Emberá Puru Water Supply and Distribution System

Darien, Panama

Prepared for Footprint Possibilities & Global Brigades Panama

Final Report - Revision 1.0
Summer/Fall 2019
CE 4916: I-Design

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Letter of Intent

November 20, 2019

Footprint Possibilities Panama
PH Mira Mar, Ave Balboa
Bella Vista, Ciudad de Panama, Republica de Panama

To: Riziero Montanari
CC: Dr. David Watkins; Mike Drewyor

Dear Rick,

The water supply and distribution system design detailed and discussed in this report was developed for the community of Emberá Puru, Panama. The system pumps water from an identified spring near the community to a water storage tank, where the water is chlorinated and distributed through a pressurized network to household taps. Compiled in the report are the accomplished tasks from the site assessment and planning & design phases. KRV Water Solutions, Inc. (KRV) worked diligently to provide the materials outlined in the transmittal.

KRV recommends that the final report, along with all attachments, be thoroughly reviewed. Due to outstanding action items and unknowns, significant design assumptions for the system were made in order to develop a design. Specifically, the design items that should be evaluated based on the design assumptions are the water collection structure, pump, pipe diameter and method of power supply. Baseline design drawings of each component, along with recommended materials, associated calculations and design alternatives, have been attached.

Thank you for selecting KRV for two of the phases of this project. We have been able to expand our knowledge, enhance our skills and contribute to the greater good. Please do not hesitate to contact the Project Manager, Victoria Quinde, if there is any clarification necessary for the design of the system detailed in this report.

Sincerely,

M. Victoria Quinde,	Kelsey M. Fournier,	Ross T. Hogan,
Project Manager	*Technical Writer*	*Applications Engineer*

Emberá Puru, Panama Water Supply and Distribution System

Submitted to:	Submitted by:
Dr. David Watkins, PE	Kelsey Fournier
Mr. Mike Drewyor, PE, PS	Ross Hogan
Footprint Possibilities Panama:	Victoria Quinde (PM)
Riziero Montanari	
Global Brigades Panama	

Mission Statement

The mission statement of KRV Water Solutions, Inc is "To improve quality of life: one community, one design, and one drop of water at a time." We implement premier engineering design of water supply, filtration and distribution systems in communities lacking consistent, sustainable and potable water. Our success is built around our partners and involved communities and is defined by designing with creativity, passion and hard work.

Project Remarks

KRV Water Solutions, Inc. consists of a three-student team in the International Senior Design Program at Michigan Technological University. The following report outlines and discusses the Water Supply and Distribution System for Emberá Puru, Panama. The design project consisted of two phases: Site Assessment (Summer 2019) and Planning & Design (Fall 2019). The report includes site assessment, design parameters, proposal and alternatives, as well as the associated engineering calculations and analyses. Additionally, the project bill of materials, estimated required budget and system operation & maintenance guidelines have also been included. Lastly, the design drawings have been included as a separate attachment.

Acknowledgments

KRV Water Solutions, Inc. would like to begin by thanking Rick Montanari of Footprint Possibilities Panama (FPP). The project design could not have been completed without the information and assistance provided by FPP's efforts on the Preliminary Site Assessment, as well as their continued support throughout the Planning & Design Phase. We would like to thank Global Brigades Panama and Julio Granados for hosting the team and providing knowledge from experience. The team would like to thank and acknowledge the Michigan Technological University faculty and Senior Design Advisors, Mike Drewyor (PE, PS) and Dr. David Watkins (PE) who provided valuable professional and technical guidance throughout the project. KRV would like to express our gratitude to Henrique (Kiko) de Melo e Silva for providing field assistance and direction while in Panama. Additionally, KRV would like to recognize the Emberá Puru community for welcoming the team into their community and hosting a

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cultural event to introduce their cultural background. The team would like to recognize the following members of the Civil & Environmental Department faculty at Michigan Technological University for assistance in structural design and analysis of the system: Dr. Theresa Ahlborn (PE), Dr. William Bulleit (PE), Dr. Andrew Swartz (PE), and Dr. Stanley Vitton (PE). Lastly, we would like to thank Father Wally Kasuboski, a.k.a. "Padre Pablo," for taking the time to give us a tour of the Fundacion San Jose de las Canasas water system that currently supplies Emberá Puru and other local communities with water.

Disclaimer

This report, titled "Water Supply and Distribution System for Emberá Puru, Panama," represents the efforts of undergraduate students in the Civil and Environmental Engineering and Mechanical Engineering-Engineering Mechanics Department of Michigan Technological University. While the students worked under the supervision and guidance of associated faculty members, the contents of this report *should not* be considered professional engineering documents.

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Executive Summary

KRV Water Solutions, Inc. (KRV) and Footprint Possibilities Panama (FPP) are developing a water system design for the Emberá Puru community located in the Darien Province of Panama. The new water supply and distribution system will be capable of providing water to a future population of approximately 670 residents, based on 4 percent growth over the next 20 years as requested by our clients. This design assumes the detachment of the current system supplying this community, which was implemented by the Fundacion San Jose de las Canasas approximately 25 years ago and has been outgrown. However, this assumption may be negated through negotiations with the Fundacion San Jose de las Canasas. The project consists of three major components: water collection structure, storage tank and supply & distribution pipeline. The water collection structure is located roughly 700 ft southeast of the Emberá Puru community at the known spring source and includes a spring box, wet well, pump station, solar array and electrical controls. The storage tank is located at the center of the community to store and feed water to the distribution system. Additionally, the storage tank includes a chlorination system, booster pump station and electrical controls. The pipeline delivers water from the water collection structure to the storage tank with an intermediate river-crossing supporting the pipeline and electrical conduit, as well as branches to a metered distribution system after the storage tank. Each of the components is separated into the established sub-components to be further detailed. In addition to the recommendation, design alternatives have been provided and are outlined in the following report to allow our clients to choose the optimal design, considering the community's preference and the system requirements. Conclusions drawn from the site assessment phase in Panama and the evaluation of these results at Michigan Technological University allowed for the transition to the design and planning phase, and ultimately the development of a design proposal for the system. The proposed system meets or exceeds design criteria provided FPP in such a way as to minimize environmental impacts and hazards to the community while supplying sanitary potable water.

The Final Deliverable provides a design proposal of the transmission system for approval based on design parameters and cost-effectiveness. The key outcomes achieved during the design process include defining the system capacity and its level of service, establishing an advantageous storage tank location, identifying an optimal pipeline route and developing a final pipeline design. The system cost and project's timeline were estimated at a 90-percent level of definition, as detailed in the following report.

1.0 Introduction

1.1 Purpose of Report

KRV Water Solutions, Inc. (KRV) has developed a design proposal for a water supply and distribution system (WSDS) for Emberá Puru, located in the Darien Province of Panama (Figure 1) in collaboration with Footprint Possibilities Panama (FPP). This project is funded and overseen by Global Brigades Panama (GBP). Currently, the existing system is inconsistent and unreliable, as the community receives water 1-2 days per week during the wet season and no water during the dry season. With population growth continuing to contribute to an increase in demand, steps need to be taken now to improve current conditions and to meet future demands.

Figure 1. Location of Project – Emberá Puru, Panama

Anticipating the long-term need for a new water source, the evaluation of potential water sources was completed by FPP. Three water sources were considered in order to determine the preferable option. The options FPP evaluated included a rural spring source previously used, a small branch of a river located near the community, and a known spring source southeast of the community (preferred). The known spring source offers significant benefits: identified as producing year-round, excellent water quality and favorable location, as it is located within walking distance of the community.

KRV proposes to provide a system design, based on the schedule shown in Table 1, which will supply water to 670 residents (projected population in 20 years assuming 4% annual growth) and the community buildings.

Table 1. Emberá Puru Water Supply Project Schedule.

Project Schedule	
June - August 2019	Project Identified & Site Assessment Complete
September - December 2019	Design & Planning
2020	Construction & System Operation

1.2 Design Project Objectives

The Design Project consisted of two phases, the Site Assessment Phase and the Planning & Design Phase. The goals of the Assessment Phase completed jointly by FPP and KRV were as follows:

- Conduct a census of Emberá Puru.
- Evaluate all potential water sources and establish the preferred water source.
- Determine the viability of preferred water source through flow rate tests.
- Establish a preferred storage tank site(s).
- Collect survey data for the supply line, trunk line, households, source and tank location; including topographic & GPS data, measurements and photo documentation.
- Collect soil samples at the spring source and storage tank site(s) and conduct soil classification and composition tests.
- Collect water samples from household taps and the source(s) and conduct water quality tests.
- Analyze and interpret all data collected, including survey data, water quality, and soil classification.
- Establish baseline design ideals and system components.
- Collect unit prices for materials in the Darien Province of Panama for reference.
- Establish relationships with the community and the water committee.
- Compile all data and conclusions (FPP and KRV) into a comprehensive Assessment Report for FPP.

Goals of the Planning & Design Phase are as follows:

- Establish Work Breakdown Structure for design activities
- Perform preliminary hydraulic evaluations to establish optimal system configuration, water storage elevation and pipe diameter requirements.
- Establish design criteria for a storage tank and select the preferred reservoir site(s) based on topographic data and community impact and recommendations.
- Finalize reservoir site based on topographic data and community recommendations, as well as finalize storage tank design and specifications with a chlorination system.
- Design a water collection structure and pumping station at the water source.
- Establish route selection criteria and finalize a preferred pipeline route considering community impact.
- Verify preliminary hydraulic evaluations and design specifications through the application of EPANet.
- Estimate electrical power and control requirements.
- Establish criteria and determine a protective barrier for the water collection structure, storage tank and river crossing.
- Provide a detailed estimate, bill of materials and construction schedule.
- Develop and finalize construction drawing set for supply pipeline, distribution system and all structures, including water collection structure, river-crossing, storage tank and protective barriers.

1.3 Key Outcomes

Key outcomes of the Final Report are as described herein.

Defining System Capacity and Level-of-Service

System capacity and level-of-service have been evaluated by defining faucet locations, determining flow rates, peak times of usage and other requests from the client and the community. Based on the gathered information and analyses, the required system throughput capacity is approximately 10,600 gallons per day for the 20-year projected population.

Establishing Storage Tank Location

The location of the 5,400 gallon, near-ground-level, water storage tank located at the center of the community was determined based on topographic data of the site and the system's output requirements. The evaluation considered safety, social and community impacts, opportunities and benefits, environmental impact, constructability and accessibility for maintenance.

Selecting Pumps

Two types of pumps were considered for the application at the known spring source: centrifugal (preferred) and submersible. Based on the longevity, serviceability, reliability and efficiency of the equipment, a decision matrix method was applied for pump recommendation. Additionally, the efficiency vs. system curve was produced for analysis of the centrifugal pump. At the water storage tank location, a small booster pump has been recommended to maintain 20-30psi of pressure throughout the distribution network, removing the necessity of a 20' elevated tank support structure which would be required for a gravity-fed system.

Establishing Control System Requirements

A control system will be required at the known spring source and storage tank. Based on the minimum voltage and amperage requirements of the systems, including pump and pump accessories, a control panel example model was provided to establish a baseline. The control system shall control the water level in the storage tank through level sensors, ensure the centrifugal pump stops running when the wet well reaches a low limit, deliver a metered dosage of chlorine solution into the supply line before it reaches the storage tank and maintain a minimum of 20psi in the distribution system.

Identifying Optimal Pipeline Route

The optimal pipeline route was determined by evaluating environmental, agricultural and social impacts that could affect the community. Other key factors considered were comparative costs and system resilience, as well as operations and maintenance procedures. Portions of an existing water distribution system were evaluated based on the potential of system tie-in. Due to insufficient information and lack of pipeline mapping, this option was determined to be inadequate. The preferred pipeline route will run from the known spring source to the storage tank located at the center of the community, then continue to each of the households. The pipeline route and the diameter of the pipe is subject to change as new information becomes available during construction.

Developing a Final Pipeline Design

After identifying an optimal pipeline route, the design of the water distribution system was completed. The development of this design consists of a 1,600-foot-long, 3” diameter PVC supply line, a 36-foot cable-supported river-crossing and a 2” diameter PVC main distribution system. Air release valves will be provided at local high points in the system, cleanouts will be provided at local low points and each household will be provided with a meter and a spigot for water delivery. In order to determine the specifications and reliability of the system design, an EPANet flow analysis model was applied [1]. Through analysis, the locations of clean-out valves, air release valves and system loops were determined.

Estimating System Costs

A cost estimate was prepared for primary components and elements of the final system design at a 90-percent level of definition and applies a detailed, unit cost approach. Including materials, labor and equipment, an approximate required budget is $235,000. Whereas, if all unskilled labor is donated, the estimated required budget is $69,000. The materials and equipment values are based on unit prices collected in November 2019 in the United States of America. The labor values have been based on estimated unit prices in Panama.

1.4 Scope of the Final Report

This Final Report provides an overview of all elements submitted for approval. The Final Report outlines and details a comprehensive design. General organization of the document is:

- Section 1. *Introduction* to the Purpose and Objectives.
- Section 2. *Site Assessment Phase* to discuss the background, problem definition and field data collection & analysis, as well as outline design takeaways.
- Section 3. *Design Parameters* to outline the ideal characteristics and risk factors, as well as design elements including criteria, constraints and assumptions.
- Section 4. *Hydraulic Properties and Water Demand Requirements* to define the system requirements based on EPANet and demand analyses.
- Section 5. *Design Alternatives* to evaluate feasible design options for the system.
- Section 6. *Design Proposal* to define the water collection structure, storage tank, preferred pipeline alignment, based on structural, hydraulic, capacity and demand calculations.
- Section 7. *Operation and Maintenance Recommendations* to outline an overview of tasks with the recommended frequency, as well as the recommended tooling and spare parts.
- Section 8. *Project Planning* to provide a detailed estimate for all related bid packages and a projected required budget, as well as an anticipated project timeline based on individual activities.
- Section 9. *Next Steps* to provide recommended outstanding action items, layout for operation and maintenance manual, educational topics for the community and external resources.
- Section 10. *Conclusion* to summarize assessment, design, analysis, operation & maintenance, project planning and next steps for completion, review and approval.
- Section 11. *References.*
- Section 12. *Appendices.*

2.0 Site Assessment Phase

During the period of August 11, 2019, to August 25, 2019, an assessment of the site for the water supply and distribution system for Emberá Puru was completed by Michigan Technological University - International Senior Design Program [2]. Various measures were accomplished during the 3-day excursion to the community, including evaluation of the existing system, collection of topographic and Global Positioning System (GPS) data, soil classification and water quality testing. Prior to Michigan Tech's arrival, a preliminary site assessment was completed by Footprint Possibilities Panama (FPP), and this provided water quality test results, GPS data locations of the households and census data for Michigan Tech's use and analysis [3]. The preliminary assessment data was utilized to understand the community situation prior to arrival on-site and to aid in the engineering analysis. Throughout this assessment section, the data collected by Michigan Tech and FPP will be compared, analyzed and discussed. The assessment identified several quality risk factors, as well as several design opportunities.

2.1 Background

Located in the rural area of Eastern Panama known as the Darien Province, the community of Emberá Puru resides on roughly 20,240 acres (approx. 32 mi^2) of collective land: Territorio Colectivo Arimae - Emberá Puru. Based on the FPP census (details in Appendix A-1), there are 305 people in the central community of Emberá Puru (318 including outlying areas). Located along the Pan-American Highway, this indigenous community has easy access to public transportation and the ability to work outside of the community given its strategic location. The majority of the men work outside of the community, and the women remain at home as home-makers, completing traditional crafts as time permits. Over time, the women within the community have taken on the responsibility of maintaining the tradition and culture for their people (Figure 2). On the other hand, the highway also separates a portion of the households from the central community due to the tendency of indigenous communities to move and spread out over time. This causes some households to be separated by established structures or community areas, for example, the highway or soccer field.

Figure 2. Emberá Puru Cultural Committee performing Traditional Dance.

2.2 Problem Definition

Currently, Emberá Puru has two existing water systems: the Fundacion San Jose de las Canasas (Foundation) system and the TRUNZ TSM185-72M Ultrafiltration system. Hereafter, these systems will be referred to as the functioning system and the abandoned system, respectively. As mentioned in the introduction, Emberá Puru does not currently receive water on a consistent basis from the functioning system.

The functioning system is a well-built and established system funded by the Foundation and built in 1994. Supplied by the Rio Sabana, the functioning system has served 13 communities along the Pan-American Highway for around 20 years and has been outgrown substantially. Emberá Puru is located at the end of the supply line, causing them to receive little to no water. This region experiences dry and wet seasons from December to May and June to November, respectively. During the wet season, the community will receive water 1-2 days per week at the first houses on the distribution system and at the houses located at low elevations. Community members have started collecting rainwater and utilizing the small river located nearby to combat the lack of water. During the dry season, Emberá Puru will rarely be reached by the existing system and the small river dries up. In order to sustain the community, portable water tanks are dropped off periodically by the local municipality.

The abandoned system with a 5,000-liter tank was installed by an unidentified agency in efforts to address the water shortage problem. The abandoned system was supplied by a remote source and the community did not have information about the system. Per FPP's preliminary assessment, this system has not functioned for approximately 7 years, and the remote source has been vandalized. Again, this left the community reliant on the Foundation's system. With population growth continuing to contribute to an increase in demand, water shortages in this region will only worsen in the years to come.

Figure 3. Source of the "Fundacion San Jose de las Canasas" Water System.

2.3 Data Collection

Michigan Tech collected data on the topography, GPS locations, soil classification and water quality to evaluate and analyze the site. The supplemental GPS data for the households and faucets, as well as water quality tests in the field, were collected to verify the baseline survey completed during FPP's preliminary assessment. Additionally, the supplemental data aided in the identification of inconsistencies and development of the potential layout for the trunk lines and distribution system. All data presented in this section was collected following the field methods and procedures outlined in Appendix A-2.

2.3.1 Topographic Data Collection

Data collection included topographic data of the trunk lines, supply line and select points of the existing system. All topographic data was supplemental to the FPP baseline survey. The data collected provides horizontal distance and vertical change between each GPS point based on the coordinates and elevation. In order to verify and supplement the GPS point information, the bearing and change in elevation have also been documented with the compass and Nikon Range Finder, respectively. Appendix A-3 holds the raw data collected from the Nikon Range Finder and compass. The GPS point information and additional maps of the points, noting the associated ID numbers, are located in Appendix A-4. Figure 4 summarizes the GPS data collected by Michigan Tech.

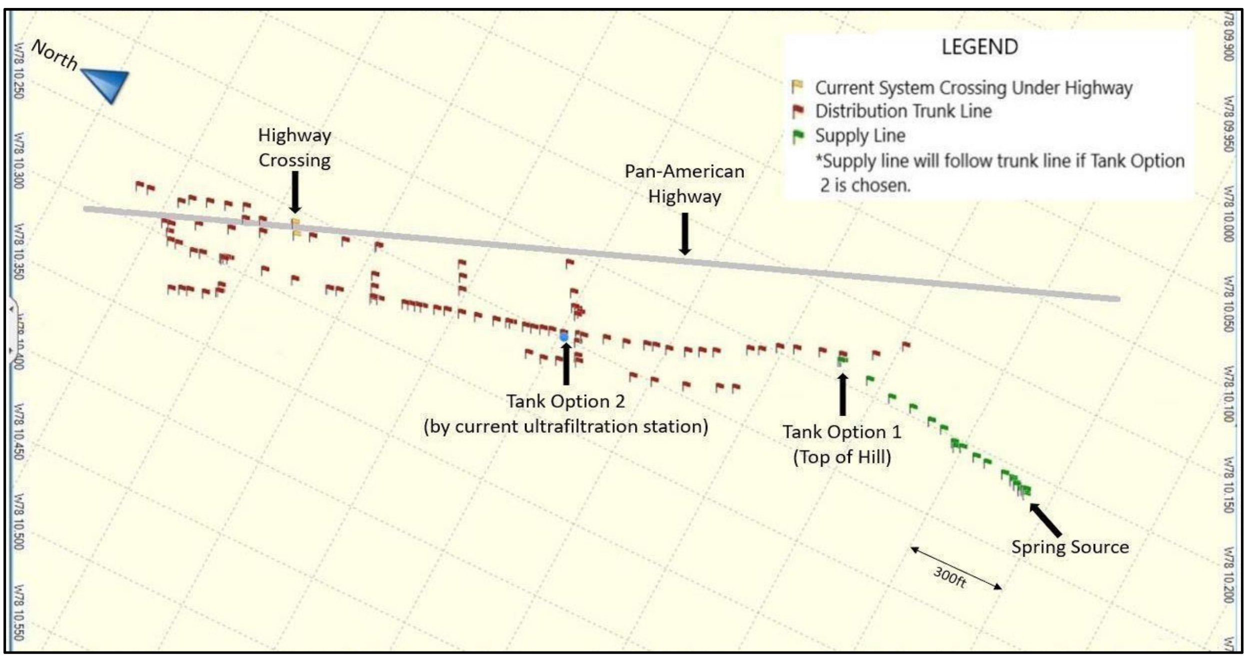

Figure 4. Map of GPS data for Trunk Line, Supply Line and Existing System Highway Crossing (MTU).

Based on the topographic data collected, there are significant elevation changes along the route of the system. Figure 5 shows an elevation profile for the supply line from the known spring source to Tank Option 2. At ground level, Tank Option 1 is 41 feet above the spring source, Tank Option 2 is 59 feet above the source, and the highest household within the central community is 63 feet above the source. This establishes the necessity of two design elements: a pump at the known spring source and an elevated storage tank to maintain line pressure. The trunk line elevation profiles can be located in Appendix A-5.

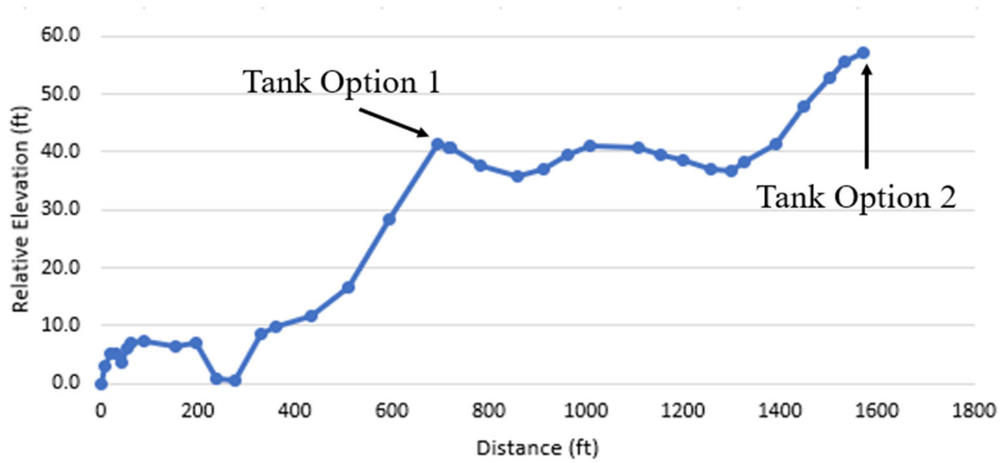

Figure 5. Profile of Topographic Data for Supply Line from Known Spring Source to Tank Option 2.

2.3.2 GPS Data Collection for Households and Faucet Locations

GPS data and distances perpendicular to the trunk line were collected for all household and faucet locations to determine the estimated Bill of Materials (BOM) and effectively route the distribution system. Appendix A-6 details the GPS point information and additional maps of the points, noting the associated ID number. The FPP baseline survey was referenced and additional points were included after verification of the survey by Michigan Tech. Figure 6 visually represents the FPP GPS data for all points of interest.

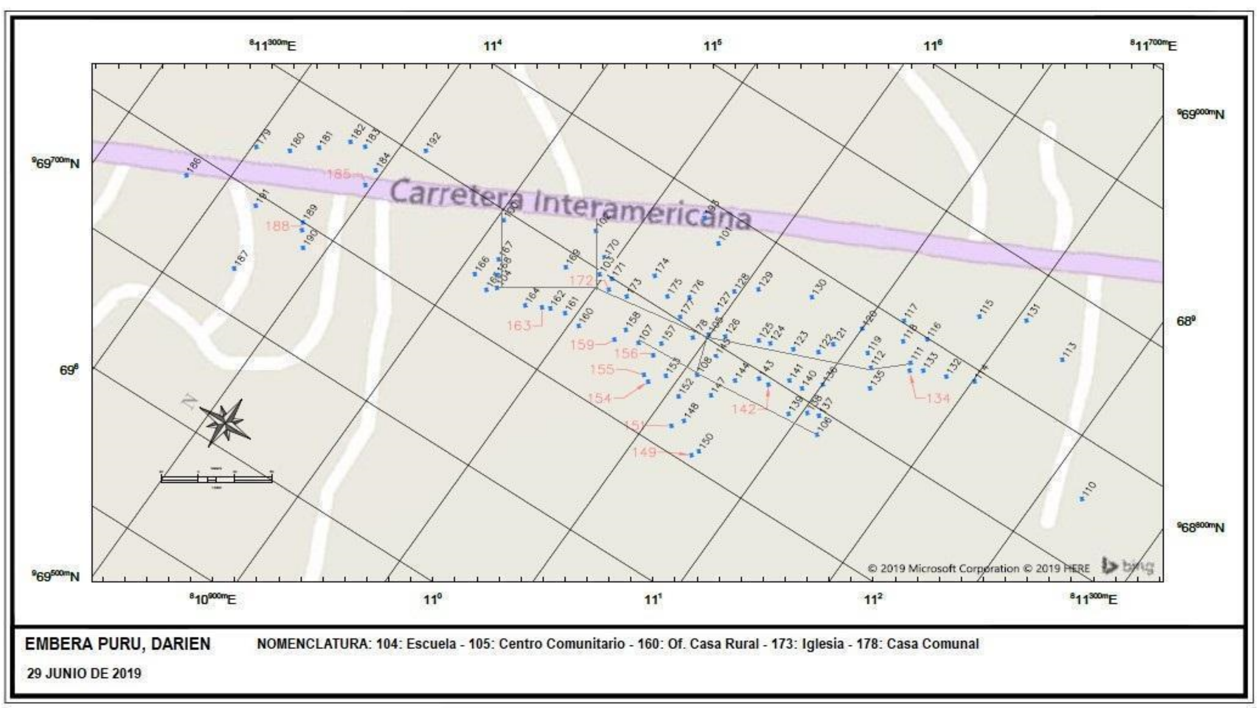

Figure 6. Original Map of all GPS Data Collected by FPP.

Based on Figure 6, the houses in the community are widely-spread, and a small portion is divided from the rest by the Pan-American Highway. The range of elevations in conjunction with the distance from the tank to the highest elevation found among these more isolated households is significant. Service to all of these households would require additional elevation of the storage tank or booster pump system and come at a significantly higher cost per household than for those in the central community. Per FPP instructions, Michigan Tech will focus on service to the central community, with additional options provided to serve the outlying communities. Appendix A-7 details inconsistencies in GPS data between FPP and Michigan Tech and summarizes the results of the comparison.

2.3.3 Soil Classification Data

A general soil classification at the spring and proposed water storage tank location was performed. Identification of the soils can provide engineering behavior and characteristics for the specific site to aid in system design and construction. The following equations were utilized to complete the classification.

$$Total\ Settled\ =\ Sand\ (mm)\ +\ Silt\ (mm)\ +\ Clay\ (mm)$$

$$\%\ (Sand, Silt, Clay)\ =\ Specific\ Soil\ Measurement\ (mm)\ /\ Total\ Settled$$

Figures 7a, 7b and 7c show the settlement of the soils for the known spring source (Left) and tank option 1 (Right) after 1 minute, 1 hour and 24 hours, respectively.


Figure 7a. Settlement after 1 minute.

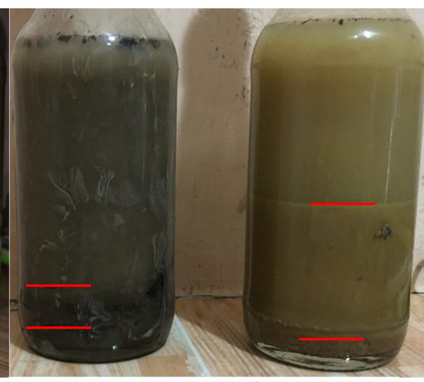
Figure 7b. Settlement after 1 hour.


Figure 7c. Settlement after 24 hours.

Table 2. Soil Classification results from the Settlement, Knife and Turbidity tests.

Location	Percentage			Knife Test	Turbidity Test
	Sand	Silt	Clay		
Spring Source	16.67%	40.47%	42.85%	Sticky, rubbery, and clumps easily	Settled slowly over time
Tank #1	Inconclusive			Sticky, rubbery, and clumps easily	Remained Turbid

Based on Table 2 and Figure 7a-c, the soil at the spring source and the storage tank location have been identified to be high in silt and clay content. This soil classification indicates a reduction of the soil bearing capacity. Accordingly, there will be increased attention to the design of footings for the structures to alleviate the potential for settlement.

2.3.4 Water Quality Testing

Prior to Michigan Tech's arrival on site, preliminary water quality testing was collected by FPP and processed through Ambitek services, given in Appendix A-8. The water sample was collected from the water seepage on the upper shelf of the source, where water was actively running toward the source pond. The results were analyzed and compared to the World Health Organization (WHO) standards [4]. The testing measured total coliforms at 3.3×10^3 FC/100mL and fecal coliforms at 72 UFC/100mL. Based on WHO standards, there should be no detectable coliform in a 100mL sample after disinfection. Turbidity was measured at 110 nephelometric turbidity units (NTU), falling well above the WHO standard of less than 4 NTU. The pH levels were measured at 7.8, within the acceptable range of 6.5 to 8.5. Total dissolved solids (TDS) were measured at 487 mg/L and are below the WHO threshold of 600 mg/L. Ambitek measured the hardness at 231 mg/L. There is no health-based standard for hardness, although a hardness greater than 200 mg/L may cause scaling. Evaluation of the collection location indicates the location may have increased turbidity and TDS levels compared to the source pond. The necessity to reduce turbidity and TDS, as well as suspended solids, has been accommodated for in the catchment design.

Michigan Tech performed water quality tests at a tap of the existing water supply system and the identified spring source pond to verify the results of the preliminary site assessment. In the preliminary site assessment, the existing, treated water supply was found to be free of E Coli and coliform, whereas the known spring source exhibited a coliform count. In order to estimate the coliform count from the 3M films, the following equation was utilized.

$$Estimated\ Coliform\ Count\ per\ ml\ = 20 * (Average\ of\ the\ count\ of\ 4\ squares)$$

Figures 8 and 9 show representative results from the water quality tests performed.

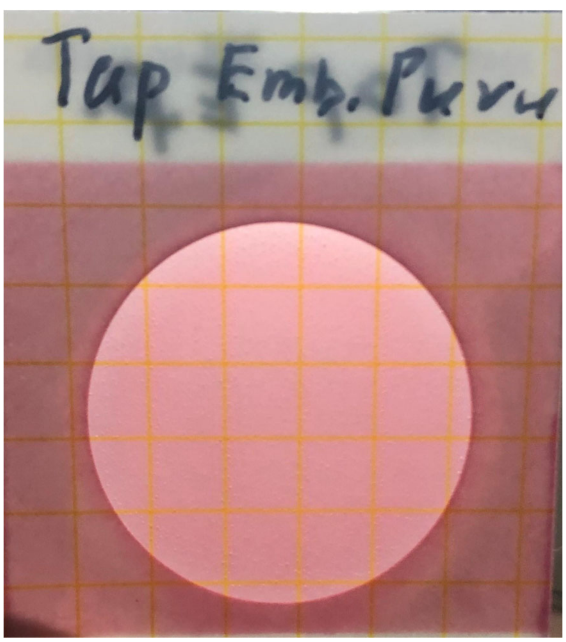

Figure 8. Result of Water Sampling from Tap.

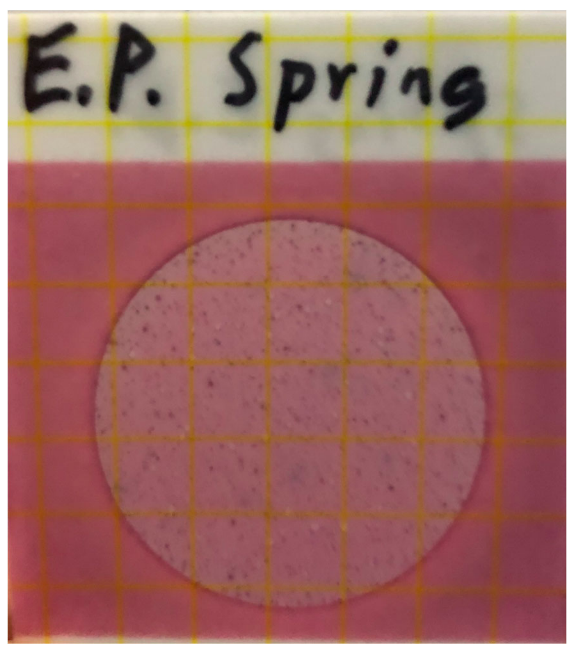

Figure 9. Result of Water Sampling at Spring.

Based on the results, the tap water from the existing water system contained no E Coli or coliform, and the collection bottle had no observable settled solids. The sample from the known spring source showed an average coliform count of 12 per square or 240 total count. The spring sample showed a thin film of sand and silt covering the bottom of the sample bottle. The water quality tests provided in this assessment are not to replace the tests completed by FPP. Water quality test results supplied by FPP were laboratory-controlled and more accurate than the field tests conducted. The tests are meant to verify the presence or absence of either E Coli or other coliforms in the sources. The observed results generally agree with the FPP results for water quality testing.

2.4 Key Design Takeaways

The site assessment phase determined the following characteristics and potential risk factors for the system design. The implementation of a centralized system utilizing appropriate technology is a requirement for the longevity of the system. Topographic data revealed the requirement of a pump at the known spring source to deliver water to the water storage tank. The water storage tank will require either elevation or an additional pump to provide adequate head to the distribution system. The water treatment will include a chlorination system to remove coliform. The distribution system should provide one-metered faucet per family and all pipes should be buried a minimum of 2-ft below grade. Soil classification determined attention to the design of the footings for the structures in order to avoid settlement. To protect the community and critical components of the system, protective barriers (e.g. fencing, locks, etc.) will be implemented.

3.0 Design Parameters

Design parameters are provided to set a standard for the water supply and distribution system design by outlining the ideal characteristics, risk factors, design criteria, design constraints and design processes to maintain consistency throughout the project phases. The design parameters outlined in this section are current as of the date of this Final Report.

3.1 Risk Factors

Associated with each of the ideal characteristics, there are potential risks that were addressed. The following items have been identified:

- *Performance risk,* related to the viability of the water source and the correct pump selection.
- *Strategic and operational risk,* related to specification of inappropriate design, missing components, or under designing the system.
- *Cost and schedule risk,* related to damaged materials during construction and underestimating labor hours required for pipe burial.
- *External hazards,* related to protective barriers (e.g. fences, locks, etc.) and weather hazards.

3.2 Design Criteria

Ideally, the system design will support the water demand for the current population of 305 people (in the central community) and a projected population of 670 people based on a 4% annual growth rate over the next 20 years. Consumption requirement for the design is 15.85 gallons (60 liters) per person each day, which is based on the World Health Organization (WHO) standards of 60-100 liters per person each day. To sustain this demand for the projected population, a tank with a capacity of 10,600 gallons would be considered optimal in order to supply a 24-hour demand for the projected population. Additionally, the entire community would be included in the distribution network.

Based on the location of the project, the implemented technology and components need to be appropriate to allow for ease of maintenance and operation. Additionally, the system design must mitigate safety and environmental hazards during and after construction. In this section, the requirements of the design based on guidelines established by Michigan Tech, FPP and GB are outlined.

The water storage tank capacity was designed to supply the 20-year projected population during the 4-hour peak usage time frame as a tank with a 24-hour capacity would be costlier. Peak usage and demand estimates are discussed in Section 4 of the report. The distribution system must provide one metered ½" tap per identified household (family) within the central community and community buildings, as well as five taps for the school. Households identified as "outlying" are not included in the distribution system. The term outlying is defined by the separation by established structures, such as a highway or soccer field, which obstruct ease of accessibility and increase cost per household to supply. All critical components in the system are required to include protective barriers to alleviate vandalism and contamination. The critical components of the system include, but are not limited to, the water source, pump station, river crossing and water storage tank.

During the construction and operation of the system, the environmental impact should be minimized. First, the system will be routed away from farming areas to protect community assets and avoid contamination of the water supply. Second, the removal of foliage and topsoil should be minimized throughout construction to preserve the existing ecosystem, specifically during the burial of pipe in areas with excessive slope. Revegetation of such areas or the use of rip rap may be necessary to prevent erosion.

Lastly, cost will be minimized without impacting the integrity of the system and the well-being of the Emberá Puru community. Labor and capital requirements will be the main focus, as decreasing the demands minimizes the costs of construction and maintenance. Specified material will be closely considered to avoid unnecessary costs through wastage and overdesign.

3.3 Design Constraints

Based on the analyses conducted for the design characteristics and components, the identified constraints include the following:

- *Viability of the Spring Source* has a large impact on the following design components: water collection structure, pump, pipe diameter, storage tank capacity and, most importantly, the output of the system.
- *Electrical Power Supply*, creates a design constraint as the capacity and routing impact the following design components: pump and control system.

3.4 Design Assumptions

As a result of unknowns, the following design assumptions were made to provide a complete design scheme for the water supply and distribution system.

- *Source Production* is assumed to be great enough to meet design criteria based on the demand pattern and usage for the projected population, as discussed in Section 4.
- *Source Continuity* is assumed based on verbal reports from community members stating that the spring does not go dry at any point during the year.
- *Required Supply* is based on WHO standard of 60 liters (15.85 gallons) per person each day.
- *Designed Supply* is based on a twenty-year population projection from the current population as discussed in Section 3.2.
- *Assumed Tap Elevation* is based on the fluctuation of household height within the community. Each household elevation was increased by 7ft from the known ground elevation as a safety factor to ensure delivery to all households.
- *Water Quality* delivered for distribution is assumed to be acceptable by the standards of Panama and WHO after settling in the spring box and disinfection by chlorination. It is recommended that further testing be done once the system is operational and prior to use.
- *All Electrical Installation* will be specified and installed by a qualified electrical worker (QEW).
- *Detaching from the Existing System* provided by the Fundacion San Jose de las Canasas is assumed as a simplification for installation. This may not be necessary, but negotiations regarding coordination of the two systems are beyond the scope of this design.
- *Labor* will primarily be donated by community members to minimize cost to the community and Global Brigades. It is recommended that, where no specialized knowledge is found within the community, local experts should be hired to complete or direct technical work as necessary.

KRV Water Solutions, Inc.

4.0 Hydraulic Properties and Water Demand Requirements

4.1 Water Balance

The volume estimate for the storage tank was based on a peak 4-hour usage estimate (4 am-7 am) for the 20-year projected population of about 670 people. The calculation was supported by an estimated daily consumption per person of 15.85 gallons (60 liters), as requested per project's stakeholders, and the daily demand pattern (Figure 10). The demand pattern is an hour-by-hour multiplier to estimate usage, where the average multiplier over a 24-hour cycle is 1. The sum of each hour's multiplier times the total estimated daily usage and divided by 24 hours is equivalent to the estimated daily usage for the community [5]. Appendix B contains a detailed analysis of water demand and usage to formulate projections, as well as detailed calculations, used to determine the required design capacity and preliminary pump requirements based on head.

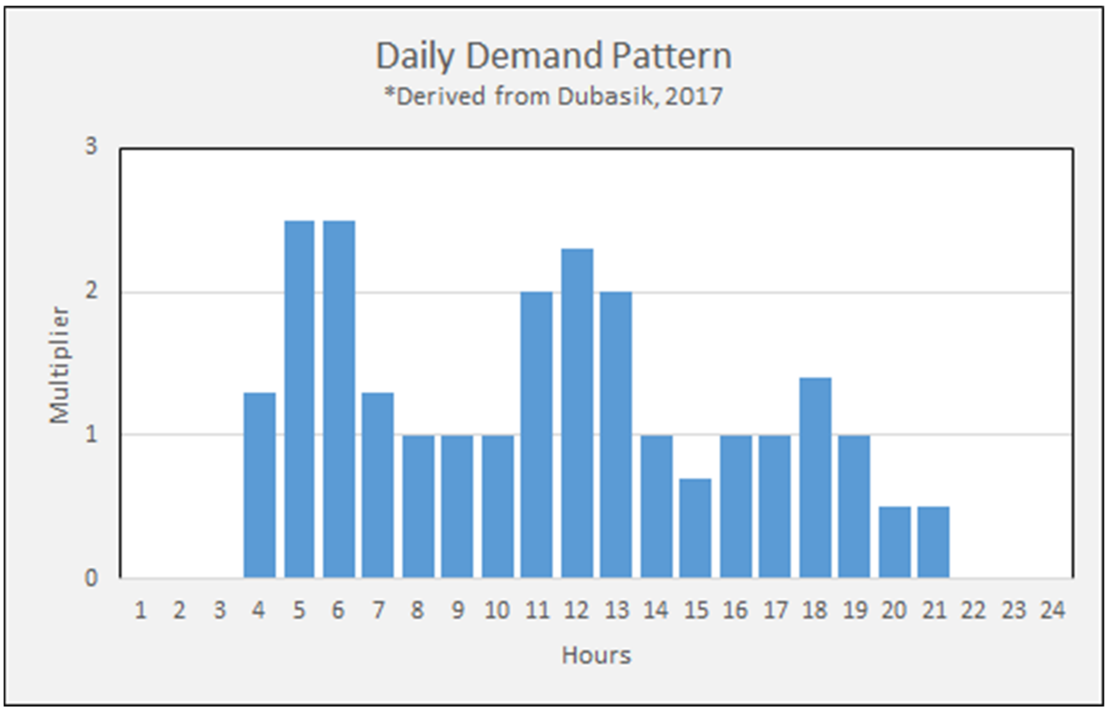

Figure 10. Estimated Daily Demand Pattern.

4.2 EPANet Modeling

The water distribution system was modeled in EPANet, a widely-utilized software application for water distribution systems. Modeling of the system aided in the design and sizing of the system. Through the application of the software, the system flow, pressure and pumping schedules were evaluated to finalize tank and pipe sizing and evaluate pump performance. The system characteristics of the model and detailed analyses can be referenced in Appendices B-3 through B-5.

The general layout of the model includes the following components: source, wet well, centrifugal pump, supply pipeline, water storage tank, booster pump and distribution network. The source of the system was modeled as a storage tank fed from a node with a negative demand (positive supply) of 7.9 gallons per minute (GPM) to simulate the behavior of a spring. The pump curve for the preferred pump option was loaded into the model to improve accuracy of the analysis, and the pump runs at about 47 GPM. Built with 3” pipe, the supply line experiences an elevation change of 67 ft to reach the tank inlet, causing the pump to overcome a total head of 72 ft, including pipe friction. The water storage tank has a capacity of 5,400 gallons and has low and high-level float sensors at 2 ft and 4 ft, respectively. Variable speed, pressure-controlled booster pumps are not well modeled in the program, so a pressure-reducing valve was used to limit output from the pump to 25 psi. Built with a combination of 2”, 1” and ½” pipe, the distribution system features 66 household taps, each with its own meter. The demand pattern discussed in Section 4.2 was loaded into the model to adjust the demand at each tap throughout the day. The model shows a maximum, instantaneous demand of 7.4 GPM for the current population and 16.3 GPM for the projected population. For both models, the minimum and maximum line pressure within the distribution system were 20.5 psi and 37.6 psi, respectively. The system is able to meet demand throughout the day in both models.

5.0 Design Alternatives

The feasible design alternatives proposed in this section are based on engineering judgment and available resources. The preferred option for design is further outlined in Section 6, whereas the other options can be referenced in Appendix C-1. Appendix C-1 provides a conceptual overview and any related research completed on the topic. Note that some of the alternatives listed below do not have an attached discussion in Appendix C-1. Each of the alternative options are placed in the order of recommendation, with the first being recommended most highly.

5.1 Emberá Puru Water System

Water Collection Structure

The water collection structure has two potential design alternatives: water collection structure (preferred) and shallow well design. Depending on the findings of the flow rate and bathymetric survey, modifications could be made to the size and shape of the water collection structure or opting for the shallow well design to achieve the desired flow rate.

Pump

When possible, the implementation of pumps should be avoided, although this system requires a pump to deliver water from the spring source to the water storage tank. The pump system options include: single-phase centrifugal pump (preferred), a three-phase pump, a staged pumping system and a single-phase submersible pump.

Power Supply

Based on the large distance required to run power to the pump station at the known spring source, the following alternatives are possible: solar array (preferred), overhead power supply or buried cable power supply.

Water Storage Tank

The water storage tank design has six potential options. Each of the options has its own advantages and disadvantages related directly to cost, technology and construction. The preferred option is a single, rectangular, reinforced concrete water tank on a 3-ft earth build with a booster pump. The five other options involve variations of the preferred option including plastic storage tanks, self-priming pumps and elevated storage tanks. Appendix C-1 details the five-water storage tank alternative options and Appendix C-3 provides estimated material quantity take-offs.

Distribution System

There is potential to connect with the functioning system for the distribution system. Due to lack of accurate information provided by the community and the Foundation, this alternative would require extensive field data collection and engineering analysis to determine the feasibility. About 46 of the identified households are included in the functioning system, therefore the system would require expansion to the remaining identified households.

5.2 Functioning System Improvement as an Alternative

As previously mentioned, Emberá Puru currently has a metered water distribution system that was built and maintained by the Fundacion San Jose de las Canasas. The system is 25 years old and the demand of the population on the distribution system has substantially outgrown the system. This leaves Emberá Puru with little to no water, as they are located at the end of the supply line. A joint effort with the Foundation has been identified as a final alternative to bring Emberá Puru a consistent and reliable water supply. An expansion plan has already been forecasted to serve all 13 communities for the next 20 to 25 years, but funding for the expansion has not yet been acquired.

The plan of action for this project would provide the following:

- Increase of current pipe diameter from 4” to 6”
- Dam expansion through dredging the bottom and increasing the water surface area
- Pump addition to increase pressure of the existing filter system and tanks

The above action plan should replace the design proposed in this report if the functioning system was determined as the optimal solution for the water shortage problems in Emberá Puru. Otherwise, in the case that the functioning system is upgraded and not utilized as the optimal solution, it is recommended to cap the central community’s connection to the functioning system and solely utilize the system implemented by the KRV and FPP design to avoid interference during construction and maintenance of the new system. It is recommended that the outlying households, excluded from the system presented here, would remain as part of the functioning system.

6.0 Design Proposal

The design proposal was developed in accordance with the guidelines established by Michigan Tech, FPP and GBP. The three main components of the water system are the water collection structure, storage tank location and pipeline (Figure 11). This section discusses the site description of each main component, and the related elements are detailed. Recommended specifications for elements within the system can be referenced in Appendix D.

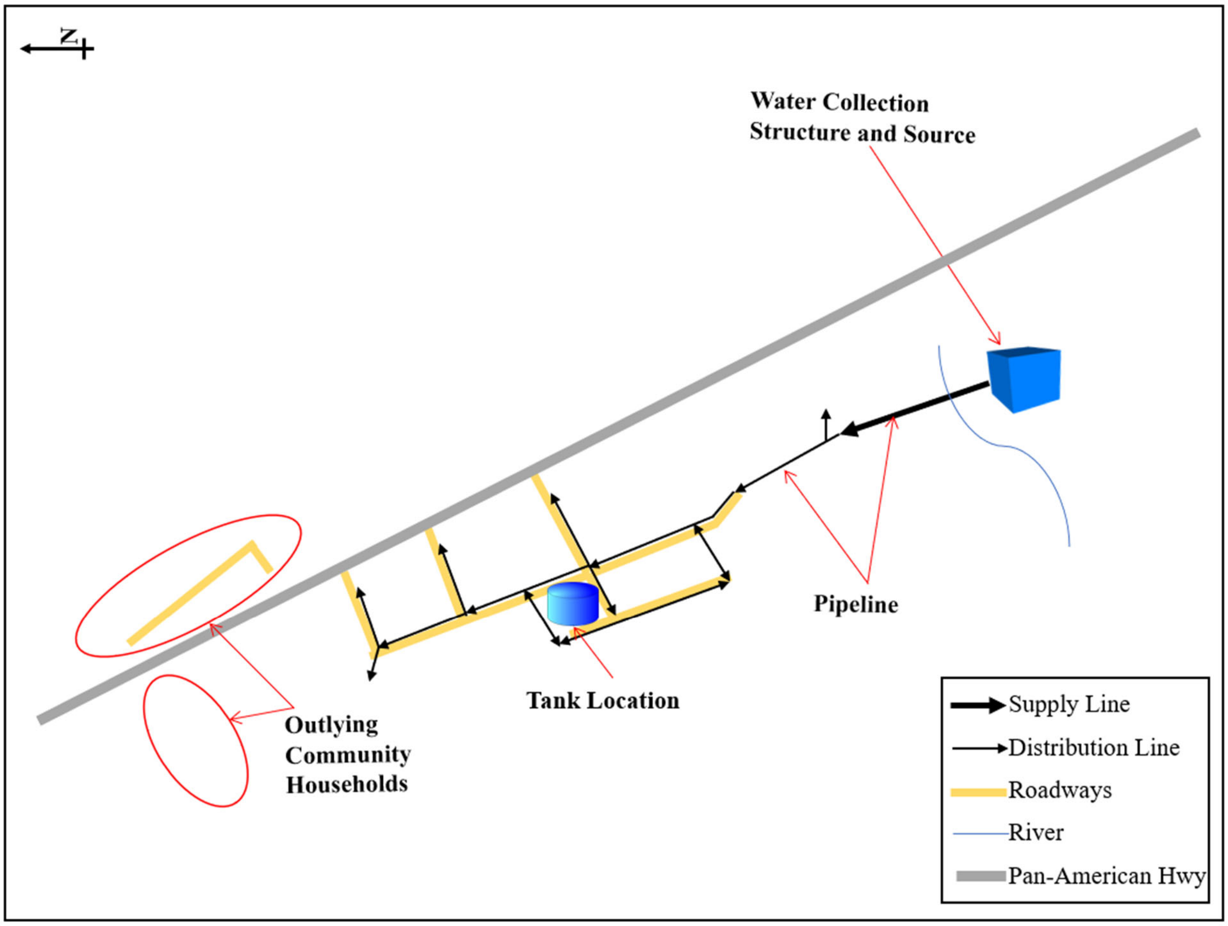

Figure 11. System Components (Not to scale).

KRV recommends a pressurized water supply and distribution system. The water collection structure consists of a reinforced concrete spring box design that is filled with rip rap to aid in the settlement of large solids. The spring box feeds through a roughing filter to a reinforced concrete wet well that stores 800 gallons of water and provides a buffer for the centrifugal pump to avoid rapid cycling. The purpose of the pump is to deliver water through the 3" supply line 1600 feet to the storage tank. The recommended pump model located at the spring source is a *364-1Al11511 Centrifugal Pump by Goulds Water Technology*. In order to cross a small river with a 36 ft bank to bank distance, a suspension bridge design capable of supporting 4.3 pounds per lineal foot will support the supply line and electrical conduit across the span.

Located at the center of the community, a single rectangular, reinforced concrete water tank with a 3-foot earth build foundation and a capacity of 5,400 gallons of water feeds the pressurized distribution line. The 10'x22' monolithic concrete slab that forms the base of the tank is sized to act as a stand-alone slab for two 6000-liter PVC tanks as an alternative. An automatic chlorination system will be implemented at the storage tank to disinfect the water. KRV recommends a device similar to the *J-PRO-22 35-Gallon Solution Tank.* The recommended distribution pump for this application is the *TW1000-30W-30 Flag Frame Booster Pump* which maintains a pressure range of 20-30psi throughout the system at up to 30gpm with a variable frequency motor. The distribution system will consist of 2" PVC trunk lines and 1" PVC branches to reduce friction head. Each of the identified households within the central community will have metered lines running to a ½" metal spigot to track water usage. Along with the pipeline network, air release, cleanout and shut off valves have been strategically placed at local high elevations, local low elevations and critical locations, respectively, and all valves will be protected by valve boxes or within fenced enclosures to reduce tampering. By Panama code and best practices, fencing will be installed around the most critical system areas around the spring, the ends of the bridge and at the storage tank. Both pump houses will be secured by a lockable steel door and all access hatches to water storage structures will be locked.

This proposed design assumes that all electrical installation specifications will be evaluated, specified and installed by a QEW. To supply power to the system, a 9-panel solar array has been specified. A control panel similar to the following example model: "SPI 50A001 Single- Phase Simplex Control Panel-SSC1B" is recommended to meet power requirements for electrical pumping and other controls at both the spring source and water storage tank sites. All electrical components, except transmission and signal wires, will be housed within fenced enclosures at the pump stations at their respective locations.

6.1 Water Collection Structure

The water collection structure will be located at the known spring source, roughly 1,450 feet SW (straight line distance) of the center of the community. Based on the relative elevations along the water system and surroundings, the water collection structure will be at the lowest elevation of the system. Elevation change in the area is not drastic, although it becomes substantial over distance. The environment around the spring source is open, without excessive ground-level foliage, but does have some overhead cover. Due to highly impervious soils and minimal foliage, there is potential for runoff during the wet season. The water collection structure will include three elements: spring box, wet well, and a pump station with electrical controls.

6.1.1 Water Collection Structure Conceptual Design

The water collection structure (Figure 12) utilizes a spring box design made from reinforced concrete to improve the water flow from the spring source, capture the water and contain the water for pumping to the storage tank. At the location of the spring, roughly 70 cubic yards of earth will need to be excavated, as the design specifies for the spring box and wet well to be constructed 6 ft below the sustained water level. The rock-filled spring box will collect water and allow for the settlement of larger solids before passing water to the wet well through a feeder pipe with a roughing filter. Holding approximately 800 gallons of water, the wet well acts as a small reservoir to provide a buffer for the centrifugal pump. During construction, the excavation for the water collection structure should be modified in order to accommodate the path of the flow.

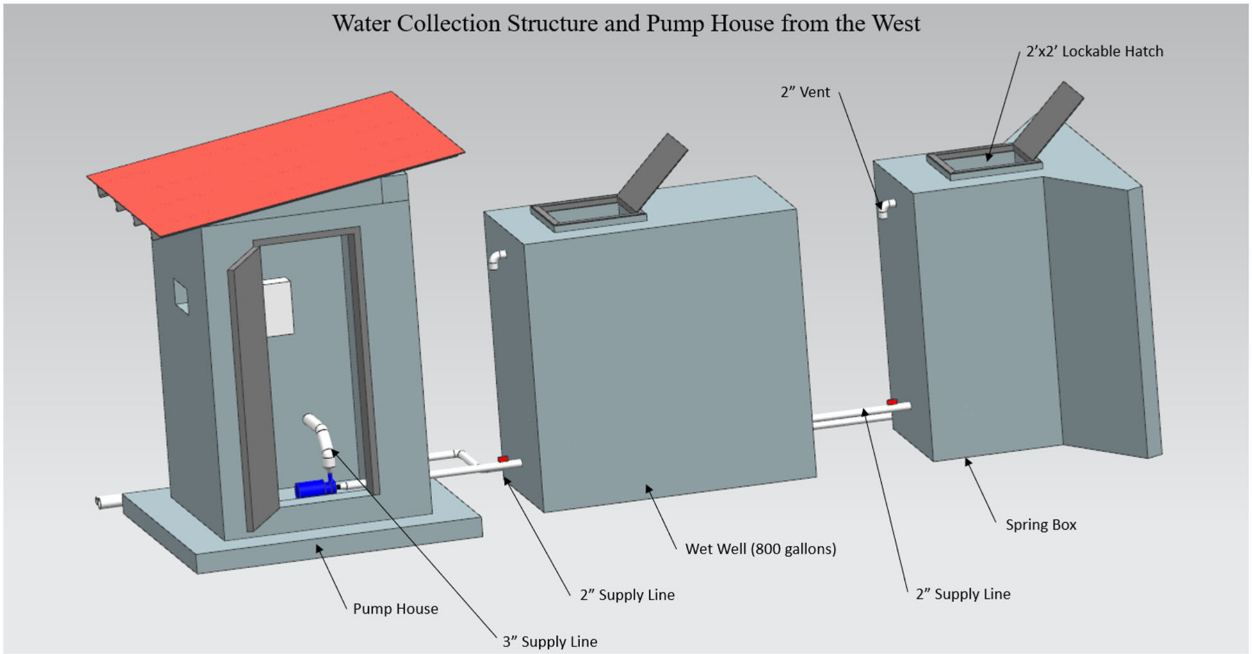

Figure 12. West-side View of the Water Collection Structure and Pump House (Conceptual 3D Model).

A PVC pipe configuration (Figure 13) will be installed, including clean out and overflow pipes connected to a common discharge pipe. This discharge pipe will be routed out of the spring depression and will be run approximately 50ft away. Additionally, PVC vent pipes are included to alleviate suction or pressure build-up and allow for airflow. Each of the PVC pipes that expose the structures to the environment will require the installation of a screen to prevent contamination from bugs, animals and outside conditions. Both structures will have a 2 ft by 2 ft aluminum, lockable hatch on the top of the structure for any required maintenance, as specified in Appendix D-1.

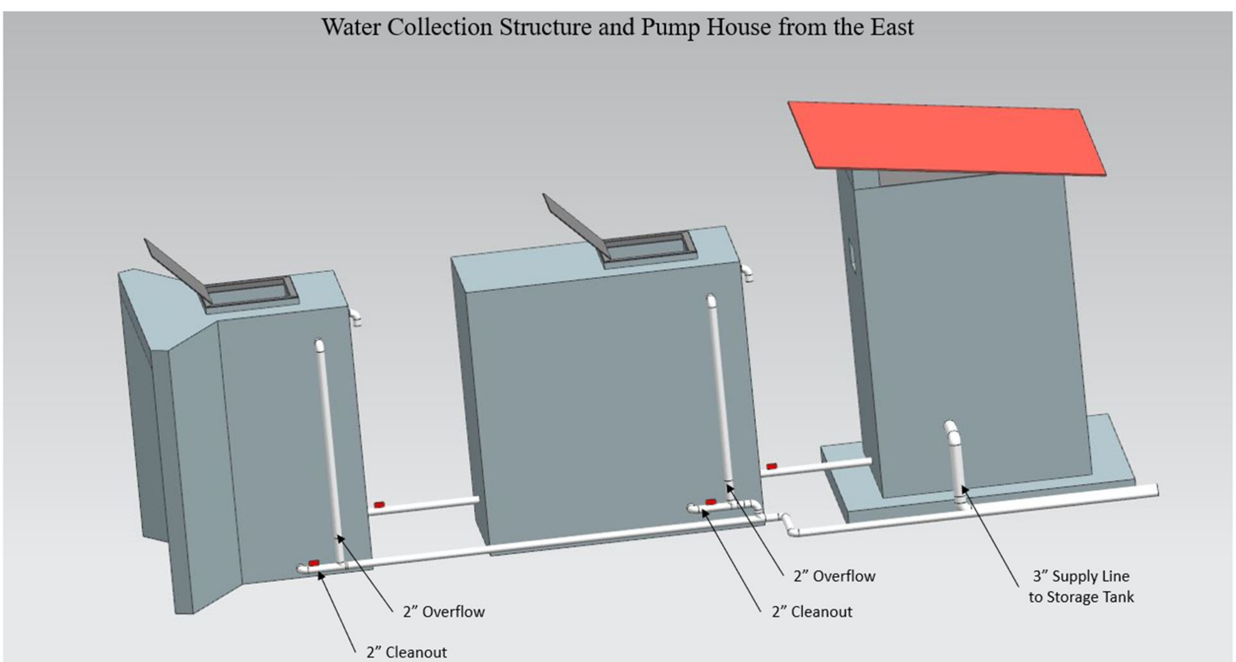

Figure 13. East-Side View of the Water Collection Structure and Pump House (Conceptual 3D Model).

6.1.2 Pump for Supply Line

Due to the storage tank being at a higher elevation than the spring, a wet well and centrifugal pump will be necessary to deliver water from the known spring source. This simple method of pumping has been selected as it facilitates access for maintenance in the future and is more cost-effective than a submersible pump. The pump should be able to supply 40-50 GPM daily and deliver at least 65ft of head to meet system requirements, based on peak usage factor, population growth calculations, system hydraulics, topography and other community requirements. Section 4 outlines the analyses and calculations related to the required flow to meet demand. Appendix B-1 outlines the preliminary head calculations prior to the implementation of EPANet. Appendix B-3 through B-5 includes the EPANet Analyses in relation to the pump and pump requirements, as discussed in Section 4.

The centrifugal pump will be connected to level sensors in the wet well to ensure it does not run dry if the water reaches a minimum level. The minimum level of the float switch is recommended to be set at 1ft in the wet well. The pump will be installed next to the wet well, which will provide enough storage capacity to allow pumping for at least 10-20 minutes to reduce cycling of the pump. Similar to the float switch in the wet well, float switches in the storage tank will signal pumping to begin at a low level and stop at a high level. The recommended low and high levels in the storage tank are 2ft and 4ft, respectively. The application of float switches reduces pump wear from frequently starting and stopping, ensures the pump does not run unnecessarily and avoids wastage.

Figure 14. Recommended Centrifugal Pump for Supply Line.

Table 3 and 4 detail specifications and the decision matrix, respectively, to select the most suitable pump. The two types of pumps investigated for the application are centrifugal and submersible pumps. Two pumps have been analyzed and a score has been assigned based on price, the maximum flow rate in gallons per minute, maximum pressure head in feet and reliability. The detailed specifications for each of the options can be referenced in Appendix D-2. Option 1 was selected as the best fit for this water system project. Option 1 corresponds to the centrifugal electric pump from Gould's (Figure 14), which has a single-phase motor, a 1-1/4-inch outlet, 110 GPM capacity and a max delivery height of 120ft (approximately 30 meters). The maximum GPM of the pump will not be delivered at the maximum delivery height, therefore the pump curve can be referenced for specific capacities to determine the associated delivery height in Figure 15. In regard to the proposed design and delivery head requirements, the pump is overdesigned; however, the pump is sufficient for any of the six water tank designs, including the elevated tower designs.

Table 3. *Centrifugal Pump Specifications for Two Options.*

	Option1	Option 2
Model	3642-1AI11511	STA-RITE JBHD
Type	Centrifugal	Centrifugal
Price	$1,500	$550
Weight	68 lbs.	42 lbs.
HP	1.5	0.75
Phase	Single	Single
MAX GPM	110	45
MAX Head	120 ft	100 ft
Discharge	1 1/4 inch	1 inch

Table 4. Decision Matrix Based on Price, Max GPM, Max Head and Reliability.

Criteria	Weighting	Option 1	Option 2
Price	2	1	2
Max GPM	1	2	1
Max Head	4	2	2
Reliability	3	2	1
Total		18	16

Further analysis of the system was completed through the development of a system curve with reference to the pump location and graphical representation of the required pump head. Figure 15 overlays the pump and system curves for this model. Located at the intersection of the two curves, the operating point of the model is 44 GPM (10 m^3/hr.) and 80 ft (24 m). Although this is not the optimal efficiency of the recommended pump, this selection allows the project's stakeholders to explore the provided design alternatives.

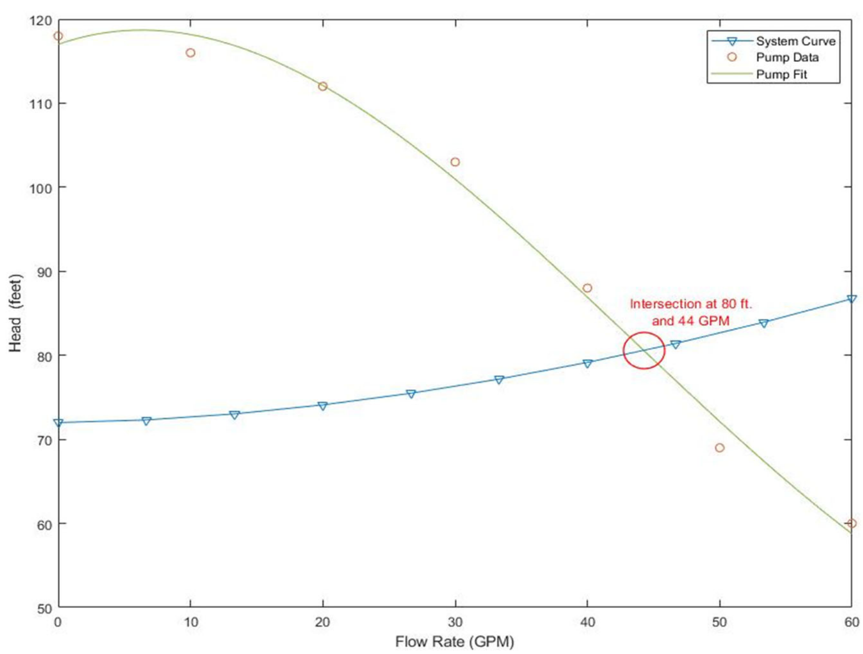

Figure 15. System Balance of Pump and System Curve for KRV Recommended Tank Option.

6.2 Water Storage Tank

The storage tank component will include two elements: an elevated water tank structure and a chlorination system. The water storage tank has two potential locations (Figure 16): Tank Option 1 roughly 840 feet SE of the center of the community and Tank Option 2 is at the center of the community (preferred). Based on the relative elevation of the households, both tank locations are at a higher elevation than most of the households, making these ideal locations. The environment around Tank Option 1 is completely open, with some grass and no foliage or overhead cover, whereas Tank Option 2 is located at the center of the community, with households and community structures close by. Due to highly impervious and compressible soils, soil erosion and settlement must be mitigated by design at both locations.

Figure 16. Map of Tank Option 1 and 2 with reference to Known Spring Source (Bing Maps).

6.2.1 Water Storage Tank Location Analysis

The location of the water storage tank was based on factors of feasibility and safety. During the evaluation process of the tank locations, the following items were considered: impact on the community, environmental impact, required height of storage tank, constructability and safety. For reference, Figure 5 shows the elevation profile of the supply line from the known spring source to Tank Option 1, then continuing to Tank Option 2.

Tank Option 1 is roughly 700 feet from the known spring source. The location is 41 feet above the known spring source and 18 feet below Tank Option 2, which would impact the booster pump efficiency. The pump would be required to work against 10 psi of head loss, therefore require a larger amount of power. Tank Option 1 is about 900 feet from the power supply tie-in and running wire would be costly. Additionally, the structure would need to be elevated to at least 38 feet to support a gravity-fed distribution system, if Option 1 was selected without the booster pump. The advantages of Tank Option 1 include the minimal disturbance and obstruction of the community sightlines and activities. Also, being closer to the known spring source reduces the cost of pipe and the additional friction head of pumping to the center of the community. Disadvantages include the reduction in efficiency and the safety risk associated with the construction of a tank elevated to this height, as well as the additional construction costs.

Tank Option 2 is roughly 1,600 feet from the known spring source. The ground level at Tank Option 2 is 59 feet above the known spring source and 4 feet below the ground level of the highest household in the central community. The booster pump at this location would be working against minimal head loss and would be situated at the electrical supply tie-in. Additionally, the structure would require 20' of additional elevation to support a gravity-fed distribution system, if Option 2 were selected without the booster pump. The required elevation would be roughly half that of Tank Option 1. One of the advantages of Tank Option 2 is the reduction in the potential of vandalism due to the location. Additionally, it is safer and less costly to construct with the lower height requirement. A drawback of the system is the tank creates an obstruction at the center of the community. Also, this tank location is further from the known spring source, which increases the amount of buried pipe and creates the potential to necessitate a larger pump to overcome the additional friction head.

EPANet was utilized (as discussed in Section 4) to analyze the tank locations based on the required height to sustain a gravity-fed distribution system. Tank Option 2 was determined to require a minimum height of 20 feet to the bottom of the tank, whereas, Tank Option 1 would require a minimum height requirement of about 38 feet to the bottom of the tank. Therefore, Tank Option 1 was determined not to be feasible based on engineering judgment and analysis. The required height would not be cost-effective for construction for any of the storage tank options and, more importantly, the construction of a gravity-fed system would not be safe. Tank Option 2 location is highly recommended.

6.2.2 Water Storage Tank Conceptual Design

The water storage tank consists of a 5,400 gallon reinforced concrete water tank elevated on a 3 ft high earth foundation. Figures 17 and 18 show a comprehensive model of the recommended storage tank site layout from the North and South perspectives, respectively.

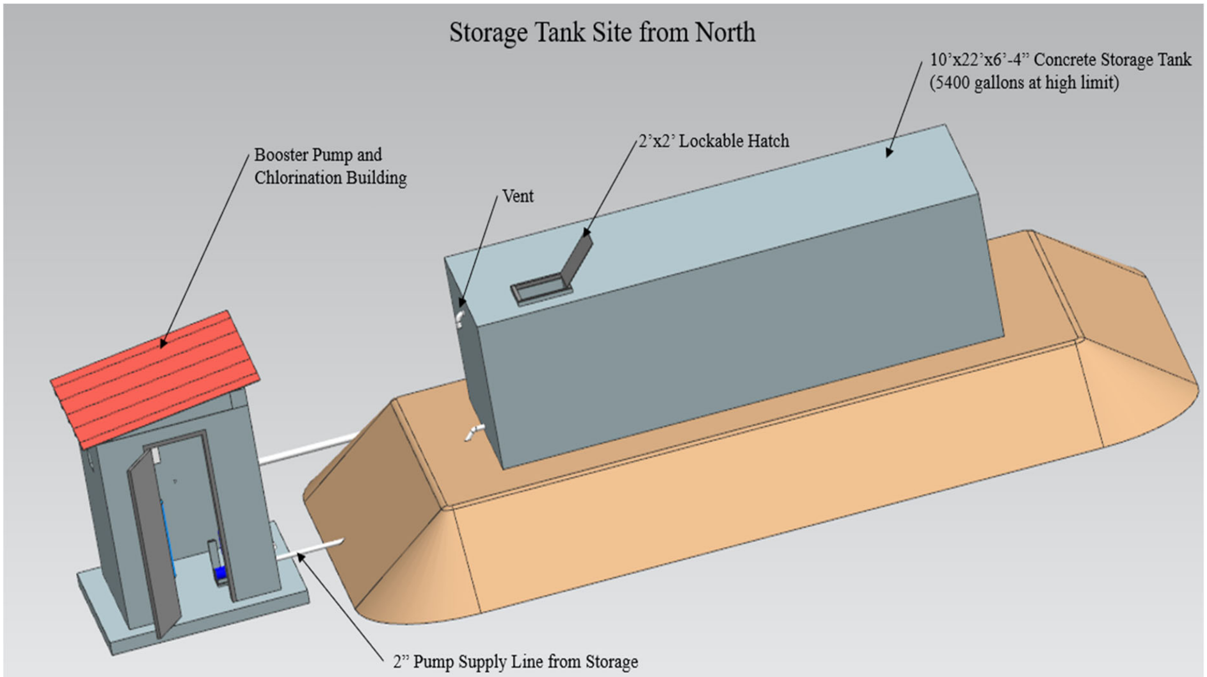

Figure 17. North-side View of Water Storage Tank and Pump Station (Conceptual 3D Model).

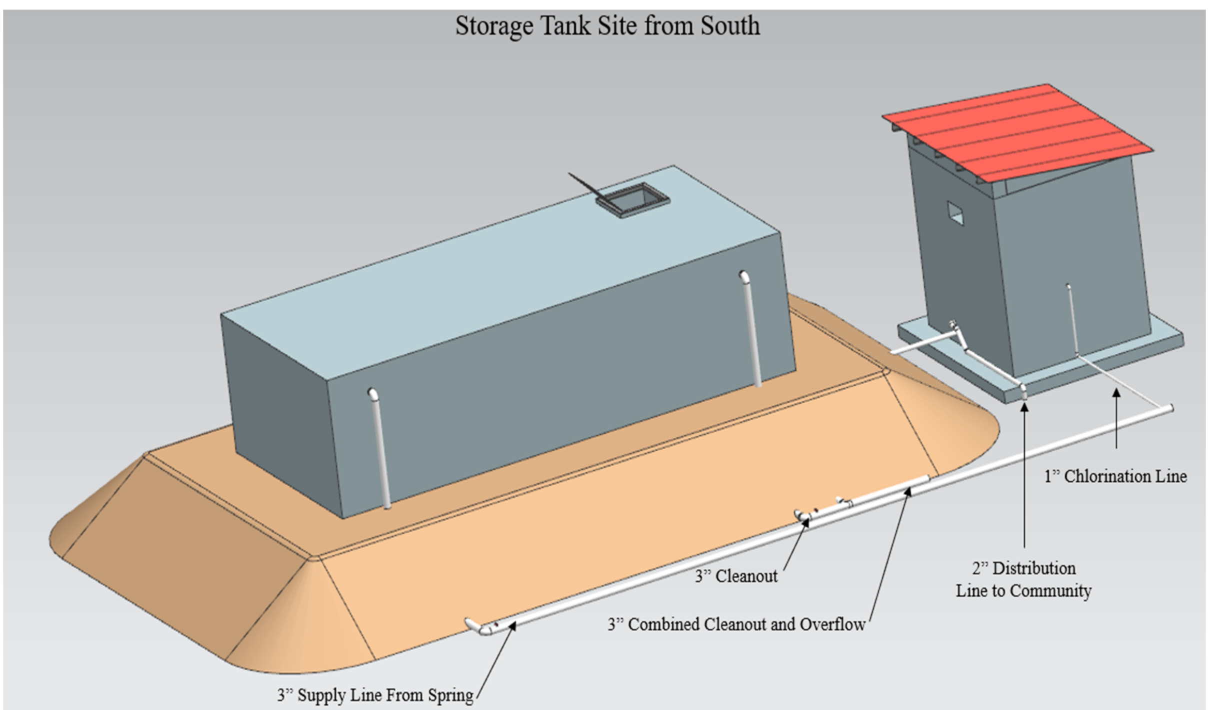

Figure 18. South-side View of Water Storage Tank and Pump Station (Conceptual 3D Model).

The earth foundation is preferred over a reinforced concrete column foundation to elevate and stabilize the structure while reducing the cost. The foundation will require the fill to be a well-graded gravel soil compacted to the specified conditions in order to ensure bearing capacity remains above the bearing pressure, therefore avoiding soil failure in shear. Based on the required loading of the structure, a minimum of 3 ft horizontal build from the structure and a minimum of 8-inch foundation into native soil are required. The maximum maintained slope should not exceed a 1.5 ft horizontal to 1ft vertical. The 3 ft landing allows for ease of serviceability and the steep slopes are specified to minimize the footprint of the structure. Riprap or gravel-like stone should be placed over the surface of the earth's foundation for erosion control. The 8-inch-thick reinforced concrete slab should be built "to grade" based on the top of the earth build. Similarly to the water collection structure, a lockable hatch has been specified for ease of maintenance, as detailed in Appendix D-1. The storage capacity is sufficient to sustain the projected population at peak usage for at least 4 hours, as discussed in Section 4 and Appendix B-2 can be referenced for calculations. Additionally, the basic geotechnical calculations for the water storage tank including soil bearing capacity and settlement for the structure are detailed in Appendix B-6 and B-7.

The assessment of this site indicates that seismic loading will control the structural demands of the water storage tank, based on the Seismic Code Evaluation of Panama (Reglamento de Diseño Estructural para la Republica de Panama: REP-2003) in conjunction with reference manuals used in the United States [6]. The code indicates that Emberá Puru has the following design characteristics: Classification D seismic performance and occupancy category II. The low center of gravity of this design alleviates the necessity for further analysis of the code; although, in the case that a sizeable earthquake was to occur, there is potential for soil liquefaction, as well as fracture of the rigid structure. The structure should be inspected by a structural engineer directly after the impact of any sizeable earthquake.

6.2.3 Water Treatment System

A key component of the design is the water treatment system, as the main goal is to provide potable water to the community based on WHO standards. A water treatment system located at the storage tank location will be used to disinfect the water prior to distribution. As discussed in Section 2, the known spring source showed the presence of coliform and suspended solids with an absence of E Coli, though E Coli was detected in the Ambitek tests.

Figure 19. Photograph of 35-gallon Chlorinator Well.

As previously stated, the water collection structure will remove a substantial portion of the suspended solids in the water due to the application of a rock filter. A chlorination system will be implemented at the storage tank to remove the coliform from the water, as this application is proven to reduce bacteria and viruses while providing residual protection against recontamination [7]. An automatic chlorination system, J-PRO-22 35-Gallon Solution Tank (Figure 19), has been selected to deliver a metered supply based on the calculated water flow rate through the pipeline, which includes a check valve, pressure gauge, ball valve, feeder and chlorine solution storage tank. The specification sheet and installation & maintenance manual for this chlorination system can be referenced in Appendix D-3.

The size of the tank will allow for adequate contact time with the chlorination solution. It was determined that the free chlorine concentration must be at least 0.6 milligrams per liter as measured at the entry of the distribution system and necessitates 26.8 minutes of contact time to adequately inactivate bacteria and viruses. Appendix B-8 details the calculations completed for the contact time.

The chlorine additive should be purchased as a pre-mixed liquid solution because gas and powder forms can be hazardous and difficult to manage. The solution will be injected at ground level rather than feeding directly into the storage tank to allow easy access for repairs and maintenance. This method is commonly implemented on water supply and distribution projects. For protection of the system, the components should be housed in a pump station. Figures 17 and 18 show the pump station configuration and the chlorine line, respectively.

6.2.4 Pump for Distribution Line

A booster pump will be implemented to pressurize the distribution line. The *TW1000-30W-30 Flag Frame Booster Pump* (Figure 20) is recommended for implementation to overcome friction and head loss throughout the network without the need for a tower structure and its associated risks, as well as allowing for ease of maintenance of the system. The pump will maintain 20-30 psi throughout the system at up to 30gpm to ensure delivery to each of the taps with sufficient pressure. Further specification of the booster pump can be referenced in Appendix D-4.

Figure 20. Recommended Booster Pump for Distribution Line.

The booster pump will be tied to a float switch to ensure it does not run dry if the water reaches a minimum level in the water storage tank. The minimum level of the float switch is recommended to be set at 2 ft and a high-level switch at 4' will indicate to the centrifugal pump at the source to turn off. The application of float switches reduces pump wear from frequently starting and stopping and ensures the pump does not run unnecessarily and avoids wastage. The pump will be installed next to the water storage tank; which has been elevated to provide 3 ft of head to the pump. The elevation could, potentially, be removed as a requirement if a suitable self-priming booster pump could be identified for implementation.

Further analysis of the system was completed through the use of EPANet, as discussed in Section 4. The total peak demand and peak household pressure were determined to be 16.3 GPM and 37.6 psi, respectively. Concluded from these results, the system capacity is sufficient and the design criteria are met.

6.3 Electrical Controls & Supply

A pad-mounted control box will be installed to provide electrical service at both the source and storage tank locations. The control box at the known spring source will function as a communicator between the centrifugal pump and level sensors at the wet well (low level shut off) and storage tank (low level demand plus high level shut off). The control box at the storage tank location will facilitate access to the system in case there is an immediate call for action and the system needs to be shut down, as well as function as a communicator between the booster pump and level sensor at the storage tank (low level shut off).

Based on the circumstances, the electrical controls and components of the spring source system could be powered through the application of solar panels with battery packs for power storage. Through evaluation of the power draw and usage of the system, the recommended system size is 2.81 kW based on a 2035-Watt power draw, 5.3 hours of usage, and an average 6 hours of full sun collected. Two- 0.3 MWh battery packs have been specified in case of overcast or insufficient power. Based on the current population, a fully charged battery pack can power the system for 48 hours (2 days) if no additional power is collected from the panels; therefore, two battery packs could power the system for 96 hours (4 days). Based on the projected population, the two battery packs could power the system for 43.2 hours (about 2 days). All calculations for power draw, power usage, solar power and battery power can be referenced in Appendix B-10.

The voltage and amperage requirements for the electrical pumping and controls at the known spring source are 115 Volts and 15 Amperes, respectively. Similarly, the requirements at the water storage tank are 115 Volts and 20 Amperes, respectively. Amperage requirements were estimated based on the pump and electrical accessories, at the respective location. The recommended electrical control panel is SPI 50A001 Single-Phase Simplex Control Panel-SSC1B. This recommendation is intended to be provided as an example, not a design specification. The associated connection diagram and schematic are detailed in Appendix D-5.

Due to the hazards involved with an improperly wired electrical system, electrical installation must be performed by qualified personnel. Additionally, specifics of the electrical controls and accessories for the system will need to be determined and specified accordingly by the qualified personnel. All completed activities and material specifications must conform to the requirements of Darien, Panama, as well as any codes in effect at the time of installation.

6.4 Pipeline

The water supply and distribution pipeline will run from the known spring source to Tank Option 2 and continue to each of the households. The straight-line route for the supply pipeline is dense with excessive foliage, whereas the distribution pipeline runs along community roads with no obstructions. In this section, the pipeline will include three elements: supply & distribution pipelines and river crossing structure.

6.4.1 Supply & Distribution Pipeline

The supply pipeline is defined as the pipe that will deliver water through a 3” PVC pipe from the known spring source to the storage tank location, spanning a length of roughly 1,600 ft to Tank Option 2. The 3” diameter pipe was specified to reduce the friction loss in the supply line. The supply line is proposed to be routed from the known spring source to the Tank Option 1 location then continuing to Tank Option 2 location along the roadside. This route was determined as optimal in order to avoid highly trafficked pathways that community members use for their daily activities. For reference, Appendix A-5 shows elevation profiles following the proposed supply and trunk line routes.

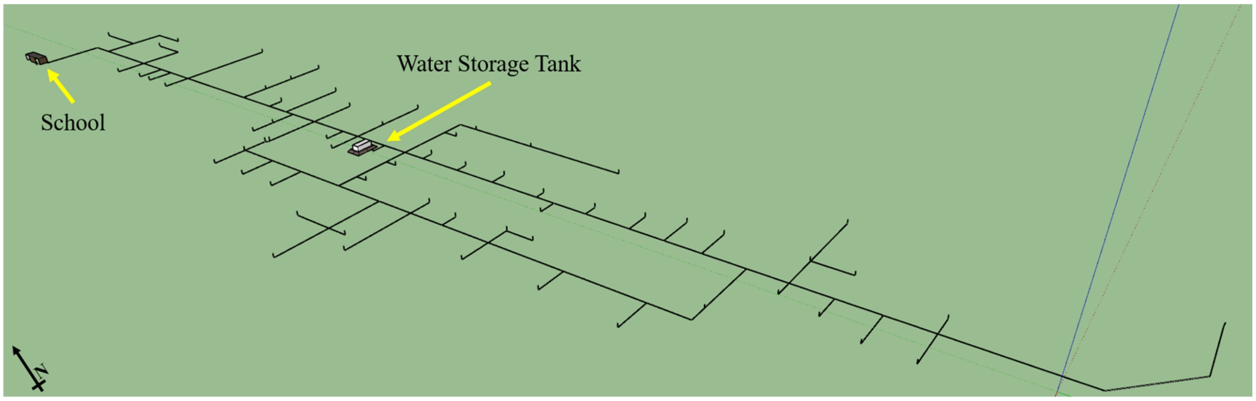

Figure 21. Distribution System Layout of the Central Community (3D Model).

The distribution pipeline (Figure 21) will feed water from the water storage tank through the trunk lines then continue to the taps through the branch lines. The trunk lines should run parallel to the roadways with the branch lines extending perpendicular to ensure easy installation, maintenance, repair and expansion. The trunk line will be constructed with 2” PVC pipe that branches to 1” PVC pipe to run to the households. Increasing the trunk line and branch pipe diameter from ½” to 1” reduces the resistance of water flow due to friction. As the system nears the household, the pipe should be reduced to ½” PVC pipe for a minimum of 2 ft prior to the 1⁄2” water meter, which will then continue to a ½” spigot connection. Based on construction decisions for the placement, the recommended water meter is available for 1” pipe connections, although overall project cost will increase.

The two system loops highlighted in red and yellow in Figure 22 have been implemented to allow for the system to sustain unaffected areas of the system during unusual conditions. Malfunctions, repairs, and maintenance are three examples of unusual conditions.

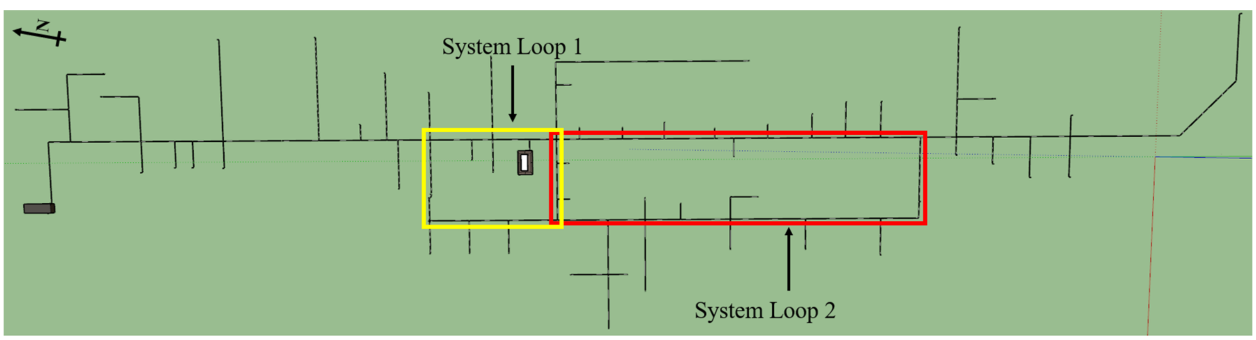

Figure 22. Depiction of System Loops on Aerial View of the Distribution System (3D Model).

The supply and distribution pipelines include valves that have been strategically placed throughout the system to function as clean-out, air release and shut off valves to effectively manage and maintain the operation of the system. Figure 23 depicts the locations of the 9 clean-out valves placed at local low elevations and 7 air release valves placed at local high elevations. There have been 11 shut off valves provided to be placed at central junctions and tee-connections located on the system loops. Each of the valves will be housed in a valve box (Figure 24), 1 ft below grade, for protection and accessibility. The burial depth at these locations will transition from the general 24” specification depth to about 8” and the pipelines should utilize proper fittings to provide a smooth transition.

Cleanout and Air Release Valve Locations

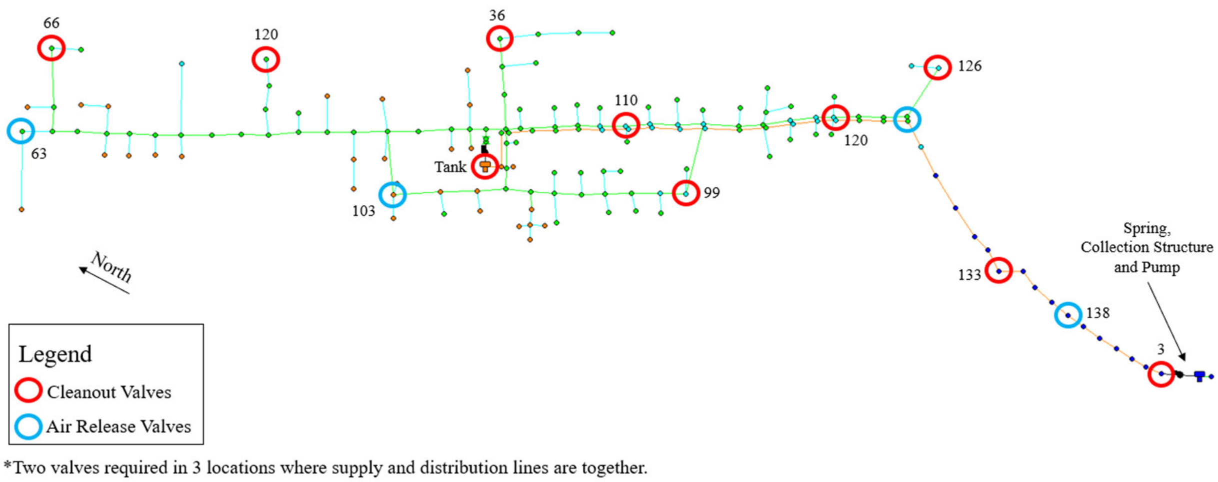

Figure 23. Map of Air Release and Clean Out Valve Locations (Not to Scale).

All pipe and pipe fittings should be SDR 26 and SCH 40, respectively in order to meet the pressure requirements of the system [8]. Specifications for pipeline elements, including recommendations for the water meters, metal spigots, air release valves and valve boxes, are in Appendix D-6. Installation of the supply and distribution pipeline should be coordinated in order to minimize the bulk cubic yards of earth moved in the operation. The distribution pipeline that is in line with the supply pipeline should be installed simultaneously to reduce the man-hours required for installation. The supply line and distribution system should be protected by bedding and covering with sand fill, prior to installation and backfill, if budget permits. Additionally, to alleviate potential rutting in the roadways, compaction methods are specified in the construction drawing set in Appendix G.

Figure 24. Recommended Valve Box.

6.4.2 River-crossing Conceptual Design

A pipe bridge with a tower to tower span of 45 ft is required to support the supply pipeline and electrical conduit across a 36 ft bank to bank river crossing (Figure 25). The recommended structure for this application is a suspension bridge design. Considering the distributed load, wind load and minimum live load, the design capacity is sufficient for the required demands. Appendix B-9 details the calculations of the pipe bridge.

This design consists of two steel towers, wire rope, two concrete anchors and stringers. The steel towers are standard 2-inch diameter steel pipe with a total length of 5.5 ft for the north tower and 4 ft for the south, allowing for a 1 ft embedment and heights of 4.5 ft and 3 ft, respectively, above grade. The footings should be cast-in-place with 1 cubic foot dimensions for ease of construction, reinforced by cages built of #4 rebar for increased structural integrity and stability. During construction, the towers must be installed perpendicular to the ground and not experience any leaning to mitigate undesired moment effects, such as torque. The towers should be capped with a ⅜-inch eyebolt attached to reduce friction and degradation of the main suspension cable over time while holding it in place. A galvanized vinyl coated steel wire rope with a diameter of 3/16 inch will be tensioned across the river to serve as a main support for the supply pipeline and electrical conduit. The main cable runs from one bank to the other in the following sequence: anchor, tower, tower, anchor. Reinforced concrete anchors support the tension force through the main cable. The 2 ft by 2 ft concrete anchors with 2.5 ft depth are reinforced with #4 rebar cages, and the wire rope shall be attached to the cage at the center near the top surface. Proper distribution of the load requires four stringers of 3/16-inch diameter with 9 ft spacing across the river span. The stringers should be looped around the main cable and pipes. The loops should be secured by two clamps with 1-inch spacing and at least 2 inches of tail remaining after the final clamp. In order to maximize the clamp strength, the clamps should be installed with opposite orientation in regard to each other. During construction, the electrical conduit should be installed above the water pipeline in case of unexpected leaks and to mitigate safety hazards.

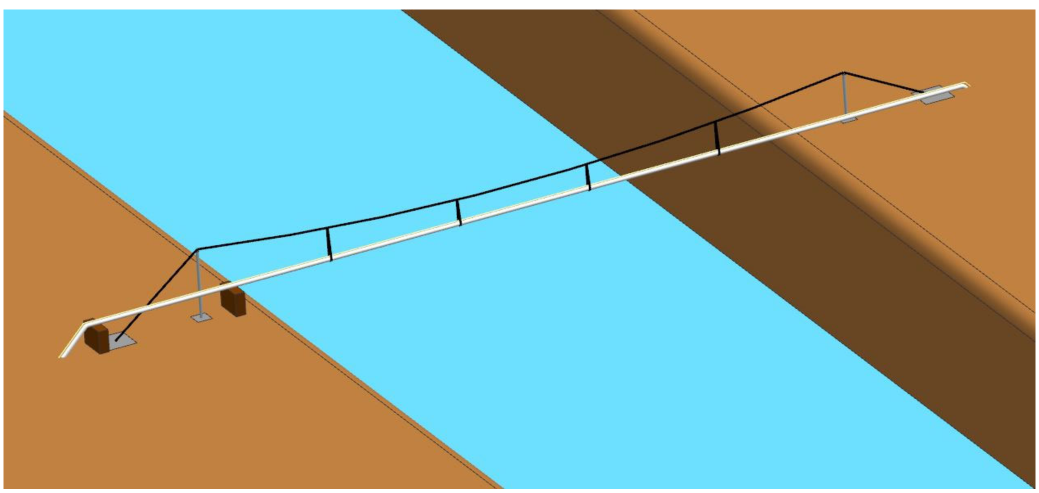

Figure 25. Conceptual Design for Pipe Bridge Across a Small River.

A clearing process is highly recommended to remove trees and brush from the construction workspace. The vegetative buffer will be limited to the extent necessary to install the structure and aid in safe construction practices, and revegetation or application of rip-rap may be necessary to prevent erosion at the river banks. It is assumed that community members will supply voluntary labor for this additional component of the design.

6.5 Protective Barriers

The system includes a multitude of sensitive, critical and expensive components that are required for operation of the water supply and distribution system which require protection. The proposed protective barriers to protect the components of the system from external hazards (e.g. unwarranted people, the environment) are outlined in this section.

6.5.1 Fence

Based on Panama Code and best practices, as referenced by FPP, the fence design is recommended to be implemented around the following structures and components: all components located at the known spring source, the structural components of the river crossing on the banks and all components at the water storage tank.

The fence design includes 9 ft fence posts supporting chain link and 15.5 gauge barbed wire. Fence posts achieve a minimum of 2 ft embedment, and the chain-link should be tensioned properly. Two strands of barbed wire should be tensioned around the perimeter at the top of the posts and 6 inches down from the top of the posts. Prior to installation, the fence perimeter should be surveyed and marked for proper placement. The fence must be installed with a 5 ft clearance on all sides of equipment and structures.

6.5.2 Pump Station

The electrical components will be housed in a pump station at the water collection structure and water storage tank locations. At the water collection structure location, the pump station houses the electrical controls and centrifugal pump; whereas the water storage tank location will house the electrical controls, booster pump and chlorination system. The interior dimensions of the buildings at the water collection and water storage tank locations are 4 ft square and 6.7 ft by 8 ft, respectively. The building (Figure 12 and Figure 17) will be constructed of masonry blocks, reinforced and poured solid at the corners, with a zinc-coated roof and include a lockable steel door for maximum security. Appendix D-7 details the recommended steel door. Situated on a reinforced concrete footing, the structure will include two windows of standard masonry size with screens installed to allow for airflow while prohibiting the entry of bugs and foliage. Detailed drawings for the pump stations can be referenced in Appendix G.

7.0 Operation and Maintenance Recommendations

The operation and maintenance of the system is crucial to the success of the system. The main topics the manual should include are detailed and the frequency of tasks is summarized in Table 5. Appendix E includes the recommended spare parts and tooling for O&M purposes. This section of the report is intended to be utilized as a reference for the development of a comprehensive O&M Manual, not as the O&M Manual itself.

Collection Structure

Being one of the three major components of the system, adequate operation and maintenance of the collection structure is imperative in keeping the system in working condition. Therefore, a designated responsible individual should ensure that the required tasks are being met and that timely updates are included in the program as needed. Typical duties of the operator will be to clean the sediment from the wet-well, replace screens in the PVC pipe as necessary, and give the pump adequate maintenance. A list of specifications for fuels, lubricants, filters, etc. for both pumps as well as troubleshooting charts or guides (which references pages in the O&M manual and manufacturer's O&M manual) should be provided.

Water Storage Tank

It is recommended that the Storage Tank is inspected at least every 6 months for defects & sanitary deficiencies. Additionally, a structural inspection of the tank and coatings by a qualified engineer should take place at least every 5 years.

Water quality (e.g. pH and chlorine residual) tests should be performed weekly. It is necessary to check and record chlorine residual at point of application, nearest household/building (required to provide CT) and at remote points. The chlorinator should also be inspected weekly to ensure proper input and output. A designated person within the community should monitor chlorine solution levels and ensure adequate stock is maintained.

Water Supply & Distribution

A leak check and a system drain/clean-out should be conducted annually. The water lines and air & clean-out valves should be inspected for corrosion and leaks.

General System Maintenance

Clearing and maintaining the clearing of critical areas are important tasks to be performed by the community. Inspection of erosion areas and of all fence perimeters should be completed every 6 months. A qualified electrician should be contacted yearly to check running amps on pumps, or immediately if unusual noises (signs that bearings are wearing out) are heard coming from the pump. Shock chlorination of the system (introduction of a large batch of chlorine to the storage tank) should be conducted at system startup, at any time the system has remained out of service longer than one or two days, and any time a break in the line has been detected and repaired. All taps should be opened for several minutes in an organized manner to ensure the higher concentration of chlorine reaches each tap and all taps shall be run again afterward to remove extra chlorine from the system.

Table 5. Frequency of O&M Tasks.

Task	Frequency
Water Collection Structure	
Clean Sediment from Wet Well	Annually
Replace PVC Pipe Screens	Every 1-3 years, or as necessary
Pump Maintenance	Reference Manufacturer's Manual
Water Storage Tank	
Water Quality Testing	Weekly
Inspection of Chlorinator	Weekly
Sanitary Deficiencies and Defects Inspection	Every 6 months
Structural & Coatings Inspection	Every 3-5 years
Pump Maintenance	Reference Manufacturers Manual
Water Supply & Distribution	
Water Line and Valve Inspection	Every 3 months
System Drainage/Clean-out and Leak Check	Annually
General System Maintenance	
Clearing Maintenance and Upkeep and Fence Perimeters	Every 1-3 weeks
Inspection of Erosion Control	Every 6 months
Electrical Component Evaluation	Annually

The frequency of tasks in Table 5 are estimates based on research and judgment. More involved guidelines should be established with the aid of Manufacturer's Manuals based on the equipment and components selected for the system.

8.0 Project Planning

8.1 Cost Estimate

A cost analysis of the design elements was conducted in order to determine the financial support required to construct the proposed water system. The cost estimate is categorized as an American Association of Cost Engineering (AACE) International - Class 4 estimate. All quantities and costs have been estimated based on current design scheme Materials and Equipment pricing is based on United States pricing, whereas labor is based on Panama standards of wages [9]. Through the utilization of community members as volunteers to complete less critical and simpler tasks, the overall project budget can be significantly reduced. Outlined below (Table 6) are the *Bid Packages*: Sitework, Collection Structure, Pipework, Chlorination System, Elevated Water Storage Tank, Pump Station, River Crossing and System Testing. The detailed cost estimate and bill of materials are located in Appendix F-1 and F-2, respectively.

Table 6. Cost Estimate for Each Bid Package in US Dollars.

Bid Package	Description	Estimated Required Budget
1	Sitework	$1,600.00
2	Collection Structure	$6,470.32
3	Pipework	$15,284.93
4	Chlorination System	$1,046.12
5	Water Storage Tank	$8,149.79
6	Pump Station	$25,286.74
7	River Crossing	$3,075.52
8	System Testing	$1,835.92
	Subtotal:	$62,749.33
	Contingency (10%):	$6,274.93
	TOTAL PROJECT BUDGET:	$69,000

The concrete material costs for all applicable elements are calculated utilizing the approved concrete mix design: one-part cement, two-parts sand and four-parts gravel. The mortar costs are calculated using the mix design: one-part cement and four-parts sand. At least one foreman will be required to oversee the work to ensure it is built to specification for the tasks involving the community. The activities that the community could potentially be utilized for include clearing, excavating, fencing, installing supply and distribution line elements and construction of some structures. These structures include the water collection structure, wet well, and river crossing. All components requiring electrical expertise will require a QEW.

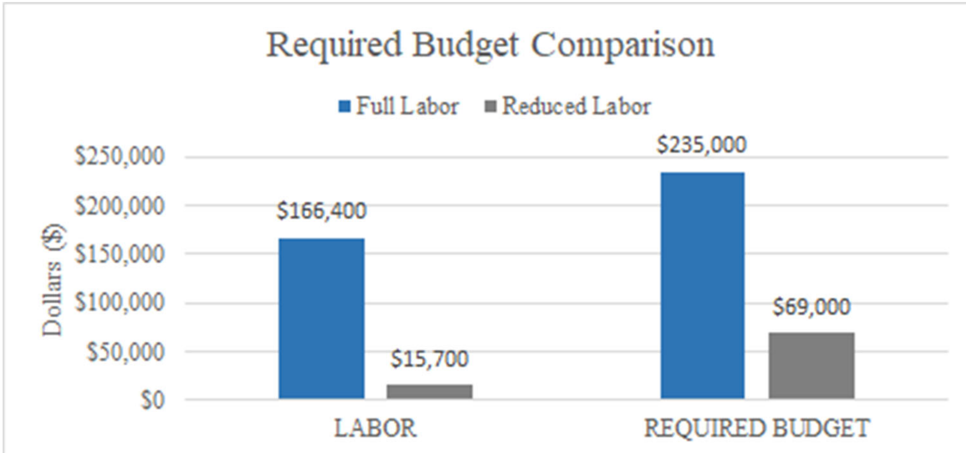

Figure 26. Comparison of Full and Reduced Labor and the effect on the Required Budget.

As shown in Figure 26, through the utilization of the community, the labor cost associated with the project was reduced by 91% percent, in turn reducing the overall cost of the project by 71% percent. For the purpose of this comparison, full labor is defined as all of the work for the project being contracted and reduced labor is defined as utilizing the community where possible with contracting one foreman to oversee the task.

Figure 27 shows the component breakdown of the estimate by bid package allowing for the analysis of items by percentage. After reducing labor costs through the utilization of community members, the largest cost item shifted from the pipework to the pump station. Due to the necessity for a QEW to complete the electrical work, as well as the installation of the solar array and storage batteries, the components included in the pump station bid package are higher than the other bid packages.

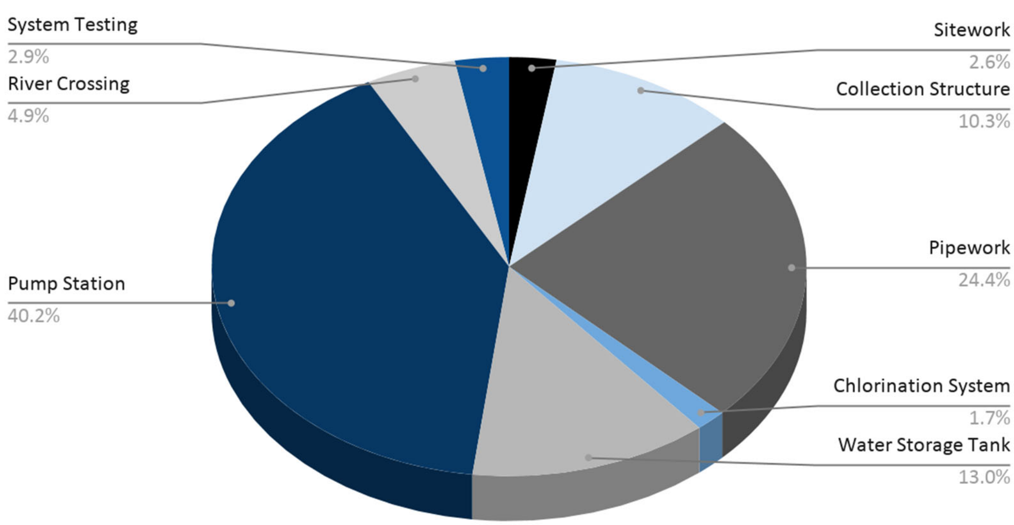

Figure 27. Component Breakdown of Estimate by Bid Package.

Figure 28 shows the component estimate breakdown by materials, labor and equipment. The largest portion of the budget is placed towards the materials; which was achievable by the utilization of the community members as volunteers.

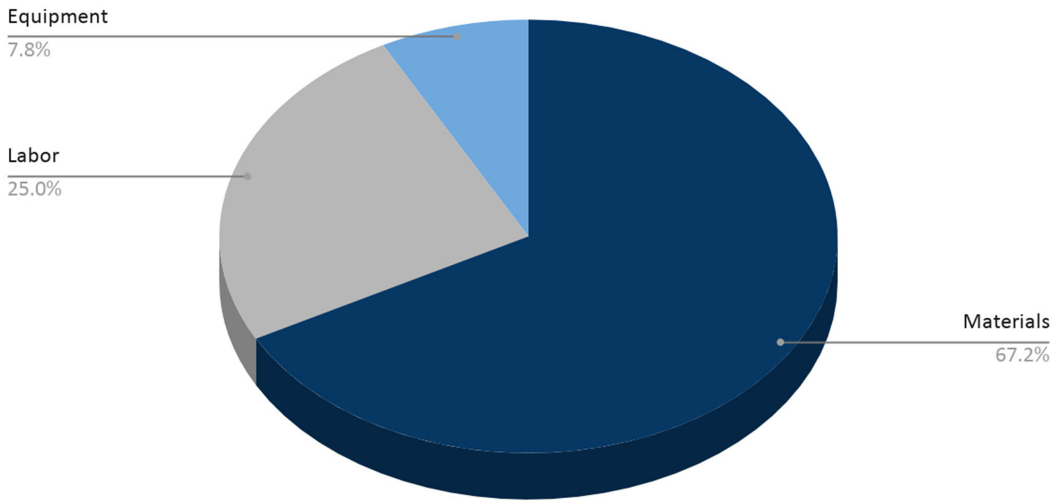

Figure 28. Component Breakdown of Estimate by Materials, Labor and Equipment.

8.2 Construction Schedule

Based on the labor information in the detailed cost estimate (Appendix F-1), KRV has prepared a project construction schedule (Appendix F-3) utilizing the critical path method. Each bid package element was further detailed to tasks and subtasks to generate a detailed construction schedule. The major activities in chronological order include the following: order materials, remove ultrafiltration system, pipe installation, build water collection structure, build water storage structure, install fencing, install pump and solar array, install chlorination system, electrical work and pre-start tasks.

Consuming a large quantity of days, the installation of pipelines and construction of the water storage tank are the most time-consuming activities of the project, as all associated labor will be completed manually. Where feasible and necessary, multiple tasks have been scheduled concurrently to reduce the overall schedule. Throughout the construction process, full community support and involvement is a key factor in the success and timely completion of each activity. The installation of protective barriers precedes the installation of critical components in order to protect the expensive and critical items of the system from the start. The entire project is estimated to span 7 months, given the schedule detailed is maintained. There have been approximately one day per week accounted for in the schedule for weather and further delays may be encountered based on the time of year the project completion is scheduled for.

9.0 Next Steps

9.1 Outstanding Action Items

After sorting and analyzing the data collected in Emberá Puru, two items have been identified as outstanding action items for necessary follow-up or further investigation. The current outstanding field items are:

- Verification of the known spring source through analysis of the flow rate during both the dry and wet season, accomplished by water removal and refill rate, along with bathymetric survey of the pond, as outlined in Appendix A-9. This is a key factor to ensure the success of this project. Also, if possible, the location of the "eyes" (ojos) of the spring is also requested.
- Identification of the electrical source to tie-in locations nearest to the potential storage tank and the spring source. Also needed is additional information about the available voltage and amperage of the existing supply, and whether there is a three-phase power available from the community's service off the main transmission line.

9.2 Operation and Maintenance Manual

A comprehensive O&M Manual should be provided to the Emberá Puru Water Committee to aid in the required tasks. This is a comprehensive document that provides all the details necessary for the entire system, as well as each individual piece of equipment to help the community keep everything running smoothly. The main topics the manual should include are outlined and frequency of tasks are summarized in Section 5, Table 5.

The O&M Manual should include checklists and be graphically oriented, including images for common problems or issues that could be encountered and what is "correct". The checklists are recommended to be formatted on an interval basis, rather than by component; whereas the O&M Manual should be formatted by component for ease of navigation. O&M Manual references for the system are provided below for use during the development of the manual and checklists. The manuals referenced do not utilize the graphics-oriented formatting, although the information included in the manuals provides quality information and a solid foundation for beginning the development of the O&M Manual. Specific chapters from the manuals that may be of use for the system outlined in this report are specified.

- Operation and Maintenance Manual: Rural Water Supply (Vol. 3) [10]
    - *Chapter 3:* Disinfection
    - *Chapter 4:* General Operation and Maintenance
    - *Chapter 5:* Supply Source and Disinfection Facilities
    - *Chapter 6:* Distribution System

- Operation and Maintenance Manual for Rural Water Supplies [11]
    - *Chapter 2:* Strategy
    - *Chapter 4:* Sources of Water Supply
    - *Chapter 5:* Transmission System
    - *Chapter 8:* Disinfection of Water
    - *Chapter 9:* Storage of Water
    - *Chapter 10:* Distribution System
    - *Chapter 11:* Pumping Machinery
    - *Chapter 12:* Water Meters, Instrumentation, and Telemetry & SCADA
    - *Chapter 13:* Drinking Water Quality Monitoring and Surveillance
    - *Chapter 14:* Water Revenue (Billing & Collection)
    - *Chapter 15:* Water Audit & Leakage Control
    - *Chapter 16:* Energy Audit & Conservation of Energy
    - *Chapter 18:* Community Participation and Complaint Redressal System of O&M of Water Supply Scheme
    - *Chapter 19:* System Management

Checklist references for the following components are provided for use during the development of the manual and checklists.

- Preventive maintenance program: Guide for small public water systems using groundwater [12]
- Operation and Maintenance of a Water Storage Tank [13]

9.3 Educational Topics for the Community

The overall success of the implementation of the water supply and distribution system is dependent on the education of the community. In this section, the following educational topics are recommended to be discussed with the community, as well as implemented into the education system in the community for future generations: Rainwater versus treated water, the importance of system maintenance, awareness of water scarcity and proper disposal of wastewater.

Rainwater versus Treated Water

The collection of rainwater is a great solution in order to promote water conservation, although the Center for Disease Control and Prevention (CDC) has indicated concerns linked to rainwater collection [14]. The rainwater can carry contaminants; for example, bacteria, parasites, viruses and chemicals and the use of rainwater has been linked to disease outbreaks. The following are potential sources of contamination and should be considered when placing collection structures or containers:

- *Dissolved* dust, smoke and soot.
- *Materials* used for roofing and storage can introduce harmful chemicals.
- *Runoff* from the roof can carry dirt and germs.

Proper collection methods and use of the rainwater is imperative to the health of the community, as the water provided by the taps is treated with chlorine to provide potable water. Potable water is defined as suitable for drinking.
For the collection of rainwater, the following measures are recommended:

- Collection structures and containers should be placed away from roof structures to reduce the potential for dirt and germs that could be collected from bird droppings, for example.
- Storage structures and containers should be placed in areas with maximum shading to reduce the potential for leaching chemicals from the container materials, as well as minimize the temperature of the water.
- Collection and storage structures and containers should include a screen to prevent debris, bugs (specifically mosquitoes) and animals from contaminating the water source.
- If the resources are available, disinfection or filtration of the water is recommended. Although, adding chlorine, iodine, or boiling the water may not remove parasites and will not remove chemicals.
- **Important:** Rainwater must be stored and used separately from treated water.

The CDC recommends that the rainwater be used for the following applications: watering plants, cleaning and bathing (avoiding mouth, nose and eyes). However, the CDC recommends to avoid the following applications: drinking, cooking, brushing teeth and cleaning dishes or watering plants that are intended for eating. The applications to avoid using rainwater are examples for proper usage of the treated water from the tap.

Exploration of the education resources from Texas A&M AgriLife are recommended to educate the youth in the community [15]. The implementation of one or more of these activities within the school system could aid in the improvement of the available water within the community, as well as the overall quality of life.

Importance of System Maintenance

Through proper and routine system maintenance, the operation of the system will be ensured and the life of the system will be extended rather than deteriorated by neglect. The following are key factors and benefits of regular system maintenance.

- Identify water line problems early.
- Prevent water-borne diseases.
- Save time and money.
- Reduce water bills [16].

After the development of a comprehensive and illustrative O&M Manual, the procedures and frequency of occurrence should be followed consistently and completely. Specifically, with the extensive and unusual amount of technology involved in the system, routine inspection and maintenance is critical.

Awareness of Water Scarcity

"Water is one of the most precious resources on the planet. More than 1 billion people do not have access to a source of clean drinking water, and around 3 billion experience water scarcity at least one month per year" [17]. Water scarcity is defined as the lack of sufficient available water resources to meet the demands of water usage within a region [18]. The Emberá Puru community has experienced a water shortage quite often and the viable water sources in the Darien Province are few and far between. In order to sustain the spring source for the system, measures should be taken to reduce the potential for wasting water. The following are the recommended methods:

- Educate to change consumption and lifestyles.
- Recycle wastewater appropriately.
- Appropriately price water.
- Look to the water committee for governance.
- Develop and enact better policies and regulations.
- Holistically manage ecosystems.
- Mitigate Pollution [19].

Based on the determination of viability of the spring source over time, the education of water scarcity may become more critical. Water resources are limited in this region and water should be conserved. Exploration of the education resources from The Water Project is recommended to educate the youth in the community [20]. The implementation of one or more of these activities within the school system could aid in the longevity of the source and system.

Disposal of Greywater

Disposal and management of greywater, or wastewater, is important in aiding the conservation of water. Properly reusing and recycling greywater can greatly influence the reduction of water from the tap. However, improper disposal of greywater can negatively impact the ecosystem and water sources in the area. For example, releasing the greywater into rivers, lakes, or estuaries causes the nutrients to become pollutants, whereas plants will value the nutrients as fertilizer. The following lists provide an outline on the basic greywater guidelines.

- Greywater cannot be stored for longer than 24 hours.
- Minimize potential for contact with greywater.
- Infiltrate greywater into the ground - do not allow for pooling or runoff.
- Avoid oversaturation of soil by matching discharge with irrigation needs.

Some examples of sources of greywater from households are washing machines, bath water and kitchen sinks. Greywater containing chemicals such as high amounts of salt, boron, or chlorine bleach should not be disposed of as outlined in this section. The water will be impactful on the plants that it comes into contact with, therefore the recommendation would be to properly dispose of the water in areas with natural drainage material and filters to remove the harmful contents [21].

Blackwater should not be confused with greywater. In contrast to greywater, black water contains feces and urine [22]. Blackwater should be disposed of properly through the use of sanitation stations or following the community bylaws/guidelines, respectively.

Exploration of the education resources from the Integrated Teaching and Learning Program at the University of Colorado Boulder, College of Engineering [23] should be encouraged. The implementation of one or more of these activities within the school system could aid in the conservation of water and mitigate pollution of the water sources in the area.

9.4 External Resources

Construction of components and elements within the system will require external resources for completion. Three external resources have been identified for the construction and maintenance of the system: material providers, qualified professionals and inspectors.

Material Providers

The system cannot be built without materials, specifically materials that meet all specifications and applicable codes. Material handlers and providers that meet desired requirements and expectations should be identified early on to ensure timely procurement and delivery, if necessary. The majority of the materials specified for the system, or the equivalent, should be available in Panama. The following materials have been identified to have potential for importation: centrifugal pump, chlorination system and booster pump.

Qualified Professionals

Activities within the construction process will require the action of qualified professionals, specifically electrical and structural work. A QEW is required for the evaluation, specification, installation, start-up and routine maintenance of all hot elements. For reference, a hot element is defined as any live conductor, which infers connection with an electrical system and possesses an electric potential relative to electrical ground. The activities related to electrical components identified to require a QEW include the following: solar array, centrifugal pump, all control panels, electrical signal wire in conduit, chlorination system and booster pump.

Structures requiring substantial elevation will require a structural engineer for analysis, design and quality control & assurance during construction. The applicable design codes for Wind and Seismic Evaluation for Panama should be practiced, as discussed in Section 6.2.2. The identified component that would require a structural engineer is an elevated water storage tank to support a gravity-fed distribution system.

Inspectors

Directly following construction, the system will require a comprehensive inspection of all components and elements to ensure proper function prior to system start-up. The major inspections and tests that will need to be performed include electrical startup testing, system startup testing, pipeline inspection, shock chlorination and system flush. The electrical startup testing will require a QEW, as previously mentioned.

Routine inspection of the system will be necessary in order to support the longevity of the system. The identified routine inspection that will require external resources include electrical components, wiring, water collection structure, water storage tank and pump stations. The frequency of inspection varies among the listed system components and should be identified by a qualified professional or standing code requirement for electrical components and structures.

10.0 Conclusion

The water supply and distribution system design proposal has been conceptualized, developed and proposed by KRV, in collaboration with FPP, for the Emberá Puru Community. The project is funded by GBP in order to provide consistent, potable water to the community and overcome water shortages. Understanding the needs of the community is essential to provide a new water system that accounts for projected population growth over the next 20 years. This design proposal allows the central community to detach from the existing system (if proven desirable), and resolve the current water problem in an affordable manner if all assumptions made above are proven to be correct.

During the Site Assessment Phase, the following site investigations were performed: topographic data, GPS data for faucet locations, soil classification and water quality testing. The system risk factors, criteria, constraints and assumptions outlined in Section 3 of this report were implemented in order to generate a comprehensive design proposal. In order to analyze the system, a daily demand pattern for anticipated water usage was implemented through water balance calculations, as well as EPANet modeling.

Throughout the design phase, a multitude of alternatives were identified for components within the system. In addition to the Embera Puru system design alternatives, the functioning system has the potential for improvement or tie-in, given additional information and analysis is conducted. For the design proposal, KRV recommends a pressurized water supply and distribution system. The water collection structure consists of a spring box design with a wet well to aid in settlement and to provide a buffer for the centrifugal pump, respectively. The pump - powered by a solar array - delivers water through the 3” supply line to the storage tank. In order to cross a small river, a suspension bridge with a 36 ft span is recommended. Located at the center of the community, a storage tank with a 3 ft earth build foundation feeds the distribution system. The footprint of the monolithic concrete slab, forming the base of the tank, is sized to accommodate the other tank alternatives, including the gravity-fed alternative (which would require additional excavation, reinforcement and concrete thickness). KRV recommends an automatic chlorination system to be implemented at the storage tank to disinfect the water and a booster pump to maintain sufficient pressure throughout the metered distribution system. All system pipelines consist of SDR 26 PVC pipe and SCH40 fittings with larger than typical diameters to reduce friction head. System valves have been strategically placed throughout the network to function as shut off, air release and clean out valves. By Panama code and best practice, critical system components require protective barriers, such as fences, locks and boxes. The estimated total required budget is $69,000 and the duration of the project is estimated at 7 months, given the schedule is maintained.

The success of the water system is centered around the participation and ownership of the community. Moving forward with the implementation of a water system within the community, the following items should be considered to set the community up for success: completion of outstanding action items, development of O&M Manual, educational exposure for the community and arrangement of necessary external resources. Looking forward, a system capable of sustaining the community with a supply of clean water consistently should be considered the main goal.

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12.0 Appendices

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Table 1. FPP Census Data.

POINT	NOTES	ADULTOS	NIÑOS
100	HWY ENTRANCE W ENTRANCE VILLAGE PANAMA	0	0
101	HWY ENTRANCE E VILLAGE PANAMA	0	0
102	HWY ENTRANCE MIDDLE VILLAGE PAMAMA	0	0
103	ROAD 1 INTERSECTION	0	0
104	SCHOOL VILLAGE ROAD N.1	0	0
105	COMMUNITY MEETING ROAD 1	0	0
106	END ROAD N.2 E	0	0
107	END ROADN.2 W	0	0
108	INTERS. END ROAD 55	0	0
109	OJO AGUA N.1 PAITO CHARA	0	0
110	BRAZO RIO TIRAO RIO BRECHA	0	0
111	END ROAD 1 E	0	0
112	MID POINT ROAD 1	0	0
113	CAISAMO ERNESTO	2	7
114	CHAMI ADRIAN	2	3
115	BILICHA CONSTANTINO	1	0
116	OPUA LUIS CARLOS	2	1
117	OPUA RENE	3	7
118	OPUA RENECITO	1	0
119	BARRIGON OSONE	5	0
120	OPUA URIPIO	2	3
121	BARRIGON MARIA	3	0
122	BARRIGON ROBINSON	2	2
123	BARRIGON ARISTARCO	4	4
124	BACORIZO ELIAS	2	6
125	BARRIGON BERTALICIA	2	2
126	BARRIGON RAUL	2	1
127	BARRIGON FERNELIO	2	4
128	CAISAMO SERGIO	3	5
129	OJENA ULISES	2	0
130	OPUA N HOME		
131	MECHECHE MIGUEL	1	0
132	VALLARINO CHAMI	2	4
133	DENSGUNA ISMAEL	4	6
134	BACORIZO EDWIN	2	4
135	BACORIZO RICARDO	2	1
136	VALLARINO CHAMI	3	4
137	FERNANDO TOCAMO	2	2
138	BACORIZO JOEL	3	5
139	ORTEGA YEISI	2	1
140	CHAMI JOEL	2	7
141	BACORIZO ERICK	2	1
142	TOCAMO FLORENCIO	1	0
143	TOCAMO VENRAL	3	4
144	BARRIGON AMARIL	2	3

POINT	NOTES	ADULTOS	NIÑOS
145	BARRIGON R HOME		
146	IGLESIA N. 1	0	0
147	BARRIGON EFRAIN	4	0
148	BARRIGON JOSELITO	2	4
149	CORDOBA ELCIDO	3	0
150	MOSQUERA C HOME		
151	CHAMI HERMINIA	3	1
152	SANDE ELADIA	1	0
153	DOHIJAMA C HOME		
154	CAISAMO LEO	2	2
155	ARIBIO WILFRIDO	4	0
156	CHAVARI YEBILETZI	2	3
157	BACORIZO JUAN	2	2
158	MENBACHE AXEL	2	5
159	SALAZAR AMANIBIA	1	0
160	OFICINA CASA RURAL	0	0
161	DOGIRAMA GILMA	2	0
162	DOHIRAMA F HOME		
163	DOGIRAMA AUNO	2	0
164	ZANAPI BETSI	1	6
165	SCHOOL GATE	0	0
166	CORDOBA SALVIO	5	1
167	DOGIRAMA RAMON	2	2
168	DOGIRAMA IRVING	2	1
169	PACHECO BENICIO	3	0
170	MENBACHE ROGELIO	2	0
171	DOGIRAMA WILLIAN	3	0
172	DOGIRAMA WILLIAN	2	0
173	CHURCH N.2 EVANGELICA	0	0
174	CORDOBA ELCIDO	3	0
175	CAISAMAS HERNAN	4	0
176	BARRIGON JAVIER	2	0
177	BERRUGATE ARMELIA	3	0
178	CASA COMUNAL	0	0
179	QUINTANA NIDIA	2	1
180	QUINTANA AYARSO	2	2
181	GUAIMORA DONALD	2	2
182	ZANAPI BENJAMIN	2	3
183	ZANAPI JORGE	3	1
184	ZANAPI F	2	3
185	ENTRANCE N SECTOR	0	0
186	ENTRANCE S SECTOR	0	0
187	END S SECTOR ROAD	0	0
188	BERRUGATE MARCELINO	2	1
189	SALAZAR MANUEL	3	0

POINT	NOTES	ADULTOS	NIÑOS
190	OPUA M HOME		
191	CHAVART ADALBERTO	2	2
192	MEMBACHE RICARDO	2	6
193	QUINTERO N HOME		
194	CASA ARTESANAL	0	0
	Total = 290	155	135

<u>Note:</u> There are an average of 3.97 persons per home and 7 homes missing, provides an estimate of 28 additional people and a count of 318 residents in Emberá Puru.

Appendix A-2: Field Methods & Procedures

Topographic Data Collection

The topographic data was collected to survey the potential water source, supply line, storage tank locations, distribution trunk lines and household branch locations. In order to efficiently perform the survey, a three-person crew utilized a Nikon Rangefinder, GPS, compass, 100-foot measurement tape, notebook, writing utensil and two reference sticks of equal height, as shown in Figure 1.

Figure 1. Michigan Tech Students Collecting Topographical Data Assisted by Community Leader. The following procedure was utilized for this method of topographic data collection.

1. Task assignments designated:
    a. Crew Member 1 - Front runner with reference stick and measurement tape
    b. Crew Member 2 - Shooter with Nikon, measurement tape (zero end), and reference stick
    c. Crew Member 3 - Tracker with notebook, pen, GPS, and compass
2. Intended route of travel determined prior to start.
3. Shooter and tracker designated starting point and front runner moved to the next variation in land profile or 100 foot distance, whichever comes first.
    a. Tracker marked WayPoint on GPS and recorded.
    b. Reference sticks at both locations were set up.
    c. First WayPoint of each survey should have no information except the GPS point.
4. Measured distance by placing both ends of the tape measure on top of the reference sticks, pulled tape taut and recorded measurement.

5. Change in slope was shot with Nikon Range Finder.
    a. Front runner placed hand on top of the reference stick flatly and in a perpendicular orientation.
    b. Shooter placed the Nikon on top of reference stick and located the front runner's hand.
    c. Shooter pressed the measurement button and angular change was recorded by the tracker.
6. Tracker determined and recorded the bearing between points with the compass.
7. Front runner remained at location until the shooter and tracker placed their reference stick in the same location. Front runner then proceeded to the next location.
8. Tracker marked WayPoint on GPS and consecutively recorded the number in reference to the steps of 4-7 recorded at the previous point.
9. Repeated steps 4-8 until final destination was reached.
10. For distribution branches, first point was retaken from an existing WayPoint and the original point was referenced by the tracker. Then steps 4-8 were repeated until final destination was reached.

GPS Data Collection of Households and Faucet Locations

FPP provided the baseline GPS data, marking the locations of structures needing a tap and several reference points. Michigan Tech performed supplemental survey work, marking the approximate household and faucet locations in reference to the distribution trunk lines. This provided branch locations and lengths to provide a tap for each household or other necessary faucet location. Households consisting of multiple structures were identified with the assistance of members of the Emberá Puru Water Committee. In order to efficiently perform the survey, a four-person crew utilized a GPS, 100-foot measurement tape, notebook and writing utensil.

The following procedure was utilized for this method of GPS data collection.

1. Task assignments designated:
    a. Crew Member 1 - Branch marker with measurement tape.
    b. Crew Member 2 - Distance runner with measurement tape (zero end).
    c. Crew Member 3 - Coordinate runner with GPS.
    d. Crew Member 3 - Tracker with a notebook and pen.
2. Intended route of travel determined prior to start.
3. Tracker and branch marker determined location on the distribution trunk line perpendicular to the household location for measurement.
4. Distance runner took zero end of tape to desired point of the household.
5. Tracker recorded distance measurement called out by the branch marker.
6. Coordinate runner marked the GPS WayPoint and called out the reference number.
7. Tracker recorded the reference number of the GPS and sketched approximate location of household on map of distribution trunk lines, as shown in Figure 2.
8. Repeated steps 3-7 until all households were complete.
9. Households not directly on a perpendicular line from the distribution trunk line (i.e. households located behind other households) were marked from the previous household location.

Figure 2. Michigan Tech Students Collecting GPS Data of Households and Faucet Locations.

Soil Classification

Soil classification tests were performed to establish basic soil composition relevant to bearing capacity for structures. In order to efficiently perform the test, a two-person crew utilized a shovel, knife, one-quart Ziploc sample bag, camera, flat-bottomed clear bottle with straight sides, time-keeping device and a black marker.

The following procedure was utilized for this method of soil classification.

1. Task assignments designated:
    a. Crew Member 1 - Digger with shovel.
    b. Crew Member 2 - Collector with sample bag, knife and sharpie.
2. Digger used shovel to dig a hole to a minimum 12” depth, as shown in Figure 3.
3. Digger cleaned bottom and edges of hole of any rocks and debris.
4. Digger used shovel to cut an even thickness vertically downward from top to bottom along at least two sides of the hole.
5. Digger thoroughly mixed soils at the bottom of the hole and deposited into sample bag until full.
6. Collector sealed and marked the sample bag.
7. Collector performed knife test at each sample location
    a. Collector inserted knife slowly at 3” depth (min) into side wall of the sample hole
    b. Collector noted appearance and physical characteristics of soil left on the knife
8. Collector photographed hole for future reference.
9. Steps 2-8 repeated at each location to collect samples.
10. Samples were transported to the testing location.
11. Bottles were filled with 1” to 1-1/2” of soil sample then more than 3⁄4 full with purified bottled water.
12. Bottles were capped and shaken until all of the soil sample was suspended.
13. Bottles were placed on a level surface for settling test, marked and photographed for top of settled material at intervals of 1 minute, 1 hour and 24 hours to determine settled percentages of sand, silt and clay respectively.
14. Bottles were allowed to settle for an additional 4 days to observe additional clearing.

Figure 3. Michigan Tech Students Collecting Soil Samples for Soil Classification.

Water Quality Testing

Water quality testing was performed to determine absence or presence of E Coli and other coliforms as well as suspended solids in water samples. To perform the tests, one person utilized a clean sample bottle, 3M™ Petrifilm™ Aqua Coliform Count Plates, 3M™ Petrifilm™ Spreader, pipettes, camera, time-keeping device and black marker.

The following procedure was utilized for this method of water quality testing.

1. Clean sample bottle was filled and emptied (at a depth of 1' to 2' below surface for pond test) with water from the source to be tested 3 times for conditioning and the fourth fill was retained as sample.
2. The bottle was capped and marked with the location where the sample was taken from.
3. Samples were transported to the testing location.
4. A test film was removed from the package.
5. After shaking the bottle to mix, a pipette was filled from at least 1" below the surface and placed on the collection area of the film and the bottle was capped and left undisturbed during incubation.
6. Per manufacturer's instructions, the top plastic was slowly rolled down over the sample and light pressure applied to the spreader over the center of the sample for even distribution.
7. Samples were marked with the source location and, as no temperature-controlled incubator was available, samples were incubated at 23-26 °C for 32 hours instead of manufacturer's recommended incubation conditions.
8. After 32 hours, films were counted per manufacturer's instructions and counts recorded.
9. Each sample was photographed before being discarded.
10. The sample bottle was observed for any settled solids.

Appendix A-3: Nikon Range Finder & Compass Raw Data (MTU)

Table 2. Nikon Range Finder & Compass Raw Data collected by MTU.

Station No.	Distance (ft)	Change Elev. (ft)	Change Deg.	Bearing
97	71	-3		65 NE
34	29		-3.2	65 NE
35	53	-4		77 NE
36	100	-10		72 NE
37	Stop Sign.			
38	47	3.8		9 NW
39	37	-1.5		2 NW
40	27		0.6	9 NW
41	27		-0.4	5 NW
42	27		-0.6	11 NW
43	42	-3		10 NW
44	14		-2.8	12 NW
45	34	-1.5		3 NW
47	55	-1		3 NW
48	49	-0.5		11 NW
49	81	-7		80 NE
50	50	-3.5		77 NE
51	50	-3		80 NE
52	Stop Sign.			
53	44	1		4 NW
54	33	1.5		1 NW
56	40	1.5		3 NW

Station No.	Distance (ft)	Change Elev. (ft)	Change Deg.	Bearing
57	23		1.9	2 NW
58	2		0.8	0 NW
59	24		2	0 NW
60	70	2.5		10 NW
61	23		-0.6	5 NW
63	School gate.			
65	42	-4.5		86 NE
66	45	-5.5		84 NE
67	100	-9		74 NE
68	HWY			
69	100	1		11 NW
70	100	1.5		16 NW
71	50	0.5		11 NW
72	100	0.5		13 NW
73	100	1		13 NW
74	100	1.5		20 NW
75	100	0.5		16 NW
76	HWY			
77	44	-0.5		78 SW
78	50	1		16 NW
79	50	-0.5		76 NE
80	50	-3		11 NW
81	61	3.5		12 NW
82	58	5.5		12 NW
83	32		2	19 NW
84	100	10		20 NE

Station No.	Distance (ft)	Change Elev. (ft)	Change Deg.	Bearing
85	38	1.5		0 N
87	Last Home.			
88	100	0.5		11 NW
89	31		-0.6	83 SW
90	27		0.6	79 SW
91	47	1.5		74 SW
92	67	-3		25 E
93	49	-2.5		7 SE
94	47	-1.5		6 SE
95	66	-3		12 SE
96	100	-4		10 SE
97.1	100	-6.5		14 SE
98	50	-1.5		16 SE
99	End Rd.			
100	65	4		7 NW
101	52	1		6 NW
102	52	0.5		6 NW
103	End Rd.			
104	30		-5.2	8 SE
105	57	-5		20 SE
106	55	-6.5		6 SE
107	66	-3		16 SE
108	25	-1.6		6 SE
109	44	0.5		8 SE
110	58	1.5		19 SE
111	44	1		19 SE

Station No.	Distance (ft)	Change Elev. (ft)	Change Deg.	Bearing
112	46	1		32 SE
113	100	0.5		20 SE
115	48	-1.5		28 SE
116	49	-2.5		16 SE
117	Road			
118	52	-1.5		29 SE
119	78	2		9 SE
120	61	3		18 SE
121	5	0		
122	22		1.6	89 SW
124	Tank			
122.1	100	-4		59 SE
125	100	-6.5		35 SE
126	End			
127	100	-13		24 SW
128	85	-11.5		32 SW
129	74	-5		19 SW
130	74	-2		20 SW
131	30		-2.4	18 SW
132	56	-8		40 SW
133	36	0.5		34 SW
134	River Bottom.			
135	44	6		34 SW
136	43	-0.5		12 SW
137	63	1		20 SW
138	27		-1.4	30 SW

Station No.	Distance (ft)	Change Elev. (ft)	Change Deg.	Bearing
139	8		-6.2	47 SW
140	12		-11.7	40 SW
141	10		9.9	45 SW
142	14		0	38 SW
143	10		-13	20 SW
145	8		-23.2	32 SW
146	Spring.			
284	100		-0.1	8 NW
285	30		-1.6	8 NW
286	5		-1.5	8 NW
287	100		0.2	2 NW
288	100		0.8	6 NW
289	100		1.4	3 NE
290	20		0.8	6 NE
291	10		13.6	0 N
292	60		0.8	9 NW
293	End Soccer Fd.			
297	100		-1.6	83 SW
298	20		-4.1	83 SW
299	12		-6.4	30 NW
300	40		0.4	23 NW
301	50		-1.6	19 NW
302	30		-1.2	18 NW
303	25		-3.2	14 NW
304	End.			
306	30		1.2	10 NW

Station No.	Distance (ft)	Change Elev. (ft)	Change Deg.	Bearing
307	50		0.8	8 NE
308	55		-1.9	14 NW
309	End.			
312	35		-8.4	76 NE
313	33		-24.8	76 NE
314	21		2	76 NE
315	End.			

Appendix A-4: Trunk and Supply Line GPS Data (MTU)

Trunk line

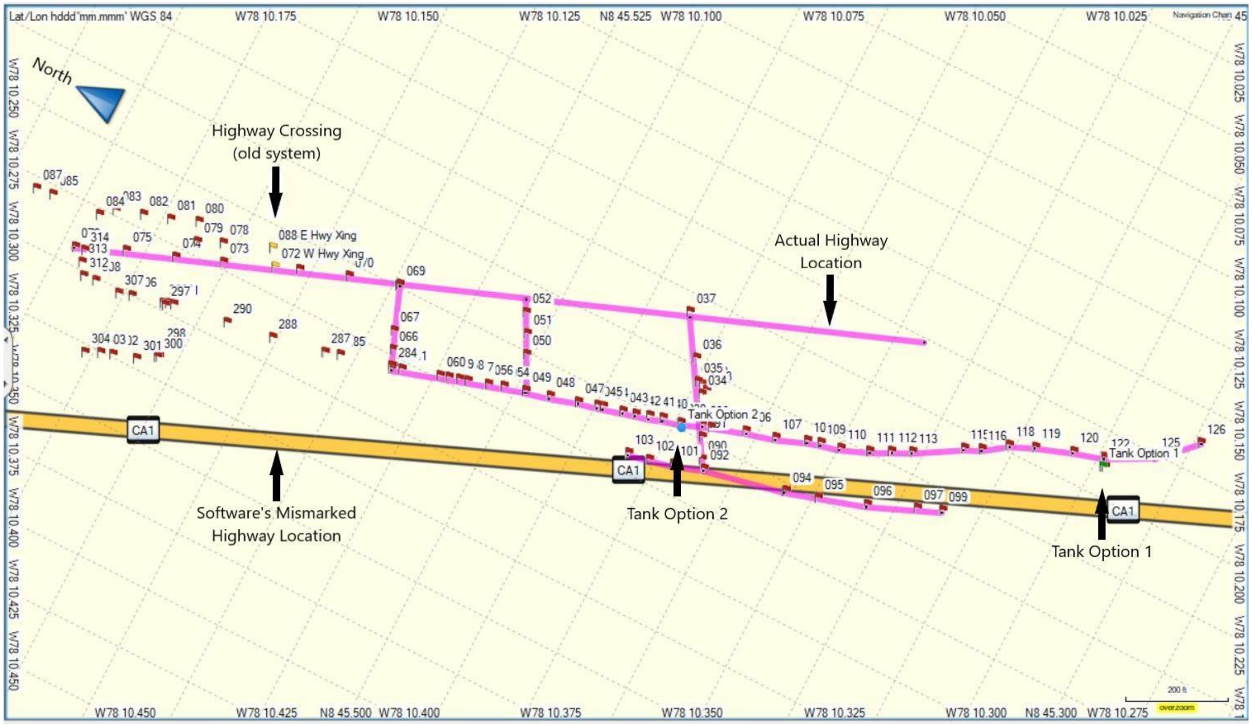


Figure 4. Map of WayPoints for Potential Trunk Line Distribution System (MTU).

Table 3. GPS Data for Trunk Line Distribution System.

GPS ID	NORTH	WEST	ELEV
32	8.757459	78.170501	56
33	8.757426	78.170523	57
34	8.757439	78.170560	56
35	8.757488	78.170499	54
36	8.757552	78.170366	53
37	8.757695	78.170116	56
38	8.757355	78.170732	55
39	8.757468	78.170788	58

GPS ID	NORTH	WEST	ELEV
40	8.757565	78.170813	58
41	8.757632	78.170839	58
42	8.757702	78.170871	60
43	8.757770	78.170892	59
44	8.757875	78.170921	59
45	8.757904	78.170931	58
47	8.758003	78.170969	57
48	8.758151	78.171017	56
49	8.758279	78.171057	57
50	8.758364	78.170844	54
51	8.758411	78.170721	53
52	8.758467	78.170601	54
54	8.758393	78.171096	56
56	8.758472	78.171130	57
57	8.758577	78.171170	59
58	8.758621	78.171185	59
59	8.758675	78.171205	59
60	8.758721	78.171222	59
61	8.758916	78.171296	59
63	8.758965	78.171305	60
65	8.758969	78.171321	60

GPS ID	NORTH	WEST	ELEV
66	8.759005	78.171208	58
67	8.759047	78.171095	57
68	8.759136	78.170819	54
69	8.759132	78.170808	55
70	8.759393	78.170910	52
71	8.759642	78.171016	53
072 W Hwy Xing	8.759763	78.171077	53
73	8.760019	78.171198	54
74	8.760258	78.171308	57
75	8.760507	78.171415	57
76	8.760757	78.171544	56
77	8.759822	78.170973	57
78	8.760068	78.171088	56
79	8.760193	78.171155	59
80	8.760234	78.171034	57
81	8.760373	78.171103	59
82	8.760514	78.171156	59
83	8.760653	78.171211	58
84	8.760721	78.171285	65
85	8.760991	78.171305	61
87	8.761082	78.171318	64

GPS ID	NORTH	WEST	ELEV
088 E Hwy Xing	8.759823	78.170973	57
90	8.757280	78.170939	59
91	8.757334	78.170808	59
92	8.757247	78.170989	59
93	8.756808	78.170882	57
94	8.756806	78.170875	58
95	8.756637	78.170823	58
96	8.756389	78.170718	55
97	8.756143	78.170591	54
99	8.756019	78.170530	54
101	8.757402	78.171051	60
102	8.757528	78.171096	60
103	8.757642	78.171118	61
105	8.757314	78.170726	60
106	8.757140	78.170645	53
107	8.756983	78.170596	51
108	8.756827	78.170521	52
109	8.756758	78.170494	52
110	8.756650	78.170467	51
111	8.756508	78.170400	51
112	8.756404	78.170336	53

GPS ID	NORTH	WEST	ELEV
113	8.756303	78.170277	54
115	8.756067	78.170104	55
116	8.755982 6	78.170057	53
117	8.755865	78.169956	52
118	8.755862	78.169954	52
119	8.755733	78.169890	51
120	8.755542	78.169803	52
121	8.755384	78.169742	52
122	8.755380	78.169746	54
124	8.755357	78.169798	54
125	8.755144	78.169592	53
126	8.754963	78.169378	53
284	8.758973	78.171307	60
285	8.759243	78.171394	66
286	8.759317	78.171423	64
287	8.759322	78.171425	65
288	8.759605	78.171493	61
290	8.759857	78.171539	59
291	8.760153	78.171590	57
292	8.760181	78.171599	58
293	8.760206	78.171614	58

GPS ID	NORTH	WEST	ELEV
297	8.760191	78.171619	57
298	8.760109	78.171877	57
299	8.760093	78.171936	58
300	8.760102	78.171943	58
301	8.760196	78.172015	59
302	8.760318	78.172060	58
303	8.760380	78.172086	58
304	8.760456	78.172131	56
306	8.760371	78.171662	55
307	8.760440	78.171687	57
308	8.760579	78.171680	57
312	8.760648	78.171689	61
313	8.760688	78.171613	59
314	8.760705	78.171536	57

Supply line

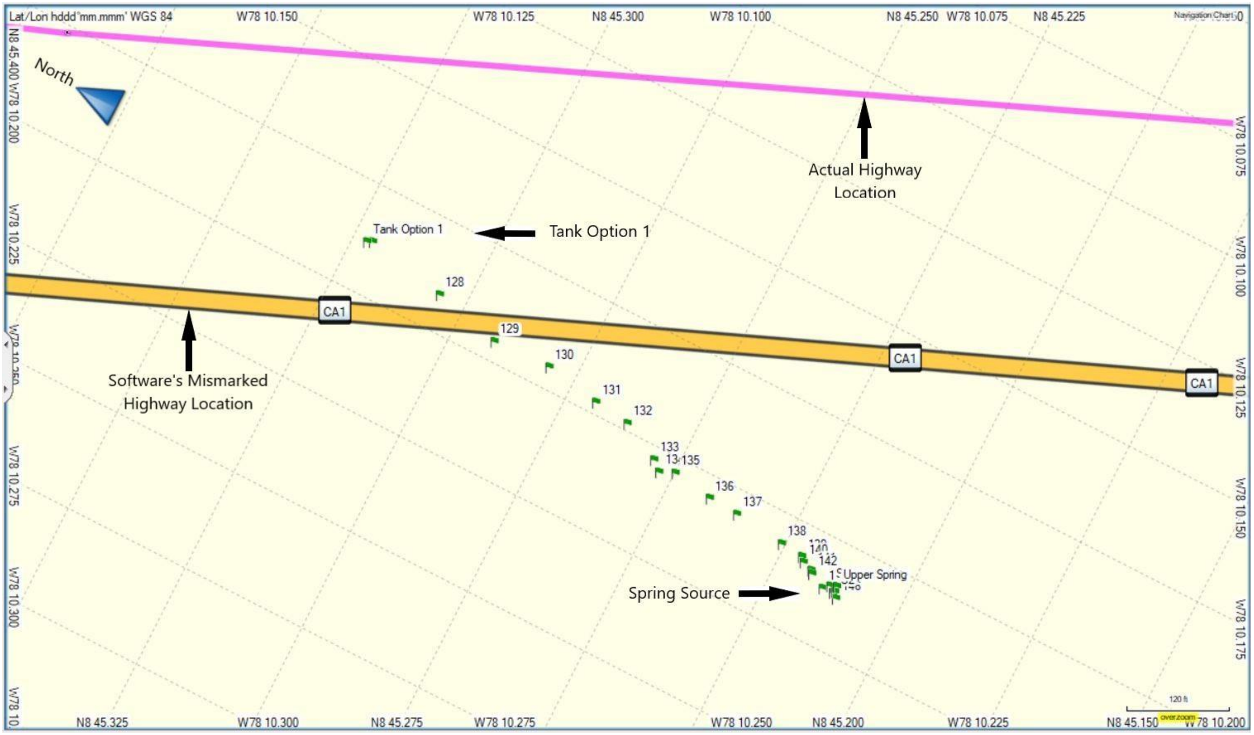


Figure 5. Map of WayPoints for Supply Line to Storage Tank (MTU).

Table 4. GPS Data for Supply Line.

GPS ID	NORTH	WEST	ELEV
127	8.755352	78.169796	56
128	8.755086	78.169861	51
129	8.754864	78.169926	49
130	8.754672	78.169917	48
131	8.754489	78.169956	48
132	8.754369	78.169974	49
133	8.754241	78.170052	55

GPS ID	NORTH	WEST	ELEV
134	8.754210	78.170086	68
135	8.754162	78.170061	62
136	8.754029	78.170087	43
137	8.753928	78.170094	44
138	8.753759	78.170117	44
139	8.753683	78.170125	45
140	8.753671	78.170142	45
141	8.753637	78.170156	47
142	8.753630	78.170167	47
143	8.753579	78.170198	48
145	8.753544	78.170195	47
146	8.753527	78.170210	48
S1	8.753561	78.170177	44
S2	8.753539	78.170188	46
Tank Option	8.755368	78.169806	54
Upper Spring	8.753541	78.170167	44

Appendix A-5: Elevation Profiles for the Trunk Line

Below, the map depicts the point locations A-F in order to simplify the referenced locations for the elevation profiles in the graphs to follow.

Figure 6. Map of Reference Point Locations for the Community.

Each of the elevation profiles in this section begins at the outlet from the water storage tank (28.5 ft) above ground level, then descends directly down to the burial elevation of the pipe (2 ft) below the ground. As a reference, a value of zero indicates the elevation of the pipe at burial elevation directly below the tank, **not** ground level below the tank.

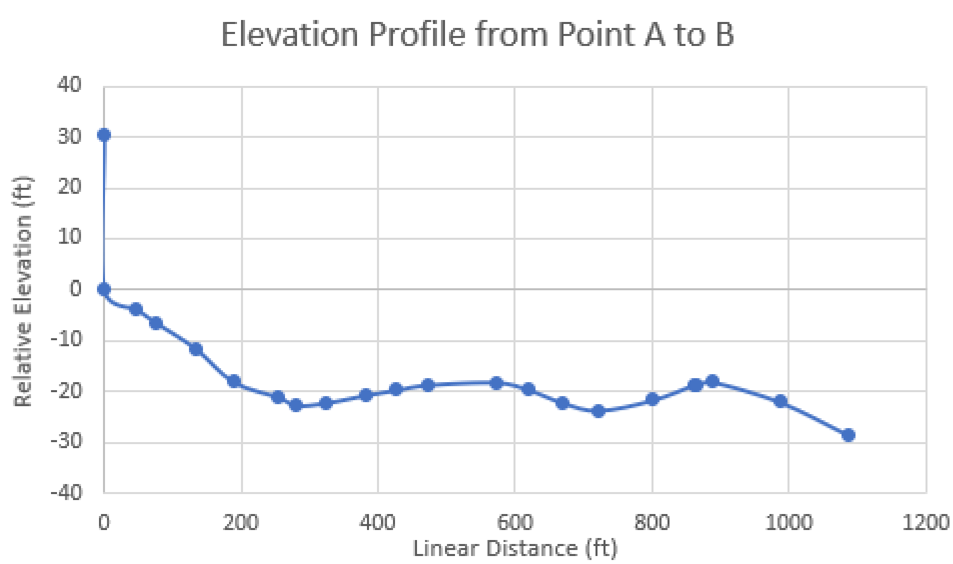


Figure 7. Profile of Topographic Data for Trunk Line from Point A to B.

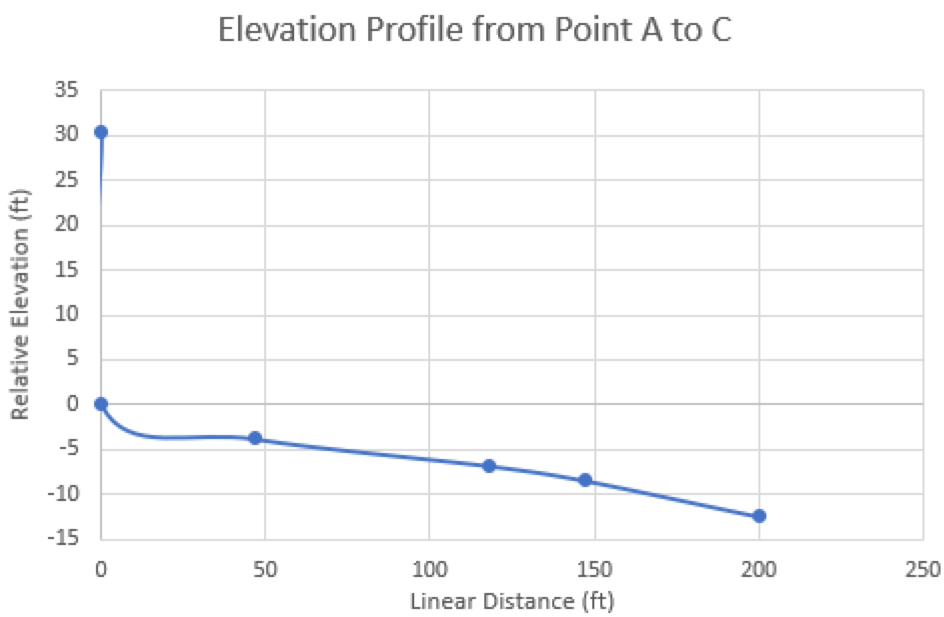


Figure 8. Profile of Topographic Data for Trunk Line from Point A to C.

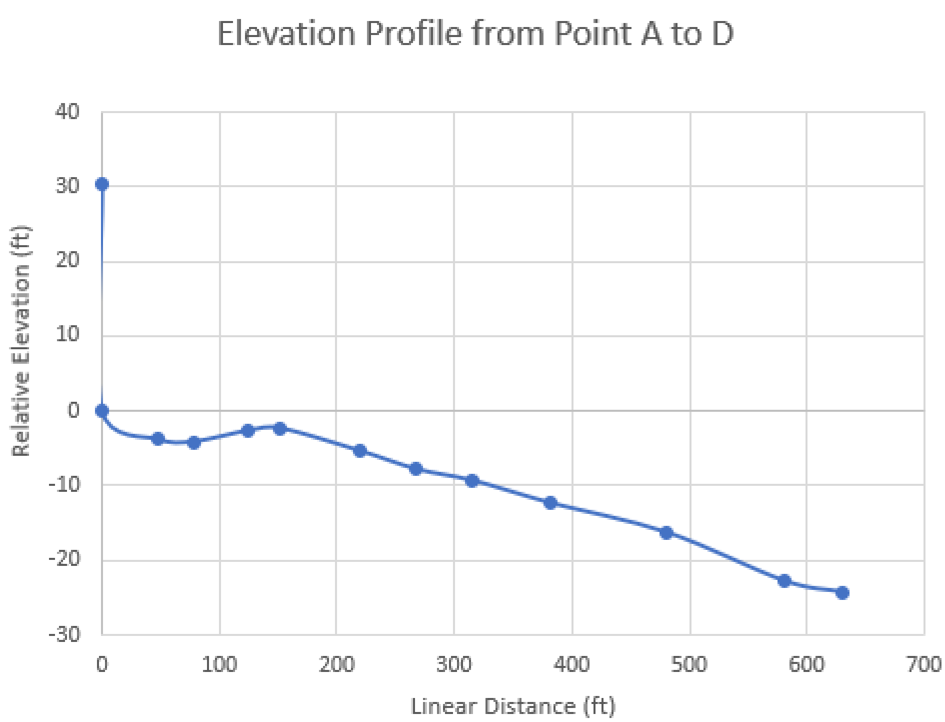


Figure 9. Profile of Topographic Data for Trunk Line from Point A to D.

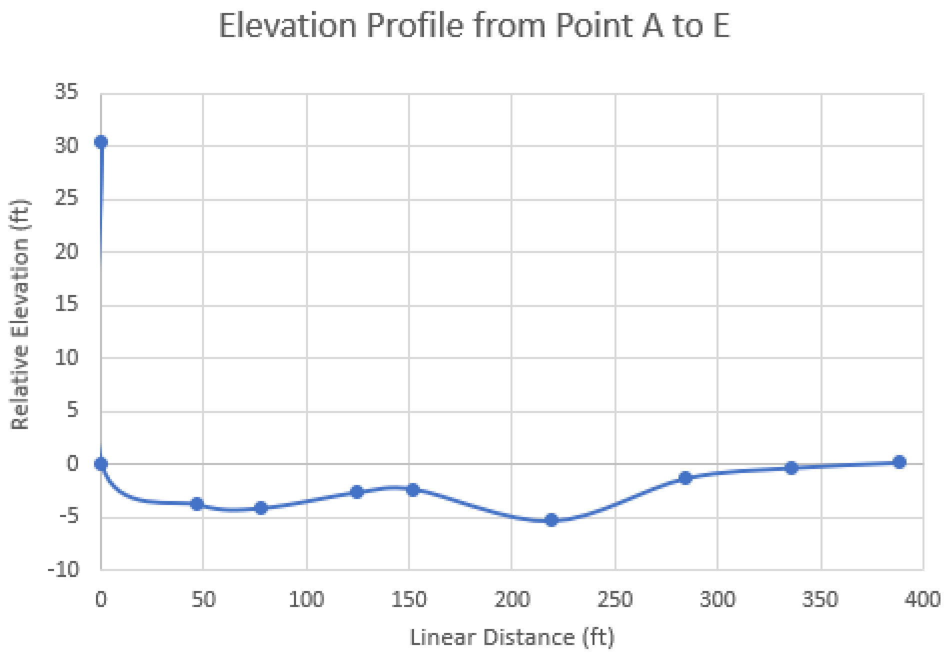


Figure 10. Profile of Topographic Data for Trunk Line from Point A to E.

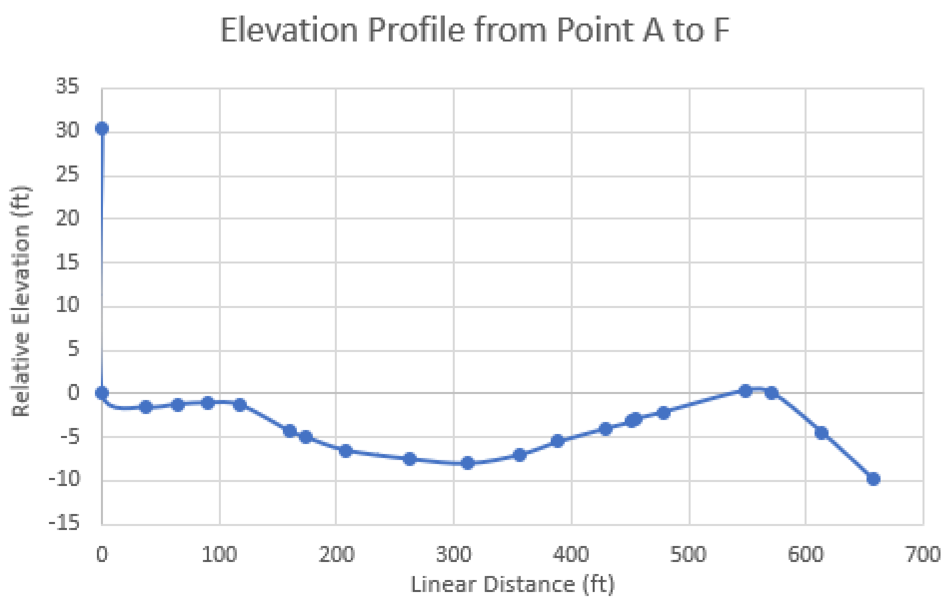
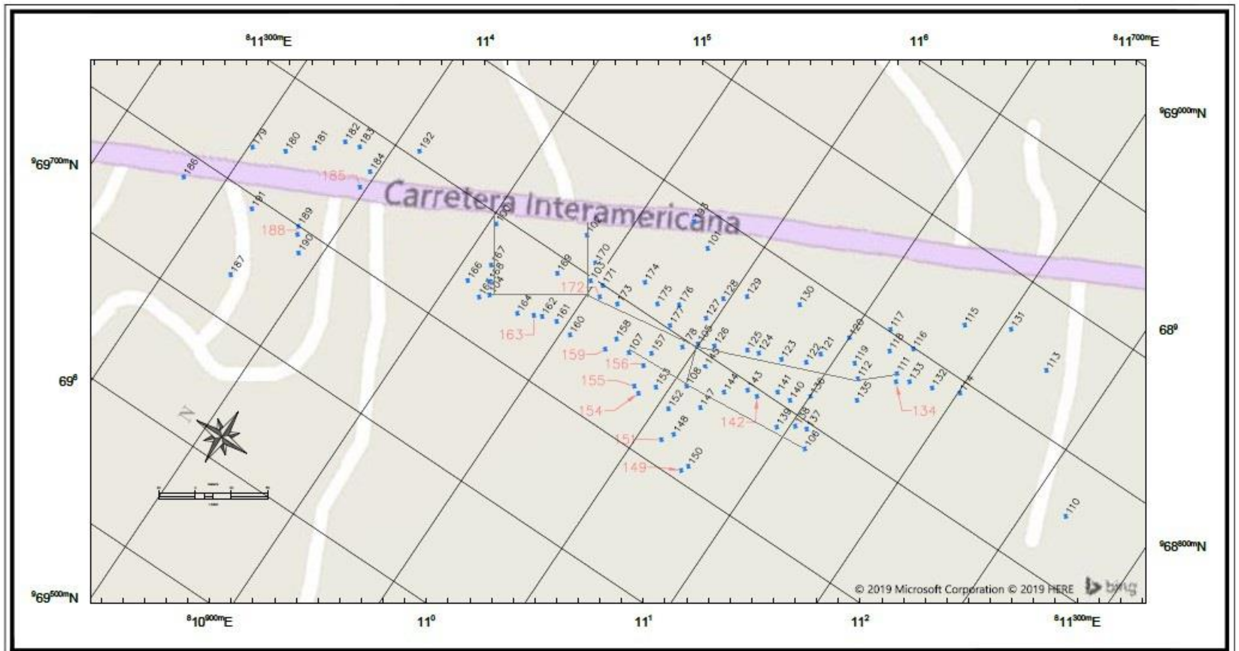


Figure 11. Profile of Topographic Data for Trunk Line from Point A to F.

Appendix A-6: Preliminary Assessment (FPP) GPS Data for Households



EMBERA PURU, DARIEN
29 JUNIO DE 2019
NOMENCLATURA: 104: Escuela - 105: Centro Comunitario - 160: Of. Casa Rural - 173: Iglesia - 178: Casa Comunal

Figure 12. FPP Map of GPS Points.

Table 5. FPP GPS Data for Buildings.
(Items in green are not households)

POINT	NORTH	WEST	ELEV
100	08°45'32.90"	78°10'14.90"	53
101	08°45'27.80"	78°10'12.30"	52
102	08°45'30.70"	78°10'13.80"	55
103	08°45'30.5"	78°10'14.10"	53
104	08°45'32.00"	78°10'16.60"	53
105	08°45'26.60"	78°10'14.60"	53
106	08°45'26.20"	78°10'15.60"	52
107	08°45'22.20"	78°10'14.40"	52
108	08°45'27.30"	78°10'16.20"	52
109	08°45'12.40"	78°10'12.80"	53
110	08°45'15.80"	78°10'13.00"	48
111	08°45'21.70"	78°10'12.30"	49
112	08°45'22.50"	78°10'13.00"	49
113	08°45'18.40"	78°10'10.00"	49
114	08°45'20.00"	78°10'11.80"	50
115	08°45'20.90"	78°10'10.20"	50
116	08°45'21.70"	78°10'11.50"	51
117	08°45'22.50"	78°10'11.40"	51
118	08°45'22.20"	78°10'11.90"	51
119	08°45'22.80"	78°10'12.70"	51
120	08°45'23.30"	78°10'12.20"	51
121	08°45'23.70"	78°10'13.00"	52
122	08°45'23.90"	78°10'13.40"	52
123	08°45'24.50"	78°10'13.70"	52
124	08°45'25.10"	78°10'13.90"	52
125	08°45'25.40"	78°10'14.00"	52
126	08°45'26.20"	78°10'14.40"	52
127	08°45'26.80"	78°10'13.90"	53
128	08°45'26.70"	78°10'13.20"	52
129	08°45'26.20"	78°10'12.80"	53
130	08°45'24.90"	78°10'12.20"	51
131	08°45'19.80"	78°10'09.60"	49
132	08°45'20.70"	78°10'12.10"	50
133	08°45'21.30"	78°10'12.30"	50
134	08°45'21.60"	78°10'12.50"	51
135	08°45'22.20"	78°10'13.50"	51
136	08°45'33.30"	78°10'14.10"	52
137	08°45'22.90"	78°10'14.90"	52
138	08°45'23.20"	78°10'15.00"	52
139	08°45'23.60"	78°10'15.30"	52
140	08°45'23.70"	78°10'14.50"	52
141	08°45'24.10"	78°10'14.50"	53
142	08°45'24.50"	78°10'14.90"	52
143	08°45'24.80"	78°10'14.90"	52
144	08°45'25.30"	78°10'15.30"	53

POINT	NORTH	WEST	ELEV
145	08°45'26.10"	78°10'15.00"	52
146	08°45'25.30"	78°10'15.30"	52
147	08°45'25.60"	78°10'16.00"	52
148	08°45'25.80"	78°10'17.00"	53
149	08°45'25.10"	78°10'17.70"	55
150	08°45'25.00"	78°10'17.50"	55
151	08°45'26.00"	78°10'17.30"	53
152	08°45'26.30"	78°10'16.50"	52
153	08°45'26.90"	78°10'16.20"	52
154	08°45'27.20"	78°10'16.60"	52
155	08°45'27.40"	78°10'16.50"	52
156	08°45'27.70"	78°10'15.90"	52
157	08°45'27.50"	78°10'15.50"	52
158	08°45'28.50"	78°10'15.70"	53
159	08°45'28.60"	78°10'16.10"	53
160	08°45'29.60"	78°10'16.30"	53
161	08°45'30.10"	78°10'16.20"	52
162	08°45'30.50"	78°10'16.30"	52
163	08°45'30.70"	78°10'16.40"	52
164	08°45'31.10"	78°10'16.60"	52
165	08°45'32.20"	78°10'16.80"	52
166	08°45'32.70"	78°10'16.60"	53
167	08°45'32.40"	78°10'15.90"	53
168	08°45'32.20"	78°10'16.30"	53
169	08°45'30.80"	78°10'15.10"	53
170	08°45'30.10"	78°10'14.30"	53
171	08°45'29.60"	78°10'14.70"	53
172	08°45'29.50"	78°10'15.00"	53
173	08°45'29.00"	78°10'14.90"	53
174	08°45'28.70"	78°10'14.00"	54
175	08°45'28.10"	78°10'14.30"	53
176	08°45'27.60"	78°10'14.00"	53
177	08°45'27.50"	78°10'14.60"	53
178	08°45'26.90"	78°10'14.90"	52
179	08°45'39.50"	78°10'16.80"	72
180	08°45'38.70"	78°10'16.40"	57
181	08°45'38.10"	78°10'15.90"	61
182	08°45'37.50"	78°10'15.30"	57
183	08°45'37.10"	78°10'15.20"	56
184	08°45'36.50"	78°10'15.60"	54
185	08° '5'36.50"	78°10'16.10"	53
186	08°45'40.60"	78°10'18.50"	57
187	08°45'38.10"	78°10'20.00"	61
188	08°45'37.20"	78°10'18.10"	65
189	08°45'37.30"	78°10'17.90"	65

POINT	NORTH	WEST	ELEV
190	08°45'36.90"	78°10'18.50"	63
191	08°45'38.60"	78°10'18.20"	62
192	08°45'35.70"	78°10'14.40"	69
193	08°45'28.50"	78°10'11.90"	51
194	08°45'31.80"	78°10'36.00"	68

Appendix A-7: Inconsistencies Found in FPP GPS Data

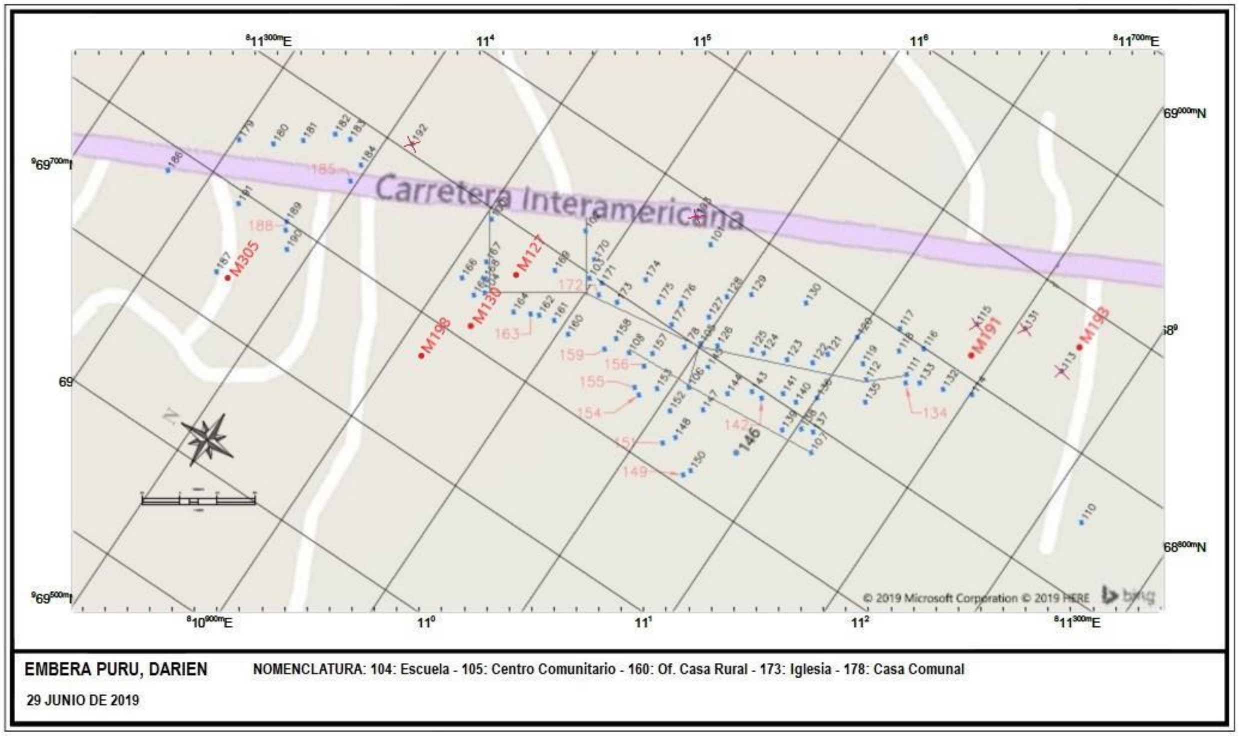


Figure 13. Map of Inconsistent GPS Points.

Table 6. Inconsistencies Found in FPP GPS Data.

FPP GPS Point	Michigan Tech GPS Point	Description of Inconsistencies
113	193	Household moved to new structure further ESE from FPP 113
115	191	Household moved to new structure further WSW from FPP 115
131		Community members identified household as abandoned.
136	159	GPS data puts FPP 136 far from marked and expected location on map. Reassigned coordinates to Michigan Tech 159 coordinates, similar to FPP marked location on map.
146	153	FPP 146 (Iglesia N. 1) was marked at identical coordinates to FPP 144 on incorrect side of road. Relocated FPP 146 to Michigan Tech 153 for old church, now used for community meetings. Michigan Tech planning a tap here.
	130	School location not identified by FPP. Michigan Tech planning for 3 taps in school.

FPP GPS Point	Michigan Tech GPS Point	Description of Inconsistencies
	127	New, four family concrete housing complex under construction after FPP was onsite. Michigan Tech planning 4 taps here.
173	114	(Church N.2 Evangelical) Michigan Tech planning a tap here.
178	105	(Communal House) Michigan Tech planning a tap here.
	305	Michigan Tech identified household near FPP 187 (End South Sector Road) and were told by community members this is part of the community.
192		Michigan Tech did not identify any house in this area. Furthest house south identified in this location matches FPP 184.
193		Michigan Tech did not identify any house in this area, across the highway from main community near the southernmost entrance (FPP 101.)
194		(Handcrafts House) Michigan Tech was not made aware of any structures in this area, GPS locates this point about 0.4 miles west of the rest of the community. No tap planned.
	198	Michigan Tech identified household behind (west of) the school, not marked by FPP.

Table 7. Results of Comparison of GPS Data Affecting System Design.

Additional Households	
3 Households Added	4 added from new construction occurring after FPP evaluation
	1 removed for household identified as abandoned since FPP evaluation
	2 added from households identified by Michigan Tech, not identified by FPP
	2 removed from households identified by FPP where Michigan Tech identified no households at corresponding locations.
Additional Tap Locations for Non-Household Use	
6 Taps Added	4 additional tap locations, 3 taps requested at school
Total Taps Added by Michigan Tech Survey to FPP Survey	
9 Taps Added	3 added from households
	6 added from non-households

Appendix A-8: Water Quality Sampling for Footprint Possibilities by Ambitek

Table 8. Emberá Puru Spring Water Quality Tests for Footprint Possibilities by Ambitek.

Tabla 4. Resultados de los análisis de la muestra MU04 (**Paito Chara – Emberá Purú Ojo # 1**) y LMP del Reglamento Técnico DGNTI-COPANIT 23-395-99.

#	Ensayo	Método	Resultado	Incertidumbre (95 % - k ≈ 2)	Unidades	LDM	LMP
1	Coliformes totales	SM 9222 B	$3.3 \cdot 10^{3}$	$\pm 0.3 \cdot 10^{3}$	UFC/100 mL	1	3
2	Coliformes fecales (termotolerantes)	SM 9222 D	72	± 6.3	UFC/100 mL	1	1
3	Turbiedad	SM 2130 B	110	± 9.7	NTU	0.08	1
4	Potencial de hidrógeno, pH	SM 4500-H+ B	7.8 (22.5 °C)	± 0.1	-	NR	6.5 - 8.5
5	Dureza	SM 2340 C	231	± 15	mg/L	NR	100
6	Alcalinidad total	SM 2320 B	116.2	± 9.9	mg/L	NR	120
7	Sólidos totales disueltos	SM 2540 C	487	± 71	mg/L	25	500

Appendix A-9: Method and Procedure for Analysis of Spring Flow Rate

The flow rate measurement from the spring will need to be collected to verify the viability of the spring source, as well as to aid in determining spring improvement recommendations and design. In order to efficiently perform the flow rate measurement, a one- or two-person crew should follow the procedure below.

If the spring is not flowing, the following procedure should be utilized for this method to measure the flow rate.

1. Determine spring is not flowing, if the spring is flowing note observations and request further direction on how to proceed.
2. Complete Bathymetric Survey, or topographic survey of the pool.
    a. Create a grid pattern of 1 to 1.5 ft increments.
    b. Designate a point of measurement (POM).
        i. Recommendation: Measure to the high bank of the pool.
    c. Measure the vertical distance from the bottom of the spring to the POM.
    d. Repeat c until the survey is complete.
3. Mark the starting point of the water level (WL_o).
4. Pump or bail a significant volume (greater than or equal to 1 ft water level drop) of water from the pond where the spring is currently filling.
5. Mark the water level after pumping (WL_p).
6. Allow the spring to refill the pond, checking the progress at the following times: 10 minutes, 30 minutes, 1 hour, 5 hours, 10 hours and 24 hours.
    a. Mark the water level and take a measurement of the change in water level compared to WL_p.
    b. Measure and estimate the general surface area of the water level at each time.
7. If possible, complete steps 1-5 again.

Appendix B: Calculations and Analyses

Appendix B-1: Preliminary Head Loss Calculations

Appendix B-2: Water Balance Analysis

Appendix B-3: EPANet Model Parameters and Calculations

Appendix B-4: Flow Balance from EPANet Model

Appendix B-5: EPANet Elevation and Pressure Maps

Appendix B-6: Soil Bearing Pressure and Capacity for Water Storage Tank

Appendix B-7: Settlement Calculations for Water Storage Tank

Appendix B-8: Contact Time Calculations

Appendix B-9: Loading and Structural Capacity Calculations for River Crossing

Appendix B-10: Power Calculations

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Appendix B-1: Preliminary Head Loss Calculations

Head Loss Calculations:

Site Details:

Friction Head @ 30 GPM per 100 ft:

2" PVC $f2_{30} := 1.6 \cdot ft$

3" PVC $f3_{30} := 0.2 \cdot ft$

Distance:

Tank Option 1: $d_{T1} := 700 \cdot ft$

Tank Option 2: $d_{T2} := 1600 \cdot ft$

Elevations:

Known Spring Source: $E_S := 0 \cdot ft$

Tank Option 1: $E_{T1} := 41.3 \cdot ft$

Tank Option 2: $E_{T2} := 59.4 \cdot ft$

Height from ground to water inlet at tank structure:

Tank Option 1 $h_{T1} := 31ft$

Tank Option 2 $h_{T2} := 13ft$

TANK 1 ANALYSIS:

Case 1. Friction Head @ 30 GPM in 2" PVC per 100ft.

Calculate Friction Head. $\text{Head1}_{f2} := \left(\frac{d_{T1}}{100 \cdot ft}\right) \cdot f2_{30} = 11.2 \cdot ft$

Calculate the Total Change in Elevation. $\Delta E := E_{T1} - E_S = 41.3 \cdot ft$

Calculate the Pressure Head. $\text{Head1}_p := \Delta E + h_{T1} = 72.3 \cdot ft$

Calculate the Total Head. $\boxed{\text{Head1}_{total2} := \text{Head1}_{f2} + \text{Head1}_p = 83.5 \cdot ft}$

Case 2. Friction Head @ 30 GPM in 3" PVC per 100ft.

Calculate the Friction Head. $\text{Head1}_{f3} := \left(\frac{d_{T1}}{100 \cdot ft}\right) \cdot f3_{30} = 1.4 \cdot ft$

Calculate the Total Head. $\boxed{\text{Head1}_{total3} := \text{Head1}_{f3} + \text{Head1}_p = 73.7 \cdot ft}$

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Kelsey Fournier
September 2019

Total Head necessary for Tank Location 1 is roughly:
2" PVC Pipe = 83.5 ft
3" PVC Pipe = 73.7 ft

TANK 2 ANALYSIS:

Case 1. Friction Head @ 30 GPM in 2" PVC per 100ft.

Calculate Friction Head. $Head2_{f2} := \left(\frac{d_{T2}}{100 \cdot ft}\right) \cdot f2_{30} = 25.6 \cdot ft$

Calculate the Total Change in Elevation. $\Delta E2 := E_{T2} - E_S = 59.4 \cdot ft$

Calculate the Pressure Head. $Head_{p2} := \Delta E2 + h_{T2} = 72.4 \cdot ft$

Calculate the Total Head. $\boxed{Head2_{total2} := Head2_{f2} + Head_{p2} = 98 \cdot ft}$

Case 2. Friction Head @ 30 GPM in 3" PVC per 100ft.

Calculate Friction Head. $Head2_{f3} := \left(\frac{d_{T2}}{100 \cdot ft}\right) \cdot f3_{30} = 3.2 \cdot ft$

Calculate the Total Head. $\boxed{Head2_{total3} := Head2_{f3} + Head_{p2} = 75.6 \cdot ft}$

Total Head necessary for Tank Location 2 is roughly:
2" PVC Pipe = 98 ft
3" PVC Pipe = 75.6 ft

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Ross Hogan
September 2019

Appendix B-2: Water Balance Analysis

All calculations in this section are preliminary and may be revised or alternative calculations used for the final design scheme.

Table 5. Volume of Water Level Analysis based on Daily Demand Pattern Multiplier and Assumptions.

General Statistics	
per person usage per day (gals)	15.85
current population	305
projected 20-year population	670

Daily Water Usage (gallons)	
Current Population	Projected Population
4800	10600

Hour	Multiplier	Usage Based on Current Population 318 people (GPH)	Change in Volume for 3.5gpm pumping (GPH)	Tank Level starting at 1000 gal. reserve (GPH)	Usage Based on Projected 20-year Population 700 people (GPH)	Change in Volume for 8.58gpm pumping (GPH)	Tank Level starting at 1000 gal. reserve (GPH)
22	0	0	222	222	0	474	474
23	0	0	222	444	0	474	948
24	0	0	222	666	0	474	1422
1	0	0	222	888	0	474	1896
2	0	0	222	1110	0	474	2370
3	0	0	222	1332	0	474	2844
4	1.3	260	-38	1294	574	-100	2744
5	2.5	500	-278	1016	1104	-630	2114
6	2.5	500	-278	738	1104	-630	1484
7	1.3	260	-38	700	574	-100	1383
8	1	200	22	722	442	32	1416
9	1	200	22	744	442	32	1448
10	1	200	22	766	442	32	1480
11	2	400	-178	588	883	-409	1071
12	2.3	460	-238	350	1016	-542	529
13	2	400	-178	172	883	-409	120
14	1	200	22	194	442	32	152
15	0.7	140	82	276	309	165	317
16	1	200	22	298	442	32	349
17	1	200	22	320	442	32	382
18	1.4	280	-58	262	618	-144	237
19	1	200	22	284	442	32	270
20	0.5	100	122	406	221	253	523
21	0.5	100	122	528	221	253	776

Minimum pumping rates (Table 5) were developed from a 24-hour cycle based on the daily demand pattern below and two constraints; return tank level to a minimum of 1000 gallons at the end of the cycle, do not drop below 100 gallons at any time. These estimates are assuming pump runs constantly to establish an absolute minimum required flow rate, not an expected design flow rate. Minimum flow rates were established by iterative calculation to find the minimum rate that met both constraints.
Tank capacities were based on the peak 4-hour water usage calculated for both the current population of 318 and the projected population of 700 plus a 1,000 gallon buffer.

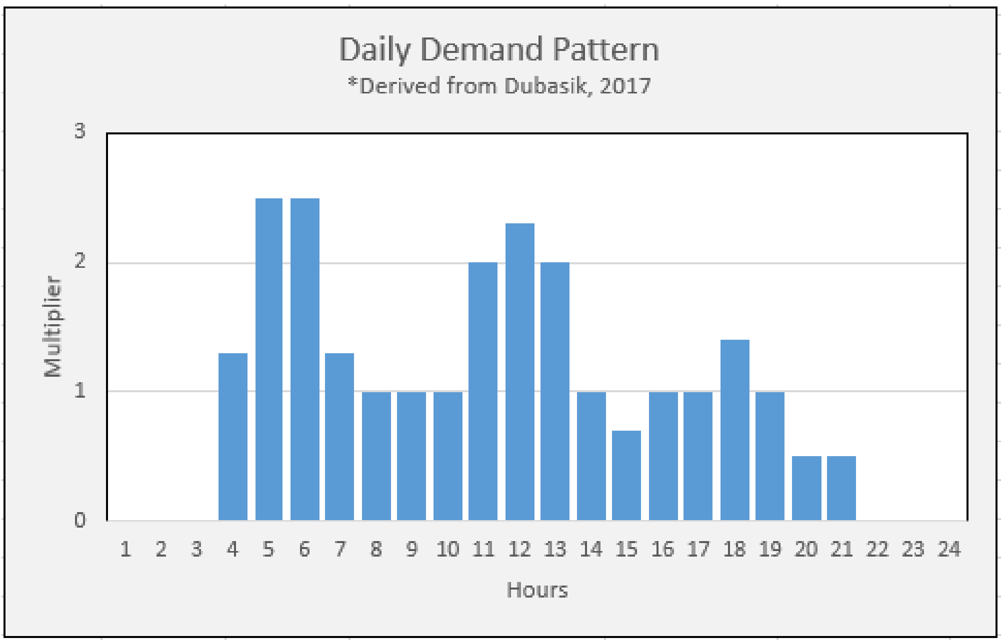
Table 6. Design Requirements for Pump (GPM) and Tank Capacity (gal) based on Current and Projected Population.

Minimum Constant Pumping to Maintain Tank Level for Current Population	
GPM	GPH
3.7	222

Tank Capacity Estimation (gallons)	
highest 4 hour usage from hours 4-7	1520
Additional 1000 gallon reserve	1000
Necessary Tank Capacity	2500

Minimum Constant Pumping to Maintain Tank Level for 20-year Population	
GPM	GPH
7.9	474

Tank Capacity Estimation (gallons)	
highest 4 hour usage from hours 4-7	3357
Additional 1000 gallon reserve	1000
Necessary Tank Capacity	4400



Section 5.2.1 - Figure 5. Estimated Daily Demand Pattern.

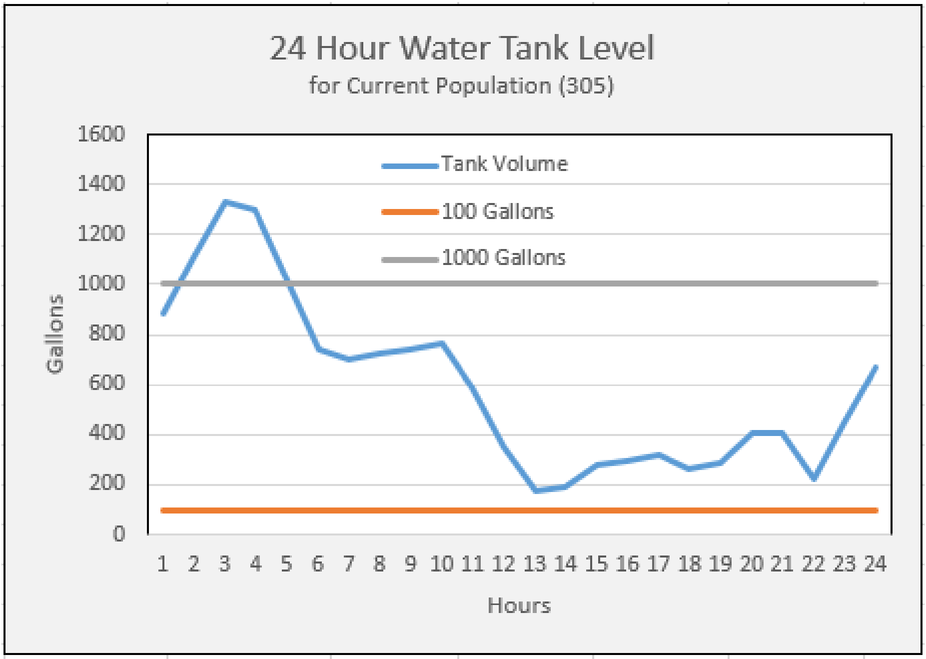


Figure 11. Water Tank Level based on Current Population over a 24-hour period. (For identified minimum flow rate.)

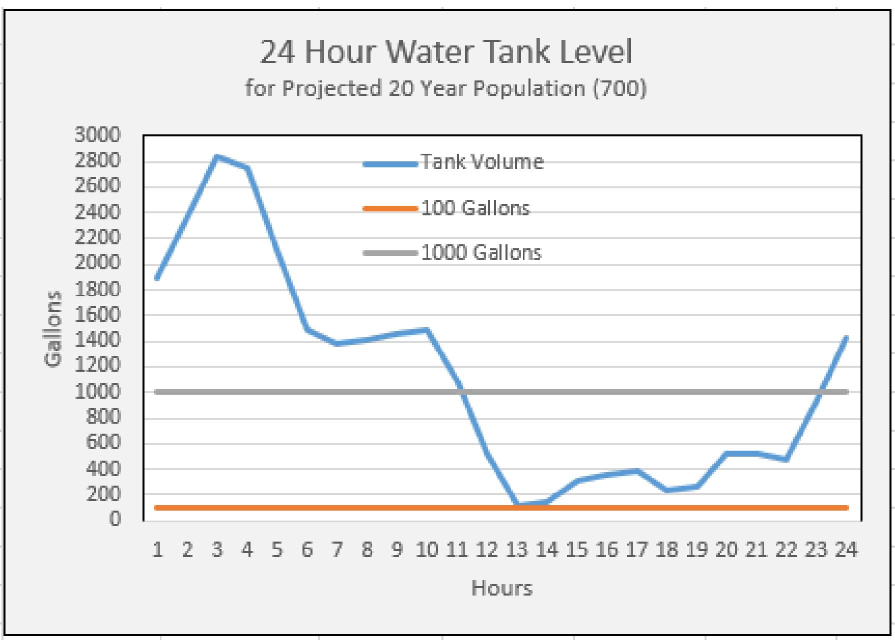


Figure 12. Water Tank Level based on Projected Population over a 24-hour period. (For identified minimum flow rate.)

Tank sizing shown in Table 6 was based on the tank capacity calculated for the projected population of 700 in Table 5. These dimensions are for the minimum desired usable capacity of the tank and may be enlarged as necessary.

Water Storage Tank Capacity Calculations:

The calculations outlined below should be utilized as reference to understand the formulas and utilized in the Water Balance Analysis tables previously presented in this appendix.

Assumptions:

Original Population:	$P_o := 305$ people
Growth Factor:	$G_f := 0.04$
Time:	$t := 20$ years
Proposed Consumption per Person:	$C := 60L = 15.85 \cdot gal$
Factor of Safety:	$FoS := 1000 \cdot gal$

Peak Usage (Current Population).		Peak Usage (Projected Population).	
Hour 4:	$U_{o4} := 260 \cdot gal$	Hour 4:	$U_{p4} := 574 \cdot gal$
Hour 5:	$U_{o5} := 500 \cdot gal$	Hour 5:	$U_{p5} := 1104 \cdot gal$
Hour 6:	$U_{o6} := 500 \cdot gal$	Hour 6:	$U_{p6} := 1104 \cdot gal$
Hour 7:	$U_{o7} := 260 \cdot gal$	Hour 7:	$U_{p7} := 574 \cdot gal$

Demand of Water:

Calculate the 24-hour Demand of Water for the Current Population.

$$\boxed{D_{o24} := C \cdot P_o = 4.834 \times 10^3 \cdot gal}$$

Calculate the Projected Population. The number is rounded up to the nearest multiple of 10.

$$P_f := P_o \cdot \left[\left(1 + G_f\right)^t \right] = 668.293$$

$$P_{fr} := 700 \text{ people}$$

Calculate the 24-hour Demand of Water for the Projected Population.

$$\boxed{D_{p24} := C \cdot P_{fr} = 1.11 \times 10^4 \cdot gal}$$

Storage Tank must be designed to cyclically provide 11,100 gallons of water per day in order to maintain demand for the projected population.

Calculate the 4-hour Peak Demand of Water for the Current Population.

$$D_{o4} := U_{o4} + U_{o5} + U_{o6} + U_{o7} = 1.52 \times 10^{3} \cdot gal$$

Calculate the 4-hour Peak Demand of Water for the Projected Population.

$$D_{p4} := U_{p4} + U_{p5} + U_{p6} + U_{p7} = 3.356 \times 10^{3} \cdot gal$$

Design Capacities:

Apply Factor of Safety to Determine the Required Design Capacities.

$$\boxed{Dcap_{o} := D_{o4} + FoS = 2.52 \times 10^{3} \cdot gal}$$

$$\boxed{Dcap_{p} := D_{p4} + FoS = 4.356 \times 10^{3} \cdot gal}$$

The required design capacity to meet the estimated 4-hour peak demand based on the original and projected populations are 2,520 and 4,400 gallons, respectfully.

Analysis of these calculations concludes that the storage tank should be designed to a minimum capacity of 4,400 gallons; therefore the preferred tank design of 6,000 gallons is sufficient.

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September 2019

Preliminary Minimum Pump Requirement Calculations:

$$D_{o24} = 4.834 \times 10^{3} \cdot gal$$

$$D_{p24} = 1.11 \times 10^{4} \cdot gal$$

Calculate the GPM required to maintain Tank Level for the Current Population. Assuming the pump runs constantly.

$$GPM_o := \frac{D_{o24}}{24 \cdot 60 \cdot min} = 3.357 \cdot \frac{gal}{min}$$

Calculate the GPM required to maintain Tank Level for the Projected Population. Assuming the pump runs constantly.

$$GPM_p := \frac{D_{p24}}{24 \cdot 60 \cdot min} = 7.705 \cdot \frac{gal}{min}$$

**The minimum required GPM for the pump, assuming constant pumping, is 7.705 GPM.
In order to maintain a level of 100 gallons in the tank at all times, the value was interpolated using the excel document.**

Therefore, the minimum required GPM for the pump, assuming constant pumping, is:

Des.cap = 8.58 GPM

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Appendix B-3: EPANet Model Parameters and Calculations

EPANet – Parameters and Setup

The general layout of the EPANet model was determined to be the following. The spring source (modeled as a node) feeds the wet well (modeled as a tank), which is pumped to the water storage tank (modeled as a tank) through the supply pipeline (modeled as pipe). From the water storage tank, the water is pumped to the taps through the distribution pipeline (modeled as pipe). The system was analyzed with the Darcy-Weisbach Equation.

The general assumptions and guidelines of the system are outlined in this document. All elevations and pipe lengths are based on field data collection from the site assessment phase (Appendix A-3 through A-6). All structures holding water (i.e. Collection Structure and Storage Tank) are modeled to allow for overflow. All pipe fittings, water gauges, and connections are assumed to have negligible friction loss in order to simplify the model. All of the households in this model have an assumed elevation of 7-ft above the known ground elevation to account for elevated households.

Spring Source:

- *Flow Rate:* 7.9 gallons per minute (constant)
- *Elevation:* 0 ft

Pump at Spring Source:

- Centrifugal Pump
- *Pump Curve:* 1
    - Appendix G-2
- *Target Flow Output Range:* 30-40 GPM

Pipeline:

- Material: SDR 26 PVC Pipeline
    - Supply Line: 3-inch diameter
    - Trunk Lines: 2-inch diameter
    - Branch Lines: 1-inch diameter
- Roughness Coefficient: 0.005

Water Storage Tank:

- *Elevation:* 62.3 ft
- *Capacity:* 5,400 gallons
    - Diameter: 15.1 ft
- *Control Measures:*
    - Initial Level: 4 ft
    - Minimal Level: 2 ft
    - Maximum Level: 4 ft

Pump at Water Storage Tank:

- Booster Pump
- *Pump Curve:* Booster Pump
- *Target Pressure Output Range:* 20-30 psi
- *Pressure Reducing Valve:* to control and maintain the pressure from the pump
    - For modeling purposes only
    - *Type:* PRV
    - *Setting:* 25 psi

Demand Pattern:

- 24-hour demand cycle for water usage
- Average multiplier = 1
- Peak Times
    - 5 A.M - 7 A.M
    - 11 A.M - 1 P.M

Table 7. EPANet Model 24-Hour Standard Run Calculations for Current and Future Population.

Current population in central community 305						
Projected future population in central community 668						
Population	**Minimum Demand (gpm)**	**Maximum Demand (gpm)**	**Lowest Distribution Pressure (psi)**	**Highest Distribution Pressure (psi)**	**Average Pump Deliver When Running (gpm)**	**Highest Pressure (psi)**
305	1.5	7.4	5.5	24.4	41.5	56.8
670	3.3	16.3	5.1	23.9	39.6	45.3

The EPANet model was tested for a 24-hour run for both current population and projected 20-year population at 4% growth per year. Results were checked for mimum and maximum demand and pressures, respectively, within the distribution lines of the community based on the estimated 24-hour demand cycle. The demands were well within system capacity. As expected, the highest pressures in the system were observed at the pump.

Appendix B-4: Flow Balance from EPANet Model

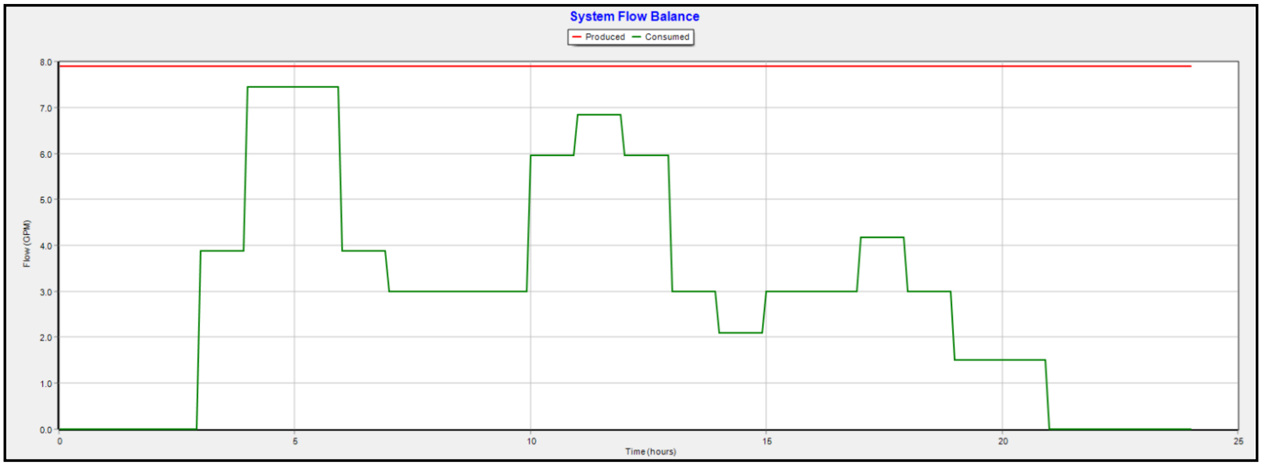

Figure 13. EPANet System Flow Balance for Current Population.

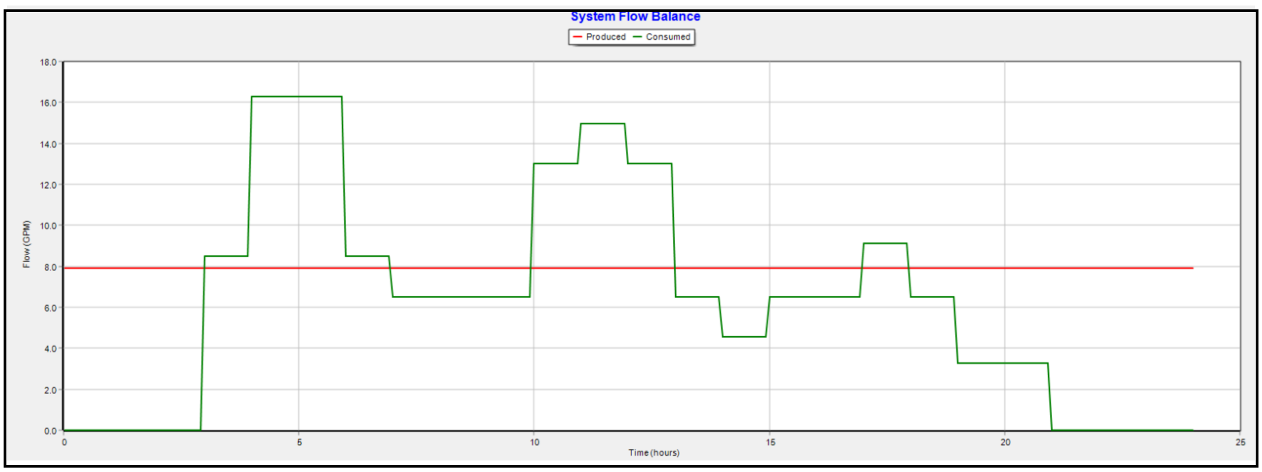

Figure 14. EPANet System Flow Balance for Projected Population.

Appendix B-5: EPANet Elevation and Pressure Maps

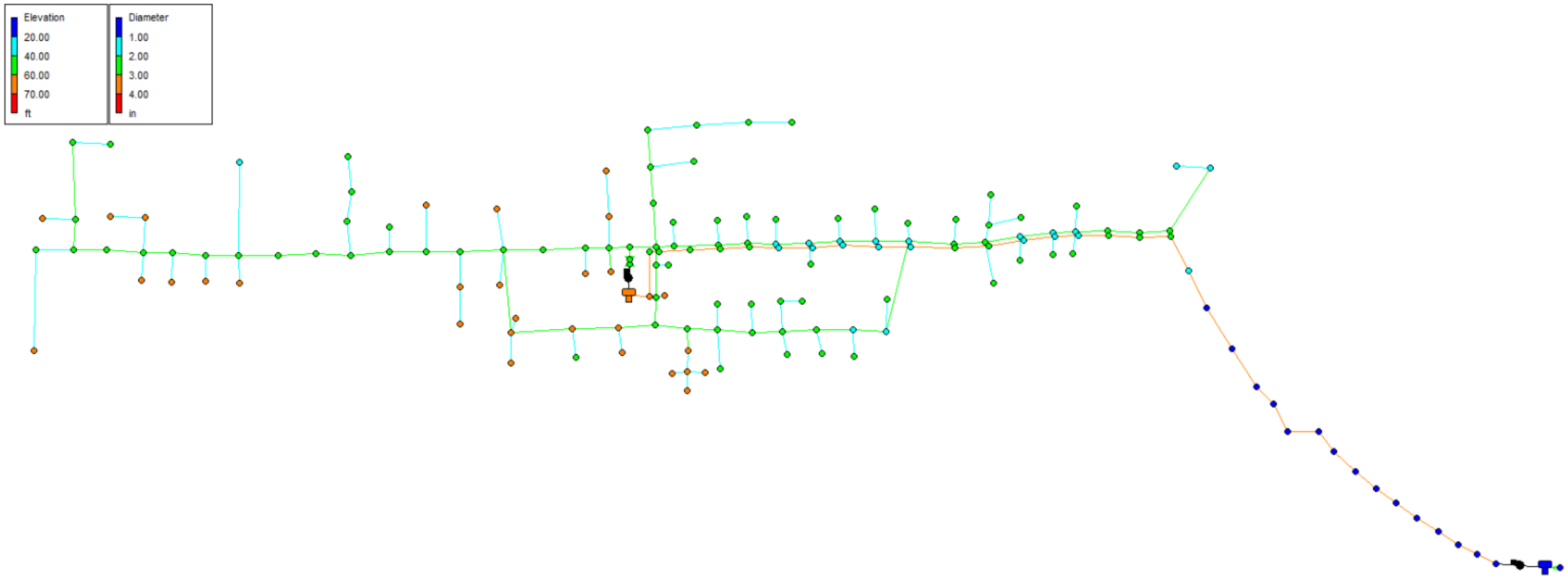

Figure #. EPANet Node Elevations and Pipe Diameters.

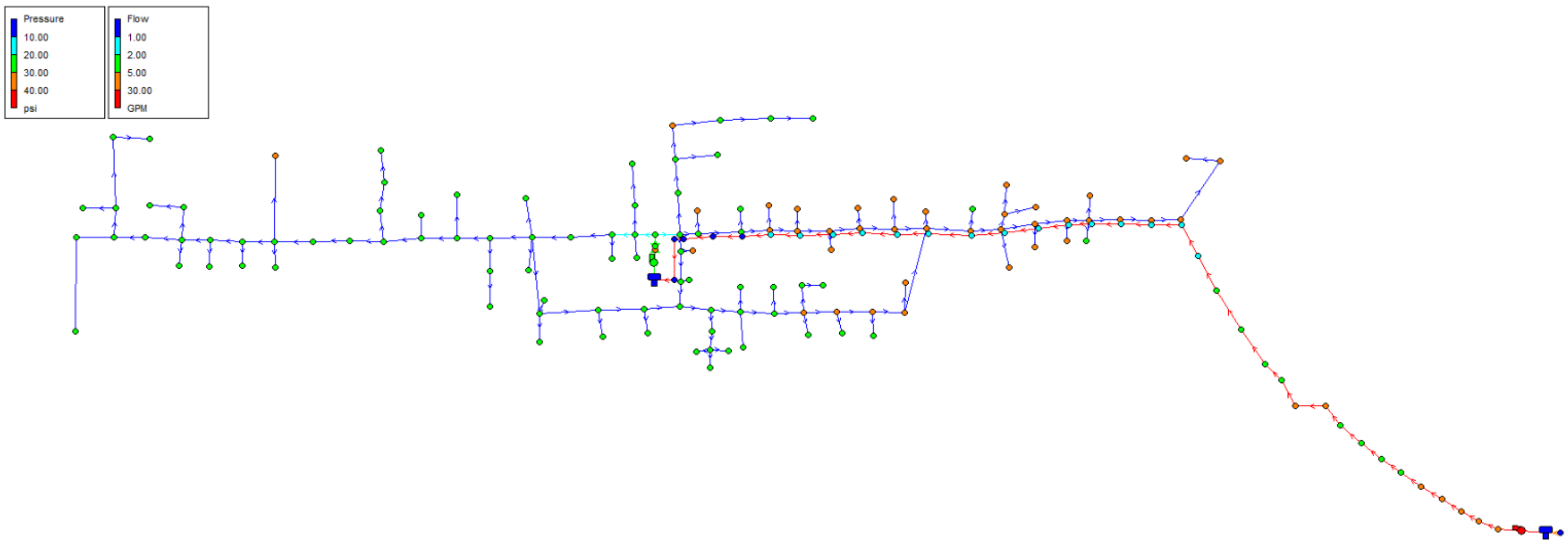

Figure #. EPANet Node Pressures and Pipe Flows for Current Population.

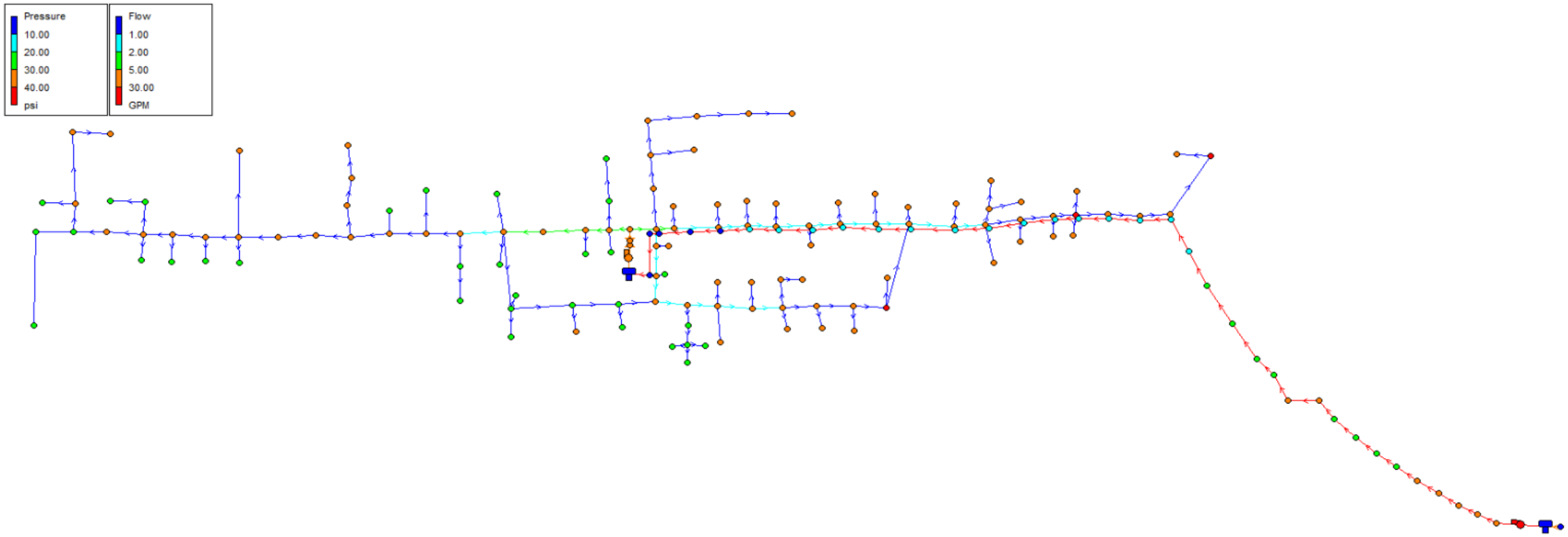

Figure #. EPANet Node Pressures and Pipe Flows for Projected Population.

Appendix B-6: Soil Bearing Pressure and Capacity Calculations for Water Storage Tank

Soil Bearing Pressure and Capacity for Water Storage Tank.

Dimensions of Square Monolithic Footing:

$L_{top} := 22ft$ $\qquad L_{bottom} := 32ft$

$w_{top} := 10ft$ $\qquad w_{bottom} := 20ft$

$t := 8in = 0.667 \cdot ft$

Calculate the Volume and Weight of the Structure:

$\gamma_c := 150 \cdot \left(\frac{lb}{ft^3}\right)$ $\qquad \gamma_f := 3000 \frac{lb}{yd^3}$

Conservative Assumption
https://harmonysandgravel.com/material-weights

$V_{top} := L_{top} \cdot w_{top} \cdot \left(\frac{8}{12} ft\right) = 146.667 \cdot ft^3$ $\qquad V_{bottom} := V_{top}$

$V_{sidelong} := \left(L_{top}\right) \cdot (86in) \cdot 8in = 105.111 \cdot ft^3$ $\qquad V_{fill} := 42yd^3$

$V_{sideshort} := \left(L_{bottom} \cdot 86in \cdot 8in\right) = 152.889 \cdot ft^3$ $\qquad W_{sideshort} := \gamma_c \cdot V_{sideshort} = 2.293 \times 10^4 \cdot lb$

$W_{top} := \gamma_c \cdot V_{top} = 2.2 \times 10^4 \cdot lb$ $\qquad W_{water} := 6000gal \cdot 8.34 \frac{lb}{gal} = 5.004 \times 10^4 \cdot lb$

$W_{bottom} := \gamma_c \cdot V_{bottom} = 2.2 \times 10^4 \cdot lb$ $\qquad W_{fill} := V_{fill} \cdot \gamma_f = 1.26 \times 10^5 \cdot lb$

$W_{sidelong} := \gamma_c \cdot V_{sidelong} = 1.577 \times 10^4 \cdot lb$

$$P := W_{top} + W_{bottom} + 2 \cdot \left(W_{sidelong} + W_{sideshort}\right) + W_{water} + W_{fill} = 2.974 \times 10^5 \cdot lb$$

Total Force Applied, reference the Column Demand Calculations for estimate.

Calculate the Bearing Pressure of the Structure:

$A_{top} := L_{top} \cdot w_{top} = 220 \cdot ft^2$

$A_{bottom} := L_{bottom} \cdot w_{bottom} = 640 \cdot ft^2$ $\qquad$ Area of the Footing

$u_D := 0$ $\qquad$ Water Table does not affect the foundation, therefore U.d = 0

$q := \frac{P}{A_{bottom}} - u_D = 464.75 \cdot \frac{lb}{ft^2}$ $\qquad$ Bearing Pressure based on simplified distribution of concentric vertical loads

The Bearing Pressure of the Column is 465 lb/ft^2.

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Kelsey Fournier
November 17, 2019

Calculate Undrained Shear Strength:

Compacted Gravel:

$$q_1 := 4.5 \cdot \frac{kg}{cm^2}$$

$$q_{u1} := q_1 = 9.217 \times 10^3 \cdot \frac{lb}{ft^2}$$

Reference:
https://civilread.com/safe-bearing-capacity-soil/

$$S_u := \frac{q_{u1}}{2} = 4.608 \times 10^3 \cdot \frac{lb}{ft^2}$$ Undrained Shear Strength

The Undrained Shear Strength is 4,600 lb/ft^2.

Calculate the Maximum Bearing Capacity: *Terzaghi's Bearing Capacity Formulas*

$$c := \frac{S_u}{2} = 2.304 \times 10^3 \cdot \frac{lb}{ft^2}$$ Effective cohesion of soil beneath footing

$$\Phi := 0$$ Effective friction angle of soil beneath footing

$$N_c := 5.7$$

$$N_q := 1.0$$

$$N_\gamma := 0$$

Terzaghi's Bearing Capacity Factors from Table 7.1 of "Foundation Design Principles and Practices (3rd ed.)

$$D := t = 0.667 \cdot ft$$ Depth of footing below ground surface

$$\sigma_{zD} := \gamma_f \cdot D = 74.074 \cdot \frac{lb}{ft^2}$$ Vertical effective stress at depth D below the ground surface

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Shape Factors:

$$s_c := \left(1 + 0.2 \cdot \frac{w_{top}}{L_{top}}\right) = 1.091$$

Terzaghi shape factors:
http://environment.uwe.ac.uk/geocal/foundations/founbear.htm

$$s_q := \left(1 + 0.2 \cdot \frac{w_{top}}{L_{top}}\right) = 1.091$$

$$s_\gamma := \left(1 - 0.4 \cdot \frac{w_{top}}{L_{top}}\right) = 0.818$$

$$q_n := c \cdot N_c \cdot s_c + \sigma_{zD} \cdot N_q \cdot s_q + 0.5 \gamma_f \cdot w_{bottom} \cdot N_\gamma \cdot s_\gamma = 1.441 \times 10^4 \cdot \frac{lb}{ft^2}$$

Consider the inclination factor:

$$d := \frac{.5}{10} = 0.05$$

Utilize Figure 7.19 from "Foundation Design Principles and Practices (3rd ed.)

$$n := \frac{\left(\frac{8}{12}\right)}{10} = 0.067$$

Utilize Figure 7.19 from "Foundation Design Principles and Practices (3rd ed.)

$$r := .3$$

Reducation Factor from Figure 7.21

$$q_{n2} := q_n \cdot r = 4.323 \times 10^3 \cdot \frac{lb}{ft^2}$$

The Maximum Bearing Capacity is 4,323 lb/ft^2.

Percent Usage of Maximum Soil Bearing Capacity by the Structure:

$$Usage := \frac{q}{q_{n2}} \cdot 100 = 10.752$$

Percent

The soil bearing capacity is sufficient to withstand shear failure with only utilizing approxiamately 10.8% of the soil bearing capacity for the preferred structure, if the fill is adequately compacted during construction.

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Appendix B-7: Settlement Calculations for Water Storage Tank

Settlement of Structure on Compacted Gravel with Some Sand.

Dimensions of monolithic footing:

$B_1 := 10ft$

$B_2 := 22ft$

$q := \frac{465}{1000}\left(\frac{kip}{ft^2}\right)$ Bearing Pressure, reference Appendix B-6 for detailed calculation.

Determine Young's Modulus and Poisson's Ratio for Gravel Soil:

$E := 170MPa = 24.656 \cdot ksi$

$v := .25$

Reference:
https://www.jsg.utexas.edu/tyzhu/files/Some-Useful-Numbers.pdf

Calculate Settlement:

$$\delta_2 := q \cdot \frac{\pi}{4} \cdot B_1 \cdot \frac{\left(1 - v^2\right)}{E} = 0.012 \cdot in$$

$$\delta_2 := q \cdot \frac{\pi}{4} \cdot B_2 \cdot \frac{\left(1 - v^2\right)}{E} = 0.025 \cdot in$$

The maximum expected settlement of the preferred design of the water storage tank on the compacted, gravel soil fill would be 0.03 inches.

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Appendix B-8: Contact Time Calculations

Chlorine Contact Time for Small Water Systems

$CT := FreeCl_{concentration} \cdot T_{contact}$

Storage Tank Volume used for Contact Time

Inside Tank Dimensions - 1340 gallons/ft of depth

$A_{tank} := 8.667\,ft \cdot 20.667\,ft = 16.641\,m^2$

$h_{min} := 0.333\,ft$

$V_{min} := 450\,gal$

$OperatingH_{min} := 2\,ft$

$OperatingV_{min} := 2680 \cdot gal$

$OperatingH_{max} := 4\,ft$

$OperatingV_{max} := 5360\,gal$

$Inflow := 40\,gpm$

$Outflow_{max} := 30\,gpm$ *Maximum design pump rate*

$E_{raffling} := 0.10$

Assuming 50 feet of 2-inch pipe for each distribution 50-ft x 1.64 gallons per 10-feet.

Pipe Segment used for Contact Time

$$S_{pipe} := 50ft \cdot \frac{1.64gal}{10ft} = 31.04\,L$$

$$Sgal_{pipe} := S_{pipe} \cdot 0.264172 = 8.2\,L$$

$$V_{eff} := 2680gal \cdot 0.3 = 3.043 \times 10^{3}\,L$$

$$Veff_{gal} := V_{eff} \cdot 0.264172 = 804\,L$$

$$Time := \frac{Veff_{gal}}{30gpm} + \frac{(8.2gal)}{30gpm} = 441.189\,s$$

$$\frac{Time}{60s} = 7.353 \quad \text{minutes}$$

Chlorination Time is 7.35 minutes

$$CT := 2\left(\frac{mg}{L}\right) \cdot Time = 0.882\,\frac{kg \cdot s}{m^{3}}$$

Or 14.7 mg-min/L

concentration of free chlorine * contact time

$$Required_{FreeClResidual} := \frac{CT}{Time} = 2 \times 10^{-3}\,\frac{kg}{m^{3}}$$

Appendix B-9: Loading and Structural Capacity Calculations for River Crossing

River Crossing Design Calculations:

Design Characteristics:

Supply Pipeline = 3" SDR 26 PVC Pipe
Electrical Conduit = 3/4" SCH40 Pipe
Signal Wire = 14 AWG Wire
Unit Wt. Water = 62.4 lb/ft^3
Span = 45 ft
Height Water Level to Top Bank = 10 ft

Design Parameters:

Design capacity must meet or exceed required demand after applied factor of safety.
Water Level to pipecrossing clearance >= 3 ft

Sizing of Steel Cable.

Calculate Distributed Weight:

$$W_{pipe} := 0.966 \frac{lb}{ft}$$

$$W_{conduit} := 0.24 \frac{lb}{ft}$$

$$W_{wire} := 0.0496 \frac{lb}{ft}$$

$$W_{water} := \left(\frac{3.068}{2} in\right)^2 \cdot \pi \cdot 62.4 \frac{lb}{ft^3} = 3.203 \frac{lb}{ft}$$

$$W_{tot} := W_{pipe} + W_{conduit} + W_{wire} + W_{water} = 4.459 \frac{lb}{ft}$$

Calculate Total Tension Force in Cable:

$$Sag := 1.5ft$$

$$L_{span} := 45ft$$

$$T_{horiz} := \frac{\left[W_{tot} \cdot \left(L_{span}{}^2\right)\right]}{8 \cdot Sag} = 752.471\ lb$$

$$T_{angle} := atan\left[\frac{(4 \cdot Sag)}{L_{span}}\right] \cdot \frac{180}{\pi} = 7.595 \text{degrees}$$

$$cosTangle := .9912270780245920$$

$$T_u := \frac{T_{horiz}}{cosTangle} = 759.13\ lb$$

Try 3/16 inch cable - Calculate Safe Load:

$$SF_{cable} := 3$$

$$T_n := \frac{(3700lb)}{SF_{cable}} = 1.233 \times 10^3 \, lb$$ (Appendix A-2)

$$T_n \geq T_u = 1$$

$$Sag_{rec} := W_{tot} \cdot \left[\frac{\left(L_{span}^2\right)}{8 \cdot T_n} \right] = 0.915 \, ft$$

Calculate Water Level Clearance based on Recommended Sag:

$$H_{tower} := 3ft$$

$$d_{pipe} := 3in$$

$$d_{conduit} := \frac{3}{4} in$$

$$H_{pipes} := d_{pipe} + d_{conduit} = 0.312 \, ft$$

$$H_{sag} := Sag_{rec} = 0.915 \, ft$$

$$H_{wb} := 10ft$$

$$H_{clear} := \left(H_{wb} + H_{tower}\right) - \left(H_{pipes} + H_{sag}\right) = 11.772 \, ft$$

$$H_{clear} \geq 3ft = 1$$

3/16 inch cable is sufficient for required demand and clearance requirement.

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December 11, 2019

Design of Steel Pipe Column.

Try 2" pipe (40-STD-40s) at 3 ft height.

$T_{angle} = 7.595$ degrees

$sinTangle := .1321169889879766$

Calculate Capacity and Demand for Axial Force and Bending Moment:

$F_u := 2 \cdot sinTangle \cdot T_u = 200.588\ lb$

$F_{bending} := .25 \cdot F_u = 50.147\ lb$

$M_u := 3ft \cdot F_{bending} = 150.441\ lb \cdot ft$

Appendix A-3:

$F_n := 38683 lb$

$M_n := 795.5 lb \cdot ft$

Employ Interaction Equations:

$$Interaction := \frac{F_u}{0.55 \cdot F_n} + \frac{M_u}{0.60 \cdot M_n} = 0.325$$

$$\frac{F_u}{0.55 \cdot F_n} + \frac{M_u}{0.60 \cdot M_n} \leq 1 = 1$$

Column is sufficient for required demand.

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Size and Burial Depth of Rectangular Concrete Anchors.

Try 2 ft x 2 ft x 2.5 ft dimensions.

$$L_c := 2ft$$

$$W_c := 2ft$$

$$H_c := 2.5ft$$

$$V_c := L_c \cdot W_c \cdot H_c = 10\,ft^3$$

Demand: $T_u = 759.13\,lb$

Capacity of Footing:

$$\gamma_c := 150\,\frac{lb}{ft^3}$$

$$\varphi := 26 \cdot \frac{\pi}{180} = 0.454\,rad$$

$$SF_{conc} := \frac{\left[\left(V_c \cdot \gamma_c \cdot \tan(\varphi)\right) + F_u\right]}{T_u} = 1.228$$

$$SF_{conc} \geq 1 = 1$$

Concrete Anchors are sufficient for required demands.

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Design Stringer Spacing.

$$Sag_{ratio} := \frac{Sag}{L_{span}} = 0.033$$

$$Drop_{ratio} := 0$$ (Conservative Assumption)

$$C_{32} := 3.682123$$ (Appendix A-4)

$$C_{34} := 3.682123$$ (Appendix A-4)

$$C := \frac{(C_{32} + C_{34})}{2} = 3.682$$

$$spacing := 9ft$$

$$y := C \cdot \cosh\left(\frac{9}{C} \cdot \frac{\pi}{180}\right) - C = 3.351 \times 10^{-3}$$

$$y := .003351\,ft = 0.04\,in$$

$$Sag_{apex} := \frac{\left(y \cdot \frac{L_{span}}{2}\right)}{spacing} = 0.101\,in$$

$$Sag_{apex} \leq Sag_{rec} = 1$$

Stringer spacing is sufficient for required demand.

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Appendix B-10: Power Calculations

Power Draw

Power Draw for Goulds 3642, 115V, 1.5hp, 3500 rpm pump at an average of 33.5 gpm output.

Horsepower to Watts using estimated low-end efficiency of η = 0.55.

$$P(Watts) = \frac{P(hp)}{\eta} \times 746\left(\frac{Watts}{hp}\right)$$

$$P(Watts) = \frac{1.5(hp)}{0.55} \times 746\left(\frac{Watts}{hp}\right) = 2035(Watts)$$

Power to average amperage during run.

$$I(amps) = \frac{P(Watts)}{V(Volts)} \times \frac{1}{\eta}$$

$$I(amps) = \frac{2035(Watts)}{115(Volts)} = 17.7(amps)$$

Water and Power Usage

Water usage for current population, W_c = 4850 gallons per day. Water usage for projected population W_p = 10600 gallons per day. Run time estimated by EPANet projected delivery of D_p = 33.5gpm for pump specified above.

Run time for current population, T_c(hours/day).

$$T_c\left(\frac{hours}{day}\right) = \frac{W_c\left(\frac{gallons}{minute}\right)}{D_p\left(\frac{gallons}{minute}\right) \times 60\left(\frac{min}{hr}\right)}$$

$$T_c = \frac{4850}{33.5 \times 60} = 2.4\left(\frac{hours}{day}\right)$$

Run time for projected population, T_p(hours/day).

$$T_p\left(\frac{hours}{day}\right) = \frac{W_p\left(\frac{gallons}{minute}\right)}{D_p\left(\frac{gallons}{minute}\right) \times 60\left(\frac{min}{hr}\right)}$$

$$T_p = \frac{10600}{33.5 \times 60} = 5.3\left(\frac{hours}{day}\right)$$

Average power use in kWh per day and monthly cost for current population, PD_c.

$$PD_c\left(\frac{kWh}{day}\right) = P(Watts) \times T_c \times \frac{1(kWh)}{1000(Wh)}$$

$$PD_c = 2035 \times 2.4 \times \frac{1}{1000} = 4.9\left(\frac{kWh}{day}\right)$$

From https://www.globalpetrolprices.com/electricity_prices/ the average cost of power in Panama is $0.17/kWh.

Average cost per month for the current population is C_c.

$$C_c\left(\frac{\$}{month}\right) = PD_c * \frac{\$0.17}{kWh} * \frac{30\ days}{1\ month}$$

$$C_c\left(\frac{\$}{month}\right) = 4.9 * 0.17 * 30 \cong \frac{\$25}{month}$$

Average power use in kWh per day and monthly cost for projected population, PD_p.

$$PD_p = 2035 \times 5.3 \times \frac{1}{1000} = 10.8\left(\frac{kWh}{day}\right)$$

Average cost per month for the current population is C_p.

$$C_p\left(\frac{\$}{month}\right) = 10.8 * 0.17 * 30 \cong \frac{\$55}{month}$$

Solar Power Calculations

Panama has yearly average of 6 hours of full sun.

from http://www.panama.climatemps.com/sunlight.php

The number of panels, N_p, required is calculated based on highest power usage, PD_p, 6 hours of full sun per day, 300Watts supplied per panel at an average 77% transfer efficiency to batteries, η_p=0.77.

$$N_p(panels) = \frac{PD_p\left(\frac{kWh}{day}\right)}{300\left(\frac{Watts}{panel}\right) \times \left(\frac{1kW}{1000Watts}\right) \times 6\left(\frac{hours}{day}\right) \times \eta_p}$$

$$N_p = \frac{10.8}{300 \times \left(\frac{1}{1000}\right) \times 6\left(\frac{hours}{day}\right) \times .77} = 8\, panels$$

The Wholesale Solar calculator with inputs of 2035 Watts, 5.3 hours of usage, and average 6 hours of full sun collected at 77% efficiency at https://www.wholesalesolar.com/solar-information/start-here/offgrid-calculator gives the following suggested system size.

System Calculation Results	
Killowatt Hours per Month:	421 kWh
Killowatt Hours per Day:	14.03 kWh
Peak Sun Hours:	6 hours/day
Mounting Option:	Roof Mounted
Shade Coverage:	No shade/full sun
Solar Panel Watts:	300 W
Number of Panels:	10
System Size:	2.81 kW

The Wholesale Solar site recommends the following system to meet demand.

From https://www.wholesalesolar.com/1891447/wholesale-solar/complete-systems/the-cabin-2.84-kw-9-panel-mission-solar-off-grid-solar-system

The Cabin 2.84 kW 9-Panel Mission Solar Off-Grid Solar System

WHOLESALE SOLAR

Wholesale Solar:
- 100% employee-owned and US-based
- Specialized in solar design & sales for DIY and wholesale customers
- In business since 2002
- See our 4.9-Star Google Reviews
- Check out our featured Customer Installs of the Month

System	Part No.	Array Size (STC)	Daily Production Estimate	Panels	Price
The Cabin 2.84 kW 9-Panel Mission Solar Off-Grid Solar System	1891447	2.83 kW	Summer 12.76 kWh Winter 6.38 kWh	9 Mission Solar 315 Mono PERC Solar Panels	Installer / Contractor Pricing $8,644.00 FREE SHIPPING Qty 1 Add to Cart

Battery Calculation

The operational time for the current population, OT_c, without sun is calculated based on usage requirements, PD_c = 4.9 (kWh/day) and the capacity, B_c, of the Crown 430 AH battery below.

$$OT_c(days) = \frac{B_c(kWh)}{PD_c\left(\frac{kWh}{day}\right)}$$

$$OT_c = \frac{10.2}{4.9} = 2\ days$$

The operational time for the projected population, OT_p, without sun is calculated based on usage requirements, PD_p = 10.8 (kWh/day) and the capacity, B_c, of the Crown 430 AH battery below.

$$OT_p(days) = \frac{B_c(kWh)}{PD_c\left(\frac{kWh}{day}\right)}$$

$$OT_p = \frac{10.2}{10.8} = 0.9\ days$$

Item	Mfg	Type	Volts (VDC)	Capacity (Ah)	Total Capacity (kWh)	Product Number	Price
Fullriver AGM 415 Ah 24 VDC 9,960 Wh (4) Battery Bank	Fullriver	Battery Bank	24VDC	415Ah	9.96 kWh	1898596	$2,395.96 Qty 1 Add to Cart
Crown 430 AH 24VDC 10,320 Wh (4) Battery Bank	Crown	Battery Bank	24VDC	430Ah	10.32 kWh	1898710	$1,471.00 Qty 1 Add to Cart
Discover Battery 220AH 24VDC w/ Xanbus 5,600 Wh (2) Lithium Battery Bank	Discover Battery	Battery Bank	25.6VDC	220Ah	5.63 kWh	1898856	$7,166.00 Qty 1 Add to Cart

KRV recommends two battery packs be purchased to extend usage without sun to 4 days for the current population and maintain more than a 2 day supply for the growing population.

Appendix C: Design Alternatives

Appendix C-1: Design Alternative Descriptions Alternative Descriptions

Appendix C-2: Power Supply Burial Cable Wire Sizing

Appendix C-3:Material Quantity Take-offs for Water Storage Tank Options

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Appendix C-1: Design Alternative Descriptions

Design Alternatives

The design alternatives for the water supply and distribution system for Emberá Puru, Panama are outlined in this document with a conceptual description and any additional information collected.

Water Collection Structure

Shallow Well Design – Based on the bathymetric survey and flowrate data, a well design could be optimal to collect the water. The well should not exceed a 20-ft depth to avoid reaching the salt layer left behind when the ocean receded.

Pump

Three-phase Pump – Single Three-phase Pump Dependent on the available electrical source, a single three-phase pump could be implemented rather than a single-phase pump. Three-phase pumps are capable of higher delivery heights than single-phase pumps and are, generally, more power efficient. Consequently, a three-phase pump may require additional installation costs, but also may see long term cost reductions as a result of reduced power use and longer life span. Compared to Alternative 1, there would not be an increase in necessary maintenance or inspection.

Staged Pumping System – A staged pumping system using the available single phase at 110V or 220V is a potential option. In this model, there would be one pump station installed at the known spring source and a second pump station installed uphill at about half the elevation difference between the center of the community and the known spring source. Advantageously, this option would reduce the total pressure head required for each pump and would not be affected by the potential electrical source constraint. A drawback of this alternative is the increased maintenance and inspection required, as well as the increase in construction and operating costs.

Single-Phase Submersible Pump – This option was determined to not be feasible based on the uncertainty of the spring source and the depth requirement for the pump to remain submersed. Additionally, the submersible pumps were not meeting the head requirements within an efficient range.

Power Supply

Overhead Power – At a distance of 1600 ft, the overhead power could be run from the central community or from the highway out to the spring source. This system would require 20-foot-tall poles with an estimated 80 foot spacing to support a 10-kV line to a 115V step down transformer.

Burial Cable Power - This option was determined to not be feasible based on the cost substantially exceeding the budget. Calculations and pricing research is included in Appendix C-2.

Water Storage Tank

Below each of the options have been described. Bill of materials take-off quantities for each of the options is located in Appendix C-3.

Option 1 - Two 8-m3 (8,000 liter) plastic water storage tanks connected in series on a 10’x22’x8” slab. This provides 4,200 gallons of water storage. The slab is supported on 5’ earth build of structural fill with 1.5ft/1ft slope extending from an 11’x23’ base.
Recommended pump for application: TW1000-30W-30 Flag Frame Booster Pump providing 30-psi at 30-GPM with a variable frequency motor.

Option 2 - Two 8-m3 (8,000 liter) plastic water storage tanks elevated by a steel structure with spread concrete footings. This provides 4,200 gallons of water storage. To sustain a gravity-fed distribution system, the bottom of the tank would require a minimum height of 20-ft to overcome head loss. No pump required.

Option 3 - A 20-m3 (20,000 liters) cylindrical reinforced concrete water storage tank elevated by reinforced concrete columns with spread concrete footings. This provides 5,000 gallons of water storage. To sustain a pressurized distribution system, the bottom of the tank would require a minimum height of 5-ft with a booster pump to overcome head loss. Associated drawings with additional design comments are attached as reference.
Recommended pump for application: TW1000-30W-30 Flag Frame Booster Pump providing 30psi at 30gpm with a variable frequency motor.

Option 4 - A single rectangular reinforced concrete water tank with an 8” slab on grade and outside dimensions of 10’ width, 22’ length and 6’-4” height (from the bottom of the slab.) This provides 6,000 gallons of water storage. A 5-ft internal height was determined for maintenance considerations. Recommended pump for application: Self-Priming Booster Pump providing 30psi at 30gpm with a variable frequency motor.

Option 5 - Two 8-m3 (8,000 liter) plastic water storage tanks connected in series on a 10’x22’x8” slab on grade. This provides 4,200 gallons of water storage.
Recommended pump for application: Self-Priming Booster Pump providing 30psi at 30gpm with a variable frequency motor.

Appendix C-2: Power Supply Burial Cable Wire Sizing

Wire Sizing for Underground Electrical

Wire size from voltage drop for power supply located near storage tank run to pump at the spring.

$$R_{wire}(\frac{\Omega}{kft}) = \frac{V_{drop}(Volts) \times 1000(\frac{ft}{kft})}{\sqrt{3} \times I_{wire}(Amps) \times L(ft)}$$

For a 115 Volt system the maximum recommended voltage drop is 1.5 Volts. Full load amp draw for the pump motor (115 Volt, 3500 RPM) is 20 amps. Distance, L, from the storage tank to the spring is 1600 feet.

$$R_{wire}(\frac{\Omega}{kft}) = \frac{1.5(Volts) \times 1000\left(\frac{ft}{kft}\right)}{\sqrt{3} \times 20(Amps) \times 1600(ft)} = 0.0433(\frac{\Omega}{kft})$$

Minimum cross-sectional area of copper to keep resistance at or below R_{wire}.

$$A_n(in^2) = \frac{0.3048 \times 10^9 \times \rho(\Omega m)}{R_n(\frac{\Omega}{kft}) \times 25.4^2}$$

Use resistivity of copper, $\rho = 1.72 \times 10^{-8}$ (Ωm), and $R_{wire} = R_n$.

$$A_n(in^2) = \frac{0.3048 \times 10^9 \times (1.72 \times 10^{-8}(\Omega m)}{0.0433(\frac{\Omega}{kft}) \times 25.4^2} = 0.188(in^2)$$

Necessary diameter, d_n(in).

$$d_n(in) = \sqrt{\frac{A_n(in^2) \times 4}{\pi}}$$

For $A_n = 0.188$ (in^2)

$$d_n(in) = \sqrt{\frac{0.188(in^2) \times 4}{\pi}} = 0.489(in)$$

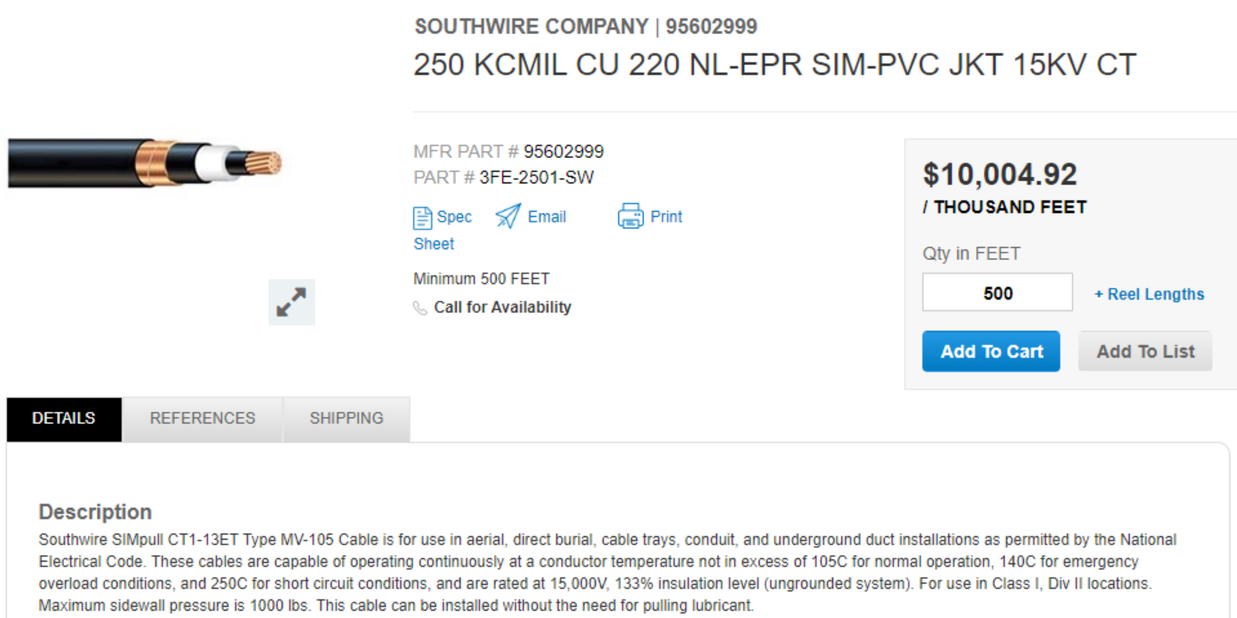
Equations from https://www.rapidtables.com/calc/wire/voltage-drop-calculator.html

From https://www.ihiconnectors.com/AWG%20wire%20sizes.htm

Logical AWG Number	AWG (and "Aught" */0 Equiv)		MCM kcmil	Circular MILS	Cross Section mm2	Metric UL486 Equivalent mm2	mm2 Lower	mm2 Higher	Cross Section in2	Diameter SOLID inch	Diameter SOLID mm	Diameter Typ. Stranded inch Approx. Max.
4	4		42	41735	21.149	21.2	16	25	0.0328	0.204	5.19	0.232
3	3		53	52627	26.6684	26.7	25	35	0.0413	0.229	5.83	0.26
2	2		66	66361	33.6281	33.6	25	35	0.0521	0.258	6.54	0.292
1	1		84	83680	42.4042	42.4	35	50	0.0657	0.289	7.35	0.332
0	1	/ 0	106	105518	53.4705	53.5	50	70	0.0829	0.325	8.25	0.373
-1	2	/ 0	133	133056	67.4249	67.4	50	70	0.1045	0.365	9.27	0.419
-2	3	/ 0	168	167780	85.021	85	70	95	0.1318	0.41	10.4	0.471
-3	4	/ 0	212	211566	107.209	107	95	120	0.1662	0.46	11.68	0.528
-3.7	4.7	/ 0	250	250000	126.677	120	120	150	0.1963	0.5	12.7	0.575
-4.5	5.5	/ 0	300	300000	152.012	152	150	150	0.2356	0.548	13.91	0.63
-5.2	6.2	/ 0	350	350000	177.348	177	150	185	0.2749	0.592	15.03	0.681
-5.7	6.7	/ 0	400	400000	202.683	203	185	240	0.3142	0.632	16.06	0.728
-6.3	7.3	/ 0	450	450000	228.018		185	240	0.3534	0.671	17.04	
-6.7	7.7	/ 0	500	500000	253.354	253	240	300	0.3927	0.707	17.96	0.814
-7.5	8.5	/ 0	600	600000	304.025	304	300	400	0.4712	0.775	19.67	0.893
-8.2	9.2	/ 0	700	700000	354.695	355	300	400	0.5498	0.837	21.25	0.964
-8.5	9.5	/ 0	750	750000	380.031	380	300	400	0.589	0.866	22	0.999

Conclusion: From these calculations for general sizing and the wire size chart below, the necessary wire size would be a minimum 250 kcmil. A direct online calculator at http://www.wiresizecalculator.net/ recommended 750 kcmil for direct burial cable. Rated cable costs are shown below. Even the minimal 250 kcmil wire would be prohibitively expensive.

From https://www.anixter.com/en_us/products/95602999/SOUTHWIRE-COMPANY/Control-and-Power-Cable/p/3FE-2501-SW



From https://www.anixter.com/en_us/products/95605299/SOUTHWIRE-COMPANY/Control-and-Power-Cable/p/3FE-7501-SW

SOUTHWIRE COMPANY | **95605299**

750 KCMIL CU 220 NL-EPR SIM-PVC JKT 15KV CT

MFR PART # 95605299
PART # 3FE-7501-SW

Spec Sheet Email Print

Minimum 500 FEET

Usually ships between 3 and 7 business days

$22,741.02
/ THOUSAND FEET

Qty in FEET

500 **+ Reel Lengths**

Add To Cart **Add To List**

DETAILS | REFERENCES | SHIPPING

Description

Southwire SIMpull CT1-13ET Type MV-105 Cable is for use in aerial, direct burial, cable trays, conduit, and underground duct installations as permitted by the National Electrical Code. These cables are capable of operating continuously at a conductor temperature not in excess of 105C for normal operation, 140C for emergency overload conditions, and 250C for short circuit conditions, and are rated at 15,000V, 133% insulation level (ungrounded system). For use in Class I, Div II locations. Maximum sidewall pressure is 1000 lbs. This cable can be installed without the need for pulling lubricant.

Appendix C-3: Material Quantity Take-offs for Water Storage Tank Options

Description	Unit	Quantity - *Option 1*	Quantity - *Option 2*	Quantity - *Option 3*	Quantity - *Option 4*	Quantity - *Option 5*	Comments
Material - Adhesives							
PVC Cement, Regular Body, Medium Set	container	13	13	13	13	13	32 oz Container
PVC Primer, Clear	container	13	13	13	13	13	32 oz Container
Material - Electrical							
2.84 kW 9 Panel Solar System	ea	1	1	1	1	1	
TW1000-30W-30 Flag Frame Booster Pump	ea	1		1			
Self-Priming Booster Pump	ea				1	1	
Electrical Control Panel for Tank	ea			1			
Electrical Wiring and Conduit	ea			1			
Centrifugal Pump	ea	1	1	1	1	1	
Flexible coupling	ea	2	2	2	2	2	
Control System for Spring Source	ea	1	1	1	1	1	
Crown 430 AH 24VDC 10,320 Watt-hour (4) Battery Bank	ea	2	2	2	2	2	
Direct BurialCommunication and Signal Wire	spool	2	2	2	2	2	1000' Long
Electrical PVC Conduit	LF	4	4	4	4	4	10' Long
Float Switches	ea	3	3	3	3	3	
Material - Fasteners and Components							
Beam Mounting Clips	ea		8				
Diagonal Mounting Clips	ea		16				
3/4x2-1/2 Structural Bolts w/Nut	box		1				
3/4 Structural Washers	box		1				
5/8x2 Structural Bolts w/Nut	box		1				
5/8 Structural Washers	box		1				
16"x16"x1.5" base plates	ea		4				
3/16 x 1-1/4 - 19W4 Grating for Landing	SF		240				
L3x3x1/4 diagonals	ea		4				
L3x3x1/4 diagonals	ea		4				
W8x18 beams	ea		4				10.5' Long
W8x40 beams	ea		2				10.5' Long
W8x40 beams			2				18.5' Long
W8x40 columns	ea		4				20' Long
8d 2-1/2 Nails	ea	1	3	1	1	1	5 lb per Box
Stopper for Stringer	ea	24	24	24	24	24	
Cable Clamps	ft	32	32	32	32	32	Assumed: 4 clips per Stringer
Cable Eyelet	ea	8	8	8	8	8	
3/8"x10-1/2" Turnbuckle	ea	2	2	2	2	2	
3/8" Quick Link	ea	2	2	2	2	2	
3/8"x6" Shouldered Eyebolt	bag	1	1	1	1	1	5 count per Bag
1-3/8"x36" Punch Flat Bar	ea	1	1	1	1	1	
1/2" Galvanized Steel Two Hole Strap	box	7	7	7	7	7	10 count per Box
#8 x 1-1/4 in. Phillips Screw	box	2	2	2	2	2	100 count per Box
Tie Wire	ft	165	205	165	165	165	
Panel Clamps	bag	8	8	8	8	8	2 count per Bag
5/16"x1-1/4" Carriage Bolt w/Nut	bag	6.25	6.25	6.25	6.25	6.25	20 count per Bag
#12x1-1/4 Inch Plastic Cap Roofing Nails	1lb/bx	1	3	1			

Description	Unit	Quantity - *Option 1*	Quantity - *Option 2*	Quantity - *Option 3*	Quantity - *Option 4*	Quantity - *Option 5*	Comments
Material - Fence							
2-3/8" Tension Band	ea	99	99	99	99	99	
6' Tension Bar	ea	33	33	33	33	33	
9'x2-3/8" Fence Post	ea	57	57	57	57	57	
6'x50' Chain Link Roll	ea	8	8	8	8	8	
6'x6' Hinged Gate	ea	4	4	4	4	4	
Farmgard 1,320 ft. 15-1/2-Gauge Barbed Wire	ea	1.16	1.16	1.16	1.16	1.16	1320 ft Long
Material - Footings & Sediment Control							
Concrete - Mix Design 1	cyd	15.07	13.07	10.07	29.07	15.07	1 Parts Cement, 2 Parts Sand, 4 Parts Agg.
Concrete - Mix Design 2	cyd			30			
Masonry Block	ea	400	400	400	400	400	16" x 8" x 8"
Cement - Mortar	cyd	1	1	1	1	1	
Structural Fill (Well-graded Gravel)	cyd	42					
Rip Rap for Settlement	ton	9	9	9	9	9	Inside Intake Structure
Material - PVC Fittings							
1" 45 Elbow, SCH 40	ea	18	18	18	18	18	
1" Cross, SCH 40	ea	2	2	2	2	2	
1" Elbow, SCH 40	ea	66	66	66	66	66	
1" Valve, SCH 40	ea	3	3	3	3	3	
1" x 1/2" Reducer SCH 40	ea	76	76	76	76	76	
1"x1"x1" Tee, SCH 40	ea	10	10	10	10	10	
1/2" MNPT x CTS Hub CPVC Adapter	ea	74	74	74	74	74	
2" 45 Elbow, SCH 40	ea	24	24	24	24	24	
2" Cross, SCH 40	ea	6	6	6	6	6	
2" Elbow, SCH 40	ea	14	12	12	14	14	
2" Valve, SCH 40	ea	20	18	18	20	20	
2" Vent Cap	ea	5	4	4	5	5	
2" x 1/2" Reducer, SCH 40	ea	1	1	1	1	1	
2"x1" Reducer, SCH 40	ea	44	44	44	44	44	
2"x2"x2" Tee, SCH 40	ea	38	38	38	38	38	
3" 45 Elbow, SCH 40	ea	12	12	12	12	12	
3" Elbow, SCH 40	ea	10	10	10	10	10	
3" Valve, SCH 40	ea	3	3	3	3	3	
3" x 1" Reducer, SCH 40	ea	1	1	1	1	1	
Injection Tee, SCH 80	ea	1	1	1	1	1	Chlorination System
Material - PVC Pipe							
3" PVC Pipe, SDR 26	LF	85	85	85	85	85	20 ft Long
2"PVC Pipe, SDR 26	LF	150	149	149	150	150	20 ft Long
1" PVC Pipe, SDR 26	LF	177	177	177	177	177	20 ft Long
1/2" PVC Pipe, SCH 40	LF	17	17	17	17	17	20 ft Long
Material - Prefabricated Plastic							
6" Water Meter Box	ea	66	66	66	66	66	
10" Circular Valve Box (12" depth)	ea	14	14	14	14	14	
J-PRO-22 15-Gallon Solution Tank	ea	1	1	1	1	1	Chlorination System
Rebar Chairs	ea	86	126	86	86	86	
Tanque Duratank HD Negro, 8000 LTS-2113GLS	ea	2	2			2	

Description	Unit	Quantity - Option 1	Quantity - Option 2	Quantity - Option 3	Quantity - Option 4	Quantity - Option 5	Comments
Material - Steel							
#3 Rebar	ea	2	2	2	2	2	20' Long
#4 Rebar	ea	178	171	128	298	178	20' Long
Y8 Rebar	ea			138			20' Long
Y10 Rebar	ea			204			20' Long
Y12 Rebar	ea			100			20' Long
Y16 Rebar	ea			72			20' Long
1/2" Male x Hose Bibb	ea	74	74	74	74	74	
2" x 2" Steel Square Bar	ea	2	2	2	2	2	4' Long
1/16" Galvanized Vinyl Coated Steel Wire Rope	roll	1	1	1	1	1	250' Long
1/16" Stainless Steel Cable	ft	24	24	24	24	24	Stringers
26'x 41" Rib Zinc Roof Panel	ea	2	7	2	2	2	
Cendrex PPA 24x36 Aluminum Hatch with keyed handle cam latch	ea	1			1		
Atlas SFD24 21 Space Rack Solid Pre-hung Steel Front Door	ea	1	1	1	1	1	
3-5/8"x10' 25Gauge Steel Stud	ea	4	4	4	4	4	
Material - Testing Materials							
Chlorine Test Kit	ea	1	1	1	1	1	Free with Specified Chlorination System
Material - Valves & Gauges							
Check Valves	ea	2	2	2	2	2	
Combination air release valve	ea	2	2	2	2	2	
Gate Valves	ea	2	2	2	2	2	
Suction and Discharge pressure gauge	ea	2	2	2	2	2	
1/2" Connection Water Meter	ea	66	66	66	66	66	
3" Sure-Vent PVC Air Admittance Valve	ea	1	1	1	1	1	
2" Sure-Vent PVC Air Admittance Valve	ea	5	5	5	5	5	
1.5" Sure-Vent PVC Air Admittance Valve	ea	1	1	1	1	1	
Material - Wood							
2x4 Lumber	ea		125				10' Long
1"x6" Lumber	ea		30				16' Long
4'x8'x1/2" Plywood	ea		2				

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Appendix D: Design Specifications and Details

Appendix D-1: Hatch for Collection Structure and Water Storage Tank

Appendix D-2: Centrifugal Pump Specifications

Appendix D-3: Water Treatment System Specifications and Installation Guide

Appendix D-4: Booster Pump Specifications

Appendix D-5: Control Panel Detail

Appendix D-6: Pipeline Elements

Appendix D-7: Door for Pump Station

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Appendix D-1: Hatch for Collection Structure and Water Storage Tank

Access Hatch Load Requirements

Let us help you find the right features for your hatch from our selection of standard assemblies, or speak with your local EJ sales representative about your project to have us custom build to meet your exact specifications.

Load Requirement Definitions

Non-traffic Load Requirement

· Non-traffic, pedestrian rated
· Material is aluminum
· 300 lb per sq ft live load
· Deflection shall not exceed 1/150th of the span

Unintended Vehicular Traffic Load Requirement

· Unintended vehicular traffic
· Material is aluminum
· 20,800 lb (16,000 lb plus 30% impact factor) on a 10" x 20" tire contact area
· AASHTO H20 Standard Specifications for Highway Bridges*
Do not place in wheel line

Vehicular Traffic Load Requirement

· Heavy duty vehicular traffic
· Material is ductile iron
· AASHTO M 306 loading*
· 40,000 lb (16,000 lb plus 250% safety factor) on a 9" x 9" tire contact area
· Proof load tested for 1 minute without failure

Airport Load Requirement

· Extra heavy duty airport and port authority traffic
· Material is ductile iron
· Proof load tested on a 9" x 9" tire contact area to a minimum of 200,000 lb

*AASHTO H20 per the Standard Specifications for Highway Bridges is theoretically calculated using safety factors vs actual proof load testing for AASHTO M 306 Standard Specification for Drainage, Sewer, Utility, and Related Castings.

ANGLE FRAME, PEDESTRIAN RATED

- Non-traffic, pedestrian rated
- Red stainless steel hold open arm
- Heavy duty stainless steel hinges
- Exposed padlock clip
- Aluminum lift handle
- Extruded aluminum frame
- 1/4" aluminum diamond plate cover

See aluminum hatch options on pages 8, 9, and 11 for additional options.

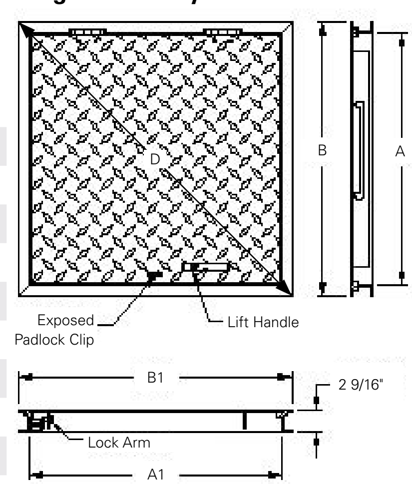
No vehicle traffic allowed.

Angle Frame, Pedestrian Rated

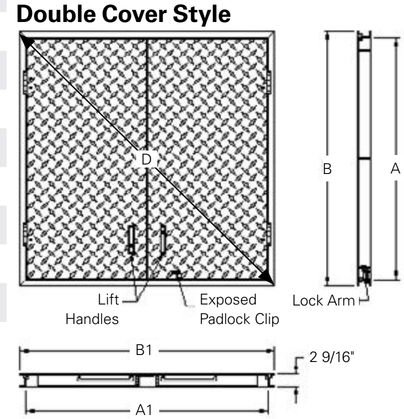
Catalog Number Aluminum	**Description**	**Inside Dimension** A x A1	**Outside Dimension** B x B1	**Diagonal** D	**Single Cover Weight**
H24241001	1 Cover Hatch	24 x 24	26 1/2 x 26 1/2	37 1/2	15
H24301001	1 Cover Hatch	24 x 30	26 1/2 x 32 1/2	41 15/16	20
H24361001	1 Cover Hatch	24 x 36	26 1/2 x 38 1/2	46 3/4	28
H30301001	1 Cover Hatch	30 x 30	32 1/2 x 32 1/2	46	25
H30361001	1 Cover Hatch	30 x 36	32 1/2 x 38 1/2	50 3/8	34
H30481001	1 Cover Hatch	30 x 48	32 1/2 x 50 1/2	60 1/16	44
H36361001	1 Cover Hatch	36 x 36	38 1/2 x 38 1/2	54 7/16	40
H36481001	1 Cover Hatch	36 x 48	38 1/2 x 50 1/2	63 1/2	52
H42421001	1 Cover Hatch	42 x 42	44 1/2 x 44 1/2	62 15/16	53
H30481101	2 Cover Hatch	30 x 48	32 1/2 x 50 1/2	60 1/16	25
H30541101	2 Cover Hatch	30 x 54	32 1/2 x 56 1/2	65 3/16	29
H36481101	2 Cover Hatch	36 x 48	38 1/2 x 50 1/2	63 1/2	31
H36601101	2 Cover Hatch	36 x 60	38 1/2 x 62 1/2	73 7/16	37
H42481101	2 Cover Hatch	42 x 48	44 1/2 x 50 1/2	67 5/16	36
H48481101	2 Cover Hatch	48 x 48	50 1/2 x 50 1/2	71 7/16	41
H48541101	2 Cover Hatch	48 x 54	50 1/2 x 56 1/2	75 3/4	45
H48721101	2 Cover Hatch	48 x 72	50 1/2 x 74 1/2	90	58
H60601101	2 Cover Hatch	60 x 60	62 1/2 x 62 1/2	88 3/8	66

Note: All dimensions are in inches. All weights are in pounds.

Single Cover Style



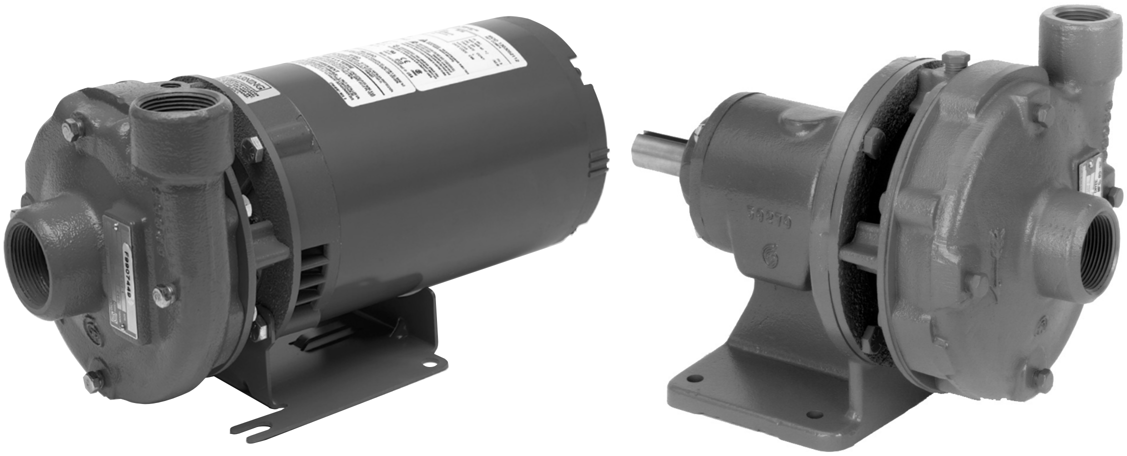
Double Cover Style



Water Solutions, Inc.

Appendix D-2: Centrifugal Pump Specifications

TECHNICAL BROCHURE
B36/3742 R4



3642/3742

CLOSE-COUPLED AND FRAME-MOUNTED CENTRIFUGAL PUMPS

GOULDS
WATER TECHNOLOGY
a xylem brand

FEATURES

Compact Design: Close coupled, space saving design provides easy installation. Flexible couplings and bedplates not required.

Mounting: Can be mounted in vertical or horizontal position.

Construction: Available in bronze fitted (BF), all iron (AI), or all bronze (AB). Bronze fitted means bronze impeller.

Impeller: Enclosed design for high efficiencies. Threaded directly on motor shaft. Stainless steel locknut on three phase models requires no clearance adjustments. Balanced for smooth operation.

Casing: Volute type, cast iron or brass construction. Back pullout design. Discharge can be rotated in eight positions. Vertical discharge standard. Tapped openings provided for priming, venting and draining.

Mechanical Seal: Standard carbon/ ceramic faces, BUNA elastomers, 300 series stainless steel components. Option seals available.

Motor: Close-coupled design. Ball bearings carry all radial/axial thrust loads. Designed for continuous operation. All ratings are within working limits of the motor.

Frame-Mounted Design: Offers flexibility of installation and driver arrangements. Cast Iron Power Frame rigidly supports the grease-for-life ball bearing shaft assembly.

OPTIONAL MECHANICAL SEALS

Materials					Part No.	Seal Type	Service
Suffix	Rotary	Stationary	Elastomer	Metal Parts			
Blank	Carbon	Ceramic	BUNA	316 SS	10K10	6	General
N		Ni-Resistant		18-8 SS	10K6		Fluct. Temp. up to 212°F
O		Sil-Carbide	EPR	316 SS	10K18	21	Hot Water up to 250°F
V			Viton		10K55		Mild Chemical

NOTE: To order an Optional Mechanical Seal, add appropriate suffix to order number. "N" for 10K6; "O" for 10K18 and "V" for 10K55. 10K55 replaces 10K24. The 10K55 has a 150 PSI rating, note that the pump's maximum working pressure is only 125 PSI.

3642/3742 NUMBERING SYSTEM

The various versions of the 3642 and 3742 are identified by a product code number on the pump label. This nuber is also the catalog number for the pump. The meaning of each digit in the product code number is shown below.

3500 RPM CLOSE COUPLED

Example Product Code **1BF11512**

1 BF 1 15 1 2 _ R

Casing Rotation, Optional
R = 3 o'clock B = 6 o'clock
L = 9 o'clock
NOTE: Rotation when viewed from suction end of pump. Standard discharge position is 12 o'clock.

Optional Seal *(chart on pg. 2)*
Blank = Standard 10K10
N = Ni-Resist 10K6
O = EPR 10K18
V = Viton 10K55

Voltage (See top of pump list)
1 = 115 5 = 230/460
2 = 115/230 6 = 190/380
3 = 230 7 = 575 ①
4 = 208-230/460 X = Non Std.

Phase (1 or 3)

HP
03 = 1/3 HP 10 = 1 HP
05 = ½ HP 15 = 1½ HP
07 = ¾ HP 20 = 2 HP

Motor Type
1 = ODP 4 = ODP with min. impeller 7 = ODP PE 0 = WD PE
2 = TEFC 5 = TEFC with min. impeller 8 = TE PE
3 = XP 6 = EXP with min. impeller 9 = XP PE

Material
BF = Bronze Fitted AI = All Iron
AB = All Bronze

Pump Size
1 = 1 x 1¼ – 5 2 = 1¼ x 1½ – 5

FRAME MOUNTED PUMPS ONLY

Example Product Code **F1BF05**

F 1 BF 05 _

Optional Seal
(chart on pg. 2)
Blank = Standard
N = Ni-Resist
O = EPR
V = Viton

HP
03 = 1/3 HP 10 = 1 HP
05 = ½ HP 15 = 1½ HP
07 = ¾ HP 20 = 2 HP

Material
BF = Bronze Fitted
AI = All Iron
AB = All Bronze

Pump Size
1 = 1 x 1¼ – 5
2 = 1¼ x 1½ – 5

F =
Frame Mounted - Grease, Lube

① 575 Volt motors have an extended lead time.

NOTE: Not recommended for operation beyond printed H-Q curve. For critical application conditions consult factory.

NOTE: Not all combinations of motor, impeller and seal options are available for every pump model. Contact Customer Service for information on non-cataloged order numbers.

NOTE: Impellers will be trimmed in 1/16" increments only. If you are ordering a trim within 1/16" of the standard impeller, you will receive the standard impeller trim.

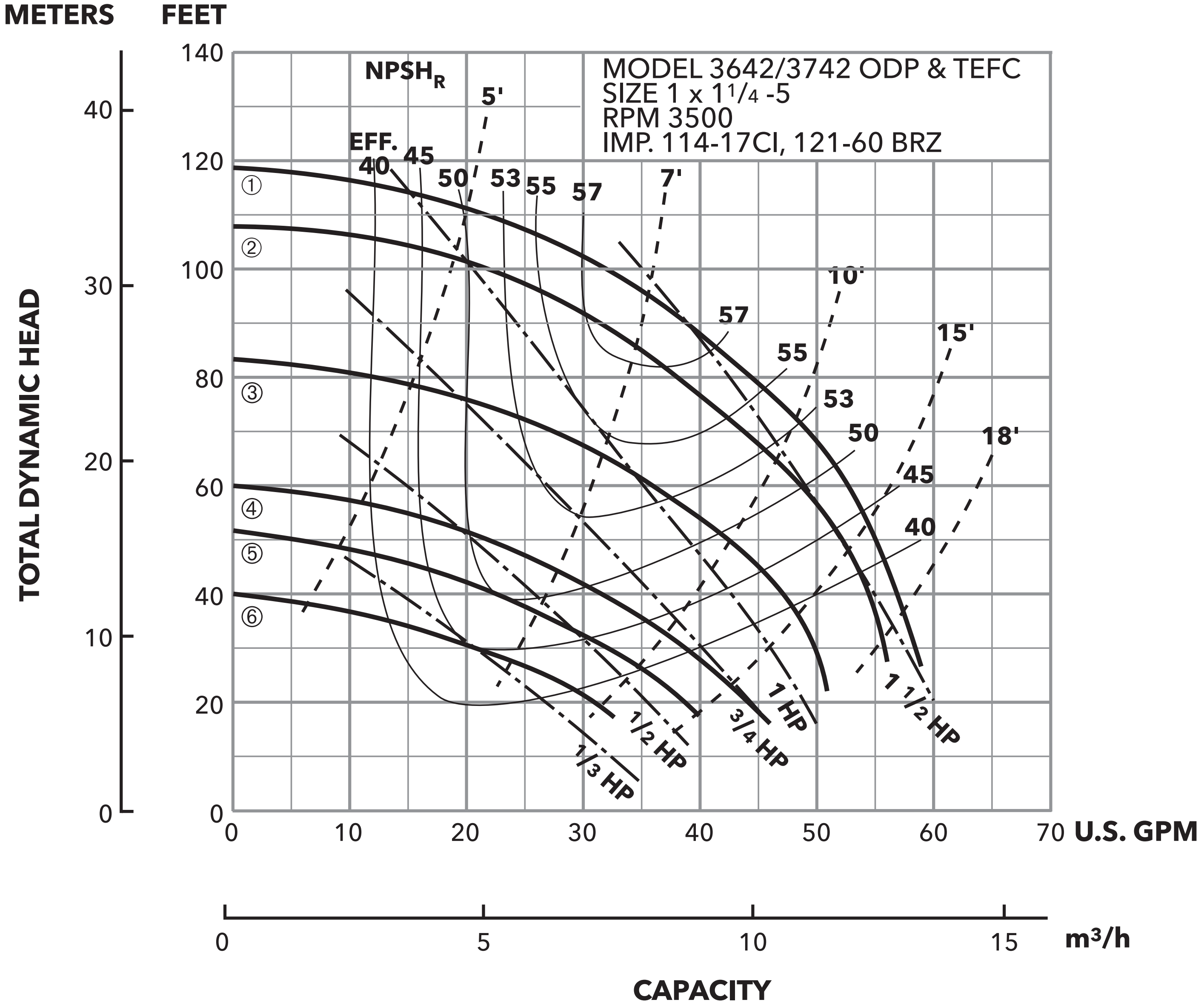
PERFORMANCE CURVE 1AI, 1BF, 1AB . . .

MOTOR SIZES* AND IMPELLER DIAMETERS

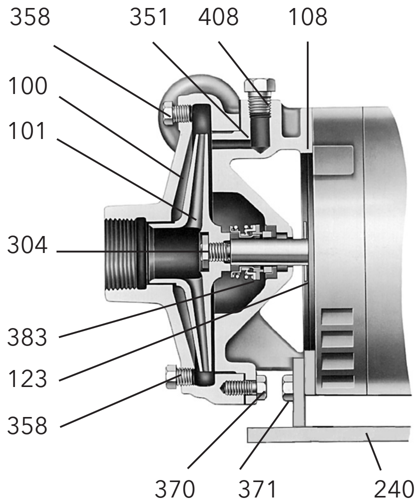
① 1½ HP ODP OR 2 HP TEFC	5⅜" DIA.	④ ½ HP ODP OR ¾ HP TEFC	3⅞" DIA.
② 1 HP ODP OR 1½ HP TEFC	5⅛" DIA.	⑤ ⅓ HP ODP OR ½ HP TEFC	3⁹⁄₁₆" DIA.
③ ¾ HP ODP OR 1 HP TEFC	4⁹⁄₁₆" DIA.	⑥ OPTIONAL TRIMMED IMPELLER	3³⁄₁₆" DIA.

* Premium efficiency where Department of Energy regulations apply. Consult factory for dimensions.

Eficacia superior donde el Ministerio de regulaciones de la Energía se aplica. Consulte la fábrica para las dimensiones.



CLOSE-COUPLED



MOTOR FRAME

Motor Frame	Single Phase		Three Phase	
	ODP*	TEFC*	ODP*	TEFC/EXPL*
48	⅓	–	–	–
56	½ – 2	½ – 2	⅓ – 2	½ – 2

* Premium efficiency where Department of Energy regulations apply. Consult factory for dimensions.

Eficacia superior donde el Ministerio de regulaciones de la Energía se aplica. Consulte la fábrica para las dimensiones.

MATERIALS OF CONSTRUCTION

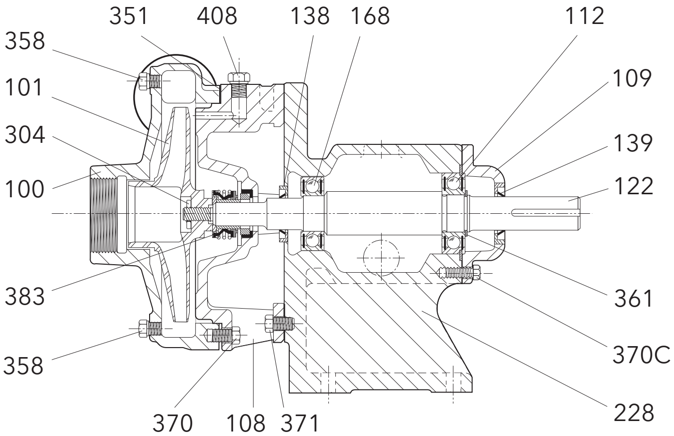
Item No.	Description	Material Code		
		Bronze Fitted	All Iron	All Bronze
100	Casing	1001	1001	1101
101	Impeller	1101	1001	1101
108	Adapter	1001	1001	1101
123	Water deflector	Rubber or Micarta®		
240	Motor Support	Steel		
	Rubber Channel	Rubber		
304	Impeller nut*	Stainless steel		
351	Gasket-casing	Composite		
358	Pipe plug ¼" vent and drain	Brass	Steel	Brass
370	Hex head cap screw adapter to case	Zinc-Plated Steel		
371	Hex head cap screw adapter to motor	Zinc-Plated Steel		
383	Mechanical Seal	See Nomenclature		
408	Prime plug – priming ¼" NPT	Brass	Steel	Brass

* Impeller nut furnished on three phase units only.

Material Code	Engineering Standard
1001	Cast iron ASTM A48 CL 20
1101	Bronze ASTM B584, C87500 Lead-Free

**Mechanical Seal Item 383						
Part No.	Service	Rotary	Stationary	Elastomer	Metal Parts	Crane Type
10K10	Standard Duty	Carbon	Ceramic	BUNA	316 SS	6
10K6	Fluct. Temp up to 212° F		Ni-Resist		18-8 SS	
10K18	Hot Water up to 250° F		Sil.-Carbide	EPR	316 SS	21
10K55	Mild Chemical		Ceramic	Viton		

FRAME-MOUNTED



MATERIALS OF CONSTRUCTION

Item No.	Description	Material Code		
		Bronze Fitted	All Iron	All Bronze
100	Casing	1001	1001	1101
101	Impeller	1101	1001	1101
108	Adapter Frame	1001	1001	1101
109	Bearing Cover	1001	1001	1001
112	Ball Bearing (outboard)	Steel		
122	Shaft	AISI 303 SS		
138	Lip-seal (inboard)	BUNA/Steel		
139	Lip-seal (outboard)	BUNA/Steel		
168	Ball Bearing (inboard)	Steel		
228	Bearing Frame	Cast Iron		
304	Impeller Locknut	AISI 416 SS		
351	Gasket	Composite		
358	Drain and Vent Plug, Casing	Plated Steel or Brass		
361	Retaining Ring	Steel		
370	Socket, Head Screw, Casing	Plated Steel		
370C	H.H. Screw, Bearing Cover	Plated Steel		
371	H.H. Screw, Bearing Frame	Plated Steel		
383	Mechanical Seal	**See Chart		
408	Priming Plug	Plated Steel or Brass		

Material Code	Engineering Standard
1001	Cast iron ASTM A48 CL 20
1101	Bronze ASTM B584, C87500 Lead-Free

****Mechanical Seal Item 383**

Part No.	Service	Rotary	Stationary	Elastomer	Metal Parts	Crane Type
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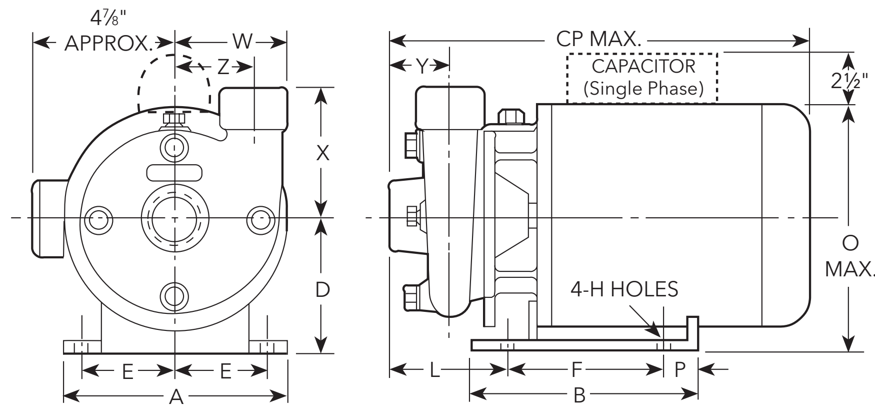
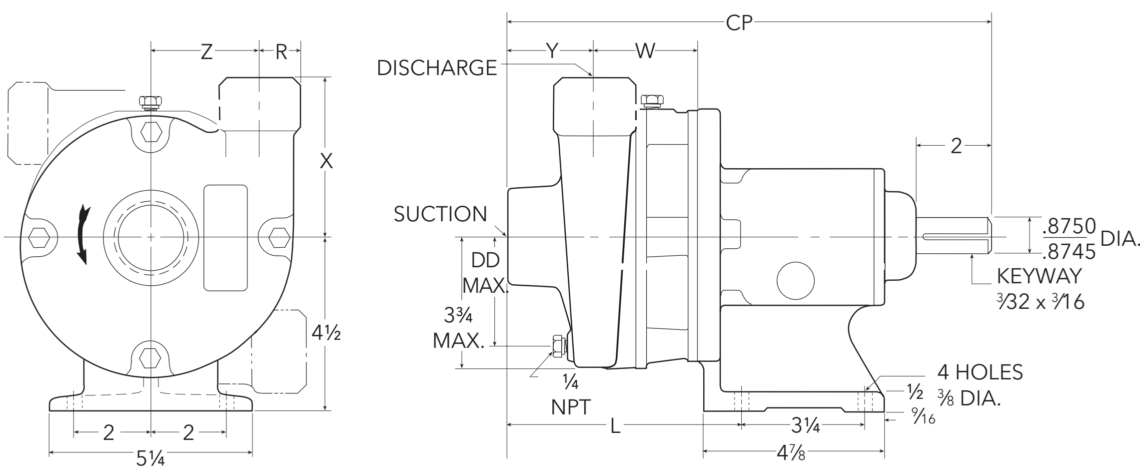
10K18	Hot Water up to 250° F		Sil.-Carbide	EPR	316 SS	21
10K55	Mild Chemical		Ceramic	Viton		

3642 DIMENSIONS AND WEIGHTS



Pump	A	B	D	E	F	H	L	O	P	W	X	Y	Z	CP	Motor Frame	Wt. (lbs.)
1x1¼-5	6¾	5⅞	4⅛	2¹⁵⁄₁₆	5	¹³⁄₃₂	3⅝	7	⁷⁄₁₆	4	4⅛	2³⁄₁₆	3¹⁄₁₆	13	48	55
														17⅜	56	67
1¼x1½-5							3⅞	7⅜			4	2¼	2¹⁵⁄₁₆	17¹¹⁄₁₆	56	68

3742 BARE PUMP DIMENSIONS AND WEIGHTS



Pump	Suction*	Discharge*	CP	DD Max.	L	R	W	X	Y	Z	Wt. (lbs.)
1 x 1¼ – 5	1¼	1	12¼	3¼	5¹³⁄₁₆	¹⁵⁄₁₆	2½	4⅛	2³⁄₁₆	3¹⁄₁₆	45
1¼ x 1½ – 5	1½	1¼	12½	3⅜	6⅛	1¹⁄₁₆	2¾	4	2¼	2¹⁵⁄₁₆	48

* NPT Connections

NOTES:

1. Pumps will be shipped with top vertical discharge as standard. For other orientations, remove casing bolts, rotate to desired position, replace and tighten ⅜ – 16 bolts to 37 lb./ft.
2. Not to be used for construction purposes.
3. Dimensions in inches

APPLICATIONS

Specifically designed for the following uses:

- Water circulation
- Booster service
- Liquid transfer
- Spraying systems
- Jockey pump service
- General purpose pumping

SPECIFICATIONS

Pump

- Capacities: to 110 GPM
- Heads: to 118 feet
- Pipe connections:

Model	Suction	Discharge
1 x 1¼ - 5	1¼" NPT	1" NPT
1¼ x 1½ - 5	1½" NPT	1¼" NPT

- Maximum working pressure: 125 PSI
- Temperature: standard seal, 212° F (100° C) maximum or 250° F (121° C) with optional high temperature seal.
- Rotation: right hand i.e.; clockwise when viewed from motor end.

Motor

- NEMA standard
- Open drip proof*, TEFC*, or (explosion proof three phase only) enclosures*.
- 60 Hz, 3500 RPM
- Stainless steel shaft
- Single phase: ½-2 HP ODP* or TEFC*. Built-in overload with automatic reset.
- Three phase: ⅓ - 2 HP: ODP*, 208-230/460 V
  ½ - 2 HP: TEFC*, 208-230/460 V
  ½ - 2 HP: expl. proof*, 230/460 V
- NEMA 56J frame motors are used on close-coupled 3642 pumps and T-frame motors are used on frame-mounted 3742 pumps.
- Overload protection must be provided in starter unit. Starter and heaters (3) must be ordered separately.

* Premium efficiency where Department of Energy regulations apply. Consult factory for dimensions.

Appendix D-3: Water Treatment System Specifications and Installation Guide

J-PRO-22 Metering Pump

Advanced dual-voltage chemical dosing pump for accurate injection of chlorine, peroxide, acid, soda ash and other chemicals for water treatment.

Available in PVC liquid ends, and also PVDF liquid ends and fittings for concentrated acids.

Specifications:

- Dual Voltage: Works for 110V to 240V 50/60hz
- Amperage use: 28 watts
- Maximum Line pressure: 110 PSI
- Stroke Frequency: 110 strokes/minute
- Stroke Speed Adjustment: 10-100%
- Pump Output: 0.1 to 22 gallons of solution per day
- Stroke Output: 0.56 o 0.9 mL depending on line pressure
- Degassing valve included for trouble-free operation
- Manual Speed Setting or Pulse Control for Proportional-Feed, and/or 4-20mA available.
- Ambient temperature recommended: -10C to 45C
- Weight: 5 kg 11 lbs

To order call 888-600-5426 or visit us at www.CleanWaterStore.com

CLEAN WATER SYSTEMS

REV.062218

J-PRO-22 110V – 230V Dual Voltage
Chlorinator Installation & Start-Up Guide

Thank you for purchasing a Clean Water System! With proper installation and a little routine maintenance, your system will be providing treated water for many years.

Please review this start-up guide entirely before beginning to install your system and follow the steps outlined for best results.

CHLORINE CAN DAMAGE CLOTHING AND IRRITATE SKIN and EYES. USE RUBBER GLOVES AND EYE PROTECTION WHEN HANDLING.

USE ONLY PURIFIED OR SOFTENED WATER TO MAKE UP CHLORINE SOLUTION, NOT RAW WELL WATER.

USE CHLORINE POWDER OR BLEACH CERTIFIED FOR DRINKING WATER, NOT LAUNDRY BLEACH.

NOTE ABOUT 220V INSTALLATIONS: pump is dual voltage AND works on 110v OR 220v.

If you plan to install to run on 220v-240v, we recommend cutting off plug and either hard- wiring to 220v circuit OR installing a 220v plug-end.

Specifications:

Pumps 0.1 to 22 gallons of solution per day
Injects into line pressures up to 110 PSI

Dual voltage. 110V or 220V, works on either voltage. Uses maximum 22 watts of power.

Dimensions:

15-gallon model: 14.5" wide x 24", height including pump is 35".

35-gallon model: 18" wide x 33", height including pump is 44".

This pump is intended for indoor use, protect from sunlight and freezing.

For assistance call: 1-831-462-8500

Contents

J-Pro-22 Metering Pump Warranty and Returns:

Your pump comes with a 1 Year Warranty from date of delivery.

If your pump fails under warranty, please call or email our office to obtain a Returns Good Authorization Number before sending us back the pump for repair or replacement under the warranty. No returns can be accepted without an RGA number.

The Warranty covers repair and/or replacement of the metering pump but not shipping costs.

While defects are rare, we do our best to respond to warranty returns fast as we can. Please allow 3 to 5 business days after pump has been returned for your pump to be repaired or a new one supplied under the warranty agreement.

If the water supply and its continuous chlorination are critical, a back-up chlorinator pump should be on hand. Shipping charges are not covered under warranty. A flat fee of $9.95 each way will be charged for ground shipping (continental US). Any expedited shipping (overnight, 2-day, etc.) is the customer's responsibility.

Conditions Not Covered by the Warranty:

Power surges or outages that cause pump failure are not covered under warranty.

Surge protection is strongly recommended. If a pump is returned for warranty replacement and the cause of failure is determined to be from a voltage spike, the pump does not qualify for replacement. This is the leading cause of failure. Pump failure during, or because of, power failure is not covered under warranty.

For Returns Contact Clean Water Systems & Stores Inc. 2806-A Soquel Ave Santa Cruz, CA 95062831-462-8500 support@cleanwaterstore.com

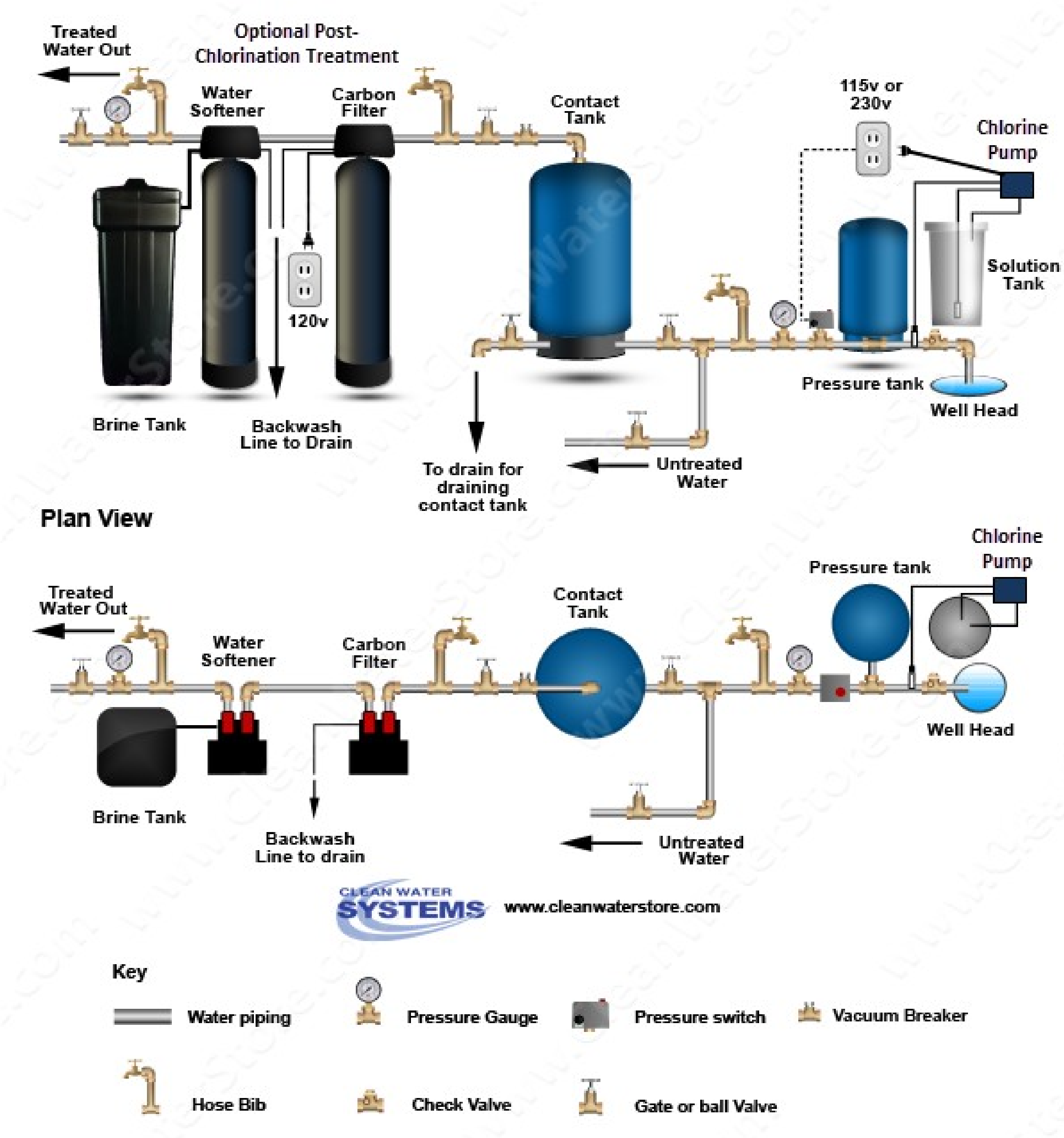
Pre-Installation

1. Review your packing list and make sure you have received all the parts before beginning installation.

2. If you turn off the water to the house and you have an electric water heater, shut off the power to the water heater before beginning installation in case water heater is accidentally drained.

3. Pick a suitable location for your chlorination system on a dry level spot where it won't be exposed to freezing temperatures or direct sunlight. Maximum line pressure is 100 PSI.

Typical Installation (Diagram)



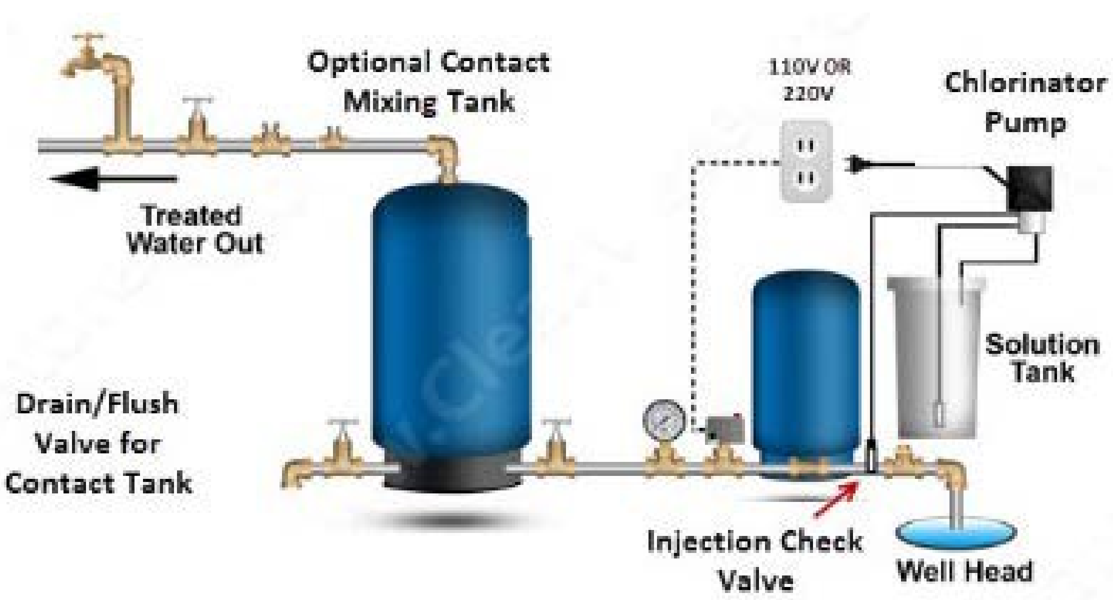
How Your Chlorine Pump Works

The pump is designed to pull chlorine solution out of a solution tank and pump a precise amount of chlorine into a pipeline under pressure.

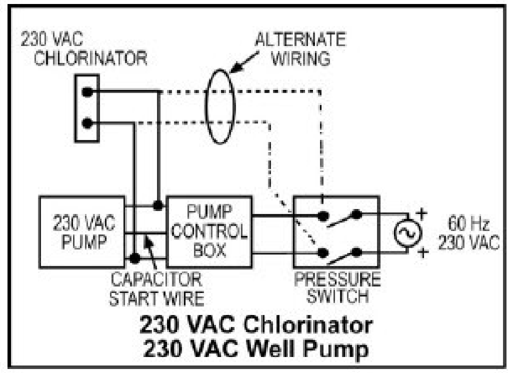
Right out of the box, this is a dual-voltage (110/220) pump. There are several ways to wire the pump such that it triggers when there is water flow.

The well pump is controlled by your pressure switch. Choosing one of the ways outlined below, the chlorinator will be installed so that it powers up and injects chlorine when the well pump and motor are turned on via the pressure switch.

1. You can install a flow switch, and plug the J-Pro22 into that.
2. You can install it on a 110 volt or 220V pressure switch, using a dedicated electrical wall outlet.
3. If you have 220v, you can purchase an adapter that converts the 110- style plug into a 220 outlet, and wire a dedicated 220 outlet to the pressure switch, OR:
4. You can cut off the plug (this Does Not void the Warranty and is what we recommend if you are using it for 220V) and wire it directly to your 220V pressure switch. This last method should only be done by a qualified technician.



Wire To Pressure Switch Option



How To Wire to Your Well's Pressure Switch

Install a dedicated wall outlet that is wired in to the pressure switch and powered up whenever the well pump turns on.

The J-Pro-22 is a dual voltage pump. It has a 110 volt-style plug.

A person who is qualified may (without voiding the warranty) cut off the plug, and wire it directly to the pressure switch terminals.

Avoid installing a dedicated wall outlet that looks like it is 110, but is actually 220.

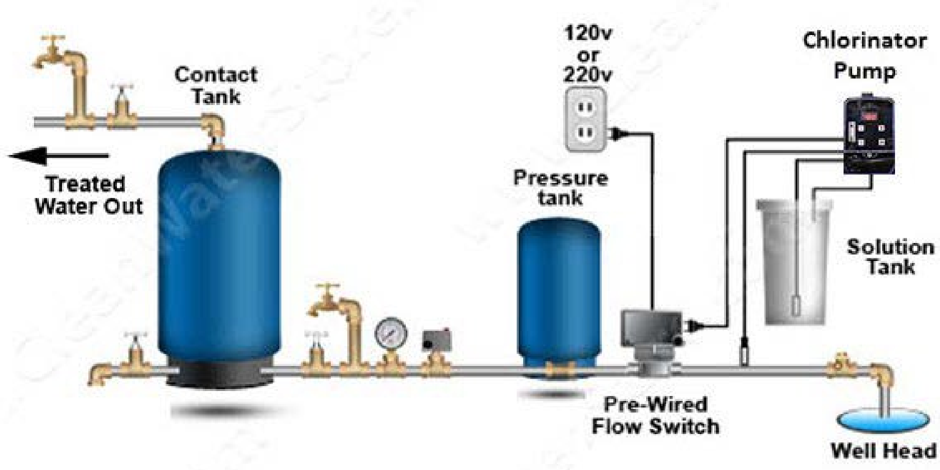
You may cut off the 110 style plug and wire a 220-style plug, and then plug that into a dedicated 220-style wall outlet.

Do not wire to Pump Capacitor Start Wire.

Use a Flow Switch Option

As an option to turn on and off the peroxide pump, install a flow switch. No electrical wiring to do and any plumber, or person familiar with basic plumbing, can install it.

Simply plumb the pre-wired flow switch into your service pipe. Plug the flow switch into a standard 120V wall outlet. Then, plug the chlorinator pump into the electrical outlet on the flow switch. Whenever there is flow, the metering pump will then turn on.



J-PRO-22 Installation Instructions:

While you can mount the pump on a shelf above the solution tank, it is strongly advised to mount the pump directly on top of the solution tank. If the tubing from the foot valve to the suction side of the pump exceeds 60", the unit will not have enough lift force to stay primed.

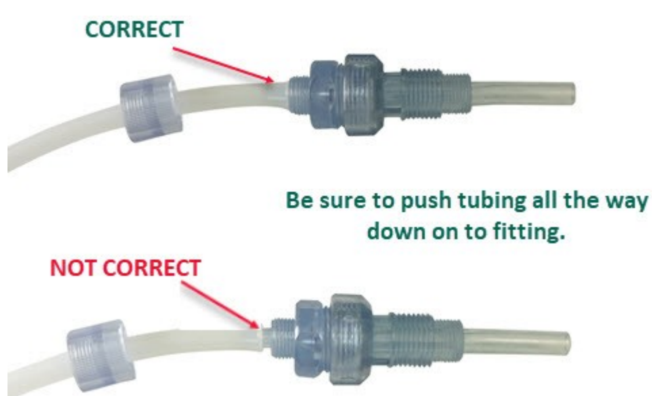
Mount Pump to Solution tank

Place pump on tank. Mark where the anchor holes will be drilled. Drill pilot holes with a small drill bit so that the pump can be mounted on the tank with two wood or sheet metal screws. We recommend screwing them in ***after*** the pump has been primed and the tubing has been hooked up for easiest installation.

Mark the holes for the suction tube and the degassing return line and drill holes.

How to Connect Tubing & Fittings

- Trim the end of the tubing square (cut with a new box cutter blade).
- Slide the connector nut onto the tube.
- Push the tubing over the conical fitting until the tubing is flush against the end of the fitting.
- Screw the connector nut on, hand tight.
- Do not use Teflon tape/ paste on the tubing fitting connections.



Use the harder/stiffer translucent tubing for connection from discharge-side (12 o'clock) to the injection check valve.

Use the softer clear tubing for the foot valve to suction-side (6 o'clock) connection.

Install Discharge Side Tubing

This is the tubing that goes from the pump discharge (outlet) to injection check valve in pipe tee.

1. Shut off well pump or water supply and de-pressurize service pipe.

2. Install injection check valve by installing a pipe tee in your pipe that has a ½” NPT fitting, where you can screw in the injection check valve (included with your J-PRO-22 pump).

3. Wrap Teflon tape on the ½” pipe threads of the injection check valve and apply a light coating of white Teflon pipe paste and install into Tee fitting.

4. Trim the end of the injection check valve fitting so that the end (where the chlorine squirts out) will be in the center of the service pipe.

5. **Make sure to install injection check valve in to pipe directly.** If the end of the check valve is not in the service pipe, it will not work. Do not install a ball valve, or any length of pipe run, coming off the tee.

6. Using a hack saw or cutter, trim the end of the injection check valve if needed, so it inserts into the water pipe as shown.

7. Install tubing that came with your pump and connect pump to injection check valve.

8. Cut tubing to desired length with enough slack to avoid kinks.

Injection check valve can be installed into PVC, copper or other piping.

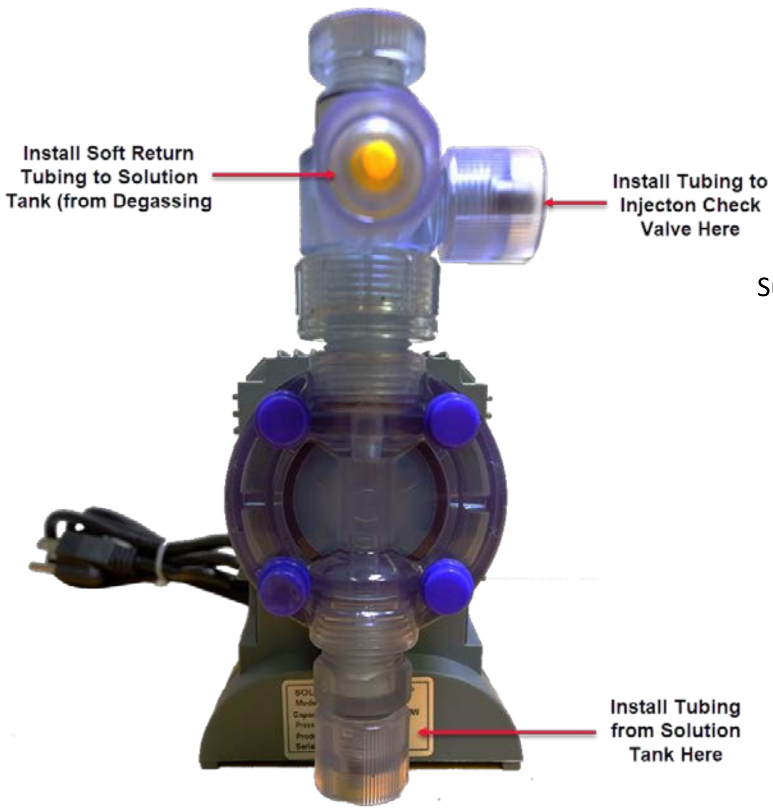
Install Suction Tubing from Pump to Solution Tank

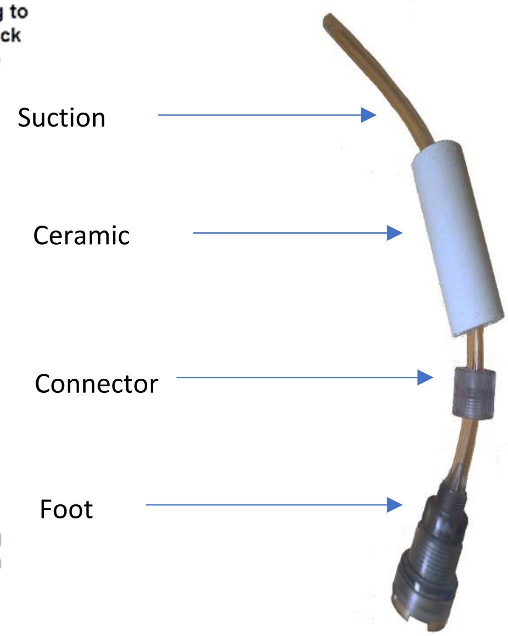
Connect hard tubing from foot valve in Solution Tank to Inlet/ Suction side of metering pump

1. Measure the tubing from the outside of the solution tank to ensure it will be 2-3” from the bottom of the solution tank.

2. Do not allow weight to sit at the bottom of the tank. Connect tubing to the foot valve and put the ceramic weight on.

3. Run the tubing up through the hole and connect to the Inlet/ Suction side of pump





Connect Tubing from Degassing Port ("Kicker Port")

You can use the soft tubing for this run, connect tubing to the degassing port fitting (labeled on the pump as "Kicker Port") and pass tubing through the hole you drilled down into the tank 4-6".

Prime & Start the Pump

1. Fill solution tank with 4 gallons of soft, distilled, or RO water, but don't add chlorine yet.
2. Connect the suction tubing to the foot valve and discharge tubing to your injection check valve.
3. Connect the degassing prime valve tubing and route to the solution tank, above the water line.
4. Open the degassing prime valve two turns counter-clock-wise to open it up. This will allow the solution to be pumped back into the tank for fast priming.
5. Turn on the pump and set Speed to 100% if not already displaying 100.
6. You will quickly see water being pumped out the degassing valve return line port.
7. Close the degassing port valve until liquid starts pumping out the discharge side.
8. Allow to run for 10-15 minutes. Check for leaks.
9. After your chlorinator pump has been running for a few days, tighten 4 stainless steel bolts on the pump end.
10. Don't over-tighten, but it is recommended to re-tighten (once) and make sure these bolts are tight after pump has been running.

Program Pump and Adjust Speed Settings

Out of the box, when you plug the unit in, the green Motor light is indicating the pump has power. It will be set at 100 and start pumping.

Press the Start/Stop button to stop the unit from pumping. The Up and Down arrows are to adjust the Speed of the pump, from 0-100.

NOTE: Pump must be allowed to run for 15 seconds at the speed setting, after you change the speed. For example: say you change the speed to 70. Let run for at least 15 seconds before unplugging pump. The pump needs 15 seconds to SAVE the new setting.

The Set button and the Auto light indicator have no function on this model, they are for use with a flow meter.

About Chlorination

Chlorine is used for three main objectives:

1. Disinfection and inactivation of pathogens in water such as E. Coli.

2. Odor control: eliminates rotten-egg, metallic and other odors in water.

3. Oxidization of iron and manganese.

When chlorine is added to water, the water has a "demand" for chlorine. When that demand is satisfied, any additional amount of chlorine added is called the "free residual". As long as you have a free residual of 0.2 ppm or higher, that water has enough chlorine, no more needs to be added.

To treat for coliform bacteria, the water must have a minimum amount of contact time typically ten minutes or more with the chlorine, and a free residual detected. For odor, iron and manganese, only a couple of minutes are needed.

What Type of Bleach To Use

We recommend using NSF Certified Chlorine Powder which has no additives or contaminants
Do not use household laundry bleach, as it contains additives
You can use liquid bleach such as 10% pool chlorine if it is free of additives
To use chlorine powder: add 1 oz powder to 1 gallon of soft or purified water to make up solution.
Each ounce of chlorine powder added to one gallon of water makes approximately a 1% or 10,000 PPM chlorine solution.

Add the Chlorine: How Much Chlorine to Add to Water

1. Once the pump is primed and pumping with water, add 5 Oz of Chlorine powder (or ½ gallon of 10% to 12% Liquid Pool Chlorine to the solution tank, and fill with purified or softened water to the five-gallon mark (you started out with 4 gallons from the instructions previous).

2. Set the pump speed at 50. If your well pump pumps between 5 and 15 gallons per minute, this will give you an applied chlorine dosage of 2 to 10 PPM. See below for more info and formula.

3. If you have a contact tank after the chlorinator, start drawing water through the system, injecting chlorine.

4. Start testing for a free residual after the contact tank.

5. The color spectrum for the chlorine free residual test kit that comes with your system goes from a pale yellow (0.2 – 0.5 PPM) to a bright yellow (1.5 – 3.0 PPM) and then orange and red, too much residual chlorine, above 4.0 ppm.

6. If you get too much chlorine you can turn down the speed of the pump or make the chlorine solution more diluted.

7. Once you are in the yellow spectrum, use the up and down arrows to adjust the speed setting, until you are measuring 0.2- 1.0 ppm residual. Usually, values 0.5 and below are too low to smell the chlorine, that is often ideal depending on the application.

Formula for Calculating Solution Strength and Settings

Note: mg/L is the same as Parts Per Million. 12% chlorine is the same as saying 120,000 PPM of chlorine. 5% household bleach is 50,000 PPM chlorine.

Start with a solution strength of 10,000 PPM (1 Oz of Chlorine Granules per Gallon of Purified Water)

How many parts per million of chlorine should I inject?

Apply 1.0 PPM of chlorine for every 1 PPM of iron; 2 PPM of chlorine for every 1 PPM of Hydrogen Sulfide and/or Manganese.

The simple formula is: Flow Rate in Gallons Per Minute GPM x Parts Per Million of Applied Dosage x 1440 Minutes in One Day = Gallons Per 24 Hour Period of Chlorine.

Example: Assume you wanted to apply 5.0 PPM of chlorine to your well water. You have a solution strength of 10,000 PPM chlorine solution strength. You know your well pump flow rate is 12 GPM.

5.0 PPM x 12 GPM x 1440 Divided by 10000 = 8.6 Gallons Per Day

What this mean is approximately 8.6 gallons of the chlorine solution will be pumped for every 24 hours your well pump runs. Your well pump does not run 24 hours each day however.

Another way to look at it, you might use 0.36 gallons (less than half a gallon) of chlorine solution, for every hour your well pump runs.

Therefore, you need a chlorinator pump that can pump 8.6 gallons in 24 hours. The JPRO-22 pump pumps 22 gallons per 24 hours. So, 22 divided by 8.6 - .39 or 39%.

Set the JPRO-22 speed to 40%, which will turn it into a 8.6 Gallon Per Day Pump. You can later turn it up or down to dial in the chlorine residual, and/or change the solution strength as needed.

Troubleshooting and Maintenance:

Most problems occur with the connections, it can sometimes be hard to push the tubing onto the cones, sometimes fittings are over-tightened, or people use Teflon tape and paste on fittings that do not need it.

If the pump pumps in manual mode and makes a thumping sound, then it is working**.**

Watch How-To Videos On Our YouTube Channel

https://www.youtube.com/cleanwaterstore

Priming Problems

1. If you cannot get it to prime, it is either because a fitting is too loose, too tight, or not installed correctly.

2. While the pump is running (usually, on Manual), observe if the fluid is coming up the tube- if you see the water going up and down in the tubing, this indicates the foot valve is not tight, or you installed the pump too high above the solution tank, or you mounted the pump improperly.

3. Sometimes, as mentioned earlier in the guide, it is because the four Allen head bolts on the grey pump head have loosened, and need to be tightened, do not over-tighten.

4. If the solution has filled the tubing, but it is not discharging, make sure the de-gas is opened, and then close it until the point when it starts pumping.

5. **The tubing going from the outlet/discharge to injection check valve will twitch and move at the same time the pump triggers, that is how you can confirm you are pumping solution.**

6. If this does not work, remove the discharge-to-injection check valve tubing from the outlet fitting, and see if it squirts out of the top- if it does, this indicates that the problem is in the injection check valve, or that you are trying to pump against greater than 100 psi.

Maintenance Tips**:** Check free-chlorine residual at least once per month and adjust the J-PRO-22Pump and/or solution strength if needed.

Winterizing: do not let the J-PRO-22Pump or tubing freeze. If you need to winterize, drain the chlorine solution tank and discard chlorine solution.

Place the suction of the pump into a bucket of clean water and allow the pump to run until the J-PRO-22Pump is free of any chlorine solution.

Remove the suction from the water and allow the pump to pump dry. Pump is ready to store.

NOTE: when diluting the bleach, use only distilled water, water from a reverse osmosis system, or at least softened water. Do not use untreated well water.

Need Assistance? Call us at 831-462-8500 or email support@cleanwaterstore.com

Spare Parts:

These installation parts are included with initial order, but you may wish to have spares on hand, or replace the injection check valve, foot valve or diaphragm later.

P7007540 Diaphragm Replacement

P7007570 Foot Valve

P7007550 Injection Check Valve

Appendix D-4: Booster Pump Specifications

TOWLE WHITNEY LLC

TW1000-30W-30 FLAG FRAME
VARIABLE SPEED BOOSTER PUMP SYSTEM

TOWLE WHITNEY LLC

TW1000-30W-30 FLAG FRAME

The ***TW1000-30W-30 Flag Frame Booster System*** is equipped with a centrifugal pump regulated by a variable frequency drive that controls the pump operation to maintain constant pressure regardless of varying demand or fluctuation in incoming pressure. This system will supply 30 *GPM with a 30 PSI* overboost.

All parts shown are included in the system
Actual system components may vary
Some assembly required

Features and Benefits:

- Residential & Commercial application
- Quiet, Compact & Powerful
- Variable Frequency Drive controlled pump
- Energy efficient operation
- Prewired & Factory Tested

Lead-Free* (Wetted) components:

- Centrifugal Pump: Cast Iron [SS Option]
- Relief valve: LF Brass or SS
- Pressure Gauge: Stainless Steel
- Transducer: Stainless Steel
- Check valve LF Brass or SS
- Fittings: LF Copper or SS

*All lead-free brass shall contain <.25% Pb

Technical Specifications:

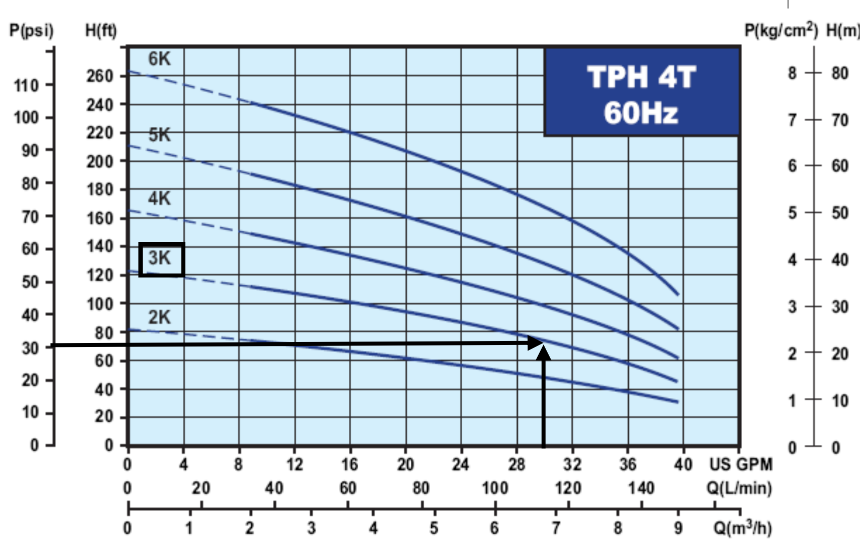
Pump:	Walrus (TEFC) [4T-3K]
Horse Power:	3/4 HP
Controller:	Vacon 20 - NEMA 1 Rating
Flow Rate:	30 GPM
Boost:	30 PSI Overboost
Suction:	1-1/4 inch
Discharge:	1 inch
Tank:	**5** Gallon [PLT-12]
Frame Size:	17” W x 25” H x 17” D
Decibel rating:	<70 db @ 3500 RPM
Weight:	65 lbs (approx.)

SPECIFY WHEN ORDERING

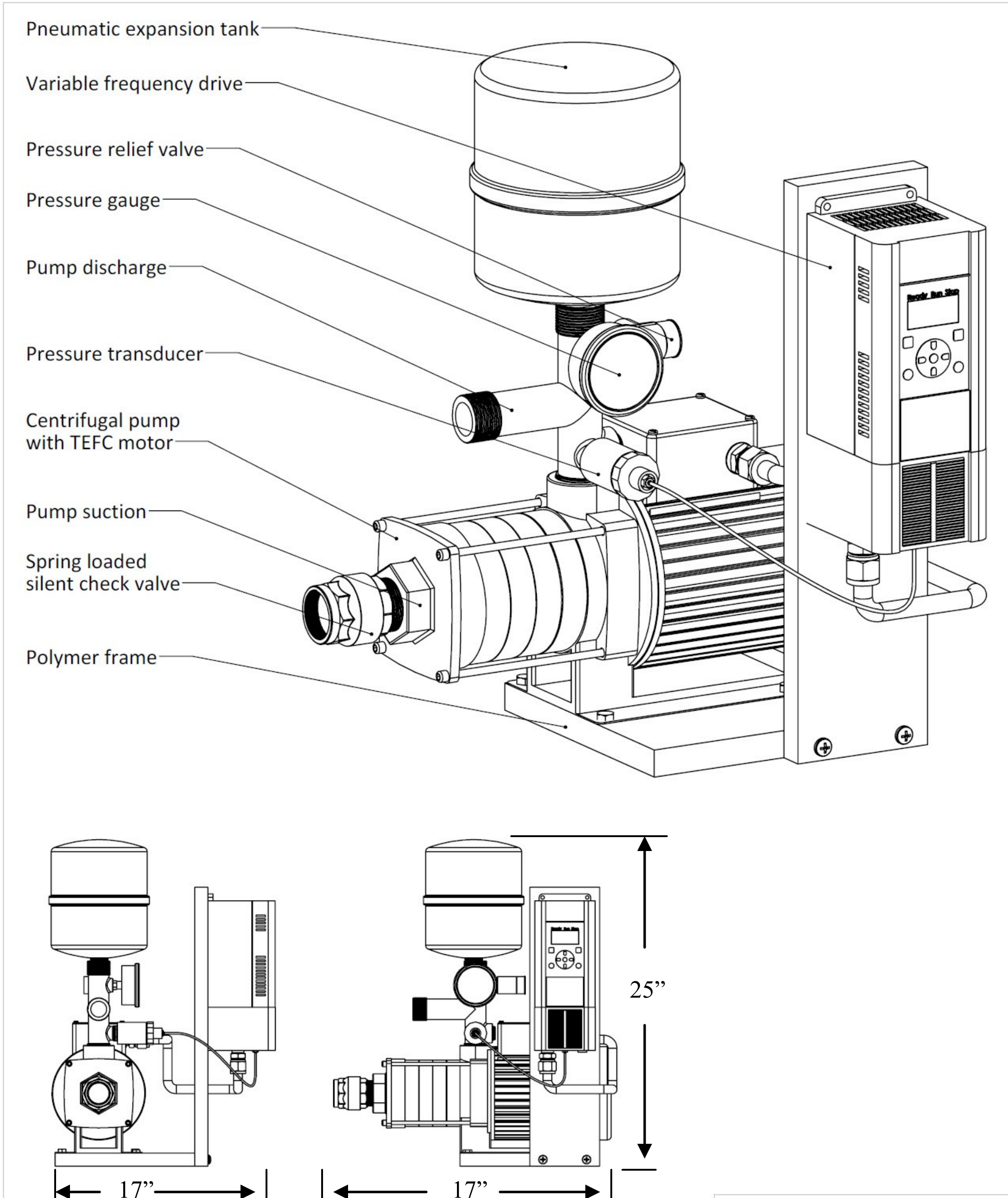
1. Discharge Pressure: __________ PSI
2. Power: Independent circuit recommended

Options	Input Current (Amps)
208-220V/1	11.2
208-220V/3	6.8
360-480V/3	3.2
*115 Plug In	16.5

*Non-GFCI Outlet required



21 Londonderry Turnpike, Hooksett, NH 03106
Tel: 603-626-7371/1-800-807-9827 Fax: 603-626-7372 www.towle-whitney.com info@towle-whitney.com



TOWLE WHITNEY LLC

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DIMENSIONS ARE SUBJECT TO CHANGE
DO NOT USE FOR CONSTRUCTION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	VID	12/5/14
CHECKED		

COMMENTS:

SIZE A | DWG. NO. 120514A | REV.

SCALE:1:10 | WEIGHT: | SHEET 1 OF 1

Assembled Units:

- All "wetted surfaces" shall be lead free (<.25% Pb) in conformance with the 1/4/14 federal law
- Shall have a variable frequency drive (VFD) with a pressure transducer, pressure gauge, and relief valve
- Each system shall have a properly sized air charged pneumatic tank
- Pump shall be connected to a separate and independent disconnect box [supplied by others]

Variable Frequency Drive (VFD) shall:

- Shall be rated using specified power requirement, efficiency shall be 98% or better at full speed
- All factory preset values and/or last saved data values must remain available to the operator in the event of a complete power outage
- Operate to a program that protects the pump against damaging hydraulic conditions such as:
  - Motor overload, pump overflow surges, loss of prime due to incoming water supply interruption, hunting, overload through frequency/current optimization, hydraulic damage by restricting the pumps to operate beyond their published end of curve
- Automatically restart after an over-current, over-voltage, under-voltage or loss of input signal protective trip
- Have an operator control panel [keypad] for customization of parameters
- Include a feature to upload / download parameters into an external device to be used with another drive or the same drive
- Have a removable non-volatile memory device
- Be capable of accepting individual analog inputs from transducer. All transducer inputs must be wired to the variable frequency drive for continuous scan and comparison function
- Utilize a proportional ladder logic program - integral - derivative control function
- Display the following values:
  - Pump running/standby, pump speed in Hz, user adjustable parameters such as PID set points
  - Motor frequency, motor current, threshold set points for PID error, minimum operating frequency
  - Troubleshooting and diagnostics of faults

Transducer:

- Shall be provided to supply all pressure signals to the variable frequency drive
- Shall be rated for required system pressure and shall be 4-20 mA analog

Centrifugal pump:

- Shall have cast iron casing with 304 stainless steel impellers. (All Stainless steel pump is an available upgrade)
- Shall have a 316 stainless steel shaft sleeve and a replaceable tungsten carbide + HNBR mechanical seal
- Mechanical seal shall be rated to withstand pressure of up to 142 PSI
- Motor shall be totally enclosed fan cooled (TEFC) and manufactured in compliance with CE, RoHS and CSA

Pneumatic expansion tank:

- Shall be rated for use with potable water with an operating pressure of a maximum 125 PSI
- Shall be pre-charged to a pressure of 10 PSI below system operating pressure

Valves and fittings:

- Shall be sized appropriately to allow water velocity not exceeding 10 ft/sec, to minimize cavitation and turbulence
- Check valve shall be spring-loaded and silent

Installation:

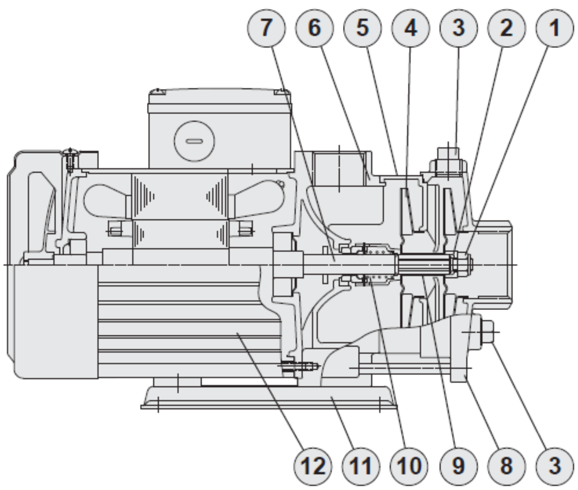
- Equipment shall be installed in accordance with applicable local building, electrical and plumbing codes
- Shall be installed indoors (unless otherwise specified) and protected from water spray

VACON 20 - NEMA 1 RATING

Supply voltage	AC drive type	Output Power and Current High Overload (150%)		
		HP	kW	I_N (A)
110-120 VAC, 1-phase	VACON0020-1L-0001-1-R02	0.33	0.25	1.7
	VACON0020-1L-0002-1-R02	0.5	0.37	2.4
	VACON0020-1L-0003-1-R02	0.75	0.55	2.8
	VACON0020-1L-0004-1-R02	1	0.75	3.7
	VACON0020-1L-0005-1-R02	1.5	1.1	4.8
208-240 VAC, 1-phase	VACON0020-1L-0001-2-R02	0.33	0.25	1.7
	VACON0020-1L-0002-2-R02	0.5	0.37	2.4
	VACON0020-1L-0003-2-R02	0.75	0.55	2.8
	VACON0020-1L-0004-2-R02	1	0.75	3.7
	VACON0020-1L-0005-2-R02	1.5	1.1	4.8
	VACON0020-1L-0007-2-R02	2	1.5	7
	VACON0020-1L-0009-2-R02	3	2.2	9.6
208-240 VAC, 3-phase	VACON0020-3L-0001-2-R02	0.33	0.25	1.7
	VACON0020-3L-0002-2-R02	0.5	0.37	2.4
	VACON0020-3L-0003-2-R02	0.75	0.55	2.8
	VACON0020-3L-0004-2-R02	1	0.75	3.7
	VACON0020-3L-0005-2-R02	1.5	1.1	4.8
	VACON0020-3L-0007-2-R02	2	1.5	7
	VACON0020-3L-0011-2-R02	3	2.2	11
	VACON0020-3L-0017-2-R02	5	4	17.5
	VACON0020-3L-0025-2-R02	7.5	5.5	25
	VACON0020-3L-0031-2-R02	10	7.5	31
	VACON0020-3L-0038-2-R02	15	11	38
380-480 VAC, 3-phase	VACON0020-3L-0001-4-R02	0.5	0.37	1.3
	VACON0020-3L-0002-4-R02	0.75	0.55	1.9
	VACON0020-3L-0003-4-R02	1	0.75	2.4
	VACON0020-3L-0004-4-R02	1.5	1.1	3.3
	VACON0020-3L-0005-4-R02	2	1.5	4.3
	VACON0020-3L-0006-4-R02	3	2.2	5.6
	VACON0020-3L-0008-4-R02	5	3	7.6
	VACON0020-3L-0009-4-R02	6	4	9
	VACON0020-3L-0012-4-R02	7.5	5.5	12
	VACON0020-3L-0016-4-R02	10	7.5	16
	VACON0020-3L-0023-4-R02	15	11	23
	VACON0020-3L-0031-4-R02	20	15	31
	VACON0020-3L-0038-4-R02	25	18.5	38

MULTISTAGE CENTRIFUGAL PUMP

TPH2T/4T/8T/12T



Motors:

- The pump is coupled with (TEFC)
  Totally Enclosed Fan Cooled, squirrel-cage motor.
- Nominal speed: 3500 rpm at 60Hz
- Protection class: IP54
- Insulation class: F

Pumps:

- Horizontal multi-stage centrifugal pump
- Non self-priming
- close coupled design
- Impellers mounted on extended motor shaft.

Materials

No.	Part name	Material		
		Standard	S series	N series
1	Lock Nut	SUS 316	SUS 316	SUS 316
2	Sleeve(Shaft End)	SUS 304	SUS 304	SUS 316
3	Water Plug	FC 20	SUS 304	SUS 316
4	Impeller	SUS 304	SUS 304	SUS 316
5	Intermediate Chamber	SUS 304	SUS 304	SUS 316
6	Pump Casing	FC 20	SUS 304	SUS 316
7	Shaft	SUS 304	SUS 304	SUS 316
8	Suction Chamber	FC 20	SUS 304	SUS 316
9	Sleeve	SUS 304	SUS 304	SUS 316
10	Mechanical Seal	Tungsten carbide + HNBR		
11	Mounted Base	Coating Steel		SUS 316
12	Motor Shell	Aluminum alloy		

SUS 304 may be replaced by SUS316 depended on stock availability.

Operating Limits:

- Ambient temperature: Max. 104°F (40°C)
- Liquid temperature range: 32°F (0°C) to 194°F (90°C)
- Operating pressure: Max. 142 psi
- Inlet pressure: Max 85 psi

Suitable Liquids:

- Clean or other non-corrosive liquids

Models: PLT-5, PLT-12, PLT-20

Air Side Pre-pressure (psi)	(bar)	Water Side Volume at 150psi (10.3 bar) (gallons) PLT-5	PLT-12	PLT-20
20	**(1.4)**	1.48	3.42	7.102
40	**(2.8)**	1.26	2.88	5.882
60	**(4.1)**	1.0	2.49	4.705
80	**(5.5)**	.80	1.85	4.009

Description	PLT-5 Order No. 0067370	PLT-12 Order No. 0067371	PLT-20 Order No. 0067372
Max. Pressure - psi	150	150	150
Max. Temp. - °F	200	200	200
Tank Volume - gal.	2.1	4.5	8.5
Tank Acceptance - gal.	1.26	2.8	3.4
Air Pre-charge - psi	20	20	20
Connections Size - in.	¾ male	¾ male	¾ male
Diameter - in.	8	10.5	12½
Length - in.	11	13.5	$19\frac{3}{16}$
Weight - lbs.	5.5	10	15

Certified to ANSI/NSF 61 (73°F/23°C)

Listed by IAPMO

Disclaimer: The manufacturer of this tank does not accept any liability or other responsibility for personal injury or property damage resulting from improper use, installation or operation of this tank or the system of which it is a part.

Notice: The expansion tank, piping and your connections may in time leak. Select a location to install the expansion tank where a water leak will not damage the surrounding area. The manufacturer is not responsible for any water damage in connection with this expansion tank.

CALIFORNIA PROPOSITION 65 WARNING

WARNING: This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm. (California law requires this warning to be given to customers in the State of California.)

For more information: www.watts.com/prop65

Limited Warranty: Watts Regulator Co. (the "Company") warrants each product to be free from defects in material and workmanship under normal usage for a period of one year from the date of original shipment. In the event of such defects within the warranty period, the Company will, at its option, replace or recondition the product without charge.
THE WARRANTY SET FORTH HEREIN IS GIVEN EXPRESSLY AND IS THE ONLY WARRANTY GIVEN BY THE COMPANY WITH RESPECT TO THE PRODUCT. THE COMPANY MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED. THE COMPANY HEREBY SPECIFICALLY DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.
The remedy described in the first paragraph of this warranty shall constitute the sole and exclusive remedy for breach of warranty, and the Company shall not be responsible for any incidental, special or consequential damages, including without limitation, lost profits or the cost of repairing or replacing other property which is damaged if this product does not work properly, other costs resulting from labor charges, delays, vandalism, negligence, fouling caused by foreign material, damage from adverse water conditions, chemical, or any other circumstances over which the Company has no control. This warranty shall be invalidated by any abuse, misuse, misapplication, improper installation or improper maintenance or alteration of the product.
Some States do not allow limitations on how long an implied warranty lasts, and some States do not allow the exclusion or limitation of incidental or consequential damages. Therefore the above limitations may not apply to you. This Limited Warranty gives you specific legal rights, and you may have other rights that vary from State to State. You should consult applicable state laws to determine your rights. **SO FAR AS IS CONSISTENT WITH APPLICABLE STATE LAW, ANY IMPLIED WARRANTIES THAT MAY NOT BE DISCLAIMED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED IN DURATION TO ONE YEAR FROM THE DATE OF ORIGINAL SHIPMENT.**

ISO 9001-2000 CERTIFIED

Booster Pump Systems

Three Year Limited Warranty

This warranty applies to booster pump systems built by Towle Whitney LLC, and shall:

- Exist 36 months from the date of shipment.
- Be in effect only after installation photographs are received by Towle-Whitney LLC.

Towle-Whitney LLC liability under this warranty shall be limited to the repair or replacement of any part or parts found to be defective (material or workmanship) within the warranty period. Towle-Whitney LLC shall determine whether the part needs to be returned, or field scrapped. The warranty excludes:

- Any water damage or consequential damage.
- Transducers & Pump Seals.
- Debris in water causing internal pump damage.
- Systems not installed in accordance with Installation and Maintenance Instructions.
- Labor, transportation, and related costs incurred by the customer.
- Misuse, negligence, inappropriate chemicals or additives in water.
- Inadequate protection from freezing.
- Lightning, high voltage spikes, accidents, floods, or acts of God.
- Re-Installation costs of repaired or replacement equipment.
- Re-Imbursement for the loss caused by interruption of service.
- Adjusting drive parameters without consulting factory.

This warranty applies to all states and territories of the United States and Canada only. There are no express or implied warranties, including merchantability or fitness for a particular purpose, which extend beyond those warranties described or referred to above.

Some jurisdictions do not allow the exclusion or limitation of incidental or consequential damages and some jurisdictions do not allow limit actions on how long implied warranties may last. Therefore, the above limitations or exclusions may not apply. This warranty gives you specific legal rights and you may also have other rights which vary from jurisdiction to jurisdiction.

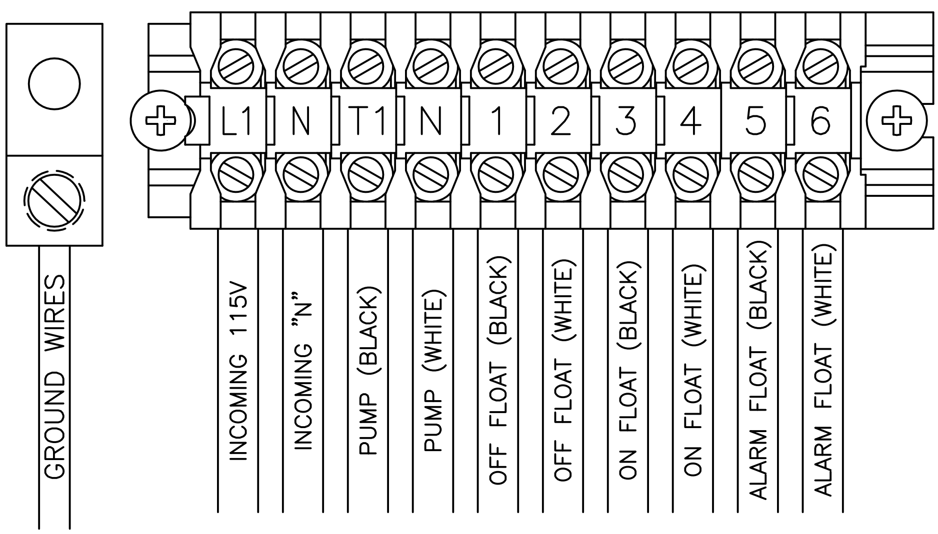
Appendix D-5: Control Panel Detail

MODEL NO.
SSC1B

PAGE
1

CONNECTION DIAGRAM

REQUIRED TORQUE FOR TERMINAL BLOCK SCREWS IS 16 in-lbs.



SPI Septic Products Inc.

CHANGES		TOLERANCES	DRAWN BY	DATE
F		DECIMALS .XXX = ±.005 .XX = ±.010 FRACTIONAL X/X = ±.1/64 ANGLES X° = ±1/2°	C. BARRICK	05/27/09
E			MATERIAL SPECIFICATION: AS NOTED	
D				
C				
B				
A				

115V SIMPLEX
TERMINAL CONNECTIONS

SCALE: FULL

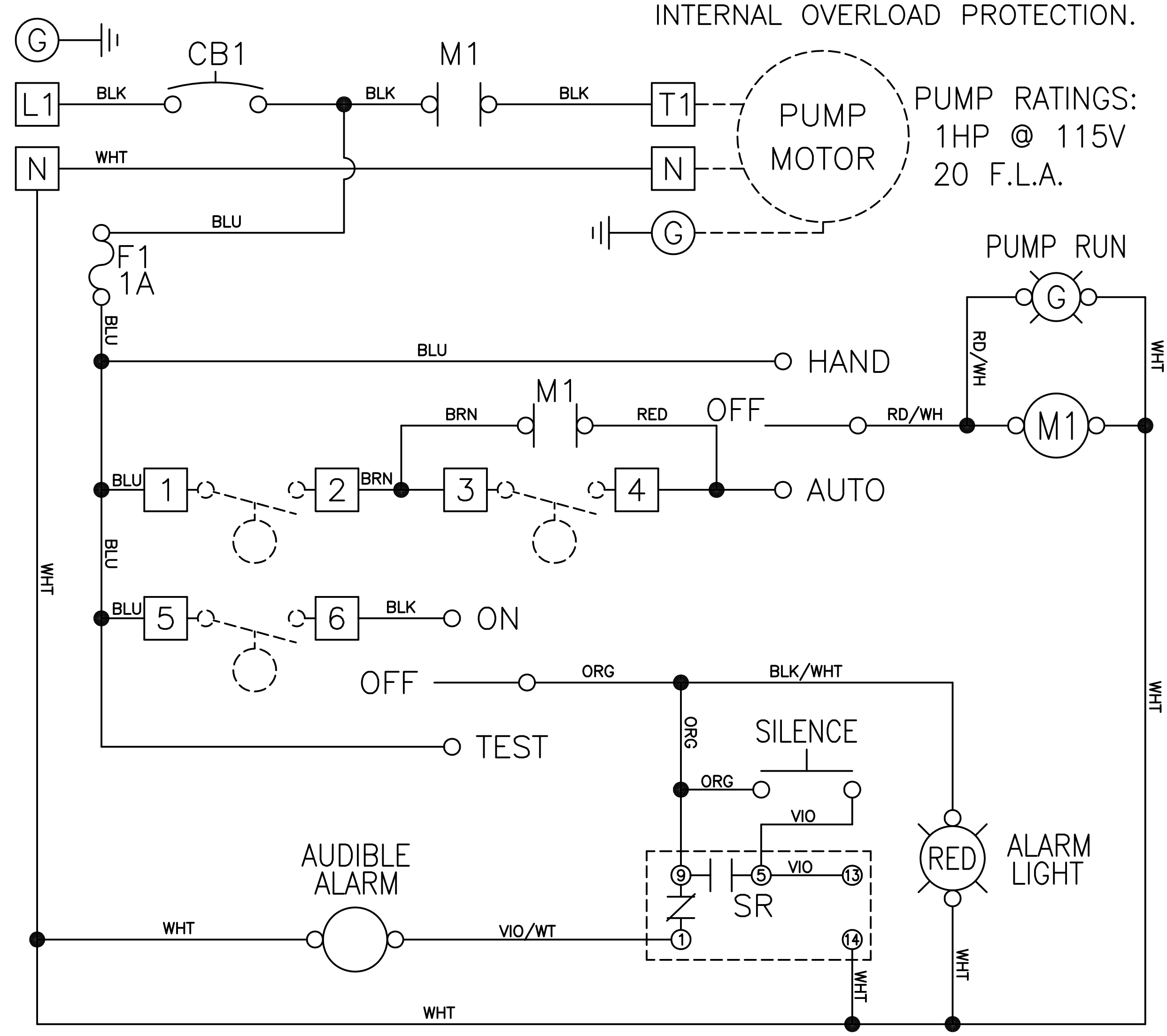
PART NO. 50A001

MODEL NO.
SSC1B

PAGE
2

POWER CIRCUIT
115V – 1PH

NOTE: PUMP MOTOR MUST HAVE
INTERNAL OVERLOAD PROTECTION.



NOTES: FLOAT SWITCH TO BE RATED 2 AMP AT 120V MINIMUM.
MAIN PANEL DISCONNECT MUST BE PROVIDED BY INSTALLER.
DASHED LINES INDICATE ITEMS NOT CONTAINED IN THE PANEL.
FIELD WIRING MUST BE A MINIMUM OF 60°C COPPER WIRE.
REQUIRED TORQUE FOR TERMINAL BLOCK SCREWS IS 16 in–lbs.

Septic Products Inc.

CHANGES	TOLERANCES	DRAWN BY	DATE
F, E, D, C, B, A	DECIMALS .XXX = ±.005 .XX = ±.010 FRACTIONAL X/X = ±.1/64 ANGLES X° = ±1/2°	D. MIDDLETON	03/22/05
		MATERIAL SPECIFICATION: AS NOTED	

115V SIMPLEX
SCHEMATIC

SCALE: FULL

PART NO. 50A001

Appendix D-6: Pipeline Elements

Pipeline

Water Meter

Manufacturer: Assured Automation (https://www.atlasied.com/sfd24)

Specification: ½" Plastic Water Meter – WM-PC-050-CF

Description: Specification sheet attached.

Metal Spigot

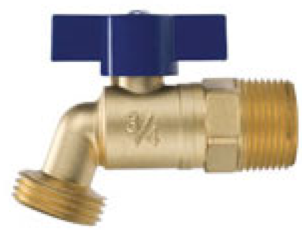
Manufacturer: NIBCO (http://www.nibco.com/Valves/Specialty-Valves/Hose-End-Valves/)

Specification: 1/2" Quarter Turn Hose Bibb – QT56X

Description: Suitable for potable water system (excluding the US). Specification sheet attached.

Features:

- Valve Pressure Rating: 125 psi to 100 degrees F
- Maximum Temperature: 180 degrees F/82.2 degrees C
- Brass Construction
- Solder cup or MIP to connection



Air Release Valves

Manufacturer: PLAST-O-MATIC (https://plastomatic.com/arv.html)

Specification: Series ARV Thermoplastic Air Release Valve

Description: Self-guided poppet assures dependable repetitive operation. Product data attached.

Valve Box

Manufacturer: Grainger (https://www.grainger.com/product/NDS-9-1-2-x-12-7-8-x-11-5-8-Round-20RE33)

Specification: 9-1/2” x 12-7/8” x 11-5/8” Round, NDS Valve Box

Description: PVC valve box suitable for use in commercial, residential, golf course, and municipal landscape applications.

WM-PC Series

Plastic Water Meter

Certified to NSF/ANSI 61-G

The WM-PC Series plastic water meter is an multi-jet style meter available in sizes from 1/2″ to 1-1/2″ with a dry type register for residential applications and designed to meet AWWA C708. The product complies with NSF/ANSI 61 Annex G and conforms with lead-free plumbing as defined by California, Vermont, Maryland and Louisiana state laws and the U.S. Safe Drinking Water Act that took effect January, 2014. It is an ideal choice for a range of municipal and industrial water metering applications.

Water flows through the meter's strainer (inlet and internal) and into the measuring chamber where it drives the impeller. A driving magnet transmits the movement of the impeller to a driven magnet located within the sealed register. The magnet is connected to a gear train which translates the impeller rotations into volume totalizers displayed on the meter's register dial face.

The WM-PC Series water meter is top loaded and consists of three basic components: main case, measuring chamber, and head ring. The main cases of all sizes are constructed with a sturdy polymer.

All meters include pipe adapters (2 gaskets, 2 couplings, and 2 nuts) with nuts and couplings made from the same polymer as the main case.

FEATURES

- All parts in contact with water are constructed of corrosion-resistant materials.
- Body is constructed of reinforced plastic.
- Impeller is the only moving part in contact with water, giving the meter long life and consistantly reliable operation.
- Extra filter at the inlet of the meter body permits cleaning without having to open the meter.
- Dial plate design in US Gallons.
- Optional pulse output consisting of plastic housing with contact reed switch and cable.

MATERIALS OF CONSTRUCTION

Body:
FRP (fiber reinforced polymer)

Internals:
Engineered thermoplastic

Magnet:
Alnico

PRESSURE RANGE

Up to 150 PSI.

TEMPERATURE RANGE

Up to 105°F.

SPECIFICATIONS

Maximum Reading:
050, 075 & 100: 9,999,999.99
150: 99,999,999.9

Accuracy:
Normal flow: ±1.5%
Low flow: ±3%

OPTIONAL PULSE OUTPUT SPECIFICATIONS

Sensor:
Reed switch

Pulse Rates:
050, 075 & 100: 1 pulse/1 gal.
150: 1 pulse/10 gal.

Maximum Current:
20 mA

Maximum Voltage:
24 VAC/VDC

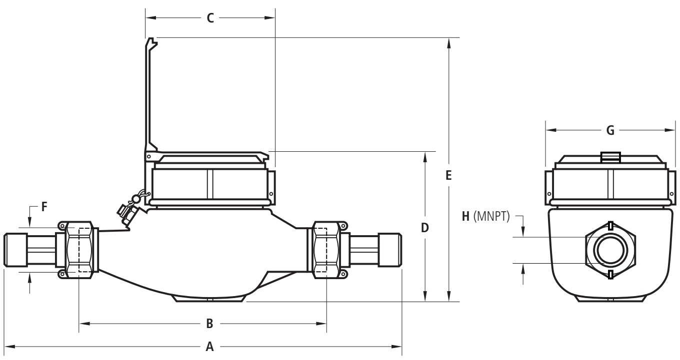
Cable Length:
4.5′ standard,
2000′ maximum run

WM-PC Series

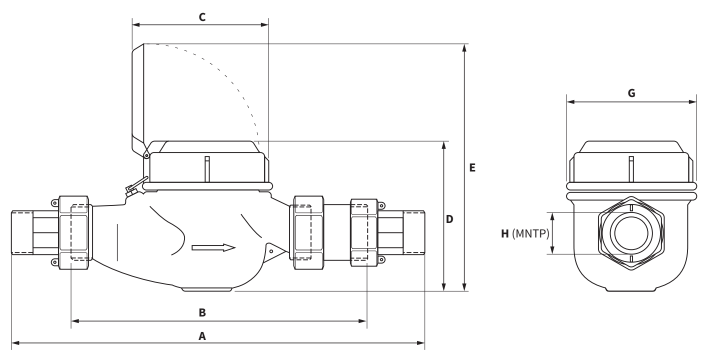
Plastic water meter
(1/2″ to 1-1/2″ end connections)

DIMENSIONS, WEIGHTS & SPECIFICATIONS

(1/2″ to 1″ end connections)



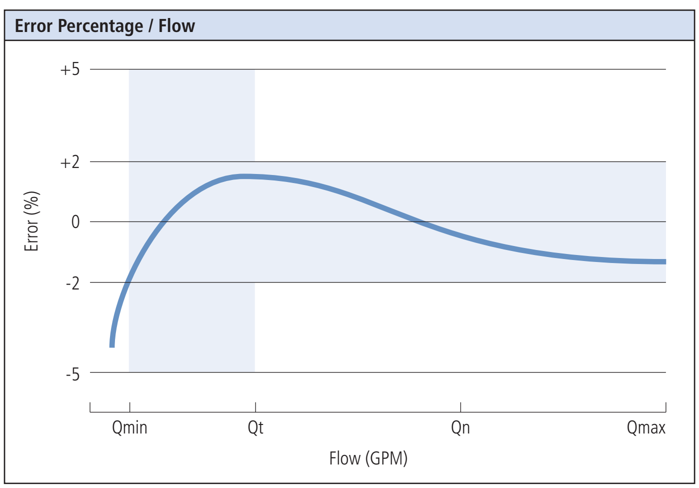
(1-1/2″ end connections)



Size	A	B	C	D	E	F	G	H (MNPT)	Flow Rate (GPM)			Normal Flow (GPM) (Qt - Qn)	Wt. (lbs.)	Model No.
									Low (Qmin)	Continuous	High (Qmax)			
5/8″ x 1/2″	10.20	6.50	3.70	4.24	7.52	0.75	3.70	0.50	0.25	10	20	1-20	1.65	WM-PC-050
5/8″ x 3/4″	11.58	7.50	3.70	4.24	7.52	1.00	3.70	0.75	0.25	10	20	1-20	1.87	WM-PC-075
1″	15.12	10.25	3.86	4.63	8.13	1.25	3.86	1.00	0.75	25	50	3-50	2.64	WM-PC-100
1-1/2″	17.00	12.00	5.13	6.38	10.25	2.31	5.25	1.50	1.50	50	100	5-100	4.78	WM-PC-150

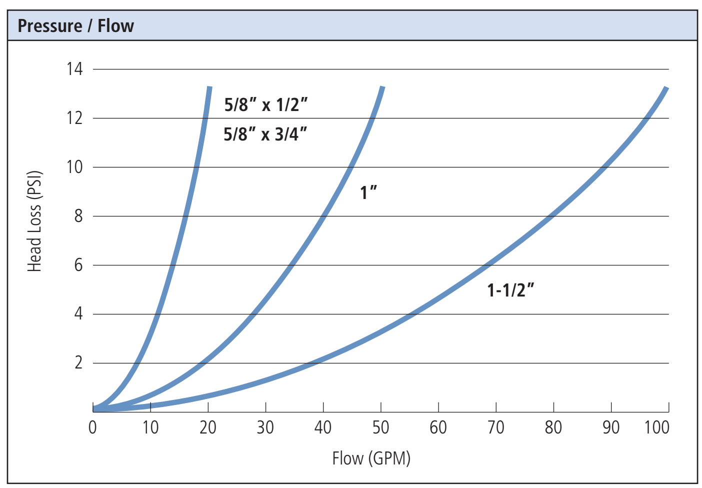
A = total length including connection and gasket without compression.

ACCURACY CURVE



Note: refer to chart above for Qmin, Qmax, Qt, Qn values

HEAD LOSS CURVES

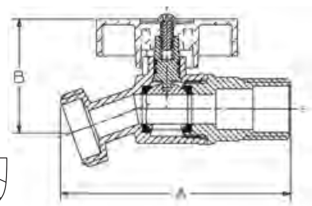


Hose Bibbs

125 lb. CWP to 100°F
Maximum Temperature 180°F

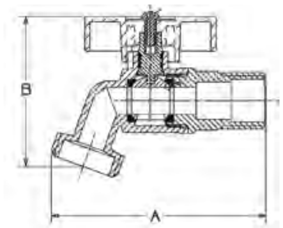
QUARTER TURN HOSE BIBBS MATERIALS LIST

PART	SPECIFICATION
Screw	Steel
I.D. Tag	Aluminum
Handle	Zinc
Stem	Brass ASTM B 16 UNS C36000
O-Ring	Nitrile
Seat	PTFE
Ball	Brass ASTM B 16 UNS C36000
Adapter	Brass ASTM B 283 UNS C37700
Body	Brass ASTM B 283 UNS C37700



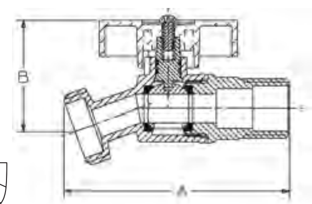
QT54X

DESCRIPTION	Nom. Size	DIMENSIONS		APPROX. NET WT.
		A	B	
NO-KINK HOSE BIB Male or Cup to Hose	½	3.15"	1.54"	.40 lb
	¾	3.15"	1.54"	.42 lb

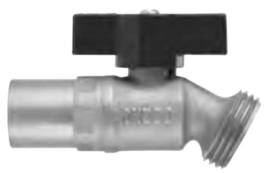
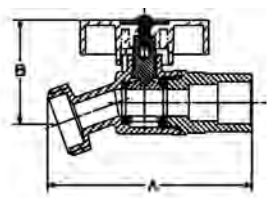
QT56X

DESCRIPTION	Nom. Size	DIMENSIONS		APPROX. NET WT.
		A	B	
HOSE BIBB Cup or Male to Hose Male Thread to Hose	½	3.15"	2.17"	.40 lb
	¾	3.15"	2.14"	.42 lb

QT55X

DESCRIPTION	Nom. Size	DIMENSIONS		APPROX. NET WT.
		A	B	
NO-KINK HOSE BIBB FIP to Hose	½	2.87"	1.54"	.40 lb
	¾	3.15"	1.54"	.45 lb

QT57X

DESCRIPTION	Nom. Size	DIMENSIONS		APPROX. NET WT.
		A	B	
NO-KINK HOSE BIBB ½ Cup or ¾ Ftg. to Hose	½" or ¾"	3.11"	1.54"	.42 lb

WARNING: This product can expose you to chemicals including lead, which is known to the State of California to cause cancer and birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

NOT FOR USE WITH POTABLE DRINKING WATER APPLICATIONS AFTER JANUARY 3, 2014.

SERIES "ARV"
THERMOPLASTIC AIR RELEASE VALVE
SELF-GUIDED POPPET ASSURES DEPENDABLE, REPETITIVE OPERATION

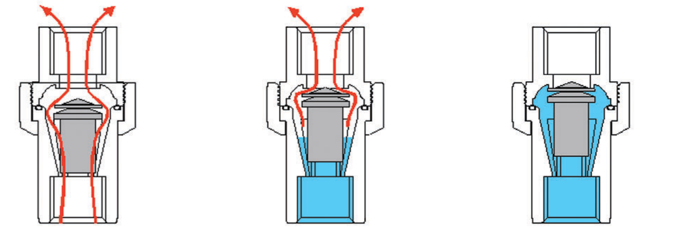
FEATURES:

- **Safety:** Allows safe expulsion of unwanted air in piping system.
- **Dependability:** Unique self-guided poppet assures minimal emission of system liquid prior to sealing.
- **Convenience:** Union simplifies valve inspection/removal with minimum piping breakdown.
- **Minimum Closing Pressure:** Closes at 0 PSI, as long as liquid is present. Valve closes as liquid rises, after virtually all unwanted air is forced out. Seals bubble-tight at system pressures as low as 10 psi (EPDM seals).
- **Cost Efficient:** Designed to improve system performance and competitively priced.
- **Superior Design:** Poppet seals more reliably than ball design; does not deform under pressure like a hollow ball.
- **Corrosion Resistant:** Top quality thermoplastics and elastomers resist chemical attack and protect system purity. No metal components in Series ARV.

DESCRIPTION

Series ARV is a normally-open valve. Until your system is pressurized, the valve is simply open, and air is present. As pressure builds within the system, unwanted air is forced to the highest point in the system, i.e., the normally-open air release valve. When pressure within the system exceeds atmospheric pressure, air is expelled. As liquid rises, the poppet becomes buoyant and eventually closes. (Note, minimum specific gravity of liquid must be .9 or higher). It is possible that trace amounts of air will remain in the system, depending on the rapidity with which the valve closes. It is also likely that some trace amounts of process liquid will be emitted. At system pressure of 10 PSI (with EPDM elastomer), the poppet will seal bubble-tight against the orifice. When pressure and liquid level drop, the valve will automatically re-open.*

The poppet is guided by a series of thermoplastic ribs within the valve. The poppet is a unique design by Plast-O-Matic Valves, Inc. that is engineered to provide a balance of buoyancy and sealability. This balanced poppet is the key to the superior performance of this valve: it is dense enough to permit maximum emission of unwanted system air, yet buoyant enough to affect a quick seal and minimize emission of the process liquid. Historically, competitive air release valves have used ball-type sealing mechanisms that either seal too rapidly or allow excessive liquid to escape.



OPEN *air under pressure flows out* — **CLOSING** *liquid causes poppet to rise; air under pressure still flows out* — **CLOSED** *as liquid continues to rise; poppet seals against orifice*

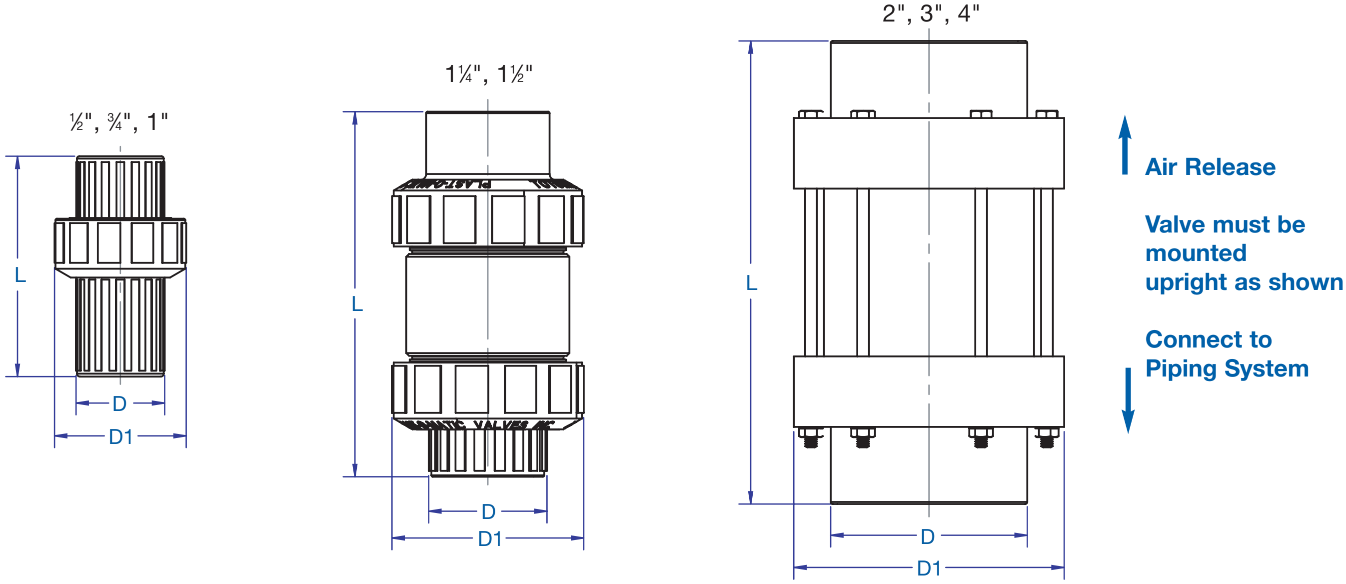
**Note:* Although Series ARV is a normally-open valve, it should not be used in lieu of a vacuum breaker due to safety considerations, such as continual emission of corrosive vapors.

ARV-1115-C-1

1384 Pompton Avenue, Cedar Grove, NJ 07009 USA (973) 256-3000 • Fax (973) 256-4745 • www.plastomatic.com

INSTALLATION:

Series ARV should be installed at the highest possible point in a piping system or vessel, and it must be oriented upright. In most cases, residual liquid and/or vapor in the valve may be expelled from the outlet port just prior to valve shut-off. Therefore, it is recommended to pipe the outlet port to a safe area for hazardous liquids, or use a standpipe for non-hazardous



SERIES ARV – DIMENSIONS AND MODEL NUMBERS									
PIPE SIZE NPT	L		D		D1		MODEL NUMBER	MAX. FLOW IN LINE SCFM	MAX. FLOW IN LINE GPM**
	in.	mm	in.	mm	in.	mm			
½"	5.3	130	1.9	48	2.8	72	ARV050EPT-PV	11	82
¾"	5.3	130	1.9	48	2.8	72	ARV075EPT-PV	11	82
1"	4.7	120	1.9	48	2.8	72	ARV100EPT-PV	12	89
1¼"	7.8	197	2.5	64	4.1	103	ARV125EPT-PV	38	284
1½"	7.8	197	2.5	64	4.1	103	ARV150EPT-PV	40	299
2"	8.4	214	3.0	76	4.1	103	ARV200EPT-PV	40	299
3"	9.8	250	4.2	106	5.8	146	ARV300EPT-PV	75	560
4"	11.7	298	5.8	146	7.9	200	ARV400EPT-PV	220	1645

ARV(series) 050 (size) EP (material) T (threaded) - PV (body material).
Part numbers shown are EPDM seals with PVC bodies.

- For FKM seals, change "EP" to "V" (ARV050VT-PV).
- For Corzan CPVC, change "-PV" to "-CP" (ARV050VT-CP).
- Standard connections are threaded. For socket connection, change "T" to "S" after seal material (ARV050EPS-PV)
- For spigot or other connection types, consult factory.
- For optional dust cap, consult factory.

** Note that excess of maximum pipeline GPM, airflow out of the valve will have sufficient force to lift and close the poppet, even though more air may be in the system. Liquid pumping into the system at flow rate exceeding maximum GPM will create air flow in excess of maximum SCFM.

ADDITIONAL SPECIFICATIONS		
Pressure required for bubble-tight seal	EPDM Elastomer: 10 PSI	FKM Elastomer 15-20 PSI
Pressure Rating at 75°F (24°C)	150 PSI	

Photos are representative. Appearance may vary based on size/materials.

ARV-1115-C-2

Appendix D-7: Door for Pump Stations

Pump Station

Steel Door

Manufacturer: AtlasIED (https://www.atlasied.com/sfd24)

Specification: Solid Steel Front Door for 24RU WMA, 100, and 200 Series Racks

Description: Installs quickly without drilling. Gripsert nuts on the SFD front doors and WMA, 100, 200, racks allow doors to be installed after the equipment is installed. All hardware and lockset included.

Features:

- 1" Depth
- All Hardware Included
- CRS Construction
- Solid Front Door Assembly

Specifications:

- Rack Units: 24
- Height: 42"
- Width: 20"
- Depth: 1"
- Shipping Weight: 23 lb.

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Appendix E: Recommended Spare Parts and Tooling

On Hand Tooling		
Item Description	**Unit**	**Quantity**
Hammer	ea	1
Rubber Mallet	ea	1
Hacksaw	ea	1
Cordless Drill	ea	1
Drill Bit Set	ea	1
Cordless Screwdriver	ea	1
Screwdriver Set	ea	1
Wrench Set	ea	1
Wire Cutter (sized for fencing)	ea	1
Bolt Cutter	ea	1
Circular Saw	ea	1
Circular Saw Blades for Wood	ea	1
Circular Saw Blades for Metal	ea	1

Item Description	Unit	Quantity
General System		
8d 2-½ Nails (5lb Box)	ea	1
3” PVC Pipe, SDR 26 - 20ft	ea	2
2” PVC Pipe, SDR 26 - 20ft	ea	2
1” PVC Pipe, SDR 26 - 20ft	ea	2
1/2” PVC Pipe, SDR 26 - 20ft	ea	2
3” Elbow	ea	2
2” Elbow	ea	2
1” Elbow	ea	4
3” 45 Elbow, SCH 40	ea	2
2” 45 Elbow, SCH 40	ea	2
1” 45 Elbow, SCH 40	ea	4
2”x2”x2” Tee, SCH 40	ea	2
1”x1”x1” Tee, SCH 40	ea	4
2” Cross, SCH 40	ea	2
1” Cross, SCH 40	ea	1
3" x 1" Reducer, SCH 40	ea	1
2"x1" Reducer, SCH 40	ea	2
2" x 1/2" Reducer, SCH 40	ea	4
1" x 1/2" Reducer SCH 40	ea	4
3" Valve, SCH 40	ea	1
2" Valve, SCH 40	ea	1
1" Valve, SCH 40	ea	1
3" Sure-Vent PVC Air Admittance Valve	ea	1
2" Sure-Vent PVC Air Admittance Valve	ea	2
1.5" Sure-Vent PVC Air Admittance Valve	ea	1
10" Circular Valve Box (12" deep)	ea	2
2" Vent Cap	ea	4
PVC Primer, Clear - 32 oz	ea	1
PVC Cement, Regular Body, Medium Set - 32 oz	ea	1
Locks	ea	2
Electrical		
Float Switch	ea	1
Gate Valve	ea	1
Fence		
6'x50' Chain Link Roll	ea	1
6' Tension Bar	ea	6
2-3/8" Tension Band	ea	12
Panel Clamps - 2 ct.	ea	3
5/16"x1-1/4" Carriage Bolt w/Nut - 20 ct.	ea	1
Farmgard 1,320 ft. 15-1/2-Gauge Barbed Wire	ea	1
Structures		
26'x 41" Rib Zinc Roof Panel	ea	1
1/16" Stainless Steel Cable	ft	12
Stoppers for Stringer	ea	2
Cable Clamps (4/stringer)	ea	4
Cable Eyelet	ea	2
Water Distribution		
1/2" Galvanized Steel Two Hole Strap - 10 ct.	ea	2
#8 x 1-1/4 in. Phillips Screw - 100 ct.	ea	1
1/2" Male x Hose Bibb	ea	4
1/2" MNPT x CTS Hub CPVC Adapter	ea	4
1/2" Connection Plastic Water Meter	ea	2
6" Water Meter Box	ea	2

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Appendix F: Project Planning

Appendix F-1: Detailed Cost Estimate

Appendix F-2: Bill of Materials

Appendix F-3: Construction Schedule

Appendix F-1: Detailed Cost Estimate

CE 4916 - Fall 2019 **Bid Packages 1 - 8**
Embera Puru Water Supply and Distribution System

General Wage	5
Electrical Wage	8

Item No.	Description	Unit	Quantity	Crew	Daily Output	Task Days	Task Hours	MATERIALS		LABOR		EQUIPMENT		Unit Price	Complete Total
								$/Unit	Cost	$/Unit	Cost	$/Unit	Cost		
Bid Package 1 - Sitework															
1.1	Removal of Ultrafiltration System	ea	1	2	1	1	8			$0.00	$0.00	$800.00	$1,600.00	$850.00	$1,600.00
	TOTALS						**8.0**		**$0.00**		**$0.00**		**$1,600.00**		**$1,600.00**
Bid Package 2 - Water Collection Structure															
2.1	Excavation - Spring Source	bcy	70	4	12	5.8	46.7			$0.00	$0.00				$0.00
2.2	Catchment Installation	ea	1	4	0.5	2	16			$346.40	$346.40	$50.00	$50.00	$396.40	$396.40
2.2.1	Concrete	yd	2.5					$84.50	$211.25					$84.50	$211.25
2.2.2	#4 Rebar 20' Long	ea	32					$6.89	$220.48					$6.89	$220.48
2.2.3	Rebar Chairs	ea	14					$1.00	$14.00					$1.00	$14.00
2.2.4	Tie Wire	ft	40					$0.02	$0.80					$0.02	$0.80
2.2.5	Form Lumber	ea	1					$200.00	$200.00					$200.00	$200.00
2.2.6	Cendrex PPA 24x36 Aluminum Hatch with keyed handle cam latch	ea	1					$495.54	$495.54					$495.54	$495.54
2.2.7	8d 2-1/2 Nails (5lb Box)	ea	0.5					$72.00	$36.00					$72.00	$36.00
2.2.8	Rip Rap for Settlement	ton	9					$16.69	$150.21			$33.33	$299.97	$50.02	$450.18
2.3	Wet Well Installation	ea	1	2	0.5	2	16			$346.40	$346.40	$50.00	$50.00	$396.40	$396.40
2.3.1	Concrete	yd	3.5					$84.50	$295.75					$84.50	$295.75
2.3.2	#4 Rebar 20' Long	ea	23					$6.89	$158.47					$6.89	$158.47
2.3.3	Rebar Chairs	ea	32					$1.00	$32.00					$1.00	$32.00
2.3.4	Tie Wire	ft	60					$0.02	$1.20					$0.02	$1.20
2.3.5	Form Lumber	ea	1					$200.00	$200.00					$200.00	$200.00
2.3.6	Cendrex PPA 24x36 Aluminum Hatch with keyed handle cam latch	ea	1					$495.54	$495.54					$495.54	$495.54
2.3.7	8d 2-1/2 Nails (5lb Box)	ea	0.5					$72.00	$36.00					$72.00	$36.00
2.4	Clean-out, Overflow, and Vent Pipe	ea	1	2	1	1	8			$173.20	$173.20			$173.20	$173.20
2.4.1	2" PVC Pipe, SDR 26 - 20 ft	20 LF	4					$11.99	$47.96					$11.99	$47.96
2.4.2	2" Valve, SCH 40	ea	4					$6.39	$25.56					$6.39	$25.56
2.4.3	2" Elbow, SCH 40	ea	7					$1.23	$8.61					$1.23	$8.61
2.4.4	2"x2"x2" Tee, SCH 40	ea	3					$1.52	$4.56					$1.52	$4.56
2.4.5	2" Vent Cap	ea	4					$11.99	$47.96					$11.99	$47.96
2.4.6	PVC Primer, Clear	32 oz/cnt	1					$10.29	$10.29					$10.29	$10.29
2.4.7	PVC Cement, Regular Body, Medium Set	32/cnt	1					$12.89	$12.89					$12.89	$12.89
2.5	Spring Fence - 200'	ea	1	4	0.5	4	32			$692.80	$692.80	$50.00	$50.00	$742.80	$742.80
2.5.1	6'x50' Chain Link Roll	ea	4					$174.20	$696.80					$174.20	$696.80
2.5.2	2-3/8" x 2-3/8"x 9-ft Fence Post	ea	26					$29.43	$765.18					$29.43	$765.18
2.5.3	6'x6' Hinged Gate	ea	1					$99.00	$99.00					$99.00	$99.00
2.5.4	6' Tension Bar	ea	14					$6.85	$95.90					$6.85	$95.90
2.5.5	2-3/8" Tension Band	ea	42					$0.98	$41.16					$0.98	$41.16
2.5.6	Panel Clamps	2/bg	2					$4.57	$9.14					$4.57	$9.14
2.5.7	5/16"x1-1/4" Carriage Bolt w/Nut	20/bg	3					$5.89	$17.67					$5.89	$17.67
2.5.8	Farmgard 1,320 ft. 15-1/2-Gauge Barbed Wire	ea	0.5					$63.25	$31.63					$63.25	$31.63
	TOTALS						**118.7**		**$4,461.55**		**$1,558.80**		**$449.97**		**$6,470.32**

KRV Water Solutions, Inc.

Item No.	Description	Unit	Quantity	Crew	Daily Output	Task Days	Task Hours	MATERIALS		LABOR		EQUIPMENT		Unit Price	Complete Total
								$/Unit	Cost	$/Unit	Cost	$/Unit	Cost		
Bid Package 3 - Pipework															
3.1	Initial Clearing of Supply Line	SF	10500	15	1	0.375	3			$0.00	$0.00	$0.01	$75.00	$0.01	$75.00
3.2	Transport of Pipe	crate	4	2	1	1	8			$86.60	$346.40	$150.00	$600.00	$236.60	$946.40
3.3a	Pipe Installation - Supply Line 10 ft	10 LF	14	8	4	21	168			$259.80	$3,637.20	$0.94	$13.13	$260.74	$3,650.33
3.3b	Pipe Installation - Distribution System 15 ft	15 LF	414	8	4	76	608			$0.00	$0.00	$0.35	$145.43	$0.35	$145.43
3.3.1	3" PVC Pipe, SDR 26 - 20ft	20 LF	85					$26.99	$2,294.15					$26.99	$2,294.15
3.3.2	2"PVC Pipe, SDR 26 - 20ft	20 LF	145					$11.99	$1,738.55					$11.99	$1,738.55
3.3.3	1" PVC Pipe, SDR 26 - 20ft	20 LF	177					$7.09	$1,254.93					$7.09	$1,254.93
3.3.4	1/2" PVC Pipe, SCH 40 - 20ft	20 LF	17					$3.96	$67.32					$3.96	$67.32
3.3.5	3" Elbow, SCH 40	ea	10					$4.69	$46.90					$4.69	$46.90
3.3.6	2" Elbow, SCH 40	ea	5					$1.23	$6.15					$1.23	$6.15
3.3.7	1" Elbow, SCH 40	ea	66					$0.42	$27.72					$0.42	$27.72
3.3.8	3" 45 Elbow, SCH 40	ea	12					$6.79	$81.48					$6.79	$81.48
3.3.9	2" 45 Elbow, SCH 40	ea	24					$1.71	$41.04					$1.71	$41.04
3.3.10	1" 45 Elbow, SCH 40	ea	18					$0.63	$11.34					$0.63	$11.34
3.3.11	2"x2"x2" Tee, SCH 40	ea	35					$1.52	$53.20					$1.52	$53.20
3.3.12	1"x1"x1" Tee, SCH 40	ea	10					$0.64	$6.40					$0.64	$6.40
3.3.13	2" Cross, SCH 40	ea	6					$3.75	$22.50					$3.75	$22.50
3.3.14	1" Cross, SCH 40	ea	2					$1.71	$3.42					$1.71	$3.42
3.3.15	3" x 1" Reducer, SCH 40	ea	1					$9.86	$9.86					$9.86	$9.86
3.3.16	2"x1" Reducer, SCH 40	ea	44					$2.73	$120.12					$2.73	$120.12
3.3.17	2" x 1/2" Reducer, SCH 40	ea	1					$12.71	$12.71					$12.71	$12.71
3.3.18	1" x 1/2" Reducer SCH 40	ea	76					$0.95	$72.20					$0.95	$72.20
3.3.19	3" Valve, SCH 40	ea	3					$26.39	$79.17					$26.39	$79.17
3.3.20	2" Valve, SCH 40	ea	14					$6.39	$89.46					$6.39	$89.46
3.3.21	1" Valve, SCH 40	ea	3					$2.59	$7.77					$2.59	$7.77
3.3.22	3" Sure-Vent PVC Air Admittance Valve	ea	1					$36.16	$36.16					$36.16	$36.16
3.3.23	2" Sure-Vent PVC Air Admittance Valve	ea	5					$24.23	$121.15					$24.23	$121.15
3.3.24	1.5" Sure-Vent PVC Air Admittance Valve	ea	1					$13.97	$13.97					$13.97	$13.97
3.3.25	10" Circular Valve Box (12" deep)	ea	14					$12.59	$176.26					$12.59	$176.26
3.3.26	PVC Primer, Clear	32 oz/cnt	12					$10.29	$123.48					$10.29	$123.48
3.3.27	PVC Cement, Regular Body, Medium Set	32/cnt	12					$12.89	$154.68					$12.89	$154.68
3.4	Faucet Setup	ea	74	2	10	7	56			$4.10	$303.40	$50.00	$50.00	$54.10	$353.40
3.4.1	1/2" Galvanized Steel Two Hole Strap - 10 ct.	10/box	7					$1.80	$12.60					$1.80	$12.60
3.4.2	#8 x 1-1/4 in. Phillips Screw - 100 ct.	100/box	2					$10.60	$21.20					$10.60	$21.20
3.4.3	1/2" Male x Hose Bibb	ea	74					$4.00	$296.00					$4.00	$296.00
3.4.4	1/2" MNPT x CTS Hub CPVC Adapter	ea	74					$0.44	$32.56					$0.44	$32.56
3.5	1/2" Connection Plastic Water Meter	ea	66	2	10	7	56	$30.00	$1,980.00	$4.59	$302.94	$50.00	$50.00	$84.59	$2,332.94
3.5.1	6" Water Meter Box	ea	66					$11.32	$747.12					$11.32	$747.12
	TOTALS						**899.0**		**$9,761.57**		**$4,589.94**		**$933.56**		**$15,285.07**

Bid Package 4 - Chlorination System															
4.1	Chlorination System Installation	ea	1	1	1	1	8			$277.12	$277.12			$277.12	$277.12
	TOTALS						**8**		**$769.00**		**$277.12**		**$0.00**		**$1,046.12**

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Item No.	Description	Unit	Quantity	Crew	Daily Output	Task Days	Task Hours	MATERIALS		LABOR		EQUIPMENT		Unit Price	Complete Total
								$/Unit	Cost	$/Unit	Cost	$/Unit	Cost		
Bid Package 5 - Water Storage Tank															
5.1	Earth Build Foundation Installation	ea	1	4		1	8			$173.20	$173.20			$173.20	$173.20
5.1.1	Structural Fill (Well-graded Gravel)	cy	42					$34.41	$1,445.22					$34.41	$1,445.22
5.1.2	Delivery of Fill	ea	1					$300.00	$300.00					$300.00	$300.00
5.2	Water Storage Tank Installation	ea	1	4		3	24			$519.60	$519.60	$100.00	$100.00	$619.60	$619.60
5.2.1	Concrete	cy	20					$84.50	$1,690.00					$84.50	$1,690.00
5.2.2	#4 Rebar	ea	175					$6.89	$1,205.75					$6.89	$1,205.75
5.2.3	Rebar Chairs	ea	200					$1.00	$200.00					$1.00	$200.00
5.2.4	Tie Wire	ft	200					$0.02	$4.00					$0.02	$4.00
5.2.5	Form Lumber	ea	1					$500.00	$500.00					$500.00	$500.00
5.2.6	8d 2-1/2 Nails (5lb Box)	ea	2					$72.00	$144.00					$72.00	$144.00
5.2.7	Cendrex PPA 24x36 Aluminum Hatch with keyed handle cam latch	ea	1					$495.54	$495.54					$495.54	$495.54
5.2.8	2" PVC Pipe	ea	1					$11.99	$11.99					$11.99	$11.99
5.2.9	2" PVC Elbow	ea	2					$1.71	$3.42					$1.71	$3.42
5.2.10	2" PVC Valve	ea	2					$6.39	$12.78					$6.39	$12.78
5.2.11	2" Vent Cap	ea	1					$11.99	$11.99					$11.99	$11.99
5.3	Water Tank Fence - 84'	ea	1	4	0.5	2	16			$346.40	$346.40	$50.00	$50.00	$396.40	$396.40
5.3.1	6'x50' Chain Link Roll	ea	2					$174.20	$348.40					$174.20	$348.40
5.3.2	2-3/8" x 2-3/8"x 9-ft Fence Post	ea	13					$29.43	$382.59					$29.43	$382.59
5.3.3	6'x6' Hinged Gate	ea	1					$99.00	$99.00					$99.00	$99.00
5.3.4	6' Tension Bar	ea	7					$6.85	$47.95					$6.85	$47.95
5.3.5	2-3/8" Tension Band	ea	21					$0.98	$20.58					$0.98	$20.58
5.3.6	Panel Clamps	2/bg	2					$4.57	$9.14					$4.57	$9.14
5.3.7	5/16"x1-1/4" Carriage Bolt w/Nut	20/bg	1.25					$5.89	$7.36					$5.89	$7.36
5.3.8	Farmgard 1,320 ft. 15-1/2-Gauge Barbed Wire	ea	0.33					$63.25	$20.87					$63.25	$20.87
	TOTALS						**48**		**$6,960.58**		**$1,039.20**		**$150.00**		**$8,149.78**

Bid Package 6 - Pump Stations															
6.1	Centrifugal Pump	ea	1	1	2	0.5	4	$1,500	$1,500	$138.56	$69.28			$1,638.56	$1,569.28
6.1.1	Check Valves	ea	2			0.5	1	$37	$37	$17.32	$34.64			$54.32	$71.64
6.1.2	Gate Valves	ea	2			0.5	1	$30	$30	$17.32	$34.64			$47.32	$64.64
6.1.3	Combination air release valve	ea	2			0.5	4	$30	$30	$69.28	$138.56			$99.28	$168.56
6.1.4	Flexible coupling	ea	2			0.5	4	$13	$13	$69.28	$138.56			$82.28	$151.56
6.1.5	Suction and Discharge pressure gauge	ea	2			0.5	4	$103	$50	$69.28	$138.56		$1,000.00	$172.28	$1,188.56
6.2	TW1000-30W-30 Flag Frame Booster Pump	ea	1					$2,000.00	$2,000.00					$2,000.00	$2,000.00
6.3	Electrical Installation	ea	1	2	1	5	40			$2,771.20	$2,771.20	$200.00	$200.00	$2,971.20	$2,971.20
6.3.1	Direct BurialCommunication and Signal Wire - 1000ft	spool	2					$198.00	$396.00					$198.00	$396.00
6.3.2	3/4" Electrical PVC Conduit - Bell-end	10 LF	4					$6.57	$26.28					$6.57	$26.28
6.3.3	Control System	ea	1					$200.00	$200.00					$200.00	$200.00
6.3.4	Float Switches	ea	2					$50.00	$100.00					$50.00	$100.00
6.4	Solar Power Array	ea	1	2			24			$1,662.72	$1,662.72			$1,662.72	$1,662.72
6.4.1	2.84 kW 9 Panel Solar System	ea	1					$8,650.00	$8,650.00					$8,650.00	$8,650.00
6.4.2	Crown 430 AH 24VDC 10,320 Watt-hour (4) Battery Bank	ea	2					$1,470.00	$2,940.00					$1,470.00	$2,940.00

Item No.	Description	Unit	Quantity	Crew	Daily Output	Task Days	Task Hours	MATERIALS		LABOR		EQUIPMENT		Unit Price	Complete Total
								$/Unit	Cost	$/Unit	Cost	$/Unit	Cost		
6.5	Pump House at the Source	ea	1	2	0.5	2	16			$346.40	$346.40			$346.40	$346.40
6.5.1	Concrete Pad	cy	0.75					$84.50	$63.38					$84.50	$63.38
6.5.2	Concrete Corners	cy	0.25					$84.50	$21.13					$84.50	$21.13
6.5.3	#4 Rebar (20' Length) Foundation	ea	20					$6.89	$137.80					$6.89	$137.80
6.5.4	#4 Rebar (20' Length) Corners	ea	8					$6.89	$55.12					$6.89	$55.12
6.5.5	Masonry Block	ea	158					$1.24	$195.92					$1.24	$195.92
6.5.6	Mortar (Type N, mixed with sand)	cy	0.5					$130.00	$65.00					$130.00	$65.00
6.5.7	26'x 41" Rib Zinc Roof Panel	ea	1					$75.30	$75.30					$75.30	$75.30
6.5.8	Rebar Chairs	ea	8					$1.00	$8.00					$1.00	$8.00
6.5.9	Tie Wire	ft	25					$0.02	$0.50					$0.02	$0.50
6.5.10	#12x1-1/4 Inch Plastic Cap Roofing Nails	1lb/bx	1					$7.75	$7.75					$7.75	$7.75
6.5.11	3-5/8"x10' 25Gauge Steel Stud	ea	3					$5.27	$15.81					$5.27	$15.81
6.5.12	Atlas SFD24 21 Space Rack Solid Pre-hung Steel Front Door	ea	1					$350.00	$350.00					$350.00	$350.00
6.6	Pump Housing at the Water Storage Tank	ea	1	2	0.5	2	16			$346.40	$346.40			$346.40	$346.40
6.6.1	Concrete Pad	cy	1.6					$84.50	$135.20					$84.50	$135.20
6.6.2	Concrete Corners	cy	0.25					$84.50	$21.13					$84.50	$21.13
6.6.3	#4 Rebar (20' Length) Foundation	ea	40					$6.89	$275.60					$6.89	$275.60
6.6.4	#4 Rebar (20' Length) Corners	ea	8					$6.89	$55.12					$6.89	$55.12
6.6.5	Masonry Block	ea	242					$1.24	$300.08					$1.24	$300.08
6.6.6	Mortar (Type N, mixed with sand)	cy	0.5					$130.00	$65.00					$130.00	$65.00
6.6.7	26'x 41" Rib Zinc Roof Panel	ea	1					$75.30	$75.30					$75.30	$75.30
6.6.8	Rebar Chairs	ea	16					$1.00	$16.00					$1.00	$16.00
6.6.9	Tie Wire	ft	25					$0.02	$0.50					$0.02	$0.50
6.6.10	#12x1-1/4 Inch Plastic Cap Roofing Nails	1lb/bx	1					$7.75	$7.75					$7.75	$7.75
6.6.11	3-5/8"x10' 25Gauge Steel Stud	1	4					$5.27	$21.08					$5.27	$21.08
6.6.12	Atlas SFD24 21 Space Rack Solid Pre-hung Steel Front Door	ea	1					$350.00	$350.00					$350.00	$350.00
	TOTALS						**114**		**$18,290.74**		**$5,680.96**		**$1,200.00**		**$25,171.70**

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Item No.	Description	Unit	Quantity	Crew	Daily Output	Task Days	Task Hours	MATERIALS		LABOR		EQUIPMENT		Unit Price	Complete Total
								$/Unit	Cost	$/Unit	Cost	$/Unit	Cost		
Bid Package 7 - River Crossing															
7.1	River Crossing Installation	ea	1	3	0.5	2	16			$346.40	$346.40		$500.00	$346.40	$846.40
7.1.1	Steel Square Bar (2"x2"x4')	ea	2					$60	$120.00					$60.00	$120.00
7.1.2	Concrete Footing for Tower	cy	0.22					$84.50	$18.59					$84.50	$18.59
7.1.3	# 3 Rebar 20' Long	ea	2					$4.79	$9.58					$4.79	$9.58
7.1.4	Tie Wire	ft	15					$0.02	$0.30					$0.02	$0.30
7.1.5	Stringers (1/16" Stainless Steel Cable)	ft	24					$0.50	$12.00					$0.50	$12.00
7.1.6	Stopper for Stringer	ea	24					$2.00	$48.00					$2.00	$48.00
7.1.7	Galvanized Vinyl Coated Steel Wire Rope 1/16 x 250'	roll	1					$117	$117.00					$117.00	$117.00
7.1.8	Cable Clamps (4/stringer)	ea	32					$5.50	$176.00					$5.50	$176.00
7.1.9	Cable Eyelet	ea	8					$2.00	$16.00					$2.00	$16.00
7.1.10	3/8"x10-1/2 Turnbuckle	ea	2					$3.66	$7.32					$3.66	$7.32
7.1.11	3/8" Quick Link	ea	2					$3.95	$7.90					$3.95	$7.90
7.1.12	3/8"x6" Shouldered Eyebolt	5/bg	1					$51.01	$51.01					$51.01	$51.01
7.1.13	1-3/8"x36" Punch Flat Bar	ea	1					$4.47	$4.47					$4.47	$4.47
7.2	River Crossing Fence - 50' each side	ea	2	4	1	2	16			$173.20	$346.40	$25.00	$50.00	$198.20	$396.40
7.2.1	6'x50' Chain Link Roll	ea	2					$174.20	$348.40					$174.20	$348.40
7.2.2	2-3/8" x 2-3/8"x 9-ft Fence Post	ea	18					$29.43	$529.74					$29.43	$529.74
7.2.3	6'x6' Hinged Gate	ea	2					$99.00	$198.00					$99.00	$198.00
7.2.4	6' Tension Bar	ea	12					$6.85	$82.20					$6.85	$82.20
7.2.5	2-3/8" Tension Band	ea	36					$0.98	$35.28					$0.98	$35.28
7.2.6	Panel Clamps	2/bg	4					$4.57	$18.28					$4.57	$18.28
7.2.7	5/16"x1-1/4" Carriage Bolt w/Nut	20/bg	2					$5.89	$11.78					$5.89	$11.78
7.2.8	Farmgard 1,320 ft. 15-1/2-Gauge Barbed Wire	ea	0.33					$63.25	$20.87					$63.25	$20.87
	TOTALS						**32**		**$1,832.72**		**$692.80**		**$550.00**		**$3,075.52**

Item No.	Description	Unit	Quantity	Crew	Daily Output	Task Days	Task Hours	MATERIALS		LABOR		EQUIPMENT		Unit Price	Complete Total
								$/Unit	Cost	$/Unit	Cost	$/Unit	Cost		
Bid Package 8 - System Testing															
8.1	Electrical Startup Test	ea	1	2	1	1	16			$1,108.48	$1,108.48			$1,108.48	$1,108.48
8.2	System Startup Test	ea	1	2	1	1	8			$554.24	$554.24			$554.24	$554.24
8.3	Pipeline Inspection for Leaks	ea	1	2	0.5	2	16			$0.00	$0.00			$0.00	$0.00
8.4	System Chlorination Shock	ea	1	1	1	1	8			$173.20	$173.20			$173.20	$173.20
8.5	System Flush	ea	1	1	1	1	16			$0.00	$0.00			$0.00	$0.00
	TOTALS						**64**		**$0.00**		**$1,835.92**		**$0.00**		**$1,835.92**

SUBTOTAL	**1291.67**	**$42,076.15**	**$15,674.74**	**$4,883.53**		**$62,634.42**
CONTINGENCY (10%)						**$6,263.44**
TOTAL PROJECT BUDGET						**$69,000**

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Appendix F-2: Bill of Materials

Description	Unit	Quantity - *KRV Recommendation*	Comments
Material - Adhesives			
PVC Cement, Regular Body, Medium Set	container	13	32 oz Container
PVC Primer, Clear	container	13	32 oz Container
Material - Electrical			
2.84 kW 9 Panel Solar System	ea	1	
TW1000-30W-30 Flag Frame Booster Pump	ea	1	
Self-Priming Booster Pump	ea		
Electrical Control Panel for Tank	ea		
Electrical Wiring and Conduit	ea		
Centrifugal Pump	ea	1	
Flexible coupling	ea	2	
Control System for Spring Source	ea	1	
Crown 430 AH 24VDC 10,320 Watt-hour (4) Battery Bank	ea	2	
Direct BurialCommunication and Signal Wire	spool	2	1000' Long
Electrical PVC Conduit	LF	4	10' Long
Float Switches	ea	3	
Material - Fasteners and Components			
Beam Mounting Clips	ea		
Diagonal Mounting Clips	ea		
3/4x2-1/2 Structural Bolts w/Nut	box		
3/4 Structural Washers	box		
5/8x2 Structural Bolts w/Nut	box		
5/8 Structural Washers	box		
16"x16"x1.5" base plates	ea		
3/16 x 1-1/4 - 19W4 Grating for Landing	SF		
L3x3x1/4 diagonals	ea		
L3x3x1/4 diagonals	ea		
W8x18 beams	ea		10.5' Long
W8x40 beams	ea		10.5' Long
W8x40 beams			18.5' Long
W8x40 columns	ea		20' Long
8d 2-1/2 Nails	ea	3	5 lb per Box
Stopper for Stringer	ea	24	
Cable Clamps	ft	32	Assumed: 4 clips per Stringer
Cable Eyelet	ea	8	

Description	Unit	Quantity - *KRV Recommendation*	Comments
Material - Fasteners and Components (Cont.)			
3/8"x10-1/2" Turnbuckle	ea	2	
3/8" Quick Link	ea	2	
3/8"x6" Shouldered Eyebolt	bag	1	5 count per Bag
1-3/8"x36" Punch Flat Bar	ea	1	
1/2" Galvanized Steel Two Hole Strap	box	7	10 count per Box
#8 x 1-1/4 in. Phillips Screw	box	2	100 count per Box
Tie Wire	ft	365	
Panel Clamps	bag	8	2 count per Bag
5/16"x1-1/4" Carriage Bolt w/Nut	bag	6.25	20 count per Bag
#12x1-1/4 Inch Plastic Cap Roofing Nails	1lb/bx	1	
Material - Fence			
2-3/8" Tension Band	ea	99	
6' Tension Bar	ea	33	
9'x2-3/8" Fence Post	ea	57	
6'x50' Chain Link Roll	ea	8	
6'x6' Hinged Gate	ea	4	
Farmgard 1,320 ft. 15-1/2-Gauge Barbed Wire	ea	1.16	1320 ft Long
Material - Footings & Sediment Control			
Concrete - Mix Design 1	cyd	29.07	1 Parts Cement, 2 Parts Sand, 4 Parts Agg.
Concrete - Mix Design 2	cyd		
Masonry Block	ea	400	16" x 8" x 8"
Cement - Mortar	cyd	1	
Structural Fill (Well-graded Gravel)	cyd	1	
Rip Rap for Settlement	ton	9	Inside Intake Structure

Description	Unit	Quantity - *KRV Recommendation*	Comments
Material - PVC Fittings			
1" 45 Elbow, SCH 40	ea	18	
1" Cross, SCH 40	ea	2	
1" Elbow, SCH 40	ea	66	
1" Valve, SCH 40	ea	3	
1" x 1/2" Reducer SCH 40	ea	76	
1"x1"x1" Tee, SCH 40	ea	10	
1/2" MNPT x CTS Hub CPVC Adapter	ea	74	
2" 45 Elbow, SCH 40	ea	24	
2" Cross, SCH 40	ea	6	
2" Elbow, SCH 40	ea	14	
2" Valve, SCH 40	ea	20	
2" Vent Cap	ea	5	
2" x 1/2" Reducer, SCH 40	ea	1	
2"x1" Reducer, SCH 40	ea	44	
2"x2"x2" Tee, SCH 40	ea	38	
3" 45 Elbow, SCH 40	ea	12	
3" Elbow, SCH 40	ea	10	
3" Valve, SCH 40	ea	3	
3" x 1" Reducer, SCH 40	ea	1	
Injection Tee, SCH 80	ea	1	Chlorination System
Material - PVC Pipe			
3" PVC Pipe, SDR 26	LF	85	20 ft Long
2"PVC Pipe, SDR 26	LF	150	20 ft Long
1" PVC Pipe, SDR 26	LF	177	20 ft Long
1/2" PVC Pipe, SCH 40	LF	17	20 ft Long
Material - Prefabricated Plastic			
6" Water Meter Box	ea	66	
10" Circular Valve Box (12" depth)	ea	14	
J-PRO-22 15-Gallon Solution Tank	ea	1	Chlorination System
Rebar Chairs	ea	286	
Tanque Duratank HD Negro, 8000 LTS-2113GLS	ea		

Description	Unit	Quantity - *KRV Recommendation*	Comments
Material - Steel			
#3 Rebar	ea	2	20' Long
#4 Rebar	ea	298	20' Long
Y8 Rebar	ea		20' Long
Y10 Rebar	ea		20' Long
Y12 Rebar	ea		20' Long
Y16 Rebar	ea		20' Long
1/2" Male x Hose Bibb	ea	74	
2" x 2" Steel Square Bar	ea	2	4' Long
1/16" Galvanized Vinyl Coated Steel Wire Rope	roll	1	250' Long
1/16" Stainless Steel Cable	ft	24	Stringers
26'x 41" Rib Zinc Roof Panel	ea	2	
Cendrex PPA 24x36 Aluminum Hatch with keyed handle cam latch	ea	1	
Atlas SFD24 21 Space Rack Solid Pre-hung Steel Front Door	ea	1	
3-5/8"x10' 25Gauge Steel Stud	ea	4	
Material - Testing Materials			
Chlorine Test Kit	ea	1	Free with Specified Chlorination System
Material - Valves & Gauges			
Check Valves	ea	2	
Combination air release valve	ea	2	
Gate Valves	ea	2	
Suction and Discharge pressure gauge	ea	2	
1/2" Connection Water Meter	ea	66	
3" Sure-Vent PVC Air Admittance Valve	ea	1	
2" Sure-Vent PVC Air Admittance Valve	ea	5	
1.5" Sure-Vent PVC Air Admittance Valve	ea	1	
Material - Wood			
2x4 Lumber	ea		10' Long
1"x6" Lumber	ea		16' Long
4'x8'x1/2" Plywood	ea		

Appendix F-3: Construction Schedule

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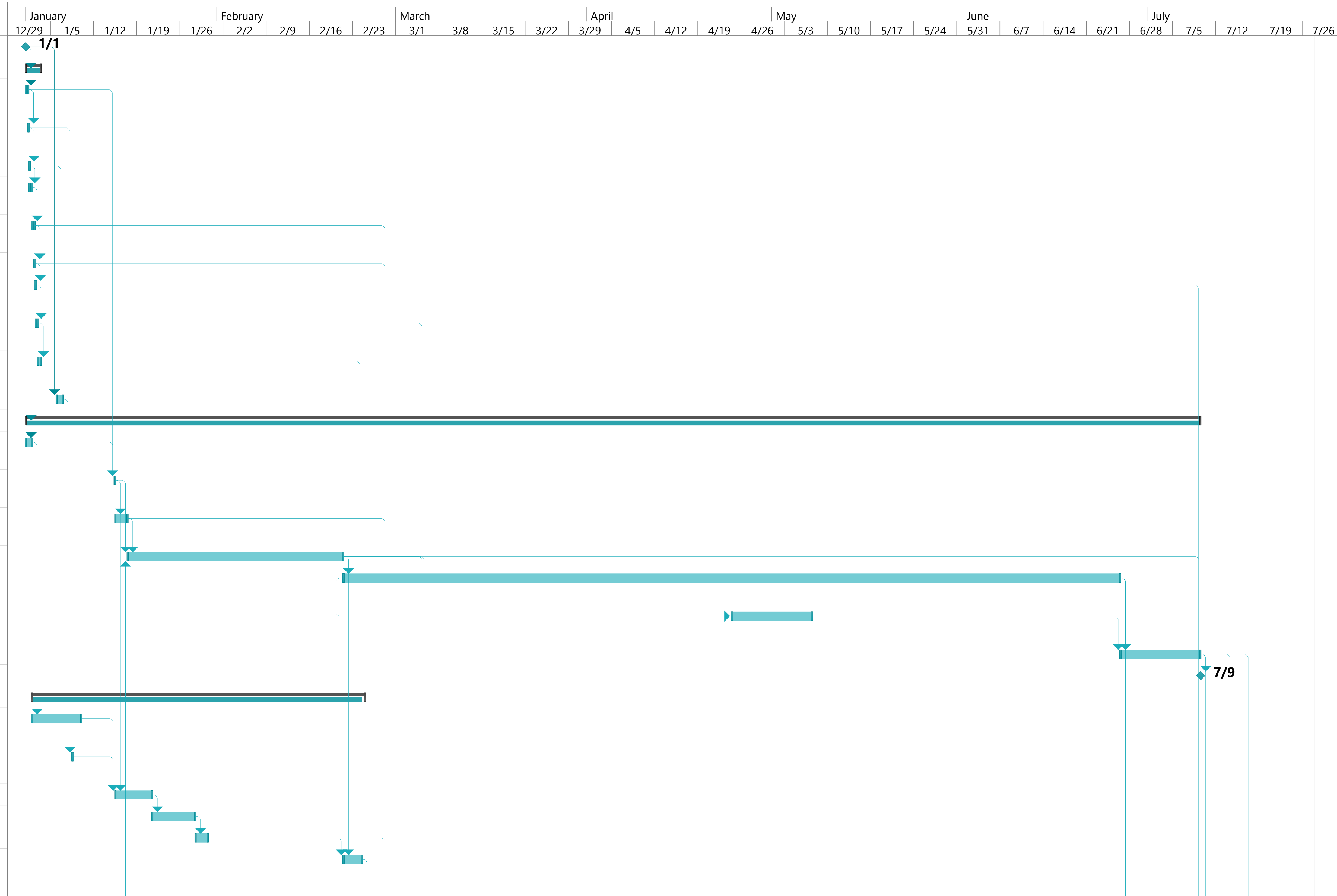
ID	Task Mode	Task Name
1		**Project Start**
2		**Order Materials**
3		Order Pipe and Components
4		Order Concrete and Rebar
5		Order Fill Material
6		Order 5000 Gallon Storage Tank
7		Order Pumps and Accessories
8		Order Solar Array
9		Order Electrical Supplies
10		Order Chlorination System
11		Order Fencing Materials
12		**Remove Ultrafiltration**
13		**Pipe Installation**
14		Foliage Clearing for Supply Line
15		Receive Pipe and Components
16		Install River Crossing
17		Install Supply Line
18		Install Distribution Line
19		Install Water Meters
20		Install Faucets
21		**Piping Complete**
22		**Build Water Collection Structure**
23		Excavation at Spring
24		Receive Concrete and Rebar
25		Install Catchment
26		Install Wet Well
27		Build Pump House
28		Connect Pipe Clean Outs and Overflows



Project: Embera Puru Project Sc
Date: Wed 11/20/19

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

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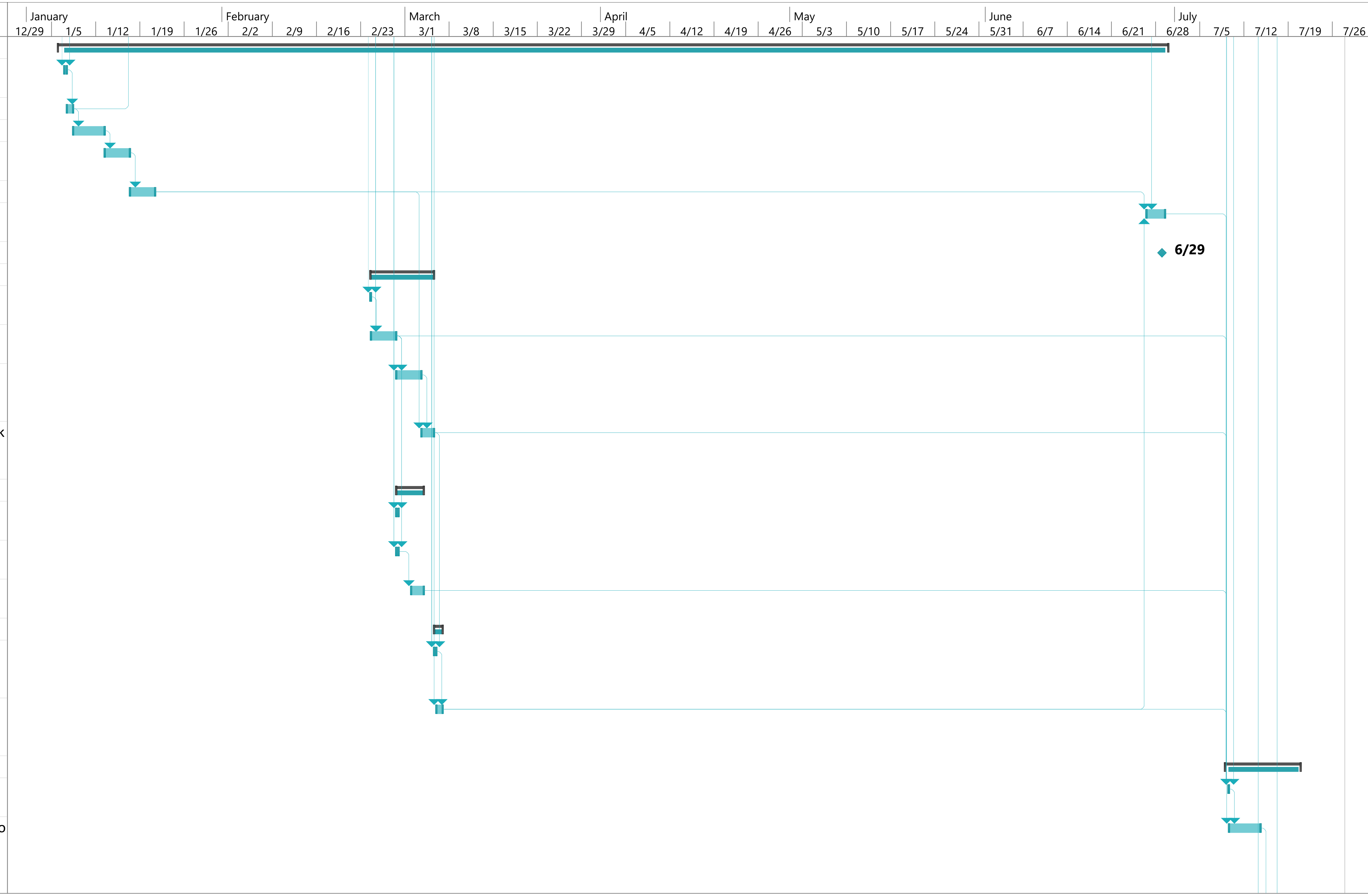
ID	Task Mode	Task Name
29		**Build Water Storage Structure**
30		Receive Fill Material
31		Place Fill Material
32		Fill Settling Time
33		Form and Pour Storage Tank
34		Build Pump House
35		Tie In to Supply and Distribution
36		**Storage Tank Complete**
37		**Install Fencing**
38		Receive Fencing Materials
39		Install Fence Around Spring
40		Install Fence Around River Crossing
41		Install Fence Around Storage Tank
42		**Install Pump and Solar Array**
43		Receive Pump and Accessories
44		Receive Solar Array
45		Assemble Solar Array
46		**Install Chlorination System**
47		Receive Chlorination System
48		Hook Up Chlorinator to Piping
49		**Electrical Work**
50		Receive Electrical Supplies
51		Lay Communication from Pump to Storage

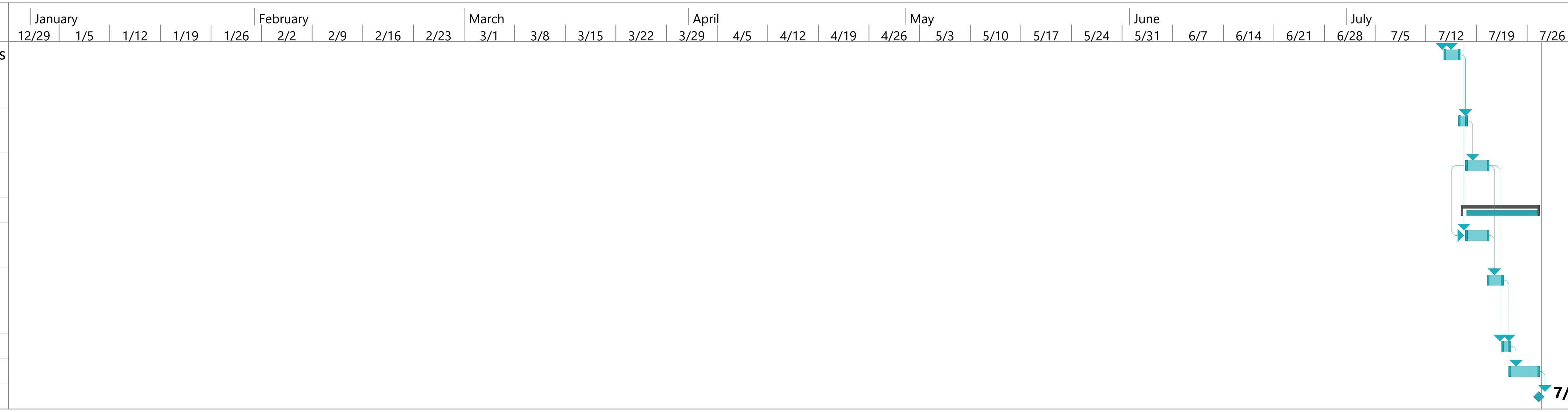


Project: Embera Puru Project Sc
Date: Wed 11/20/19

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

KRV Water Solutions, Inc.

ID	Task Mode	Task Name
52		Wire Pump Electrical Components
53		Wire Chlorination System
54		Electrical Startup Testing
55		**Pre-Start Tasks**
56		System Startup Test
57		Pipeline Inspection for Leaks
58		Shock Chlorination
59		System Flush
60		**Project Complete**



Project: Embera Puru Project Sc
Date: Wed 11/20/19

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

KRV Water Solutions, Inc.

Appendix G: Construction Drawing Set

(Bound Separately)