Utilizing Rain Barrels to Reduce Stormwater Runoff

Executive Summary

The most pressing concern in the Main South area of Worcester, Massachusetts presently is the pollution due to stormwater runoff. This problem intensifies the effects of environmental injustice in the neighborhood because it increases the amount of exposure the residents have to harmful contaminants.

The goal of our project is to further reduce the amount of stormwater runoff in the Main South area to help alleviate the environmental injustice area by using a smaller scale, less expensive solution to this problem: implementing rain barrels into the neighborhood. In order to do this, we outlined and followed a detailed plan to make our project a lasting success, which consisted of four main objectives:

1. Designing a rain barrel that is feasible for all residents
2. Prototyping our rain barrel design in order to evaluate its effectiveness
3. Creating a manual that will ensure successful implementation of our design
4. Educating the community about the benefits of implementing our design to their homes

Using qualitative research we were able to design a rain barrel that suited the needs of a large majority of the community. We considered the quantitative data in our prototype to predict the amounts of water collected, water pressure for distribution, and general flaws in the prototype. The remaining two objectives used a hybrid of research methods. Developing a manual was based on the prototype and depicted a step-by-step procedure to construct congruent barrels. In order to educate the residents we informed them of the benefits of rain barrels in communities by presenting facts, figures, and advantages if implemented. While following these steps, we came up with a few findings.

When brainstorming design options for our rain barrel, we had to first come up with all the essential functionalities for it to be practical in Main South. There are certain aspects of the design that are universal to all rain barrels, such as a water-tight outlet, an overflow drain, and a screen at the opening in the lid. Those criteria came from studying existing rain barrels. We also interviewed members of the community to understand how they would utilize rain barrels. By keeping the needs of community members in mind, we created a list of criteria for the design of the prototype, including: low cost, a large removable lid, and an elevated barrel.
Utilizing Rain Barrels to Reduce Stormwater Runoff

By using the universal features and the criteria we set, we were able to create a successful design for a rain barrel, shown in Figure A. Our design has the following features:

- Large, removable lid
- Numerous smaller holes in barrel lid and aluminum screen for inlet of water
- Overflow drain with screen
- Water-tight faucet for outlet of water
- Opaque barrel

![Figure A: Final Design](image)

All rain barrels have three major characteristics that can slightly vary between each design: the intake with a screen, the overflow valve, and the spigot. It is important that there is a screen in the opening at the top. We chose an aluminum mosquito screen. Aluminum was a better choice than the fiberglass because it won’t deteriorate as quickly and is tear resistant. We cut a 22 inch square of the material and placed it over the open barrel and simply screwed on the lid of the barrel to secure the screen. To allow water to enter the barrel, numerous smaller holes were drilled in the lid of the barrel rather than one large hole. This makes the entire lid of the barrel an inlet for rain water, while protecting the screen below the lid. A barrel with a large hole in the lid is a safety hazard around small children because the aluminum screen is not strong enough to prevent them from falling into the barrel and drowning. Furthermore we placed rocks on the lid to limit the splashing of the water from the downspout because rocks have a rounded surface whereas the lid has a flat surface. With the lid complete we moved on to the overflow valve.

The overflow valve is a necessary aspect of the design. In a heavy rainstorm, there is no way the barrel will have the capacity to hold all of the runoff from the roof. The valve should be close to the top of the barrel. The same screen used for the inlet hole in the top of the barrel should be used in the opening of the overflow valve, and should be attached with glue or a zip-tie. The only two pieces that make up the overflow valve are two 1.5 inch PVC adapters. The
Utilizing Rain Barrels to Reduce Stormwater Runoff

adapters were very affordable, coming out to only $3.26 at Home Depot. The last step in constructing our rain barrel was the spigot.

The spigot is an outlet that allows water to be retrieved from the barrel, either by connecting a hose if there is enough pressure, or releasing it into a watering can. Our design uses a ¾ inch brass spigot with male threading, a 1 inch galvanized washer, a ¾ inch rubber o-ring, and a ¾ inch galvanized 90 degree elbow. All of these parts totaled $7.78 at Home Depot and Barrows Hardware. It is desirable to have the spigot as close to the bottom of the barrel as possible to not leave a great amount of water in the barrel that cannot be released. The installation of the spigot concludes the construction of the rain barrel.

The most difficult, but most important part to find for our rain barrel was the barrel itself. The barrel was the most expensive and it was difficult to find a less expensive alternative. The barrel must be opaque. A transparent barrel will allow sunlight to reach the water and cause algae to grow inside the barrel. For the prototype we decided to buy a $30 barrel from a shop on Main Street. This brought the total price of our first barrel, not including the screen, to $43.22. This price was more than we expected considering our budget. After much searching, we found a $10 barrel at Bill Herlihy Barrel Co Inc., drastically lowering the total cost of the rain barrel to about $28.00.

Another important factor in deciding on the design of the barrel was to make sure we had the available tools in the Main South garage. The only tools we needed were a hole saw kit and a drill to cut the holes for the spigot, overflow and the holes in the lid of the barrel, scissors to cut the screen to the right size, and pliers to tighten the spigot assembly.

Through testing of our prototype, we found one major drawback of our design. During our flow testing, we found that our flow rates were small and decreased as the barrel emptied. We took measurements and found that a full barrel had a flow rate of 1.6 gallons per minute which decreased to below .3 gallons per minute as the barrel reached empty. The results of this test show that using a hose attached to the spigot is not a viable option for this rain barrel because of the lack of water pressure. This is one drawback of our design, because in order for a resident to water their lawn with a hose, they would have to install a costly pump.

During our leakage test, we found a single leaking area below the spigot to be about 8 drops per minute. We resolved this issue with lubricant on the o-ring that sits between the
adapter and the inside of the barrel, as well as tightening our elbow piece significantly with pliers. Further observation showed that there was no further leaking.

A flaw that we noticed the day after our prototype was built was the rusting of our iron adapter on the inside of the barrel that connects to the spigot. For the following iterations we have decided to use a more durable material that will not corrode in a day, such as a stainless steel or a galvanized elbow.

The results of this testing helped us realize which parts of the design needed fine tuning, and also showed us a major drawback of our design. In our manual we explain how a resident would go about creating enough water pressure to use a hose with the barrel.

With any project, it is important to gain feedback from an outside point of view. We held a small workshop for members of the MSCDC and the Regional Environmental Council (REC) to test the effectiveness of our manual. We realized that our pictures were very helpful but our wording was sometimes misleading. The people who attended the workshop asked perfect questions that showed us where our manual needed editing. Our workshop was a necessary step in the editing process of our manual. Without feedback from people outside of our project, we would not have seen where our manual was confusing or misleading.

According to the census, there are 67,028 houses in Worcester, MA over an area of 37 square miles. Based on this data, we extrapolated an estimated 967 houses in Main South with an average roof size of approximately 1700 square feet. During the average rainfall event, the houses in Main South produce approximately 142,444 gallons of water. If we assume each house in Main South had a rain barrel with the overflow routed to a permeable surface, the overall runoff would be decreased by approximately 11.047%, but with the overflow not routed to a permeable surface this number would decrease to 4.125%. This is a significant reduction in the amount of stormwater runoff that is held back from the combined sewer system.

Due to the weather not being ideal for rain near the end of the term, we recommend that the MSCDC follow up on the project deliverables in the spring. At this point, the MSCDC should advertise the present stock of barrels and encourage that the residents invest in rain barrels. Based on interest from the previous interactions, the MSCDC should distribute the manual to the interested parties in addition to holding various workshops. With the MSCDC’s influence and involvement in the community in addition to their excellent track record we are confident that the project will be a success.
Utilizing Rain Barrels to Reduce Stormwater Runoff

By demonstrating the use of rain barrels in Main South, we have helped create a sense of environmental awareness and showed the residents that they can improve their quality of life one rain barrel at a time. Not only did rain barrels offer an economic benefit for those using them by reducing their water bill, but they decreased the spread of contaminants into the watershed system and eased some of the stress on the treatment facility.
Utilizing Rain Barrels to Reduce Stormwater Runoff

Abstract

Our project goal was to implement rain barrels in the Main South neighborhood to reduce stormwater runoff. Using a suitable design for the neighborhood, we produced a manual and taught the Main South Community Development Corporation how to build rain barrels. We recommend the MSCDC install the rain barrels in the spring and distribute our manual to the community.
Utilizing Rain Barrels to Reduce Stormwater Runoff

Michael J. Flaherty
Douglas C. Lucas
Baillie R. McNally
Gabriel G. Morell-Pacheco
Worcester Polytechnic Institute
15 December, 2010
Utilizing Rain Barrels to Reduce Stormwater Runoff

**Authorship**
Baillie McNally- Executive Summary, Abstract, Environmental Justice in Main South, Objective One, Finding Two, Finding Four
Doug Lucas- Possible Solutions to the Stormwater Runoff Issue, Methodology Introduction, Objective Four, Finding One, Finding Three
Mike Flaherty – Introduction, Environmental Justice and Quality of Life of Inner Cities, Stormwater Runoff, Objective Three
Gabriel Morell- Implementing Rain Barrels to Alleviate Stormwater Runoff Issue, Objective Two, Finding Five, Summary
Utilizing Rain Barrels to Reduce Stormwater Runoff

List of Figures
Figure 1: Map of KGH Neighborhood Project .................................................................................. 16
Figure 2: Diagram of a functional Rain Barrel .............................................................................. 21
Figure 3 : Chart of Why Residents live in the KGH Neighborhood .............................................. 23
Figure 4 : Elevated Rain Barrel ..................................................................................................... 31
Figure 5 : Final Design ..................................................................................................................... 31
Figure 6 : Great American Rain Barrel .......................................................................................... 32
Figure 7: Three Main Features of a Rain Barrel ........................................................................... 32
Figure 8 : Overflow Assembly ....................................................................................................... 33
Figure 9 : Spigot Assembly Parts ................................................................................................... 34
Figure 10 : Opaque Barrel .............................................................................................................. 34
Figure 11: Drill ................................................................................................................................. 35
Figure 12: Hole Saw Kit .................................................................................................................. 35
Figure 13: Splash Test .................................................................................................................... 36
Figure 14 Iron Adapter .................................................................................................................... 36
Figure 15 : Flow Test ...................................................................................................................... 37
Figure 16 : Flow Graph .................................................................................................................. 37
Utilizing Rain Barrels to Reduce Stormwater Runoff

Chapter 1: Introduction

As the gaps between economic classes in society widen and the living conditions for people in inner cities worsen, some people are exposed to greater environmental hazards than others. The separation of the groups will result in environmental justice. Environmental Justice is the belief that all people are entitled to a safe, productive, and sustainable “environment”. The definition implies all aspects of environments such as ecological, physical, social, economical, and political. Environmental justice is an idea revolved around exposure. Most factors of environmental injustice are exposure to an unhealthy area. With greater exposure come greater injustices. Environmental justice refers to the difference in social and economic statuses of communities. People in environmental justice communities live, work, and raise their families in areas that are in close proximity to polluting highways, airports, train tracks, refineries, ports, dumps, and other industrial activities (Bucknum, 2010). Tzoulas et al. has proven that there is a “link between an individual’s socio-economic position and their health” (2007). A recent study done in Alameda, CA by the Prevention Institute found that for every $12,500 in income difference between two families, a member of the wealthier family is expected to live one year longer than a member of the other family. Similar evidence has been found across the country, which proves environmental injustice is a large-scale issue (Bucknum, 2010).

There are a number of contributing factors of environmental injustice. Some factors that lead to environmental injustice are crime and vacancy, exposure to harmful toxins, and contamination due to stormwater runoff. Urban blight can lead to environmental injustice. Urban blight is defined as “a critical stage in the functional or social depreciation of real property beyond which its existing condition or use is unacceptable to the community” (Breger, 1967). Since many buildings and factories are seemingly useless to a community, urban blight can lead to vacant buildings. Vacant buildings usually encourage crime and violence and the community tends to shy their attention away from the area. As the city becomes tainted with crime the environmental injustice becomes more concentrated within the community.

Environmental injustice can also be intensified by urban sprawl. Urban sprawl is “low-density, spatially dispersed, and segregated land use (European Environmental Agency, 2006).” When cities become crowded, the quality of life diminishes within the city. People who are financially able tend to move to the suburbs. These people actively participate in policy-making
Utilizing Rain Barrels to Reduce Stormwater Runoff

decisions that affect those who live in the city. Those living in cities with pollution, poor housing availability, and crime may not have any say in these policies that can be disadvantageous. Due to their economic status they cannot afford to move out of the city, therefore they are forced to live in a less healthy environment. The quality of their environment is further deteriorated by the lack of green space. Suburban development causes green space to become less abundant in areas surrounding cities (Motsenbocker, 2010). As green spaces in suburban areas diminish, the remaining green spaces within the city become disconnected causing them to become less beneficial. By banishing green space, the environmental injustice becomes more concentrated.

In the Main South neighborhood of Worcester, Massachusetts, environmental injustice is active and thriving. The neighborhood is in a densely populated, urban area. This leads to exposures of harmful toxins, pollutants, and a lifestyle that sacrifices health. The majority of the city is constructed of impermeable surfaces. This leads to a greater amount of stormwater runoff. Because the area itself is urbanized, it leads to contaminated surfaces coated with phosphates, nitrates, and other harmful toxins and metals. Other forms of contamination come from non-point sources. Non-point sources include sources of contamination such as canine waste, salt used to eliminate ice from pavement, pesticides, oil from automobiles, and metal from construction amongst various other factors. The stormwater runoff will collect any and all contaminants in its course, thus polluting the water and transporting the contaminated water to a community. Here, residents are exposed to the toxins contributing to the active environmental injustice.

Currently, the city of Worcester and the EPA are in a law suit over the water treatment facility in Worcester. A large portion of Worcester’s residents are served by a combined sewer system (CSS). This means the stormwater and the sewage run in the same pipes. Since the area has large amount of paved areas, it is greatly impermeable, thus the CSS is exceeding its capacity for water. The excess amount of water results from a lack of permeable surfaces. Without a great percentage of permeable surfaces, less water is being absorbed naturally and more water will be forced to run over impermeable surfaces that lead to the CSS. The capacity of the CSS does not sufficiently transport water in a timely fashion, as a result flooding results. When the storm drains flood, toxins and harmful waste stagnate in a given location and create an unhealthy
Utilizing Rain Barrels to Reduce Stormwater Runoff

environment for the community. As the flooding becomes more prevalent, the contamination of the area grows worse and makes the environmental justice more concentrated.

In order to combat the issue of stormwater runoff and neutralize the environmental injustice, the Main South Community Development Corporation (MSCDC) has been researching possible defense mechanisms. To match the standards set by the EPA, Worcester would have to spend roughly 200 million dollars just to upgrade the system. The money will most likely be paid out by raising the price to the ratepayers. However, upgrading the system would be expensive, contested, and long term. The solution would take an extended period of time to complete, implement, and make a difference in the environment. The MSCDC has begun to think of low-impact development (LID) solutions.

LID is geared to treating the environmental injustice on site as opposed to central systems like street drains. The MSCDC has been revitalizing neighborhoods with green infrastructure and working to make the Main South neighborhood a healthier environment. LID solutions are generally effective in a timely manner, cheap, and easily implemented. Common LID solutions include rain gardens. By increasing the amount of permeable surfaces in a region, the stormwater runoff will essentially decrease since more water is being absorbed into the earth. Not only is a rain garden naturally filtering through rain water and retaining any water from entering a system such as a CSS, it also gives a healthier aspect to the neighborhood by improving the air quality. Another popular way to promote LID solutions is rain barrels. By collecting rain off of roofs, it essentially withholds rain from entering the CSS. By retaining water from entering the CSS, a community-wide project could alleviate the stormwater issue. The CSS will have to obtain less stormwater, thus causing less flooding in the community. As a result of less flooding and less runoff, less contaminant matter will be exposed in the community.

Our team worked with the MSCDC to implement rain barrels as a LID solution that is an inexpensive and effective way to promote green infrastructure. Green infrastructure is our environment’s ability to naturally sustain air and water quality within a community. With the knowledge of green infrastructure, the goal of our project was to implement rain barrels in the Main South Area of Worcester, Massachusetts to help alleviate environmental injustice and reduce the problems of stormwater runoff. The Main South area was selected as the focus of our project because of the prevailing environmental injustice active in the community. The MSCDC
Utilizing Rain Barrels to Reduce Stormwater Runoff

uses federal, state and local resources to revitalize these communities and help alleviate the issues that intensify environmental injustice.

We achieved our goal by reaching our four major objectives. They are as follows:

1. Design a rain barrel
2. Build a prototype
3. Produce a manual
4. Outreach to the community

Our report will cover the following topics:

1. Environmental Justice in Main South
2. Stormwater Runoff
3. Possible Solutions to the Stormwater Runoff Issue
4. Implementing Rain Barrels to Alleviate Stormwater Runoff
5. Methodology of Our Project
6. Findings and Discussion
7. Summary
Chapter 2: Background

The Main South neighborhood is an underprivileged community consisting of low-income families. These families suffered from the characteristic symptoms of environmental injustice such as urban blight and urban sprawl until a non-profit organization revitalized the neighborhood.

The Main South Community Development Corporation (MSCDC), which began in 1986, is a community force that helped to alleviate environmental injustice that occurred in the Main South area in Worcester, Massachusetts. They did this by revitalizing existing communities and creating safe, affordable housing for first time homebuyers. Their mission is as follows:

“The Mission of the Main South CDC is to improve the quality of life for ourselves, our families, and our neighbors by working together on projects and issues that will maintain and/or create safe affordable housing for low-to-moderate income individuals, support economic opportunities for businesses and residents of Main South, enhance the physical image of the area, and instill a sense of neighborhood pride and commitment”

(“Main South CDC,” n.d.).

The primary focus of the MSCDC has been the Kilby/Gardner/Hammond neighborhood project (Figure 1). The KGH project created over 80 units of affordable housing for first-time homebuyers, as well as a new Boys and Girls Club the revitalization of land that will hold a new athletic field for Clark University. To revitalize the land, the MSCDC had to remove oil tanks, asbestos, and 6 industrial buildings and replenish the contaminated soil. The Boys and Girls Club includes a pool, gym, kitchen, cafeteria, daycare center, and will share the new Clark University field upon its completion (“Main South CDC,” n.d.). When looking at the definition of environmental justice, it is clear why this neighborhood was chosen for redevelopment.
The MSCDC is combating the effects of urban blight and vacant lots in the KGH neighborhood. They have already turned many vacant lots and abandoned industrial buildings into affordable housing. Now they are working to gain foreclosed and abandoned buildings to renovate into more affordable housing ("Main South CDC," n.d.). With these improvements, the KGH neighborhood will feel less and less of the negative effects of vacant lots and buildings in cities.

This 30 acre site was also feeling the effects of urban sprawl. To combat these effects, a key component of this project is “Smart Growth” ("Main South CDC," n.d.). “Smart Growth” focuses on creating housing opportunities, building attractive communities, making development decisions cost effective, and strengthening existing communities (National Center, 2010). By using the principles of “Smart Growth,” the MSCDC is helping prevent the negative effects of urban sprawl that intensifies environmental injustice.
Utilizing Rain Barrels to Reduce Stormwater Runoff

Not only did the project create safe and affordable housing to improve the quality of life of the residents, they also removed vacant lots, abandoned buildings, and many toxins from the land, thus improving the environmental injustice that occurred there. However, the most pressing concern in Main South presently is the pollution due to stormwater runoff.

**Stormwater Runoff**

Stormwater runoff occurs when rainfall is not naturally absorbed into the ground, but moves across impervious surfaces, picking up contaminants such as E. coli, phosphates and nitrates. These contaminants can be traced back to sources such as normal atmospheric organisms (E. coli), automobiles, canine waste, and factory pollution (phosphates and nitrates). When stormwater slowly flows underground, it is naturally filtered of all pollutants and eventually flows into streams and lakes. The development of urban cities impedes the ability for stormwater to naturally filter in the ground because of the construction of buildings, roads and other impervious surfaces (City of Bremerton, n.d.) In some cases, this polluted stormwater flows into a storm sewer system that flows directly into a body of water that is used for swimming, fishing, or provides drinking water (EPA, 2003). Otherwise, the polluted stormwater flows into a CSS which combines sewer and storm drain pipelines into one line before treatment.

The Main South area of Worcester is serviced by a 150 year old CSS system. Worcester’s stormwater runoff problem is due to the inadequate capacity of the water treatment facility. If the capacity of the CSS is exceeded, backup of stormwater and sewage occurs in the streets of the neighborhood due to combined sewer system (CSS). This is becoming a more frequent problem as a result of more water in the atmosphere. Studies prove the total amount of water in the atmosphere is increasing at a rate of 7% per Kelvin of global surface warming (Wentz, 2007). This shows the effects of global warming and green house gases and how they act on the amount of rainfall in a given storm. With more water in the atmosphere comes more rain to fall, thus increasing the stormwater runoff and the risk of contaminated flooding.

This problem intensifies the effects of environmental injustice. Only part of Worcester, including the Main South area, is serviced by a CSS. The residents of Main South, unlike residents of Worcester outside the boundaries of the CSS, are exposed to these contaminants when flooding occurs. There are different types of solutions to address the issue of stormwater
runoff. Large-scale solutions that may take decades to become beneficial are effective but also expensive. Small, local projects can be just as beneficial when implemented correctly.

**Possible Solutions to the Stormwater Runoff Issue**

There are two types of solutions to this problem: long-term and short-term. Worcester’s water treatment facility, Quinsigamond Avenue CSS Treatment Facility, is having trouble meeting EPA standards for eliminating phosphates and nitrates from the increasing amount of water that enter the facility from the CSS. The city of Worcester would have to spend roughly two-hundred million dollars in order to update the system to match the EPA limits. On October 21, 2010 Nick Kotsopoulos of the Telegram and Gazette reports increasing the rate of sewage use could potentially bankrupt the residents of the area if the increase goes through. This would intensify environmental injustice in the Main South community because it would detriment the residents financially. Therefore, the City of Worcester is appealing the National Pollutant Discharge Elimination System permit issued by the EPA. Kotsopoulos reported that “the Upper Blackstone district’s board of directors has decided to appeal the permit issued by the EPA for the plant because it believes the pollutant limits in it are ‘without scientific basis and will not result in meaningful benefits’ for the Blackstone River and Narragansett Bay.” The City of Worcester realizes that this expensive, large-scale solution to the stormwater runoff problem would create more financial issues for the residents of Worcester, therefore intensifying the environmental injustice even further.

Another long-term, but not necessarily expensive solution is to implement green infrastructure into an urban community. Green infrastructure’s basic ideas about land use planning, and environmental conservation originated in the early 1900’s. As defined by the Green Infrastructure Work Group (2010):

> “Green infrastructure is our nation’s natural life support system, an interconnected network of waterways, wetlands, woodlands, wildlife habitats and other natural areas; greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for America’s communities and people” (Benedict and McMahon, 2002, p.6).
Utilizing Rain Barrels to Reduce Stormwater Runoff

The concept of Green Infrastructure: linking parks, green spaces, and natural areas to benefit people, benefit biodiversity, and counter habitat fragmentation, can be traced back to a few early visionaries. Frederick Law Olmsted, a landscape architect of the early 20th century, stated “no single park, no matter how large and how well designed, would provide the citizens with the beneficial influences of nature” (Benedict and McMahon, 2002, p.8). He insisted that parks needed “to be linked to one another and to surrounding residential neighborhoods” to be able to provide all of their potential advantages (Benedict and McMahon, 2002). It is imperative for Green Infrastructure to be implemented correctly in order to be entirely beneficial.

There are many factors to think about when attempting to implement green infrastructure. Available resources, proper planning of the functionality of the project, planning for the future and self-sustainability of the project, and public awareness are the main categories of ingredients needed to construct a healthy and efficient result (Benedict and McMahon, 2002). A project without any single one of these attributes will never become completely successful.

Functions of green infrastructure are substantially more efficient and beneficial when the intricate pieces are interconnected with other green space elements. In-depth planning and cooperation is vital to prevent the creation of isolated wilderness islands, which disrupt the balance of natural systems and lead to permanent loss of biological diversity (Benedict and McMahon, 2002). To protect the large quantity of resources invested, much foresight and caution must be used. Preparations have to be made to ensure the self-sustainability of the ecosystem. Certain doors should be left open to accommodate for future infrastructure developments –grey or green- to be easily integrated into the network (Benedict and McMahon, 2002). Because restoration of green space is far more expensive than preservation, protection of a green space system’s functionality is advantageous.

Green infrastructure has countless benefits for urban communities, such as Main South. These include: improving water, soil and air quality, stormwater runoff and erosion control, creation of green collar jobs, improving public health, enhancement of urban aesthetics, preservation of biological diversity, and generation of harvestable biomass (Dunn, 2010; Bucknum, 2010). Green infrastructure is efficient and practical, both economically and environmentally. It provides an array of functions and values that help stabilize human and environmental systems. Green infrastructure is an entirely beneficial investment that creates a base for future growth while also guaranteeing the availability of essential natural resources for
Utilizing Rain Barrels to Reduce Stormwater Runoff

generations to come. The MSCDC has worked to address the stormwater runoff problem in the Main South area using the basic principles of green infrastructure.

The MSCDC has taken steps to reduce the amount of water running onto impermeable surfaces in the neighborhood. Many of the houses in the KGH neighborhood were renovated with “green” features, including gutters with downspouts that go directly into the earth (“Main South CDC,” n.d.). This directs runoff from the roof into the ground where it is soaked up by grass and nearby plants. This system is superior to having traditional downspouts that direct runoff to the street. This solution was not an extremely expensive add-on to the houses, yet greatly reduces the amount of stormwater runoff going through the CSS, thus alleviating the environmental injustice within the neighborhood. In an attempt to further reduce the amount of stormwater runoff in the Main South area, our team implemented rain barrels by using the principles of green infrastructure.

Implementing Rain Barrels to Alleviate Stormwater Runoff Issue

A simple way to address the stormwater runoff issue further is through rain barrels. We worked with the MSCDC to raise enthusiasm and awareness about the benefits of rain barrels and how it was useful in Main South. We designed a strategy to get people to utilize natural water for everyday uses to limit the residents’ water bill and save money. By freeing personal funds it can lead to improving the quality of life in the area. Rain barrels are simple to utilize and benefit from.

Rain barrels are easily utilized at any abode. The barrels modeled by Figure 2 were designed to collect the rain off of roof tops and preserve the water to be used elsewhere. Reschke et al. of Master Gardeners (2010) describes a simple device consisting of PVC piping, a 55 gallon barrel, and a screen gate. She demonstrates how rain barrels can limit how much tap water a family uses, provide cleaner and more pure water for household needs, and can enhance the green infrastructure of the community.
Along with financial and environmental benefits to the community, rain barrels have an enormous economic impact on the city in which it is implemented. A water conservation project was put into action in Chicago and as of 2009, the city saved $62,118 in sewer avoidances and $73,950 in water conservation totaling over $135,000 in benefits and costing the residents a little over $40 a barrel (Freitas, 2009). Chicago Spokesperson, Jillian Horist, acknowledged one barrel is not sufficient, but since ordering 3,500 barrels between the summer of 2008 and July of 2009, she sees the project making a lasting effect (Taliaferro, 2009). When there is a considerable amount of rain in a short period of time we can divert some of the natural water into the rain barrels to obtain a reserve supply of water. According to Reschke et al. of Master Gardeners (2010), Rain Barrels in Illinois saved home owners an average of 1,300 gallons of water in peak summer months. The water saved was used for any practical use from watering the lawn to topping off the family swimming pool. Since the water used is natural and not from tap, the lawn is receiving high quality water that is “softer” than treated tap water which is doped with calcium and sodium bicarbonate. Another LID project associated with retention is rain gardens. Rain gardens can efficiently remove the amount of phosphates and atrazine in water that is filtered through a garden by 90-100% (Yang, 2010). Also the peak flow can be reduced through the garden by 56% according to Yang’s studies (2010). Thus the soil is active and healthier
allowing a green infrastructure increase. It is important we spread this idea of LID to the urban communities, where it is most needed.

A series of factors determine the success of implementing rain barrels in urban communities. In any community project, it is essential to start with a strong educational background. Bringing in a team of experienced individuals is a standard practice in many successful community projects. For example, “The NRC Standards clearly identifies the need for ongoing partnerships among scientists, teacher educators, teachers, and school districts (Rao, 1999)”. The MSCDC’s current partnership with Clark in the construction of a Boys and Girls Club has instilled community pride, which will continue for years to come.

When implementing any community-wide project it is important that the residents of the community are involved and interested, most specifically the youth. Projects that meet the interests of the populations in question are bound to be successful (Bauer-Armstrong, et al 2010). We hope that by creating interest in the community, we can have a long lasting and sustainable impact. Our involvement in the Main South Celebrates Festival was one step in fostering this community interest.

Basing community projects from inside schools has been a standard course of action for the fostering of community interest. The projects in question are generally successful and long lived, having been taken care of by the students themselves and overseen by the teachers. Having students implement rain gardens has been successfully done in the past. Using native plants and those suitable to growing in rain runoff, a school in Maryland planted a rain garden to control erosion and limit the polluted runoff, which eventually reaches the ocean (Anne Raver, 2010). The students implemented their garden behind the school in order to reduce the street runoff that is forced by the flowing water into the sewers. As a long-term project it was carried on by next year’s students. By letting the students take control of the project and having it positively affect the community, it became theirs and they could be proud of it. We can promote long-term involvement by using the youth as stewards of the project. The youth can also bring the project to a greater scale by educating friends and family and promoting interest outside the classroom.

Community approval of any project is an important factor in the success of the project. The resident’s of the KGH neighborhood’s outlook on the project is an important consideration of the Main South CDC. They continue to conduct surveys in order to make the best decisions
Utilizing Rain Barrels to Reduce Stormwater Runoff

for the community. From 2002 to 2005, the community thought positively of the project because it created affordable housing and tackled safety and unsanitary living issues. Figure 3 shows a survey taken by Clark University Students illustrating the reasons residents live in the KGH neighborhood. From this survey, it is plain to see that affordable housing is the biggest reason to live in the KGH neighborhood as well as the Main South CDC improving the quality of life in this neighborhood (“Main South CDC,” n.d.).

![Figure 3: Chart of Why Residents live in the KGH Neighborhood](Note: Main South Community Development Corporation. (n.d.). Retrieved from ttp://mainsouthcdc.org/)

It is important to gain the residents’ approval of the project, and to reach out to others to inform them of these opportunities. The Main South Celebrates! 2010 Festival, sponsored and organized by the Main South CDC was a great way to promote community involvement (Main South CDC, 2010). For this festival, we created a display for residents of the Main South area to learn more about implementing green infrastructure in the KGH neighborhood. The festival was a way for the team to reach out to the community and explain what rain barrels are, how they work, and why they are important. This was the team’s first encounter with the community before the project started. Later we hosted workshops for the community on creating and maintaining rain barrels.

As it currently stands, the KGH neighborhood has been receiving a great deal of environmental justice. Our project carried on the existing environmental justice through the implementation of rain barrels in the community as an addition to the many green initiatives
already in the area set forth by the MSCDC. In order to do this, we outlined and followed a detailed plan to make our project a lasting success.
Chapter 3: Methodology

The goal of our project was to implement rain barrels in the Main South region to help alleviate environmental injustice and relieve Worcester’s congested water treatment facility. We accomplished our project goal by identifying four main objectives. These objectives included:

1. Designing a rain barrel that is feasible for all residents
2. Prototyping our rain barrel design in order to evaluate its effectiveness
3. Creating a manual that will ensure successful implementation of our design
4. Educating the community about the benefits of implementing our design to their homes

Using qualitative research we were able to design a rain barrel that suited the needs of a large majority of the community. We considered the quantitative data in our prototype to predict the amounts of water collected, water pressure for distribution, and general flaws in the prototype. The remaining two objectives used a hybrid of research methods. Developing a manual was based on the prototype and depicted a step-by-step procedure to construct congruent barrels. In order to educate the residents we informed them of the benefits of rain barrels in communities by presenting facts, figures, and advantages if implemented. In the following sections, each objective will be discussed and we will demonstrate how we completed each objective and how it pertained to our goal.

Objective One: Design a Rain Barrel

Our first objective is to create a design for a rain barrel. It was useful to study previous designs of rain barrels in order to ensure the success of our design. How the residents planned to use the barrels and how much they are willing to spend on each barrel were important factors that affected our design. We also had to be knowledgeable of what tools were available at the MSCDC. In order to collect all of this evidence, there were a few steps we needed to take.

Studying existing rain barrels was the most effective way to research ideas for this design. We conducted detailed quantitative research on successful rain barrels, from resources such as the Environmental Protection Agency (EPA) website. It was also beneficial to visit sites where rain barrels are already implemented to observe what aspects of the design make those rain barrels successful. This qualitative data gave us a firsthand account on design options.
Utilizing Rain Barrels to Reduce Stormwater Runoff

Next we identified the needs and common water usages of the residents. This data did not necessarily affect the rain barrel itself but greatly affected the design of the water distribution system. We had direct one-on-one meetings with members of the community who are knowledgeable about rain barrels to gain this data. Once we gained a clear understanding of how the majority of the residents will use the water, a sufficient universal design was drafted. This data is important because it affected some aspects of our design.

The final step in designing a rain barrel was to determine the availability of materials and tools. By researching local vendors we found affordable materials within Main South to use for the construction of the barrels. Finding the materials in Main South ensured that they will be readily available to residents and we also helped stimulate the local economy. We observed the availability of tools at the MSCDC garage. Based on this data, our design was altered to ensure construction was reasonable.

Designing a rain barrel is an important part of the project because it is the cornerstone of our entire goal. Studying previous designs, taking into account the needs of the residents, and determining the availability of materials and tools are important steps in completing this objective. Once we decide on an efficient design, a prototype will be created in order to test our rain barrel before releasing it to the community.

**Objective Two: Build Prototype**

Once the research of prior rain barrels and a sufficient design was decided on, we continued and moved into the prototyping phase. During this step we first acquired needed materials, conducted unit tests and further refined our design based on the testing results.

The first task was to collect the most cost appropriate materials that we used to build our first prototype. We knew that the City of Worcester has previously partnered with the Great American Rain Barrel Company to encourage residents of Worcester to invest in rain barrels. Their rain barrels were sold at half price, which was still a costly price of $60. We wanted to make our rain barrels more affordable for the Main South community. To do this we obtained the costs of our materials at different hardware stores and found the suitable tools to work with the said materials. This step ensured the prototype we built was cost appropriate and reasonable for the targeted residents to build.
Utilizing Rain Barrels to Reduce Stormwater Runoff

We then constructed the first prototype based on our design and with the materials we identified as appropriate. This barrel went through a series of tests to ensure it had no faults and was appropriately constructed. The tests simulated normal use of our design in the area. We further refined our design based on any negative results of the testing, and continued testing until we were satisfied with the result. With these results in mind and a finalized barrel design, we moved forward to the next objective, developing a manual.

Objective Three: Produce a Manual

Once we had successfully tested the prototype to ensure it will be the final design, we developed an instructional manual. The purpose of this step was to make sure our design has lasting success in Main South once our project is complete. The manual helped maintain a consistency among the products and ensure proper procedures to produce a quality rain barrel. To produce an effective manual we researched existing manuals and kept in mind the bilingual nature of the Main South area.

Based on research of existing manuals, we found that visuals limit discrepancies. When we examined the manual from the EPA we noticed the manual was well written and very detailed but lacked visuals. Even though it was detailed, there lies a chance the language could be misleading. To ensure proper construction of the rain barrels, we decided images could promote consistency. The images we used for the manual were directly taken from our prototype. Since the photos were original, it was personal to our design and not a generic picture.

In order to ensure the translation on the manual was correct, we worked in conjunction with Clark University students enrolled in the Spanish Service Learning class. These two students had already helped our team create a display about rain barrels for Main South Celebrates! These students were utilized as a qualitative resource for the translation and helped connect the translations to images used in the manual. To assure the manual was universal for the Main South area it needed to include an important information section.

Within the section of vital information there had to be information to make the barrels work efficiently. The manual contained maintenance tips and a trouble-shooting guide if there are any problems. Also to assure the rain barrel is utilized year after year we offered winterizing
Basic tips to preserve the barrel increase the rate of return. When the manual was finalized we were able to effectively spread knowledge to the community.

**Objective Four: Community Outreach**

We then focused on creating and keeping public interest. With a fully functional, efficient rain barrel and a step-by-step guide on how to easily make your own barrel already constructed, the next step was to grab the public’s attention. The interest and support of Main South’s residents was vital to the success and longevity of our project.

We intended to spark interest in our project by first making sure the problems that stormwater runoff causes in terms of numbers along with the many benefits of implementing rain barrels were advertised. The community was made aware that rain barrels save money on water bills, improve the quality of tap water, and help reduce the overcapacity workload put on Worcester’s water treatment facility. This information was spread to locals in a number of ways. We created a display for the *Main South Celebrates!* festival that included benefits that caught the public’s eye, such as monetary savings and easy construction. Students from Clark University working with the MSCDC also made a tri-fold brochure on stormwater management. It was important that the residents of Main South were well informed about the problem of stormwater management and how rain barrels are a simple solution.

It is very important that we illustrated to the public how easy and inexpensive it is to make and maintain a rain barrel. The smaller the amount of money and time that needs to be invested in a rain barrel, the smaller the risk that is taken when investing in one. A great way we illustrated exactly how effortless and economical it was to construct a rain barrel was to hold a workshop for members of the MSCDC and Regional Environmental Council (REC), who work in concert with the MSCDC on similar projects. This workshop taught them how to construct a rain barrel in an easy to follow, hands on learning environment. This allowed for more people to be aware of our project that can spread the word to other residents of Main South. The self-sustainability of our project was vastly increased since those who came to our workshop became knowledgeable about rain barrel construction and upkeep.

Once the public understood the purely positive impact of rain barrels they were much more accepting of our attempt to help them improve their neighborhood. With the people’s interest, approval, and involvement we were assured that our project will be extremely
Utilizing Rain Barrels to Reduce Stormwater Runoff

successful. We were also confident that rain barrels will be an important part of the community long after our project ends. While completing this detailed list of steps, we found out what criteria our barrel should hold up to, what features the design should include, and also a few aspects of the barrel that had to be refined further.
Chapter 4: Findings and Discussion

Finding One: Design Criteria

When brainstorming design options for our rain barrel, we had to first come up with all the essential functionalities for it to be practical in Main South. There are certain aspects of the design that are universal to all rain barrels, such as a water-tight outlet, an overflow drain, and a screen at the opening in the lid. Those criteria came from studying existing rain barrels. We also interviewed members of the community to understand how they would utilize rain barrels. By keeping the needs of community members in mind, we created a list of criteria for the design of the prototype, including: low cost, a large removable lid, and an elevated barrel.

First and foremost the design had to be inexpensive. The KGH neighborhood, while rich in culture and diversity, lacks residents with excess income to invest in improving their environment. This is why the MSCDC funded a project to design and implement inexpensive rain barrels in Main South.

Due to community research, we decided a barrel with a threaded, removable lid must be a design criterion. Having a barrel with a large, easily removable top permitted easy cleaning and easy access to the water inside. When interviewing residents we found that many had potted plants in and around their houses. It is not practical or even possible to water inside plants with a hose. Dipping a watering can into the top of the barrel is also much a much faster method of acquiring water than using the gravity fed spigot. Over an extended period of time small debris and algae can build up inside the barrel. A sizeable lid opening permits the easy removal of such obstructive matter.

The final criterion was that the barrel must be elevated in order for the spigot to be functional, shown in Figure 4. This does not necessarily increase the water pressure coming out of the spigot, but it allows a watering can to be filled below the spigot. A hose could be attached to the spigot, but there will only be enough water pressure if the rain barrel is on a hill and the lawn or garden that is being watered by the hose is below that.
Main South is a unique area with equally unique needs. For a rain barrel initiative to be successful in such an area all of these requirements had to be proficiently met. Using accurate research we were able to select proper materials and features for our rain barrel design.

Finding Two: Rain Barrel Design

By using the universal features and the criteria we set, we were able to create a successful design for a rain barrel, shown in Figure 5. Our design has the following features:

- Large, removable lid
- Numerous smaller holes in barrel lid and aluminum screen for inlet of water
- Overflow drain with screen
- Water-tight faucet for outlet of water
- Opaque barrel

There are certain aspects of the design that are universal to all rain barrels, such as an outlet with a seal that prevents leaks, an overflow drain, and a screen at the opening in the lid. Those features came from studying existing rain barrels. Other features such as elevating the barrel, having a large, removable lid with threads, an opaque barrel, and a water inlet with
Utilizing Rain Barrels to Reduce Stormwater Runoff

numerous smaller holes were features that came about from our discussions with members of the Main South community and a member of Water Engineering at Worcester’s Department of Public Works.

All rain barrels have three major characteristics that can slightly vary between each design: the intake with a screen, the overflow valve, and the spigot. The three features are shown in Figure 7. It is important that there is a screen in the opening at the top. We chose an aluminum mosquito screen. Aluminum was a better choice than the fiberglass because it won’t deteriorate as quickly and is tear resistant. We cut a 22 inch square of the material and placed it over the open barrel and simply screwed on the lid of the barrel to secure the screen. To allow water to enter the barrel, numerous smaller holes were drilled in the lid of the barrel rather than one large hole. This makes the entire lid of the barrel an inlet for rain water, while protecting the screen below the lid. A barrel with a large hole in the lid is a safety hazard around small children because the aluminum screen is not strong enough to prevent them from falling into the barrel and drowning. Furthermore we placed rocks on the lid to limit the splashing of the water from the downspout because rocks have a rounded surface whereas the lid has a flat surface, shown in Figure 6. With the lid complete we moved on to the overflow valve.

Figure 6: Great American Rain Barrel
greatamericanrainbarrel.com/page009.htm

Figure 7: Three Main Features of a Rain Barrel
http://www.lid-stormwater.net/raincist_specs.htm
Utilizing Rain Barrels to Reduce Stormwater Runoff

The overflow valve is a necessary aspect of the design. In a heavy rainstorm, there is no way the barrel will have the capacity to hold all of the runoff from the roof. The valve should be close to the top of the barrel. The same screen used for the inlet hole in the top of the barrel should be used in the opening of the overflow valve. The only two pieces that make up the overflow valve are two 1.5 inch PVC adapters, shown in Figure 7. The adapters were very affordable, costing only $3.26 when purchased at The Home Depot in Worcester, MA. When attached together through a hole in the barrel they provide a proficient means for excess water to exit the rain barrel. Unless another barrel is connected for additional water collection, there is no need for the overflow valve to have a complete seal. It is important that the overflow leads away from the base of the barrel, but for the purposes of our project, we will leave this part up to the barrel owners. The last step in constructing our rain barrel was the spigot.

![Overflow Assembly](image)

The spigot is an outlet that allows water to be retrieved from the barrel, either by connecting a hose if there is enough pressure, or releasing it into a watering can. Our design uses a ¾ inch brass spigot with male threading, a 1 inch galvanized washer, a ¾ inch rubber o-ring, and a ¾ inch galvanized 90 degree elbow, all shown in Figure 9. All of these parts totaled $7.78 from The Home Depot and Barrow’s Hardware Store, a local business on Main Street in Worcester, MA. For the spigot to be water tight these components have to be installed in the right order. We assembled the spigot in this order, from the outside: the spigot with the washer placed on it, through a hole in the barrel, and then the lubricated o-ring on the spigot threads inside the barrel, all held in place by the elbow. It is desirable to have the spigot as close to the bottom of the barrel as possible to not leave a great amount of water in the barrel that cannot be released. The installation of the spigot concludes the construction of the rain barrel.
The most difficult, but most important part to find for our rain barrel was the barrel itself. The barrel was the most expensive and it was difficult to find a less expensive alternative. The barrel must be opaque. A transparent barrel will allow sunlight to reach the water and cause algae to grow inside the barrel. For the prototype we decided to buy a $30 barrel from a shop on Main Street, shown in Figure 10. This brought the total price of our first barrel, not including the screen, to $43.22. This price was more than we expected considering our budget. After much searching, a different barrel distributor, Bill Herlihy Barrel Co., offered barrels for $10, drastically lowering the total cost of the rain barrel to about $28.00. The complete list of materials and vendors is in appendix C.
Utilizing Rain Barrels to Reduce Stormwater Runoff

Another important factor in deciding on the design of the barrel was to make sure we had the available tools in the Main South garage. The only tools we needed were a hole saw kit and a drill to cut the holes for the spigot, overflow and the holes in the lid of the barrel, scissors to cut the screen to the right size, a flashlight or headlamp to see inside the barrel, and pliers to tighten the spigot assembly. The drill and hole saw kit are shown in Figures 11 and 12.

With these simple tools, the residents of Main South will easily be able to build their own rain barrels when our project ends. After we decided on our final design, we built our first prototype and conducted tests to ensure the rain barrels efficiency.

**Finding Three: Design Refinement**

After we built our prototype, we found a few aspects of our initial design had to be slightly altered. We came across a few issues with splashing, the overflow, leakage, rusting, and the flow rate during our testing phase. Based on these results we refined our design in order for it to be a successful prototype.

Initially, we had a small set of holes on the top of the lid to let the water in from the downspout. Using a hose to simulate rain water from a downspout, shown in Figure 13, we found that the surface of the lid caused water to splash out. We resolved this by drilling more holes to minimizing the surface area of the lid, while maintaining the integrity of the screen. The decreased surface area decreased the splash-out significantly.
The overflow on our design is large, but can be made larger to compensate for the amount of flow from the downspout. In our prototype the overflow screen is held in place by friction. We decided that gluing or zip-tying a cutout of a circle of screen onto the overflow pipe were better solutions than this.

During our leakage test, we found a single leaking area below the spigot to be about 8 drops per minute. We resolved this issue with lubricant on the o-ring that sits between the adapter and the inside of the barrel, applying thread lock to the threads of the spigot, as well as tightening our iron piece significantly with a wrench. Further observation showed that there was no further leaking.

A flaw that we noticed the day after our prototype was built was the rusting of the iron adapter on the inside of the barrel we originally used to connect to the spigot, as seen in Figure 14. For the following iterations we have decided to use a more durable material that will not corrode in a day, such as stainless steel or galvanized elbows.
Utilizing Rain Barrels to Reduce Stormwater Runoff

During our flow testing shown in Figure 15, we found that our flow rates were small and decreased as the barrel emptied. This behavior is illustrated in Figure 16. We took measurements and found that a full barrel had a flow rate of 1.6 gallons per minute which decreased to below .3 gallons per minute as the barrel reached empty. The results of this test show that using a hose attached to the spigot is not a viable option for this rain barrel because of the lack of water pressure. This is one drawback of our design. In order for a resident to water their lawn with a hose, they would have to install a costly pump.

<table>
<thead>
<tr>
<th>Time</th>
<th>Volume (Gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>53.83393</td>
</tr>
<tr>
<td>5</td>
<td>45.80226</td>
</tr>
<tr>
<td>10</td>
<td>38.20473</td>
</tr>
<tr>
<td>15</td>
<td>31.04134</td>
</tr>
<tr>
<td>20</td>
<td>24.3121</td>
</tr>
<tr>
<td>25</td>
<td>19.10236</td>
</tr>
<tr>
<td>30</td>
<td>15.19506</td>
</tr>
<tr>
<td>35</td>
<td>12.15605</td>
</tr>
<tr>
<td>40</td>
<td>7.814603</td>
</tr>
<tr>
<td>45</td>
<td>6.078025</td>
</tr>
<tr>
<td>50</td>
<td>6.078025</td>
</tr>
</tbody>
</table>

Figure 15: Flow Test

Figure 16: Flow Graph
Utilizing Rain Barrels to Reduce Stormwater Runoff

The results of this testing helped us realize which parts of the design needed fine tuning, and also showed us a major drawback of our design. In our manual we explain how a resident would go about creating enough water pressure to use a hose with the barrel.

Finding Four: Revisions to the Manual

With any project, it is important to gain feedback from an outside point of view. We held a small workshop for members of the MSCDC and the Regional Environmental Council (REC) to test the effectiveness of our manual, which can be found in Appendix A. We realized that our pictures were very helpful but our wording was sometimes misleading. The people who attended the workshop asked perfect questions that showed us where our manual needed editing.

To start with the spigot assembly directions, we found that some more detail needed to be added about actually using the tools. When you drill a hole with a hole saw, you have to clear the saw of any plastic debris before going to the next hole. The builders also found that it was very difficult to see inside the barrel when fastening the o-ring and elbow to the spigot assembly. For this, we added that using a flashlight or headlamp would be helpful.

For the overflow valve, the builders were confused about the placement of the valve on the barrel. The pictures were very explicit, but the wording was edited so there was no more confusion. We also changed the order of those steps to make them easier for builders to follow.

The last suggestion the builders had for our manual was including a small inch scale on the manual so a tape measure would not have to be a needed tool. We added this to the bottom on the front page in order to make it easier for builders to approximate where to drill each hole.

Our workshop was a necessary step in the editing process of our manual. Without feedback from people outside of our project, we would not have seen where our manual was confusing or misleading.

Finding Five: Calculation of Percentage of Runoff Held Back from CSS

By extrapolating historic data, we were able to calculate the percentage of stormwater runoff that can potentially be held back from the CSS if every house in Main South had a rain barrel (the table below shows the results). According to the census, there are 67,028 houses in Worcester, MA over an area of 37 square miles. Based on this data, we apply that there are approximately 1811 houses per square mile in Worcester, MA. The main south neighborhood
Utilizing Rain Barrels to Reduce Stormwater Runoff

covers .534 square miles. Applying the average number of houses in Worcester to the area of main south gives us approximately 967 houses in Main South. Our measurements from Google Earth maps indicate that the average roof size in Main South is approximately 1700 square feet and that the percentage of impermeable surfaces in the Main South is approximately 62.8% (a figure of the impermeable surfaces is found in Appendix D). With these numbers, we have determined that the surface area of impermeable surfaces in Main South is .335 square miles. The roof area for houses in main south is approximately .059 square miles. Out of the impermeable surfaces in main south, 17.6% are roofs of houses. Based on historical data, the average rainfall event in Worcester is approximately .139” over the year. During the average rainfall event, the houses in Main South produce approximately 142,444 gallons of water. If we assume each house in Main South had a rain barrel with the overflow routed to a permeable surface, the overall runoff would be decreased by approximately 11.047%, but with the overflow not routed to a permeable surface this number would decrease to 4.125% (the process used to produce this number is found in Appendix D). By using a simple implantation of rain barrels, Main South can significantly reduce the amount of stormwater runoff flowing to the combined sewer system.

<table>
<thead>
<tr>
<th>Information</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houses In Worcester</td>
<td>67028</td>
</tr>
<tr>
<td>Area of Worcester [Square Miles]</td>
<td>37</td>
</tr>
<tr>
<td>Houses per square mile (Worcester)</td>
<td>1811.567568</td>
</tr>
<tr>
<td>Measured Area of Main South [Square Miles]</td>
<td>0.5338</td>
</tr>
<tr>
<td>Approximate Number of Houses in Main South</td>
<td>967.0147676</td>
</tr>
<tr>
<td>Measured Average Roof Size of a house in Main South [Square Feet]</td>
<td>1700</td>
</tr>
<tr>
<td>Measured Percentage of Impermeable Surfaces in Main South</td>
<td>62.8</td>
</tr>
<tr>
<td>Calculated Impermeable Area in MS [Square Miles]</td>
<td>0.3352264</td>
</tr>
<tr>
<td>Calculated House Roof Area in MS [Square Miles]</td>
<td>0.058964315</td>
</tr>
<tr>
<td>Calculated Percentage of Roof Area as part of the Impermeable Surface</td>
<td>0.175894008</td>
</tr>
<tr>
<td>Rain barrel Capacity [Gallons]</td>
<td>55</td>
</tr>
<tr>
<td>Average Rainfall Event [Inches]</td>
<td>0.139</td>
</tr>
<tr>
<td>Roof Runoff per Event [Gallons]</td>
<td>142444.9004</td>
</tr>
<tr>
<td>Total Rain Barrel Capacity [Gallons]</td>
<td>53185.81222</td>
</tr>
<tr>
<td>Rain Barrel Overflow [Gallons]</td>
<td>89259.08819</td>
</tr>
<tr>
<td>Overall Runoff Amount/Event [Gallons]</td>
<td>1289435.843</td>
</tr>
<tr>
<td>Percent Runoff Reduction if Permeable Surface for Overflow</td>
<td>11.04707157</td>
</tr>
<tr>
<td>Runoff Reduction if Impermeable Surface for Overflow</td>
<td>4.124735055</td>
</tr>
</tbody>
</table>
Chapter 5: Summary

Stormwater runoff is a large issue in Main South. Our solution helped decrease the environmental impact of having large swaths of impermeable surfaces. These surfaces concentrate toxins from above ground into the drain systems and affect the health of Blackstone River area as well as having the potential to overload a treatment system not designed for the problem of yearly increased rainfall. The chosen solution to this problem at a local level was the implementation of rain barrels in the main south community in an attempt to sequester the water and reduce the amount that goes onto impermeable surfaces.

Throughout our project, we extensively researched rain barrels as a method to alleviate the environmental injustice by reducing stormwater runoff in Main South. Based on our research into existing barrels and discovering the needs of the community, we created a feasible design for a rain barrel and built and tested a prototype. Our testing revealed several improvements that could be made to the barrel. When we ran into issues, we adjusted our design until the issues had been resolved. The results of the tests made it certain that our design was ideal to the needs of the community and addressed the issues of stormwater runoff that were meant to be addressed. We then used our design as the basis for a manual meant to be handed out to interested community members. Our manual went through thorough editing while being tested by people outside of our project.

Due to the weather not being ideal for rain near the end of the term, we recommend that the MSCDC follow up on the project deliverables in the spring. At this point, the MSCDC should advertise the present stock of barrels and encourage that the residents invest in rain barrels. Based on interest from the previous interactions, the MSCDC should distribute the manual to the interested parties in addition to holding various workshops. With the MSCDC’s influence and involvement in the community in addition to their excellent track record we are confident that the project will be a success.

By demonstrating the use of rain barrels in Main South, we have helped create a sense environmental awareness and showed the residents that they can improve their quality of life one rain barrel at a time. Not only did rain barrels offer an economic benefit for those using them by reducing their water bill, but they decreased the spread of contaminants into the watershed system and eased some of the stress on the treatment facility.
Utilizing Rain Barrels to Reduce Stormwater Runoff

References


Utilizing Rain Barrels to Reduce Stormwater Runoff


Hager, M. C. (2003). Lot-level approaches to stormwater management are gaining ground. Journal of Surface Water Quality Professionals, 4(1)


Retrieved from Business Source Premier database.


Utilizing Rain Barrels to Reduce Stormwater Runoff

http://find.galegroup.com/gtx/infomark.do?contentSet=IAC-Documents&type=retrieve&tabId=T004&prodId=SPN.SP24&docId=A76080222&source=gale&srcprod=SP24&userGroupName=mlin_c_worpoly&version=1.0

Stormwater Runoff. *City of Bremerton.* (n.d.) Retrieved from
http://www.cityofbremerton.com/content/sw_stormwaterrunoff.html


Appendix A: How to Build a Rain Barrel

HOW TO BUILD A RAIN BARREL

Materials You’ll Need

- 55 gallon plastic barrel
- Brass faucet (3/4 inch male threaded)
- Washer (1 inch)
- O-ring (3/4 inch)
- Stainless steel elbow (3/4 inch)
- 3/4 inch PVC Sch. 40 adapters (1 male, 1 female)
- Aluminum screen
- Lubricant
- Thread Lock
- Bricks
- Elbow that fits your downspout (flexible or aluminum)

Tools You’ll Need

- 1 inch, 2 inch, and 2 1/2 inch hole saw
- Drill
- Large pliers
- Scissors
- Flashlight or headlamp

Construct a Rain Barrel Following Four Easy Steps In Under an Hour!

- Downspout attachment
- Lid with holes and screen
- Overflow valve
- Spigot assembly

Maintenance

- To winterize: empty your barrel and stand upside down or store indoors.
- If leaking around spigot, lubricate the o-ring and tighten the stainless steel elbow with pliers.
- Check barrel and clear vegetation and debris.
- Inspect the screen for tears and rips.

For more information, go to: www.mainsouthcdc.org

WPI
Utilizing Rain Barrels to Reduce Stormwater Runoff

HOW TO BUILD A RAIN BARREL (CONTINUED)

Spigot Assembly
1. Lay the barrel on its side.
2. With the 1 inch hole saw, drill a hole 4 inches (using scale on front page) above the bottom of the barrel (see figures 1 and 2). Clean all debris from the hole and drill.
3. Attach washer to male threaded spigot, apply thread lock to the threads of the spigot, then thread through the barrel (see figure 3).
4. Lubricate and add the o-ring to the spigot threads inside the barrel while using a flashlight/headlamp (see figure 4A), then fasten with stainless steel elbow and tighten with pliers while holding spigot firmly on the outside (see figure 4B).

Overflow Valve
1. Position the overflow valve on the barrel a 1/4 clockwise turn from the spigot.
2. Using a 2 1/2 inch hole saw, drill a hole near the top of the barrel (see figures 5 and 6). Clean all debris from the hole and drill.
3. Place male adapter through the barrel from the inside. Lubricate the threads.
4. Thread on female adapter to male adapter (see figure 7). This does not need to be a water tight seal.
5. Cut a 6 inch square piece of screen with scissors and attach to the male adapter with glue or a zip-tie. Trim excess screen as needed (see figure 8).

Lid with Holes and Screen
1. First mark about 16 evenly spaced holes on the lid with a marker.
2. Using a 2 inch hole saw, drill through marked holes in lid (see figures 9 and 10).
3. Cut aluminum screen in a square with 22 inch sides (figure 11).
4. Cover the opening of the barrel with the screen and drape over the threads (see figure 11).
5. Secure lid by making sure the threads lock in the screen (see figure 12).
6. Trim screen around lid with scissors.

Downspout Attachment
1. Elevate barrel with cinder blocks/bricks.
2. Cut downspout to a height just above the lid of your barrel when elevated. Attach elbow to downspout (see figures 13 and 14).
3. Redirect water flow towards the top of the barrel.
Appendix B: Rain Barrel Custom Options

RAIN BARREL CUSTOM OPTIONS

Make your barrel aesthetically pleasing:
- Paint the barrel (figure 2).
- Plant flowers and vegetation around the barrel (figure 3).
- Large, smooth rocks on the top of the barrel, which also reduces splashing (figure 4).

To harvest more water, add another barrel:
- Lead a PVC pipe from the overflow valve of your first barrel to the drain of the added barrel (figure 6).
- Materials you will need:
  1. 1-1/2 inch PVC pipe
  2. PVC glue

Where does your overflow go?
- Install a hose on your barrel to direct your overflow to:
  1. Your garden or lawn (figure 1).
  2. Backwash hose
  3. Hose clamp

Want more water pressure?
- Easy tips for increasing water pressure:
  1. Install a motor pump (figure 6).
  2. Install an air compressor (figure 7).

Appendix B: Rain Barrel Custom Options
## Appendix C: List of Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Vendor</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot; brass faucet</td>
<td>Home Depot</td>
<td>$4.49</td>
</tr>
<tr>
<td>1&quot; galvanized washer</td>
<td>Barrows</td>
<td>$1.19</td>
</tr>
<tr>
<td>1 1/4 o-ring</td>
<td>Barrows</td>
<td>$0.39</td>
</tr>
<tr>
<td>3/4&quot; galvanized elbow</td>
<td>Home Depot</td>
<td>$1.71</td>
</tr>
<tr>
<td>2&quot; male PVC adapter</td>
<td>Home Depot</td>
<td>$2.21</td>
</tr>
<tr>
<td>2&quot; female PVC adapter</td>
<td>Home Depot</td>
<td>$1.32</td>
</tr>
<tr>
<td>Gutter Elbow</td>
<td>Home Depot</td>
<td>$2.39</td>
</tr>
<tr>
<td>Cinderblock (16&quot;X12&quot;X8&quot;)</td>
<td>Home Depot</td>
<td>$2.39</td>
</tr>
<tr>
<td>Barrel</td>
<td>Bill Herlihy Barrel Co Inc, Chicopee, MA</td>
<td>$10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$26.09</strong></td>
</tr>
</tbody>
</table>

### Multi-Use Items

<table>
<thead>
<tr>
<th>Multi-Use Items</th>
<th>Vendor</th>
<th>Cost</th>
<th>Potential # Barrels</th>
<th>Cost for one barrel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zip-tie (10-pack)</td>
<td>Home Depot</td>
<td>$1.69</td>
<td>10</td>
<td>$0.17</td>
</tr>
<tr>
<td>Aluminum Screen (30&quot;X86&quot;)</td>
<td>Barrows</td>
<td>$6.99</td>
<td>6</td>
<td>$1.17</td>
</tr>
<tr>
<td>Thread Lock</td>
<td>Home Depot</td>
<td>$5.97</td>
<td>13</td>
<td>$0.46</td>
</tr>
<tr>
<td>Lubricant</td>
<td>Barrows</td>
<td>$1.99</td>
<td>13</td>
<td>$0.15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$1.95</strong></td>
</tr>
</tbody>
</table>

**Estimated Cost of one barrel** $28.04
Utilizing Rain Barrels to Reduce Stormwater Runoff

Appendix D: Calculations

Rainfall Data

<table>
<thead>
<tr>
<th>Month</th>
<th>Avg Prec/Event</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0.14</td>
<td>3.11</td>
</tr>
<tr>
<td>Feb</td>
<td>0.08</td>
<td>1.73</td>
</tr>
<tr>
<td>Mar</td>
<td>0.19</td>
<td>4.7</td>
</tr>
<tr>
<td>Apr</td>
<td>0.31</td>
<td>8.3</td>
</tr>
<tr>
<td>May</td>
<td>0.19</td>
<td>5.12</td>
</tr>
<tr>
<td>Jun</td>
<td>0.09</td>
<td>2.16</td>
</tr>
<tr>
<td>Jul</td>
<td>0.16</td>
<td>4.3</td>
</tr>
<tr>
<td>Aug</td>
<td>0.03</td>
<td>1.01</td>
</tr>
<tr>
<td>Sep</td>
<td>0.07</td>
<td>1.98</td>
</tr>
<tr>
<td>Oct</td>
<td>0.11</td>
<td>3.12</td>
</tr>
<tr>
<td>Nov</td>
<td>0.12</td>
<td>3.26</td>
</tr>
<tr>
<td>Dec</td>
<td>0.18</td>
<td>4.57</td>
</tr>
<tr>
<td>YrAvg</td>
<td>0.139166667</td>
<td>3.613333333</td>
</tr>
</tbody>
</table>

Map of Impermeability in Main South
### Utilizing Rain Barrels to Reduce Stormwater Runoff

#### Calculations of Potential Savings

<table>
<thead>
<tr>
<th>Shortname</th>
<th>Data Source</th>
<th>Quantity</th>
<th>Math</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIW</td>
<td>Census</td>
<td>67028</td>
<td>N/A</td>
<td>Houses In Worcester</td>
</tr>
<tr>
<td>AOW</td>
<td>Census</td>
<td>37</td>
<td>N/A</td>
<td>Area of Worcester [Square Miles]</td>
</tr>
<tr>
<td>HPSM</td>
<td>Calculated</td>
<td>1811.567568</td>
<td>HIW/AOW</td>
<td>Houses per square mile (Worcester)</td>
</tr>
<tr>
<td>MAMS</td>
<td>Measured</td>
<td>0.5338</td>
<td>N/A</td>
<td>Measured Area of Main South [Square Miles]</td>
</tr>
<tr>
<td>HiMS</td>
<td>Calculated</td>
<td>967.0147676</td>
<td>HPSM/MAMS</td>
<td>Approximate Number of Houses in Main South</td>
</tr>
<tr>
<td>ARS</td>
<td>Measured</td>
<td>1700</td>
<td>N/A</td>
<td>Measured Average Roof Size of a house in Main South [Square Feet]</td>
</tr>
<tr>
<td>PoIS</td>
<td>Measured</td>
<td>62.8</td>
<td>N/A</td>
<td>Measured Percentage of Impermeable Surfaces in Main South</td>
</tr>
<tr>
<td>IAMS</td>
<td>Calculated</td>
<td>0.3352264</td>
<td>MAMSxPoIS/100</td>
<td>Calculated Impermeable Area in MS [Square Miles]</td>
</tr>
<tr>
<td>HRA</td>
<td>Calculated</td>
<td>0.058964315</td>
<td>HiMSxARSx[SqFt/Mi]</td>
<td>Calculated House Roof Area in MS [Square M]</td>
</tr>
<tr>
<td>PRA</td>
<td>Calculated</td>
<td>0.175894008</td>
<td>HRA/IAMS</td>
<td>Calculated Percentage of Roof Area as part of the Impermeable Surface</td>
</tr>
<tr>
<td>RBC</td>
<td>Measured</td>
<td>55</td>
<td>N/A</td>
<td>Rain barrel Capacity [Gallons]</td>
</tr>
<tr>
<td>ARE</td>
<td>Calculated</td>
<td>0.139</td>
<td>See RainFallData</td>
<td>Average Rainfall Event [Inches]</td>
</tr>
<tr>
<td>RRE</td>
<td>Calculated</td>
<td>142444.9004</td>
<td>ARSxHiMSx[SqIn/SqFt]x[CuIn/Gal]xARE</td>
<td>Roof Runoff per Event [Gallons]</td>
</tr>
<tr>
<td>RBCa</td>
<td>Calculated</td>
<td>53185.81222</td>
<td>RBCxHiMS</td>
<td>Total Rain Barrel Capacity [Gallons]</td>
</tr>
<tr>
<td>RBO</td>
<td>Calculated</td>
<td>89259.08819</td>
<td>RRE-RBCa</td>
<td>Rain Barrel Overflow [Gallons]</td>
</tr>
<tr>
<td>ORA</td>
<td>Calculated</td>
<td>1289435.843</td>
<td>IAMSx[SqFt/SqMi]x[SqIn/SqFt]xAREx[CuIn/Gal]</td>
<td>Overall Runoff Amount/Event [Gallons]</td>
</tr>
<tr>
<td>RRP</td>
<td>Calculated</td>
<td>11.04707157</td>
<td>RRE/ORAx100</td>
<td>Percent Runoff Reduction if Permeable Surface for Overflow</td>
</tr>
<tr>
<td>RRI</td>
<td>Calculated</td>
<td>4.124735055</td>
<td>RBCa/ORAx100</td>
<td>Runoff Reduction if Impermeable Surface for Overflow</td>
</tr>
</tbody>
</table>