

Using Water Meter Data to Develop a Remote Monitoring System for a Large Rural College Campus

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Abstract - This project aims to interpret and collect water meter data for use by Sweet Briar College's Physical Plant team to aid in water leak detection and mitigation. The primary goal is to interpret data from a water meter on the campus's potable water supply and create a user interface for Physical Plant workers to record and monitor usage remotely. Different hardware configurations were considered and analyzed during the design process, but ultimately, a non-invasive, ultrasonic flow sensor and a SoundWater Flow Computer were chosen for data collection and processing. An application, created through prompt engineering with ChatGPT, serves as a user interface where user-input sensor measurements from the Sweet Briar Water Tank and flow volume measurements from the SoundWater Flow Computer can be used to help determine the presence of a water leak on Sweet Briar College's campus. Under this system, water volume data would need to be collected at the flow computer site and the water level data would be collected remotely through an established application used by physical plant workers. The application created in this project would then work to interpret and store the data input in the system. This new leak detection system can aid the physical plant workers in more efficient and straightforward water leak solutions to prevent water loss issues on the Sweet Briar College campus.

Keywords—water leak, piping, leak detection, water monitor

I. INTRODUCTION

A. Start of Phases One and Two

This research project aims to continue and expand the progress that has been made in the hopes of implementing a leak detection system for the Sweet Briar College Campus. These efforts began in response to a pipe leak incident in the fall of 2022 where the resulting water loss was so severe that the college was forced to send students home from school. The initiative to develop a way to more efficiently detect leaks was formed in three major phases. Phase one began soon after the leak incident, when former Sweet Briar students started their Capstone project focused on preventing future water leaks at Sweet Briar. A big deliverable of their project findings is that they developed a map of the metal piping on campus using ArcGIS since they were able to trace the metal piping on campus using a ground penetrating radar (GPR) [1]. The team outlined several different ways their work could continue, one of which

was to implement water meters to help detect leaks [1]. Phase two began a year later when the author continued the work done by Moock and Williams in their capstone project. The goal of phase two was to determine the proper hardware to effectively detect leaks on Sweet Briar's campus. The main outcome of this project was a better understanding of the water flow network as well as discovering a suitable water meter along with useful water meter locations for campus. The water meter selected and purchased during this phase was the SoundWater Cypress flowmeter [2]. Within phase two, there were determined to be three ideal locations for the water meter to be installed: the mainline, horse stables, and Woodland Rd. Work had been done to begin preparing the main line location for a water meter installation [3]. Below in Figure 1 is one of the maps that Moock and Williams created which the author used to help determine ideal locations for water meter sites [1].

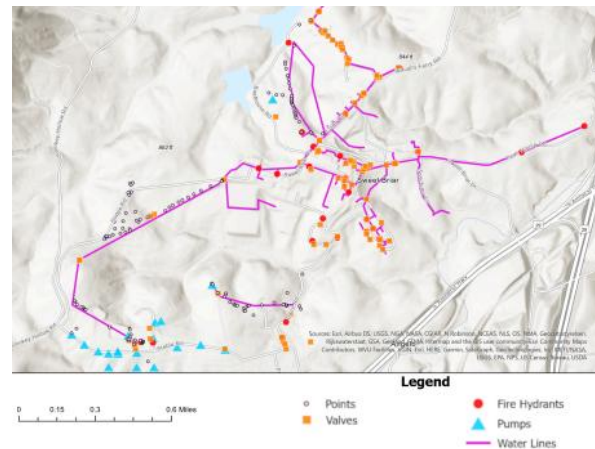


Fig. 1. Moock and Williams' Map of the Water Pipe Network [1].

B. Continuation of Phase Two

In continuation of the second phase, a vault or box had to be implemented as excavation had to take place to expose the metal piping along the main line location, leaving a significant hole. A concrete vault was installed (essentially a concrete lining forming box in the existing hole with a metal lid to protect the

meter from the elements). After the vault's installation was completed, the electrical set-up was completed to provide a power source for the water meter inside the vault, leaving the last step of this process to be the installation of the water meter. To continue this research, it is essential that the main line location is completed so that the meter can be installed correctly and data from that meter can be collected. Furthermore, the two additional locations noted in the previous research could be used to both close the material balance on the water pipe network and provide additional information on water consumption for the largest residential community on campus [3]. To provide more information on how the material balance could be closed, there is one water tank on Sweet Briar's campus with only one source of water, the Amherst County Water Tank. The main line pipeline, which is where the water meter location is along, is the only input source of water that Amherst County's water feeds the Sweet Briar Tank through. The Sweet Briar Tank also has two outputs: the main line pipeline and the horse stables pipeline. The main line pipeline was found to both feed and draw water from the tank, so water flows in either direction in the piping. The other output is the horse stables pipe line which feeds into the campus' extensive horse stables and arenas for the equestrian program [3]. Figure 2 shows both how the flow behaves while the Sweet Briar water tank is being filled by the Amherst County Water Tank and as water is being drawn solely from the Sweet Briar Water Tank.

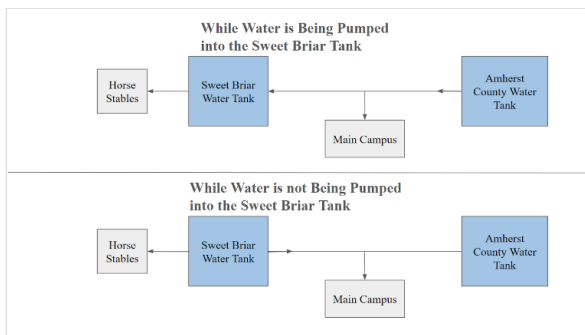


Fig. 2. Water Flow Diagram of Sweet Briar Campus

C. Start of Phase Three

This project begins phase three of the initiative where the proper hardware gets installed and a remote leak detection system gets developed and implemented. The major goal of this phase is to develop a way to detect leaks using a water meter. While installing a water meter is helpful, water meters by themselves cannot detect leaks. Water meter data only primarily indicates water consumption and movement. However, using the knowledge of the material balance can make leak detection possible with water meters, even with just a single water meter. In order to do this, there would need to be some way of adding and subtracting water flows to close the material balance. Since doing this math daily would be confusing, there must be some sort of system put in place to both remotely monitor the data and combine the flows. Creating this system is the goal of this project and the final phase of the initiative.

D. Location Considerations

Before work on the current project started, the team wanted to determine which locations should be prioritized. The full installation of the incomplete sites requires four major steps. The first step is to check for both power and utility lines at each site. This step must be completed before any excavation begins. If there are no power or utility lines, the site must be excavated to expose the piping and prepared with the proper power supply set-up so the meter can then be installed. Afterwards, the Bluetooth signal must be converted to either a Wi-Fi or cellular signal to allow for remote leak detection. This step is necessary as the flow meter can only interface through Bluetooth and Bluetooth is not ideal for remote monitoring applications [2]. Lastly, there must be a way to synthesize the data easily and quickly so physical plant workers can monitor for water leaks as water meter data alone is not helpful for leak detection. At the beginning of this project, only installation of the main line site had been started and progress was in the middle of step two as a valve box was installed, but the water meter had yet to be installed.

TABLE I. LEAK DETECTION CHECKLIST

Leak Detection Checklist		
Main Line	Horse Stables	Woodland Rd.
1. Check for power and utility lines.	1. Check for power and utility lines.	1. Check for power and utility lines.
2. Prepare location and install meter.	2. Prepare location and install meter.	2. Prepare location and install meter.
3. Change meter signal from bluetooth to wifi or cellular.	3. Change meter signal from bluetooth to wifi or cellular.	3. Change meter signal from bluetooth to wifi or cellular.
4. Synthesize data and send it to the physical plant team	4. Synthesize data and send it to the physical plant team	4. Synthesize data and send it to the physical plant team

As each of these sites would require significant time, it was determined that the focus of this research project would be on completing the tasks for the main line site. Therefore, a significant part of this project was spent exploring methods of leak detection using only one water meter. Not only would this make the leak detection easier to achieve for longevity purposes, but it would also make this project more cost-effective, which is one of the main considerations for this project.

II. METHODS AND MATERIALS

A. Exploring Remote Leak Detection Hardware and Software Options

Early in the research process, using an Arduino Uno was explored to determine whether it was a suitable remote leak detection option. An Arduino Uno is a microcontroller board which are designed to read various inputs, like sensors, and output various responses, like turning an LED light on. The functions of this device are controlled by user-input programs [4]. This option was considered as Sweet Briar College owns several Arduino Unos and they could be tested with the system. It was thought that these devices could easily interface with the

SoundWater water meter and send messages to the physical plant team. However, the sources found for Arduino integration did not include helpful information on how to connect the type of ultrasonic water meter sensor that the college owns with an Arduino. For example, there is a source that outlines how to connect an Arduino to an ultrasonic sensor, but not the type of industrial water meter that the college owns. It is more aimed to help those who want to learn Arduino functions in a classroom setting [5]. Beyond the information for Arduino information being difficult to find, including an Arduino in the system's set up would make maintenance difficult for the physical plant workers. If the Arduino stops working, it would be very challenging for them to fix the hardware or software failure to fix the system. Due to information on Arduinos being difficult to find to determine ways to integrate them into the system and longevity concerns with maintenance, it was decided to stop and move to a different remote set-up option. Although the Arduino was not further considered, looking into this device allowed for more thought on what functionality the remote system should include.

The next option that was considered was the SoundWater Computer. This device was considered primarily because it is produced by the same company that produced the water meter the college owns. Additionally, this device automatically calculates and measures the total forward and backward volume of water flow in gallons [6]. This feature is especially useful as in the previous option with an Arduino Uno, additional coding would be required to produce these measurements. Due to the benefits of the flow computer device, it was determined that the project will go forward with the purchasing and installation of this device in conjunction with an app that can easily aid physical plant workers in leak detection.



Fig. 3. SoundWater Flow Computer [7].

B. Site Visits and Vendor Communication

In the beginning of this project, it was discovered that the electrical wiring had not yet been fully installed for the water meter installation. Soon after this discovery, work was done

alongside the physical plant team to connect the meter to the power source and connect it to Bluetooth in order to interface with the data that the meter collects. However, the team had a difficult time connecting the device with Bluetooth although the correct voltage and wire connections were confirmed. With more troubleshooting, the cause of the Bluetooth connection failure could not be properly determined. The meter was then sent to SoundWater to determine what the issue in the flow meter was, include the MODBUS adapter in the meter, and purchase the SoundWater Flow Computer. The MODBUS adaptor allows the water meter to connect to the flow computer. Once SoundWater inspected the flow meter, they discovered that internal circuits and hardware were fried from an extreme voltage being applied to the device. As the team ensured the proper voltage had been applied to the device, it was determined that the surge in voltage was caused by lightning. While the power at the site is grounded, there is an area of exposed piping about a quarter of a mile from the water meter site. This piping is made of ductile iron and a lightning strike could certainly allow for the voltage to travel to the water meter. The solution to this problem is to ground the exposed piping so the meter site can also be fully grounded. After the site was grounded, the installation of the meter and computer was able to proceed.

C. Application Considerations and Generation

After initial work on the project, it was determined that the only way for the volume measurements to be useful was to create an application to help the physical plant team more clearly spot leaks. Since the project's central topic is not computer science, ChatGPT was used to create the code for the application. In the first iteration of the code, which was generated using ChatGPT, the prompt input to the chat bot is shown below:

"I would like to make an app to use for my college's physical plant team to aid with water leak detection. I would like this app to be as simple as possible for the user. I am most familiar with using Python, but I can try to use a new computer language. We have a water meter set up already and we will have a flow computer set up soon that can add and subtract flow measurements. The water meter is set up near the water tank. I would like this app to take the measurement of the water flow volume (which this flow computer can calculate) and input the volume that the water tank rose and compare those values. If these values have a difference of more than ten percent, I would like the app to output an error message. Where the water meter is located is the water tank's only input of water, but the tank contains two water outputs. I would like the app to allow for the input on the amount of water volume that left the tank along with the negative water volume calculated by the flow computer. If the app could subtract the flow volume from the flow computer from the water tank, the app could say that the Horse Stables water line is the remaining amount. Lastly, I would like the app to store these inputs and outputs with the dates that they were made. Could you give me code to achieve this?"

This above prompt was written based upon the assumption that in order to determine the presence of a leak, the total inputs and outputs of water in the Sweet Briar Water Tank for a given time was required. Since Amherst County supplies the Sweet Briar with water, if the values for the input water volume were compared for both the water tank and flow computer, then more accurate leak detection results could be obtained. This logic could also be done in reverse, but since only one of the two outputs are known, combining the output measurements would produce the horse stables output.

In the above prompt, a 10 percent error is stated as the standard of how much deviation should occur before the code sends an error message to the user. The standard was found in a journal article published by *Biores Scientia* where it is stated that the recommended standard benchmark for an unaccounted for loss of water is 10 percent. This means that efforts should be put in place to reduce water loss above 10 percent and in this project, this could be seen as the error or differences in measurements [8].

After the first iteration of the application code, multiple troubleshooting steps were taken. The first iteration was not perfect, but it was a good starting point. ChatGPT was able to assist in all troubleshooting efforts. In between each iteration, the code would be run, tested with testing data, and then ChatGPT would be informed of what needed to be changed, added, or what should not be included. As an example of this, at one point, the code provided a user input for the total backward volume twice instead of an input for the total backward volume and an input for the total forward volume. Additionally, the chatbot would assist with errors in the code. If the code ran with an error, the error message would be sent to the chatbot and a new iteration of the code would be given, aiming to fix the given error. The chatbot was especially helpful in modifying the program to allow data to be exported and saved into Excel so the physical plant team would have an easier time with storing and interpreting data [9].

Further into the iterative process, it was decided that knowing the exact times when the water tank receives water or when water is drawn solely from the water tank is no longer necessary, since this can be more accurately determined using the net values. Instead of needing exact time-stamps or information on when the water tank is being filled, all that is needed is the approximate change in water level and volume. Because the logic for the code had drastically changed, the following prompt was given to ChatGPT:

“I would like a new code. I still would like this to be an app used by Physical Plant. I would instead like the user to input two things: the total net volume of water with the water meter and the current total volume of water in the water tank. Both of those measurements will be in gallons. I would like the app to make calculations for the day so there should be a morning and afternoon measurement. This app should be able to calculate the difference between their water volumes and store that value as a separate measure: Daily Horse Stables Water Consumption. As there are two outputs and only one input, the difference between these measurements should be the horse

stables (the other output). I would like the app to be able to store horse stables measurements so Physical Plant can determine if the measurement is within the normal range for the system. I would like plenty of comments in this code to make it beginner friendly. Can you make this code?”

The iterative process for the code following this was the same as before. Additionally, ChatGPT fixed incorrect logic given to the prompt. It was later assumed that the absolute values of the water volume inputs would be needed to calculate the horse stables output. Instead of including absolute values into the calculations in the code, it explained why absolute values were the incorrect approach for this application since the sign changes are necessary information to produce accurate results [9]. As a last major modification to the code, it was discovered that physical plant workers only receive the water level height in feet instead of water level volume. However, this water level can easily be converted to a volume. The tank is 40 feet tall and it holds 500,000 gallons of water, so the feet can be converted through this relationship. With this relationship, ChatGPT was asked to replace the user input for water tank volume in gallons to a user input for tank height in feet. With this input, the chatbot was also asked to use the above feet to gallons relationship, which would mean that each foot is equal to 12,500 gallons of water, to convert the units in the code and calculate the horse stables output.

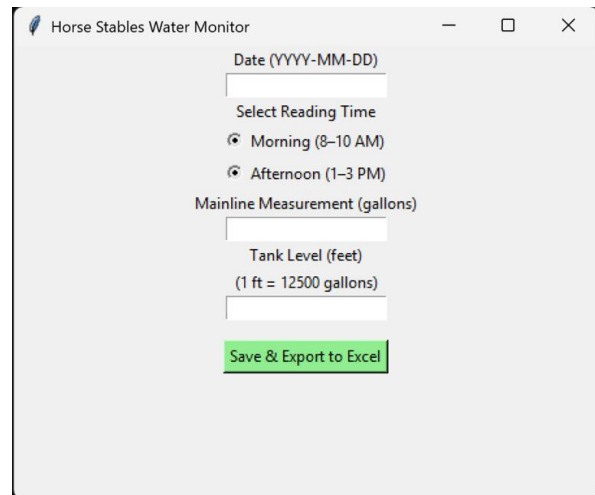


Fig. 4. Horse Water Monitor App Screen [9].

Figure 4, as shown above, shows the display of the Horse Stables Monitor App. The user is able to input the date, what time the measurement is taken, and the flow computer measurement, and the tank water level [9].

Results

A. Site Visits and Vendor Communication

After the water meter was sent to SoundWater, they completed the repair work needed from the voltage damage. The SoundWater Flow Computer and the MODBUS Adaptor Board were purchased. These items were then shipped to Sweet Briar. In the meantime, the Physical Plant team ensured that the main line water meter site was grounded. First, they ensured that Sweet Briar Water Tank was grounded then proceeded to ground the exposed pipe across the creek. The SoundWater shipment has just arrived and so far, there has not been enough time to install it and test the Horse Stables Monitor App. This task of installing the meter and flow computer and testing the data with the app alongside the Physical Plant Team will take place shortly.

B. Application Proof of Concept

Without the meter installed, real measurements could not currently be gathered, so in the following example, testing data are used to demonstrate a proof of concept of the Horse Stables Monitor App. In this example, the morning mainline measurement is 200,000 gallons and morning tank height is 37 feet. These measurements are recorded in the app. What this looks like with the app is shown in Figure 5 below.

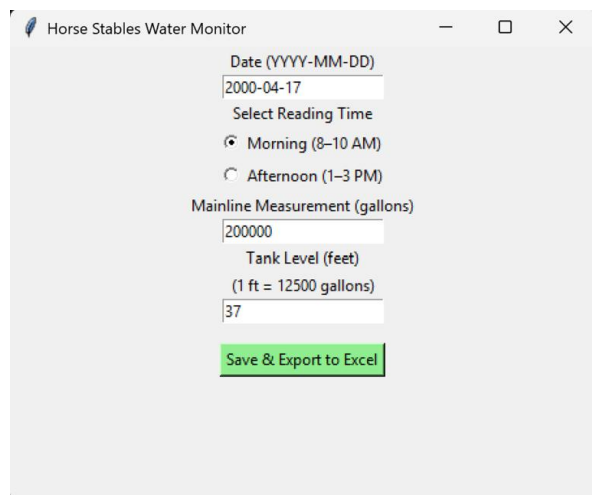


Fig. 5. Example of the App Display with Test Data [9].

For the afternoon data, the mainline measurement is 150,000 gallons and the tank height is 36.5 feet. These measurements are also recorded in the app. The app shows what the spreadsheet looks like after both data entries are completed in Figure 6.

1	Date	Morning Mainline	Morning Tank (gal)	Afternoon Mainline	Afternoon Tank (gal)	Mainline Net	Horse Stables Usage
2	4/17/2000	200000	462500	150000	456250	-50000	-43750
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

Fig. 6. Example Excel Sheet Using Test Data [9].

As a simple test, the math of what the app calculates can be done manually to prove that the values it outputs are accurate. For the mainline net measurement, this is simple 200,000 gallons subtracted from 150,000 gallons to get the result of -50,000 gallons. For the horse stables usage, the first step is to convert the morning tank height from feet to gallons. Since it is established that the 400,000 tank is 40ft, it is then known that every foot in tank height is 12,500 gallons. With this in mind, 37 feet can be multiplied by 12,500 gal/ft to receive 462,500 gallons of water in the tank. If the afternoon tank height of 36.5 feet is gone through the same conversion, it equates to 456,250 gallons of water in the tank. Now for the final check, the tank volume net value is 462,500 gallons subtracted from the 456,250 gallons which results in -6,250 gallons of water. This value, subtracted from the mainline net, which is -50,000, gives the result of -43,750 gallons of water. This would indicate that this volume of water was drawn from the horse stables area of campus. ChatGPT also assisted with understanding and developing the logic and calculations involved in the application.

C. Interpretation of Data

While output from the Horse Stables Water Monitor Application alone cannot directly detect leaks, a record of this data could. With continued measurements from the app, data will continue to be collected in the Excel sheet. After a few weeks, establishing normal baseline values will be obtained. This means that the physical plant team, after sufficient data is collected, could interpret the water volume being drawn from the Horse Stables output as either a normal and expected measurement, or something that needs to be further investigated. While in the timeline of this research, this could not be obtained, further use of the app will only help the points form a trend. As this is an Excel sheet, the physical plant team may also use a number of data graphs or charts to better understand and interpret the measurements.

III. DISCUSSION

Through this project, one location was selected to be the focus of this research, the main line water meter location. The research then went on to prove that a material balance could be achieved with only one water meter which could be used to aid the Sweet Briar Physical Plant Team in leak detection. While the leak detection is not fully remote, the data collection and interpretation are far easier with the implementation of the SoundWater Flow Computer in conjunction with the Horse Stables Monitor Application. The app uses the main line water meter net values alongside the Sweet Briar Water Tank height values to output the daily water volume output that is drawn from the horse stables area on campus. With further use of this app, established normals can be obtained to make the output that the app produces useful and valuable for the physical plant team. The only major shortcoming of this system is that it assumes one thing: there are no significant leaks at the start of data collection. If there is significant leakage in the water network, the established normal estimates developed from the

measurement outputs would no longer be good benchmarks for future recorded data. However, with the assumption that there are no current water loss issues with the network, this system could be sufficient in determining major leakage on the Sweet Briar Campus.

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