The University of Iowa
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FINAL DELIVERABLE

Title	Bellevue Stormwater Management Structure and Plan for New Residential Development
Completed By	Diana Gerxhaliu, Cassidy Lindow, Faye Momodu
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UI Department	Department of Civil & Environmental Engineering
Course Name	CEE:4850:0001 Project Design & Management
Instructor	Richard Fosse
Community Partners	City of Bellevue, Jackson County Economic Alliance

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City of Bellevue Expansion Project
Final Design Report

INNOVATIVE INFRASTRUCTURE

Requested by: *Jackson County Economic Alliance*

Prepared by: Diana Gerxhaliu, Cassidy Lindow, Faye Momodu

December 2019

University of Iowa
Department of Civil and Environmental Engineering

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Section I Executive Summary

The following document is a final stormwater design report for the City of Bellevue Expansion Project. Innovative Infrastructure consists of two teams that worked cohesively to create a land development and stormwater management design for a 50-acre parcel in Bellevue, IA. Bellevue is a city in Jackson County, Iowa. The city lies along the Mississippi River and is next to Bellevue State Park. In 2018, the population of Bellevue was 2,196. Jackson County Economic Alliance is the sponsor of this new development and tasked Innovative Infrastructure to research and design different alternatives for stormwater management.

The client's goals for stormwater management are to slow down stormwater, allow pollutants to settle, and have a habitat that can support wildlife. All proposed designs incorporate these factors, as shown in the Appendices. Innovative Infrastructure determined what locations within the 50 acres of land were the best site location for stormwater management. Various alternatives were considered and presented to the client, but two stormwater strategies were chosen. These strategies work seamlessly with the land development layout of the parcel to design a sustainable development.

The scope of services for this project include a site plan with construction boundaries for the parcel. An existing and future grading and utilities plan have been included. The stormwater management system was sized along with the inlet and outlet structures. Lastly, a vegetation plan was completed as well as an operations and maintenance plan. For this design, Diana was in charge of the Civil 3D drawings, the basemap, and the grading plan. Faye designed the bioretention cell and chose the needed vegetation. Cassie designed the retention basins, stormwater collection system, and completed the cost estimate.

To best fit the site as well as accomplish the goals, two retention basins and a bioretention cell were designed. A hydraulic analysis for a 100 year storm has been completed to calculate the amount of runoff pre and post development. Hydrology Studio, an accredited software, helped calculate the retention basin dimensions required to hold the runoff and infiltrate into the soil. Using the ISWMM manual, the bioretention cell has been designed and calculations are shown in Appendix A. The bioretention cells are designed to improve the water quality and attract more pollinators to the development. The bioretention cells will temporarily store and readily infiltrate the runoff from the proposed area. The majority of the runoff from the site will drain to the north and south retention basins. A stormwater collection system was also designed for the water to go into the two stormwater strategies.

Figure 1.1: Vision for Bioretention Cell

The total estimated cost for the stormwater system is **$628,500**. The annual cost for operations and maintenance is $4,415. The project will be done in three phases and the first phase will cost **$184,536** which includes the temporary stormwater protection needed.

This development will provide a great living environment for future residents of Bellevue, Iowa. It will permit the development of this property without adverse stormwater impacts on adjacent properties.

Section II Organization Qualifications and Experience

1. Name of Organization

Innovative Infrastructure: Stormwater Management Division

2. Organization Location and Contact Information

Innovative Infrastructure is located in the Seamans Center at 103 S Capitol St, Iowa City, IA 52252. The main contact and project manager for this project will be Cassidy Lindow. Cassidy can be reached via email: cassidy-lindow@uiowa.edu or by phone: 920-264-2273.

3. Organization and Design Team Description

The stormwater division of Innovative Infrastructure is a group of advanced University of Iowa students in the capstone design class instructed by Richard Fosse. Each member of the team has a unique specialty that compliments the other members. Cassidy and Faye are specializing in environmental engineering while Diana specializes in civil engineering. Cassidy Lindow was the project manager. Cassidy led the work on the cost estimate, storm sewer design and support for other design drawings. Faye Momodu was the editor for the project. She led the work on the reduction of pollutants, wildlife habitats, and bioretention cell design. Diana Gerxhaliu was the technical support. Diana led the work on the site design and final plan drawings.

Section III Design Services

1. Project Scope

The scope of this project was to design different alternatives for stormwater management structures for a 50 acre plot of future developed land. The stormwater division provided 3 alternative methods for stormwater management for the land. Our division worked in collaboration with the land development division to design a stormwater management system, and a site plan. Both divisions worked together, so that the final designs complement each other. The Stormwater Management project scope is listed below.

- Base Map
- Design Alternatives
- Grading Plan
- Sizing of Inlet and Outlet Structures
- Stormwater Collection System Design
- Retention Basin Designs
- Bioretention Cell Design
- Vegetation and Monitoring Plan
- Operations and Maintenance Plan

2. Work Plan

A Gantt chart, shown in Table 3.1, was created in order to easily portray the timeline of the semester long project. This Gantt chart identifies all of the large project goals and deadlines. Responsibilities were assigned to each team member to ensure an even distribution of the tasks. Cassidy took the lead of the cost estimate, hydraulic analysis, design of retention basins, and organization of the team. Faye took the lead on choosing the vegetation, the landscaping plan, and the design of bioretention cells. Diana took the lead for the base map, grading plan and all AutoCAD and Civil 3D tasks along with the stormwater construction drawings.

Table 3.1: Gantt Chart for Stormwater Management Project

Topics	September	October	November	December
Site Visit				
Proposal				
Finalize Alternatives				
Site Location/Selection				
Site & Grading Plan				
Construction Notes				
Construction Drawings Set				
Stormwater System Design				
Draft of Report				
Draft of Poster				
Draft of Presentation				
List of Materials				
Cost Estimate				
List of Entity or Agency; Permits				
Submit draft to client				
Revise all draft documents				
Submit final documents				
Submit final documents to client				
Final Presentation				

Table 3.1: Highlights the main tasks that were completed and whom was leading the completion of said task. Project Manager, Cassie Lindow led the tasks in yellow. Faye Momodu led the tasks in red, and Diana Gerxhaliu led the tasks in green, and the entire group worked on the tasks in orange.

Table 3.2: Responsibilities for Team Members for Final Report

Final Report	12/13/19
Executive Summary	All
Experience with Similar Projects	Diana
Project Scope	All
Work Plan	Cassie
Method/Design Guides	Faye
Constraints	Faye
Challenges	Diana
Societal Impact	All
Design Alternatives Considered	Faye
Final Design Details	All
Engineer's Cost Estimate	Cassie
Proposal Attachments	Diana

Section IV Constraints, Challenges and Impacts

1. Constraints

Constraints for this project include space, environmental considerations, time, and accessibility to the project site. The 50 acre area of land that has been purchased limits the project to a few areas of a specific size which reduces options for the project. The regulations are enforced by the Environmental Protection Agency as well as Iowa DNR. Time is a constraint for this project as all final designs are due December 13th, 2019.

Constraints can also be based on a parcel of land and its condition. A soil analysis was completed to ensure infiltration of the stormwater was possible. Since Iowa's soil is mostly clay based, the soil analysis was important to consider for possible stormwater alternatives.

2. Challenges

Challenges for the project included continuous access to a small cabin on the back of the property, and a site depression at the SW corner of the parcel, as well as connecting the drainage of this parcel to Bellevue's wastewater treatment plant. Another challenge was keeping up with the ideas from the land development group, so that the alternatives from stormwater were in compliance with their design ideas. Also, as a big group with two divisions, time management and group organization were key to getting work done efficiently and being successful for this project. Continuous communication was key throughout this project to create one seamless design from the two divisions.

A challenge for the team was learning new technical software. Most of the team has not had exposure to stormwater modeling programs, GIS or Civil 3D, so the usage of this technology was challenging. This was an expected challenge within any design project.

3. Societal Impact within the Community and/or State of Iowa

The City of Bellevue is a community of around 2,100 people. In the 2010 Census, Jackson County had a population of 19,848, a slight decrease from 2010. 41 percent of Jackson County is made up of unincorporated areas meaning that the City of Bellevue is the second largest community. The demographic of the City of Bellevue is mostly baby boomers, thus an aging population. This development will encourage more young families and adults to move into this smaller community. In 2017, a group of students from the University of Iowa developed a marketing strategy for Jackson County. Their goal was to capitalize off of the natural features and cultural amenities within the county. Jackson County is actively looking to grow their community by using these campaigns and development projects to attract the younger generation. With project ideas like this one, the impact on City of Bellevue and Jackson County have the opportunity to grow. This project is largely supported by the City of Bellevue, especially financially. By developing a community that caters to a younger demographic, the population can stay consist or increase in the future.

The negative impacts of stormwater components of this project will be minimal and will mainly occur during times of construction. There are few trees in the designated area that may need to be removed. Erosion control practices such as silt fences and silt bags will be used to minimize the potential risk of stormwater eroding the soil during construction. These are affordable solutions to avoid any loss of topsoil from the development. Overall, this project can benefit the City of Bellevue by providing more housing opportunities in a sustainable development.

Section V Alternative Solutions That Were Considered

There were originally three alternatives that were considered for the project. The first alternative was constructed wetlands, followed by a stormwater pond and lastly a biofiltration swale. Each alternative was analyzed based off of what fits best for the design as well as what fits our client's needs.

Throughout the semester, our team was able to visit with the City of Bellevue regarding their vision and needs for the stormwater system. They expressed that the stormwater system needs to have good public perception with low cost and low maintenance requirements. They also preferred a method that blends in well with the landscape and does not contain standing water at all times.

The first stormwater alternative suggested by the team was constructed wetlands. Figure 5.1 shows a vision of what our team had in mind for this alternative. Benefits of constructed wetlands at the Bellevue site include being inexpensive to construct and operate for any volumes of water. They are also easy to maintain since they regenerate on their own and require little upkeep. One of the objectives that the client had was that they wanted a stormwater solution that supports wildlife and habitat. Constructed wetlands play an important role in the ecology, and support wildlife as many species of birds and mammals rely on them for food, water, and shelter, especially during migration and breeding. The downside of this alternative is that wetlands limit what can be done on the land as they take up a lot of space. Wetlands also contain a permanent pool of water at all times, and this is something that the client expressed they did not want.

Figure 5.1: Constructed Wetlands Vision

Alternative number two was stormwater ponds. Stormwater ponds are thought of as either wet or dry. Wet ponds are sized to consistently have a pool of water, not depending on the weather (Ponds, 2015). Dry ponds are a grassy, dry area the majority of the time, except for after a storm event. Once the dry ponds contain water, the water will infiltrate into the soil to create a dry pond within days. The advantage to stormwater ponds is that they can be designed to be used in common areas and can be designed to attract local wildlife. The vegetation that surrounds the shore of the pond provides a filter before water enters into the retention pond, thus improving the quality of the water entering the pond (Chavan, 2018). One downside to stormwater ponds is the required maintenance. Without proper maintenance, nutrients such as nitrogen and phosphorus that are typically found in stormwater runoff can accumulate in wet ponds leading to degraded conditions such as low dissolved oxygen, algae blooms, unsightly conditions and odors. Also, draining and cleaning of a stormwater pond can be expensive and time consuming (Chavan, 2018). When presenting the alternative of stormwater ponds to the City of Bellevue they expressed concerns about the required maintenance. Bellevue is a smaller town and they have concerns about who will be responsible for the maintenance of the stormwater ponds. The cost of maintaining the stormwater ponds was also a concern for the city. Figure 5.2 shows the vision the team had for the stormwater ponds.

Figure 5.2: Stormwater Pond Vision

Stormwater alternative 3 was a biofiltration swale. Biofiltration swales are used to provide treatment of the surface runoff. Biofiltration swales slow down stormwater, provide the uptake of pollutants and help settle pollutants. They aid in providing stormwater quality by using grass or other dense vegetation to filter sediment and oily materials out of stormwater when designed properly (ERRATA, 2016). If properly designed, biofiltration swales can be very aesthetically pleasing as they usually they look like flat-bottomed channels with grass growing in them and they blend in easily with the landscape. Biofiltration swales can be a lower construction cost for stormwater measures. There is a higher maintenance cost for this alternative since inspecting the swales at least every six months is required to make sure that adequate grass growth is maintained and removal of built up sediment and debris in the swale.

Initially, when presenting this stormwater alternative to the client this was their top choice. They liked the way that it would blend in with the landscape and they felt it was the best fit for the site. After the city selected this alternative, our team had the opportunity of meeting with Amy Bouska who is with the Johnson County Soil and Water Conservation District. Amy works directly with the Iowa Department of Natural Resources Stormwater Manuals (ISWMM) and based on the standards for the design of a biofiltration swale our team learned that we would not be able to meet those standards. The design of a biofiltration swale requires 1,200 linear feet of bioswale. The amount of linear footage is critical to the design of a bioswale as the water needs to be in contact with the vegetation of the bioswale long enough to achieve water quality. We also learned that our large site of 50 acres was too much drainage for a bioswale. Amy suggested that the best stormwater measures for our site are bioretention cells to achieve water quality and retention basins to control the water quantity. After speaking with the client and receiving approval from them regarding the new stormwater alternatives, our team decided to proceed with the final design of bioretention cells and two dry retention basins.

Section VI Final Design Details

Grading Design

The grading plan maintains positive drainage, ensures water is draining away from the foundation down to the roads, or lower retention basins, then enters a storm water drainage and exits the property. The grading plan shows how much cut and fill is needed for the site, and defines information that the proposed site will exhibit post construction. Existing contour lines show a lower area by the Southwest corner of the parcel, in which the city of Bellevue had borrowed soil for a project and everything else was relatively flat agricultural land. There is no need of buying soil, all will be moved within the parcel as necessary.

With the grading plan final revisions done, there is a net of 1698 cubic yards of cut required within the parcel, mainly needed for the Southwest corner, roads, and the entrances to match the highway 52 elevations. A slope of ⅓" per foot is used for the entire site. Based on the lot divisions, water drains away from buildings and down to the roads and the roads drain to the two retention basins located in the Southwest and Northeast corners of the site. The majority of storm water drainage from this development will be directed to stormwater management facilities before leaving the site.

Block 1 and half of block 4 on the east side of the site will drain to the ditch, and block 2 will be draining down to the road and there is no drainage coming into block 2. Block 7 and half of 8 on the South side of the parcel will drain down to the hill and the other half of block 8 will be draining to the road. These are the four blocks that are draining off site, and block 3, 5, 6, and half of 8 drainage is kept on site. Block 3 will be draining inwards to the small vegetation area, which will require a stormwater intake there that will be tied into the storm sewer system. Block 5 and 6 displays a ridge view with the middle lines acting as high points and the lots draining down to the lower points (roads). Lastly, the front of the blocks 2, 3, and 6 must drain to the streets. Then, the roads drain to the retention basins nearby. See Figure 6.1 for a detailed overall block, and road drainage visual of the site.

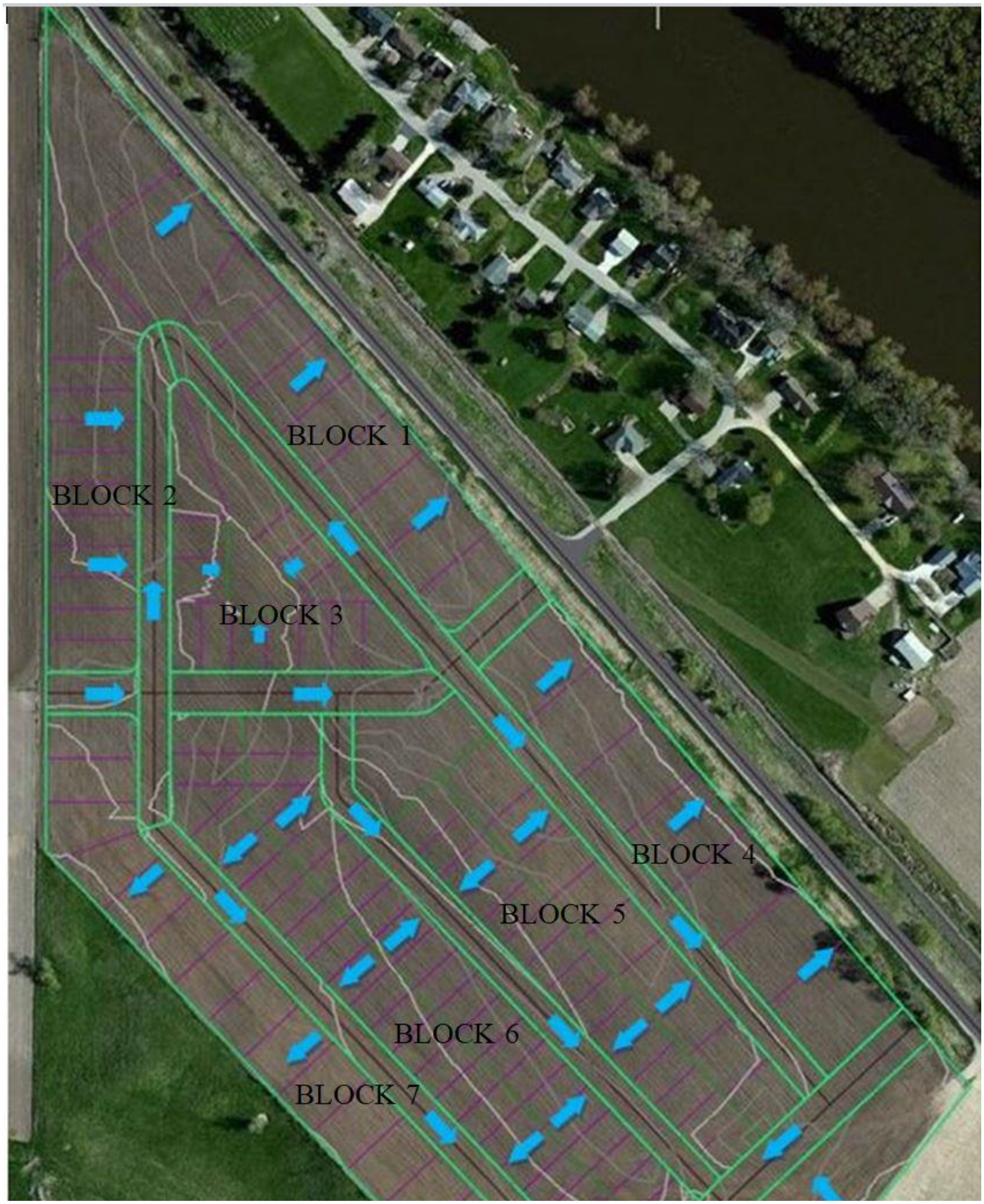

Figure 6.1: Overall drainage view of the site

Basin Design

In order to find the correct volume that needed to be retained onsite, a hydraulic analysis was conducted for the pre and post development of our parcel. This hydraulic analysis included finding the overall precipitation of the area and a soil analysis to find the overall runoff for pre and post development. Since this project was 50 acres, the TR-55 method was used to find the runoff value. First, to find CN, the soil type needed to be determined. The soil type for the parcel was found to be a silt loam which correlates with Soil Type B thus CN 81 for pre development. For post development, the CN was weighed, shown in Appendix B.1. The region of this design gives the value of annual precipitation. With the TR-55 method using the 100-year storm, the time of concentration, runoff, and peak runoff rates were found. This was calculated for pre, during and post development for onsite and offsite. Based off of the grading plan, the water flows to the north and south corners which are where the basins are located.

Once the runoff amount was known, the water quality volume was also calculated. The 50 acre site was assumed 0% impervious pre development whereas after development, the site is 62% impervious. Using this value, a simulation was completed using Hydrology Studio. This accredited program allowed for both basins to be sized. Various charts about the drainage time, peak runoff, and discharge was made, shown in Appendix B.2. The north and south basins were sized according acres of runoff. Both designs for the basins can be found in the attached construction drawings. Both designs accommodate the maximum amount of storage required for a 100 year storm.

Hydrology Studio software also used the flow rate to find the outlet structure of the basin. The structure consists of a rectangular weir, a box riser, with a culvert and outlet orifice. This structure allows for water to run into the basin through the culvert and exit using the 2' orifice. If there is overflow from the culvert, the rectangular weir will be utilized. The outlet structure is sized to accommodate the 5 year storm runoff from the stormwater collection system.

For the outlet of the retention basin, a culvert was added to drain to two prospective areas. For the north basin, the excess water will drain into the highway ditch on the east of the development. The outlet flow into the ditch was limited to a velocity of 5 ft/s due to the specifications in SUDAS. For the south basin, the water will drain into Duck Creek, located in the southwest corner. Again, the outflow culvert was sized to the SUDAS standards of maximum discharge into the creek. All of the structure layouts can be found in the supplement construction drawings.

Stormwater Collection Design

The stormwater collection system was completed designed in Civil 3D using the Pipe Networks function. Profiles were designed for every road profile and station. Using the hydraulic analysis from the retention basin, the amount of water needed to flow to each basin was calculated. The north basin accounts for the runoff from the main arterial road and north. Whereas the south basin accounts for the rest of the south stormwater collection system. All stormwater pipes are reinforced concrete pipes at varying slopes based on the road elevations. Based on ISWMM specifications, there will be 48” stormwater manholes every 400’ of road, totaling 11. The stormwater pipes are located 1.5’ of the curb on the inside of the road curvature. The collection system uses curb open inlet structure on the curbs and gutters for the water to enter. Based on the grading plan and road design, the stormwater will be able to drainage to the side gutters for collection. These inlets will be located every 400’, and are shown in Figure 6.2. The stormwater collection system was sized to hold a 5-year design storm based on SUDAS recommendation.

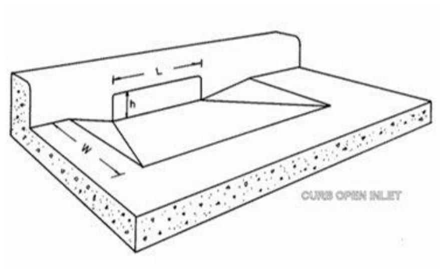

Figure 6.2. Stormwater Inlet Structure

Bioretention Cell Design

Required Water Quality Volume (WQv)

The water quality volume is the storage needed to capture and treat the runoff from 90% of the average annual rainfall. The way this was calculated was by using ISWMM Chapter 5 - Section 4. The total drainage area for each cell is typically 05.-2.0 acres (ISWMM, Chapter 5). The proposed site location for the bioretention cells is east of the multi-family housing lots. The location of bioretention cells on the site have been included in the construction drawings. This area of the site consists of 6.85 acres total, in which 69% or 4.72 acres are impervious acres. Our team has decided to have the total drainage area for each cell at the maximum of 2 acres each. Using the 4.72 acres that are impervious, a total of three bioretention cells are recommended. The preceding calculations have been calculated for one bioretention cell. To calculate the water quality volume we used the total drainage area and impervious percentage. Then using the first 1.25” of rain in a storm, (ISWMM) Chapter 8, the total water quality volume was determined to be 6089.33 ft^3. See Appendix A.1 for detailed design calculations.

Pretreatment Practice

Bioretention practices can fail if too much debris or sediment is allowed to enter the cell, reducing the ability of the modified soil layer to infiltrate stormwater. Pretreatment is needed to filter or capture larger sediment particles, trash, and debris before it can enter the ponding area. Pretreatment practices also help reduce incoming runoff velocity. The recommendation for pretreatment of the bioretention cell is various sizes of riprap. See Appendix A.2 for a figure of the riprap in combination with the bioretention cells which occurs before the drainage enters the cell. In this development, the pretreatment location can vary based on the amount of usable space.

Recommended Footprint of WQ Ponding Area

The temporary ponding area provides for temporary surface storage of the runoff before it infiltrates into the soil bed. Typically limited to a depth of 6-9 inches (ISWMM- Chapter 5 - Section 4). The ponding area is intended to drain dry within 4-12 hours after typical storm events, and should never have standing water longer than 24 hours after very rare events (ISWMM- Chapter 5 - Section 4). To calculate the required ponding area to treat the WQv the total cross-sectional depth of 3.25 feet was multiplied by the WQv of 6089.33 ft^3. The recommended coefficient of permeability for the modified soil mix in the cross-section is 2 feet/day. It is recommended that a WQv ponding depth of 6-9 inches should be planned over the level bottom of the bioretention cell (ISWMM- Chapter 5 - Section 4). For this design a ponding depth of 9 inches or 0.75 ft was selected. To find the average WQv ponding depth 0.75 ft was divided by 2 to give a final total of 0.375 feet of average WQv ponding. The recommended desired time to drain the modified soil layer is 1 day (ISWMM- Chapter 5 - Section 4). Using these values the required ponding area to treat WQv was calculated to be 2729.7 ft^2. This value is the flat area of the bioretention cell. See Appendix A.2 for the detailed calculations.

Design Surface Geometry of WQv Ponding Area

Using ISWMM - Chapter 5 - Section 4, the cell should typically be at least two times longer than it is wide, as measured along the direction of flow (longer flow paths through the system increase filtration and percolation). To calculate the geometry of the ponding area the length to width ratios were used and the calculated dimensions are: Width = 37 feet, Length = 74 feet. See Appendix A.3 Design for the detailed calculations.

Subdrain System Design

For a bioretention cell, the subdrain system is needed to drain the aggregate layer over a 24-hour period. The subdrain will drain into the ditch along highway 52.

The design flow rate was first calculated by using the recommended coefficient of permeability of 2 ft/day was used and multiplied by the ponding area of 2800 ft^2 and then converted to ft^3/s. The design flow rate was calculated to be 0.063188 ft^3/s. See Appendix A.4 for the detailed calculations. According to ISWMM - Chapter 5 -Section 4, the minimum recommended diameter of 8 inches will have sufficient capacity for this flow. This size is recommended for cleaning and inspection. Perforated pipe underdrains are recommended. They provide an outlet for filtered water in areas with soils with poor percolation rates and act as a secondary outlet where soil percolation rates are better (ISWMM - Chapter 5 -Section 4).

It is recommended that the length of pipe should be determined, so that the area within 1 foot either side of the subdrain is at least 10% of the required ponding area. To calculate the length of the pipe 10% of the ponding area of 2729.7 ft^2 was used and divided by 2. The length of the pipe was calculated to be 136.48 ft, but rounded up to 140 feet of subdrain needed. Subdrains should be installed at least 3 inches above the bottom of the aggregate layer (ISWMM - Chapter 5 - Section 4). See Appendix A.4 for the detailed calculations.

Staged Outlet Design

To avoid excessive ponding depths and drawdown times, outlet controls are needed to manage runoff from larger storm events. An overflow spillway set above the ponding depth can release flows in a non-erosive manner. Amy Bouska of the Johnson County Soil and Water Conservation District recommends using a solid overflow pipe that is raised 6-9 inches from the ground. An example of an overflow pipe in a bioretention cell can be seen in Figure 6.3 and labeled number 8.

Figure 6.3. Bioretention cell schematic

Vegetation

Plants in bioretention cells enhance infiltration and provide an evapotranspiration component. Native species provide resistance to moisture changes, insects, and disease and provide uptake of runoff water and pollutants. Deep-rooted native plants are recommended to maintain high organic matter content in the soil matrix, provide high infiltration rates, and provide uptake of runoff water. The denser that the plants are in the bioretention cell, the less maintenance is required. Our client has expressed the need to keep the maintenance of any stormwater methods are simple as possible. The more diverse the planting selection, the more maintenance is required, so we recommend for this design that only three different plant species are used in each bioretention cell. To keep the vegetation as dense as possible, 1 plant per square footage of the bioretention cell will be needed. Using the total of the three bioretention cells, and the square footage of 2730 ft^2 for each bioretention cell a total 8190 plants are needed. Our team recommends the following plant species; Helenium Autumnale (Sneezeweed), Rudbeckia Hirta (Blackeyed Susan), and Aromatic Aster. This vegetation was chosen to adhere to the local vegetation that had high infiltration rates, but can be adjusted based on the client’s desires.

Operations and Maintenance Plan - Retention Basin

The operations and maintenance needed for this project closely follow the guidelines set various Iowa manuals for stormwater management. In Table 6.1, the retention basin maintenance needs are specified. Proper continuous inspection ensures the longevity of the basin's efficiency. Checking the inlet and outlet structures at both basins is required to avoid any buildup. All caution signs surrounding the basins should be in place and legible. Most importantly, during maintenance inspections, ensure that no erosion of the basin sides have occurred. As erosion increases inside of the basin, its efficiency and risk of failure increases.
For the stormwater collection system, maintenance is only needed when problems occur. To avoid larger corrosion issues, the chosen pipes include corrosion resistance measures. The largest maintenance piece is ensuring the inlets throughout the development are clear of debris. Having an inlet or grate free of debris and trash warrants no water backup along the road or inside the collection system. If blockages are found within the system, it is best to flush out the entire system.

Table 6.1: Retention Basin Maintenance (ISWMM C3)

Activity	Frequency
Inspect wet basins to ensure they are operating as designed	At least once a year.
Mow the upper-stage, side slopes, embankment and emergency spillway.	At least twice a year.
Check the sediment forebay for accumulated sediment, trash, and debris and remove it.	At least twice a year.
Remove sediment from the basin.	As necessary, and at least once every 10 years

Maintenance Plan - Bioretention Cell

Bioretention cells require seasonal maintenance. It is imperative that they be maintained to function properly and provide continuous visual aesthetics. Routine landscape maintenance includes removal of undesirable and dead vegetation, replenishing the mulch layer as needed, and removal of accumulated sediment in pretreatment areas. In Table 6.2, the bioretention maintenance requirements are specified.

Table 6.2. Bioretention cell maintenance requirements (ISWMM C5-S4 - Bioretention Systems)

Activity	Schedule
• Prune and thin out plants when needed. Remove weeds throughout the growing season, preferably by pulling or trimming. Replace plants when needed. • Replace mulch when erosion is evident and/or weed growth is excessive. • Remove trash and debris from pretreatment area and bioretention cell.	Fall, spring, as needed
• Inspect inflow points for clogging (offline systems). Remove any sediment. • Inspect filter strip/grass channel for erosion or gullying. Re-seed or sod as necessary. • Trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation.	Semi-annually
• Look for evidence of standing water in the observation port. This may be a sign of hydraulic failure.	Annually
• Replace modified soil layer when ponding greatly exceeds the design drainage time.	As necessary

Section VII Engineer's Cost Estimate

Within the stormwater management cost estimate, various aspects of the construction process were included. All cost of specific construction materials are included along with the labor, equipment contingency, and engineering services costs. The unit prices were estimated using the RS Means Construction Estimating resource. The annual stormwater cost estimate is taken separately for the Operations and Maintenance Plan. The cost estimate for the stormwater management including one year of Operations and Maintenance is $628,500. The annual cost for Operations and Maintenance is $4,415. Contingency was taken as 10% of the overall project and engineering services was 15%. Since the project will be completed in phases, a Phase 1 cost estimate were also included.

Table 7.1: Stormwater Management Cost Estimate

System	Item	Quantity	Unit	Unit Price	Total
Stormwater Collection System	Stormwater Collection - RCP	7107	L.F.	$45.00	$319,815
	Inlet Structure	15	Ea.	$2,200.00	$33,000
	Storm Drainage Manholes	11	Ea.	$1,725.00	$18,975
Stormwater Management	Outlet Structure	2	Ea.	$4,500.00	$9,000
	Basin Excavation	11500	C.Y.	$6.25	$71,875
	Bioretention Cell Excavation	1012	C.Y.	$6.25	$6,325
	Bioretention Cell - Soil Media	222.64	C.Y.	$25.00	$5,566
	Bioretention Cell - Gravel	101.2	C.Y.	$30.00	$3,036
	Bioretention Cell - Top Mulch	40.48	C.Y.	$32.00	$1,295
	Erosion Control	1	lsum	$3,000.00	$3,000
Temporary Protection	3' Silt Fence	1500	L.F.	$4.00	$6,000
	5'x5' Silt Bag	10	Ea.	$62.00	$620
Plants	Helenum Autumnale	2730	Ea.	$2.50	$6,825
	Rudbeckia Hirta	2730	Ea.	$2.50	$6,825
	Aromatic Aster	2730	Ea.	$2.50	$6,825
				Total	**$498,982**

Note: This cost does not include land purchases need for land easements to connect off-site utilities.

Table 7.2: Annual Operations and Maintenance Cost Estimate

Annual Expenses					
Operations and Maintenance	Mowing Maintenance - Park and Basins	4.5	Ac	$78.00	$351
	Lawn Maintenance - Park and Basins	4.5	Ac	$320.00	$1,440
	Vegetation Maintenance	4.1	Ac	$451.00	$1,849
	Weed Planting Bed	1250	S.Y.	$0.62	$775
				Total	**$4,415**

Table 7.3: Total Stormwater Cost Estimate

Stormwater Collection System	$372,000
Stormwater Management	$100,000
Temporary Protection & Plants	$27,000
Operations and Maintenance - Annual	$4,500
Contingency (10%)	$50,000
Engineering & Administration (15%)	$75,000
Total Stormwater Project Cost	**$628,500**

Table 7.4: Phase 1 Stormwater Cost Estimate

Phase 1					
Stormwater Collection System	Stormwater Collection - RCP	2841	lf	$45.00	$127,845
	Inlet Structure	7	Ea.	$2,200.00	$15,400
	Storm Drainage Manholes	5	ea	$1,725.00	$8,625
Stormwater Management	Outlet Structure	1	ea	$4,500.00	$4,500
	Basin Excavation	3125	C.Y.	$6.25	$19,531
	Erosion Control	1	lsum	$1,500.00	$1,500
Temporary Protection	3' Silt Fence	750	lf	$4.00	$3,000
	5'x5' Silt Bag	5	ea	$62.00	$310
				Total	**$180,711**

Table 7.5: Phase 1 Operations and Maintenance Cost Estimate

Annual Expenses					
Operations and Maintenance	Mowing Maintenance - Park and Basins	2.75	Ac	$78.00	$215
	Lawn Maintenance - Park and Basins	2.75	Ac	$320.00	$880
				Total	**$1,095**

Table 7.6: Phase 1 Stormwater Management Total Cost Estimate

Phase 1 Stormwater Project	$181,000
Contingency (10%)	$18,000
Engineering & Administration (15%)	$27,000
Total Stormwater Project Cost	**$226,000**

Section VIII Appendices

Appendix A - Bioretention Cell Calculations

A.1 - Total Water Quality Volume (WQv) Calculations
A.2 - Pretreatment Practice
A.3 - Ponding Area to Treat WQv Calculations
A.4 - Geometry of WQv Ponding Area Calculations
A.5 - Subdrain System Design Calculations

Appendix B - Retention Basin Design

B.1 - Hydraulic Analysis Calculations
B.2 - Hydrology Studio Graphs

Appendix C - References

Appendix A.1 – Total Water Quality Volume (WQv) Calculations

$$WQv = Rv\,(P)(DA)(42,560\ sf/ac)(1\ ft/12\ in)$$

Drainage area to be treated, in acres (DA) = 2 acres

(Rv) = 0.05 + 0.009(I)

(Rv) = 0.05 + 0.009(69)= 0.671

Impervious % (I) = 0.69

P = WQ rainfall depth (recommend using 1.25" for Iowa)

$$WQv = (0.671)(1.25\ in)(2\ ac)(43560\ sf/ac)(1\ ft/12\ in) = 6,089.33\ ft^3$$ per bioretention cell

Appendix A.2 - Pretreatment Practice

Figure 8.2 Pretreatment Rip Rap

Appendix A.3 - Ponding Area to Treat WQv Calculations

$Af = WQv \ x \ df \div [k(hf + df)tf]$

WQv = $6,089.33 \, ft^3$

Df = filter bed layer depth

K = coefficient of permeability (Recommended to use 2 ft/day for modified soil mix)

Hf = average WQv ponding depth (9 in of ponding depth recommended for design)
$9 \ in = 0.72 \, ft \div 2 = 0.375 \, ft \ of \ ponding$

Tf = desired time to drain modified soil layer, in days (recommend using 1 day)

$Af = (6089.33 \, ft^3 \ x \ 3.25 \, ft \div [(2 \, ft/day)(0.375 \, ft + 3.25 \, ft)(1 \ day] = 2729.7 \, ft^2$

Appendix A.4 - Geometry of WQv Ponding Area Calculations

$L = 2W$

$WL = 2729.7\ ft^2$

$W x\ 2\ x\ w\ = 2729.7\ ft^2$

$w^2 = 1364.85\ ft^2$

$w = 36.9\ ft$

Width = 37 ft

Length = 74 ft

Appendix A.5 - Subdrain System Design Calculations

$$Q = KAf(1\ day/24\ hrs)(1\ hr/3600\ s)$$

K = coefficient of permeability, (Recommended to use 2 ft/day for modified soil mix)

Af = Required ponding area to treat WQv (2729.7 ft2)

$$Q = (2ft/day)(2729.7\ ft^2)(1\ day/24\ hrs)(1\ hr/3600\ s) = 0.0632\ ft^3/s$$

Ponding area $(2729.7\ ft^2)\ x\ 10\% = 272.97\ ft^2 \div 2 = 136.48 \sim 140\ ft\ of\ subdrain$

Appendix B.1 - Hydraulic Analysis Calculations

Table 8.2: Predevelopment flow - Onsite

Pre - Parcel (South)							
	CN	Max Retention (s)					
Runoff CN	81	2.345679					
	L	Tc					
Time of Conc	2.967482	4.945803	hr				
	Frequency (yr)	Rainfall, P (in)	Runoff, Q (in)				
Runoff	100	7.22	5.010053				
	Ia/P	Co	C1	C2	qu (ft^3/s/mi^2)	qp (cfs)	m3/s
Peak Runoff Rate	0.064977	2.55323	-0.61512	-0.16403	137.7713	**21.0308**	0.420616

Table 8.3: During Construction Flow - Onsite

During - Parcel (South)		19.5 ac					
	CN	Max Retention (S)					
Runoff CN	86	1.627907					
	L	Tc					
Time of Conc	2.50597127	4.176619	hr				
	Frequency (yr)	Rainfall, P (in)	Runoff, Q (in)				
Runoff	100	7.22	5.577469				
	Ia/P	Co	C1	C2	qu (ft^3/s/mi^2)	qp (cfs)	m3/s
Peak Runoff Rate	0.04509438	2.55323	-0.61512	-0.16403	151.956181	**25.82321**	0.516464
During - Parcel (North)		30.5 ac					
	CN	Max Retention (S)					
Runoff CN	86	1.627907					
	L	Tc					
Time of Conc	2.03689634	3.394827	hr				
	Frequency (yr)	Rainfall, P (in)	Runoff, Q (in)				
Runoff	100	7.22	5.577469				
	Ia/P	Co	C1	C2	qu (ft^3/s/mi^2)	qp (cfs)	
Peak Runoff Rate	0.04509438	2.55323	-0.61512	-0.16403	171.512043	**45.58812**	

Table 8.4: Post Development Flow - Onsite

Post - Parcel (South)		19.5				
	CN	Area	Type	CN*Area	CN Weighted	Max Retention (S)
Runoff CN	85	2.925	Town Homes	248.625	76.3	3.106159895
	69	2.925	Open Space	201.825		
	98	2.925	Paved	286.65		
	70	10.725	1/4 acre lots	750.75		
	L	Tc	Tc			
Time of Conc	3.42494969	5.708249	4.366811			
	Frequency (yr)	Rainfall, P (in)	Runoff, Q (in)			
Runoff	100	7.22	4.486766			
	Ia/P	Co	C1	C2	qu (ft^3/s/mi^2)	qp (cfs)
Peak Runoff Rate	0.08102493	2.55323	-0.61512	-0.16403	148.073854	**31.66151222**
Post - Parcel (North)		30.5				
	CN	Area	Type	CN*Area	CN Weighted	Max Retention (S)
Runoff CN	85	4.575	Town Homes	388.875	76.3	3.106159895
	69	4.575	Open Space	315.675		
	98	4.575	Paved	448.35		
	70	16.775	1/4 acre lots	1174.25		
	L	Tc	Tc			
Time of Conc	2.78385773	4.639763	3.549419			
	Frequency (yr)	Rainfall, P (in)	Runoff, Q (in)			
Runoff	100	7.22	4.486766			
	Ia/P	Co	C1	C2	qu (ft^3/s/mi^2)	qp (cfs)
Peak Runoff Rate	0.1267313	2.55323	-0.61512	-0.16403	167.094041	**35.72845484**

Table 8.5: Offsite Pre and Post Development

Pre - Offsite		216.5				
	CN	Max Retention (s)				
Runoff CN	81	2.34567901				
	L	Tc (hr)				
Time of Conc	4.03867659	6.73112765				
	Frequency (yr)	Rainfall, P (in)	Runoff, Q (in)			
Runoff	100	7.22	5.01005342			
	Ia/P	Co	C1	C2	qu (ft^3/s/mi^2)	qp (cfs)
Peak Runoff Rate	0.06497726	2.55323	-0.61512	-0.16403	115.426823	**17.6199121**
During - Offsite		216.5				
	CN	CN * Area	CN Weighted	Max Retention (s)		
Runoff CN	86	4300	82.1547344	2.172153		
	81	13486.5				
	L	Tc (hr)				
Time of Conc	3.89088127	6.48480212				
	Frequency (yr)	Rainfall, P (in)	Runoff, Q (in)			
Runoff	100	7.22	5.14014052			
	Ia/P	Co	C1	C2	qu (ft^3/s/mi^2)	qp (cfs)
Peak Runoff Rate	119.113573	2.55323	-0.61512	-0.16403	117.910309	**18.4663646**
Post - Offsite		216.5				
	CN	CN * Area	CN Weighted	Max Retention (s)		
Runoff CN	75	3750	79.6143187	2.560555		
	81	13486.5				
	L	Tc (hr)	Tc			
Time of Conc	4.21854266	7.03090443	5.37864189			
	Frequency (yr)	Rainfall, P (in)	Runoff, Q (in)			
Runoff	100	7.22	4.85472828			
	Ia/P	Co	C1	C2	qu (ft^3/s/mi^2)	qp (cfs)
Peak Runoff Rate	103.878116	2.55323	-0.61512	-0.16403	131.263267	**19.4161346**

Table 8.6: Calculations for WQv for Site

Current @ 0% Impervious					
P	1.25	in			
Rv	0.5				
A	2178000				
WQv	113437.5	ft^3	drawdown volume		
Post Construction @ 5.76 acres of open space& lots backyards so 62% Impervious					
P	1.25	in			
Rv	0.50558				
A	2178000				
WQv	**114703.5**	ft^3			
Difference	1265.963	ft^3	* the amount we need to store/ca		
			larger storms when 100%		
Depth	2	ft			
Volumes:					
South Basin	86027.6	ft3			
North Basin	28675.87	ft3			
Orfice Design	Qavg	Orifice Area(ft2)	Orifice Diameter		
South Basin	0.796552	0.165432	0.45895	5.5074	6 inch Orifice
North Basin	0.265517	0.055144	0.264975	3.1797	4 inch Orifice

Table 8.7: Impervious Areas Based on Phasing

Impervious Calc		
Area 1		
Homes	39820	ft2
Multi	33600	ft2
Road	89220	ft2
Total Area	707313.271	ft2
Total Impervious	162640	
	0.22994055	impervious %
Area 2		
Homes	0	ft2
Multi	33600	ft2
Road	174640	ft2
Total Area	298621.184	ft2
Total Impervious	208240	
	0.69733834	impervious %
Area 3		
Homes	150230	ft2
Multi	0	ft2
Road	225040	ft2
Total Area	1235988.11	ft2
Total Impervious	375270	
	0.30361943	impervious %
Total Impervious		
	0.33281703	%

Table 8.8: Section 6 Return Period Patterns (ISWMM C3)

Table 2B-2.07: Section 6 - East Central Iowa
Rainfall Depth and Intensity for Various Return Periods

	Return Period															
	1 year		*2 year*		*5 year*		*10 year*		*25 year*		*50 year*		*100 year*		*500 year*	
Duration	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***
5 min	0.38	4.56	0.44	5.30	0.54	6.56	0.63	7.65	0.76	9.18	0.86	10.3	0.97	11.6	1.23	14.8
10 min	0.55	3.33	0.64	3.87	0.8	4.8	0.93	5.58	1.11	6.70	1.26	7.60	1.42	8.54	1.80	10.8
15 min	0.67	2.70	0.78	3.14	0.97	3.88	1.13	4.53	1.36	5.45	1.54	6.18	1.73	6.94	2.20	8.81
30 min	0.95	1.90	1.11	2.22	1.38	2.76	1.61	3.22	1.94	3.88	2.20	4.40	2.47	4.95	3.14	6.29
1 hr	1.23	1.23	1.44	1.44	1.80	1.80	2.11	2.11	2.58	2.58	2.96	2.96	3.36	3.36	4.37	4.37
2 hr	1.51	0.75	1.77	0.88	2.22	1.11	2.62	1.31	3.22	1.61	3.71	1.85	4.24	2.12	5.60	2.80
3 hr	1.68	0.56	1.96	0.65	2.47	0.82	2.93	0.97	3.63	1.21	4.22	1.40	4.85	1.61	6.50	2.16
6 hr	1.97	0.32	2.30	0.38	2.89	0.48	3.45	0.57	4.3	0.71	5.02	0.83	5.8	0.96	7.87	1.31
12 hr	2.28	0.19	2.65	0.22	3.31	0.27	3.93	0.32	4.88	0.40	5.68	0.47	6.56	0.54	8.87	0.73
24 hr	2.60	0.10	3.01	0.12	3.75	0.15	4.42	0.18	5.44	0.22	6.29	0.26	7.22	0.30	9.64	0.40
48 hr	2.98	0.06	3.43	0.07	4.22	0.08	4.93	0.10	6.01	0.12	6.90	0.14	7.86	0.16	10.3	0.21
3 day	3.28	0.04	3.72	0.05	4.51	0.06	5.24	0.07	6.32	0.08	7.22	0.10	8.19	0.11	10.7	0.14
4 day	3.53	0.03	3.98	0.04	4.78	0.04	5.50	0.05	6.58	0.06	7.49	0.07	8.46	0.08	10.9	0.11
7 day	4.17	0.02	4.67	0.02	5.53	0.03	6.29	0.03	7.39	0.04	8.30	0.04	9.25	0.05	11.6	0.06
10 day	4.75	0.01	5.30	0.02	6.24	0.02	7.04	0.02	8.20	0.03	9.12	0.03	10.0	0.04	12.4	0.05

D = Total depth of rainfall for given storm duration (inches)
I = Rainfall intensity for given storm duration (inches/hour)

Table 8.9: TR-55 Coefficient Tables (ISWMM C3)

Table 2B-4.06: Coefficients for SCS Peak Discharge Method

I_a/P	C_0	C_1	C_2
0.10	2.55323	-0.61512	-0.16403
0.30	2.46532	-0.62257	-0.11657
0.35	2.41896	-0.61594	-0.08820
0.40	2.36409	-0.59857	-0.05621
0.45	2.29238	-0.57005	-0.02281
0.50	2.20282	-0.51599	-0.01259

Note: Values are for Type II rain distribution, which applies to all of Iowa.

Source: TR-55, USDA

Table 2B-4.07: Adjustment Factor (F_p) for Pond and Swamp Areas that are Spread Throughout the Watershed

Percentage of pond and swamp area	F_p
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Source: HEC-22, FHWA

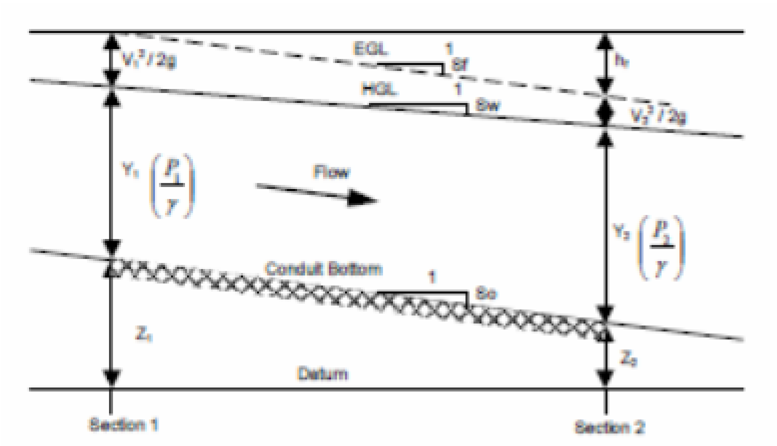

Figure C13-S4- 1: Terms Used in the Energy Equation

Figure 8.2: Energy Diagram For Stormwater Pipes (ISWMM C13)

Appendix B.2 - Hydrology Studio Graphs

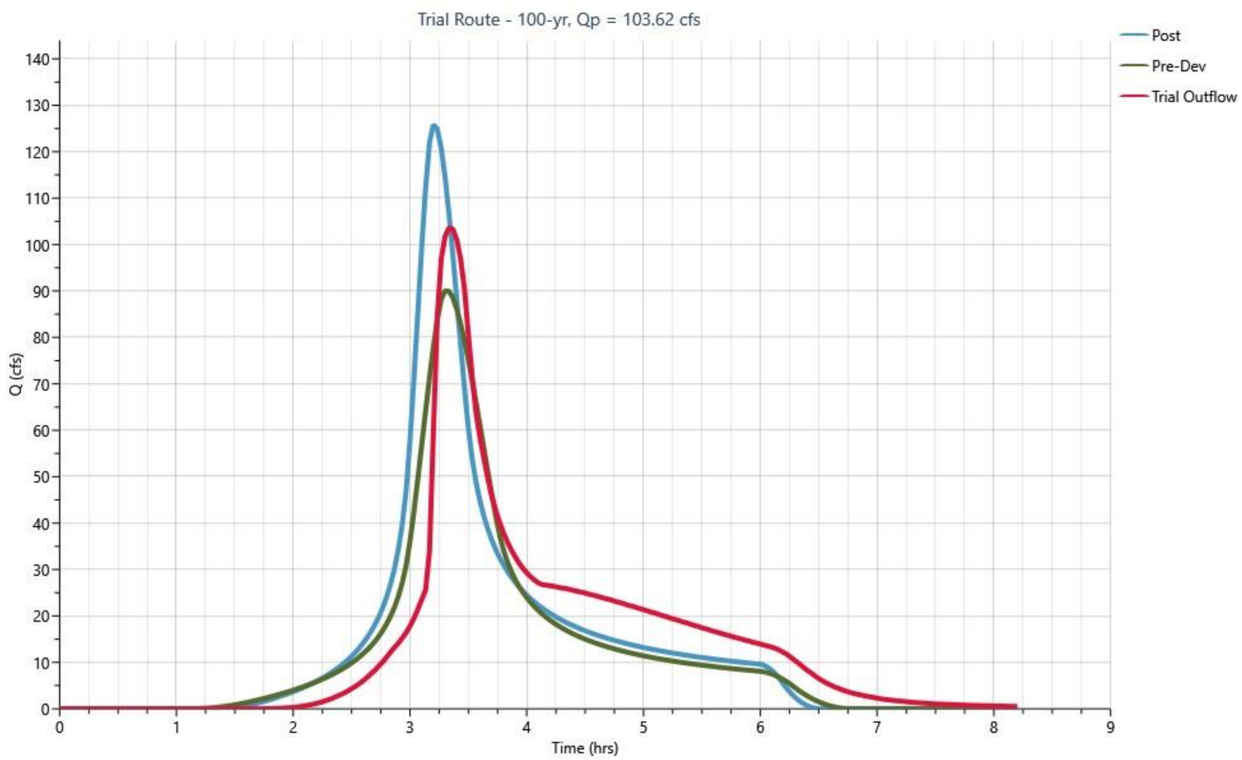

Figure 8.3: 100-year Storm Runoff - North Basin

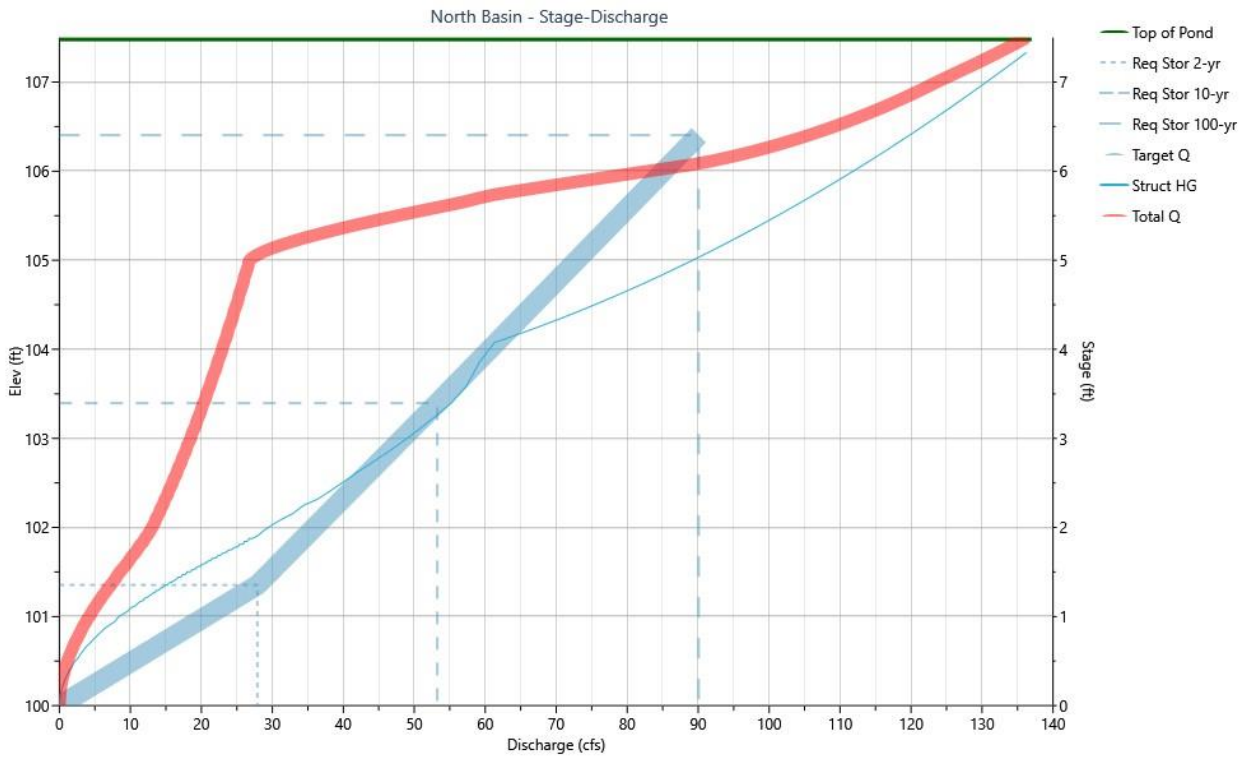

Figure 8.4: Discharge - North Basin

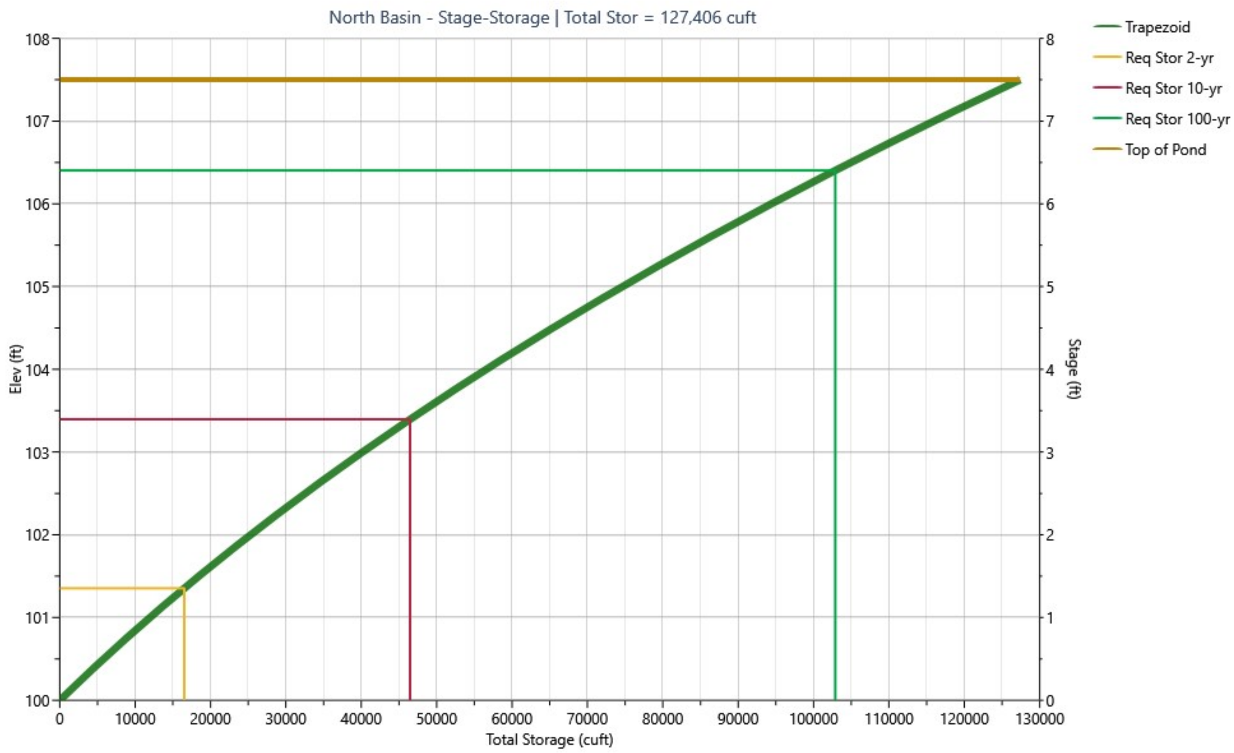

Figure 8.5: Storage at Various Storm Levels - North Basin

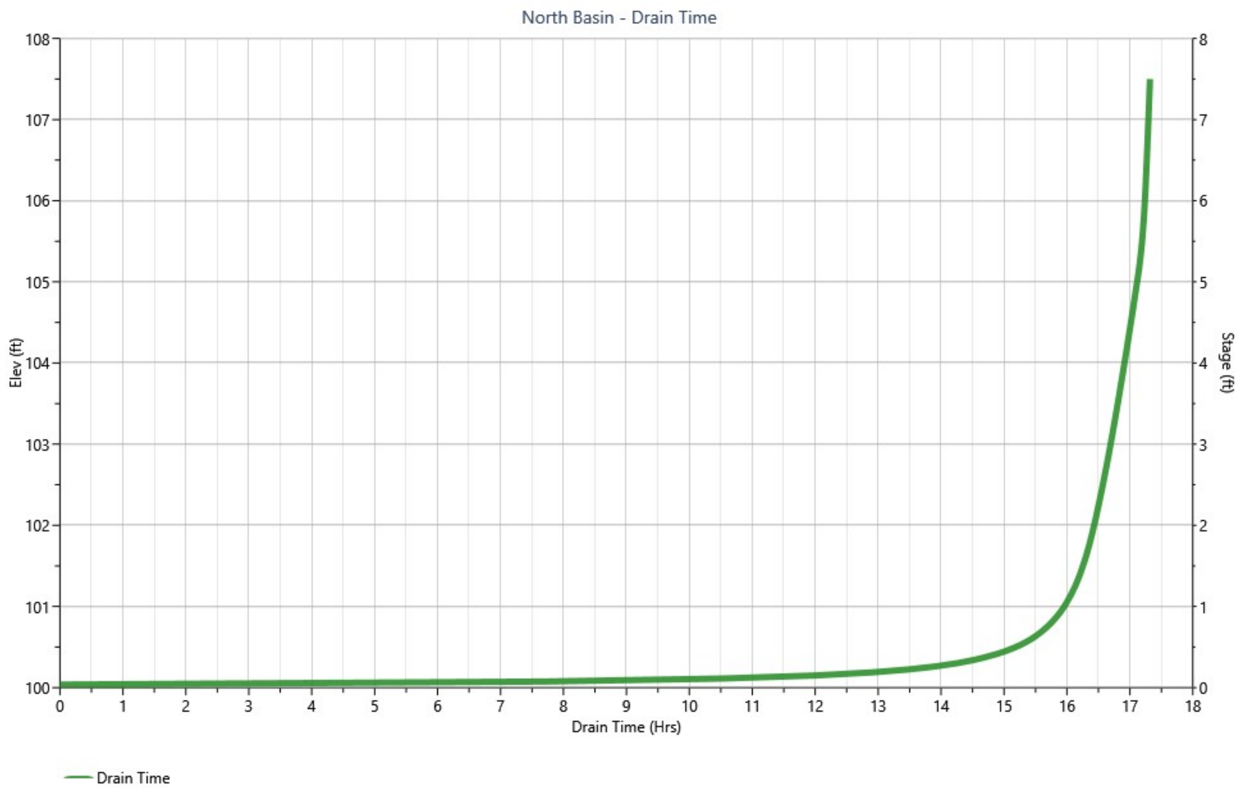

Figure 8.6: Basin Drainage Time - North Basin

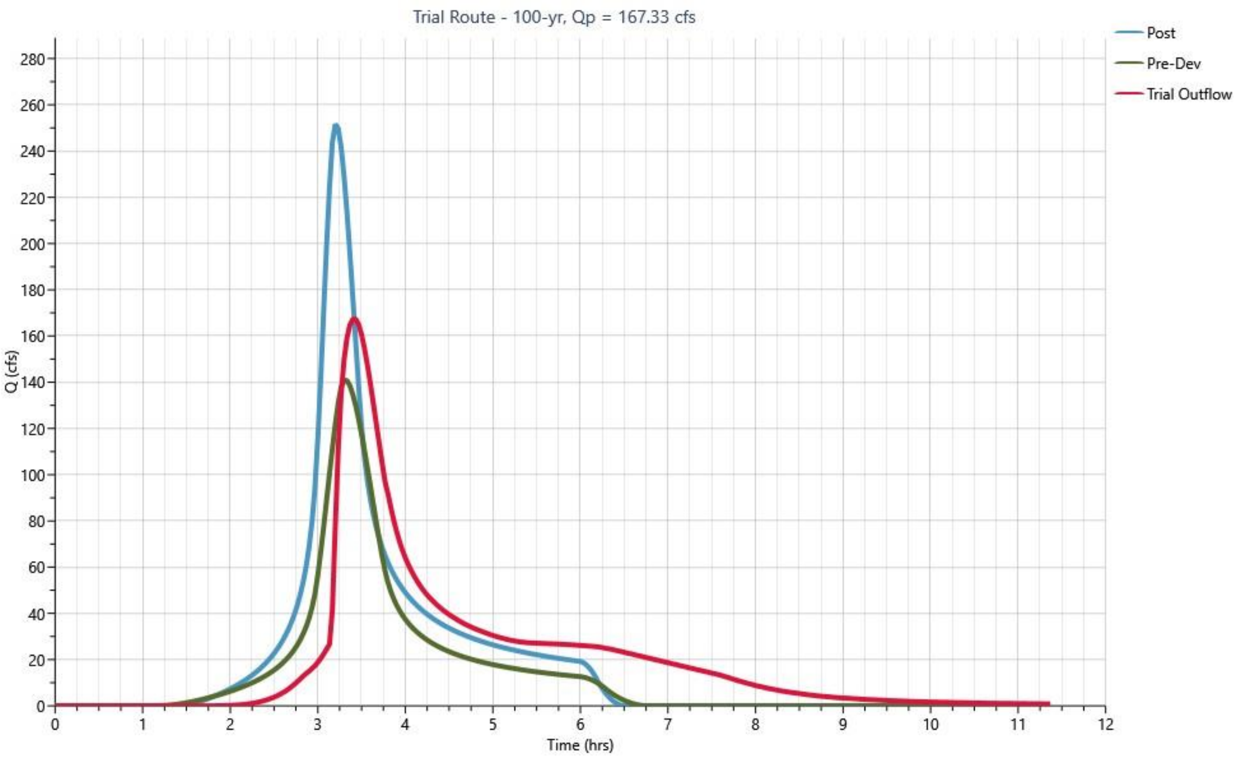

Figure 8.7: 100-year Storm Runoff - South Basin

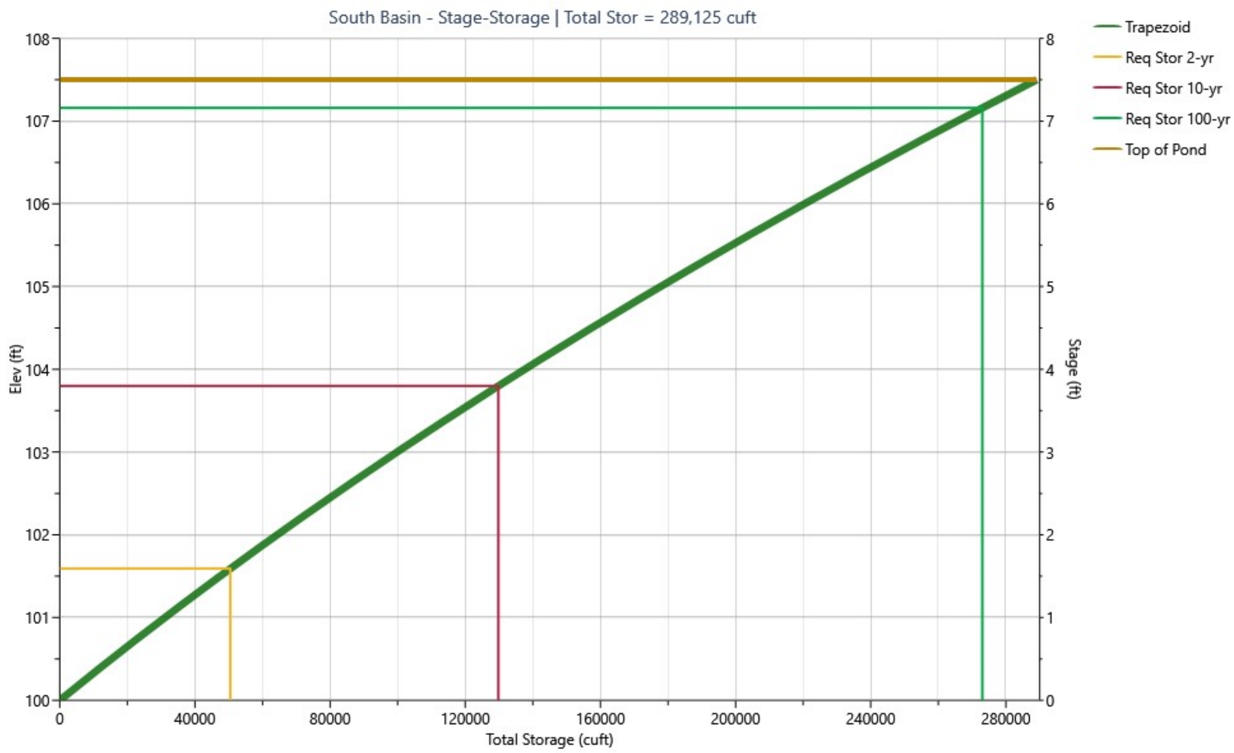

Figure 8.8: Storage at Various Storm Levels - South Basin

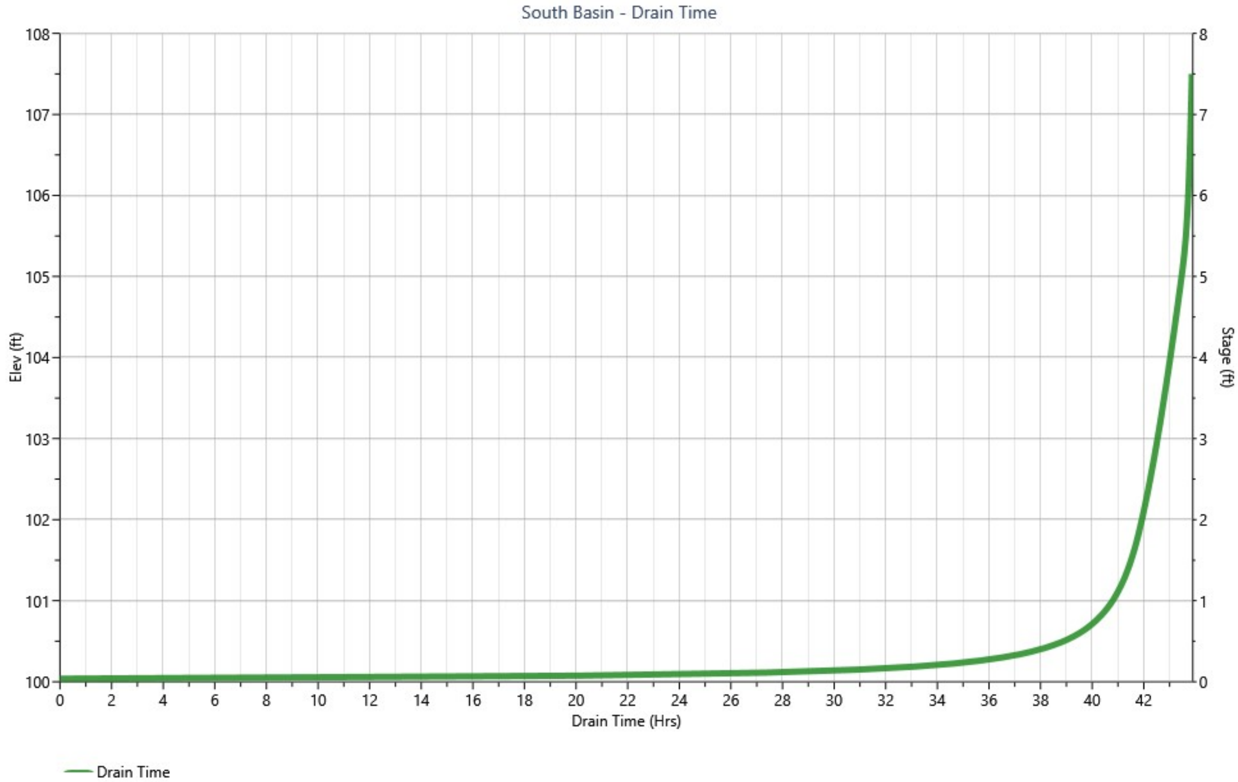

Figure 8.9: Basin Drainage Time - South Basin

Table 8.10: Max Storage Quantities - North Basin

Ret Pd (Yrs)	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2	27.90	15.40	102.41	31,217
10	53.24	29.33	105.12	76,842
100	90.07	103.62	106.35	101,839

Table 8.11: Max Storage Quantities - South Basin

Ret Pd (Yrs)	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2	43.63	16.85	102.57	84,328
10	83.27	45.95	105.44	196,450
100	140.88	168.86	107.21	275,587

Appendix C - References

"Buy Native Wildflower Seeds: Plants: Grasses: Rushes: Sedges: Savannas: Prairies: Perennials: Wetlands: Woodlands." IonXchange.com, 2019, ionxchange.com/.

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