Ikwavila Water System

Authors:
Erik Boyum
Amanda Dahl
Steven Maurer
Katie Nelson
Jarrod Neuharth
Sarah Thunstrom

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

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1 Contact Information

1.1 University of Minnesota Students

Erik Boyum
Mechanical Engineering Student
Phone: 763.568.8158
Email: boyum039@umn.edu

Amanda Dahl
Biomedical Engineering Student
Phone: 651.361.0445
Email: dahl1002@umn.edu

Steven Maurer
Mechanical Engineering Student
Phone: 651.368.4242
Email: rmaure134@umn.edu

Katie Nelson
Mechanical Engineering Student
Phone: 612.750.7266
Email: nels8336@umn.edu

Jarrod Neuharth
Mechanical Engineering Student
Phone: 507.676.4599
Email: neuha034@umn.edu

Sarah Thunstrom
Chemical Engineering Student
Phone: 763.670.9739
Email: thun0051@umn.edu

1.2 Instructors

Dr. Paul Strykowski
University of Minnesota
Phone: 612.626.2008
pstry@umn.edu

Dr. Ken Smith
3M Corporation
Phone: 651.336.7273
klsmith@mmm.com

Ben Koch
University of Minnesota
Phone: 612.625.6813
koch0137@umn.edu

1.3 Saint Paul Partners

Hannal Gadwe
Phone: 011 255 658 006100
Email: hannalgadwe@gmail.com

1.4 University of Iringa Student / Translator

Ahmed Abdallah
Phone: 255 777 52 53 03 or 255 718 51 15 12
Email: ahmedzenjibar20@gmail.com

1.5 Water Committee Members

Melielio Mato
Designation: Committee Member
Phone: 0785306211

Micho S. Mliaya
Designation: Secretary
Phone: 0688717010

Pelasa Mbdso
Designation: Accountant
Phone: 0659324854

Ephrem Mato
Designation: Plumber/Handyman
Phone: 065419254

Fatuma Mbembai
Designation: Committee Member
Phone: 0719742205

George Kioniani
Designation: Treasurer of Makifu Parish
Phone: 0754081976

Mckip Shabieiwa
Designation: Co-Pastor of Makifu Parish
Phone: 0688678573

MCHG. N. Madembo
Designation: Pastor of Makifu Parish
Phone: 0715581188

Lonjino Mkubce
Designation: Committee Chair
Phone: 0678337194

Benedict H Mpute
Designation: Village Executive Officer(VEO)
Phone: 0653648723

Hosea Gadwe
Designation: Committee Chair
Phone: 0753950039

2 Executive Summary

The focus of this report is creating a reliable water system that provides clean water for the following string of villages in the Tungamalenga area: Kisilwa, Kitilangolo, Mahuninga, Ikwavila, and Mahove. These villages are located in the Iringa Rural Region and approximately 100 km southwest from Iringa Town. The existing water system was originally installed in 1982 and does not provide water to the village of Ikwavila. The current water system was built over 20 years ago and is showing signs of disrepair. Broken and malfunctioning spigots and exposed pipe were observed in the system (Figure 1). The current villages served by the water system are: Kisilwa, Kitilangolo, Mahuninga, and Mahove (Figure 2). The water source of the system is the Iyungili River, which can provide more water than the system currently delivers. From a flow estimate, it was determined that the current tank has an overflow of 247,000 L/day in the wet season, while the projected water demand for Ikwavila in 10 years is only 4,669 L/day.

Currently, Ikwavila has a population of 161 people and no access to a clean or sufficient water supply. The main sources of water are surface sources, a water hole, and a small creek. During the wet season the people dig holes near their homes and collect surface water for their drinking water and daily needs. During the dry season the women walk 820 m to gather water from a water hole and use a small creek 920 m away mostly to provide water to their livestock. The water hole tested positive for dangerous bacteria such as salmonella and klebsiella.

In the team's discussion with the water committee, the water committee expressed that their first concern was getting water to Ikwavila. Their second focus was to increase the water flow in the spigots at the end of the system. From their suggestions, the goal of this project is to provide reliable, clean water to the village of Ikwavila and to update the existing water system that provides water to the neighboring villages. The proposed plan is to tap into the existing, underutilized system and use gravity to deliver water to Ikwavila and then begin to upgrade the system starting with a new pipe from the tank that will run parallel to the existing line. These two goals are accomplished in a series of three phases. This first phase will tap into the existing system and run a pipeline to the village of Ikwavila where a new 10,000 L tank will be installed. The tank is included so that water will fill at night and be able to serve the water needs of the village throughout the peak hours of the day without negatively affecting any of the other villages on the line. Phase 1 is estimated to cost $9,189.

The second phase will add a second pipe outlet to the source tank and replace the existing system up to the new Ikwavila tee. This new line will be all 4" piping whereas the current pipeline reduces to 3". The increased pipe diameter will allow for lowered frictional losses and increased flow rate for the entire system. Phase 2 is estimated to cost $48,751. The third and final phase will continue the new mainline pipe for the rest of the length of the existing line, again the new pipe will be 4" whereas the current piping decreases to 2" and finally to 1.8" towards the end of the line. This final phase is estimated to cost $37,052. The total population that will benefit from the new line and upgrades proposed in Phases 1, 2, and 3 of this report is 4,663 persons. The villagers will be expected to contribute to the total cost of the project in the form of labor for a total contribution of $9,746 for all three phases.

3 Project Profile

3.1 Project Type

The team visited Ikwavila and the surrounding villages on January 8-10, 2016. During this time the group talked to the local water committee and observed the tank and pipeline system. The proposed system is gravity fed system. There is an existing river water source, the Iyungili River, that supplies the surrounding area with clean water. From a flow measurement, the current tank was estimated to have an overflow of 247,000 L/day. Two aspects to note of this flow measurement was that the overflow pipe at the tank was moved in order to see the amount overflowing and that the measurement was taken during the wet season - it rained for a few hours every day while we were in Ikwavila. The excess volume of water and current location of the source are both suitable to provide gravity fed water to the population of Ikwavila Village. The current supply currently provides water to a number of neighboring villages through a 7,369 m long existing pipeline. This proposal involves three phases that will involve installing a new pipeline to bring water to Ikwavila and installing a second mainline that will serve as a replacement and backup to the current pipeline. The new line to Ikwavila will provide a minimum of 4,669 L per day to a 10,000 L tank located along the main road in Ikwavila. Three spigots will be placed near the tank and receive water locally from the 10,000 L tank.

3.2 Project Beneficiaries

This project has two main beneficiaries. The population of Ikwavila village, whom currently has no consistent, clean water supply, will be served directly with a new clean water supply available near their village center. The population of Ikwavila is currently 161 and the system will provide enough water for the population for at least 10 years with an assumed growth rate of 1.5% per year.

The villages of Mahuninga, Kisilwa, Mahove and neighboring sub-villages will also benefit from the installation of the proposed water system. These villages have a current total population of 4,502 and are obtaining their water through a water system that was installed in the 1982.[3] The aging infrastructure shows signs of disrepair that were documented during our visit (see Figure 1). The proposed water line will function as not only a route for water to reach Ikwavila but also as an upgrade of the current system supplying this larger surrounding population. An adjacent upgrade of the old line is essential to the future stability of the water supply to the entire region.

(a)

(b)

(c)

(d)

Figure 1. a) A broken spigot in Kisilwa that was stuck open. b-c) Broken pipes on the Mahove line. d) View of spigot piping within concrete structures.

3.3 Project Implementing Organization

Established in 2002, St. Paul Partners (SPP) is a 501c3 non-profit organization that provides drinking water to the people of Tanzania, specifically in the Iringa Region. The vision of SPP is “to assist and enable the Tanzanian people to obtain universal access to safe water, community by community.” To accomplish this vision, SPP works with other organizations to help implement projects in Tanzania. Some partner organizations include H2O for Life, Bega Kwa Bega, Winter Wheat Foundation, and Water to Thrive.

3.4 Project Location

The proposed water system will serve a number of villages near Tungamalenga, in the Iringa region of Tanzania. The sub-villages that will be benefit from this project include: Kisilwa, Mahuninga, Ikwavila, and Mahove. Figure 2 below shows the relevant villages and sub-villages for reference. GPS coordinates are shown on Figure 2 in degrees at approximate village centers. For example, Mahuninga’s village center is located approximately at 7.9282 S, 35.066 E.

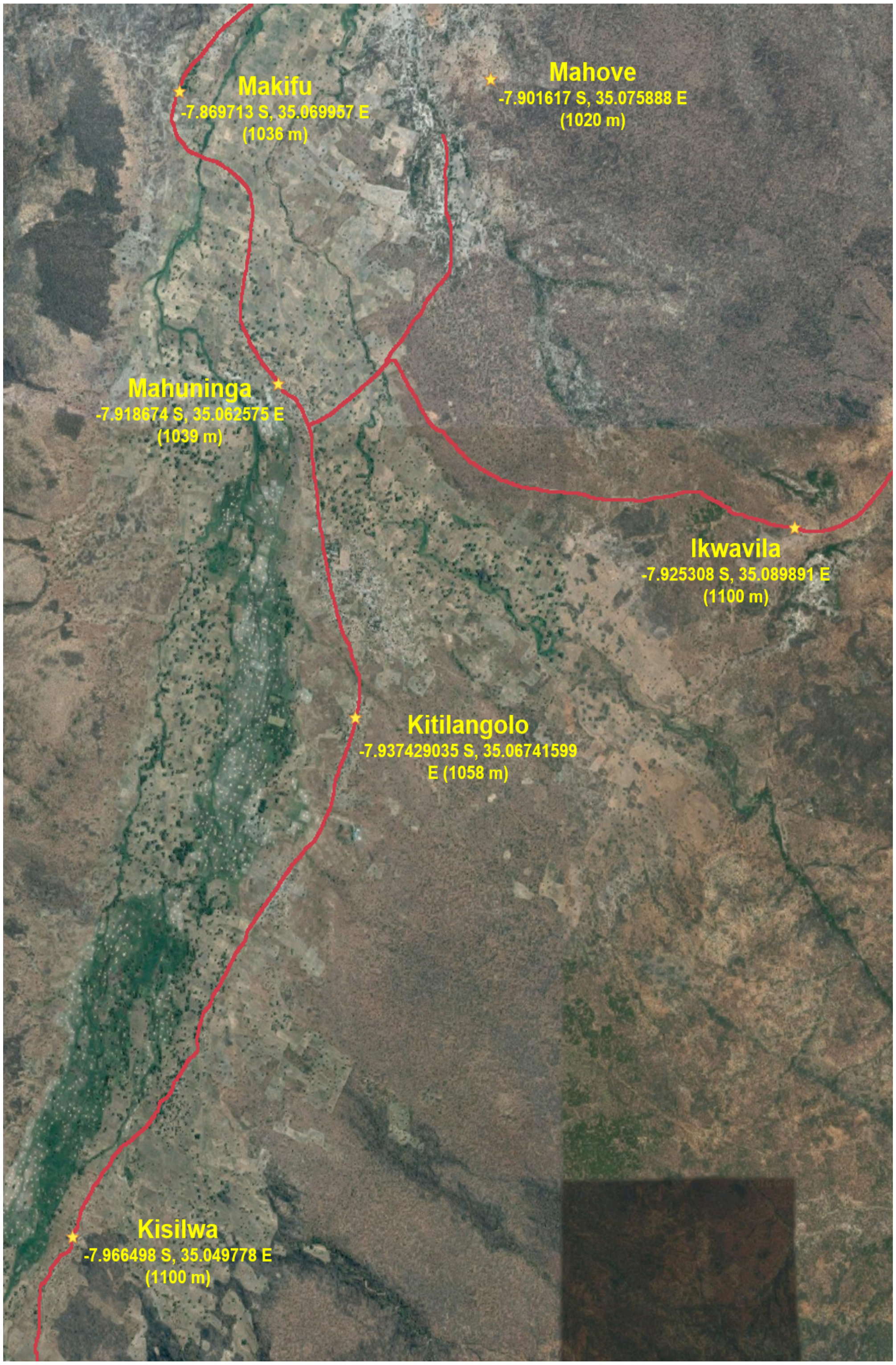

Figure 2. Map of the villages and the sub-villages in the Tungamalenga area. The red lines represent the established roads.

3.5 Budget Summary

Table 1. Proposal budget estimate.

Phase	Price (TZS)	Price (USD)
Phase 1 Estimate	20,366,038	9,189
Phase 2 Estimate	105,981,091	48,751
Phase 3 Estimate	80,547,409	37,052
Total Estimate	**206,894,538**	**94,992**

4 Background and History

4.1 Current Situation

Ikwavila, a sub-village of Mahuninga, is located approximately 100 km southwest of Iringa near Ruaha National Park. The village has a population of 161 persons and is comprised primarily of Maasi people. Their current water supply is insufficient and contaminated. The people of Ikwavila currently obtain their water from a stream and a small water hole beneath a tree pictured in Figure 3. We were unable to measure the refill rate of the standing water source directly, but information provided to us from the villagers indicates that the refill rate is not sufficient to provide the recommended 25 Liters per person per day of water to the entire population of Ikwavila. The water from the stream source was tested using a Pathoscreen test kit which tests for harmful bacteria such as salmonella.[4] The test was positive which shows that the water is contaminated. A picture of the stream water test is shown in Figure 4 next to a sample test obtained from the existing water system that supplies the surrounding villages. Additional specifics on the test kits are available online[4].

(a) (b)

Figure 3. a) Water hole beneath a tree in Ikwavila where current residents gather water. b) Stream in Ikwavila where livestock get water

(a) (b)

Figure 4. a) Quality test of water hole in Ikwavila where current residents gather water. A black color indicates the presence of bacteria. b) Clean water test for the tank in Kisilwa.

4.2 History

The existing water system serves Mahuninga, Kisilwa, Mahove, and neighboring sub-villages outside of Ikwavila. The system was installed in 1982 which included a tank supplying water to Kisilwa and Mahuninga. More recently, the government assisted with the installation of a newer concrete tank and in 2011 a water line to the sub-village of Mahove was added. The concrete tank has a volume of approximately 90,000 L and collects water from the Iyungili River in the mountains. It is a completely gravity driven system and has 21 spigots for public access. The village of Ikwavila is located approximately 3 km east of where this primary water main runs, has never had access to this water supply, and still relies on traditional water sources.

4.3 Challenges

A meeting with the water committee on January 9, 2016 confirmed that their first priority is to provide clean, safe water for Ikwavila. The water committee also brought up issues with the flow of their current system in Mahuninga during demand hours. The committee has established a money collection system. Unfortunately, there has been some confusion about where the collected money has gone. There was a recent change in the committee members in 2014 so this problem may have been solved. According to the topography map, the city center of Ikwavila is located at an elevation that is higher than the supply tank[2]. However, the GPS data taken shows that Ikwavila's city center is below the tank. This means that water might not be brought to the center of Ikwavila without installing a pump of some kind, however a gravity fed system may be able to bring water much closer to the villagers.

5 Water Needs

Presently, the population of Ikwavila is 161 people. The water needs are calculated based on 25 L per person per day. The projected population size for the project is based on the standard inflation rate of 1.5% per year. When comparing the population data obtained in 2016 to the population data obtained in 2011[3] the growth rate is much potentially much higher (~10% per year), however the accuracy of the population data is not known. The current water system supplies water to the people of Mahuninga, Kisilwa, and the sub-village of Mahove according to the Mahove Report[3]. It is necessary to ensure that the water system will continue to provide water for all affected individuals until at least 2026.

Table 2. Population and expected growth with required water supply of villages and sub-villages in the Tungamalenga area.

Village	Sub-villages	Population 2016	Required Water Supply (L/day)	Projected Population 2026	Projected Water Demand 2026 (L/day)
Mahuninga	**Ikwavila**	161	4025	187	4669
	Majengo A	784	19600	909	22736
	Majengo B	701	17525	813	20329
	Uyamba	741	18525	860	21489
	Kitilangolo	526	13150	610	15254
Makifu	**Mahove**	250	6250	290	7250
Kisilwa	**Kisilwa**	1500	37500	1740	43500
	Isukutwa				
	Misufi				
	Total	4663	116575	5409	135227

6 Proposal Overview

6.1 Phase I

Water sources near Ikwavila are extremely limited. Investigation in Ikwavila led to the discovery that their primary water supplies are small, natural pools and streams. In addition, land drilling around the area has been historically unsuccessful. As a result, the most effective way to get clean water to Ikwavila is to use the nearby existing infrastructure. Our proposal consists of three phases listed in priority. Phase 1 is to add a new pipe to the existing water system that allows local access to the neighboring water supply for the people of Ikwavila. The new pipeline will connect to the existing infrastructure via a T-junction placed on the pipe in Kitilangolo, located at approximately (-7.938554976 S, 35.06695901 E). The new line would connect upstream of the existing connection to the Mahove line to avoid crossing pipelines. The line will run as directly as possible towards Ikwavila Village Center located at approximately (-7.925308 S, 35.089891 E). The line will consist of only 2” HDPE pipe. The water supply will feed into a 10,000 Liter tank in Ikwavila, which will distribute water to three local spigots. Elevation data collected during our time in the area suggests that Ikwavila is 15 meters below the tank in elevation. To account for potential error in GPS data, two steps will be taken. First, the system included in this proposal is designed for only 10 meters of head allowing for 5 meters of GPS error. Additionally, it is proposed that during construction the line can be shortened and the tank location moved south west towards Kitilangolo in an attempt to lower the final elevation of the tank. An acceptable head should be able to be obtained without moving the tank unreasonably far from the Ikwavila village center. Figure 5 below shows a map of the proposed system.

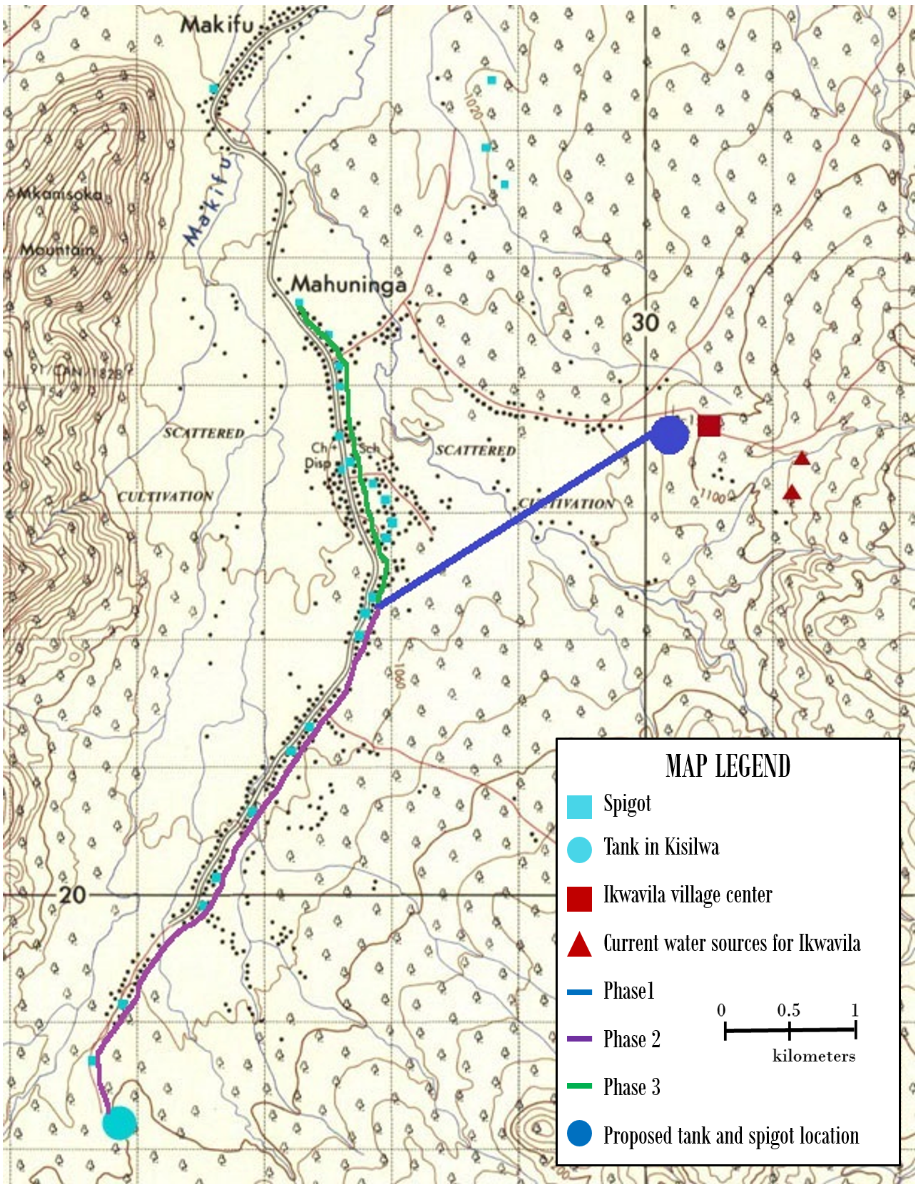

Figure 5. Map of the proposed phases for the water distribution system

The line added in Phase 1 will draw water from the existing source. Thus, the system is designed to function in a way such that the villages that currently are supplied through system do not experience the negative effects of loss of flow. At all times the villages of Kisilwa, Mahuninga, and Mahove that are currently on the system will be able to obtain flows that provide for their entire daily need within twelve hours. This is because they do not have tanks for storage and must get water from taps during the day. Ikwavila will receive flow during the day that fills the tank constantly. This flow is complimented by constant elevated flow during the night when nobody else is using water. During the night hours, water will fill the Ikwavila tank and provide additional water for usage during the daytime high-use hours. This allows the system to handle higher peak flows in the larger villages of Mahuninga and Kisilwa.

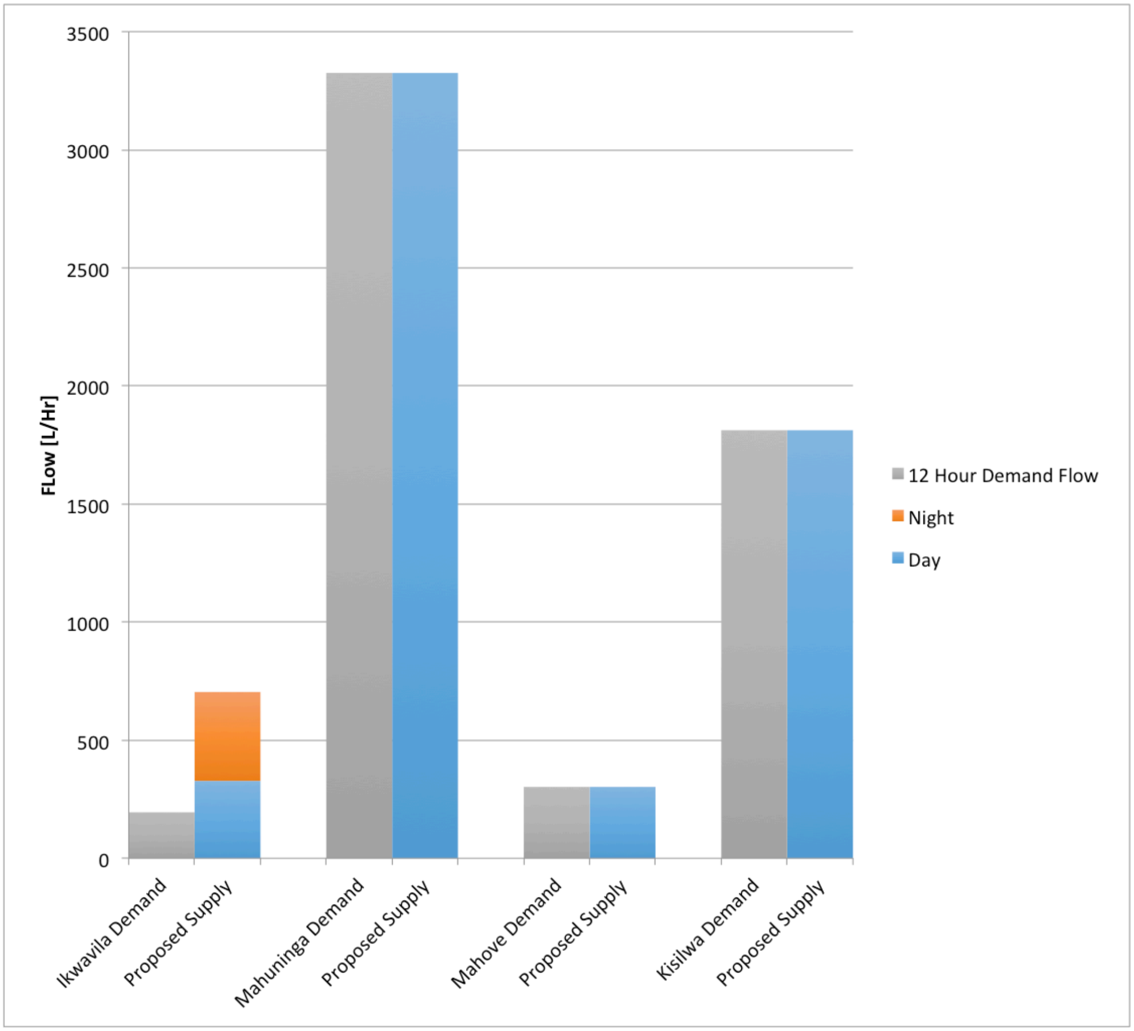

Figure 6: Flow rate for each village vs. pipe size for Ikwavila line.

The pipe size of 2” was chosen based on a computer simulation that calculated flow rates for various pipe sizes. The goal of the simulation was to determine the minimum size needed to deliver the desired flow rate in Ikwavila. Results comparing 2” and 3” pipe were performed. While pipe smaller than 2” in diameter could be used, the tank in Ikwavila would need to be placed at a lower elevation, and thus much farther away from the Ikwavila village center. Since the 2” pipe can provide enough flow, the 3” pipe becomes an unnecessary additional expense.

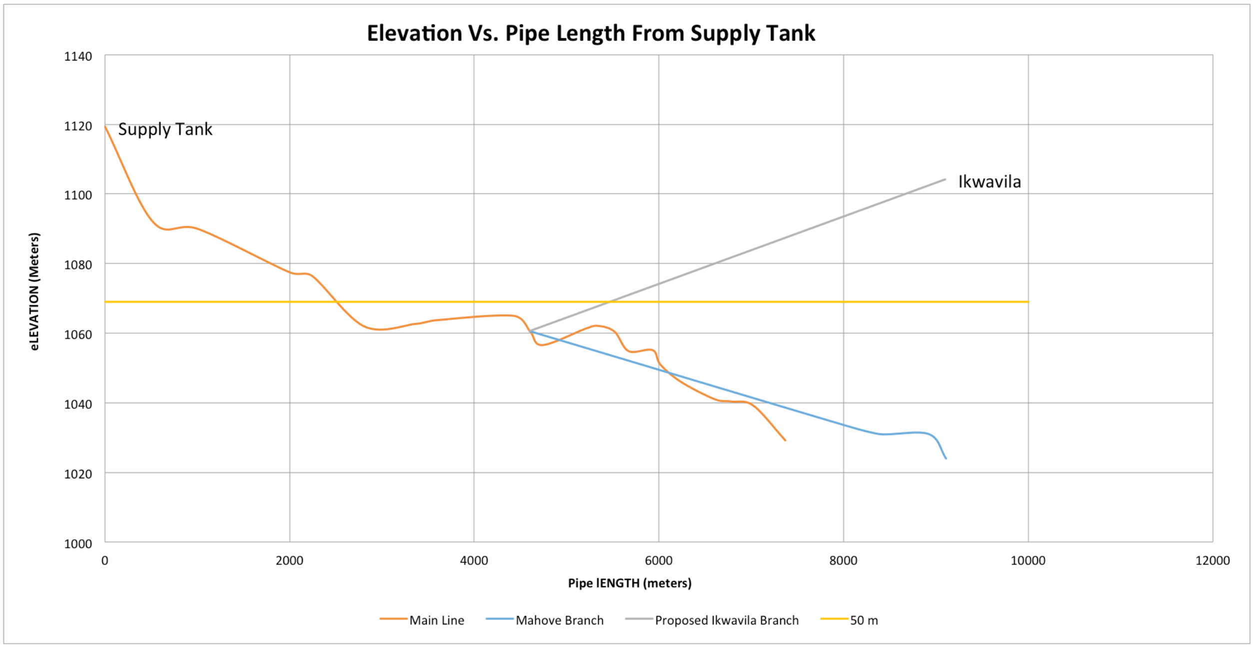

Figure 7. Plot of the elevation versus the pipe from the supply tank.

6.2 Phase 2

In the second phase, it is proposed that a new, 4" diameter pipeline be constructed from the tank in Kisilwa to the junction in Kitilangolo (Figure 5). After this has been completed, all of the spigots south of Kitilangolo can be transferred onto this new line. This will provide an update for a portion of the 20+ year old system. The new pipeline should be kept close to the old one so as to make the transition of the spigots easier.

6.3 Phase 3

In the third phase, it is proposed that the remainder of the old system, excluding the branch to Mahove, be replaced with 4" diameter pipe. In addition, all of the spigots should be transferred to the new line. Similar to the second phase, the new pipe should be kept close to the old pipe to make transition of the spigots easier. This phase will complete the update of the old system. If necessary, replacing the source tank and pipe in Kisilwa should also be taken into consideration.

6.4 Alternative Plans

Alternative designs were also considered, including a pipeline directly from the tank in Kisilwa and a branch off of the Mahove line (Figure 8). A pipeline straight to Ikwavila from the existing tank would allow it to be independent of the main line, however the cost per capita is extremely high and it would require much more work to build. Branching off of the Mahove line is another option, however knowledge of the system is limited and Mahove is in a very low area.

These designs would work according to computer simulation, but are not recommended as primary options.

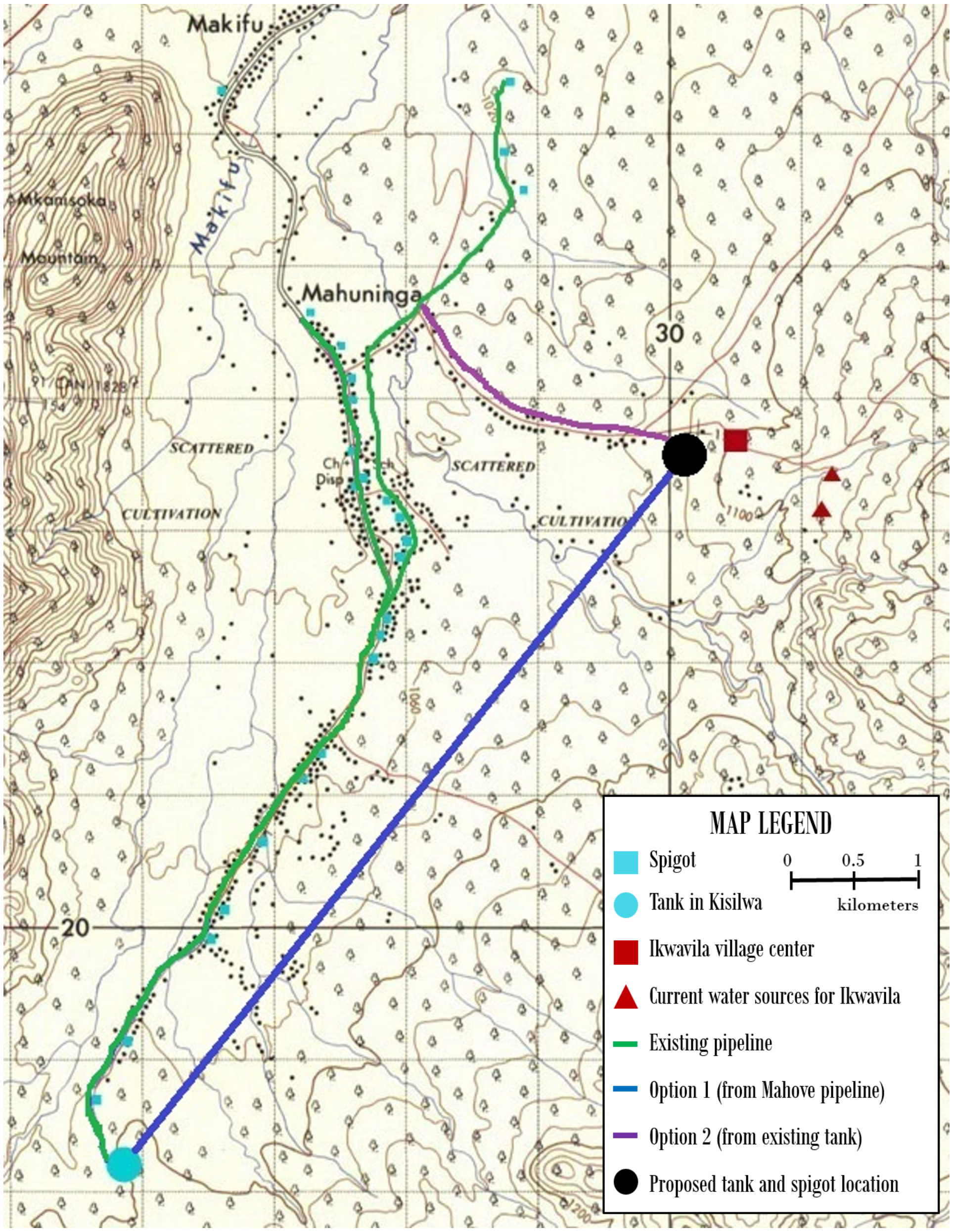

Figure 8: Map of the alternative plans for the water distribution system[2]

7 Proposal Implementation

7.1 Phase I

The main priority is to provide Ikwavila with easier access to clean water. This will be accomplished with the implementation of Phase I, which can be identified in Figure 5 and section 6.1 of the Proposal Overview.

Before the implementation of Phase I can begin, permission to dig trenches will need to be obtained from any villagers that own land along the proposed Phase 1 pipe route outlined in Figure 5. These logistics will be handled by the local water committee.

Elevations will need to be confirmed before a precise tank location in Ikwavila can be determined. If it is determined that the pressure head requirements outlined in section 6.1 have not been met, the location of the 10,000 L tank in Ikwavila can be move from the current proposed location (-7.925308 S, 35.089891 E) to a lower elevation to the southeast. Once a final tank location is confirmed, the concrete pad for the tank can be constructed, the tank can be mounted, and three spigots can be installed on the side of the tank.

Once permission from the land owners has be granted, the trench from Kitilangolo to Ikwavila can be dug. It is suggested that the most direct route be taken from the junction in Kitilangolo (-7.938554976 S, 35.06695901 E) to the location of the 10,000 L tank in Ikwavila, however, the actual path of the pipe will depend on the terrain and other obstacles, and will be determined by the local project supervisor/engineer. The trench should start at a location just south of the current junction in Kitilangolo (Figure 9) to avoid crossing paths with the line that branches off to Mahove, and the trench should be no less than 1 m deep to ensure the pipe will be adequately protected from activity on the surface. Once the trench is complete, the 2” HDPE pipe can be laid and connected to the tank in Ikwavila. The 2” pipe can then be connected to the main line in Kitilangolo. Once the line is completely in place and connected to both the main line in Kitilangolo and the 10,000 L tank in Ikwavila, it should be checked for any leaks before the trench is finally backfilled.

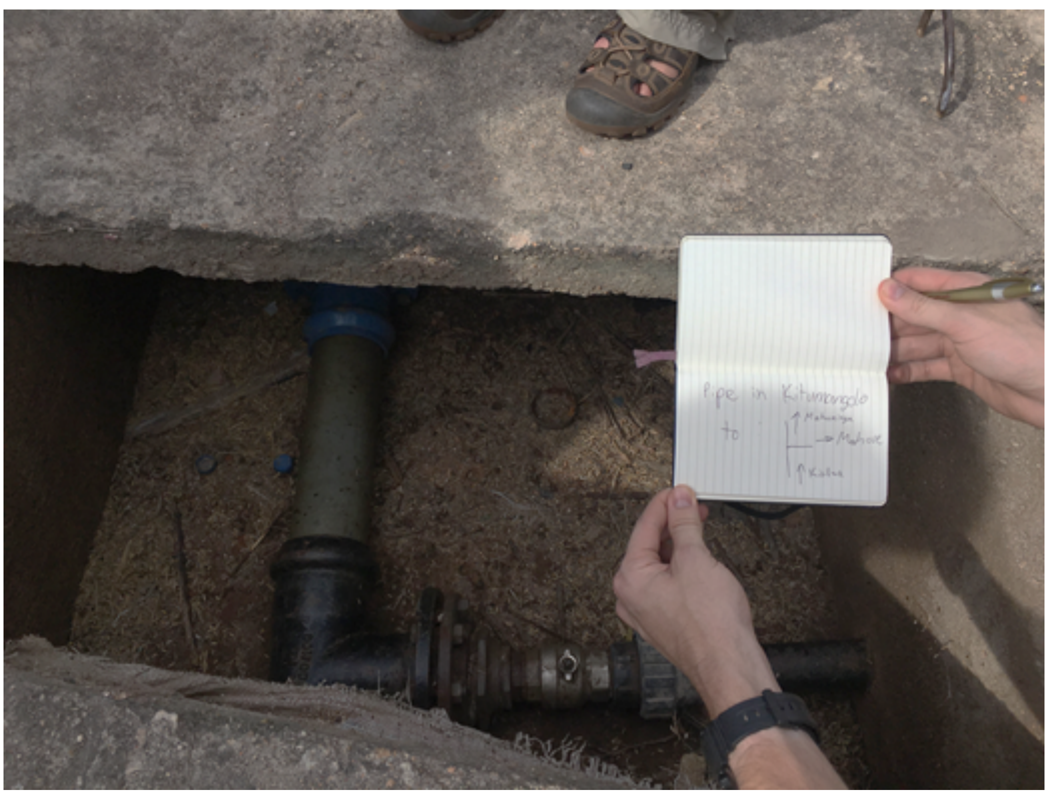

Figure 9: T-Junction in Kitilangolo (-7.938554976 S, 35.06695901 E).

7.2 Phase 2

Part of the Phase 2 proposal consists of switching the existing spigots from the existing main line onto the new portion of the main line that will be installed, therefore, it would be ideal to install the new main line from Phase 2 as close to the existing line as possible. This would not only minimize the amount of materials needed to switch the spigot lines to the new main line, it would also minimize the time that the system would be shutdown to perform the switch. The problem with this, however, is that the path of the current main line is unknown. It is probable that the current line runs parallel to the road, however, this may not be the case. If the line was not installed along the road, it is very possible that there have been new buildings that have been built on top of the existing line in the 20 plus years since its installation. Depending on exactly where the current line runs, Installing the new main line right alongside it might require an excessive number of pipe fittings in order to maneuver the pipe around buildings. This would not only add an unpredictable cost to the installation, it would also increase the energy losses in the system. For these reasons it is recommended that the new main line proposed in Phase 2 be installed in close proximity to the road. There are several benefits to this suggestion:

- It will greatly reduce the number of required pipe fittings.
- Permission would not need to be acquired from landowners to dig on their land.
- It would provide easy access to the line for maintenance and repairs.
- It would guarantee that buildings would not be built on top of the new line in the future.

The new 4” HDPE pipe will be installed at a depth of no less than one meter and T-fittings will be installed in the pipe at locations where the spigots lines will be connected (refer to table in Appendix 12.4 for spigot locations). Once the new pipe has been laid, the tank will need to be drained in order to connect the new line to the tank with a 4” gate valve. This should be done during a time of low water demand as it will effectively shut down the system. At this point the spigots can be swapped from the existing main line onto the new main line. As each spigot is removed from the existing line, a plug will be placed in the old main line as it will still be used to deliver water to the villages north of the junction in Kitilangolo. Before backfilling over the new main line, the system should be checked for any leaks.

7.3 Phase 3

Phase 3 implementation will be nearly identical to Phase 2. The new portion of 4” HDPE pipe will be installed north of the junction in Kitilangolo (-7.938554976 S, 35.06695901 E) to the end of the line in Mahuninga (Figure 5). It will be installed in close proximity to the road and at a depth of no less than 1 m. T-fittings will be installed in the pipe at locations where the spigots lines will be connected (refer to table in Appendix 12.4 for spigot locations). The new line will be connected to the portion of line installed in Phase 2, and the remaining spigots north of the junction in Kitilangolo will be transferred from the old main line to the new line. Again, a plug should be inserted in the old line at every location where a spigot line is removed. This will ensure that the old line can still be used in the future if needed.

8 Project Budget

8.1 Phase I Budget

The Phase 1 project budget total comes to an estimated $9,189. Table 3 displays the breakdown of materials, labor, shipping, and contingency costs in both Tanzanian shillings and U.S. dollars. The cost includes all piping from the current system to Ikwavila (1) which will be class C HDPE piping with a burst pressure of 10 bar. Additional surveying should be done between the current line and Ikwavila to obtain additional elevation data. When the pipe is less than 50 meters below the tank, HDPE piping with a burst pressure of 6 bar can be used which will decrease the cost of the project. Since only two elevation points were obtained (at the current system and in Ikwavila) and the first point was more than 50 meters below the tank, the higher burst pressure pipe is used for the entire line as an overestimate.

A 2” gate valve (2) is needed at the new tee off of the mainline in order to control flow to Ikwavila and allow for a shut off for maintenance purposes. Couplings (3) are included in the price as an initial estimate for fittings, additional fittings and pipe installation materials may be needed. Also, three spigots are included in the price, these will be installed off of the tank in Ikwavila and will be the access point for the villagers. A 10,000 L sim tank is included, this volume exceeds the current daily needs for Ikwavila and will allow the system to accommodate further growth in the region.

The labor costs are calculated as follows: cost to dig a trench that is 1 m deep x 0.5 m wide x 6 m long is Tsh. 10,000 per day, to backfill the trench after the piping is installed is Tsh. 10,000 per laborer per day where each laborer can backfill ~15 m in one day. The labor to build the cement pad for the tank is calculated as 20% of the total material costs (11-15). The cost of labor for pipe installation is 20,000 for one fundi and 50,000 for 5 laborers per kilometer of pipe. Finally, the shipping costs are calculated as 20% of the total material costs and the contingency (17) is calculated as 10% of the total cost of the project.

The village contributions for this project will be in the form of labor for digging and back filling the trench, helping to install the pipeline and building the cement pad for the 10,000 L tank. The village contribution comes to a total of $1,675.

Table 3. Detailed budget for Phase 1.

	Item	Size/Description	Unit Cost (Tish)	Quantity	Total Cost (Tish)	Total Cost (dollars)
1	HDPE pipe Class C	2"	889800	10	8,536,148	3,927
2	Gate Valve*	2"	71500	2	143,000	66
3	Couplings*	2"	9900	9	89,100	41
4	Spigots (bib cock UK type)*	1"	8800	3	26,400	12
5	Labor to dig trench	Laborer	10000	239.8	2,398,333	1,103
6	Labor to backfill trench	Laborer	10000	95.9	959,333	441
7	Labor to install pipe	Fundi+5 Laborers	80000	1.439	115,120	53
8	Sim Tank	10,000 L	2400000	1	2,400,000	1,104
9	Flanged Tee*	4"	82500	1	82,500	38
10	Hardcore		30000	9.2	276,000	127
11	Aggregates		60000	1.6	96,000	44
12	Sand		60000	3	180,000	83
13	Cement		16000	15	240,000	110
14	Reinforcement		16000	12	192,000	88
15	Labor (20% of material cost)				196,800	91
16	Shipping Costs				2,452,230	1,128
17	Contingency			10% of total	1,593,073	733
	Total				**19,976,038**	**9,189**

* = pricing taken from Mahove report and increased by 10% for inflation.

8.2 Phase 2 Budget

The Phase 2 project budget total comes to an estimated $48,751. Table 4 displays the breakdown of materials, labor, shipping, and contingency costs in both Tanzanian shillings and U.S. dollars. The cost includes all piping from the source tank in Kisilwa to the proposed tee in Kitilangolo (1). The first 2,809 m of pipe will be class B HDPE pipe with a burst pressure of 6 bar. This length of pipe is all less than 50 meters below the source tank. The remaining 1,614 m of pipe will be class C HDPE pipe with a burst pressure of 10 bar (2). There is also 150 m of class C 1" piping with a burst pressure of 10 bar that will be used to tee off to each spigot (3).

A 4" gate valve (4) is needed at the tank to control flow and shut the system off as needed for maintenance. Eight 4" flanged tees (5) are included to accommodate the spigots that will be transferred to the new line. Couplings (6) are included in the price as an initial estimate for fittings, additional fittings and pipe installation materials may be needed. Again, as in Phase 1 the cost of new spigots (7) is included in the cost estimate.

The labor costs are calculated the same as in Phase 1. The village contributions will again be in the form of labor for digging and back filling the trench, and helping to install the pipeline. The village contribution comes to a total of $4,828.

Table 4. Detailed budget for Phase 2.

	Item	Size/Description	Cost (Tish)	Quantity	Total Cost (Tish)	Total Cost (dollars)
1	HDPE pipe Class B	4"	710000	56	39,887,800	18,348
2	HDPE pipe Class C	4"	915000	32	29,536,200	13,587
3	HDPE pipe Class C+	1"	889800	1	889,800	409
4	Gate Valve	4"	300000	1	300,000	138
5	Flanged Tee*	4"	82500	8	660,000	304
6	Couplings*	4"	17600	88	1,548,800	712
7	Spigots (bib cock UK type)*	1"	8800	8	70,400	32
8	Labor to dig trench	Laborer	10000	738.2	7,381,667	3,396
9	Labor to backfill trench	Laborer	10000	295.3	2,952,667	1,358
10	Labor to install pipe	Fundi+5 Laborers	80000	2.003	160,240	74
11	Shipping Costs				14,254,760	6,557
12	Contingencies			10% of total	8,338,757	3,836
	Total				**105,981,091**	**48,751**

\+ =150 m of piping for spigots, this pipe will also be used in Phase 2

8.3 Phase 3 Budget

The Phase 3 project budget total comes to an estimated $37,052. Table 5 displays the breakdown of materials, labor, shipping, and contingency costs in both Tanzanian shillings and U.S. dollars. The cost includes all piping from the proposed tee in Kitilangolo to the end of the main line (1) which will be class C HDPE pipe with a burst pressure of 10 bar. The first 2,809 m of pipe will be class B HDPE pipe with a burst pressure of 6 bar. Couplings (2) are included in the price as an initial estimate for fittings, additional fittings and pipe installation materials may be needed.

Thirteen 4” flanged tees (7) are included to accommodate the spigots that will be transferred to the new line.

The labor costs are calculated the same as in Phase 1 and 2. The village contributions will again be in the form of labor for digging and back filling the trench, and helping to install the pipeline. The village contribution comes to a total of $3,243.

Table 5. Detailed budget for Phase 3.

	Item	Size/Description	Cost (Tish)	Quantity	Total Cost (Tish)	Total Cost (dollars)
1	HDPE pipe Class C	4"	915000	59	53,911,800	24,799
2	Couplings*	4"	17600	58	1,019,392	469
3	Spigots (bib cock UK type)*	1"	8800	13	114,400	53
4	Labor to dig trench	Laborer	10000	491	4,910,000	2,259
5	Labor to backfill trench	Laborer	10000	196.4	1,964,000	903
6	Labor to install pipe	Fundi+5 Laborers	80000	2.946	235,680	108
7	Flanged Tee*	4"	82500	13	1,072,500	493
8	Shipping Costs				10,996,860	5,059
9	Contingencies			10% of total	6,322,777	2,908
	Total				**80,547,409**	**37,052**

9 Future Projects

While we believe these three phases will accomplish our main goals of providing clean water to Ikwavila and updating the out-of-date system, there is the potential of more projects to be completed in this area. Our team has identified and outlined three of these future projects below.

If there is a need for the water in Ikwavila to be distributed, a pump-driven system is proposed to bring water to other locations in the village. Spigots may also be placed on the pipeline toward Ikwavila to provide water for any villagers west of the new tank.

The tank in Kisilwa and the pipe from the river source are both over 20 years old. It is proposed that these two components of the water system be replaced. If required, this phase should proceed Phase 2 to ensure that the water system is not affected by failure of these components.

The pipeline to Mahove, implemented in 2012, can be replaced as needed. Rather than completely replacing the pipeline from the T-junction in Kitilangolo (just south of Mahuninga), it is proposed that a new branch be constructed only along the road to Mahove.

10 Conclusion

The villages of Mahuninga, Kisilwa, Mahove, and neighboring sub-villages have had a successful water distribution system in place for over 20 years. With this proposal, clean water can be distributed to the sub-village of Ikwavila while providing a much needed upgrade to this outdated system. The success of this long-lasting system demonstrates that the local community is capable of sustaining an expansion and upgrade to it.

11 References

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12 Appendices

12.1 EES Code Simulating Flow-rate to Ikwavila at Night

This code assumes that all taps are off, and the only flow is to the 10,000 L tank in Ikwavila. It is assumed that this would be the scenario for roughly 8 hours every night.

```
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  [N-s/m^2]   {kinematic viscosity of water}
epsilon = 0  [m]   {inner pipe wall roughness}
g = 9.81 [m/s^2]
loss05 = 1.0


{diameters}
{Main Line}

d_T_0      = 4.124486667*0.0254 [m]

d_0_1      = 3.37458*0.0254 [m]

d_1_2      = 2.362206*0.0254 [m]




{ Spigot }

d_s = 1 *0.0254 [m]
```

{Distance from tank}

{4" }

L_T_0 =1995.6 [m]

{L_0_1 = 6170 [m]}

{3inch to Tee}

L_0_1 = 2605 [m]

{ line to Ikwavila }

{L_1_2 = 3249 [m]}
L_1_2 = 3270 [m]

{Elevations}
z_T = 1119 {Tank}
z_1 = 1046
z_2 = z_T - x
z_0 = 1077

x = 15

{Pressure}
P_T = 0 [Pa] {tank}
P_2 = 0 [Pa]

{Corss section area}
A_T_0 = pi*d_T_0^2/4
A_0_1 = pi*d_0_1^2/4
A_1_2 = pi*d_1_2^2/4

{Volumetric flow rates}

```
Q_T_0 = Q_0_1

Q_0_1 = Q_1_2

{peak flow}

{Q_1_2 = 5.40394E-05  {to ikwavila}}

{
Q_3_5 = 0.002771111   {to mahuninga}
Q_1_4 = 0.000251736  {mahove}
Q_0_6 =  0.001510417  {kisilwa}
}

{

Q_1_2 = 5.40394E-05   {to ikwavila}
Q_3_5 = 0.000923704   {to mahuninga}
Q_1_4 =  8.3912E-05    {mahove}
Q_0_6 =  0.000503472  {kisilwa}

}

{
Q_1_2 = 0.000324236    {to ikwavila}
Q_3_5 = 0.005542222  {to mahuninga}
Q_1_4 =  0.000503472   {mahove}
Q_0_6 =  0.003020833 {kisilwa}
}

{Average velocities}
V_0_1     =  Q_0_1     / A_0_1
V_1_2     = Q_1_2     / A_1_2
{
V_1_3     = Q_1_3     / A_1_3
V_1_4     = Q_1_4     / A_1_4
V_3_5     = Q_3_5     / A_3_5
V_0_6     = Q_0_6     / A_0_6
}
V_T_0     = Q_T_0     / A_T_0
```

```
{Relative Roughness}
ed_T_0 = epsilon/d_T_0
ed_0_1 = epsilon/d_0_1
ed_1_2 = epsilon/d_1_2

{
ed_1_3 = epsilon/d_1_3
ed_1_4 = epsilon/d_1_4
ed_3_5 = epsilon/d_3_5
ed_0_6 = epsilon/d_0_6
}

{Reynolds Numbers}
Re_T_0 = rho*V_T_0*d_T_0/mu
Re_0_1 = rho*V_0_1*d_0_1/mu
Re_1_2 = rho*V_1_2*d_1_2/mu
{
Re_1_3 = rho*V_1_3*d_1_3/mu
Re_1_4 = rho*V_1_4*d_1_4/mu
Re_3_5 = rho*V_3_5*d_3_5/mu
Re_0_6 = rho*V_0_6*d_0_6/mu
}

{Call Friction Factor}
f_T_0 = ff(Re_T_0, ed_T_0)
f_0_1 = ff(Re_0_1, ed_0_1)
f_1_2 = ff(Re_1_2, ed_1_2)
{
f_1_3 = ff(Re_1_3, ed_1_3)
f_1_4 = ff(Re_1_4, ed_1_4)
f_3_5 = ff(Re_3_5, ed_3_5)
f_0_6 = ff(Re_0_6, ed_0_6)
}
{-------------------------------------------------------------}
{-------------------------------------------------------------}

{Governing Equations}

{Main lines}
(P_0-P_T) / (rho*g) + z_0-z_T = -V_T_0^2/(2*g)*(f_T_0*L_T_0/d_T_0)
(P_1-P_0) / (rho*g) + z_1-z_0 = -V_0_1^2/(2*g)*(f_0_1*L_0_1/d_0_1)
(P_2-P_1) / (rho*g) + z_2-z_1 = -V_1_2^2/(2*g)*(f_1_2*L_1_2/d_1_2)*KV_2

{
```

```
(P_3-P_1) / (rho*g) + z_3-z_1 = -V_1_3^2/(2*g)*(f_1_3*L_1_3/d_1_3)
(P_4-P_1) / (rho*g) + z_4-z_1 = -V_1_4^2/(2*g)*(f_1_4*L_1_4/d_1_4)*KV_4
(P_5-P_3) / (rho*g) + z_5-z_3 = -V_3_5^2/(2*g)*(f_3_5*L_3_5/d_3_5)*KV_5
(P_6-P_0) / (rho*g) + z_6-z_0 = -V_0_6^2/(2*g)*(f_0_6*L_0_6/d_0_6)*KV_6
}

{------------------------------------------------------}
{------------------------------------------------------}


{losses}



KV_2 = 5




{Flow rate, in pipes L/hr}

Flow_Lhr_T_0 = Q_T_0 *1000*3600

Flow_Lhr_0_1 = Q_0_1 *1000*3600

Flow_Lhr_1_2 = Q_1_2 *1000*3600

{

Flow_Lhr_1_3 = Q_1_3 *1000*3600

Flow_Lhr_1_4 = Q_1_4 *1000*3600

Flow_Lhr_3_5 = Q_3_5 *1000*3600

Flow_Lhr_0_6 = Q_0_6 *1000*3600

}

{Pressure in pipes in psig}
{
pconvert = 14.7/101325
psig_1 = P_1 * pconvert
psig_2 = P_2 * pconvert
```

```
psig_3 = P_3 * pconvert
psig_4 = P_4 * pconvert
psig_5 = P_5 * pconvert
psig_6 = P_6 * pconvert

}
```

Nighttime EES Code Solution (Ikwavila's flow-rate is in green)

Unit Settings: SI C kPa kJ mass deg

$A_{0,1} = 0.00577$	$A_{1,2} = 0.002827$	$A_{T,0} = 0.00862$
$d_{0,1} = 0.08571$	$d_{1,2} = 0.06$	$d_s = 0.0254$
$d_{T,0} = 0.1048$	$ed_{0,1} = 0$	$ed_{1,2} = 0$
$ed_{T,0} = 0$	$\varepsilon = 0$ [m]	$Flow_{Lhr,0,1} = 1868$
$Flow_{Lhr,1,2} = 1868$	$Flow_{Lhr,T,0} = 1868$	$f_{0,1} = 0.03414$
$f_{1,2} = 0.03088$	$f_{T,0} = 0.03621$	$g = 9.81$ [m/s^2]
$KV_2 = 5$	$loss05 = 1$	$L_{0,1} = 2605$ [m]
$L_{1,2} = 3270$ [m·]	$L_{T,0} = 1996$ [m]	$\mu = 0.0011$ [N-s/m^2]
$P_0 = 410770$	$P_1 = 710685$	$P_2 = 0$ [Pa]
$P_T = 0$ [Pa]	$Q_{0,1} = 0.0005189$	$Q_{1,2} = 0.0005189$
$Q_{T,0} = 0.0005189$	$Re_{0,1} = 7007$	$Re_{1,2} = 10011$
$Re_{T,0} = 5733$	$\rho = 1000$ [kg/m^3]	$V_{0,1} = 0.08993$
$V_{1,2} = 0.1835$	$V_{T,0} = 0.0602$	$x = 15$
$z_0 = 1077$	$z_1 = 1046$	$z_2 = 1104$
$z_T = 1119$		

12.2 EES Code Simulating Flow-Rate to Ikwavila During Peak Demand.

This code represents the flow to Ikwavila during peak demand when all other villages are getting 2.5 times their required flow. It can be seen from the solution to the code (see below) that the flow to Ikwavila is low, however, due to the large flow-rate to Ikwavila at night, the 10,000 L tank, along with the flow during the day, is enough to meet the demands of the village.

```
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  [N-s/m^2]   {kinematic viscosity of water}
epsilon = 0  [m]   {inner pipe wall roughness}
g = 9.81 [m/s^2]
loss05 = 1.0


{diameters}


{Main Line}
d_T_0       = 4.124486667*0.0254 [m]

d_0_1       = 3.37458*0.0254 [m]

d_0_6       = 2.362206*0.0254 [m]

d_1_2       = 2.362206*0.0254 [m]

d_1_3       = 3.37458*.0254  [m]

d_1_4       =  2.362206*.0254 [m]

d_3_5       = 1.71428664   [m]


{ Spigot }

d_s = 1 *0.0254 [m]

{Distance from tank}

{4" }

L_T_0 =1995.6 [m]
```

{L_0_1 = 6170 [m]}

{kisilwa model}

L_0_6 = 2 [m]

{3inch to Tee}

L_0_1 = 2605 [m]

{ line to Ikwavila }

{L_1_2 = 3249 [m]}
L_1_2 = 3270 [m]

{line to mahuninga}

{2.1 inch}
{L_1_3 = 1863 [m]}

L_1_3 = 933 [m]

{1.8 inch}

L_3_5 = 3468

{line to mahave}

{L_1_4 = 3477 [m]}
L_1_4 = 3477 [m]

{Elevations}
z_T   = 1119 {Tank}
z_1 = 1046
z_2 = z_T - x
z_3 = 1054
z_4 = 1030

z_5 = 1040
z_0 = 1077
z_6 = 1080

```
x = 10



{Pressure}
P_T = 0 [Pa] {tank}
P_2 = 0 [Pa]
P_5 = 0 [Pa]
P_4 = 0 [Pa]
P_6 = 0 [Pa]


{Corss section area}
A_T_0      = pi*d_T_0^2/4
A_0_1      = pi*d_0_1^2/4
A_1_2      = pi*d_1_2^2/4
A_1_3      = pi*d_1_3^2/4
A_1_4      = pi*d_1_4^2/4
A_3_5      = pi*d_3_5^2/4
A_0_6      = pi*d_0_6^2/4

{Volumetric flow rates}



Q_T_0 = Q_0_1 + Q_0_6

Q_0_1 = Q_1_2 + Q_1_3 + Q_1_4

Q_1_3 = Q_3_5

{peak flow}

{Q_1_2 = 5.40394E-05  {to ikwavila} }

Q_3_5 = 0.001847407  {to mahuninga}
Q_1_4 =0.000167824  {mahove}
Q_0_6 =  0.001006944 {kisilwa}

{

Q_1_2 = 5.40394E-05   {to ikwavila}
Q_3_5 = 0.000923704   {to mahuninga}
```

```
Q_1_4 =  8.3912E-05    {mahove}
Q_0_6 =  0.000503472  {kisilwa}

}

{
Q_1_2 = 0.000324236    {to ikwavila}
Q_3_5 = 0.005542222  {to mahuninga}
Q_1_4 =  0.000503472   {mahove}
Q_0_6 =  0.003020833 {kisilwa}
}

{Average velocities}
V_0_1      =  Q_0_1      / A_0_1
V_1_2      = Q_1_2      / A_1_2
V_1_3      = Q_1_3      / A_1_3
V_1_4      = Q_1_4      / A_1_4
V_3_5      = Q_3_5      / A_3_5
V_0_6      = Q_0_6      / A_0_6
V_T_0      = Q_T_0      / A_T_0

{Relative Roughness}
ed_T_0 = epsilon/d_T_0
ed_0_1 = epsilon/d_0_1
ed_1_2 = epsilon/d_1_2
ed_1_3 = epsilon/d_1_3
ed_1_4 = epsilon/d_1_4
ed_3_5 = epsilon/d_3_5
ed_0_6 = epsilon/d_0_6


{Reynolds Numbers}
Re_T_0 = rho*V_T_0*d_T_0/mu
Re_0_1 = rho*V_0_1*d_0_1/mu
Re_1_2 = rho*V_1_2*d_1_2/mu
Re_1_3 = rho*V_1_3*d_1_3/mu
Re_1_4 = rho*V_1_4*d_1_4/mu
Re_3_5 = rho*V_3_5*d_3_5/mu
Re_0_6 = rho*V_0_6*d_0_6/mu

{Call Friction Factor}
f_T_0 = ff(Re_T_0, ed_T_0)
f_0_1 = ff(Re_0_1, ed_0_1)
f_1_2 = ff(Re_1_2, ed_1_2)
```

```
f_1_3 = ff(Re_1_3, ed_1_3)
f_1_4 = ff(Re_1_4, ed_1_4)
f_3_5 = ff(Re_3_5, ed_3_5)
f_0_6 = ff(Re_0_6, ed_0_6)
{-------------------------------------------------------------}
{-------------------------------------------------------------}

{Governing Equations}

{Main lines}
(P_0-P_T) / (rho*g) + z_0-z_T = -V_T_0^2/(2*g)*(f_T_0*L_T_0/d_T_0)
(P_1-P_0) / (rho*g) + z_1-z_0 = -V_0_1^2/(2*g)*(f_0_1*L_0_1/d_0_1)
(P_2-P_1) / (rho*g) + z_2-z_1 = -V_1_2^2/(2*g)*(f_1_2*L_1_2/d_1_2)*KV_2
(P_3-P_1) / (rho*g) + z_3-z_1 = -V_1_3^2/(2*g)*(f_1_3*L_1_3/d_1_3)
(P_4-P_1) / (rho*g) + z_4-z_1 = -V_1_4^2/(2*g)*(f_1_4*L_1_4/d_1_4)*KV_4
(P_5-P_3) / (rho*g) + z_5-z_3 = -V_3_5^2/(2*g)*(f_3_5*L_3_5/d_3_5)*KV_5
(P_6-P_0) / (rho*g) + z_6-z_0 = -V_0_6^2/(2*g)*(f_0_6*L_0_6/d_0_6)*KV_6

{-------------------------------------------------------------}
{-------------------------------------------------------------}


{losses}

KV_2 = 5
{
KV_2 = 5
KV_3 = 10000
KV_4 = 1000
}



{Flow rate, in pipes L/hr}

Flow_Lhr_T_0 = Q_T_0 *1000*3600

Flow_Lhr_0_1 = Q_0_1 *1000*3600

Flow_Lhr_1_2 = Q_1_2 *1000*3600

Flow_Lhr_1_3 = Q_1_3 *1000*3600

Flow_Lhr_1_4 = Q_1_4 *1000*3600
```

```
Flow_Lhr_3_5 = Q_3_5 *1000*3600

Flow_Lhr_0_6 = Q_0_6 *1000*3600



{Pressure in pipes in psig}
{
pconvert = 14.7/101325
psig_1 = P_1 * pconvert
psig_2 = P_2 * pconvert
psig_3 = P_3 * pconvert
psig_4 = P_4 * pconvert
psig_5 = P_5 * pconvert
psig_6 = P_6 * pconvert

}
```

Peak Demand EES Code Solution (Ikwavila's flow-rate is in green)

Solution

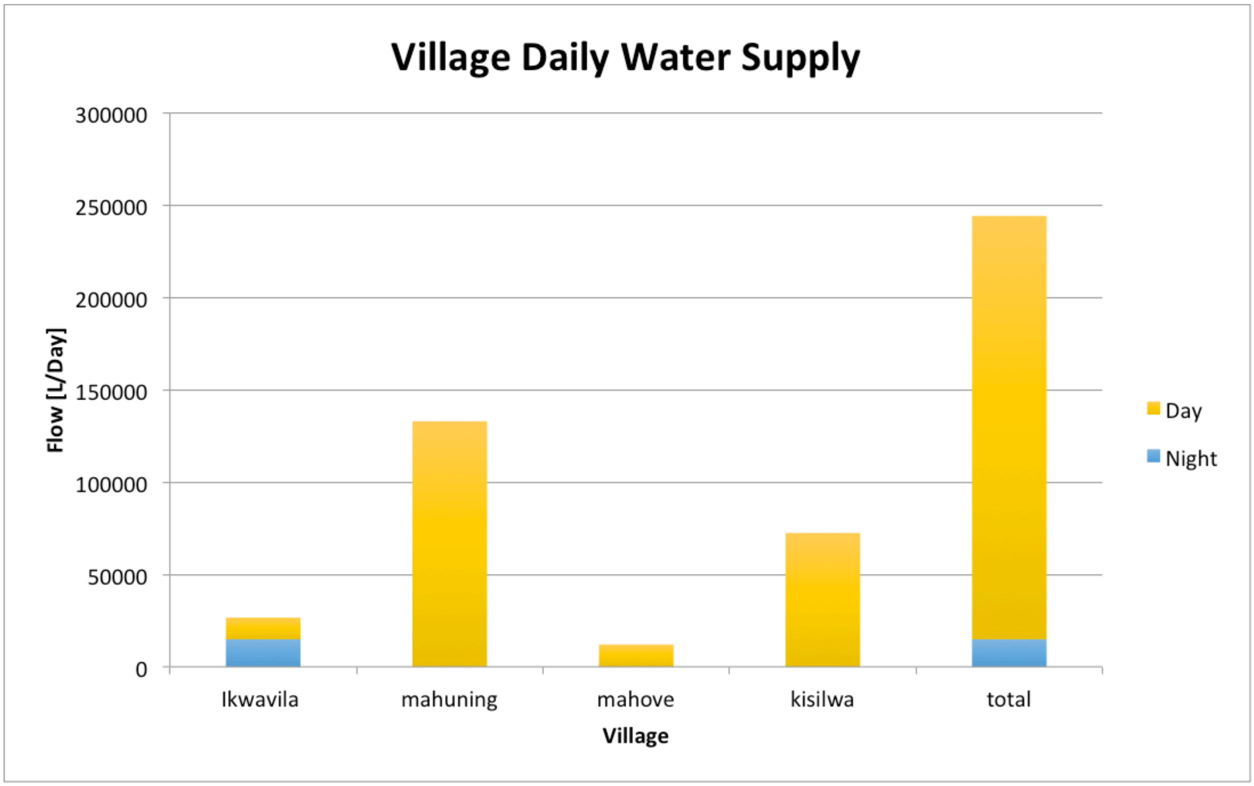
Main | ff

Unit Settings: SI C kPa kJ mass deg

$A_{0,1}$ = 0.00577	$A_{0,6}$ = 0.002827	$A_{1,2}$ = 0.002827	$A_{1,3}$ = 0.00577	$A_{1,4}$ = 0.002827	$A_{3,5}$ = 2.308	$A_{T,0}$ = 0.00862	$d_{0,1}$ = 0.08571
$d_{0,6}$ = 0.06	$d_{1,2}$ = 0.06	$d_{1,3}$ = 0.08571	$d_{1,4}$ = 0.06	$d_{3,5}$ = 1.714 [m]	d_s = 0.0254	$d_{T,0}$ = 0.1048	$ed_{0,1}$ = 0
$ed_{0,6}$ = 0	$ed_{1,2}$ = 0	$ed_{1,3}$ = 0	$ed_{1,4}$ = 0	$ed_{3,5}$ = 0	$ed_{T,0}$ = 1.505E-36	ε = 0 [m]	$Flow_{Lhr,0,1}$ = 9800
$Flow_{Lhr,0,6}$ = 4531	$Flow_{Lhr,1,2}$ = 731.9	$Flow_{Lhr,1,3}$ = 8313	$Flow_{Lhr,1,4}$ = 755.2	$Flow_{Lhr,3,5}$ = 8313	$Flow_{Lhr,T,0}$ = 14332	$f_{0,1}$ = 0.02222	$f_{0,6}$ = 0.02454
$f_{1,2}$ = 0.04067	$f_{1,3}$ = 0.0231	$f_{1,4}$ = 0.04027	$f_{3,5}$ = 0.04105	$f_{T,0}$ = 0.02132	g = 9.81 [m/s²]	KV_2 = 5	KV_4 = 117.5
KV_5 = 1.531E+07	KV_6 = 4186	loss05 = 1	$L_{0,1}$ = 2605 [m]	$L_{0,6}$ = 2 [m]	$L_{1,2}$ = 3270 [m·]	$L_{1,3}$ = 933 [m]	$L_{1,4}$ = 3477 [m]
$L_{3,5}$ = 3468	$L_{T,0}$ = 1996 [m]	μ = 0.0011 [N-s/m²]	P_0 = 368698	P_1 = 597636	P_2 = 0 [Pa]	P_3 = 499018	P_4 = 0 [Pa]
P_5 = 0 [Pa]	P_6 = 0 [Pa]	P_T = 0 [Pa]	$Q_{0,1}$ = 0.002722	$Q_{0,6}$ = 0.001259	$Q_{1,2}$ = 0.0002033	$Q_{1,3}$ = 0.002309	$Q_{1,4}$ = 0.0002098
$Q_{3,5}$ = 0.002309	$Q_{T,0}$ = 0.003981	$Re_{0,1}$ = 36763	$Re_{0,6}$ = 24282	$Re_{1,2}$ = 3922	$Re_{1,3}$ = 31184	$Re_{1,4}$ = 4047	$Re_{3,5}$ = 1559
$Re_{T,0}$ = 43986	ρ = 1000 [kg/m³]	$V_{0,1}$ = 0.4718	$V_{0,6}$ = 0.4452	$V_{1,2}$ = 0.07191	$V_{1,3}$ = 0.4002	$V_{1,4}$ = 0.07419	$V_{3,5}$ = 0.001
$V_{T,0}$ = 0.4618	x = 15	z_0 = 1077	z_1 = 1046	z_2 = 1104	z_3 = 1054	z_4 = 1030	z_5 = 1040
z_6 = 1080	z_T = 1119						

12.3 Graph Showing Village Water Supply

This graph displays the daytime flows when all the villages on the main line are getting 2.5 times their required flow, and the nighttime flow to Ikwavila assuming all Spigots are off.



12.4 Table of Spigot GPS Locations and Data for Existing System

4" Main Line
3" Main Line
2.1" Main Line
1.8" Main Line
2" Mahove Line

GPS Point	ID	Degrees Latitude	Degrees Longitude	Radians Longitude	Radians Latitude	Horizontal Distance Between Spigots (m)	Elevation (m)	Change in Elevation Between Spigots (m)	Actual Distance Between Spigots (m)	Pipe Length From Tank to Spigot (m)
746	MASSIVE TANK	-7.97385402	35.04988901	-0.139170007	0.611735966		1119.282227		0	0
745	SPG 1	-7.969621997	35.04784601	-0.139096144	0.611700309	522.5	1091.859009	-27.4	523.3	523.3
744	SPG 2	-7.965794988	35.050074	-0.13902935	0.611739194	492.4	1089.855225	-2.0	492.4	1015.7
755	SPG 3	-7.958886037	35.05555501	-0.138908766	0.611834856	980.6	1077.526001	-12.3	980.7	1996.4
756	SPG 4	-7.956931964	35.05662404	-0.138874661	0.611853514	247.7	1076.418213	-1.1	247.7	2244.1
742	SPG 5	-7.952469019	35.059048	-0.138796768	0.61189582	564.7	1061.922852	-14.5	564.9	2809.0
741	SPG 6	-7.948228028	35.06179199	-0.138722749	0.611943712	561.7	1062.674194	0.8	561.7	3370.6
740	SPG 7	-7.946463972	35.063017	-0.13869196	0.611965092	238.8	1063.76355	1.1	238.8	3609.5
757	SPG 8	-7.940142006	35.06669397	-0.138581621	0.612029268	813.2	1064.983765	1.2	813.2	4422.7
738	SPG 9	-7.938554976	35.06695901	-0.138553922	0.612033893	178.9	1060.601807	-4.4	179.0	4601.7
735	SPG 10	-7.937429035	35.06741599	-0.138534271	0.612041869	135.1	1056.566162	-4.0	135.2	4736.8
759	SPG 11	-7.933372026	35.06835803	-0.138463463	0.612058311	463.1	1061.22998	4.7	463.1	5200.0
760	SPG 12	-7.932361001	35.06885299	-0.138445817	0.612066949	125.2	1062.121094	0.9	125.2	5325.2
761	SPG 13	-7.930714963	35.06838896	-0.138417088	0.612058851	190.2	1060.508545	-1.6	190.2	5515.3
762	SPG 14	-7.929646019	35.06749101	-0.138398432	0.612043179	155.2	1054.841919	-5.7	155.3	5670.7
763	SPG 15	-7.928762985	35.06532798	-0.13838302	0.612005426	259.8	1055.124634	0.3	259.8	5930.4
764	SPG 16	-7.92814197	35.06579401	-0.138372181	0.61201356	86.3	1050.927734	-4.2	86.4	6016.9
733	SPG 17	-7.926238021	35.06520703	-0.138338951	0.612003315	221.5	1046	-4.9	221.6	6238.5
765	SPG 18	-7.922980981	35.06514299	-0.138282105	0.612002198	362.2	1041.046387	-5.0	362.3	6600.8
766	SPG 19	-7.92133796	35.06499697	-0.138253429	0.611999649	183.4	1040.348999	-0.7	183.4	6784.2
767	SPG 20	-7.919281041	35.06442097	-0.138217529	0.611989596	237.5	1039.177734	-1.2	237.5	7021.7
768	SPG 21	-7.91701097	35.06227897	-0.138177908	0.611952211	347.1	1029.193359	-10.0	347.2	7368.9
731	SPG 22	-7.902230993	35.05635398	-0.137919949	0.611848801	1770.6	1036.000000	6.8	1770.6	9139.5
749	SPG M1	-7.908842973	35.07671898	-0.13803535	0.612204237	3477.5	1033.000000	-27.6	3477.6	8079.3
750	BURST PIPE	-7.906297976	35.07540604	-0.137990931	0.612181322	318.4	1030.961304	-2.0	318.4	8397.7
751	MAHOVE PREACH PT. SPG M2	-7.901606038	35.07588096	-0.137909042	0.612189611	524.4	1031.000000	0.0	524.4	8922.1
752	BROKEN PIPE SPG M6	-7.901490033	35.07756103	-0.137907017	0.612218934	187.3	1024.000000	-7.0	187.4	9109.5

12.5 Figure of Concrete Pad for The Tank in Ikwavila - Including Dimensions

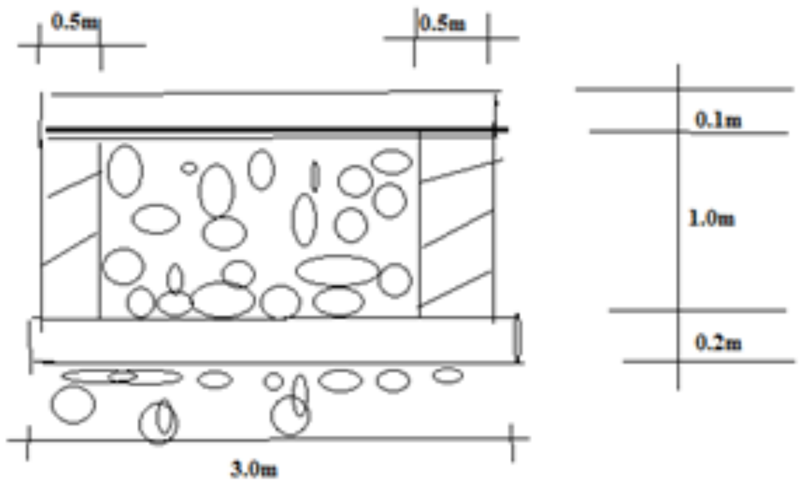


Diagram of concrete pad for tank.