Gamification to Educate on Combined Sewer Overflows and Improve Water Conservation

Loyola University Chicago

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Abstract

Loyola University Chicago has a model campus for conscious and responsible stormwater mitigation which is imperative to maintaining the water quality of local bodies of water such as Lake Michigan and the Chicago River. However, even though we are already a nationally leading university in stormwater management, there is much more that can be done. Reducing and delaying student water usage overall, especially during times of large rainfall events, will allow the strain on wastewater treatment infrastructure to decrease. Our app will display water usage in dorms to increase student awareness of water conservation and provide them with ways they can improve their habits. There will also be alerts provided through our app when there will be a large rainfall event, so students know when to reduce their water usage to help prevent a combined sewer overflow event. Students in the dorms with water monitors will be given a goal to reduce their water usage by 10%, delay their water usage during a heavy rainfall event, and weekly prizes if they continue to participate in the competition. This will encourage students to download and continue to check the app for updates and useful information. Our app will not only educate students on their effect on the environment, but also provide them with resources so that they can make a change. Learning these behaviors in college is likely to positively impact the environment by recalibrating student's behavior so they continue conserving water throughout their life.

Introduction

The aim of our project is to reduce combined sewer overflow events by educating students and creating a more environmentally conscious campus through an app that is both Android and iOS compatible. Loyola University Chicago currently implements all eight of the best management practices given by the Chicago Stormwater Ordinance Manual but all of these are infrastructure based and passive [1]. Our project seeks to add a user active measure to engage and educate students about water issues Chicago faces and how combined sewer overflow events occur. Our team had created a prototype app that informs students about water conservation through a fun facts page and a weekly water conservation challenge. A raindrop tracker will display the dorm's progress towards reaching their goal of reducing water usage by 10%. The other important feature of our app is a weather tracker, so that students will know when a large rainfall event is going to occur to help reduce the strain on the sewer system. We have taken inspiration from similar projects that focus on using social media to educate the public on the linkages between rainfall events and stormwater. The Friends of the Chicago River is an organization that sends out email notifications for heavy rain events and seeks to inform the general Chicago area about the health of the Chicago River [2]. New York also had a similar program called Wait. In this program, residents sign up to receive SMS messages before a large rainfall event as well as educational resources [3]. We hope to implement an app similar to these projects to create a more informed student base at Loyola University Chicago. By developing an app that uses similar strategies as mentioned above and creating a competitive environment we hope to lower water usage overall and develop new habits that will continue for the rest of student's lives.

Background Research

In order to support our project, we have researched the impact of competitions on student behavior, stormwater management in Chicago, and the importance of water conservation.

Role of Competition on Behavioral Change

As students transition to college, they form new habits and routines for how they spend their time. These habits often continue long after they leave their college's campus. If a competition at a university is conducted, it is most successful if it asks very little of students. Students will not want to participate if the changes that are being proposed have a significant impact on their daily lives and habits [4]. App notifications that have fun facts or reminders for students is effective in individually connecting students and informing them on their role in water conservation [4]. Furthermore, the most successful way to keep students interested and engaged is to provide them with up-to-date feedback which was done through a competition at Oberlin College. Real-time feedback on electricity and water use was given to students according to their floor along with a fun fact to educate them [5]. This was successful because students were able to check their floor's progress whenever they wanted. Students also were very interested in small scale comparisons between dorms and even between floors within the same dorm [6]. If this data is presented in an informational and easy to understand format students will continually check and

try to improve their readings [7]. Since university students do not feel the direct financial impact of a water or electricity saving competition, there needs to be several different approaches to appeal to all students. However, it is important to understand that students are very open to the idea of helping the environment. Students living in dorms realize that environmental issues will have an impact on them as they grow older and that these issues are becoming a growing concern [5]. Therefore, they are very open to making changes in their lives that will better the future. Most students transitioning into their college life do not have an accurate idea of their own water consumption. This is elevated by the fact the residence halls do not charge students for individual water use. Making students aware of their water consumption could possibly shock them into understanding this matter [8]. Most students are surprised to learn that an eight-minute shower with a shower head flow rate of 2.2 gallons uses 17.6 gallons of water [9]. While this number is already high, many people take even longer showers which then wastes even more water. Education also plays a long-term role in lasting impacts. Students understanding and forming water conservation methods are more likely to do the behaviors taught after the competition ends [10]. Based on these studies, an application that educates students and promotes behavioral changes would accomplish our objective of overall water conservation.

Water Conservation

"Anyone who can solve the problems of water will be worthy of two Nobel prizes—one for peace and one for science." John F. Kennedy

Even though Earth is covered in water, only a small portion is freshwater. Most freshwater is found underground or in the form of glaciers, leaving even less accessible water for human use [11]. Irrigation to grow food is the largest use of freshwater on Earth [12]. As the population of Earth increases there will be an increased demand for food and water [11]. The use of water is increasing as living conditions improve and as agricultural techniques become more advanced, but for at least one month in the year, two-thirds of humans face water scarcity [13]. It has been found that when freshwater is not abundant, health issues and poverty are more common [11]. Even though Lake Michigan has a plentiful supply of water, the rest of the world is not as fortunate and face difficulties everyday due to their lack of water. It is also predicted that as the climate continues to change this will affect global water patterns [14]. Since this is a large unknown as to how the Earth will continue to change, it is important to begin water conservation habits. As one person begins to practice them, others will notice and change their habits as well [14]. Many people spend portions of the year experiencing droughts which has led to an increased use of water-saving applications and education on the importance of conserving water [14]. It is imperative to begin proper water conservation habits no matter where one lives, so that humans are prepared for any living situation and appreciate the resources they have.

Stormwater Management

Stormwater runoff, household sewage, and industrial wastewater are often collected in the same water pipe known as combined sewer systems (CSOs). These pipes are designed to transport combined wastewater into a wastewater treatment plant that will treat the wastewater and discharge it into a body of water. However, when there is heavy rainfall, the wastewater treatment plants become overloaded and discharges the overflow into rivers, streams, and other bodies of water. This can be seen in Figure 3 where the baseload and stormwater combine and go over Stickney's maximum capacity. This is a threat to our well-being and the biodiversity of our bodies of water, as these CSOs contain untreated industrial and human waste [15]. Stickney Water Reclamation Plant is one of the largest water treatment plants in the world. To create improved infrastructure to mitigate CSOs would be very expensive; however, implementing a conservation system would be both effective and inexpensive. A solution is to reduce the residential flow component to the wastewater treatment plant during periods of high stormwater flows. This will create more room for the stormwater in the combined sewage system and will prevent wastewater from entering the bodies of water via CSOs. An alert system in the form of an application will allow this solution to be implemented in the Loyola University Chicago community.

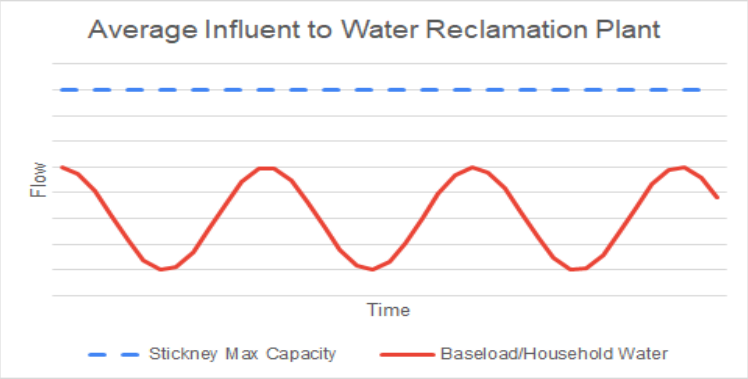

Figure 1: Graph Displaying Average Influent to Stickney

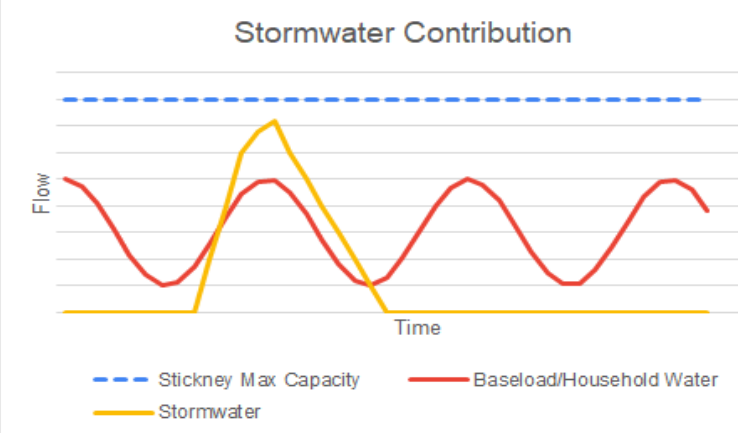

Figure 2: Graph Displaying a Stormwater Curve

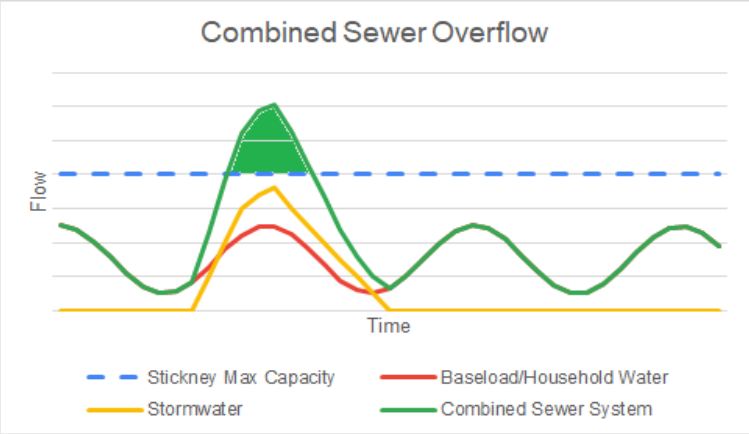

Figure 3: Graph Displaying CSO Event

Site Location

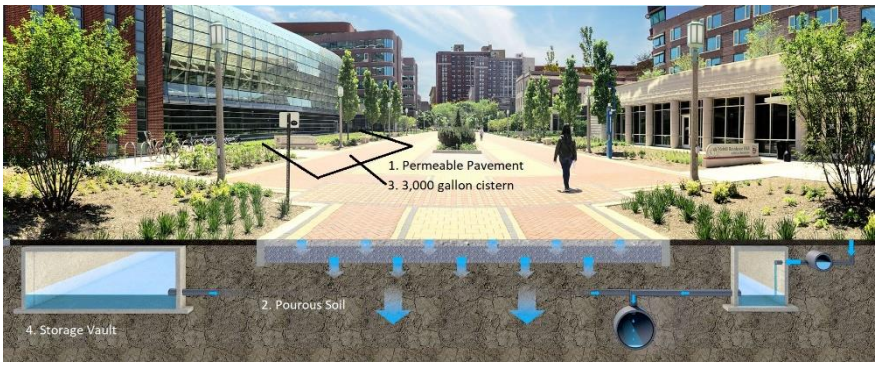

Figure 4: Existing stormwater management that can be seen in front of the Institute of Environmental Sustainability [16]

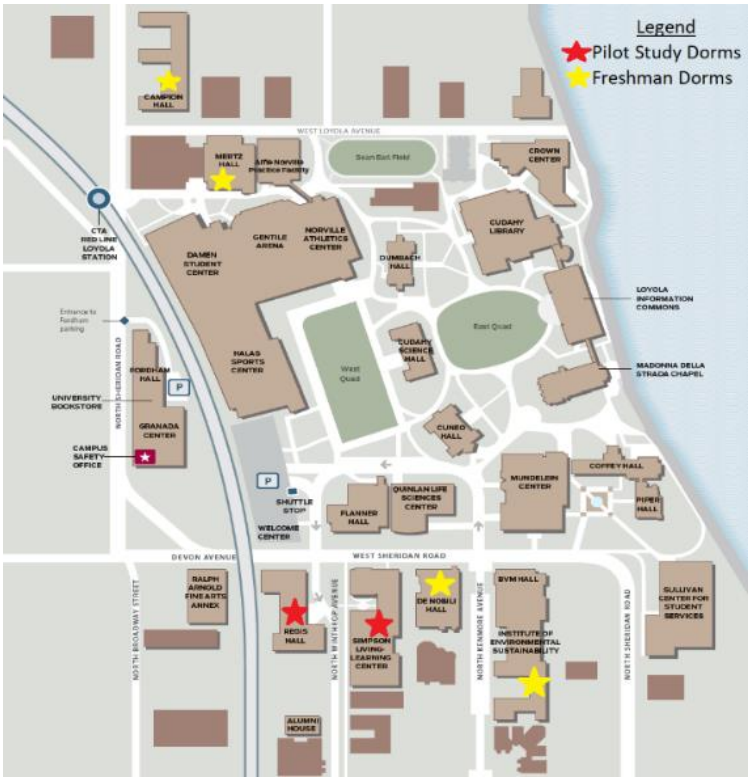

Figure 5: Map of Loyola University Chicago Lakeshore campus [17]

The goal for our project is that every freshman dorm will be incorporated in our campus wide water conservation competition. In order to ensure the success of the larger project we will begin with two freshman dorms that are called Regis Hall and Simpson Living-Learning Center. To get control data we will install the water monitors and track each dorms' average water data for one month. Based off this data the students living in each dorm will be encouraged to download our app and participate in our one-month LUC Water Challenge to reduce their average water usage by 10%. If this pilot study is successful, we will attach water monitors and conduct our competition in the rest of the freshman dorm buildings which include Campion Hall, Mertz Hall, De Nobili Hall, and San Francisco Hall (attached to the Institute of Environmental Sustainability). Loyola University Chicago also implements all eight best management practices given by the Chicago Stormwater Ordinance Manual which include bioinfiltration systems, drainage swales, green roofs, natural landscaping and stormwater trees, permeable pavement, roof runoff BMPs, vegetated filter strips, and detention systems [1]. We hope to delay further capital investment on infrastructure by taking a behavioral approach which will not only benefit Loyola University Chicago's campus, but also the Earth as a whole when the students leave college and begin to live on their own.

Site Problem

Figure 6: Stickney Water Reclamation Plant [22]

The Stickney Water Reclamation Plant serves the city of Chicago, and can process up to 1.4 billion gallons/day but typically only processes 700 million gallons/day [18]. This extra capacity can be filled when there is as little as a 0.3-inch rainfall event [19]. Chicago has recognized the need for better CSO management and are in the process of building the Tunnel and Reservoir Plan also known as TARP. By then end of the completion of this project it will be able to retain 20.55 billion gallons total. The reservoirs and tunnels are still being excavated, but the ones that have been completed have reduced CSO events from 100 days per year to 50 days per year [20]. While this project has been effective it is very expensive. The Majewski Reservoir holds 350-million-gallons and the construction costed $45 million [21]. The other reservoirs are the McCook reservoir which holds 10 billion gallons of water and the Thornton Composite Reservoir is still being constructed but can currently hold 7.9 billion gallons of water [21]. These reservoirs are much larger and therefore the cost is much greater. Our app is a cost-effective way to reduce CSOs by reducing and delaying water that goes into the sewer system during a rain event. Many students on campus are unaware of CSOs and their effect on the local water. This can lead to wasteful behavior and students inadvertently contributing to CSO events. By simply encouraging students to students to avoid showering, washing their clothes, or doing dishes just before and during rain events, the strain on the sewer system will decrease at a minimal cost.

Goals

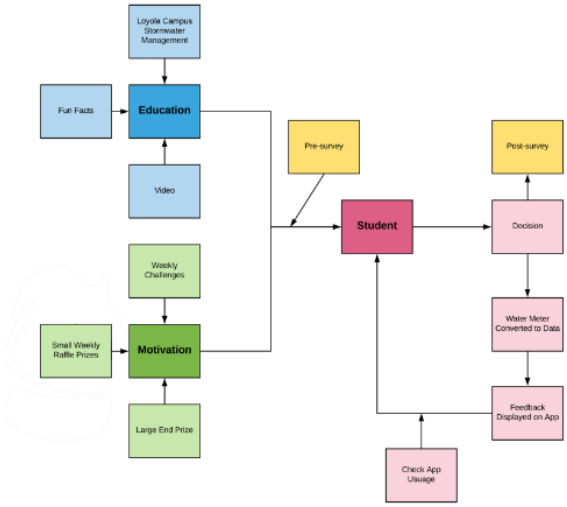

Figure 7: System diagram showing all aspects of the plan and the influence on students

Community Engagement

This project's central focus is reaching out to educate students and providing them with resources to change their habits. We aim to bridge the connection between innovation and community through developing an app that will be accessible to students. In order to motivate students to download this app, an incentive will be given to a dorm that reduces water usage by 10%. There will also be a weekly challenge, and if students participate, they will receive a smaller prize such as a gift card or Loyola merchandise. Surveys will also be used to gather information on how informed students are about water conservation and combined sewer overflows before starting the competition and after. Benefits of this project include forming long-term habits that will not only help the individual, but the environment overall. These benefits are quantified through Stickney's records which show the negative impact of combined sewer overflows on the environment. Alongside working with all freshman students, we plan to work with facilities on campus to install the water monitors. This process also includes educating the community about things already in place on the Loyola University Chicago campus. We plan to forge partnerships with clubs and facilities around campus that have similar goals, such as Loyola's Energy Manager, the Director of Sustainability, and the Engineers for Social Justice club.

App Usage

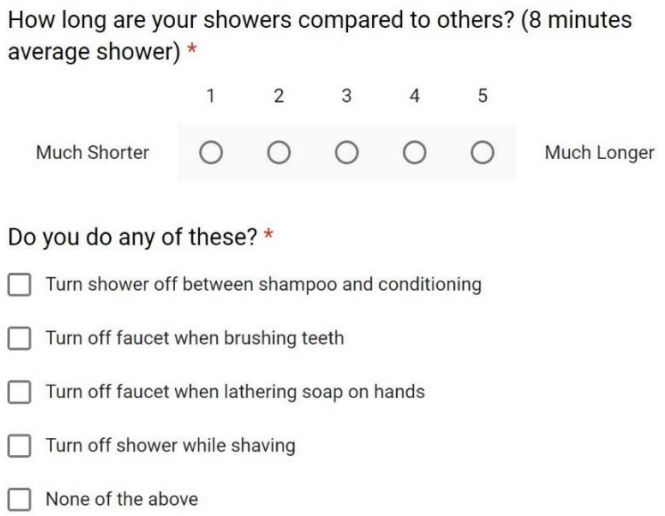

Figure 8: Example of Pre-Competition Survey Questions to Assess Student's Water Conservation Knowledge

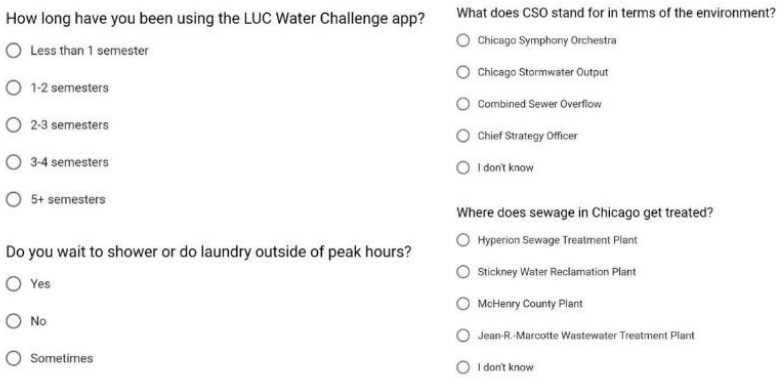

Figure 9: Example of Post-Competition Survey Questions to Determine Gained Knowledge and Monitor Continued Habits

We expect to see a correlation between the app implementation and a reduction of water usage. Not only reduction of water use, but also water use during peak hours of the day and during rainstorms. We plan on using the water monitor's data to see if there is a drop in overall water usage. A long-term expected outcome would be for students to continue this behavior throughout their lifetimes. We plan on asking users of the app to take surveys before using the app, and every semester afterwards that they spend at Loyola. By comparing the answers of the pre- and post-surveys we expect to see a reported increase of environmental habits and a decrease of water usage.

Design Solution

Our solution for the problem of combined sewer overflows on Loyola University Chicago's campus is an informative and interactive app for students. In order to make the app recognizable we have designed a mascot named BLUe Wolf. Loyola's mascot is LU wolf and this new mascot allows for a recognizable icon for our project. The app will always have the weather on the main page and will send out notifications when there will be an upcoming period of heavy rainfall. There will be tips on how to reduce water usage during a storm such as not showering, doing laundry, or dishwashing until the rain has subsided. Additionally, there will be a raindrop tracker that will allow students to see their dorms progress towards their goal of reducing their water usage by 10%. It will fill up based on the real-time data that is read from the water monitors and will display the percentage remaining until the goal is reached. At the bottom of the main page is a weekly challenge that students can participate in to learn more about water conservation. These weekly challenges will include using our shower timer, taking a shower with only a bucket of water, and doing smaller loads of laundry with a friend. On our fun facts page, we will update the fun facts to keep students interested and educated on water conservation and combined sewer overflows. Not only will this page have general fun facts, but also fun facts about Loyola's campus and the stormwater infrastructure that is already in place. There will also be a settings and feed-back feature in order to improve the application and to make it accessible to all students. The app will be android and iOS compatible because it will be coded using Apache Cordova. This application development platform allows our coding team to code in HTML which is then able to be used for both types of devices. The application is cost-effective and non-invasive solution to deescalate combined sewer overflow events.

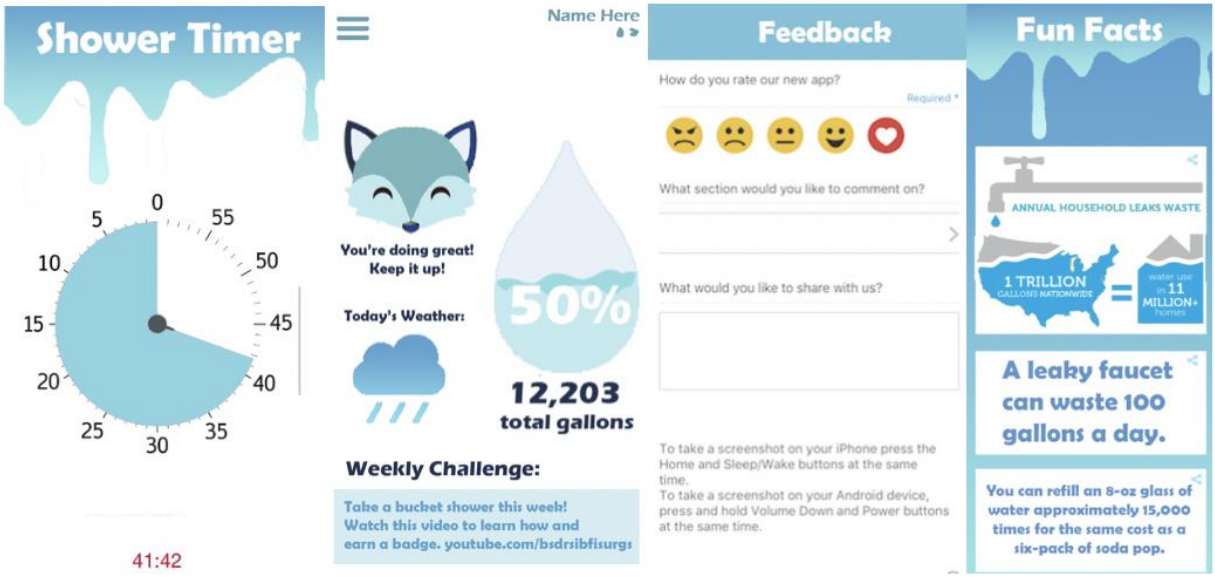

Figure 10: Images of app prototype

Project Phasing

Phase 1 Spring 2020: Our first stage of this project is to meet with facilities to determine the feasibility of attaching water monitors onto pipes in Simpson Living-Learning Center, Regis Hall, and the other freshman dorms on campus.

Phase 2 Fall 2020: The second step will be to install 2 BACnet compatible water monitors to pipes that lead to Simpson Living-Learning Center and Regis Hall which will be the dorms for our pilot study. We will begin to develop our app based off the prototype that was designed. Then we will integrate the data that we collect into our app so that it is able to be accessed by students.

Phase 3 Spring 2021: In order to encourage the students to download our app we will conduct a competition for the students living in either Simpson Living-Learning Center or Regis. The students will be able to participate in water conservation activities and if the dorm is able to reduce their total water usage by 10% every student that has our app will win a prize.

Phase 4 Fall 2021: If this pilot study is successful in encouraging students to actively use our app and reduce water usage, facilities will invest in additional water monitors and attach them to all the freshman dorms. Then we will have a full campus competition to see which dorm can use the least amount of water in a one-month time span. The winning dorm will receive a large prize, and weekly prizes would be implemented for students that participated in the weekly challenge.

Phase 5 Spring 2022: If the previous competition is successful, we will continue to host the competition each year in the fall and students that have previously participated will be able to continue to access the app to get the weather updates that alert for combined sewer overflows and fun facts on water conservation. Data will also be collected in the spring through surveys to see if the learned behaviors fostered by our competition are continued in the students' daily lives overtime. Our project ensures that every incoming freshman class is aware of combined sewer overflows and is informed on the infrastructure that Loyola already has in place.

Maintenance

Loyola University Chicago has already implemented several different forms of stormwater management. Our app is intended to educate students on infrastructure that is already in place rather than add more without explaining to people why it is necessary. For our project to be successful, we need to install water monitors onto pipes in dorm buildings. Once this is completed the data will go directly into our app through a Loyola University Chicago database, and the only maintenance necessary will be if there is an issue with the monitor. The team met with facilities and investigated the feasibility of attaching water monitors to pipes in two freshman dorms called Regis Hall and Simpson Living-Learning Center. The water monitors are non-invasive, so they are not permanent and require little assistance to install. The suggested water monitor is BACnet compatible because facilities uses this to transfer data onto a database

that our team would have access to. This would allow for our team to monitor the real-time data and notify facilities if there appears to be a problem with the readings. Facilities has agreed to assist the students in installing the water monitors and changing them if there is an issue. Additionally, our app will be coded and tested by a team of students, but there may be technical issues that need to be resolved or improved. This will be done by students that are working on this project, and other students that are in Loyola University Chicago's Engineers for Social Justice Club that have joined our coding team. Aside from these two aspects we do not foresee any other maintenance that is required for our project.

Cost and Funding

The BACnet compatible water monitors will be purchased by facilities. We have proposed to facilities that since our app is reducing costs for the university on water and sewage bills then the savings could be used to upload our app on the Apple App Store and Google Play Store. This will cost about $124 for our first year because the Google Play Store charges $25 and the Apple App store charges $99. Then we will need an additional $99 to continue to have our app on the Apple App Store each year [23]. Facilities has agreed to purchase the water monitors and support our project in any way needed. Additionally, we have met with the director of the Institute of Environmental Sustainability and he has agreed to provide funding for prizes for the interdorm and campus wide competition. As seen in phase 5, we are hoping this project continues, so we are trying to keep costs at a minimum.

Calculations

The data that we have from the dorms were obtained from residence life at Loyola University Chicago. From this data we have done calculations on our two dorms that will be in our pilot study, Regis Hall and Simpson Living-Learning Center.

Dorm	Occupants	Toilets	Showers	Washers
Regis Hall	469	231	231	14
Simpson Living-Learning Center	464	116	116	16

The average shower is about eight minutes, and the average shower head flow rate is 2.2 gallons per minute [9]. For our calculations we assumed that each student would take one shower per day.

$$\text{Number of Students} \times 1 \frac{shower}{day} \times 8 \text{ min} \times 2.2 \frac{gallons}{min}$$

$$\text{Number of Regis Students} \times 1 \frac{shower}{day} \times 8 \text{ min} \times 2.2 \frac{gallons}{min}$$

$$469 \times 1 \frac{shower}{day} \times 8 \text{ min} \times 2.2 \frac{gallons}{min} = 8254.4 \text{ gallons}$$

$$\text{Number of Simpson Students} \times 1 \frac{shower}{day} \times 8 \text{ min} \times 2.2 \frac{gallons}{min}$$

$$464 \times 1 \frac{shower}{day} \times 8 \text{ min} \times 2.2 \frac{gallons}{min} = 8166.4 \text{ gallons}$$

This is a total of 16,420.8 gallons of water that are used when students shower in only two out of the six freshman dorms on campus. A college campus such as Loyola University Chicago uses large amounts of water because there are thousands of students showering, flushing toilets, doing laundry, and washing dishes. These calculations show that within two dorms there are thousands of gallons of water being used per day. If during a rainstorm event some of this water does not go into the sewer system, then Loyola student's will be helping to reduce CSO's and wastewater will not go into our bodies of water.

Future Collaborations

In the future, we hope to be able to collaborate with other students and departments to ensure the longevity of our project. We hope to collaborate with both freshman resident assistants and residence life staff to ensure that all students feel included and comfortable with a competition taking place in their dorm. We hope to spark interest in some of the students who connect with the app and have them continue to work on the project to help maintain it. If there is success on Loyola's campus, we can expand this project to other universities and conduct a water conservation amongst campuses in Chicago. We can also share our findings with other universities and provide them with tools to develop their own app similar to ours so that they too can educate their student body on stormwater management and water conservation.

Conclusion

Natural waterways are an important part of the ecosystem and need to be protected. The city of Chicago's combined sewer system struggles to handle the large increase in volume of water falling during large rain events and resorts to discharging wastewater to bodies of water through combined sewer overflows. Through the help of our app and research on water conservation, we aim to educate Loyola students on combined sewer overflows and the importance of reducing water usage. We hope to inspire students to decrease the amount of water their dorm building uses by 10% through incentives, helpful tips, and fun facts. The reduction of water usage, especially during large rain events, will help reduce the number and volume of combined sewer overflows, leading to higher water quality in our natural waterways. The development of the app, installation of the water meters, and overall research of Loyola's campus requires full campus participation for it to continue in the future. Our team has laid out our plan for the app and begun making the connections needed for the project's future. With the help of the Loyola maintenance and facilities department, residence assistants, and future students, the Loyola campus will reduce its water usage and contribute to a reduction in combined sewer overflows and thus local water quality.

Acknowledgements

Lead Faculty Advisor

Gajan Sivandran, Ph.D., Clinical Assistant Professor- Environmental Engineering

Faculty and Staff Members

Mark Albert, Ph.D., Assistant Professor of Computer Science

Linda Brazdil, Ph.D., FYRE Program Director

Aaron Durnbaugh, MS, Director of Sustainability

Hamlet Gonzalez, Assistant Director Campus Operations

Linley Miller, Ph.D., Senior Lecturer and Director, Center for Science and Math Education

Brian O'Malley, Operating Engineer, Energy Manager

Outside Sources

Erin Morey, WAIT Director, NYC Environmental Protection

Student Roles

Anisha Kapoor: Served as the lead researcher & student outreach coordinator. The position of lead researcher defined pertinent topics of focus, designated topics for exploration, and compiled findings in the final report. As the student outreach coordinator, student behavior and mindset were observed through conversation along with online surveys. The role entailed formulating questions to be answered by students and actively encouraging student participation.

Max Kurinsky: Coordinated with Loyola Residence Life Department and facilities to gain permission to install flow monitoring devices. Conducted research on student dorms to find accurate data on the amount of water using devices such as showers, toilets, and sinks. Assisted in editing and formatting the research paper and research presentation.

Brooke Lepore: Team leader and primary writer for the report. Oversaw the coordination with faculty and team advisor. Assisted in background research and finalizing design solution and calculations.

Jack Segal: Presentation coordinator responsible for the creation of research presentation. Assisted in preparing public-speaking techniques for an effective presentation.

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