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Juan Pio Water Supply for Small Community

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In this section,the teamwould like to acknowledge all the people who helped to a great extent throughout the duration of this project. From receiving the information package to the final piece of pipe glued together, BLUE Missions Group was a massive part in this project. Jorge Rodriguez, the Vice President of BLUE Missions Group and main point of contact for the team, was not only a huge help in this project, but was also a huge personal influence on everyone who was a part of this project. Another key part of this trip was Brayan Pichardo, a BLUE employed civil engineer, who helped with the design and analysis of this project. All of the group leaders, Ruben, Wilmer and Tiana, who helped with the construction process and acted as translators between the volunteers and the local community, made the construction process and trip in general possible. The BLUE social media team, Leslie, Fernando, Mariana and Teo, took most of the pictures in this report and also acted as translators for the volunteers and people in the community. All of the other volunteers who, not only also helped translate, but also helped in the process of acclimating while in the Dominican Republic. To the USI faculty, Dr. Hall and Dr. Kuban who helped with the design process and fundraising for the trip. The faculty advisor from USI, Dr. Hill, who helped the team through the design and analysis of this project.

Abstract

The purpose of this project was to help those less fortunate than what we see in our everyday lives. The team plans to give access to clean water and sanitation to families in the Dominican Republic. People in these rural areas resort to walking and carry water through rugged terrain for miles to get unfiltered, unsafe water to their families. Through the Blue Missions group, there have been over 36 thousand people connected to water and over 12 thousand people connected to improved sanitation. This work was all due to the over 5 thousand volunteers helping to make this happen.

This project aims to provide the people of Juan Pio a more efficient and safer alternative to fresh water. A dam will be built to hold water for a system of pipes to filter, contain, and deliver water to over 98 families. A holding tank will be used to contain filtered water for the use at any time. This report will go through the design process of the system and tank, the travel experience of the team, and the impact of the project within the community.

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<u>BLUE MISSIONS:</u>

JUAN PIO WATER SUPPLY TO SMALL COMMUNITY

1 INTRODUCTION

1.1 BLUE MISSION

Blue Missions is a non-profit organization that strives to bring clean drinking water to families in the Dominican Republic, Colombia, and Nicaragua. Founded in 2011, Blue Missions has been connecting communities with clean drinking water and sanitation, striving to alleviate poverty and create opportunities for those who lack basic human needs. Blue Missions has brought cleaner water to 36,456 people to date ("Our Work").

1.2 PROJECT LOCATION

This project is located in the Dominican Republic, in the Province of Puerto Plata, the Municipality of Yessica and in the community of Juan Pio. The coordinates of Juan Pio are 19°35'27.4" N, 70°32'21.3" W.

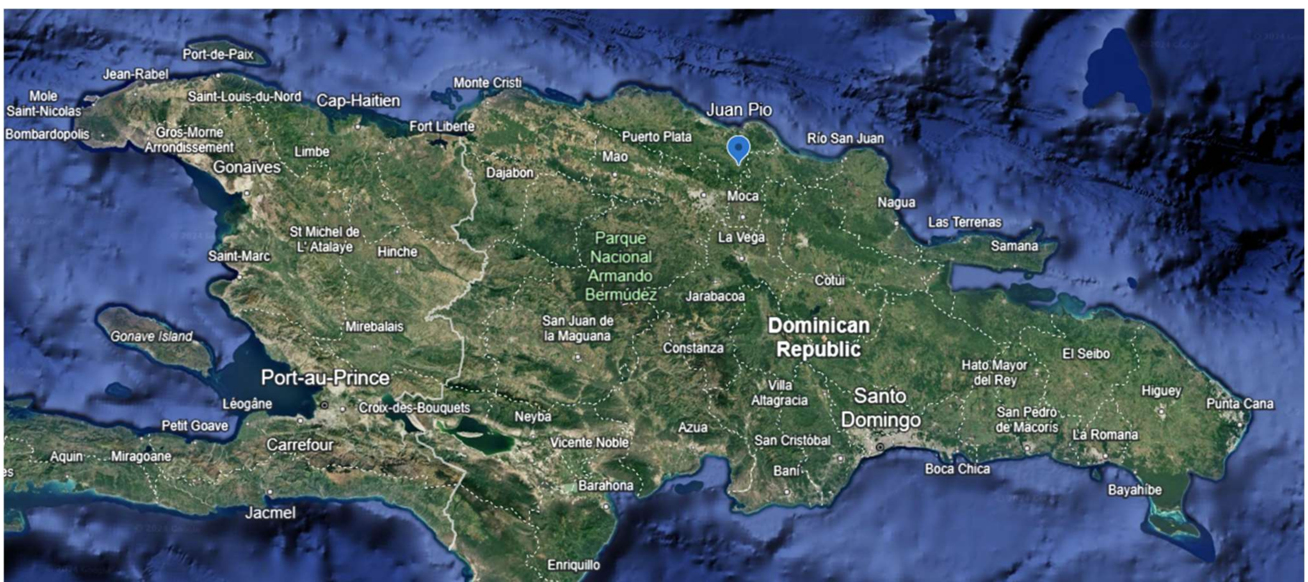

Figure 1: Aerial View of the Dominican Republic

1.3 THE PROBLEM

The 31 families living in Juan Pio are currently receiving their water via a self-made piping system built by themselves years ago. Due to the age of their system, it is beginning to fail; reducing the amount of water they receive. The existing piping network did not consist of a filtration tank or a holding tank for the dry season, which are two huge parts to this project. The existing piping is currently sitting on top of the ground and covered with rocks and boulders. With the large amounts of cattle that roam in the area, the cattle are stomping on the existing piping and smashing the piping, lowering the water pressure of the system. If the system were to completely fail, the woman, 58% of the community's population, would have to resort to making the half mile trek to the river to get the water for their families. The main issue in designing this system was deciding the size of pipe to use in the project. Since the materials in the area are scarce, the team was limited to using two and four inch pipes in the system. Luckily for this project, there was a water source higher in elevation than the community, so a gravity fed system was able to be utilized instead of needing a pump.

1.4 LIAISONS

Our liaisons for this project are: Jorge Rodriguez (Chiqui), VP at Blue Missions and our main point of contact for any questions, Brayan W Pichardo the lead engineer with BLUE Missions, Lucia, Manager of Volunteer Experience at BLUE Missions, Dr. Hall and Dr. Hill.

Chiqui was the team's first contact with the BLUE Missions Group. Chiqui gave the team the original information about the project, a KMZ file in Spanish, providing locations of the source, filter tank, holding tank, houses and piping routes.

Brayan was the contact for the design needs for this project. At the beginning of the project, Brayan had gave the team information on previous BLUE Missions projects and how they were designed and constructed. Some of the traditional methods used by BLUE Missions were to use a three-chambered filtration tank, a larger holding tank and to use two-inch piping.

Lucia was the team's main point of contact for the logistics of the construction trip. Lucia helped to organize the plane tickets, bus-rides in the Dominican Republic and customs papers for the Dominican Republic. A week before the construction trip, Lucia set up a teams meeting for all the volunteers involved with the project outlining what clothes to pack, what snacks were recommended, what type of toiletries would be needed, gear such as a mosquito net and where the team would be meeting at the airport.

2 DESIGN SCOPE

The water distribution system is comprised of the source, a filtration tank, a holding tank, and a simple pipe network, as shown below in Figure 2: Google Earth Image Mapping Route of Piping and Locations of Source And Tanks .

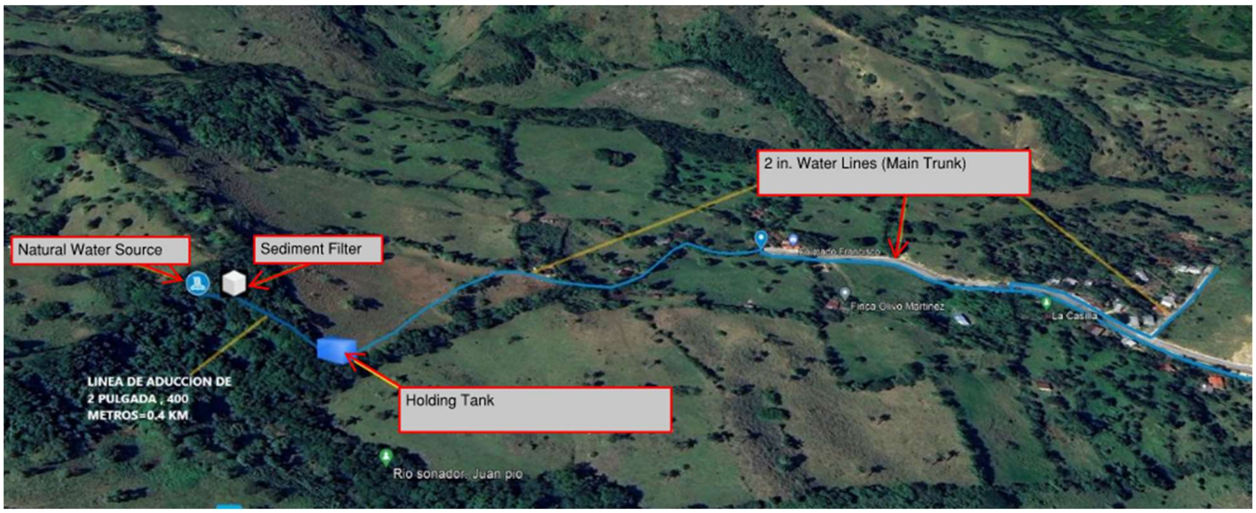

Figure 2: Google Earth Image Mapping Route of Piping and Locations of Source And Tanks

The source is a natural spring that had been redirected and contained in a small concrete culvert. Via 4-inch PVC pipe, the water pooled from the source is transported to the sediment filter. The sediment filter has 3 chambers: with the first containing large rocks and gravel, the second containing gravel and sand, and the final containing no sediment. Once the water is passed through the sediment filter, it is transferred to the holding tank. When the holding tank fills completely, the water starts to make its way through the 2-inch pipe network. The main trunk line supplies 22% of the 31 houses, until it splits into two main trunks that supply either side of the road. Looking west, the left trunk line is responsible for 26% and the right responsible for 52% of the total system load. Each house is connected to the trunk lines via ½ inch pipe that is T-ed directly in and ran to their water features.

The project team verified the system with several design checks. Reasonable assumptions had to be made to verify the system, since the team was not able to bring instruments or record any data points while on site. Although assumptions had to be made, the system was known to work and the verification methods yielded results accurate to what was expected to be seen.

2.1 EPANET MODEL

The water distribution modeling software EPANET was originally used to determine flows and pressures of the system. The entire water distribution system was laid out accurately to Juan Pio. Using Google Earth, elevations, northings, and eastings of each point of interest were recorded and converted into pipe length using Equation 1: Pipe Length Equation. Appendix N.1 shows all pipe length calculations.

Equation 1: Pipe Length Equation

$$\sqrt{(Northing_2 - Northing_1)^2 + (Easting_2 - Easting_1)^2 + (Elevation_2 - Elevation_1)^2}$$

The team ran into difficulties using the software to accurately model the sediment filter and run a steady state model. An error of negative pressures in the system was not able to be resolved. Instead, the team decided that hand calculation would be necessary to validate the design. Although EPANET was not used to validate any data, it proved useful to the team as a reference for pipe lengths and elevations. Below is the final version of the EPANET model before it was abandoned.

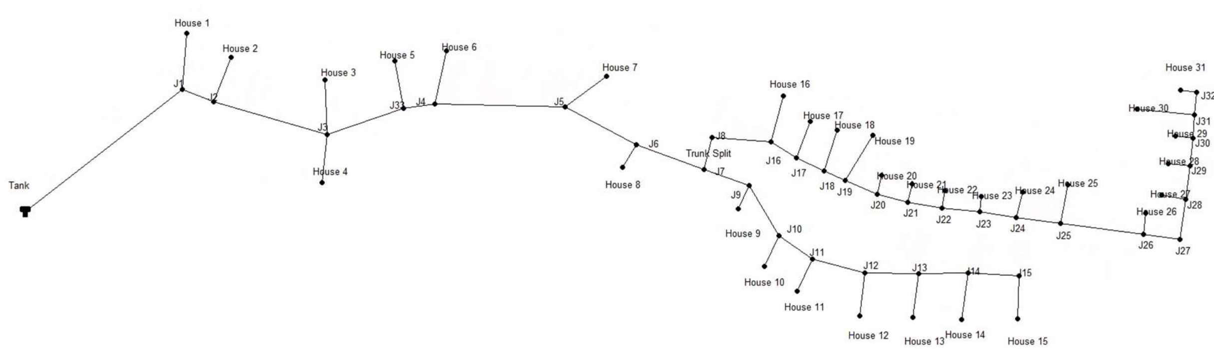

Figure 3: Abandoned EPANET Model

2.2 *SYSTEM DESIGN*

To begin hand calculations the team needed to estimate a velocity for the water coming from the source to the filter. Using the energy equation for water between two points, an assumed velocity was calculated.

Equation 2: Energy Equation

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$$

where:

P = Pressure at Point

V = Velocity

γ = Specific Weight of Water

Z = Elevation

g = Gravity (32.2 ft/s^3)

h_L = Head Losses

Using the energy equation at the surface of the water at both the filter and source, the velocity at Point 1 is equal to zero. Knowing that Point 1 and 2 are open to the atmosphere, both P terms are equal to zero. Expanding the five head losses: entrance, exit, valve, friction, and filter; the equation can be simplified, leaving us with Equation 3.

Equation 3: Initial Velocity Equation

$$V_2 = A_{pipe} \sqrt{\frac{(z_1 - z_2 - h_{filter})2g}{(\sum K_L + \frac{fL}{d})}}$$

where:

h_{filter} = 1 (assumption)

d = Diameter of Pipe (0.333 ft)

L = Length of Pipe (62.37 ft)

K_L = Sum of Loss Coefficients (2)

f = Friction Loss Coefficient = 0.02 (assumption)

Calculating velocity through the filter as 6.5 ft/s, the calculation was iterated to model a more accurate friction loss coefficient. The results of the iteration are found below in Table 1 and Table 2. The head losses were reiterated along with the flow calculations.

Table 1: Flow Calculations

Flow Calcs		
z_1	846	ft
z_3	841.5	ft
f	1.53E-02	
L	62.37	ft
g	32.2	ft/s^3
k_{exit}	0.5	
$k_{entrance}$	1	
k_m	0.05	
d_{pipe}	0.333	ft
A_{pipe}	0.087	ft^2
v	0.624	ft/s
Q	0.054	ft^3/s
v_{filter}	0.014	ft/s
Q	24.45	gal/min

Table 2: Head Losses Through Filter

Head Losses	
h_{exit}	0.425 ft
$h_{entrance}$	0.850 ft
h_{valve}	0.043 ft
h_f	3.182 ft
h_{filter}	2 ft
Sum	6.5 ft

The Carmen-Kozney equation was attempted to be used for head loss through the filter sediment but the results were unreasonably high so instead the team decided, with the guidance of Dr. Hill, that it would be best to assume a head loss of 2 ft. and move forward with other calculations.

Next the flows at different elevations were calculated using Equation 3 by substituting z_2 with elevations of interest. Table 3 shows the results of these calculations which are also plotted in the Flow vs. Elevation Curve in Figure 4.

Table 3: Flow at Different Elevations

Elevation	Velocity	Flow (ft^/s)	Flow (gal/min)
846	0.624	0.054	24.45
847	0.708	0.062	27.72
848	0.783	0.068	30.65

Based on personal experience of living in Jaun Pio for five days, it was determined that the peak water demand would be at 6 p.m. The people of Jaun Pio would begin cooking at showering for the day around this time every day. Therefor, 40% of the days water supply would be used at this time. This is important as the peak load will affect the pressures in the system. Each person was assumed to use 17.5 gallons of water per day. Assuming each house holds 3 people, each house requires 52.5 gallons of water each day. The team split the demand of the system into three legs as that's how the system is laid out. Leg one includes all the houses that the main trunk line supplies before it split. Leg two includes all the house on the east side of the road after the trunk line split. While leg three includes all the houses on the west side of the road after the trunk line split. The max demands at 6 p.m. were calculated using Table 4 below.

Table 4: Maximum Load on System

Section	# of Houses	% of Houses	GPM by percentage	40% GPM
L1	7	23%	6.92	2.77
L2	8	26%	7.91	3.16
L3	16	52%	15.82	6.33
Totals:	31		30.65	12.26

Using the demand of the each leg of pipe calculated above, the pressures at each extreme were calculated to ensure that all assumptions were reasonable and yielded reasonable results. The pressures at the furthest house on each leg were calculated in Table 5 below.

Table 5: Peak Pressures at Peak Demand

	Furthest house on 3	Furthest house	Closest House
P_2 psf	5629.3	7278.6	9251.1
P_2 psi	39.09	50.55	64.24

Finally the time the fill the storage tank was calculated to be sure it would always be full for the people of Jaun Pio. Using the flows calculated in Table 3, the volume of the tank was used to simplify the time the fill the tank at different elevations. Table 6shows those calculations.

Table 6: Time Range to Fill Tank

Elevation	Velocity	Flow (ft^/s)	Flow (gal/min)	Volume (ft^3)	Δt	Δt (min)	Δt (hr)
846	0.624	0.054	24.45	1016.28	41.57	310.93	5.18
847	0.708	0.062	27.72	1016.28	36.66	274.21	4.57
848	0.783	0.068	30.65	1016.28	33.16	248.03	4.13

2.3 DESIGN OUTCOMES

From the equations and calculations above, there are a few key points that can be taken from this project. Total flow through the system to the holding tank, head losses in the system, time to fill the holding tank and water pressures at each house.

The total flow through the system varies depending on the level of the water at the source. Based on the rough measurements taken of the inside of the source and the calculations explained in the previous section, the flow throughout the system will be anywhere between 25 to 30GPM, as shown in Figure 4: Flow vs. Elevation of Source below. Given the total flow through the system and the size of the holding tank, the holding tank should take anywhere between 4 to 5 hours. As the water level at the source rises, the time for the tank to fill decreases. This is due to the fact that as the water level at the source rises, the total flow in the system will rise.

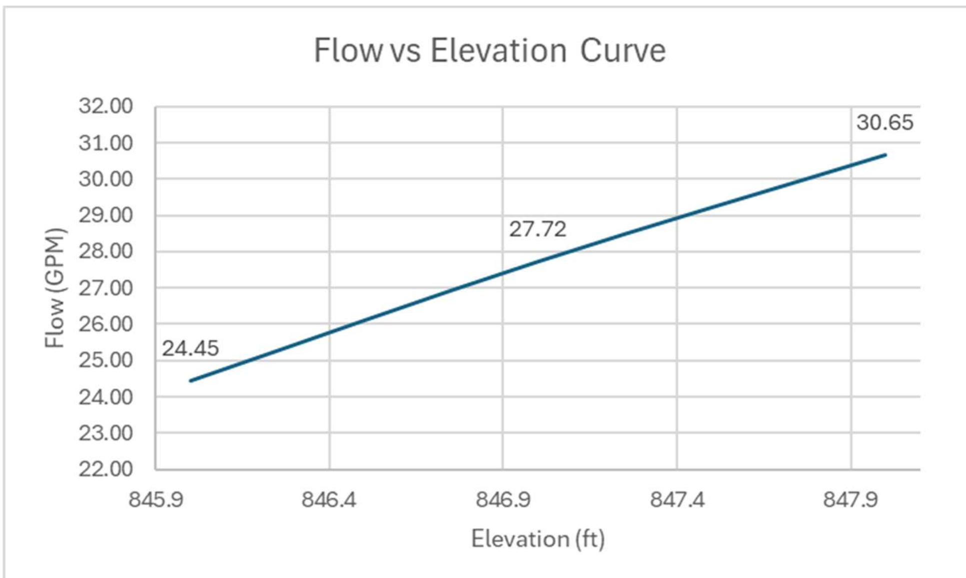

Figure 4: Flow vs. Elevation of Source

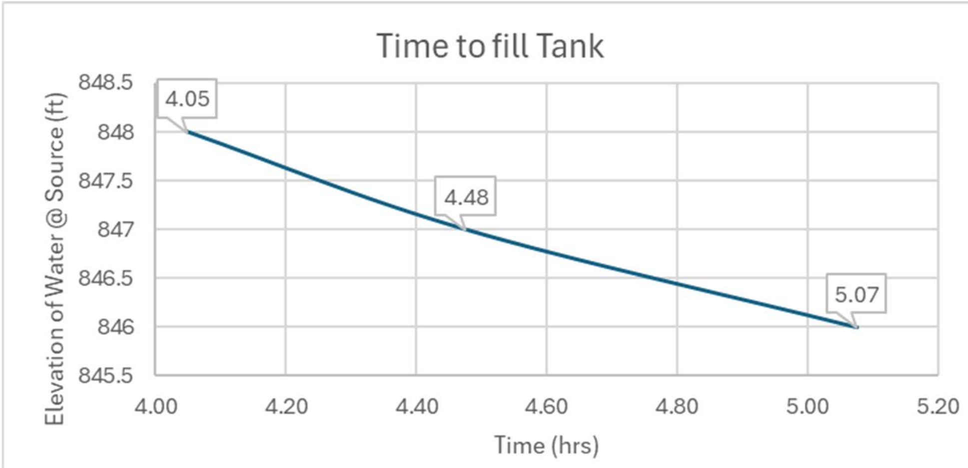

Figure 5: Time to Fill the Tank

The pressures at each of the houses is the final outcome needed to say that this system will work. According to the EPA, builders should ensure that water pressure does not exceed 80psi and the pressure reducing valve should be set between 45 and 60psi (EPA).

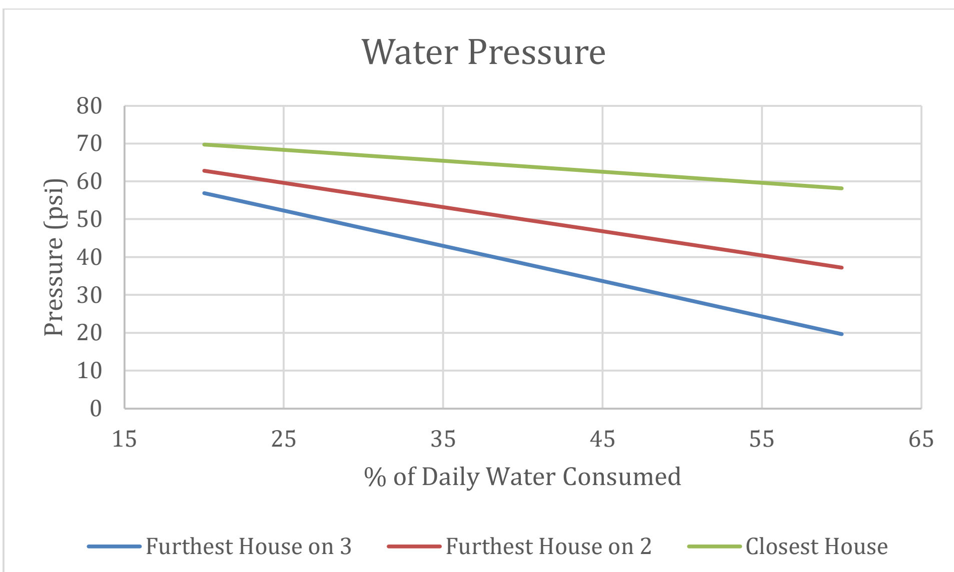

Figure 6: Water Pressure at Different Houses

The found the pressures at the furthest house on each of the legs of the system as well as the pressure of the closest house to the holding tank.

2.4 TANK DESIGN

The holding tank in this system is where the filtered water will be stored for future use. The main purpose of this tank is have a reservoir for storing water, instead of just having pipes straight from the filter tank to the houses. There is a shutoff valve connecting the filter tank to the holding tank to prevent the holding tank from overflowing, saving water. Having a straight piping system with no holding tank would put large amounts of stress on the pipes, as they would be under constant pressure. During drier seasons, the holding tank will act as a reserve water source that can be used until more rainfall occurs or the mountain spring begins to flow again.

The tank was designed to have a six-inch foundation with #4 rebar on one-foot centers. After talking with Brayan, this seemed to be very custom for many of the BLUE projects. Brayan explained to us that most of the soil around the parts of the island that they build on is all very similar. The soil on the island is a sandy silt, riddled with rocks and boulders. The rocks and boulders in the soil add to the density of the sandy silt, increasing the bearing capacity of the soil.

The walls of the tank were to be built with 8"x8"x16" CMU's. The CMUs were to be placed over top of rebar sticking out of the foundation of the tank. The rebar protruding from the foundation would run through each layer of CMU's and then be bent at the top of the walls of the tank and connect the lid of the tank to the walls of the tank. With the CMUs being offset as they were laid, the vertical rebar will help hold the walls together in case of settlement. The CMUs were also core-filled, where concrete is poured into the holes of the CMUs, which along with the rebar, will help counteract the hydrostatic force of the water in the tank.

The lid of the tank was designed to have #4 rebar on 8" centers. The spacing of the rebar was based on the spacing of the vertical rebar in the holes of the CMUs. The use of the #4 is due to the fact that materials are scarce in the area and #4 rebar is the most common rebar. Since the concrete would be a shovel mix, mixed on site, there is no way to tell exactly what the compressive strength of the concrete would be. With the experience the team has had in construction materials and some collaboration with Dr. Hall, it was assumed that the shovel mix would have a compressive strength of 3000 pounds per square inch (psi). The team discussed with Dr. Hall that after observing the concrete, the water content in the mix was very high. A high water content was helpful for the constructability of the lid but decreases the strength of the concrete. An analysis was done to see the max moment in the middle of the slab, to see if the lid would pass. The team decided to conservatively do a one-way slab analysis on the lid of the tank. A one-way slab analysis assumes a one-foot strip of concrete, that is simply supported. The tank lid is considered a two-way slab, but the one-way analysis is a conservative estimate, so the lid would pass the two-way analysis.

For the analysis, the team assumed a dead load of 75plf, the weight of the concrete itself, and a live load of 20plf, which could be people standing on the lid or tree branches falling on the lid. The team used a load combination of 1.2D+1.6L, where D is the dead load and L is the live load. This load combination is from the Building Code Requirements for Structural Concrete (ACI 318-19) (Moehle et al.). The ultimate moment in the middle of this simply supported section is quantified by the equation shown below.

Equation 4: Ultimate Moment Equation

$$M_u = \frac{wL^2}{8}$$

The above equation yields an ultimate moment of 31.5 k"/ft. The design capacity of the concrete slab is found by first finding the area of steel in the concrete, A_s. the area of steel in the concrete, then finding the moment arm for the moment caused by the steel in the concrete and multiplying them together.

Table 7: Capacity of Lid Variables

Capacity of Lid		
h	6	in
d	4.5	in
b	12	in
a	0.59	in
A_s	0.3	in^2
M_n	76	k"/ft
φM_n	68	k"/ft
s_{max}	11.88	in

With the variables from the equation above, using the equation below, a max capacity of 68k"/ft is allowed for this section to pass the analysis. With the capacity of the lid higher than the demand of the lid, a factor of safety of 2.2 is safeguarding the tank lid from failure.

Equation 5: Factored Max Moment Capacity

$$\varphi M_n = A_s f_y((d - a)/2)$$

3 CONSTRUCTION

3.1 PIPE NETWORK

The pipe network for Juan Pio began weeks before the team's arrival to the Dominican Republic. A crew from Blue Missions, along with help from some of the locals, dug most of the trenches for the pipe for us. Previous Blue Missions trips laid the piping system on top of the ground and covered the pipe with large rocks for protection. The team learned that just covering the piping system with larger rocks does not protect against the cattle that graze the fields. The piping system was to be buried around 1 foot in the ground to protect against the weight of the cattle. Being the ground consisted of mostly rock; some areas were forced to be shallower than 1 foot.

3.1.1 Pipe Transport

The first morning the team woke up, the job was to get as much pipe up the mountain as possible. The piping materials had been dropped off by Blue Missions workers before the team arrived. The total stretch of the pipe network was around ¾ of a mile with the two main trunk lines. The method for getting the piping up the mountain was to carry one 2 inch by 19 foot stick of pipe on the shoulder. The Blue Missions leader said this would be the safest option due to the terrain. The pipes were laid out in a manner that would prevent leaking in the joints. The bell end of the pipe was always laid in the orientation of being at a higher elevation than the non-bell end. This would allow gravity to not push against the edge of the next pipe, instead the water flowed out the end of the first and into the bell of the second pipe, Figure 7: Pipe Transport (1) below.

Figure 7: Pipe Transport (1)

The hill in the background of the image above was the obstacle of the trek to the tank, filter, and source. This hill had a steep grade, was hard to navigate due to rocks and boulders, and was extremely slippery due to the mud. These conditions made it necessary for the team to have one hand available to help balance themselves or brace themselves in case of slipping.

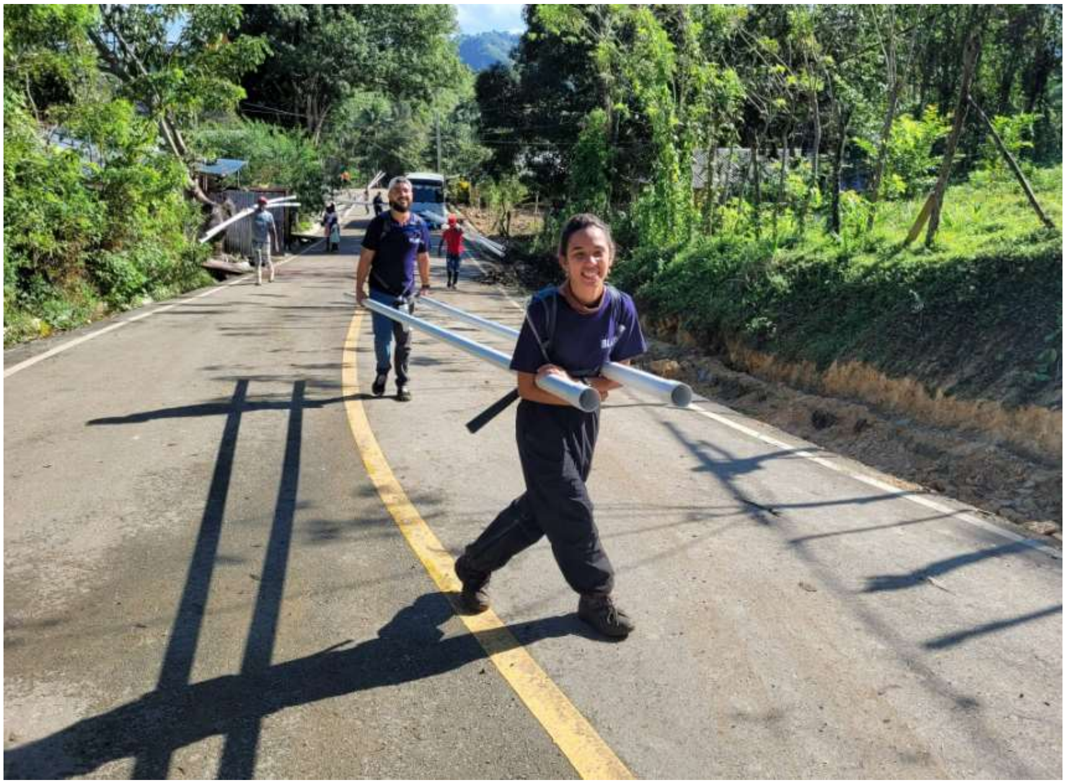

Figure 8: Pipe Transport (2)

Figure 8: Pipe Transport (2) above shows an alternative way to carry pipe. This involves two team members, each carrying one end of a pipe in each hand. This method was more efficient than one person carrying one pipe, but was not practical to use on the steep slope. This method was used to carry pipe on the easier treks, such as on the road and on the open pastures.

3.1.2 Pipe Glueing

After the pipe was all laid out, the team then went back to glue all of the pipes together. This process is very similar to the process used here in the United States. The pipes were first wiped off or cleaned with a rag or towel to remove any dirt and ensure a tight seal, then the bell of the first pipe and the end of the next pipe were coated in PVC glue. After glueing the pipes, the two ends of the pipe were pushed together and held for ten seconds for an optimal seal on the pipe.

Figure 9 Pipe Connection

3.1.3 Trench Backfilling

The final part of the piping layout the team was tasked with was covering the pipe in the trenches. This task was much easier in some areas than it was in others. Figures 4 and 5 below show some of the easier areas, where there was more soil to work with. These areas allowed the team to use shovels to reuse the soil that was trenched in the first place. The larger rocks, which can be seen in the background of Figures 4 and 5 were thrown out of the way, so that their jagged edges did not puncture the pipe by either the weight of themselves or the extra weight of the grazing cattle above.

Figure 10 Trench Covering (1)

Figure 11 Trench Covering (2)

Other areas were handled in a different manner. If the trench was not in a pasture, where cattle would be walking over the pipe, an assortment of materials would be used to fill the trenches. Figure 12: Alternative Trech Filling below shows a trench that is between a ditch and a barbed wire fence. The cattle cannot cross the fence, so there is no worry of the cattle stomping on the pipe. These trenches were not dug as deep, and were backfilled with the large gravel that dug out of the trench. This large gravel was moved the easiest with a pickaxe. Figure 13: Backfilling with a Pickaxebelow shows one of the locals backfilling with a pickaxe.

Figure 12: Alternative Trech Filling

Figure 13: Backfilling with a Pickaxe

3.1.4 Individual Taps

The final part of the piping system was to tap ½ inch pipe off the main 2-inch pipe to each house. Figure 14: 1/2 inch Pipe Taps below shows two ½ inch pipes, tapped into the main 2-inch pipe, that are the sources of water for a house. Some house had one tap and others had more, depending on how many amenities they have that use running water. Every tap has a shutoff valve close to the main pipe in case of emergency, similarly to houses in the United States have water shutoff valves that will shut off the water to all systems using that water.

Figure 14: 1/2 inch Pipe Taps

The team only performed a select few of the taps as seen in Figure 14: 1/2 inch Pipe Taps above. The town of Juan Pio was then left with the necessary tools and knowledge to then finish their own taps anywhere on the main line. The Vice President of Blue Missions, Chiqui Rodriguez, called this, “the town having some skin in the game”. Chiqui did not want the town to feel reliant on the work being done for them, which is why they were encouraged to help with the project, and were even left with a little bit of work to do themselves.

3.2 FILTRATION SYSTEM

The filtration aspect of this project is a relatively small tank consisting of three chambers, as seen in Figure 15: Filtration Chambers below. The top of Figure 15: Filtration Chambersbelow shows the input to the tank, which is at the top of the chamber. The outlet of the chamber is at the bottom of Figure 15: Filtration Chambers, which is also toward the top of the side of the tank to allow for sediment to separate from the water and settle in the bottom of the tank.

Figure 15: Filtration Chambers

The first chamber of the tank is the input to the tank, where water from the source first enters the tank. This chamber will act as the first form of filtration for the water. This tank will be filled with pea gravel to filter out any larger debris or sediment. Water will travel through the pea gravel to the bottom of the first chamber where there are two holes entering the second chamber. Figure 16: First Chamber below shows the holes to the second chamber where daylight is seen entering the bottom of the chamber. These holes will be covered with large stones to prevent the pea gravel from flowing over into the second chamber. Figure 16: First Chamber16 below is not the finished first chamber, as there is still the need for a finish coat of cement to make the tank impermeable. A finish coat on the tank is shown in Figure 18: Cement Finishing Process below. Figure 19: First Chamber Finished also shows the larger stones which were discussed above.

Figure 16: First Chamber

Figure 17: Second Chamber

Figure 17: Second Chamber above shows the second chamber, which is the second aspect of filtration for this system. The second chamber consists of a clarifier weir, which will allow all of the water to rise up above the weir and flow over the weir. The sediment will settle to the bottom of the second chamber, which will have pipe at the bottom with a flush valve on the outside of the tank. This flush valve will allow the community to clean the sediment out of the second chamber when needed.

The third chamber, shown at the bottom of Figure 15: Filtration Chambers, will be a larger chamber than the first two. This will be a settling chamber, like the second chamber, but with a pipe outlet instead of a weir. This chamber will also allow the water to rise to the outlet pipe as the leftover sediment falls to the bottom of the chamber. This chamber will also have a pipe at the bottom with a flush valve outside the tank, as shown in Figure 15.

The next task the team did was to finish the filtration tank. This process was done by mixing cement with water to create a mostly watertight coating. Having this coating on the inside and the outside of the tank will eventually break down and allow minimal water to permeate through the wall. Since water will pass through the concrete mixture, maintenance of recoating the walls of the tank will be needed.

Figure 18: Cement Finishing Process

Figure 19: First Chamber Finished

Figure 20: Finished Filtration Tank

3.3 *HOLDING TANK*

Before the project team arrived, the holding tanks construction had already begun. The tank was a 4m x 4m x 2m (13.12ft x 13.12ft x 6.56ft) CMU block structure built on top of a 12-inch concrete slab. The team was tasked with waterproofing the tank and pouring a 6-inch steel reinforced lid with a 4 ft x 4 ft access port in the south-east corner of the tank. The access port is intended to be used for easy access for cleaning and chlorine tablets.

Figure 21: Existing Condition of Tank

Shown above, in Figure 21, was the existing condition of the holding tank when the team arrived. The tank's lid had not been formed or poured at this point. The inside of the tank had already been skim coated with cement to provide a watertight barrier, shown in Figure 22.

Figure 22: Interior of Tank

Figure 23: Formed Tank Lid and Rebar Reinforcement

In Figure 23, shown above, was the process of reinforcing the holding tank's lid. Vertical #4 rebar had already been cemented into the CMU block, so the task was to bend existing bar over to connect it to the lid reinforcing; as well as tie all the new reinforcement in order to ensure the proper spacing of 8" on center.

Figure 24: Material Transportation Method

All of the concrete materials were brought up the mountain using mules, as shown above in Figure 24, including what would be comparable to 53's in the US, sand, and cement. Also shown in Figure 24 is the forming used for the pour. Scrap wood of various sizes and quality was used to contain the concrete as it was being poured. The forming was secured by regular carpenter nails, nailed directly into the CMU block.

Figure 25 Concrete Transportation "Bucket Brigade"

Using the concrete materials delivered via mule, the team made a pile of rock, sand, and cement near the holding tank and begun mixing by hand. After all of the materials were sufficiently mixed, a moat was formed in the mixture to contain water. Using the water source, water was added to the mixture and the team begin mixing. Shown above in Figure 25 was the “Bucket Brigade” where the entire project team grabbed pales of concrete to transfer onto the lid of the tank. One by one the buckets were emptied onto the lid and sent back down to be refilled.

Figure 26 Concrete Pouring

Figure 26 shows the concrete about half poured and the team members on the lid emptying the buckets, consisting of two Blue Missions members and five volunteers.

Figure 27 Concrete Finishing

The concrete was finished using a small 8 inch tool compared to the typical 20-30 inch tools used in the States, as shown in Figure 27 above. The finish and level of the lid was not perfect and would most likely not pass as acceptable in the US but it was certainly good enough for what the community was looking for. The next day, part of the project team returned to the tank to finish the skim coating on the outside. Without the skim coating the holding tank would be more susceptible to weathering and not be as reliable to ensure clean water is making it to the taps at each home.

4 IMPACT

4.1 BLUE MISSION DATA

BLUE Missions puts out an impact report every year detailing the number of people they help every year. According to the 2023 BLUE Mission Impact Report, they have connected 33,684 people to clean water and 11,034 people to improved sanitation with a total of 229 projects, to date (Missions, B). Sanitation projects were set up similarly to the water distribution and filtration project seen above, but instead of building tanks, filters and trenching pipes, they would go to a village and build 14 latrines. These latrines are what first world citizens would call outhouses, but to the people in these communities, they are much cleaner and safer than what they are used to.

In 2023 BLUE Missions worked on 38 infrastructure projects connecting 3,344 people to clean water and 1,384 people to sanitation. This process took the help of 851 volunteers to help complete these projects in just one year. The total cost of the water program for the year of 2023 was $311,298 with an average cost per person helped of about $93 per person helped. Figure 28 is a cost breakdown of percentages of money and what they are used for.

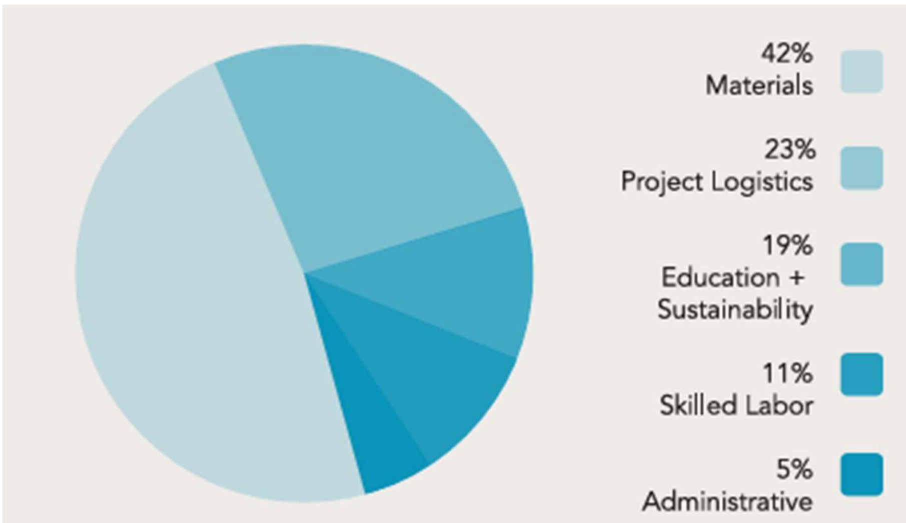

Figure 28: Cost Breakdown

Every volunteer that attends these trips must pay their own way for transportation, as well as come up with a donation to help pay for the project. For the trip to Juan Pio, the total cost of the trip per person was $2,100. This cost was broken into trip expenses and the Community Contribution Fee (CCF). The trip expenses were everything from plane tickets and bus rides to food and water provided to us for the week, which came out to be $1,350. The other $750 paid to BLUE Mission was for the CCF, which all goes toward the price of materials for the projects. The CCF is usually fundraised by the volunteer by whatever means they have access to. If the volunteer is not able to fundraise the entire amount, they would be charged the difference. If a volunteer is able to fundraise more than the required amount, 100% of that difference will go directly to the project, or to the next materials of the next project.

4.2 PUBLIC HEALTH, SAFETY, AND WELFARE

The largest impact category this Capstone projects encompasses is the public health, safety and welfare of people. By giving people access to clean water, the team was able to greatly improve the public health of every person in the community of Juan Pio. Those individuals no longer must drink, cook with, or bathe in unfiltered, dirty water as they were before. Having filtered water helps these people with everything from decreasing the number of parasites people are getting from drinking unfiltered water to having clean water to wash their clothes. Water no longer needs to be rationed throughout the day between different tasks.

4.3 ENVIRONMENTAL

The environmental impact of this project was mostly in the construction phase. Comparing this project to a similar project being built in the United States, this BLUE project was very environmentally friendly. This project was all built by hand, without the use of heavy machinery. Any major obstacles were avoided due to the lack of machinery needed to deal with obstacles like large boulders, trees, and creeks. Materials were not disposed of on-site; they were taken by BLUE Mission workers back to the city to be disposed of. BLUE Mission Group takes pride in being environmentally friendly. If there is a stream that would need to be tapped into to serve a water distribution system, BLUE makes sure that there are no towns downstream that will be affected.

4.4 ECONOMIC

The main economic impact of this trip was that most of the trip was fundraised for the people of Juan Pio. All of the volunteers of the trip paid for materials when they paid BLUE Missions Group to go on the trip. There was also a sponsor for this trip, Renaissance Restoration, a company from Tennessee, who also helped fund a lot of this trip. Without the funding from the volunteers and this sponsor, the community of Juan Pio would not be able to afford all of the materials needed to complete this project.

One of the economic advantages of this project was that people no longer need to buy bottled water, if they chose to buy water instead of boiling water. While in the Dominican Republic for the construction trip, the team drank from five-gallon bottled water. The community no longer needs to buy these now that they have filtered water at their house. Having running, filtered water at each house will also free up time for the community to search for another income, to be able to afford more things like sinks, showers and washing machines.

4.5 Social and Cultural

The Dominican Republic often leans on traditional gender roles for people in the community. This being said, the women of the families are often in charge of caring for the family and doing most of the duties around the home. The men are in charge of caring for the family in a more financial way, whether this means raising cattle, working the convenience store, or in rare occasion traveling to work for a paycheck. While the men are away doing their duties, the women, and sometimes even the children, were the ones that would have to make the trip to get buckets of water several times a day. As this trip was not short, and with having to make the trip several times a day, collecting water was what the women spent the majority of their day doing. If the children were having to help collect water, or any other chores around the household, they were not able to attend school.

With having running water at every house in the community, the women have more time to maybe work for a paycheck or have the time to teach some of the children. The kids will have fewer chores to do around the house, allowing them to attend school on a regular basis. While on the construction trip, the women of the community came together to talk to all of the volunteers about how much they appreciated the team for financing and building this water distribution system and how much easier their lives would be after it is finished. The women were so looking forward to having running water for amenities such as sinks, toilets, and showers.

5 CONCLUSION

The Juan Pio water distribution system project was successful in serving the community and meeting their specific needs. Each house in the community has at least 2 water taps ran to their houses to be used as the families see fit. A complete technical analysis was carried out to ensure the safety and reliability of the water system; including pressure and velocity verification. In the end, Juan Pio will benefit from the efforts of the team for years to come.

REFERENCES

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APPENDIX

Table N.1 Pipe Length Calculations

Point Name	Pipe #	Northing	Easting	Elevation (ft)	Elevation (m)	Pipe Length (m)	Pipe Length (ft)
Dam		338555.53	2166395.10	845	257.556		
	Pipe 1				0	19.0118413	62.3748
Filtration		338557.69	2166413.90	839	255.7272	0	0.0000
	Pipe 2				0	70.31211886	230.6828
Tank		338592.46	2166465.39	731	222.8088	0	0.0000
	Pipe 3				0	107.2038863	351.7188
J1		338572.97	2166570.41	701	213.6648	0	0.0000
	Pipe 4				0	96.60744854	316.9536
J2		338477.5	2166584.65	688	209.7024	0	0.0000
	Pipe 5				0	65.53432274	215.0076
J3		338481.02	2166649.49	659	200.8632	0	0.0000
	Pipe 6				0	60.72969787	199.2444
J4		338435.75	2166689.97	660	201.168	0	0.0000
	Pipe 7				0	58.04408768	190.4334
J5		338436.16	2166747.08	626	190.8048	0	0.0000
	Pipe 8				0	166.1443032	545.0929
J6		338522.62	2166888.32	582	177.3936	0	0.0000
	Pipe 9				0	10.39470553	34.1034
J7		338527.11	2166897.69	581	177.0888	0	0.0000
	Pipe 10				0	14.12777449	46.3510
J9		338533.31	2166910.37	579	176.4792	0	0.0000
	Pipe 11				0	13.50212857	44.2983
J10		338542.63	2166920.02	574	174.9552	0	0.0000
	Pipe 12				0	33.57153981	110.1429
J11		338570.49	2166937.93	556	169.4688	0	0.0000
	Pipe 13				0	30.11447622	98.8008
J12		338596.12	2166952.97	540	164.592	0	0.0000
	Pipe 14				0	32.4906951	106.5968
J13		338623.86	2166969.55	529	161.2392	0	0.0000
	Pipe 15				0	13.84730113	45.4308
J14		338634.33	2166978.53	525	160.02	0	0.0000
	Pipe 16				0	6.203169525	20.3516
J15		338638.67	2166982.92	523	159.4104	0	0.0000
Trunk Split							
J7		338527.11	2166897.69	581	177.0888	0	0.0000
	Pipe 17				0	11.47275032	37.6403
J8		338516.23	2166901.33	581	177.0888	0	0.0000
	Pipe 18				0	23.45362549	76.9476
J16		338528.17	2166921.48	577	175.8696	0	0.0000
	Pipe 19				0	7.64365275	25.0776
J17		338533.04	2166927.3	574	174.9552	0	0.0000
	Pipe 20				0	5.036885165	16.5252
J18		338536.23	2166931.15	572	174.3456	0	0.0000
	Pipe 21				0	2.247955302	7.3752
J19		338538.23	2166932.13	571	174.0408	0	0.0000
	Pipe 22				0	9.026478392	29.6144
J20		338547.02	2166934.09	569	173.4312	0	0.0000
	Pipe 23				0	2.310608613	7.5807
J21		338545.5	2166935.72	567	172.8216	0	0.0000
	Pipe 24				0	5.624909969	18.4544
J22		338550.56	2166938.1	565	172.212	0	0.0000
	Pipe 25				0	3.938224493	12.9207
J23		338554.04	2166939.84	563	171.6024	0	0.0000
	Pipe 26				0	4.924523059	16.1566
J24		338558.36	2166942.02	560	170.688	0	0.0000
	Pipe 27				0	4.792945583	15.7249
J25		338562.47	2166944.31	557	169.7736	0	0.0000
	Pipe 28				0	25.06258558	82.2263
J26		338583.88	2166956.62	543	165.5064	0	0.0000
	Pipe 29				0	14.03598763	46.0498
J27		338595.8	2166963.93	539	164.2872	0	0.0000
	Pipe 30				0	13.91663045	45.6582
J28		338586.66	2166974.42	540	164.592	0	0.0000
	Pipe 31				0	22.21859807	72.8957
J29		338572.97	2166991.92	540	164.592	0	0.0000
	Pipe 32				0	18.38393601	60.3148
J30		338561.66	2167006.41	541	164.8968	0	0.0000
	PIpe 33				0	16.86098896	55.3182
J31		338551.19	2167019.57	545	166.116	0	0.0000
	PIpe 34				0	26.94607352	88.4058
J32		338535.85	2167041.18	561	170.9928	0	0.0000

Table N.2 Design Factors Considered

Design Factor	Section
Public Health, Safety, and Welfare	4.2
Environmental	4.3
Economic	4.4
Social	4.5
Cultural	4.5

Table N.3 Reference Standards

Reference Standard	Section
ACI 318-19 Building Code Requirements for Structural Concrete	See References
EPANET Reference Manual	See References