Milestone 2

Project Overview

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Rainwater Irrigation Milestone 2

Version 3

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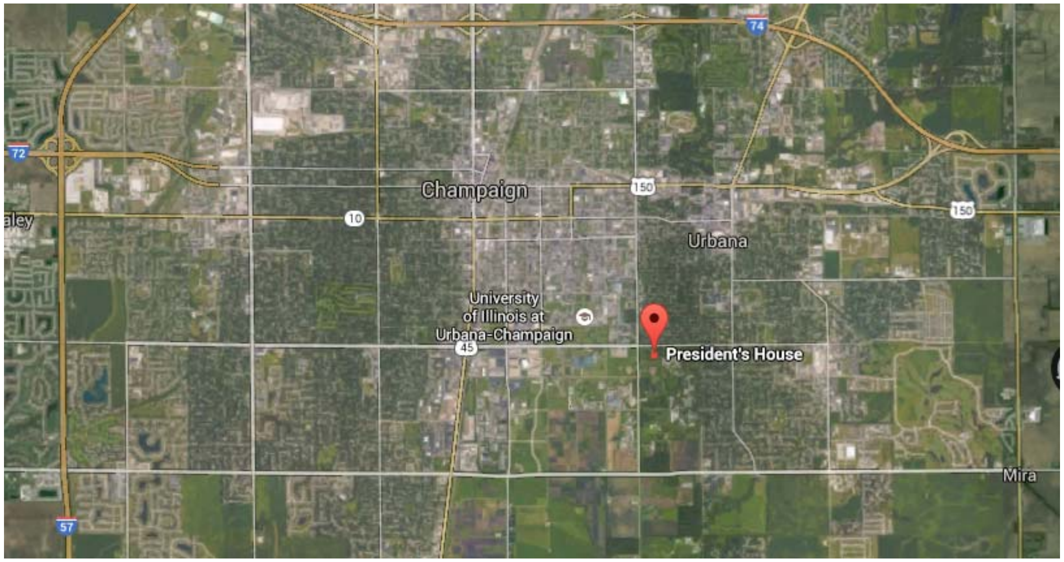
At the President's House on the campus of UIUC, the irrigation system uses, on average, 1,930 KGL of potable water per year. The primary objective of this project will be to determine the feasibility of creating a system that is capable of capturing stormwater and reusing it for irrigation in place of potable water, with the Presidents House as a model. According to the 2015 Illinois Climate Action Plan (iCAP), one of their objectives is to implement four pilot projects that demonstrate the potential for water or stormwater reuse by the 2020 fiscal year (iCAP 2015). What this shows is that the UIUC has already committed to the reduction of potable water use and would certainly be interested in beginning a project to demonstrate the capabilities of stormwater reuse.

We were able to conclude that capturing the stormwater runoff from the chosen watershed would be able to sustain the irrigation needs at the President's House using only stormwater. This potentially saves up to $6,000 per year on the water bill. The final design that was chosen for stormwater reuse is a pond. A pond is the most economically feasible solution and could also become a public amenity if properly maintained. Other solutions considered was a trickle irrigation system, permeable pavers to capture rainwater, and a tank attached to stormsewers.

The final design of the stormwater irrigation system was a 5270 cubic yard pond. The cost of the excavation would be approximately $46,000, which delivers an expected payback period of 7.8 years.

Introduction and Background

Water is a resource that is, for the most part, taken for granted in this country. Americans use water for purposes where it is unnecessary for the water to be perfectly clean. For example, the water that is used in this country to flush toilets is perfectly potable water. In some places, how much water that is available is not a question. Unlike the current drought in the American Southwest, the Champaign Urbana area has plenty of clean drinking water to go around for its citizens. But this waste of clean drinking water can still cause problems. That water must be cleaned before it can be used and that process uses up energy, increasing the carbon footprint. According to a study by the American Council for an Energy-Efficient Economy, the mean energy required for source conveyance, treatment, and distribution of watery is 2,300 kWh/million gallons (Young 2015). What this shows, is that significant quantities of energy go into processing water across the country, and for some very unnecessary purposes. What this results in, is a waste of energy and a waste of money. One site around the UIUC campus that uses a significant amount of potable water when it really shouldn't is the grounds of the President's House. In fact, according to the water meters for the irrigation system at the grounds, in an average year over 1800 KGL of potable water are consumed. It is plain to see that this is simply a waste of perfectly good drinking water, water that must be treated purchased. In order to reduce, or potentially remove this waste, we will be looking into the feasibility of designing a system that captures rainwater for later use as a source of irrigation for the President's House.



Similarly, people have been utilizing cisterns and rain barrels to collect rain water for later irrigation. Currently homeowners are utilizing this old infrastructure to collect runoff to irrigate their own personal gardens. On a larger scale, in Saint Anthony Village, MN, the city has created a system that takes in backwash from a water treatment plant and stormwater runoff, stores and treats the water, and uses the water for irrigation of a 20 acre site (Hudalla). This example is very similar to our proposed idea in that the city takes in rainwater, stores it, and later uses it for irrigation. One main difference is that this facility has a treatment plant attached to it as it is used to remove phosphorus. This is a feature to this facility because phosphorus removal from the water was a main objective of that project. In our case however, we will be looking at irrigating solely off of rainwater and are not concerned with phosphorus removal. Also, this project will be looking at irrigating an area with an annual demand that is less than a third seen in Saint Anthony. This example gives insight into the feasibility of being able to irrigate an area with stormwater runoff and reduce the use of potable water by an irrigation system with high water consumption.

Project Objectives

The objectives of this project are to analyze and assess the current irrigation system that is in place at the President's House on the campus of UIUC and to devise a feasible plan that can efficiently take advantage of rainwater and use it for later irrigation. This study is important because it has the potential to save vast quantities of potable water, which currently averages just below 2 million gallons of water annually. The only energy input that the captured rainwater would require is the electricity to pump the water from the storage site to the irrigation site. The saving of this water would not only reduce the carbon footprint but also reduce, if not eliminate, the water bill for irrigating the grounds of the President's House. Therefore, planning a way to harness rain runoff could bring both environmental and economic benefits to fruition. By the end of this study, the feasibility of harnessing rainwater will be well understood. Possible methods of intercepting runoff, storing water, and then delivering the water to its necessary location will all be considered and the most beneficial options of all of these aspects will be compiled into one comprehensive plan that can determine the overall feasibility of reusing rainwater in this location for irrigation.

Project Scope

Task 1: Identify current consumption of water

In order to properly move forward with a solution to the irrigation demands of the President's House, the team first had to obtain records of irrigation usage at the location. Obtaining a record of the consumption is vital to understand what the collection goal will be as well as the future cost analysis. We were able receive monthly data on the consumption of water from a meter dating back to the 2011 fiscal year via interview with Morgan Johnston.

Task 2: Obtain precipitation records

Before calculations can be made for the volume of collectable water, we must first understand the historical rainfall of the Urbana area. The team decided that an average monthly record of rainfall for this town would be sufficient in any later calculations for stormwater collection.

Task 3: Choose a feasible location for watershed

The team will then decide upon a location for a watershed that appears promising as far as volume that could be collected. This can be done via a geographic information system (GIS) to view topography as well as existing irrigation lines and stormwater sewers.

Task 4: Calculate collectable volume from chosen watershed

The collectable volume of water will be calculated from month to month using the average rainfall data for the region. This depth of water can be multiplied by the impermeable surface that the stormwater is being collected from. In this case, the area will be that of a parking lot and the roofs surrounding it. Finally, this volume will be multiplied by a runoff coefficient relating to the terrain.

Task 5: Plot consumption and collection to determine size of storage

We will then be able to plot the cumulative collection and demand of water at the site. If the collection line stays above the consumption, we will be able to determine that in an average year, the President's House will be able to function solely off of water collected from stormwater runoff. The storage capacity of runoff will be determined by the largest difference between the two plots.

Task 6: Final design and location

The final design will be one that affordably achieve the capacity needed to allow the system to run solely on stormwater runoff. For example, an option where excavation of soil is the main cost will be preferred over one with even more construction costs, like the removal of pavement. The location will be one in close proximity to the President's House and requires the construction costs.

Task 7: Cost analysis

The cost analysis will be determined by reviewing similar systems and what their respective costs were, as well as looking up rs means values for different aspects of a design such as excavation. The estimated cost of constructing the system will be used along with the current cost of potable water being consumed to give an accurate rate of return on this investment. In addition, this cost analysis will determine if the system is economically feasible.

Alternative Solutions Under Consideration

Most possible solutions to our potable irrigation problem involve different methods of collection. The only alternate solution that was seriously considered during the early stages of our project was permeable pavers. The goal behind permeable pavers is to collect water in a basin underneath otherwise impermeable pavement.The space between the pavers is filled with a loose gravel, to allow percolation of water. Not only does this reduce standing water, but if measures are taken to collect the water, it can be put to use. The Aquascape consulting team, based out of the West Chicago store, employ pavers such as these for patios in proximity to a water feature, with a cistern underneath to contain the water collected. The water can then be pumped out as needed.

We chose not to use this method while still focused on the Hartley Garden, due to the relatively small size of the nearby parking lot. It is even less apllicable for the presidents estate, due to the extremly high water demand in the summer. Despite its limitations in the context of our irrigation problem, permeable pavers and pavement are an effective, low maitenance method for collecting stormwater.

A trickle irrigation system was also considered in order to reduce water consumption. While this, was a very viable solution to Hartley Garden's irrigation, it would not be effective for turf irrigation. Lawn maitenance would put the drip lines at risk, and any associated repairs mitigate any savings to be made from water consumption.

The decision to switch from an underground tank to a surface pond was made late in the project, in the interest of cost. Our original plans called for a collection tank to be placed along a storm pipe, underneath existing pavement. Such a set up would be very expensive, compared to the alternative clay lined pond. The pond also outclasses the tank in that it has aesthetic value and provides a visual feature to showcase the project.

Preliminary Results and Discussion

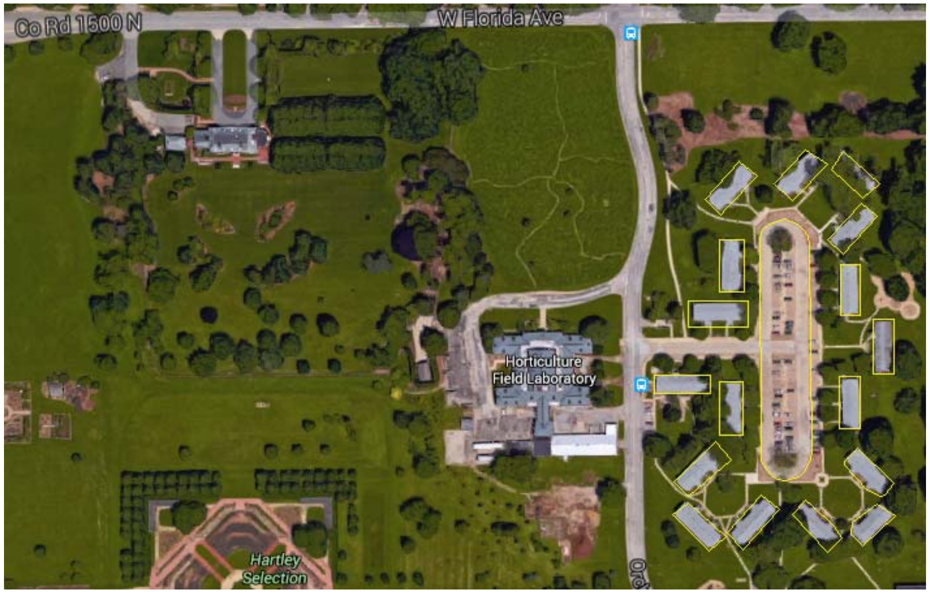
According to data recorded at the President's House dating back to the the 2011 fiscal year, the average consumption of potable water used for irrigation is 1,930 KGL per year, which sums to an expense of approximately $5,915.76 per year.

TABLE 1:

Average Monthly System Volumes			
	Consumption (gal x 10^3)	Rainfall (in)	Collected (gal x 10^3)
JUL	424.50	4.7	288.92
AUG	412.66	3.93	241.58
SEPT	483.72	3.13	192.41
OCT	270.22	3.26	200.40
NOV	55.62	3.68	226.22
DEC	39.02	2.73	167.82
JAN	51.76	2.05	126.02
FEB	2.74	2.13	130.93
MAR	0.00	2.86	175.81
APR	0.36	3.68	226.22
MAY	36.66	4.86	298.75
JUN	152.76	4.34	266.79

Table 1 shows the average consumption per month as well as the average rainfall per month and the calculated volume that can be collected. Collection volumes were calculated by multiplying the rainfall by the acreage, converting to thousands of gallons and multiplying by the runoff coefficient of 0.98 for an impermeable surface. This was necessary in order to compare the amount that was consumed each month to the volume that we could collect with the surface we are collecting water from.

Figure 1:



In Figure 1, the areas outlined in yellow were calculated via an online acreage calculator. The area that we will be collecting from totals to approximately 2.31 acres. The rainwater that falls on these areas will be the volume of water that we can collect. These areas were calculated using an online area caclulator (Free Map Tools, 2015)

TABLE 2:

Cumulative System Volumes			
	Consumption (gal x 10^3)	Collection (gal x 10^3)	Difference (gal x 10^3)
MAR	0	176	176
APR	0	402	402
MAY	37	701	664
JUNE	190	968	778
JULY	614	1256	642
AUG	1027	1498	471
SEPT	1511	1690	180
OCT	1781	1891	110
NOV	1837	2117	281
DEC	1876	2285	409
JAN	1927	2411	484
FEB	1930	2542	612

Table 2 shows the cumulative consumption of potable water by the President's House and the cumulative collection of water from the parking lot and the surrounding buildings. The difference between the two columns is shown as well. The largest difference (highlighted in yellow) will be used as the capacity of the storage container. March was chosen as the beginning month because it is the first month without any recorded consumption of water. Also, it would be the first month that the surroundings would be thawing after the winter, allowing for collection of water to begin.

Figure 2:

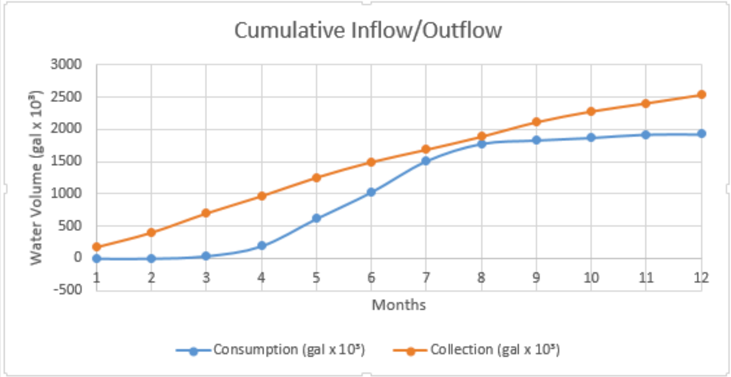


Figure 2 shows the cumulative consumption along with the cumulative collection of water. It can be seen that the consumption line never crosses the collection line, indicating that the system would be capable to satisfy the water demand of the President's House.

The design solution that was chosen for this task was a pond. For a pond, the preliminary cost of excavation will be the biggest initial cost and therefore a cheaper and just as effective solution as any described in the alternative solutions section.

Figure 3:

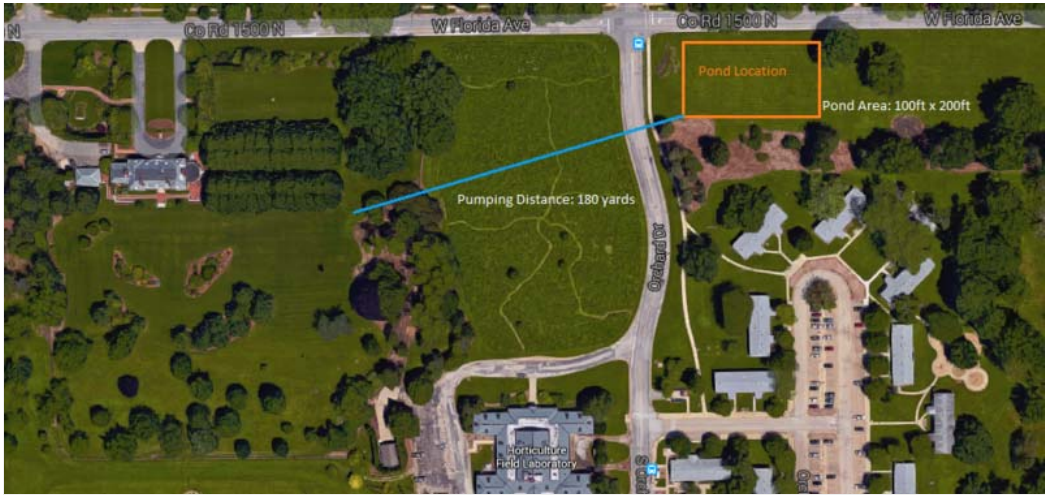


Figure 3 shows the location chosen for the pond and the pumping distance required to connect with the existing irrigation lines at the President's House. This distance was determined using an online distance map (Map Tools, 2015).

This location was chosen because of its close proximity to the collection area (parking lot and buildings in the lower right corner of Figure 3) and to the President's House. In addition, the trees located to the South of the location will provide shade during hot, sunny days to reduce the volume loss due to evaporation.

Pond Design:

From analyzing the amount of water that we are capable of collecting, we determined earlier in this section that 778 thousand gallons was the required reuse volume. For excavation purposes, this number was converted to 3850 cubic yards. For the pond design, this is the amount that the volume will be able to fluctuate. However, there were other factors that played a role in determining the design of the pond. These factors were given in an article by the United States Environmental Protection Agency:

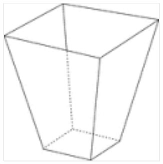
1. Permanent pool depth
2. Slope of banks

3. Length to width ratio

Here, the permanent pool depth of 1 meter or approximately 3.3 feet was determined to be the required depth of the permanent pool of the pond. Also, a slope of 1/2 was determined to be the steepest slope that should be designed. That is, you go down 1ft for every 2ft of horizontal movement. In addition, a length to width ratio of 1:2 is also recommended (USEPA, 1999). In this case, because the width of approximately 100ft was a limiting factor, it was determined that the length of the pond would be 200ft.

Using these factors up above, we were able to determine the volume of the permanent pool and also the overall depth of the pond. This was done in by treating the two sections of the pond as two frostrums of a rectangular pyramid stacked on top of each other. Or two shapes similar to the one in Figure 4

Figure 4:



Using the geometry of the shape in Figure 4 and the design factors listed above, the team was able to determine that the permanent pool volume will be 1390 cubic yards and the overall depth of the pond will be 9.7 feet.

Another design feature that was considered was the soil type in the pond location. Using a geographic information system by the United States Department of Agriculture, we were able to determine that the soil in this location are Catlin silt loam and Flanagan silt loam, which comprise of approximateley 50% of the soil composition (USDA, 2015). Because these soil types have moderate and somewhat poor drainage respectively, and are likely to have less permeable soils underneath, it can be discerned that not a considerable volume of water will be leached into the groundwater.

Cost Analysis:

For the cost analysis, it was determined that the larges cost of the project would be the excavation of the pond. In this case, the overall volume of excavation will be the reuse volume and the permanent pool volume which sums to a total of approximately 5270 cubic yards. According to the RS Means for excavation, a price of $8.70 per cubic yard would be a conservative number (RS Means, 2015). From this, it can easily be determined that the initial excavation cost will be approximately $46,000. Considering that the arboretum spends $5,915.76 on water in an average year, this will result in a payback period of about 7.8 years.

Costs that will be required for project completion yet were not calculated include the following:

- Pump - to deliver water to site
- Trench - for piping to site
- Piping - to site
- Running powerlines - to power pump
- Maintenance

These costs were not taken into account because they were assumed to be relatively small with respect to the initial excavation of the pond. However, these costs should be considered in further detail if this project comes to fruition. These would certainly extend the payback period of the project, but for something that is long term like a pond, a 7.8 year payback period gives a fair amount of wiggle room. Dollars and cents aside, this project has the capability of reducing UIUC's consumption of potable water by nearly 2 million gallons, a factor that would be very appealing to the university.

Schedule Update

The team is keeping up with this current form of our schedule quite well. Consumption and cost of the water has been assessed and the design of the proposed system has been completed. The design process went quickly with respect to the general design. The biggest obstacle in completing this task was determining the exact volume that the tank should be capable of holding. The most difficult task to date has been the estimation of costs. Because few projects of similar design to this have been completed, it is somewhat difficult to accurately assess the cost of the tank. However, a best estimate will be made on time with the little data that is available.

This schedule is an update from the previous milestone. Revisions were necessary because the previous version had no measurable deliverables and no specific deadlines. This version of the schedule has been key to keeping the team on task.

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