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Retrofitting Trinity's Water Fountains: Senior Design Project - Fountain

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Pledged:

Abstract

The primary objective of this project was to reduce plastic waste from Trinity University. Specifically, the projects aim was to decrease plastic water bottle use on campus. Three approaches were used to achieve this objective. First, a retrofit kit was created that can be used on 77% of the water fountains on campus. The retrofit kit includes the addition of a secondary nozzle to the water fountain which makes it easier to refill reusable water bottles for a variety of reasons. Second, water contaminant testing was completed by San Antonio Water System. The tests showed that although water bottles had lower contaminant levels, both drinking fountain water and bottled water samples met all EPA quality standards. The third component of our project included an awareness campaign to inform students about the benefits of using reusable water, as well as the existence of our retrofit design on Moody 1st. After the campaign, a survey showed that 16% of students are aware of the retrofitted fountain on Moody 1st, that 93% of students would use a one-handed bottle refill device, and that 97% of students would be more willing drink tap water after being shown that it met all water quality standards. Thus, the installation of our retrofit kit on additional drinking fountains on Trinity's campus is highly recommended.

Executive Summary

The goal of our project is to encourage a more environmentally friendly culture at Trinity by increasing the frequency with which students refill reusable water bottles using the campus' drinking water fountains. Three approaches are used to meet this goal. First, a water fountain retrofit will be designed which will allow students to refill water bottles on campus without having to tip the water bottle. The retrofit will also include a filter which will ensure heightened water quality at retrofitted water fountains. Second, a comparison between the contaminant levels found in bottled water and tap water will be used to show that both sources of water are equally safe for ingestion. Third, the benefits of using refillable water bottles in place of plastic water bottles will be marketed to students on campus.

To test our solution to the design problem, several qualitative and quantitative tests are performed to evaluate the effectiveness our design. First, several tests are conducted on the retrofit kit to ensure that our design meets our original design criteria. Additionally, water samples are taken around campus at drinking fountains and from water bottles sold on campus. These samples are then analyzed with the aid of San Antonio Water System to ensure the qualtiy of both types of samples. Also, a promotional campaign through various media on campus will attempt to inform students of our initiative on campus and try to promote a Refill, Reduce, Recycle, Refill culture on campus. With these efforts, the success of our project will be evaluated.

After running these tests on our design, we received positive results in each sub-section of our design project. The retrofit kit successfully met all of our project objectives and provided a viable alternative to buying water bottles on campus. The water quality analysis proved that the water from the drinking fountains on campus meets all quality standards set forth by the EPA and is perfectly safe to drink. Our promotional campaign with limited means was able to reach about 16% of the student body, but with further resources will achieve greater success.

After completing this design project, we successfully designed a retrofit kit to a majority of water fountains on campus, ensured the water on campus is safe to drink, and promoted our design to the student body. We recommend further implementation of our design around campus and to continue with the promotional campaign to reduce plastic waste generated at Trinity.

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1. Introduction

1.1 The Rising Issue of Plastic Disposal

Disposing of manmade waste is one of many environmental issues today. A combination of factors, including the sheer scale of waste generated annually and the diversity of materials disposed of, make efficient waste disposal a complex problem. Specifically, wastes made from plastic materials are not biodegradable. In fact, plastics are new enough that no data exists to pinpoint the expected lifetime of plastics in landfills. Many scientists believe that these plastics will break down only after thousands of years (Weisman, 2007). As a result, plastics will increasingly contribute to the quantity of human waste in the future. Reducing the use of plastic water bottles would curb this trend.

1.2 Project Description

At Trinity University, the quantity of plastic water bottles disposed of annually is noteworthy. Currently, Trinity University enrolls about 2,700 students. A conservative estimate would be that on average each student purchases about 10 water bottles a month, or about 100 water bottles per school year. Thus, Trinity University disposes over 270,000 water bottles annually. Moreover, the cost of plastic water bottles is prohibitive. At Trinity, water from plastic bottles costs nearly $10 per gallon. Generally, a decrease in the use of plastic water bottles on campus would save students money and be a boon to the local environment.

A localized trend on campus is for students to carry reusable water bottles. This project intends to popularize this trend by addressing obstacles to the use of reusable water bottles at Trinity. The primary goal of this project is to design a kit which can be used to retrofit drinking fountains on campus. This project should make it easier to refill reusable water bottles as well as show whether or not the drinking water is of the same or better quality than water from plastic bottles. A successful design will improve the cost, in terms of time, money, and ease of use, of using reusable water bottles for students on campus. Finally, implementation of the design must be sufficiently inexpensive that the university would conceivably apply it to water fountains across campus. Also, a campus wide campaign will be run to increase awareness of the negative outcomes which result from plastic water bottle use. This campaign will educate students about the deleterious effects of plastic waste, the economic cost of using plastic water bottles, and the high quality of water from drinking fountains. The quality of water from drinking fountains on campus will be tested with the financial and technical aid of the San Antonio Water System. The cost of this testing was covered completely by the San Antonio Water System. Without their aid, the full completion of this project would not have been possible.

Overall, this project will apply engineering solutions to make reusable water bottles easier to use in practice. Successful completion of the project will decrease Trinity's plastic waste output and allow the university to take another step in the direction of environmental sustainability.

There are several constraints that have influenced the direction of the design for this project. Economic issues are often significant factors in designs as engineers are always looking for better and cheaper ways to accomplish a goal. This project is no exception. A cheaper design is more likely to be applied to a larger number of fountains on campus. Therefore, the retrofit needs to cost no more $400. This price will help enable the retrofit's use on a majority of the water fountains campus-wide. In addition, the retrofit needs to be relatively low maintenance. Annual maintenance should cost no more than $150 (the approximate price of our most expensive piece and labor) and all additional parts should be easily accessible. A low initial cost will make the design marketable to organizations on Trinity that may be willing to fund the application of the design. Also, greater ease of maintenance will make installation more desirable for Physical Plant, which will be responsible for installing and maintaining the retrofits. Health and safety are also important constraints to consider, especially when dealing with a human being's reliance on uncontaminated water. Therefore, all of the water dispensed by the retrofit must meet EPA standards for water quality. Using the retrofit itself to refill a reusable bottle must also not cause any potential injury.

A fundamentally important constraint on the project is the environment. The retrofit needs to be applicable to the large majority of water fountains on campus, because accessible retrofits are more likely to be used by Trinity students and faculty. Over time this will increase the use of refillable water bottles and reduce the amount of plastic water bottles sold on campus. Depending on the effectiveness of the design, the retrofit could be constructed on many campuses. Greater use of the retrofit will decrease plastic waste.

2. Design Description

All of this information, along with a great deal of background research, has provided an excellent foundation for choosing the design that will best fit the stated objectives of this project. The major components of the design are the construction of the retrofit to a water fountain, and water quality testing.

The retrofit we have designed will come in a kit with all of the materials needed to construct a functional bottle refilling device on the top of the water fountain that only requires one hand to use. This retrofit will be applicable to multiple types of water fountains. Each water fountain model on campus does have a strainer to trap particles but in particular any model made after 2000 does have some type of filtration in its internal components. Instead of destroying the filtration system, the final design will simply add a filter to the water inlet or source of the fountain. Then, the internal piping will be simply rerouted to allow for a separate line to feed the new dispenser, while still maintaining the integrity of the original water fountain and its cooling and filtrating functions. In addition, adding the retrofit in this manner will also ensure the water coming from the new dispenser will be of high quality and cooled by the fountain. Pictures and technical drawings of the entire final design can be found in Appendix H. Finally, necessary water quality testing will be performed to ensure that the retrofit is providing clean and safe water to the Trinity community.

2.1 The Filter

The purpose of this subsection is to take the inlet water provided from the wall and run it through a filter to remove unwanted components from the water which affect its taste and color. From the inlet feed the water passes through a particle strainer, a 3/8" MIP union, a ball valve, then a 3/8" MIP x 3/8" Compression elbow followed by a 3/8" Compression x ¼" MIP union which connects the inlet water to the inlet of the filter.

Figure 1: Retrofitted piping leading to the inlet of the filter.

Figure 2: The outlet of the filter.

The filter used is an AP717 Aqua-Pure Water Filter. It is a simple charcoal filter and restricts the passage of materials as small as 5 microns. It has an intended service life of one year.

From the outlet of the filter there is a 1/4" MIP x 3/8" Compression elbow, followed by a 3/8" Compression elbow, then approximately 20 inches of copper piping. The supply line continuing to the fountain will connected to the inlet of the reservoir tank by a 3/8" Compression union during the internal repiping.

2.2 The Internal Re-piping

There are a few minor changes which need to be made to the internal re-piping of the water fountain in order to get water to the additional water fountain dispenser. Typical fountain schematic will be discussed using parts in reference to Fig. 4 and Fig. 5.

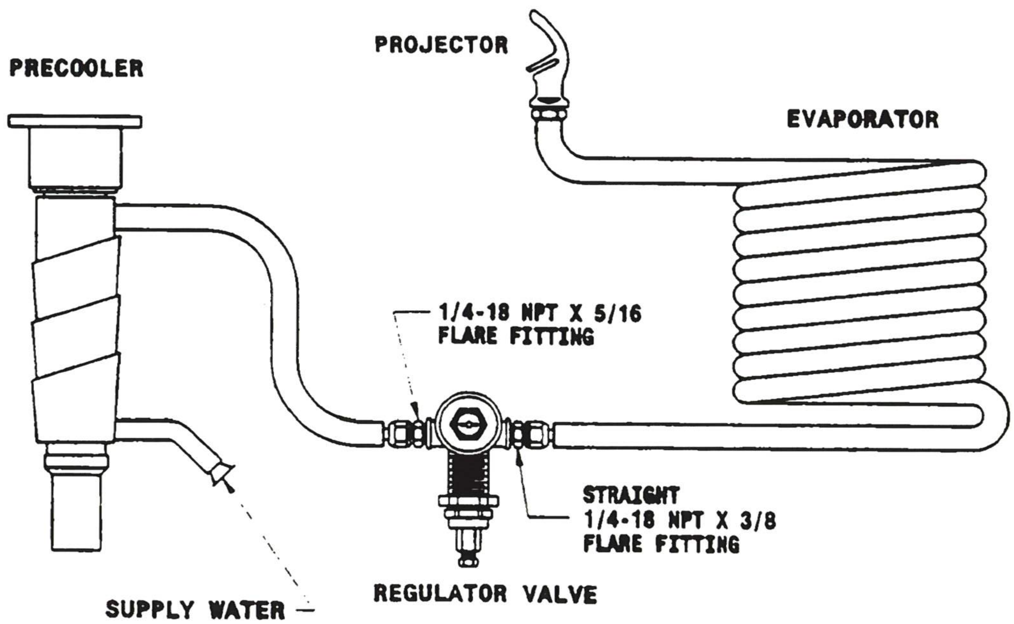

Figure 3: Pre-existing water fountain schematic

From the outlet of the water filter, the flow line for the water typically goes through a pressure regulator in order to regulate the pressure of the water coming into the fountain. This is where the first modification takes place. A cut in the water line is made approximately 6 inches from the inlet of the pressure regulator in Fig. 4. From this cut a 3/8" brass union will be added along with approximately 4 inches of piping (Fig. 5, label 7). An additional cut needs to be made to the line entering the inlet of the water storage tank (Fig. 4, post-regulator valve). The union from the inlet of the water fountain will be joined with the inlet of the water storage tank (Fig. 5, label 7). This new piping ensures that all water entering the fountain goes through the refrigeration cycle in the reservoir tank. The next cut that needs to be made to the internal piping is roughly 4 inches past the output of the reservoir tank. A 3/8" tee will be placed here (Fig. 5, label 2). The other two lines will be constructed from additional piping. One line will need to be long enough to travel to the inlet of the pressure regulator (Fig. 5, labels 2&3). The second line will travel to a 3/8" gate valve, then to the retrofit dispenser (Fig. 5, label 1). The gate valve is in place just in case there any construction needs to take place on the retrofit dispenser; the main function of the water fountain will not be compromised.

On the other hand, an additional cut needs to be made in the line from the outlet of the pressure regulator. From this cut the water will flow to the standard bubbler on the fountain (Fig. 5, labels 4-6).

In total there are three main cuts which need to be made. The first is cut from the inlet of the fountain to the water storage tank, or reservoir tank (Fig. 5, label 7). The second cut goes from the outlet of the water storage tank to both the inlet of the pressure regulator and the inlet of the retrofit water fountain dispenser (Fig. 5, labels 1-3). The third and final cut is located from the outlet of the pressure regulator to the original water fountain bubbler (Fig. 5, labels 4-6).

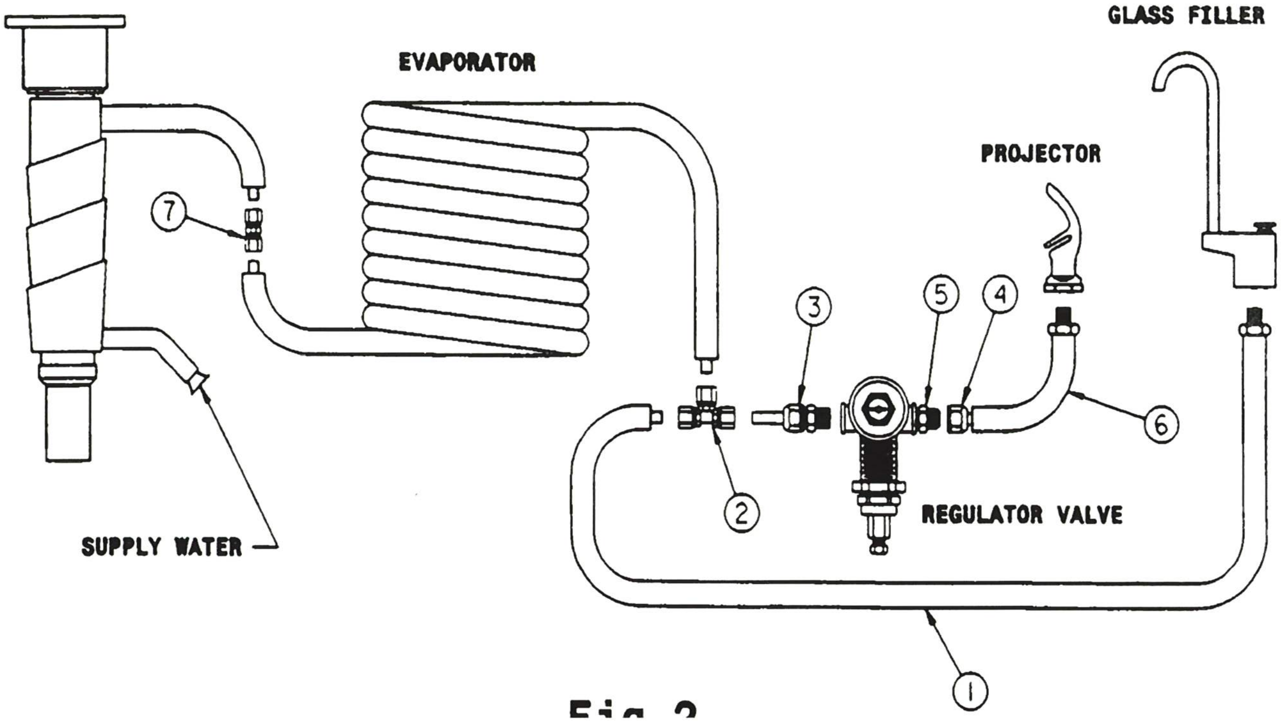

Figure 4: Retrofit to water fountain.

Once the internal piping of the water fountain has been adjusted the only component left in the design is the new chrome water dispenser (see Appendix A). The dispenser is simply screwed on to the 3/8" male nipple that protrudes from the hole in the top of the water basin.

Figure 5: Picture of dispenser connected to bowl.

The dispenser is screwed on tightly to this part of the line and turned so the outlet of water is facing the drain across the bowl. Lastly, any parts used to stabilize the dispenser are added if necessary. These include a hexagonal lock nut just underneath the water basin for stability and the application of plumber's glue at leaky portions of the pipe.

2.3 Water Quality

The second component of our project is to determine if our design delivers quality water comparable to that found in commercially available plastic water bottles. Legally enforceable limits for the maximum concentration of every hazardous and unaesthetic contaminant are set by the Environmental Protection Agency (EPA). Specific limits can be found on the EPA's website ("Drinking Water Contaminants", 2010). Undesirable contaminants are split into two categories, primary contaminants, which when ingested in certain quantities can cause known health effects, and secondary contaminants, which adversely affect the taste, color, and cloudiness of water and can cause skin or tooth discoloration at higher concentrations ("Drinking Water Contaminants", 2010). Primary standards can be further broken into categories, including microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides. Secondary standards set by the EPA are not legally enforceable at the national level. In some states, however, legislation has been passed to make secondary contaminant levels enforceable by law. Water which does not meet secondary contaminant levels is not used as public drinking water in Texas (Texas 123). Additionally, oversight of monitoring requirements, analytical requirements, reporting requirements, and compliance determination is done at the state level. In Texas, this is overseen by the Texas Commission of Environmental Quality (TCEQ).

Water quality tests must be completed by a certified laboratory to ensure the quality of the drinking fountain water on campus. Water quality tests would have to be run at multiple drinking fountains on campus and on multiple samples of water from plastic bottles to formulate statistically reliable results. Since water from plastic bottles comes from the same source, there would be less variation in contaminant levels among different water bottle samples. Thus, fewer samples of bottled water need to be collected. An ideal testing matrix would include seven samples from various drinking fountain locations on campus, and three water bottle samples. However, given our cost constraints, even this could prove difficult. A list of the different types of contaminant tests available, and their approximate price, is given in Table 1. The approximate costs for each test were forecast for us by Cal Chapman (personal communication, November 12, 2010), a member of the engineering board of advisors for Trinity's engineering department, who has a wide range of experience in the field of environmental engineering. The purpose of each test is explained in more detail in the water testing section. Information in that section which does not contain a direct reference was given to us by Cal Chapman (personal communication, November 12, 2010) or consisted of general knowledge.

Table 1: List of water quality tests and their approximate price per sample.

Test	Approximate Price per Sample
BAC-T	$20-$25
Minerals suite	$80-$120
Trihalomethanes (THMs)	$150-$170
Haloacetic acids (HAAs)	$200
Phthalates	$350-$400
Heavy metals/add mercury	$125-$200/+$30

Ideally, we wanted to test for each of these contaminants in our water source. However, given our budget constraints, help from local laboratories was necessary for comprehensive testing. The testing was completed for us complements of the San Antonio Water System. The actual cost of these tests was about $7000.

3 Methods

3.1 Prototype and Final Design Methods

A variety of experiments were tested on the water fountain prototype and final design to analyze the design objectives. Principal tests included a flow rate analysis, temperature of water analysis, a safety test, and an evaluation of the ease of maintenance and ease of use of our design. From the principal tests we hope to prove our final design will provide a viable option for drinkable water on Trinity University Campus.

The first test is a flow rate analysis. To consider the final design a success the water coming out of retrofit dispenser must fill a standard 32 oz Nalgene bottle in less than 45 seconds. To run the flow rate analysis test the equipment needed is a standard 32 oz Nalgene bottle and a stopwatch. Procedurally, when the level of the dispenser is depressed, the timer is started, then immediately stopped when the Nalgene bottle is completely filled. The time it takes for the dispenser to distribute the 32 oz of water is determined by the time elapsed on the stopwatch. Also, the flowrate of the dispenser is determined by dividing 32 oz by the elapsed time. The flow rate and elapsed time are tested at various times in the day to simulate different levels of water usage. The flow rate of the dispenser was tested 10 times in order to generate statistically conclusive data.

In addition, the flowrate of water coming out of the standard bubbler on the final design was experimentally determined. The methods for the flowrate of the bubbler experiment were identical to the retrofitted dispenser flowrate experiment. Comparing the flowrate out of the dispenser and out of the standard bubbler will give a quantitative comparison of flowrate out of both outlets of the retrofitted water fountain. In addition, the test will also prove if a typical reusable water bottle can be filled in a comparative time to the soda fountain dispensers found in the Coates and Mabee Dining Halls.

Another primary test is the temperature of the water coming out of the retrofit. It is important that the water coming out of the retrofit is comparable to the temperature of the water coming out of the original bubbler. The test for water temperature is also rudimentary. A water sample from the retrofit spout and from the original water fountain spout are collected and the temperatures of both are measured. The test requires two thermometers so the temperatures of both samples could be calculated concurrently. The water temperature from both outlets is collected to potentially verify that the temperature of the water from the bubbler and the dispenser is consistent. It should be noted that the temperature tests are done in conjunction with the flowrate tests, i.e. once the flowrate of the water coming out of either the bubbler or dispenser is determined, the temperature of the water was simultaneously analyzed. The tests are also run within only a few minutes of each other. This makes it possible to determine the limits of the refrigeration system in the water fountain. The prototype and final design both have a thermocouple refrigeration cycle. What this means is that when the temperature of the water in the reservoir tank becomes too hot, the refrigeration cycle is activated. The limits of the refrigeration cycle are tested because water was constantly flowing in and out of the water fountain during constant use, which theoretically means the water inside of the reservoir tank is not settled for long enough to be completely refrigerated before it leaves the water fountain. The prototype water fountain bypassed the refrigeration system. Therefore it is assumed that there would be a large discrepancy between the water temperature from the retrofit and the original bubbler. The final design, on the other hand, does provide refrigerated water to both the water fountain dispenser and the original bubbler. The protocol run on the prototype to determine the temperature of the water was similarly run on the final design. The temperature test, like the flowrate test was repeated over 30 times during various times of day and season.

We also tested the ease of use of the fountain by seeing if the retrofit could be used with one hand. The ease of use test was a qualitative question asked to 10 persons in Moody Engineering Building. The questioned asked was "is it easier to refill a bottle with the original bubbler or the retrofitted dispenser." Each person was allowed to try refilling their bottles both ways if they wished, so that an appropriate answer could be determined.

3.2 Water Quality Testing and Analysis

The water quality test will determine whether bottled water and drinking fountain water meet EPA contaminant level standards for potable water. The experimental setup will consist of several commonly used water quality tests in the water treatment industry.

3.2.1 Parameters to be Tested

The test matrix will consist of the BAC-T, mineral suite, trihalomethane (THM), haloacetic acid (HAA), phthalate and heavy metal concentration tests. For a detailed listing of the specific contaminants detected using each water test, as well as approximate test pricing, see

Appendix F. The BAC-T test is meant to measure the general level of bacteria in a water sample. It does this by measuring the level of coliform bacteria, which is an indicator of the magnitude of bacterial contamination in a water sample ("Bacterial Contamination…", n.d.). The test registers as either positive or negative. The minerals suite measures the mineral content of a water sample, which is directly related to the hardness of the water. Trihalomethanes and Haloacetic acids are by-products of excess disinfection. Trihalomethanes are molecules in which three of the four hydrogen atoms in C_2H_4 are replaced with halogens. Long term exposure to these molecules in excess concentrations can have carcinogenic effects ("Drinking Water Contaminants", 2010). Haloacetic acids are carboxylic acids where a hydrogen atom has been replaced by a halogen atom. Long term exposure at high concentrations can lead to liver, kidney, or central nervous system problems, as well as increased risk of cancer ("Drinking Water Contaminants", 2010). Phthalates can be found in plastics and are known to leach from plastics after extended periods of time. Long term excessive exposure to phthalates can cause pregnancy complications, liver problems, and increased risk of cancer ("Drinking Water Contaminants", 2010). Heavy metals can cause a wide variety of detrimental health effects in high doses. The heavy metals test measures the concentration of several heavy metals of particular concern. Testing for mercury generally costs an additional $30.

3.2.2 Water Testing Procedure

First, a specific set of test dates will be scheduled with TCEQ certified labs, which will have certified technicians arrive, with the necessary testing materials, at Trinity. Before each sample is collected, the water source will be flushed. This involves running water out of the fountain for 5 minutes. This ensures that the water sample collected is representative of water inside the distribution system. The technicians will collect the water samples at all of our requested locations into sterile glassware designed for water sample collection. Water samples will be collected from water fountains at the following locations:

- Moody Engineering Science Building third floor Room
- Moody Engineering Science Building first floor by the Machine Shop
- Bruce R. Thomas Residence Hall third floor by elevators

- Northrup Hall first floor by the elevators
- Elizabeth Coates Library third floor by the elevators
- The Bell Center third floor entrance
- Mabee Dining Hall near the cash registers
- Fire hydrant behind library

Three water bottle products will be purchased on campus and given to the lab technicians. Water bottle samples will undergo the same water quality tests as the tap water samples (Appendix F). Bottled water samples will be taken from the following water bottle products:

- Ozarka (1.00 L)
- Dasani (0.500 L)
- Smart Water (1.00 L)

3.2.3 Comparison and Analysis of Data

Analysis of the water quality tests will consist of a comparison between the contaminant levels found in the bottled and tap water sources. The concentration of each contaminant in each type of water source will be averaged for comparison. For this comparison, the percent difference in the concentration for each contaminant will be considered. When comparing tap water to bottled water, the bottled water will be the standard to which tap water is compared (in other words, contaminant levels in the tap water will be expressed as a percent of the concentration found in the bottled water). Furthermore, the concentration of each contaminant in tap water and bottled water will be compared to the maximum contaminant level allowed by EPA standards. Each concentration level will be expressed as a percent of the maximum contaminant level set the by EPA. Also, the reporting limit (RL) of the instruments will be noted for each test. The reporting limit is the minimum value the instrument is sensitive enough to measure.

3.2.4 What Each Contaminant Test for the Water Testing Will Determine

Several broad conclusions will be possible based on the results of our analysis. The first possibility is that the water tests indicate that the tap water is significantly more contaminated than bottled water, and even unhealthy to drink. Due to the extensive testing required of all water distributors in the United States, this is highly unlikely. This possibility is only added here to ensure the development of a truly comprehensive list of alternatives that is free of assumptions. The other possibility is that the contaminant levels in bottled water are slightly higher or lower than the contaminant levels in tap water. This would be the case if there was measurable variation in the contaminant levels, but that those variations do not imply potential long term health effects as a result of prolonged consumption. The possibility of long term health effects will be determined using the EPA's maximum contaminant levels. Additionally, the presence of trihalomethanes would indicate that bottled water either undergo the same chemical treatment as tap water, or that bottled water is in fact collected from a tap water source. The third possibility is that potentially harmful levels of contaminants are found in bottled water and arise from the plastic water bottle container. This possibility would be confirmed by a significantly higher concentration of phthalates in bottled water than tap water.

Overall, the water test should determine whether our design delivers quality water comparable to that found in commercially available plastic water bottles. Specifically, the BAC-T test, mineral suite, and heavy metal tests will be used to determine if the general bacteria, mineral, and heavy metal levels in the water is considered safe to drink, according to EPA guidelines, respectively. The THM test along with the HAA test will be used to determine the level of byproducts produced by excess chlorination, a process commonly used in tap water treatment facilities. The phthalate test will determine the level of phthalate additives, which are used to make plastic bottles more pliable but can leach from the plastic to the internal liquid.

3.3 Promotional: RRRR

The Reduce, Reuse, Recycle, Refill campaign is carried out by various forms of media in order increase the user awareness of the design and relevant environmental issues. Simply the installation of a bottle refill device does not attend to the design problem at hand: reducing plastic waste at Trinity University. User awareness of the issue at hand, promotion of the device's use, and awareness of consumer preference can all shape the effectiveness and direction of the design in order to meet the design requirements. In order to promote a Reduce, Reuse, Recycle, Refill campaign on Trinity's campus, four promotional tools were taken into consideration: a promotional video, a newspaper article in the Trinitonian, support from influential members of the San Antonio and Trinity communities to verbally back the project, and a student survey to test project awareness and seek user feedback.

The student survey as shown in Appendix D is designed to discover how a typical student is consuming water on campus (Questions 1-2), seek feedback from the user (Questions 3-5), and test awareness of the design (Question 6). The student survey will be administered as a brief, anonymous 6-question survey in the high-traffic area of Coates University Center. The responses were placed in a box for recording and ensuring anonymity. Student groups such as Greek Life, Residential Life, and Service Organizations received a print version of the survey because they represent a fairly accurate representation of the involved Trinity University community in combination with the Coates Center survey. Emphasis was placed on student groups, as they have regular meetings with large members of the Trinity University student body and are more likely to complete the survey.

The survey will undergo statistical analysis under the assumption that the responses of any student group or random group of students who receives the survey will answer similarly and therefore their responses can be combined. This assumption concerning different survey mediums will be assessed for validity by calculating the percent differences in the response percentages for each question. The survey will run over the span of five days and it will be assumed to only be taken once per user. Analysis of the survey by is to be used to assess project awareness and provide further recommendations. Specifically, each survey will be counted and recorded into excel, and the average, mode, 95% confidence interval, and percent difference calculations will be determined. Data will be presented graphically and separately by each question. Yes/No or Either/Or responses are recorded as a "1" for yes and a "0" for no, while bottle purchase times are recorded by a numerical value of "0" for under five minutes, and by the respective values of 5, 10, 15 and 20 for the other responses. The student bottle refill kit location preference will be presented as a strictly numerical bar graph, since the statistical analysis cannot differentiate the multiple responses to the question per survey.

Print media in the Trinitonian newspaper is aimed at raising awareness of the both the amount of plastic Trinity University students dispose of and how the final design can aid in lowering that waste output. A promotional news article in the Trinitonian newspaper reaches students each Friday and is also available online. An informal interview was setup with an article writer, where facts and opinions provided by the Design Team members, advisor, and other students were used by the journalist to construct the article (Appendix E).

Promotional YouTube videos have become one of the most popular marketing techniques geared toward a younger audience. In order to make a promotional video for this design effective, one must take into account the following: user awareness, valued opinions, and general interest. The promotional video takes user awareness into account by displaying facts obtained from the water quality testing results, bottled water to tap water comparison analysis, and educational research. Valued opinion is expressed from members of San Antonio Water System and Trinity University faculty by quotation. General interest will be captured using visually pleasing video effects with the help of faculty and students in the communications department. Upon You-Tube upload, the video can be sent out to students and comments will allow a forum for responses to the video, the project, and environmental engineering discussion. The promotional video can be viewed from the attached DVD labeled "Promotional Video" that is attached to the back cover of this report.

4 Results

4.1 Prototype Testing

The prototype needed to meet all relevant design constraints and project objectives as described previously in the Prototype Methods section. The results of the safety, temperature, ease of use, bottle refill time, and ease/cost of maintenance tests run on the prototype are as follows:

Safety of the retrofitted fountain provided two results. The first result of safety testing for the prototype showed the new nozzle placement prevented splashing of water into the fountain basin. Thus, the prototype met basic safety requirements. The second part of the safety testing will be discussed in the water quality testing analysis in detail (see section 4.2). The bench top retrofit kit that was installed on the experimental fountain provided by physical plant provided problems of water temperature discrepancy and splashing. In order to improve the safety of the retrofit kit for the prototype version, the team resolved the issue of excessive splashing by changing nozzle to one that fit more bottle types. The nozzle placement was also changed to a location on top of the fountain instead of beside the fountain.

Cold water was included in the prototype design by re-piping the fountain as discussed in the design overview. Previously, the bench top design had bypassed the refrigeration system, and there was a 30±0.9°F temperature discrepancy in the water temperature from the retrofit and the original bubbler. The American College of Sports Medicine discovered that the desired drinking temperature of water is between 41-59°F (Convertino et al 3). The results of the temperature test on the revised prototype revealed our design operated at an average of 49.0±0.5°C. This was the desired result, and each of the 23 temperature trials fell within the desired temperature options with a 95% confidence interval of 0.75°F. Presentation of these results provides an important step in making fountain water refill more desirable to the Trinity population. The 23 temperature trials were assessed at different climates because there was a three month time period to run the temperature tests. The first temperature test was run in the cold month of January at 38°F, and the second in early April at an outside temperature of 94°F. The consistency in results agree with the group's claims that the fountain water line temperature is controlled by an internal refrigerant control system that keeps the temperature stable regardless of outside conditions.

The result of the bottle refill time test confirmed that bottle refill time is more consistent for the prototype than the original fountain bubbler, and that the time is also shorter (see Appendix C, Figure C-1). The 32oz Nalgene bottle was refilled in an average of 17.37 ± 0.26 seconds using the device as opposed to 23.51 ± 0.77 seconds using the bubbler spout. A 95% confidence interval was used for this analysis. All trials filled the 32oz Nalgene bottle well under the design constraint of 45 seconds. On average, a user would save 5-7 seconds by using the retrofitted nozzle instead of the standard bubbler. A secondary result of the bottle refill time test was that refill from the retrofit spout eliminated all water waste that was encountered when refilling with the standard bubbler. This is in contrast to using the standard bubbler, in which water often drains down the side of the Nalgene and does not completely refill it.

One last project objective related to prototype testing and analysis was more difficult to prove because it concerned inexpensive and easy maintenance. Maintenance on the kit could not occur any more than one time per year. To ensure that our design met this project objective, materials and parts were chosen to last at least one year. The charcoal filter has a service life of 1 year, and the piping is designed to last as long as the fountain itself. To ensure that maintenance would take no longer than 45 minutes, all pieces for the retrofit kit are push-to-connect type piping or easily removable brass or copper fittings. To ensure the device would take no more than $150 to repair, the most expensive part of the retrofit kit is the $100 spout and labor costs for the 45 minutes would be estimated generously at $50 per hour. Labor and maintenance costs do not cover the actual fountain device itself, only the installed retrofit kit.

4.2 Water Quality Testing and Analysis

From the water quality testing that was conducted for us complements of SAWS, we were attempting to determine whether or not the water coming out of the drinking water fountains from various locations on campus was safe to drink and at a comparable quality to that of bottled water. If we could prove this from the water quality tests, we could integrate these results into our promotional campaign and strengthen our case for students to use retrofitted water fountains. As discussed previously, SAWS assisted us in taking samples from drinking water fountains at various locations around campus and of the three water bottle brands that are sold on campus. Following are the results that SAWS delivered to us and the results in tabular form can be seen in Appendix J-L.

First off, the simplest of the water quality tests that were performed on all of the samples was the BAC-T test. This test is performed almost every single week by major water distribution plants to ensure that the water they are providing is safe to drink. This water quality test evaluates the levels of contaminants or bacteria in the water sample. There is no numerical data returned from this test, only a positive or negative response; positive if there were bacteria present and negative if there was not. All of the Bac-T tests that were ran on the water samples taken around campus and from the water bottles came back negative. This was a good sign and proved that the water coming out of the fountains met the EPA standards for bacterial levels.

The next water quality test that was performed on the various samples was a Chlorine Residual. SAWS puts Chlorine into the water in order to kill bacteria in the water, so for this test any value above 0.75 mg/L for this Chlorine residual is a good sign. Of the 7 drinking water fountains on campus, 4 had Cl_2 residual values above 0.75 ppm, with the only locations that did not have a Cl_2 were the two fountains in Moody and the water fountain in Mabee. The water technicians from SAWS believed this result to be a result of the filters that had been installed on these fountains. The maximum contaminant limit that the EPA sets for this test is 4 mg/L or 4 ppm. All locations that were sampled including the water bottles reported values below this maximum limit.

The next test performed on the water samples was a mineral suite that tested for the level of inorganic anions in the water. The minerals that we chose to test for included Bromide, Chloride, Fluoride, Nitrate, Nitrite, and Sulfate. In addition to these minerals, a test for the total amount of dissolved solids was also conducted. As seen in Appendix J-L all locations that were surveyed had concentrations far lower than the maximum contaminant level (MCL) of each contaminant tested for. This was important because if any of the samples had contained a concentration of any of the minerals tested for above the MCL set by the EPA, this would show that the water from the water fountains was unsafe to drink. Since this was not the case, this data strengthened our RRRR campaign.

The next water quality test that was performed on the water samples tested the concentration of Trihalomethanes in each sample. The THM's that this water quality test tested for were Bromodichloromethane, Bromoform, Chloroform, and Dibromochloromethane. The MCL for the total amount of Trihalomethanes in a single water sample is 0.08 mg/L. Every sample that was taken from the drinking water fountains and the water bottles reported levels of THM's far below the MCL for this contaminant. The average concentration for the samples from the water fountains and the water bottles were 0.000924 mg/L and 0 mg/L, respectively. Again, the results from this test were positive and ensure that the water on Trinity's campus is safe to drink.

Additionally, the concentrations of certain Heavy Metals were also tested at all of the sampling locations, as well as the water bottles. The Heavy Metals that this water quality test detects concentrations of were Arsenic, Cadmium, Chromium, Copper, Lead, Manganese, Nickel and Zinc. As with the previous tests, samples from the water fountains and the water bottles all reported Heavy Metal concentrations far below the MCL for each of the metals. Further in depth results from this water quality test can be found in Appendix J-L.

The last two water quality tests that were performed on the water samples taken by SAWS tested the concentrations of Phthalates and Halo-Acetic Acids in each sample. In every single sample taken at the water fountains and the water bottles, there were neither phthalates nor halo-acetic acids detected. This was a positive result as concentrations of these contaminants can lead to ill health effects. Since there no traces of these contaminants anywhere on campus, this gave us good results to report on for our promotional campaign.

With this data, we performed several statistical analysis procedures on the data to ensure that the results that we obtained are statistically significant and that we could report the data and be confident in the results obtained. As a basic start, we took the mean and the standard deviation of the levels of the contaminants in each of the samples. In addition to this, we also wanted to have a high confidence that the samples that were taken would be an accurate representation of the water on campus. To do this, we calculated the standard deviation for each contaminant concentration (Appendix J). For all contaminants, the average contaminant concentration value was lower than the MCL by several factors.

4.3 Promotional Campaign Results and Assessment

The student evaluation survey serves as the primary means of assessing the effectiveness of the campaign and the promotional tools used. The survey results assess user preference, feedback, and project awareness. The final sample size for the survey included 238 students (n = 238), which is roughly 10% of the Trinity University student body. A total of 180 surveys were recorded by paper and 58 were recorded online via the online resource Survey Monkey. All statistical and graphical results can be found in Appendix B. Assuming the survey was only taken once per student and that online and paper surveys could be combined, the following results were obtained:

Currently, fountain water is still considered inconvenient. Only 27% of students surveyed prefer fountain water over bottled water, and students grossly underestimate the time it takes to purchase a new bottle from Coates Commons or Mabee Dining Hall (Appendix B, Fig.B-1). Surveyed students believe it takes an average of 6.74 minutes to purchase a new bottle, when in reality it can be close to 10 minutes. This time was estimated using the average travel time from Chapman Hall, which holds more classes than any other building, to Coates University Center (Appendix B, Fig.B-2).

It can also be determined from the data that students would likely use the retrofitted fountains should they be installed across campus. Of the sample size, 93% recorded they would use the device if installed, and 97% recorded they would be further encouraged if the devices and fountain water were proven to meet all water quality standards (Appendix B, Fig.B-3,4). If the devices were to be installed across campus, the highest recorded responses indicated Coates Library, Coates University Center, the Bell Center and Mabee Dining Hall would be optimal locations (Appendix B, Fig.B-5). Students would more likely use the retrofitted water fountains if they were located in high traffic areas.

As a measure of project awareness and plastic waste reduction, 16% of the students surveyed had visited the device installed on Moody Engineering Building's first floor (Appendix B, Fig.B-6). This value was affected by the fact that the design team was without marketing skills, had limited monetary resources, and primarily focused on the design aspect of the project. Another possible cause of the low student use is that the promotional video did not have time to spread through the student body as quickly as predicted. Also, Moody Engineering Building is an extremely low traffic building on campus. User comments revealed many students do not even know the location of the building for them to use the device. However, the awareness objective was still met in that a portion of the student body had visited the device and contributed to reducing plastic waste. After the release of the student survey, significant support for the project by Kelley Neumann of San Antonio Water System (SAWS) and Trinity University President Dennis Ahlburg created a valuable resource for the success of the project. Continued support and funds to properly market the project have the potential of driving the project toward complete success.

To assess the assumption concerning the combination of online and paper surveys, the percent difference in percentage response was performed on all questions except for the numerical recording of retrofit installation preference question (Appendix B, Fig.B-5). Question 1, which evaluates student perceived bottle purchase time, has three responses which have over a 60% difference in the response percentage make up between the online and paper surveys (Appendix B, Fig.B-1). The two survey mediums also have different mean and mode values: paper surveys indicate students mostly consider bottle purchase time under 5 minutes, but online surveys indicate a response of 10 minutes. For the case of this question, it cannot be assured that the medium of the survey did not affect the results. Either way, the only statistically sound conclusion for this question is that students underestimate the bottle purchase time from Coates or Mabee. Questions 2, 3, 4 and 6 have much lower percent difference (most well below 30% difference) between the online and paper surveys (Appendix B, Fig.B-2-4,6). This could be correlated to the either/or and true/false nature of the question design. All but two responses for these questions had a percent difference below 35%, but percent difference did not reach above 41%. This might be due to the more extreme response these questions received, because the responses with the higher percent differences were responses which comprised below 10% of the overall response for the answer. Overall, it can be recommended that the assumptions for the survey analysis held true with the exception of the first question, where only limited conclusions about the trend should be made. All other questions do not appear heavily affected by the difference in the medium of the survey presentation.

5 Conclusions and Recommendations

Overall, our final design not only met all of our objectives, but also functioned as designed. The purpose of this project was to reduce plastic waste on Trinity's campus by promoting the refilling of water bottles and providing, through our final design, a viable alternative to buying water bottles. The four main constraints that we listed in our charter for the water fountain retrofit were: environment, economic, health and safety, and manufacturability.

The environmental constraint has proven to be an important one throughout the design process. As a result, we made the final retrofit as attractive as possible to students, faculty, and visitors on campus by implementing a polished chrome water dispenser that did not clutter the rest of the surrounding fountain (Fig.H-4). The group's attempt to publicize the need for our design and its functionality on campus included running an article in the university paper, posting an informative video online, and surveying the student body. Through these methods, data was acquired that ascertained a high level of student interest in using the retrofit instead of buying new water bottles, if it was provided in high traffic areas and buildings. This constraint also played a major factor when designing our retrofit to allow for refrigerated water to flow through the bottle filling dispenser. According to the college of sports medicine, refrigerated water is preferred for people drinking water (Convertino et al 3). Thus, producing cold water increased the possible popularity of our retrofit. Our final design also saved water by minimizing spilling while filling the water bottle in comparison to the water spilled when attempting to refill a bottle using the original fountain nozzle.

The economic constraint was important in order to implement the final design. It compelled us to keep the design simple and concentrate on pressure measurements in order to minimize overall cost of materials, and ensure that the pressure from the retrofit properly refilled the reusable water bottle. Our retrofit not only refilled the bottle faster than using the original fountain head (Fig.C-1) but each kit also cost less than $200.

Health and Safety was also important for implementation of the design, in that it would not be useable at all if it did not meet drinking water standards. Concern for the health and safety of our design led us to pursue water quality testing from SAWS for the drinking fountain water on campus along with the water being dispensed from our retrofit. The results from this testing proved that the drinking fountain water on campus and from our retrofit is safe to drink.

Finally, the manufacturability is also a key for successful implementation of the design. We wanted to ensure that the retrofit was not too difficult to install and was applicable to multiple water fountain models across campus. In order to maintain the manufacturability of our retrofit, we had to minimize pipe cuts and expensive customized parts and pipe fittings. This had a major influence on the look and makeup of our final design, as the fewer amount of expensive and different parts allowed the final design to be as easy to manufacture and install across campus as possible. Our final design only requires three major pipe cuts and is made up of inexpensive standardized parts (Appendix M).

Overall, we designed and built a fully functioning prototype on campus, and publicized its positive impact to the surrounding public. We proved through testing that the retrofit refilled water bottles at more than acceptable flow rate and produced water that was as safe to drink as bottled water at a desirable temperature. Through all these actions, we created a final design that met our goals and resulted in a product that is capable of improving the environmental impact of Trinity University's campus.

In the future, we recommend that more of the final retrofit kits be installed across campus in high traffic areas (Fig.B-5). Installing the kit at a greater number of locations will give students more opportunities to use refillable water bottles. In the future, as more of the retrofits are installed it would be helpful to find ways to minimize construction time and possibly find a method of installation that minimizes the small leaking issues in the bubbler that we had to fix in our final prototype on the first floor of Moody. On a larger future scale, if the water fountain retrofits are successful on Trinity's campus, then a desirable next step would be to promote the design and refill culture at other universities in San Antonio, and across the country. As a suggestion, part of this promotional effort should include a disclaimer to students about washing their refillable water bottles prevent the accumulation of bacterial deposits inside their bottles. Receiving a patent on the design is a possible course of action if it aids in this spread of the design to other locations. Continued support from the Trinity community as well as an increase in installed devices will ensure the success of the project beyond the team's presence at the university.

6 Bibliography

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Appendix A: Schematic of Final Water Dispenser

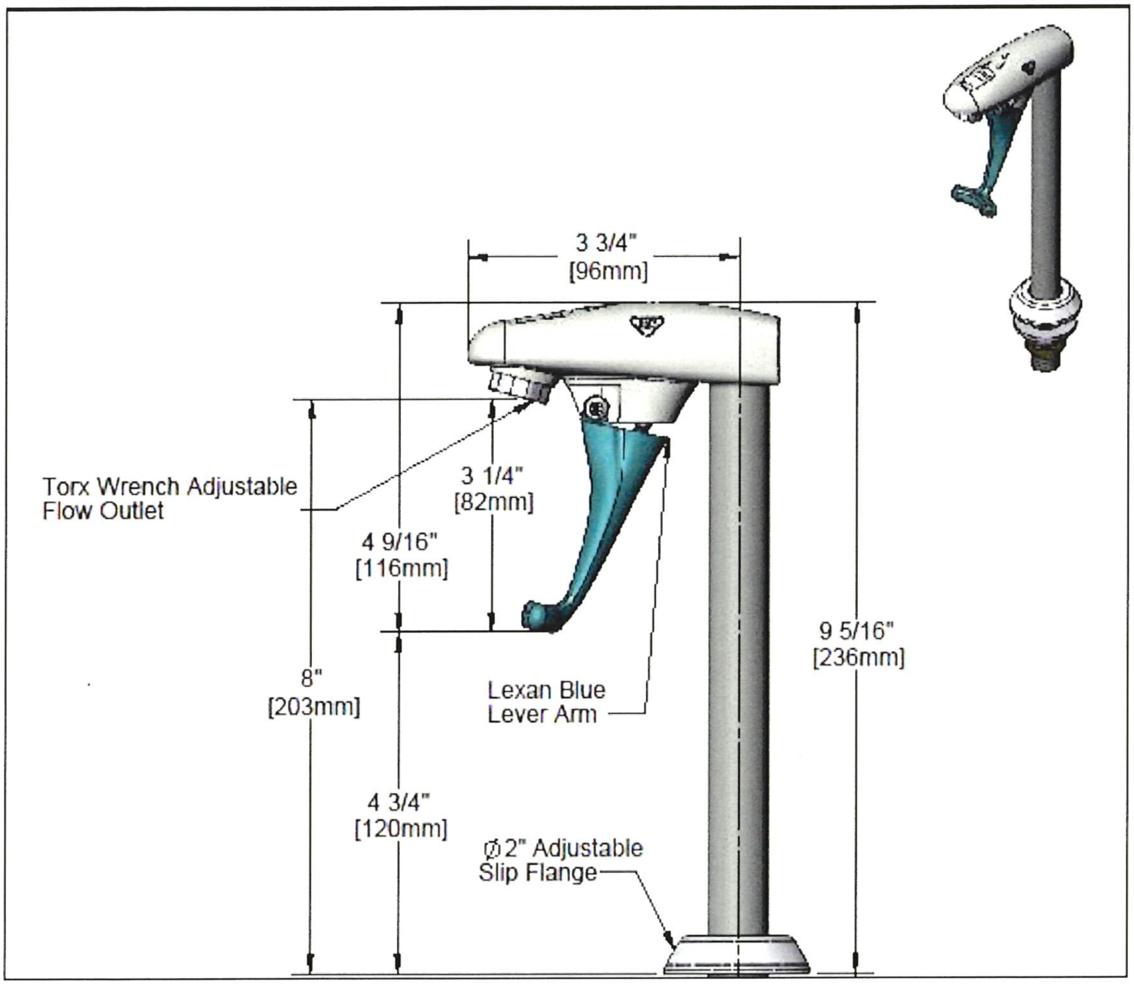


Figure A-1: Pedestal Type Glass Filler, Push Back Design, Adjustable Flange, Blue Self-Closing Lexan Arm

Appendix B: Graphical and Statistical Results of Student Evaluation Survey

	handout	online	total	% diff
under 5 mins	58	13	71	35.905
5 mins	42	13	55	4.0201
10 mins	45	27	72	60.241
15 mins	24	4	28	63.636
20+ mins	9	1	10	97.436

stdev	6.04134
confidence	0.88256
mean	6.74157

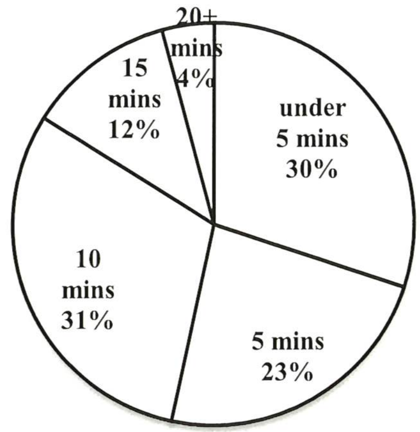


Figure B-1: Survey Question 1: Evaluation of student perceived bottle purchase time. Students sampled perceive an average of 6.74 minutes for bottle purchase time.

	handout	online	total	% diff
bottled	132	42	174	1.2618
fountain	48	16	64	3.3898

stdev	0.44345
confidence	0.06478
mean	0.73333

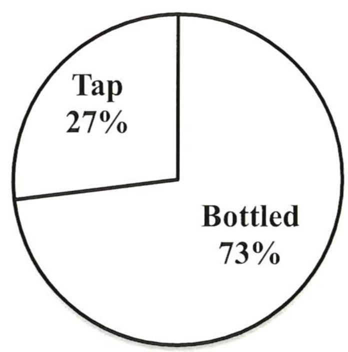


Figure B-2: Survey Question 2: Evaluation of overall student preference between Fountain and Bottled Water.

	handout	online	total	% diff
Yes	166	55	221	2.8251
No	14	3	17	33.498

stdev	0.26857
confidence	0.03923
mean	0.92222

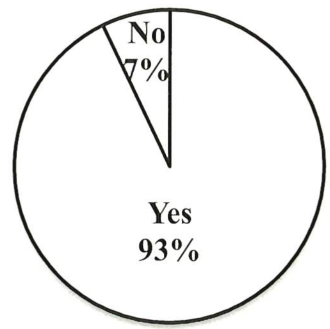


Figure B-3: Survey Question 3: Evaluate whether or not students would use a one-handed bottle refilling device if installed across Trinity's campus.

	handout	online	total	% diff
Yes	174	57	231	2.7857
No	6	1	7	40.237

stdev	0.18001
confidence	0.0263
mean	0.96667

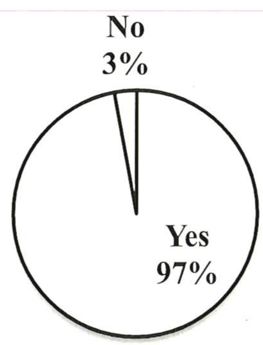


Figure B-4: Survey Question 4: Evaluate whether students would be more likely to drink fountain water if proven to meet all water quality standards.

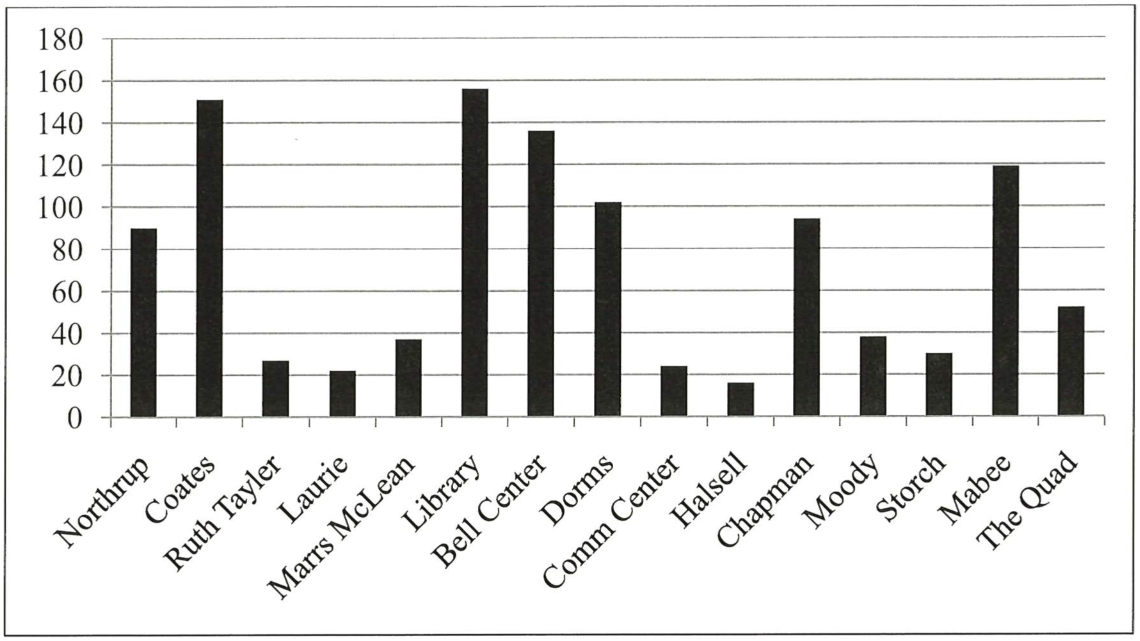


Figure B-5: Survey Question 5: Recorded tally of student response to desired placement of bottle refilling devices if located on campus.

	handout	online	total	% diff
Yes	25	12	37	39.335
No	155	44	199	12.655

stdev	0.44345
confidence	22.6435
mean	0.13889

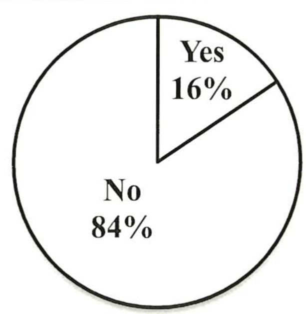


Figure B-6: Survey Question 6: Evaluation of the sample to determine whether the student has visited the installed retrofit device on Moody Engineering Building first floor. The percentages here represent an assessment of the promotional success of the project.

Appendix C: Fluids and Temperature Testing Data

Table C-1: Dispenser vs. fountain results

Run	Inlet Pressure [Turn]		Dispenser				Fountain			
			Time to Fill [sec]	Flowrate [ozps]	Temp of Water [C]	Temp of Water [F]	Time to Fill [sec]	Flowrate [ozps]	Temp of Water [C]	Temp of Water [F]
1	Half	1	17.5	1.8285714	7.9	46.22	24.1	1.32780083	9.2	48.56
2	Half	2	18.4	1.7391304	11.5	52.7	23.3	1.37339056	9.5	49.1
3	Half	3	17.9	1.7877095	9.5	49.1	24.6	1.30081301	7.9	46.22
4	Half	4	17.7	1.8079096	9.7	49.46	23.8	1.34453782	11.7	53.06
5	Half	5	18.1	1.7679558	10.7	51.26	24.5	1.30612245	8.8	47.84
6	Full	6	17	1.8823529	9.5	49.1	22.5	1.42222222	8.8	47.84
7	Full	7	17.2	1.8604651	10	50	23.5	1.36170213	9.9	49.82
8	Full	8	16.7	1.9161677	9.8	49.64	22.7	1.40969163	9	48.2
9	Full	9	16.8	1.9047619	8.9	48.02	22.5	1.42222222	8.8	47.84
10	Full	10	16.4	1.9512195	8.7	47.66	23.6	1.3559322	8.8	47.84
STDEV			0.656675127	0.0696211	1.013026269	1.823447285	0.77093017	0.04476267	1.010170503	1.818306905
95% Confidence			0.25741192	0.027291	0.397099001	0.714778201	0.30219908	0.01754664	0.395979561	0.712763209

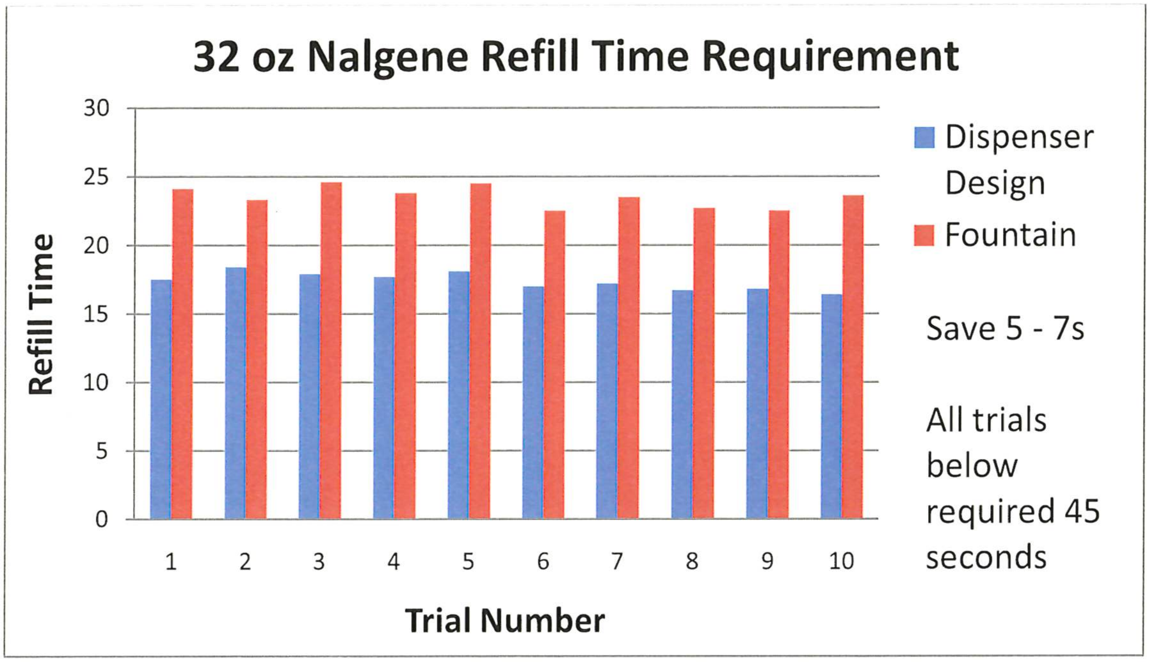


Figure C-1: Refill time of bottle using both the designed dispenser and the bubbler of the fountain

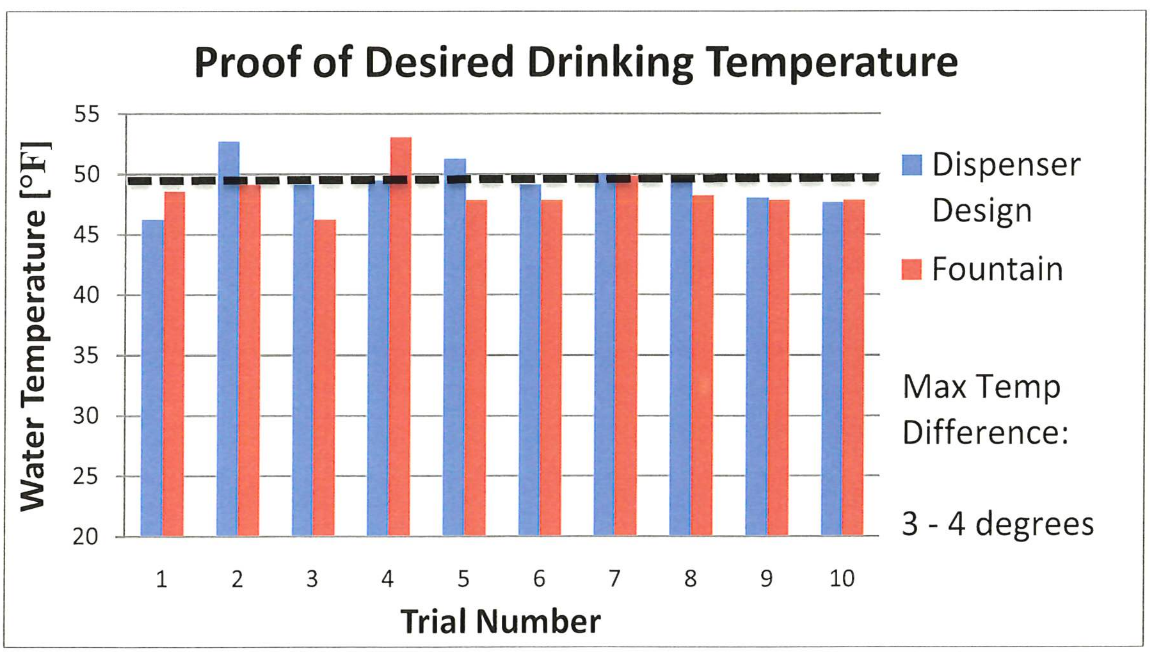


Figure C-2: Drinking temperature of water from both the fountain bubbler and the designed dispenser

Appendix D: Promotional Survey

TRINITY UNIVERSITY SENIOR ENGINEERING:
WATER FOUNTAIN RETROFIT GROUP SURVEY

1. How long does it take you to purchase a new water bottle from Coates or Mabee when you are in class or in your dorm?
   - ◯ Under 5 minutes
   - ◯ 5 minutes
   - ◯ 10 minutes
   - ◯ 15 minutes
   - ◯ 20 or more minutes
2. Do you prefer bottled water or tap water?
   - ◯ Bottled Water
   - ◯ Tap Water
3. Would you be more willing to consume drinking fountain water if it was proven to meet all water quality standards?
   - ◯ Yes
   - ◯ No
4. Would you use a one-handed bottle refilling device if it was installed inside classroom and dorm buildings?
   - ◯ Yes
   - ◯ No
5. Where would installing a bottle refill device be most convenient for you? (You can pick more than one)
   - ◯ Northrup Hall
   - ◯ Coates University Center
   - ◯ Ruth Taylor
   - ◯ Laurie Auditorium
   - ◯ Marrs McLean Science Center
   - ◯ Coates Library
   - ◯ Bell Athletic Center
   - ◯ Upper Campus Dorms
   - ◯ Richardson Comm Center
   - ◯ Halsell Building
   - ◯ Chapman Center
   - ◯ Moody Engineering Building
   - ◯ Storch Memorial Building
   - ◯ Mabee Dining Hall
   - ◯ Freshman Quad Dorms
6. Have you visited the bottle refilling device on Moody Engineering Building first floor?
   - ◯ Yes
   - ◯ No
7. Please list any comments on the back of the survey

Figure D-1: Promotional Survey

Appendix E: Trinitonian Newspaper Article

Senior engineering projects revamp water fountains

■ Students work to reduce water bottle waste, increase Nalgene use on campus

BY ERICA JONES
REPORTER

Most majors at Trinity have a final project that incorporates their past four years of research. For engineering students, these senior projects can help change Trinity's campus and possibly the world.

Alana Hochstein, senior engineering major, worked with a team of students to adapt the water fountains on campus to allow students to fill up their reusable water bottles with cleaner water more easily. The group noticed the trend on campus of more students carrying around nalgenes and other water bottles. However, the bottles were hard to fill in a typical water fountain.

"All the freshmen are given a free nalgene from TUVAC when they get on campus. We wanted to create something that would encourage them to use it more often," Hochstein said.

Although initiatives to recycle plastic containers are already in place on campus, according to Hochstein, they are not doing enough.

"Plastic is too new of an invention to truly know how it breaks down over time. Scientists think it would take about 1,000 years to biodegrade, but we have no way to be sure," Hochstein said. "Recycling plastics is expensive. We're better off saving money and not throwing away plastics."

Mahbub Uddin, professor of engineering science and chair of the entrepreneurship center, advised the students on the project and believes in their cause both for the Trinity community and beyond.

"The project is focused on environmental sustainability, not only for this nation but also for the world," Uddin said. "Clean water is the number one issue across the globe. Trinity students buy around 250,000 water bottles a year. That is around 250,000 bottles we have to pay to recycle or to sit in a landfill where they can possibly be destroying our environment."

To keep costs and the user learning curve down, the team plans to keep the function and basic design of the water fountain the same but add a tube so that users can put their water bottle under the stream. They intentionally made the stream of water narrow to ensure various sizes of containers will be compatible.

Lori Taffet, sophomore, purchases bottled water regularly on campus.

"The dining halls are the only places it's easy to fill up a water bottle and they are far away from my dorm and most of my classes," Taffet said. "I also think bottled water tastes cleaner than the water that comes out of the tap."

"Plastic is too new of an invention to truly know how it breaks down over time. Scientists think it would take about 1,000 years"
ALANA HOCHSTEIN

The group addressed this concern by designing their retrofit fountains to contain extra filters to further clean the water before it enters the bottle. In their research, they conducted various water tests using various brands of bottled water and San Antonio tap water.

A water bottle friendly prototype is already in place in Moody Engineering building. In order to make this idea a reality on campus, Hochstein encourages students to spread the word about it and voice concerns about plastic recycling to school administrators and Facilities Services.

Senior engineering projects in previous years include: power plant noise reduction, a radiation detection device and an interactive play area for the San Antonio Children's Museum.

"Bottled water, gallon for gallon, costs more than gasoline. These projects are meant to make students think and to challenge them," Uddin said. "Hopefully this will instigate change in the Trinity community."

Figure E-1: Trinitonian article for RRRR campaign

Appendix F: Details for the Water Testing, EPA Requirements, and Pricing

Table F-1: EPA water testing details and requirements

Test Name	Tests specifically for:	Texas Commission of Environmental Quality and EPA Standards	Approximate Price per Sample
BAC-T	level of coliform bacteria as a measure of the general bacteria level		\$20-\$25
Minerals suite	Nitrate Nitrite Arsenic Fluoride Aluminum Copper Manganese Sulfate Chloride TDS (Total Dissolved Solids)		\$80-\$120
Trihalomethanes (THMs)	Trihalomethanes produced by excess chlorine disinfection processes: Trichloromethane(chloroform) $CHCl_3$ Dibromochloromethane $CHClBr_2$ Bromodichloromethane $CHCl_2Br$ Tribromomethane (bromoform) $CHBr_3$	Total trihalomethane concentration < 80 PPB	\$150-\$170

Haloacetic acids (HAAs)	Haloacetic acids produced by excess disinfection processes		$200
Phthalates	Benzyl butyl phthalate Bis(2-ethylhexyl) Adipate Bis(2-ethylhexyl) Phthalate Dicyclohexyl Phthalate Diethyl Phthalate Di-iso-decylphthalate Di-iso-nonylphthalate Dimethyl Phthalate Di-n-butyl Phthalate Di-n-hexyl Phthalate Di-n-octyl Phthalate Di-n-pentyl Phthalate Di-n-propyl Phthalate		$350-$400
Heavy Metals	Al - Aluminum Ar - Arsenic Mn – Manganese Ni – Nickel Cu – Copper Cd – Cadmium Cr – Chromium Pb – Lead Zn - Zinc;		$125-$200

Appendix G: Work Breakdown Structure and Schedule

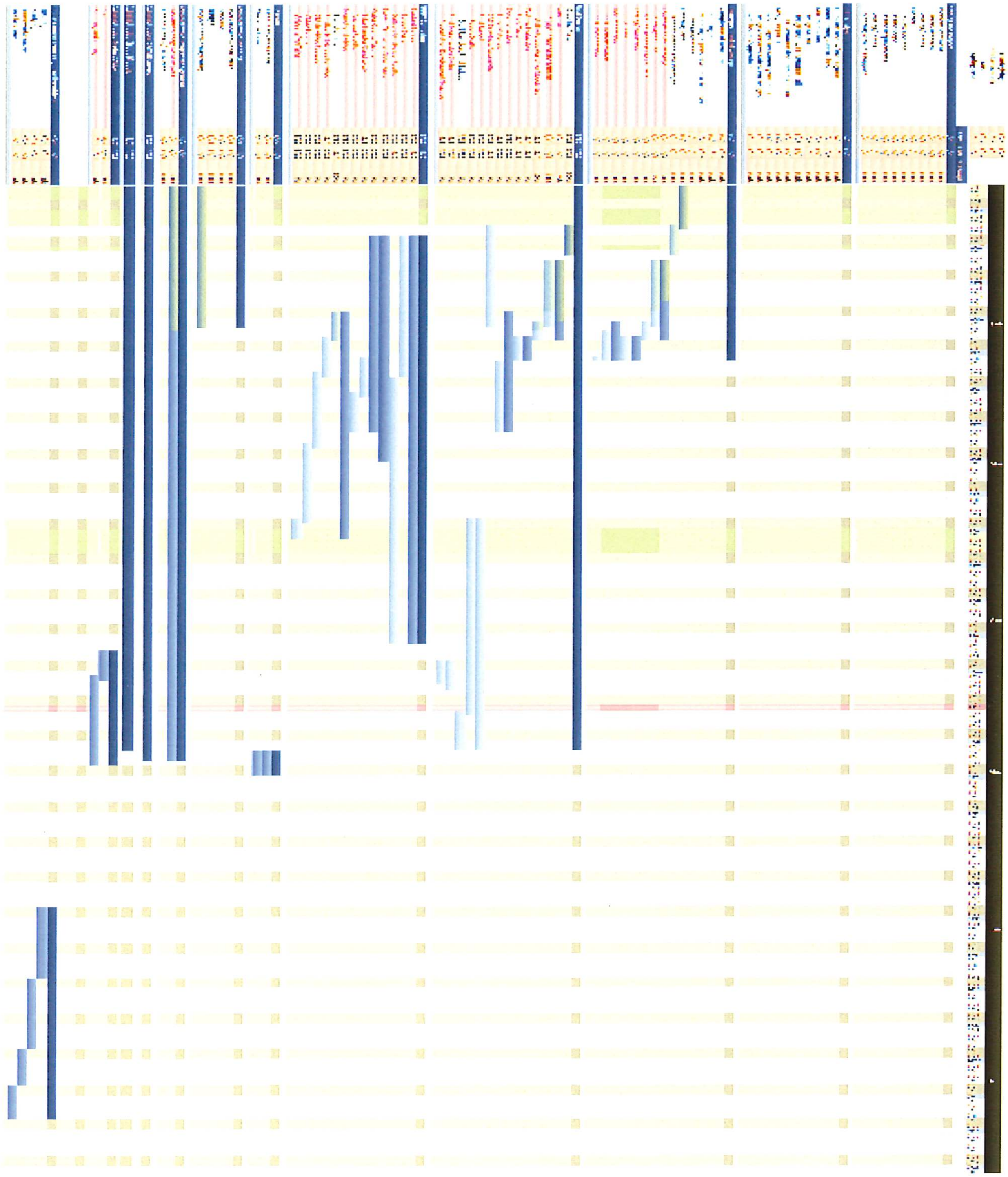


Figure G-1: Gantt chart schedule

Appendix H: Technical Drawings and Pictures of Final Design

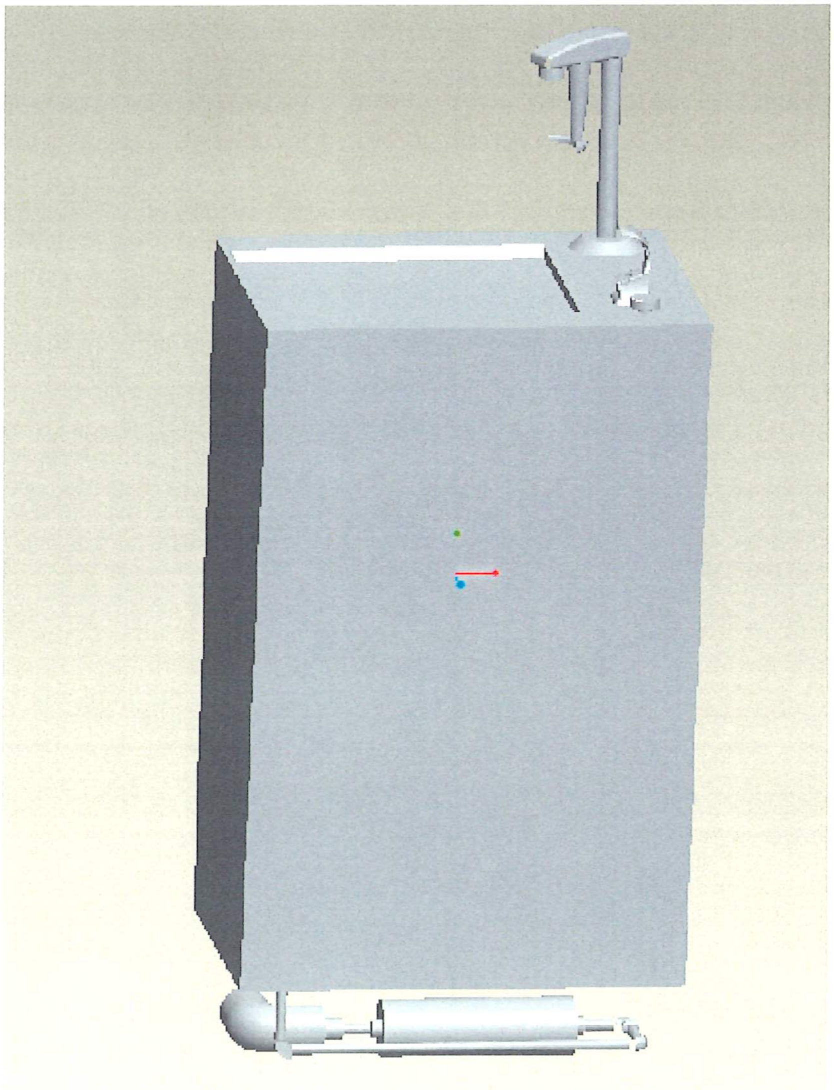


Figure H-1: Final Pro-Engineer drawing of final design

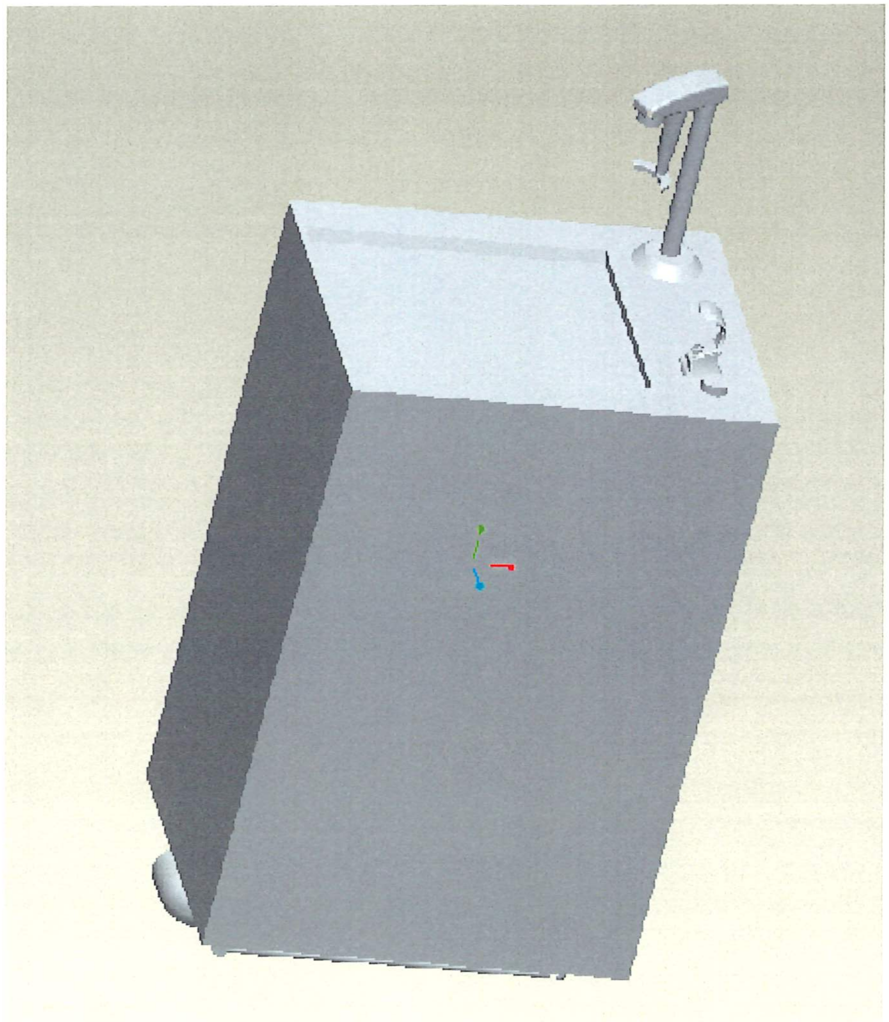


Figure H-2: Pro-Engineer drawing of final design

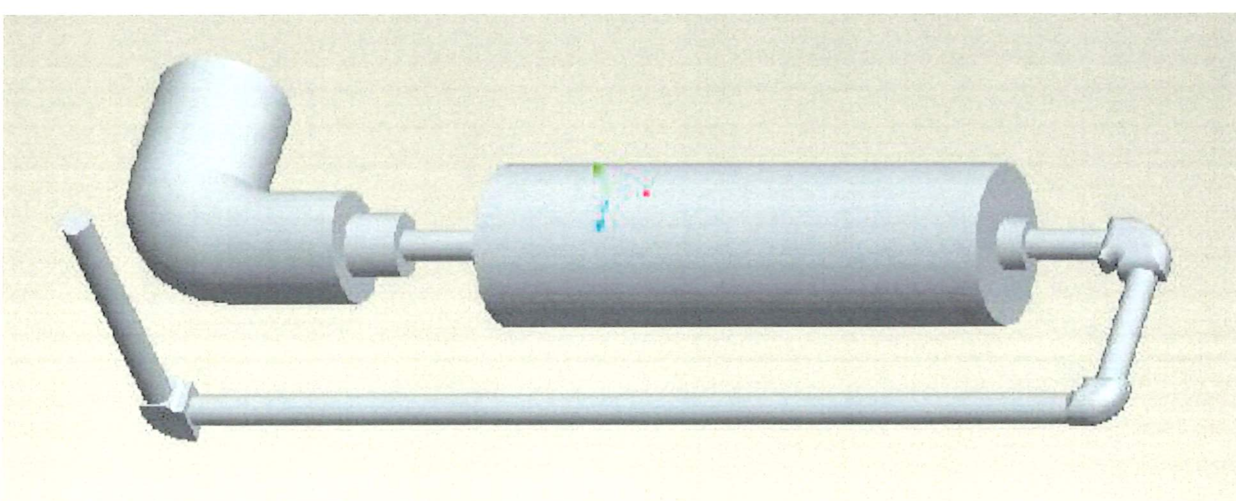


Figure H-3: Pro-Engineering drawing of filter and piping to the fountain

Figure H-4: Photograph of final design on the first floor of Moody Engineering Building

Figure H-5: Photograph of water dispenser used in final design

Appendix I: Final Budget

Submitted By: Alana Hochstein, Timothy Sowers, Luke Shattuck, William Keiser, Bryan Caffey
Group Name: Water Fountain Retrofit
Advisor Name: Dr. Mahbub Uddin

Income

Date	Sponsor	Description	Status	Budgeted Amount	Actual Amount	Notes
9/1/2010	Engr Dept	Senior Design Project Allotment		$1,200	$1,200	
9/28/2010	Physical Plant	Halsey Taylor WM8A fountain		$400	$378	
10/20/2010	Graingers	Return on Pressure Regulator	cleared	48.74	48.74	
1/16/2010	SAWS	Water Testing	planned	$10,000	$7,000	
1/23/2010	Shop	Screws and Pipe cuts	planned	$60		
2/23/2010	Tim Sowers	Water Bottles for testing using Tim Sowers' University Meal Plan	cleared	$10	10	
Total Income				$11,719	$8,637	

Expenses

Date	Vendor	Item Description	PO #	Status (Planned/ Pending/ Cleared)	Budgeted Amount	Actual Amount	Status (Check one): Internal	Dept Purchase Order	PCARD	Reim-burse-ment	Notes
9/28/2010	Physical Plant	Halsey Taylor WM8A fountain		cleared	$400	$378	X				Necessary for performing water testing and experimenting on benchtop designs
10/3/2010	Home Depot	Parts to Install Benchtop Fountain in lab		cleared	$50	$48				X	standard hose connections
10/12/2010	Grainger	Pressure Regulator and Gagues		cleared	$60	$62				X	Used to regulate flow from sink for our benchtop model to act like normal fountain
10/21/2010	Grainger	New Pressure Regulator		cleared	$100	$103		X			Had to exchange the other regulator for this more expensive one because it fit the pressure range we needed
10/22/2010	Shop	Parts (pipe fittings)			$4	$4	X				Parts from Shop don't count towards budget
10/25/2010	Home Depot	pipe splitter and fittings		cleared	$5	$5				X	To install pressure regulator and water filter
10/26/2010	CHIcompany	Soda Nozzle/Dispenser		cleared	$101	$101		X			To use for Benchtop and run experiments on
11/1/2010	Home Depot	Drain tubing and split plug		cleared	$29	$29				X	Plugs allowed us to stop/start installation at various parts of the design
11/2/2010	Home Depot	filter and dispenser materials		cleared	$14	$14				X	Parts needed to fully install filter
11/6/2010	Home Depot	pipe fittings and soda split		cleared	$48	$48				X	Installation pieces to connect water line to the design
11/10/2010	CHIcompany	Soda Safety Levers		pending	$26	$26				X	Purchase of various kinds to choose one for Prototype model
11/13/2010	Home Depot	Dispenser Mounting Materials		pending	$17	$17				X	For Benchtop design
1/16/2011	SAWS	Water Testing		cleared	$10,000	$7,000	X				To improve the impact of the design. Using results to promote the design and a refill culture
1/16/2011		30 Water Bottle Samples		planned	$10	$10				X	Necessary for water testing analysis
1/19/2011	Grainger	Prototype Quick Connect Fittings		cleared	$86	$86				X	for prototype but did not work + overnight shipping
1/20/2011	T&S	Glass Filler		cleared	$108	$108		X			for Prototype
2/1/2011	Grainger	braided connector		cleared	$7	$7				X	for Prototype
2/4/2011	Home Depot	pipe fits and Reducer		cleared	$26	$26				X	for Prototype
2/7/2011	Grainger	pipe fit - elbows		cleared	$12	$12				X	for Prototype
1/23/2011	Shop	pipe cuts		cleared	$60		X				Parts from Shop don't count towards budget
3/3/2011	Grainger	brass elbow		cleared	$14	$14				X	for prototype fix
3/7/2011	Grainger	hex locknuts (4)		cleared	$10	$10				X	for Prototype fix
3/31/2011	Ginny's Printing	Promotional material (ads, etc)		planned	$100	$100		X			To promote a refill culture
3/31/2011	Home Depot/Grainge rs/T&S	2 extra Prototype models (2 for physical plant)		planned	$350	$350		X			retrofit to physical plant (dual model fits)
Total Expenses					$11,636	8557.37					

	Budgeted	Actual	
Budget Remaining	$83	$79	$835
			$262

Notes:
* Always use Trinity Tax Exempt Form for purchases
* Please submit reimbursement receipts within one week of purchase

Figure J-1: Final budget spreadsheet

Appendix J: Contaminant Concentration Data, Analysis of BAC-T, CL2, Inorganic Anions, Trihalomethanes, Heavy Metals, Semi Solvable Organics and Haloacetic Acids. Comparison of measured concentration to Maximum Contaminant Level (MCL). Instruments had a minimum sensitivity, or reporting limit (RL).

	MCL	RL	tap avg	tap std dev	bottle avg	bottle std dev
BAC-T	neg	n/a	neg	n/a	neg	neg

	MCL	RL	tap avg	tap std dev	bottled avg	bottled std dev
CL2 Residual Total (mg/L)	4	n/a	0.567	0.388	0.000	0

Inorganic Anions	MCL	RL	tap avg	tap std dev	bottled avg	bottled std dev
Bromide (mg/L)	none	0.1	0.272	0.662	0.062	0.107
Chloride (mg/L)	none	5	17.4	0.157	6.24	6.46
Fluroide (mg/L)	4	0.1	0.617	0.107	0.000	0
Nitrate + Nitrate (mg/L)	10	0.6	1.52	0.672	0.397	0.687
Nitrate-N (mg/L)	10	0.5	1.52	0.672	0.397	0.687
Nitrite-N (mg/L)	1	0.1	0	0	0	0
Sulfate (mg/L)	250	5	28.6	0.0488	3.57	6.18

	MCL	RL	tap avg	tap std dev	bottled avg	bottled std dev
Dissolved Solids, Total (mg/L)	none	10	308.9	6.3	31.7	7.51

Total Trihalomethanes	MCL	RL	tap avg	tap std dev	bottled avg	bottled std dev
Bromodichloromethane (mg/L)	none	0.5	0.000274	0.000470	0	0
Bromoform (mg/L)	none	0.5	0.000534	0.000378	0	0
Chloroform (mg/L)	none	0.5	0	0	0	0
Dibromochloromethane (mg/L)	none	0.5	0.000971	0.000376	0	0
Total THMs (mg/L)	0.08	2	0.000924	0.00158	0	0

Heavy Metals	MCL	RL	tap avg	tap std dev	bottled avg	bottled std dev
Arsenic, Dissolved (mg/L)	0.01	0.00100	0	0	0	0
Cadmium, Dissolved (mg/L)	0.005	0.00300	0	0	0	0
Chromium, Dissolved (mg/L)	0.1	0.00200	0	0	0	0
Copper, Dissolved (mg/L)	1	0.00200	0.0590	0.0298	0	0
Lead, Dissolved (mg/L)	0.015	0.00100	0.00144	0.00313	0	0.0000
Manganese, Dissolved (mg/L)	0.05	0.00300	0	0	0.00122	0.00211
Nickel, Dissolved (mg/L)	0.1	0.00200	0.000437	0.0012	0	0.0000
Zinc, Dissolved (mg/L)	5	0.00200	0.212	0.515	0.00196	0.00339

Semi Solvable Organics (Phthalates)	MCL	RL	tap avg	tap std dev	bottled avg	bottled std dev
Hexachlorocyclopentadience (mg/L)	0.05	0.0011	0	0	0	0
Propachlor (mg/L)		0.00082	0	0	0	0
Hexachlorobenzene (mg/L)	0.001	0.0011	0	0	0	0
Simazine (mg/L)	0.004	0.00054	0	0	0	0
Atrazine (mg/L)	0.003	0.0011	0	0	0	0
Metribuzin (mg/L)	none	0.0022	0	0	0	0
Alachlor (mg/L)	0.002	0.00078	0	0	0	0
Metolachlor (mg/L)	none	0.00097	0	0	0	0
Butachlor (mg/L)	none	0.00056	0	0	0	0
Dimethyl Phthalate (mg/L)	none	0.0054	0	0	0	0
Diethyl Phthalate (mg/L)	none	0.0054	0	0	0	0
Di-n-butyl Phthalate (mg/L)	none	0.0065	0	0	0	0
Benzyl butyl phthalate (mg/L)	none	0.0054	0	0	0	0
Bis(2-ethylhexyl) Adipate (mg/L)	none	0.0065	0	0	0	0
Bis(2-ethylhexyl) Phthalate (mg/L)	none	0.0065	0	0	0	0
Di-n-octyl Phthalate (mg/L)	none	0.0022	0	0	0	0
Benzo(a)pyrene (mg/L)	0.0002	0.00022	0	0	0	0

Haloacetic Acids	MCL	RL	tap avg	tap std dev	bottled avg	bottled std dev
Chloroacetic Acid	none	0.002	0	0	0	0
Dichloroacetic Acid	none	0.001	0	0	0	0
Bromoacetic Acid	none	0.001	0	0	0	0
Trichloroacetic Acid	none	0.001	0	0	0	0
Dibromoacetic Acid	none	0.001	0	0	0	0
Total Haloacetic Acids	0.06	n/a	0	0	0	0

Appendix K: Contaminant Data, Fountain Water, Preliminary Results.

	North-rup	Lib	Moody 1	Moody 3	Bell	Thomas	Mabee
BAC-T	neg	neg	neg	neg	neg	neg	neg

	North-rup	Lib	Moody 1	Moody 3	Bell	Thomas	Mabee
CL2 Residual Total (mg/L)	1	0.87	0.15	0.11	0.79	0.83	0.22

Inorganic Anions	North-rup	Lib	Moody 1	Moody 3	Bell	Thomas	Mabee
Bromide (mg/L)	1.77	0	0	0	0	0	0.133
Chloride (mg/L)	17.2	17.3	17.6	17.5	17.3	17.4	17.6
Fluroide (mg/L)	0.59	0.629	0.758	0.756	0.583	0.478	0.526
Nitrate + Nitrate (mg/L)	0	1.78	1.83	1.72	1.77	1.79	1.76
Nitrate-N (mg/L)	0	1.78	1.83	1.72	1.77	1.79	1.76
Nitrite-N (mg/L)	0	0	0	0	0	0	0
Sulfate (mg/L)	28.6	28.7	28.7	28.6	28.6	28.6	28.6

	North-rup	Lib	Moody 1	Moody 3	Bell	Thomas	Mabee
Dissolved Solids, Total (mg/L)	315	308	303	305	310	319	302

Total Trihalomethanes	North-rup	Lib	Moody 1	Moody 3	Bell	Thomas	Mabee
Bromodichloromethane (mg/L)	0	0.0009	0	0	0	0	0.00103
Bromoform (mg/L)	0.00079	0.0009	0	0	0.0007	0.00062	0.00066
Chloroform (mg/L)	0	0	0	0	0	0	0
Dibromochloromethane (mg/L)	0.00101	0.0015	0.00062	0.00058	0.0009	0.00076	0.00148
Total THMs (mg/L)	0	0.0033	0	0	0	0	0.00317

Heavy Metals	North-rup	Lib	Moody 1	Moody 3	Bell	Thomas	Mabee
Arsenic, Dissolved (mg/L)	0	0	0	0	0	0	0
Cadmium, Dissolved (mg/L)	0	0	0	0	0	0	0
Chromium, Dissolved (mg/L)	0	0	0	0	0	0	0
Copper, Dissolved (mg/L)	0.0290	0.0294	0.0789	0.102	0.0651	0.0789	0.0294
Lead, Dissolved (mg/L)	0	0	0.00171	0	0	0	0.0084
Manganese, Dissolved (mg/L)	0	0	0	0	0	0	0
Nickel, Dissolved (mg/L)	0	0	0.00306	0	0	0	0
Zinc, Dissolved (mg/L)	0.0129	0.0035	0.031	0.0194	0.0282	0.0123	1.38

Semi Solvable Organics (Phthalates)	North-rup	Lib	Moody 1	Moody 3	Bell	Thomas	Mabee
Hexachlorocyclopentadience (mg/L)	0	0	0	0	0	0	0
Propachlor (mg/L)	0	0	0	0	0	0	0
Hexachlorobenzene (mg/L)	0	0	0	0	0	0	0
Simazine (mg/L)	0	0	0	0	0	0	0
Atrazine (mg/L)	0	0	0	0	0	0	0
Metribuzin (mg/L)	0	0	0	0	0	0	0
Alachlor (mg/L)	0	0	0	0	0	0	0
Metolachlor (mg/L)	0	0	0	0	0	0	0
Butachlor (mg/L)	0	0	0	0	0	0	0
Dimethyl Phthalate (mg/L)	0	0	0	0	0	0	0
Diethyl Phthalate (mg/L)	0	0	0	0	0	0	0
Di-n-butyl Phthalate (mg/L)	0	0	0	0	0	0	0
Benzyl butyl phthalate (mg/L)	0	0	0	0	0	0	0
Bis(2-ethylhexyl) Adipate (mg/L)	0	0	0	0	0	0	0
Bis(2-ethylhexyl) Phthalate (mg/L)	0	0	0	0	0	0	0
Di-n-octyl Phthalate (mg/L)	0	0	0	0	0	0	0
Benzo(a)pyrene (mg/L)	0	0	0	0	0	0	0

Haloacetic Acids	North-rup	Lib	Moody 1	Mood y 3	Bell	Thomas	Mabee
Chloroacetic Acid	0	0	0	0	0	0	0
Dichloroacetic Acid	0	0	0	0	0	0	0
Bromoacetic Acid	0	0	0	0	0	0	0
Trichloroacetic Acid	0	0	0	0	0	0	0
Dibromoacetic Acid	0	0	0	0	0	0	0
Total Haloacetic Acids	0	0	0	0	0	0	0

Appendix L: Contaminant Data, Bottled Water and Control (hydrant), Preliminary Results.

	Smartwater	Dasani	Ozarka	hydrant
BAC-T	neg	neg	neg	neg

	Smartwater	Dasani	Ozarka	hydrant
CL2 Residual Total (mg/L)	0	0	0	0.86

Inorganic Anions	Smartwater	Dasani	Ozarka	hydrant
Bromide (mg/L)	0	0	0.185	0
Chloride (mg/L)	12.9	0	5.81	17.5
Fluroide (mg/L)	0	0	0	0.442
Nitrate + Nitrate (mg/L)	0	0	1.19	1.78
Nitrate-N (mg/L)	0	0	1.19	1.78
Nitrite-N (mg/L)	0	0	0	0
Sulfate (mg/L)	0	10.7	0	28.8

	Smartwater	Dasani	Ozarka	hydrant
Dissolved Solids, Total (mg/L)	39	24	32	304

Total Trihalomethanes	Smartwater	Dasani	Ozarka	hydrant
Bromodichloromethane (mg/L)	0	0	0	0
Bromoform (mg/L)	0	0	0	0.00057
Chloroform (mg/L)	0	0	0	0
Dibromochloromethane (mg/L)	0	0	0	0.00066
Total THMs (mg/L)	0	0	0	0

Heavy Metals	Smartwater	Dasani	Ozarka	hydrant
Arsenic, Dissolved (mg/L)	0	0	0	0
Cadmium, Dissolved (mg/L)	0	0	0	0
Chromium, Dissolved (mg/L)	0	0	0	0
Copper, Dissolved (mg/L)	0	0	0	0.00399
Lead, Dissolved (mg/L)	0	0	0	0
Manganese, Dissolved (mg/L)	0	0	0.00365	0
Nickel, Dissolved (mg/L)	0	0	0	0
Zinc, Dissolved (mg/L)	0	0	0.00587	0.00275

Semi Solvable Organics (Phthalates)	Smartwater	Dasani	Ozarka	hydrant
Hexachlorocyclopentadience (mg/L)	0	0	0	0
Propachlor (mg/L)	0	0	0	0
Hexachlorobenzene (mg/L)	0	0	0	0
Simazine (mg/L)	0	0	0	0
Atrazine (mg/L)	0	0	0	0
Metribuzin (mg/L)	0	0	0	0
Alachlor (mg/L)	0	0	0	0
Metolachlor (mg/L)	0	0	0	0
Butachlor (mg/L)	0	0	0	0
Dimethyl Phthalate (mg/L)	0	0	0	0
Diethyl Phthalate (mg/L)	0	0	0	0
Di-n-butyl Phthalate (mg/L)	0	0	0	0
Benzyl butyl phthalate (mg/L)	0	0	0	0
Bis(2-ethylhexyl) Adipate (mg/L)	0	0	0	0
Bis(2-ethylhexyl) Phthalate (mg/L)	0	0	0	0
Di-n-octyl Phthalate (mg/L)	0	0	0	0
Benzo(a)pyrene (mg/L)	0	0	0	0

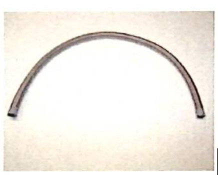
Haloacetic Acids	Smartwater	Dasani	Ozarka	hydrant
Chloroacetic Acid	0	0	0	0
Dichloroacetic Acid	0	0	0	0
Bromoacetic Acid	0	0	0	0
Trichloroacetic Acid	0	0	0	0
Dibromoacetic Acid	0	0	0	0
Total Haloacetic Acids	0	0	0	0

Water Fountain Retrofit Instillation Instructions

Halsey Taylor Model - WM8A and SW

Item	Part	Description
1	[2]	PENTEK Inline Water Filter ¼" inlet/outlet or comparable (part#-1EDA6)
2	 [4]	(3) 3/8" All-tube elbow with inserts (Watts part#-A-115)
3	 [4]	3/8" Compression to 5/16" MIP Elbow
4	 [4]	3/8" MIP to 3/8" Compression
5	 [4]	3/8" Compression to ¼" MIP Elbow

6	 [4]	Ander-Lign Compression Tee 3/8” OD w/Insert (Watts part#-A-114)
7	 [4]	(2) Tube to Tube Valve w/Insert (Watts part#-A-140)
8	 [2]	(2) 3/8” Street Elbow (part#-510-302HC)
9	 [4]	(2) 3/8” Brass Pipe Nipple (Watts part#-A-785)
10	 [4]	(4) 3/8” Tube to FIP couple w/Insert (Watts part#-A-117)
11		T&S B-1220 Deck Mounted Push Back Glass Filler with 9 5/16” High Pedestal-3/8” Female Inlet
12	 [2]	3/8” Locknut (part #-510-902HC)

13	 [2]	Halsey Taylor Bubbler Gasket
15	 [4]	5/16" MIP to 3/8" Compression Union
16	 [4]	(3) 3/8" Compression Union (Watts part#-A-183)
17	 [4]	(2) Ander-Lign 3/8" Compression X ¼" MIP Union (Watts parts#-A-122)
18	 [2]	20 inch 3/8" Compression X 3/8" Compression braided stainless steel hose
19	 [2]	Poly-Tubing
20	 [2]	Glass Filler Bubbler

21	 [2]	Connector ¼" Tubing
22	 [2]	Tee ¼" Tubing
23	 [2]	Elbow ¼" Tubing

*see bibliographic references [2] and [4] for image sources

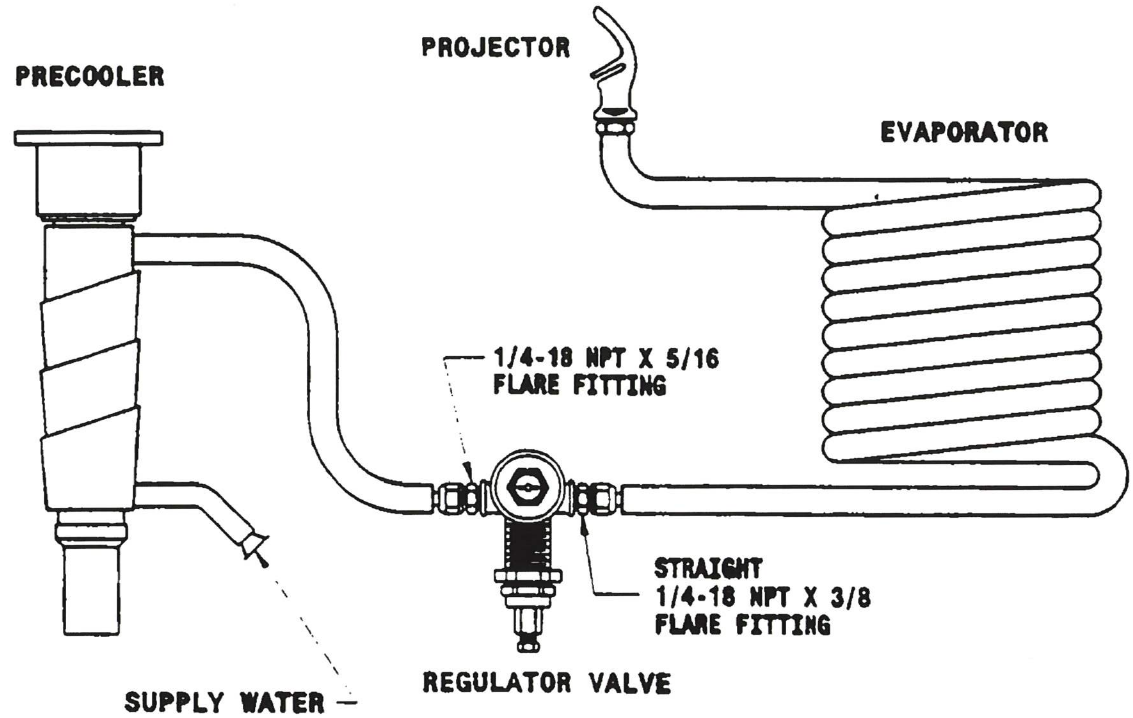


Figure 1. Pre-existing water fountain schematic

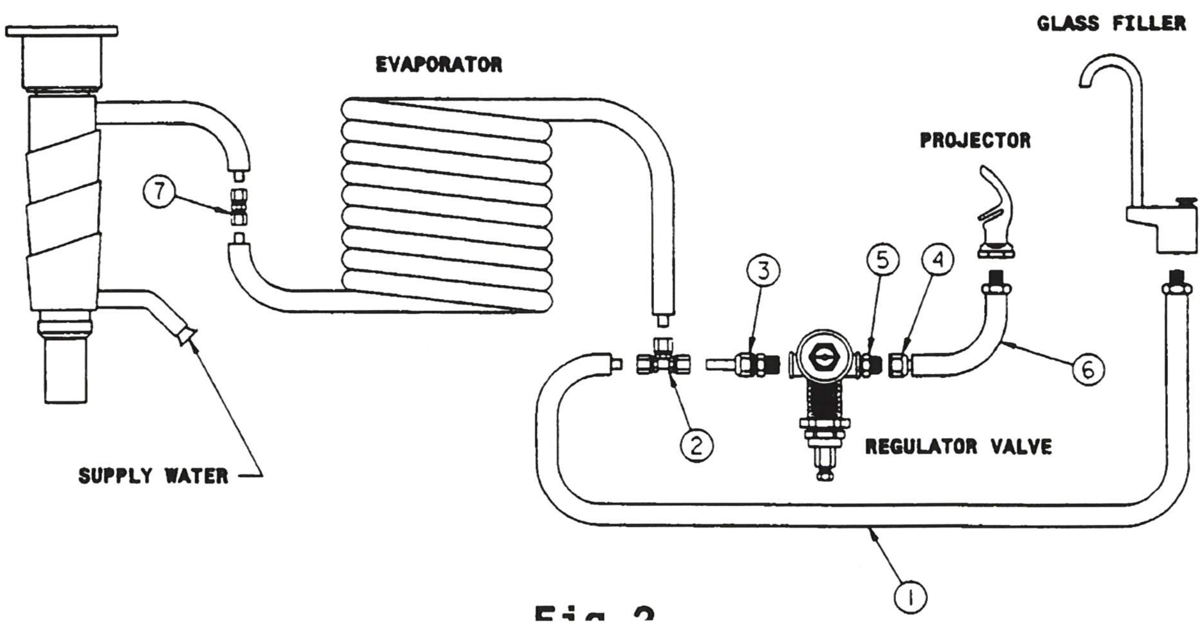


Figure 2. Retrofit to water fountain schematic

Required Tools

To install this kit the following tools are required:

- Philips screwdriver
- Flathead screwdriver
- Flat-nose pliers
- 3/8" Socket Wrench
- Adjustable Wrench
- Teflon Tape
- Tubing Cutters-(For Copper Tubing)

Instillation Instructions

STEP 1

Remove the Front Panel

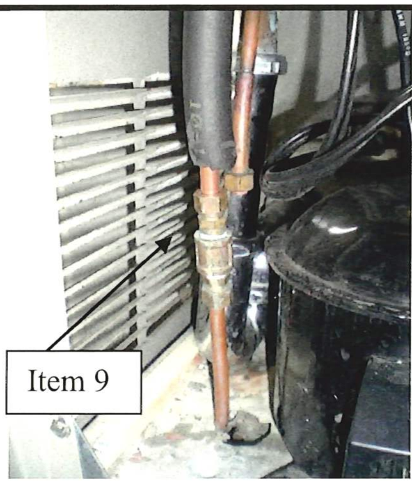
- Remove screws on the under side of the front panel (facing the water fountain)
  - Remove front panel
  - Disconnect the fountain from the electrical supply
  - Turn of the water supply (ball valve by inlet)

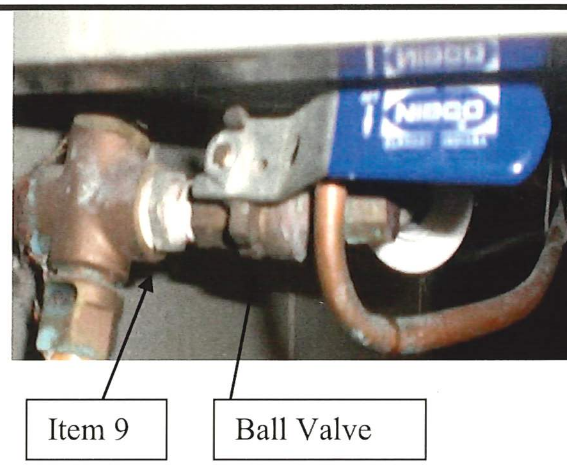
STEP 2

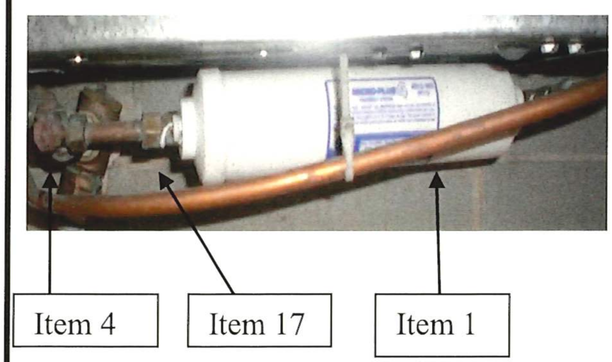
Remove Side Panels and Basin Top

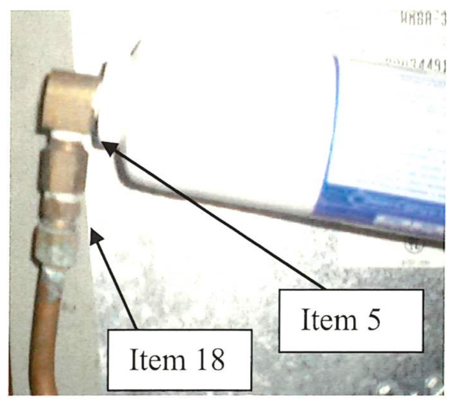
- Unscrew the screws on the under side of the left and right panels
- Unscrew the screws connecting the panels to the top basin
- Unscrew the screws connecting the side panels to the frame (front side)
- Remove the side panels
- Remove the top

- Disconnect the p-trap from the drain of the water fountain
- Unscrew the bubbler and remove the cooler push button. Remove the basin top









STEP 3

Adding the Filter

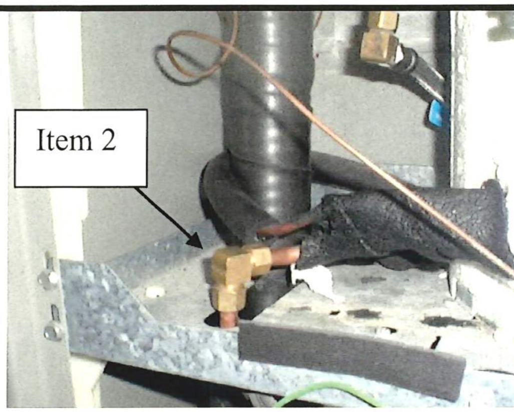
- Cut the supply line midway up the water fountain (roughly even with the top of the compressor) and remove the piping
    - Remove the ball valve
- Connecting the filter
    - From the outlet of the strainer add Item 9

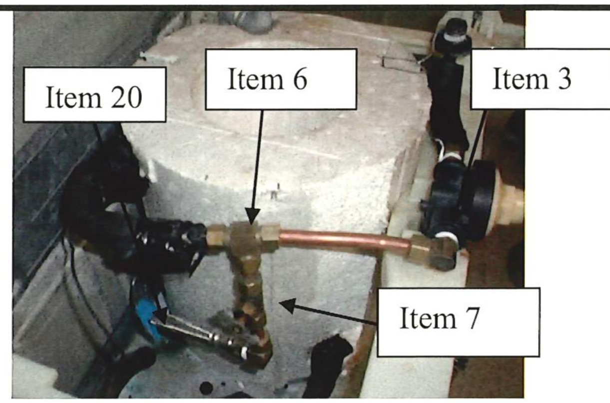
- Add the ball valve that was previously removed
    - Add Item 4
    - Add 2 inches of copper piping from the Compression end of Item 4
    - Add Item 17 (goes into the inlet of the filter)
    - Add Item 1 (filter) then Item 5
- Reconnecting the supply line
    - Add Item 18 then approximately 20 inches of copper piping, redirected through the hole for the inlet supply water
    - With Item 9 connect the new piping from the outlet of the filter to 10 inches of new copper piping (this piping will eventually be directed into the reservoir tank in *STEP 5*

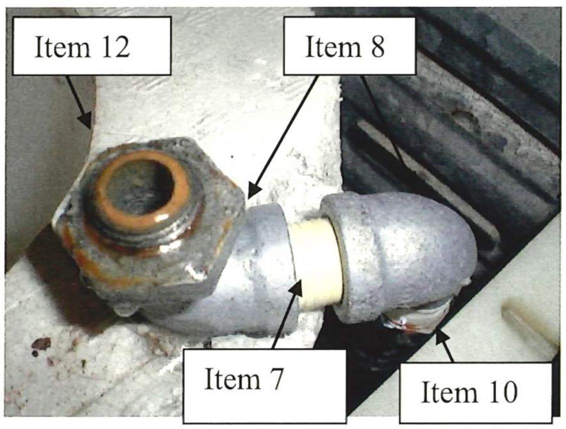
STEP 4

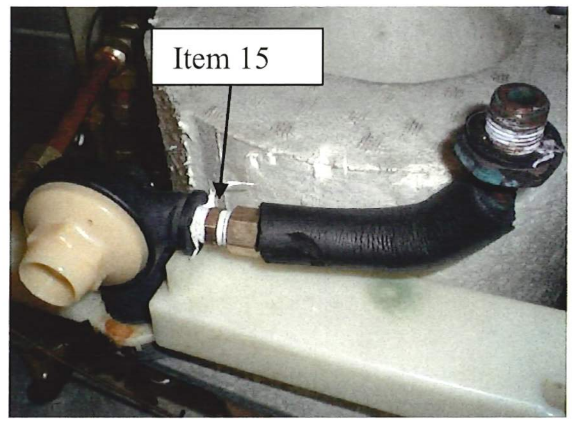
Cut and Remove Internal Piping

- Cut supply at locations 2,4 and 7. This is the inlet of the water storage tank, the supply line, and the inlet the pressure regulator.
    - Watch out for any water stored in the reservoir tank and internal piping
    - Save the line from the outlet of the pressure reservoir tank (the one with the bubbler still attached)
    - Remove all other cut piping









STEP 5

Reconnect Internal Plumbing

- Connect water inlet line to reservoir tank inlet
  - Using Item 2 or 21 reconnect the inlet line from the outlet of the filter to the reservoir inlet line cut in *STEP 4*
- Connect reservoir outlet to tee
  - From outlet of reservoir chiller connect the piping to Item 6 or 22
- Connect soda fountain filler supply
  - From one outlet of the tee connect Item 7 (not necessary for push to connect configuration)
  - From the outlet of the gate valve connect Item 20 (use polytubing for push to connect configuration)
  - Wrap the braided hose around the backside of the reservoir tank
  - Connect Item 10 to the Compression end of the braided hose
  - Add Item 8, then Item 9, then an addition Item 8
  - Added Item 12 to the female end of the street elbow
  - For the Push to connect configuration only Item 20 needs to be connected to the polytubing coming from the split
  - Situate this piping to rest on the top of the reservoir tank (some Styrofoam my

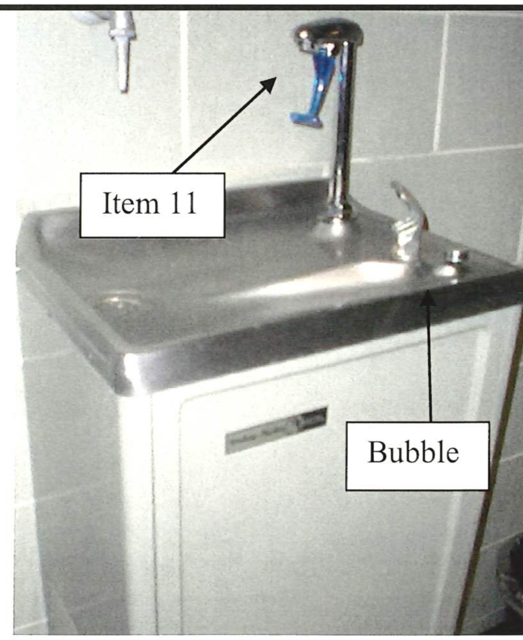
need to be cut)

- Connect tee to regulator
    - Connect the 5/16" MIP side of Item 3 into the inlet of the water regulator
    - Cut a 4 inch long piece of copper piping
    - Connect one end of the piping to the outlet of the tee, and the 3/8" Compression side of Item 3
    - For push to connect configuration just need a new cut of polytubing from the second outlet of the tee to the regulator
- Connect bubbler tube to regulator
    - From the outlet of the pressure regulator add the 5/16" MIP side of Item 15
    - Connect the piping with the bubbler attached in *STEP 4* to the 3/8" Compression side of Item 15
    - For push to connect configuration just need a new cut of polytubing from the regulator to the bubbler

STEP 6

Reassemble Unit

- Connect bubbler and Soda Fountain Filler
    - Replace the top basin and side panels of the fountain (The female connections for the bubbler and soda fountain filler should line up with the holes on the basin
    - Assemble the bubbler and glass filler (Item 11)
- Reassemble the unit and leak check
    - Turn on water supply
    - Run water through bubbler
    - Check all connections for water leaks
    - Reconnect electrical supply
    - Replace front panel



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Promotional Video

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