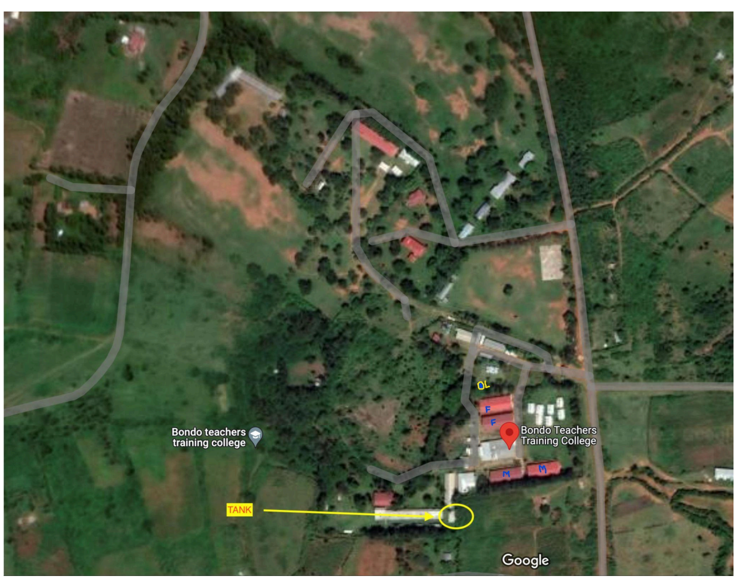
Well-Pump System at the Bondo Teachers Training College in Bondo, Kenya

1. Project Description

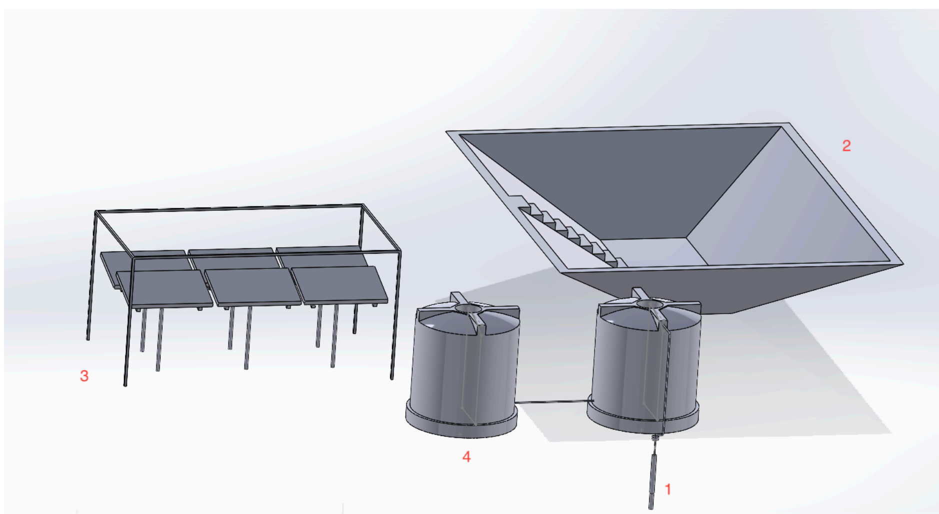
The Bondo Teachers Training College (BTTC) is a school in Bondo, Kenya, focused on training the next generation of teachers within the region. The school houses over 600 students and has 60 faculty, in addition to being surrounded by approximately 100 households within a one mile radius from the school. Currently, the surrounding community and BTTC rely on water being pumped from a nearby river for drinking, cleaning clothes, cooking, and feeding livestock. The community is often unable to meet the financial burden of paying for the pump, leaving the BTTC having to pay the expensive cost. In addition, the river runs dry from October to January each year, leading to the BTTC having to pay for water to be shipped to the campus, a fee even more expensive than having to pay for the electricity to operate the already unreliable pump. Unlike the water from the nearby river Yala, the water shipped comes from nearby lakes and requires treatment at the BTTC to avoid sickness from the contaminated water.

Our university's Engineers Without Borders (EWB) chapter has been working closely with the BTTC and members of the community to solve this problem, and we have designed and prototyped a well system that will alleviate many of the challenges this community currently faces. During July of 2023, the team implemented a rainwater catchment system for the Naki Secondary School, a one hour drive from the BTTC. During this time, the team was also looking for future projects, and met with members of the BTTC to discuss what problems the community was dealing with. This was when the team first realized the issues with the current method of water collection, and began brainstorming ways to help the community. Once arriving back in the United States, the team started proposing solutions. The best solution was determined to be a solar powered well which would pump greater than 20,000 Liters per day and store the water in multiple 10,000 Liter tanks, in addition to a 70,000 Liter tank which the team would repair in July of 2024.



Aerial view of BTTC
Key: OL - Location of Borehole   Tank - 70,000 Litre tank location   F - Female dormitories   M - Male dormitories

Since the project has begun, the team has completed multiple milestones to ensure the completion and implementation of the project in July of 2025. The first major step of the project was to gain an understanding of head loss and determine what size pump would be required to not only provide enough water for the community, but also pump the water out of a borehole which could be as deep as 400 feet. Once the pump was selected, the power requirements had to be understood, and the team selected six-410 Watt solar panels to power the pump. Piping was then chosen to both withhold the water pressure requirements and also have a diameter to easily mate with the pump. The school had a previous 70,000 Liter concrete tank for water storage which had cracked due to the cyclical rains and then drying of the tank, and the team plans on fixing this using a fiberglass laminate or a large HDPE sheet in the summer of 2024 to provide a place to not only store rainwater but also excess water pumped from the well which may already fill up two 10,000 Liter tanks the team plans on purchasing. After choosing the major parts of the design, the team was able to create a materials budget which also included minor purchases, such as tools for construction, a chain-linked fence with barbed wire for protection of the solar panels, and other miscellaneous purchases necessary for the design. With the materials budget complete, the team was able to create a CAD drawing of the design to better understand what the final project would look like. Since completing the design phase, the team has also performed prototyping and experimentation to better understand engineering concepts in areas such as fluid mechanics. Overall, the team is on track to implement our project in July of 2025 to help alleviate the problems currently suffered by members of the BTTC and the surrounding community.



CAD Drawing of our design
1) Pump   2) 70,000 Litre tank   3) Solar panels   4) Two 10,000 Litre tanks

2. Collaboration of students, faculty, and licensed professional engineers

The EWB chapter members working on this task involves the collaboration of professional engineers, students, faculty, and other stakeholders that have contributed to the success of the project thus far. The team meets each week and is composed of three student project leads, two professional engineers, and fifteen student members. The professional engineers on the project have over forty years of experience as engineers combined, and both work specifically within the realm of civil engineering focused on water resources. Their expertise has been pivotal in teaching members of the team how engineering concepts taught in the classroom are used in the real world.

In addition to the team that meets weekly, there are other faculty members and mentors at the university which provide guidance to the team. One of these is Engineers Projects in Community Service (EPICS), a program at the university focused on helping students tackle real-world problems using engineering, which provides both funding and engineering expertise to our team. We have presented our work thus far to panels of engineers selected by EPICS, and the team has been able to gain valuable feedback from these professionals on our project. We have also consulted faculty members at the university, such as a professor with a background in structural engineering, who was able to provide the team feedback regarding our original design which contained a water tower.

Outside of the weekly meetings and consultations, the faculty and professional engineers have interacted with the students outside of the classroom to show key principles of engineering. When the team traveled to Kenya in the summer of 2023 to look for new projects, the guidance from one of our professional engineers was essential. He had experience not only within the field of water resources engineering, but also implementing such projects within Kenya. His experience with understanding how to accomplish these projects within a foreign country has been pivotal to our success and has given us confidence that our project will be a success.

Learning surveying from one of our P.E.'s

One of the major milestones of the project was performing fluid mechanics experiments to gain a better understanding of the basics of head loss and how it relates to aspects of a piping system, such as pipe diameter and length. The team tested the effect of pipe diameter, pipe length, and type of pump used in a system on the flowrate to demonstrate these relationships. Using this data, pump curves were prepared, and the team was shown how some pumps are more optimal than others depending on the head needed by the system. One of the professional engineers guided the team through these experiments, explaining the concepts with equations from physics while also demonstrating them to help everyone gain an intuitive understanding. In the next semester, the team performed prototyping and additional experiments, this time with a well pump, similar to the one which will be used for our final design. The professional engineer had experience working with these pumps, and was able to guide the team in setting up the pump as well as explaining the mechanisms that make the pump function. During these experiments, the professional engineer also went over skills such as soldering and placing wire caps that the team will use when constructing our system in Kenya. Although the team had seen videos and learned about many of these ideas in the classroom, this advice was crucial because we had lacked the hands-on experience that only an experienced engineer would have.

The collaboration between various faculty, engineers, and the students has been pivotal to the success of the project thus far. Without the guidance from experienced engineers and faculty, the team would not have been able to take our engineering principles learned in the classroom and apply them to a real project. The experience our mentors have had working with communities nearby the BTTC in Kenya has also given us a framework which we can use to again ensure the success of our project.

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

The project included many aspects pertaining to the protection of health, safety, and welfare of the public that have been addressed by the team, teaching our team members the impact that engineering decisions have on the community which they intend to help. When working on a project that could impact the lives of more than 1,400 people, the team needed to consider both the reliability and dependability of the water that the project would supply. In terms of reliability, the team has considered purification techniques that would be necessary for protecting the health of those drinking the water from the well. First, the team plans to test the well water once the well is drilled, as this will determine what types of treatment the water will need. Since the project's water source is groundwater, the main pollutant concerns stem from heavy metals, nitrates, and volatile organic compounds (VOCs). To test for heavy metals, the team will perform a Palintest. This detection device is portable, and accurately tests for pollutants including lead, copper, arsenic, and mercury. Nitrates will be tested for using Colorimetric Test Kits which use color to indicate their presence on-site. Lastly, Photoionization Detectors (PID) will be used to provide immediate readings of VOCs in the field. The results of these three tests will help determine which types of water treatment will be necessary for the project.

In addition to making sure the water is safe to drink, the team also has understood that the community will rely on our system for water, and it is essential to make sure that our system does not fail and leave the community without a water supply. When selecting parts, the team took into consideration the overall lifespan of each part, and found that the 10,000 Liter tanks intended to store water from the well have the lowest estimated lifespan at 16 years, with the other parts lasting up to a lifetime. This helps ensure that the storage of the well water will not be impaired for at least the better part of two decades and that the function of the well will persist for much longer. Additionally, continued contact with the community will establish the proper function and maintenance of the well, such as going over ways to troubleshoot issues that may occur. The team intends to both visit the community yearly while also being in constant contact with the BTTC to ensure any issues with the well can be addressed as soon as they occur.

Overall, this project has highlighted how engineering can be used to help solve challenges faced by communities globally, and has in addition taught our team members lessons that extend beyond technical aspects of being an engineer. The solution we have found to this problem in this specific community can be extended to others, and has taught our team members how we can use what we have learned in the classroom to make a positive impact worldwide. In addition to the technical skills the team has learned throughout this project, the team has also learned how to function effectively, and each member has learned to collaborate effectively with one another. By splitting the students into multiple interdisciplinary teams, such as one team working on the CAD, another working on fundraising, one working on a head loss calculations script, and another focusing on the bill of materials, each team member took responsibility for their own work and had to work together for this project to succeed. These non-technical skills have been essential to our team's success and will continue to help our team members be successful when helping communities worldwide when they enter the workforce after university.

4. Multidiscipline and Allied Profession Participation

This project involved multiple disciplines both within and outside of engineering, making it a suitable project for teaching team members how to work in an interdisciplinary team. One engineering discipline involved was mechanical engineering, and specifically the branch of fluid mechanics. Students had to learn basic principles of head loss and energy conservation in order to select the correct components, such as the pump, for the well system. In addition, the branch of structural engineering was involved in the project, specifically when the team considered a water tower to house the tanks for the system. The team ultimately did not utilize this structure (due to finding it more cost effective to simply have a one-foot foundation for the tanks), but collaborated with a professor at our university, to learn the basics of this design. The team learned principles such as static analysis of our structure as well as proofing for static loads such as wind, and discussed seismic loads such as earthquakes.

Another engineering discipline involved in this project was electrical engineering, which was relevant when designing a solar powered system for the pump. The team needed to determine how many panels and which size of them would provide enough power for the pump throughout the day. Additionally, the team did not end up utilizing batteries (due to the high cost and necessity to replace them every few years), but considered creating a system of batteries that would retain power captured during the day to power the system at night. Practically, the team also learned concepts such as how to solder wires and utilize wire caps, as these are going to be essential when connecting the 20 foot wire from the pump to an additional 400 feet of wire in order to reach the solar panels. Finally, the team utilized concepts from civil engineering, and specifically the branch of environmental engineering, when considering ideas for water treatment such as testing the well water and then considerations for filtration systems if needed.

Due to the interdisciplinary aspects of engineering, the team also had to learn and implement skills from other professions. For example, the team learned the importance of project management, and had to utilize skills such as creating schedules, managing disagreements between team members, and finding ways to fundraise for the project. Some of these fundraisers included a raffle, getting donations through gofundme, and having a charity event at a local restaurant. Additionally, skills such as accounting proved to be useful when the team needed to create a budget and manage our funds for the overall project. This showed the team that although some parts might be more suitable from an engineering standpoint, cost is an important factor that must be considered. Overall, the multiple professions and branches of engineering taught the team many valuable skills that are essential to working in an interdisciplinary team in engineering.

5. Knowledge and Skills Gained

Many of the students involved in the project had never taken a fluid mechanics class prior to the beginning of the project, and the team relied heavily on professional engineers and other mentors to teach these concepts to the team. In order to design a well-pump system, the most fundamental knowledge our team needed to have was an understanding of certain concepts in fluid mechanics. Specifically, the team had to learn about head loss and conservation of energy (Bernoulli's equation), and how minor changes to different parameters of the design affects each of these variables. For example, during prototyping the team tested multiple pumps connected to pipes which had different lengths, diameters, and were made from different materials. Unlike in a traditional fluid mechanics class, where a teacher would simply show the equation for major head loss, the team was clearly able to see through experimentation the inverse relationship between diameter and head loss, as well as the proportional relationship between pipe length and head loss. These experiments also allowed the students to construct pump curves for two different pumps, where the pump head in meters would be reflected in the y-axis, and the flowrate in meters cubed per second would be represented by the x-axis. These pump curves ended up being useful when the team had to select a pump, since we wanted a pump that would have an optimal flow rate when the head was

Performing fluid mechanics experiments approximately 400 feet (122 meters). From this knowledge of fluid mechanics that is commonly not demonstrated experimentally in the classroom, our team members will have a greater understanding both mathematically and intuitively of these ideas, better helping them solve engineering problems when they enter the engineering workforce.

When devising a solution to an engineering problem, our team found it pivotal to utilize programs which could simulate and model our design. One of these programs used was MATLAB, which allowed us to apply our knowledge of fluid mechanics to simulate head loss in piping systems with different parameters (such as overall pipe length, pump head, pipe diameter, etc.). For example, our team found that the head loss for a smooth 100 meter vertical pipe would be less than a meter, demonstrating that head loss will be negligible for our design. This allowed us to make the design decision to purchase a pump that would have a head slightly higher than the depth of the well, whereas if head loss was much greater, the team would have had to purchase a pump with a much greater head. Another program utilized by our team was SolidWorks, which was used to create a CAD model of our well-pump system. This let our team visualize what our design would look like when it is implemented in Kenya. Both of these programs are extremely useful in professional practice, as creating both mathematical and visual models can help provide a proof of concept for engineering projects.

Our team in Kenya during our 2023 trip

In addition to technical and practical engineering knowledge, the team members also learned soft skills that are essential for engineers in the professional world. Traveling to Kenya and working with a community across the globe has taught our team members aspects of cultural competency that are essential for any engineer. When working with an underserved community, our team also had to understand that there is an ethical responsibility that each member had to undertake. We recognized that any shortcut in the design process could negatively impact an already struggling community, and each member took responsibility in avoiding any bad outcomes. Additionally, our team members learned skills such as collaboration when working both with our community partners and with each other on this project. The multiple groups that would work on different aspects of the design had to make sure that their ideas would suit their part as well as the project as a whole. This taught the important skill of being dependable as well, as each team had to make sure their work would match the quality expectations for the project as a whole. These skills that our team members learned are essential in any profession, and most importantly will prepare each individual for success when working as a professional engineer after completing their studies.