process. Therefore it has strong credibility for sustainability and low-environmental impact. Also, subsequently, fewer life-cycle considerations.

Social

The main social factor to consider is to adapt to the cultural difference and, thus, having a program which would easily be introduced into the community effectively and efficiently. The reed bed system meets these criteria. It requires low levels of maintenance and can be easily built.

The Reasons for a Reed Bed System

As grey water is found in high volumes on the Tonle Sap Lake in Cambodia, it is necessary to initiate a device or program, which is simple and easily implemented, to aid in the waste management and the education system of this developing country.

Trade Off Table

The trade off table is a compilation of the main components for the choice of our project in designing and constructing an education system, to teach Cambodian children how to build a reed bed to filter grey or black water into less toxic and cleaner water to be re-used. The scores compiled below are gathered by the statistics of material and maintenance cost, its impact on the environment and the effects and changes for the current Cambodian community.

Firstly, the main component we took in consideration was the total cost of the project. The reed bed project was the cheapest out of the three due to the involvement in the process of the operation and also the materials required to construct such a device and program. The materials consisted piping which cost around $US0.30 per foot, therefore around about $US12, a good investment to educate the Cambodian society for many years to come. Materials also include rocks and reeds (Phragmite Karka) which are found within the region and would not involve any costs. The second component consisted of the impact on the environment; this played a major role in the choice for the initiative for the project. The reed beds, mechanism consists of filtration and natural river flow and the end result is only cleaner and re-usable water which can be used for washing and watering plants. Finally, the cultural impact of the design is seen to have minimal alterations to the current lifestyle of the Cambodians, as the design is aided to educate school children who have not developed and fully adapted to the life of their elders.

The other alternative, piping received a lower score due to the shape and sizes of the pipes that needed to be constructed. The change in shape and size requires additional human resources and machinery which are quite costly. The cost of piping for public toilets cost ten-fold compared to the piping involved in the design of the reed bed. This is because the pipes needed come in larger sizes therefore requiring larger revenue to develop such a mechanism to be incorporated into the daily lives of the Cambodian society, thus a lower score than reed beds. This also leads onto the problem of how it will be adapted into society. As for many years, the inhabitants of Tonle Sap have little or nearly no

exposure to new technology due to its living standards as part of a developing country. As to its impact on the environment, the piping going under the water would have severe complications with the marine life, destroying habitats and not being able to adapt with the change in current due to typhoons in the region.

The final alternative, The Bio-digester, had the lowest score due to the process of maintenance and the materials needed such as cement and plastic which are not easily found or cheap. On average it costs around $US0.50 to $US0.69 per square foot (media 1250, 2009) and as stated before the "cheapest" found working bio-digester is in Sante Fe which costs $US300. Therefore, giving it the lowest rating out of the three designs considered into development. The environmental impact that the bio-digester contributes to the Cambodian society is that it produces a strong stench and would possibly not be tolerated by the Cambodian community as their previous methods are seen to be more " suitable" for them.

Table 3: Trade-Off Table

Components (weighting)	Cost (50%)	Environment (20%)	Cultural Impacts (30%)	Overall Outcome
	Score /10	Score /10	Score /10	Score /100
Reed Beds	8	8.5	8	81
Bio- Digester	4	6	5	47
Piping	6	8	6	64

Our Proposal

We propose to establish:

1. A reed bed sewage treatment system to be installed on a small scale i.e. in local schools
2. An education program that
    a. raises awareness of the need to manage and dispose of waste sustainably and responsibly;
    b. which empowers the Tonle Sap locals to maintain the reed bed system; and feel a sense of ownership over the entire environmental project

The reed bed system is effective because it helps filter out grey water resulting in cleaner water with less chemicals, such as ammonia, oil sediments and even alkaline, which may leak from the car batteries used by the Tonle Sap inhabitants to power their electricity. The choice to initiate such a program was based on many beneficial advantages (cost, environmental, social) as discussed that will benefit the community and its people in Cambodia.

The Reed Bed System

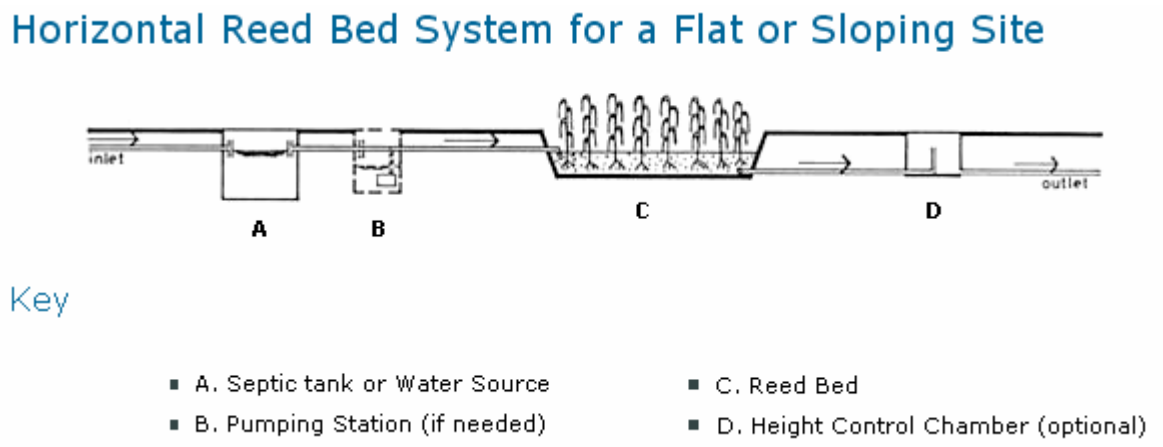


Figure 4: A design of a simple reed bed system (Smith, T 2009)

Depending on the set up of a reed bed system, different types of water can be treated, from black water (sewage) to grey water (used water without faeces) to the Tonle Sap river water.

One of the greatest strengths of the reed bed system is its flexibility.

Typical reed beds consist of four main parts:

- Water Source/ Primary Treatment
- Pumping Station (optional)
- Reed Bed
- Height Control Chamber (optional)

A. Water source / Primary treatment

If the reed bed system is required to treat black water then the water source must be some source of primary treatment. The most common one is the septic tank that allows solids in water to settle to the bottom of the tank, and greases/oils to form a layer at the top of the water. The cleaner water is extracted from the middle of the tank and sent to the reed bed for secondary treatment.

Instead of a septic tank something like a bio digester may be implemented instead. Here the pathogens and waste would break down forming methane (which may be used as a source of energy). One of the disadvantages of standalone bio digesters is that they produce a waste effluent. Paired with a reed bed system, the reeds are able to treat the effluent from the bio digester without any problems.

If the reed bed filter is required to treat grey water then the water source can simply be a grey water tank (or pumped directly from homes). However grey water reuse is a non-issue in the Tonle Sap region. (*Engineers Without Borders Australia – 2009 EWB Design Challenge* 2009)

The reed bed treatment system may also be used to directly treat river water for use. Currently, the residents in the Tonle Sap region directly bathe, wash, and drink, from the contaminated river. If fresh clean water is difficult to come across, the river may be the water source directly filtering/treating the water for use. (*Engineers Without Borders Australia – 2009 EWB Design Challenge* 2009)

B. Pumping station (optional)

The pumping station transmits the water from the water source into the reed bed. Due to the seasonal flooding of the Tonle Sap region as well as the close proximity to water, a pumping station may not be required. Preferably gravity would be able to run the water from the source/primary treatment unit to the reed bed. Electrical pumping stations can be used for larger reed beds although this is not viable in a Tonle Sap context which cannot afford electrical pumping stations, instead a small mechanical pump can suffice for this role.

C. Reed Bed

This is where the secondary filtration and treatment of water occurs. Below is a diagram of a basic reed bed with the necessary items labelled. The reed bed is the core part of the reed bed system and on its own is able to naturally and effectively filter contaminated water.

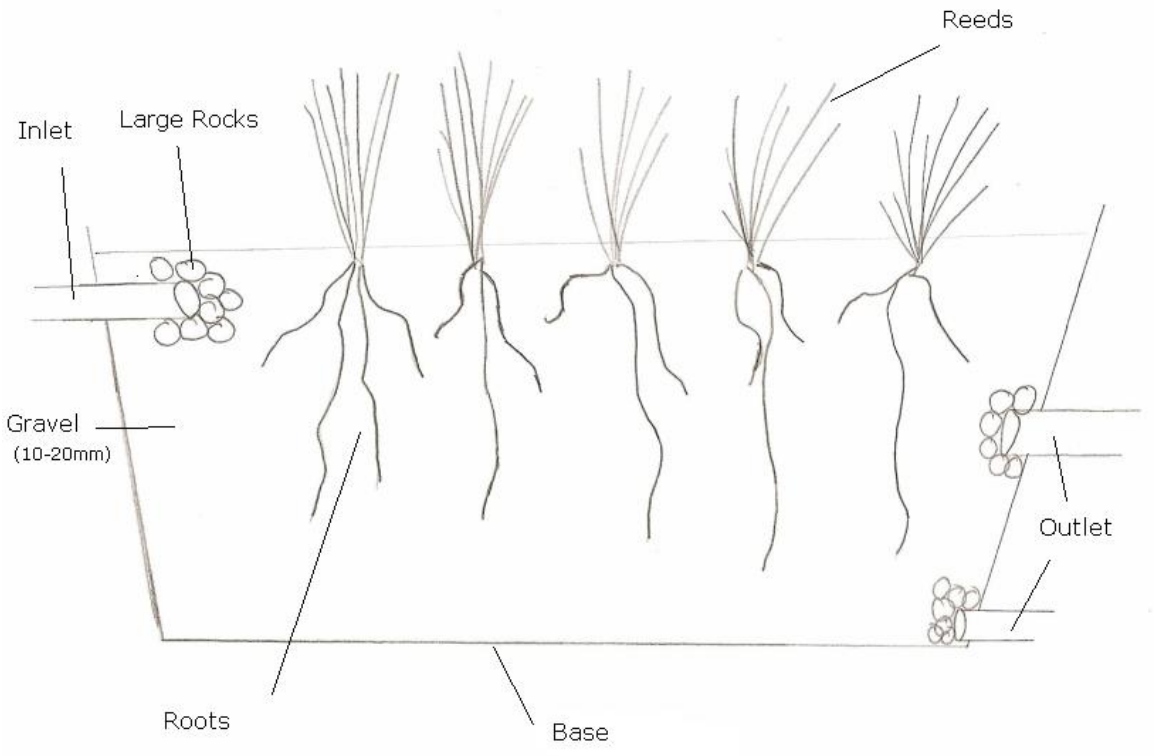
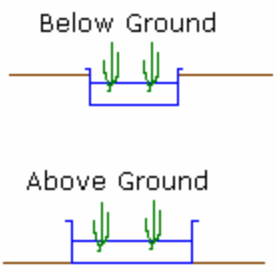


Figure 5: Diagram showing structure of a generic reed bed

The entire reed bed may be either above ground or below ground. The differences are summarised below.

Table 4: Advantages and disadvantages of below and above ground reed beds

	Advantages	Disadvantages
Above	- No digging required - Easier to implement/maintain	- Requires a more rigid base material



	- More resistant to changing water levels.	
Below	- Effective in unflooded areas - Base material can be less material. - More durable	- Requires a lot of man power to create the holes for the reed bed and piping - Harder for maintenance.

The Height Control Chamber (optional)

Aptly named, it controls the height of the water level.

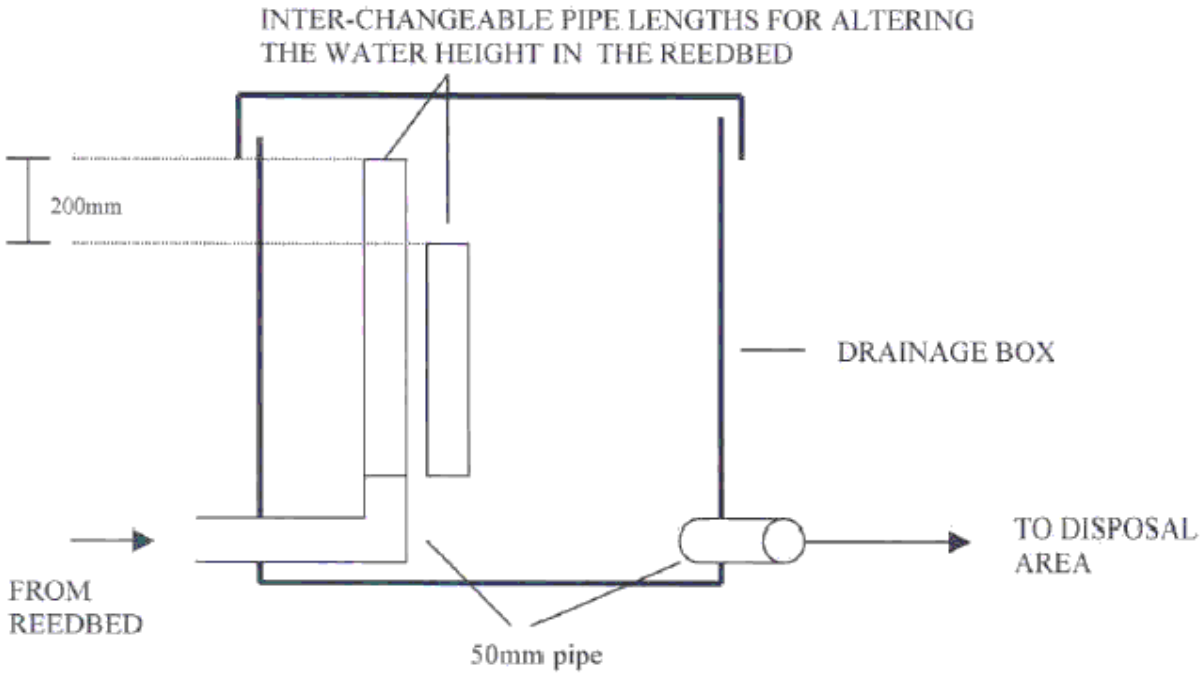


Figure 6: Diagram of a height control chamber (Smith, T 2009)

It is easy to see how the height control chamber works. The water height in the reed bed corresponds to the height of the pipe end in the height control chamber. At lower water heights some reeds, such as the Phragmites Australis, are able to grow faster. (Olson, B E 2007)

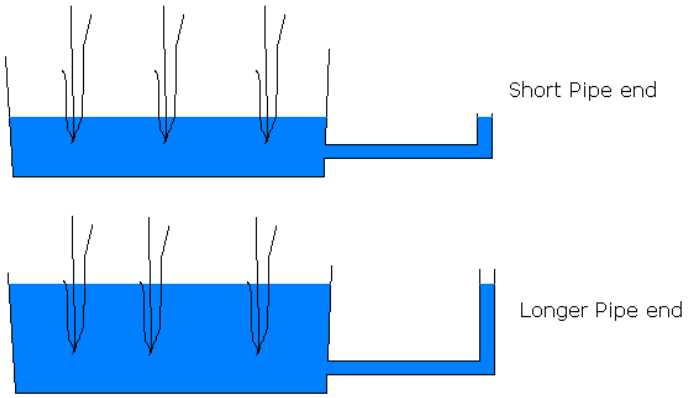


Figure 7: An illustration of a height control

Main Parts of the Reed Bed System

The main constituents of a reed bed:

The base

The base is generally any large container able to hold the contents of the reed bed. This container can be any material that satisfies three main criteria

1. Chemically Inert

   The material of the base must not reactive, and especially resistant to water.

2. Rigid

   If the base is entirely above ground, the material must be rigid enough to support the contents of the reed bed and water. If below ground, the material can simply be a liner, such as a High-Density-Polyethylene liner. (Lismore City Council 2005)

3. Cheap

   The base of the reed bed is the largest and more difficult item to obtain in the reed bed. A good base material should be cheap. Some cheap examples are recycled materials such as unused barrels, discarded water tanks/septic tanks.

If suitable recyclable materials are not available the base may be constructed from purchased materials such as polyethylene.

If it is easier to obtain multiple smaller bases, then the reed bed system may be constructed as a small system of reed beds as shown below in the diagram.

Filling of the Reed Bed

Reed bed filled entirely of 10-20 mm in diameter gravel; with larger (100mm in diameter) rocks near the inlet and outlet of the reed bed. The larger rocks near the inlet/outlet are to prevent clogging. (Lismore City Council 2005)

Inlet/Outlet pipe

Pipes of about 100 mm in diameter that satisfy the same requirements as the base. Sewer grade PVC pipes are an excellent choice.[1] (Lismore City Council 2005)

Reeds

Many different species of reeds can be used. Below is a table showing some commonly used reeds.

Table 5: A list of effective reeds used in reed beds

Species name	Common name	Height (m)
Baumea articulata	Jointed twigrush	2.5
Baumea rubiginosa	-	1
Bolboschoenus fluviatilis	marsh clubrush	2.5
Eleocharis sphacelata	Tall spikerush	2
Lepironia articulata	-	4
Phragmites australis	Common reed	4
Schoenoplectus mucronatus	-	1
Schoenoplectus validus	River clubrush	3
Typha orientalis	Bullrush or cumbungi	4

(Lismore City Council 2005)

Phragmites australis, as seen above is the closest to *phragmites karka*, native in Cambodia. Conviently, it is the common reed.

Biological Process of Reed Beds

The uniqueness of our Reed Bed system naturally lies in the chemical and biological makeup of the reeds themselves. Particularly in our chosen plant, the *phragmites karka*, oxygen levels throughout the body, from the leaves, to stem and the root system are extremely high. Such an environment within the reed allows for certain micro organisms to thrive and reproduce within the rhizosphere, or in other words, the root system. These micro organisms are thus responsible for the aerobic and anaerobic regions that exist within the plant, effectively creating zones which effectively filter out bacteria and other unwanted organisms contained within the treated water. (Johnston Smith, 2009)

However, the reeds themselves do not entirely make up the Reed Bed System. Gravel and rocks also play an important role in the water treatment abilities of the system. Pollutant chemicals and ions such as arsenic, nitrogen and even phosphate are easily removed from the water passing through the system. This is done by the natural attractiveness of the gravel towards metal ions such as arsenic and phosphate. As such, the water that passes through the reed bed system undergo a filtration and chemical treatment “facility”, effectively producing clean, reusable water for domestic purposes. (Johnston Smith, 2009)

Cambodian Pilot Plant

Part of our plan to integrate and phase in reed bed filters is to introduce a few pilot plants into select communities within the Tonle Sap region. Our aim is to target permanent schools and help them construct their own reed bed filter.

By giving the responsibility reed bed treatment unit to a school, we aim to induce a sense of ownership and enthusiasm towards the construction, understanding and maintenance of reed beds within the Tonle Sap region. Furthermore by initially setting up pilot plants at schools, the reed bed will not only have people to maintain it, the children will also gain a practical aspect of education. This will be particularly effective will the theoretical aspect of education discussed later.

Although the reed bed system will definitely be able to treat water, this is only a secondary objective, with the primary being educating and inspiring the Tonle Sap residents and children.

Location

As stated previously we want our pilot reed bed filters to be incorporated into a school environment. Thus they must obviously be within the vicinity of a Tonle Sap school. Ideally the school will be relatively large (greater impact regarding education) and have some spare land to hold the reed bed.

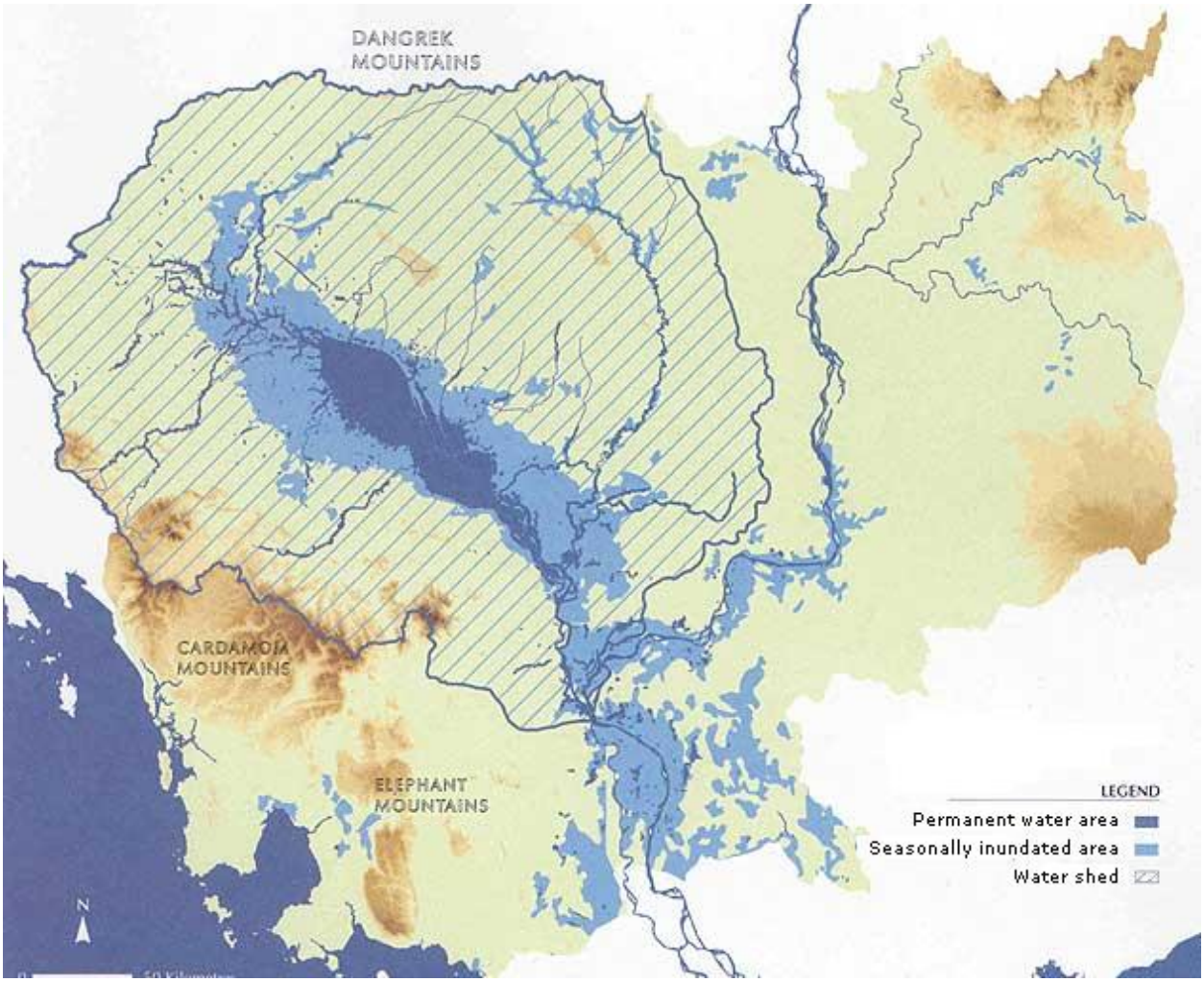


Figure 8: Map depicting the flood areas around Tonle Sap (Fox, I 2004)

The school must belong in or near the seasonally inundated area, as shown above in the medium-blue-shade, in order for the Reed Bed system to work effectively.

The location of the reed bed should also have high levels of sunlight to promote the growth of the reeds and overall efficiency of water treatment.

Reed Bed Dimensions

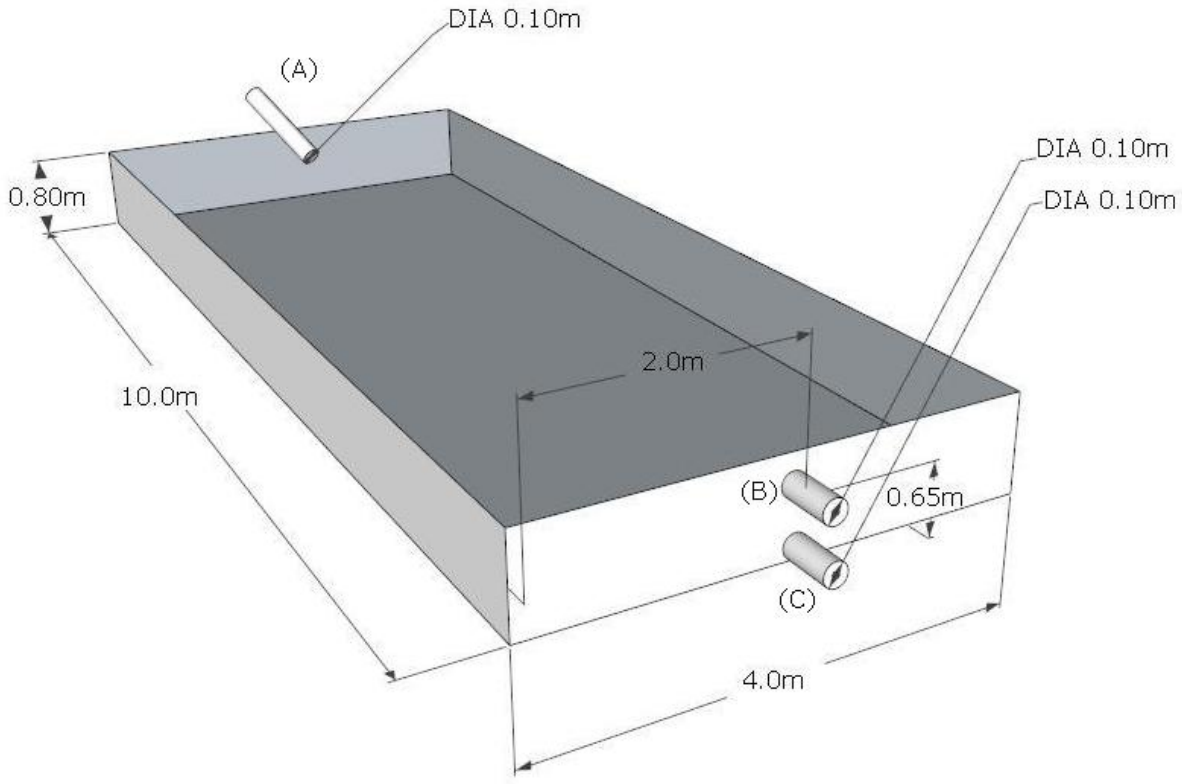


Figure 9: Diagram depicting dimensions of Tonle Sap pilot reed bed

Material Costs

Table 6: Items and costing required for reed bed

Part	Item & Cost	Alternatives
membrane/base:	62.4 m^2 Polystyrene sheeting / 2.5 cm thickness. $36	Usage of unused materials such as broken water tanks. $Free 10x6m Blue Tarpaulin Sheet $52
Piping	12-20 m of 100mm diameter blue piping $20.25-$34*	Hand made bamboo pipes $0 - $4
Filling/Substrate	19 m^3 DIA 10-20mm gravel $0-190[t] 1.25 m^3 DIA 100mm rocks $0-12.5[t]	Soil $0 - ?
Reeds	Phragmites Karka $0	Phragmites Australis $0
Total cost: $0 - 288.5		

* Similar 20cm diameter pipes cost $27 per 4 m length, 20 cm pipes require 4x as much material as 10cm diameter pipes. 25% of $27 is $6.75.

[t] No given price for gravel. Sand is given at $10 per m^3. Gravel takes up more space and is easier to come across than sand. Possible to collect the gravel.

The Reeds: Phragmites Karka

Wikramanayake & Rundel 2001

The Phragmites Karka been chosen for use in our Tonle Sap pilot plant due to three main reasons:

1. Native to Tonle Sap

Reeds are commonly seen as hardy, resistant, and considered in some areas as invasive. By introducing a species that is native to the region the ecology of the area will not be disturbed, preserving the area's natural value. Hence, it is not environmentally intrusive.

Furthermore this ensures that identifying, gathering, cultivating of the reeds within the reed bed will be relatively simple tasks.

2. Great for reed bed filter

Phragmites Karka are great plants within reed bed filters with higher efficiency and consistency in water treatment than the other commonly used reeds. (Parco & Kanzler unknown date) This will mean that Tonle Sap residents are able to get more out of their reed bed filter.

3. Other uses

Besides being a great reed for water treatment. Phragmites Karka has numerous other uses such as thatching to make mats and bedding, particularly for animals. The stems can also be made into items such as nets and arrow shafts. (Saltonstall, K 2006) These alternative uses are important if the reed is to be harvested.

Planting the reeds

Phragmites Karka grows more effectively in shallow waters. A layer of sand may be placed on top of the gravel as a bed for the seeds. If using shoots or stems, they should be trimmed to a length of 20 cm before placing the clump in the gravel. (Lismore City Council 2005)

The reeds should be placed at least 25cm away from the sides of the reed bed membrane as the roots grow quite aggressive and could puncture the material if growing in a too restricted area(Davidson *et al* 2005). There needs to be clumps of at least 4-5 reed plants per m^2, the higher the reed density, the greater the capacity of treatment possible by the reed bed. (Lismore City Council 2005)

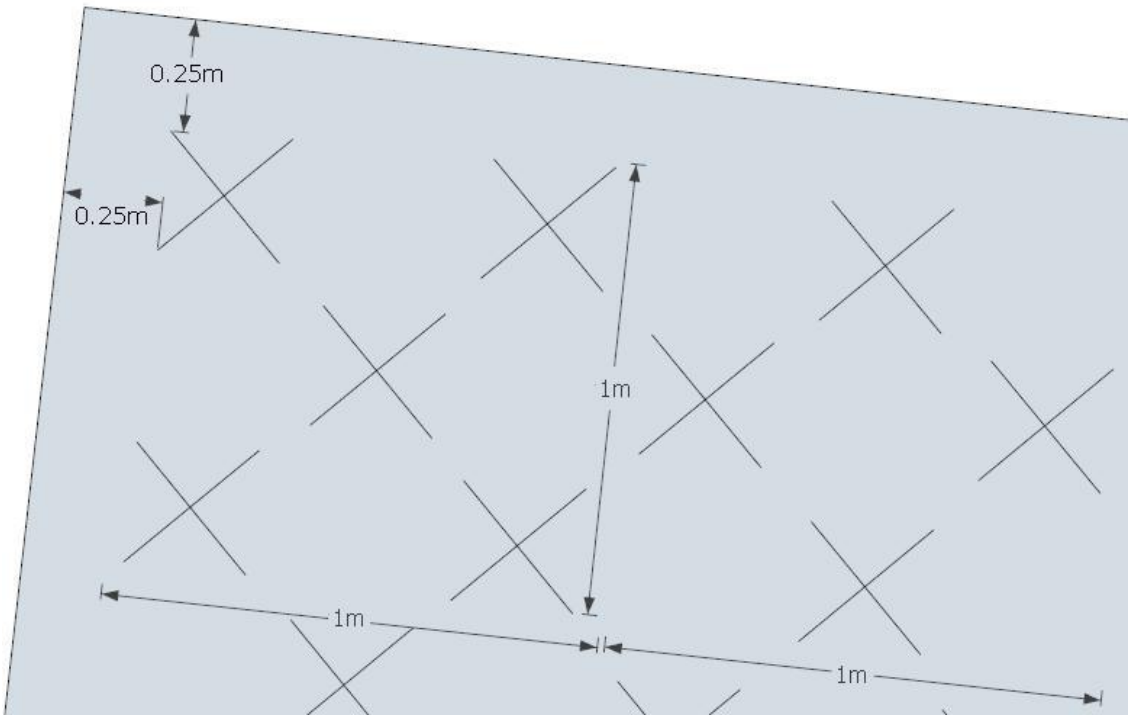


Figure 10: A diagram showing the location of reeds in a criss-cross pattern.

Treatment Performance

Table 7 displays reed bed treatment performance, "as measured by percent reduction in concentration, obtained from 28 studies, on four different types of wastewater, conducted since 1995. Wetted depth of the beds in these studies varied between 40 cm and 60 cm." (Davidson *et al* 2005).

Table 7: Treatment performance summary (HRT = Mean Hydraulic Residence Time)

wastewater type		HRT days	BOD %reduction	TSS %reduction	TN %reduction	TP %reduction	FC log reduction
Combined*	Mean	8.9	92.5	88.7	60.2	25.0	2.5
Greywater	Mean	5.2	83.8	81.5	62.0	46.8	1.8
Laundry	Mean	6.1	61.2	82.7	62.4	31.9	0.8
School	Mean	11.5	74.9	79.3	38.1	33.7	1.7
All studies	Mean	8.3	81.3	82.9	56.5	34.9	1.9
	Min	3.7	34.7	55.9	8.1	-21.7	0.4
	Max	17	96.6	97.9	93.8	76.6	3.3
	n	32	28	23	24	26	27

* combined wastewater = domestic blackwater and greywater

(Davidson et al 2005)

The table displays a mean biochemical oxygen demand (BOD) reduction of 92.5%. This is rate of oxygen used up by organic organisms and directly correlates to the amount of organisms within a water sample. The total suspended solids (TSS) is also reduced on average by 88.7%, TSS relates to the amount of particles (solids) in the water. TN and TP correspond to total nitrogen and total phosphorus which are nutrients links to the growth of bacteria and other micro-organisms.

The rate of treatment will effectively be determined by the mean hydraulic residence time. Assuming a mean of 9 days and a water height of 60cm, water will be treated at 24m^3 a day, which equates to just over 110 L / hour treated.

Height Control Chamber

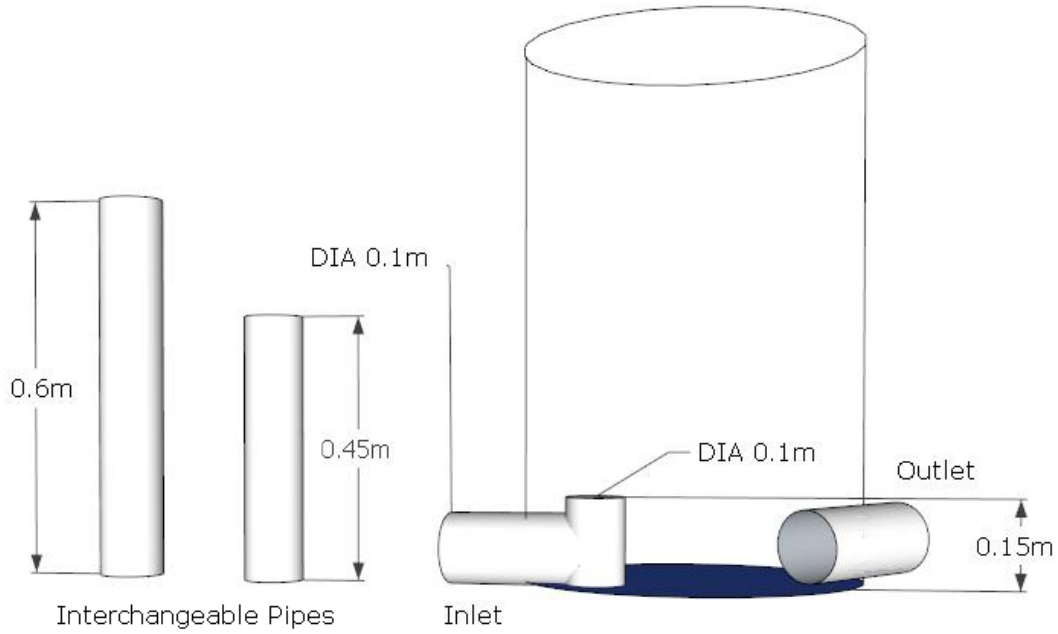


Figure 11:

Diagram and specifications of height control chamber

Inlet connected to pipe (B) in reed bed figure 11

Outlet connected to a regular barrel for reuse.

The role the height control chamber is as described from page 21 onwards.

Part	Item & Cost	Alternatives
Container	Sealed Plastic Drum $US2	Drum with screw lid $US3 Any other containers that are more than 75cms high

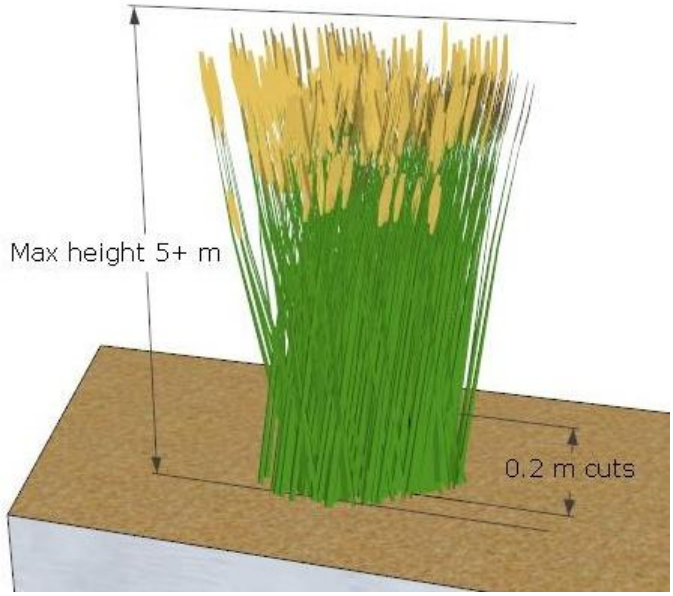
Piping	1.5 m of 100mm diameter blue piping $US3	Hand made bamboo pipes $US0 - $1
Total cost: $US2 - $US5		

Maintenance

One of the major advantages of reed bed treatment plants is the fact they require very little maintenance. There are a few steps that will help promote the effectiveness of reed beds.

Harvesting

On the second year and thereafter the reeds should be harvested annually at least once, up to twice a year. The Phragmites Karka should be cut to roughly 20cm above the gravel surface. The reeds may then be reused for activities such as thatching.



Reed component thanks to 'Jonathon' from Google Sketch up database.

Checking blocking to Pipes

The main types of blockages that occur will be from the roots of the Phragmites. Hence, ensure that they do not grow too aggressively near the piping. This can be done by trimming and harvesting the reeds every so often, but also a plastic barrier can be created between the reed roots and the reed bed membrane.

Annual draining

Pipe C in figure 11 (reed bed design) is a lower pipe that allows for draining of the reed bed. This allows the upper region of the reed bed to dry out and de-clog. The water should be slowly reduced to minimize the amount of wastewater exiting the system at a time.

The major factor opposing the longevity of reed beds is the fact that overtime particles and waste will tend to build up, particularly near the piping causing a reduction in efficiency over time and eventually a complete breakdown. It is crucial that annual draining in to remove solids occurs. Introduction of native earthworms to break down the sediments can also be quite efficient in unclogging the system. (Davison *et al* 2005)

Ethics of the Engineering Work

Ethics

Throughout the implementation of this project, we strive to comply with the nine Tenets of the Code of Ethics as outlined by the Institution of Engineers, Australia. As stated in the Code of Ethics, we are to "respect the inherent dignity of the individual, act on the basis of a well-informed conscience, in the interest of the community." We, the Waste busters, believe strongly in upholding the dignity of the Tonle Sap residents, by not disrespecting their established cultural practices. We are focused on fostering the sustainability of the Tonle Sap ecosystem as well as encouraging the responsible stewardship of the Region from the residents. We believe that it is a basic right for these people to live above their current sub-standard living conditions for physical and psychological wellbeing issues. Our belief complies with Tenet 1 of Engineers Australia, Code of Ethics which states that "members shall place their responsibility for the welfare, health and safety of the community before their responsibility to sectional or private interests." (Institution of Engineers Australia, 2000)

At all times in the implementing of this scheme shall we strive to "act with honour, integrity and dignity" (Tenet 2, Institution of Engineers Australia, 2000) to garner trust from the community. We believe it necessary to respect the established cultural traditions. A problem that lies with international aid, is that there is a natural tendency for the more privileged parties to impose their ideas and beliefs onto the community requiring aid. This is an exact violation of the *Rights Ethical Perspective* which states that "each person has a fundamental right to be respected and treated as a free and equal rational person capable of making his or her own decisions" (Lukoskie, D., no date) We are not attempting to override their existing and established cultural traditions (like in the tragic instances of European colonialisation) but we merely intend to improve their livelihood.

Our project is ethical as we adopt a utilitarian perspective towards our proposal; in the words of Jeremy Bentham, our proposal's education and physical reed bed component aim to achieve the "greatest good for the greatest number" (Bentham, 1781). Our groups two objectives, as underlined below,:

1. To equip the residents of Tonle Sap with knowledge in health safety regarding water and water treatment methods, in particular reed-beds

2. To increase and raise awareness on hygiene standards in the Tonle Sap Region. This falls in line with the utilitarian ethical perspective; that by providing the residents with the knowledge of sustainable water treatment methods and by increasing the awareness on hygiene standards, greater good in terms of improved living standards and sustainability of the Tonle Sap ecosystem will result.

The harvesting of the reeds; *Phragmites Karka* every year will also provide the Tonle Sap villagers with another natural resource. The harvested reeds can be used for thatching, or also provide financial gain through the sale of it to potential customers. This benefit complies with the utilitarian perspective by providing the greatest good, (achieved by providing an avenue for financial gain), for the greatest amount of the Tonle Sap residents.

The reed-bed management system is also environmentally ethical as the majority of the system utilises the reed-plant: *Phragmites Karka*. The reeds are the main components facilitating the natural treatment of the grey water. The system does not contribute to the increase in greenhouse gas emissions and exacerbate global warming, rather through the innate plant process of photosynthesis and respiration, recycles carbon dioxide into oxygen.

Ethics & Education

A stumbling block for the provision of international aid is that it naturally fosters a "culture of dependency" (Vocke,W, 2009). In the example of aid provision on the African continent, Dambrisa Moyo (2009) states that, "…the fundamental problem with these large aid flows…is the fact that [they] disenfranchise Africans…Africans cannot hold their governments responsible…They are propped up by the aid model… They do not deliver anything. The society is becoming worse." This situation can be applied anywhere where foreign aid is being provided in financial and material means and can be equally applied to the Tonle Sap Region, Cambodia. There is a real danger with this EWB Challenge, to provide the material resources needed by the Tonle Sap villagers but not empower them to take ownership of the solutions provided to the various environmental and health problems. The obvious solution to this dilemma would be to create the aid locally, making the project sustainable and manageable by the villagers of Tonle Sap.

The provision of education in water-health safety, water-treatment methods and the raising of awareness of critical hygiene standards are indeed ethical, complying with the *Utilitarian* and *Rights* ethical perspective. Education always provides greater benefit to each student, hence, impacting the community in which the student belongs to. An education of waste management to the children of Tonle Sap would allow them to understand at a young age the necessity for responsible stewardship of their land. Hence, hopefully as adults, they will retain the understanding of the importance of sustainable waste-management behaviour and bring improvement to the Tonle Sap ecosystem.

Impact Assessment

Millennium Development Goals (MDGs)

The Millennium Development Goals (MDGs) set by UNICEF have been created to combat the poverty and low living conditions in the developing nations around the world. The MDGs consist of eight goals as listed below (UNICEF MDG Report, 2008):

1. The eradication of extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

These are the latest goals from UNICEF set in 2008 to be achieved by 2015. Our group are assisting in ensuring the success of some of these goals, for example, the universal primary education. The different diseases that may arise as a result of insufficiently acting on the waste-management issue will cause the Cambodian economy to suffer as the Government will plough funds into the purchase of vaccinations and use donated funds to improve the health system to accommodate the increase in people infected or affected by the diseases.

Economic Impacts of this project

Cambodia is one of numerous developing economies in the South-East Asia region. The Project will directly benefit an estimated 1.09 million people with improved drinking water, of which about 0.72 million will also benefit from improved sanitation facilities in the project area. (World Bank Report, 2008) The Project is expected to realise its anticipated benefits without significant negative impacts.

The designs of this project are economically viable because of the cost savings relative to the current water usage to be derived, and improvements expected with the health status of the population from the cleared water. The reed bed system will have a low total economic cost; this reduces the needs of the households to use more resources to maintain their minimal water consumption. The only economic costs from this project are the payments that have to be made to the labourers.
Evidence that the reed bed system is the preferred form of waste management and sanitation is its adoption by many foreign authorities on the basis of economic factors. The capital cost of this system depends on the availability of land and natural resources; such as clay, soil and other natural materials. The capital costs in comparison with other system is much lower; by about 33% (World Bank Report, 2008). Many of the materials required to develop this project can be bought or can be found in Cambodia itself so as to minimise the costs in acquiring and transporting the materials. For example, the plant *Phragmites Karka* is a native reed, which can be obtained freely from the natural habitat. We also intend on ensuring that this project doesn't create adverse effects on the economy or the personal budgets of the local villagers. With this in mind, we will be using materials sourced from Cambodia.

The labour used for the construction of this project will be the local Tonle Sap villagers. In doing this, we are assisting the improvement and growth of the local Tonle Sap economy. Hence, this project will *create* jobs for the villagers, not *take away* jobs.

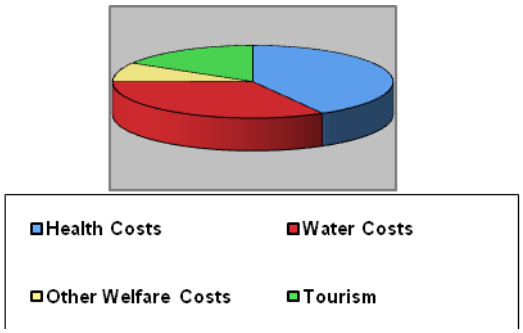


Figure 1: Economic Costs of poor sanitation in 2005, by impact ($US millions)
(Overall economic costs = $US448 million)

Figure 2 compares the different costs to the economy due to poor waste management and sanitation, in 2005, in US dollars. It can be seen that without the proper management of waste and sanitation, the costs to the economy are focused mainly on the management of water and the health of people living in the area can be quite severe.

Social Impacts of this project

The social costs of this project may be negative because the Cambodians may not understand the purpose of this reed bed system. As we know, they do not understand the importance of proper water treatment and sanitation. They may not understand how to maintain the system or its proper usage. It is for this reason that our group has decided on an educational system to teach and foster the Cambodians' understanding of sanitation and water management and its importance and why this project could be for their own good in the long term, as it will improve health and as the same time improve education and the environment (Aardvark, 2008).

Although, the project is for the better of the local people who use that Tonle Sap, our group fear there is a 50-50- chance it will not be widely accepted by the locals, for various reasons; for example,

they may not understand that sanitation is a very important issue that needs to be addressed immediately. It may also be the case that the locals may not like westerners coming in.

Environmental Impacts of this project

The environmental impacts of this project may be positive, however, this may only be the case if our group correctly addresses the needs and requirements of environment protection. Our group have made it a priority to develop a system that minimises its effects on the environment.

The project is not believed to have any detrimental effects on the environment because we are using a reed that is readily available in Cambodia; called *Phragmites Karka*. By doing this our group have eliminated the need to introduce a new species of plan into the Cambodian ecosystem. This will therefore eliminate any potential foreign species or other pests from entering the country's borders and potentially harming the country's vegetation and the economy.

The Aardvark article (Aardvark, 2008) describes how the reed bed technology can achieve one of the Millennium Development goals; which is to halve the proportion of people without access to sustainable and safe drinking water and basic sanitation. Currently, the developing nations around the world struggle from a massive shortage of resources for the construction of wastewater treatment systems.

Education

Current situation & the Need for Education

In Tonle Sap, "70% of children do not finish primary school, compared to the national average of 60%" (L&L, 2007, p. 9). This is a massive concern for the parents of the children and, collectively, it is a problem for the region. If this continues, children will not have the education standard required in jobs and will be less developed intellectually. This will correlate to further degradation of the Tonle Sap society and environmental problems will deepen dramatically.

Currently, in Tonle Sap, teachers are paid for "including environmental education alongside school lessons" (L&L, 2007, p.92). However, the effect of this cannot be gauged effectively. Though, at least there is an initiative taken in environmental education in Tonle Sap and this would ensure, at the least, the recognition and awareness of the waste problem in the area. Students would be able to discuss environmental issues specifi to their Tonle Sap region once they gain more knowledge on the waste problems of Tonle and, through discussion, ideas for solutions would arise. Even if these solutions are not plausible, this promotes the type of thinking that is required by the villagers of Tonle Sap if it is to be saved from complete ruin.

Educating the school students on the environment has been furthered by the Ministry of Environment (MoE) of the Royal Government of Cambodia, who "appointed Live & Learn Environmental Education (L&L) to carry out the National Environmental Education and Awareness Campaign (NEEAC) under Component One of the Tonle Sap Environmental Management Program (TSEMP)" as part of an agreement, dated 6th June 2005(L&L, 2007, p.5). The NEEAC had promoted the awareness of

environmental issues on a larger scale to Tonle Sap, thus informing many villagers of the problems and linking them to the current situation.

This Environmental Education and Ecologically Sustainable Development program that took place in Tonle Sap, focused on educating “local communities, teachers and primary school students” on the environmental issues affecting Tonle Sap (J.E.E.F 2007). This campaign continued from July 2005 to February 2007(J.E.E.F 2007). Through campaigns, flipchart training and other various activities, the project aimed to raise awareness of the environmental dilemmas of Tonle Sap and to promote education throughout the community (J.E.E.F 2007). Although the campaign had finished a couple of years ago, it highlighted the importance of commitment to “pubic awareness at a public level” (J.E.E.F 2007).

Engineers Without Borders (EWB) is aiming to continue from the progress of the NEEAC. Only through building upon the work of other organisations can this problem and issue of waste management be addressed. Personal hygiene issues are being instructed at schools, with students being taught not to swim in the lake. However, many do not understand the seriousness of this issue. One of the teachers in the Chong Khneas primary school of Tonle Sap reflected that “many of the children suffer from fever and sometimes diarrhoea from playing in the water either during school hours or when they are at home. We see kids with scabies and itching, and they are often off school for up to five days at a time with such problems. We try to teach them the difference between dirty and clean bath water, and the basics of personal hygiene. But it is hard." (Sharp 2008). An arising concern is the lack of class attendance due to illness which is preventable I proper physical measures e.g. signs warning no drinking or playing; and education is in place.

The message is getting across to the children due to the extensive efforts of the organisations such as Live and Learn and Rural Friend Community for Development (RFCD). EWB will sustain and further promote education. Being born into this village, the children require a proper education so they will not perish early in their life. With “83 children out of 1,000 perishing before they are five”, something needs to be changed so that there is continual improvement (Sharp 2008).

The current situation in regards to waste issues and waste management in Tonle Sap dictates that more needs to be done. The current state of affairs is grim and further action needs to be taken. Hence, the education system will be introduced. The education program will aim to teach children whilst also raising awareness of the waste management issue to the rest of the village. With previous campaigns and now this EWB project, the awareness levels of the waste issue in Tonle Sap will certainly rise.

Why this education system is being introduced

Education is the catalyst of having a sound foundation for knowledge. It fosters growth in the mind, spirit and body. Being subjected to an education program simply provides the children with an opportunity to learn. With this tremendous task of cleaning up Tonle Sap ahead of the villagers, the education program is the best way to bring about a united effort; children are given a share of the responsibility of taking care of their home land.

An issue that is hindering the education program is that "this natural icon is under increasing pressure from unsustainable human activity. The environment is being heavily degraded and without intervention and behaviour change, the whole fragile ecosystem is in danger of collapsing" (L&L 2007, p. 5). Human activity is the cause of this problem. The only positive from this is that humans can stop what they are doing that is harming the environment. However, this is very substantial task and requires gradual accomplishments before the grand solution is achieved.

"Unsustainable human activity" includes:

- Defecation in the lake
- Dumping domestic waste into the lake
- Overfishing
- Deforestation

(L&L, 2007)

Another reason for introducing the education system is the introduction of new technology in the form of the reed-bed system. The villagers of Tonle Sap need to be educated on how to use it and, in the future, how to build it. If no one knows how to use it, the whole system will be redundant. Thus, education is a very important aspect of waste management. The reed-bed system is seen as a major development in the Tonle Sap region and, by introducing it, EWB is looking to maintain it and hopefully replicate it around the region. By focusing on this aspect, the project aims to solve this smaller issue of gray water. Hopefully, other projects will develop and our aspects of waste management are addressed.

Tonle Sap is borne to many waste management issues and the villagers must understand the problems that can arise from them. Hence, apart from educating them on the new reed-bed system, they will be taught about all the issues ranging from water-related diseases to personal hygiene so that they grasp a firm understanding of them.

Rather than the introduction of a village-wide education program, the targeted group would be the school. A greater education program may conflict with the culture of the community. Many of the villagers have been living in Tonle Sap for many years and they would be accustomed to a certain lifestyle. By introducing an educational program into the whole community, there will be disagreements due to the proposed changes the program may bring. The inertia of the adult villagers must be considered in this case and, by introducing a school-based education system, the young students are targeted. They are more susceptible to change and would be able to develop a firm foundation on the importance of waste management.

Generally, the villagers have embraced the programs initiated by non-profit organisations. These programs have provided education for children and parents would prefer that children gain knowledge

rather than accompanying them fishing. As long as EWB's education program does not conflict with the lifestyle of Tonle Sap, it will be welcomed by the villagers.

Our Aims and Objectives

The introduction of this education program aims to

- inspire future generations to develop fresh and new ideas to help their community

Our objectives include:

- Educating students on sustainable and healthy use of the Tonle Sap habitat
- How to effectively use and reap the most benefit from the reed bed

Our aim is for the community to change incrementally for the better rather than introducing intrusive, large changes that could disrupt the community. Thus, an education program will "strive to encourage every person to believe that he or she can bring about global change and aim to increase people's ability to transform visions into reality" (L&L 2007). By promoting more sustainable human behaviour, the education program will develop students' ability to act and think sustainably in their consideration of their future.

Overall, students will gain skills, which helps with future employment and personal knowledge. If students are able to succeed in the future when they are working, parents will likely keep other children in school and, hopefully, the cycle continues.

Our education system is looking to:

- Educate students on sustainable human activities,
- Educate students on how to use the reed-bed system, and
- Educate students on the issue of waste management and other related issues

Advantages and Potential Difficulties of the small classroom tutorial

Advantages

- *Less expensive to run*, i.e. less resources and conflict, since the education program is based in the classroom rather than large community groups.
- *Disagreements would be easier to handle*. Due to the scale of the education program, there would less likely be conflict with the students as compared to, say, the adult villagers. Any conflict that may arise can be dealt with by teachers and arguments are less likely to be confrontational.
- *School structure is already in place*. The necessary environment, i.e. school classroom, chairs, boards, tables, and other equipment, is already in place, so less additional costs will be incurred and, plus, the students will be in a familiar environment. Hence, they do not have to adapt to a new physical classroom structure.
- *Smaller classroom tutorials can be replicated easily if it is successful*. Starting small gives the chance to expand in the future should the program prove to be successful.
- Allows students to make friends and build their confidence. Students will develop relationships with other locals and enjoy themselves.
- Future teachers may be inspired.

Difficulties

- *Students may want more fun over work*. These issues are serious and if students choose not to participate or actively engage in the content than the tutorial would be ineffective. At their age it is reasonable to assume that they would not want to tackle such difficult issues as waste management and they may perceive it that way as well.

- *Pressure of the future on the children.* A lot of questions will be asked about why students have to learn all this and they may feel pressured to gain knowledge because they will have some responsibility on their own futures and the future of the region.
- *Information may be too strenuous and tiresome.* All the lectures and life knowledge that the students need to learn may just be too much for them to handle because of the significant weight. It is tiresome to learn about real life issues as compared to, say, mathematics.
- *Having larger community groups who are interested may be a better alternative*. There are many locals who are concerned about the dire conditions of Tonle Sap. They would be more inclined to learn and to use their positions to help the region. Students may not be keen on learning about all of this.

To justify having the small classroom tutorial, it would not be as intense and serious as the issues that will be taught. The learning environment that EWB is trying to foster is one that is relaxed and fun, where students can learn and actively engage. At first, there may be a feeling of reluctance but students will soon realise that it is just like every other school day. In fact, more engaging activities will be introduced. Lecture material will be simplified so that students will be able to follow along and the teachers can adjust their pace to suit the class.

Who will be involved

Engineers training local villager on maintenance

Since the reed-bed system contains pipes and other materials, a local villager has to be taught on maintaining the system so that the system can endure for a longer period of time. Training will be practical with the engineer showing the villager how to take care of the system. The system must be accessed after the monsoonal periods of Tonle Sap to check for any damage reed plants or pipes.

Engineer training teachers on how to use the reed-bed system

The reed-bed system is a new piece of technology in Tonle Sap and, since it is presiding at the school, teachers will be taught on how to use the reed-bed system. This not only ensures that some of the villagers know how the system works, but it also allows them to teach the students (i.e. passing on knowledge). Practical demonstrations and participation will help teachers develop some useful skills which could be passed students.

Teachers learn about all the topics to teach children

EWB representatives will update teachers on the issues that need to be taught to the students. Through the provision of detailed information and textual resources, teachers will gain a further interest in their village and, hence, relate all the topics to the students. Resources that will be provided include:

- Books,
- Guides,
- Syllabus on waste management,
- Lecture material
- Manuals on the reed-bed system,
- Flipcharts, and
- Videos

Readily available books in the classroom allow students to pursue any interest they have. Educational books foster the development of knowledge in students, whilst fictional books provide entertainment and pleasure.

The study material will be provided to the community and the local authorities will take control and implement the teaching strategies. The content will be simple for the children to understand with

pictures to accommodate their learning. Plays on different type of diseases, for example, may be used as a tool for students to show other students what they have learnt, which is entertaining and educational.

Rather than sending in a large group of people into Tonle Sap to “fix” the region and enforce change, the people of Tonle Sap will be shown how to do it themselves. They gain a sense of responsibility to the community and also will develop skills and sustainable thinking. The cost of hiring non-local teachers or paying representatives of EWB to teach in the classrooms would be more than the cost of training the local teachers.

Education on the construction of reed-beds

To educate the villagers on the construction of reed-beds, first they need to know about all aspects of the reed-bed system. The reeds will be native to the area so they will be easy to harvest. Each component and its function will be described and villagers will get a chance to use the manual pump. First of all, a local, well-respected citizen of Tonle Sap needs to be the taught in managing the construction. The role of this manager is to have all the necessary information for construction to gather necessary workers to help construct the reed-beds. The village chief will be in charge of authorising task. Engineers will first teach a keen group of locals with the manager. Practical participation will be encouraged and training will be on-going until the selected villagers are able to build a reed-bed themselves. This also gives important roles to them and they feel a sense of accomplishment and self-importance. (Reference to section _____ on how reed-beds work etc.)

Advantages of having locals involved

- There is no language barrier. Local teachers and villagers can communicate more effectively to students than compared to a non-local. This ensures that two-way communication is established and that students also develop fluency in their own language, which is very important to the people of Tonle Sap.
- Empowerment. The local people will feel a greater sense of importance because they are empowered to help their own village. Rather than being told what to do, the villagers are informed on how to improve their lives. Basically, having important roles gives them a chance to take charge and to be in control of their own lives and situation.
- Personal rapport is established. Students would be able to closely relate to someone who is from the community and who has lived in these conditions. A non-local resident may not have a

deeper understanding of the region and the culture compared to a local villager, so it is important that students feel that connection to a teacher.

- Development of the community. Not only are the students benefiting by gaining an education but the local adults may learn from their children. Students may inform their parents on what they have learnt at school and evenly the message will get across to the community. Teachers are developing more and more each time and there are more adept people in understanding and battling waste management.

Disadvantages of having locals involved

- Resistance to teach. As well as students may refuse to listen, teachers may refuse to work. This may be due to a lack of incentive, something that personally benefits them in the immediate circumstances. It would be difficult to keep everyone happy and providing constant materialistic or monetary incentive does not encourage the empowerment and responsibility that is sought after. Hence, only those enthusiastic about helping the community and the children will be trained and hired as the teachers.
- Resistance to learn. Local villagers, as stated before, are accustomed to a certain way of living. They may feel powerless in their current situation, already knowing all the facts but feeling as though there is nothing they can do. This program is not introduced to force them to listen or to force them to learn. It is their choice in the end.
- Costs of training. Those who are training he locals have to be paid. It is costly to spend time in developing teachers on the course content and on how to teach about the environmental issues. On top of that, teachers' salaries have to paid for the increase in the content they have to teach. Also, for villagers learning about the construction of reed-bed systems, the on-site

engineers who are giving instructions require support for being at another country and working as a trainer.

In regards to the disadvantages, our program is looking to break down any resistance to learn and to teach, through a more exciting and sustainable routine. The disadvantages are only hypothetically speaking. As stated before, villagers have been enthusiastic and very supportive with programs initiated by L&L and RFCD and this program will be no different. As for monetary needs, as much funding is required for this program to work and, since it is a worthwhile cause, costs should not be a hindering factor at the moment.

School-based Education

- Local teachers
- How to use the reed-bed system
- Lectures on key issues
- Activities

Local teachers

The local teachers will lecture students in the classroom based on the student material provided by EWB. This small classroom tutorial will be full participative with teachers constantly asking students questions about what they have learnt and rewarding students for correct answers with incentive programs, such as a star chart with the student getting the most stars at end of a period receiving prizes, including a bag of lollies or other treats. Also, reading together and role plays provide an interactive way to learn and have fun. Local teachers have to also continue their roles in teaching the children how to read and write.

From the personal experience of Miss McKay (2008), “the most touching part of the experience for me was the requests I received: toothbrushes, toothpaste, and soap. We had the goodies in see-through bags and one little boy lit up at the sight of a tube of Aquafresh and made a motion to me by parting his lips and running his little finger across his little teeth.” All these items that we may take for granted are viewed as luxuries for the children. So, EWB would provide supplies of toothbrushes, toothpaste and soap as incentives for the students.

EWB will also finance boats for students to travel to and from school. A student may be responsible for picking up and taking home a few other students. Since poor families would only be able

to afford one boat, and it must be used for fishing, this allows students to make the distance to school. Hopefully, attendance rates will increase.

Reed-bed system

The reed-bed system is very intriguing and, naturally, students would want to get involved. So, teachers will encourage students to participate in using the manual pump of the reed-bed system. Also, the teachers will explain the aspects of the reed-bed system to the students, i.e. the plants, the gravel and etc., so that the students gain a thorough understanding how the system works whilst appreciating how the input can result in the output, that can be used for washing and cleaning.

Lectures

Key issues such as water-related diseases, fishing, defecation in water, swimming in the water, drinking water and many others will be taught to students. This vastly increases their knowledge on the various issues in the Tonle Sap region, thus allowing them to make informed decisions when they are choosing whether to swim in the lake or not, as an example. Another example would be to recognise symptoms of a disease and to understand what to do should they appear. Forming classrooms into groups with each group performing a role play would be a fun way to learn.

Classroom activities

Classroom activities keep the students' lives from being mundane. They may include board games, silent ball, basketball, hands down thumbs up and trivia. This develops enjoyment in the students and gives an incentive for them to attend school and learn. In addition, it gives balance to the lives of the students and shows them that they can have fun despite all the issues surround them.

Teachers can further develop their relationship with students and students can develop their relationships with each other.

Syllabus

Introduction to the syllabus

The syllabus that will be introduced into the school will only cover the lectures on the reed-bed system and waste issues. The normal program already initiated by the school on teaching students to read, write and calculate will not be changed.

Considerations

Our first consideration was to adopt a syllabus similar in structure to the New South Wales high school syllabus. However, the syllabus was too complicated and too advanced for the needs of Tonle Sap. Despite this, the syllabus was only a proposed idea and aspects of the former syllabus will be used. Hence, a simpler syllabus will be adopted. The lecture material is also too advanced and wordy for children. So, the study material will be simplified and just as informative.

Previous syllabus & lecture material

Aim

The aim of Tonle Sap Waste Management syllabus is to encourage students to learn about the importance of waste management, related issues and it's relation with the Tonle Sap region, whilst enjoying and valuing the experience in developing socially, intellectually and emotionally.

The study of waste management

Understanding is a key concept in the study of waste management. For students to truly understand it, they are exposed to a variety of issues relating to Tonle Sap. Students develop an

understanding of waste management by exploring a range of topics associated with waste management and the Tonle Sap region.

A section of the syllabus will show the outcomes of the education program. An example of this would be:

Students will:

- Develop emotionally, intellectually and socially as they learn about the issues related to the Tonle Sap region, in particular waste management
- Gain an understanding of the importance sustainable behaviour in regards to the economy,environment and socially

Students will learn to:

- Identify unsustainable human activities currently taking place in Tonle Sap
- Discuss the issues arising from unsustainable waste management
- Assess the alternative actions that can be taken instead of disposal of waste in the lake

(Board of Studies NSW, 2009)

Explanation

The syllabus is guide for teachers as well as students to see the overview of what is to be taught and learnt respectively. As each point is covered, the teacher makes a note of it and progresses to the next point. Depending on the nature of the dot points, a few may be covered each day or maybe only

one. Teachers will be provided with lecture materials on each and they will be thorough in detail and the teachers are encouraged to use their own explanatory skills to get the message across to the students.

The syllabus will also be amended as different issues arise and other issues become less apparent. Real life case studies will be included so that the students gain a further perspective on issues around the world that are similar to those in Tonle Sap. Thus, they will gain an appreciation of the education program that is in place and develop critical analysis of the issues that are affecting the world. Students will be exposed to a range of texts to ensure that they gain a range of perspective on issues and understandings of problems. This will develop their problem solving abilities in terms of considering different alternative courses of action for each issue.

An example of lecture material would include:

Effective waste management strategies contribute to the creation of a cleaner, less wasteful and more sustainable society.

Management of waste is a basic requirement of ecologically sustainable development.

In an effort to reduce adverse environmental effects, it involves waste material:

- monitoring
- collection
- transport
- processing
- disposal.

Waste materials can originate from a variety of sources and include industrial, agricultural, commercial and domestic activities.

Effective waste management strategies assist in minimising or avoiding adverse impacts on the environment and human health, while allowing economic development and improvement in the quality of life.

The aims of waste management are to:

- conserve resources of water, energy, raw materials and nutrients
- control pollution of land, air, water and sediment
- enhance business performance and maintain corporate social responsibility

- improve occupational health and safety.

Many governments and organisations are adopting ‘zero waste’ policies.

This whole-of-system approach aims to reduce waste at the source through product design and producer responsibility.

It also includes waste reduction strategies further down the supply chain such as:

- cleaner production
- product dismantling
- recycling
- repair
- reuse.

Source: CSIRO 2008

This particular lecture will cover the dot points such as:

- Define the aim of waste management
- Identify the impact of effective waste management

Proposed syllabus

The teachers will be provided with a copy of the syllabus, which contains details of what will be taught to the students. Lecture material will be given in the form of booklets to every student. The syllabus will cover the dot points as stated above in the previous syllabus. However, the content will not be as comprehensive. For example, the material covering the dot point “Identify unsustainable human activities currently taking place in Tonle Sap” will contain pictures of “dos” and “don’ts”, with the “dos” representing the sustainable activities (i.e. what you should do) and the “don’ts” showing unsustainable practices (i.e. what you shouldn’t do).

An example of a classroom activity would be a play where each group of students presents to the class the effects of a water-related disease. Groups are given 5 minutes each to present and this encourages team work as well.

Cambodian Primary School Syllabus

The education system will be targeting primary school students, with addition material being included in there syllabus. The syllabus of primary schools in Cambodia consists of studies in "arithmetic, history, ethics, civics, drafting, geography, hygiene, language, and science" (U.S. Library of Congress, 2007). Hygiene is closely related to waste management and, so, EWB will closely work with the Ministry of Education and the primary school to further enrich the students' learning of personal hygiene.

The Cambodian national education syllabus dictates that primary school program consists of comprehensive studies in the national language, Khmer, and also other vital subjects as shown in the following table. We will incorporate studies in waste management in social studies and provide additional lectures. Due to the demanding hours of schooling, the practical experience in regards to using the reed beds will provide a break from theoretical learning.

The Primary Programme for children aged 7 to 12	
School Hours	**Subjects**
8.00 a.m. - 11 a.m 2.00 p.m - 5.00 p.m	Subjects taught in Khmer: Khmer, Mathematics, Science, Social Study, Christian Education Subjects taught in English: English, Christian Education, Art & Craft, Physical Education, Computer

(Source: Methodists School of Cambodia, 2007)

Comparison to NSW Board of Studies syllabus

The most important thing about the syllabuses is the content i.e. the subjects that are being taught to the students. In terms of dedicated school contact hours and the schooling resources, the primary school has those aspects taken cared of.

The Board of Studies kindergarten to year 6 education syllabus (primary school) consists of studies in English, Mathematics, Science and Technology, Human Society and its Environment (HSIE), Physical Development, Health and Physical Education (PDHPE) and creative arts (Board of Studies, 2009).

The new education system in Tonle Sap will adopt a few aspects from this syllabus. Studies on technology, due to the introduction of the reed-bed system, will be introduced. In addition, there will be focus on the Human Society and it Environment studies because it directly correlates to the waste management issue of Tonle Sap. Both these subjects will be covered theoretically and practically. The primary school syllabus of NSW is more appropriate to draw ideas from than the high school HSC syllabuses because the target in Tonle Sap is primary schools and also the syllabus is simpler.

The effectiveness of the studies of HSIE and Technology in NSW has resulted in many primary school students being capable in their use of computers and their understanding of a cleaner and safer environment. Our aim is to have this effect on the students in Tonle Sap.

Although, Tonle Sap cannot fully adopt the syllabus NSW incorporates as it takes away significant content from their current national syllabus and the changes will just be too much.

In regards to hours spent on teaching this new content, an hour a day of each school day would be the aim. However, if there are any issues, the education system will undertake a review process and changes will be made accordingly.

Review

At the end of each school term, students will have an opportunity to talk to their teachers about any issues in regards to school. This is purely voluntary and it will be known to students that their issues will be shared with representatives of EWB. This talk will basically give students time to reflect no what they have learnt, what they have liked and what they have disliked.

Community meetings will be held monthly to discuss any aspects of the children's education and to find solutions to any problems.

On every 6-month basis, the education system will be under review by an independent board of 6 members from EWB. This review process will be on going for a week, where teachers and the village chief discuss with the board about the current situation of the education program. Once the board members have gathered all the facts, they will have independent discussions to determine where to improve in the education program.

This education system is not perfect but it can be refined. By reviewing it on a regular basis, anything that is not working can be eliminated and anything that is successful can be improved further. Also, by taking into account the views of students and teachers, the board gains a better understanding of the current situation. Thus, any disagreements may be prevented and the program can be made more interesting should it become boring the students and/or teachers.

Once the board has finished with review, any changes will be implemented. The impact of the change will be judged throughout the term until the next review period, in which further action can be taken if necessary.

It must be noted that all these processes can only be gone through with if there is the permission of the government. Any implementation of change in the education program must be passed through the government before it takes effect in the classroom.

Advantages and Disadvantages of the review system

Advantages

- Allows the system to be refined and evaluated so that there is continual improvement.
- Takes into account the opinions of teachers, students and others who may be concerned. The teachers and students would feel valued as they are being listened to and that there concerns are being addressed.
- Gives feedback to EWB on what is working and what is not so that future decisions made on related issues are well informed.
- The syllabus can be updated to meet current standards of education.

Disadvantages

- The process may not deal of any immediate problems that may arise well before the end of term.
- The process may be long and arduous if there is a conflict of interest between teachers and students and also if there is a disagreement between board members.

The review process is available to maintain the happiness between teachers, students and others involved. An idea is formed on whether the roles of teachers are sustainable and whether the program itself is going to succeed. However, the affects of the program itself on the Tonle Sap environment cannot be measured in the short-term

Recommendation

The importance of the education program in relations to Tonle Sap can be summed up in this quote: “Education needs to address challenges by promoting change. The public has a crucial role to play in managing the Tonle Sap’s resources. To be sustained, economic development must be friendly to the environment and responsible to society. But there is no quick fix. The long-term vision requires commitment and approaches at all levels of Cambodian society” (L&L 2007, p. 139).

The education program must be sustained if it is to have any effect on the region. Everyone involved must be committed to the task of saving the diverse region of Tonle Sap or else the progress of the NEEAC will be for nothing. If an aspect of this project does not go according to plan then it is recommended that the project is reviewed and that more funds be invested into it. Changes have to take place if this region is to survive and it is recommended that this level of involvement from those outside of Cambodia continue as it is gradually making progress.

It is worthwhile to put your efforts into saving a region that is so diverse and rich in culture. Countries around the world should look to donate a percentage of their income to help those developing nations that require assistance. It is recommended that other organisations donate and help out the education program in Tonle Sap as this would definitely save lives and take the region forward in its attempt to better manage waste.

The importance of the education program can be summed up in the quote from the Live and Learn (L&L) NEEAC Information guide (2007):

> “The values needed to sustain the Tonle Sap’s natural resources will not come from environmental education alone. But education is the central pillar to promote such values. It must strive to encourage every person to believe that he or she can bring about global change and aim to increase people’s ability to transform visions into reality. Education has to foster values, behaviour and lifestyles to sustain development and develop future-oriented

thinking."

The further construction of reed-bed systems will only be possible if the knowledge of construction is provided to the villagers. The education on the construction of reed-bed systems has to be sound so that those who are taught will fully understand its design specifications and the process. This allows villagers to build for themselves. It is recommended that villagers learn this relatively new skill in technology.

Construction Schedule

Week 1 – Week 3:

Announcement of reed bed

Collection/Purchase of all required materials

Surveying of nearby area for ideal reed bed locations

Week 3 – week 5

Digging of trench for reed bed membrane & Pipes

Week 5 – Week7

Construction of reed bed: Membrane, pipes.

Filling with gravel

Planting of reeds

Week 7 – Week 8

Construction of height control chamber as needed.

Week 8 – Week 12

Construction of pipeline from water source to reed bed

Installation of Septic tank/Grey water tank/ pump (optional / as required)

May take shorter than week 12 depending on geography and/or function of reed bed.

Week 15

Test run of entire system to identify disconnections / errors.

Week 16

Repair any overseen defect in system

Begin use of reed bed system.

Bibliography

Asiaroom Travel, 2009*, Tonle Sap Lake in Cambodia*, [Online], Available at: http://www.asiarooms.com/travel-guide/cambodia/cambodia-tourist-attractions/tonle-sap-lake-in-cambodia.html [19 September, 2009]

Bentham, J. 1781, *An Introduction to the Principles of Morals and Legislation*. Austine: Constitution Society. [Online], Available at: http://www.constitution.org/jb/pml.txt [19 September, 2009]

Board of Studies NSW 2009, *Chemistry Syllabus Stage 6,* [Online], Available at: http://www.boardofstudies.nsw.edu.au/syllabus_hsc/pdf_doc/chemistry_stg6_syl.pdf [19 September]

Board of Studies NSW 2009, *English Syllabus,* [Online], Available at: http://www.boardofstudies.nsw.edu.au/syllabus_hsc/pdf_doc/english_syl.pdf [19 September 2009]

Brown, Joseph Mark. Effectiveness of Ceramic Filtration for Drinking Water Treatment in Cambodia, [Online] Available at: http://ceae.colorado.edu/mc-edc/pdf/joe%20brown%20dissertation.pdf [17 October 2009]

Buan Xuan An et al. Installation and performance of lowcost polyethylene tube biodigesters on small-scale Farms, [Online] Available at: http://www.betuco.be/biogaz/Installation%20low-cost%20polyethylene%20tube%20biodigesters%20on%20farms.pdf [17 October 2009]

Clearwater, 2007, the use of Reed Beds for Treatment, [online], Available at: http://www.clearwater.asn.au/domestic_infoexchangedetails.cfm?ID=525 [19 September 2009]

CSIRO 2008, *Waste management solutions (Overview),* [Online], Available at: http://www.csiro.au/org/WasteManagementOverview.html [19 September 2009]

Davison, L, Headley, T and Pratt, K 2005, 'Aspects of design, structure, performance and operation of reed beds – eight years' experience in northeastern New South Wales, Australia'*, Water Science & Technology,* vol. 51, no. 10, pp 129-138, [Online] Available at: http://www.clearwater.asn.au/resources/435_1.340_TI_JW_DavisonReedBeds.pdf [20 September 2009]

Engineers Without Borders Australia – 2009 EWB Design Challenge 2009, video recording, You Tube, unknown. Featuring the Tonle Sap region.

Engineers Without Borders Australia, 2006, *Engineers Without Borders Australia*, bangonit, [Online] Available at: http://www.ewb.org.au/about/?p=0 [20 September 2009]

Environmental Management, 2008, Reed Beds, [Online], Available at: http://www.environmentalmanagement.com.au/pdf/reed%20beds.pdf [21 September 2009]

Fox, I 2004, 'Country Water Action: Cambodia Living with floods on Tonle Sap Lake', in *Asian Development Bank* accessed 17 September 2009, from <http://www.adb.org/Water/Photos/CAM/CAM-tonlesap-intro.asp>

Japan Environmental Education Forum (J.E.E.F) 2007, *Database of Environmental Education Related Organizations Among Asian Countries,* [Online], Available: http://www.jeef.or.jp/EAST_ASIA/programs/view/3782 [19 September 2009]

Lismore City Council, 2003, *The use of Reed Beds for Treatment of sewage and wastewater from Domestic Households*,[Online],Available at: http://www.aila.org.au/canberragarden/water/Reedbed.pdf [17 September, 2009]

Live & Learn (L&L): Environmental Education 2007, NEEAC *Tonle Sap Information Guide,* [Online], Available: http://www.livelearn.org/resources/manuals/NEEACInfo_Guide_ENGLISH.pdf [19 September 2009]

Lukoskie, D, *Different Ethical Perspectives*. [Online], Available at: http://cseserv.engr.scu.edu/StudentWebPages/DLukoskie/perspectives.htm [19 September, 2009]

McKay, Miss. 2008, *Day 2: Cambodia's Tonle Sap Lake and the trip to Ko Samui,* [Online], Available: http://www.travelblog.org/Asia/Cambodia/North/Tonle-Sap/blog-252276.html [19 September 2009]

Moyo, D, 2009, *Dead Aid: Why Aid Is Not Working and How There Is a Better Way for Africa*. [Online], Available at: http://www.cceia.org/resources/transcripts/0142.html [20 September, 2009]

N/A. World Bank, 2008, (WSP) *Water and Sanitation Program: Economic Impacts of Sanitation in Cambodia Summary.* Available from: http://www.wsp.org/UserFiles/file/529200894119_ESI_Short_Report_Cambodia.pdf [19 September 2009]

N/A. Ecotechnologies International, 2003, Ecotechnologies International, Ingenieurburo Blumberg, Reed Bed Technology. Available from www.ecotechnologies-international.com [19 September 2009]

N/A. Statistics and Tourism Information Department, Phnom Penh, 2007-2008. Cambodian Economic data. Available from http://www.nationmaster.com/country/cb-cambodia/eco-economy [19 September 2009]

Olson, B E 2007, *Phragmites Control Plan,* U.S. Fish and Wildlife service, Utah, accessed 19 September 2009, from < http://www.fws.gov/bearriver/Phragmites_Control_Plan.pdf>

Parco, G F & Kanzler A unknown date, 'Engineered reed bed treatment system as a low cost sanitation option for the philippines', in *Asian Development Bank,* accessed 19 September 2009, from http://www.cd3wd.com/cd3wd_40/ASDB_SMARTSAN/Parco-Kanzler.pdf

REUK, 2006, Compost Toilet (piping), [online], Available: http://www.reuk.co.uk/Introduction-to-Compost-Toilets.htm [19 September 2009]

Queen's Printer for Ontario, 2009, Water Resources Glossary, Ontario, accessed 20 October 2009, from http://www.mnr.gov.on.ca/en/Business/Water/2ColumnSubPage/STEL02_163778.html#glossG

Saltonstall, K 2006, 'Phragmites australis(grass)', in *Global invasive species database,* accessed 19 September 2009, from http://www.issg.org/database/species/ecology.asp?fr=1&si=301

Sante Fe Woman's group, 2007, Bio- Digester Designs, [online], Available: http://www.ruralcostarica.com/biodigester.html [20 September 2009]

Sharp, R. 2008, *A Poisoned Paradise: Cambodia's Water Crisis*, [Online], Available: http://www.alternet.org/water/80520/?page=entire [18 September 2009]

Smith, T 2009, 'Reed Bed Sewage Treatment Systems', in *Johnson Smith Consulting Limited: Consulting engineers* [Online] Available at: http://www.johnstonsmith.co.uk/fact17.html [17 September 2009]

The Institution of Engineers, Australia 2000, *Code of Ethics*, Chatswood: The Institution of Engineers, Australia

Vocke, W, 2009, *Global Ethics Corner: International Aid: Does Help Hurt?* Carnegie Council for Ethics in International Affairs. [Online], Available at: http://www.cceia.org/resources/transcripts/0148.html [19 September, 2009]

Wikramanayake, E & Rundel, P 2001, 'Tonle Sap-Mekong peat swamp forests (IM0165)' in *World Wild Life* [Online] Available at: http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0165_full.html [20 September 2009]

Cambodia's Economic statistics; Available from http://www.nationmaster.com/country/cb-cambodia/eco-economy (accessed 19th September 2009)

National Dialogue on Water Environment partnership in Asia (25-26.09.08), *Department of Environment*, Available from http://www.wepa-db.net/activities_200810Cambodia.htm (accessed 14th October 2009)

Reedbed Technology for Waste Water Treatment in a Global Context, *Aardvark*, Available from http://www.rentareedbed.com/Information/Reedbed%20technology%20for%20waste%20water%20treatment%20in%20a%20Global%20Context.pdf (accessed 14th October 2009)

Species diversity and ecology of Tonle Sap Great Lake, Cambodia, *Aquatic Sciences*, Available from http://www.springerlink.com/content/5vp3228372q02220/ (accessed 14th October 2009)

The Reed-Bed System diagram; *Ecotechnologies International*, Available from www.ecotechnologies-international.com (accessed 19th September 2009)

The Millennium Development Goals Report 2008, *United Nations*, Available from http://www.un.org/millenniumgoals/pdf/The%20Millennium%20Development%20Goals%20Report%202008.pdf (accessed 14th October 2009)

(WSP) Water and Sanitation Program: Economic Impacts of Sanitation in Cambodia Summary, A five country summary conducted in Cambodia, Indonesia, Laos PDR, The Philippines and Vietnam under the Economics of Sanitation Initiative (ESI), by the *World Bank Report*. Available from; http://www.wsp.org/UserFiles/file/529200894119_ESI_Short_Report_Cambodia.pdf (accessed 19th September 2009)

Board of Studies 2009, *K-6 Educational Resources for Australia Teachers and students, Kindergarten to Year 6*, [Online], Available: http://k6.boardofstudies.nsw.edu.au/ [20th of October 2009]

Methodists School of Cambodia 2007, *Curriculum,* [Online], Avaliable: http://www.msc.edu.kh/curriculum.html [20th of October 2009]

U.S. Library of Congress 2007, *Cambodia – EDUCATION,* [Online], Available: http://countrystudies.us/cambodia/52.htm [20th of October 2009]