Irrigation Development to Improve the Lives of Impoverished Children

Kanchanaburi, Thailand

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Executive Summary

Abusive environments, the sex trade, and drug addiction, common throughout slum communities in Thailand, often impair the development of residents, especially children. In 1997, Thailand's Duang Prateep Foundation (DPF) established the New Life for Abused Children Project to improve the lives of children living in these conditions. The New Life Project provides a safe and supportive environment for children and prepares them for successful reentry into society. In essence, the Foundation offers them a "new life." Operating a project like this is expensive, so New Life is integrating an oil palm plantation to generate revenue and become more financially self sufficient. The revenue from the plantation will allow the New Life Project to continue supporting children without having to rely completely on donations. At the same time, the oil palm plantation will contribute to the children's education by teaching them how to palm oil products. Seeing the results of their hard work contributing to the Foundation will increase their sense of self worth and aid in their rehabilitation.

The plantation at New Life remains unfinished. Most of the 32 hectares of land are yet to be developed. Our project goal was to design a model irrigation system that complements the social and environmental parameters at New Life. Additionally, we created a fund raising brochure to assist with the continued expansion of the plantation and an operation and maintenance manual to promote the longevity of the system. We anticipate that our project and its supplements will contribute to the New Life Project and, ultimately, give more children the opportunity to escape the struggles of slum life.

To accomplish our goal we established three main objectives:

- Assess the current social and environmental conditions of the plantation;
- Design a model irrigation system that can be applied in each subsequent expansion of the plantation;
- Aid in future expansion by creating a fundraising brochure and an irrigation education manual.

To accomplish these objectives, we evaluated the current conditions at the plantation. We began with a general assessment of the development procedures and existing irrigation methods. We then focused on one specific area called "Block3," a 10 acre (4 hectare) section of the 80 acre (32 hectare) plantation, and used it as the area of focus for a model irrigation system. Block3 exhibits characteristics representative of the entire plantation. The oil palms are already planted on Block3 and are in need of irrigation. In the assessment of Block3 we focused on the layout of the field, number of palm trees, and amount of available water for irrigation.

Through our data collection and analysis four major findings emerged for the Block3 irrigation system:

- Environmental parameters;
- Social parameters;
- Appropriate irrigation components;
- Optimized design.

The *environmental parameters* of Block3 greatly influenced the design of the irrigation system and the selection of each major component. Initially, we determined that the quantity of water available in the reservoir is sufficient for year round irrigation. We designed the system to distribute all of the water solely from that resource. We used surveying and

AutoCAD to find the exact area and layout of the land and ultimately to determine the configuration and layout of the water distribution system. To choose the most appropriate filter, we tested the reservoir water for impurities and found its contents to be at a moderate to high level of concern for clogging. The most appropriate emitters were found after determining the infiltration rate of the soil and performing a mock irrigation test. Based on the selection of the other components, we chose a pump that was compatible with their specifications as well as the environment.

The *social parameters* of the New Life plantation were identified by observing the existing irrigation design and operation. We evaluated the components of the current system and the operator's backgrounds to establish the current level of technology and maintenance practices. When selecting the components of the new irrigation system we considered this level of technology to ensure that the new system was at a similar level. These observations also led to our recommendations for the future operation and maintenance of the irrigation system.

The assessment of Block3 enabled us to design a model irrigation system for the plantation. By comparing different irrigation methods we determined drip irrigation to be the most appropriate for the New Life Project. We optimized the specifications of the Block3 drip irrigation system for cost and performance. These analyses enabled us to choose from a range of components that complemented the current level of technology at the New Life Project. Apart from the necessary components we considered potential benefits of other design options, such as a water tower and a fertigation system. Flexibility in our design was crucial if our design was to become a model irrigation system for the entire plantation. The New Life Project will be able to manipulate the model irrigation system in the future and tailor it to each "Block" of the 32 hectare plantation.

Our findings enabled us to create the final design for an appropriate model irrigation system for the New Life Project. We presented the New Life Project with three final designs that were optimized for the least amount of power needed, the lowest cost, and finally our recommended design. Each design incorporated the technological and social considerations identified above. A summary of these designs is shown below in Table 1. Each design and the individual listing of components are displayed in tables in the Findings and Discussions Chapter.

Optimization	**Cost (Baht)**	**Cost (USDollars)**
Lowest Required Power	111,092	2,849
Lowest Cost	50,566	1,297
Appropriate System for New Life	75,515	1,936
A conversion rate of 39Baht=1USDollar was used at the time of this publication		

Table 1: Model irrigation optimizations for the New Life Project

Specifically, the design deemed to be the most appropriate for the New Life Project was optimized for cost and functionality, as well as agronomic considerations. The cost and functionality were addressed by selecting lateral and main line tubing sizes that would not require an excessive amount of power while conserving cost. The lateral and main line tubing account for over half of the total cost for the drip irrigation system. The agronomic considerations were addressed by incorporating two emitters for each oil palm. Roots grow towards water; therefore, using two emitters allows the roots to grow towards both emitters rather than in one concentrated area. The cost analysis of the irrigation system addressed the importance of designing for both performance and cost.

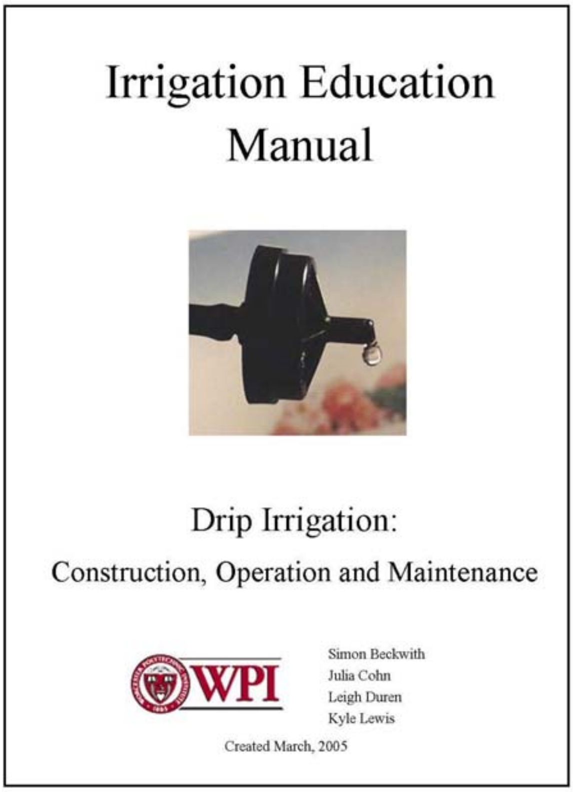

Figure 1: Cover of the *Irrigation Education Manual*

Using our findings from the environmental and social parameters, irrigation components, and optimal irrigation design, we created two deliverables to promote the success of the irrigation system; 1) An irrigation education manual, and 2) A fund raising brochure. The irrigation education manual seeks to promote the proper management and maintenance of the irrigation system. New Life can give this manual to the current operators that rotate monthly, as well as any new operators. The manual was specific for drip irrigation systems and explains the function and importance of each major component. The manual is located in Appendix M, and the cover page is shown in Figure 1.

We created the fundraising brochure to encourage donations for implementing the irrigation system. With this proposal the New Life Project can inform potential donors about the importance of the irrigation system for the expansion of the Project. The cover of the brochure, shown in Figure 2, introduces the necessity of the project and requests donations. The proposal, located in Appendix N, was created in an attractive brochure format to encourage donors to help finance the implementation of the system.

In summary, our research enabled us to optimize a drip irrigation design that complements the environmental and social conditions of the New Life plantation. The design will contribute to successful development at New Life. To further aid their development, we created a brochure for fundraising and a manual for drip irrigation system management and maintenance. It is our intention that these contributions aid in the expansion of the New Life Project and ultimately provide more opportunities for underprivileged children to be given a new life.

Figure 2: Cover page of the fundraising brochure

Abstract
The New Life for Abused Children Project in Kanchanaburi, Thailand was established to rehabilitate underprivileged children and prepare them to reenter society. The Project is currently integrating a 32 hectare oil palm plantation into their program, but they lack a proper irrigation system. Based on environmental and social assessments of the project we designed a model system for irrigation as well as an irrigation education manual and fundraising brochure to support the system.

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1 Introduction

The Klong Toey slum is the largest slum community in Bangkok with approximately 130,000 residents, 46,800 being children (Oxfam, 2003). Unfortunately, children born into a struggling community are immediately disadvantaged. The Thai government attempts to assist slum communities by providing free education, but far too often children do not have the mandatory birth certificates required to attend school, let alone money to buy uniforms and books. Many children become addicted to drugs and are often lured into the sex trade. Indeed, many children are led into a state of hopelessness.

The New Life for Abused Children Project is a rehabilitation center specifically for children who have fallen victim to poverty and the conditions of slum life. Located 200 km outside of Bangkok in the rural province of Kanchanaburi, the New Life Project gives children an opportunity to escape the toils of the slum. The rural and nurturing environment of the Project encourages regular development and the importance of education. At the New Life Project, the children are given the opportunity to attend a nearby school where they interact with the local children. The older girls are given the opportunity to participate in vocational training courses. The directors of the New Life project believe that “the climate of safety, the sharing and cooperation in the group and the sense of 'family' amongst staff and girls all help to ensure that, when it is time for the girls to leave the project, they will do so secure in the knowledge that they can face whatever life brings with confidence” (Duang Prateep Foundation (DPF), 2003).

To promote the rehabilitation process, as well as its sustainability, the New Life Project has decided to integrate an oil palm tree plantation into the Project’s activities. The palm products will be sold and the revenue generated will allow New Life to continue operating without having to rely solely on donations. Eventually, the children will help make products from the palm oil. Seeing the success of their hard work contributing to the foundation will encourage the children’s sense of self worth and aid in their rehabilitation. (DPF, 2003). Currently the Foundation is utilizing only 6.5 hectares out of the total 32-hectares available for the palms. Due to the lack of an effective irrigation system, and the funding necessary to create one, development is being hindered. The design of an irrigation system can improve the environmental conditions at the plantation. At this point, New Life does not have a design for an appropriate irrigation system for their plantation.

For New Life to develop 32 hectares of palm trees, it is essential that they have an appropriate irrigation system. The system should be compatible with the environment as well as distribute the ideal amount of water to the palms. To assist New Life, our goal was to utilize the land and available water on the plantation to design a model system for irrigation. Additionally, we sought to address upcoming development by creating an irrigation education manual and a fundraising brochure. We designed the model system for one field in particular, Block3, which contains palm trees and has an immediate need for irrigation. The design process began by researching several areas of irrigation technology and performing the necessary data collections onsite. We assessed the social and environmental parameters to ensure that it would operate properly using a determined range of technology. We also created a fundraising brochure to encourage donations for the implementation of the system and an irrigation education manual to promote proper operation and longevity.

Expansion at the New Life Project will create greater opportunities for the slum children. Increasing the amount of trees at New Life will eventually increase the funds brought in by the palm oil. In turn this profit will allow more children to escape slum life and develop in the environment of the New Life project. Oil palms can produce fruit for 15 years, which will create a lasting and much needed source of income for the Foundation and its many projects. With an effective design, expansion at the plantation will continue and more underprivileged children will be given the opportunity for a new life.

2 Background

The New Life for Abused Children Project plans to use the oil palm revenues to financially support their rehabilitation center, allowing more children to heal and grow in a safe, nurturing environment. For the plantation to generate significant revenues, however, it is essential for the New Life Project to have an appropriate irrigation system. To understand the connection between an irrigation system and the development and sustainability of the New Life Project, this chapter begins by describing the sponsoring organization. In this section the intent of the Duang Prateep Foundation is outlined as is the New Life for Abused Children Project itself. This section seeks to make the connections between how the oil palm plantation will contribute to the development of the Project and how an effective irrigation system is necessary to accomplish such development. The next section discusses the different irrigation options. The methods of irrigation and their applicability to the oil palm plantation are explained here. The chapter concludes with an explanation of the social considerations that were addressed to design the appropriate irrigation system for the New Life Project.

2.1 Giving Children a "New Life": The Duang Prateep Foundation

The Duang Prateep Foundation (DPF) was established in 1978 as a result of the conditions in the Klong Toey slum of Bangkok, Thailand. Duang Prateep means "flame of hope" and the mission of the Foundation is to act as a light for struggling communities. The Foundation was established by Prateep Ungsongtham, a woman whose dedication and enthusiasm has improved countless lives. Prateep Ungsongtham established the Foundation with only 5 workers. Since then, the Foundation has thrived and now consists of over 100 full-time staff members, 20 full-time volunteers and receives donations from people around the world. The Foundation has taken the initiative to address the problems that face the underprivileged populations of Thailand, primarily people living in the Klong Toey slum. The DPF is recognized throughout Thailand as one of the few organizations that represent and support the poor. As the Foundation grows, it assists a greater number of people by creating new programs and projects. One of these projects is the New Life for Abused Children Project (DPF, 2003).

The New Life for Abused Children Project was established in 1998 to offer a safe living environment for children suffering from the impacts of a struggling community. Many of these children are orphans, victims of domestic abuse, or exploited by the drug and sex trade. Based on a similar project for boys, the New Life for Abused Children Project provides children with a chance to escape the pressures they face in their daily lives. The children are given the opportunity to attend a local school and mingle with some of the local children. The Project also utilizes the land for education by growing palm trees, a variety of flowers, and raising animals. Having the children care for the plants and animals helps instill a sense of self worth and aids in their rehabilitation. Typically, the children remain at the Project for three years and live in comfortable dormitory complexes. During this time it is the mission of DPF to provide the children with an environment where they can gain the self-confidence and life skills necessary for them to return home or start a new life elsewhere (DPF, 2003).

To support the rehabilitation program at the New Life Project there are 32 hectares of land dedicated for growing oil palms. The New Life Project intends to use the palm oil in a variety of products to be created by the plantation's residents. One purpose for the oil is to make products such as soap. Products like these can be easily and enjoyably made by the children. In addition to making useful goods, the children gain a sense of self worth by seeing the results of their hard work. The palm oil and products are then sold in the market to create revenue for DPF and ultimately to make the New Life project more financially self sufficient. By making project sites, such as the New Life Project, more self sufficient the DPF can conserve funds to expand and help more people.

In order for New Life to support itself, an irrigation system must be installed to preserve its financial resources, the oil palms. It is our goal to provide the New Life Project with tools to fund, construct, operate, and maintain an irrigation system. In order to accomplish this goal, our irrigation system must correspond to the following three factors:

- Environmental Consideration;
- Irrigation Equipment;
- Social Factors.

Only when all of these factors are understood can an appropriate irrigation system be designed.

2.2 Environmental Considerations at the New Life Palm Tree Plantation

To design and optimize an irrigation system for the New Life palm tree plantation, several ecological and geological factors must be considered. Without an in-depth understanding of the plantation and its many factors, an irrigation system can not be optimized to maximize cost with performance. The layout of the land and its properties are essential for calculating the amount and size of materials that will be the most suitable for watering the plantation. The reader is provided with a description of the current layout of the plantation and the environmental features of the area. A discussion follows on the life sustaining demands of the oil palm trees.

2.2.1 Water and Land at the New Life Project

The most important factor of any irrigation system is its water source. At the New Life Project, almost all of the developing areas are located near a water source. These water sources consist of six man-made reservoirs, one well, and one water tower and well combination. The reservoirs consist of large square depressions that reach below the water table. They replenish from rain water and groundwater and are currently the main water resource for the plantation. All the reservoirs are exposed at the surface and they do not receive much cover from local vegetation. The direct exposure that the reservoirs receive from the sun and atmosphere increase the rate of evaporation and growth of algae. The effects of evaporation are difficult to observe, but algae growth and clay content are evident from the green-brown water seen in Photograph 1. The single well at New Life does not provide water for irrigation purposes. The well supplies water to a system of storage tanks closer to the foundation center. The water is pumped approximately one kilometer to the foundation for use in the buildings and consumption.

Photograph 1: One of the six open reservoirs at the New Life Project

In 2002, the Australian and New Zealand embassies of Bangkok, along with the Australian-New Zealand Woman's Group, donated a state of the art water tower and well combination. Originally, it was powered by a windmill that was replaced by a submersible well pump, located underground. The pump worked for a short time, but stopped working and still remains out of order. The system is shown in Photograph 2.

Photograph 2: Water tower irrigation system at New Life

To complete our project goal of designing a model irrigation system for New Life, we were given a parcel of land known as "Block3". Block3 is a long field with a reservoir on the far side. The field is about 3.8-hectares (9.5-acres), or about 12% of the entire plantation. The majority of the land has been cleared and cultivated with approximately 424 young oil palms. A small area, approximately 0.7-hectares (1.7-acres) nearest to the reservoir, is undeveloped, but will eventually hold oil palms. The layout and physical appearance of the field can be seen in Photograph 3.

Photograph 3: Block3 at New Life Project

With a description of the New Life plantation and the Block3 layout, we can now turn to an investigation of the typical climate for the area. The investigation provided insight into the geographical location and weather patterns associated with the area. This information assisted in defining the parameters of our irrigation design.

2.2.2 Climatic and Geologic Factors

Thailand has a large range of climates that can significantly influence irrigation. For this reason we researched the location and climate factors of the New Life Project area. The project site is located within the Tha Muang district which is in the province of Kanchanaburi. The region is known to be the central part of Thailand ("Driving in Thailand", n.d.). Two detailed maps are provided below to place Kanchanaburi into perspective. Map 1 shows Kanchanaburi's location relative to the entire country of Thailand. Map 2 is specific to Kanchanaburi province. Map 2 shows in detail the location of cities, rivers, and districts. The Tha Muang district is located on the bottom right hand corner of Map 2.

Map 1: Location of Kanchanaburi within Thailand (http://www.kanchanaburi info.com/en/mapThai.html)

Map 2: Map of the Kanchanaburi Province (http://www.kanchanaburi-info.com/em/mapproe.html)

Geographic, geologic, and hydrologic maps of Thailand, provided by Clark University's Burnham Map and Aerial Photography Library, contained insight into environmental variables that an appropriate irrigation system must compensate for. Important variables, determined by geographic location, include average rainfall, average temperature and soil. The rainfall in Kanchanaburi affects the water available for irrigation. Interestingly, Kanchanaburi experiences dry spells and periods of torrential rain. Over the past 50 years, the dry season (December, January and February) has averaged less than one inch of rain per month. The start of the rainy season, which lasts from May to October, begins with the southwestern monsoon. September and October are the wettest months of the year, and average around seven inches of rain per month (Weatherbase, n.d.). The area has a considerable amount of water throughout the year despite periods of little rainfall (Central Thailand, n.d.). The weather patterns of the New Life Project area will determine how often and when the irrigation system will be in use. At the present time, Kanchanaburi province is experiencing a particularly severe drought with no rain in over four months.

Varying temperatures throughout the year are other important variables which affect the volume of water available in the plantation's reservoirs. If the temperature, then the evaporation rate is high, and the water volume of the reservoirs will decrease. In addition to a lack of water, salinity of the water increases the possibility of making the land infertile for future crops. The average temperature for the Kanchanaburi province is 82^{o}F (27^{o}C), ranging from 72^{o}F (22^{o}C) to 93^{o}F (34^{o}C) throughout the year (Weatherbase, n.d.) An ideal irrigation system must be able to compensate for the effects of fluctuating temperatures and varying rates of evaporation.

The soil conditions at the New Life Project directly determine the rate at which water can be delivered to the palms. This rate is determined by the soil type, and is known as the infiltration rate. Percolation tests measure the amount of time it takes for the water to fill the voids between the soil particles. A slow infiltration rate implies small soil particles, such as clay, and a fast rate implies larger particles, like sand. The voids between smaller particles are filled more easily, which causes swelling of the soil. Once the soil swells, the rate of infiltration slows (Gustafson & Machmeier, 2005). The size of the soil particles, varying from clay (less than 0.002 mm) all the way to stones (greater than ten inches), affects the drainage of the soil. The coarse-textured soils have a lower water retention rate than fine textured soils (Soil Texture, 1978). Balancing the soils retention rate with the delivery rate is very important because it effects how much water is actually being delivered to the root system. If the delivery rate and retention rate are high, then water is not absorbed by the plants and, instead, pools on the surface. The pooling of water is also known as run-off, and is ineffective because the water can more easily evaporate or stream away from the plant. Ideally, water being delivered to a plant must closely match the rate at which the water infiltrates into the ground. The soils at the New Life Project can be seen in Photograph 4. Because the soil at Block3 is clayish, the infiltration rate is rather low. Correspondingly, the delivery rate of our design must be appropriate to the soil conditions at the New Life Project.

Photograph 4: Soil at the New Life Plantation

Determining the environmental conditions at the New Life Project helped identify factors for designing a complete and appropriate irrigation system. Before moving to the irrigation system specifics we now turn to a discussion of oil palms. Understanding the crop is also important for choosing appropriate irrigation components.

2.2.3 Oil Palm Plantation

A comprehensive understanding of the oil palm trees located at the plantation allows for a proper evaluation of crop placement and water needed for optimal growth. Oil palms (*Elaeis guineensis*) are the largest species of palm trees and are also a very profitable crop. The Food and Agriculture Organization of the United Nations (FAO) report that the oil palm “produces the largest amount of oil per hectare when compared with any other oil crop” (Griffee, 2003, ¶2).   As shown in Photograph 5, the fruit grows at the base of the branches and turns black when it is ripe.

Photograph 5: Oil Palm (http://www.ecoport.org)

There are two species of oil palms, the *dura* type and the *tenera* type. In the last fifty years the FAO has worked in Africa to grow hybrid species of oil palms to maximize the production of useable oil (Agriculture21, 2002). The New Life Project plans to plant around 4,800 oil palm tree seedlings from the south of Thailand as they are donated. New Life believes these seedlings are Te-Dura oil palms and considers these palms to be the best available. Given the environmental conditions discussed, the most important factors of the oil palm to understand for irrigation design include the root system, water demands, and soil requirements of the palm trees. Understanding these factors enabled us to cater our irrigation system to the needs of the oil palms.

The root system for oil palms consists mainly of horizontal roots that grow within the top meter of soil. These roots, which can grow up to 20m from the base of the tree, are very superficial and are easily disturbed by soil compaction. The roots growing vertically into the ground are penetrating roots that anchor the tree (Griffee, 2003). Also, according to Griffee (2003), the most important feature of the soil is that it must be able to physically support the palm tree and hold it upright. Figure 3 gives a computer generated schematic of the oil palm root system. Understanding the root system of the oil palm allowed us to determine the best location to deliver water. The roots are densest directly underneath and near the palms trunk. For optimal water consumption water should be delivered in this area.

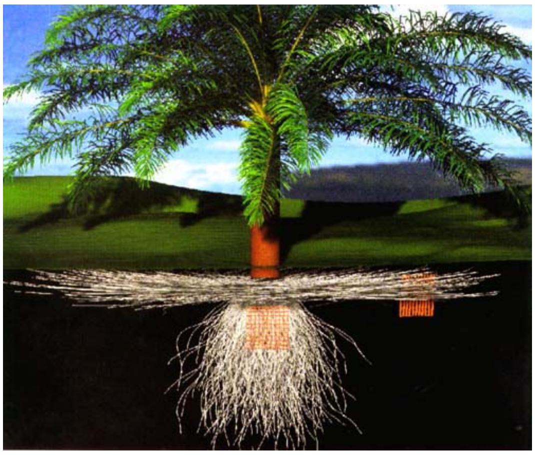


Figure 3: Root system of the oil palm (http://www.ecoport.org)

For optimal growth, oil palms must live in certain climates and receive necessary amounts of nutrition. Oil palm grow best within a temperature range between 30-35^{o}C (86-95^{o}F). Ideally the temperature should not fall below 20^{o}C (68^{o}F) making the climate at the New Life plantation suitable. Oil palms require a minimum of 5-hours of intense sunlight per day (Griffee, 2003). The sunlight hours available to the oil palms depends on their spacing. The closer the trees the less sun they receive. New Life has spaced their palms in a nine by nine meter grid. Once the palms are fully grown, the spacing will be optimal for balancing the number of trees with sunlight demand. For the first year, oil palms should receive two-gallons of water per day. From the second to the eighth year, a supply of four-gallons every three to four days should be applied to the oil palm. After maturity at the eighth year, water can be applied weekly (Pakissan, 2005).

The techniques used by the New Life Project on developing and planning the palm tree plantation are to continue expansion as funds become available. The plantation currently hosts about 1,200 oil palms with plans to plant 4,800 more over the next ten years. Knowing the number of trees and area they will cover is necessary because the water demand influences the design of the irrigation system. The placement of the palms on the plantation and the location of the plantation relative to available water resources affect irrigation demands. Future placement of the oil palms will affect the design and cost of the irrigation system, making placement important to optimize growth and cost.

The environmental conditions and demands of oil palms contribute to the process of determining an appropriate irrigation system. The primary function of an irrigation system is to provide water, but it is also important to consider how the water will be provided and if it is appropriate to the land and the crop. We now move to a discussion on various types of irrigation systems. Primarily we will consider the ability of each system to facilitate the growth of oil palms in the given environmental conditions.

2.3 Irrigation Systems

Factors that contribute to determining the best type of irrigation system include the amount of available water, the crop, environmental conditions, and available funding. The New Life Project has a scarce amount of water available during the dry season. They must use this water to irrigate the oil palms which are planted on a relatively flat plot of mostly clay soil. To fund the irrigation system, New Life relies solely on donations. The ideal irrigation system must account for the all of these factors. We will now discuss possible types of irrigation systems.

2.3.1 Types of Irrigation Systems

There are four basic types of irrigation systems: drip, sprinkler, furrow, and border. Each of these systems is ideal for different environmental and agricultural situations. The following section describes each system in detail and its applicability to the New Life Project.

Drip irrigation is the current method of irrigation at the New Life Project. In drip irrigation, water is delivered to the plant root through emitters. A variant of the drip irrigation method is called subsurface drip irrigation. In a drip irrigation system the emitters are above the surface, see Photograph 6, while in the subsurface drip irrigation the emitters are underground. Both systems can be designed for water delivery by a pressurized pump or an elevated water tower where the water is delivered by gravity (Finkel, 1982).

Photograph 6: A small scale drip irrigation system (http://www.xeriscape.net/images/SubIrrigationSite.jpg

Drip irrigation requires regular maintenance to clean the silt and algae that accumulates in the tubing. The accumulation causes blockage which can lead to failure of the entire system. Minor blockage can cause water to be emitted inconsistently. An adequate filtration system is a preventative measure that will prolong the times between cleaning. Above ground drip systems are easier to clean, but subsurface systems are more appealing to the eye, have less water loss, and apply water to the roots more effectively (Finkel, 1982). With the visible lines and visible emitters, it is also much easier to diagnose problems with above ground systems. Functionality is important to the plantation at New Life, and straightforward maintenance procedures are also important. Above ground drip irrigation is more appropriate to the New Life Project because they already know how to build the lines of the above surface drip system, and subsurface systems are more problematic. According to Dasberg & Or (1999), the emitting lines will be above ground, while the main lines should still be underground.

Another method of irrigation is *sprinkler irrigation*. Distributing water through a sprinkler irrigation system is similar to drip irrigation. The difference is that the water is pressurized and forced out of an above ground emitter instead of trickling. Photograph 7 is an example of sprinkler irrigation.

Photograph 7: Sprinkler Irrigation System (http://mi.water.usgs.gov/splan6/sp08904/saginawcty.php)

In order to force the water from the system, sprinkler irrigation requires significantly more pressure than drip irrigation. Added pressure requirements increase the rate of energy consumption of the system. Sprinkler irrigation is beneficial for crops that need water distributed evenly, like grass (Finkel, 1982). However, oil palms do not require an even water distribution. With sprinkler irrigation "the whole orchard, including the inter-row spaces, is wetted, thereby interfering with management operations, damaging soil structure, and resulting in soil compaction, particularly if traffic occurs soon after wetting" (Dasberg & Or, 1999, p.125). As mentioned above, the horizontal roots of the oil palm are very easily disturbed by soil compaction. Sprinkler irrigation has a high water loss, is inefficient in windy and high temperature conditions, and has potentially higher costs in construction and operation.

Border irrigation and the similar *furrow irrigation*, are gravity fed systems that require deep trenches to transport water from a nearby reservoir. The system is usually implemented when the land is uncultivated so that digging is easy and inexpensive.

Photograph 8: Furrow Irrigation (http://home.howstuffworks.com/irrigation2.htm)

As shown in Photograph 8, the trenches are graded before the crops are planted (Finkel, 1982). Furrow and border irrigation also require a plentiful water source to flood the trenches. The crops are planted on ridges and the shape of the furrows can vary depending on the slope of the land and the required distribution of the water (Brouwer, n.d.).

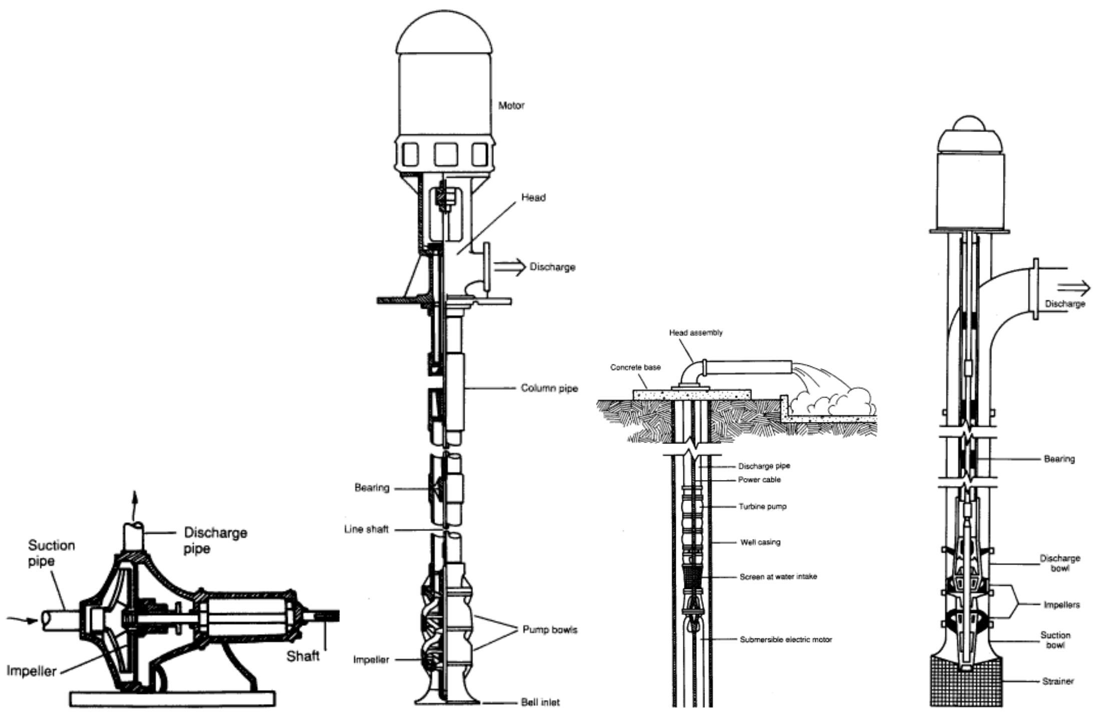
After briefly investigating the principles of drip, sprinkler, border, and furrow irrigation we conclude that drip irrigation is most appropriate to New Life. Drip irrigation delivers water to the root of the trees. This promotes growth while conserving water which is especially important because there is a limited supply of water in the area. Additionally, it decreases the salinity of the soil by reducing the amount of water lost through evaporation. Although the investment of a drip irrigation system can be expensive, Section 2.3.2, Components of Drip Irrigation, explains the importance of each aspect of drip irrigation and its relevance to New Life. With a thorough understanding of each component, a better understanding of the system as a whole will follow.

2.3.2 Components of Drip Irrigation

To optimize the drip irrigation system each component must be carefully chosen specific to the field. The first component is the pump that brings water to the system. From the pump, water can either go to a storage tank or through filters to the lines for distribution. Although it is possible to calculate parameters such as exact volumetric output necessary, evapotranspiration rate of the oil palms, or the pressure drop around corners, the "usefulness of scientific approach for design is limited by lack of information on soil hydraulic properties, the lack of consideration of plant root uptake, and the incompatibility of scientifically based recommendations with commercially available products" (Dasberg & Or, 1999, p.49). Instead, we decided to use a combination of a scientific and analytical approach to identify the components of the drip irrigation system for New Life. Based on this approach, we considered both environmental and social factors in order to design a technologically appropriate irrigation system.

2.3.2.1 Pumps

According to Scherer (1993), there are typically four types of pumps used in irrigation. These include the centrifugal, deep well turbine, submersible and propeller pumps. Considering their advantages and disadvantages, each type of pump is ideal for different situations. The ideal pump depends on the water sources available at the plantation, the volumetric flow rate necessary for the design, and the total dynamic head. Head is an important term that will be used throughout this report. It refers to the pressure that a height of a vertical column of water would provide which is based on the density of water and gravitational force. For example, a column of water that is 2.31 feet high provides one pound per square inch (psi) of pressure. Any of the pumps shown in Figure 4 could apply to the irrigation system at the New Life Project. Choosing the correct pump required us to investigate each one of the following pumps.



Horizontal Centrifugal Deep Well Turbine Submersible (Installed in well) Propeller

Figure 4: Various Water Pumps (http://www.ext.nodak.edu/extpubs/ageng/irrigate/ae1057w.htm)

In an irrigation system it is necessary to move water from the water source to the distribution system. Ideally, the water supply is at a high elevation and flows through the system by gravity, but a pump is usually needed to supply the pressure. In practice, two types of pumps are commonly used in drip irrigation, centrifugal and submersible pumps. The centrifugal pump is optimal for pumping from water sources that are less than 15 feet deep while a submersible works best for water sources that are deeper than 20 feet (Appalachia, 2004). Two other types of pumps, submersible pumps and propeller pumps are also used but not as frequently.

Centrifugal pumps are commonly used in irrigation systems because they are low cost, easy to maintain, relatively easy to install, and easy to inspect. Centrifugal pumps provide constant pressure head (Scherer, 1993). They cannot pump air and must be primed with water before being used. The New Life Project currently already uses a centrifugal pump at a well about 1km away to provide water to the main facility. They also use a portable centrifugal pump to transport water from the reservoirs.

Deep well turbines are used where a centrifugal pump is not sufficient, such as where the water table is very low. These pumps have a much higher efficiency than centrifugal pumps, but are also more expensive and harder to maintain. For a deep well turbine to work correctly, it must be perfectly aligned with the energy source and have a stable, usually concrete foundation, to be mounted on (Scherer, 1993).

A submersible pump is similar to a deep well turbine, but the motor is installed in the pump itself. Submersible pumps require a high amount of energy and must be wired to the electricity source in a water tight connection. Submersible pumps are usually more expensive than deep well turbines because of their unique type of motor (Scherer, 1993).

Finally, propeller pumps are used for low lift and high flow applications and cannot be used for suction lift, such as drawing water from a well. A propeller pump alone is limited to about 20feet (6.1meters) of pressure head. Adding additional stages of propeller pumps can increase the amount of pressure head but does not double it (Scherer, 1993).

Although each of these pumps could theoretically be used at New Life, we will be focusing on the centrifugal pump to incorporate into the design. Also, centrifugal pumps are very common and already familiar to the New Life Project. Appendix A includes a more thorough explanation of how a centrifugal pump works.

2.3.2.2 Water Sources

The source of water for any irrigation system determines the initial quality, and processing steps needed to make it suitable for irrigation. Different water sources are optimal for different types of irrigation. This section focuses on the problems and advantages associated with water sources for drip irrigation.

An effective well not only provides water to the system, but can also minimize cleaning of the distribution system. A well can be the first line of defense against silt and clogging particles, but can also contain significant amounts of sand and gravel. The amount of water and impurities in the system depends on the depth and location of the well. Defense against clogging particles can be implemented by digging below the water table, vertically inserting a punctured tube, and filling in the area with sand. The sand acts as a filter while allowing the water to be collected in the tube (ERM Consultants, 2004). A filled well is safer for people then an open well that anyone or anything could fall into. Once a well is installed, a pump can either transport water to a storage tank or directly to the distribution system.

Currently, New Life has six different reservoirs on site and is planning on constructing two more. While the reservoirs do create available water, the "water from reservoirs is the most problematic for drip irrigation, as it contains not only suspended solids, but also appreciable amounts of algae, zooplankton, bacteria and other organic material" (Dasberg & Or 1999, p.95). Without filtering, these organic materials will eventually cause a drip irrigation system to fail.   The irrigation system for Block3 will incorporate its associated reservoir therefore, a filtration system will be crucial to the design.

2.3.2.3 Water Quality

Salinity, the amount of salt in the water, is an important consideration in terms of crop yield and crop health. Dasberg & Or (1999) explain that the sustainability of many drip systems are dependant on the management of the soil salinity which affects the growth of the crop.

Although all irrigation waters have some salinity, drip irrigation is better for brackish water than both sprinkler and furrow irrigation because of the way it is applied. Also, with drip irrigation, the leaves of the plant are not wetted, so the leaves don not burn or absorb the salts (Dasberg & Or, 1999). Because drip irrigation is considered high frequency irrigation, there is less time between applications and therefore the water has less time to evaporate, preventing an increase in salinity of the soil. Lastly, because the application is concentrated there is continuous leaching from the active root zone to the secondary, outer roots. Even with these advantages, there is still a build up of salt which can be flushed out by heavy rainfall. For the typical climate of New Life, the irrigation season lasts about 6-months and the rainy season lasts about 6-months, both irrigating the crops and leaching the salinity from the soil.

Poor quality water containing gravel, silt, micro-organisms, chemical precipitates, and other impurities cause a problem for drip irrigation because the emitters can become easily clogged. Dasberg & Or (1999) reported a study done by Bucks et al. (1982) in which they made a classification on the severity of the problems caused by impurities in the water. They split the impurities into three categories: "physical- caused by sand grains, sediment or foreign materials such as pieces of plastic or insect fragments; chemical- precipitation of carbonates at high pH, iron and manganese complexing with the aid of bacteria, and sulfur depositing from water due to certain bacteria; and biological- microbial slime, algae or plant roots" (Dasberg & Or, 1999, p.12). Initial clogging is usually from the physical impurities, while gradual clogging is caused by the chemical and biological impurities. Although these problems can be slightly remedied by choosing the appropriate emitter type and design, the best remedy is to evade the clogging all together with a sufficient filtration system. Appendix B lists the water impurities most conducive to clogging in drip irrigation systems and the level of concern associated with the concentration of the impurity.

2.3.2.4 Filters

As mentioned previously, the best way to prevent the major problem of drip irrigation, clogging of emitters, is to sufficiently filter the water. Filtration is a serious issue because filtration failure can cause clogging and lead to the demise of the system (Dasberg & Or, 1999). There are different filters depending on the size of the impurities and whether the impurities are organic or inorganic. Filter specifications can be further optimized for specific flow rates and capacity for sediment collection. Both primary and secondary filtration is necessary and is determined by the concentration of impurities in the water supply.

A first line of defense against larger sand particles and silt is a centrifugal sand separator. The water is spun so that the centrifugal force pushes the large particles to the wall of the filter. The particles are then collected at the bottom of the filter while the clean water is pushed out of the top. The impurities collected by the centrifugal sand separators can be emptied by hand or with a special valve (Dasberg & Or, 1999).

Gravel or media filters are "essential for primary filtration of irrigation water from open water reservoirs, canals or rivers in which algae may develop" (Dasberg & Or, 1999, p.24). Gravel filters use fine gravel or coarse quartz sand placed at the bottom of a tank with the water entering from the top. Cleaning can be done manually by reversing the direction of the flow and opening the water drainage valve, also known as backflushing. Self cleaning filters based on pressure drop or set time intervals are also available at a higher cost (Dasberg & Or, 1999).

According to Dasberg and Or (1999), screen filters are installed as a final filtration as a final defense against clogging. The amount and size of material that is filtered depends on the mesh size of the screen. Mesh size corresponds to the number of holes per inch, which in turn corresponds to screen hole opening diameters. Screen filters may by cleaned manually by taking the screen out and washing it. Automatic cleaning by back-flushing is also available and is determined by an acceptable amount of head loss.

Disk filters are effective in filtering organic matter and algae. Open reservoirs contain significantly more organic matter and algae than wells. Similar to screen filters, disk filters also use mesh to filter water, but are available in much finer mesh sizes. Disk filters work through a series of aligned disks which create cavities and turbulent flow in the filter. Disk filters can be cleaned manually by detaching them and reversing the direction of the flow through the filter or automatically by backwashing the system. Disk filters are versatile and can replace secondary screen filters for low flow rates (4-30m^3/h). At higher flow rates (over 500m^3/h), they can even replace the media filters for primary filtration (Dasberg & Or, 1999).

2.3.2.5 Water Towers

Water towers conserve energy in irrigation systems. The towers support a volume of water great enough to provide the area with sufficient water and pressure head. Jeff Kitchen, Vice President of Municipal Operations for Tank Engineering and Management Consultations explains that the low water level in the tank determines the minimum pressure needed in the system. The minimum head is the pressure required at the furthest point in the system. According to Dandy and Hassanli (1996), pressure head can be optimized through a system of valves and conserved by watering the plantation in shifts. A proper structure ensures that the oil palms receive the correct amount of water while not posing as a safety hazard. Specifications of the tower will depend on the required pressure head, the necessary volume, and affordability of materials.

Towers and tanks are constructed or prefabricated out of a variety of materials. Tank materials include wood, various metals, plastic and XR-5 fabric. Each material has its own advantages and disadvantages. Black plastic tanks, for example, limit light penetration which reduces the growth of water born algae (Diverse, n.d.) and tanks made of XR-5 fabric are collapsible. Towers are usually made of wood or metal, but can sometimes be made of concrete. If we decide to incorporate a water tower, each material will be evaluated on cost and functionality to determine if it will be integrated into the design (Interstate Products, n.d.).

2.3.2.6 Fertilization

The future soil quality of a plantation must be taken into consideration when designing a sustainable irrigation system. Over time, crops extract nutrients from the soil which can lead to infertile land. To avoid nutrient depletion and maintain fruitful crops the land should be replenished through fertilization. The New Life plantation currently uses two types of fertilization. The first type has been a local custom and is common throughout Asia (Pakissan, 2005): it involves planting and growing banana trees simultaneously with the oil palms. When the banana trees die, they decompose and return to the earth as a fertilizer for the nearby oil palms. The second method used by the foundation is distributing the organic matter found in the reservoirs, which is a common practice in Kanchanaburi.

Applying fertilizer to a crop through a drip irrigation system is done by a process called chemigation, or more commonly known as fertigation. Dasberg and Or (1999) suggest that this method of fertilization is necessary when designing a drip irrigation system because “the nutrients from the root zone are depleted quickly and a continuous application of nutrients along with the irrigation water is necessary for adequate plant growth” (p.96). Fertigation is a labor and cost saving process compared to manual forms of fertilizing. The process also delivers fertilizers more precisely to the root system. In addition, fertigation can cater to the nutrient demands of different crops by varying the fertilizer concentrations being delivered. However, the benefits of fertigation are limited to only fertilizers that can be completely soluble in water. Fertilizers that do not dissolve or only partially dissolve in water can clog and degrade the distribution system (Dasberg & Or, 1999).

When designing a drip irrigation system with a fertigation system considerable attention must be given to safety. The system should be checked for potential problems that could cause back-flow into the water source. Safety valves and injection equipment should remain in good working condition so that harmful concentrations of fertilizer are not released in to the atmosphere. Reactions can potentially occur between the fertilizer and the material in the water. For this reason, the impurities in the water should be tested, so that harmful by-products are not being created and released from the system (Dasberg & Or, 1999).

There are several methods of applying fertilizer to the mainline flow of an irrigation system. The most inexpensive method makes use of the Venturi Tube Principle. When the flow of a main line is constricted, a pressure differential is created which can be used to suck fertilizer into the flow. The process is effective and cost efficient, but many problems still exist. The constriction of the pipe decreases the overall pressure head of the mainline by about one-third. The inflow of fertilizer concentration can be controlled with a valve, but is still difficult to regulate the rate at which the fertilizer is delivered. It is difficult to regulate because the suction power depends on the flow and pressure of the water receiving the fertilizer (Dasberg & Or, 1999).

The most common fertigation system is the By-Pass System. The system is setup so that water from the main line travels to a tank storing fertilizer. The water dissolves the fertilizer and is piped back to the mainline where the water re-enters the system. The advantages of this system are that it is simple to construct, operate, and no external power is needed.

Additionally, the setup is not affected by changes in pressure that may occur in the mainline. The disadvantages are that the fertilizer tank has to be refilled manually and, whenever the tank has to be refilled, fertilization has to be cut off from the mainline for safety measures. This method of fertigation also has an inconsistent output concentration of fertilizer; the most concentrated times occur when the fertilizer is newly refreshed and the concentration levels decrease as it empties (Dasberg & Or, 1999).

The injection method of fertigation uses an additional pump to deliver fertilizer in solution to the mainline. The pumps are able to supply fertilizer at a constant desired rate. The fertilizer concentration is determined before it is injected into the mainline. However, water flow fluctuations and mechanical failures can change expected fertilizer concentrations greatly. The injection system is the most versatile system, but also costs more to maintain (Dasberg & Or, 1999).

Clearly there are many different options for fertigation. Regardless of the method, it is a necessary component to consider when designing a drip irrigation system. The type of system depends primarily on how the fertilizer and water are transported in the system, which leads to our next topic, distribution lines.

2.3.2.7 Distribution Lines

Drip irrigation uses a series of interconnected pipes and tubes to distribute the water. Many factors influence the shape and size of the system. These factors and their affect on the system must be balanced carefully to optimize the water, cost, and material efficiency.

The main lines are larger pipes, usually made of polyethylene (PE) or polyvinyl chloride (PVC), that are connected to the filter. These main lines run above or below ground and then branch off into smaller, lateral lines, which run along the crop rows. The main lines should have valves to open or close the lines to prevent backflow after operation, and also to allow the field to be watered in sections. The main lines connect to lateral lines, made of PE. The lateral lines run from the main line along the row of crops to supply water. The amount of lateral tubing needed depends on the number of oil palms and their spacing. The lateral lines connect to the emitter lines, commonly known in the field as spaghetti tubing. The spaghetti tubing is small, flexible tubing that extends from the lateral line and holds the emitter.

2.3.2.8 Emitters

The final component of drip irrigation is the emitter, which delivers the water to the crops. The spaghetti tubing prevents the emitter from aiming in the wrong direction if the lateral lines get twisted or moved. Emitters are sold based on their emission rate which can vary from 1.2L/h (0.31gal/h) up to 100L/h (26gal/h) (Netafim, 2005). Emitters are designed to be pressure compensating any where from 10-40psi (0.7-2.8bar). Therefore, the emission rate is unaffected by small fluctuations in pressure and delivers a consistent amount of water to the crop. The water demand, number of the palms, and the percolation rate of the soil determines the number and type of emitters to be used.

From the pump to the emitter, each component of the irrigation system is essential for a complete and appropriate design. Another important consideration besides the technical components is the cost of the system. We now turn to a discussion on the economic considerations for designing an optimal irrigation system.

2.4 Economic Considerations

The cost associated with a drip irrigation system is based on a variety of factors. In order to optimize the design it is essential to choose the most appropriate components with the lowest cost. There are many different ways to optimize drip irrigation systems, Dandy and Hassanli (1996) even developed a method for optimizing drip irrigation systems based on over 20 different parameters. In the design for the New Life Project, cost was an important parameter. The main variables are the dimensions of the field, the soil composition, and the pressure head required by the pump. The soil composition and type determine the depth and application rate, which cannot be greater than the storage capacity and infiltration rate of the soil. The agronomic requirements are determined by the amount of time the irrigation system will be used, and the rate at which the water is discharged. The depth of the root system, number of trees, and climate determines these two parameters. The products involved in building the system, such as the materials for pumps, towers, and wells are an important cost consideration.

Additionally, the annual energy requirement of the system is an ongoing cost for the Foundation. Choosing an efficient motor and pump can be more expensive initially, but will minimize the long term costs of the irrigation system. The current price of electricity in

Thailand is around 1.95baht/kWh ($0.05/kWh) (World Energy Council, 2005). The power requirements of the motor are based on the motor and pump efficiency, the volumetric flow rate of the water, and the total pressure head provided by the pump. The annual energy requirement will be determined by the horsepower of the pump.

The New Life Project estimated the budget for the irrigation system at $25,000 but through our methodology a more accurate number will be obtained. Prices of components will vary, so varying designs and components prices will be given to New Life to enable them to choose the one most appropriate to their budget. An example of a varying design that would affect price is using a series of disk filters instead of a screen and disk filter combination. Investigating options in design will help to minimize cost. Long term costs will include energy costs.

Functionality and cost were not the only components that were incorporated into the design of an optimal drip irrigation system. We also considered the ability of the users operating the system. The following section will discuss the necessary social considerations for designing a drip irrigation system for the New Life Project.

2.5 Social Considerations

There are two social considerations that must be addressed in the design of an irrigation system. First, an irrigation system is not a self operating system. It requires proper operation and management to function appropriately. An irrigation education manual accompanying the system can potentially increase performance and longevity of the system. Second, in order to build an irrigation system it is essential for New Life to raise the required amount of money to build the system. These two social aspects are discussed below.

2.5.1 Irrigation Management

Aside from the technical components of an irrigation system, it is essential to consider the social aspects of managing an effective system. Too often the complications of operating an irrigation system are overlooked. This potentially leads to a situation where a system design is based on a set of technical specifications but does not perform as well as expected. Wade and Seckler (1990) claim that, one of the most important areas to consider is the interaction between engineers and management scientists for the connection between the physical and managerial design of irrigation systems. For the success of an irrigation system, it is vital to provide guidelines indicating how to correctly operate the system.

Studies done by Wickham and Valera (1978) show the effects of changing the management system on physically changed irrigation systems. There are few studies however on poor performance of unchanged irrigation systems. Even without concrete evidence of the positive effects of organizational changes in irrigation systems, operators including national governments have still decided to make changes. For example, The World Bank has been very influential in making changes on management techniques and has made suggestions for improvements in India, the Philippines and Morocco.

History has proven that for any irrigation system it is necessary to include an education manual to extend the longevity of the system. To reach this step and build the irrigation system, New Life must have adequate funding. We discuss the fundraising strategy for the New Life palm tree plantation in the next section.

2.5.2 Funding for the New Life Project

The Duang Prateep Foundation and its many subdivisions rely on donations to continue operation. Since August 31, 1978, the Duang Prateep Foundation has been a registered charity. They create flyers in Thai, English, and Japanese to promote their projects and raise money. Donations are made from all around the world with many from Japan, Germany and the United States. The Duang Prateep Foundation accepts donations by credit card, bank transfer, check, or money order to an account that the Duang Prateep Foundation has at the Thai Farmers Bank located in Klong Toey, Bangkok. Donations made from the United States and Germany are tax deductible when made through registered support organizations in the respective country. These include the Flame of Hope Foundation in Wisconsin US and the Freunde der Duang Prateep Foundation in Weil am Rhein, Germany (DPF, 2003).

Khru Prateep has expressed sincere interest in a fundraising brochure for the irrigation system for Block3. The Duang Prateep Foundation will give the brochure to potential donors outlining specifications of the irrigation project and its estimated cost. The budget proposal for the New Life Project oil plantation is given in Appendix C. There were 424 oil palms planted on Block3 prior to an established irrigation system. Oil palms, when properly cared for, generate a relatively stable income, but since the oil palms cannot be harvested until the fourth year, the start up costs must be acquired through donations. With a more comprehensive irrigation system, the trees will grow and New Life will be on its way to being more financially self sufficient.

3 Methodology

The goal of our project was to contribute to the successful expansion of the New Life oil palm plantation. We accomplished this goal by utilizing the land and water sources at New Life to develop a model design for a drip irrigation system. To address the upcoming expansions, we made recommendations for future construction, operation, and maintenance. Our goal was achieved using both qualitative and quantitative research methods. The process began with an assessment of the current conditions at the New Life plantation. The assessment enabled us to design the model irrigation system and establish water management techniques. The following section outlines the methods and importance of each step used to achieve our goal.

3.1 Assessing the Current Conditions at the New Life Project

To design an appropriate irrigation model and promote its successful operation, we evaluated the current land and water resources as well as the current irrigation methods of the New Life plantation. These environmental and social parameters established the appropriate level of technology and specifications of each component in the system and enabled us to formulate recommendations. The environmental assessment focused on Block3 and evaluated the layout of land, area, number of trees, amount of available water, and soil type. We assessed the social parameters by observing the current irrigation system design and operation. We specifically examined the rationale behind its operation, how effectively it performed, and the interaction between the operators and the system. The following section explains the assessments that we made in order to fully understand the conditions at New Life and their impacts on our project.

3.1.1 Current Plantation Land and Water Resources

In order to assess the physical layout and resources available at the New Life Project, we performed interviews with the New Life staff translated by Khru Prateep and Khun Khantong. The interviews provided important information about the prior and future development of the plantation that we could not acquire through observation. This gave us a general understanding of the decision making process New Life uses to develop the plantation and enabled us to utilize the available resources. It also informed us about the resources available for the model design and future expansion. We paid particular attention to the location of the developed oil palm fields in relation to the available water resources. The relative locations directly affect the irrigation design. More importantly, these interviews motivated us to perform quantitative assessments that needed to be accomplished to fully assess the area. Ultimately, the interviews, observations, and surveying allowed us to create a map of Block3 for our model design.

We conducted initial observations and interviews to gain information about the current state of Block3 and the development process that New Life follows for expansion. We learned from Miss Oo Supa, New Life's oil palm expert with a degree in Agriculture, that 424 oil palms were planted in Block3 nine square meters apart. The spacing of the trees is important both for sunlight and root growth. Unilever (2005), a company dedicated to improving the environment, as well as the Food and Agriculture Organization (Griffee, 2003) also recommends the palms to be planted nine meters apart. We used this information to determine the total number of trees that will be in the undeveloped area of Block3. The undeveloped area of Block3 must be taken into consideration because planting additional oil palms in this area will increase the demand of the irrigation system. The number of trees on Block3 when it is completely developed was used to determine if the reservoir is large enough to support fully grown oil palms at the driest time of the year. After the initial assessment of Block3, we assessed the adjacent reservoir which supplies water to the field.

It was important to calculate the size and fluctuating volume of the reservoir to determine if it held a sufficient amount of water to support the Block3 oil palms. We gained knowledge about the water level fluctuations of the reservoir from the head of the New Life Project, Khun Praklong. Khun Praklong has been the head of the New Life Project for 13 years and has seen these fluctuations many times. We assessed the plantation during the dry season, but the reservoir was not at its lowest level. The reservoir used for Block3 fills completely during the rainy season and drops one-meter below the level that we observed during the dry season. With this information, we were able to determine the volume of the reservoir at its maximum and minimum and determine if it would provide Block3 with a sufficient amount of water. This was an essential step towards our goal of designing a model irrigation system because it determined whether or not we needed to incorporate another water source into our design.

After the initial interviews and observations, we surveyed Block3 to determine the layout of the entire field, the area, number of trees, and amount of available water in the reservoir. We completed the surveying using equipment provided by the Chulalongkorn University Surveying Department. The surveying equipment used was a total station, prism pole, level, and level rod. See Appendix D for pictures of the equipment and their definitions and uses. The measuring equipment known as a total station is used to find distances to specified points, a process called taking a shot. To find the area of the field, both developed and undeveloped, we shot points along the perimeter of the field. Photograph 9 shows a shot being taken on the plantation. We also shot points of oil palms in the developed section to use as a pattern for predicting the location of trees in the undeveloped area. With these shots, we made an AutoCAD map of the plantation. This map helped to calculate the length of lateral and main tubing and aided in the irrigation design.

Photograph 9: Surveying Block3 at the New Life plantation

After shooting the field, we also shot the corners of the reservoir to find its position relative to the field and volume. This information is crucial for irrigation design because it determines the amount of water available and the length of mainline tubing. To determine the volume, we combined the perimeter shots with slope and depth measurements. We measured three times across the reservoir to account for depth changes and improve the accuracy of the results, shown in Photograph 10. The slope of the reservoir bank was calculated using simple trigonometry. Measurements were taken to create a right triangle from the water surface to the ground surface. We later determined the length of the mainlines using AutoCAD. The reservoir assessment influenced many design process decisions, such as the type of pump, type of filters, and layout of the distribution system.

Photograph 10: Measuring the depth of the reservoir on Block3

After recording all the shots, we entered the locations into AutoCAD to produce a two dimensional map. AutoCAD is a program used by engineers, surveyors, and companies around the world including Astraco (Thailand) Ltd., a local irrigation company. Using the features of AutoCAD allowed the user to calculate distance and area from the data points collected during surveying. Over all, the survey provided a bird's eye view of Block3 and enabled us to super impose the irrigation system on the map, showing the exact location of the irrigation system in Block3.

To assess the drainage rate of the soil at New Life we performed a percolation test as shown in Photograph 11. Determining the drainage rate is essential for designing an irrigation system because it specifies the required flow rate from the emitter. The water must exit the system close to the rate of infiltration because a higher rate will cause runoff (Dasberg & Or, 1999). To conduct the percolation test, we used equipment obtained from the Water Management Department at Chulalongkorn University. We assessed the variation of the soil by walking around Block3 and concluded that the soil does not vary greatly. We conducted the percolation test on two different areas of the field. Two areas were sufficient because of the small variation in soil type. Unsaturated and saturated percolation tests take into account that the soil will dry between watering periods, but ideally should never be completely dry. To determine the saturated percolation rate we performed the test twice on the same area of soil, (See Photograph 11). Using the average of both tests, we calculated the percolation rate, which is the average time in minutes for the water level to drop by 0.025 meters (Hygnstrom, Skipton, Woldt 2002). Using the results of the percolation test we determined the ideal output rate of the emitters for the Block3 irrigation system in units of volume per unit time.

Photograph 11: Percolation test at Block3

The methods of assessing the current environmental parameters of Block3 enabled us to evaluate the layout of land, area, number of trees, amount of available water, and soil type at New Life. The data collection was essential for the design of Block3 because the parameters defined multiple parameters for choosing the components of the irrigation system. Before moving to the design, it was important to understand the current operation methods which we discuss in the next section.

3.1.2 Current Irrigation Methods

Through interviews and observation, we assessed the components and operation of the current irrigation system. We researched New Life's methods of fertilization, the watering schedule of the plantation, and the cycle of workers that operate the system. Identifying the technological background of the workers allowed us to understand which methods can improve in the operation and maintenance of the New Life irrigation system. The following section explains our procedure for assessing the current irrigation methods.

While we observed the system function under normal conditions, we simultaneously assessed many aspects of the operation, one being the level of technology. Assessing the level of technology included determining the current type of system, pump, distribution line material, distribution line sizes, connections between tubing, and emitters. By identifying the components that the operators at New Life were already familiar with, we were able to determine which type of irrigation products could be appropriate to incorporate into the Block3 design. Without sacrificing effectiveness, we matched the level of technology of the model design with that of the current system to ensure that the irrigation system would be appropriate to the New Life Project.

One aspect of the current system that was of particular importance to our project was the type and amount of maintenance performed on the system. Any procedures beyond normal maintenance, such as consistently fixing the same leak, are unnecessary and should be corrected. Khun Khantong explained the current system maintenance and we identified procedures that could improve the efficiency of the current system. We addressed these procedures in the Block3 design and incorporated recommendations for improvements into an irrigation education manual.

Researching the current irrigation methods was important because it allowed us to design an irrigation system at the appropriate level of technology and make recommendations for future operation. These evaluations allowed for the improvement of the current system and development techniques. At this time, the development involves building reservoirs as the water source for irrigation. In the next section, we begin our evaluation of the reservoirs to determine the affect of the reservoir water on the performance of the current system and the selection of components for the model system.

3.2 Evaluating the Quality and Quantity of the Block3 Reservoir

Effectively utilizing available water resources is essential for proper irrigation. Effective utilization is accomplished by complementing the quality and quantity of available water. Each of these factors is crucial for the design of the system and if any are ignored, the system may fail due to insufficient water supply or clogging. To determine if there is a sufficient amount of water for irrigation, we calculated and compared the water demand of Block3 and the volume of water available. We assessed the quality of the water by performing lab tests. This section details the assessments of the Block3 reservoir.

The water demand of the Block3 system fluctuates throughout the year depending on the amount of precipitation. We accounted for the maximum demand during the driest time to promote successful growth of the palms year round. The output of the water depends on the number of palms being irrigated, the daily water demand of each oil palm, the evaporation rate of water from the soil, the volume of the distribution system, and the compensation for the inevitable small leaks throughout the system. We determined the optimal water demand of an oil palm by using information from pakissan.com, the Pakissan Agri Professionals and Institute Network (2005). The water demand for the oil palms increases with age, so in order to determine the maximum output we used the water demand for a fully developed tree. In comparison to the other factors affecting water demand, evaporation rate is negligible (Dasberg and Or, 1999) and was not calculated. We used the main line and lateral line diameter to determine the volume of the distribution system. To account for the inevitable small leaks throughout the system including those that remain un-noticed, we added a small percentage to the total output as recommended by Professor Hart, Worcester Polytechnic Institute, Department of Civil Engineering. The amount of water lost to leakage gradually increases over time, sacrificing more of the total output of the system so it is very important to compensate for this in the design. We determined the required water output of Block3 by combining the water demand of the oil palms, volume of the distribution system and the leak factor associated with irrigation systems.

After we determined the amount of water that must be supplied to Block3, we determined if there is enough water available in the reservoir to support the system. From the assessment discussed previously in Section 3.1.1., we based our calculations for the system at full output with the reservoir at its lowest level to ensure that there would be an adequate water supply throughout the year. The reservoir reaches below the water table so as water is removed by either the irrigation system or evaporation, it is replenished by ground water. This ensures that there is water in the reservoir even during unusually dry conditions.

Dasberg and Or (1999) advise against open water reservoirs for drip irrigation systems. For this reason, we tested water samples from the Block 3 reservoir and compared it the well water used to supply the New Life Buildings. Testing both water sources provided data for making recommendations for future water sources at New Life. Dr. Fuangfa Unob and Dr. Apichat Imyim, the liaisons for the water quality testing group, from Chulalongkorn University provided us with the appropriate equipment to conduct the test. To ensure accurate data, we collected the samples below the water surface in plastic bottles. The samples tested by the Inductively Coupled Plasma (ICP) by Elements method were filtered onsite and collected into smaller, plastic bottles because this method of testing requires a filtered sample. The samples tested by other methods were collected in larger one liter bottles. We preserved the water samples by storing them in a cooler below 40°F until we performed the water tests.

The water sample testing was performed at the Chemistry Labs in the Mahamakut Building on the Chulalongkorn Campus. Dr. Unob and Dr. Imyim, and the Water Quality Group

(Nick Marcoux, Jessica Martinez, Mike Plumer & Lynn Reni) assisted with testing techniques and equipment. We determined what impurities to test for based on the Kansas State University Irrigation Management Series Publication, Subsurface Drip Irrigation Systems (SDI) Water Quality Assessment Guidelines (2003). We used litmus paper to conduct an onsite pH test. Dr. Unob and Dr. Imyim performed the ICP by Elements test to analyze the water for metals. The total suspended solids test was performed by adapting three valid methods based on the equipment available at Chulalongkorn. See Appendix H for the adapted version and references. Although it is recommended to test for nitrates and bacterial population, the testing equipment was not available. After finding the concentrations of the above listed impurities, we were able to use the table provided by the Irrigation Management Series (2003) to determine the level of concern for each impurity. The level of concern aided in choosing the appropriate filtration system for the reservoir.

As the Background Chapter emphasized, the water source is the most important element in irrigation. For this reason, our reservoir evaluations were performed first. After evaluating the water resource we focused on the other components of drip irrigation and assessed them in terms of their applicability to the model design for the New Life Project. The next section discusses the necessary evaluations for choosing components of the drip irrigation system.

3.3 Evaluating Components of Drip Irrigation

After assessing the current conditions and the reservoir at the New Life Project, we began making decisions for the irrigation design of Block3. In this section, we explain the decisions and calculations for choosing the irrigation components. Specifically, we detail the steps taken to find the water demand and pressure needs of Block3 because these values are the two most important criteria for selecting a pump. We also investigate the benefits of variable designs including a water tower and fertigation system. The selections of the final designs were based primarily on cost and performance. Assessing the individual components of a drip irrigation system was used to determine their arrangement in the model irrigation system.

During our assessment of New Life's current situation we calculated the infiltration rate of the soil. The infiltration rate determines the appropriate discharge rate for each emitter and the time needed to water the plantation. Relating the infiltration rate to the discharge rate minimizes the amount of water accumulating at the soil surface and provides water to the root system. To optimize water uptake by the oil palm, we generated different models by varying discharge rates and the number of discharge points per palm. We then calculated the time each model would need to distribute the necessary amount of water to each palm. Based on a comparison of the cost and time for each model in a spread sheet we chose the most suited rate of discharge and number of discharge points for Block3.

The emitter for Block3 was determined by matching the desired discharge rate with emitters from Super Products, Netafim, and Agrifim. We compared emitters from each company based on cost, pressure requirements, and discharge rate. The appropriate emitter was low in cost, had low pressure requirements, and the required discharge rate. Determining the emitters used in the irrigation design provided us with: the exact discharge of each emitter, the required operating pressure or pressure range, the diameter of the emitter opening and the cost of the emitters. The emitter was the first component to determine because it provides the total flow rate of the system, the operating pressure to include in the total dynamic head, and the smallest particle size that needs to be filtered.

The next component of drip irrigation to determine was the lateral and main line tubing. From our research we learned that larger diameter tubing has smaller frictional losses. This was reconfirmed by performance specifications for lateral tubing in the Netafim 2005 Product Catalog. Using the AutoCAD map of Block3, we superimposed the distribution design on top of the map to gain a visual image of the layout and to determine the length of the lateral and mainline tubes. We used the total lengths to estimate future pricing of the materials and to calculate the pressure loss from friction. Pressure losses were calculated for various sizes of main and lateral line tubing. Our group traveled to local distributors, such as Super Products and Astraco (Thailand) Ltd., and performed online searches to compare the pressure constraints of the different tubing to find the most suitable tubing for the design. We then calculated the total head loss of varying tube sizes using equations provided by Dasberg and Or (1999). The optimal diameter of the tubing was determined by comparing the cost and pressure losses due to friction. By determining the length and diameter of the lateral lines, we were able to determine the proper size fittings to connect the main lines and lateral lines.

We determined the most appropriate filter for the Block3 design based on the impurities found earlier during the evaluation of the reservoir water, the size of the emitter opening, and the volumetric flow rate per unit time of the water delivered to the system. Based on the concentration of impurities in the reservoir water we compiled a list of possible filters that would provide acceptable quality water to Block3. Acceptable quality water has particles no larger than 10% of the diameter of the emitter. Another consideration was the volumetric flow rate of the system because filters have a maximum volumetric rate for operation. Based on the previously mentioned considerations, we made a list of possible filters. The list included many different types of filters such as media, screen, and disk filters because they are all capable of filtering out the same types of impurities. The final decision was based on initial costs, but mainly on required maintenance. We did not consider self-cleaning filters based on their high cost and potential complications if the automation fails.

One optional component in drip irrigation is to include a fertigation system. We considered the cost and simplicity of each of the three methods explained in the Background Chapter (p.22). The complexity, cost and required maintenance of each system determined if a fertigation system would be appropriate for the New Life Project. Adding a fertigation system would be beneficial to the irrigation system but we decided not to include it in the final design. The reasons for not including a fertigation system in the model design are detailed in the Findings and Discussions Chapter, but it is important to mention the decision here because it would have changed our methodology from this point on. The last step is to determine the pump needed to provide water to the distribution system.

The first consideration for determining the appropriate pump was to decide whether or not to include a water tower in the design. A water tower reduces the power and flow rate required for the pump. To determine if this would be ideal for New Life, we researched the advantages and disadvantages that are associated with water towers, focusing mainly on price, level of technology, and required maintenance. We then compared these parameters to the advantages and disadvantages of using a pump only. The performance of the tower was based on its contribution to the water pressure, and the associated decrease in pump size. The level of technology level was an important consideration because prolonged periods of downtime are likely if the system breaks down. M.P.L. (Thailand) Co., Ltd, a Bangkok water tower company, provided insight to analyze the contributions of a water tower to decide if we should include one in the design. The decision not to include a water tower is detailed in the Findings and Discussion chapter. It is important to mention the decision here because, if included, a water tower would add more factors to consider when determining the appropriate pump.

The total dynamic head of the system is an important parameter to identify in order to determine an appropriate pump. The elevation changes determined earlier in the surveying process is one component of the total dynamic head. The largest change in elevation was added to the total dynamic head to ensure that the pump would be able to provide water to the highest point of Block3. See Appendix A for a visual representation of total dynamic head.

The calculations for total dynamic head and flow rate of the system were determined from the choice of emitter size, lateral tubing, main line tubing, and static head. The total dynamic head calculations allowed us to compare the performance specifications of available pumps to find pumps that were appropriate for Block3. To find the available pumps we researched pump manufacturers and suppliers using the World Wide Web. We limited our research to centrifugal pumps because of the advantages discussed previously in the Background Chapter. We examined the pumps manufactured by Berkeley and Y Best Electrical Co. Ltd, as well as those carried by Sile Co. Ltd., located in Bangkok. All of the acceptable pumps were compared based on their cost and performance. Cost was the determining factor during the final selection.

After we determined all the materials necessary to construct the Block3 system, we compiled an extensive list of irrigation suppliers. This allowed us to determine which suppliers carry the necessary materials as well as to compare the availability and price of the materials. We used the list both in the selection of the irrigation components and later in the development of the fundraising brochure. The list included the address, phone number, and fax number of each company both for our own use and the use of New Life in the future.

The final step in our design process was to combine all the information we gathered on the individual components of a drip irrigation system and incorporate it into various designs for Block3. We included a variety of designs so that New Life could use them in the future and adapt them to different parts of the plantation. The designs were based on optimizing the total system features, while remaining within a reasonable budget.

3.4 Summary

By beginning with a detailed assessment of the current situation at New Life, we were able to give New Life both a useful design for Block3 and predict concerns associated with future development. Starting our design with effective water resource techniques allowed us to utilize the resources available on Block3. Combining the water resource knowledge with the appropriate irrigation components enabled us to create a model irrigation system and fundraising brochure for New Life. With this brochure New Life will be able to inform potential donors and further the expansion of the program. It is our intent to ensure the continued success of the model irrigation system by providing the system operators with an irrigation education manual. In review, this process has led to a successful proposal for expansion and improvement of the New Life Project.

4 Findings and Discussion

The methods of data collection and analysis discussed in the previous chapter resulted in the findings presented below. We organized the information into four major findings, each of which is dependant on one another to create an appropriate irrigation system for the New Life Project. The four major findings are:

- Identification of environmental parameters;
- Identification of social parameters;
- Components of an appropriate design;
- Optimization of the design.

This chapter describes the data used to establish our findings and their interdependence and usefulness in achieving our goal.

4.1 Identification of Environmental Parameters

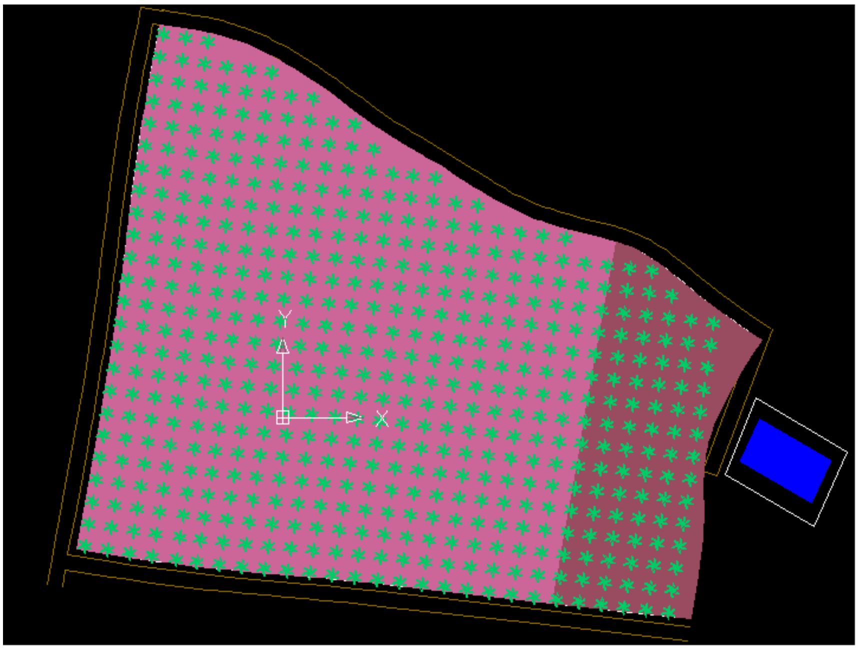
The environmental parameters of Block3 directly affect the technology and components of the irrigation system design. Assessing the soil parameters influenced our choice of an emitter. The evaluation of the field determined the amount of material required for a complete design as well as the most appropriate pump for the design. Our evaluation of the reservoir determined the quantity and quality of the water source for Block3. The quantity of water available identified whether or not it was necessary to include an additional water source and the quality of the water defined the criteria for an appropriate filter. The fertilization limitations of Block3 led to future recommendations for the plantation development. We identified these variables ultimately to begin the component selection process for the model design.

Evaluation of Soil

From the results of our percolation test we calculated the infiltration rate to be 53 minutes according to the definition of Hygnstrom, Skipton and Woldt (2002). The infiltration rate defines how fast water can be delivered to the soil. The infiltration rate assisted in calculating acceptable discharge rates for the Block3 soil that will not cause pooling of water or run-off. These parameters narrowed the range of possible discharge rates for the emitter to 0.3 to 2 gallons per hour (gal/h), equivalent to 1.2 to 8 liters per hour (L/h).

Evaluation of Field

The assessment of the field consisted of surveying Block3 to calculate its area, shape, elevation change, and the position of the reservoir relative to the field. These factors relate to a drip irrigation system by determining the parameters for the amount of lateral and main line tubing, the daily water demand, and the elevation change which all contribute to the required power of the pump. From our surveying, we produced an AutoCAD map of Block3 (Map 3). The light pink area represents the developed area which already contains oil palms and the dark pink is the undeveloped area. The oil palms are planted nine by nine-meters apart; we used this data to determine that Block3 can support a maximum of 27 rows with 515 palm trees. The map of the prospective layout aided in determining the amount of lateral and main line tubing, number of emitters, and number of connectors needed to irrigate Block3. Also using AutoCAD, we calculated the total area of Block3 to be 10.2 acres (4 hectares) which equates to 12 percent of the plantation. We plotted several elevation changes and determined that the largest elevation change is 19.2feet (5.85m) above the level of the reservoir. Identifying the highest point in the field was used later in our irrigation design to determine the pressure required from the pump to reach this point. The precision of surveying practices used in this assessment increased the accuracy of the design.



Map 3: AutoCAD map of Block3 produced from surveying

Evaluation of Reservoir

Water from reservoirs can be problematic for drip irrigation because particles in the water can cause clogging. As shown in Table 2, after an assessment of the quality of water in the Block3 reservoir, we identified that impurities in the Block3 reservoir water are at a moderately high level of concern and therefore can cause clogging of the emitters. The total suspended solids test revealed moderate levels of concern, while the pH is at a high level of concern. The high level of concern indicates the amount of filtration needed before water enters the distribution system. As the amount of total suspended solids increases, the amount of filtration required increases. A high pH can indicate chemical precipitates which can potentially form in the tubing and clog the emitters. A comparison of impurities in well water verses reservoir water is shown in Table 2.

	Acceptable Water	**Reservoir**	**Well Water**	**Risks Associated**
pH	<7	8	7	Precipitation of Chemicals
Calcium (meq/L)	~0	1.13	5.49	Precipitation
Magnesium (meq/L)	~0	.0066	.0058	Precipitation
Sodium (meq/L)	~0	.013	n/a	Precipitation
Iron (mg/L)	~0	n/a	0	Precipitation
Manganese (mg/L)	~0	n/a	n/a	Precipitation
Total Suspended Solids (mg/L)	<50	64.8	~0	Clogging of Emitters

Level of Concern Key
Low
Medium
High

Table 2: Water quality assessment results

The limitations of the water quality tests include time restraints and available equipment. There were several different methods available to test water for total suspended solids, but we did not have all the materials to follow any one method in its entirety. We adapted the procedure from three different sources (See Appendix H for the adapted version). The results have a slight degree of error because some of the solids adhered to the disposable aluminum dish, as shown in Photograph 12, and were not included in the end weight of the glass filter. If the weight of the solids left in the disposable aluminum dish was 1.75mg or greater, the level of concern for total suspended solids would be raised to a high level of concern. These findings provided us with essential information in determining the type and size of the most appropriate filter for the Block3 reservoir.

Photograph 12: Glass filter and aluminum dish after the reservoir total suspended solids test

We also tested to find the elements in the water using a method known as Inductively Coupled Plasma (ICP) by Elements. The most significant result revealed that the well water contains almost five times as much calcium as the reservoir. As seen in Table 2**,** this is a high level of concern because of the potential for calcium carbonate precipitates to form which can clog the system. The calcium would also react with phosphate fertilizers if a fertigation system were to be added. Results show that while the reservoir has significantly higher suspended solids, the concern for particular elements is not as high. To determine which water source actually provides the best source of water requires extensive chemical testing for physical, chemical, and biological matter. Only then, can the disadvantages associated with each type of impurity be weighed to determine the best water source for future development.

In determining the quantity of water in the Block3 reservoir, we concluded that it can adequately irrigate the oil palms throughout the year. This initial finding was very important because it ruled out the need to create another water source. With this finding we were able to move on to the design of the irrigation system, rather than design a well or additional reservoir. We calculated the wet season volume of the reservoir to be approximately 1.4 million gallons (4000m^3) and the dry season volume to be approximately 270,000gal (1000m^3). The equations and measurements used for calculating the volume of the reservoir are located in Appendix I.

To calculate the water demand of Block3, we used the AutoCAD map to determine that there will be 515 palms in Block3 when it is fully developed. Knowing that the water demand for each tree is 2 gallons per day (gpd) (7.57L/day), we calculated the total water demand of the oil palms to be 1030gpd (3.9m^3/day). To determine the total water demand, however, we added the total water demand of the oil palms with the total amount of water needed to fill the tubes of the distribution system. The calculated result is the maximum amount of water needed during one watering period for Block3. To account for potential leaks we added an additional 10% to the total water demand of Block3. The comparison between the supply and demand of water showed that in the driest season the reservoir is capable of sustaining Block3 for 147 days without being replenished by the water table or rain, see Table 3 for the fluctuations of the reservoir throughout the year. Considering that the dry season is typically only 92 days long, we concluded that the Block3 system will not need additional water resources in the future.

	Volume of Reservoir (gal)	Days Supply
Minimum	271,865	147
Current	862,141	467
Maximum	1,393,582	756

Table 3: Amount of water in the Block3 reservoir

Fertilization Limitations

New Life hoped to use the organic matter in the reservoirs as fertilizer. As mentioned in the Background Chapter, we found that this is not possible with drip irrigation because organic matter can clog the emitters. Currently, New Life grows banana trees next to the palms and allows them to die after a few years, fertilizing the soil as they decompose. This is a common practice throughout Asia (Pakissan, 2005). New Life also spreads ashes from burned brush beneath the oil palms as fertilizer. The methods for determining if the soil contains an appropriate balance of nutrients require extensive chemical testing. The amounts of nitrogen (N), phosphorous (P), potassium (K), and magnesium (Mg) available in the soil determines the amount and type of fertilizer necessary to reach the proper balance of nutrients. The identification of the soil testing procedures was beyond the scope of this project and was the main reason for not including a fertigation system. This was an important decision because fertigation systems affect the size of the pump and require additional components. Since fertilization is important to maximize the growth of the oil palms, we made recommendations about options for future fertilization.

The identification of the environmental parameters provided us with a range of performance criteria to choose irrigation equipment. A summary of the parameters are in Table 4.

Summary Table of Environmental Parameters	
Field	
Area	10.2 acres (4 hectares)
Number of Trees	515
Daily Water Demand	1030gpd (3.9m3/day)
Rows of Trees	27
Elevation Change	19.2ft (5.85m)
Reservoir	
Lowest Volume	271,865gal (1000m3)
Maximum Volume	1,393,582gal (4000m3)

Table 4: Environmental Parameters

Designing an irrigation system based only on the environmental parameters would result in a functional system, but it would not necessarily be appropriate for New Life. For our irrigation system to be successful we needed to choose irrigation equipment that addressed both the environmental and social parameters of the New Life Project. The next section describes the social parameters we identified.

4.2 Identification of Social Parameters

Several parameters were identified and used to determine the level of appropriate technology and the range of appropriate costs for the model irrigation system. Identifying the development strategies of the plantation allowed us to address the social parameters of funding, while assessing the current irrigation system and its components addressed the social parameters used to select components for the model design.

Development Strategy for the Plantation

The current development plan at New Life is driven by their ability to fundraise. This finding enabled us to make recommendations for development in the future. Due to the financial constraints of the development process, we recognized the emphasis of cost on the irrigation design. The typical pattern of development consists of creating an open reservoir, clearing and tilling the land, planting the oil palms, and constructing an irrigation system as funds become available. Currently, there are six open reservoirs on the plantation (see Photograph 13). As previously explained in the assessment of the environmental parameters, it is not possible to utilize the reservoirs without a proper irrigation system. For Block3, there was only enough funding to partially develop the area. Because of this, many of the oil palms are suffering. In an effort to bring water to the oil palms, New Life invested in a temporary pipe and a pump system that will eventually be replaced later by a permanent irrigation system. With these findings we were able to make recommendations for future water source development methods.

Photograph 13: Two of the six reservoirs throughout the plantation

Current Irrigation Components and Operation

We assessed the Foundation's current irrigation system and operation to determine the appropriate range of technology for the model system components. Blending the technical and social aspects of irrigation is essential for an effective, long lasting design. These findings determined the content for the *Irrigation Education Manual*, such as methods for improving some of the irrigation practices currently used at the plantation. The factors discussed below are considerations that we addressed to optimize the irrigation design for appropriate technology and create the education manual.

Currently, the New Life system uses a sprinkler type of emitter. Though sprinkler emitters do not operate like drip emitters, their installation and maintenance is very similar. Because the sprinkler emitters cover a large area, it may look like they supply more water when compared to drip emitters. We addressed this by including a schematic and explanation of how drip emitters efficiently deliver water to the roots in the *Irrigation Education Manual*. Finding that New Life already uses an emitter in their watering process made the integration of a drip emitter into the model system relevant and applicable to the New Life Project.

The current irrigation system at New Life is not supplying adequate water to the palms. The inadequate water supply was evident through observing the fruit bearing oil palms. The fruit of the oil palms should be red when unripe, and black when ripe as shown in Photograph 14.

The fruit shown in Photograph 15 was unable to fully develop which can be deduced from its dry, brown appearance. These findings revealed that our irrigation system must supply the oil palms with more water than they are currently receiving. Taking into consideration that the current irrigation period for each field is under one hour, we designed our system to meet this time restriction while delivering the appropriate amount of water to the palms.

Photograph 14: Ripe and unripe oil palm fruit at the New Life Project

Photograph 15: An oil palm at the New Life Project bearing undeveloped fruit

The current system requires an excessive amount of maintenance. This is primarily due to the lack of a filtration system. Photograph 16 is a picture of a centrifugal pump that pumps water directly from the reservoir. The reservoir water contains suspended biological and physical matter that causes the sprinkler emitters, Photograph 17, to frequently clog. The system operators clean each emitter about twice a week. Keeping in mind that the system is run only three times a week, this amount of maintenance is considered excessive. These findings solidified the need for a filtration system, which we also concluded in our assessment of the reservoir. This finding also identified that the operators are unfamiliar with filtration systems. Their unfamiliarity with filtration systems made it essential to choose effective, low maintenance filters and to include detailed instructions about installation, operation and maintenance of filters in the *Irrigation Education Manual*.

Photograph 16: Pumping reservoir water directly into the main line

Photograph 17 : Sprinkler emitter on the lateral lines

The current system lacks a filter, which is the main reason for maintenance problems, but some of the operational procedures could also be improved. Currently, when operators can not unclog emitters they remove them completely from the pipe. Although this brings more water to that specific area, it causes pressure loss down the rest of the line resulting in uneven water distribution. During operation, it was evident that the distribution rate from each emitter varied greatly. Some emitters were spraying water straight into the air while others did not even produce a trickle. This finding revealed more criteria for choosing emitters. The criteria are that the emitters must be easy to clean and able to conserve pressure. It also established criteria to include in the *Irrigation Education Manual* to assist the workers in correctly cleaning the emitters.

The sprinkler emitters are also placed directly on the lateral lines, which can be problematic; one small turn in the line can cause a number of emitters to emit in the wrong direction. We considered this problem during the design phase of our project. We addressed the problem by including emitter lines, known in the irrigation field as spaghetti tubing. The spaghetti tubing is flexible and comes off the lateral line, making the emitter less affected by the movement of the laterals.

Unclamped laterals ends, leaks from holes in tubing and loose connections all cause pressure losses throughout the system. Most, but not all of the lateral lines were properly clamped. A properly clamped end at the New Life Project is shown in Photograph 18. To promote proper maintenance in the future we addressed these issues in the *Irrigation Operation Manual*. We did this by including end line fittings in the system design, and describing their importance in the construction procedures. We also considered the risk of leaks during the selection of tubing and connectors. The New Life Project does not currently use connectors, which motivated us to explain their importance and give explicit construction instructions.

Photograph 18: A properly clamped lateral line at the New Life Project

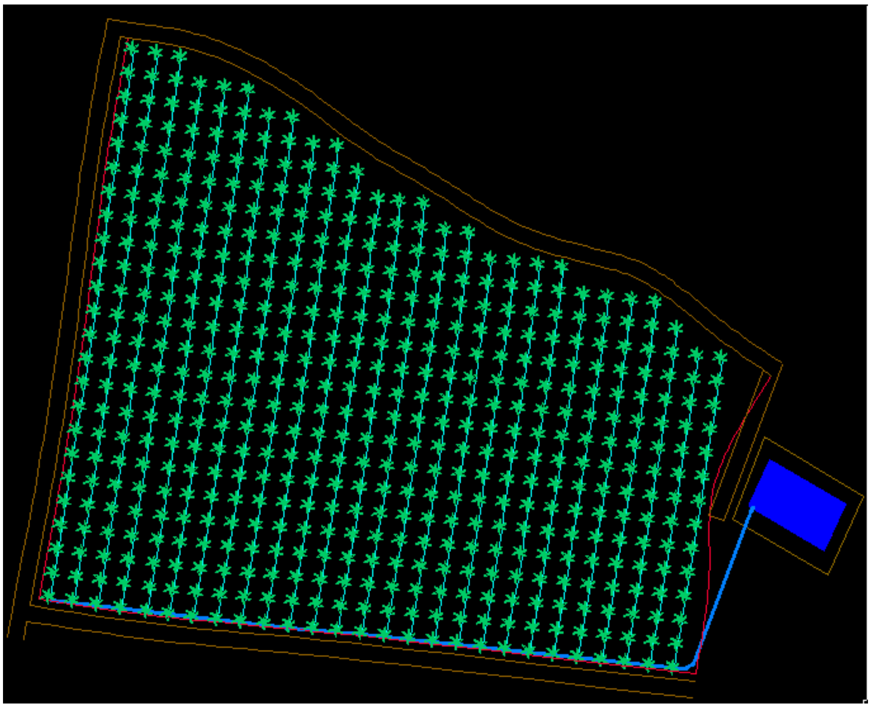
In summary, by reviewing the current development and operation methods of the New Life project we developed an appropriate range of components. Blending the social and environmental parameters, explained in this section, aided in the selection of appropriate irrigation equipment and identified procedures to include in the *Irrigation Education Manual*.

4.3 Components for an Appropriate Irrigation System Design

From the comprehensive work by Dasberg & Or (1999), we determined that the appropriate drip irrigation system for New Life includes a pump, filtration system, main lines, lateral lines, emitter lines, and drip emitters. This selection of irrigation components was reaffirmed by a drip irrigation publication series from Kansas State University (2003), Netafim, and Super Products Co. As we explain below, the order for choosing irrigation components progresses in the order of emitter, lateral tubing, main tubing, filter, and lastly pump. During this process we combined the social and environmental parameters detailed in the previous section to choose the most appropriate technology for New Life.

The *emitter* was the first component chosen because its selection determines the final pressure and flow rate needed at the end of the system. From the environmental and social findings we determined that the emitter must deliver the proper amount of water to the oil palms, not cause runoff, require an acceptable amount of pressure, be easy to clean, and supply water to the oil palms in a reasonable amount of time. Considering the criteria to minimize the length of the watering period, we chose to run the mock test with the greatest output emitter in the range defined by the environmental parameters, the 8L/h (2gph) emitter. The 8L/h emitter was acceptable because it did not cause runoff, operates at 10-40psi (0.7 to 2.8 bar), provides water to Block3 in about an hour, and can be easily cleaned. We did not use the emitters ranging from 1.2L/h (0.3gph) to less than 4L/h (1gph) because the watering time would exceed two hours. Although more than two hours would be an acceptable watering time now, as the New Life Project implements more irrigation systems two hours per field may be too long. We also only considered emitters that can be manually cleaned so the operators are able to properly maintain the system. The other consideration for emitters was whether to use one or two emitters per tree. Although it is more expensive, two emitters per tree better fits the agronomic requirements of the palm trees; the roots of the palm trees grow towards the water, so with only one emitter the root system would be very concentrated. Using two emitters will distribute the water more evenly and spread out the root system, increasing the health of the palms.

The *lateral* and *main* lines were chosen next, shown in Map 4 as the blue lines. We determined the amount of lateral and main line tubing using AutoCAD based on the number and spacing of trees on the plantation and the distance between the reservoir and the field. In addition to the larger lines, we included small spaghetti lines that connect the emitter to the lateral lines. We included spaghetti tubing to minimize the movement of emitters when lateral lines are shifted. With additional tubing the emitters are more independent of the lateral lines because they are not directly attached. Also, we incorporated stakes to pin down and immobilize the lateral lines. The introduction of these simple components will decrease irregular watering and maintenance.



Map 4: Lateral and main line tubing for Block3

Once the length of tubing was known for the lateral and main lines, the next step was to determine the appropriate sizes. For our application, lateral lines come in a range of 0.5in to 1in (1.2cm to 2.5cm) and main line tubing comes in a range of 1.25in to 2.5 in (3.2cm to 6cm). With a diameter range for lateral and main lines, we made a matrix for the flow rate of each combination, both with a 4L/h emitter and 8L/h emitter. This made for a combination of 24 different flow rates; the matrices and calculations are displayed in Appendix L. The flow rate matrices were the first step in deciding the appropriate size of the main and lateral tubing. The next step in determining the main and lateral tubing size was to determine their pressure loss, also known as head loss.

The head loss was also used to determine the most appropriate pump, using head loss equations from Dasberg & Or, 1999. Head loss in the lateral and main lines is determined by the flow rate and diameter of the tubing, which is determined by the emitter choice and the size of the lateral and main lines. The head loss equation and other equations used are listed in Appendix J. To find the appropriate size of the lateral and main tubing, we optimized the system for the least amount of power needed for operation and the lowest cost of the tubing. Power is determined by the total flow rate and total dynamic head. The tables in Appendix L were used to calculate both flow rate and head loss for each combination of tubing, and consequently the required pump.

The design requires many fixture connections between pipes and emitters. An elbow connector allows sections of main line tubing to make right angles, for example, around the corner of the field. Start connectors join the lateral lines and main lines. Mini-connectors attach spaghetti lines to the lateral lines. The design requires a start connectors for each row of Block3 and smaller connectors for the lateral tubing and spaghetti tubing. Each connector was chosen to be simple as well as effective at preventing leaks. If breaks occur in the system, connectors can also be used to attach sections of broken pipe. We documented how and when to implement connectors in the *Irrigation Education Manual*.

A series of *disk filters* will make the reservoir water suitable for irrigation by removing particles that could clog the system. Although media filters are usually the initial source of filtration for reservoir water, a series of disk filters can provide the same results. We chose to implement a series of disk filters for the following three reasons: (1) Super Products Co., and Netafim suggested a series of disk filters in place of a media filter. (2) Media filters require back flushing, generally a much more extensive cleaning procedure than disk filters. (3) Disk filters are more economically feasible. The Dasberg and Or (1999) publication recommends media filters, but their publication reflects practices that are six years old. We followed a similar implementation as Netafim and Super Products Co. because both distribute the most recent irrigation technology. The disk filters are put in series of increasing mesh size to prolong the time in between cleanings and to minimize the amount of maintenance. The appropriate disk filter will strain out particles as small as 10% the size of the emitter opening to prevent clogging. To prevent clogging, the design will consist of two, two-inch disk filters, the first being 120 mesh and the second at 140 mesh. A shut off valve is required after the second filter, along the mainline, to prevent the back flow of water when the pump is turned off or when cleaning one of the disk filters.

As mentioned in the Background Chapter and previously in the *Environmental Parameters,* we did not include a fertigation system in the design. While fertilization helps maximize the growth of the oil palms we found that it is not a requirement for the design and was a secondary concern. Providing clean water to the irrigation system was the primary consideration in the appropriate design. Fertigation requires using a completely water soluble fertilizer to prevent clogging the pipes. In general this is difficult to find, but it is especially difficult to find completely soluble phosphorus fertilizer, one of the three basic nutrients for oil palms (Snyder & Thomas, 2004). If we included a fertigation system it would have added to the total dynamic head of the system and changed our calculations from this point forward.

Using a water tower in the model irrigation design would have changed the pump selection. When using a water tower, the pump does not have to provide as much pressure head because the gravity from the water tower is used to provide pressure head. The construction cost of a water tower for such a small field is not cost effective. As our calculations show in Appendix L, the power required for the pump is not high enough to require a water tower for pressure. We made the decision not to use a water tower and then were able to use our calculation matrices to pick the most appropriate pump for each design.

The most appropriate *pump* for the Block3 drip irrigation system will provide the proper amount of pressure head for emitter operation, as well as compensate for head losses throughout the system. Electricity is available at the reservoir, which was the determining factor in using an electric pump rather than a gasoline pump. Pumps are chosen based on the amount of total dynamic head and flow rate they provide. We did calculations for each system at 25psi, 30psi, and 35psi (1.7, 2 and 2.4 bar respectively) because the emitters operate anywhere from 10psi to 40psi (0.7bar to 2.7 bar). The calculations done to find the pressure losses throughout the system, and therefore the appropriate pumps are listed in Appendix L.

With the completion of the tables in Appendix L, we had essentially 72 possible designs. The designs vary according to emitter, lateral tubing size, main tubing size, and operating pressure. The next section explains the optimizations for choosing the most appropriate system for the New Life Project. To provide the most flexibility to the New Life Project we optimized our design for three different parameters. The next section discusses these parameters and presents each design as a unit, with the associated costs listed for each design.

4.4 Three Alternatives for Irrigation System Design

Using the design matrices and cost lists, we optimized the irrigation design in three different ways to produce the most appropriate design for the New Life Project. The irrigation design was optimized for:

- Lowest Power Requirement, Shortest Watering Time, Optimal Water Distribution;
- Lowest Cost;
- Appropriate Design for the New Life Project.

In each design the main variations were the number of emitters per tree, the diameter of the main and lateral line tubing and the size of the pump. The filtration system is the same regardless of the rest of the design because it is defined by the environmental and social parameters. We optimized each design for the emitters to operate at 25psi (1.7bar). We chose 25psi because it is the average of the operating pressure range for the emitters. This allows for unaccountable head losses in the future, such as silt accumulation, and for variations in the pump selection. Finding a pump with the exact flow rate and total dynamic head is unlikely. Choosing a pressure of 25psi allows for the pump to supply either slightly higher or lower power than is needed and still supply the appropriate amount of water to the system. We compared the first two optimizations to make an appropriate design for the New Life Project and to demonstrate the many factors that go into irrigation design.

Lowest Power Requirement, Shortest Watering Time, Optimal Water Distribution

This design captures all of the desired components of drip irrigation; it will require the smallest pump and provide the water quickly as well as distribute it evenly to the roots of the palm tree by using two emitters per tree.

Optimization: Lowest Required Power, Shortest Operating Time, Best Distribution of Water					
Component	**Quantity**	**Price (Baht)**	**Total (Baht)**	**Total (US$)**	**Supplier**
Emitter (4L/hr)	1030	4.5	4,635	118.85	Four Bros
Spaghetti Tubing (5mm)	1030	4	4,120	105.64	Four Bros
Spaghetti Connector (5mm)	1030	1.03	1,061	27.20	Netafim
Lateral Tubing (2.5cm)	4635m (24rolls)	3500/200 m	84,000	2,153.85	Super Products
Connector Coupling (2.5cm)	24	70	1,680	43.08	Four Bros
Start Connectors (2.5cm)	27	14	378	9.69	Super Products
Main Line Tubing (6.3cm)	305 (2rolls)	3900/150	7,800	200.00	Super Products
Connector Coupling (6.3cm)	1	195	195	5.00	Four Bros
2 Inch Filter	2	2750	5,500	141.02	Super Products
2 Inch Filter Disk	2	1650	3,300	84.62	Super Products
Pressure Gauge	1	574.2	574	14.72	Netafim
Needle for Testing Valve	1	261	261	6.69	Netafim
Pump	1	n/a			
TOTAL			113,504	2,910.36	

Table 5: Cost and Components for the first optimization

The main variation in this design includes using the smallest pump, while still provide the proper amount of water to the system in the appropriate watering time, one hour. This design also includes two emitters per tree to suit the agronomic requirement of the palm trees. Although we did find suppliers that carry the appropriate size pump, we were unable to obtain prices. However, even though this design seems to capture the desired components of irrigation design, we will demonstrate in our third optimization that even without the pump, this design is significantly more expensive due to the cost of 2.5cm (0.98in) lateral tubing. Based on the optimization of the tubing (see Appendix L), providing water in the shortest amount of time using the smallest pump requires large diameter lateral and main lines. Excluding the price of the pump, 2.5cm lateral line tubing makes up over fifty percent of the cost of the entire system. This design demonstrates how important it is to carefully consider each component to optimize the cost. At first, it may seem that the pump would affect the total cost the most, but this design proves that it is very important to consider each component.

Optimization: Lowest Cost					
Component	**Quantity**	**Price (Baht)**	**Total (Baht)**	**Total (US$)**	**Supplier**
Emitter (4L/hr)	515	4.5	2,318	59.42	Four Bros
Spaghetti Tubing (5mm)	515	4	2,060	52.82	Four Bros
Spaghetti Connector (5mm)	515	1.03	530	13.60	Netafim
Lateral Tubing (1.6cm)	4635	5.5	25,493	653.65	Super Products
Insert Connector (1.6cm)	24	70	1,680	43.08	Netafim
Start Connectors (1.6cm)	27	10	270	6.92	Super Products
Main Line Tubing (4cm)	305 (3 rolls)	3524/100	10,572	271.08	Netafim
Connector Coupling (4cm)	3	140	420	10.77	Four Bros
2 Inch Filter	2	2750	5,500	141.02	Four Bros
2 Inch Filter Disk	2	1650	3,300	84.62	Super Products
Pressure Gauge	1	574.2	574	14.72	Super Products
Needle for Testing Valve	1	261	261	6.69	Netafim
Pump	1	n/a			Netafim
TOTAL			52,978	1,358.39	

Table 6: Cost and Components for Optimizing the Lowest Cost

Lowest Cost

This design was optimized solely based on cost. In this design, watering time takes two hours, twice as long as the other two designs, and includes only one emitter per tree. Ideally, watering should be done in the morning so that there is not too much evaporation. The emitters in this design are smaller than in the previous design. In order to reduce cost, the main and lateral lines also have smaller diameters because of the expense of larger tubing. Keeping the expansion of the entire plantation in mind, this design would require two hours of watering a day in potentially eight different sections the size of Block3. To further reduce expenses, if one pump were to be shared between the sections, the irrigation time could last up to 16. The final consideration for this design is that it includes only one emitter per tree.

One emitter per tree would provide enough water, but it would not give the optimal water distribution to the roots. With only one emitter per tree, the roots would be very concentrated. Also note that the price of this design does not include a pump either.

Optimization: Appropriate Irrigation System for New Life					
Component	**Quantity**	**Price (Baht)**	**Total (Baht)**	**Total (US$)**	**Supplier**
Emitter (4L/hr)	1030	4.5	4,635	118.85	Four Bros
Spaghetti Tubing (5mm)	1030	4	4,120	105.64	Four Bros
Spaghetti Connector (5mm)	1030	1.03	1,061	27.20	Netafim
Lateral Tubing (2cm)	4635	7	32,445	831.92	Four Bros
Insert Connector (2cm)	24	6.52	156	4.01	Netafim
Start Connectors (2cm)	27	12	324	8.31	Super Products
Main Line Tubing (5cm)	305m (3 rolls)	5237/100m	15,711	402.85	Netafim
Connector Coupling (5cm)	3	165	495	12.69	Four Bros
2 Inch Filter	2	2750	5,500	141.02	Four Bros
2 Inch Filter Disk	2	1650	3,300	84.62	Super Products
Pressure Gauge	1	574.2	574	14.72	Super Products
Needle for Testing Valve	1	261	261	6.69	Netafim
Pump	1	6932.53	6,933	177.76	Sile (Thailand) Co., LTD.
TOTAL			77,503	1,987.26	

Table 7: Cost and Comparison for Appropriate Design Optimizations

Appropriate Design for the New Life Project

To best meet the needs of the New Life plantation, this design optimized cost while providing two emitters to each tree. In all designs the spaghetti tubing was estimated at a length of 0.5m to allow the emitters to be placed on opposite sides of the tree, and to ensure they will not move if the lateral tubing is twisted or repositioned slightly. Also note, the cost of the pump is included in this design. The pump provides slightly more pressure head and flow rate than is needed for the system, so it will operate at a pressure slightly higher than 25psi. By minimizing the diameter of the tubing while choosing a pump that could still provide water to the system in one hour and including two emitters, we optimized the design for both cost and functionality.

Each design involves components from different suppliers in order to minimize costs. In reality, it may be more convenient to buy all components from one supplier which would increase the cost of each design. From our experience, Netafim offers the most components as well as consulting services.

For a complete visualization of the components chosen, their function and construction, operation, and maintenance procedures and a synthesis of the system as a whole, see Appendix M, which contains the *Irrigation Education Manual*.

4.5 Creating Tools for Operational Efficiency and Fundraising

We used our findings to make two deliverables that will aid in the future development. First, we made an Irrigation Education Manual for operators of the system because they change monthly, and usually have had no prior training or experience with irrigation systems. See Appendix M for the complete *Irrigation Education Manual*. Second, we created a proposal in a professional, informative, and attractive manner to be used for fundraising located in Appendix N. Determining what information to use and how to present it effectively came from the procedures discussed in this section.

After assessing the current situation at the New Life Project we used the identification of social parameters to determine ways to improve operational efficiency. We created an irrigation education manual to aid in the proper construction, operation, and maintenance procedures for the system in the future. Before deciding the layout and design, we identified all the information to include in the manual. We included information addressing any previously observed concerns, as well as the new technology being integrated into the Block3 design. We incorporated figures and diagrams to provide additional resources for different learning styles. Also, keeping the reader in mind, we organized the manual into sections beginning with an explanation of the overall system, construction, operation, and maintenance techniques and concluding with troubleshooting methods.

In order to educate donors about the New Life plantation and encourage them to help support their expansion, we created a professional brochure describing the Block3 irrigation system. Tony Ponderis, an expert fund-raising consultant for non-profit organizations, has identified the key components for creating fundraising proposals:

- Campaign Chair's message;
- Mission and vision;
- Overview of background and history;
- Programs and services;
- Case for support of particular project - assessment of need;
- Drawings, tables, and diagrams relating to the campaign;
- Ways to Give (cash, check, credit card, multi-year installments);
- "Named Gift Opportunities" for endowment and capital campaigns; "Membership Categories" for annual fund campaigns;
- Acknowledgements for donated and in-kind services for campaign publications. (Ponderis, 2004)

Within the proposal there is considerable flexibility when ordering the elements. From our research we were able to compare these fundraising strategies to the current methods of The Duang Prateep Foundation. Using brochures from previous DPF fundraising campaigns, we looked for patterns to determine what information has encouraged donations. We also interviewed Khun Khantong, DPF Head of Fundraising, and acquired specific information that the Duang Prateep Foundation requires for the Block3 proposal.

4.6 Findings and Discussion Summary

In conclusion, through our research and observations we were able to produce a model irrigation system design for the New Life Project. From our findings we also created a fundraising brochures and irrigation education manual to assist in the development of the plantation. The next chapter summarizes the project and includes the limitations of our findings. It also covers recommendations for the New Life Project to follow up with to maximize the success of the system.

5 Summary

The New Life Project envisions generating revenue through goods produced from palm oil within the next ten years. To achieve this goal, the New Life project is in the process of developing 32 hectares of land and installing irrigation systems as donations allow. Currently, the development process is proceeding at varying rates throughout the plantation. For this reason we addressed issues that would assist in the development process. The major development aspects that we concentrated on are funding, construction, and operation of the system. From our research and findings we were able to provide three final products and recommendations:

- Model irrigation system design;
- Fundraising brochure;
- Irrigation operation manual;
- Recommendations for future growth and development.

These products were identified as being essential elements to the implementation and success of the irrigation system and over all development of the New Life Project. This section reviews the two categories of findings used to design the irrigation system, as well as the findings applied to create the fundraising brochure and operation manual.

Model Design

Before designing an irrigation system we identified the social and technical aspects that would influence the design. The initial technical findings involved determining the quality and quantity of water in the reservoir. These findings were necessary for choosing a filtration system and determining if there was sufficient water in the reservoir to support the oil palms. The surveying done on Block3 was used to create an AutoCAD map of the area, which was essential for calculating the maximum number of trees and water demand of Block3. Through surveying we were also able to find the total elevation change throughout the field which affects the necessary performance by the pump. By comparing the minimum volume of water in the reservoir and the maximum water demand of the palm trees we made the important initial finding that there is sufficient water in the reservoir to support Block3. Our findings also included the infiltration rate of water into the ground, by means of a percolation test, which determined a range of appropriate emitters.

In addition to our scientific tests, our observations of the current irrigation system at New Life brought us to important findings. We identified the irrigation components currently in use at New Life: a portable two horsepower pump, PVC mainlines, PE lateral lines, and sprinkler emitters. This finding was important because the new irrigation system design must implement a comparable level of technology that the New Life operators can manage. We also observed the operation of the system and discovered appropriate irrigation methods to continue in the future and new methods that can be implemented. Also, we found that the New Life expands their plantation in sections as they receive funding. In each area they first build a reservoir and then develop a field adjacent to the water source. Based on these finding we were made recommendations for future development, operation and maintenance of the plantation. By following through with these recommendations, the New Life Project will benefit from the increased production from the plantation.

Our major finding was the appropriate design of an irrigation model for the New Life Project. To begin the design, we used the social and technological specifications identified above. The first, most influential component determined, was the emitter. The emitter influences the total system by determining the overall flow rate and pressure at the end of the system. To further the optimization of the design, we varied tubing size and filters to calculate the flow rate and pressure at the beginning of the system. These variations all required different sized pumps to deliver water to the system. At the conclusion of our design process, we presented three designs to the New Life Project, each optimized for a different parameter. The three designs were optimized based on lowest power requirements, lowest cost, and the appropriate design for New Life. The appropriate design is shown in Table 8.

Optimization: Appropriate Irrigation System for the New Life Project					
Component	**Quantity**	**Price (Baht)**	**Total (Baht)**	**Total (US$)**	**Supplier**
Emitter (4L/hr)	1030	4.5	4,635	118.85	Four Bros
Spaghetti Tubing (5mm)	1030	4	4,120	105.64	Four Bros
Spaghetti Connector (5mm)	1030	3	3,090	79.23	Four Bros
Lateral Tubing (2cm)	4635	7	32,445	831.92	Four Bros
Insert Connector (2cm)	24	6.52	156	4.01	Netafim
Start Connectors (2cm)	27	13.42	362	9.29	Netafim
Main Line Tubing (5cm)	305m (3 rolls)	5237/100m	15,711	402.85	Netafim
Connector Coupling (5cm)	3	165	495	12.69	Four Bros
1 Inch Filter	1	1988.36	1,988	50.98	Netafim
2 Inch Filter	1	2750	2,750	70.51	Four Bros
2 Inch Filter Disk	1	1650	1,650	42.31	Super Products
Pressure Gauge	1	574.2	574	14.72	Super Products
Needle for Testing Valve	1	261	261	6.69	Netafim
Pump	1	6932.53	6,933	177.76	Sile (Thailand) Co., LTD.:
TOTAL			75,171	1,927.46	

Table 8: Cost and components for the appropriate design for the New Life Project

The design was optimized for cost while still providing two emitters to each tree. This design waters Block3 in one hour, and two emitters per tree allows the roots to grow more symmetrically.

Fundraising Brochure and Education Manual

To support the implementation of a successful irrigation system, we created two deliverables to promote operational efficiency and aid in fundraising. To promote the future success of the irrigation system we provided the system operators with an informative manual on irrigation construction, operation and maintenance. The manual explains the function and importance of each component in the irrigation system and how they all work together. See Appendix M, for the *Irrigation Education Manual*. Additionally, we created a professional, informative, and attractive fundraising brochure. The brochure encourages donors to help finance the implementation of the irrigation system. With this brochure New Life will be able to inform potential donors of the importance of the irrigation system for the development and potential for financial self sufficiency of the New Life Project. The fundraising brochure is located in Appendix N.

Recommendations

The drip irrigation system we designed for the New Life Project has provided them with a model design as well as educational material for operation. A main focus during the creation of the irrigation system was to utilize the resources that were available at the plantation. Through our research we developed three recommendations that would greatly improve the efficiency of the plantation and quality of water delivered to the irrigation system. Briefly, these recommendations are to use

- Well water rather than reservoir water;
- Fertilization scheme to maximize growth;
- Chemical water treatment to promote longevity.

By following through with these recommendations the effectiveness of the irrigation system will improve greatly. We now turn to a discussion of the importance and benefits of the recommendations.

1. Water Sources

Of all the factors affecting the irrigation design, the water source clearly has the largest impact on the design. The water source determines the filtration components and also influences the choice of pump, two of the most expensive components of the design. Although drip irrigation is possible and common with open reservoirs, many sources advise against it, including Dasberg and Or (1999) who state that “water from reservoirs is the most problematic for drip irrigation, as it contains not only suspended solids, but also appreciable amounts of algae, zooplankton, bacteria and other organic material" (p.95). In the future development of the New Life Project, wells could provide a cleaner, more manageable source of water for drip irrigation. Well water may have more sand and gravel than reservoirs, but it does not contain nearly the same amount of biological impurities. Biological impurities are much more difficult to filter out effectively.

2. Fertilizer

To maximize the growth of the oil palms, a more comprehensive fertilizing scheme should be introduced. The fertilization can be done manually or through a fertigation system that can be added to the drip irrigation system we have proposed. We did not include a fertigation system in our design because of time constraints and the knowledge that a fertigation system can be introduced after the initial construction. If a fertigation system was to be deemed appropriate over manual fertilization, our research shows that "if electrical power is available, than an electrical injection pump is the best solution" (Dasberg & Or, 1999). Fertigation system suppliers are listed in Appendix E. Although the first step is choosing the fertilizing system, other considerations are needed including the type of fertilizer, the amount of fertilizer, and the rate of injection. One difficulty with fertigation is that the fertilizer must be completely soluble and could potentially react with impurities in the irrigation water. A list of fertilizers suitable for fertigation (Dasberg & Or, 1999) and the proper balance of nutrients from Asia Program of the Potash & Phosphate Institute (Uexkull, n.d.) are contained in Appendix F for future use. The three major advantages of fertigation over manual fertilization are: it is labor and cost saving, the application is more precise, and the amounts of individual nutrients can be readily adapted (Dasberg & Or, 1999). However, manual fertilization could be a successful technique if the proper amounts of nutrients are delivered to the oil palms. Whichever method is chosen, we recommend the development and implementation of a fertilization scheme particular to oil palms.

3. Water Treatment

Our final recommendation, also relating to water quality, is that the addition of chemical water treatment will promote the longevity of the system. For reservoirs, "filtration by media or disk filters is insufficient, and water treatment by chloride is essential" (Dasberg & Or, 1999). The treatment is needed to rid the system of the biological impurities contained in reservoir water. These biological impurities will not harm the system immediately but can build up over time. Through our research we identified three common types of chemical treatment: chlorination, treatment with acid, and bactericides. Bactericides and chlorination are used to prevent organic growth. Treatment with acid can prevent the precipitation of calcium carbonate sediment and iron carbonate within the tubes. The Kansas State Irrigation Management Series (2003), recommends testing for 11 parameters. These parameters and their hazard levels are listed in Appendix G. Due to the limitations of our resources, we were only able to complete two of the 11 parameters identified by the series. Additionally, the total suspended solids test that we completed was done to choose our filter; it was not used to identify schemes for chemical treatment. To implement a chemical treatment plan a much more thorough water analysis must be performed. The impurities identified from the recommended tests can aid in the future choice of a chemical treatment plan.

Project Outcomes

As a reminder, the larger motivation for the implementation of an irrigation system is to contribute to the successful development of the New Life Project for Abused Children. Upon the completion of our goal, we provided the New Life Project with three essential elements to assist with their development and a set of recommendations to stably continue development. They are:

- Model drip irrigation system;
- Irrigation education manual;
- Fundraising brochure;
- Recommendations for future development.

Our goal was designed to address each stage required for implementing an irrigation system; these stages are funding, construction, and operation. It is our intention that this contribution to the New Life Project will provide support for irrigation implementation and continued operation in the future. Following through with our design and suggestions will aid in development towards the self-sustainability of the New Life Project and the opportunity for more children to develop in a safe and caring environment.

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Appendices

A. Centrifugal Pumps

A centrifugal pump consists of two main parts, the impeller and the volute. The impeller moves the water inside the casing and the volute forces the water to leave the leave the pump. As seen in Figure 1, this is accomplished by offsetting the impeller inside the volute so that it is near the cut-water spot so the water will discharge (Pump World, 2004). Centrifugal pumps can be driven by any common method and different models can meet the demands of almost any situation.

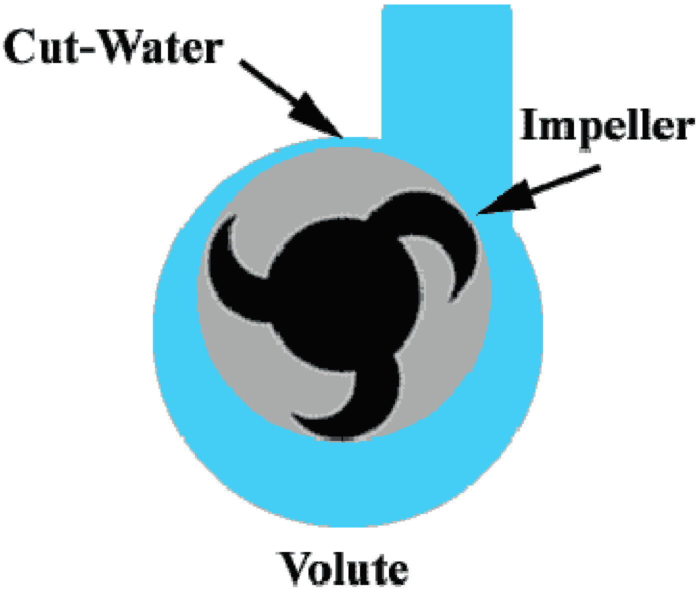


Figure 1: Parts of a centrifugal pump (http://www.pumpworld.com/centrif1.htm)

In order to determine the appropriate centrifugal pump it is necessary to determine factors such as the total static head, **pressure head, and friction head**. As seen in the figure below, the total static head is the height the pump must lift the water. Pressure head is the amount of pressure needed in the distribution system for the emitters to operate properly. Friction head is the pressure decrease when water flows through pipe networks. The sum of these three components is the total dynamic head (TDH) of the system.

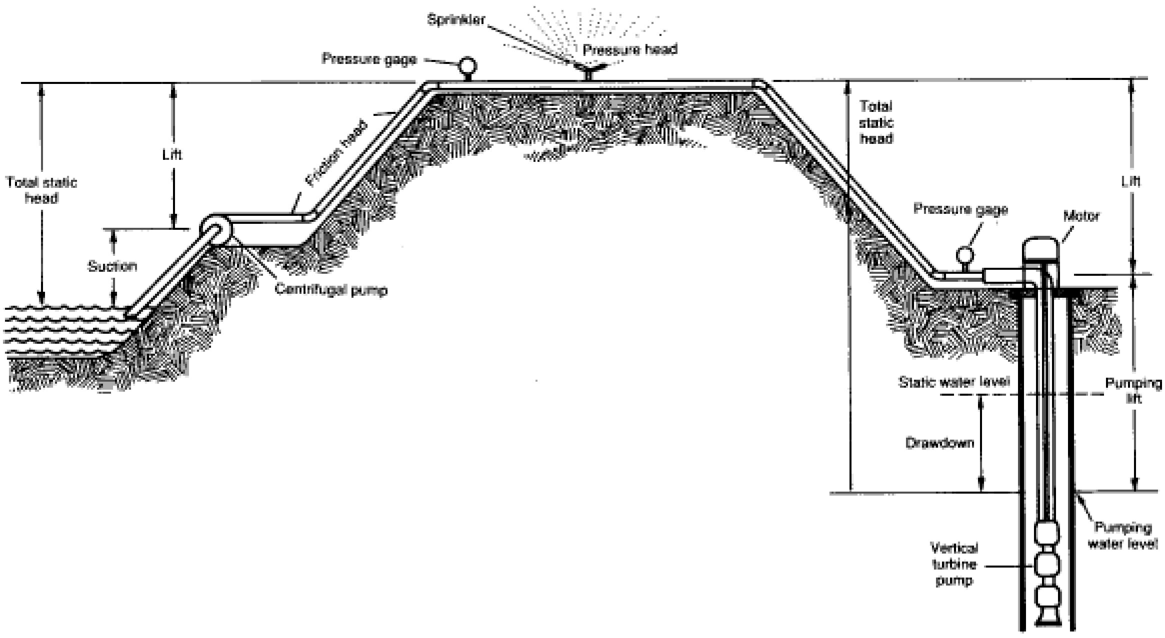


Figure 2: Explaining total dynamic head
(http://www.ext.nodak.edu/extpubs/ageng/irrigate/ae1057w.htm)

After determining the TDH it is then possible to determine the power required to operate the pump. The power to move the associated water, water horsepower must first be calculated for the system.

$$WaterHorsePower = \frac{FlowRate \times TDH}{3960} \quad \textit{(Scherer, 1993)}$$

The actual power needed to operate the pump is slightly higher however because the pump and drive shaft are not completely efficient. The actual power required by the pump is called the brake horsepower.

$$BrakeHorsepower = \frac{WaterHorsepower}{PumpEfficency \times DriveEfficency} \quad \textit{(Scherer, 1993)}$$

One last consideration for the centrifugal pump is that it cannot pump air. Before starting the pump it must be primed, meaning there must be water in the intake pipe and the casing when the pump is turned on. To compensate for this many centrifugal pumps are now designed to hold a small amount of water but if this is not the case water must be added to the pump in order for it to work (Jess Stryker's, 2003).

B. Water Quality Guidelines for Drip Irrigation

Adapted from Rogers, Lamm, & Alam, 2003.

Water Quality Guidelines			
Constituent	Level of Concern		
Clogging Potential	Low	Moderate	High
pH	<7.0	7-8	>8.0
Iron (Fe) mg/L	<0.2	0.2-1.5	>1.5
Manganese (Mn) mg/L	<0.1	0.1-1.5	>1.5
Hydrogen Sulfide (H2S) mg/L	<0.2	0.2-2.0	>2.0
Total Dissolved Solids mg/L	<500	500-2000	>2000
Suspended Solids (mg/L)	<50	50-100	>100
Bacterial Count (#/mL)	<10,000	10,000-50,000	>50,000

C. The New Life Project Budget

The start up costs for the Kanchanaburi plantation site were estimated to be 6,600,000 baht ($153,400). Donations came through the celebration of the 25th anniversary of the Duang Prateep Foundation, in which sponsors from around the world were asked to join them in this endeavor. New Life ensures their donors that the money is going to a good cause; "Let us plant your donation, we will nurture it so that it flourishes and produces a rich harvest to help disadvantaged and abused children over many years" (DPF, 2003) and even writes thank you notes to all of their donors. The initial costs were divided up per tree, equaling 1,500baht ($35 dollars). According to Khru Prateep, the founder, 1,500baht is "all it costs to prepare, plant and care for one tree during the first four years, before harvesting can begin" (DPF, 2003). The breakdown of the start up cost estimation can be seen in Table 1.

Total budget (4 years from April, 2003 to March, 2007):

	Thai Baht	US dollars
Cost of land (32 hectares)	3,400,000	79,070
Cost of tree seedlings, 4,400 trees @100 baht each	440,000	10,233
Cost of labour during planting, 4,400 trees @100 baht each	440,000	10,233
Cost of land preparation and materials	130,000	3,023
Cost of installing irrigation system	1,048,000	24,372
Signs with names of donors	88,000	2,047
Cost of tree maintenance, 48 months	864,000	20,093
Cost of transportation	190,000	4,419
TOTAL	6,600,000	153,490

Table 1: New Life Predicted Budget (http://www.dpf.or.th/eng/palm_eng.html)

We know that the most current plan for the Kanchanaburi plantation incorporates planting 6,000 trees. That means that the figures in this budget may not reflect the most recent decisions. The most current estimation may be closer to 9,000,000 baht ($209,307) to compensate for the extra 1,600 trees. Khru Prateep has informed us that New Life has already received a 7 million baht in donations. These donations were given specifically for the initial costs of establishing the oil palm plantation. New Life has already spent about 4 million of this and plans on utilizing the remaining 3 million baht to cover operation and maintenance costs until the crops begin to produce fruit. Currently, New Life has not received the estimated 1 million baht that they expect will cover the construction implementation of the entire irrigation system.

After the initial four years prior to harvesting, New Life, Kanchanaburi plans on generating the profits shown in Table 2.

Estimated income and expenditure 2007 to 2011

Year	2007	2008	2009	2010	2011
Income : Baht	910,000	1,190,000	1,610,000	1,890,000	2,310,000
US$	21,163	27,674	37,442	43,953	53,721
Expenses : Baht	700,000	700,000	700,000	700,000	700,000
US$	16,279	16,279	16,279	16,279	16,279
Profit: Baht	210,000	490,000	910,000	1,190,000	1,610,000
US$	4,884	11,395	21,163	27,674	37,442

Table 2: Estimated income and expenditure for New Life 2007 to 2011 (http://www.dpf.or.th/eng/palm_eng.html)

D. Surveying Equipment: Definitions and Uses

Total Station – This device is used to locate points by measuring distances and angles. When a total station is locating a point it is called taking a shot. The station is built of several different components. The level and legs that the gun rest upon ensure that the level will give consistent shots regardless of slope. The scope allows the user to point and focus the station in the direction of the point being shot. The shooting device used by the station is called a *prism pole*. The total station has a built in calculator and display screen for showing the angle and distance that the point shot is from the total station.

Prism Pole – The prism pole functions as the locator while the total station functions as the recorder. To locate a point the prism pole is placed at a desired location. When the total station takes a shot it shoots an ultraviolet ray of light out towards the desired point, and reads it when it is reflected off the prism pole.

Level – The level is an instrument used to measure the elevation change of an area. The level consists of a scope that can only rotate horizontally and an internal level to ensure is straight up and down. Changes in elevation are observed by viewing a *level rod* through the scope and reading the corresponding value.

Level Rod – The level rod is an elongated measuring stick that is used to measure elevation change. The rod is notched in increments that allow one to read the values when viewing the rod through a *level*. The *level* and level rod are used together to calculate elevation changes.

E. Thailand Irrigation Equipment Suppliers

Company	Components Carried					
	Emitter	Tubing	Filters	Fertigation	Chemigation	Pump
Netafim Thailand Co., Ltd. 5th Floor, TPS Building. 1023 Pattanakarn Road, Suanluang, Bangkok 10250 Tel: +662 717 8167 72 Fax: +662 717 8158 netafim@netafim.co.th www.netafim.co.th	x	x	x	x	x	x
Four Bros Supplies Ltd. Part 32/26 Soi Saleenimit, Sukhumvit 69 Bangkok Thailand 10110 Phone: +66-2-3918063 Fax: +66-2-3812189	x	x	x			x
Astraco Asia Trading (Thailand) Co., Ltd. 1168/23, 14th Floor Lumpini Tower Rama IV Road, Thungmahamek Sathorn, Bangkok Thailand 10120 http://www.astraco.co.th/ Tel: +66-2-679-7741 Tel: A22+66-2-679-7742 Fax: +66-2-285-5993 E-mail: astraco@astraco.co.th	x	x	x			x
Super Products 1785-9 Phaholyothin 31 Bangkok Thailand 10900 Tel: +66-2-930-1190 Fax: +66-2-930-1308	x	x	x	x	x	x
Sile (Thailand) Co., Ltd. 279/29 Suthisamvinigchai Rd. Samsen-nok Huaykwang, Bangkok 10320 Tel: 0-2274-7950 Tel: 0-2274-8675						x
T.C. Filter and Engineering Ltd., Part. Address : 78 Moo 3 Pakkret, Pakkret Nonthaburi, Thailand 11120 Tel : +66 (0) 2960 7968-9 Fax : +66 (0) 2960 9984			x			

F. Fertilizers Suitable for Fertigation

(Dasberg & Or, 1999)

Name	Chemical Form	$N-P_20_5-K_20$ Content (%)	Solubility g/l at 20C	Remarks
Ammonium Nitrate	NH_4NO_3	34-0-0	1830	Incompatible with acids
Ammonium Sulfate	$(NH_4)_2SO_4$	21-0-0	760	Clogging with hard water
Urea	$CO(NH_2)_2$	46-0-0	1100	
Urane Solution	$CO(NH_2)_2$ NH_4N0_3	32-0-0	High	Incompatible with Ca(NO3)
Monoammonium	$NH_4H_2PO_4$	12-61-0	282	Not to be used with hard water (containing Ca)
Phosphate Diammonium	$(NH_4)_2HP_2$	18-46-0	575	Contains Phosphorus at high solubility
Phosphate Potassium Choloride	O_5KCl	0-0-60	347	Chloride toxic for some crops, cheapest K source
Potassium Nitrate	KNO_3	13-0-44	316	Expensive, high Nitrate
Potassium Sulfate	K_2SO_4	0-0-50	110	Excellent source of sulfur, Clogging with hard water
MonoPotassium Phosphate	KH_2PO_4	0-52-34	230	
Phosphoric Acid	H_3PO_4	0-52-0	457	Incompatible with Calcium

World Fertilizer Use Manual
Author: H.R. von Uexkull, Director (rtd), E. & S.E. Asia Program of the Potash & Phosphate Institute/International Potash Institute, Singapore (http://www.fertilizer.org/ifa/publicat/html/pubman/oilpalm.htm)

Present fertilizer use in major growing areas for young, mature palms (4-10 years old)						
Country	**Yield level (t/ha FFB)**	**Soil**	**kg/palm/year**			
			N	**P2O5**	**K2O**	**MgO**
Malaysia	26-32	Alluvial	0.90-1.35	0.33-0.50	1.80-3.00	0.135
	22-28	Inland	0.84-1.25	0.50-0.65	2.40-3.30	0.27-0.40
		(Sedentary)				
	20-26	Peat*	0-0.45	0-0.35	2.40-3.00	-
Indonesia	22-30	Volcanic	0.90-1.35	0.46-0.70	1.70-1.80	0.35-0.40
	20-26	Podzolic	0.90-1.35	0.70-0.90	1.50-3.00	0.35-0.40
		(Sedentary)				
Thailand	**14-18**	**Sedentary**	**0.84-1.05**	**0.50-0.66**	**1.80-3.00**	**0-0.14**
Papua New	20-28	Volcanic**	0.60-0.80	0.23-0.46	0-1.20	0-0.14
Guinea	18-26	Alluvial	0.40-0.60	0-0.23	1.80-2.40	-
West Africa	10-18	Sedentary sands	0.20-0.50	0.23	0.60-1.80	0-0.27
Latin	16-24	Volcanic**	0.45-0.68	-	-	0.20-0.27
America	17-25	Alluvial	0.45-0.68	0.45-0.68	0.60-1.20	0-0.27
	15-22	Sedentary	0.30-0.60	0.45-0.68	0.90-1.80	0.20-0.27
Borate is now commonly applied to young palms (up to year 6) at rates starting from 50 g/palm/year and increasing up to 150 g/palm/year. * During the immature phase finely ground limestone is applied twice at a rate of 6-8 kg/palm. ** When no potash (KCl) is used on K-rich, young volcanic soils, ammonium should be the preferred N source in order to provide adequate chloride.						

G. Water Quality Analysis Recommendations

(Rogers, Lamm & Alam, 2003)

1. Electrical Conductivity (EC)- measured in ds/m or mmho/cm- a measure of total salinity or total dissolved solids
2. pH- a measure of acidity- 1 is very acid, 14 is very alkaline, and 7 is neutral
3. Cations- measured in meq/L, (milliequivalent/liter), includes: Calcium (Ca), Magnesium (Mg), and Sodium (Na)
4. Anions- measured in meq/L, includes: Chloride (Cl), Sulfate (SO4), Carbonate (CO3) and Bicarbonate (HCO3)
5. Sodium Absorption Ratio (SAR)- a measure of the potential for sodium in the water to develop sodicity, deterioration of soil permeability, and toxicity to crops. SAR is sometimes reported as Adjusted SAR. The Adjusted SAR value accounts for the effect of the HCO3 concentration and salinity in the water and the subsequent potential sodium damage
6. Nitrate nitrogen (NO3-N) measured in mg/L (milligram/liter)
7. Iron (Fe), Manganese (Mn), and Hydrogen Sulfide (H2S)- measured in mg/L
8. Total Suspended Solids- measured in mg/L of particles in suspension
9. Bacterial Population- a measure or count of bacterial presence in #/ml
10. Boron- measured in mg/L for crop toxicity concern
11. Presence of oil- would be a concern for excessive filter clogging. It may not be a test option in some labs and could be considered an optional analysis

Water Quality Guidelines

(Rogers, Lamm & Alam, 2003)

Constituent	**Level of Concern**		
Clogging Potential	**Low**	**Medium**	**High**
pH	<7.0	7-8	>8.0
Iron (Fe) mg/L	<0.2	0.2-1.5	>1.5
Manganese (Mn) mg/L	<0.1	0.1-1.5	>1.5
Hydrogen Sulfide (H2S) mg/L	<0.2	0.2-2.0	>2.0
Total Dissolved Solids (TDS) mg/L	<500	500-2000	>2000
Total Suspended Solids (TSS) mg/L	<50	50-100	>100
Bacteria Count (#/mL)	<10,000	10,000-50,000	>50,000
Crop Effect Potential			
EC- mmho/cm	<0.75	0.75-3.0	>3.0
NO3 mg/L	<5	5-30	>30
Specific Ion Toxicity			
Boron mg/L	<0.7	0.7-3.0	>3.0
Chloride meq/L	<4	4-10	>10
Chloride mg/L	<142	142-355	>355
Sodium (Adj. SAR)	<3.0	3-9	>9

H. Testing Procedure for Total Suspended Solids

Scope and Application: This method is applicable to drinking, surface, and saline waters, domestic and industrial wastes with a practical range of determination of 2mg/L to 20,000mg/L.

Summary of Method: A well-mixed sample is filtered through a standard glass fiber filter, and the residue retained on the filter is dried to a constant weight at 103-105^{o}C.

Definitions: Total suspended solids is defied as those solids which are retained by a glass fiber filter (0.7 micron pore size) and dried to a constant weight at 103-105^{o}C.

Sample Handling and Preservation: Refrigeration or icing to 4^{o}C to minimize microbiological decomposition of solids is required.

Materials:

- Glass microfiber filter disks
- Disposable aluminum dishes
- Tweezers
- Suction flask, 1000mL
- 47mm glass microanalysis filter holder (funnel, clamp, and base)
- Drying over for operation at 103-105^{o}C
- Analytical balance
- Distilled Water

Procedure:

1. Before sampling, prepare glass fiber filter by first soaking them in distilled water, drying them at 103^{o}C, and weighing and recording their weights.
2. Place the dried, weighed glass fiber filter onto a filtering flask, wrinkled side up.
3. Place the filter on the base, clamp on funnel and apply vacuum. Wet the filter with a small volume of distilled water to seal the filter against the base
4. Shake the sample vigorously and transfer a portion of the sample to the filter using a large volumetric pipette. Remove all traces of water by continuing to apply vacuum after sample as passed through.
5. Record the volume of the water filtered.
6. Remove the filter from the base. Dry at least one hour at 103-105^{o}C in the disposable aluminum dish.
7. Remove the filter from the oven, and weigh.

Calculation:

$$TSS = \frac{(A - B) \times 1000}{C}$$

Where: A= End weight of filter (mg)
B= Initial weight of filter (mg)
C= Volume of water filtered (mL)

References:

ESS Method 340.2: Total Suspended Solids, Mass Balance (1993). Environmental Sciences Section Inorganic Chemistry Unit, Wisconsin State Lab of Hygiene. Retrieved February 4, 2005, from the World Wide Web: http://www.epa.gov/glnpo/lmmb/methods/methd340.pdf

How to Measure TSS and Turbidity (2004). Washington State Department of Ecology: Water Quality Program. Retrieved February 4, 2005, from the World Wide Web: http://www.ecy.wa.gov/programs/wq/plants/management/joysmanual/4tss.html

Total Suspended Solids (n.d.). Purdue University. Retrieved February 4, 2005, from the World Wide Web: http://pasture.ecn.purdue.edu/~eql/H20TSS.htm

I. Reservoir Volume Calculation Methods

The volume of the reservoir was approximated as a flat topped pyramid:

$$Volume = \frac{b \times w \times h}{3}$$

Where: b=base
w=width
h=height

The slope of the reservoir was calculated to be approximately -30degrees.

	Lowest	Current	Highest	Subtraction Factor
Length (m)	30.47	33.9	38.7	25.67
Width (m)	16.9	20.4	25.3	12
Height (m)	8.88	9.88	11.28	7.85
Volume (m^3)	718.1933	2277.538	3681.454	
Volume (g)	271865.7	862141.8	1393582	
Days Supply	239.9521	760.9371	1229.993	

The height of the reservoir was calculated as if it were a full pyramid. The subtraction factor represents the pyramid that the bottom of the reservoir makes going into the ground. This volume is soil, so it is subtracted from the total volume.

J. Equations Used in Irrigation Component Calculations

Equation Name	Equation	Variables	Source
Tubing Head Loss	$HL = 14.03 \times Q^{1.85} D^{-4.87} L$	HL= Head Loss Q=flow rate (L/s) D=tube diameter (cm) L= tube length (m)	Dasberg & Or, 1999
Water Horsepower	$WHP = \frac{(TDH)(Q)}{3960}$	WHP= Water Horsepower TDH= Total Dynamic Head (ft) Q=flow rate (gal/min)	Scherer, 1993
Total Dynamic Head	$TDH = SH + OpP + HLF + HLM + HLL$	TDH= Total Dynamic Head SH= Static Head (ft) OpP= Operating Pressure (ft) HLF= Head Loss due to Filter HLM= Head Loss due to Main Lines HLL= Head Loss due to Laterals	Scherer, 1993
Brake Horsepower	$BHP = \frac{WHP}{PumpEff \times DriveEff} \times 2$	BHP= Brake Horsepower PumpEff= Pump Efficiency Drive Eff= Drive Efficiency	Scherer, 1993

Conversion Factors Used in Irrigation Design			
Length	**Volume**	**Pressure**	**Area**
1m = 3.28ft	1L=0.26417205 gal	1bar = 14.5037738psi	10,000m^2=1hectares
1ft = 0.305m	1gal = 3.785L	1psi = 2.31ft	1 hectare= 2.5acres
	1 L = 1000mL		
	1m^3=264.17205 gal		
Abbreviations			
m = Meter	L = Liter	psi = Pounds per Square Inch	
ft = Foot	gal = Gallon	bar = Bar	
	m^3= Cubic Meter		
	mL= Milliliter		

K. Price Comparisons for Irrigation Components

The following table contains prices from four irrigation companies located in Bangkok, Thailand: Netafim, Super Products, Four Bros, and Astraco. Each company carries similar products although some have a more extensive selection than others. The prices were obtained through direct contact with each company.

	Component	Netafim (baht)	Super Products (baht)	Four Bros (baht)
Emitters	4 L/H Pressure Compensating Emitter		5	4.5
	8 L/H Pressure Compensating Emitter		5	4.5
Piping/Tubing	Polyethylene Pipe, Class 4, 16 mm diameter, 200m rolls	10.71	5.5	7
	Polyethylene Pipe, Class 4, 20 mm diameter, 200m rolls	14.69	10.5	7
	Polyethylene Pipe, Class 4, 25 mm diameter, 100m rolls	22.93		
	Polyethylene Pipe, Class 4, 25 mm diameter, 200m rolls		17.5	
	Polyethylene Pipe, Class 4, 32 mm diameter, 100m rolls	36.65		
	Polyethylene Pipe, Class 4, 32 mm diameter, 200m rolls		28.75	
	Polyethylene Pipe, Class 4, 40 mm diameter, 100m rolls	35.24	52.5	
	Polyethylene Pipe, Class 4, 50 mm diameter, 100m rolls	52.37	62.5	
	Polyethylene Pipe, Class 6, 63 mm diameter, 50m rolls	141.33		
	Polyethylene Pipe, Class 4, 63 mm diameter, 50m rolls		77	
	Polyethylene Pipe, 63 mm diameter, 150m rolls		26	
	Spagetti Tubing, 200 m rolls	4.58	4.8	4
Tubing Connectors	Insert Connector, 16 mm diameter	5.09		
	Insert Connector, 20 mm diameter	6.52		
	Connector Coupling, 20 mm diameter	64.08	60	60
	Connector Coupling, 25 mm diameter	75.24	70	70
	Connector Coupling, 32 mm diameter	105.48	140	
	Connector Coupling, 40 mm diameter	167.04	165	
	Connector Coupling, 50 mm diameter	213.48	195	165
	Connector Coupling, 63 mm diameter	348.12		195
Elbows	Elbow Insert Connector, 16 mm	11.97		
	Elbow Coupling Connector, 20 mm	72.72		
	Elbow Coupling Connector, 25 mm	84.24		
	Elbow Coupling Connector, 32 mm	118.08		
	Elbow Coupling Connector, 40 mm	196.2		
	Elbow Coupling Connector, 50 mm	243.72		
	Elbow Coupling Connector, 63 mm	379.44		
Reducing Connector	Reducing Coupling 40 mm to 32 mm	258.84	120	
	Reducing Coupling 50 mm to 40 mm	364.32	180	
	Reducing Coupling 63 mm to 50 mm	500.04	240	
Lateral Connectors	Spagetti Connector, 5 mm	1.03	1.2	3
	Start Connector for Polyethylene, 16 mm	13.42	10	
	Start Connector for Polyethylene, 20 mm	13.42	12	
	Start Connector for Polyethylene, 25 mm		14	
Pressure Gauge	Pressure Gauge	574.2	990	
	Needle for Testing Valve	261.36		

	Component	Netafim (baht)	Super Products (baht)	Four Bros (baht)
Filter	1" Filter	1998.36		2000
	2" Long Disk Filter		2,750.00	9000
	2" Long Disk Filter Cartridge		1,650.00	
Filter Connectors	Saddle 40 mm	43.92		
	Saddle 50 mm	48.96		
	Saddle 63 mm	87.84		

Pump Pricing and Specifications

Distributor	Model#	1 ~ 230 V - 50 Hz	3 ~ 230/400 V - 50 Hz	Max Total Dynamic Head (ft)	Max Flow Rate (gal/min)	Power (hp)	Suction Size (in)	Discharge Size (in)	Weight (kg)	Cost (baht)
Berkley Pumps :										
SSCX Centrifugal	SS1-1/4XN-2			125	92.5	2	1.50	1.25	**NA**	29640
	SS1-1/4XN-2-1/2			138	100.0	2.5	1.50	1.25	**NA**	33000
C Series Cast Iron	C1-1/4TPMS			150	70.0	3	1.50	1.25	25	45600
Y Best Electrical Co. Ltd Pumps:										
SS Self-priming	S-0150H			**NA**	55.0	1	**NA**	2.00	30	n/a
	S-0250			**NA**	59.0	2	**NA**	2.00	34.0	n/a
Sile (Thailand) Co., LTD.:										
CM Series	CM 32-160 A		x	118	30.8	4	1.50	1.00	42	13483
	CM 32-200 C	x	x	128	30.8	5	1.00	1.50		n/a
	CMT 200		x	115	31.7	2.2	1.00	1.00	23	6933
	CMT 300		x	115	37.0	3	1.00	1.00	23.5	n/a
	CMT 204		x	115	31.7	2.2	1.25	1.00	23	n/a
	CMT 304		x	115	37.0	3	1.25	1.00	23.5	n/a
MB Series	MB 200	x		123	26.4	2.2	1.50	1.25	21.7	7693
	MBT 200		x	123	26.4	2.2	1.50	1.25	21.7	n/a
	MBT 300		x	126	39.6	3	1.50	1.25	21.7	n/a
MP Series	MP 200/4	x		125	31.7	2	1.25	1.00	21.3	9978
CHT Series	CHT 550		x	121	52.8	5.5	3.00	2.00	38.7	n/a
CA Series	CA 32-160 A	Unknown		118	26.4	4	1.97	1.26		n/a

Pump Pricing and Specifications

Distributor	Model#	1 ~ 230 V - 50 Hz	3 ~ 230/400 V - 50 Hz	Max Total Dynamic Head (ft)	Max Flow Rate (gal/min)	Power (hp)	Suctio n Size (in)	Discharg e Size (in)	Weight (kg)	Cost (baht)
Sile (Thailand) Co., LTD.:	CA 32-200 C	Unknown		125	39.6	unknow n				n/a
CM Series	CM 100	x		97	15.9	1	1.00	1.00	30.8	n/a
	CMT 100		x	97	15.9	1	1.00	1.00	14	n/a
	CM 32 - 160 A		x	92	26.4	3	1.00	1.50	42	n/a
CH Series	CH 200	x		92	26.4	2	2.00	2.00	52.8	n/a
	CHT 200		x	92	26.4	2	2.00	2.00	24	n/a
Super Products:										
MB Series	MB 200	x		123	26.4	2.2	1.50	1.25	21.7	15500

L. Spreadsheet for Pump Calculations

Please note that the colors used (red, orange, and yellow) are used for the visualization of data only; the colors are specifically for the reader. The yellow blocks represent the lowest numbers in the matrix, the orange the middle values, and the red the values with the highest magnitude. Adding colors to the tables gives a very interesting effect at first. The reader will notice that the total dynamic head tables are identical in the distribution of their colors, for both the 4L/h emitters and 8L/h emitters. The flow rate tables also have the same distribution of colors. However, when calculating the power, the color distribution changes quite drastically from 4L/h to 8L/h. Without knowing the calculations behind the values this may seem quite puzzling, but it is due to the fact that the pressure losses from lateral tubing have an exponential relationship and increase quite drastically as the flow rate increases. This data also reinforces why choosing the emitter as the first component of the irrigation system was so important: it affects head loss throughout the system, making the choice of lateral tubing sizes crucial and the over all power required to run the system.

Another note is that the Brake Horsepower calculations are by estimation, with an assumed value of 0.5 pump efficiency and 1.0 drive efficiency. These numbers were calculated purely for the reader as an estimation of what the horsepower required may be. In reality, pump manufacturers choose the pump based on total dynamic head and flow rate. The actual pump efficiency and drive efficiency are specific to the pump and known by the manufacturer. The actual horsepower of the pump chosen for the designs may or may not match the brake horsepower calculated here.

One 4 L/hr Emitter per Oil Palm
Calculations to Determine Flow Rate

Flow Rate=(Water Demand+Volume of Distribution System)/(Watering Time)×1.1 for Leak Compensation

Water Demand

Number of Trees	515
Water Demand Per Tree (gal)	2
Total Water Demand (gal)	1030

Volume of Distribution System

Main Piping Diameter (in)	Main Piping Diameter (cm)	Main Piping Diameter (m)	Main Piping Radius (m)	Length of Mainline (m)	Volume of Mainline (m^3)	Total Volume of Mainline (gal)
1.26	3.20	0.032	0.016	304.82	0.25	64.76
1.57	4.00	0.040	0.020	304.82	0.38	101.19
1.97	5.00	0.050	0.025	304.82	0.60	158.11
2.48	6.30	0.063	0.032	304.82	0.95	251.02
Lateral Piping Diameter (in)	**Lateral Piping Diameter (cm)**	**Lateral Piping Diameter (m)**	**Lateral Piping Radius (m)**	**Length of Lateral (m)**	**Volume of Lateral (m^3)**	**Total Volume of Lateral (gal)**
0.47	1.20	0.012	0.006	4635	0.52	138.48
0.63	1.60	0.016	0.008	4635	0.93	246.19
0.79	2.00	0.020	0.010	4635	1.46	384.67
0.98	2.50	0.025	0.013	4635	2.28	601.04

10% Leak Compensation

Max Compensation (gal)	94.10
Min Compensation (gal)	61.66

Watering Time

2 hours

Flow Rate

Max Flow Rate (gal/hr)	1035.13
Min Flow Rate (gal/hr)	678.28
Max Flow Rate (gal/min)	17.25
Min Flow Rate (gal/min)	11.30

One 4 L/hr Emitter per Oil Palm
Calculations to Determine Flow Rate

Flow Rate=Demand/Day + Volume of Distribution System + 10% Leak Compensation

Flow Rate					
Total Flow Rate (gal/hr):					
		Mainline Diameter (cm)			
		3.2	**4**	**5**	**6.3**
Lateral Diameter (cm)	**1.2**	678.2834	698.3192	729.625	780.7231
	1.6	737.5224	757.5581	788.8639	839.962
	2.0	813.69	833.72	865.03	916.1261
	2.5	932.69	952.73	984.04	1035.133

Note the color scheme of the flow rate matrix explained in detail on page L-19.

One 4 L/hr Emitter per Oil Palm
Calculations to Determine Total Dynamic Head

Total Dynamic Head= Static Head + Pressure Loss + Operating Pressure

Static Head (ft)		19.2
Operation Pressure Options (ft)		
	25psi	57.75
	30psi	69.3
	35psi	80.85
Pressure Loss From Filter (ft)		3.40

Pressure Loss =Main and Lateral Line Pressure Loss + Filter Pressure Loss

Pressure Loss from Main Lines

Diameter (cm)	**3.20**	**4.00**	**5.00**	**6.30**
Rate of Total Delivery (L/h)	2060	2060	2060	2060
Rate of Delivery (L/s)	0.5722	0.5722	0.5722	0.5722
Total Main Tubing (m)	304.82	304.82	304.82	304.82
Total Main Line Head Loss (m)	5.2786	1.7806	0.6006	0.1949
Total Main Line Head Loss (ft)	17.31	5.84	1.97	0.64

Pressure Loss From Lateral Lines

Diameter (cm)	**1.2**	**1.6**	**2**	**2.5**
Rows with 24 palms				
Rate of Delivery (L/h)	96	96	96	96
Rate of Delivery (L/s)	0.0267	0.0267	0.0267	0.0267
Total Lateral Piping (m)	216	216	216	216
Head Loss Due to Laterals (m)	1.527	0.376	0.127	0.043
Head Loss Due to Laterals (ft)	5.010	1.234	0.416	0.140
TOTAL: for 3 Rows	**15.029**	**3.702**	**1.249**	**0.421**
Rows with 23 palms				
Rate of Delivery (L/h)	92	92	92	92
Rate of Delivery (L/s)	0.0256	0.0256	0.0256	0.0256
Total Lateral Piping (m)	207	207	207	207
Head Loss Due to Laterals (m)	1.353	0.112	0.069	0.069
Head Loss Due to Laterals (ft)	4.437	0.369	0.227	0.227
TOTAL: for 3 Rows	**13.312**	**1.106**	**0.680**	**0.680**

One 4 L/hr Emitter per Oil Palm
Calculations to Determine Total Dynamic Head

Diameter (cm)	1.2	1.6	2	2.5
Rows with 22 palms				
Rate of Delivery (L/h)	88	88	88	88
Rate of Delivery (L/s)	0.0244	0.0244	0.0244	0.0244
Total Lateral Piping (m)	198	198	198	198
Head Loss Due to Laterals (m)	1.192	0.099	0.061	0.061
Head Loss Due to Laterals (ft)	3.909	0.325	0.200	0.200
TOTAL: for 2 Rows	**7.819**	**0.650**	**0.400**	**0.400**
Rows with 21 palms				
Rate of Delivery (L/h)	84	84	84	84
Rate of Delivery (L/s)	0.0233	0.0233	0.0233	0.0233
Total Lateral Piping (m)	189	189	189	189
Head Loss Due to Laterals (m)	1.044	0.087	0.053	0.053
Head Loss Due to Laterals (ft)	3.424	0.285	0.175	0.175
TOTAL: for 2 Rows	**6.848**	**0.569**	**0.350**	**0.350**
Rows with 20 palms				
Rate of Delivery (L/h)	80	80	80	80
Rate of Delivery (L/s)	0.0222	0.0222	0.0222	0.0222
Total Lateral Piping (m)	180	180	180	180
Head Loss Due to Laterals (m)	0.908	0.075	0.046	0.046
Head Loss Due to Laterals (ft)	2.980	0.248	0.152	0.152
TOTAL: for 1 Row	**2.980**	**0.248**	**0.152**	**0.152**
Rows with 19 palms				
Rate of Delivery (L/h)	76	76	76	76
Rate of Delivery (L/s)	0.0211	0.0211	0.0211	0.0211
Total Lateral Piping (m)	171	171	171	171
Head Loss Due to Laterals (m)	0.785	0.065	0.040	0.040
Head Loss Due to Laterals (ft)	2.574	0.214	0.132	0.132
TOTAL: for 3 Rows	**7.723**	**0.642**	**0.395**	**0.395**
Rows with 18 palms				
Rate of Delivery (L/h)	72	72	72	72
Rate of Delivery (L/s)	0.0200	0.0200	0.0200	0.0200
Total Lateral Piping (m)	162	162	162	162
Head Loss Due to Laterals (m)	0.673	0.056	0.034	0.034
Head Loss Due to Laterals (ft)	2.207	0.183	0.113	0.113
TOTAL: for 2 Rows	**4.413**	**0.367**	**0.226**	**0.226**

Calculations to Determine Total Dynamic Head

Diameter (cm)	1.2	1.6	2	2.5
Rows with 17 palms				
Rate of Delivery (L/h)	68	68	68	68
Rate of Delivery (L/s)	0.0189	0.0189	0.0189	0.0189
Total Lateral Piping (m)	153	153	153	153
Head Loss Due to Laterals (m)	0.572	0.048	0.029	0.029
Head Loss Due to Laterals (ft)	1.875	0.156	0.096	0.096
TOTAL: for 4 Rows	**7.500**	**0.623**	**0.383**	**0.383**
Rows with 16 palms				
Rate of Delivery (L/h)	64	64	64	64
Rate of Delivery (L/s)	0.0178	0.0178	0.0178	0.0178
Total Lateral Piping (m)	144	144	144	144
Head Loss Due to Laterals (m)	0.481	0.040	0.025	0.025
Head Loss Due to Laterals (ft)	1.577	0.131	0.081	0.081
TOTAL: for 4 Rows	**6.310**	**0.524**	**0.322**	**0.322**
Rows with 15 palms				
Rate of Delivery (L/h)	60	60	60	60
Rate of Delivery (L/s)	0.0167	0.0167	0.0167	0.0167
Total Lateral Piping (m)	135	135	135	135
Head Loss Due to Laterals (m)	0.400	0.033	0.020	0.020
Head Loss Due to Laterals (ft)	1.312	0.109	0.067	0.067
TOTAL: for 1 Row	**1.312**	**0.109**	**0.067**	**0.067**
Rows with 14 palms				
Rate of Delivery (L/h)	56	56	56	56
Rate of Delivery (L/s)	0.0156	0.0156	0.0156	0.0156
Total Lateral Piping (m)	126	126	126	126
Head Loss Due to Laterals (m)	0.329	0.027	0.017	0.017
Head Loss Due to Laterals (ft)	1.078	0.090	0.055	0.055
TOTAL: for 1 Row	**1.078**	**0.090**	**0.055**	**0.055**
Total Lateral Head Loss (ft)	**74.325**	**8.630**	**4.279**	**3.451**

****Exclude 1.2cm laterals from here on****

The 1.2cm laterals were excluded because they produced significantly more pressure loss than the other laterals.

One 4L/hr Emitter per Oil Palm Pump Calculations

Total Dynamic Head (ft)

Operating Pressure: 25psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	106.29	94.82	90.95	89.62
2	101.94	90.47	86.60	85.27
2.5	101.11	89.64	85.77	84.44

Operating Pressure: 30psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	117.84	106.37	102.50	101.17
2	113.49	102.02	98.15	96.82
2.5	112.66	101.19	97.32	95.99

Operating Pressure: 35psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	129.39	117.92	114.05	112.72
2	125.04	113.57	109.70	108.37
2.5	124.21	112.74	108.87	107.54

×

Total Flow Rate (gal/min)

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	12.29	12.63	13.15	14.00
2.0	13.56	13.90	14.42	15.27
2.5	15.54	15.88	16.40	17.25

÷3960=

Water Horsepower for Each Pressure

Operating Pressure: 25psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	0.3299	0.3023	0.3020	0.3168
2	0.3491	0.3175	0.3153	0.3288
2.5	0.3969	0.3594	0.3552	0.3679

Operating Pressure: 30psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	0.3658	0.3391	0.3403	0.3577
2	0.3887	0.3580	0.3573	0.3733
2.5	0.4423	0.4058	0.4031	0.4182

Operating Pressure: 35psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6
1.6	0.4016	0.3760	0.3787	0.3985
2	0.4282	0.3985	0.3994	0.4178
2.5	0.4876	0.4521	0.4509	0.4685

Note the distribution of color. Here, the total flow rate is the dominating factor in determining the necessary horsepower.

Optimization Comparing Each Operating Pressure

Optimization for Water Horsepower (4L/hr)

Operating Pressure: 25psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	0.32994	0.30232	0.30197	0.31682
2	0.34911	0.31745	0.31528	0.32877
2.5	0.39692	0.35945	0.35523	0.36788

Operating Pressure: 30psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	0.36579	0.33915	0.34031	0.35765
2	0.38867	0.35798	0.35733	0.37331
2.5	0.44226	0.40576	0.40306	0.41819

Operating Pressure: 35psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	0.40164	0.37597	0.37866	0.39848
2	0.42822	0.39851	0.39938	0.41784
2.5	0.4876	0.45207	0.4509	0.46851

$\div(0.5\times1)\times2$

Optimization for Brake Horsepower (4L/hr)

Assume: Pump Eff=.5 Drive Eff=1

Operating Pressure: 25psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	1.31976	1.20929	1.20786	1.26728
2	1.39645	1.2698	1.26112	1.31509
2.5	1.5877	1.43778	1.42091	1.4715

Operating Pressure: 30psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	1.46317	1.35659	1.36125	1.43061
2	1.55467	1.43191	1.42932	1.49323
2.5	1.76906	1.62303	1.61225	1.67278

Operating Pressure: 35psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	1.60658	1.50389	1.51464	1.59394
2	1.71289	1.59403	1.59752	1.67136
2.5	1.95041	1.80829	1.80359	1.87405

Note: This is a comparison of horsepower required for all operating pressures. Therefore, the values for horsepower were compared collectively and the colors are distributed according to the magnitude of values for all 36 values, instead of within each individual operating pressure.

One 8L/hr or Two 4L/hr Emitters per Oil Palm Calculations to Determine Flow Rate

Flow Rate=(Water Demand+Volume of Distribution System)/(Watering Time)×1.1 for Leak Compensation

Demand Per Day

Number of Trees	515
Water Demand Per Tree (gal)	2
Total Water Demand (gal)	1030

Volume of Distribution System

Main Piping Diameter (in)	Main Piping Diameter (cm)	Main Piping Diameter (m)	Main Piping Radius (m)	Length of Mainline (m)	Volume of Mainline (m)	Total Volume of Mainline (gal)
1.26	3.20	0.03	0.02	304.82	0.25	64.76
1.57	4.00	0.04	0.02	304.82	0.38	101.19
1.97	5.00	0.05	0.03	304.82	0.60	158.11
2.48	6.30	0.06	0.03	304.82	0.95	251.02
Lateral Piping Diameter (in)	**Lateral Piping Diameter (cm)**	**Lateral Piping Diameter (m)**	**Lateral Piping Radius (m)**	**Length of Lateral (m)**	**Volume of Lateral (m)**	**Total Volume of Lateral (gal)**
0.47	1.20	0.01	0.01	4635	0.52	138.48
0.63	1.60	0.02	0.01	4635	0.93	246.19
0.79	2.00	0.02	0.01	4635	1.46	384.67
0.98	2.50	0.03	0.01	4635	2.28	601.04

10% Leak Compensation

Max Compensation (gal)	188.21
Min Compensation (gal)	123.32

Watering Time

1 hour

Flow Rate

Max Flow Rate (gal/hr)	2070.27
Min Flow Rate (gal/hr)	1356.57
Max Flow Rate (gal/min)	34.50
Min Flow Rate (gal/min)	22.61

One 8L/hr or Two 4L/hr Emitters per Oil Palm
Calculations to Determine Flow Rate

	Total Flow Rate (gal/hr):				
		Mainline Diameter (cm)			
		3.2	4	5	6.3
Lateral Diameter (cm)	1.2	1356.57	1396.64	1459.25	1561.45
	1.6	1475.04	1515.12	1577.73	1679.92
	2.0	1627.37	1667.44	1730.06	1832.25
	2.5	1865.39	1905.46	1968.07	2070.27

One 8L/hr or Two 4L/hr Emitters per Oil Palm
Calculations to Determine Total Dynamic Head

Total Dynamic Head= Static Head + Pressure Loss + Operating Pressure

Static Head (ft) 19.2

Operation Pressure Options (ft)

30psi	69.3
35psi	80.85

Pressure Loss From Filter (ft) 3.40
1.47psi

Pressure Loss= Main and Lateral Line Pressure Loss + Filter Pressure Loss

Pressure Loss from Main Lines

Diameter (cm)	**3.2**	**4**	**5**	**6.3**
Rate of Total Delivery (L/h)	4120	4120	4120	4120
Rate of Delivery (L/s)	1.1444	1.1444	1.1444	1.1444
Total Main Tubing (m)	304.82	304.82	304.82	304.82
Head Loss Due to Mains (m)	19.0292	6.4190	2.1653	0.7026
Head Loss Due to Mains (ft)	62.42	21.05	7.10	2.30

Pressure Loss From Lateral Lines

Diameter	**1.2**	**1.6**	**2**	**2.5**
Rows with 24 palms				
Rate of Delivery (L/h)	192	192	192	192
Rate of Delivery (L/s)	0.0533	0.0533	0.0533	0.0533
Total Lateral Piping (m)	216	216	216	216
Head Loss Due to Laterals (m)	5.506	1.356	0.458	0.154
Head Loss Due to Laterals (ft)	18.060	4.449	1.501	0.506
TOTAL: For 3 Rows	**54.180**	**13.347**	**4.502**	**1.519**
Rows with 23 palms				
Rate of Delivery (L/h)	184	184	184	184
Rate of Delivery (L/s)	0.0511	0.0511	0.0511	0.0511
Total Lateral Piping (m)	207	207	207	207
Head Loss Due to Laterals (m)	4.877	1.201	0.405	0.137
Head Loss Due to Laterals (ft)	15.997	3.941	1.329	0.448
TOTAL: for 3 Rows	**47.991**	**11.823**	**3.988**	**1.345**
Rows with 22 palms				
Rate of Delivery (L/h)	176	176	176	176
Rate of Delivery (L/s)	0.0489	0.0489	0.0489	0.0489
Total Lateral Piping (m)	198	198	198	198
Head Loss Due to Laterals (ft)	14.094	3.472	1.171	0.395
TOTAL: for 2 Rows	**28.187**	**6.944**	**2.342**	**0.790**

One 8L/hr or Two 4L/hr Emitters per Oil Palm
Calculations to Determine Total Dynamic Head

Rows with 21 palms				
Rate of Delivery (L/h)	168	168	168	168
Rate of Delivery (L/s)	0.0467	0.0467	0.0467	0.0467
Total Lateral Piping (m)	189	189	189	189
Head Loss Due to Laterals (m)	3.763	0.927	0.313	0.105
Head Loss Due to Laterals (ft)	12.344	3.041	1.026	0.346
TOTAL: for 2 Rows	**24.687**	**6.082**	**2.051**	**0.692**
Rows with 20 palms				
Rate of Delivery (L/h)	160	160	160	160
Rate of Delivery (L/s)	0.0444	0.0444	0.0444	0.0444
Total Lateral Piping (m)	180	180	180	180
Head Loss Due to Laterals (m)	3.275	0.807	0.272	0.092
Head Loss Due to Laterals (ft)	10.741	2.646	0.893	0.301
TOTAL: for 1 Row	**10.741**	**2.646**	**0.893**	**0.301**
Rows with 19 palms				
Rate of Delivery (L/h)	152	152	152	152
Rate of Delivery (L/s)	0.0422	0.0422	0.0422	0.0422
Total Lateral Piping (m)	171	171	171	171
Head Loss Due to Laterals (m)	2.829	0.697	0.235	0.079
Head Loss Due to Laterals (ft)	9.280	2.286	0.771	0.260
TOTAL: for 3 Rows	**27.841**	**6.859**	**2.314**	**0.780**
Rows with 18 palms				
Rate of Delivery (L/h)	144	144	144	144
Rate of Delivery (L/s)	0.0400	0.0400	0.0400	0.0400
Total Lateral Piping (m)	162	162	162	162
Head Loss Due to Laterals (m)	2.425	0.597	0.202	0.068
Head Loss Due to Laterals (ft)	7.955	1.960	0.661	0.223
TOTAL: for 2 Rows	**15.910**	**3.919**	**1.322**	**0.446**
Rows with 17 palms				
Rate of Delivery (L/h)	136	136	136	136
Rate of Delivery (L/s)	0.0378	0.0378	0.0378	0.0378
Total Lateral Piping (m)	153	153	153	153
Head Loss Due to Laterals (m)	2.061	0.508	0.171	0.058
Head Loss Due to Laterals (ft)	6.759	1.665	0.562	0.189
TOTAL: for 4 Rows	**27.037**	**6.660**	**2.247**	**0.758**
Rows with 16 palms				
Rate of Delivery (L/h)	128	128	128	128
Rate of Delivery (L/s)	0.0356	0.0356	0.0356	0.0356
Total Lateral Piping (m)	144	144	144	144
Head Loss Due to Laterals (m)	1.734	0.427	0.144	0.049
Head Loss Due to Laterals (ft)	5.687	1.401	0.473	0.159
TOTAL: for 4 Rows	**22.747**	**5.604**	**1.890**	**0.638**

One 8L/hr or Two 4L/hr Emitters per Oil Palm
Calculations to Determine Total Dynamic Head

Rows with 15 palms				
Rate of Delivery (L/h)	120	120	120	120
Rate of Delivery (L/s)	0.0333	0.0333	0.0333	0.0333
Total Lateral Piping (m)	135	135	135	135
Head Loss Due to Laterals (m)	1.442	0.355	0.120	0.040
Head Loss Due to Laterals (ft)	4.731	1.166	0.393	0.133
TOTAL: for 1 Row	**4.731**	**1.166**	**0.393**	**0.133**
Rows with 14 palms				
Rate of Delivery (L/h)	112	112	112	112
Rate of Delivery (L/s)	0.0311	0.0311	0.0311	0.0311
Total Lateral Piping (m)	126	126	126	126
Head Loss Due to Laterals (m)	1.185	0.292	0.098	0.033
Head Loss Due to Laterals (ft)	3.887	0.957	0.323	0.109
TOTAL: for 1 Row	**7.773**	**1.915**	**0.646**	**0.218**
GRAND TOTAL: for All Rows	**271.827**	**66.964**	**22.589**	**7.620**

****Exclude 1.2cm laterals from here on****

As with the calculations for the 4L/hr emitters, the 1.2cm lateral tubing had an unacceptably high range of head loss and was not used in any further calculations.

One 8L/hr or Two 4L/hr Emitters per Oil Palm

Pump Calculations

Total Dynamic Head (ft)

Operating Pressure: 25psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	209.48	168.12	154.17	149.37
2	165.10	123.74	109.79	102.69
2.5	150.14	108.77	94.82	82.40

Operating Pressure: 30psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	221.28	179.92	165.97	161.17
2	176.90	135.54	121.59	116.79
2.5	161.94	120.57	106.62	101.82

Operating Pressure: 35psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	232.83	191.47	177.52	172.72
2	188.45	147.09	133.14	128.34
2.5	173.49	132.12	118.17	113.37

×

Total Flow Rate (gal/min)

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	24.58	25.25	26.30	28.00
2.0	27.12	27.79	28.83	30.54
2.5	31.09	31.76	32.80	34.50

÷3960=

Water Horsepower for Each Pressure

Operating Pressure: 25psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	1.3005	1.0720	1.0237	1.0561
2	1.1308	0.8684	0.7994	0.7919
2.5	1.1787	0.8723	0.7854	0.7180

Operating Pressure: 30psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	1.3737	1.1473	1.1021	1.1395
2	1.2117	0.9512	0.8853	0.9007
2.5	1.2713	0.9670	0.8832	0.8872

Operating Pressure: 35psi

Lateral Diameter (cm)	Mainline Diameter (cm): 3.2	4	5	6.3
1.6	1.4454	1.2209	1.1788	1.2212
2	1.2908	1.0323	0.9694	0.9897
2.5	1.3620	1.0596	0.9788	0.9879

Note the difference in color distribution of the Water Horsepower as compared to that of the 4L/h emitters. Here, the Total Dynamic Head dominates the calculation.

Optimization Comparing Each Operating Pressure

Optimization for Water Horsepower (8L/hr or 2x4L/hr)

Operating Pressure: 25psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	1.3005	1.0720	1.0237	1.0561
2	1.1308	0.8684	0.7994	0.7919
2.5	1.1787	0.8723	0.7854	0.7180

Operating Pressure: 30psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	1.3737	1.1473	1.1021	1.1395
2	1.2117	0.9512	0.8853	0.9007
2.5	1.2713	0.9670	0.8832	0.8872

Operating Pressure: 35psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	1.4454	1.2209	1.1788	1.2212
2	1.2908	1.0323	0.9694	0.9897
2.5	1.3620	1.0596	0.9788	0.9879

$\div(0.5\times1)\times2$

Optimization for Brake Horsepower (8L/hr or 2x4L/hr)

Assume: Pump Eff=.5 Drive Eff=1

Operating Pressure: 25psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	5.201888	4.288197	4.094819	4.224374
2	4.523342	3.473646	3.197714	3.167533
2.5	4.714829	3.489302	3.141685	2.872043

Operating Pressure: 30psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	5.49491	4.58918	4.40824	4.558097
2	4.846624	3.80489	3.541395	3.602602
2.5	5.085395	3.867827	3.532649	3.548877

Operating Pressure: 35psi

Lateral Diameter (cm)	Mainline Diameter (cm) 3.2	4	5	6.3
1.6	5.781724	4.883786	4.715021	4.884748
2	5.163058	4.129115	3.877795	3.958873
2.5	5.448109	4.238333	3.915329	3.951429

Note: This is a comparison of horsepower required for all operating pressures. Therefore, the values for horsepower were compared collectively and the colors are distributed according to the magnitude of values for all 36 values, instead of within each individual operating pressure.

Optimization for Brake Horsepower (4L/hr)

Assume: Pump Eff=.5 Drive Eff=1

Operating Pressure: 25psi		Mainline Diameter (cm)			
		3.2	4	5	6.3
Lateral Diameter (cm)	1.6	1.320	1.209	1.208	1.267
	2	1.396	1.270	1.261	1.315
	2.5	1.588	1.438	1.421	1.472

Operating Pressure: 30psi		Mainline Diameter (cm)			
		3.2	4	5	6.3
Lateral Diameter (cm)	1.6	1.463	1.357	1.361	1.431
	2	1.555	1.432	1.429	1.493
	2.5	1.769	1.623	1.612	1.673

Operating Pressure: 35psi		Mainline Diameter (cm)			
		3.2	4	5	6.3
Lateral Diameter (cm)	1.6	1.607	1.504	1.515	1.594
	2	1.713	1.594	1.598	1.671
	2.5	1.950	1.808	1.804	1.874

Optimization for Brake Horsepower (8L/hr or 2x4L/hr)

Assume: Pump Eff=.5 Drive Eff=1

Operating Pressure: 25psi		Mainline Diameter (cm)			
		3.2	4	5	6.3
Lateral Diameter (cm)	1.6	5.202	4.288	4.095	4.224
	2	4.523	3.474	3.198	3.168
	2.5	4.715	3.489	3.142	2.872

Operating Pressure: 30psi		Mainline Diameter (cm)			
		3.2	4	5	6.3
Lateral Diameter (cm)	1.6	5.495	4.589	4.408	4.558
	2	4.847	3.805	3.541	3.603
	2.5	5.085	3.868	3.533	3.549

Operating Pressure: 35psi		Mainline Diameter (cm)			
		3.2	4	5	6.3
Lateral Diameter (cm)	1.6	5.782	4.884	4.715	4.885
	2	5.163	4.129	3.878	3.959
	2.5	5.448	4.238	3.915	3.951

A final comparison to see the affect that flow rate, lateral diameter, and main line diameter have on the over all power required for operating the system.

M. Irrigation Education Manual

The irrigation manual is contained in the next 12 pages. It is designed to address each component of irrigation and it's applicability to the construction and operation as well as the maintenance procedures associated.

Irrigation Education Manual

Drip Irrigation:

Construction, Operation and Maintenance

Simon Beckwith
Julia Cohn
Leigh Duren
Kyle Lewis

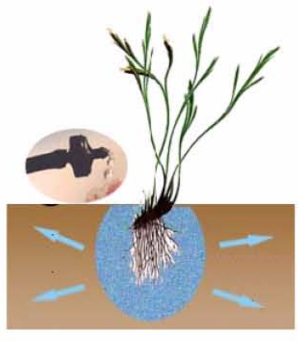
Created March, 2005

Table of Contents

Manual Overview

The following manual is intended as a guide to assist in the proper operation, maintenance and construction of a drip irrigation system. The benefits of drip irrigation are great, but you must be careful when using the system. This manual provides background and instructions about drip irrigation for effective watering and extending the life of the system. Reading and following this guide will help the irrigation system succeed.

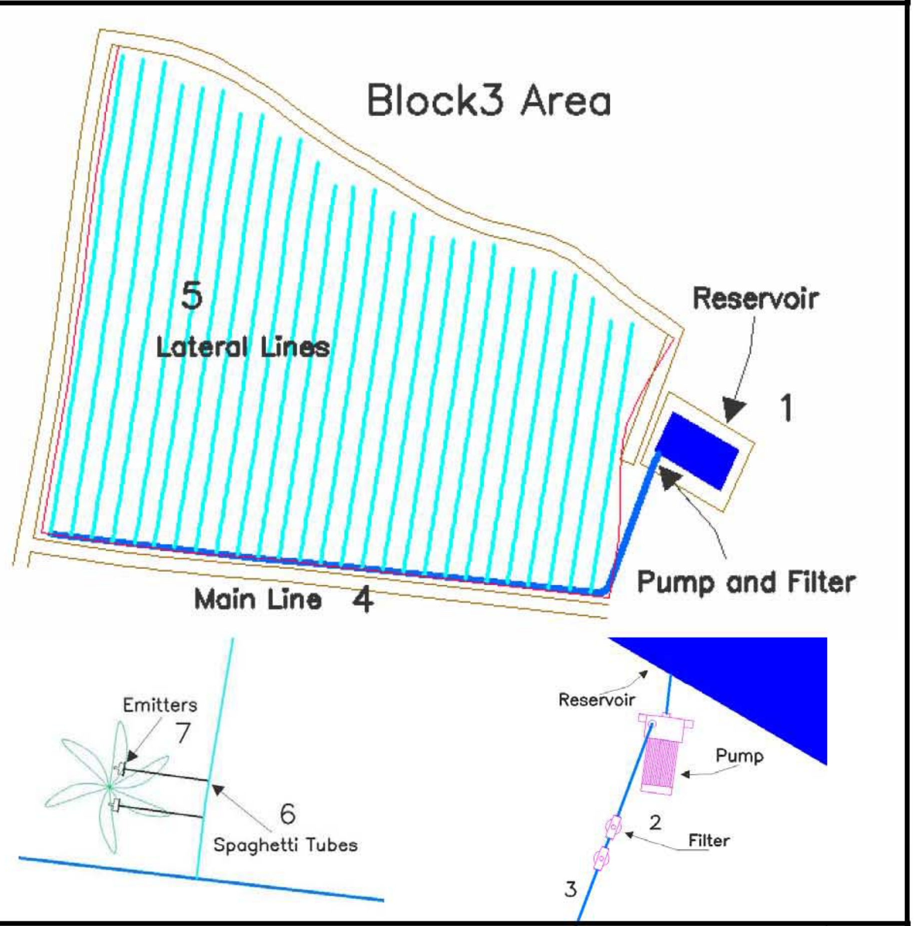
In drip irrigation, water trickles from the emitter to the roots of the tree. While at first glance it does not look like the emitter is supplying enough water to the tree, given enough time the trickle of water is enough because the water is supplied directly where it is needed. Supplying water this way effectively delivers water to the plant while conserving water. These benefits suit the dry conditions and scarce water sources at the New Life oil palm plantation very well. The emitters are very important to the system, so it is essential to keep them clean. The opening of the emitter is really small so it is important to keep sand out of the tubes to prevent the emitters from clogging.



The main components of a drip irrigation system are the pump, filter, tubing and emitter. This manual provides a description of each component and how they relate to each other as well as the process of drip irrigation. It includes the procedures for how to assemble, operate and maintain the system. As you read this manual keep in mind that following these procedures will decrease the amount of repairs necessary for the system and will promote its success.

1

Drip Irrigation System



In a drip irrigation system, the pump draws water from the reservoir (1) and delivers it to the system. The water then travels through the filter (2). The filter cleans the water from the reservoir to prevent the system from clogging. The filter connects to the main line (3). The main line (4) lies along the edge of the plantation. The main line connects to the lateral lines. The lateral lines run along each row (5). At each oil palm, spaghetti tubing connects to the lateral lines (6). Emitters (7) connect at the end of the spaghetti tubing. The emitters provide water to the roots of the tree.

2

Drip Irrigation Components

Pump:
Supplies water to the irrigation system

Filter:
Used to remove impurities from water to prevent clogging in the system

Fittings:
Used to connect components to main line tubing

Pressure Gauge:
Used to monitor the pressure in the system

Tubing:
Spaghetti, Lateral, Main
Carries water from the water source to the emitters

Valve:
On/off controller for water flow

Elbow Connection:
Used to connect tubing around corners

Punch Tool:
Used to make holes in lateral tubing to connect emitters

Connectors:
Start connectors connect lateral line to main line
Mini connectors connect emitters to lateral lines

End-line Fitting:
Used to clamp the ends of lateral lines

Stake:
Used to hold down lateral lines

Emitter:
Device that provides water to the base of the tree

Maintenance Procedures

The following maintenance procedures are essential for the success of the palm tree plantation and are referenced throughout the rest of this manual. Refer back to this page as needed when conducting the daily operation, seasonal maintenance and troubleshooting procedures.

Steps for flushing the system:

1. Remove the cap from main line and the end-line fitting  from the lateral lines.
2. Check the connection between the pump  and the filter  and make sure it is tight.
3. Open the valve. 
4. Turn on the pump. 
5. Run the pump for 10 minutes or longer until the water coming out of the pipes is clean.
6. Turn off the pump. 
7. Close the valve. 
8. Recap the end of the main line and clamp the lateral lines with an end-line fitting. 

Steps for cleaning the filter:

1. Remove the cover of the filter  and slide out the inner disk. 
2. Rinse the inner disk with clean water.
3. If dirt remains, scrub the filter with a toothbrush to remove any remaining dirt. Be careful not to damage the disk screens.
4. Rinse the disk with clean water again.
5. Return the disk to the filter housing.

Steps for cleaning the emitters:

1. Twist the cap off the emitter. 
2. Clean out any dirt or debris from the opening of the emitter.
3. Reconnect the cap of the emitter to the base of the emitter.

Daily Operation Checklist

Before operation:

☐ Prime the pump.  Put water into the intake valve of the pump to prevent any air pockets in the path from the reservoir to the pump.

☐ Remove the cover from the filter  and check if the disk is clean. If there is a lot of dirt follow the maintenance procedures to clean the filter.

During operation:

☐ Turn on the pump  and verify is operating correctly. Listen for unusual noises or watch for vibrations in the pump which indicate malfunction.

☐ Check the pressure gauges  on the filters. If the pressure has dropped over 2 psi, see the troubleshooting procedures.

☐ Walk through the field and visually inspect the overall system.
1. Check the tubing  for bursts or leaks.
2. Check the output of the emitters  and make sure water is being supplied to the trees.

After Operation:

☐ Turn off the pump. 

☐ Close the valve. 

☐ Unplug the pump. 

☐ Check the filter  and clean it if necessary.

Seasonal Maintenance Procedures

Completed Before and After the Dry Season

Pump:

☐ Remove weeds from the area around the pump.

☐ Disconnect the pump from the irrigation system and check that it is working properly.

Filter:

☐ Remove the disk from the housing of the filter.

☐ Replace the old disk with a new disk.

☐ Return the disk to the filter housing.

Tubing:

☐ Inspect the system for any visible cuts or breaks.

☐ Verify the proper clamping of the main line and lateral line ends.

☐ Check that the emitters are ½ meter away from the base of the tree and facing the proper direction.

Overall system:

☐ Flush the system before operating it for the first time each season and at the end of the season.

6

System Construction Directions

To construct the irrigation system, begin at the water source:

1. Cut a piece of the main line tubing  and use it to connect the pump  and the 120 mesh filter.  Use a fitting,  match the diameter of the pipe to each component. Tighten the pipe carefully to prevent damaging the threads on the connector.

2. Using a portion of the main line tubing  connect the 120 mesh filter  to the 140 mesh filter. 

3. Using a piece of the main line tubing  connect the 140 mesh filter to the valve. 

   It is important that the filters are positioned securely and do not rest on the ground. One option is build a stand for the filters and use clamps to attach the filters to the stand.

4. Following the instructions from the filter manufacturer, attach two pressure gauges  to each filter.  Double check the installation of the filter, valve and pressure gauge to make sure they are facing the correct direction relative to the water flow.

5. Prepare the distribution system. Take the roll of tubing  and leave it in the sun for a few hours to make the plastic more flexible and easier to place. It is very important that the tubing is straight and does not have any kinks that could block the flow of the water.

6. Lay the main line  around the edge of the field. At the corner of the field use an elbow connector  to redirect the pipe along the field. Carefully avoid getting dirt into the tubing because it will clog the system

7. Cover the end of the main line tubing  with a cap.

Construction Directions Continued

8. Starting at the end of each row lay the lateral tubing in a straight line approximately ¾ meter away from the row of palm trees. Place the tubing on the ground loosely to allow for any slight expansion of the material. Temporarily cover the ends of the tubing with tape to keep dirt out of the tubing until they are connected.

9. At each row along the mainline drill a hole in the tubing. Using a start connector, connect the lateral line to the main line.

10. Along the lateral line, use the punch tool to make a hole in the tubing at each tree. When making the holes, it is very important to use the proper tool to prevent leaks in the system.

11. Remove the cap from the main line and the tape from the lateral lines.

12. Follow the maintenance procedures to flush the system.

15. Take the spaghetti tubing and cut it into ½ meter sections.

16. Connect one emitter to each section of spaghetti tubing.

17. Using the mini connector, attach the spaghetti tubing to the lateral line.

18. Place each emitter ¼ meter away from the base of the palm tree. Place the emitter on its side and avoid facing the emitter into the ground to prevent dirt from getting into the emitter and clogging the hole. Once the emitters are placed, avoid moving their location so that the same area is wetted during each watering period.

19. Use metal stakes to hold down the lateral tubing near every tree.

20. Remove the end cap and end-line fittings and flush the entire system. It is always important to flush the system after adding new components to the system.

Troubleshooting Procedures

Type of Problem	Probable Cause	Solution Procedure
Low Pressure		
Pressure Drops 2+ psi	Dirty filter	Check if the filter is dirty Follow procedure for cleaning the filter if necessary
Pressure Drops 2+ psi **Filter is clean**	Break/leak in the system	Check for major breaks/leaks Follow the appropriate procedure for repairing leaks
Pressure Drops 2+ psi **Filter is clean** **No major breaks/leaks**	Old filter	Replace the disk in the filter
Clogging		
Laterals, Mainline	Sand particles and organic matter in the system	Flush the system
Emitter	Sand particles and organic matter in the emitter	Follow maintenance procedure for cleaning emitters
Emitter **Emitter is clean**	Emitter is broken	Cut the emitter off of the spaghetti tubing and attach a new emitter
Minor Leaks		
At connections	Component is not connected tight enough to the tubing	Push the component into the tube until it locks in place
In tubing	Hole in tubing	Wrap rubber strip over the hole to keep the water in the tube
Major Leaks		
In Laterals or Mainline	Broken section of pipe	Using a fitting to reconnect the two pieces of pipe
Miscellaneous		
No water from pump	Air in the intake valve	Prime the pump

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N. Fundraising Brochure for Drip Irrigation

This shows the general layout of the front and back of the brochure. When it is put together, the dotted lines align and indicate where the donor can cut the donation form to mail it in. The pages of the brochure are shown in detail in the following pages.

The Duang Prateep Foundation

Oil Palm Irrigation at The New Life for Abused Children Project

Irrigation Proposal:

Funds requested to install a drip irrigation system to aid in the growth of oil palms. With the successful growth of the oil palms will come fruitful harvests to aid in sustainability of the New Life for Abused Children Project. Ultimately, your donation will provide more children the opportunity for a new life.

Duang Prateep Foundation
24 Lock 6, Art Narong Road
Klong Toey, Bangkok 10110 THAILAND

Phone: +66 (0)2 249-4880, 249-3553, 671-4045-8
Fax: +66(0)2 249-5254, 249-9500
E-mail: dpffound@ksc.th.com Website: www.dpf.or.th

Cover Page

Irrigation, Rehabilitation for Abused Children, and the Sustainability of the New Life Project

Irrigation: Just as children grow and develop in the proper environment, so do oil palms. In order for the oil palm plantation to reach its potential, the proper environment- sunlight, soil, and water- is crucial. An irrigation system for the plantation will provide the necessary water to the oil palms.

Rehabilitation for Abused Children: Over the next few years, the oil palms will grow and produce fruit. The fruit will be used to make many different products. Some of the products will be made by the children which gives a sense of self worth and aids in their rehabilitation.

Sustainability of the New Life Project: The products will also provide income to work towards the sustainability of the New Life Project. Sustainability will provide the opportunity for the Duang Prateep Foundation to reach out to more struggling, young children.

Inside of Brochure Page 1

The New Life for Abused Children Kanchanaburi Project

The Duang Prateep Foundation established the New Life for Abused Children Project in Kanchanaburi Province in 1998, ten years after establishing the similar program for boys in Chumphon. Located in Kanchanaburi, the site is designed to rehabilitate children with drug addiction and other social problems. Additionally, it provides a safe living environment for young children who are victims of abuse or have no one to care for them. Typically, children remain at the project site for 3 years. The New Life Project gives the residents the opportunity to mingle with other children by attending a local school. There is also on-site vocational training for older children. Children also learn agricultural skills and are taught responsibility through caring for small gardens and animals at the project site. Since the start of the project, 600 children been prepared for successful reentry into society.

Inside of Brochure Page 1

The Children at the Project

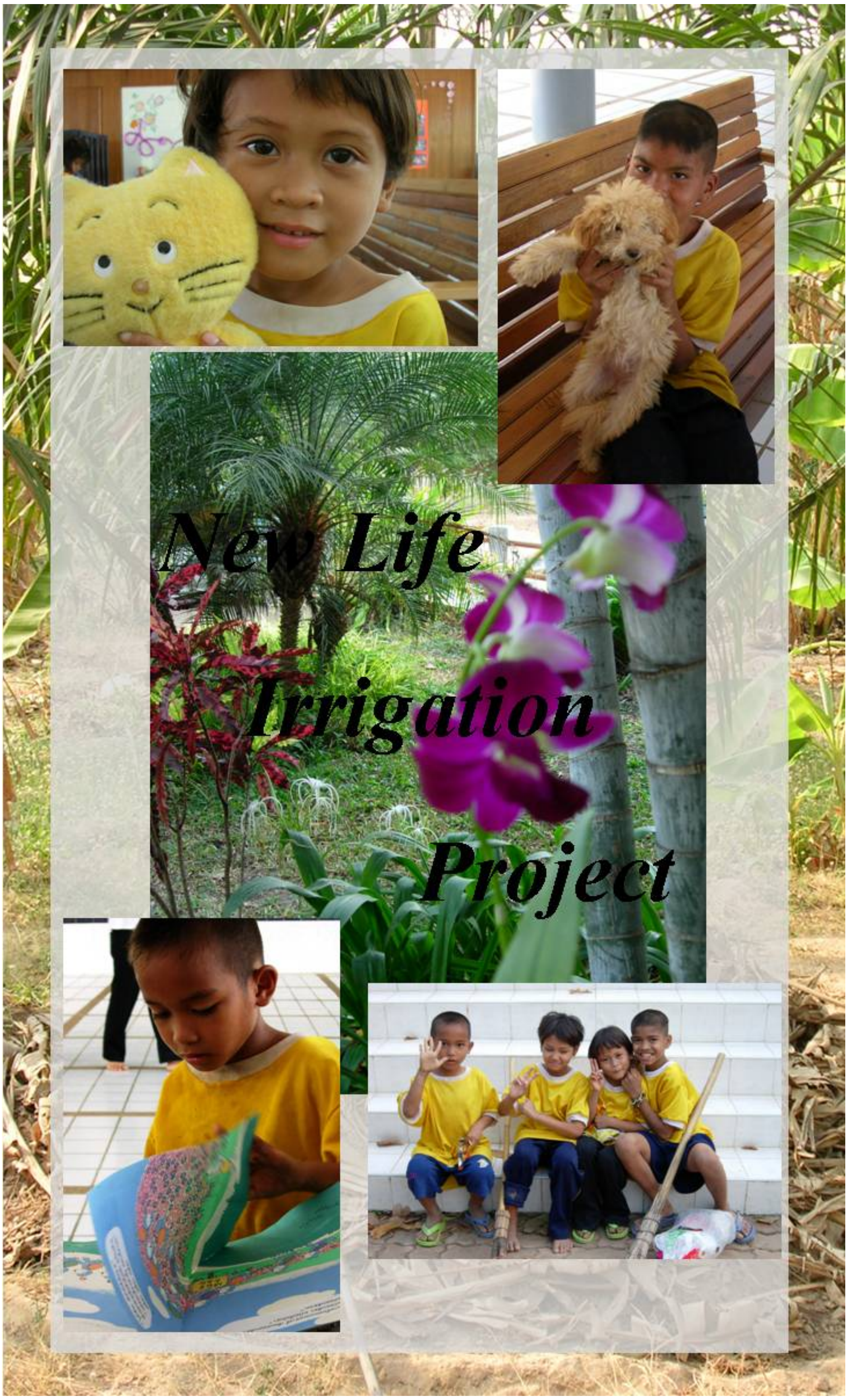
Who are they and where do they come from?

- Children, some brothers and sisters, who come from abusive environments or were once homeless

- Children who are at risk for drug abuse, exploitation, and crime
- Slum children with a feeling of hopelessness and alienation
- Children with parents that are unable to care for them

- Girls and young women who have been raped, beaten or who have been dependant on drugs

Inside of Brochure Page 3



Inside of Brochure Page 4

Irrigation for New Life for Abused Children Project Donation Form

I am enclosing a cheque ( ) money order ( ) or documentation of bank transfer ( ) *(tick as appropriate)*

I have completed credit card details ( )

Please charge the sum of __________ baht to my Visa/Mastercard ***(circle as appropriate)*** numbered

_____-_____-_____-_____ issued by __________________.

(name of bank or issuing organisation)

Name on card:________________________________

Expiry Date:__________________________________

Name:____

Address: ______________________________________

____

I would like to receive monthly English language email newsletters from the DPF ( ) *(tick if appropriate)*

Email address: _______________________________

Signature: ____________________________________

Donations for the Duang Prateep Foundation can be made by credit card; transfer to the DPF account at the Klong Toey branch of the Thai Farmers Bank, account number 017-2-06336-5, by money order, or by cashiers' or personal cheques. Our bank does charge us for handling cheques. When making a bank transfer it is important to forward a copy of the documentation to DPF. We can then trace your contribution and issue a receipt. If you have made a donation to the DPF and have received no acknowledgement from us within a month, please contact us so that we can try and trace your contribution.

US Taxpayers: Contact Ms. Karen Dahl:
Email <kdahl@frontiernet.net> Tel: (608) 637-7710

German Taxpayers: Make donations to account of "Freunde der Duang Prateep Foundation" e. V at the Deutsche Bank Loerrach, Konto 290320, BLZ 63 700 24. For further information contact Mr. Juergen Goepfert:Email <info@duang-prateep.de>Tel: 07621 798923

Outside of Brochure Page 1

The Figures

It is estimated that in 2011 the oil palms will be able to supply 65% of the income required to sustain the Kanchanaburi New Life Project.

	Thai Baht	US Dollars
Irrigation System for 4 hectares of land	95,000	2,500
Irrigation System for the Entire	760,000	20,000

At the time of this publication 1USDollar=39Baht

A Message From Khru Prateep

Outside of Brochure Page 2

The New Life Palm Tree Plantation

The oil palms will provide income for the New Life Project, making it more self sustaining. Of all oil producing plants, oil palms produce the most oil per hectare. Currently the Chumphon site for Abused Children has 1,320 oil palms which raise 20,000 baht per month. The success of the oil palm plantation in Chumphon can be attributed to sufficient rainfall in the area. The 32 hectares in Kanchanaburi will eventually hold 6,000 oil palms. If Kanchanaburi sees the same success as Chumphon, it could potentially raise 90,000 baht per month.

Why a Drip Irrigation System?

The irrigation system will supply water to the oil palm trees to maximize their growth. Since limited water is available at the site, a drip irrigation system will promote growth while conserving water. The system delivers water directly to the root of the trees where it is needed. This also prevent wasting precious water. The investment in the irrigation system will be repaid through the successful growth of the oil palm trees.

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