Designing a Conservative Water Distribution System for Igunda and Nyanzwa Village

ME 3080 - Design for Life: Water in Tanzania, January 2018

Becky Nelson
Hayley Ortbals
James Trebesch

College of Science and Engineering
University of Minnesota
Minneapolis, MN 55455

Figure 1: The full Igunda team at the water committee meeting. (James Trebesch, January 2018)

Executive Summary

The purpose of this project is to design a water system to supply the villages of Igunda and Nyanzwa with potable water for drinking and cooking. Currently, villagers are mainly using bacteria-contaminated sources for consumption, resulting in illness and death. During our group's visit to the area, the only source of clean water was a hand-pump shared by the 6,400 residents. Because of the high-demand and difficulty for villagers to reach this hand-pump, many collect water from the nearby Great Ruaha River and Little Ruaha River, which both have a history of causing illness and tested positive for harmful bacteria. The current government-funded system is also fed by this contaminated water. The two villages are located in a horse-shoe shaped valley. The elevation grade slopes gently downward as one travels north through the villages. These geographic attributes make Igunda and Nyanzwa an ideal location to implement a water system.

The proposed system is comprised of a borehole and submersible pump that supplies water to a storage tank at the highest point of the two villages and a gravity-fed main that supplies four distribution points. Another borehole with a hand-pump will provide an additional distribution point with an option for future expansion of the system using this borehole as a water source. The distribution points cover important community buildings, such as the medical dispensary and primary school, along with locations in each sub-village of the main population center of the area. The two sub-villages not covered by the proposed system, Majengo and Kidohoho, have had hand-pumps repaired or installed since our group's visit in January and currently have access to clean water.

The system is powered by 2 solar panels placed on the roof of the Nyanzwa primary school, and will run for approximately 8 hours per day. With a conservative estimate of 1400 liters per hour as the output of the well, the 4 distribution points connected to the gravity main system can serve 1200 people per day, and the hand-pump in Idodi can serve and additional 500 people per day. Our group hopes that providing these residents with accessible and potable water will dramatically improve the health, productivity and well-being of the villages of Igunda and Nyanzwa.

Table of Contents

1. Contact Information

Name	Phone # (All Begin with 062)	Position
Village Leadership		
L. R. Mwafute	084 8582	Pastor Elect
Kawsa Mageka	132 3674	-
Donald Amipu	026 1786	VEO
Isacic Mwamba	547 1250	M/K/Balaza Kaia
Abedi Magembe	524 4494	Mjumbe
Maqreiiw Qoupo	-	Mjumbe
Lavyeruo ame	-	Mjumbe
Shnui Muiilai	164 8172	-
John Lugondi	547 1037	Mjumbe S/K
Tosiao Makova	124 6193	-
Simon Nya	164 9421	Fundi Bomba
Wazia A. H.	931 9749	Mjumbe
Salehe D. Lwendo	124 0949	Mjumbe, S/K
Daniel Wolfe	556 0701	M/Kati/Kiton GOJ
Kasiahi Mwkeakole	557 8463	-
Hassan Moembul	164 8386	Mjumbe Igunda
Tedy Choabi	399 9565	Mjumbe
Damas Mwongi	-	Mjumbe
Nikodem Makeja	346 8016	Mjumbe
Coodwini Maketa	165 0910	Pastor Lutheran
Instructors		
Dr. Catherine French	763-227-6575	cfrench@umn.edu
Dr. Ken Smith	651-336-7273	klsmith@alum.mit.edu
Dr. Paul Strykowski	612-716-8596	pstry@umn.edu
Ethan Brownell	-	brow3885@umn.edu
Student Engineers		
James Trebesch	612-356-3704	jamestrebesch@gmail.com
Matthew Oldenkamp	907-350-2742	olden060@umn.edu
Clay McCarthy	651-336-9546	mccar843@umn.edu
Audrey Sebastian	952-838-5968	sebas032@umn.edu
Hayley Ortbals	816-352-5799	ortba001@umn.edu
Becky Nelson	612-310-5640	nels8898@umn.edu

2. Project Profile

2.1 Project Location

The Igunda area is approximately 10 hours by bus from the Tanzania Capital of Dar es Salaam. The village is 30-45 minutes off the trans-Africa highway down a bumpy gravel road. The village is at the end of the road with no through traffic. There is no electric power currently installed or planned. It is a remote village with subsistence farming comprising most of the economic activity in the area.

Region: Iringa, Tanzania

Villages: Nyanzwa & Igunda

Coordinates:

Nyanzwa Center: 7.354683°S, 36.281450°E

Igunda Center: 7.347917°S, 36.286217°E

Climate: Elevation ~550m, wet season December-April, dry season May-November.

Figure 2.1 depicts the location of Igunda and Nyanzwa relative to the Iringa region of Tanzania. A more detailed map of the villages' major population center can be seen in Figure 3.1.

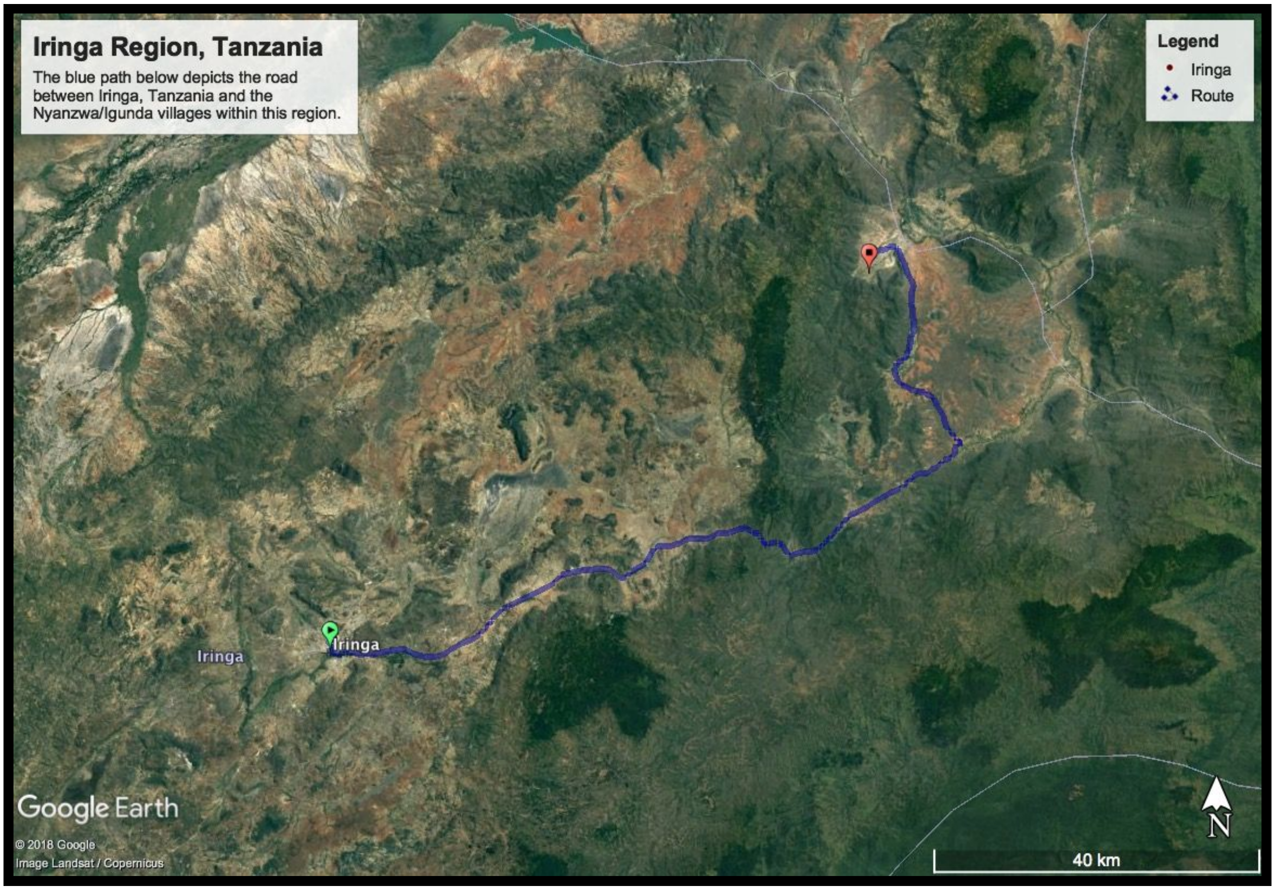


Figure 2.1: Map of Iringa Region (Google Earth, Audrey Sebastian 2018)

2.2 Projected Budget

Table 2.1. Estimated budget for the system (in US dollars)

Material Costs	$20,514.00
Labor Costs	$2,570.00
In-Kind Contributions	($974.00)
10% Contingency	$2,211.00
Total Required Funds	$24,321.00

3. Background

3.1 Village Structure

Upon arriving in Igunda and meeting with the local water committee, our group came to understand that Igunda and the neighboring village of Nyanzwa are very closely linked. They use the same water system, water committee, schools and dispensary. It was obvious that the villages have a deep bond, as the villages were recently split into two different entities due to population growth. We learned that Igunda has six sub-villages: Madukani, Balali, Idodi, Beku, Majengo, and Kidohoho. The population of Igunda alone is 3,200, and Nyanzwa also has a population of approximately 3,200. Like Igunda, Nyanzwa has six sub-villages: Temela, Mpilipili, Nyembeni, Minazini, Sokoni, and Mpakani. The major population center of these two villages lies within a 4 km^2 area, largely concentrated at their border. This area is shown in Figure 3.1, a hand drawn map of the region. With such a large population and distribution, it is clear that multiple phases of water systems will be necessary to meet both the village needs, and the corresponding Tanzanian guidelines.

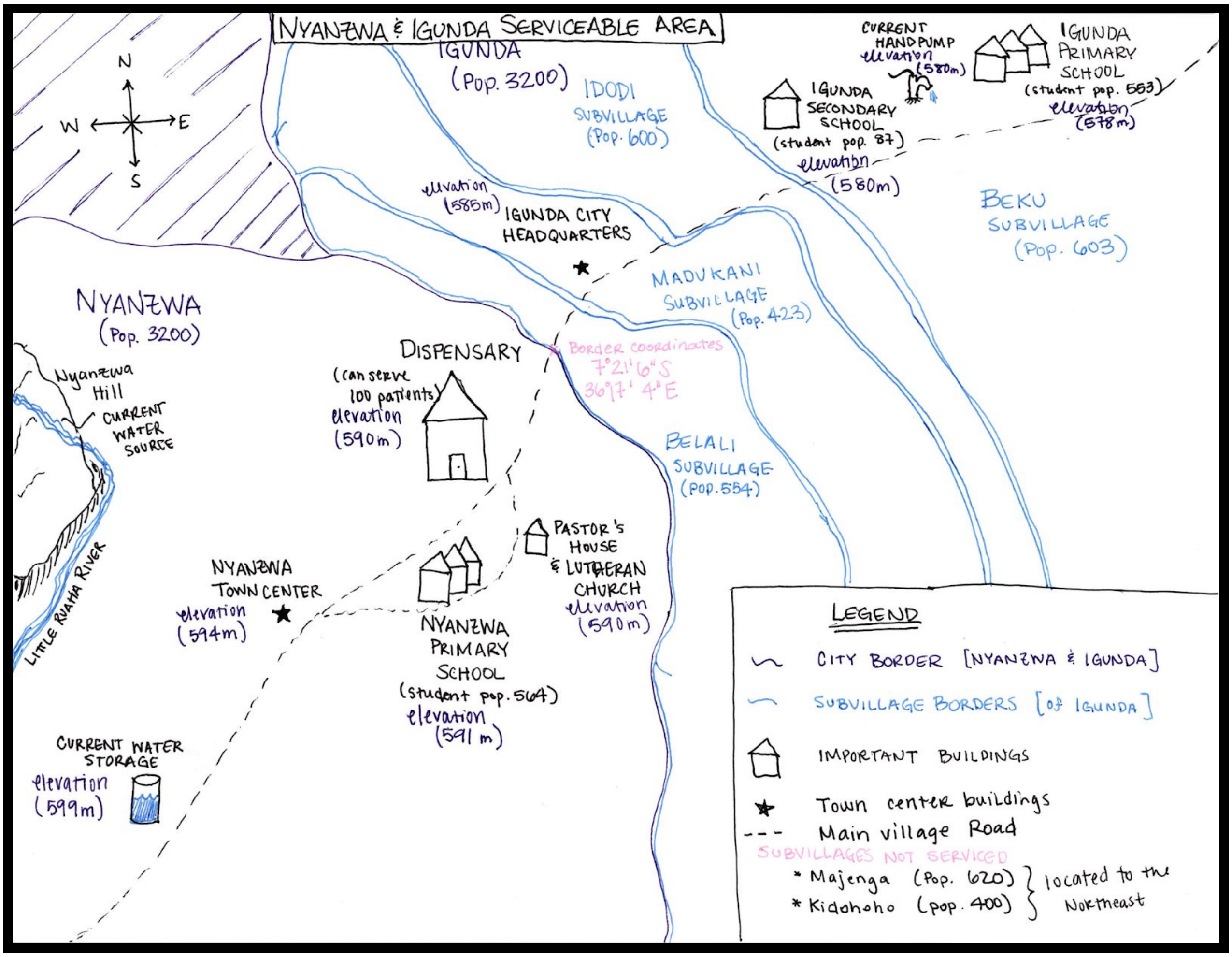


Figure 3.1: Major population center of Nyanzwa & Igunda (Audrey Sebastian, February 2018)

3.2 Current Water System

The current system in the Nyanzwa and Igunda villages begins at the Little Ruaha River just south of Nyanzwa. It was implemented approximately 10 years ago by the Tanzanian government. The system starts in a vegetated area in the surrounding mountains to the southwest of the village. The inlet to the system sits in a concrete cistern placed in the river to filter out mud and debris. However, during the rainy season, the cistern fills up with mud and the entire system is unusable. During the rainy season, the system annually fails due to the age of the system, the haphazard construction and the placement of the piping. During our visit, a large section of piping was washed away and went missing. This renders the system useless until the residents can recover the missing pipe out of the river. The local fundi communicated that once the river level goes down they will locate the missing pipe and restore the system to normal use. In Figure 3.2.1, a typical repair can be seen. Fabric and an inner tube have been used to connect two dissimilar pieces of water piping together.

Figure 3.2.1: Common repair to the government system (James Trebesch, January 2018)

Within several weeks of our visit, Ethan Brownell was in the region supervising the placement of a hand pump in the associated, yet remote sub-village of Kidohoho. While he was working there it was reported that four residents of the area had died due to water related illness. It was understood that the contaminated water came from the broken government source, which had been repaired and put back into use.

Figure 3.2.2: A portion of the aqueduct used for agriculture and the piping for village water (James Trebesch, January 2018)

Figure 3.2.3 shows the water source near the intake for the government system along with a portion of the piping. Two of the most important aspects communicated here are the amount of particulate in the water and the placement of the piping. The water quality is concerning due to the amount of debris it contains. The silt and mud the water carries cause problems for the free flow of the water through the pipes. During our observatory hike, we observed monkey feces along the banks of the river. When the feces are washed into the river, bacteria and contaminants can be carried into the water and transported to the distribution points in the villages. Another item of interest is the placement of the piping. Due to the piping's placement, it is vulnerable to damage if the flow of water becomes too turbulent. A washout caused the failure that rendered the system useless while the team visited.

Figure 3.2.3: The government water source and a portion of piping (James Trebesch, January 2018)

The government system is more effective during the dry season and serves 6 distribution points throughout the two villages. The water was analyzed using a bacterial water test and found to be contaminated. This information was reinforced by the water committee's claim that many villagers become ill after drinking the water from the taps. This river source is not filtered or treated in any way. The government distribution points are the same as drinking straight out of this river. The goal of our design is to provide safe water without treatment stations to make the solution as simple and economical as possible.

In Figure 3.2.4, the river water and the sample with testing mixture are pictured. The sample "incubated" for 24 hours in the pocket of a team member to keep the sample warm and to induce bacterial growth if present. The results of the test can be seen in Figure 3.2.5. The black color indicated a large amount of bacterial growth occurred in the 24 hour period. The test results demonstrate that the water is not potable. This water is suitable for agricultural irrigation, but is not safe for human consumption.

The water from the borehole hand pump in Beku tested negative for bacterial cultures. Our group assumes that the aquifer below the villages provides a viable source for safe drinking water.

Figure 3.2.4. Becky Nelson with a river water sample being tested for contaminants (James Trebesch, January 2018)

Figure 3.2.5. Becky Nelson with the incubated water from the river source (James Trebesch, January 2018)

There are two existing hand pumps in the Igunda village. The first one is the previously-mentioned site in Beku; the other is in the sub-village of Majengo. During our visit, the Majengo pump was not working due to a broken O-ring. This is a relatively straight-forward repair if the replacement part and fundi are available. The pump in Beku is fully functional and the entire village relies on it for clean water. This pump can be seen in Figure 3.2.6. A biological water test showed that the water from this pump is clean and safe. The estimated output of this well is 1400 liters per hour. If the hand pump is operated for 12 hours a day it provides less than five liters of water per person, per day, which is well below the Tanzanian guideline suggestion of 25 liters per person per day.

Figure: 3.2.7: Clay McCarthy collecting a water sample from the hand pump in Igunda. Testing indicates that the water is safe to drink. (James Trebesch, January 2018)

Since our visit in January, Saint Paul Partners have installed a third hand pump located in the Kidohoho sub-village center. The residents of Kidohoho previously had to travel two to three kilometers to reach clean water at the hand pump in Beku. Due to this prohibitive distance, their main water source was the Great Ruaha River. The river is pictured in Figure 3.2.7. This water also shows signs of contamination, and the residents are at risk of crocodile attacks near the riverbank.

Figure 3.2.7: Ethan Brownell in the Kidohoho sub-village, at the Great Ruaha River (James Trebesch, January 2018)

3.3 Demand and Priorities

The majority of the residents in the villages do not have adequate access to clean water. The large spread of the villages can be seen in Figure 3.3.1. Residents in the southwest part of the region must walk several kilometers each way to get clean water. These distances are well beyond the Tanzania proximity guidelines for water systems.

The residents who have seasonal access to the current government system are supplied with contaminated water which routinely causes sickness or death. Between the time we visited the villages in January 2018, and as of March 2018, it has been reported by Ethan Brownell that four fatalities have occurred due to water-related illnesses.

It is not practical for the majority of the villagers to use the clean water source at the Beku hand pump due to distance. All villagers need a water source that is reliable, accessible and safe to drink. Our group hopes to address this critical situation.

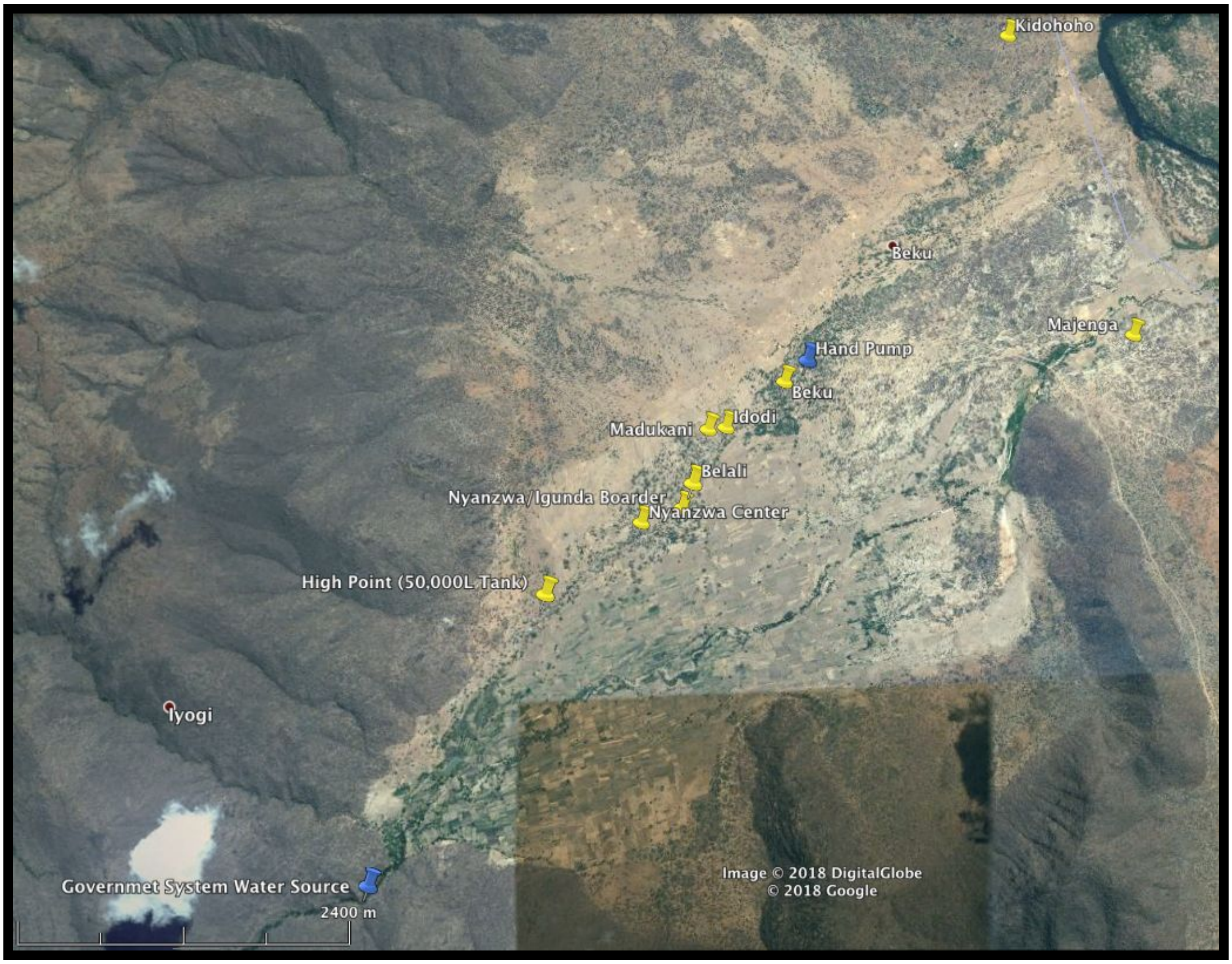


Figure 3.3.1: Pertinent locations in the region (Google Earth, Audrey Sebastian 2018)

In addition to the requirements for safe drinking water, patients of the dispensary need clean water to recover more easily for common ailments. The children and staff of the villages' three schools need a source of water within close proximity. This will allow them to complete an entire day's school tasks without having to take prolonged breaks to acquire clean water. The water committee also urged our group to supply distribution points in the most central and populus part of each sub-village. Nyanzwa and Igunda will both benefit from such a system.

4. Tanzania Design Criteria

The Tanzania guidelines are a set of suggestions that engineers use to help determine the type of water system that will meet the residents' needs. They are very helpful in providing the criteria for an optimal water system. At times, these criteria are not feasible due to the many challenges that present themselves when planning a system in less than optimal conditions. Our design goal is to provide access to potable water to a maximum number of residents.

This design complies with the guidelines as close as possible with consideration to varying actual conditions. Due to the population of the area and the geographical features, adaptations need to be made with regard to the guidelines. The guidelines specify that a system should provide each person with 25 liters of water per day. Our group determined that 10 liters per person per day is sufficient for consumption and cooking, while other sources may be used for additional water needs.

Although the Tanzania guidelines are not followed exactly, best efforts have been made to do so. The guideline suggests that residents do not have to walk more than 400 meters to a distribution point (DP). This design has four DPs which meets the travel distance for 1,200 to 2,000 villagers. The distribution points that we have proposed will provide 10 liters of water per day for the 1,200 residents serviced by the submersible pump system. Ten liters of water per minute are supplied to each tap at a distribution point, and the velocities of the water in the pipes are greater than 0.5 meters per second while not exceeding 1.5 meters per second.

Table 1: List of Sub-village Populations and Infrastructure Users

Location	People Per Location	2018			2018 Estimate (2% Population Increase)		
		Population	Demand per person per day (L/person/day)	Demand per Day (L/day)	Population	Demand per person per day (L/person/day)	Demand per Day (L/day)
Dispensary	Patients	100	10	1000	158	10	1585
	Staff	3	10	30	5	10	48
Nyanzwa Primary School	Students	564	10	5640	894	10	8939
	Staff	7	10	70	11	10	111
Beku		603	10	6030	956	10	9557
Madukani		423	10	4230	670	10	6704
Balali		554	10	5540	878	10	8780
Iodi		600	10	6000	951	10	9509
Nyanzwa		1150	10	11500	1823	10	18226
Conservative Project Demand	Phase 1	1000	10	22510	1020	10	35676

5. Proposed Systems

5.1 Key Assumptions

For this design, several assumptions were made. In February 2018, a mud rotary well was drilled in the Igunda sub-village of Kidohoho and had a measured lower bound output of 1400 liters per hour. We assumed that our system will have the same output as the Kidohoho well, since the yield is unknown until a well is drilled. The well output is the major difference between our conservative design and the optimistic design proposed by the other Igunda team. We also assumed that a mud rotary well would work for our system since it has historically been successful in this area. Igunda and Nyanzwa are not connected to the electric grid, so our system would use solar power for the pump and would be able to operate 8 hours a day.

Based upon the measured amount of 1400 liters per hour available at the current hand pump located in Beku, the team determined that 1,120 residents can be served 10 liters of water per person per day from the proposed water system and another 500 residents from the hand-pump in Idodi. If it is found that upon drilling and testing of the borehole that the well can produce more water than estimated this design can be expanded to the second phase, or the the optimistic design from the other team can be implemented.

5.2 Lower Bound Output Proposal (Two-Phase System)

The goal of this system is to provide water to Igunda by drilling at two locations, which are marked as Primary School and Idodi in Figure 5.1. During the first phase, a gravity fed solar-powered system will be implemented at the Nyanzwa drilling location and will distribute water to the dispensary, Nyanzwa primary school, and the Igunda sub-villages Balali and Madukani. The two solar panels used to power the submersible pump will be placed on the roof of the primary school. There will be four distribution points from two different tanks: one 10,000L tank sitting on a five-meter tall riser next to the primary school and another 5,000L tank for the dispensary. A hand pump will be installed at the Idodi drilling location to provide water to the sub-villages that are not being served by the first solar-powered system. During the second phase, the Idodi bore hole would be converted into a second gravity fed system and would serve the two remaining sub villages, assuming the water committee is confident they can maintain two systems.

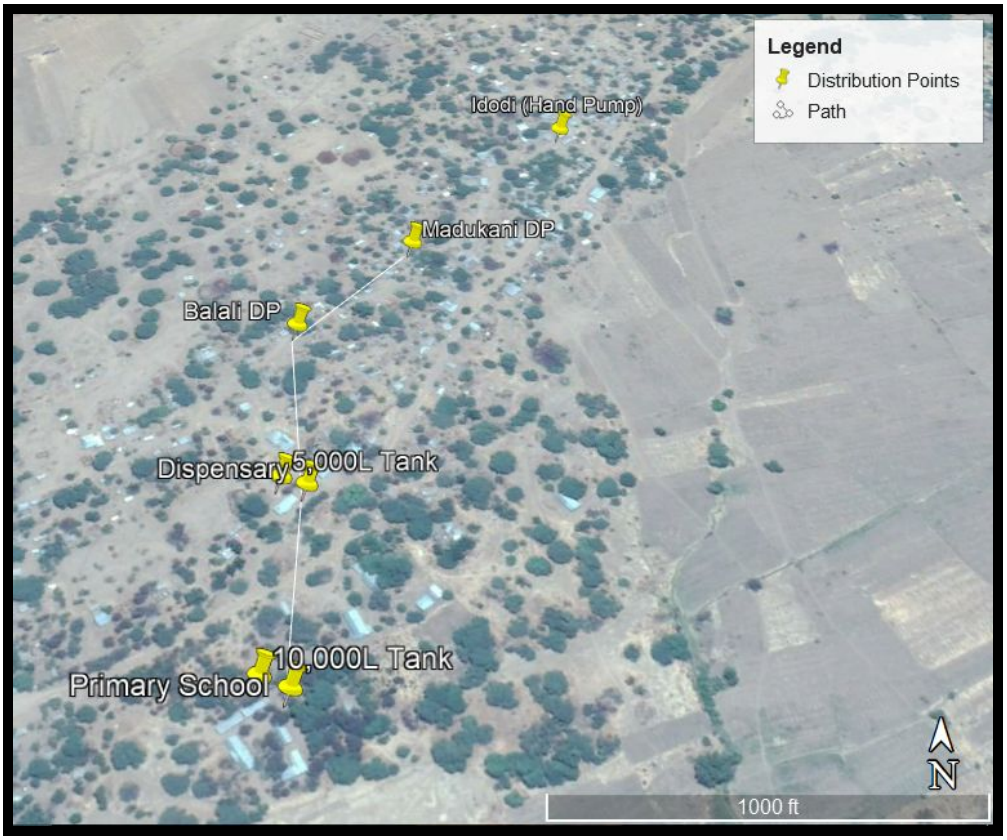


Figure 5.1: Map of drilling locations and distribution points for the first phase of the two-phase system. (Google Earth, Becky Nelson January 2018)

The proposed tank locations and distribution points for the first phase are shown in Table 5.1. The two tanks are located next to the distributions points with the highest elevation in this system. This geographic area has little elevation change, which is shown in Table 5.2. To get enough head to distribute water to the four distribution points, the 10,000L tank will need to be placed on five-meter tall concrete risers, and the 5,000L tank will need a two-meter tall riser. Throughout the system, 32 mm outside diameter HDPE pipe will be buried 1 meter deep. Figure 5.1 shows the path the pipe will follow. This system will serve 10 liters of water a day to approximately 1,200 people in addition to the primary school and dispensary. The handpump in Idodi is estimated to serve 500 people per day.

Table 5.1. Distance between prospective system distribution points and elevation changes.

From	To	Distance (m)	Elevation Change (m)
10,000L Tank	Primary School	1	-5.00
5,000L Tank	Dispensary	1	-2.00
Nyanzwa Primary School	Dispensary	180	+0.05
Dispensary	Balali DP	170	-2.63
Balali DP	Madukani DP	135	-2.32

Table 5.2. Elevation values of critical locations measured from the highest point in the village.

Location	Absolute Elevation Change (m)	GPS Locations
Concrete Tank	0	7° 21' 35.61" S, 36° 16' 28.87" E
Primary School	-11.92	7° 21 '16.77" S, 36° 17' 1.48" E
Dispensary	-11.87	7° 21' 10.94" S, 36° 17' 1.97" E
Balali DP	-14.5	7° 21 '5.24" S, 36° 17' 1.79" E
Madukani DP	-16.82	7° 21' 1.71" S, 36° 17' 5.41" E

In the second phase, another gravity fed system will be implemented using the borehole from the Idodi hand pump, assuming a high enough well output. This will serve the sub-villages of Idodi and Beku with clean water, which together have a population of 1200 people, as well as a primary and secondary school. The number of distribution points depends on the well output of this bore hole, which can be tested during the first phase. It would be advantageous to convert the hand pump to a distribution system because it would be able to serve more people safe water, and the system would come closer to meeting the Tanzanian design guidelines. The community also wanted at least one distribution point in every sub village; while this was not feasible in the first phase, it could be completed during the second phase. Two separate systems could prove to be a challenge to maintain for the community, so it will be important to ensure the water committee is sustaining their first system before a second one is built. The water committee would have to be diligent in collecting funds and coordinating maintenance when needed for the system.

6. Design Impact

Due to the dramatic under-service that the village currently experiences, any improvement in water quality and volume will have a dramatic and recognizable benefit to the residents of Igunda and Nyzawna. There are various societal and economic impacts that need to be recognized and addressed throughout the engineering and implementation phases. The most pertinent items that helped us determine what type of system to design are to: improve the lives of the residents, ensure all religious and political groups receive access, serve significant geographic locations, and provide a system that is financially viable.

The distribution points were chosen based on conversations with the water committee during our site visit. One of the most important locations that needs clean water is the dispensary. The dispensary is the one location in the area where child birthing services and basic medical care are offered. Clean water is a very important part of providing basic medical care. Providing a clean water source to this critical piece of community infrastructure will have the most dramatic long term impact on the village. The distribution point near the Nyanzwa primary school will increase productivity of students while ensuring that they are supplied with clean water during the school day. The remaining distribution points were placed in densely-populated locations in the sub-villages of Balali and Madukani to serve a maximum number of people.

One of the key considerations of the system is that the villagers have fair and equal access to the water. Although we were associated with the Lutheran church, the water system should be available to all religions and tribes. It is important to establish that this system is a public project for the good of all people, and continued education should be provided once the system is in place so that all have access to its benefits. This will help assure community ownership so that all residents foster a vested interest in clean water.

Although the proposed system will be mostly funded by a group from outside of the village, ensuring the financial accountability of the water committee is absolutely necessary to ensure the village can maintain the system independently. Based on the incredibly warm reception and interactions we experienced during our visit, the villagers are excited to work with Saint Paul Partners and Bega Kwa Bega and are willing to learn about current systems in the Iringa region.

7. Implementation Budget

Table 7.1: Material Costs

Item	Amount	Cost per Unit ($ dollars)	Total Cost ($ dollars)
Materials Transportation	5	225	1125
Distribution Points	4	250	1000
32 mm Pipe (150 m)	1	135	135
Mud Rotary Drilled Well	1	3800	3800
Mud Rotary w/Hand Pump	1	4200	4200
Borehole Pump (Grundfos SQ3-65)	1	2300	2300
Borehole Cover Plate	1	70	70
Solar Panel	2	300	600
Control Unit	1	675	675
Drop Cable (10mm^2 x 4)	50	11	550
Surface Cable (10mm^2 x 4)	30	8	240
Safety Rope (Roll)	1	45	45
Adaptor Set (1.5”)	1	23	23
UPVC Pipe (1.5”)	16	20	320

5,000 Liter Poly-tank	1	350	350
10,000 Liter Poly-tank	1	1360	1360
2 meter tall tower	1	1100	1100
5 meter tower	1	2621	2621
Grand Total			$20,514

Table 7.2: Labor Costs

Item	Price ($ USD)	Unit Basis	Quantity	Total ($ USD)
Pump and Solar Panel Transportation	660.00	Per installation	1	660.00
Pump and Solar Panel Installation	660.00	Per installation	1	660.00
Digging Trenches (1m depth) and Pipe Installation	2.00	Per meter	487	974.00
Review by Tanzanian Engineer	23.00	Per hour	12	276.00
In-Kind Contributions (Labor Costs)	2.00	Per hour	374	-974.00
Total				$1,596

8. Summary and Conclusions

The villages of Igunda and Nyanzwa located in the Iringa region of Tanzania share a close bond. Many of their resources and infrastructure are shared, including schools, the medical dispensary and the water system. Each village has an approximate population of 3,200 people, for a total population of 6,400.

The two villages are in desperate need of safe and clean water. While the existing system installed by the government is functional during the dry season, it is contaminated with deadly bacteria. The surrounding rivers are also not safe to drink from. The only source of clean water available to the villagers during our visit in January was a single hand-pump located in the Igunda sub-village of Beku. Our group hopes to bring more water and distribution points to these communities.

The shared water committee of Igunda and Nyanzwa was excited to meet with our group. Learning about their history of water-related illnesses showed us how important it is to implement a water system that can bring the villagers more accessible, clean water. The water committee has a fee-collection plan in place to maintain the water system, and the community is eager to have a new, functional system.

Our group suggests implementing a two-phased system in the villages of Igunda and Nyanzwa. The estimated cost of the system is $25,295 with $974 of labor digging trenches as an in-kind contribution from the villagers. Therefore, the total required funds for the proposed system is $24,321. Distribution points will serve the medical dispensary on the border of the two villages, the primary school shared by both villages, and the sub-villages of Balali and Madukani. A hand pump will be installed in the sub-village of Idodi that could be converted into a water source for a second phase of the water system in the future. Knowing that the current borehole in Beku produces 1400 liters of water per hour, it is a conservative assumption that our system can serve 10 liters of water to over 1000 people per day. With priority distribution points at the local schools and dispensary, and others placed strategically to serve as many sub-villages as possible, our group hopes to increase the health and welfare of both villages.

9. References

We would like to thank Audrey Sebastian, Clay McCarthy and Matt Oldenkamp for their contributions to this report.

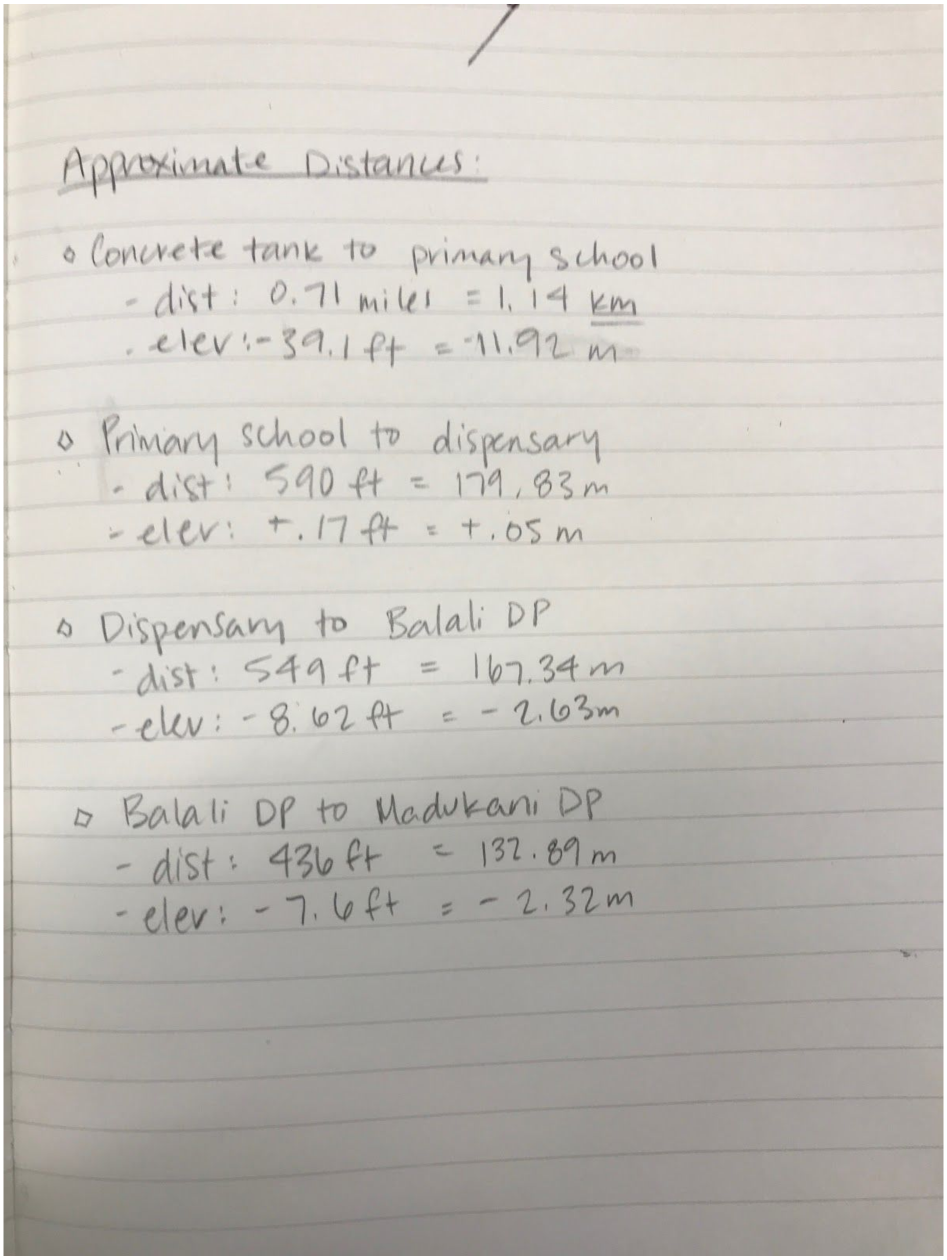
The following online Pump Power Calculator was used:

"Pump Power Calculator." *Densities of Solids*,

www.engineeringtoolbox.com/pumps-power-d_505.html.

APPENDIX

Appendix A: Approximate System Distances



Approximate Distances:

- Concrete tank to primary school
  - dist: 0.71 miles = 1.14 km
  - elev: -39.1 ft = -11.92 m
- Primary school to dispensary
  - dist: 590 ft = 179.83 m
  - elev: +.17 ft = +.05 m
- Dispensary to Balali DP
  - dist: 549 ft = 167.34 m
  - elev: -8.62 ft = -2.63m
- Balali DP to Madukani DP
  - dist: 436 ft = 132.89 m
  - elev: -7.6 ft = -2.32m

Appendix B: Cost Estimates

James Trebesch <trebe012@umn.edu>

Fwd: Approximate cost of a 5 meter tower

Rebecca Nelson <nels8898@umn.edu> Wed, Jan 31, 2018 at 1:02 AM
To: trebe012@umn.edu

Sent from my iPhone

Begin forwarded message:

From: Ken Smith <klsmith@mmm.com>
Date: January 24, 2018 at 11:50:30 AM CST
To: "Rebecca Nelson " <nels8898@umn.edu>, James Snyder <jbsnyder@mmm.com>, "Audrey Sebastian " <sebas032@umn.edu>, "Matthew Oldenkamp " <olden060@umn.edu>, "Clay McCarthy " <mccar843@umn.edu>, "Hayley Ortbals " <ortba001@umn.edu>
Cc: "Dorothy Cheng " <dcheng@umn.edu>
Subject: FW: Re: Approximate cost of a 5 meter tower

Team Igunda – details from Byemerwa to cost out a 5 meter tower!

From: amos byemerwa [mailto:amosbyemerwa@yahoo.com]
Sent: Tuesday, January 23, 2018 10:22 PM
To: Ken Smith <klsmith@mmm.com>
Subject: [EXTERNAL] Re: Approximate cost of a 5 meter tower

Dear All.

I have made the following assumptions to come up with a cost estimate of Tsh. 5,700,750 (USD 2621 approx) for the 5.000 SIM Tank on 5m high raiser. The The tower will have a base slab of reinforced concrete , 300mm thick and a top slab of 200mm. The wall has been proposed to be of concrete blocks (0.45mx 0. 23mx 0.15m).The diameter of the 5,000 litres sim tank is approximately 2.0m. The bottom sbab would be 2.8m x 2.8 m and top slab 2.5 m in diameter. The unit cost of concrete has been estimated to be 350,000 per cubic meter (all inclusive).

S/N	Description	Quantity	Unit	Unit Rate (Tsh.)	Total Cost (Tsh.)
1	Foundation Excavation	Sum			300,000

2	Base Concrete	2.7	m3	350,000	945,000
3	Tank raiser 5.0m	500	blocks	5,000	2,500,000
4	Top slab	1.25	m3	350,000	437,500
5	Transport of materials				1,000,000
	Sub Total				5,182,500
	Miscellaneous + Contingency , Add 10%				518,250
	Grand Total				5,700,750
				USD 2621	

Labour charges are included in the above estimates.

Best Regards.
Eng. A.M.S Byemerwa,

Mobile Tel. +255 0754 332397 .

On Wednesday, January 24, 2018, 3:00:03 AM GMT+3, Ken Smith <klsmith@mmm.com> wrote:

Amos – do you have or can you provide any ball park estimate of the cost of building a 5 meter tower for a 5000 liter sim tank? There is some discussion about Nyanzwa and a possible distribution system designed by students. One question which is largely unknown by us is a representative/very rough cost of such a tower.

Asante,

Ken

Appendix C: EES Code

EES was used to calculated the minimum pipe diameter needed to ensure all pressures were positive and below pipe maximum pressure specifications, which would result in a viable system. Shown below in the results figure, a pipe diameter of 32 mm results in pressures within the correct range.

Conservative System EES Code

```
Function ff(Re, ed)
If (Re >2300) Then
        ff:= 1/(1.8*log10( (ed/3.7)^1.11+6.9/Re))^2
Else
        ff:=64/Re
Endif
End

{Constants}
rho = 1000 {kg/m^3} {density of water}
mu = 0.0011 {Ns/m^2} {dynamic viscosity of water}
epsilon = 0.2/1000 {m} {inner pipe wall roughness}
g = 9.81 {m/s^2}

{System Characteristics}
L12 = 1 {pipe run from tank to first main line DP branch off, m}
L23 = 179.83 {pipe run, m}
L3T2 = 1 {DP to dispensary tank main line branch off, m}
L34 = 166.34 {pipe run, m}
L45 = 132.89 {pipe run, m}
L2D1 = 10 {Branch off 10m from main line}
L3D2 = 10
L4D3 = 10
L5D4 = 10
L3T2b = 10

{Relative Roughness}
ed12=epsilon/d12
ed23=epsilon/d23
ed3T2=epsilon/d3T2
ed34=epsilon/d34
ed45=epsilon/d45
ed2D1=epsilon/d2D1
ed3D2=epsilon/d3D2
ed4D3=epsilon/d4D3
ed5D4=epsilon/d5D4
ed3T2b=epsilon/d5D4
```

```
{Known Elevations from highest village point}
z1 = z2+5 {m}
z2 = -11.92 {m}
zD1 = z2
z3T2 = z2
z3 =  -11.87 {m}
zD2 = z3
z4 = -14.5 {m}
zD3 = z4
z5 = -16.82 {m}
zD4 = z5
z3T2b = 2 {m}

{Volumetric Flow Rates}
Q12 = 0.0003888889 {1400 L/hr to m3/s}
Q23 = Q12
Q3T2 = Q12
Q34 = Q12
Q45 = Q12
Q2D1 = Q12
Q3D2 = Q12
Q4D3 = Q12
Q5D4 = Q12
Q3T2b = Q12


{Area of Pipe Cross-Section; Internal}
d12 = .032 {50mm pipe}
d23 = d12
D3T2 = d12
d34 = d12
d45 = d12
d2D1 = .032
d3D2 = d2D1
d4D3 = d2D1
d5D4 = d2D1
d3T2b = d2D1

A12=pi*(d12/2)^2
A23=pi*(d23/2)^2
A3T2=pi*(d3T2/2)^2
```

```
A34=pi*(d34/2)^2
A45=pi*(d45/2)^2
A2D1=pi*(d2D1/2)^2
A3D2=pi*(d3D2/2)^2
A4D3=pi*(d4D3/2)^2
A5D4=pi*(d5D4/2)^2
A3T2b=pi*(d3T2b/2)^2

{Average Velocities in Pipe Sections}
v12=Q12/A12
v23=Q23/A23
v3T2=Q3T2/A3T2
v34=Q34/A34
v45=Q45/A45
v2D1=Q2D1/A2D1
v3D2=Q3D2/A3D2
v4D3=Q4D3/A4D3
v5D4=Q5D4/A5D4
v3T2b=Q3T2b/A3T2b


{Reynolds Numbers}
Re12=rho*v12*d12/mu
Re23=rho*v23*d23/mu
Re3T2=rho*v3T2*d3T2/mu
Re34=rho*v34*d34/mu
Re45=rho*v45*d45/mu
Re2D1=rho*v2D1*d2D1/mu
Re3D2=rho*v3D2*d3D2/mu
Re4D3=rho*v4D3*d4D3/mu
Re5D4=rho*v5D4*d5D4/mu
Re3T2b=rho*v3T2b*d3T2b/mu

{Call Friction Factor Routine}
f12=ff(Re12, ed12)
f23=ff(Re23, ed23)
f3T2=ff(Re3T2, ed3T2)
f34=ff(Re34, ed34)
f45=ff(Re45, ed45)
f2D1=ff(Re2D1, ed2D1)
f3D2=ff(Re3D2, ed3D2)
f4D3=ff(Re4D3, ed4D3)
f5D4=ff(Re5D4, ed5D4)
f3T2b=ff(Re3T2b, ed3T2b)
```

```
{Boundary Conditions}
P1=0 {Zero gage pressure at source and tanks}
PD1=0
PD2=0
PD3=0
PD4=0
P3T2b=0

{Governing Equations}
(P2-P1) / (rho*g) + z2 - z1 = -V12^2/(2*g)*(f12*L12/d12)
(P3-P2) / (rho*g) + z3 - z2 = -V23^2/(2*g)*(f23*L23/d23)
(P3T2-P3) / (rho*g) + z3T2 - z3 = -V3T2^2/(2*g)*(f3T2*L3T2/d3T2)
(P4-P3) / (rho*g) + z4 - z3 = -V34^2/(2*g)*(f34*L34/d34)
(P5-P4) / (rho*g) + z5 - z4 = -V45^2/(2*g)*(f45*L45/d45)
(PD1-P2) / (rho*g) + zD1 - z2= -v2D1^2/ (2*g) * (f2D1*L2D1/d2D1+K2D1)
(PD2-P3) / (rho*g) + zD2 - z3= -v3D2^2/ (2*g) * (f3D2*L3D2/d3D2+K3D2)
(PD3-P4) / (rho*g) + zD3 - z4= -v4D3^2/ (2*g) * (f4D3*L4D3/d4D3+K4D3)
(PD4-P5) / (rho*g) + zD4 - z5= -v5D4^2/ (2*g) * (f5D4*L5D4/d5D4+K5D4)
(P3T2b-P3T2) / (rho*g) + z3T2b - z3T2= -v3T2b^2/ (2*g) * (f3T2b*L3T2b/d3T2b+K3T2b)


{Compute P2 in psig}
P2psig=P2*14.7/101325

{Compute P3 in psig}
P3T2psig=P3*14.7/101325

{Compute P3T2 in psig}
P3psig=P3*14.7/101325

{Compute P4 in psig}
P4psig=P4*14.7/101325

{Compute P5 in psig}
P5psig=P5*14.7/101325
```

Unit Settings: SI C kPa kJ mass deg

A12 = 0.0008042	A23 = 0.0008042	A2D1 = 0.0008042	A34 = 0.0008042	A3D2 = 0.0008042	A3T2 = 0.0008042	A3T2b = 0.0008042	A45 = 0.0008042	A4D3 = 0.0008042	A5D4 = 0.0008042
d12 = 0.032	d23 = 0.032	d2D1 = 0.032	d34 = 0.032	d3D2 = 0.032	d3T2 = 0.032	d3T2b = 0.032	d45 = 0.032	d4D3 = 0.032	d5D4 = 0.032
ed12 = 0.00625	ed23 = 0.00625	ed2D1 = 0.00625	ed34 = 0.00625	ed3D2 = 0.00625	ed3T2 = 0.00625	ed3T2b = 0.00625	ed45 = 0.00625	ed4D3 = 0.00625	ed5D4 = 0.00625
ε = 0.0002	f12 = 0.03729	f23 = 0.03729	f2D1 = 0.03729	f34 = 0.03729	f3D2 = 0.03729	f3T2 = 0.03729	f3T2b = 0.03729	f45 = 0.03729	f4D3 = 0.03729
f5D4 = 0.03729	g = 9.81	K2D1 = 406.7	K3D2 = 193	K3T2b = -972	K4D3 = 219.8	K5D4 = 259.7	L12 = 1	L23 = 179.8	L2D1 = 10
L34 = 166.3	L3D2 = 10	L3T2 = 1	L3T2b = 10	L45 = 132.9	L4D3 = 10	L5D4 = 10	μ = 0.0011	P1 = 0	P2 = 48914
P2psig = 7.096	P3 = 23925	P3psig = 3.471	P3T2 = 24279	P3T2b = 0	P3T2psig = 3.471	P4 = 27064	P4psig = 3.926	P5 = 31720	P5psig = 4.602
PD1 = 0	PD2 = 0	PD3 = 0	PD4 = 0	Q12 = 0.0003889	Q23 = 0.0003889	Q2D1 = 0.0003889	Q34 = 0.0003889	Q3D2 = 0.0003889	Q3T2 = 0.0003889
Q3T2b = 0.0003889	Q45 = 0.0003889	Q4D3 = 0.0003889	Q5D4 = 0.0003889	Re12 = 14067	Re23 = 14067	Re2D1 = 14067	Re34 = 14067	Re3D2 = 14067	Re3T2 = 14067
Re3T2b = 14067	Re45 = 14067	Re4D3 = 14067	Re5D4 = 14067	ρ = 1000	v12 = 0.4835	v23 = 0.4835	v2D1 = 0.4835	v34 = 0.4835	v3D2 = 0.4835
v3T2 = 0.4835	v3T2b = 0.4835	v45 = 0.4835	v4D3 = 0.4835	v5D4 = 0.4835	z1 = -6.92	z2 = -11.92	z3 = -11.87	z3T2 = -11.92	z3T2b = 2
z4 = -14.5	z5 = -16.82	zD1 = -11.92	zD2 = -11.87	zD3 = -14.5	zD4 = -16.82				

Appendix D: Pump Power Demand Calculation

$$P_{h(kW)} = q \rho g h / (3.6\ 10^6)$$

where

1.4	*q - flow capacity (m^3/h)*
1000	*ρ - density of fluid (kg/m^3)*
9.81	*g - gravity (m/s^2)*
60	*h - differential head (m)*
0.6	*η - pump efficiency*

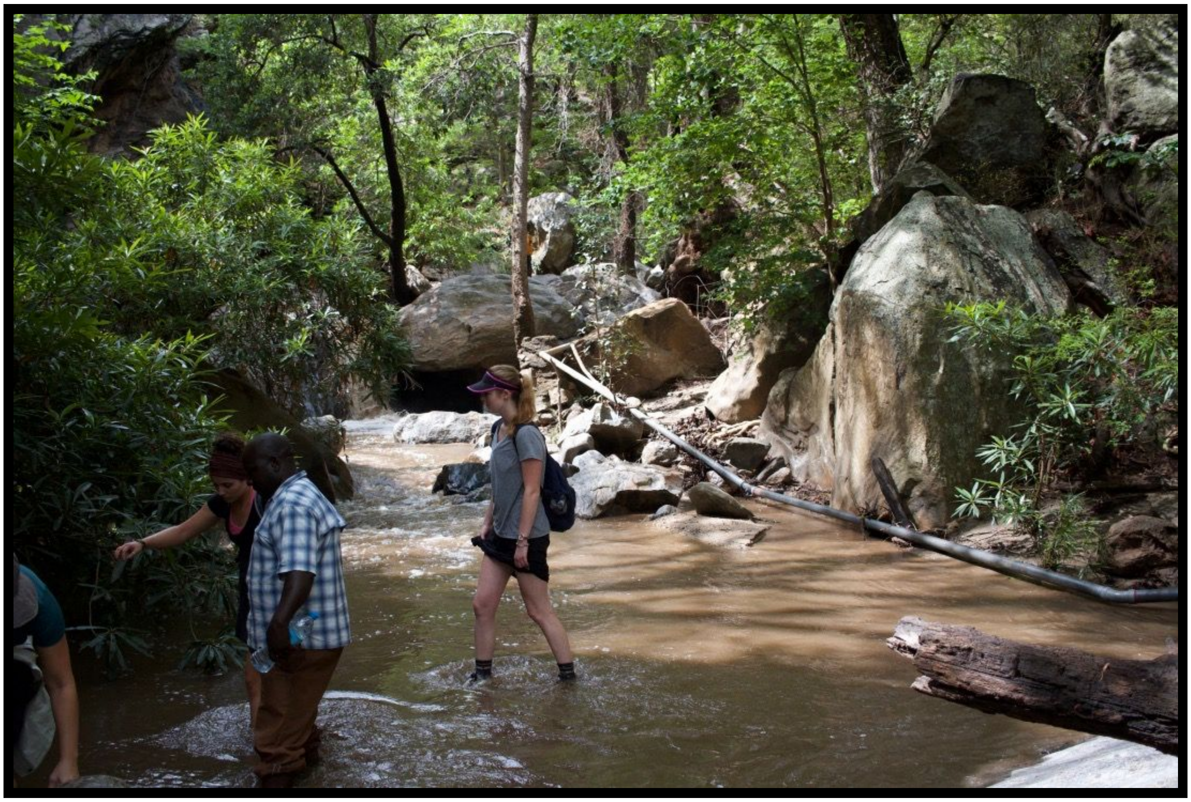
From www.engineeringtoolbox.com

Hydraulic Power: 0.23 (kW) 0.31 (hp)

Shaft Power: 0.38 (kW) 0.51 (hp)

Therefore, two 250 Watt solar panels will be installed to cover any power losses within the system.

Appendix E: Additional Photos




OFISI YA H/MASHAURI YA KIJIJICHAIGUNDA


KEITH A OLSON
1936-2009
Founder of St Paul Partners
This is what I was called to do
St Paul Partners