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Comment [R1]: A good illustration of a title page for this report.

A cover page is always used for reports.

**Flood Mitigation & Water Storage:
A Change for Food Security in
Timor-Leste**

CLIMATE CHANGE

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Executive Summary

As a result of East Timor's environmental and socio-economic vulnerabilities, the people heavily depend on natural resources that are conversely sensitive to changes in climate. Due to subsistent farming practices, the country experiences a deficit in agricultural production. Resulting susceptibilities to climate change due to hazards such as fierce winds, irregular rainfall patterns and flash floods, have recently worsened agricultural production and food security. Consequently, these hazards obliterate what diminutive East Timor's self-sufficient farmers can provide to the rest of the community.

A solution must be created to increase East Timor's current food security as well as account for conditions which may change in the future. To reduce the effects of droughts on crops during the dry season, effective water management must be implemented so that crops may have enough water to effectively grow during the dry season. To reduce the effects of flash floods during the wet season, flood mitigation is required so that crops may not be washed away. If these two strategies are implemented, farmers would be able to grow crops all year round, increasing their yield each year and improve their food security.

Rehabilitating small-scale irrigation canals in rural communities, where flash floods are commonly frequent, has already played a crucial role in slowly aiding the community in terms of food insecurity, however this will not adequately provide sustainable profit in the long term.

A range of alternatives to be implemented were considered. The most suitable option was determined by assessing the solution that best delivered the given criteria set in the design requirements. These options included embankments, irrigation canals, water tanks, seeds of life and fertilisers.

We have deduced to integrate three different design options (options 1, 2 & 3) into one final solution. This involves combining the embankment, canal and water tank system. The embankment and canals will be used to divert heavy flood waters away from the farmlands and the community of Codo. Water will be channeled into water tanks that are installed underground which will contain a basic filtration system to cleanse the water.

We have selected the underground option because the earth is a natural insulator and will keep the water cool during summer and warm during winter. It also simplifies the system by using gravity as a control for water flow.

Comment [R2]: The format of the report is in accordance with a formal style and the executive summary should provide an overview, method of analysis, findings and recommendations. Often an outline of the background issues, what needs to happen and the reasons for the proposed options are included.

Sometimes the executive summary can be called the abstract of the report.

This information should be approximately no more than one page and needs careful planning to ensure that the essence of the report is captured and that a CEO of an organization clearly understands what the report's issues and recommendations are.

Comment [R3]: This is an explicit topic sentence that reflects the purpose of the research project.

Comment [R4]: The writers have provided a strong statement which justifies the research project, providing a good overview of what issues must be addressed in the research process.

Comment [R5]: Another strong statement that provides the second reason for the research. There is more detail here and this adds to a sound overview of the research issues of the report. A cause and effect approach provides coherence to the executive summary and a basis for the recommendations.

Comment [R6]: This paragraph acts as a good link between the purpose and recommendations and highlights what the future needs are. This provides strong support for the recommendations of this report.

Comment [R7]: The words define very strongly what the solution would be and build on the idea of long-term sustainability.

Comment [R8]: This topic sentence provides more detail about the solution and long-term sustainability. It forms part of the Recommendations.

Comment [R9]: This outlines the engineering depth and research of the report.

Comment [R10]: This explains more about the recommendations of this report and could be linked to the previous paragraph.

Comment [R11]: The focus and assessment criteria of this report are to find an engineering solution. Factors such as costing and time management have been mentioned in subsequent pages.

Team Reflection

We saw the project as a great opportunity for us to express our skills in innovative thinking as engineers. We found the report structure extremely helpful and guiding as it provided us with a clear sense of direction.

We constructed a project schedule and a Gantt chart to demonstrate the work required to be delivered within allocated time frames. Working in a team meant that roles were equally distributed within the group which enabled a faster approach in completing the overall report.

Our team was able to effectively communicate and openly between all members of the group. Issues concerning the report were discussed within the team; however, issues within the team itself were minimal.

The largest obstacle we faced while working on the challenge was combining each person's writing style into one report. We also initially struggled with everyone's interpretation of the final design as some found it hard to grasp the full concept of it as each person's perception varied. This was overcome through graphical drawings and descriptions, followed by lengthy discussions.

Working as a team, we often struggled to find a time slot where everyone was available because everyone had different timetables and thus there were very little options for a suitable meeting time. We overcame this problem as some team members volunteered to stay back and wait for the remainder of the team on Mondays.

If we had to do it again we would focus on a much simpler design solution and evaluate that in greater depth.

The most enjoyable part of the Challenge experience was the feeling that we could use our knowledge and skills to help other people.

Comment [R12]: Reports do not usually contain a team reflection element, but the assessment criteria stated that it was essential in this report. It was beneficial to identify the issues in teamwork and how communication plays a vital role. Discussing the difficulties also restates that this Report was a collaborative process.

Comment [R13]: The use of the 3rd person supports a collaborative approach and team work.

Comment [R14]: For more information about writing in a report format go to: <http://www.uts.edu.au/current-students/support/helps/self-help-resources/academic-writing/reports>

Comment [R15]: A good example of using a semi-colon. This shows the connection between two clauses, with a connective word 'however'.

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Comment [A16]: A separate page lists the table of contents and all sections and sub-sections that are included in the report.

For more information about writing in a report format go to:

<http://www.uts.edu.au/current-students/support/helps/self-help-resources/academic-writing/reports>

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Introduction

East Timor is a small country on the island of Timor, which is located above the Northern Territory, Australia. The country is quite mountainous in nature, with the majority of land area containing slopes of 8-25 degrees, and up to 44% of the land area containing slopes of greater than 40 degrees (Barnett, Dessai & Jones 2007). Codo is a small village within the Lautem District, which is located in the northeast of East Timor.

East Timor gained its independence from Indonesia in 1999. This caused great conflicts between East Timor and Indonesia, which led to great destruction of East Timor's environment. As the country has gained its own independence, it struggles to develop as it was left with a very limited amount of resources.

East Timor is suffering from food insecurity where it is producing lower yields of crops than required by the population. Agriculture is the main source of food for East Timor as approximately 85% of the population are subsistence farmers (farmers who only grow crops for their own needs) (Molyneux et al. 2012). East Timor experiences a dry season (where no rainfall occurs) and a wet season (where large amounts of rainfall occur). As a result of these weather conditions, two major problems face these farmers - droughts during the dry season, where crops dry up or become stunted in growth, and flash floods during the wet season, where crops are washed away. Due to this, farmers are only able to plant and harvest once a year between the dry season and the wet season (Engineers Without Borders 2013; Barnett, Dessai & Jones 2007). This reduces the country's food security and has already led to severe and chronic malnutrition within the population. Other problems facing farmers include low yielding crops, poor soil composition, steep slopes, soil erosion and post-harvest losses due to insects and natural decomposition.

Predicted factors, such as a rapidly increasing population and climate change affecting future rainfall conditions, will greatly reduce East Timor's food security. The population of East Timor is expected to almost triple by 2050, from 1,066,000 in 2010 to 2,960,000 in 2050. This would place added stress on food demand in East Timor. As well as this, East Timor's climate is expected to become 1.5°C hotter and 10% wetter on average by the year 2050, which would cause further problems with agriculture (Molyneux et al. 2012). If problems are not solved, food security will be greatly reduced due to the increasing demand for food and the reduction in the number of crops produced each year.

The purpose of this report is to identify possible solutions that may be implemented into Codo, and to suggest a final solution to improve the food security of Codo. This final solution may then be used to help other communities, and help improve the country's food security as a whole. Improving the country's food security will help aid East Timor in its development.

Comment [R18]: The introduction always begins on a separate page.

Comment [R19]: This topic sentence provides geographical information and is written in the present tense. Always ensure the verb tense is correct and consistently used throughout.

For assistance with grammar go to: <http://www.uts.edu.au/current-students/support/helps/self-help-resources/grammar>

Comment [R20]: This paragraph is linked by the historical background to the first paragraph. Note the correct use of the present and past tense.

Comment [R21]: A succinct way of expressing this topic sentence.

Comment [R22]: Evidence provides justification for this brief and could have been referred to in the executive summary. However, it is clearly stated in the introduction, is a strong statement and a vital element for this research.

Comment [R23]: A good concluding paragraph for the introduction. The purpose of the report is clarified and easily understood.

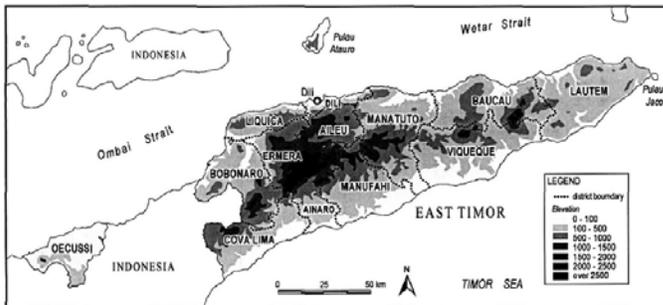


Figure 1. East Timor, districts, and topography.

1. Problem definition

1.1 Problem scope

East Timor is suffering from food insecurity where it is producing lower yields of crops than required by the population. This is due to low yielding crops, poor soil composition, steep slopes, highly variable rainfall, soil erosion and post-harvest losses caused by insects and natural decomposition. As a result of this, the majority of East Timor's population suffers from malnutrition. Predicted factors, such as a rapidly increasing population and climate change, will greatly reduce East Timor's food security (Molyneux et al. 2012).

1.2 Technical Review

East Timor is suffering from food insecurity where it is producing lower yields of crops than required by the population. Agriculture is the main source of food for East Timor as approximately 85% of the population is comprised of subsistence farmers (farmers who only grow crops sufficient for their own needs) (Molyneux et al. 2012). East Timor experiences a dry season (where no rainfall occurs) and a wet season (where large amounts of rainfall occur). As a result of these weather conditions, two major problems face these farmers: droughts during the dry season, where crops dry up or become stunted in growth, and flash floods during the wet season, where crops are washed away. Due to this, farmers are only able to plant and harvest once a year between the dry season and the wet season (Engineers Without Borders 2013; Barnett, Dessai & Jones 2007). This reduces the country's food security and has already led to severe and chronic malnutrition within the population. Other problems facing farmers include low yielding crops, poor soil composition, steep slopes, soil erosion and post-harvest losses due to insects and natural decomposition.

Comment [R24]: This is the body of the report and sub-sections clearly identify the essential elements of this detailed report. The reader can easily focus on the important aspects of the report through the use of the sub-sections; viz 1.1, 1.2, etc.

Comment [R25]: A good topic sentence which is the main point of the paragraph and sub-section 1.2.

Comment [R26]: Two citations have a greater impact and justify this technical review.

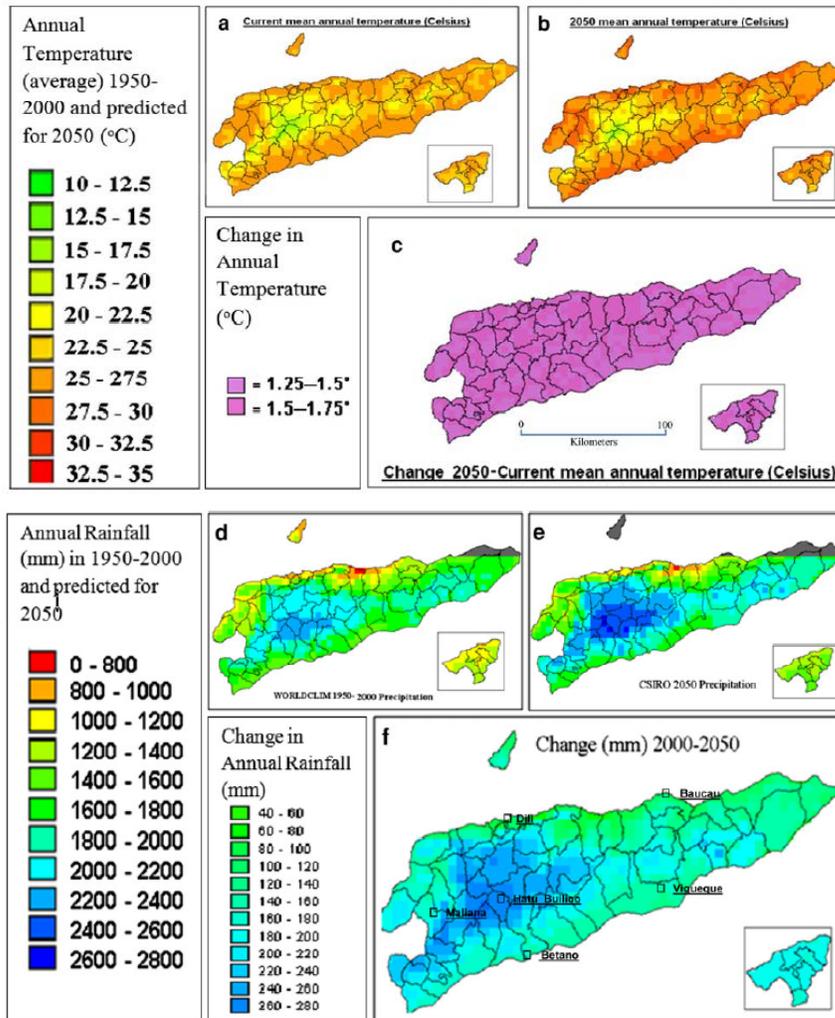


Fig. 4 The current (~1950–2000) (a, d), predicted for 2050 (b, e) and the difference between 2050 and current (c, f) mean annual temperatures (a–c) and rainfall (d–f) for Timor Leste. The *inset* is for the Timor Leste enclave of Oecussi in West Timor. The values of temperature change have been grouped into one band and colour (1.25–1.75°C). This was because there was no spatial pattern or

difference between areas across the country that justified separation or identification. The current values were obtained from the WORLDCLIM database and 2050 predicted values were for the A2A scenario of the CSIRO model in the WORLDCLIM database (www.worldclim.org/futdown.htm). The change maps were drawn using the DIVA-GIS programme

Figure 2: Current and predicted rainfall for East Timor (Molyneux et al. 2012, p. 830)

Comment [R27]: All the charts in this report are referenced correctly and are valid data to support the research.

Predicted factors, such as a rapidly increasing population and climate change affecting future rainfall conditions, will greatly reduce East Timor’s food security. The population of East Timor is expected to almost triple by 2050, from 1,066,000 in 2010 to 2,960,000 million in 2050. This would place added stress on food demand in East Timor.

As well as this, East Timor's climate is expected to become 1.5°C hotter and 10% wetter on average by the year 2050, which would cause further problems with agriculture (Molyneux et al. 2012). If problems are not solved, food security will greatly reduce due to the increasing demand for food and the reduction in the number of crops produced each year.

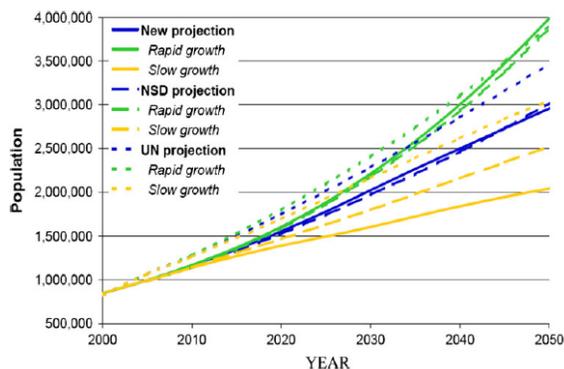


Figure 3: Projected changes in population in Timor-Leste (Molyneux et al. 2012, p.825)

A solution must be created to increase East Timor's current food security as well as account for conditions which may change in the future. To reduce the effects of droughts on crops during the dry season, effective water management must be implemented so that crops may have enough water to effectively grow during the dry season. Also, to reduce the effects of flash floods during the wet season, flood mitigation is required so that crops may not be washed away. If these two strategies are implemented, farmers would be able to grow crops all year round, increasing their yield each year and improve their food security.

An existing solution that has already been implemented into East Timor is the 'Seed of Life' (SOL) program, which aims to increase food security by increasing the yields produced by crops. The solution introduces natural crops (a similar species to that which was already growing), which produce higher yields per harvest and can withstand the change in climate and poor soil composition found within East Timor. The program has been testing and integrating different species of crops already being grown such as cassava, sweet potato, rice and maize. This includes farmer participation and surveys so that crops do not clash with local preferences. Farmers are then asked to trial successful crops on a small section of their farm with their normal crops, and to treat the crops as they would normally (Molyneux et al. 2012). This solution accounts for cultural suitability as well as conditions that are predicted to change in the future.

The World Food Programme has implemented another solution in East Timor. It has already undertaken one of East Timor's biggest strives for enhanced agricultural production and food security through their 'Food for Assets' (FFA) program. Their solution for an increased potential in farming practices started with recruiting people from food-deprived rural communities during the dry season. Currently operating are more than seven thousand men and women, being taught how they could improve rural

farming. This is done through programmes such as the improvement of community water ponds, the rehabilitation of small-scale irrigation canals, and land reclamation and clearance (World Food Programme 2005).

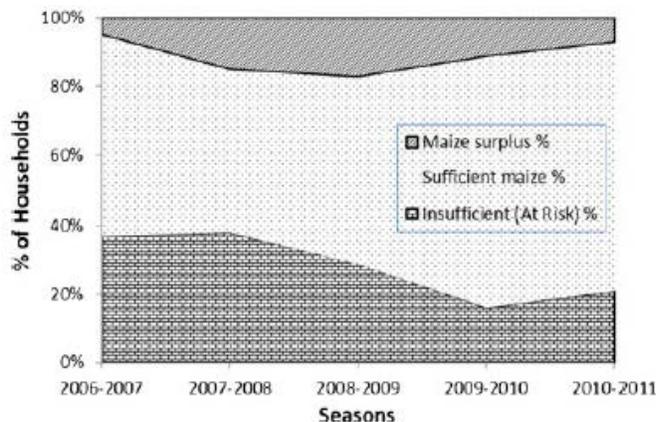


Figure 4: Percentage of perceived maize grain sufficiency for the year among households (da Costa et al. 2013, p. 87)

Irrigation is crucial for agricultural production in East Timor as the country greatly experiences vulnerabilities to climate change, particularly from its highly variable rainfall. However, such systems would only benefit their functionality in the wet season, due to insufficient water in the dry season and no significant water storage systems for year-round irrigation of crops. Currently ineffective are one thousand hectares of irrigation rice systems that require reinforcement. This is mainly due to East Timor's poor soil composition. East Timor's soil is known to be rocky, alkaline, unfertile, unable to store water, and easy to erode. Flash floods would encourage soil erosion, which affects farming. Resultant landslides would further encourage deforestation and cause a decrease in water quality. Likewise with droughts, there would be a stop in agricultural production and a decrease in food security, as increased temperatures would result in evaporation of water from agricultural origins such as paddies (Barnett 2007).

Rehabilitating small-scale irrigation canals in rural communities, where flash floods are commonly frequent, has already played a crucial role in slowly aiding the community from food insecurity. This movement, without many costs, has improved flood mitigation where floods wash away crops. This current operating system delivers the need for redirecting water flow from rainfall during the wet season. However, in the long term, this would be an ineffective solution as there is no control over the excess floodwaters during the heavy rainfall seasons. As a result, a new system must be implemented.

1.3 Design requirements

When designing and implementing a solution, regulations in the community must be explicitly defined and prioritised. This involves delivering measurable priorities that outline viable design options. Selective criteria are provided to certify that the design requirements align with the expectations of the community, sustainable development, ethics and technical functionality.

The proposal should consider:

Cultural

- a) Does the solution take the necessary steps to protect, preserve the existing natural environment and encourage traditional practices? If not, are the people willing to adapt? (Engineers Without Borders 2013).

Importance - This design requirement is important as it considers the community's social, religious and cultural beliefs so that conflicts may not arise.

Comment [R28]: The report writers use an interesting approach to emphasise the relevance of the five design requirements by showing this under a side heading 'Importance' and as a separate section.

Economical

- a) The benefits of the solution must outweigh the costs.
- b) The solution must be economically suitable to design, develop, implement, test and maintain the proposed solution.
- c) The solution must be inexpensive for the local community.
- d) Must consider the community's budget.

Importance – The solution must consider its budget as the community has limited funds, and will help decide whether the solution is worth investing in. The solution must also be cheap and affordable so that farmers may be encouraged to try alternative solutions. A cost-effective solution also allows for it to be used in wider communities, creating a greater impact.

Comment [R29]: See comment above.

Sustainability

- a) The solution should take into consideration local knowledge such as local opinions (Hollander & Kahl 2008).
- b) The solution must use and take advantage of the local resources available to the people of East Timor. Preferably, the resources are not to be imported.
- c) Is the solution able to account for future generations given the high population growth rate and high levels of food insecurity of East Timor?
- d) The solution must be long term.
- e) Is the solution strong and durable? Does it require upgrades or changes over time?

Importance – The solution must be durable and operate for the long-term, so that there may not be added costs to rebuild and maintain the solution. The solution must also be able to support future generations because East Timor has one of the highest population growth rates in the world and food insecurity is very high. Thus, the solution needs to be able to cope with increasing future demand. It must also have the strength to withstand changes in climate so that it could last as long as possible. The solution must also be made to fit the needs and lifestyle of the community it is being built for, so that the community may be encouraged to use it rather than abandon it (Hollander & Kahl 2008).

Comment [R30]: See comment on previous page.

Technical Functionality

- a) Does the solution deliver its designed purpose?
- b) The appropriateness and sufficiency of local resources for the development of the solution.
- c) Availability of volunteers from the local community that will aid and assist in maintenance.

Importance - Technical functionality must consider the quality of the design solution in carrying out its purpose and its value to the community and the environment. This includes the availability of participants and materials involved in the development of the new system (Friday 2004).

Comment [R31]: See previous comment on previous page.

Environmental Impact

- a) Design implications that may affect environment and weather.

Importance - It is essential to examine the various factors that may radically manipulate the surrounding environment and community. By disregarding these issues, small initial implications may arise into larger external environmental factors that may eventually escalate beyond our control (Hollander & Kahl 2008).

Comment [R32]: This is the last of the justifications for the design requirements and all are easily found in the report. This brings a strong focus to the report and is an excellent way to build your analysis.

Option Design : Technical Review Solution			
Design Requirement	Yes(Y)	No(N)	Reasons for importance/Comments
1. Cultural Sensitivity			
a. Maintain equipment	Y		The solution requires very little maintenance as most materials are durable. Any maintenance required can be carried out by locals.
b. Protect environment	Y		While the solution does not force farmers to change their traditional farming methods, it seeks to introduce a new alternative for water storage and source of water during the dry season.
2. Longevity of Solution			
a. Future generations	Y		Farmers are involved in decision making and can pass knowledge down to children as they are actively involved in the construction of the solution. Therefore, future generations are prepared.
b. Long term	Y		The materials used are durable and locally available thus prolonging the life of the system.
c. Strong/Durable	Y		The system has been reinforced with compacted rocks so that water does not erode away the embankments.
3. Economic Viability (cost)			
a. Low cost & Affordable	Y		The solution is low cost as it is composed of local resources.
b. Cost effective	Y		The solution provides water to families during the dry season, thus combatting low food insecurity and therefore cost effective as the water can be used for irrigating crops.
4. Sustainability			
a. Local knowledge	Y		The local villagers are actively involved throughout the implementation and design. Their input is regarded as vital as they are most familiar with their environment.
b. Local resources	Y		The local materials are used so that the design is sustainable. If maintenance is required, resources will be available to locals and thus they can carry out any repairs themselves.
c. Education & Training	Y		The local community is educated and trained during the implementation phase so that they can maintain the solution over time and pass it down to future generations.
d. Opportunities for locals	Y		Provides chances for locals to have an alternate water source and also prevents flooding of crops during the wet season. It provides them with the opportunity to increase food security.

Comment [RT33]: This is regarding cost.

Design Options

1.4 Detail of Option 1 - Embankments

An embankment is a raised mound or wall made up of dirt and reinforced by stone. An embankment can be used as a device to mitigate floodwaters. It works by redirecting the flow of water run-off during the wet season. By doing this it can prevent flash flooding and the effects that it would have on the people of Codo, such as damaged crops and a lowered food supply. The water can also be redirected into storage facilities allowing the positive use of that water.

Economical

- The cost of an embankment can be relatively cheap as it can be made with local materials such as dirt and stone. However, depending on the size of the embankment, the accompanying costs of labour and heavy machinery (if required) vary.

Sustainability

- If there is damage to the embankment, it can be fixed relatively quickly and easily as the materials that will be needed to fix the problem are readily available, or can be sourced in a short amount of time.

Cultural

- This design will have a positive effect on the community as it combats the increasing effects on climate change, by using the embankments as flood mitigation, which is also a method of redirecting water run-off that can be later used.
- Embankments can be retro-fitted to suit the needs of the community i.e. more crops, larger embankment.

Environmental Impact

- This design should have a minimal environmental impact, as it could be made on land that is close to the village, and is not in use by the population.
- Embankments are not very intrusive to the environment, as they do not introduce chemical substances, which may change the balance of the ecosystem.
- Diverted waters must have a place to be diverted to. If not diverted properly, other areas may become more flooded and cause damage to the environment.

Technical Functionality

- The solution helps to both divert floods and provides an increased crop yield, therefore making it a functional solution.

1.5 Detail of Option 2 – Irrigation Canals

Irrigation is crucial for agriculture in East Timor as the country suffers from droughts and irregular rainfall patterns. However, irrigation would only benefit their functionality in the wet season, due to insufficient water in the dry season and no significant water storage systems for year-round irrigation of crops.

Flood mitigation may be achieved by rehabilitating small-scale irrigation canals placed on mountainous slopes near Codo where flash floods are commonly frequent. This will provide several channels to redirect large volumes of water flow during the wet season. In addition to the community's benefit, a walkway sheltering above the flood irrigation can be crafted to prevent further soil erosion and land degradation from human activity.

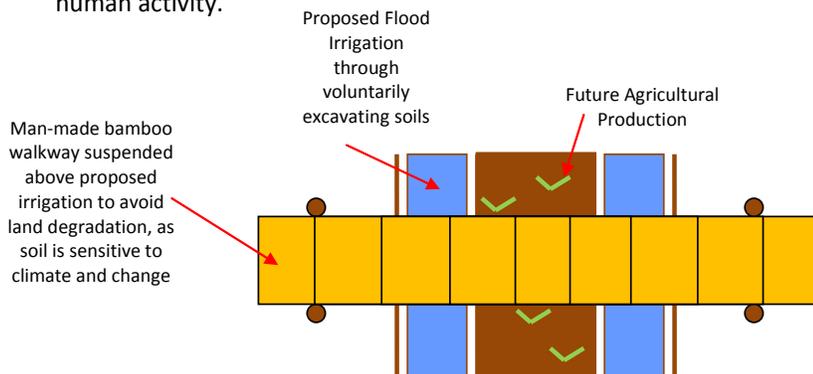


Figure 5: Site Plan

Cultural

- Initially, vegetation in the designated area will be removed in order to excavate the canals.
- Once the project is built, vegetation will be replanted in order to build resistances against the water flow, strengthening the usage of canals as well as restoring the natural environment.
- Traditional farming techniques are unaffected by the project.
- The project is highly dependent on the capacity of the community to volunteer to build canals and repair them to endure weathering throughout the year.

Economical

- Requires minimal funds as the project relies on volunteers from the local community and utilises local materials found in the natural environment.
- The majority of the project requires little skill in excavating and repairing the canals.

Sustainability

- Jobs or a dedication to improve the community can act as an incentive for people to build and maintain the canals, as it requires a low skill capability.

- The project provides a solution to cultivating hillside vegetation, as there are reduced chances of water washing away the vegetation.
- The solution only requires local materials found in the natural environment.
- Due to high occurrences of problems that cause land degradation in East Timor, as long as the community creates periodic maintenance times to fix the canals, the project can act as a long-term solution to climate change and food security.
- Canals must be dug during the dry season as the canals will initially be vulnerable to heavy rainfall due to the subsoil and topsoil being removed, exposing them to soil erosion.
- The canals will ultimately be able to reduce soil erosion and resist weather damage to a moderate degree as it mitigates the impact of floods by slowing and redirecting the water flow.

Technical Functionality

- The solution mitigates flooding through re-routing the water flow, reducing the accumulation of water and the washing away of the soil nutrients as the water runs down the hill.
- In the event that there is too much excess water flow, there can be canals that lead to the river to further mitigate potential flooding.
- The use of the locally found bamboo sticks will aid in the planning and positioning of the canals, avoiding incorrect placement of canals which may cause the flow of water to be directed into an unwanted area and may cause further flooding.

Environmental Impact

- Moderate environmental impact as this design solution seeks to alter parts of the country's landscape.
- Vegetation in the designated area is cleared in order to excavate the canals.
- After the canals are dug, they will initially be more susceptible to soil erosion due to surface modification, exposing the subsoil to low-fertility in the short term.
- In the long run, due to the modification of the slope steepness, the soil will be less susceptible to rainfall splashing, surface runoff and scouring, ultimately minimising flooding in the designated areas.

1.6 Detail of Option 3 – Water Tanks

The solution of water tanks will be able to cater for communities with water related needs. Water can be stored not only for drinking use (after it has been purified using boiling and filtration processes) but also for bathing, washing clothes and farming.

The water tanks can be constructed within the ground from mud bricks and clay. They will be covered with a lid in order to keep disease carrying organisms and dirt out. Water can be obtained using buckets. For drinking purposes, the water must first be purified through boiling.

Cultural

- The input of local builders could be valuable as they will have greater knowledge about building with natural resources. This will help the locals feel connected to the project and as a result accept it into their lives.
- Traditional practices will not be influenced or altered. The tanks will aid farmers with agricultural produce because of the large storage of water available to them. It will not hinder traditional farming practices, but instead work to make farming easier.

Economical

- The total cost of the project was a big factor in the design solution. Engineers must always keep the overall cost of a design as low as possible without compromising the structural integrity. Mud bricks can be used instead of steel for the water tank design for these reasons.
- Mud bricks can be constructed from materials found in nature. They are composed of sand, silt, clay, organic matter, and carbonates, in the appropriate ratios. These materials are all locally available, whereas steel would need to be imported. Although this cost could be met for a small-scale project, if we were to consider wide-scale implementation across East Timor, the costs would be inappropriate.
- In the case of possible future repairs or maintenance, because materials are found from nature, there will be no future costs in the long term as there would be with steel. Steel would need to be imported every time a repair needs to be made, whereas mud bricks could be remade.
- Due to the cost of the project being so small, other communities could take advantage of the design and implement it themselves if they are in a similar condition. The benefits of the design far outweigh the costs of implementing the solution, which make it a very attractive feature.
- The costs of water tanks would be recouped once they are implemented and functioning. Farmers can use stored water in dry seasons, when rain is scarce, in order to keep the plants hydrated. As a result, agricultural production will see an increase year round, since produce will no longer rely on seasonal changes. Therefore, it is also an economical option because farming exports can be increased.

Sustainability

- The materials used, as discussed, will not need to be imported. Mud bricks take advantage of East Timor's natural resources. The components of mud bricks (i.e. sand, silt, clay, organic matter, and carbonates) are abundant in nature, which means the sustainability of the tanks is high.
- The weather in the region of Codo follows the tropic's monsoonal pattern, which is a 4-6 month wet period that begins in December. Therefore, the design solution works at a high level because it will be able to collect water during this period and store it for use during the drier seasons. Furthermore, studies suggest that over the next 40 years there will be a 10% increase in rainfall in East Timor

(Molyneux et al. 2012). These trends mean that the future need and relevance for this system will become even greater.

- East Timor's future need for water is an impending problem. Data from a 2004 census indicates that half of the present population of East Timor is under the age of 15. A prediction by the World Bank (2008) suggests that the population will likely increase to 1.78 million by 2025 with a further increase to 2.96 million by 2050. Our design solution will cater for future needs when the demand for water increases as the population increases.
- If constructed correctly, mud brick structures can have long lifetimes. This has been tested and proven by ancient civilisations such as the Egyptians and Greeks who have used mud bricks for structures that are still standing.
- The water tanks will be stored in the ground, which will minimise the effects that weathering can have on the integrity of the structure, since East Timor experiences such extreme weather conditions. This will help maximise the lifetime of the tanks and thus require less maintenance in the future.

Technical Functionality

- The design solution executes its purpose in that it efficiently provides water to the locals for their everyday needs such as drinking (after it has been purified), bathing and washing clothes, while also giving farmers the water they need for their crops.
- Sand, silt, clay, organic matter, and carbonates are all very abundant materials. They all come from the ground so can be found virtually everywhere within East Timor's environment.
- The use of mud bricks for the construction of the water tanks does not heavily require specialised skills as much as construction with metals or plastics. This is because all the materials are found naturally in the environment and do not need industrial processes to create.
- By respecting the communities' values and promising a cost effective solution to their problem, this solution may be able to gain their trust and co-operation with the project so that they may be on board with the project and be able to aid and assist in future maintenance.

Environmental Impact

- The mud bricks, once formed, need to be sun dried so that they may properly gain their structural rigidity. As a result, the project will need to be executed during the warmer seasons, as sun is needed in the construction process.
- The water tanks will be as non-invasive to the environment as possible. They will be hidden in the ground so they will not interrupt the beauty of the landscape. In addition, any greenery found on the project site that has been excavated, will be replanted close by to not only preserve the habitats of the local fauna, but also not to ruin the natural scenery of the environment.

1.7 Detail of Option 4 – ‘Seeds of Life’

The ‘Seed of Life’ (SOL) programme is an evaluation programme, which aims to increase food security by increasing the yields produced by crops. The solution introduces natural crops (a similar species to that which was already growing), which produce higher yields per harvest and can withstand the change in climate and poor soil composition found within East Timor. The programme has been testing and integrating different species of crops already being grown in East Timor, such as cassava, sweet potato, rice and maize. This includes farmer participation and surveys so that crops do not clash with local preferences. Farmers are then asked to trial successful crops on a small section of their farm with their normal crops, and to treat the crops as they would normally (Molyneux et al. 2012).

Cultural

- The solution addresses the impact of climate change on the community of Codo by building on the communities’ existing strengths, as it provides alternate choices for crops, and provides crops that can thrive in the current and future climates, thus increasing food security.
- While the solution does not force farmers to change their traditional farming methods, it seeks to introduce new crop species to the environment.

Economical

- The solution is low cost, as farmers grow the crops alongside their seasonal crops and can grow and plant their own seeds. The initial cost of importing seeds will be the only major cost as farmers can then grow their own seeds.
- Tests have shown that the crops from the SOL (Seeds of Life) programme have proven to increase crop yields thus increasing potential income for farmers.

Sustainability

- The design is sustainable as local farmers pick the crops that suit them from the trial stations. Their input is regarded as vital.
- Although the crops may be initially imported, once farmers start growing them, they will be available locally.
- Farmers are informed/trained and educated on the SOL research station days where they evaluate which crops suit them the best.
- The crops create greater farming opportunities for farmers by providing more promising crop yields during the unstable climate conditions, thus improving their livelihood through greater food security.

Technical Functionality

- The solution increases crop yields by growing more reliable crops that can withstand the varying climate of East Timor, because of climate change, and thus increases food security.
- Local farmers volunteer to test and trial the crops and thus provide valuable feedback. No maintenance is required, other than regular traditional farming techniques. Thus, the solution is functional as it carries out its purpose and

increases the much-needed food for security and provides a valuable source of income for the families.

Environmental

- The design affects the environment as it aims to introduce a new crop species to the natural ecosystem. The introduced species may affect the natural flora and fauna and thus there always lies an environmental risk with this solution.

Number of farmers	Maize	Cassava	Rice	Sweet Potato	Peanut
345	Red	Yellow		Blue	
274	Red	Yellow			
174	Red	Yellow	Green	Blue	
150	Red	Yellow	Green		Purple
141	Red	Yellow	Green		
125	Red		Green		
68	Red				
68	Red				
55	Red	Yellow			Purple
37	Red	Yellow	Green		Purple
29	Red			Blue	
10	Red		Green		Purple
4	Red				Purple
3	Red			Blue	Purple
1	Red		Green	Blue	
1	Red		Green	Blue	Purple

Figure 6: Crop combinations grown by maize farmers in Timor-Leste (da Costa et al. 2013, p. 87)

1.8 Detail of Option 5 – Fertilisers

This solution focuses on addressing the issue of poor soil by using fertiliser to dramatically boost the yields in of all the food crops. Currently the use of fertiliser by farmers is scarce and studies have shown that whilst the use of high yielding cultivators has improved the crop yields, by using fertiliser, even greater crop yield increases are possible if the minimal amounts of fertiliser are used effectively. ‘The World Bank identified the lack of fertiliser and other technological innovations as the reason for the lack of poverty reduction in Sub-Saharan Africa’ (Molyneux et al. 2012, p. 823).

Comment [R34]: The World Bank is capitalised, as it is a specific bank (proper noun) that deals with world issues.

Cultural

- The solution builds on the community’s strengths of farming and encourages them to recycle and grow natural fertiliser. This increases crop yields and improves soil quality.

-
- The solution aims to improve the existing natural environment. The farmers grow their crops as they normally would, but instead they have the option to use fertiliser to boost increases in crop yields.

Economical

- The cost of fertiliser can be expensive if the fertiliser is imported. The benefits may not outweigh the costs in this case.
- This cost for the solution can be lowered dramatically if the fertiliser is grown naturally from compost, manure or leaves.

Sustainability

- The local farmers go about their traditional farming methods, but instead they have the added option of using fertiliser to help improve crop quality and boost yields.
- The design aims to take advantage of local resources by encouraging farmers to grow natural fertiliser from leaves, droppings from livestock, and any other organic waste materials, thus encouraging recycling and sustainability.
- This solution may not be entirely sustainable as it is not a long-term solution. This is because the time in which they use the fertiliser entirely depends on how long the farmers can keep making their own natural fertiliser.

Technical Functionality

- The solution aims to increase crop yields but the effects heavily rely on the farmer's ability to produce a decent quality fertiliser. If not done properly, the farmer may do more harm than good to their crops.

Environmental impact

- The design has minimal effect on the environment, as the farmers use local resources to produce the fertiliser. The fertiliser will also help improve soil quality and not reduce it.

1.9 Detail of Option 6 – No Change

Do nothing at all. Leave the village as it is.

1.10 Option Selection

We have decided to integrate three different options (options 1, 2 & 3) into one final solution. This involves combining the embankment, canal and water tank system. The embankment and canals will be used to carry the water from the catchment area, whilst also acting as barriers for flood prevention. The water will be directed into water tanks that are installed underground which will contain a basic filtration system to cleanse the water. Canals are also used as a means for overflow prevention for the water tanks.

We have selected the underground option because the earth is a natural insulator and will keep the water cool during summer and warm during winter. It also simplifies the system by using gravity as a control for water flow.

2. Design Description

2.1 Summary of the Design

The proposed design solution is a combination of design options one, two and three allowing us to provide a solution for both the wet and dry seasons of Codo whose weather patterns have been changing due to climate change. It does this through the mitigation of floods and storage of water, effectively reducing flooding and providing a water source for the community during the dry season. However, there are trade-offs caused by system modifications which are necessary in order to completely integrate the chosen design options in the system.

Using a rainy day for an example, the rain will travel down the slope of the hill where it meets the embankments and gabion blocks. Through these, the speed of the water flow is reduced as both structures are used to block off solids and silt.

Due to the water being blocked off, it is forced to move to the sides where it meets the entrances of the canals. These canals will then re-route the water flow towards a line of water tanks embedded into the ground where it can be accessed by the community.

In the event that the water tanks are filled, the excess water can be diverted away using canals that lead to local rivers, avoiding potential flooding in residential areas.

By re-routing the water flow, damage done to the crops and soil is minimized during the wet season while the re-routing systems provide water to be stored in the tanks mitigating the damage caused by dry weather. This allows the growth of crops through the dry season while fulfilling community needs such as for washing and drinking water.

2.2 Detailed Description

In Codo, there are two main distinct seasons in a typical year. During the wet season, there are excessive amounts of rain causing a loss of crops due to flooding and soil erosion from water accumulation. Similarly, the dry season also has an adverse effect on the livelihood of the crops as there is not enough water to grow the crops. The proposed solution attempts to counter both these problems through the use of embankments and a water tank system which then can be used for irrigation or drinking water.

The proposed project is intended to provide a solution for food security and climate change. It does this through the mitigation of floods and storage of water, effectively reducing flooding and providing a water source for the community during the dry season. This is essential for the livelihood of crops as crops require water throughout the year to be cultivated. However, too much water will cause the crops to be flooded, detrimental to the already limited food supply in East Timor.

The design will effectively utilise East Timor's topography as the majority of the lands in East Timor have slopes of 8-25 degrees as well as regions with slopes exceeding 40 degrees. Applying this knowledge, the proposed solution works by re-routing the water flow from times of heavy rainfall using embankments and canals then collecting it through a system of water tanks.

Since East Timor is prone to heavy rainfall, the canals are to be dug 1.5m wide and 1m deep. This will allow sufficient space for a large amount of water to flow through towards the tanks, increasing the potential for water to be stored. In addition, the embankments are to be 1.5-2m high and 1-1.5m wide. This will block off silt and solids that are accumulated with the water running down the hill. The embankments will also channel the water flow to the sides, allowing the water to be directed into the canals. There are four water tanks to be used with the dimensions of 1.5m wide and 10m deep, to allow enough water to be stored for half a year, reducing the effect of the dry season as there is now a constant water supply.

The embankments and canals are situated on a hill allowing water to flow down under gravity without the need for any assistance. Using a rainy day for example, the rain will firstly fall upon the top of the hill where it travels downwards towards the embankments and gabion blocks. The gabion blocks are used to block off silt and other solids, acting as a barrier to reduce the speed of the water flowing downwards.

The embankments then channel the water towards the canals. This allows the water flow to be re-routed towards a line of water tanks that are embedded into the ground to either side of the village. These tanks will then store the water which can be used for the community's needs.

In the event that the water tanks are full, the excess water can be diverted away using canals which lead to local rivers so that flooding is avoided in residential areas. Furthermore, to ensure safety for the community, bamboo covers are placed over the top of the water tanks which prevent people and animals from falling into the tank.

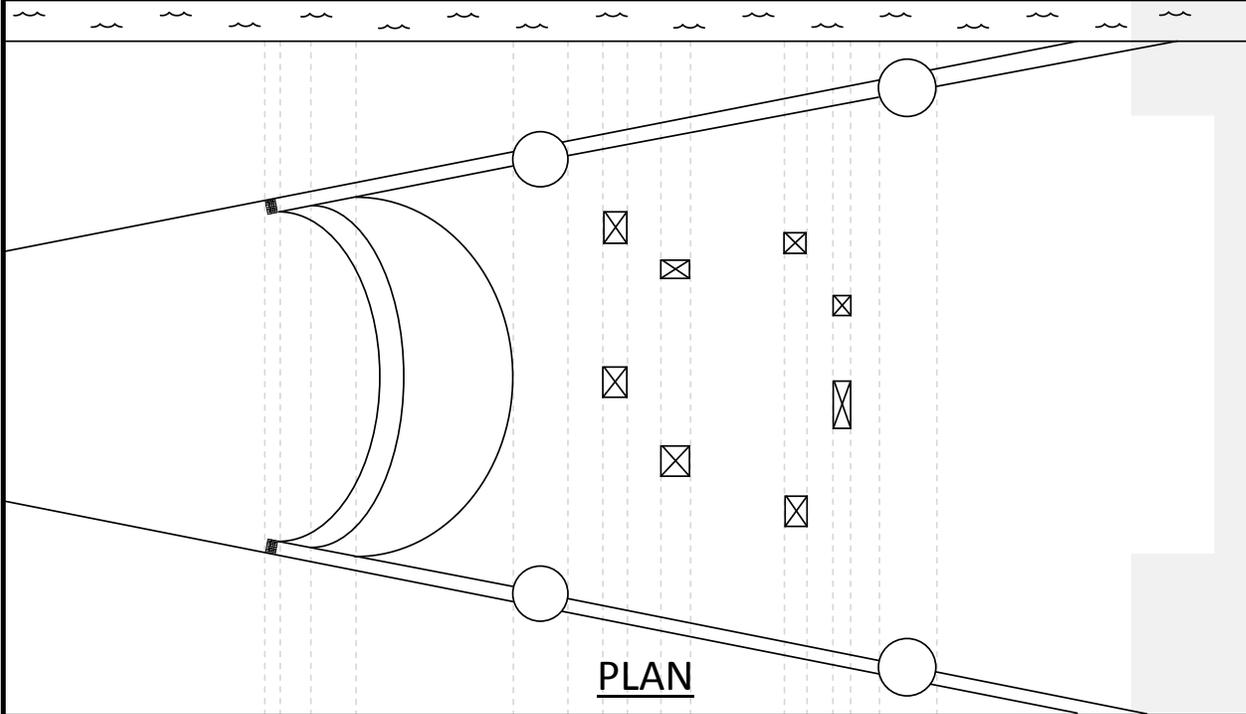
By re-routing the water flow, damage done to the crops and soil is minimized during the wet season while the re-routing systems provide water to be stored in the tanks mitigating the damage caused by dry weather. This allows the growth of crops through the dry season and fulfills other needs from the community such as for washing and drinking water.

Functional description of the proposed solution

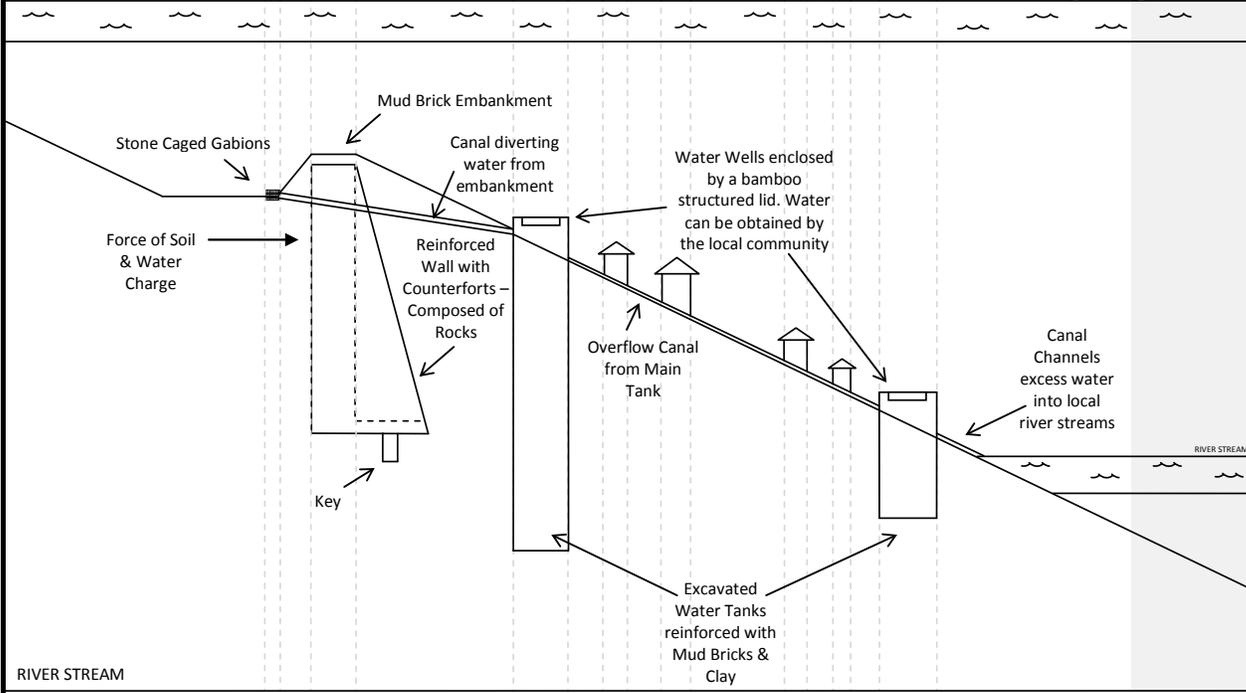
1. Rain falls on top of the hill.
2. The water flows down the hill due to gravity.
3. Water runs through the gabion blocks where the water flow is slowed to a reduced pace; silt and solids that flowed with the water are blocked off by the blocks.
4. The embankment slows the water flow by blocking it causing water to flow from the sides.
5. This water is caught by the entrances of the canals.
6. The water travels through the canals.
7. The water from the canals then flows into the water tanks, effectively storing the water for future needs.
8. The stored water can then be collected using a bucket.

The proposed earth and rock-fill embankment must be designed to function under the climatic conditions forecasted throughout its lifespan in Codo, East Timor in order to resist deformation. Other aspects that largely influence the deformation of the structure involve inconsistencies during the construction phase. This predicament may simply arise from such anomalies as surface fractures or shrinkage cracks. These are minor cracks that form whilst the material shrinks due to the pressure of the surrounding fluids/water and thermal movement/expansion. Despite appearing small externally, they propagate largely from within, eroding the composition's internal structure and ultimately result in the failure of the structure in the long term.

It is an engineer's responsibility to be mindful of the materials selected, as certain materials have unique behaviours that react differently in conditions foreign to them. It is crucial to regulate and respond to these environmental factors that would immensely contribute to the countering behaviour of the materials, as this can simply arise through negligence to perform regular maintenance operations. Disregarding this factor, Codo will continue to suffer from low yields in agricultural production and water sanitation due to external environmental factors that will rapidly escalate beyond its control (Hollander & Kahl 2008).



PLAN



SIDE ELEVATION

2.2.2 Functional Description

Embankments

The embankment works by acting as a barrier which controls the direction of water flow as it flows down the hill from the catchment area and is subsequently diverted into the corresponding water tanks through the usage of canals.

The embankment also serves as a potential barrier to prevent the village of Codo from flash flooding and water surges as it directs the water away and around the village whilst slowing the flow.

Canals

The canal is a type of in-ground trench which carries the flow of water from one place to another. In this design, after the water has been directed to the canals from the embankment, the canals are used to carry and deliver the water to the water tanks.

The canals are also used as an overflow prevention technique to transfer water between tanks in the case of overflow. In the case that there is still too much excess water, the canals can carry this water to the river which is near Codo.

Although vegetation around this designated area must be excavated in order for the canals to be dug out, the plants are to be replanted once the canals are completed. This is in order to restore most of its former natural landscape and to act as vegetative barriers for the canals against heavy water flows.

Gabion Filters

These filters are used to block off solids and silt that travel with the water and also aid in slowing down the rapid water flow from the hill into a more controlled flow.

Water Tanks/Wells

The purpose of the water tanks is to store the collected water. The water from the canals enters the tanks at the top and is extracted using buckets, like a traditional well system. Therefore, it serves as a water source for the community. By having the tanks underground also helps keep the water insulated and therefore cooler in summer and warmer in winter.

These water tanks will be placed in the ground to avoid them affecting the natural view of the landscape.

Vegetation

The vegetation is to be planted on the embankments and any area where soil erosion could be a problem. The purpose of the vegetation is to use the roots to lock the loose soil in place and reduce the soil erosion during the heavy rainfall season and thus reduce the soil pollution of the water. Thus, the vegetation will also keep the soil in the embankments firm and compact and thus maintain structural integrity.

2.2.3 Manufacturing Procedure

In this design, the community and the environment had to be considered in order to choose the materials that best suited our project. Taking this into consideration, it was decided that mud bricks were to be used to construct the walls of the embankments, canals and water tanks as they were ecologically friendly, requiring only natural resources and minimal funds to build.

Mud bricks are composed of earth with a clay content of 50-80% added with a mixture of sand, silt, gravel and carbonates. The carbonates found from limestone (a locally found resource) act to harden the bricks. The sand and gravel act as a skeletal frame for the bricks. Sand also limits the extent of cracking caused from shrinkage caused during the drying process in manufacturing and as well as expansion that occurs from exposure to moisture. Clay is the key ingredient for mud bricks, acting as a binder and increases the bricks resistance to water erosion. It also heightens the density of the bricks.

The material ratio in the mixture is significant as too much sand will result in weak and brittle bricks and excessive clay will cause the finished bricks to shrink and crack under heat. Thus, the ratios of the components must be correct for strong mud bricks with the appropriate resistance to erosion and cracking.

Using these materials, they are mixed with water and stabilising materials such as straw to make the mud brick mixture less prone to excessive shrinkage by significantly improving the tensile strength of the bricks and reducing its stickiness, allowing easier mixing. The mixture is left to soak by ponding overnight. Other alternatives for stabilizing materials include cut grass, weeds and tree bark.

The next day, the mixture is kneaded to a fine consistency until uniform throughout. If this is unsatisfactory, it will lead to cracks and breakages. The mixture is then poured into metal moulds, filled firmly, and dried in the sun for a period of 6-7 days during the dry season. This is to allow time for the mud bricks to harden and to avoid wet season rainfall.

3 Design Description Supporting Documents

3.1 Implementation Plan (Process)

3.1.1 Implementation Overview

The proposed solution shall be installed during the dry season. This is because time is required for mud bricks to harden during dry weather and time is needed to avoid uncompleted canals and embankments being instantly washed away from rainfall during the wet season which will only further increase soil erosion.

In order to test the design, the embankments and canals should be observed during the first rainfall in the wet season to see if they are operating correctly and confirm that the rain is guided by the embankments and canals into the water tanks. Through this observation, the design's performance can be analysed.

If successful, the people of East Timor can return to their daily routines and use the newly implemented design for their farming and personal needs.

3.1.2 Component List

The components needed to realise our design are:

- Sand
- Silt
- Clay
- Carbonates
- Various sized rocks

3.1.3 Implementation Procedure

1. Firstly, the canals will be dug 1.5m wide and 1m deep using shovels. The insides of the canals will be aligned with mud bricks. The soil dug from the canals will be used to raise the embankments which will be internally reinforced with rocks/gravel while soil will be compacted around them and the outside will be lined with mud bricks. The overflow canals linking the tanks together are to be 1m deep and 0.5m wide.

2. For the embankments, they are to be 1.5-2m high and 1-1.5m wide (thickness). To construct the embankments, firstly a trench of 1m deep and approximately 30cm wide will be dug into the ground along the length of the embankment. Bamboo pipes of around 2-2.5m long are to be placed vertically in the trench and the spaces in the trench are to be filled with a mixture of large and small rocks/gravel and stones. Once the ground is packed, the bamboo pipes should be protruding out of the ground at around 1-1.5m high. These will act as the supports for the embankments. Next, the soil/dirt excavated from the canals will be used to build the embankments. A mixture of soil/rocks/gravel is to be placed around the bamboo pipes and compacted. This should

Comment [R35]: This is a good illustration of how a section of a report uses sub-sections and further sub-sections.

be around 1m high. The remaining soil/mud is to be firmly packed around this core structure so that the embankments are now around 1.5-2m high and 1-1.5 wide (thickness). Then all the way around the entire base, mud bricks and clay can be used to align and fortify the embankment and also strengthen it. These bricks should first be dug around 30cm into the ground and then laid upwards from there. If possible, vegetation, grass, trees or plants can be planted into the soil of the embankments to further strengthen and prevent soil erosion.

The embankments will direct the water flow from the catchment area to the water tanks.

3. The water tanks will be groundwater tanks with an open top to act as a well. The tanks will be a multipurpose tank/well. They will be 1.5m wide and 10m deep. The secondary tanks which are the overflow back-up tanks are to be dug 1.5m wide and 6m deep. They will be dug into the side of the hill to allow gravity to direct the flow of water into the tanks. After digging out the tanks, time should be allowed for the soil of the tank walls to dry out. Once the tanks are dug, the walls will be lined with mud bricks and then sealed using a mud/clay coat which is then thoroughly dried. The coat acts as a water proofing. Above ground, mud bricks are to be laid to create a circular well wall rising approximately 0.5m high. This is also to be sealed with clay. A circular lid is to be constructed using bamboo pipes strapped together. Wooden planks or tin sheets can also be used.

4. From the meeting point between the embankment and tanks, there will be short canals to carry the flow into the tank. These short canals will house gabion filters to filter out the water. They are located here so that they are easily accessible as they will require maintenance by the locals to be cleaned once a month during the rainy season and once every 3 months during the dry season.

The Gabion filters are also located in front of the embankments to act as a water break to slow the flow of water whilst also filtering the water from sediment. The canal will be located towards the top of the tank. The filter boxes are going to be composed of rocks encased in caged netting.

3.1.4 Additional Uses

The strength in this design solution is that it provides multiple uses to cater for the essential needs of the community. The solution has been designed in a way that other applications of the system are also possible.

The main function of the solution is to mitigate flood waters. This is a considerable issue because of the monsoonal weather conditions combined with the mountainous terrain in the Codo district. The embankment channels rainwater into the

canals, stopping the water from pouring down the hills and flooding the land below. It is a safety precaution that keeps the villages safe from flash flooding.

An additional use of the system is the provision of water to the locals for their basic needs such as drinking, bathing and washing clothes. The water will also be channelled from the tanks to local farms for their crops and animals. This will supply a steady source of water for agriculture to thrive and for the economy to prosper. The tanks will also act as emergency reservoirs for water in the dry seasons since the weather conditions in Codo follow distinct patterns.

3.2 Discussion

3.2.1 Strengths and Weaknesses

STRENGTHS

- Provides a continuous water supply for crops in the dry season by storing water during the wet season.
- Canals redirect water to avoid water accumulation that can cause soil erosion.
- Improves soil fertility as the soil nutrients are retained through flood mitigation and irrigation systems using canals, embankments and gabions.
- Participation of the community as labour is needed to dig and repair canals, embankments and water tanks.
- Through increased agricultural production, excess crops can be exported for money which results in a higher economic base as there is less reliance on imports.
- Usage of local materials which are found in the natural environment within the country.
- Due to mitigation of water accumulation, more vegetation can be grown on the hillside.
- Stabilised economy due to a more reliable agricultural sector.

WEAKNESSES

- The surface modification may expose subsoil to low fertility that could affect short-term income.
- Highly reliance on volunteers; if there are not enough volunteers, it may result in longer periods of construction and delays due to the time restrictions caused by the rainy season.
- Incorrectly placed canals may result in more damage to the soil as the positioning of the canals may allow the water to wash the soil away more easily.
- As the canals are built, there is short-term damage to subsoil which results in the risk of water washing the canals away.
- There is a limited time frame for the construction to take place. Since year-round monsoonal patterns fluctuate with only few occasions experiencing dry season, a balanced mix of dry and wet season weather is required as soil is more

manipulative when damp but the flood will conversely destroy the construction, and therefore dry seasons are also essential.

- Since it takes time for the project to be effective, in the short-term, the design will not provide adequate aid to farmers.
- Benefits of the implemented system will not take place until it has been approved by engineers and evaluated to be fully operational, which would require a fair amount of time.
- The infertility of soil settlement induced by the ever-changing climate changes within the community of Codo in East Timor implying that there are several contributing factors beyond human control. For instance, the soil being inundated with water during the monsoon, conflicting with the rare occasions of droughts will inevitably generate issues degrading the sturdiness of the structure, and more importantly its foundation. If the groundwater rises due to heavy rainfall, pressure will be increasingly exerted onto the structural foundation walls and floor. In the rare case of extended dry periods, the soil will wither in size as evaporation of water takes place, enabling the foundation to settle. As a result, this settling may cause a portion of the structure to sink.
- Pressure is exerted from the water within the soil. However, the amount of this water will vary in accordance with seasonal drought and rain, especially in clay soil. Soil due to its composition of solids and fluids, is in motion, and will continually exert pressure and shift the foundation. The intensive study of soil mechanics and earth retaining structures will beneficially equip an engineer with the knowledge to respond to this particular situation in Codo, East Timor.

3.2.2 Next Steps

Since the people of the local community are volunteering to build this design the group has suggested they should be allowed to take ownership of the project.

The project will further enhance improvements in soil fertility as the problem of water accumulation and soil erosion caused by water freely flowing down the hills will be immensely reduced to a minimum. The design will also aid in combating the increased heavy rainfall caused by climate change. This will allow vegetation to be grown near the canals as water can be retained as well as redirecting the water using the canals, possibly allowing more valuable crops to be grown on the hillside. Furthermore, the canals will also enable storage of the water by redirecting the water to water tanks. This can be used by the local community for farming and personal reasons.

By providing water during the dry season, it will improve the survivability of crops. As a result, this will induce higher agricultural production yields and strongly resolve food insecurity issues as there is a higher output of food. If necessary, the excess crops can then be exported to foreign countries for money which can then be used for economic purposes and increase the economic status of the country as a whole.

4 Evaluation

4.1 Evaluation Plan

Cultural

- Our solution does not affect traditional farming practices within Codo, except where farmers source their water and considers these cultural changes.
- Our solution is built by the local community so that a sense of joint ownership between the villagers may be achieved, and cultural clashes may not occur through joint ownership between a foreign group and the villagers of Codo. An advantage of having the community build the project is that they may have a say in the building and design of this project, allowing the project to avoid sacred or important sites, as well as giving the villagers a choice as to how this project will affect their lifestyle.
- One aspect which may clash with religious/cultural values is in the time in which the project must be built i.e. this project may not be able to be built on days on which religious or cultural events occur. For example, Ramadan is a religious, Islamic event where people fast during the day. If heavy amounts of work are done, this may affect the health of those who celebrate it.

Economic

- The majority of the components required to construct this project are naturally and locally sourced, reducing the country's economic strain.
- The project is designed so that it is sustainable and long-lasting. If maintenance is required, it is inexpensive and easy to maintain, thus allowing it to be economically feasible.

Sustainability

- Features, such as the water tanks, were modelled after ancient structures. These ancient structures have been able to stand the test of time and some are still used today. This model allowed us to come up with a design that will hopefully last for many years, making the solution sustainable.
- Most materials required for construction and maintenance of the design solution are locally and naturally sourced, which allows construction and maintenance to become much easier.
- Training programs on how to build the projects, as well as basic sciences related to the project, are put in place so that with this knowledge the community will know how to build, as well as maintain, the design solution.
- This solution also considers and takes advantage of future conditions, especially climate change, allowing it to operate in the long-term.

Technical Functionality

- The solution achieves our desired purpose which is to increase food security by allowing farmers to harvest higher yields per year of crops. This is accomplished through flood mitigation during the wet seasons, and by providing water storage and irrigation during the dry season.

- This solution may have issues with the availability of volunteers as this large-scale project must be built by them, and villagers are still considered malnourished.

Environmental Impact

- Reusing excavated soil by a 'cut and fill' method. The soil that will be excavated for the canals and water tanks will be reused for the embankment walls and mud brick mixtures.
- Vegetation that has been removed from the project site will be replanted close-by, so as not to significantly alter the habitats of the animals.
- Using non-toxic materials for construction. Mud brick mixtures are made from natural materials found from the ground. They will not leech chemicals or toxins into the environment and kill local flora and fauna. There are also non-toxic by-products from our project.
- The implemented system will have no carbon footprint. The system's process works on its own without the need for energy input. It is therefore a clean process.

5 Evaluation of Supporting Documents

5.1 Cost Analysis

Economic feasibility delineates the overall expenditure required for the design, development, implementation, testing and evaluation of the proposed solution.

The proposed alternative is economically feasible as local natural resources are easily attainable within the country. The majority of the proposed development simply requires voluntary work in excavating existing soils to create the tanks embedded in the ground. They will be composed of mud bricks which are a mixture of sand, silt, clay, organic matter, and carbonates in the appropriate ratios which are resources readily available in Codo, East Timor. This would be a more viable option than importing foreign supplies from other countries as materials behave uniquely in certain environments and may not comply with the climatic conditions in East Timor.

Additionally, maintenance and sustainability operations are inexpensive as the proposed materials render the system eco-friendly. As a result, influences on the environment are reduced to a minimum. The expenses relating to the engineering application of soil mechanics normally required to monitor the overall system and its longevity to withstand the long-term climatic environmental changes would not be necessary as the system could effectively function of its own accord in the environmental context.

The proposal is inexpensive for the local community as the water provided is naturally collected through rainfall and obtained through existing wells.

It is important to monitor the budget when implementing the proposed solution as this will encapsulate the total expenses made and will be crucial in considering whether the solution is a suitable investment in the context of the community.

5.2 Regulatory and Safety Considerations

Regulatory and safety considerations underline a crucial input into the preliminary planning layout of the design solution to be implemented. These factors ensure that the communities revolve around the solution and are well informed of the safety hazards and consequences faced when disregarding these fundamental principles. Engineering implications have been embedded into the systems to minimise these social concerns.

One essential safety precaution is that people may trip and fall into the well, resulting in severe injuries to the person or even fatalities due to the extreme height of the designed wells for large volumes of water. To prevent this from occurring, well walls are constructed to a certain height beyond child reach and suitable for an average person. Furthermore, a cover is placed on top which will be composed of bamboo sticks tied together. This will enable maximum security for child protection in the event that children attempt to climb into the well as well as a means for preventing insects and bugs flooding into the filtered water tanks.

Another consideration may involve volunteers digging for long periods, instigating relentless harm to their health. In order to avert this problem, a time schedule designating a suitable working scheme will structure the hours and breaks during development and maintenance of the system. This will enable adequate, practical resting periods during construction.

Finally, local workers could misconstrue the design solution as they might possibly commence digging in other places instead of the designated area. Thus, the water flow could lead to weaker or undesirable areas, resulting in higher levels of soil erosion and flooding in areas where the water should have been diverted to channels. To avoid this problem, training will be provided and project planners may be necessary to supervise the construction. Additionally, small wooden poles can be placed in the areas to indicate particular localities, such as where the canals, water tanks and embankments should be excavated.

6 Conclusion

The main objectives of this design solution are to lessen the burden created by the floods which disrupt the growth of crops as they are washed away and to create a water supply that can be used throughout the year. This is accomplished through the collection and storage of water in the wet season, allowing it to be effectively used for farming and other needs during the dry season where there are long periods of drought. We believe that our design solution successfully fulfills these objectives through an effective and reliable rainwater catchment and storage system.

In addition, taking into account these objectives, the design solution also factors in sustainability, environmental and economic considerations. Though it requires periodic maintenance, it does not influence or alter traditional farming practices but instead reduces certain difficulties of farming. Furthermore, it only uses locally-sourced natural materials requiring no foreign materials to be imported. It also reduces the cost of the design solution so that it is economically feasible for the community.

Overall, we highly recommend this design solution to the people of Codo as it will bring about a much-needed strategy for flood mitigation and food security, including the promotion of growth in the agricultural sector and the economy.

7.0 RECOMMENDATIONS FOR FURTHER ACTION

One recommendation to improve the reliability of the design solution and its structural strength to withstand changes in the climate would be to conduct experiments on the mud brick composition ratio. This is to improve the mud bricks' resistance to shrinkage cracks that are detrimental to the longevity and structural integrity of the water tanks.

Another recommendation is to conduct experiments using the solution on a smaller scale in order to test its endurance and performance as well as to identify any unforeseen weaknesses before the project is executed on a larger scale.

Comment [R36]: This is the appropriate place for the conclusion of the report. It often precedes the recommendations section.

Comment [R37]: This is a sound conclusion and no new material must be added here. This illustrates what evidence has been provided in the body of the report.

Comment [R38]: This is the final recommendation for this report and uses a separate heading.

If the intention of the report has been to identify additional actions to be taken as a result of the findings, they should form part of the recommendations section.

Comment [A39]: Recommendations are a vital part of a formal report and are also included in the table of contents page.

For more information about writing in a report format go to:
<http://www.uts.edu.au/current-students/support/helps/self-help-resources/academic-writing/reports>

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Comment [R40]: All references are formatted correctly using the UTS Harvard Referencing System in this instance.

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Appendix

PROJECT SCHEDULE

A = Anthony J = Jeremy L = Lovepreet M = Maynard R = Robert T = Tirth

Comment [R41]: This is the correct position for an appendix that is added to a formal report.

Task	Member/s Assigned	Description
i. EXECUTIVE SUMMARY	J, A, M	
ii. TEAM REFLECTION	ALL	This Project Schedule along with a Gantt Chart will support the project
iii. TABLE OF CONTENTS	M	
iv. LIST OF FIGURES	M	
1. PROBLEM DEFINITION		
1.1 Problem Scope	A	
1.2 Technical Review	M, A, L	
1.3 Design Requirements	M, A, L	
DESIGN OPTIONS		
1.4 Detail Of Option 1	T	Embankments
1.5 Detail Of Option 2	J, M	Irrigation & Flood Mitigation
1.6 Detail Of Option 3	R	Water Tanks
1.7 Detail Of Option 4	L, A	Seeds Of Life
1.8 Detail Of Option 5	L	Fertilisers
1.9 Detail of Option 6	ALL	
1.10 Option Selection		* Acquire & Expand from previous group report
2. DESIGN DESCRIPTION		
2.1 Summary of the Design	T, L, R, J	* Our proposed solution is a combination of design options 1, 2 & 3
2.2 Detailed Description	T, L, R, J	
2.2.1 Functional Block Diagram	J, M	
2.2.2 Functional Description	T, R, J	
2.2.3 Manufacturing Procedure	T, R, J	
3. DESIGN DESCRIPTION SUPPORTING DOCUMENTS		
3.1 Implementation Plan (Process)	L, A, M, T	
3.1.1 Implementation Overview	L, A, M, T	
3.1.2 Component List	T, R	
3.1.3 Implementation Procedure	ALL	
3.1.4 Additional Uses	T, R	
3.2 Discussion	J, R, A, M	
3.2.1 Strengths and Weaknesses	ALL	
3.2.2 Next Steps	J, R	
4. EVALUATION		
4.1 Evaluation Plan		
5. EVALUATION SUPPORTING DOCUMENTS		
5.1 Cost Analysis		
5.2 Regulatory & Safety Considerations		
6. CONCLUSION		
7. RECOMMENDATIONS FOR FURTHER ACTION		
v. REFERENCES		

