WATER SUPPLY, DISTRIBUTION AND STORAGE
SAN PABLO DE AMALI, ECUADOR

1. Project Description:

San Pablo de Amali, Ecuador is a small subtropical farming community located on the western slope of the Andes Mountains with an estimated population of 200 people. The Community has struggled with a failing drinking water supply system, devastating floods, massive landslides, political instability, and prolonged economic crises throughout its history. It is estimated that nearly 50% of the total 200 people living in the community are below the poverty line.

In the 1970's, the local County Government (Chillanes County) originally built a new drinking water system in San Pablo de Amali. After the system was built, it was handed over to the community to own, operate, and maintain. The original drinking water system included a concrete impoundment to collect water from a nearby stream and a 2" galvanized pipe to convey water to a treatment facility. The water treatment facility included a 50 sq. ft. gravity sand filter and a chlorine tablet disinfection system. Once treated, the water was stored in a 500-gallon concrete tank to provide water to nearly a mile of water distribution piping that served the community.

Figure 1: Nonfunctional Gravity Sand Filter

Without the proper training, skills, spare parts, materials, basic tools or funding, the community did the best with what they had to keep the system running for nearly 50 years. However, soon after the water system was commissioned, the community could not afford chlorine tablets, so the disinfection facility quickly went unused, and the community went back to boiling drinking water. In addition, the intake facility did not account for sediment transport and the filter was not designed with a backwashing feature, so the filter would routinely get clogged with sand and silt. Due to high sediment fouling of the filter, it was ultimately by-passed and decommissioned. In the early 2000's, a landslide washed out the concrete intake, impoundment, and galvanized piping, so the community had to improvise by using an old milk jug with holes cut into it as a water intake device. The milk jug was zip-tied to 1" diameter HDPE tube. Although the tubing had been patched and repaired several times, for the last several years, the distribution piping has been getting clogged by silt and sand entering the system. Many of the community members gave up on the drinking water system and reluctantly went back to carrying 5-gallon buckets of water up the mountain to their homes multiple times a day before boiling it for consumption.

In June 2018, the Peace Corp contacted our non-profit, student organization, asking for help with the San Pablo de Amali community's failing water supply system. Eager to help, we arrived in the community in January 2019 to complete the first assessment trip. It was the first time many of the students were able to go into the field and apply the curriculum they had been learning, allowing them to better understand how engineering is done in practice. During the first assessment trip, the engineering students worked alongside Professional Engineers (P.E.s) to collect GPS elevation points, soil samples, sediment transport samples, and bacteria and turbidity samples. They also mapped the existing water system and structures, generated questions for the community, and wrote technical memorandums. These memorandums were their basis of information for design when they arrived back in the United States (U.S.). Because their client and job site were not easily accessible once they left Ecuador, the students learned the importance of collecting accurate and detailed information.

Two months after completing the first assessment trip, the community suffered from a catastrophic landslide where lives were lost and drastic changes were made to the water system, roads, bridges, stream channels, and homes. Knowing that this could significantly impact their design, we returned to the community in June 2019 to re-collect data for the changed conditions. During the second trip, they were able to hold several meetings with the Chillanes County Mayor and the Director of Public Works (DPW) who is also a Licensed Professional Engineer from Ecuador. By working with the Mayor and DPW, we acquired the county's water system standards, specifications, and standard details in AutoCAD. Knowing how our plans to correct the San Pablo de Amil drinking water supply system would greatly help the community, the Mayor agreed to provide additional labor, sand, gravel, and an excavator to help with the forthcoming construction phase.

Once they were back in the U.S., the team used the collected data to design the new drinking water system. Since most of the existing water system was in such poor shape, we worked closely with the community to decide upon providing a new water system in place of rehabilitating the existing one. During the design phase, they prepared 35%, 75%, 95% and final design plans to submit to Ecuador's local Director of DPW and the Community for their approval. We also sent the same submissions to various P.E.s in the U.S. for their review. Input provided by the U.S.-based P.E.s was invaluable in pointing out potential problems and how we could avoid them. The final design submission was finished in November 2019 and our student organization negotiated a non-binding contract with the Community and the DPW. This contract was developed to better define the promises each group made to support the project. During the design phase, we also worked with the Community to develop a "Community Water Board of Supervisors" (CWBOS). The CWBOS is comprised of five elected community members to govern over the new water supply system.

We put our construction management skills to the test and laid out a detailed, logistical plan to complete the construction within ten days, allowing for only one day of float. In January 2020, we traveled back to the community. The construction team included three P.E.s, twelve engineering students, labor forces from the DPW, and dozens of Community members. To our success, all the pre-planning paid off and the construction was completed within 9 days. The water system included a new 40,000-gallon side stream impound with a composite dam to capture water and allow sediment transport to settle before the intake screen. The composite dam included an emergency spillway, a 300 V-Wire micron screen, valving, and 2" HDPE raw water piping. The raw water piping fed two 1,000-gallon HDPE storage tanks further down the mountain. The storage tanks were mounted on a sturdy, reinforced 6-inch thick concrete pad. The tank also included a float valve, flow meter, valves, overflow, and drain lines. Working closely with a Professional Water Resources Engineer, we were able to size the water storage tank to provide ample water for the entire community. The storage tanks were connected to nearly a half mile of 2" Sch 40 PVC distribution piping. Due to the nearly 45 degrees slope of the mountain, we needed to reduce the water pressure with breaker tanks. The breaker tanks were controlled with a float valve to allow the system to restart building

Figure 2: 300 Micron Intake Screen

pressure as it traveled down the mountain. Once the water system was tested, commissioned, and disinfected, we put it into service. All the community houses that were connected to the system started receiving a range of pressures from 20-80 psi. We are still in contact with the CWBOS on a regular basis to ensure that the system is working properly and to help troubleshoot any problems that may be arising.

We were originally scheduled to return in January 2021 to provide a second phase to the project. This second phase would include the connection of more houses, an additional water filter, and an ultraviolet disinfection system. Since the disinfection system is remote and needs electricity to run, the plan is to power the device using a micro hydro turbine backed by a battery bank. Unfortunately, COVID-19 has delayed the Phase 2 construction and we have not yet been able to return to the community. However, they are continuing to refine their plan and continue to fundraise so that they can return to the community in January 2022 to finish what we started.

2. Successful collaboration of faculty, students, and licensed professional engineers:

Were licensed professional engineers (P.E.s) involved?

Professional civil engineers, structural engineers, and water resource engineers were involved during the entire project. Three P.E.s joined the students on their trip to Ecuador and additional P.E.s provided a third-party quality review of the plans. During the review, the P.E.s mentored the students on how to think through the logistical challenges faced specifically when working abroad. Examples of the areas in which the P.E.s provided recommendations included substitution of materials and alternative ways to design when obstructions occurred in the field.

Figure 3: Installation of Distribution Piping

How did the students, faculty, and P.E.s interact?

Since the students working on the design ranged from freshman to seniors, a primary focus for the faculty and P.E.s was to mentor the students so each could begin discerning which field of engineering he or she was most interested in pursuing. Having the students work with P.E.s enabled them to take their academic knowledge and be able to express and format their work in a professional manner. Students were separated into various teams, each representing a necessary task within the project including a water impoundment team, water distribution team and water storage tank team. The students coordinated with P.E.s to conduct biweekly meetings. These meetings updated the team on the status of the project and created a forum to discuss problems and reach proactive solutions.

What did the students learn through the collaboration that would not have been learned in the classroom?

In the field, students learned how to construct a water distribution system in a hands-on environment with the collaboration of P.E.s. By allowing students to physically construct these components, they were able to identify potential problems before they occurred, which will only improve their work as future licensed Professional Engineers. Additionally, students learned the importance of providing a design that is formatted to the needs of the client, in this case, the San Pablo de Amali community. By travelling to the community to implement the design hands-on, they communicated and interacted with the community members, understanding their needs and what they wanted to be constructed for their infrastructure. Working directly with a community abroad is something that cannot be experienced in a classroom setting that adds great benefit to engineering students' technical and interpersonal skills. This broadens students' perspectives and presents them with real-world scenarios and design solutions. Additionally, with the experience from the P.E.s, students were able to open their minds to not just designing a functional water distribution system, but also learn how to manage all aspects of a project. For instance, all materials within the system needed to be readily accessible and durable so the community can fix the system if any problems arise in the future.

3. Protection of public health, safety, and/or welfare of the public:

Did the project include aspects that affect the health, safety, and/or welfare of the public?

The project's outcome directly affects the health, safety, and welfare of the community as the water system provides a vital resource to people's homes. Previously, community members would need to travel long distances to the river to transport the water to their homes where the water had to be boiled. The piping system our organization implemented will improve the welfare of the community as they will no longer need to travel long distances to the river to obtain water. Furthermore, if the filtration and disinfection system is installed in the future, the homes will have potable water transported directly to their homes. The UV disinfection system will improve people's health and largely minimize the risk of contracting disease from drinking water as it will kill bacteria. The planned future phases will also incorporate connections to more houses in the community, which will further the impact of the project.

Figure 4: With Clean Water the future of San Pablo de Amali is in good shape.

How was public protection addressed?

Members of the team communicated with the community to have a clear understanding of their wants and needs for the water system. They worked for the community and developed relationships with them to understand their background and how they want to improve their welfare with this project. As the work was completed, they would frequently update the community on the progress and what the end goals of each phase are. In the work zone, the P.E.s had construction management experience, which they utilized to ensure the work was conducted safely.

Which project features raised students' awareness about the impact of engineering decisions?

Through this project, the students were able to see how engineering directly impacts the welfare of people. At the conclusion of the most recent phase in January 2020, they saw the fruit of their work when the water ran through the piping and successfully arrived at people's homes when we opened the tap. This concretely shows how engineering is what allows vital resources such as water to be distributed to people's homes through design and construction work. By seeing it firsthand, the students have a greater appreciation of the field and a closer look at the creative design process.

Did the project highlight how engineering can help solve problems faced by communities nationally or worldwide?

When the team finished the project, they could see a direct improvement within the community. The people that were connected to the newly installed water system would rush towards the team, excited that there was running water. The project accentuated the desire of the community to have clean water, but also revealed the absence of proper infrastructure and knowledge for the community to improve their own situation. Students learned how difficult it is to accomplish even the simplest of tasks without running water, which is something most people take for granted. The team's engineering background helped a community thrive due to the hard work and commitment we were able to dedicate in the design and construction of this drinking water system.

Did the project foster student self-reliance, cooperation, or responsibility?

During construction of the project, our organization was given the tools to become more self-reliant. The students were responsible for finding a solution based on the knowledge and mentoring from the Professional Engineers that occurred leading up to the implementation. They cooperatively found solutions to issues by working closely as a team that were not visible until they were seen in-person. Working in a real-world scenario made students become more self-reliant and cooperative as they had to brainstorm issues that would arise spontaneously.

4. Multidiscipline and/or allied profession participation

There were interactions among many disciplines of engineering to design and install a system that was both reliable and easily maintained. The team practiced a multidiscipline approach to resolve potential conflicts in the planning and to practice forward thinking to take advantage of the brief time overseas. Documentation and logistics planning were of utmost importance to facilitate construction and installation of the water supply, water distribution, and storage. Incorporating all system components to create an easily maintained, effective water system, students learned valuable information from the licensed engineers who not only assisted in the technical portions of the project, but also in the client-partner relationship and project planning. Below are just a few examples of multidisciplinary participation.

Was more than one engineering discipline involved? (for example, mechanical and electrical engineering)

Mechanical and Control Systems Engineering: The students sought advice from a Professional Mechanical and Control Systems Engineer to help them understand how to control the water flow within the water distribution system. They learned and installed a hydraulically triggered float valve on the supply line to avoid the tank from being overfilled. Once the valve was installed, they calibrated the float to shut off the water supply about six inches from the top of the tank. We also learned about flow meters and why they are important.

Figure 5: The new water system can provide 35-gpm of water to the community.

Environmental Engineering: With preliminary research on U.S. water quality standards and which characteristics and measurements assure potable water standards, students followed lab procedures in quantifying the safety of the water. Bacteria samples were taken using membrane filters so that the results were available within 24 hours of obtaining the sample. Three samples per testing source were acquired and the number of bacteria within each sample was recorded. Performing these tests on-site allowed the students to make quick judgements to explore local availability of water disinfection methods as a temporary resolution until a permanent method of disinfection could be designed and implemented.

Surveying: The students improved their understanding of surveying while working alongside P.E.s who taught them things that are beyond a classroom curriculum. Since Ecuador has limited topographic data, the team needed to survey the entire area using a global positioning system (GPS). Consulting with a NCEES Licensed Land Surveyor, the students selected a sturdy handheld GPS receiver that offered enough accuracy, simplicity, and dependable data retrieval. Under the guidance of a Professional Engineer, the students set out to collect thousands of data points along the proposed project site. The data was downloaded and imported into ArcMap for further analysis.

Did the project include other professions? (for example, architecture or accounting)

Politicians: During the construction phase, the students worked with the Chillanes County Mayor as well as the Community Leader to gain support for the project. During the construction phase, the team quickly realized there was a local election, where many of the politicians who were running for the election wanted to be part of a good cause.

Skilled and Unskilled Laborers: During the construction phase, the students worked with both skilled and unskilled laborers. This profession was clearly the most important to the success of the project. Without this profession we would have not accomplished the project at all. We learned to treat all workers on the project with dignity, respect, and fairness.

Foundation Accountants: Since our students needed to fundraise nearly $40,000 to complete the project, they needed to work with various accountants, administrative assistants, and the Universities foundation Account Manager.

Figure 6: We worked with all types of other professions.

Was more than one branch of a particular engineering discipline involved? (for example, two branches of civil engineering, such as geotechnical and transportation)

Civil Geotechnical Engineering: Undoubtedly, geotechnical was the most important engineering discipline for this project. The Andes Mountains can be very vulnerable to rock movement and debris which consists of loose and fragmented rocks mixed with aluminum oxide and organic matter. The team consulted with a Professional Geotechnical Engineer to better understand how to design and construct the four-foot-high composite earth dam. The composite dam included an emergency spillway, compacted soil, a geomembrane core, topped with very large, imbricated rocks placed in a stair step pattern on the front of the dam. The team also consulted with the same engineer to help better classify the soil conditions prior to the excavation of the distribution piping and concrete pad.

Civil Water Resources Engineering: Professionals taught the students important concepts of hydraulics that are necessary for designing an efficient system. Students learned common practices and components of a water system to understand how they work together to create an easily maintained, sustainable system. With guidance from a P.E., students used EPANet to model the existing failing system as well as the newly improved water system.

Civil Structural Engineering: The students consulted a Professional Structural Engineer to help design the concrete pad for the water storage tanks structure. The concrete pads needed to carry a very heavy load with a very low soil bearing capacity. In addition, students consulted the same Engineer to help design pipe hangers to support the water distribution piping. The distribution piping needed to be supported along the side of a concrete bridge. The P.E. helped select an aluminum hanger to avoid corrosion.

Civil Construction: Prior to the ten days construction period, the students consulted a Professional Construction Manager to assist in developing a critical path method schedule. Due to the large volume of work that needed to be completed in the short amount of time, multi-tasking was necessary for various components of the construction. To get this project accomplished, they divided the labor pool among three student-run construction teams and one small logistics team. Each construction team had a daily production rate and/or daily goals to meet. At the end of each day, the logistics team would hold a meeting and the construction teams would report out on the daily progress. If the construction teams were missing materials, tools or even labor, the logistic team would devise a plan to overcome the obstacle. The project finished on time because of the invaluable information we received from the Professional Construction Manager.

5. Knowledge or Skills Gained

Figure 7: We are in good hands with these future Licensed Professional Engineers

What engineering and other non-technical knowledge/skills did the students gain?

Communication is a key component while coming to a solution to a problem. Along with communication among the students and professional engineers, it is important to communicate with the community to ensure the product is what was expected. The significance of a client-partner relationship with the community positively impacted the students and facilitated the understanding that, although a perfect design may be constructed, if it does not meet the "client" or intended usage needs, it is a worthless effort.

How were the knowledge/skills gained important to professional practice?

There was no better feeling than when members of the community thanked the team for their hard work in taking the time to improve their quality of life. The lessons learned from this project and the San Pablo de Amali community are something they will carry and appreciate for a long time to come. In doing so, they will continue to realize that, as engineers, they have a responsibility to society to never overlook a community's declining public welfare.

Did the project include consideration of professional practice concepts such as project management, ethics, contracts, or law?

One of the most important skills learned was the need for a contract. Since the team received support from the County Government and the community, they decided to enter a "non-binding contract" with all three parties. They developed a written contract to better define the promises each of the three groups made to support the project.