Envisioning a Better Rural Water Supply for Hancock County

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Sponsor: Jubilee Project, Inc.

Background

In late 2018, Jubilee Project, Inc. sought to collaborate with Milligan Engineering to assess the water quality of a mountain-spring source and improve water availability. This rural water supply provides water to the Cedar Grove Baptist Church and serves as a primary water source to surrounding communities in Hancock County, TN. The goal of our collaboration is to produce a reliable supply of clean water for the church's drinking fountain and bathroom, and offsite use including cooking, cleaning, and drinking.

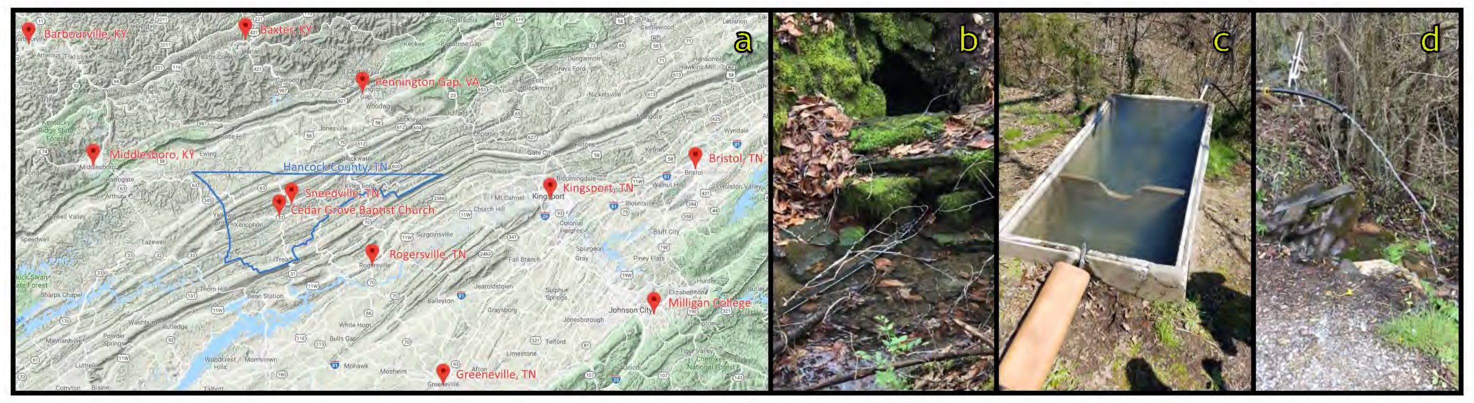

Figure 1. (**a**) Map of Hancock County and old (**b**) source, (**c**) storage box, and (**d**) collection pipe.

Original Design Implementation

At the 2019 RISE Above Conference, Milligan engineering students presented their analysis of Cedar Grove's water source and an initial design proposal. Analysis showed that the source water was contaminated with fecal coliform and high levels of suspended solids. In late 2019, implementation of the proposed spring box, ¼-mile of buried polyvinyl chloride (PVC) pipe, sediment filter, carbon filters, ultraviolet (UV) light disinfection system, and hydrant was found to successfully provide clean water.

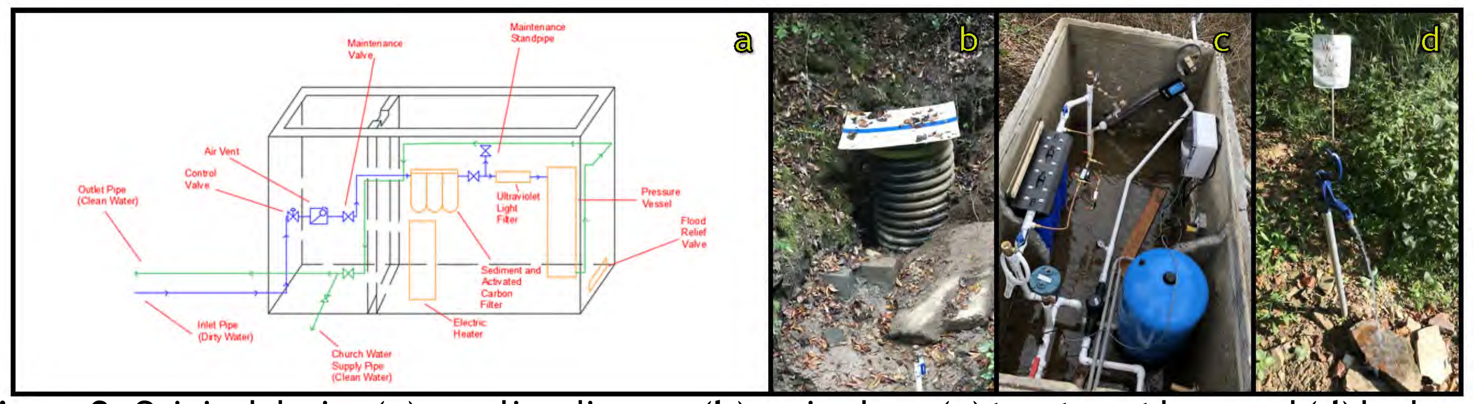

Figure 2. Original design (**a**) one-line diagram (**b**) spring box, (**c**) treatment box, and (**d**) hydrant.

However, it was discovered that 1" diameter PVC pipe had been buried and debris had been allowed into the pipe during installation, both contributing to complaints about low flow from end users. It was also found that the PVC had only been buried 15" deep, making a catastrophic pipe rupture up to 20 × more likely based on Air-Freezing Index analysis using data from weather stations neighboring Cedar Grove. Other shortcomings of the initial implementation, taken as design considerations, are as follows:

- No detection or signaling of premature degradation of UV lamp
- No detection or signaling of potentially unsafe water status
- No detection or signaling of premature clogging of the sediment and carbon filters
- Inefficient treatment box heating
- Absence of data logging for tracking system usage and performance
- Damage to equipment from hydraulic shock
- Potential safety hazard when servicing the treatment box alone due to lid design

Reenvisioned Electrical Design

The manufacturer of the UV disinfection system specifies that the bulb should be replaced yearly, but it is not guaranteed that the supplied UV dose will always be sufficient to sterilize harmful bacteria. The addition of a feature to monitor UV dosage was developed, utilizing a microcontroller and UV sensor.

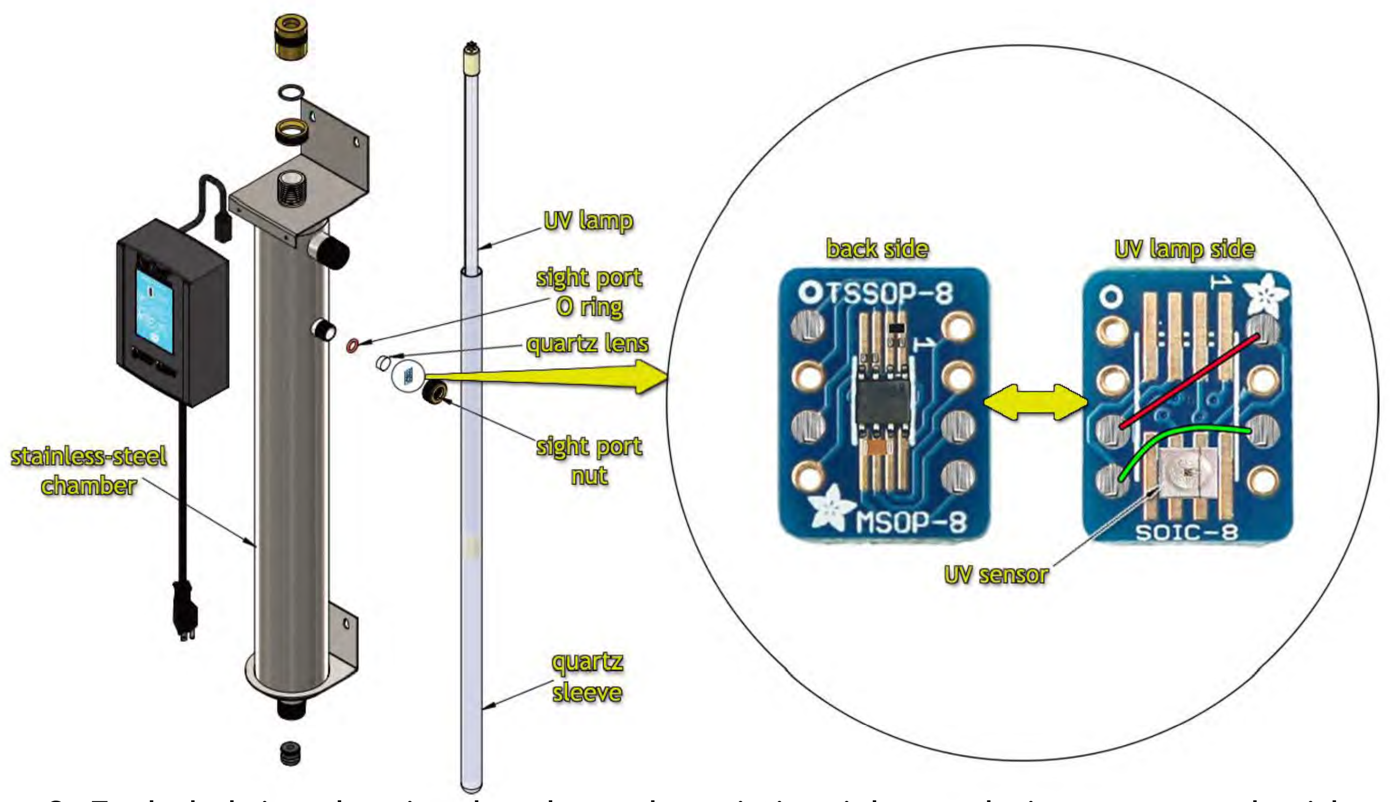

Figure 3. Exploded view drawing that shows the existing sight port being repurposed, with a new quartz lens and surface-mount UV sensor circuit inserted into the existing UV disinfection system.

If unsterilized water is allowed past the UV light, ozonation is required to reestablish sterility. The microcontroller is programmed to detect such occurrences, as caused by insufficient UV dose, brownout, or loss of power, and signal the unsafe state via light-emitting diodes. The microcontroller is to also monitor the differential pressure across the pre-UV filters to detect and signal when they need to be replaced. To offset shortcomings in the installing contractor's implementation of the buried PVC, a new design feature was developed that uses a relay, temperature sensor, and the microcontroller to automatically trickle water through a solenoid valve during freezing conditions. To efficiently maintain safe internal temperature, a new heater was specified with an anti-freeze setting to only switch on below 40 °F. To assist in the implementation of the new electrical design and development of the microcontroller code, a GitHub repository was established at https://github.com/jjgiesey/Sneedville_Milli-microcontroller.

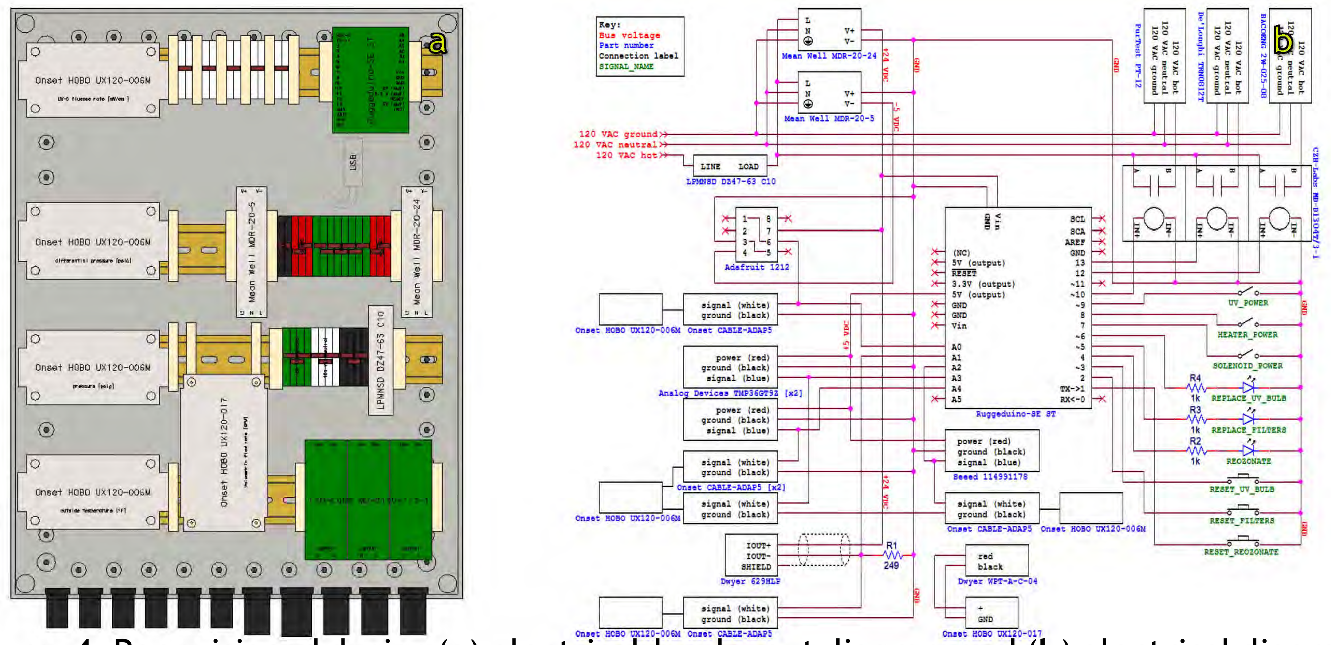

Figure 4. Reenvisioned design (**a**) electrical-box layout diagram and (**b**) electrical diagram.

Reenvisioned Mechanical Design

Instrumentation for measuring gauge pressure, differential pressure, temperature, flow rate, and energy consumption was integrated into the system. Transmitter data is read in parallel by data loggers and the microcontroller to allow both ongoing and real-time assessment of system usage and performance. This feedback aided in troubleshooting the issues with low flow, with peak flow rate improving from less than 1.0 gal/min to 4.5 gal/min. Another change made in the mechanical design touchup was the relocation of the pressure vessel to protect against hydraulic shock. Removing and replacing the original lid that covered the water treatment system was potentially dangerous for a single person. To aid in the safe maintenance of the system, the existing lid design was reimagined to incorporate hydraulic cylinders that assist in easily lifting and gently closing the 100-pound lid, requiring no more than 50 pounds-force to open to an angle of at least 60 °, while closing with no more than 67.4 pounds-force.

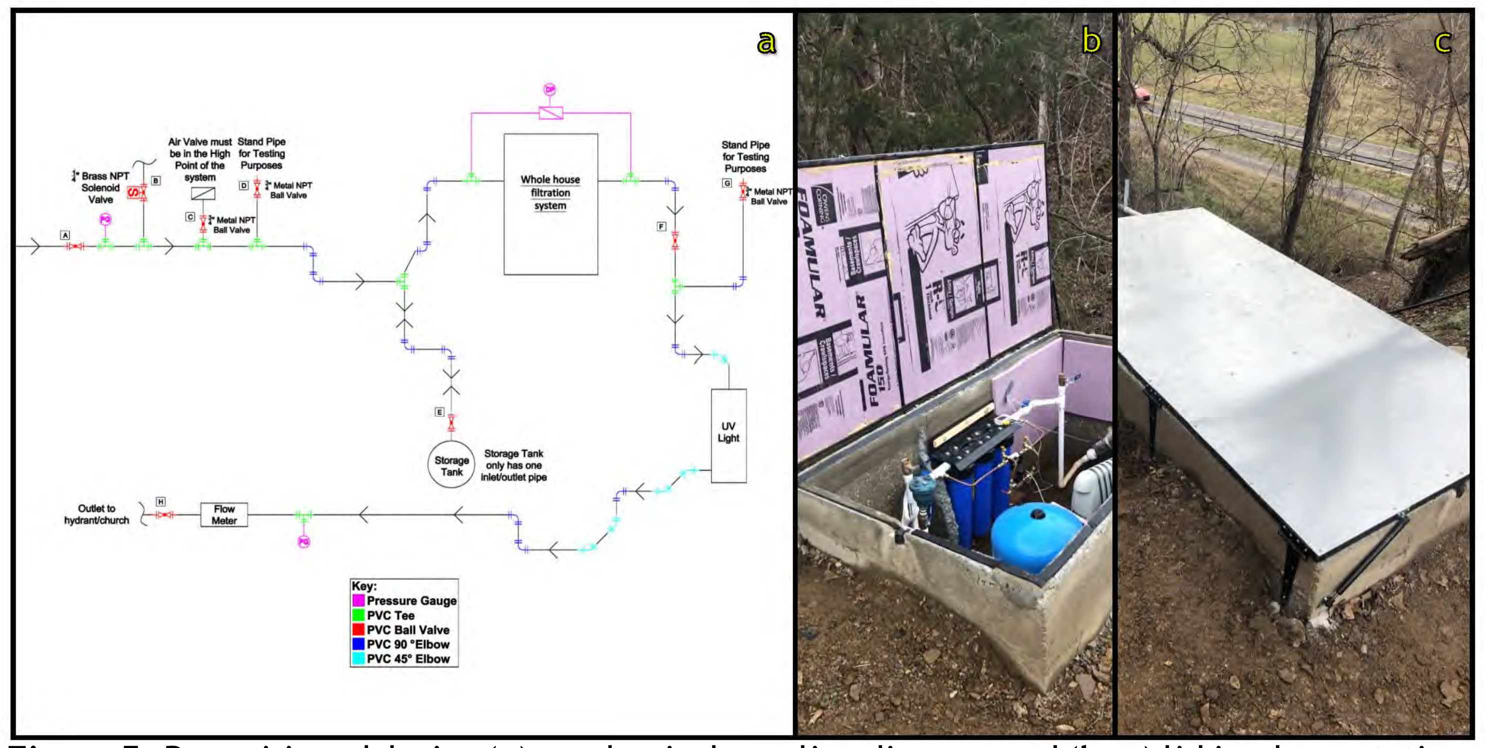

Figure 5. Reenvisioned design (**a**) mechanical one-line diagram and (**b**, **c**) lid implementation.

Conclusions

Due to the circumstances surrounding the coronavirus pandemic, we were not able to finish implementing our complete design as planned. If this project has taught us one thing, it is that the most frustrating problems can sometimes turn out to feel the most rewarding. After graduation and expiration of the statewide stay-at-home order, we plan to persevere in finishing the realization of our new features and testing against our engineering characteristics. Future work includes fitting the UV sensor circuit, integration testing of the microcontroller code, wiring the new electrical box and signaling panel, and installing the trickle solenoid. Regardless, the primary objectives—providing a clean water supply and improving availability—have been achieved. Addition of our microcontroller program and UV sensor circuit will allow clear indication of unsafe water status and when consumables need to be replaced, improving confidence in water safety for end user and provider alike. On top of the already implemented anti-freeze mode heater, implementing the trickle solenoid would ensure that our concerns of long-term thermal reliability have been addressed. The introduction of data logging for system assessment and the upgrades to the lid for safer maintenance are anticipated to substantially improve long-term system availability. Altogether, the improvements to the existing rural water supply should allow it to reliably provide safe and clean-tasting water for years to come, furthering the partnership built on the shared mission of Milligan College and Jubilee Project, Inc. to improve the lives of underserved populations.

Acknowledgements

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