Water 4 Trees

Report for Roselle Park Environmental Commission: Sustainable Tree Watering System

May 3, 2021

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Abstract

This project is part of the Senior Capstone for the School of Environmental and Sustainability Sciences in which students collaborate as a team to address the needs of a real-world client. The Borough of Roselle Park Environmental Commission approached our group about finding a sustainable solution to watering new street trees. Specifically, our group was tasked to design an automatic and sustainable water system that would water newly planted trees and save the Borough time and money usually required for tree maintenance. Our group was also able to develop a list of potential trees and locations for planting throughout Roselle Park.

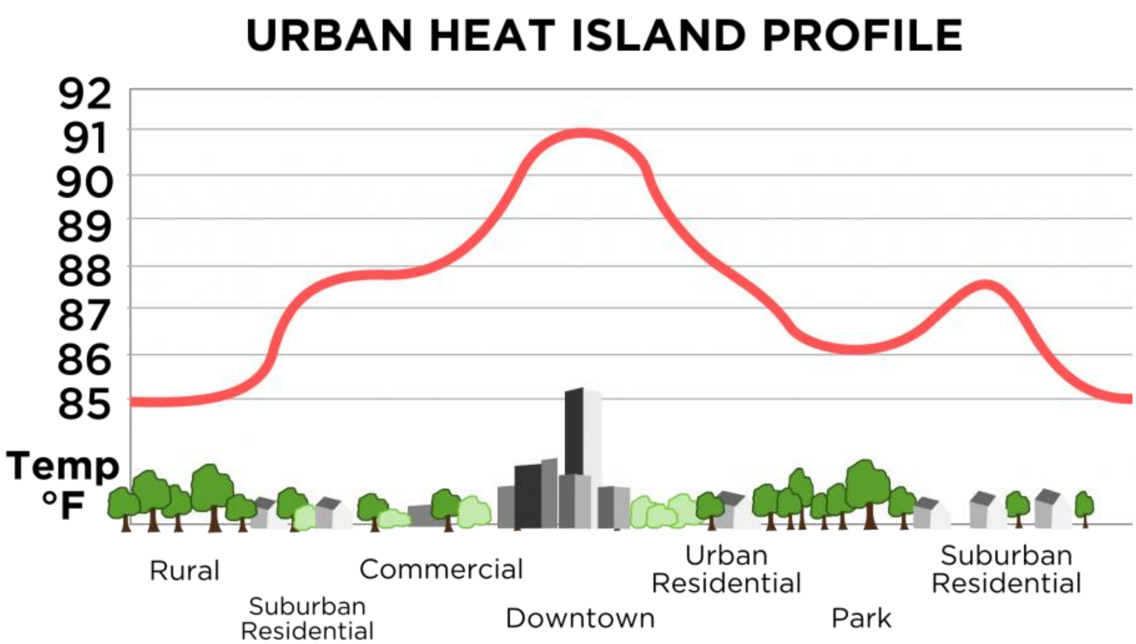
The steps that we took to address our client's needs were to: 1) Conduct research about irrigation systems that would work well with rain barrels to automatically deliver water to planted trees; 2) Research ways to find solar-powered automatic systems that distribute water from the barrel to the plants; 3) Research tree species that would be ideal in an urban community with limited water; and 4) Conduct field surveys to find a suitable location for this system because we needed a location that would have a good collection of rain.

It is our hope, and that of our client, that this system will serve as an example of how the Borough of Roselle Park and all urban areas can sustainably tend to urban trees. By incorporating this watering system, cities can have the flexibility to plant more trees which ultimately can help address issues of poor air quality, storm water management and heat island effects while simultaneously making the community more aesthetically pleasing and biodiverse.

STATEMENT OF PROJECT NEEDS

IMPORTANCE OF TREES

trees play essential roles in regulating climatic conditions at scales ranging from the local to global levels. In urban environments in which concrete and asphalt rapidly replace tree cover, there is a general rise in temperature and an increase in stormwater runoff. While our client is trying to achieve multiple goals through increasing tree cover such as air quality and visual appeal, the main objectives are to mitigate this “heat island effect” and increase in runoff. Heat islands are becoming increasingly common, but what exactly are they? Heat islands occur in urban areas where there many structures such as buildings, roads, and homes that absorb and re-emit heat from the sun. Urban heating many cause extra warming in cities on top of the warming already caused by climate change (Harvey 2019).



This heat island effect is especially prevalent in Roselle park since out of the five climate regions in New Jersey, Roselle Park is situated in the most urban one, the Central Climate Zone (ERI 2020).

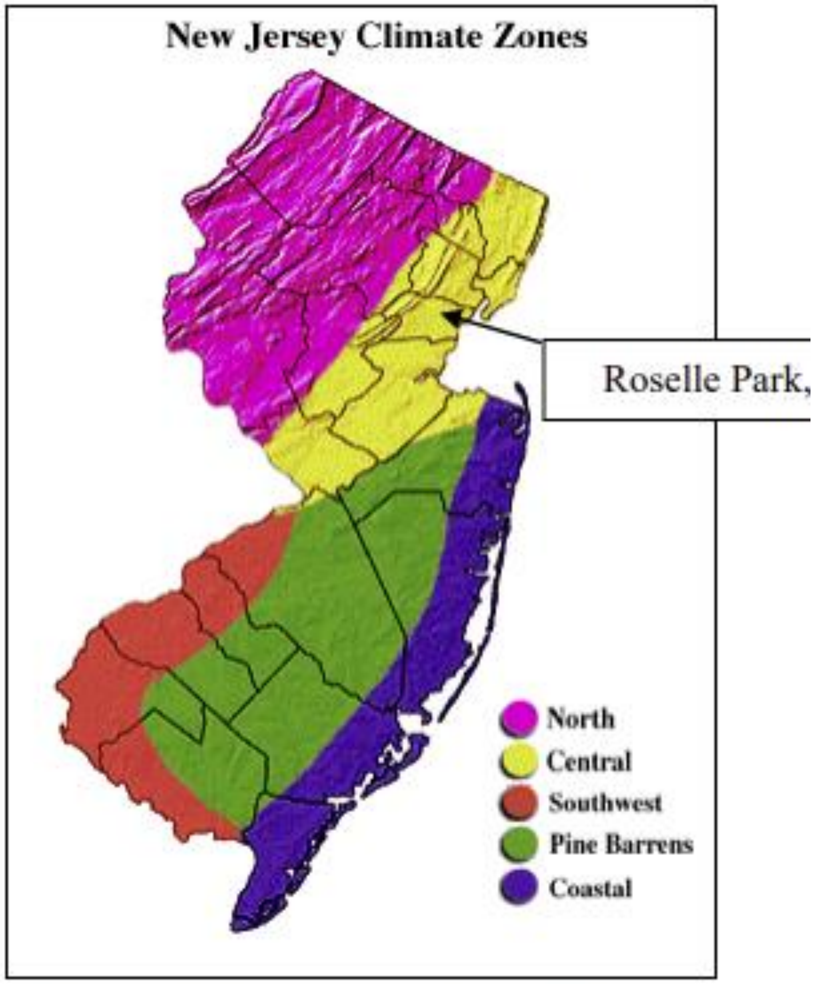


Figure 7. New Jersey Climate Zones
(Office of the NJ State Climatologist)

In addition to the heat island effect, the industrial nature of the area produces large quantities of airborne pollutants like methane (CH_4), carbon dioxide (CO_2), and nitrogen dioxide (NO_2) that further deplete environmental and human health. With urban structures retaining more heat, and greenhouse gases warming the atmosphere, Roselle Park along with the rest of the Central zone is in a perpetual state of warming. Heat Index is reduced by trees absorbing heat radiation before it reaches ground surfaces. Lessening the amount of heat radiation that is absorbed into pavement, and asphalt is crucial in preventing the heat index from rising any further. Air pollutants are reduced by trees absorbing pollution into their leaf stomata and then diffusing it into intercellular spaces. The results of trees on air pollution were apparent in a 1994 study where scientists estimated that New York City removed about 1,821 metric tons of air pollution at a benefit of $9.5 million (Nowak 2002).

Roselle Park needs to increase their urban tree cover to not only reduce the heat island effect and air pollutants but also to lessen stormwater runoff, which is a key factor in flooding. While most of Roselle Park is not in any immediate danger of flooding, there are still areas that must be watched carefully since they sit in either the 100-year (1% probability) or 500-year flood zone (0.2% probability).

Table 31. FEMA National Flood Hazard Layer

Flood Hazard	Acres*	% of Total Municipal Area*
100-year Flood (1% annual chance)	27.84	3.55%
500-year Flood (0.2% annual chance)	7.29	0.93%
Not in Flood Zone	748.57	95.52%
Total Borough Acreage:	**783.70**	**100%**

Source: FEMA National Flood Hazard Layer (2019)
**GIS Acres Used to Tabulate Data*

Targeted tree planting is shown by research to reduce peak flood flows up to 40% (The Woodland Trust), showing that trees are very efficient with preventing flooding. Without trees, rain runs off soil and into rivers and streams, raising the water level far above capacity. The role that trees play in reducing flooding is by intercepting that rainwater, then absorbing and delaying its progress downstream. Studies have shown that trees reduce surface water runoff up to 80%

better than asphalt (Armson et. al 2011). Trees also help keep soil in place so that water can be contained even further beyond the vegetation. The leaves of trees play a role in the prevention of flooding as well. When raindrops collide with the leaves, water hits the ground in lower quantities (Powell 2016). With the many benefits that trees provide listed above, it's a necessity that urban areas like Roselle Park implement a sustainable planting strategy to mitigate the harmful consequences that a lack of vegetation brings.

COST OF TREES

While we are aware of the benefits of having tree coverage and the risks of not having any, many urban areas around the world cannot begin increasing the amount of trees they plant because of the financial cost. Along with planting and maintaining trees, other associated costs include purchasing materials and irrigation. The Environmental Protection Agency released a statement regarding the cost of planting and maintaining trees, "A study of urban forestry programs in five U.S. cities showed a range of expenditures: annual costs ranged from almost $15 per tree in the Desert Southwest region to $65 per tree in Berkeley, California. Pruning was often the greatest expenditure, accounting for roughly 25–40% of total annual costs (approximately $4–$20/tree). Administration and inspection costs were the next largest expenditure, ranging from approximately 8–35% of annual expenditures (about $4–$6/tree). Tree planting, surprisingly, accounted for just 2–15% of total annual urban forestry expenditures (roughly $0.50–$4/tree) in these cities." In almost every situation, the benefits of increasing urban tree cover will substantially lower costs for the city. While some conditions may vary like community and tree species, it is also stated by the EPA that on a per-tree basis, the cities accrued benefits ranging from about $1.50–$3.00 for every dollar invested (EPA 2020).

CLIENT OBJECTIVES

INCREASE IN TREE COVER

The Borough of Roselle Park desires to increase its tree cover to improve the quality of life, combat heat island effects, increase stormwater management capacity among other environmental and social benefits. Unfortunately, as we discussed the cost of increasing tree cover is often very expensive and out of the budget range for cities with a limited budget. The main challenge that is being faced by many cities looking to increase their urban tree cover is that newly planted trees require regular watering, especially during warm weather, for approximately two years. Relying on rain to be a new tree's only source of water is not effective, therefore watering must be completed either by Department of Public Works staff, or potentially a hired contractor (depending on the choice of the borough). Of course, both of these methods require money and time for staff or contractors.

The Borough of Roselle Park's Environmental Commission has tasked our group with exploring the feasibility of developing a closed, self-watering, gravity-fed system that could serve the function which staff or contractors currently must fill. Solving this issue would save the Borough both time and money. The Borough of Roselle Park is requesting that this system is comprised of a catching container, ideally a rain barrel or tub that is fitted with a water collecting apparatus to increase the surface area of water collection. This system is also expected to have a hose or tube that would deliver water to between one and five trees, and a spout with a timer system to regularize the timing of watering.

Aside from being asked to build a protype of the requested system, our group has also been asked to research and recommend future locations where this system will take place. We were also asked to find a list of suitable trees that would not only benefit from the prototype, but also from the locations that we found. All of this information will save Borough time if future implementation of our prototype is acted upon.

DETERMINE LOCATIONS FOR FUTURE INSTALLATIONS

Lastly, after all of the previous tasks have been completed, our group has been asked to create a criterion full of information for future installations that could be used by not only Roselle Park, but also other cities. The following information is being requested to be included on the criteria:

a. Characteristics of locations for implementation (based on lessons learned from identification of five initial spots)
b. Cost-benefit analysis based on lessons learned that includes evaluation of:
    i. Types of materials
    ii. Size and weight of system vs. # of trees able to be watered
    iii. Cost of materials
    iv. Estimated length of life of system
    v. Estimated staff time or contractor costs

PROTOTYPE DESIGN AND MATERIALS

BUDGET

The Borough of Roselle Park Environmental Commission has given us a budget of $1000 to design a prototype of the sustainable enclosed watering system. With this budget in mind, our group was able to come up with the system design through a lot of brainstorming and research. Many of the parts that we decided to purchase were small pieces used to hold the system together such as the ¾-IN FHT Swivel Union, Latex Coated Large 3-CT, 16-14 AWG Vinyl Butt Splice 10Pk, the multiple adapters, studs, brasses, and male disconnects. Our group also purchased a backup irrigation kit just in case the premium drip irrigation kid did not have everything we needed. The main parts we had to buy include a Shurflo Revolution Standard 12v Automatic Demand Pump to pump water from the rain barrel to the kit. We also bought a solar panel with its mounting bracket, solar panel battery pack, waterproof off grid-kit, and solar timer. We purchased many different weighted blocks, stones and concrete pads to build the stand for the system. An HDX Tote was used to hold the wiring, timer, and pump. Lastly, we bought a transfer pump to help the flow of the water to the irrigation kit. A more detailed list of our purchases required for the prototype construction will be listed in Appendix A at the end of the paper.

RESULTS

TREE LOCATION

Our client first requested that we come up with a list of suggested locations implementation within the Borough of Roselle Park for our gravity-fed, self-watering system. There was a specific list of requirements that we had to consider when developing ideas for site locations:

a. Located on borough property
b. Suitable for tree planting in area and suggestions of how many to install
c. Heat island locations (based on Environmental Resource Inventory)
d. Visible for increased public awareness and demonstration of sustainable watering systems.
e. Priority should be given to feasibility of open locations where the system must collect its own water

It was important for our group to keep in mind that Roselle Park is a very small city (roughly one square mile) and many of the areas that seemed to be ideal locations were technically on the outside of the Borough's borders.

With these requirements in mind, and with the help of the Roselle Park Environmental Commission, we were able to come up with a list of potential locations. The list consists of these five-potential locations for future tree plantings:

a. **Roselle Park Youth Baseball Field** is a priority area for communal green space and has a high visibility as it is situated between the Roselle Park Recreation Center and the borough's middle school. The soil is suitable for planting as the park already accommodates many large-scale trees and there is enough open space that the system can be properly displayed without interference from nearby vegetation or borough structures. The ideal site for implementation would be the sitting area near the tennis courts or off to the side of the parking lot. A maximum of 3 trees would be ideal at this site taking overlap into account.

b. **Girl Scout Park** has a high visibility rate that would allow for a majority of the community to encounter the system. There is an open field that can accommodate a maximum five trees, although a lesser number would most likely be ideal.

c. **Woodside Gardens Apartments** is the first location on this list to be featured as a hotspot in the urban island heat effect. There is a potential opportunity to increase the quality of life in this area and there is an open field right next to the apartments that boosts that opportunity immensely. If the system can run properly in this area and reduce the effects of the overwhelming temperatures, and air pollution even by the slightest, then the potential to replicate this system for other hot spots in need of greenery is increased.

d. **Roselle Park Train Station** presents an interesting opportunity to utilize the slopes in order to collect rainwater more efficiently than the open fields mentioned above. The lack of available space means that a maximum of two trees can be planted in this area but the benefits of having more greenery in an urban hotspot is beneficial. There is patch of grass near the parking lot that the rainwater collection system can be built just out of reach of commuters but visible all the same.

The Roselle Park Community Garden was suggested as a location by the Roselle Park Environmental Commission because it is located behind a gate with security cameras, protecting the prototype from public interaction. In addition, young fruit trees were already established at the site, so there was no need to purchase specimens for this project. A shed on the property also created an ideal structure from which to divert rain into our rain barrel. There is other construction taking place at this location, ensuring that Roselle Park employees are generally working on the property most days. This is very helpful because when building the drip irrigation kit, there were multiple times where we were able to ask questions to the head gardener.

BUILDING THE PROTOTYPE

Once our group had established the location and the trees that would be used, it was time to start construction of our system. Since this was a system that we were building from scratch that was not preexisting, our group had to pull information and ideas from many different places combined with our own ideas and knowledge. Once we had figured out a possible way to construct such a system and obtained majority of the parts, we began construction in multiple phases that all involved extremely important and detailed steps. The completion of all eight phases took approximately 15 hours to develop, but this time included problem-solving and extensive note taking. It is very likely that this amount of time will can be shortened substantially once people perfect their techniques based on the steps we've described below.

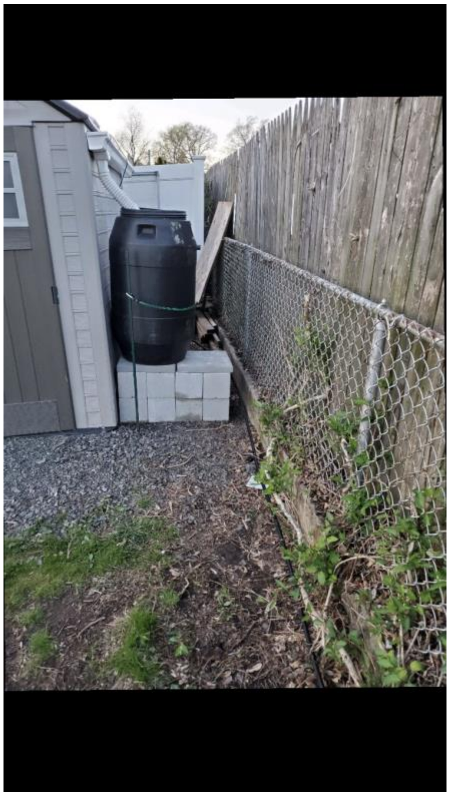
Phase 1 (About 2 hours to complete)

1. Once the Roselle Park Community Gardens was decided upon, the proper location to build the system was apparent via the use of an apparatus, the shed.
2. Removed the debris (leaves, branches, weeds) around the area.

Phase 2 (About 1 hour to complete)

1. Purchased concrete blocks and slabs to build the rain barrel to a height that allowed for more efficient gathering of rainwater.
2. Removed the rocks from the immediate site around the shed so the rain barrel would not tip over.
3. Leveled the soil around the shed so the concrete blocks could be even with each other increasing stability of the system.
4. Stacked two rows of concrete blocks, with 4 in a row, on top of each other, making sure they were level with each other.
5. Placed two concrete slabs on top of the blocks to further level the surface and provide a platform for the rain barrel to stand on.
6. Placed the rain barrel on top of the slabs, once everything was leveled.

7. Stuck two metal stakes into the ground on opposite sides of the rain barrel, to increase security on windy days.
8. Ran a bungee cord from one stake to the other, wrapping around the rain barrel holding it tight in one place.



Phase 3 (About 1.5 hours to complete)

1. Measured the length of the side of the shed that the rain barrel sits on.
2. Purchased gutter materials (Traditional 4.5-in x 120-in White K Style Gutter, Traditional 5-in x 9-in White K Style Gutter Drop Outlet, 2x3 Flex Elbow, White, Gutter End Cap, Vinyl, White, Hidden Hook vinyl K-style Hidden Hanger).

3. Using the measurement on the shed, we cut the White K Style Gutter to a foot greater in size with an electric saw blade.
4. Made a marking of where the hangers will go on the gutter with a pencil.
5. Using the marks, drilled 9mm holes into the gutter.
6. Placed the hangers on the holes and drilled nails into them making sure they were secure.
7. Stuck the drop outlet on the gutter and sawed off the remaining piece so that the gutter is the same size as the shed.
8. Plugged both ends of the gutter with water sealant and then stuck the end caps on, so no water escapes.
9. Attached the flex elbow to the bottom of the drop outlet and drilled a nail to the connecting point, so that the pieces will not come unattached.
10. Took the gutter with all its attachments and drilled in into the side of the shed with the rain barrel.
11. Extended the flex elbow of the gutter into the rain barrel so that rainwater will flow right into the barrel.

Phase 4 (About 2.5 hours to complete)

1. Bought a 55psi Pentair water pump motor to increase the water pressure of the system.
2. Took the red wire first and stripped the end of it.
3. Stuck a butt splice to the end of the wire and clamped it down using the wire cutters.
4. Took the wire from the motor and inserted it into the other end of the butt splice.
5. Clamped down that wire as well.

6. Measured of 2 ft of extra wire and then cut it.
7. Using the wire stripper took off the end of that 2 ft wire.
8. Repeated steps 1-7 with a black wire this time.
9. Used the heat gun on the splices to shrink them and make them watertight.
10. Bought a 12-volt F terminal battery to use as a main component.
11. Adjusted the stripping gauge to ¼ inch.
12. Stripped off the end of the leftover red wire.
13. Clamped a terminal on to the end of that wire.
14. Stripped off the end of the leftover black wire.
15. Clamped a terminal on to the end of that wire.
16. Took two feet of each wire and cut them.
17. Took the end of the cut wire with the terminals placed and stuck them into the receiver of the battery, the red wire inserted into the red receiver and the black into the black receiver.
18. Stripped the end of both wires opposite of the inserted terminals.
19. Took a HDX tote and measured the inside base of it.
20. Bought a flat piece of wood and using the measurement of the base of the tote, cut the wood to the same size using an electronic saw.
21. Mounted the pump to the flat wood piece by drilling 4 wood screws through the base of the pump into the wood.
22. Placed the mounted pump into the HDX tote.
23. Measured the distance of the base of the tote to the port of the pump and then drilled a small hole into the side of the tote using that measurement.

24. Using the previous hole as a reference point, took a hole-saw and cut a 1 ½ to 2 in hole into the side of the tote.
25. Repeated steps 22-23 for the other side of the tote.
26. Took clear tubing and cut it into 3 in pieces using a pair of scissors.
27. Plugged the tubing into the intake side of the pump through the hole in the side of the tote.
28. Screwed a clamp down on the tubing to make sure its connection with the pump is secure.
29. Screwed female connection onto the clear tubing plugged into the intake side of the pump.
30. Plugged clear tubing into the output side through the hole in the tote.
31. Screwed a clamp down on the tubing to make sure its connection with the pump is secure.
32. Screwed male connection onto the clear tubing plugged into the output side of the pump.
33. Placed the battery into the tote.
34. Took a solar controller and plug the wires from the battery into the battery terminals on the solar controller.
35. Battery indicator lit up from this.
36. Took wires from the pump and plug them into the load inputs on the solar controller.
37. Hooked up the irrigation timer on the output side of the pump, via the male connector.
38. Programmed the timer to the accurate month, day, year and time.

39. Programmed the desired irrigation schedule into the timer.
40. Hooked up an inline filter to the rain barrel.
41. Attached a liter hose to the end of the filter and run the hose into the intake side of the pump, inserting it into the female connection.
42. Inserted a pressure regulator into the other end of the timer to reduce the pressure from 55psi to 15psi.

Phase 5 (About 2 hours to complete)

1. Bought a 20-amp solar panel with connections.
2. Inserted bolts into Z Bracket mounts.
3. Took the Z Bracket mounts with the bolts inserted into them and placed them into holes on the four corners on the back of the solar panel.
4. Placed wedges and nuts on the ends of the bolts while inserted into the panel.

5. Took a wrench and tightened the nuts so that the bolts with the Z Bracket mounts would be attached to the panel.
6. Positioned the completed solar panel on top of the shed roof and drilled long screws into the panel through the roof to hold the panel there.
7. Angled the wire down from the panel to the HDX tote with the pump.
8. Spliced the panel's wire so that the inside wiring was exposed.
9. Inserted the wire into the solar charge controller's solar panel ports.
10. Solar panel light lit up indicating that the panel was charging the battery.

Phase 6 (About 1 hour to complete)

1. Leveled the soil around the shed so the concrete blocks could be even with each other increasing stability of the system.

2. Stacked two rows of concrete blocks, with 4 in a row, on top of each other, making sure they were level with each other.
3. Placed two concrete slabs on top of the blocks to further level the surface and provide a platform for the HDX tote to stand on.
4. Once everything was leveled, placed the HDX tote on top of the slabs.
5. Closed the tote with its lid and put a tarp over it to ensure the wiring will not short-circuit.
6. Cut some mesh covering into pieces and placed them over the rain barrel so that leaves, debris, and other unwanted materials will not pollute the water.

Phase 7 (About 1.5 hours to complete)

1. Connected the mainline tubing to the pressure regulator.
2. Laid out the ½” mainline tubing so that it reaches to the furthest tree.
3. Used steel wire stakes to secure the ½” tubing in place as needed.
4. Cut off any excess tubing.
5. Flushed the line with water to remove debris.
6. Installed the Perma-loc Tubing End Cap to close the line.

Phase 8 (About 3 hours to complete)

1. Using the Punch Tool included in the kit, punched a hole in the mainline tubing to attach the tree rings.
2. Cut a section of solid ¼” tubing to reach from mainline to where the watering rings would circle around the tree.
3. Inserted a ¼” barbed coupler into one end of the previous section of solid ¼” tubing.

4. Pushed the open end of the barbed coupler into the hole punched in the mainline tubing.
5. Inserted a barbed tee fitting at a 90-degree angle, that connects the drip line ring to the feed line.
6. Determined what size tree ring were needed to adequately cover the root zone area of the tree.
7. Cut the ¼" drip line to length per tree requirements.
8. Connected the ¼" drip line to one side of the barbed tee fitting, ringed it around the tree and connected the other end to the remaining barb on the tee fitting.
9. Repeated these steps for each tree in the system.

TREE CHOICE

Along with creating the prototype, we were also asked to come up with a list of suitable trees that would benefit from this project. The potential tree locations were asked to be only native trees if possible and was to be found using only primary research from our group along with Borough tree recommendations. Our group was told that the Borough would be providing supporting vegetation around the tree. This would be important for absorbing stormwater, reducing water evaporation, and creating complimentary ecosystem in the immediate area around the tree. These plants would not be using water from the system we build because that water is inly for the trees.

Roselle Park Environmental Commission member Daniel LaPorte shared a list of thirty trees recommended in the Community Forest Management plan. We as a group used that information and conducted our own research to decide on the five most suitable trees. These trees consist of:

a. **The Sugar Maple (*Acer saccharum*)** needs open space and moist soil to thrive making it an ideal candidate for the open spaces listed as potential sites. The soil in areas such as the baseball field and park are of the Boonton-Urban land-Haledon complex variety meaning the maple can grow in these locations effectively.

b. **Ginko (*Ginko biloba*)** is considered a salt tolerant shade tree that can cool surrounding structures if positioned correctly. This type of tree would serve its purpose best at the Woodside Gardens Apartments, although it can be planted just about anywhere. The primary idea behind using this tree is to help rectify the issue of the Urban Heat Island Effect using the natural properties of the Ginko biloba.

c. **Flowering Dogwood (*Cornus florida*)** is a native tree to New Jersey that can be used to greatly enhance a view given the natural beauty of its flowers in the spring and changing leaves. Popular locations like the Turner Park Gazebo would benefit from such a scenic tree as the site is used for a variety of formal functions like weddings.

d. **Sweet Birch (*Betula lenta*)** grows best in open park areas making it a perfect fit for three of the five locations listed below because of the open space that is needed for them to spread out. These locations include the Roselle Park Community Garden and the Roselle Park Youth Baseball Field. It attracts a multitude of aesthetic wildlife like butterflies and songbirds by its pleasant smell and beautiful flowers.

e. **Eastern Redbud (*Cercis canadensis*)** is a small tree native to New Jersey that can provide an appropriate accessory to trees by attracting pollinators. It has beautiful pink flowers in the spring that can enhance the aesthetic appeal of a location such as the Roselle Park Train Station.

CONCLUSION

When the Roselle Park Environmental Commission gave us the tasks of building a self-watering, gravity fed, sustainable, automatic tree watering system and selecting a location and tree type to go with the system, we knew there would be a lot of research and innovation combined with back-and-forth discussion with the Environmental Commission members that would have to take place. While our group was able to research many different locations that would potentially be suitable for our system, once we were allowed to look at the Roselle Park Community Garden, we knew that this would be the best location for our self-watering system. This location came pre-equipped with four trees, a shed that was able to be used as a water gathering apparatus, and multiple gardeners who were able to offer advice.

Throughout the couple of weeks that were taken to decide on the location, our group was waiting for our ordered parts to arrive at Kean University. Once these parts were obtained, construction was able to begin. Since there are no preexisting systems of what we were constructing that already exist, many of the steps that were taken were based on trial and error. Some of these mistakes were seen early on when we realized that we would need a pump that was not ordered to increase the water pressure being taken out of the rain barrel and distributed to the drip irrigation system. Later on, in the construction of our system, the size of the circles of tubing that went around the trees was initially too small, so we had to go back and redo all of the tubing. Although once the tubing was redone, we were able to manually activate the system to see if it would work and while water was being pumped through the irrigation system, multiple leaks throughout the tubing was exposed. These leaks were unable to be patched thus having to be replaced.

Once the new tubing was connected, we ran into the problem that after about thirty seconds our system would continuously shut down despite being set for twenty minutes. After discussing potential reasons for this with one of the gardeners who was experienced with rain barrels, we were able to figure out that one of the female connections were on backwards which was causing the system to power down. After fixing this issue, our system was able to run uninterrupted for twenty minutes like we set. Once the twenty minutes were done, the system shut down automatically. These were issues that were made but are very avoidable for future installations now that we have experience of what is required to build one of these systems whether it be for Roselle Park or other cities.

The importance of a sustainable, self-watering system for urban trees far extends beyond the borders of Roselle Park. The prototype that we developed has great potential to help save towns money that would otherwise be required to pay contractors to maintain these trees and can be reused once the trees are well established and no longer need extensive care. The increase in urban tree cover will ultimately benefit Roselle Park and other towns that adopt this technique by mitigating urban heat island effects and stormwater runoff that extensive economic and environmental damage.

Appendix A

ITEM	COST	PURPOSE
Shurflo Revolution Standard 12v Automatic Demand Pump Classic RV Pump 4008-101-E65	$103.96	To increase the water pressure of the system so that the rain barrel can reach far distances.
20A Solar Charge Controller Solar Panel Battery Intelligent Regulator with Dual USB Port 12V/24V PWM Auto Paremeter Adjustable LCD Display	$14.39	Connects the battery, solar panel, and transfer pump while also adjusting the amperage between them.
Newpowa Solar Panel Mounting Z Bracket with Nuts and Bolts Supporting for RV, Boat, Wall, Off Grid Roof Installation A Sets of 4 Units Sliver Aluminum	$9.50	Allows the solar panel to be mounted on flat surfaces.

Newpowa 20W Watts 12V Mono Solar Panel Waterproof Off Grid Kit-20W Solar Panel+10A PWM Charge Controller (Come with Cable and Connectors) +Battery Cable for RV Marine Car Motorcycle Battery Charge	$48.84	Used in conjunction with the solar charge controller to power the battery using solar energy. Without it, the battery would run out of charge and would need to be replaced manually.
3 Pack -12V Water-resistant Add-A-Circuit Blade Type Inline Fuse holder with Cap16 Gauge (Larger)	$7.99	Connects circuits and waterproofs them.
BNTECHGO 16 Gauge Silicone Wire Kit Red Black White Blue and Green Each 25ft 16 AWG Stranded Wire	$34.98	Connecting wire for the transfer pump and the battery that allows them to be plugged into the charged controller.
Premium Drip Irrigation Kit	$203.09	Complete, self-contained drip irrigation kit that comes with tubing needed to create a working irrigation system.

Claber Tempo Hybrid Solar Timer	$126.24	Timer that allows for drip irrigation to be automatically dispensed.
(2) ¾-IN FHT Swivel Union	$13.36	Connects ¾ in. tubing
6ftx8ft blue/Green Tarp	$7.48	Covers the tote, keeping rainwater away from the electrical components.
(2) 23.3 IN Gray Square Stone	$17.98	Provides a landing for the rain barrel to sit on.
(8) 8-8-16 Light Weight Block	$15.12	Increases the elevation of the rain barrel when stacked.
Latex Coated Large 3-CT	$4.98	Gloves for working
(4) 6-8-16 Normal Weight Block	$6.32	Increases the elevation of the tote when stacked.
(2) 16-4-16 Concrete Pad	$11.16	Provides a landing for the tote to sit on.
48’’ Flat Bungee W/Carabiner	$4.97	Wraps around the rain barrel to keep it steady and secure.

(3) Hidden Hook vinyl K-style Hidden Hanger	$14.70	Allows the gutter to hand from the roof of the shed.
Amerimax Traditional 4.5-in x 120-in White K Style Gutter	$4.58	Main piece of the gutter that collects water.
Amerimax Traditional 5-in x 9-in White K Style Gutter Drop Outlet	$8.98	Sends rainwater downward.
AMERIMAX HOME PRODUCTS 37084 2x3 Flex Elbow, White	$2.87	Funnels rainwater into the rain barrel.
(2) Amerimax T0511 Gutter End Cap, Vinyl, White	$8.48	Caps the end of the gutter so water doesn't leak from the ends of the gutter without going into the barrel.
Wagner Furno 300 Heat Gun	$23.00	Shrinks the butt splices to tighten connections between wires.
Male Disconnect 16-14 AWG, 250'' NYL	$3.36	Allows for output tubing to be connected to the system.
16-14 AWG Vinyl Butt Splice 10Pk	$1.98	Connects wires together.

3/4’’ Barb X 3.8’’ FHT Adapter Brass	$12.43	Connects different components that need to be screwed in like the timer to the tubing.
½’’ Barb X ¾’’ MIP Adapter Nylon	$2.35	Plugs onto the transfer pump to connect pieces of tubing
¾’’ MHT X ½’’ MIP Adapter Brass	$5.18	Connects hoses and hose fittings together
BR Vinyl Tube	$15.68	Tubing that extends from both the output and input of the transfer pump.
1-1/8’’ Shockwave Hole Saw	$14.97	Attachment piece for an electric drill that increases the hole size that can be drilled into the size of the tote.
SS Clamp 3/8’’ x 7/8’’ DIA 10Pk	$8.94	Secures the input and output tubing on the transfer pump.
HDX 7 Gallon Tough Tote	$5.98	Keeps the system secure and resistant to poor weather conditions.

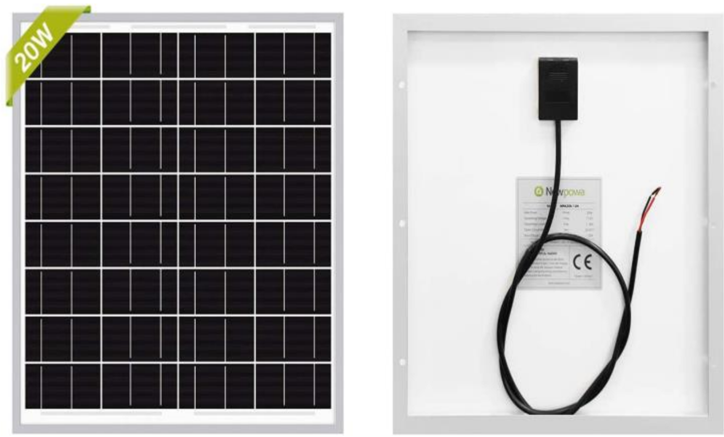
Claber Rain Sensor	$52.55	Shuts off the irrigation system when 2 ounces of water has collected in the sensor.
Wood Screw Assorted Brass	$5.29	Screws to drill the transfer pump into the lumber.
HD Self-ADJ. Wire Stripper	$9.99	Strips wires so their electrical currents can be connected together. Also cuts pieces of wire off.
SLA12-12F2 Duracell Ultra 12V 12AH AGM SLA Battery with F2 Terminals	$49.99	Provides power to the system.
Raindrip Drip Irrigation Tree and Shrub Kit	$56.98	Tubing inside connects to the filter also present. They both then connect to the spigot on the rain barrel.
Severe Weather 5/4-in x 6-in x 16-ft Premium Pressure Treated Lumber	$24.43	For securing, and elevating the transfer pump and battery inside the tote.

Total: $963.07

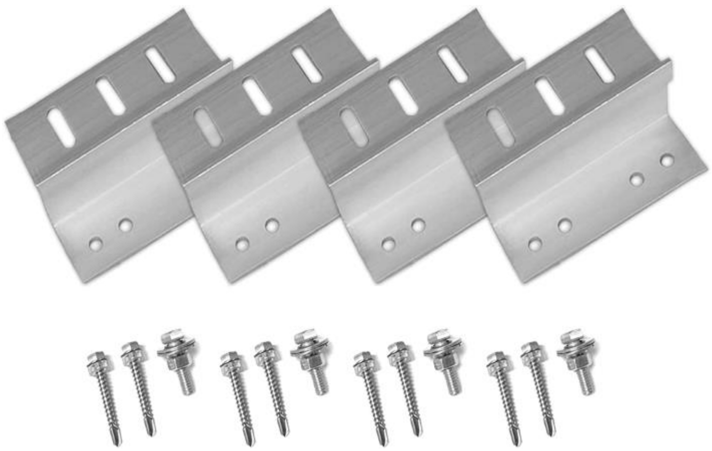
Appendix B

Shurflo Revolution Standard 12v Automatic Demand Classic RV Pump 4008-101-E65

20A Solar Charge Controller Solar Panel Battery Intelligent Regulator with Dual USB Port 12V/24V PWM Auto Parameter Adjustable LCD Display



Newpowa 20W (Watt) Solar Panel Monocrystalline 12V



Newpowa Solar Panel Mounting Z Bracket with Nuts and Bolts

BNTECHGO 16 Gauge Silicone Wire Kit Red Black White Blue and Green Each 25ft 16 AWG Stranded Wire

SLA 12-12F2 Duracell Ultra 12V 12AH AGM SLA Battery with F2 Terminals

Premium Drip Irrigation Kit for Trees

Claber Tempo Hybrid Solar Timer

Claber Rain Sensor

3/4-IN FHT Swivel Union

Amerimax Traditional 4.5-in x 120-in White K Style Gutter

Hidden Hook vinyl K-style Hidden Hanger

Amerimax Traditional 5-in x 9-in White K Style Gutter Drop Outlet

AMERIMAX HOME PRODUCTS 37084 2x3 Flex Elbow, White

Amerimax T0511 Gutter End Cap, Vinyl, White

Wagner Furno 300 Heat Gun

Male Disconnect 16-14 AWG, 250” NYL

16-14 AWG Vinyl Butt Splice 10Pk

¾” Barb X 3.8” FHT Adapter Brass

½” Barb X ¾” MIP Adapter Nylon

¾” MHT X ½” MIP Adapter Brass

BR Vinyl Tube

1-1/8” Shockwave Hole Saw

SS Clamp 3/8” x 7/8” DIA 10PK

HDX 7 Gallon Tough Tote

Wood Screw Assorted Brass

HS Self-ADJ. Wire Stripper

Raindrip Drip Irrigation Tree and Shrub Kit

Severe Weather 5/4-in x 6-in x 16ft
Premium Pressured treated Lumber

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