Team 6: Islands in the Street
Urban Bioretention Islands

Project Proposal and Feasibility Study

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Calvin College
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Executive Summary

Team 6 Islands in the Street has studied the feasibility of designing bioretention islands in urban areas in Grand Rapids, Michigan. In urban areas, rainfall picks up pollutants from roofs, sidewalks, and roads, and carries those pollutants through the storm sewer system and eventually to local streams, rivers, and lakes. A bioretention island is a form of stormwater best management practice that routes this stormwater runoff into an engineered system which uses natural infiltration and plants to filter pollutants from the water and reduce the volume of the runoff. This alleviates the negative effects downstream.

The team has studied other bioretention projects, including a recently-completed project in Grand Rapids, known as the Plainfield Avenue Project. The team has set up sampling equipment to collect samples from this existing project, in order to study the effectiveness of the project to eliminate pollutants in the runoff. This data will be used to create a new bioretention island design that will contain improvements upon the existing design. Due to limited laboratory hours and the variability of the weather, the team has been unable to collect water samples. This process will be postponed until spring 2013.

The cost estimate incurred by the team is expected to be $364, solely attributed to the materials used for constructing the scale model. The cost estimate for a sample bioretention island project containing four one hundred-foot islands is approximately $260,000.

The team picked several project site locations, and after performing soil boring tests and completing a decision matrix, has decided on two project site locations for the new design. These sites are located on Monroe Avenue, between Pearl Street and Weston Street; and Michigan Street, between Coit Avenue and Monroe Avenue. At these locations, the soil is conducive to natural infiltration, the existing traffic patterns will be minimally affected, and there is ample space, plenty of possible funding, and a necessity for bioretention.

The next stage in the design process will be analyzing the new locations hydrologically to determine how the bioretention islands will perform; modeling the island design hydraulically, to determine the nature of the flow of water through the islands; studying and selecting soils and plants that will be most effective in pollutant filtration; and performing traffic studies and analyzing an implemented island’s effect on the current traffic patterns.
Table of Contents

1 Introduction ..................................................................................................................................... 1

2 Project Management ........................................................................................................................ 3

2.1 Team Organization ..................................................................................................................... 3

2.1.1 Roles of Team Members ....................................................................................................... 3

2.1.2 Organization Chart ................................................................................................................ 3

2.1.3 Team Meetings ...................................................................................................................... 3

2.1.4 Document Organization ........................................................................................................ 3

2.2 Schedule Management .............................................................................................................. 6

2.3 Budget Management ................................................................................................................... 6

2.4 Method of Approach ................................................................................................................... 6

3 Requirements .................................................................................................................................... 7

3.1 Performance ................................................................................................................................ 7

3.1.1 Water Quality ........................................................................................................................ 7

3.1.2 Water Quantity ....................................................................................................................... 7

3.2 Location ....................................................................................................................................... 7

3.2.1 Business District ................................................................................................................... 7

3.2.2 Road Width ............................................................................................................................ 8

3.2.3 Timeframe Coincidence ........................................................................................................ 8

3.2.4 Treatment Area ..................................................................................................................... 8

3.3 Size ................................................................................................................................................ 8

3.3.1 Length ................................................................................................................................... 8

3.3.2 Width ..................................................................................................................................... 8

3.4 Safety ............................................................................................................................................ 8

3.4.1 Significance ........................................................................................................................... 8

3.4.2 Motorists ............................................................................................................................... 8

3.4.3 Pedestrians ............................................................................................................................ 9

3.5 Durability ..................................................................................................................................... 9

3.5.1 Plants and Soils ..................................................................................................................... 9

3.5.2 Curbs ..................................................................................................................................... 9

3.6 Maintenance ................................................................................................................................. 9

3.7 Deliverables ................................................................................................................................ 9

4 Task Specifications and Schedule ................................................................................................. 10

4.1 Project Categories ....................................................................................................................... 10
4.2 Task Completion Level

5 Basis of Design

5.1 Plainfield Avenue Bioretention Island Project

5.1.1 Background

5.1.2 Bioretention Islands

5.1.3 Surrounding Areas

5.2 Design Components

5.2.1 Structure

5.2.2 Layout

5.2.3 Catch Basins

5.2.4 Infiltration Basins

5.2.5 Soils

5.2.6 Plants

5.2.7 Traffic & Road

5.2.8 Project Sites

5.2.9 Cost

5.2.10 Storm Events

5.3 Scale Model

5.3.1 Purpose

5.3.2 Design

6 Conclusion

7 References

8 Acknowledgements

8.1 Calvin College

8.2 City of Grand Rapids

8.3 Fishbeck, Thompson, Carr & Huber, Inc

8.4 Miss Dig
Table of Figures

Figure 1. Project location; on left, the red region shows Grand Rapids within Kent County, which is represented in red on the right. Image courtesy of Wikimedia Commons. ................................. 1
Figure 2. Team members, from left to right: Matthew Smith, Corey Van Dyk, Todd Jacobs, and Daniel Starkey. ......................................................................................................................................... 2
Figure 3. Organization Chart .......................................................................................................................................................................................................................... 5
Figure 4. Project Task Sequence .......................................................................................................................................................................................................................... 11
Figure 5. Ribbon-Cutting Ceremony for Plainfield Avenue Project .......................................................................................................................................................................................................................... 12
Figure 6. Isco Sampler (image courtesy of www.isco.com) .......................................................................................................................................................................................................................... 13
Figure 7. Volume of Runoff Removed from Storm Sewer System by Bioretention Bump-outs .......................................................................................................................................................................................................................... 15
Figure 8. Plan View of Preliminary Design for Bioretention Island .......................................................................................................................................................................................................................... 16
Figure 9. Profile View of Preliminary Design for Bioretention Island .......................................................................................................................................................................................................................... 17
Figure 10. Flow Paths through Bioretention Island for Varying Storm Events .......................................................................................................................................................................................................................... 18
Figure 11. Detail of Typical Catch Basin .......................................................................................................................................................................................................................... 19
Figure 12. Details for Infiltration Basins .......................................................................................................................................................................................................................... 19
Figure 13. Soil Depths for Preliminary Design of Bioretention Island .......................................................................................................................................................................................................................... 20
Figure 14. First Island at Location 1 (image courtesy of Google Maps) .......................................................................................................................................................................................................................... 23
Figure 15. Second Island at Location 1 (image courtesy of Google Maps) .......................................................................................................................................................................................................................... 23
Figure 16. First Island at Location 2 (image courtesy of Google Maps) .......................................................................................................................................................................................................................... 24
Figure 17. Second Island at Location 2 (image courtesy of Google Maps) .......................................................................................................................................................................................................................... 24
Figure 18. Islands at Location 3 (image courtesy of Google Maps) .......................................................................................................................................................................................................................... 25
Figure 19. Island at Location 4 (image courtesy of Google Maps) .......................................................................................................................................................................................................................... 25
Figure 20. Soil Layers for Possible Project Site Locations .......................................................................................................................................................................................................................... 26
Figure 21. Profile View Sketch of Scale Model .......................................................................................................................................................................................................................... 30
Figure 22. Plan View Sketch of Surface of Scale Model .......................................................................................................................................................................................................................... 31
Figure 23. Plan View Sketch of Subsurface of Scale Model .......................................................................................................................................................................................................................... 31

Table of Tables

Table 1. File Organization of Folder ‘Team06’ on the Engineering Shared Drive ................................................................. 4
Table 2. Median Pollutant Concentrations for Urban Areas in the Great Lakes Region .......................................................................................................................................................................................................................... 7
Table 3. Summary of Volume Calculations for Bioretention Bump-outs .......................................................................................................................................................................................................................... 14
Table 4. Strengths and Weakness of Plant Candidates .......................................................................................................................................................................................................................... 21
Table 5. Decision Matrix for Project Site Location .......................................................................................................................................................................................................................... 27
Table 6. Estimated Cost Breakdown of Proposed Model .......................................................................................................................................................................................................................... 28
Table 7. Construction Cost Estimate .......................................................................................................................................................................................................................... 29
1 Introduction

Team 6 (Islands in the Street) is designing bioretention islands to manage stormwater in an urban environment. For this project, Grand Rapids, Michigan (Figure 1) serves as that environment. Grand Rapids, the second largest city in Michigan, has a population in excess of 188,000, according to the United States 2010 Census Bureau data.1 “Furniture City” is home to five of the world’s largest office furniture companies, and plays an important role in the field of health care as well as the automobile and aviation manufacturing industries. Grand Rapids has thriving business districts and an active population, which contribute to necessity of pollution reduction.

![Figure 1. Project location; on left, the red region shows Grand Rapids within Kent County, which is represented in red on the right. Image courtesy of Wikimedia Commons.](image)

Bioretention is the process by which stormwater is held and contaminants are filtered out in a treatment area. It also reduces the volume of runoff immediately following a storm event, distributing runoff volume over time, thus mitigating flooding. In an urban environment, this is especially important, due to large areas of impervious materials such as building roofs and pavement. A bioretention island is unique among other stormwater best management practices (BMPs), since it is located in a road median.

Before the team designs new bioretention islands, the team analyzed the performance of a recently completed bioretention project, consisting of seven islands on Plainfield Avenue, in northeast Grand Rapids. Water sampling from these islands will allow the team to improve upon the Plainfield Avenue design to create a bioretention system that better removes pollutants. We have determined viable locations for this new design and have selected a single site from those locations.

Team 6 consists of four senior engineering students with concentrations in Civil & Environmental Engineering at Calvin College in Grand Rapids. The team members (Figure 2) are Todd Jacobs, Matthew Smith, Daniel Starkey, and Corey Van Dyk.

Todd Jacobs is a senior engineering student at Calvin College with a concentration of civil/environmental engineering. He worked this past summer as an intern for Kent County Road Commission. He expects to enter the workforce following graduation in May.
Matthew Smith studies Civil/Environmental Engineering at Calvin College. His hometown is Griffith, IN, but he currently lives with his wife in Grand Rapids, MI, during their final year at Calvin. Over the last two summers, he has interned with a large steel-producing company called ArcelorMittal, in East Chicago, IN. During his time there, he experienced various aspects of environmental engineering, including regulations put in place by the Environmental Protection Agency (EPA) and Indiana Department of Environmental Management (IDEM). Because of his studies and internship experiences, Matthew is interested in continuing with environmental engineering as his career, especially related to water resources.

Daniel Starkey is studying civil/environmental engineering at Calvin College in Grand Rapids, Michigan. He is from Columbus, Ohio and was married in January of 2012. He studied abroad in the Netherlands for a semester and he hopes to return someday to work there. He interned last summer in Dublin, Ohio at a mid-sized civil engineering consulting firm called Hull & Associates, Inc. He is interested specifically in working with water and looks forward to joining the workforce after graduation and contributing to society in a meaningful way.

Corey Van Dyk is a senior engineering student at Calvin College with a concentration in civil/environmental engineering. He grew up near Chicago and worked in Grand Rapids this past summer as an intern in the traffic division of URS Corporation. He also spent time working as an operator at the West Michigan Traffic Operations Center (WMTOC) for Michigan Department of Transportation (MDOT). He expects to pursue graduate school next year for a master’s degree in civil engineering.

Calvin College is a Christian liberal arts college with an enrollment of approximately 4,000 undergraduate students. Calvin offers an ABET accredited Bachelor of Science in Engineering degree (BSE), with concentrations in Chemical, Civil & Environmental, Electrical & Computer, and Mechanical Engineering.

In conjunction with the project, the team is attending a design course required for all senior engineering students at Calvin College. This course is taught by four professors, one from each engineering concentration offered at Calvin. In addition to outlining the details, requirements, and deadlines for the project, the course focuses on using design norms and a Christian worldview to guide task specification and design. The primary design norms on which the team has concentrated are stewardship, integrity, and caring. An additional goal for the course is using analysis and prototyping of the design; we aim to achieve this by constructing a scale model of a bioretention island. Other aspects of engineering that have been emphasized through the course are team building, research techniques and professionalism.
2 Project Management

2.1 Team Organization

2.1.1 Roles of Team Members

Many of the tasks to be completed will be performed as a team, although a member of the group will take
the lead on some of the larger tasks. Todd Jacobs acts as the head of research and will take the lead on
the bioretention design, working with the soils and plants in the islands. Jacobs will also pilot the
construction of the scale model. Matthew Smith is the webmaster and is responsible for correspondence
with our client and industrial consultant. Smith’s other duties include leading the hydraulic design and
acting as a document editor for the team. Corey Van Dyk coordinates scheduling and will be in charge of
the road design, including traffic considerations. Van Dyk also acts as one of the team’s document
editors. Daniel Starkey directs the sampling of the Plainfield Avenue islands and will lead the hydrologic
design, specifically watershed delineation and storm event analysis. Starkey also manages the budget of
the team. In addition to their primary duties, Starkey and Smith will also provide Quality Assurance for
all tasks completed by the team including, but not limited to, sampling, calculations, AutoCAD drawings,
tables, and figures. When Starkey or Smith is primarily responsible for a task, Quality Assurance must be
provided by the team member who did not take primary responsibility.

2.1.2 Organization Chart

A basic chart representing the organization of groups and individuals related to the project is shown in
Figure 3.

2.1.3 Team Meetings

Formal team meetings are held twice a week for approximately an hour during which the team reports on
the work done and plan the tasks that need to be completed next. For tasks that require multiple team
members, additional work meetings are scheduled. Meetings with the team advisor, Professor David
Wunder, are held whenever there is a need to discuss aspects of the project with him.

2.1.4 Document Organization

All electronic documents are kept in Calvin College’s “Shared Drive” through the file path
S:\Engineering\Teams\Team06. The folders contained in the team folder are outlined below in Table 1.
Additionally, hard copies of research documents and important correspondence are kept in folders at the
work station.
Table 1. File Organization of Folder ‘Team06’ on the Engineering Shared Drive

<table>
<thead>
<tr>
<th>Folder Name</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget</td>
<td>cost estimates for team, project</td>
</tr>
<tr>
<td>Business Plan</td>
<td>documents for corresponding business course</td>
</tr>
<tr>
<td>Drawings</td>
<td>AutoCAD, hand sketches</td>
</tr>
<tr>
<td>Important Correspondence</td>
<td>significant emails from advisor, client, industrial consultant</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>website files, other files</td>
</tr>
<tr>
<td>Plainfield Project Data</td>
<td>sewershed areas, island drawings</td>
</tr>
<tr>
<td>Poster</td>
<td>team poster files, pictures for poster</td>
</tr>
<tr>
<td>Presentations</td>
<td>class update presentations, final presentations</td>
</tr>
<tr>
<td>Reports</td>
<td>industrial brief, PPFS, final report</td>
</tr>
<tr>
<td>Research</td>
<td>material for urban stormwater management, bioretention, case studies, LID</td>
</tr>
<tr>
<td>Schedule</td>
<td>work breakdown schedule</td>
</tr>
<tr>
<td>Testing Results</td>
<td>laboratory results from the Plainfield Avenue project</td>
</tr>
</tbody>
</table>
Figure 3. Organization Chart
2.2 Schedule Management

The team typically evaluates the schedule of tasks to be completed once a week and updates it based on progress made or the surfacing of other necessary activities. Corey Van Dyk acts as the team’s project coordinator, outlining the upcoming tasks at team meetings and leading task prioritization. When scheduling issues arise, tasks with critical deadlines are prioritized. Tasks that must be completed in order to begin other tasks are also prioritized, as their completion will allow further work. Finally, priority is given to tasks which require immediate response, such as water sampling during a storm event. When multiple tasks require priority, decisions are made on a case-by-case basis, including dividing the tasks among team members. For a complete schedule of the project, see Section 4.2 of this report. The number of hours worked on the project per week per team member varies depending on deadlines and availability, with a range between four and twenty hours.

2.3 Budget Management

Daniel Starkey is assigned to manage the team’s budget. The budget acts as a constraint for the design of the model, limiting the funds available to spend on each item. When an issue arises related to the budget, the team must make decisions on the degree of necessity for a given item and on possible alternatives to that item.

Because we are not constructing actual bioretention islands, the budget for the proposed site works differently than that of the scale model. This budget is maintained by analyzing construction costs for the Grand Rapids area. Additionally, the proposed project does not share the limited budget aspect that the team project has, relaxing the constraint for maximum cost. However, cost must remain low to facilitate funding and the ultimate feasibility of the project.

Preliminary cost estimates and budget information can be found in Subsection 5.2.9 of this report.

2.4 Method of Approach

The basic design methodology involves first testing the Plainfield Avenue bioretention islands, and then designing islands at a new location based on the performance of those on Plainfield. While some aspects of design, such as determining a new location, can be done without Plainfield’s testing results, other features, such as soil type and island size, could be affected by information on the performance of the Plainfield islands. The design itself is partitioned into four categories. The bioretention design focuses primarily on the soils and plants used in the islands. The hydraulic design involves the infiltration basins and pipes in the island, including the underdrain and catch basin pipes. The hydrologic design includes examining watersheds and the analysis of storm events. The road design investigates how lanes should be designed around the islands and the effect the islands will have on traffic movements.

The primary research methods used include use of case studies from all over the country, in order to retrieve bioretention principles and ideas. The team also examined the Low Impact Development (LID) Manual for Michigan to obtain design guidelines. Many resources were found via online databases; Glen Remelts of Calvin College’s Hekman Library trained us in the use of these databases and provided some research ideas.

Team communication is kept open, with opportunities to share new ideas ranging from minor editorial preferences to major alterations in scope definition. Efforts are made to respect the suggestions of team members, even when making decisions which lack universal agreement. Team members are flexible in the decision making process, which creates less friction during team meetings and task completion. Disagreements are not taken personally but are recognized as mere differences in project ideas.
3 Requirements

3.1 Performance

The design of the bioretention islands must meet several standard goals set forth by the LID Manual for Michigan.

3.1.1 Water Quality

The bioretention system should be able to remove 70-90 percent of total suspended solids (TSS), approximately 60 percent of total phosphorus, and 40-50 percent of total nitrogen. Since many other contaminants sorb to solid particles, the removed TSS should also have a significant impact on removal of other contaminants like bacteria from animal waste, nutrients from fertilizer, hydrocarbons and heavy metals from automobiles, and chlorides from road salt. Table 2 shows typical pollutant levels in effluent stormwater in urban areas of the Great Lakes region.

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Typical Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td>100</td>
</tr>
<tr>
<td>Biological Oxygen Demand (BOD)</td>
<td>9</td>
</tr>
<tr>
<td>Chemical Oxygen Demand (COD)</td>
<td>65</td>
</tr>
<tr>
<td>Total Phosphorus (TP)</td>
<td>0.33</td>
</tr>
<tr>
<td>Soluble Phosphorus (SP)</td>
<td>0.12</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen (TKN)</td>
<td>1.5</td>
</tr>
<tr>
<td>Nitrite or Nitrate (NO(_2) or NO(_3))</td>
<td>0.68</td>
</tr>
<tr>
<td>Total Copper (Cu)</td>
<td>0.034</td>
</tr>
<tr>
<td>Total Lead (Pb)</td>
<td>0.14</td>
</tr>
<tr>
<td>Total Zinc (Zn)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Table 2. Median Pollutant Concentrations for Urban Areas in the Great Lakes Region

The pollutant removal is an essential aspect of environmental stewardship which the team values in its design.

3.1.2 Water Quantity

The main goal for bioretention with regards to water quantity is to reduce the peak runoff rate. The goal for LID as stated in the 2008 LID Manual for Michigan is to maintain the pre-settlement runoff volume. However, this project will retroactively address stormwater runoff concerns in an urban setting, and it is not necessarily feasible to return the stormwater runoff to pre-development levels. In cases like this, the LID Manual suggests that the goal be to completely retain a one-year 24-hr storm event and release it or let it infiltrate over at least a 24-hour period.

3.2 Location

A significant part of the design will be selecting an appropriate location for the construction of bioretention islands. There are multiple things to consider when selecting a site.

3.2.1 Business District

Since the recession began in 2008, many state governments lack the available funds for non-essential infrastructure projects. The City of Grand Rapids has a limited budget for regular maintenance and scheduled resurfacing of public roads. Therefore, the Plainfield Avenue bioretention islands project relied heavily on privately donated money from the surrounding business and the Creston Neighborhood Association. The team hopes to achieve a similar level of local support for the project and is therefore looking for a stretch of road with a business district that would be interested and willing to support the
project. In addition to water quality management, a project like this would be beneficial to local businesses by aesthetically improving the streetscape and by slowing down traffic, making the area more pleasant and safe for pedestrian traffic.

3.2.2 Road Width

In order to fit the bioretention islands in the middle of the street, a minimum road width is required. Preliminary design and review of similar projects indicate that at least 10 feet is required. For this reason, any possible locations must be at least 3 lanes wide. This would usually be a two-way street with a middle turn lane, but a 4-lane road could be considered as well.

3.2.3 Timeframe Coincidence

One thing to be considered for any project is its constructability. For any project that requires asphalt removal, it is good to coordinate all projects in the area so that they can happen at one time, thus avoiding repetitive construction and resurfacing of the road, which is both costly to the government and inconvenient for drivers. For this reason, an ideal location will have scheduled road maintenance sometime in the near future that can coincide with the construction of the proposed bioretention islands.

3.2.4 Treatment Area

Another consideration for picking a location is how great of an impact the project will have on the stormwater runoff in the area. This is manifested in two ways: the number of effective stormwater management structures already in place, and the current water quality of the stormwater runoff in the area. In order to maximize the impact of the project, the ideal location would not already have effective stormwater management and would have stormwater runoff that would benefit significantly from treatment of pollutants. Assuming that the amount of traffic on a road is closely related to the amount of pollutants in the runoff, a location with heavier traffic is preferable. Since the volume of runoff is directly related to the amount impervious surfaces, the ideal location would also have a high percentage of impervious surfaces nearby.

3.3 Size

3.3.1 Length

The length of the bioretention islands will be limited by the specific site location. The islands can be any length, but can only occupy stretches of road that will not otherwise obstruct driveways or intersecting roads.

3.3.2 Width

The width of the median will also be dictated by the specific site location. In order to accommodate the necessary features, the bioretention island will need to be at least 10 feet wide, but could be wider if the road width allows it.

3.4 Safety

3.4.1 Significance

Safety should always be an important consideration in any design. In this particular project, safety of motorists and pedestrians will be a high priority. Safety is a key parameter related to the focus of caring in the team’s design.

3.4.2 Motorists

A properly designed bioretention island will not obstruct the view of the driver. Standard sight distances must be maintained according to The American Association of State Highway and Transportation Officials (AASHTO) Green Book. In addition, standard signage must be present to warn the driver of
the presence of the median after each break in the median. Since the bioretention islands will be depressed instead of raised, as in the case of a normal median, special consideration should be given to ensure vehicles cannot easily cross the median into oncoming traffic.

3.4.3 Pedestrians

Pedestrian safety must be provided by discouraging jaywalking and providing crosswalks where appropriate. Crosswalks should adhere to all design guidelines in the AASHTO Green Book.5 Plants and trees in the bioretention islands shall not obscure the pedestrian’s view of vehicles when crosswalks are present.

3.5 Durability

3.5.1 Plants and Soils

Plants within the bioretention islands must be able to grow in conditions of standing and fluctuating levels of water. They must also be salt resistant and cold resistant in order to withstand Michigan winters. The selection and installation of soils should prevent against erosion and allow adequate infiltration.

3.5.2 Curbs

The curbs must be durable enough to withstand the inevitable abuse that snowplows will inflict during winter months.

3.6 Maintenance

A detailed plan for maintenance and cleaning must be provided with the final design. Also, a plan and method of monitoring the performance of the islands should be specified that should include monitoring both the capacity and quality of the stormwater treatment provided by the bioretention system. The cost of maintenance – an estimated $30,000 endowment for the life of the project – is included in the construction cost estimate in Table 7, found in Subsection 5.2.9.

3.7 Deliverables

A formal presentation as well as a final report detailing the final design will be required at the conclusion of this project. Also, a scale model, representing the look and function of the final design, is required.
4 Task Specifications and Schedule

4.1 Project Categories

The team met with the client, the City of Grand Rapids, to discuss the scope of the project. The main contact is Carrie Rivette, a stormwater project engineer. The City of Grand Rapids was willing to act as the team’s client, while the team would collect pollutant data for the Plainfield Avenue Bioretention Island project. In addition, the team calculated the reduction in volume discharge for two other stormwater projects the City of Grand Rapids recently completed in the same area as the Plainfield Avenue project. After the Plainfield Avenue project was chosen, the team began to research the topic of bioretention islands and other stormwater management tools.

The team split the design aspect of the project into four main areas: road traffic design, hydrology, hydraulics, and bioretention. The road traffic design deals with the road configuration and layout of the islands. The hydrology is the flow of water through the bioretention system, based on catchment areas and storm events. The hydraulics is the organization of the different parts of the bioretention island, including the placement of the basins and pipes. The bioretention section is the process of soil and plant selection that will work best in the islands based on necessary pollutant removal and the type of pollutants entering the islands.

4.2 Task Completion Level

The team is currently waiting for a rain event to occur, during the hours for which it is possible to take the samples to the lab. Once the samples are collected, the team will have to wait to get the results from the lab to finish and validate the final design. The team completed volume reduction calculations for the two addition projects, which helped to show additional watershed information. The team outlined the process to complete the volume reduction calculations for Plainfield Avenue Islands. The team has done significant research and will continue researching to find ample information on bioretention islands. The team tested soil at four possible locations for the new design. A decision matrix was created to determine the top two locations. The team constructed preliminary drawings of the new bioretention islands, which include profile and plane views along with detailed drawings of the catch basins and infiltration basins. Also, the team has a preliminary design for the working, scale model and necessary materials for its construction.

Road traffic design will determine the road configuration to best deal with traffic flows and have a negligible impact on existing traffic levels. The team will determine and model the average daily traffic (ADT) for the new site location. The necessary road configuration will affect the length and width of the bioretention islands. Hydrologic design will determine the volume of water that the bioretention system experiences during a storm event. This will determine the number of catch basins that flow into the island, based on the size of the storm event. The hydrology will be modeled with HEC-HMS. The hydraulic design of the islands consists of the most effective use of pipes and infiltration basin locations to provide maximum storage capacity. The hydraulics will be modeled using EPA-SWMM. This modeling will provide the storage volume capacity of the islands. Bioretention will explore the type of soils that provide the balance of pollutant removal and infiltration. Plant selection will focus on species that are resistant to salt and extreme low temperatures, to survive Michigan’s cold winters. The team will use both research and data from the Plainfield Avenue Project to determine the specific pollutants that need to be filtered. Currently, each team member has completed at least 50 man-hours. The grand total for first semester was in excess of 200 man-hours. During the second semester, there will be an increase of approximately five hours per week per team member, because the majority of the ground work is completed and the team will focus solely on the new design. Also, we will create final drawings of our bioretention islands and a working scale model. There will be a total of approximately 460 man-hours for second semester. The total will be approximately 690 man-hours for the entire design.
Figure 4. Project Task Sequence

Phase One

Plainfield Ave

Islands → Setup ISCO Samplers → Attempted Water Sampling

Two Additional sites

Analyze the volume reduction of each structure → Determine the total effect on the whole watershed

Research

Similar Projects → Other LID Structures

New Site

Locations

Four Possible Sites → Tested Soil → Decision Matrix

Phase Two

Plainfield Ave

Interpret data from water samples → Analysis volume reduction/pollution removal

New Site

Hydrology: Flow through the system

Road Traffic Design: Road Configuration

Hydraulics: The island layout of pipes and basins

Bioretention: Plant and soil

AutoCAD drawings

Physical Model: Show Flow through the system

Model

Tested Soil → Decision Matrix
5 Basis of Design

5.1 Plainfield Avenue Bioretention Island Project

5.1.1 Background

The general approach to stormwater management has changed from conveyance of runoff away from developed sites to retaining the water on-site. As a result, many municipalities have begun implementing stormwater retention and infiltration projects. When the City of Grand Rapids planned to upgrade sewer pipes and separate combined sanitary and storm sewers underneath Plainfield Avenue, Breese Stam, a Senior Design Engineer with the city, proposed the implementation of bioretention median islands. The project garnered much support from surrounding businesses and the surrounding residents through the Creston Neighborhood Association. When public funding for the project faltered, the local community donated private funds to keep it going; in the end, privately donated funds totaled more than $150,000. This is the one of the first projects in which bioretention islands have been installed in the middle of a street; it also exemplifies a unique private-public funding partnership that could set a precedent for future projects. Construction of the project began in August 2012 and was completed in September 2012. The team attended the ribbon-cutting ceremony for the project on September 12.

The team was put in contact with Carrie Rivette from the City of Grand Rapids, who has helped provide information on the project. Because the design is brand new and bioretention itself has only emerged in the past twenty years, the city was very interested in determining the effectiveness of the new installations. The team agreed to help the city study the project, anticipating the benefits the study could
provide for the new design. In addition, the city asked the team to perform some calculations to determine the volume of stormwater that is removed by another project in the surrounding area implementing bioretention as well as pervious pavement.

5.1.2 Bioretention Islands

There are seven bioretention islands located along a one-mile stretch of Plainfield Avenue. The islands are seven feet wide and, with curbs and gutters, occupy the ten foot wide middle turn lane. They range in length from 58 feet to 222 feet. The islands treat a total watershed of 3.3 acres, and during a 1-inch storm event, the islands treat 89,600 gallons of runoff.\(^8\)

To determine the performance of the islands, the team proposed a sampling method that involved using Isco samplers to collect water at the start and end points of the flow through the bioretention island. An Isco sampler, shown in Figure 6, is a computerized device that uses a motor, a pump, a flexible collection hose, and a small reservoir to collect samples at programmed designated time intervals during a storm event. During the beginning of a storm event, the sampler is turned on, and the team collects grab samples. These samples are collected and prepared using properly calibrated instruments and containers. Measurements taken in the field include pH, dissolved oxygen (DO), and temperature. All of the sampling equipment is provided by the City, and the samples are analyzed by the City’s laboratory contact, Industrial Pretreatment. The samples must be taken and submitted to the laboratory within a certain timeframe during a given week. The laboratory is open for limited hours on Monday through Thursday. Because of this strictly prescribed scheduling and the variability of the weather, the team never had the chance to collect samples from the islands, and thus obtain pollutant removal data. This process will therefore have to be postponed until spring.

![Isco Sampler](image courtesy of www.isco.com)

5.1.3 Surrounding Areas

There are two main sites that were the focus of the new stormwater management infrastructure. The first site is located west of Plainfield Avenue (Site 1). At this location, there are 8 bioretention sites as well as one road that had pervious pavement installed along one side for parking. The bioretention installations for these projects are sections of the curb that bump out into the road, providing designated on-street parking and providing space for bioretention at the same time. The other site is located east of Plainfield (Site 2) and has 10 bioretention bump-outs, one bioswale, and several sections of pervious pavement.

To begin calculating the amount of runoff these installations remove from the existing stormwater sewer system, the team first needed to calculate the storage volume that could be expected from these structures. There are four basic kinds of storage in most stormwater management structures: surface storage, soil storage, subsurface storage, and infiltration storage.\(^3\) Surface storage is the water that can be stored above
grade and it calculated by multiplying the ponding depth and the average surface area. Soil storage is the water that can be stored in the void spaces of the soil and is calculated by multiplying the volume of soil by the void ratio of the soil. Subsurface storage refers to any engineered structure below grade that can store runoff, such as an underdrain or a catch basin. Calculation of this value depends on what kind of subsurface storage is present. Infiltration storage is an equivalent volume that accounts for the rate that water infiltrates into the surrounding soils. It can be calculated by multiplying the surface area through which water can infiltrate by the infiltration design rate and by the infiltration period (usually 6-12 hours). The City of Grand Rapids provided detailed drawings of the bioretention bump-outs implemented at Site 1 and the team used these to make the volume calculations. The team had to make several assumptions in order to perform the calculations. The team assumed a void ratio of 0.4 for the amended soil and for the storage media in the infiltration basin. The team also assumed an infiltration rate of 1.63 inches per hour, which is the design rate for Loamy Sand, a common soil type in the area. A conservative infiltration time of 6 hours was used. This particular design uses a subsurface infiltration basin, which increases its storage significantly. The results of the calculations are shown in Table 3.

**Table 3. Summary of Volume Calculations for Bioretention Bump-outs**

<table>
<thead>
<tr>
<th>Total Volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Storage Volume</td>
</tr>
<tr>
<td>Soil Storage Volume</td>
</tr>
<tr>
<td>Infiltration Basin</td>
</tr>
<tr>
<td>Surface Volume</td>
</tr>
<tr>
<td>Subsurface Volume</td>
</tr>
<tr>
<td>Infiltration Volume</td>
</tr>
<tr>
<td><strong>Total Bioretention Storage</strong></td>
</tr>
</tbody>
</table>

The same method of calculation can be easily adapted and used for virtually any LID structure. Similar calculations can be performed for the volume reduction provided by pervious pavement, but the City has not provided adequate construction details to perform these calculations.

Once the storage capacity is known, the area surrounding each bioretention structure must be studied in order to determine the contributing area. Once this is known, a runoff coefficient can be applied to determine what volume of water will run off into the structures for specific rain events. To determine the contributing area, team members used Rolatape® measuring wheels to measure the distance to the up-stream catch basin. The team assumed that the contributing area included half of the road along the measured distance as well as the lots adjacent to that side of the road. Runoff coefficients were provided by the city for the area. The coefficient used was 0.3, which is consistent with other sources for residential areas. The team calculated the volume of runoff that contributes to each structure. Figure 7 shows the volume of runoff removed by all the bioretention bump-outs as a function of the amount of rainfall.
As the rainfall increases, more and more of the bump-outs reach full capacity and can only remove 4,760 gallons of runoff. The bioretention structures that have the largest contributing area reach this maximum first. When one inch of rain has fallen, the majority of the structures reach full capacity. For a one inch rainfall event, 77,950 gallons of runoff are removed. By 3.3 inches of rainfall, all structures reach maximum capacity, and the volume removed is 90,400 gallons.

5.2 Design Components

5.2.1 Structure

The borders of the bioretention island will act as curbs for the rest of the street, so they will be constructed out of concrete. The curbs of the island will be constructed to withstand a certain level of wear and tear, associated with snow plows. The curbs will be founded more deeply in the road than normal curbs to achieve this level. The island will be concave so it can contain a certain calculated volume of water, when needed.

5.2.2 Layout

The bioretention island should be located in the middle of the road, in the space that would otherwise be a shared left turn lane (SL/TL) or regular median. Thus the width of the island will be limited by the availability of median space in the selected road. The location and length of the island, within the median space, is dictated by the positioning of existing drive ways and intersecting roads which require left turn movements.

There may be catch basins located on the sides of the streets which will be connected by piping to the infiltration basins in the island. Water will flow from the street to the catch basin. From the catch basin, the water will flow to the primary infiltration basin (ditch basin). For low volumes, this will be the water’s last stop, as it infiltrates into the ground, and becomes ground water. For higher volumes, the ditch basin will overflow into the island. The water will then infiltrate into the island’s soil, and for even higher volumes, the water will flow to the secondary infiltration basin (leaching basin). An underdrain (perforated pipe) exists underneath the island. The underdrain collects water from the surrounding area,
keeping the local water table at a desirable level. The water in the underdrain flows to the leaching basin. Within the leaching basin, the water has a chance to infiltrate into the ground, unless there is a significantly high volume, in which case, the water overflows directly into the existing storm sewer system. Within the island, there will be a certain combination of plants and soils, which will help in the infiltration and evapotranspiration aspects of bioretention. Error! Reference source not found. and Figure 9 show the plan and profile, respectively, of the general layout of how the islands will work. Figure 10 shows the flow of water through the island for varying degrees of rainfall intensity.

Incorporated into the island will be an access point through which the water quality can be tested regularly, according to a monitoring schedule. This will facilitate the determination of the performance of the island.

![Figure 8. Plan View of Preliminary Design for Bioretention Island](image-url)
Figure 9. Profile View of Preliminary Design for Bioretention Island
Figure 10. Flow Paths through Bioretention Island for Varying Storm Events
5.2.3 Catch Basins

The position of the catch basins will partially depend on the existing locations of catch basins, which originally fed the storm sewers directly. Primarily, though, the position of the catch basins will depend on the location of the island, as they must be located near the island’s ditch basin, allowing shorter connecting pipes. The catch basins will be designed to hold a certain volume of water to allow for settling, before flowing to the ditch basin. A typical catch basin detail is shown in Figure 11.

![Figure 11. Detail of Typical Catch Basin](image)

5.2.4 Infiltration Basins

There will be primary and secondary infiltration basins, called ditch basins and leaching basins, respectively. The ditch basin collects water from the catch basins on the side of the road. It gives the water a chance to infiltrate into the ground, and then allows the water to overflow into the island, during high volumes. The leaching basin collects overflow from the island and also contains holes in the sides for collecting water from the surrounding area, with the same function as the underdrain: to maintain the water table at a desirable level. Details for typical infiltration basins are shown in Figure 12.

![Figure 12. Details for Infiltration Basins](image)
5.2.5 Soils

The soils in the island itself consist of a top layer of a mulch blanket or some form of geotextile to minimize soil erosion during high-volume rain events. Below that will be approximately three feet of planting soil. The planting soil is necessary to facilitate the growth of plants within the infiltration basin. For the purpose of infiltration, the planting soil will include 30-50 percent sand.3 Within the planting soil, at least 18 inches below the surface, there will be an underdrain, in order to control the level of the local water table and drain the surrounding soil if it is excessively saturated during a high-volume rain event. Below the planting soil lies the in situ soils, which are analyzed for the project site location analysis in Subsection 5.2.8. Figure 13 shows the profile arrangement of the various soil depths within the bioretention island.

![Figure 13. Soil Depths for Preliminary Design of Bioretention Island](image)

5.2.6 Plants

The plants to be selected for integration into the bioretention island include those that are local, salt-resistant, require minimal maintenance, and grow primarily vertically. Ideally, plants in the island will have all of these characteristics, but the health and functionality of the plants will be the highest priorities. Some possible types of plants are grasses, flowers, and trees. Grasses and the roots of trees allow for further erosion prevention. Flowers facilitate the goal of aesthetic improvement of the urban environment. Western Michigan lies in a region that the United States Department of Agriculture (USDA) designates as Hardiness Zones 5 and 6. The USDA Hardiness Zones record a region’s average extreme low temperature. These zones are then referenced when describing a plant’s ability to thrive in a certain area.11 This will be a basis of plant selection for the bioretention islands. See Table 4 for an analysis of possible plants to be implemented in the islands. The appendix contains an image and description for each of the plants listed in Table 4.
Table 4. Strengths and Weakness of Plant Candidates

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trees</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accolade elm (“Morton”)</td>
<td>• grows well in most soils</td>
<td>• does not grow well in extremely saturated soils</td>
</tr>
<tr>
<td></td>
<td>• drought-tolerant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• cold hardy</td>
<td></td>
</tr>
<tr>
<td><strong>Shrubs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scarlet Pavement Rugosa Rose</td>
<td>• disease-resistant</td>
<td>• annual pruning required</td>
</tr>
<tr>
<td></td>
<td>• cold hardy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• survive in poor soils</td>
<td></td>
</tr>
<tr>
<td>Neon Flash Japanese spirea</td>
<td>• high snow damaged tolerance</td>
<td>• no salt tolerance</td>
</tr>
<tr>
<td></td>
<td>• pruning not required</td>
<td></td>
</tr>
<tr>
<td><strong>Flowers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butterfly milkweed</td>
<td>• can grow on various soils</td>
<td>• intollerant of shade</td>
</tr>
<tr>
<td></td>
<td>• high drought tolerance</td>
<td>• no salt tolerance</td>
</tr>
<tr>
<td>“Stella de Oro” daylily</td>
<td>• adapted to multiple soils</td>
<td>• short lifespan</td>
</tr>
<tr>
<td></td>
<td>• drought resistant</td>
<td>• low salt tolerance</td>
</tr>
<tr>
<td>Becky Shasta daisy</td>
<td>• adapted to multiple soils</td>
<td>• low salt tolerance</td>
</tr>
<tr>
<td></td>
<td>• drought resistant</td>
<td></td>
</tr>
<tr>
<td>Kobold spike gayfeather</td>
<td>• minimal maintenance required</td>
<td>• adapted to limited soils</td>
</tr>
<tr>
<td></td>
<td>• moderate lifespan</td>
<td>• low salt tolerance</td>
</tr>
<tr>
<td>Orange coneflower</td>
<td>• flourish in ordinary soils</td>
<td>• maintenance required</td>
</tr>
<tr>
<td></td>
<td>• extreme temperature resistant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• drought resistant</td>
<td></td>
</tr>
<tr>
<td>Brilliant sedum</td>
<td>• adapted to multiple soils</td>
<td>• maintenance required</td>
</tr>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pennsylvania sedge</td>
<td>• drought resistant</td>
<td>• thrives in dry soil</td>
</tr>
<tr>
<td>Kaskade Japanese silver grass</td>
<td>• disease resistant</td>
<td>• needs regular watering</td>
</tr>
<tr>
<td>Purple moor grass</td>
<td>• drought resistant</td>
<td>• needs full sun</td>
</tr>
</tbody>
</table>

5.2.7 Traffic & Road

One goal for the design of the bioretention islands is to have no negative impact on traffic patterns. One method used to achieve this was by choosing site locations for which the lane configuration would not need to be changed, as that would require more road construction, as well as increase the cost. All two-lane roads were dismissed as unfeasible locations, as were multilane roads which lacked a shared left-turn lane (SLTL). Preference was given to roads which had wider SLTLs, allowing for more space for the island.
Another technique to minimize impact on traffic will be through careful placement of islands to avoid blocking driveways and cross streets. Several sites were chosen in part because of the inactivity in the SLTLs at that specific location.

High traffic volumes on a road (but not in a SLTL), increased the feasibility of a given location, as more vehicles contribute more contaminants to the stormwater. This is taken into account in the “Necessity” component of the location analysis, discussed below.

5.2.8 Project Sites

To decide on a location for the implementation of the new bioretention island design, the team brainstormed locations, using Google Maps as a reference, which could potentially fit the necessary requirements. The team discussed about 10 to 15 possible locations, and narrowed this down to four final possible candidates for the project site.

These four possible candidates are the following:

- Location 1: Monroe Avenue NW between Pearl Street NW and Louis Street NW; another possible location, where Monroe Avenue NW becomes Market Avenue NW between Fulton Street NW and Weston Street NW
- Location 2: Michigan Street NW between Coit Avenue NW and Monroe Avenue NW
- Location 3: Leonard Street NW between Muskegon Avenue NW and McReynolds Avenue NW
- Location 4: Leonard Street NE between Plymouth Avenue NE and Ball Avenue NE

Location 1 is shown in Figure 14 and Figure 15; Location 2 is shown in Figure 16 and Figure 17; Location 3 is shown in Figure 18; and Location 4 is shown in Figure 19. The team analyzed these sites based on several criteria. These criteria include soil composition, impervious coverage, effect on traffic, available space, and potential funding.
Figure 14. First Island at Location 1 (image courtesy of Google Maps)

Figure 15. Second Island at Location 1 (image courtesy of Google Maps)
Figure 16. First Island at Location 2 (image courtesy of Google Maps)

Figure 17. Second Island at Location 2 (image courtesy of Google Maps)
In order to analyze the soil composition for each site and make sure the water table was low enough below ground level so that it would not inhibit infiltration, the team performed soil tests at each location. To do this, the team was required to obtain a temporary occupancy permit for each location. Then the team called MISS DIG System, Inc. in order to make sure it was safe to dig at each location. MISS DIG System, Inc. is a company that specializes in safety and damage prevention pertaining to underground utilities. After these first steps were taken, the team used a soil boring hand auger, borrowed from Fishbeck, Thompson, Carr & Huber (FTC&H), to dig to about eight feet underground and record the levels of each soil layer. At each of the four locations, the first one to two feet was sod, top soil, planting soil or mulch. The other soil types that the team came across were sand, loamy sand, and clay. Figure 20 shows the soil layers for each of the four locations.
Location 1 is strong in all of the above-mentioned criteria. Its soil consists of loamy sand and sand, all the way down to 9 feet. There are two areas here that contain enough space (both length and width) to contain a good-sized bioretention island, due to an excess of open SLTL space. At these areas, if the bioretention islands are implemented there, it will have a negligible negative effect on traffic. This area, although located in the middle of downtown Grand Rapids, is also located right next to a park, known as Rosa Parks Circle. Because of the park, the amount of impervious coverage is reduced, and thus infiltration is needed slightly less. There are, however, plenty of buildings and pavement surrounding the rest of the area. Surrounding Location 1 are many businesses and institutions, including The B.O.B., TGIF, Rosa Parks Circle, an art museum, and several banks and other restaurants. Due to the aesthetic improvement effect that a bioretention island would have on this area, it is conceivable that these businesses and institutions would be willing to provide funding to support the construction of this project.

Location 2 is fairly strong in most of the criteria, except for soil. Its soil consists of loamy sand, with some small aggregate, all the way down to about 6 feet; however, the soil testing was impeded by an unknown engineered structure below ground. It is possible that this sort of structure runs throughout this area. Based on visual inspection both at the site and through Google Maps, the team deduced that placing
an island at a couple of available lengths of road would have a negligible negative impact the traffic. Although the width of the SLTL is comparable to that of Location 2, the length available was slightly less, due to an increased number of driveways and access roads. The area surrounding Location 2 is highly urban, since it is in downtown Grand Rapids. It is in the middle of what is known as the “Medical Mile,” surrounded by large buildings and impervious pavement. Thus, Location 2 can definitely benefit from the implementation of a bioretention island. Finally, surrounding Location 2 are several businesses and institutions, including Van Andel Institute, Helen Devos Children’s Hospital, Spectrum Health, and Michigan Medical. It is conceivable that these businesses and institutions would be interested in the positive environmental and community impact that bioretention islands could have, and thus would want to provide funding for the construction of this project.

Location 3 is moderate in all of the criteria. The soil consists of sand to about 3 feet, where the team encountered large aggregate. While sand is good for infiltration, the aggregate made it hard to dig, and the team was unable to go any further with the sample. In this location, the driveways and intersections are close together, not allowing for a lot of length for a bioretention island. Also, the existing SLTL is narrower than in Locations 1 and 2. The traffic in this area would be affected more negatively, since it is generally a more compact area. While there are buildings and parking lots in the surrounding area, Location 3 is significantly more residential than Locations 1 and 2, and has less of a need for bioretention.

Location 4 is poor to moderate in most of the criteria, except for effect on traffic. This area is wide open, with no great need for left turn movements, so a bioretention island’s effect on traffic would be minimal. Its soil consists of loam and loamy sand to about 6.5 feet. From there, the soil becomes clay and near impossible to dig with a hand auger. If the clay continues for a decent depth, it will render natural infiltration nearly impossible. In the area of Location 4 there is a strip mall, but nothing else. Possible funding would be lacking in this area. There is only one length of road in this area that could fit between the driveways to the strip mall, so the length available is minimal, and the width of the existing SLTL is narrower than in Locations 1 and 2.

The team constructed a design matrix for the four locations. Table 5 shows this decision matrix. Because of their strengths in all 5 criteria, the team decided on Locations 1 and 2 for implementation of the new bioretention island design.

Table 5. Decision Matrix for Project Site Location

<table>
<thead>
<tr>
<th>Category</th>
<th>Soil</th>
<th>Effect on Traffic</th>
<th>Potential Funding</th>
<th>Available Space Width</th>
<th>Necessity</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.6</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Location 1</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>32.2</td>
</tr>
<tr>
<td>Location 2</td>
<td>5.5</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>Location 3</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>23.1</td>
</tr>
<tr>
<td>Location 4</td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>19.3</td>
</tr>
</tbody>
</table>

5.2.9 Cost

The cost of the project is broken up into two categories: cost for the team and actual construction cost of the islands. The team’s cost is the real costs the team will incur throughout the academic year. The construction cost is the estimated cost to construct the final design. The majority of the team costs will be related to the construction of a scale model of the final bioretention island design. The team aims to
create a model that will simulate a storm event and the ensuing runoff, infiltration, and bioretention. Table 6 illustrates the estimated cost breakdown for the proposed model.

**Table 6. Estimated Cost Breakdown of Proposed Model**

<table>
<thead>
<tr>
<th>Element</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plywood</td>
<td>$20.00</td>
</tr>
<tr>
<td>Aquarium</td>
<td>$120.00</td>
</tr>
<tr>
<td>Sheet Metal</td>
<td>$30.00</td>
</tr>
<tr>
<td>Gravel</td>
<td>$8.00</td>
</tr>
<tr>
<td>Soil</td>
<td>$12.00</td>
</tr>
<tr>
<td>Lining</td>
<td>$10.00</td>
</tr>
<tr>
<td>Pump</td>
<td>$60.00</td>
</tr>
<tr>
<td>Flexible Hose</td>
<td>$7.00</td>
</tr>
<tr>
<td>Valve</td>
<td>$3.00</td>
</tr>
<tr>
<td>PVC Pipes</td>
<td>$10.00</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>$280.00</td>
</tr>
<tr>
<td>Contingency</td>
<td>$84.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$364.00</td>
</tr>
</tbody>
</table>

Construction costs were estimated using budget information obtained from the City of Grand Rapids for the recently completed Plainfield Avenue bioretention project. The information included the City Engineer’s estimate for each aspect of project completion as well as the bid packages from five different construction companies. For estimating the cost of final design, the team selected line items that it deemed applicable and estimated an average unit cost by looking at the line item from all five construction companies. For the sake of this estimate, the team assumed that the final design would consist of four bioretention islands each 100 feet long. The construction cost estimate is contained in Table 7.
Funding for the engineering budget will be provided exclusively by Calvin College. If the final design were to be constructed, the funding for the project would need to be raised through state funds and from private donors. An application would be made for a Michigan Department of Transportation (MDOT) Enhancement Grant and an MDOT Resurfacing Grant. The private donors would likely be the business owners and institutional heads in the surrounding area of the project site.

5.2.10 Storm Events

The typical design storm used for LID structures is a twenty-four hour, two year storm event. According to *Rainfall Frequency Atlas of the Midwest* Bulletin 71, such a storm in Kent County, Michigan produces 2.37 inches of rainfall depth.

The team will create a hydrologic model using HEC-HMS computer software. Frequency and duration of the design storm will be inputs for the model, as will be the contributing area. The soil type and land use, used to determine the runoff coefficient, will also be an input for the software. The team will run models using the Rational Method and SCS Method. The Rational Method uses the following equation to determine the peak discharge, \( Q \):

\[
Q = CIA
\]

(eq. 1)

where \( C \) is a runoff coefficient, \( I \) is the rainfall intensity, and \( A \) is the contributing area. The SCS Method uses unit hydrographs to determine the peak discharge.
The runoff response for the site locations will be calculated in a similar manner to what was done for Plainfield Avenue’s surrounding areas in Subsection 5.1.3. The volume reduction due to infiltration and the peak reduction due to detention of stormwater in the island will be determined. Next, the effect of the bioretention island on the stormwater system can be understood.

5.3 Scale Model

5.3.1 Purpose

A scale model of a sample bioretention island will be created to demonstrate the design and function of the actual islands. The goal is to illustrate the flow of the water through the catch basin, infiltration basins, pipes, and the island itself, on its way to the storm drain. The model will serve as an educational tool for teaching about our individual project, in addition to stormwater management and BMPs in general. The team’s vision for the model is that it will be used in the lobby of Calvin College’s Engineering Building in order to generate interest in and appreciation for stormwater management and green infrastructure, encouraging stewardship for the earth.

5.3.2 Design

The model will be a one inch to one foot (1":1’) scale model with pump-operated storm simulation capabilities. There will be a circulating water stream with an adjustable valve to simulate various storm events. The final design of the model is yet to be decided. It will either be housed in a fish tank or will be constructed of plywood and Plexiglas. Either way, the design will permit observation of the model at work. Half of the model’s surface will be removable, with the street cut down the middle, to show a cross-section of the island, including the infiltration basins, the underdrain, and the soils. The model will represent a 48-foot island, which is shorter than real-world islands, but will be sufficient in demonstrating their function. A reservoir in the back of the model will house the pump necessary to transport the water to a shower head at the front end.

Preliminary sketches were drawn for the scale model, at a one inch to one foot scale (1":1’). A profile view of the scale model is illustrated in Figure 21. Plan views for the surface and subsurface of the scale model are shown in Figure 22 and Figure 23.

![Figure 21. Profile View Sketch of Scale Model](image-url)
Figure 22. Plan View Sketch of Surface of Scale Model

Figure 23. Plan View Sketch of Subsurface of Scale Model
6 Conclusion

Team 6 concludes that the urban bioretention project is indeed feasible. Through the use of a decision matrix, drawings, research, soil testing, and traffic observation, the team determined the two chosen locations on Monroe Avenue and Michigan Street to be the most feasible sites for the bioretention island design. Though unable to collect water sampling data, the team is prepared to move on with designing the structural layout and performing the hydrologic modeling.
7 References


8 Acknowledgements
8.1 Calvin College
Glen Remelts, research
Steven VanderLeest, course instructor
David Wunder, advisor
8.2 City of Grand Rapids
Breese Stam, Plainfield project information
Carrie Rivette, Plainfield project information and City of Grand Rapids liaison
Harold Boucher, sampler setup
Industrial Pretreatment, water sampling data
Jonathan Oeverman, soil boring permit
8.3 Fishbeck, Thompson, Carr & Huber, Inc.
Claire Schwartz, industrial consultant and LID manual
Elise Tripp, soil boring equipment
8.4 Miss Dig
## Appendix

<table>
<thead>
<tr>
<th>Image</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="http://www.beavercreeknursery.com/plantdetails.cfm?ID=581" alt="Shrub Image" /></td>
<td>Rosa rugosa</td>
<td>Scarlet Pavement Rugosa Rose</td>
<td>“Rugosa roses are named for their rugose, or ‘wrinkled’, leaves. Very fragrant single red-mauve flowers in June, with some rebloom through the summer. Wonderful fruit (hip) display from late summer into winter. Very good fall color.” <a href="http://www.beavercreeknursery.com/plantdetails.cfm?ID=581">Link</a></td>
</tr>
<tr>
<td><strong>Spiraea japonica</strong></td>
<td><strong>Neon Flash Japanese spirea</strong></td>
<td>“A new spirea discovered in the wilds of Japan. More vigorous than 'Anthony Waterer', new growth has a tinge of burgundy on edges. Summer display of bright reddish pink flower clusters that look like a flash of neon against a dark evening sky.”</td>
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<tr>
<td><strong>Flowers</strong></td>
<td><strong>Asclepias tuberosa</strong></td>
<td><strong>Butterfly milkweed</strong></td>
<td></td>
</tr>
<tr>
<td><img src="https://commons.wikimedia.org/wiki/File:Asclepias_tuberosa.jpg" alt="Asclepias tuberosa" /></td>
<td><img src="https://commons.wikimedia.org/wiki/File:Asclepias_tuberosa.jpg" alt="Asclepias tuberosa" /></td>
<td>“Asclepias tuberosa is a species of milkweed native to eastern North America. It is a perennial plant growing to 0.3–1 metre tall, with clustered orange or yellow flowers from early summer to early fall.”</td>
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</tr>
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<td><strong>Wikipedia</strong></td>
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<tr>
<td><img src="http://www.beavercreeknursery.com/plantdetails.cfm?ID=758" alt="Daisy" /></td>
<td>Daisy</td>
<td><em>Leucanthemum x superbum</em></td>
<td>“The flowers are huge with pale lemony yellow large golden eye. As they age they will fade to a creamy yellow.”</td>
</tr>
<tr>
<td>Image</td>
<td>Name</td>
<td>Description</td>
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<tr>
<td><img src="https://commons.wikimedia.org/wiki/File:Rudbeckia_fulgida02.jpg" alt="Rudbeckia fulgida" /></td>
<td>Rudbeckia fulgida</td>
<td>Orange coneflower</td>
<td>“Perennial herbaceous plants growing up to 120 cm tall, growing from rosettes that develop at the end of stolons.”</td>
</tr>
<tr>
<td>Plant Name</td>
<td>Common Name</td>
<td>Description</td>
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<tr>
<td>Sedum spectabile</td>
<td>Brilliant sedum</td>
<td>“Deep lavender flowers from late summer to first frost. Light green, fleshy succulent foliage forms rounded mounds. Full sun to light shade. Tolerates a range of well drained, moisture retentive soils.”</td>
<td></td>
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</table>

http://www.beavercreeknursery.com/plantdetails.cfm?ID=964

<table>
<thead>
<tr>
<th>Plant Name</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Carex pennsylvanica</td>
<td>Pennsylvania sedge</td>
<td>“This sedge forms short clusters and spreads slowly by rhizomes to form a lush carpet. This thick mat of growth provides excellent seasonal cover for foraging small songbirds and the insects and other small animals they love to eat. Reddish-brown, thimble-like flowers top the narrow, fine textured leaves in spring. A number of birds and small mammals feed on the seeds.”</td>
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<tr>
<th><strong>Miscanthus sinensis</strong></th>
<th><strong>Kaskade Japanese silver grass</strong></th>
<th>“Upright clumping grass. Purple/pink in July/August bloom. Turns white in early fall. Named for the bright orange red foliage. Nice as a specimen or small group.”</th>
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<tr>
<th><strong>Molinia caerulea</strong></th>
<th><strong>Purple moor grass</strong></th>
<th>“Molinia caerulea is a bunchgrass tussock-forming perennial, growing up to 90 cm tall, (taller when sheltered by gorse and heather), with many closely packed stems.”</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="https://commons.wikimedia.org/wiki/File:Molinia_caelurea_5952_001.jpg">Image</a></td>
<td><a href="https://en.wikipedia.org/wiki/Molinia_caerulea">Image</a></td>
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