Thailand Water Supply System

Senior Project I

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December 2011

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A Senior Design for Senior Project I Submitted to the Faculty of

The College of New Jersey

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In partial fulfillment of the degree of
Bachelor of Science in Civil Engineering

December 12, 2011

Abstract

The village of Nong Pit in the Phrao district of Thailand does not have a sufficient water supply during the dry months of the year (February-April). They requested a piping system to move water from a small waterfall in a nearby stream into a set of tanks above the village. The water will be distributed to the town as needed for all purposes other than drinking. Surveying data of the path, the stream cross section and flow were gathered during site reconnaissance to determine design constraints. The distance from the proposed source to the desired storage tank location was found to be 1880.7 meters with a change in elevation of 2.51 meters. The flow through a weir on the stream was found to be 1.17 cubic meters per second which needs to fill a capacity of 64.5 cubic meters per day. Open Channel Flow theories were applied to find the flow through the stream at various possible water surface elevations. Using fluid mechanics theories, the needed changes in elevation and flows required to fill the tanks were calculated based on time and were compared to the data collected to ensure adequate flow in the stream. Aside from the requested design, another design solution being explored utilizes a turbine located at the bottom of a waterfall that will power a pump that can move the water to any desired location. Depending on the most efficient and cost effective design, a distribution system will be designed to spread the water from the storage tanks to each home. The project will be implemented in May 2012.

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Chapter 1: Introduction

The village of Nong Pit is located in the Phrao district of Thailand. In this northern mountain section of the country, the village does not receive adequate water supply during the dry season which lasts between the months of February and April. A stream flows near the village and the villagers requested a system that would transport water from the stream to a set of tanks located on a hillside above the village. The village has a population of 760 people with 216 homes and requires on average 64.5 cubic meters of water each day based on a factor of safety of 20 percent. A gravity fed piping system will be designed utilizing fluid mechanics and will determine the change in elevation required to ensure an adequate supply of water flowing from the stream to the tanks. Open channel flow calculations were performed to determine the flow of water in the stream at various water surface elevations as well as the flow exiting a weir located at the bottom of the stream. These flows were compared to the flows calculated in the gravity fed system to ensure the stream is capable of supplying enough water. Another option being considered utilizes the waterfall that is located at the water source that will flow into a turbine which will power a pump. The pump will add energy to the system so water can flow to the set of tanks at any location. Of these two designs, the best will be implemented based on efficiency and cost. A distribution system, based upon the piping system, will be designed to move the water from the storage location to each house in the village.

Chapter 2: Team Management

The Thailand Water Supply System Senior Project Group consists of Amanda Feeley, Jayme Lynch and Ian Burton as the Project Manager. The three group members met with Dr. Michael Horst, the Project Advisor, weekly on Wednesdays at 10:00 am. During the first meeting, Senior Project I was discussed which encompassed reviewing and analyzing the data collected. The goals to complete for the end of the semester were set at this meeting. By collaborative efforts and the delegation of specific tasks, the data collection and analysis required for the Thailand Water Supply System was completed.

At the weekly meetings, the group would cover the work that has been completed since the last meeting, problems encountered and future plans for the project. Each meeting, Ian Burton had an agenda that listed the general topics that needed to be discussed and then recorded the meeting's minutes. At the conclusion of the meetings, these minutes were posted onto the project's website.

The first task of analysis required combined efforts. After the meeting with Dr. Horst, the team determined a time to meet and complete calculations. These included the analysis of the water usage data, AutoCAD drawing, creating a rating curve and weir analysis. Once the initial data was reviewed, the design options were discussed.

Each member was assigned a design option and began individual design calculations. If any member encountered problems in their own design, the others were consulted to reach a solution. If no solution was reached or seemed viable, it was discussed with Dr. Horst in the meetings or through email.

The TCNJ EWB Chapter was updated on the progress of the project and design. Though input from the organization was asked, the final decision and designs were required by the senior project team.

Prior to each presentation and report, the group met to collectively develop and practice the presentation. This was done for the proposal presentation, realistic constraints presentation, progress report presentation and the Senior Project I presentation.

Next semester, during Senior Project II, the designs will be finalized. Each member will work individually and report their work during the weekly meetings. The group will meet more regularly to determine the optimal design based on cost and efficiency. In these meetings, a detailed plan will be developed for the implementation of the design in Thailand to limit any possible problems that may occur.

Chapter 3: Specifications

A specification is said to be a "set of conditions and requirements of precise and limited application that provide a detailed description of a procedure, process, material, product, or service for use primarily in procurement and manufacturing". Specifications are extremely important to follow because they ensure that the project or whatever the task may be is being completed in the correct manner.

The purpose of the Thailand Water Supply Project is to supply the village of Nong Pit with water when otherwise they would have a shortage. Water will be piped into each household. There are set specifications for pressures and flows through household or residential faucets. These specifications are as follows: for flow the maximum is 1.5 gallons per minute (9.5×10^{-5} m^3/s) and the minimum is 0.8 gallons per minute(5.0×10^{-5} m^3/s), and for pressure the maximum is 60 pounds per square inch (0.0853 kg/m^2) and the minimum is 20 pounds per square inch (0.02844 kg/m^2). These are the extreme values, but for pressure in a residential area it is preferred to stay between 40 and 50 psi.

The village consists of approximately 760 people. The average water amount that is used in the span of a day is 64.5 cubic meters. This is what the water supply system must be able to provide. Since water use is primarily in the day time hours, the tanks will need to be filled to this capacity within a 10 to 15 hour period.

Chapter 4: Background

Engineers Without Borders is a non-profit organization that works to better the quality of life in other countries. The College of New Jersey Engineers Without Borders Chapter was established in 2007 and first worked on a project with Warm Heart World Wide; a non-profit organization that houses and educates children in Thailand. Previously, EWB-TCNJ designed and implemented a water distribution system in the orphanage. A drinking well was dug and the water was pumped into a water tower and was distributed to the various buildings. Through Warm Heart World Wide, EWB-TCNJ has acquired the present project in Nong-Pit, a village located near the Warm Heart head office. With Warm Heart, the team was able to communicate with the villagers on Nong Pit.

Between May 15, 2011 and May 22, 2011, Ian Burton, Amanda Feeley and Kevin Dischino (all active members of the TCNJ Chapter of EWB) along with Dr. Horst traveled to Thailand to assess the area and collected pertinent data necessary to develop design solutions to the problem. The group met with the village leader and a few other men to discuss the problem and their desired solution. At this meeting, the grouped learned the basic parameters of the problem. Data was collected during the week which would be analyzed and used in the design. This data is further discussed in Chapter 5.

Chapter 5: Site Reconnaissance

5.1 Overview

Three students and Dr. Horst traveled to Nong Pit to collect data for the project. The group first learned in a meeting with the village leader the number of people and homes in need of water. The students surveyed the land collecting distances and elevation changes. Also, the cross section of the stream was surveyed along with a weir connected to the stream. After the trip, water usage data was collected by Warm Heart and sent to the group. This data was analyzed to determine possible designs.

5.2 Surveying Site

The Thailand assessment trip took place between May 15, 2011 and May 22, 2011. The group met Michael Shafer, the founder of Warm Heart World Wide, to discuss the basics of the project. The group then met with the village leader to discuss the problem and their solution. Since the primary language of Thailand is Thai a translator was scarcely available to the group. Often the communication done during the surveying was achieved through picture drawing as well as gestures. During the end, the children of the village, who were learning English in school, were able to help in translating.

The group was led to the desired water source which was located above a small waterfall. Throughout the week, surveying data was taken from this source to the villagers' desired location for the storage tanks. Data collection consisted of foresights and back sights for each segment of the path as well as distances of the segments. The materials provided were a scope on a tripod, a Philadelphia rod (in meters) and a distance-measuring wheel. The surveying was broken up into two days. During the first day, data was collected from the source down to a road that traveled directly above the village. On the second day, surveying data was taken from the desired storage tank location to the same point on the road from the previous day. The location of the storage tanks was on a hillside located on the opposite side of the road above the town.

Initial calculations were performed to determine if the change in elevation was sufficient for the proposed design. The elevations were found using standard surveying calculations. Subtracting the foresight from the back sight values gave the change in elevation for each segment that was surveyed. The total change in elevation that was calculated between the source and the proposed location for the tanks on the hillside was 2.51 meters, and the total distance along the entire path surveyed was approximately 1880.7 meters. In anticipation that a change of 2.5 meters was not enough to provide the necessary amount of water, the group analyzed the area for the possibility to change the locations of both the source and the storage tanks. The proposed source was not at the top of the stream so it was determined that the source could be moved further up the mountain if needed. The change in elevation was determined at a point up stream to determine the slope and depth of water. Also, the tanks on the hill could move approximately 7 meters further down the hill while still remaining above the village. This would alter the pressure of the water flowing into the town and will be considered in design option three.

The villagers desired water to flow from the source to tanks and from the tanks down into the town where it would be distributed. The tanks on the hillside would allow the village to expand up the hill, which could not happen if the tanks were located in the current village center. Along with the surveying data, a cross section was taken of the stream at the water source, just above the waterfall. The maximum depth was found to be 0.3 meters. This depth, according to the villagers, is fairly low. All of the data was taken before the rainy season so the water levels were not as high. They assured the group that at times the water could be up to 9 feet higher than its observed value. This would be taken into account when designing the system.

Located near the point where the stream met the road, the stream passed over a weir. The cross section and depth of the weir were recorded to ensure proper design. The analysis of this can be seen in Section 5.5.

The storage tanks the villagers plan to use are concrete rings that stack together. They said it is typical to have four rings per tank. The dimensions were taken to determine the number of tanks required.

5.3 Village Water Usage

After the assessment trip to Thailand, Warm Heart World Wide was able ascertain water usage data for the village for one month. The data showed each person that uses water and the amount they used. The total usage of the town for one month was 1614 cubic meters of water. This was divided by 30 days and determined their daily use of water was 53.8 cubic meters. A factor of safety of 20 percent was applied so the volume used for the design was 64.5 cubic meters of water.

5.4 Storage Tanks

The villagers of Nong Pit had previously used a set of tanks for another project. They requested the same tanks, which were made from concrete rings, to be used for this project. Multiple rings would stack to make a tank and the villagers said that four rings would be used for this system. The ring had an inside diameter, d, of 1.2 meters and a height, h, of 1 meter. Using Equation 1, the volume, V, of the ring could be calculated.

$$V = \pi \frac{d^2}{4} h \quad \ldots\ldots (1)$$

One ring would have a volume of 1.13 cubic meters. Stacking 4 rings would produce a total volume of 4.52 cubic meters requiring a total of 15 stacks to hold the required 64.5 cubic meters of water. If 5 rings were stacked together, then 12 stacks would be required to meet the capacity. The final design will determine if this is a cost efficient set of tanks. If not, an alternative will be presented that is realistic to implement in the area.

5.5 Weir Analysis

Located downstream of the water source, there was a weir that was used to determine the flow in the river. A weir analysis was performed using Equation 2, where y_{cr} is the critical depth which was measured to be 0.4826 meters and the base width, B, was recorded as 1.1176 meters. The gravitational constant, g, was taken as 9.81 meters per second squared.

$$\boldsymbol{y_{cr}} = \sqrt[3]{\frac{\left(\boldsymbol{Q}/\boldsymbol{B}\right)^2}{\boldsymbol{g}}} \quad \ldots\ldots (2)$$

The flow, Q, was calculated to be 1.1735 meters cubed per second. This was used to insure that the flow required in the designed gravity fed pipe system is less than the flow in the stream.

5.6 Varying Flow

AutoCAD was use to draw a profile of the trail from the water source to a nearby road and from the tanks located on the hillside to the road. The cross-section of the river was also drawn and used to determine the flow at different water surface elevations. Seven different elevations were taken into account with low water surface elevations (meaning there is very little water flowing through the stream) and high water surface elevations (meaning the stream is flowing full). Manning’s equation, shown in Equation 3, was used to determine the flow where the area, A, and the wetted perimeter were measured using the AutoCAD drawing for elevation. The hydraulic radius, R, was determined by dividing the area, A, by the wetted perimeter. The roughness coefficient, n, was taken as 0.045 and the slope was 0.043 meters per meters. The slope was found using Equation 3 using the previously determined flow of 1.1735 meters cubed per second, the respective area and radius at 0.3 meters. This slope was then used to determine the flows at various depths.

$$Q = \frac{1.0}{n} A R^{2/3} S^{1/2} \quad \ldots\ldots (3)$$

This was used to insure that there was enough flow in the river no matter what the water level was. This flow at each elevation was graphed as shown in Figure 5.6-1.

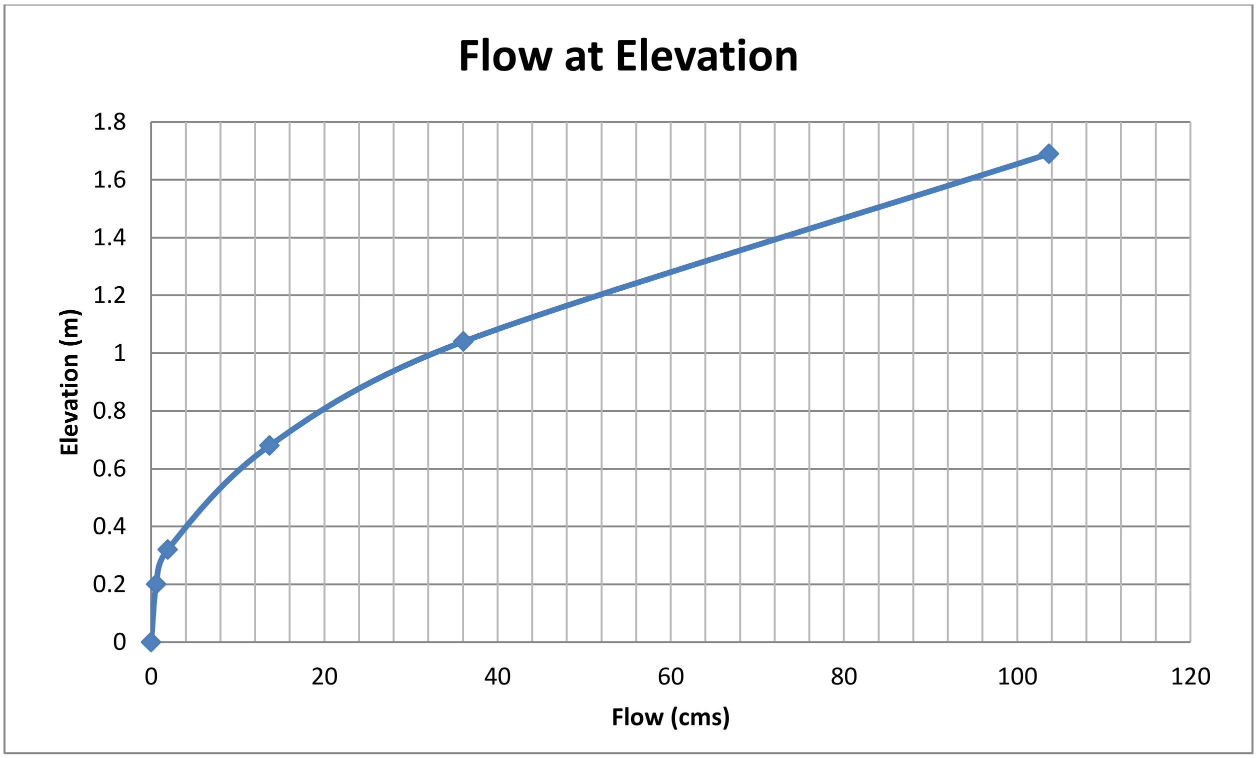


Figure 5.6-1 Curve of Flow at Various WSEL

The flow in the river increases with the water surface elevation therefore, during any season, dry or rainy, the stream will have enough flow for the system to provide enough water to the village without being depleted.

5.7 Conclusion

An assessment trip to Thailand in May 2011 provided the team with all of the data that will be used to design the Water Supply System. Surveying data was used to find distances as well as changes in elevations. This was crucial in determining if the project was feasible and if anything needed to be changed from what the village leader proposed. Cross sections of the source as well as the weir were used to find flows of water through the stream. It was determined that even when the water is at its lowest, it still has the capacity to fulfill the people's needs. This data will be applied to the possible designs and when returning to Thailand, the final design will be implemented.

Chapter 6: Gravity Fed Piping System

6.1 Overview

The system specifically requested by the village leader of Nong Pit was a gravity fed piping system. They requested this because it would be a simple system that would require little to no maintenance unlike one utilizing a pump or water tower. It should be the most cost efficient option considering the minimal supplies required. Though a water source and a tank location were given by the village, surveying data revealed that the change in elevation of 2.5 meters may be insufficient for a gravity system. To minimize the change in elevation, the system was based on the tanks being filled in a period between 10-15 hours. This would allow the tanks to fill over night when the water would not be used and during the day when water is needed, the tanks would be full. This design will need to determine the final change in elevation between the source and elevation, the time required to fill the tanks based on the elevation, the pipe diameter used to transport the water and the specifications of the tanks that will be used to store the water. This was an iterative process where different variables were changed several times to present several solutions. Times varying from 2-15 hours were applied to both a 0.0508 meter (2 inches) diameter and a 0.076 meter (3 inches) diameter pipe where the largest hours provided applicable elevation changes.

6.2 Analysis

To determine if the system could be created between the desired source and tank location, the time to fill the tanks needed to be determined. The friction loss, FL, through the system was placed in terms of velocity as seen in Equation 4. The friction factor, f, was assumed to be 0.02 using engineering judgment. The length, L, of the system was determined from the surveying data to be 1880.7 meters and a diameter, D, of 0.0508 meters (2 inches) was assumed for the system. The velocity through the pipes, v_2, was unknown but the gravitational constant, g, was known to be 9.81 meters per second squared.

$$FL = f \frac{L}{D} \frac{v_2^2}{2g} \quad \ldots\ldots (4)$$

The velocity through the pipes was determined using Bernoulli's Equation, Equation 5. The velocity at section one, v_1, was the velocity at the source which was assumed to be zero. Any velocity at the source would have minimal effect on the system. Gravity, g, was known to be 9.81 meters per second squared. The pressure at the surface of the water at the source was zero and the specific weight of water, γ, was known to be 9.81 kilo-Newtons per cubic meter. Though the actual elevations, z_1 and z_z, were not determined, the difference of the two elevations was found to be 2.51 meters. The pressure at the tanks, P_2, was assumed to be zero and the friction loss, FL, was in terms of velocity previously.

$$\frac{v_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = \frac{v_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + FL \quad \ldots\ldots (5)$$

This equation was rearranged and set equal to velocity as seen in Equation 6.

$$v_2 = \sqrt{\frac{\Delta z}{f\frac{L}{D}-1}2g} \quad \ldots\ldots (6)$$

The velocity was found to be 0.258 meters per second. To find flow, the cross sectional area of the pipe, A, was found using Equation 7 where a diameter, D, of 0.0508 meters (2 inches) was used.

$$A = \frac{\pi D^2}{4} \quad \ldots\ldots (7)$$

The area was found to be 0.00203 meters squared. Utilizing the previously calculated velocity, v, and area, A, the flow, Q, was determined using Equation 8.

$$Q = vA \quad \ldots\ldots (8)$$

The flow through the pipes was found to be 0.000523 cubic meters per second. The time, t, was found using Equation 9 where the volume, V, was known to be 64.5 cubic meters and the flow, Q, previously calculated.

$$Q = V/t \quad \ldots\ldots (9)$$

The time it would take to fill the tanks at the requested change in elevation would be 123426.7 seconds (34.3 hours). Since this time is insufficient, alternatives were considered.

Rather than having a fixed change in elevation to find time, a calculation was performed with a fixed time to fill the tanks which would determine the flow. A time of 2 hours, 7200 seconds, was entered into Equation 9 with the same volume to find a flow of 0.009 cubic meters per second. This flow was compared to the flow of the stream at the lowest depth which was 1.17 cubic meters per second at a depth of 0.3 meters. Since the required flow in the system is less than the minimum flow in the stream, the stream can adequately supply the system with water and the system will not drain the stream.

Equation 8 was used to find a velocity based on the flow of 0.009 cubic meters per second and the same area used previously of 0.00203 meters squared. The velocity was found to be 4.424 meters per second. To calculate the friction losses, the Reynolds Number, Re, was calculated using Equation 10. The velocity, v, was previously calculated to be 4.424 meters per second and the diameter, D, was 0.0508 meters (2 inches). The viscosity, υ, of water was based on an assumed water temperature of 60° F and found to be 1.124×10^{-6} meters squared per second.

$$Re = \frac{vD}{\upsilon} \quad \ldots\ldots (10)$$

The Reynolds Number was found to be 1.999×10^{5}. Using Moody's Diagram, Figure 6.2-1, a friction factor was found to be 0.0155.

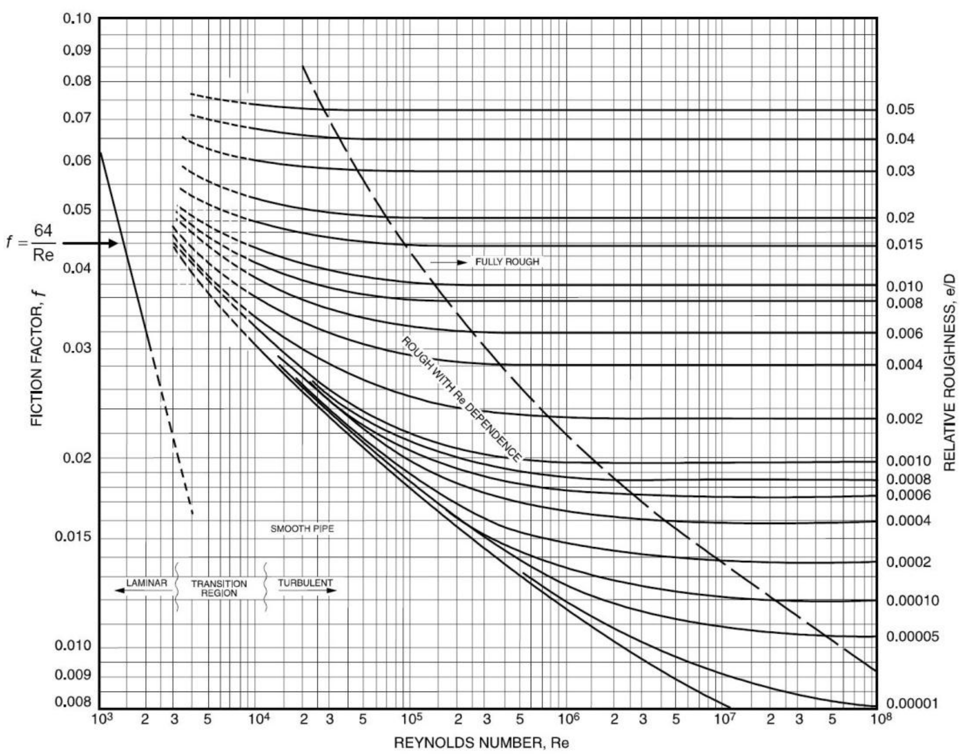


Figure 6.2-1 Moody's Diagram

Using Equation 4, the friction losses were found to be 572.42 meters. The change in elevation was found using Bernoulli's Equation rearranged as seen in Equation 11.

$$\Delta z = \frac{v_2^2}{2g} + FL \quad \ldots\ldots (11)$$

The change in elevation for two hours was found to be 573.42 meters. Since this elevation is impractical, the process was repeated for various times that do not last longer than the night but would produce a reasonable elevation change. To determine the best possible design, the constant diameter of 0.0508 meters (2 inches) was altered to find the required change in elevation.

6.3 Results

Analysis of the proposed system had an elevation change of 2.5 meters and would fill the tanks in 34 hours which was insufficient. An increase in elevation change would decrease the time. The required change in elevation based on varying times with a constant diameter of 0.0508 meters (2 inches) can be seen in Table 6.3-1.

Table 6.3-1 Results from 0.0508 m Pipe

Time (hr)	Flow (cms)	Velocity (m/s)	Friction Factor	Change in Head (m)
2	0.009	4.42	0.016	573.419
4	0.004	2.21	0.018	166.436
6	0.003	1.47	0.019	80.537
8	0.002	1.11	0.021	47.379
10	0.002	0.88	0.021	31.061
11	0.002	0.80	0.0212	25.915
12	0.001	0.73	0.0214	21.981
14	0.001	0.63	0.02175	16.413
15	0.001	0.59	0.022	14.462

As seen in the table, the required change in elevation decreased as the time to fill the tanks increased.

This process was repeated using a diameter of 0.076 meters (3 inches) instead of 0.0508 meters (2 inches). The results can be seen in Table 6.3-2.

Table 6.3-1 Results from 0.076 m Pipe

Time (hr)	Flow (cms)	Velocity (m/s)	Friction Factor	Change in Head (m)
2	0.009	1.96	0.0172	83.845
4	0.004	0.98	0.0198	24.122
6	0.003	0.65	0.0217	11.748
8	0.002	0.49	0.0229	6.973
10	0.002	0.39	0.024	4.677
11	0.002	0.35	0.0246	3.961
12	0.001	0.32	0.0252	3.410
14	0.001	0.28	0.0261	2.594
15	0.001	0.26	0.0266	2.303

Again, the time increases as the required change in elevation decreases. These increases in time allows for a plausible change in elevation.

6.4 Conclusion

Utilizing Bernoulli's Equation, analysis of the proposed parameters and new parameters were determined. With a change in elevation of 2.5 meters between the source and tanks, it would take 34 hours to meet the need of 64.5 cubic meters. The locations need to be changed to create a larger change so the tanks will fill in a reasonable time. A minimal time would require a large elevation change therefore a larger time between 10 and 15 hours (overnight) will be used so it will require a minimal change. For next semester, the final design will consist of a pipe material and dimensions that work best for the system while maintaining cost efficiency. The tank material will be finalized that is cost efficient and attainable in Thailand.

Chapter 7: Turbine/Pump Piping System

7.1 Overview

The design requested by the village, which was a gravity fed system with a set of tanks on the mountain, may be inadequate. In order to allow the villagers to have the tanks in the desired position or a higher position, a pump was introduced. The pump will be powered by a turbine so that the system will be self-sustainable. The design will require a turbine that can produce enough energy to power the pump by using the flow and change in elevation of a waterfall. The pump will be selected by developing a system head curve, which is flow vs. energy, and comparing it with a pump head curve, which is supplied by the pump manufacture, to determine how much energy will be added to the system.

7.2 Analysis

In order to develop the system head curve, different times between 6 and 15 hours were used. The total energy, E_t first was calculated using Equation 12 where E_2 is the energy at the tanks, E_1 is the energy at the water source and Losses are the friction losses within the system.

$$E_t = E_2 - E_1 + Losses \quad \ldots\ldots (12)$$

The energies, E, were found for each of the different times using Bernoulli's equation as shown in Equation 13. The velocity, pressure and elevation are represented by v, P and z respectively. The gravitational constant, g, is 9.81 meters per second and specific weight of water, γ, is 9.81 kilo-Newton per cubic meter.

$$E = \frac{v^2}{2g} + \frac{P}{\gamma} + z \quad \ldots\ldots (13)$$

Equations 12 and 13 were then combined, as shown in Equation 14. Since there was no pressure at the water source and at the tanks, the pressure head, $\frac{P}{\gamma}$, for both is zero. There was very little velocity at that water source so it was negligent. The friction losses were taken into account within the system as shown in Equation 4. The friction factor, f, and the velocity, v, were previously calculated, seen in Table 6.3-1, for each of the times. The length was from the water source to the tanks and found to be 1880.7 meters. A diameter, D, was assumed to be 0.0508 meters (2 inches) and the gravitational constant, g, was known to be 9.81 meters per second squared. A factor of safety of 10 percent was applied in order to account for minor losses.

$$E_t = \left(\frac{v_2^2}{2g} + \cancel{\frac{P_2}{\gamma}} + z_2\right) - \left(\cancel{\frac{v_1^2}{2g}} + \cancel{\frac{P_1}{\gamma}} + z_1\right) + f\left(\frac{L}{D}\right)\frac{v^2}{2g} \quad \ldots\ldots (14)$$

This was used to form Equation 15 to determine the total energy in the system for the times between 6 and 15 hours. A change in elevation of 2.51 meters was used based on the desired locations. The velocity at the tanks was previously determined and shown in Table 6.3-1.

$$E_t = \frac{v_2^2}{2g} + \Delta z + f\left(\frac{L}{D}\right)\frac{v^2}{2g} \quad \ldots\ldots (15)$$

The flow, Q, then needed to be calculated in order to construct the system head curve. This was completed by using Equation 9, where the Volume, V, is 64.56 cubic meters and the time, t, is the times between 2 and 15 hours.

A pump head curve was supplied by the manufacturer Taco for a centrifugal pump. This pump was used because it supplied pump head curves for various numbers of horsepower rated pumps. Numbers were recorded from the supplied graph and used to form the same graph on excel. This was completed for a ½ HP, ¾ HP and 1 HP pump. These pump head curves and the system head curve were place on the same graph. The operating point, where the two curves met, was found by placing a trendline on the curves and finding the corresponding equation of the line. Each of the pump head curve trendline equations were set equal to the system head curves trendline equation to find the intersection point. Equation 9 then was used to determine the amount of time, t, it would take to fill the tank. The flow, Q, was found for each pump head curve at the operating point and the volume, V, is 64.56 cubic meters.

Further research needs to be completed in order to determine the exact pump that will be used and at what horsepower. Also the turbine needs to be selected. This will be completed by determining the head distance from the top of the waterfall to the bottom and the flow traveling through the pipes to the turbine. The turbine needs to be able to produce enough energy to power the pump and the pump needs to be able to supply the system with enough energy to fill the tanks at the villager's desired location in a short period of time. The dimensions of the pipe in order to complete the design will also need to be determined.

7.3 Results

Table 7.3-1 shows the times used and the calculated flow and energy of the system head curve.

Table 7.3-1 System Head Curve Data

Time (hour)	Flow (m^3/s)	Energy (m)
6	0.00299	85.586
8	0.00224	49.219
10	0.00179	31.319
11	0.00163	25.673
12	0.00149	21.357
14	0.00128	15.248
15	0.00120	13.108

The least amount of time was desired so more energy needs to be added to the system. This was confirmed by the table as it shows that as the time it takes to the fill the tank increases, the less flow and energy was needed. Figure 7.3-1 shows the system head curve.

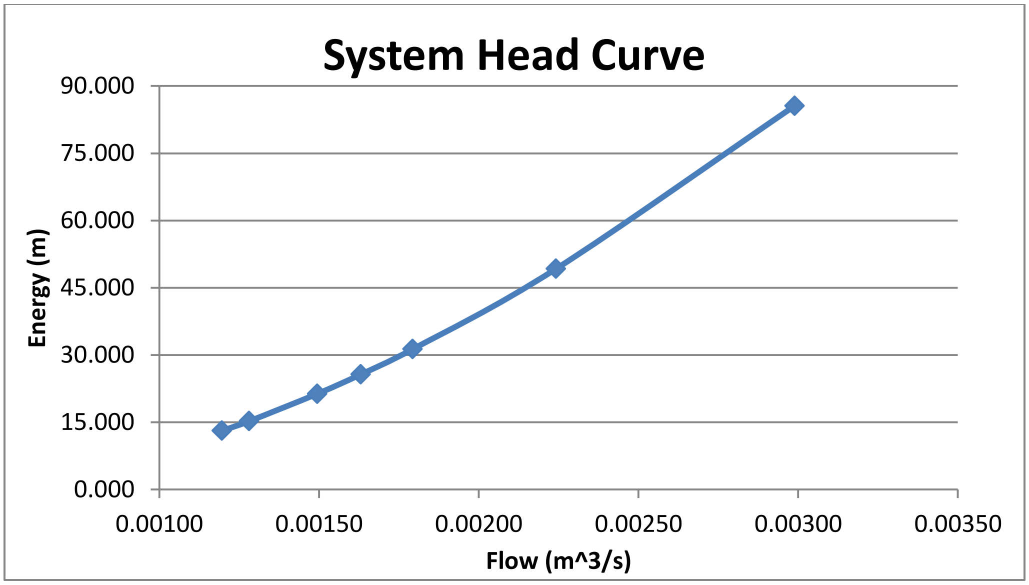


Figure7.3-1 Graph of System Head Curve

As seen in Figure 7.3-2, the system head curve and the pump head curve are graphed together to find the operating point.

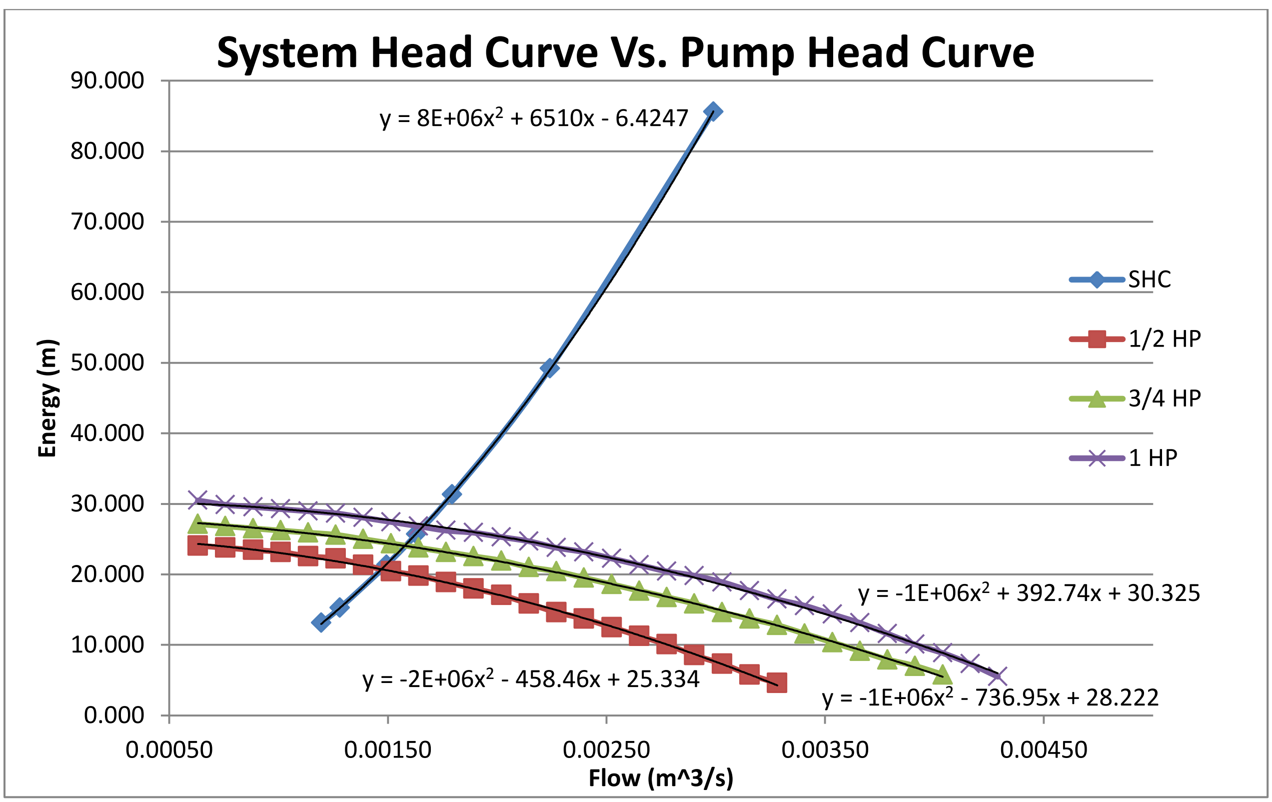


Figure 7.3-2 Graph of System Head Curve vs. Pump Head Curve

The higher horsepower pumps add more energy to the system. Based on the operating point, the flow and energy for the ½ HP, ¾ HP and 1 HP pumps were determined and seen in Table 7.3-2. The flow was also used to determine the time it would take for the tanks to fill.

Table 7.3-2 Time Determination for Different HP Pumps

PHC	Flow (m^3/s)	Energy (m)	Vol (m^3)	Time (sec)	Time (hr)
1/2 HP	0.001467	18.709	64.56	44008.18	12.22
3/4 HP	0.001600	24.483	64.56	40350.00	11.21
1 HP	0.00171	28.749	64.56	37776.48	10.49

The highest horsepower pump would allow the water to flow into the tanks in the shortest amount of time because of the increase in energy added to the system.

7.4 Conclusion

A system head curve was produced using Bernoulli's equation and the different amount of time between 6 and 15 hours. A pump head curve was also found from a centrifugal pump for a ½ HP, ¾ HP and 1 HP pump. These were graphed together to find the operating points and the corresponding flow and energy. This was used to determine how much time it will take to fill the tanks and how much energy will be added to the system for each of the pumps. For next semester, the right pump needs to be chosen so that it supplies enough energy to the system to fill the tanks in the villager's desired location and in a timely manner. The turbine needs to be able to produce enough electricity from the flow and head of the waterfall to power the turbine.

Chapter 8: Distribution System

8.1 Overview

To complete the Thailand Water Supply System there must be a distribution system from the storage tanks to the town. This distribution will be based upon the location of the storage tanks which is dependent on the most efficient and cost effective piping design. In order to accurately design the system, a layout of the Thailand village has been requested from our correspondence there. A layout is still awaiting arrival from Warm Heart World Wide, if this is not obtained, a layout will be assumed based on the observations made during the assessment trip. Two designs are currently being researched.

8.2 Analysis

Two main distribution system designs are being analyzed. The first one is a looped system. This system contains pipes interconnected throughout the schematic so that water can move through the entire system back and forth, depending on the point of largest demand. A system like this requires a lower velocity and a lower head loss. This is a valuable feature because it would provide more flexibility due to the constraining tank location. This type of system also has a greater capacity to hold water, which is also a good factor due to the size of the village. The only downfall is the high cost. A looped system would consist of many more pipes than the second system being analyzed; an example of this type of system can be viewed in Figure 8.2-1. This grid type of system would have each outlet connected by more than one pipe. This will have to be considered when the final budget is set and all fundraising money is gathered.

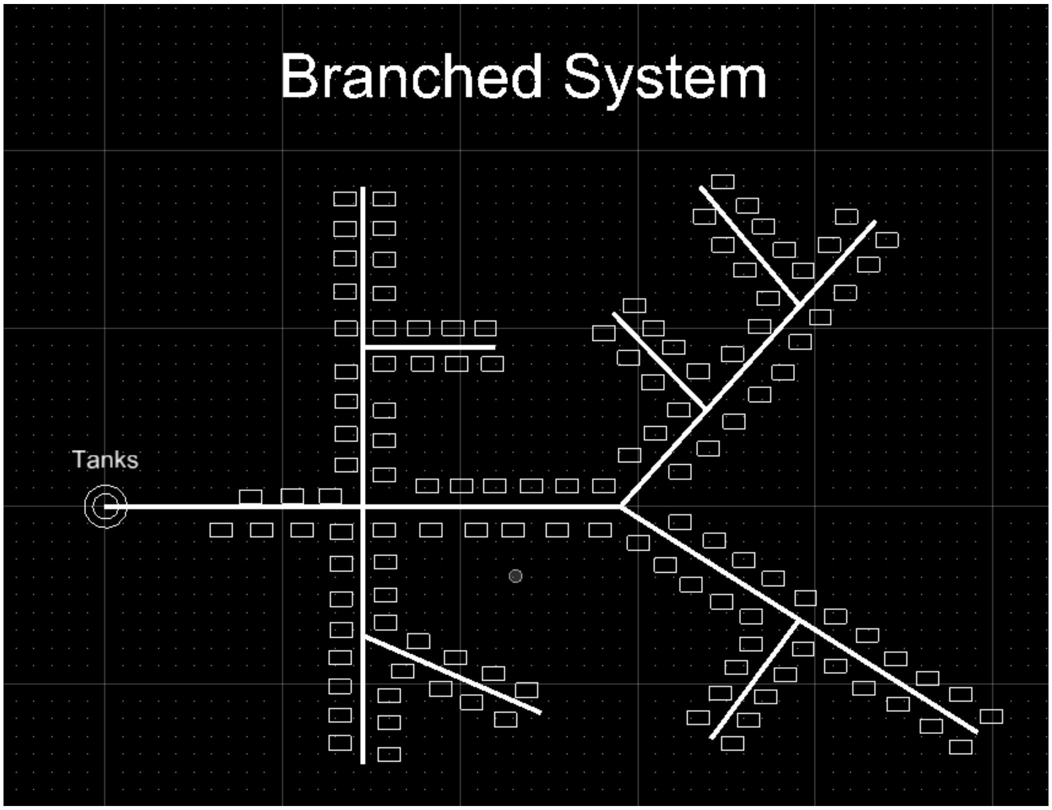


Figure 8.2-1 Example of Branched Distribution System

The second distribution system is a branched system. This consists of pipes that form only one path from the source to the household. This "dendritic" type system greatly contrasts from the looped system. It requires a faster velocity and a greater head loss. This design depends on the final chosen location for the tanks and can only be implemented if the tanks provide the needed head. Though it also has a reduced capacity, it is less costly. It requires much less piping than the former system does, requiring only one pipe connected at each outlet, leading back to the tanks; an example of this type of system can be viewed in Figure 8.2-2.

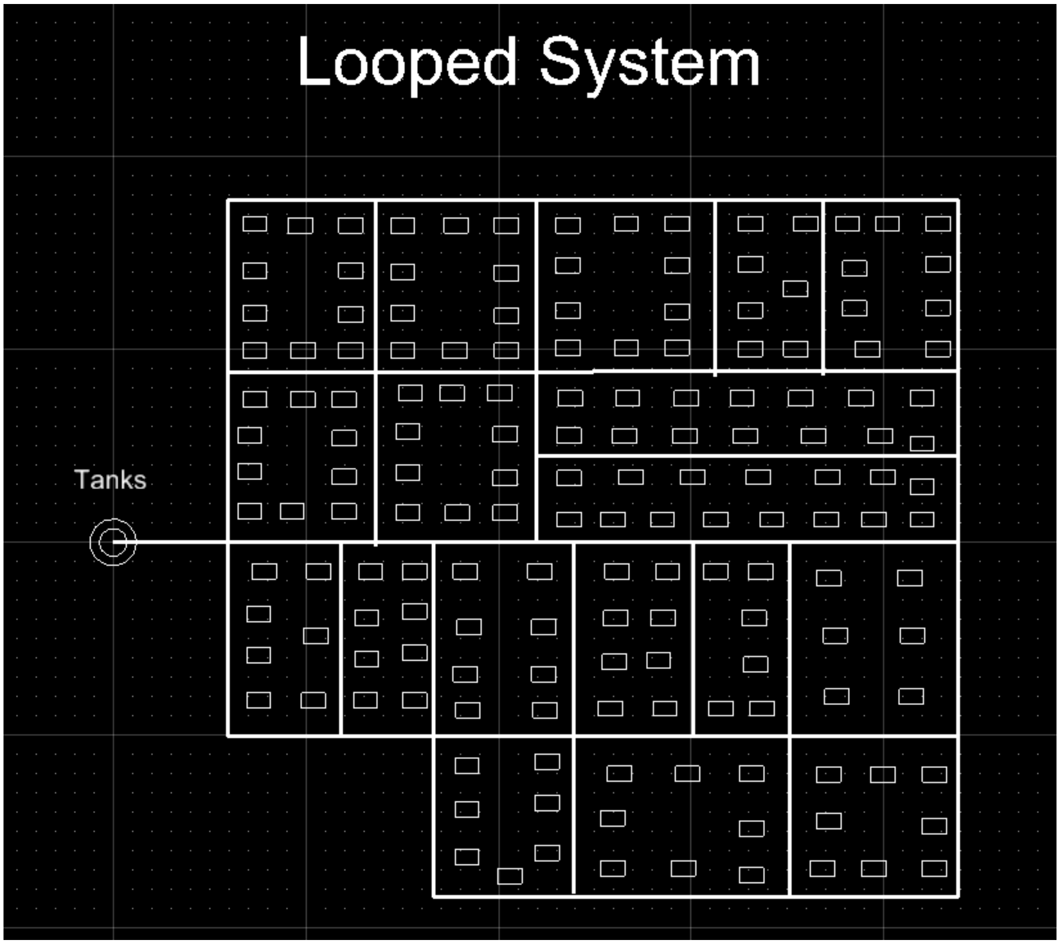


Figure 8.2-2 Example of Looped Distribution System

8.3 Conclusion

The complete design of the distribution system will be completed next semester. Friction and minor losses will be calculated in order to design a fully functioning and efficient piping system. Different pipe sizes are selected in order to avoid high velocities. A preferred velocity is to be between 3 and 5 feet per second squared. So once the flow through the system is found the pipe size can be determined based on a velocity assumed to be within this range. The geometry of the system will be designed in order to ensure that the system has an internally consistent distribution of flows. This would mean that all of the flow entering the system would equal all of the flow exiting the system.

Chapter 9: Cost/Budget

The supplies and cost are dependent on the chosen design. For both the gravity fed system and the turbine/pump system, piping materials and the storage tanks will be needed to transport and hold the water. The turbine/pump design will require a turbine and a pump that is adequate for the system. Once the dimensions and specifications for the materials are finalized, the materials will be researched and the budget will be determined.

The main cost of this project will be the travel costs to get to Thailand. It is estimated that six students and a faculty advisor will be going on the implementation trip. Plane tickets, lodging and food will be the main cost.

Since this is an Engineers Without Borders TCNJ Student Chapter project, all the fundraising from the chapter will be allocated for the cost of supplies. The chapter has funds already present in the account but this year many fundraisers have been and will be completed to raise money. These fundraisers include working at the Sun National Bank Center, an Applebee's pancake breakfast, a t-shirt sale and a flower sale. It is anticipated that The College of New Jersey's School of Engineering will be assisting with the payment of the plane tickets to and from Thailand

Chapter 10: Schedule

The data collection of the project was completed during the assessment trip in May of 2011 and other data was sent over the summer. September was allocated for the proposal and the analysis of the data. The water usage data was analyzed along with the surveying data. Flow values were determined based on both the weir and the cross section of the stream. Upon conclusion of the data analysis, the individual designs were explored in October and November.

Results were shared since aspects of each design were dependent on each other. For example the turbine/pump system utilized the gravity fed system friction values for a specified time. Upon conclusion of the progress report, the final report was compiled and the team determined the goals for next semester based on what had been completed during Senior Project I.

The main design portion of Senior Project will take place over winter break and through next semester. A poster competition in Atlantic City in the middle of March would require all designs to be complete at this point. Since there are three separate design portions these will be done individually. Group and advisor meetings will still regularly occur. Designs will be completed by mid-February. The group will decide as a whole on what materials should be used to implement the project. The final design will have to be based on the cost of the possible materials as well as the efficiency of the system. Designs, materials, and future plans of implementation will be presented at the poster competition. The entire project will be finalized through the rest of the semester. The team as well as other students from EWB-TCNJ will travel to Thailand to implement the final Water Supply System.

Chapter 11: Conclusion

The Thailand Water Supply System Senior Project will provide water to the village of Nong Pit located in Thailand during the dry months of the year. A stream flows near the village and the requested system would transport water via gravity from the stream to a set of tanks located on a hillside above the village. The village has a population of 760 people with 216 homes and requires an average of 64.5 cubic meters of water a day based on a factor of safety of 20 percent. During site reconnaissance, the area provided a proposed distance from the water source to the storage tanks to be 1880.7 meters at a change in elevation of 2.51 meters. The requested tanks would be composed of four concrete rings containing a volume of 4.52 cubic meters requiring 15 tanks to hold the 64.5 cubic meters of water. The assessment trip revealed a flow of a weir in the stream of 1.17 cubic meters per second. Using Open Channel Flow theory, possible flows were determined in the stream at various water surface elevations. Both flows from the weir and cross section were compared to flows required to fill the tanks. The flow and change in elevation required to fill the tanks in a specified time was found using Bernoulli's Equation. The tanks will be designed to fill overnight requiring a smaller change in elevation and a flow consistently lower than the one recorded in Thailand. Pipe diameter that provides a reasonable change in elevation for the area, cost of the gravity fed system, and tank specifications will be finalized next semester.

Another design option being considered utilizes the waterfall that is located at the water source that will flow into a turbine which will power a pump. The pump will add energy to the system so water can flow to the set of tanks at any location. A system head curve was created and a pump and turbine will be chosen based on cost and performance. The performance of the system depends on the operating point of the System Head Curve and the Pump Head Curve. Several options will be explored to determine the best pump and a plausible change in elevation that is more advantageous than the gravity fed system.

Based on the efficiency and cost of the two piping designs, a distribution system will be designed to move the water from the storage location to each house in the village. Two piping systems were researched and the final solution will depend on the piping system utilized and the efficiency of the system. Once completion of the optimal design based on efficiency and cost, the project will be implemented in May 2012 by Engineers Without Borders - The College of New Jersey Chapter.

Appendix A: Project Overview

Team Members

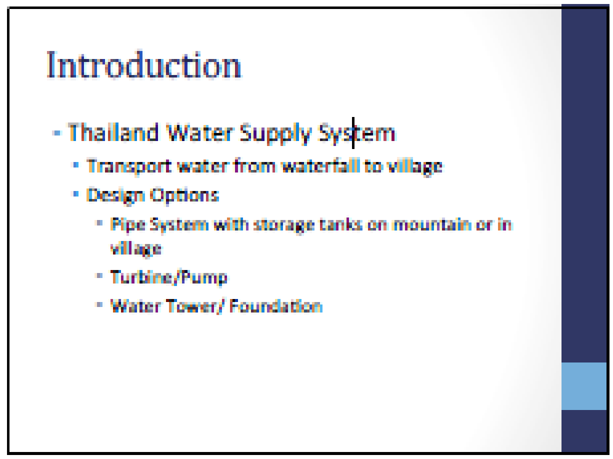
Ian Burton is a senior civil engineering major at The College of New Jersey and is from Hillsborough, New Jersey. He is the project manager and his responsibility for the Thailand Water Supply System Project is the gravity fed piping system design. He is the President of the TCNJ chapter of Engineers Without Borders and has been a member of TCNJ's American Society of Civil Engineers since his freshman year. After graduation, Ian hopes to obtain his Master's degree in Civil Engineering and plans to pursue a career in engineering.

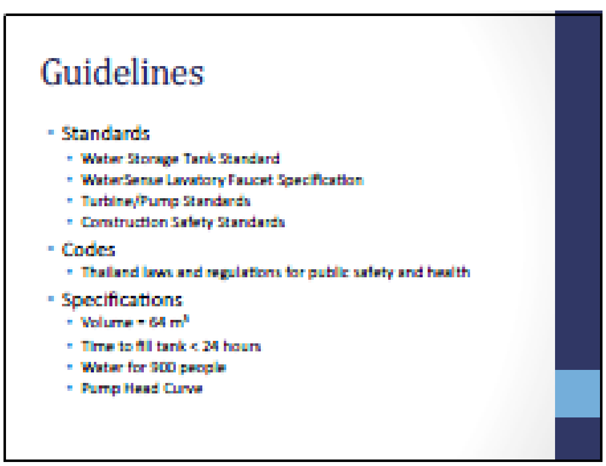
Amanda Feeley is a senior civil engineering major at The College of New Jersey and if from Lakewood, New Jersey. Her responsibility for the Thailand Water Supply System Project is the distribution system design. Amanda is the Vice President of the TCNJ chapter of Engineers Without Borders. This past year she worked at the Ocean County Engineering Department as an intern. After graduation she hopes to obtain a career within the field of civil engineering and in the future complete a Master's degree.

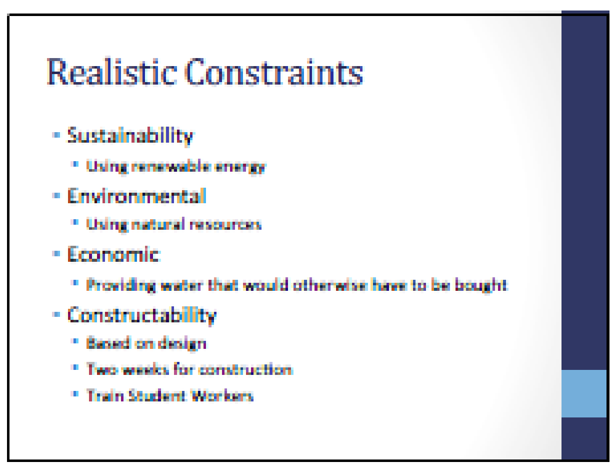
Jayme Lynch is a senior civil engineering major at The College of New Jersey and is from Vernon, New Jersey. Her responsible for the Thailand Water Supply System Project is the turbine/pump piping system design. Jayme is the Treasure of the TCNJ chapter of Engineers Without Borders, a member of TCNJ's American Society of Civil Engineers, and is actively involved in ASCE's Community Outreach program. For the past two years, she has been working at Lakeland Surveying in Rockaway, New Jersey and after graduation plans to obtain a career in water resources engineering.

Engineering Standards Form

Standards and Constraints Presentation







Realistic Constraints

- Ethical
  - Respect culture
- Health and Safety
  - Design for Irrigation only
  - No traitorous hike for water
  - Safety During Construction
- Social Impact
  - Place water tanks/tower in desirable location for Thai people
- Political Impact
  - Head Man control of water supply

Economic Goals

- Materials
  - Piping
  - Turbine/ Pump
  - Tanks
  - Tower/ Foundation
- Value for villagers
  - Waterfall produces electricity through turbine
    - Not using outside resources

Environmental Goals/Sustainability

- Turbine producing electricity to power pump
- Gravity Feed
- Long lasting supplies

Questions/ Comments

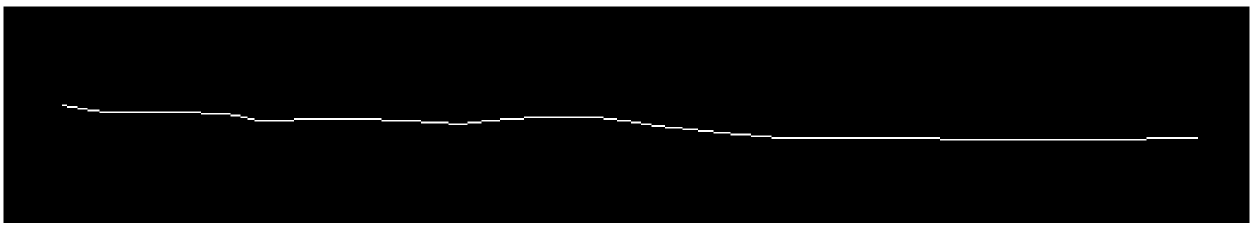
Codes and Specifications

1. WaterSense Lavatory Faucet Specification

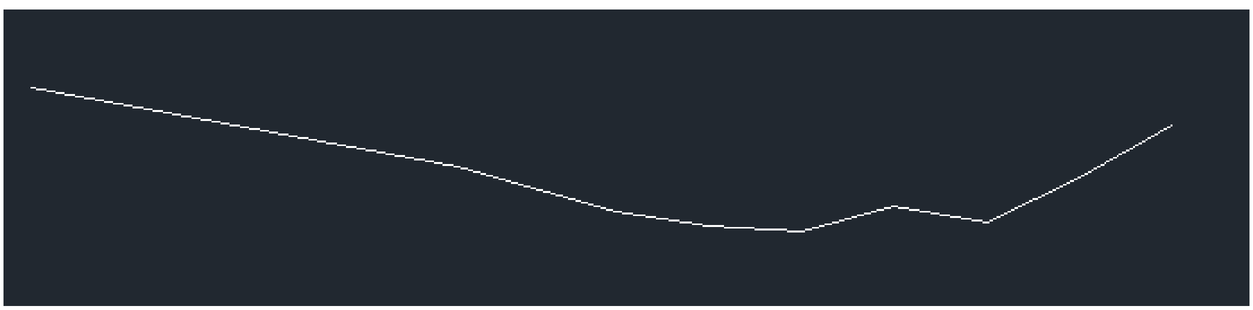
Engineering Tools: AutoCAD

Waterfall to Road

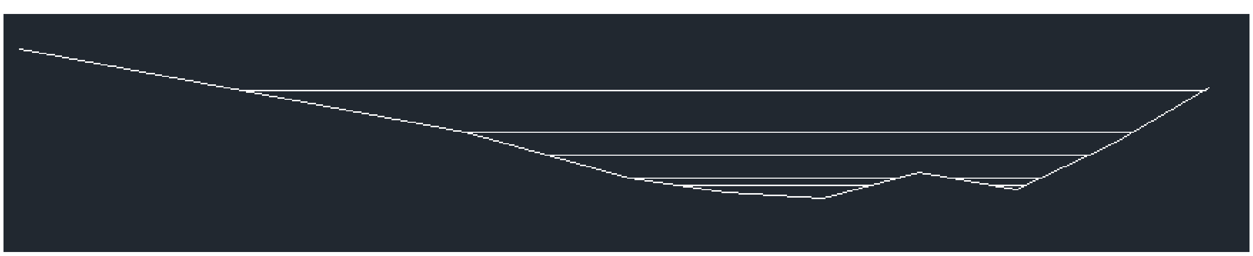
Tanks to Road



River Cross-Section



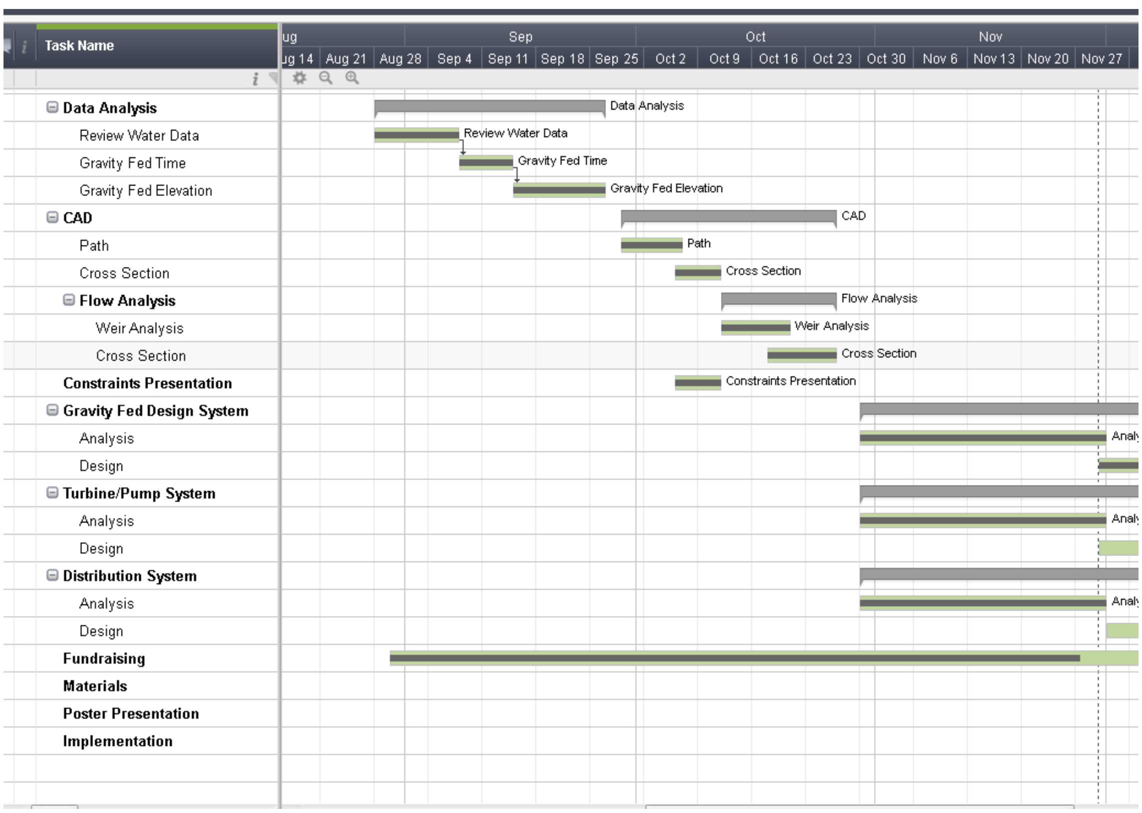
River Cross-Section Water Surface Elevations



Appendix B: Team Management

Gantt Chart

Task Name	Start Date	End Date	Duration	Predecessors	% Complete	Assigne
Data Analysis	**08/28/11**	**09/26/11**	**22**		**100%**	
Review Water Data	08/28/11	09/07/11	9		100%	
Gravity Fed Time	09/08/11	09/14/11	5	4	100%	
Gravity Fed Elevation	09/15/11	09/26/11	8	5	100%	
CAD	**09/29/11**	**10/26/11**	**20**		**100%**	
Path	09/29/11	10/06/11	6		100%	
Cross Section	10/06/11	10/11/11	4		100%	
Flow Analysis	**10/12/11**	**10/26/11**	**11**		**100%**	
Weir Analysis	10/12/11	10/20/11	7		100%	
Cross Section	10/18/11	10/26/11	7		100%	
Constraints Presentation	10/06/11	10/11/11	4		100%	
Gravity Fed Design System	10/30/11	02/08/12	74		49%	
Analysis	10/30/11	11/30/11	24		100%	
Design	11/30/11	02/08/12	51		25%	
Turbine/Pump System	10/30/11	02/08/12	74		32%	
Analysis	10/30/11	11/30/11	24		100%	
Design	11/30/11	02/08/12	51		0%	
Distribution System	10/30/11	02/08/12	74		32%	
Analysis	10/30/11	11/30/11	24		100%	
Design	12/01/11	02/08/12	50		0%	
Fundraising	08/30/11	05/11/12	184		35%	
Materials	02/08/12	02/29/12	16		0%	
Poster Presentation	03/14/12	03/15/12	2		0%	
Implementation	05/14/12	05/31/12	14		0%	



Meeting Minutes

Meeting 1: Minutes

Date: Wednesday, August 31, 2011, 10:30 AM
Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

The group discussed the general goals of Senior Project I and Senior Project II along with the specific project. The objective of the project, "Thailand Water System," is to pipe water from a local stream to a set of tanks that would provide extra water to the village of Nong Pit in Thailand.

The goal of Senior Project I is to analyze the data in preparation of the design. From the summer trip, elevations points, distances and water usage data was obtained. The elevations need to be charted to determine the actual and needed head change between the water source and the storage tank location. The water usage needs to be analyzed to determine the amount of water needed for daily storage. The stream cross section needs to be analyzed to determine if there is enough water capable of filling the tanks.

The goal of Senior Project II is to design parts of or different versions of the project. One option for design would consist of each member being responsible for the design of a specific component of the system. These components would consist of structural analysis for the water tanks, a foundation design to support the tanks, and fluid mechanics to transport the water. The other option would be for each member to design an alternative solution. The first of the present three options is a simple design of pipes starting at the stream and ending at the tanks located on the ground which is on a hill above the town. The second option is a series of pipes that run to a water tower in the town and then distribute the water through the village. The final design would consist of a turbine located at the bottom of the waterfall (source) that would power a pump that could move the water to any location whether it be the tanks on the ground or water tower in the town.

The next meeting will be on Wednesday September 7, 2011 at 10:00 am in Dr. Horst's office. The agenda will consist of the determination of the grade distribution and the finalization of the proposal.

Meeting 2: Minutes

Date: Wednesday, September 7, 2011, 10:00 AM
Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

The proposal of the project was discussed. Dr. Horst reviewed the written proposal and filled out the grading rubric for the course. Then the presentation was reviewed. It was emphasized that time was a significant factor. Though several topics had to be discussed such as the overview, the designs for each member, the budget and the timeline, the presentation could be vague since it was just a proposal. As the semester progresses, the details will become clearer and each member's role along with the budget and timeline will be defined. Once the proposal is concluded, the data can be analyzed. By the next week, the CAD drawing should be completed and the water data should be reviewed for a better understanding.

Meeting 3: Minutes

Date: Wednesday, September 14, 2011, 10:00 AM
Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

The meeting began with a review of the Proposal Presentation. Professor Nolfo asked a question concerning the water purification for the project. Horst confirmed our answer given, that the water being supplied is for irrigation and other purposes that do not require drinking and purification. Then the calculations performed by the group were reviewed. The initial calculation was of the time needed to fill the desired volume with the given head difference. Since the time was 1.3 days, the calculation was done backwards to find the required head to fill the tanks in 2 hours. A mistake was made in the calculation but Dr. Horst was able to point out our mistake and so the calculation could be redone. A weir equation and critical flow calculation can be performed to determine the flow capacity in the stream and related to the cross section of the stream. The Auto-CAD drawing will be completed when the labs have the program. The website was created but Dr. Krstic had to review the guidelines in Senior Project I to place on the TCNJ Engineering Website. The project title has been changed to Thailand Water Supply System. During the next meeting, the correct calculations and cross section data will be reviewed.

Meeting 4: Minutes

Date: Wednesday, September 21, 2011, 10:00 AM
Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

At this meeting, the calculations performed were reviewed. The flow was determined using the weir data collected in May. The critical depth, base width and gravity were used to solve the flow and was found to be 1.1735 m^3/s. Thus, the tanks holding the needed 64 m^3 of water would fill in approximately a minute with that flow. Therefore, the stream holds enough water for their demand. Jayme showed Dr. Horst the calculations for the change in head and the time needed to fill the tanks. It was performed at various times (2, 10, 12, 15 hours) and the head that would be needed. We discussed approximately the change in elevation from the tank location. The villagers wanted to tanks at one location on top of a hill but a larger head was needed so the hill elevation was estimated to be 6-8 meters. From here, the preliminary designs will be reviewed and final calculations will be completed determining the values we will use.

Meeting 5: Minutes

Date: Wednesday, September 28, 2011, 10:00 AM

Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

The first topic discussed was the soil data. No soil information was found online but Dr. Horst agreed that there should be some site holding data about soil in the general area of northern Thailand. Then the upcoming progress report and presentation was reviewed. We briefly reviewed the topics that had to be covered during the presentation which included everything we did in Thailand such as the data collecting and problems we encountered. Along with the trip information, we will discuss all of the calculations and checks performed during the past month's work and upcoming work. Finally we briefly discussed the needed information for choosing a turbine. Jayme began research and will do further research based on the flow and time required to pick a pump and then pick a turbine. Next week we will review the turbine information along with any found soil data.

Meeting 6: Minutes

Date: Wednesday, October 5, 2011, 10:00 AM

Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

The first topic discussed was the soil data. No soil information was found online but Dr. Horst agreed that there should be some site holding data about soil in the general area of northern Thailand. Jayme shared with Dr. Horst her findings on pumps and turbines. We established that a large industrial pump was necessary but either way, manufacturers will need to be called to receive the pump head curves for calculations. Pumps were briefly looked at while in Thailand but unfortunately no prices were recorded. The group recalled that the pumps were cheaper in Thailand than would be in the United States. The budget was quickly discussed reviewing the possible costs for piping, pumps and transportation. Being an EWB project, the EWB accounts were discussed figuring out how much the club had in comparison to how much we could use. The next meeting the pumps, soils data and more calculations will be reviewed.

Meeting 7: Minutes

Date: Wednesday, October 12, 2011, 10:00 AM

Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch

Amanda Feeley

Summary:

Some soil descriptions were located for Phrao but no numbers such as specific weight was found. Dr. Horst will try to locate the previous project's data to use or confirm the online search. When designing, any codes, standards and laws will be U.S. laws instead of Thai regulations. This is because it would be difficult to find foreign regulations and Dr. Horst stated it is customary for this situation to use U.S. standards. There is a minimal elevation change between the source and the tank location. With the addition of friction losses and minor losses, the elevation change may be in the opposite direction so a pump may be needed. Also, to fill the tanks faster, a pump could be used. Therefore, a pump will be needed but of minimal power. Jayme will continue to look for possible pump to meet our needs. Finally the poster competition was discussed to complete the travel proposal form. The dates and location were confirmed to be in the Taj Mahal in Atlantic City from March 21-22.

Meeting 8: Minutes

Date: Wednesday, November 2, 2011, 10:00 AM
Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

Since the last meeting, a lot of information was gather and analyzed which was all covered in the Progress Report Presentation. Jayme and Amanda created a cross section of the stream and recorded the areas and perimeters at specified elevations. That data was entered into excel and I created a graph and chart of the flows at each elevation. Jayme worked on her pump data and created the SHC and compared it to a couple of PHCs. Prior to the presentation, Dr. Horst and the group finalized on the three design aspects each member will be working on during the rest of the year (two semesters). The designs are listed below:

Ian: Designing a Gravity Fed System
Jayme: Designing a Turbine/Pump System
Amanda: Designing a Distribution System

With the new designs, no steel tower or foundation is needed so the soil data search has ended and there is no need for standards on these designs.

The log books were finished and handed in to Dr. Horst for his review.

At the next meeting, we will discuss any further calculation or design that is needed before the completion of the report and final presentation. We need to determine a computer program to use, Modern Engineering Tools.

Meeting 9: Minutes

Date: Wednesday, November 9, 2011, 10:00 AM
Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

First, the grouped discussed the Progress Report Presentation and Dr. Horst observed that we needed to explain our theory a little better because we stated facts they may not have been understood by the audience.

Discussing the design, the concern was brought up that the flow data gathered in Thailand was higher than the previous day. It was a concern that the data would alter the design incorrectly. Dr. Horst stated that with even a lower flow than we observed, it is more than enough to meet our goal.

Jayme asked about her design of the Turbine and Pump. Dr. Horst gave her his estimate of the waterfall height, 30 feet. Also, he clarified that flow entering the turbine is not the flow of the stream. Instead she should use the orifice equation to determine the flow through the pipe that enters the turbine.

Amanda inquired about receive a village plan and we determined that we should email Dr. Schaffer to get a rough plan.

I will research tanks to meet their needs and try to satisfy their wants for next week and the group will start preparing the report to complete by the end of the month.

Meeting 10: Minutes

Date: Wednesday, November 16, 2011, 10:00 AM

Attendance: Dr. Horst, Advisor
Ian Burton, Project Manager
Jayme Lynch
Amanda Feeley

Summary:

At the meeting, I briefly discussed my research into tanks. I researched precast concrete tanks in the United States for references. Dr. Horst suggested that I contact Dr. Shaffer and ask him to talk to the villagers of Nong Pit. They should know the various sizes and the prices for tanks since they have some now and they have a large volume to fill.

Jayme asked about the orifice equation and Dr. Horst briefly reviewed the theory.

Amanda did some work on the distribution system but she needs both information from the other designs and she would like the layout of the village. Dr. Horst suggested that she contact Warm Heart weekly to remind them she needs this design so we can get it in a timely manner. In the meantime, she will work on the basic design using the standards of pressures from household sinks rather than fire systems.

The Dean allocated $400 to Dr. Horst’s senior project groups. It was determined that the money should cover the hotel rooms putting three people in a room. Unfortunately, gas and food may not be covered if the groups decide to go.

Finally, the group will be presented the project to TCNJ EWB Chapter and receive any help the club is willing to offer though the final design and report will be created and submitted by the senior project group alone.

For the next meeting, the Graph of Flow vs WSEL will be created and the team will start putting together the Senior Project I Report.

Contacts

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Warm Heart Thailand-Office	Physical Address: 290 M. 4 T. Maewan, A. Phrao, Chiang Mai 50190 Thailand	(0)53-017056	Mailing Address: P.O. Box 8, A. Phrao Chiang Mai 50190 Thailand

Safety Essay

The construction of the water supply system will be implemented in Thailand in May of 2012. There are some safety issues that need to be considered. Thailand has a very different culture that needs to be respected. It is important not to upset the local people to avoid confrontation. Research will be done to avoid misunderstandings. For instance, certain colored clothing represents political parties which have caused conflict to break out in the country in the past. Also, criticism of the king may result in a confrontation.

The construction has potential safety hazards. All students must have appropriate apparel when constructing. Some necessary clothing apparel includes long sleeves and long pants, work boots and hats. Bug spray and sun screen must be applied regularly. This is very important since mosquitoes in the area may have malaria and the tropical area means the student are more vulnerable to UV rays.

For the construction of the piping system, it will be required that the worker knows how to use the appropriate tool, especially in terms of power tools. There needs to be a safe area around the worker to ensure that no one gets hurt. In case there is a small accident, a first aid kit should be always available. Once in Thailand, the location of the nearest hospital needs to be determined in case a serious accident should occur. Warm Heart World Wide or the village will provide transportation in any incident that it is required.

Appendix C: Methodology Pictures

Stream Cross Section (Proposed Source)

Stream Waterfall at Source

Surveying Data from Day 1: Water Source to Road

Points	Distance Between BS and FS	Back Sight	Front Sight	Elevation Change
Planned Water Tank Location	14.8	1.36	3.51	-2.15
	19.8	0.33	3.15	-2.82
	54.6	0.91	0.17	0.74
	40	1.22	3.02	-1.8
	15.2	0.19	3.22	-3.03
	10.4	0.72	3.74	-3.02
	17	0.34	0.29	0.05
	24.6	3.25	1.5	1.75
	35.7	1.22	1.47	-0.25
	39.9	0.36	1.74	-1.38
	44.6	0.14	2.86	-2.72
	20.5	3.6	0.22	3.38
	39	3.25	0.69	2.56
	45.4	2.2	2.38	-0.18
	24.6	0.09	3.42	-3.33
	24.5	0.14	3.14	-3
	26.5	0.19	2.87	-2.68
	24.4	0.03	3.62	-3.59
	47.7	0.26	3.82	-3.56
On Road	249.2	0.68	1.55	-0.87
On Road	79.5	2.45	2	0.45
Total Distance (meters)	897.9		Total Elevation Change (meters)	-25.45

Surveying Data from Day 2: Storage Tanks to Road

Point Description	Distance	Backsight	Foresight	Elevation Change
Waterfall	*14.8*	1.32	0.91	0.41
	32.8	2.98	0.25	2.73
	16.3	2.78	3.74	-0.96
	22	0.38	2.17	-1.79
	33	3.54	3.98	-0.44
	36.5	0.41	3.54	-3.13
	19	0.15	1.86	-1.71
	31.1	2.65	0.73	1.92
	54.5	1.18	0.35	0.83
	24.5	2.62	0.81	1.81
	20.2	0.57	3.76	-3.19
	21.5	0.24	3.8	-3.56
	39.4	0.3	3.6	-3.3
	21.5	0.24	3.59	-3.35
	66.4	0.36	3.53	-3.17
	53.5	0.1	3.23	-3.13
	44.8	0.63	2.3	-1.67
	100.4	0.46	3.68	-3.22
	70.8	0.76	1.07	-0.31
	53.1	0.85	1.41	-0.56
	23	2.11	0.55	1.56
	22.3	1.46	1.82	-0.36
	20.6	0	2.12	-2.12
	29.3	0.61	1.77	-1.16
	30	1.45	2.08	-0.63
Road/Trail-head	*81.5*	0.68	1.77	-1.09
				-29.59
	982.8		Elevation change-Path to stream bed	1.63
			Total Elevation Change	-27.96
Total Distance	1880.7			

Surveying Data of River Cross Section at Source

River Cross Section		
Point	Horizontal Coordinate (meters)	Elevation (meters)
0	0	0.4
1 (River Bank when low)	7	1.7
2	9.6	2.42
3	11.12	2.66
4	12.64	2.74
5	14.16	2.34
6	15.68	2.61
7	17.2	1.88
8	18.72	1.02
Max Depth of Stream	0.3	

Surveying Data Upstream

Up Stream		
Point	Horizontal Coordinate (meters)	Elevation (meters)
	32	2
Max Depth of Stream	0.1	

Weir Measurements

Down Stream Weir		
	Inches	Meters
Width	44	1.1176
Height	19	0.4826
Area	836	0.53935376
Flow	1.173550744	

Tank Measurements

Tank Number			
Diameter	1.2		
Height	1		
Volume	1.130973355		
Volume 4 Ring	4.523893421	Number Tanks	14.27089
Volume 5 Ring	5.654866776	Number Tanks	11.41671

Water Usage Data of Nong Pit

ลำดับ	ชื่อ-สกุล (Name)	บ้านเลขที่	หมู่ที่	ก่อนใช่น้ำ (Begin)	หลังใช้น้ำ (End)	รวมใช้น้ำ (Total)	หน่วยละ (Cost/Unit)	รวมเงิน (Total Cost)
1	นายทา ผัดแก้ว		2	288	289	1	5	10
2	นายครรชิต มหานิล		2	915	915	0	5	10
3	นายชูชาติ ถุงคำ		2	4	4	0	5	10
4	นายนิมิตร เมืองแก้ว		2	77	77	0	5	10
5	นายอุทัย ทองฤทธี		2	481	485	4	5	20
6	นายใจ๋ หลวงปา		2	425	425	0	5	10
7	นางบัวลอย คำมูล		2	26	27	1	5	10
8	นายก้อน ประกิจ		2	421	423	2	5	10
9	นายชาณรงค์ สิทธิกุล		2	84	87	3	5	15
10	นายดี วัตรสุข		2	566	569	3	5	15
11	นางบัวคำ นุวัง		2	9	10	1	5	10
12	นายพรชัย พลอยหนุน		2	908	913	5	5	25
13	นางดี บัวเที่ยง		2	873	876	3	5	15
14	นายแก้ว บัวเที่ยง		2	471	477	6	5	30
15	นายเจริญ วัตรสุข		2	934	936	2	5	10
16	นายศรีวรรณ ประกิจ		2	48	48	0	5	10
17	นายสม บุญเป็ง		2	28	33	5	5	25
18	นายประพันธ์ เดชะอูป		2	665	666	1	5	10
19	นายถาวร บุญทราย		2	105	108	3	5	15
20	นายกิตติ กิติวงค์		2	853	860	7	5	35
21	นายสม บุญทราย		2	294	306	12	5	60
22	นายบุญเรือง เดชะอูป		2	27	39	12	5	60
23	นางสมหมาย สุ่มมาตร์		2	419	419	0	5	10
24	นายวัย ทองฤทธิ์		2	424	434	10	5	50
25	นายดวงจันทร์ พลอยหนุน		2	664	668	4	5	20
26	นายคำปัน พลอยหนุน		2	269	269	0	5	10

27	นางบัวผัด เปี้ยหล้า		2	607	607	0	5	10
28	นายพุทธ พลอยหนุน		2	101	101	0	5	10
29	นายพิษณุ สร้อยศรี		2	251	260	9	5	45
30	นายคำบาล ทองฤทธิ์		2	299	314	15	5	75
31	นายธวัช บุญทราย		2	263	268	5	5	25
32	นายประทอน บุญทราย		2	129	129	0	5	10
33	นายถนอม บัวเที่ยง		2	521	526	5	5	25
34	นายคำปิง ศรีคำปัน		2	930	936	6	5	30
35	นายใหล พลอยหนุน		2	713	717	4	5	20
36	นายเชาว์ อาพร		2	975	984	9	5	45
37	นายคำปัน เป็งน้อย		2	401	412	11	5	55
38	นายศรี แสงมมต์		2	215	215	0	5	10
39	นายดวงจันทร์ ประกิจ		2	261	272	11	5	55
40	นายบุญทา ประภา		2	149	162	13	5	65
41	นายสมบัติ วรรณกอง		2	621	631	10	5	50
42	นายหมื่น มหานิล		2	175	186	11	5	55
43	นายชัย ประภา		2	333	338	5	5	25
44	นายสม ประภา		2	734	745	11	5	55
45	นายต๋าคำ เดชะอูป		2	591	597	6	5	30
46	นายอ้าย แสงสิงห์		2	119	119	0	5	10
47	นายใจ๋ หลวงปา		2	900	997	97	5	485
48	นายปุ๊ด ประกิจ		2	454	458	4	5	20
49	นายบุญเลิง แดนพนา		2	933	947	14	5	70
50	นางธรรมวรรณ ทองฤทธิ์		2	246	258	12	5	60
51	นายมานิตย์ เดชะอูป		2	127	129	2	5	10
52	นายดี ใหม่คำ		2	188	191	3	5	15
53	นายถวิล สุเมย์		2	376	376	0	5	10
54	นายยูน บุญทราย		2	90	92	2	5	10
55	นายอินทร์ บุญทราย		2	654	663	9	5	45
56	นายแก้ว ศรีนวล		2	308	311	3	5	15
57	นยสิงห์คำ ศรีนวล		2	536	544	8	5	40
58	นางสายทอง ยะคำป้อ		2	581	593	12	5	60
59	นายหล้า จันทร์ต๊ะบุญ		2	498	500	2	5	10
60	นางบัวลอย คำมูล		2	324	328	4	5	20
61	นายจันทร์แก้ว เดชะอูป		2	108	108	0	5	10
62	นายติ๊บ ประกิจ		2	339	347	8	5	40
63	นายถา เหล็กซุป		2	346	354	8	5	40
64	นายสุพจน์ ใหม่คำ		2	483	499	16	5	80
65	นายมุก ทองดี		2	676	669	-7	5	-35
66	นายอนันต์ บุญทราย		2	197	208	11	5	55
67	นายจรัญ มณีโชติ		2	204	207	3	5	15

68	นายสมศักดิ์ ประกิจ		2	190	194	4	5	20
69	นางแสง บุญเรือง		2	601	606	5	5	25
70	นายสมยง พลอยหนุน		2	870	873	3	5	15
71	นายยงยุทธิ์ ปันติ๊บ		2	15	16	1	5	10
72	นายคำ ปันติ๊บ		2	160	160	0	5	10
73	นายนิมิตร เมืองแก้ว		2	369	374	5	5	25
74	นายอินถา บุญทราย		2	692	703	11	5	55
75	นายวุฒิ เป็งน้อย		2	999	1004	5	5	25
76	นายคำปัน แสงสิงห์		2	146	148	2	5	10
77	นางจำ ปันติ๊บ		2	128	148	20	5	100
78	นายศรีวรรณ จันทร์ต๊ะ		2	121	121	0	5	10
79	นายถนอม ผัดแก้ว		2	42	43	1	5	10
80	นายจันทร์นวล เดือนมนตร์		2	879	886	7	5	35
81	นายศรี อาภร		2	375	380	5	5	25
82	นายถาวร บุญทราย		2	738	759	21	5	105
83	นายไพโรจน์ สว่าง		2	124	128	4	5	20
84	นาวดวงทอง ปันติ๊บ		2	610	615	5	5	25
85	นางต๋า มหานิล		2	945	951	6	5	30
86	นายอินศร มหานิล		2	113	116	3	5	15
87	นายศรี มหานิล		2	182	190	8	5	40
88	นายอานันท์ ผัดแก้ว		2	658	667	9	5	45
89	นายวิไล ผัดแก้ว		2	489	489	0	5	10
90	นายทองคำ อาภรณ์		2	785	787	2	5	10
91	นายอิ่นคำ มณีโชติ		2	669	672	3	5	15
92	นายดี วัตรสุข		2	98	102	4	5	20
93	นายทา ผัดแก้ว		2	91	91	0	5	10
94	นายจรูญ เดชะอูป		2	334	337	3	5	15
95	นางบัวผัด เปี้ยหล้า		2	23	33	10	5	50
96	นายประพันธ์ เดชะอูป		2	259	270	11	5	55
97	นายเป็ง ชัยชนะ		2	298	306	8	5	40
98	นายแดง เปี้ยหล้า		2	827	831	4	5	20
99	นายสุทัศน์ บูญทา		2	1	2	1	5	10
100	นายสุรพล ผัดแก้ว		2	110	119	9	5	45
101	นายอดิเรก นุวัง		2	542	548	6	5	30
102	นางสมพร บุญเรือง		2	259	259	0	5	10
103	นายบุญมี ยาคุณดี		2	357	368	11	5	55
104	นางบุญส่ง ชัยทอง		2	417	428	11	5	55
105	นางหน้อย เดชะอูป		2	651	656	5	5	25
106	นายจันทร์แก้ว บุญเรือง		2	151	163	12	5	60
107	นายไกรศรี หน่อปัน		2	291	301	10	5	50
108	นายสุทัศน์ บูญทา		2	127	128	1	5	10

109	นายก้อน ประกิจ		2	193	195	2	5	10
110	นางบัวคำ นุวัง		2	560	563	3	5	15
111	นางแสง แก้วตาวงค์		2	132	136	4	5	20
112	นางจำ ปันติ๊บ		2	27	28	1	5	10
113	นายศรีวรรณ จันทร์ติ๊ะ		2	156	156	0	5	10
114	นงคำผง ชัยทอง		2	561	565	4	5	20
115	นายหลวง เดชะอูป		2	262	279	17	5	85
116	นายเงินพร บุญทราย		2	708	714	6<1>	5	10
117	นายทา ทองฤทธิ์		2	47	59	12	5	60
118	นายเขียว บุญทราย		2	332	341	9	5	45
119	นายฉลอง ราชบัญฑิต		2	18	25	7	5	35
120	นายเมือง เดชะอูป		2	725	727	2	5	10
121	นายสุคำ แสนศรีวิชัย		2	291	294	3	5	15
122	นายสมชาย บุญศรี		2	534	540	7	5	35
123	นายสน นุวัง		2	642	649	7	5	35
124	นายไพวัลย์ ประกิจ		2	636	655	19	5	95
125	นายสมพร หม่อนแก้ว		2	274	278	4	5	20
126	นางดี ผัดแก้ว		2	310	321	11	5	55
127	นายมาราศรี นุวัง		2	44	45	1	5	10
128	นายชูชาติ ถุงคำ		2	208	216	8	5	40
129	นายไกรทอง ศรีนวล		2	142	146	4	5	20
130	นายวรพจน์ ประกิจ		2	151	156	5	5	25
131	นายทา ผัดแก้ว		2	324	338	14	5	70
132	นายนวล ศรีนวล		2	34	35	1	5	10
133	นายจันทร์ตา ศรีวิชัย		2	199	207	8	5	40
134	นายวินัย สวนคำ		2	452	454	2	5	10
135	นางหน่อย<ป่าฮิ้น>		2	1	1	0	5	10
136	นายตุ่ม ผัดแก้ว		2	16	17	1	5	10
137	กองทุนหมู่บ้านม.2		2	2	2	0	5	10
138	นางมณเฑียร ดวงงา		2	2	2	0	5	10
139	นายสุพจน์ ใหม่คำ		2	1	1	0	5	10
140	นายทา ผัดแก้ว		2	4	7	3	5	15
141	นายสมบุญ มณีรัตน์		2	816	899	83	5	415
142	นายอุทัย ปัญญานะ		2	710	719	9	5	45
143	บ้านพักครู		2	139	142	3	5	15
144	นางผง ผกาแก้ว		2	536	538	2	5	10
145	นางประจวบ ยะคำป้อ		2	136	147	11	5	55
146	นางนิศารัตน์ เพียรพนัสศักดิ์		2	883	893	10	5	50
147	นายมนตรี มุ่งสวัสดิ์		2	215	214	-1	5	10
148	โรงเรียนหนองปิด		2	198	256	58<38>	5	190
149	นายบุญตัน บรรพกิจ		2	489	486	-3	5	10

150	นายสว่าง ประกิจ		2	253	278	25	5	125
151	นายอ๊อด หน่อนำ		2	156	176	20	5	100
152	วัดหนองปิด		2	733	803	70<10>	5	50
153	นางหงษ์คำ ปุกจันทร์		2	344	365	21	5	105
154	นายสมชาติ ปุกจันทร์		2	78	79	1	5	10
155	นายเรืองเดช ธนะวัฒน์		2	183	210	27	5	135
156	นายดำรงค์ ใจแก้ว		2	782	805	23	5	115
157	นายอินทร์รัตน์ ฟูเกิ้ม		2	535	542	7	5	35
158	อนามัยหนองปิด		2	219	257	38	5	190
159	นายสว่าง ประกิจ		2	21	20	-1	5	10
160	นายสมเพชร อินฟู		2	52	51	-1	5	10
161	นายสมบุญ สุรินทร์รังษี		2	453	460	7	5	35
162	นายไล บุญตันหล้า		2	687	704	17	5	85
163	นายคำมา ประกิจ		2	259	261	2	5	10
164	นางมาลี โอดปาละ		2	414	417	3	5	15
165	นายสมบุญ ไชยกอง		2	124	112	-12	5	-60
167	นางธิดา ทรายมุล		2	241	247	6	5	30
168	นายแสวง ชัยประสิทธิ์		2	27	48	21	5	105
169	นายศรีวรรณ ก้องวงค์		2	797	802	5	5	25
170	นายเมืองมล คำเขียว		2	133	140	7	5	35
171	นายสวาส หน่อนำ		2	864	859	-5	5	-25
172	นายบุญส่ง สิทธิกุล		2	821	835	14	5	70
173	นายเสถียร คำเขียว		2	989	983	-6	5	30
174	น.ส.บัวตอง วันดี		2	14	15	1	5	10
175	นายทอง ประกิจ		2	65	68	3	5	15
176	นายมานิตย์ ขาวผอง		2	107	121	14	5	70
177	นายวินัย ไชยกอง		2	244	237	-7	5	10
178	นายทองเล็ก ปันติบุ่ง		2	962	975	13	5	65
179	นายเป็ง ขอดแก้ว		2	692	705	13	5	65
180	นายเจริญ สามวิล		2	529	533	4	5	20
181	นางจันทรา ปันติบุ่ง		2	294	300	6	5	30
182	นายสมรัตน์ สิทธิ		2	899	926	27	5	135
183	นายสมเพชร อินฟู		2	723	737	14	5	70
184	นายสมชาย จอมแปง		2	898	919	21	5	105
185	นายบุญนาค ขาวผ่อง		2	427	432	5	5	25
186	นางผง ผกาแก้ว		2	17	25	8	5	40
187	นายรุ่ง ผกาแก้ว		2	586	599	13	5	65
188	นางอังสนา ฉัตรทอง		2	238	249	11	5	55
189	นายหนึ่ง ไชยแสง		2	345	357	12	5	60
190	นายจรัญ ขาวผ่อง		2	29	29	0	5	10
191	นายสวิง ประกิจ		2	449	482	33	5	165

192	นายสวาส หน่อนำ		2	680	705	25	5	125
193	น.ส.บัวตอง วันดี		2	701	729	28	5	140
194	นายเมืองมล อุปคำ		2	212	214	2	5	10
195	นายบุญส่ง คำเขียว		2	183	194	11	5	55
196	นายสมบุญ ทนงค์กิจ		2	445	455	10	5	50
197	นายสุทิน สิทธิกุล		2	112	112	0	5	10
198	นายสิงห์คำ กันธะวิรส		2	503	510	7	5	35
199	นายจันทร์ สุภาศร		2	578	585	7	5	35
200	นายแดง พรมใจ		2	22	22	0	5	10
201	นายแดง งุนคำ		2	482	482	0	5	10
202	นางธิ งุนคำ		2	693	696	3	5	15
203	นายยืน สิทธิกุล		2	856	686	12	5	60
204	นางสุกันธา พรมใจ		2	120	138	18	5	90
205	นายอุดม พรมใจ		2	594	617	23	5	115
206	นางก๋องคำ แผนทอง		2	414	419	5	5	25
207	นายสว่าง ประกิจ		2	406	413	7	5	35
208	นายถนอม คุณยศยิ่ง		2	183	188	5	5	25
209	นางชุ่มใจ ประกิจ		2	92	97	5	5	25
210	นายเงิน มูลวอ		2	184	188	4	5	20
211	นายยงยุทธ ผกาแก้ว		2	231	251	20	5	100
212	นายจำรัส วงค์ทันใจ		2	69	98	29	5	145
213	นายดวงสอน ประกิจ		2	929	954	25	5	125
214	นายแสง ศรีมูล		2	202	203	1	5	10
215	นางเป็ง ทนงกิจ		2	195	208	13	5	65
216	นายวิทยา สิทธิ		2	3	7	4	5	20
217	นายวิทยา สิทธิ		2	4	8	4	5	20
	Total for one month (cubic meters)					1614		
	Month					12		
	Total for one Year (cubic meters)					19368		
	Average Daily Use (cubic meters)					53.8		