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A Comparative Evaluation of Green Stormwater Infrastructure Tools: Co-Benefits and Alternative Funding

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Abstract

Green Stormwater Infrastructure (GSI) is a complicated concept for the majority of the population due to complexities of the technologies and the dearth of research done on co-benefits offered by the multiple types of GSI. As GSI and its co-benefits are an interconnected complex system, it is important to create tools that can offer accurate information and predictions of the co-benefits. These tools also offer more chances to identify places for alternative funding for GSI beyond water related organizations. This study compares and evaluates the differences between three tools, the Green Values National Stormwater Management Calculator, the Environmental Protection Agency's National Stormwater Calculator, and the Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs tool. Each tool offers a detailed analysis of different parts of the GSI selection, from life-cycle cost analysis to the variety of co-benefits offered to the level of performance of the BMP in stormwater management. This study is conducted by evaluating five representative rain gardens for the city of Philadelphia, and simulating their effects through each tool to examine data requirements and outputs. The results indicate functionality, ease of use, similarity and/or dissimilarity of the estimated hydrologic results, water quality, cost, and co-benefits of these tools. Co-benefit considerations may inform possibilities for leveraging funding from multiple utilities in a city. The Green Values Tool is the easiest to use, with the EPA Stormwater Calculator and the CLASIC Tool requiring more detailed inputs and handlings. The CLASIC Tool offers both the most detailed and highest number of co-benefits, the Green Values Tool offers some co-benefit analysis, and the EPA Stormwater Calculator did not cover co-benefits at all. All three tools contain a cost analysis function where the analysis for the CLASIC Tool and the Green Values Tool are similar, but the EPA Stormwater Calculator differs. The CLASIC Tool and the EPA Stormwater Calculator provide alike hydrologic budgets but the Green Values Tool estimates tends to vary. The CLASIC Tool is the only tool that provides water quality estimates. By analyzing and comparing the three tools, better choices can be made by governments and communities and offer more opportunities to look for alternative funding for GSI projects, all of which offer a healthier and greener future to the world.

Disciplines

Earth Sciences | Physical Sciences and Mathematics

A COMPARATIVE EVALUATION OF GREEN STORMWATER INFRASTRUCTURE TOOLS: CO-BENEFITS AND ALTERNATIVE FUNDING

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ABSTRACT

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Green Stormwater Infrastructure (GSI) is a complicated concept for the majority of the population due to complexities of the technologies and the dearth of research done on co-benefits offered by the multiple types of GSI. As GSI and its co-benefits are an interconnected complex system, it is important to create tools that can offer accurate information and predictions of the co-benefits. These tools also offer more chances to identify places for alternative funding for GSI beyond water related organizations. This study compares and evaluates the differences between three tools, the Green Values National Stormwater Management Calculator, the Environmental Protection Agency's National Stormwater Calculator, and the Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs tool. Each tool offers a detailed analysis of different parts of the GSI selection, from life-cycle cost analysis to the variety of co-benefits offered to the level of performance of the BMP in stormwater management. This study is conducted by evaluating five representative rain gardens for the city of Philadelphia, and simulating their effects through each tool to examine data requirements and outputs. The results indicate functionality, ease of use, similarity and/or dissimilarity of the estimated hydrologic results, water quality, cost, and co-benefits of these tools. Co-benefit considerations may inform possibilities for leveraging funding from multiple utilities in a city. The Green Values Tool is the easiest to use, with the EPA Stormwater Calculator and the CLASIC Tool requiring more detailed inputs and handlings. The CLASIC Tool offers both the most detailed and highest number of co-benefits, the Green Values Tool offers some co-benefit analysis, and the EPA Stormwater Calculator did not cover co-benefits at all. All three tools contain a cost analysis function where the analysis for the CLASIC Tool and the Green Values Tool are similar, but the EPA Stormwater Calculator differs. The CLASIC Tool and the EPA Stormwater Calculator provide alike hydrologic budgets but the Green Values Tool estimates tends to vary. The CLASIC Tool is the only tool that provides water quality estimates. By analyzing and comparing the three tools, better choices can be made by governments and communities and offer more opportunities to look for alternative funding for GSI projects, all of which offer a healthier and greener future to the world.

Introduction

One inch of rain falling on one acre of land, a size equivalent to that of a football field, is equivalent to 27,154 gallons of water. The North American average precipitation rate is up by 1.81 inches from 1895 to 2018, which means an additional 49,150 gallons of water will fall on that acre (Assessing the U.S. Climate in 2018, 2018). This increase of precipitation, particularly on the East Coast as seen in Figure 1, is causing immense pressure on aging infrastructure and damages to towns and cities. One way to reduce that pressure is to implement Green Stormwater Infrastructure (GSI) systems, which increase infiltration and reduce runoff to stormwater/sewer collection systems and surface waters. There are many different types of GSI with varying effects on hydrologic and water quality responses as well as social, economic, and environmental co-benefits . Co-benefits of GSI include, but not limited to, urban heat island mitigation, improved air quality, reduced energy costs, improved community livability and health, and green jobs (CNT, 2011).

While GSI is a relatively new alternative to grey infrastructure, which deals exclusively with the excess water, it allows a community or city to effectively address a wide range of issues through co-benefits. Finding the most efficient way to implement GSI is a priority as there are many options available. This project conducts a comparative evaluation of three different GSI evaluation tools with functionality to quantify co-benefits of GSI systems. The three tools are the Green Values National Stormwater Management Calculator (Green Values Tool), the Environmental Protection Agency's National Stormwater Calculator (EPA Stormwater Calculator), and the Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs tool (CLASIC Tool). The ease of use and functionality of these tools are assessed by creating five representative rain gardens for the city of Philadelphia in Pennsylvania (Figure 2). All five rain gardens are modeled by each tool. This study provides a comparative assessment of these GSI tools for community to municipal level applications.

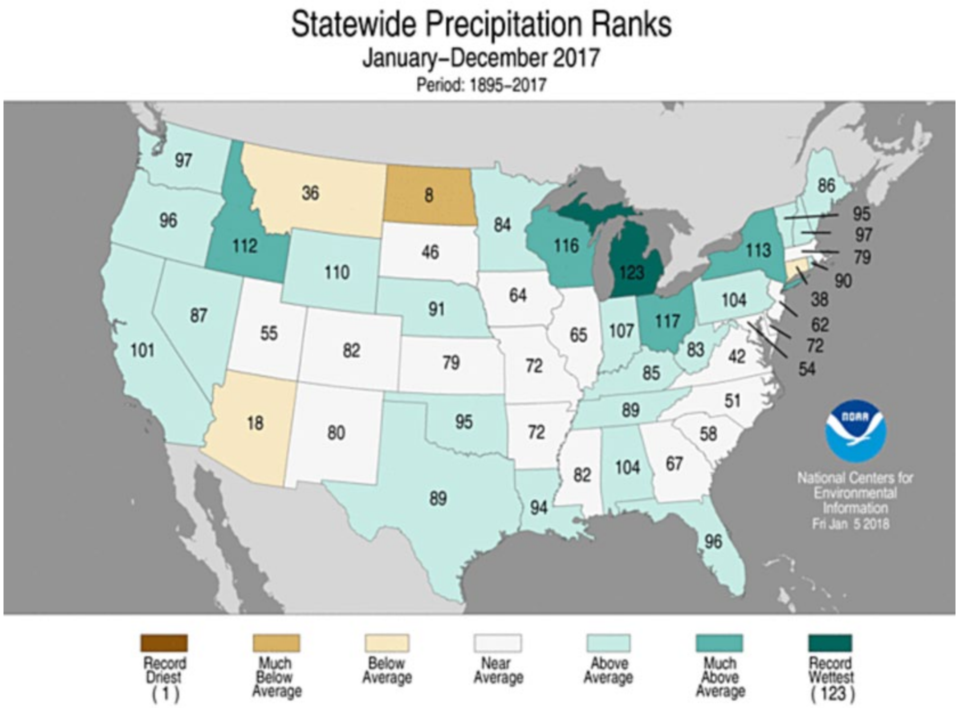

Figure 1: State Precipitation in inches, NOAA (Source: https://www.ncdc.noaa.gov/sotc/national/201713)

Figure 2: Map of US – Philadelphia highlighted, Printable Map Collection (Source: https://adagebiopower.com/pa-state-parks-map/pa-state-parks-map-where-is-philadelphia-pa-philadelphia-pennsylvania-map/)

Background

Green Stormwater Infrastructure is defined as “the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters” according to the Clean Water Act, Section 502 (US EPA, 2015). Green infrastructure covers a large range of new and old studies, from analysis of urban recharge of a watershed as a result of faulty irrigation and other human effects (Passarello, Sharp, & Pierce, 2012) to the use of game theory to incentivize communities to invest in green infrastructure (William, Garg, & Stillwell, 2017). While green research is broad, green infrastructure is still an emerging way to manage how water interacts with communities and cities. There is a fine balance between the effectiveness of the proposed infrastructure, the cost to implement it, and the overall efficiency of the infrastructure chosen (Toran & Jedrzejczyk, 2017).

As climate change continues to affect the world in more drastic ways, stormwater and flooding risks to assets and communities from climate extremes are on the rise (US EPA, 2015). It is evident that wet regions are becoming wetter, while dry areas are trending toward drier conditions. These changes can cause challenges with our current water infrastructure systems. Green infrastructure offers communities the resources to increase their time to react to these changes by lessening the burden places on these storm sewer systems. There has been limited research into the co-benefits associated with green infrastructure that offer intriguing possibilities for additional funding. Implementing GSI improves many aspects of the environment and modern life: water, energy, health, air quality, community livability, and habitat improvement as can be seen in Table 1 (CNT, 2011). However, most research has focused on the outcomes of stormwater management and its immediate effects on the environment and the water table (Nimmer, Thompson, & Misra, 2009). The aspects listed above have received a critical lack of both attention and analysis. This is especially true when considering how to accurately and ethically advise on what type of GSI to implement for a community. There are many tools and calculators that offer advice or recommendations as to which BMP to implement on each site, but it is difficult to determine how helpful the tools actually are.

Table 1: Table depicting benefits and practices offered by different types of GSI (Source: CNT, 2011)

Benefit	Reduces Stormwater Runoff											Improves Community Livability						
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

It is difficult to convince communities to implement GSI methods over existing grey stormwater infrastructure as the exact payoff is hard to calculate before the project begins. The environmental and quality of life improvements associated with GSI range from saved money in energy costs to better water quality to improved recreational activities and access. Finding ways to clearly communicate the cost and benefits of GSI will be instrumental in convincing communities that it is a worthwhile investment. These conversations will be supported by research and data that is easily understood and communicable so that everyone may discuss what is best for the larger whole. The most effective decisions come from having the most information possible and should be facilitated by tools and analysis that are efficient and offer clear recommendations on improvements possible. The potential for Green Stormwater Infrastructure tools to assist in these decisions is immense, yet care must be taken when selecting which tools to use as each project requires different priorities.

Methods

This comparative study is carried out by using three different tools: the Green Values National Stormwater Management Calculator, the Environmental Protection Agency's National Stormwater Calculator, and the Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs tool. Five representative rain gardens – designed specifically for the city of Philadelphia, Pennsylvania, USA – have been created with help of the Philadelphia Water Department's data (PWD). All of the five proposed rain gardens, known as projects 1-5, will be hypothetically built on a non-permeable parking lot, with varying sizes and vegetation. A baseline will be included where the tool will be run with no GSI on the site. The lot for the polygon is the University of Pennsylvania's Penn Parking Lot, Lower Walnut St, Philadelphia, PA 19104. The site will be the entire lot of the proposed site for each project. The five rain gardens' data will then be fed through each tool and the resulting information compared on a number of criteria to evaluate the tools' inputs needed, useability, and their results.

Once all fifteen data sets have been collected, each tool's data set will be compared to the other sets to see the overall strengths and weaknesses. Several criteria will be chosen to compare and contrast the tools: the degree of translation of the rain garden data that needs to be fed into each tool; the inherent assumptions provided by the tool; the co-benefits offered by the rain garden according to the tool; the projected costs of implementation and rain garden lifecycle; the water quality change predicted by the tool; and the opportunities offered to locate additional funding prospects via co-benefits. Then each tool will be compared directly against each other by the runoff and the volume captured, project by project. The ease of use of each tool and the fact that each tool is designed for a different scale of project will also be considered. These criteria will help show where the potential of combining separate funding streams and increasing the ability of stormwater utilities and local governments to push for public GSI on private properties can be (CNT, 2020).

The parameters of each criteria have been specifically chosen to be comparable in a quantifiable manner. The degree of translation is measured in the number of data points that have to be translated or manipulated to be fed into each tool from the base data set created. The inherent assumptions is measured by the number of assumptions noted in each tool. The co-benefits is measured by the number offered by the tool and the details of each co-benefit. The cost of implementation and lifecycle upkeep is measured in multiple sections; the construction of the rain garden, the lifecycle costs, and its maintenance costs. The water quality is measured by the reported change in the water quality from the baseline, with a focus on the change in contaminate load. The additional funding opportunities is calculated by analyzing the co-benefits proffered from each tools' results and exploring appropriately related sources. The direct comparison is measured by comparing the runoff reduced by the addition of GSI, and the total volume captured according to the tool for each project. The ease of use of the tool is considered in terms of the combination of the number of degrees of translation needed and the number of inherent assumptions for each tool. The intended scale of the project will be taken from each home website of each tool.

Once all the data has been collected, a comparative evaluation will be done to determine which tool is strongest in which criteria. The ease of use, the use of planning versus analysis, the drawbacks of the tools, and the potential combinations will be analyzed as well. Recommendations will then be made for how to best use or combine these resources. This will allow for better GSI implementation and provide potential new areas to focus future efforts on alternative and additional funding opportunities for GSI projects.

Results

The five representative Rain Gardens, referred to as projects 1 through 5, were created based off of Philadelphia Rain Gardens. Each was placed at the University of Pennsylvania's Penn Parking Lot, Lower Walnut St, Philadelphia, PA 19104, seen in Figure 3 below.

Figure 3: Location of proposed projects in red polygon at center (Source: CLASIC Select Area)

The data used to create those Rain Gardens is summarized below in Table 2.

Table 2: Data Inputs used for all 3 Green Stormwater Infrastructure Tools

Project ID	Baseline	1	2	3	4	5
BMP Type	N/A	Rain Garden	Rain Garden	Rain Garden	Rain Garden	Rain Garden
Vegetated Area (ft^2)		600	700	1300	3000	5000
Vegetated Area (Acres)		0.0138	0.0161	0.0298	0.0689	0.1148
Number of Trees		0	1	5	10	16
System Function		Detention/ Slow Release	Detention/ Slow Release	Detention/ Slow Release	Detention/ Slow Release	Detention/ Slow Release
System Model Input Category		Biorientation (unlined)	Biorientation (lined)	Biorientation (unlined)	Biorientation (lined)	Biorientation (lined)
Impervious DA (ft^2)	105000	8000	11000	40000	85000	105000

Pervious DA (ft^2)		0	0	20000	0	0
Total DA (ft^2)	105000	8000	11000	60000	85000	105000
Total DA (Acres)		0.184	0.253	1.377	1.951	2.410
Percent area into RG		7.5%	6.4%	2.2%	3.5%	4.8%
Total New Greened				35.5%		
System Underdrain		YES	YES	YES	YES	YES
Raw Storm Size Managed (in)	1.2	1.2	1.4	1.8	2	2.2
Previous Cover	Impervious	Imperious	Impervious	Pervious	Impervious	Impervious
Vegetation Type		Grass	Grass	Grass	Grass	Grass
Ponding Depth (in)		8	8	8	8	8
Zip Code	19104	19104	19104	19104	19104	19104

The three input tables, for the Green Values Tool, the EPA Stormwater Calculator, and the CLASIC Tool are shown below in Tables 3, 4, and 5 respectively.

Table 3: Data Inputs for Green Values Tool

	Baseline	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
Site Information						
Lot Type	Commercial Lot	Commercial Lot	Commercial Lot	Commercial Lot	Commercial Lot	Commercial Lot
Total Lot (ft^2)	105,000	8,000	11,000	60,000	85,000	105,000
Impervious Area (ft^2)	105,000	8,000	11,000	40,000	85,000	105,000
Pervious Area (ft^2)	0	0	0	20,000	0	0
Green Improvements - Rain Garden						
Zip Code		19104	19104	19104	19104	19104
Rain Garden		Redirection	Redirection	Redirection	Redirection	Redirection
Parking Surface Replacement (ft^2)		600	700	1300	3000	5000

Construction Specifications - Rain Garden						
Ponding (in)		8	8	8	8	8
Amended Soil (in)		8	8	8	8	8
Amended Soil Porosity		0.35	0.35	0.35	0.35	0.35
Aggregate (in)		8	8	8	8	8
Aggregate Porosity		0.25	0.25	0.25	0.25	0.25
Cost Estimates - Rain Garden						
Construction Costs ($ per ft^2)		6.07	6.07	6.07	6.07	6.07
Annual Maintenance Costs ($ per ft^2)		0.41	0.41	0.41	0.41	0.41
Typical Useful Life (years)		22.5	22.5	22.5	22.5	22.5
Green Improvements - Tree						
Number of Trees		0	1	5	10	16
Canopy (ft^2)		N/A	200	200	200	200
Canopy Porosity		N/A	0.01	0.01	0.01	0.01
Tree Pit (ft^2)		N/A	16	16	16	16
Soil (in)		N/A	18	18	18	18
Soil Porosity		N/A	0.4	0.4	0.4	0.4
Cost Estimates - Tree						
Construction Costs ($ per ft^2)		N/A	250	250	250	250
Annual Maintenance Costs ($ per ft^2)		N/A	180	180	180	180
Typical Useful Life (years)		N/A	80	80	80	80

Table 4: Data Inputs for EPA Stormwater Calculator

	Baseline	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
Location						
Zip Code	19104	19104	19104	19104	19104	19104
Lot (acres)	2.41	0.184	0.253	1.377	1.951	2.41

Soil Type						
Soil Type	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
Soil Drainage						
Soil Drainage (in/hr)	0.4	0.4	0.4	0.4	0.4	0.4
Topography						
Topography	Flat with 2% Slope	Flat with 2% Slope	Flat with 2% Slope	Flat with 2% Slope	Flat with 2% Slope	Flat with 2% Slope
Precipitation/ Evaporation						
Rain Gauge	Philadelphia Franklin Institute	Philadelphia Franklin Institute	Philadelphia Franklin Institute	Philadelphia Franklin Institute	Philadelphia Franklin Institute	Philadelphia Franklin Institute
Weather Station	Philadelphia Franklin Institute	Philadelphia Franklin Institute	Philadelphia Franklin Institute	Philadelphia Franklin Institute	Philadelphia Franklin Institute	Philadelphia Franklin Institute
Climate Change						
Future Climate Change Scenario	No Change	No Change	No Change	No Change	No Change	No Change
Time Period	Near Term (2020-2049)	Near Term (2020-2049)	Near Term (2020-2049)	Near Term (2020-2049)	Near Term (2020-2049)	Near Term (2020-2049)
Land Cover						
Percent Impervious	100	100	100	64	100	100
Percent Lawn	0	0	0	36	0	0
LID Controls						
Percent Rain Garden	0	8	6	2	4	5
Ponding (in)	N/A	8	8	8	8	8
Soil Media Thickness (in)	N/A	12	12	12	12	12
Soil Media Conductivity (in/hr)	N/A	10	10	10	10	10
% Capture Ratio	N/A	5%	5%	5%	5%	5%
Design Storm Size (in)	N/A	1.2	1.4	1.8	2	2.2
Project Cost						
Project Type	N/A	Re-Development	Re-Development	Re-Development	Re-Development	Re-Development
Site Suitability	N/A	Moderate	Moderate	Moderate	Moderate	Moderate
Cost Region Multiplier	N/A	Philadelphia - 1.13	Philadelphia - 1.14	Philadelphia - 1.15	Philadelphia - 1.16	Philadelphia - 1.17
Results						

Years to Analyze	N/A	13	13	13	13	13
Event Threshold (in)	N/A	0.1	0.1	0.1	0.1	0.1

Table 5: Data Inputs for CLASIC Tool

	Project 1	Project 2	Project 3	Project 4	Project 5
Create Project					
Project Boundary	Parking Lot Polygon	Parking Lot Polygon	Parking Lot Polygon	Parking Lot Polygon	Parking Lot Polygon
Subunits	Single Subunit	Single Subunit	Single Subunit	Single Subunit	Single Subunit
Land Use	NLCD 2016	NLCD 2017	NLCD 2018	NLCD 2019	NLCD 2020
Soil	SSURGO	SSURGO	SSURGO	SSURGO	SSURGO
Climate Data					
Precipitation	Philadelphia International Airport 1990-2009	Philadelphia International Airport 1990-2010	Philadelphia International Airport 1990-2011	Philadelphia International Airport 1990-2012	Philadelphia International Airport 1990-2013
Evaporation	Philadelphia Drexel University	Philadelphia Drexel University	Philadelphia Drexel University	Philadelphia Drexel University	Philadelphia Drexel University
Model Defaults					
Subunits	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table
Water Quality	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table
Overland Flow	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table
Infiltration	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table
Technology Effluent	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table	CLASIC Input Table
Lifecycle Cost					
Closest City	Philadelphia	Philadelphia	Philadelphia	Philadelphia	Philadelphia
Distance (miles)	1	1	1	1	1
Regional Cost	1.11	1.11	1.11	1.11	1.11
Study Period (yr)	30	30	30	30	30
Annual Discount Rate	0%	0%	0%	0%	0%
Build Scenario					
Rain Garden Small					

Number of Rain Gardens	6	7	3	0	0
Class size	100 ft^2	100 ft^2	100 ft^2		
Ponding Depth (in)	8	8			
Filter Media Depth (in)	18	18			
Impermeable Liner	Not Included	Not Included			
Seepage Rate (in/hr)	0.5	0.5			
Underdrain	Included	Included			
Drain Time (hr)	72	72			
Underdrain Offset Height (in)	0	0			
Vegetation	28	28			
Installation Type	Seed	Seed	Seed		
Mowing	Not Required	Not Required	Not Required		
Irrigation System	Not Included	Not Included	Not Included		
Includes Tree	Not Included	1 Tree Included	1 Tree Included		
Technology Placement	Surrounding Pervious	Surrounding Pervious	Surrounding Pervious		
Percent Impervious Area Captured	10	10	10		
Depth to Capture	1	1	1		
Rain Garden Medium					
Number of Rain Gardens	0	0	1	3	5
Class size			1000 ft^2	1000 ft^2	1000 ft^2
Ponding Depth (in)			8	8	8
Filter Media Depth (in)			18	18	18
Impermeable Liner			Not Included	Not Included	Not Included

Seepage Rate (in/hr)			0.5	0.5	0.5
Underdrain			Included	Included	Included
Drain Time (hr)			72	72	72
Underdrain Offset Height (in)			0	0	0
Vegetation			Grass	Grass	Grass
Installation Type			Seed	Seed	Seed
Mowing			Not Required	Not Required	Not Required
Irrigation System			Not Included	Not Included	Not Included
Includes Tree			2 Trees Included	2 Trees Included	2 Trees Included
Technology Placement			Surrounding Pervious	Surrounding Pervious	Surrounding Pervious
Percent Impervious Area Captured			10	10	10
Depth to Capture			1	1	1
Assess Co-Benefits of Scenarios					
Level of Importance	2	2	2	2	2

Table 6: CLASIC Input Table

Subunit ID	**Area (Ac)**	**Impervious (%)**	**Slope (%)**	**Open (%)**
1	1.84	87	1	0
Low (%)	**Medium (%)**	**High (%)**	**Other (%)**	**c_tss (mg/L)**
0	0	100	0	62
c_tp (mg/L)	**c_tn (mg/L)**	**c_fib (cfu/100 mL)**	**Length (ft)**	**Width (ft)**
0.23	2.2	3600	50	1603.01
SCS Soil Hydrologic Group	**f_i (in/hour)**	**f_f (in/hour)**	**Decay Rate (1/hr)**	**Dry Time (days)**
other	0.51	0.5	1	7
Land Use	CTSS (mg/L)	CTP (mg/L)	CTN (mg/L)	CFIB (cfu/100 mL)
other	58.58	0.24	2.41	5437

high	62	0.23	2.2	3600
medium	59	0.26	2.6	5000
low	58	0.27	2.6	5200
open	56	0.25	2.5	4400
Land Use	Length (ft)			
other	200			
high	50			
medium	100			
low	150			
open	200			
Soil	Fi (in/hour)	Ff (in/hour)	Decay (1/hour)	Dry Time (days)
A	5	1	2.5	7
B	4.5	0.6	6.5	7
C	3	0.5	6.5	7
D	3	0.5	6.5	7
other	0.51	0.5	1	7
Technology	CTSS (mg/L)	CTP (mg/L)	CTN (mg/L)	CFIB (cfu/100 mL)
Rain Garden	10	0.24	1.04	400

The output of the Green Values Tool is in Appendix A. The EPA Stormwater Calculator outputs are in Appendix B, and the CLASIC Tool outputs are in Appendix C. A baseline, with an area of 2.41 acres but with no GSI's, was included for the EPA Stormwater Calculator and for the CLASIC Tool, but not for the Green Values Tool. The criteria for the comparison analysis talked about in the methods is in the data table below, Table 7, as is the direct comparison data, found in Table 8.

Table 7: Comparisons Table

Comparisons Table		
Translation's Required		
Green Values	0	
EPA Stormwater	3	
CLASIC	1	
Inherent Assumptions		
Green Values	7	15
EPA Stormwater	8	
CLASIC	19	
Co Benefits		
Green Values	7	
EPA Stormwater	0	
CLASIC	16	
COSTS	Costs Table (Table 11)	
Water Quality	Water Quality Table (Table 12)	
Alternative Funding Possibilities		
Green Values	7	
EPA Stormwater	N/A	
CLASIC	16	

Table 8: Direct Comparisons

Direct Comparison	**Baseline**	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**	**Annual Rainfall**	
Runoff (in)							Green Values	45.16"
Green Values	29.16	11.594	12.402	9.462	16.551	14.171	EPA Stormwater	50.18"
EPA Stormwater	44.05	41.7	42.28	28.41	42.87	42.58	CLASIC	40.4"
CLASIC	31.3	29.5	29.5	27	29	29		
Green Values % Change		60.24%	57.47%	67.55%	43.24%	51.40%		
EPA Stormwater % Change		5.33%	4.02%	35.51%	2.68%	3.34%		
CLASIC % Change		5.75%	5.75%	13.74%	7.35%	7.35%		

Volume (ft^3)								
Green Values	0	506.8	632.9	1306.1	2950	4888.9		
EPA Stormwater	N/A	N/A	N/A	N/A	N/A	N/A		
CLASIC	0	760	886.667	1596.667	3800	6333.333		

The degree of translation is the number of times a data point from the base data in Table 2 had to be converted, translated, or extra information was needed. The translation needed for each tool is as follows: 0 needed for the Green Values Tool; 3 needed for the EPA Stormwater Calculator; and 1 needed for the CLASIC Tool. The Green Values Tool did not need any data points translated to create the inputs needed. The EPA Stormwater Calculator needed 3 data points translated which were the soil type, the topography of the area, and the Site Suitability. The soil type of the area was found by looking up the average soil type for Philadelphia which was found to be sandy loam. The topography was found by analyzing the parking lot chosen and it was flat with an allowance of a 2% slope. The Site Suitability was found by comparing the given options to the parking lot and choosing the most representative selection. The CLASIC Tool had 1 translation with the Drain Time for the rain gardens, which was found to be 72 hours as per the PWD's current practices.

The inherent assumptions are the automatically suggested parameters that came with each tool. Each project was edited to match the initial data, or a translation made if that was possible. All other inputs were the inherent assumptions of each tool. The inputs for each tool can be seen above in Tables 3, 4, and 5.

The Green Values Tool had 7 inherent assumptions for Project 1, and 15 for Project's 2 through 5. Project 1's inherent assumptions were the Amended Soil, the Amended Soil Porosity, the Aggregate, the Aggregate Porosity, the Construction Costs of the Rain Garden, the Annual Maintenance Cost of the Rain Garden, and the Typical Useful Life of the Rain Garden. Project's

2 through 5 had the inherent assumptions of the Amended Soil, the Amended Soil Porosity, the Aggregate, the Aggregate Porosity, the Construction Costs of the Rain Garden, the Annual Maintenance Cost of the Rain Garden, the Typical Useful Life of the Rain Garden, the Canopy, the Canopy Porosity, the Tree Pit, the Soil Depth, the Soil Porosity, and the Construction Costs of the Trees, the Annual Maintenance Cost of the Trees, and the Typical Useful Life of the Trees. All of the values for the inherent assumptions are found in Table 3.

The EPA Stormwater Calculator has 8 inherent assumptions built into the tool. Those assumptions are the Soil Drainage, the Climate Change modifier, the Soil Media Thickness, the Soil Media Conductivity, the Percent Capture Ratio, the Cost Region, the Years to Analyze, and the Event Threshold. Each project had the same inherent assumptions as the tool did not include trees into the analysis. All of the values for the inherent assumptions are found in Table 4.

The CLASIC Tool has 19 inherent assumptions built into the tool. The assumptions are the Land Use, the Soil database, the Subunits, the Water Quality, the Overland Flow Length, the Infiltration, the Technology Effluent, the Closest City, the Regional Cost Factor, the Study Period, the Annual Discount Rate, the Filter Media Depth, the Seepage Rate, the Vegetation type, the potential for Routine Mowing, the Irrigation inclusion or exclusion, the Tree inclusion or exclusion, the Percent Impervious Area Captured, and the Depth to Capture. All of the values used for the projects for the inherent assumptions are found in Table 5.

The Green Values Tool shows 7 co-benefits offered. The 7 shown by the tool are the Reduced Energy Use from Trees, the Reduced Air Pollutants from Trees, the Carbon Dioxide Sequestration from Trees, the Compensatory Value of Trees, the Groundwater Replenishment, the Reduced Treatment Benefits, and the Increased Real Estate Value. The EPA Stormwater Calculator does not cover the co-benefits offered by using GSI as opposed to grey infrastructure, rather it focuses on the change in water. The CLASIC Tool offers 16 different co-benefits. The co-benefits are Property Values, Avoided Costs from Illness, Avoided Costs from Combined Sewer Treatment, Potential impacts from Nuisance Floods, Building Energy Efficiency, Avoided Water Treatment, Employment Opportunity, Health Impacts form Air Quality, Mental Health, Thermal Comfort, Increased Supply from Harvested Stormwater, Public Awareness of Stormwater and Water Systems, Potential Avoided Social Strain Associated with Nuisance Flooding, Ecosystem Services, Groundwater Flow, and Carbon Sequestration.

The results of the Green Values Tool can be found in appendices A, but the specific co-benefits results are below in Table 9. The co-benefits results are measured in dollars saved both annually and by the lifecycle benefits timescale. The specific co-benefit results for CLASIC can be found below in Table 10. The table reports a score which is assigned by CLASIC with 5 being the best score possible. As there are no co-benefits identified by the EPA Stormwater Calculator, there is no results table.

Table 9: The Green Values Tool Co-Benefits Results

Green Values	**Project 1**		**Project 2**		**Project 3**		**Project 4**		**Project 5**	
Co-Benefits	**Annual**	**Life cycle Benefits**	**Annual**	**Life cycle Benefits**	**Annual**	**Life cycle Benefits**	**Annual**	**Life cycle Benefits**	**Annual**	**Life cycle Benefits**
Reduced Energy Use from Trees			$36.00	$732.58	$180.00	$3,662.91	$360.00	$7,325.82	$576.00	$11,721.31
Community Total	$31.30	$636.93	$316.36	$6,437.75	$1,413.42	$28,762.42	$2,991.75	$60,880.64	$4,755.37	$96,769.44
Reduced Air Pollution from Trees			$0.18	$3.68	$0.91	$18.42	$1.81	$36.83	$2.90	$58.93
Carbon Dioxide Sequestration from Trees			$0.12	$2.44	$0.60	$12.21	$1.20	$24.42	$1.92	$39.07
Compensatory Value of Trees			$275.00	$5,596.11	$1,375.00	$27,980.55	$2,750.00	$55,961.09	$4,400.00	$89,537.75
Groundwater Replenishment	$23.25	$473.05	$30.49	$620.53	$27.42	$557.95	$177.31	$3,608.23	$260.36	$5,298.16

Reduced Treatment Benefits	$8.05	$163.89	$10.56	$214.98	$9.50	$193.30	$61.43	$1,250.06	$90.20	$1,835.53
Total	$31.30	$636.93	$352.36	$7,170.33	$1,593.42	$32,425.33	$3,351.75	$68,206.45	$5,331.37	$108,490.75

Table 10: CLASIC Co-Benefit Results

CLASIC	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
Economic Co-Benefits					
Property Values					
Avoided Costs from Illness		2.3	5	3.7	3.7
Avoided Costs from Combined Sewer Treatment					
Potential impacts from Nuisance Floods					
Building Energy Efficiency					
Avoided Water Treatment					
Employment Opportunity	2.6	3.1	2.7	3.4	5
Social Co-Benefits					
Health Impacts form Air Quality		2.3	5	3.7	3.7
Mental Health	2.3	2.3	5	3.5	3.5
Thermal Comfort					
Increased Supply from Harvested Stormwater					
Public Awareness of Stormwater and Water Systems	3.3	3.6	4.1	3.1	3.7
Potential Avoided Social Strain Associated with Nuisance Flooding	2.7	2.7	5	3.2	3.2
Environmental Co-Benefits					
Ecosystem Services	1	1	1.7	1	1
Groundwater Flow	2.8	2.8	5	3.1	3.1
Carbon Sequestration					

The Costs of each project are split up into multiple categories depending on each tool. The exact numerical results are in Table 11 below. The Green Values Tool shows the Initial Cost, the Maintenance Cost, and the Lifecycle Cost. The EPA Stormwater Calculator shows the

Capital Cost and the Maintenance Cost but for annual values. The CLASIC Tool shows the Construction Cost, the Maintenance Cost, the Rehabilitation Cost, and the Lifecycle Cost.

Table 11: Costs Table for Green Values, EPA Stormwater, and CLASIC Tools

Costs	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
Green Values					
Initial Cost	$26,212	$35,865	$252,478	$270,322	$338,569
Maintenance Cost	$7,128	$10,031	$39,750	$79,141	$97,692
Lifecycle Cost	$180,337	$252,478	$994,623	$1,980,847	$2,447,241
EPA Stormwater					
Capital Cost (annual)	$8,202.05	$8,205.92	$8,310.01	$8,735.27	$9,092.82
Maintenance Cost (annual)	$61.49	$63.41	$115.04	$325.99	$503.36
Maintenance Cost (30 yrs)	$1,844.70	$1,902.30	$3,451.20	$9,779.70	$15,100.80
CLASIC					
Construction Cost	$81,810	$98,700	$101,099	$176,397	$293,995
Maintenance Cost	$60,726	$78,967	$63,887	$90,132	$150,220
Rehabilitation Cost	$49,998	$61,586	$45,528	$57,402	$95,670
Lifecycle Cost	$192,534	$239,253	$210,514	$323,931	$539,885
Annual Construction	$2,727	$3,290	$3,369	$5,879	$9,799
Annual Maintenance	$2,024	$2,632	$2,129	$3,004	$5,007
Annual Rehabilitation	$1,666	$2,052	$1,517	$1,913	$3,189

The change in Water Quality is mentioned only briefly in the Green Values Tool and in more depth in the CLASIC Tool. The Green Values Tool shows the reduction in treatment benefits and is measured in dollars saved. This is obliquely tied to the change in water quality as there are less pollutants, nutrients, or other substances that require treatment to remove which in turn saves money. The reduced treatment benefit results are shown in Table 12 below. The CLASIC Tool measures hydrologic and water quality performance together. The hydrologic performance is measured by the percent change in volume from baseline for the runoff, the infiltration, and the evaporation. All the results are found in Table 12. The water quality is reported by the percent change in contaminant load, where a positive percentage reflects an increase from baseline and a negative percentage represents a decrease from baseline. The CLASIC Tool covers the total suspended solids, the total nitrogen, the total phosphorus, and the fecal indicator bacteria. The tool also covers the annual cost of nutrient load reduction for the total nitrogen and the total phosphorus, also found in Table 12.

Table 12: Water Quality

Water Quality	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
CLASIC					
Percent Change in Volume from Baseline					
Runoff	-5.90%	-5.90%	-13.90%	-7.60%	-7.60%
Infiltration	31.90%	32.90%	71.60%	37.70%	37.70%
Evaporation	4.50%	4.50%	14.50%	9%	9%
Percent Change in Contaminant Load					
Total Suspended Solids	-8.80%	-8.80%	-18.50%	-9.50%	-9.50%
Total Nitrogen	-7.80%	-7.80%	-16.80%	-8.80%	-8.80%
Total Phosphorus	-5.80%	-5.80%	-13.70%	-7.50%	-7.50%
Fecal Indicator Bacteria	-9%	-9%	-18.80%	-9.60%	-9.60%
Annual Cost of Nutrient Load Reduction					
Total Nitrogen	$0.00	$0.00	$0.00	$0.00	$0.00
Total Phosphorus	$0.02	$0.02	$0.01	$0.02	$0.03
Green Values	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
Reduced Treatment Benefits (annual)	$8.05	$10.56	$9.50	$61.43	$90.20

Alternative Funding Possibilities are potential places to look for funding through the argument that the co-benefits offer more reasons for non-water related fields to fund and support GSI. The Green Values Tool shows the increase in the owner's financial stake in the project, the money saved in groundwater treatment and replenishment, and the increase in real estate values. This would indicate that a case could be made to those living nearby that investing in the GSI would prove more profitable long term as a neighborhood decision regarding real estate values. The EPA Stormwater Calculator focuses on the changes in runoff and infiltration and rainfall as a result of GSI which limits the pool of prospective funding to groups already invested in water and GSI. The CLASIC Tool offers a much larger pool of prospective funding opportunities as the range of co-benefits shown is slightly more than twice the size as the Green Values Tool.

The Direct Comparison of each tool was done by finding the runoff in inches from each tool per project and comparing them to each other, and against the baseline runoff. The same was done with the volume in cubic feet, and the results are in Table 8. The percent change in runoff was also calculated and is also shown above.

Discussion

Each of the three Green Stormwater Infrastructure Tools excels in a different aspect of GSI. The Green Values Tool is extremely user friendly, and offers a direct comparison of BMP and non-BMP developments to develop the site. The EPA Stormwater Calculator shows the change in hydrology and rainfall due to the presence of BMP's and allows for a baseline comparison supported by graphs and tables of those changes. The CLASIC Tool covers the co-benefits offered by GSI extensively, and can compare multiple scenarios of different types and quantities of GSI's easily.

To better compare and understand the three tool's uses and differences, several testing criteria were established in the methods section. These criteria are as follows: the degree of translation; the inherent assumptions made by the tools; the co-benefits offered and reported; the costs as the construction, maintenance, and lifecycle costs of the GSI's; the change in water quality due to the presence of GSI; the alternative funding locations through the co-benefits offered; and the direct comparisons of the runoff in inches and the volume in cubic feet. After comparing those criteria, the ease of use, the use in planning versus analysis, the intended scale of the tool, the drawbacks of the tools, and the potential combinations were considered for each.

The number of translations needed by the Green Values Tool was zero. All of the information needed to run the tool was found in Table 2 above. The number of translations needed to run the EPA Stormwater Calculator was 3, and the number needed for the CLASIC Tool was 1. The number of needed translations from the initial data also plays a part with the inherent assumptions of the tool in how user friendly the tool is. The Green Values Tool has 7 inherent assumptions, the EPA Stormwater Calculator has 8, and the CLASIC Tool has 19. These two criteria combined shows the general ease of use of the tool, as the more translations and inherent assumptions needed makes picking up the tool slightly more complicated. However, the detailed inherent assumptions and options lets the tool offer more information, especially for co-benefits and therefore for alternative funding possibilities. These comparisons can be found above in Table 7. Therefore, the Green Values Tool, with no translations needed and lowest inherent assumptions, is most easy to use.

Another important aspect of analyzing these GSI Tools is to see what, if at all, they say about the co-benefits offered by GSI's. The Green Values Tool offers information on 7 types of co-benefits, the EPA Stormwater offers no co-benefit analysis, and the CLASIC Tool shows 16 different types of co-benefits. All of these co-benefits can be seen in Table 9 and Table 10 above. The Green Values Tool focuses mostly on the air quality and tree-based co-benefits like carbon sequestration. It also reports all findings in terms of dollars saved, which creates a financial lens with which to view the GSI's results. The CLASIC Tool however reports on many more co-benefits which are categorized into three groupings: Economic, Social, and Environmental. The results for this tool are assigned a score from 1 to 5, with 5 being the best score. According to the CLASIC Tool, these particular rain gardens offer the following as economic co-benefits: reduced costs from illness, and increased employment opportunity. The social co-benefits are increased mental health, increased public awareness of stormwater, and reduced social strain due to nuisance flooding. They also offer increased ecosystem services and groundwater flow for environmental co-benefits. The CLASIC Tool's system of assigning score numbers means that it is straightforward to track the co-benefit changes per scenario, which would allow for tailoring in the planning stages. Out of all three tools, CLASIC offers the most comprehensive co-benefit analysis.

One critical part of any project is determining the budget needed to achieve one's goals. The GSI Tools all include some sort of cost estimate or analysis in their set up which allows for proper planning. The costs are shown in Table 11 above. The Green Values Tool shows the cost estimates in terms of initial cost, maintenance costs, and lifecycle costs. The EPA Stormwater Calculator has the cost estimates in terms of the capital costs and maintenance costs but for an annual rate. The CLASIC Tool measures costs in construction, the maintenance, the rehabilitation, and lifecycle. The rehabilitation cost measures the cost needed to return the GSI back to original function. The tool also measures the average annual cost over the design life of the GSI. All three of the tools have different cost estimates. The interesting comparisons occur when looking at the data graphed against one another, when possible.

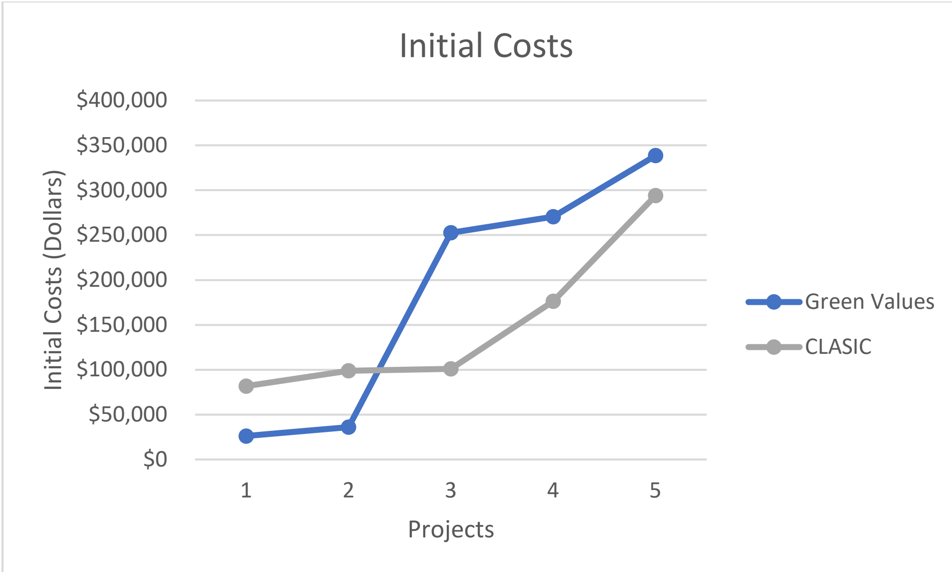

Figure 4: Initial Costs

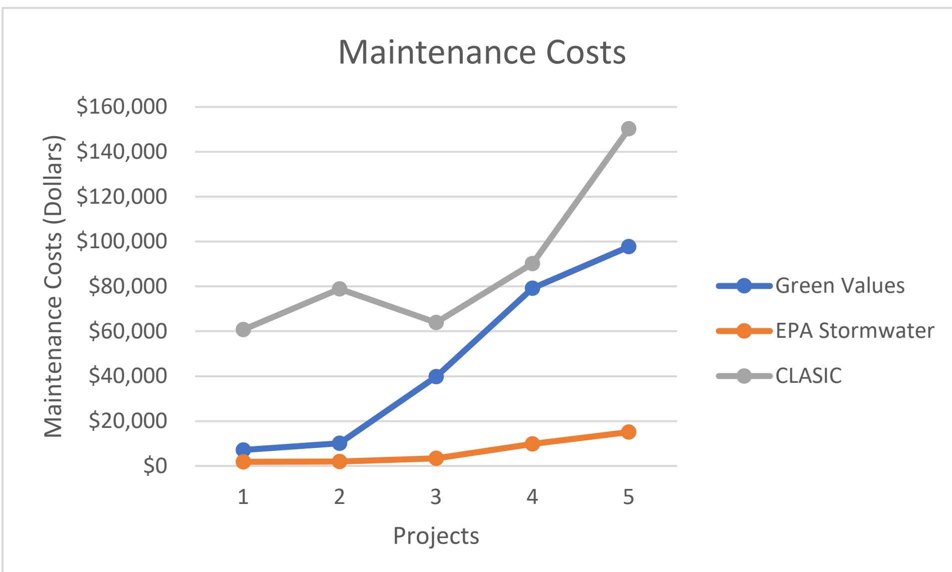

Figure 5: Maintenance Costs

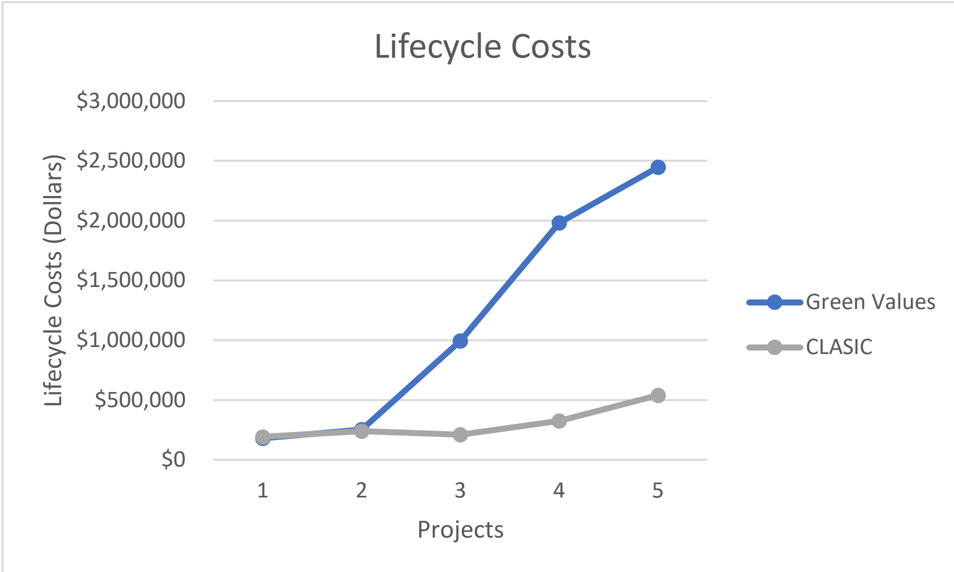

Figure 6: Lifecycle Costs

The lifecycle costs for the Green Values Tool and the CLASIC Tool are extremely similar for the smaller rain gardens, but then differ by a factor of 2 by project 5. The Initial Costs for the Green Values and CLASIC Tool's do not have an overall trend or change, except for the fact that the CLASIC Tool's estimation is overtaken by the Green Values Tool's estimation after project 2. The Green Values Tool's jump in estimation for projects 3 through 5 in Figure 6 is likely due to the valuation of the increase in area in the tool's cost analysis. Out of all the tools, the EPA Stormwater has the lowest values across all cost estimates. When using this aspect of each tool, it is essential to double check the data inputted into the tool as well as the inherent assumptions so that the result is as accurate a prediction as possible.

The water quality assessment made by the tools is important for a variety of reasons. The EPA tests water for total coliform bacteria, nitrates, total dissolved solids, and other such factors for health reasons (US EPA, 2005). GSI can reduce those numbers which makes knowing what to expect in terms of water quality change due to the selected GSI's important. The Green Values

Tool shows the reduced treatment benefits annually in terms of dollars saved, shown in Table 12. The EPA Stormwater Calculator does not cover water quality. The CLASIC Tool does cover water quality and hydrology, and the results can be seen in Table 12. The tool predicts a reduction from the baseline for the total suspended solids, the total nitrogen, the total phosphorus, and for the fecal indicator bacteria. It also shows the annual cost of nutrient load reduction annually, where for these scenarios only the total phosphorus was shown to have a change. Tracking the predicted change in water quality is vital for projects focusing on following EPA Guidelines or when working on a municipal level project. If water quality change is a prevailing reason behind the decision to include GSI in a project, then the CLASIC Tool would provide the most information about the change.

Alternative funding possibilities and opportunities are found by analyzing the co-benefits suggested by each tool as those provide potential places or groups that might be interested in funding BMP's and GSI. Therefore, the number of alternative funding opportunities matches the number of unique co-benefits offered by each tool. By showing that there is a marketable reason such as avoided costs from illness or an increase in property value, cases can be made to encourage other groups to invest in GSI such as hospitals and Home Owners Associations. By investigating who exactly would benefit from a co-benefit of a GSI project, it becomes possible to identify and encourage multigroup funding.

The Green Values Tool shows 7 different co-benefits, but the focus is on reduced energy costs, reduced air pollution, better groundwater treatment and the increase in property values. Therefore, if using the Green Values Tool to help locate alternative funding, it would be wise to look for groups already supporting increasing property values, dealing with groundwater treatment, or helping with pollution. Some such groups could be neighborhood groups, sewer treatment businesses, or local hospitals or clinics in places with poor air quality. The CLASIC Tool reports for these rain gardens that the co-benefits are reduced costs from illness, increased employment opportunity, increased mental health, increased public awareness of stormwater, reduced social strain due to nuisance flooding, increased ecosystem services, and better groundwater flow. Alternative funding might be found in wellness groups, hospitals, local gardens, and anywhere that anyone has to deal with nuisance flooding. Using the GSI Tools co-benefit results as a first step in locating places where cases can be made for alternative funding is a great way to start building an interconnected network of people, groups, and business dedicated to a greener and healthier way of life.

The Direct Comparisons chosen for these projects were the runoff in inches per tool, and the volume captured in cubic feet by each tool. Additionally, the percent change in runoff was graphed. All three tools had the change in runoff due to each GSI, but the EPA Stormwater Calculator did not provide the volume captured numerically. The Runoff Direct Comparisons Graph is below as Figure 7, the Volume Direct Comparisons Graph is Figure 8, and the Percent Change in Runoff is Figure 9.

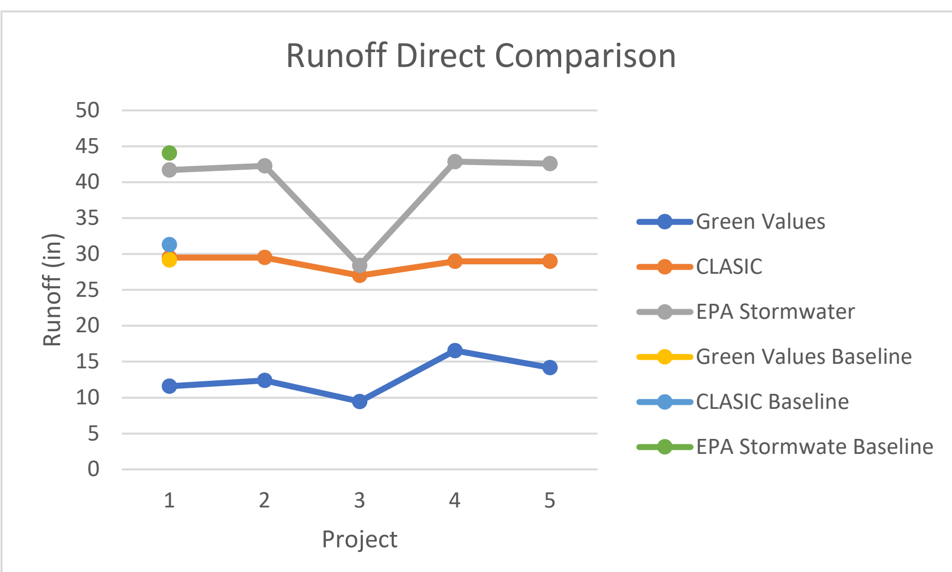

Figure 7: Runoff Direct Comparison

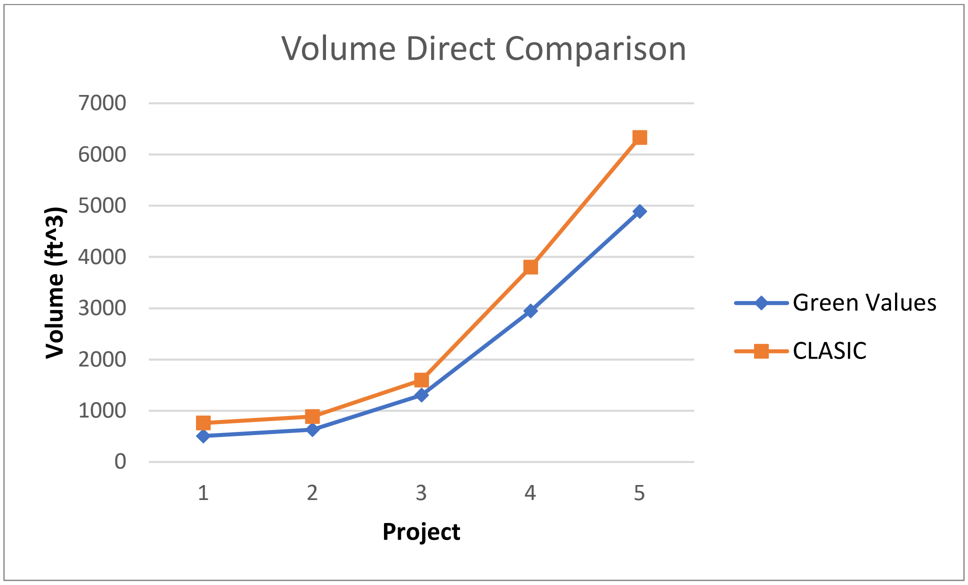

Figure 8: Volume Direct Comparison

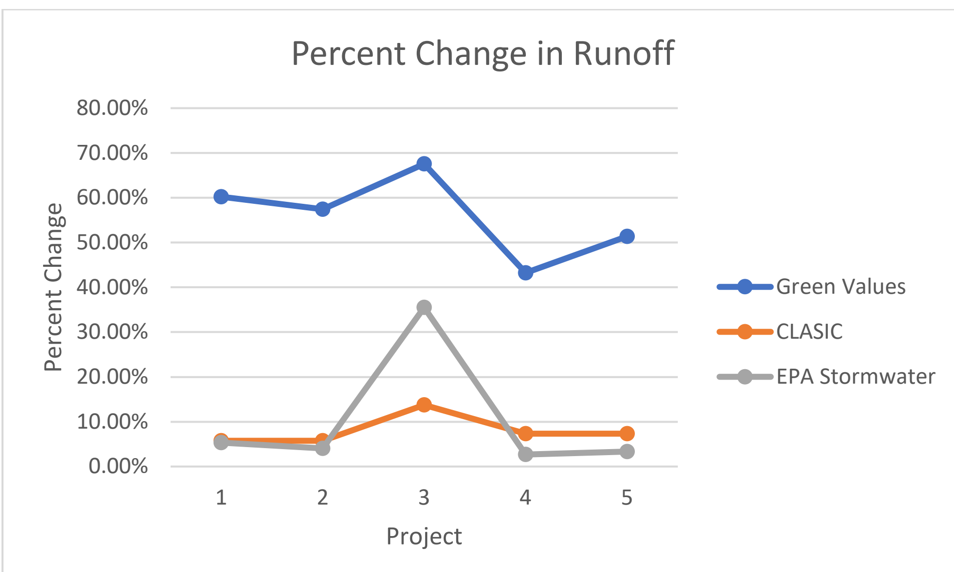

Figure 9: Percent Change in Runoff

As seen in the Runoff Direct Comparisons graph, each tool predicted that the introduction of GSI's would reduce the runoff. The Green Values Tool predicted that it would reduce the largest amount of runoff, nearing 70% for project 3, but also had the lowest runoff values. The EPA Stormwater Calculator predicted the highest runoff values and the lowest percent change, with the exception of project 3. The CLASIC Tool reported mid level runoff, and a lower percent change. For the volume captured, both tools were within the same level of magnitude for the first three projects, but the CLASIC Tool reported greater volume captured for projects 4 and 5.

Three ways to use these tools are planning, analysis, and cost specific analysis. A planning use of a tool would be to use it to plan out a GSI project, compare which GSI's to use and in what quantities, to make the case for potential funding agreements for the projects, and to predict the change in water quality. To use the tools for analysis would be to put already started or completed projects into the tool for co-benefit analysis or for more specific hydrology based questions. Planning requires the least amount of actual information and all three of the tools would work for that purpose. It would show the co-benefits of the proposed projects, which could be used to search for alternative funding. Analysis is a more difficult aspect as it requires much more detailed information for the actual projects, that all the inherent assumptions match the area the project will be built in, and that the correct tool is chosen for the analysis desired. Water quality change could also be analyzed, but only by using the CLASIC Tool. A cost specific analysis is more complicated as the correct financial information is needed on top of everything else required for the more general analysis. The high variability found in the cost data from each tool means that selecting the best tool is perhaps the most important part of the cost analysis.

The intended scale of each tool is essential in deciding which tool to use for which scenario or project. The Green Values Tool is intended for site specific projects, the EPA Stormwater Calculator is meant for neighborhood sized projects, and the CLASIC Tool is meant for municipal sized projects. The Green Values Tool is designed to help plan GSI for single buildings or neighborhoods (CNT, 2006). The EPA Stormwater Calculator is designed for reducing runoff for small site hydrology project (US EPA, 2019). The CLASIC Tool is intended to be used by managers and operators of stormwater systems or municipal government managers and operators (Colorado State University One Water Solution, 2021). The scale for the intended use of the tool makes some of the drawbacks and benefits of each tool much clearer. The Green Values Tool does not allow for site comparison within the tool, as that is not immediately needed for a single site project but is very easy to use as a GSI tool. The EPA Stormwater Calculator is meant for larger scaled projects, allows for one inherent comparison against a baseline, and covers the change in runoff and storm events thoroughly; however, it does not scale up well and becomes less reliable at larger sites. The CLASIC Tool is meant for municipal use with a focus on co-benefits and water quality but requires more information and understanding to run.

Each of these tools are useful GSI tools, but when being used it is critical to not neglect their drawbacks. The Green Values Tool offers a basic dive into GSI's and is very easy to use. Nonetheless, there are only straightforward co-benefits offered, and there is very little analysis given about water quality change. It also can only be used to run one scenario at any given time. The EPA Stormwater Calculator is comprehensive when it comes to the hydrology side of GSI and can compare two scenarios at once, but offers no co-benefit analysis at all, does not cover the water quality section of GSI, and does not include trees in any capacity. The CLASIC Tool has the highest amount of co-benefit analysis and can run multiple scenarios of various GSI's at once, but the number of trees in a project is dependent on the size of the GSI and not an input which makes accounting for the actual planned number of trees difficult.

While each tool has its own particular strengths and weaknesses -- depending on what the user wishes to accomplish -- a different tool or a combination of tools should be used. For a quick, easily interpreted, with some co-benefits but with a variable cost analysis and no internal comparison tool, the Green Values Tool works for quick planning. The EPA Stormwater Calculator is incredibly helpful for straight hydrology and offers comprehensive graphing and a baseline to scenario comparison, but offers a very basic cost analysis, no co-benefit analysis, and no water quality analysis. These two combined would create a more comprehensive look at the GSI being planned, but care would have to be taken in the data translation. Trees would pose a problem as the EPA Stormwater Calculator does not account for them but it is possible to use i-Tree Hydro or other tools to account for those changes to the area. The CLASIC Tool is the most successful in analyzing co-benefits, and therefore alternative funding potential, can run multiple scenarios at once which is instrumental for planning and time management, and does predict the change in water quality.

Conclusion

In conclusion, the Green Values National Stormwater Management Calculator, the Environmental Protection Agency's National Stormwater Calculator, and the Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs tool all offer ways to analyze, plan, or engage with the potential of GSI and BMP's in a useful fashion. Each communicates the results effectively, with the Green Values Tool having the least success in that area. It allows for a quick and easy analysis done for a project, but each scenario must be done one by one. The EPA Stormwater Calculator has the hydrology of a GSI on a site well graphed, and allows for two scenarios to be run, one baseline and one comparison, but offers no co-benefits or water quality analysis. The CLASIC Tool offers the most comprehensive co-benefit analysis which allows for a much more targeted alternative funding search and information on the predicted change in water quality. Each of these tools could be used together but the data translations must be done carefully, along with the inherent assumptions which would need to be edited to match across the board. Each offers a comprehensive cost analysis, but the timeframe and the accuracy to the location and interest would have to be specifically chosen to match the desired location.

The GSI Tools vary across all the categories. The Green Values Tool has the least amount of translations needed, the least amount of inherent assumptions, is the easiest to use, has the second highest number of co-benefit's, shows the second highest number of alternative funding locations, offers a cost analysis, has the highest runoff percent change but a more sedate volume captured, and offers some water quality assessment. The EPA Stormwater Calculator has the most translations needed, the second most inherent assumptions, is moderately difficult to use, has no co-benefits, only helps with water based funding opportunities, offers a cost analysis, has the most consistent runoff percent change but no volume captured, and does not touch upon the change in water quality. The CLASIC Tool has the second highest translations needed, the highest inherent assumptions, is moderately difficult to use, has the most co-benefits, has the most alternative funding locations, shows a cost analysis, shows the percent change in runoff and volume captured, and offers a comprehensive analysis of the change in water quality. All three have their strengths and weaknesses, but knowing that these tools are available can help businesses, communities, and governments to identify alternative funding and encourage more GSI projects.

All of the tools can be used by a community to add more GSI to their neighborhood, which would allow for a greener and healthier environment. Which tool to use depends on the intent of the project; where the Green Values Tool would be most useful for a single site, the EPA Stormwater Calculator would help most for a project concerned with the change in runoff, or where the CLASIC Tool would help predict the change in water quality or using the numerous co-benefits to assist with alternative funding locations. The size of the project matters, as does the location which influences the inherent assumptions and cost analysis. Ultimately, all three of the tools can be used to pursue alternative funding, with the EPA Stormwater limiting its use to already hydrology based groups, and can be used to run comparisons of different Green Stormwater Infrastructures' for the same space to make the best decisions going forward for groups and projects of all sizes.

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Bibliography

CNT. (2020). Increasing Funding and Financing Options for Sustainable Stormwater Infrastructure. Retrieved from https://www.cnt.org/publications/increasing-funding-and-financing-options-for-sustainable-stormwater-management

CNT. (2006) The Green Values Stormwater Management Calculator Methods. Retrieved from https://greenvalues.cnt.org/Green-Values-Calculator-Methodology.pdf

CNT. (2011). The value of green infrastructure: A guide to recognizing its economic, environmental and social benefits. Retrieved from https://www.cnt.org/publications/the-value-of-green-infrastructure-a-guide-to-recognizing-its-economic-environmental-and

Colorado State University One Water Solution (2021). Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC). Retrieved from https://clasic.erams.com/static/er2_clasic/docs/CLASIC_UserGuide.pdf

Nimmer, M., Thompson, A., & Misra, D. (2009). Water table mounding beneath stormwater infiltration basins. *Environmental and Engineering Geoscience, 15*(2), 67-79. doi:10.2113/gseegeosci.15.2.67

NOAA, 2019. Assessing the U.S. climate in 2018. (2019-02-06T08:14:23-0500). Retrieved from http://www.ncei.noaa.gov/news/national-climate-201812

Passarello, M. C., Sharp, J. M., & Pierce, S. A. (2012). Estimating urban-induced artificial recharge: A case study for Austin, TX Urban-induced recharge. *Environmental and Engineering Geoscience, 18*(1), 25-36. doi:10.2113/gseegeosci.18.1.25

Toran, L., & Jedrzejczyk, C. (2017). Water level monitoring to assess the effectiveness of stormwater infiltration trenches. *Environmental and Engineering Geoscience, 23*(2), 113-124. doi:10.2113/gseegeosci.23.2.113

US EPA, O. W. (2005). Home Water Testing? Retrieved from https://library.hud.ac.uk/pages/referencing-niceguidelinesguidance/

US EPA, O. W. (2019). National Stormwater Calculator. Retrieved from https://www.epa.gov/water-research/national-stormwater-calculator

US EPA, O. W. (2015). What is green infrastructure? Retrieved from https://www.epa.gov/green-infrastructure/what-green-infrastructure

William, R., Garg, J., & Stillwell, A. S. (2017). A game theory analysis of green infrastructure stormwater management policies. *Water Resources Research, 53*(9), 8003-8019. doi:10.1002/2017WR021024

Appendix A

	Baseline			Project 1		
Rain Garden Specification	0 Rain Gardens			1 Rain Garden		
Total				$8,402.00		
Capital				$3,642.00		
Maintenance				$246.00		
Potential Increased Capacity				506.8 ft^3	3791.1 gallons	
Amount				600 ft^2		
Tree Specification	0 Trees			0 Trees		
Total						
Capital						
Maintenance						
Potential Increased Capacity						
Site Overview						
Total Cost				$8,402.00		
Increase in Volume Capture				506.8 ft^3	152%	
Land Use	**Original Area**	**Area including BMP**		**Original Area**	**Area including BMP**	
Total Impervious area (ft^2)	105,000	105,000		8,000	7,400	
Parking Surface (ft^2)	105,000	105,000		8,000	7,400	
Rain Garden (ft^2)	0	0		0	600	
Tree (ft^2)						
Total Landscape Area (ft^2)	0	0		0	0	
Total BMP Area (ft^2)	0	0		0	600	
Total Lot Area (ft^2)	105,000	105,000		8,000	8,000	
Benefits	**Annual**	**Lifecycle Benefits**		**Annual**	**Lifecycle Benefits**	
Reduced Energy Use from Trees						
Community Total				$31.30	$636.93	
Reduced Air Pollution from Trees						
Carbon Dioxide Sequestration from Trees						
Compensatory Value of Trees						
Groundwater Replenishment				$23.25	$473.05	
Reduced Treatment Benefits				$8.05	$163.89	
Total				$31.30	$636.93	
Increased Real Estate Value	**Existence**	**Area**		**Existence**	**Area**	
Value from Rain Garden				2.80%	0.20%	
Value from Trees						
Total						
Cost Summary	**W/out BMP**	**W/ BMP**	**Savings**	**W/out BMP**	**W/ BMP**	**Savings**
Cost to Develop	$2,439,618.00			$185,876.00	$180,337.00	3% in net value
Development	**Initial Cost**	**Annual Maintenance**	**Life Cycle Cost**	**Initial Cost**	**Annual Maintenance**	**Life Cycle Cost**
w/out BMP's	$320,250.00	$97,650.00	$2,439,618.00	$24,400.00	$7,440.00	$185,876.00
w/ BMP				$26,212.00	$7,128.00	$180,337.00
Difference				-$1,812.00	$312.00	$5,539.00
Runoff and Hydrology						
Runoff	**w/out BMP**	**w/ BMP**	**Difference**	**w/out BMP**	**w/ BMP**	**Difference**
Ave. Annual Rainfall	45.16"			45.16"		
Runoff	29.166"	29.166"	0%	29.166"	11.594"	60%
Runoff Volume (ft^3)	255198.1	255198.1	0	19443.7	7729.2	11714.5
Runoff Volume (gallons)	1909014.8	1909014.8	0	145448.7	57818.4	87630.4
Ave. Storm Rainfall	2.47"	2.47"		2.47"		
Runoff	2.241"	2.241"	0%	2.241"	1.6"	29%
Runoff Volume (ft^3)	19608	19608	0	1493.9	1066.5	427.5
Runoff Volume (gallons)	146678.3	146678.3	0	11175.5	7977.8	3197.7
Hydrology	**w/out BMP**	**w/ BMP**	**Difference**	**w/out BMP**	**w/ BMP**	**Difference**
Initial Abstractions	0.04"	0.04"	0.00%	0.04"	0.19"	0.15%
Initial Abstractions Volume (ft^3)	357.14	357.14	0	27.21	128.57	101.36
Initial Abstractions Volume (gallons)	2671.61	2671.61	0	203.55	961.78	758.23
Ave Cumulative Abstractions	0.2"	0.2"	0.00%	0.2"	0.96"	0.76%
Ave Cumulative Abstractions Volume (ft^3)	1785.71	1785.71	0	136.05	642.85	506.8
Ave Cumulative Abstractions Volume (gallons)	13358.07	13358.07	0	1017.76	4808.89	3791.13
Curve Number	98	98		98	91.2	
Volume						
Rain Garden (ft^3)	0			506.8		
Rain Garden (gallons)	0			3791.1		
Trees (ft^3)						
Trees (gallons)						
Percentage of Volume Capacity Capture Goal	0%	0.5" for 8,000 ft^2		152%	0.5" for 8,000 ft^2	
Required Volume Capture Potential (ft^3)		4375		506.8	333	
Required Volume Capture Potential (gallons)		32727		3791.1	2491	

	Project 2			Project 3		
Rain Garden Specification	1 Rain Garden			1 Rain Garden		
Total	$9,802.00			$18,204.00		
Capital	$4,249.00			$7,891.00		
Maintenance	$287.00			$533.00		
Potential Increased Capacity	591.3 ft^3	4423 gallons		1098.1 ft^3	8214.1 gallons	
Amount	700 ft^2			1300 ft^2		
Tree Specification	1 Tree			5 Trees		
Total	3,733			$18,665.00		
Capital	250			$1,250.00		
Maintenance	180			$900.00		
Potential Increased Capacity	41.6 ft^3	311.2 gallons		208 ft^3	1555.9 gallons	
Site Overview						
Total Cost	$23,337.00			$55,073.00		
Increase in Volume Capture	632.9 ft^3	138.10%		1306.1 (ft^3)	78.40%	
Land Use	**Original Area**	**Area including BMP**		**Original Area**	**Area including BMP**	
Total Impervious area (ft^2)	11,000	10,284		40,000	38,620	
Parking Surface (ft^2)	11,000	10,284		40,000	38,620	
Rain Garden (ft^2)	0	700		0	1300	
Tree (ft^2)	0	16		0	80	
Total Landscape Area (ft^2)	0	0		20,000	20,000	
Total BMP Area (ft^2)	0	716		0	13800	
Total Lot Area (ft^2)	11,000	11,000		60,000	60,000	
Benefits	**Annual**	**Lifecycle Benefits**		**Annual**	**Lifecycle Benefits**	
Reduced Energy Use from Trees	$36.00	$732.58		$180.00	$3,662.91	
Community Total	$316.36	$6,437.75		$1,413.42	$28,762.42	
Reduced Air Pollution from Trees	$0.18	$3.68		$0.91	$18.42	
Carbon Dioxide Sequestration from Trees	$0.12	$2.44		$0.60	$12.21	
Compensatory Value of Trees	$275.00	$5,596.11		$1,375.00	$27,980.55	
Groundwater Replenishment	$30.49	$620.53		$27.42	$557.95	
Reduced Treatment Benefits	$10.56	$214.98		$9.50	$193.30	
Total	$352.36	$7,170.33		$1,593.42	$32,425.33	
Increased Real Estate Value	**Existence**	**Area**		**Existence**	**Area**	
Value from Rain Garden	2.80%	0.30%		2.80%	0.50%	
Value from Trees	5%	0.10%		5%	0.40%	
Total	7.9%%	0.40%		7.90%	0.90%	
Cost Summary	**W/out BMP**	**W/ BMP**	**Savings**	**W/out BMP**	**W/ BMP**	**Savings**
Cost to Develop	$255,579.00	$252,478.00	1.20%	$989,817.00	$994,623.00	-0.50%
Development	**Initial Cost**	**Annual Maintenance**	**Life Cycle Cost**	**Initial Cost**	**Annual Maintenance**	**Life Cycle Cost**
w/out BMP's	$33,550.00	$10,230.00	$255,579.00	$136,000.00	$39,600.00	$989,817.00
w/ BMP	$35,865.00	$10,031.00	$252,478.00	$140,932.00	$39,750.00	$994,623.00
Difference	-$2,315.00	$199.00	$3,101.00	-$4,932.00	-$150.00	-$4,805.00
Runoff and Hydrology						
Runoff	**w/out BMP**	**w/ BMP**	**Difference**	**w/out BMP**	**w/ BMP**	**Difference**
Ave. Annual Rainfall	45.16"			45.16"		
Runoff	29.166"	12.402"	57%	12.226"	9.462"	23%%
Runoff Volume (ft^3)	26735	11368.2	15366.8	61129.5	47312.4	13817
Runoff Volume (gallons)	199992	85040.1	11495.9	457280.1	353921.7	103358.5
Ave. Storm Rainfall	2.47"			2.47"		
Runoff	2.241"	1.648"	26%	1.638"	1.457"	11%
Runoff Volume (ft^3)	2054.2	1510.5	543.7	8187.9	7284.9	903
Runoff Volume (gallons)	15366.3	11299.1	4067.2	61249.6	54494.8	6754.8
Hydrology	**w/out BMP**	**w/ BMP**	**Difference**	**w/out BMP**	**w/ BMP**	**Difference**
Initial Abstractions	0.04"	0.18"	0.14"	0.18"	0.24"	0.06%%
Initial Abstractions Volume (ft^3)	37.41	163.99	126.57	909.09	1188.08	278.99
Initial Abstractions Volume (gallons)	279.88	1226.72	946.83	6800.47	8887.43	278.99
Ave Cumulative Abstractions	0.2"	0.89"	0.69%	0.91"	1.19"	0.06%%
Ave Cumulative Abstractions Volume (ft^3)	187.07	918.94	632.87	4545.45	5940.38	1394.93
Ave Cumulative Abstractions Volume (gallons)				34002.36	44437.16	10434.8
Curve Number	98	91.8		91.7	89.4	
Volume						
Rain Garden (ft^3)	591.3			1098.1		
Rain Garden (gallons)	4423			8214.1		
Trees (ft^3)	41.6			208		
Trees (gallons)	311.2			1555.9		
Percentage of Volume Capacity Capture Goal	138.10%	0.5" for 11,000 ft^2		78.40%	0.5" for 8,000 ft^2	
Required Volume Capture Potential (ft^3)	632.9	458		1306.1	1,667	
Required Volume Capture Potential (gallons)	4734.2	3426		9770.1	12,470	

	Project 4			Project 5		
Rain Garden Specification	1 Rain Garden			1 Rain Garden		
Total	$42,010.00			$70,016.00		
Capital	$18,210.00			$30,350.00		
Maintenance	$1,230.00			$2,050.00		
Potential Increased Capacity	2534 ft^3	18955.6 gallons		4223.3 ft^3	31592.7 gallons	
Amount	3000 ft^2			5000 ft^2		
Tree Specification	10 Trees			16 Trees		
Total	37,329			$59,727.00		
Capital	2,500			$4,000.00		
Maintenance	1,800			$2,880.00		
Potential Increased Capacity	416 tf^3	3111.9 gallons		665.6 ft^3	4979 gallons	
Site Overview						
Total Cost	$121,349.00			199,759		
Increase in Volume Capture	1,950 ft^3	83.20%		4,888.90	111.70%	
Land Use	**Original Area**	**Area including BMP**		**Original Area**	**Area including BMP**	
Total Impervious area (ft^2)	85,000	81,840		105,000	99,744	
Parking Surface (ft^2)	85,000	81,840		105,000	99,744	
Rain Garden (ft^2)	0	3000		0	5000	
Tree (ft^2)	0	160		0	256	
Total Landscape Area (ft^2)	0	0		0	0	
Total BMP Area (ft^2)	0	3,160		0	5,256	
Total Lot Area (ft^2)	85,000	85,000		105,000	105,000	
Benefits	**Annual**	**Lifecycle Benefits**		**Annual**	**Lifecycle Benefits**	
Reduced Energy Use from Trees	$360.00	$7,325.82		$576.00	$11,721.31	
Community Total	$2,991.75	$60,880.64		$4,755.37	$96,769.44	
Reduced Air Pollution from Trees	$1.81	$36.83		$2.90	$58.93	
Carbon Dioxide Sequestration from Trees	$1.20	$24.42		$1.92	$39.07	
Compensatory Value of Trees	$2,750.00	$55,961.09		$4,400.00	$89,537.75	
Groundwater Replenishment	$177.31	$3,608.23		$260.36	$5,298.16	
Reduced Treatment Benefits	$61.43	$1,250.06		$90.20	$1,835.53	
Total	$3,351.75	$68,206.45		$5,331.37	$108,490.75	
Increased Real Estate Value	**Existence**	**Area**		**Existence**	**Area**	
Value from Rain Garden	2.80%	1.10%		2.80%	1.90%	
Value from Trees	5%	0.80%		5%	1.30%	
Total	7.90%	1.90%		7.90%	3.20%	
Cost Summary	**W/out BMP**	**W/ BMP**	**Savings**	**W/out BMP**	**W/ BMP**	**Savings**
Cost to Develop	$1,974,929.00	$1,980,847.00	-0.30%	$2,439,618.00	$2,447,241.00	-0.30%
Development	**Initial Cost**	**Annual Maintenance**	**Life Cycle Cost**	**Initial Cost**	**Annual Maintenance**	**Life Cycle Cost**
w/out BMP's	$259,250.00	$79,050.00	$1,974,929.00	$320,250.00	$97,650.00	$2,439,618.00
w/ BMP	$270,322.00	$79,141.00	$1,980,847.00	$338,569.00	$97,692.00	$2,447,241.00
Difference	-$11,072.00	-$91.00	-$5,918.00	-$18,319.00	-$42.00	-$7,623.00
Runoff and Hydrology						
Runoff	**w/out BMP**	**w/ BMP**	**Difference**	**w/out BMP**	**w/ BMP**	**Difference**
Ave. Annual Rainfall	45.16"			45.16"		
Runoff	29.166"	16.551"	43%	29.166"	14.171"	51%
Runoff Volume (ft^3)	206589	117234.8	89354.2	255198.1	123994.7	131203.4
Runoff Volume (gallons)	1545392.9	876977.3	668415.6	1909014.8	927544.9	981469.8
Ave. Storm Rainfall	2.47"			2.47"		
Runoff	2.241"	1.855"	17%	2.241"	1.744"	22%
Runoff Volume (ft^3)	15873.2	13140.7	2732.5	19608	15255.9	4352.2
Runoff Volume (gallons)	118739.6	98298.9	20440.7	146678.3	114121.9	32556.4
Hydrology	**w/out BMP**	**w/ BMP**	**Difference**	**w/out BMP**	**w/ BMP**	**Difference**
Initial Abstractions	0.04"	0.12"	0.08%	0.04"	0.15"	0.11%
Initial Abstractions Volume (ft^3)	289.12	879.12	590	357.14	1334.93	977.79
Initial Abstractions Volume (gallons)	2162.74	6576.24	4413.51	2671.61	9985.97	7314.35
Ave Cumulative Abstractions	0.2"	0.62"	0.42%	0.2"	0.76"	0.56%
Ave Cumulative Abstractions Volume (ft^3)	1445.58	4395.58	2950	1785.71	6674.65	4888.93
Ave Cumulative Abstractions Volume (gallons)	10813.68	32881.21	22067.53	13358.07	49929.84	36571.76
Curve Number		98	94.2	98	92.9	
Volume						
Rain Garden (ft^3)	2534				4223.3	
Rain Garden (gallons)	18955.6				31592.7	
Trees (ft^3)	416				665.6	
Trees (gallons)	3111.9				4979	
Percentage of Volume Capacity Capture Goal	83.20%	0.5" for 85000 ft^2			111.70%	0.5" for 8,000 ft^2
Required Volume Capture Potential (ft^3)	2,950	3,542			4,888.90	4,375
Required Volume Capture Potential (gallons)	22067.5	26496			36571.8	32727

Appendix B

National Stormwater Calculator Report

Results

Site Description

Capstone

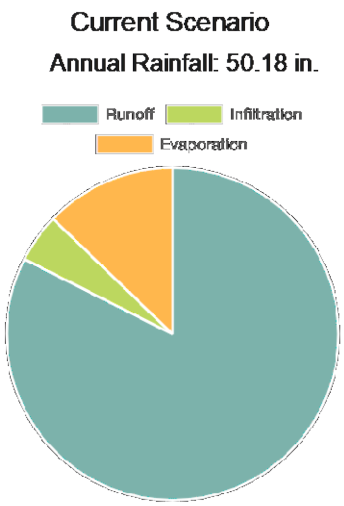
Parameter	Current Scenario	Baseline Scenario
Site Characteristics		
Site Area (acres)	0.184	2.41
Hydrologic Soil Group	B	B
Hydraulic Conductivity (in/hr)	0.4	0.4
Surface Slope (%)	2	Flat (2% Slope)
Precip. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Evap. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Climate Change Scenario	None	None
Land Cover		
% Forest	0	0
% Meadow	0	0
% Lawn	0	0
% Desert	0	0
% Impervious	100	100
LID Controls		
% Disconnection	0	0
% Rain Harvesting	0	0
% Rain Gardens	8 / 5	0
% Green Roofs	0	0
% Street Planters	0	0
% Infiltration Basins	0	0
% Permeable Pavement	0	0
Analysis Options		
Years Analyzed	20	20
Ignore Consecutive Wet Days	False	False
Wet Day Threshold (inches)	0.1	0.1

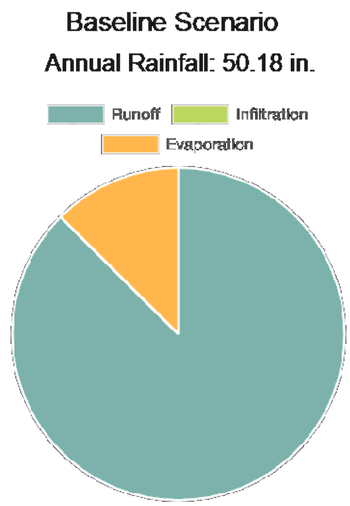
National Stormwater Calculator Report

Results

Site Summary

Capstone





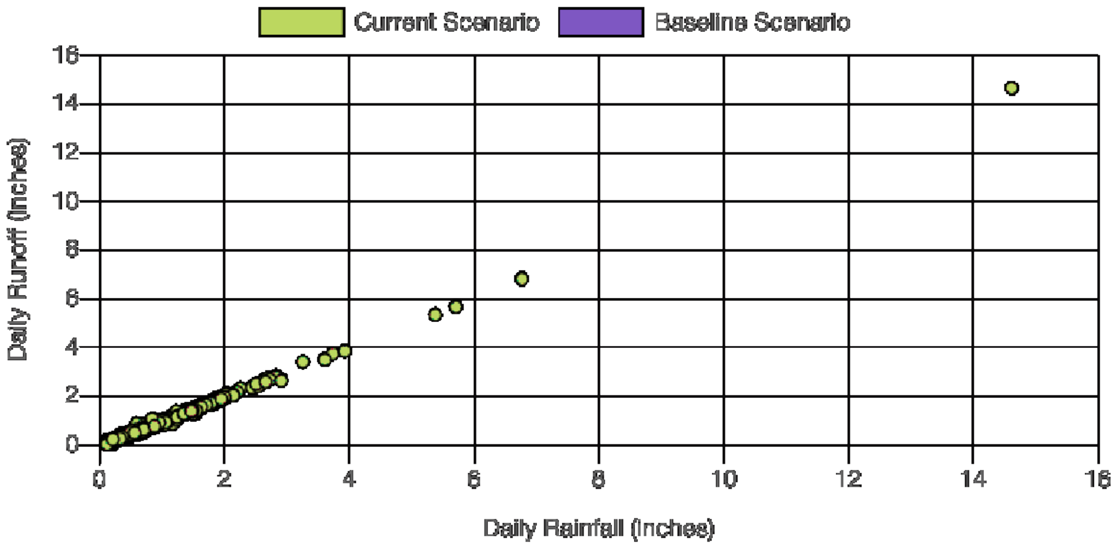
Statisic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	50.18	50.18
Average Annual Runoff (inches)	41.70	44.05
Days per Year with Rainfall	77.34	77.34
Days per Year with Runoff	65.34	66.50
Percent of Wet Days Retained	15.51	14.02
Smallest Rainfall w/ Runoff (inches)	0.11	0.11
Largest Rainfall w/o Runoff (inches)	0.21	0.21
Max Rainfall Retained (inches)	0.34	0.30

National Stormwater Calculator Report

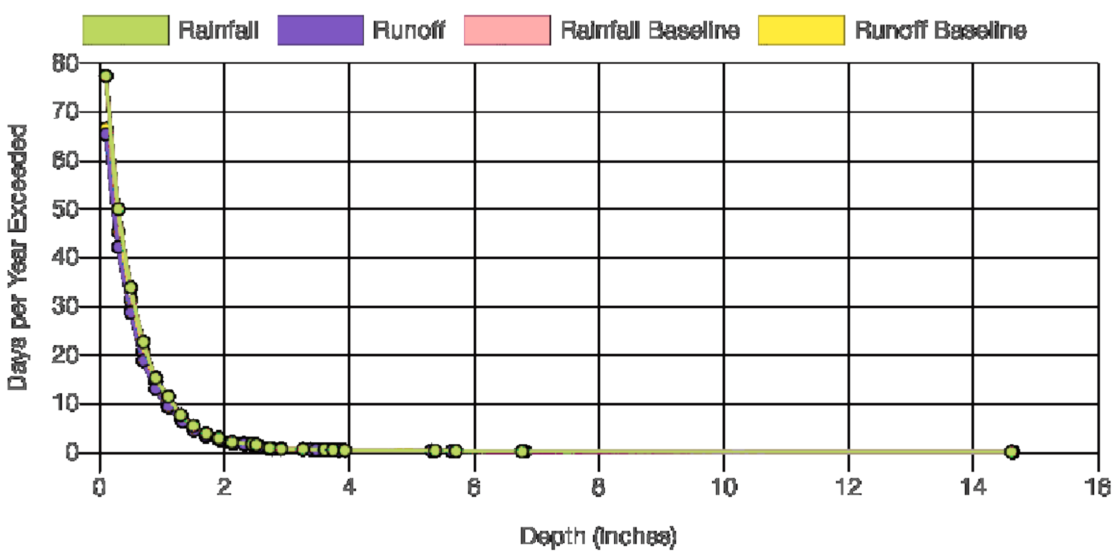
Results

Capstone

Rainfall / Runoff Events



Rainfall / Runoff Exceedance Frequency

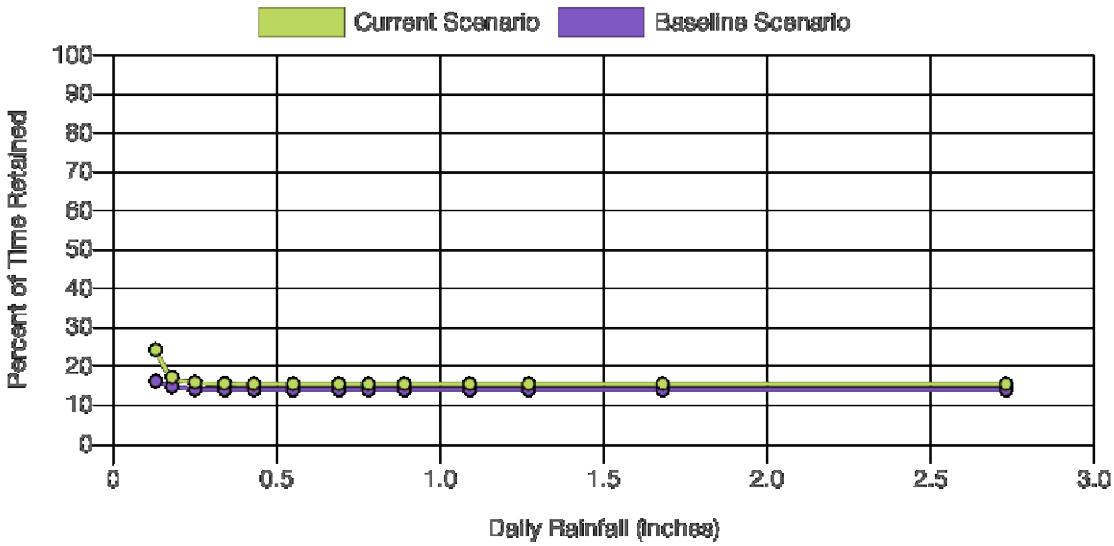


National Stormwater Calculator Report

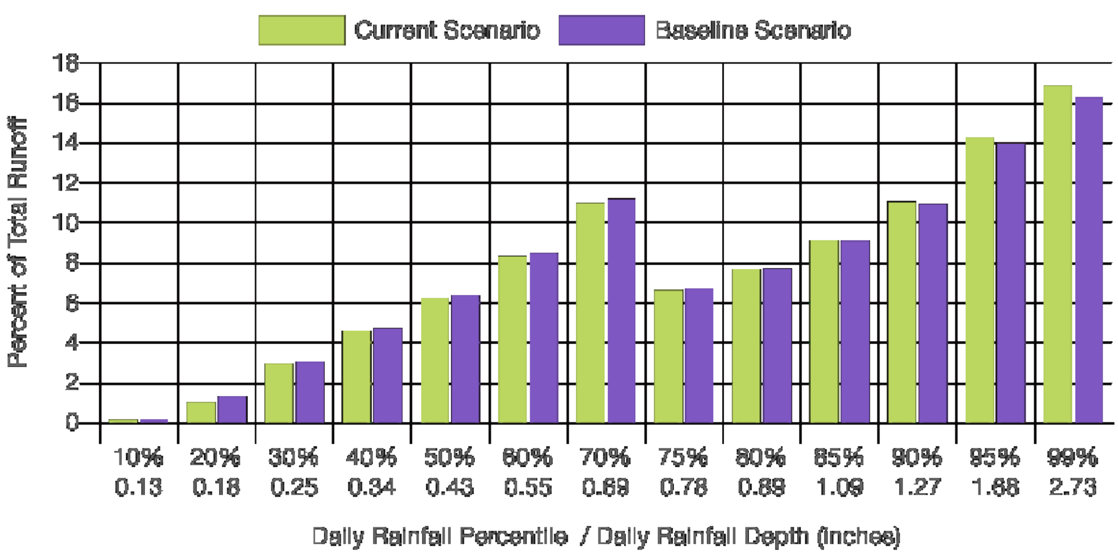
Results

Capstone

Rainfall Retention Frequency



Runoff Contribution by Rainfall Percentile

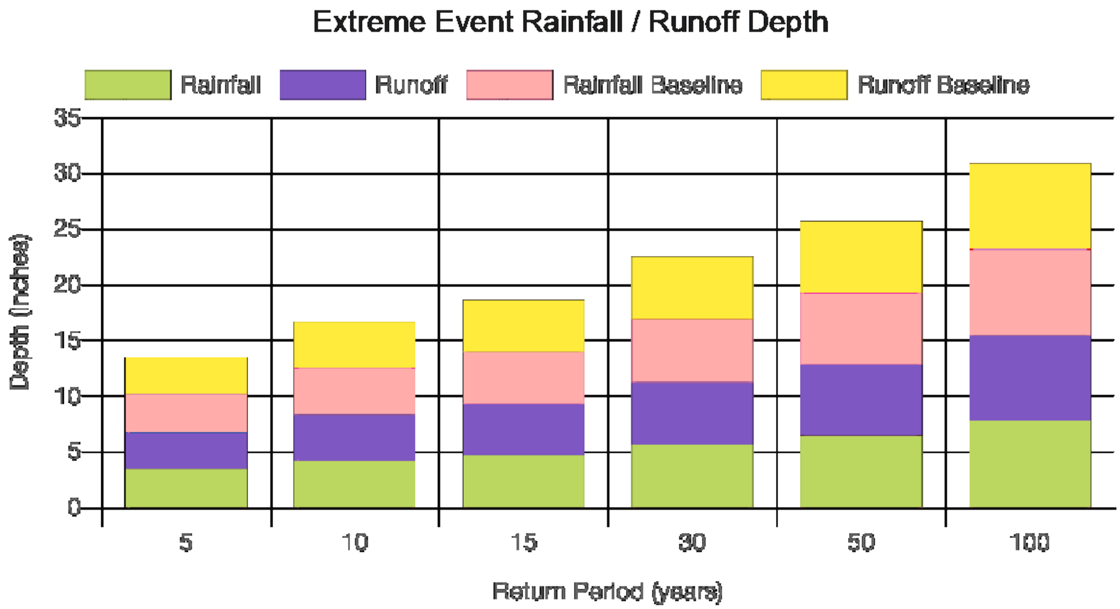


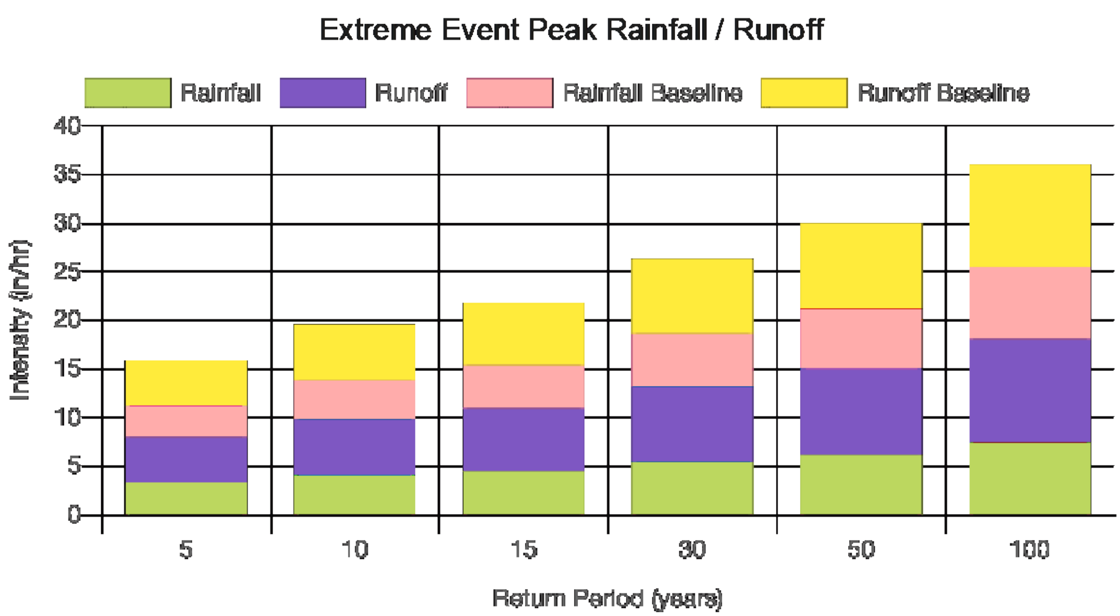
National Stormwater Calculator Report

Results

Capstone

Extreme Event Rainfall / Runoff





National Stormwater Calculator Report

Results

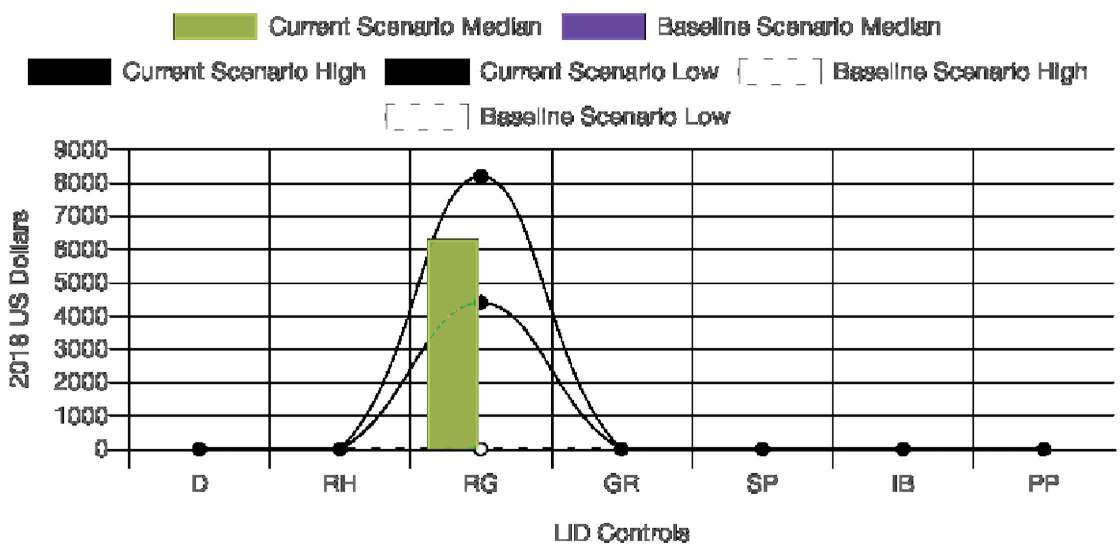
Capstone

Cost Summary

Estimate of Probable Capital Costs (estimates in 2018 US.$)

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	8 (C) / 0 (B)	NA (C) / NA (B)	$4402.66 - $8202.05	$0.00 - $0.00	$4402.66 - $8202.05
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report

Results

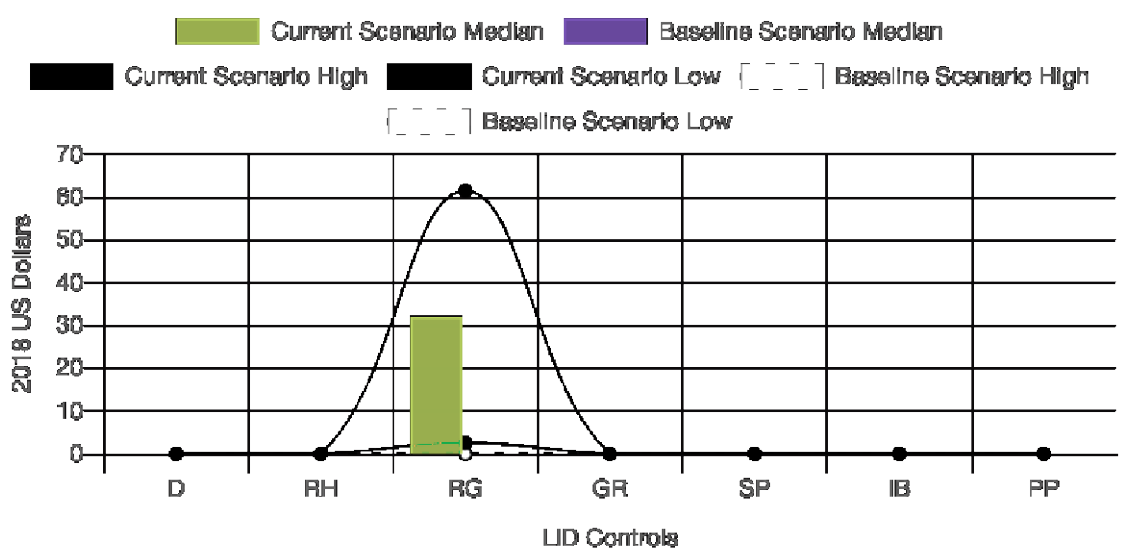
Capstone

Cost Summary

Estimate of Annual Probable Maintenance Costs

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	8 (C) / 0 (B)	NA (C) / NA (B)	$2.54 - $61.49	$0.00 - $0.00	$2.54 - $61.49
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report

Results

Site Description

Capstone

Parameter	Current Scenario	Baseline Scenario
Site Characteristics		
Site Area (acres)	0.253	2.41
Hydrologic Soil Group	B	B
Hydraulic Conductivity (in/hr)	0.4	0.4
Surface Slope (%)	2	Flat (2% Slope)
Precip. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Evap. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Climate Change Scenario	None	None
Land Cover		
% Forest	0	0
% Meadow	0	0
% Lawn	0	0
% Desert	0	0
% Impervious	100	100
LID Controls		
% Disconnection	0	0
% Rain Harvesting	0	0
% Rain Gardens	6 / 5	0
% Green Roofs	0	0
% Street Planters	0	0
% Infiltration Basins	0	0
% Permeable Pavement	0	0
Analysis Options		
Years Analyzed	20	20
Ignore Consecutive Wet Days	False	False
Wet Day Threshold (inches)	0.1	0.1

National Stormwater Calculator Report

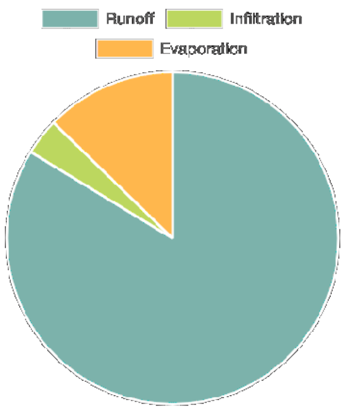
Results

Site Summary

Capstone

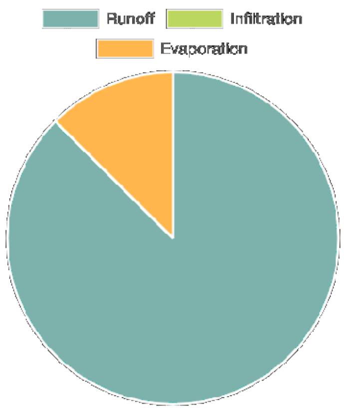
Current Scenario

Annual Rainfall: 50.18 in.



Baseline Scenario

Annual Rainfall: 50.18 in.



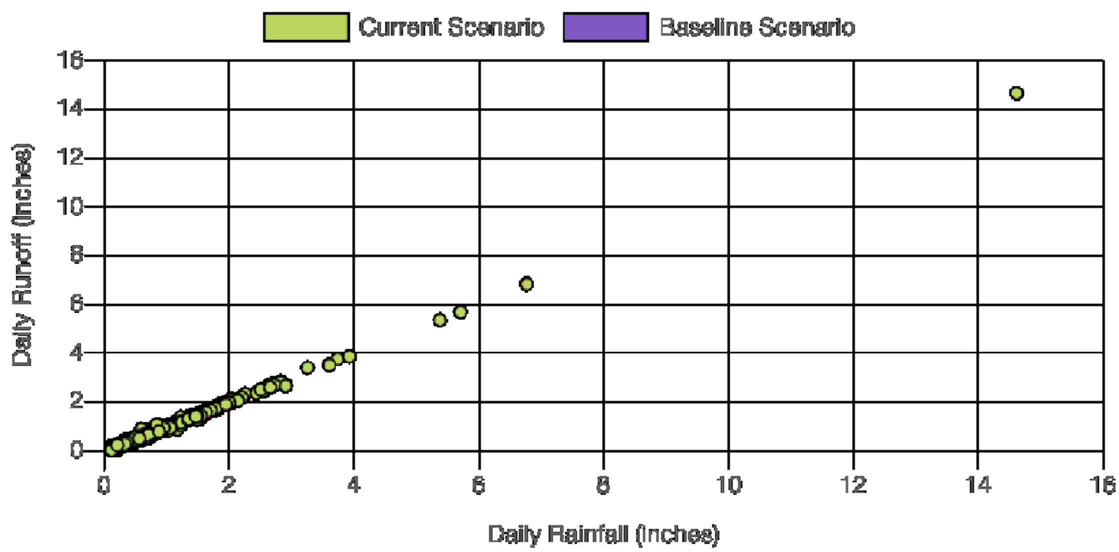
Statisic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	50.18	50.18
Average Annual Runoff (inches)	42.28	44.05
Days per Year with Rainfall	77.34	77.34
Days per Year with Runoff	65.73	66.50
Percent of Wet Days Retained	15.01	14.02
Smallest Rainfall w/ Runoff (inches)	0.11	0.11
Largest Rainfall w/o Runoff (inches)	0.21	0.21
Max Rainfall Retained (inches)	0.33	0.30

National Stormwater Calculator Report

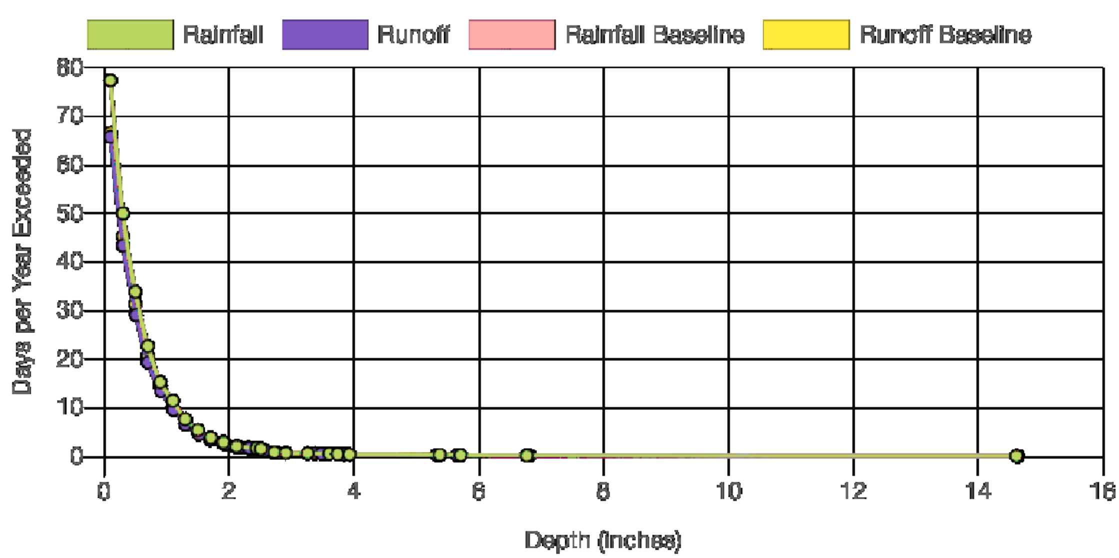
Results

Capstone

Rainfall / Runoff Events



Rainfall / Runoff Exceedance Frequency

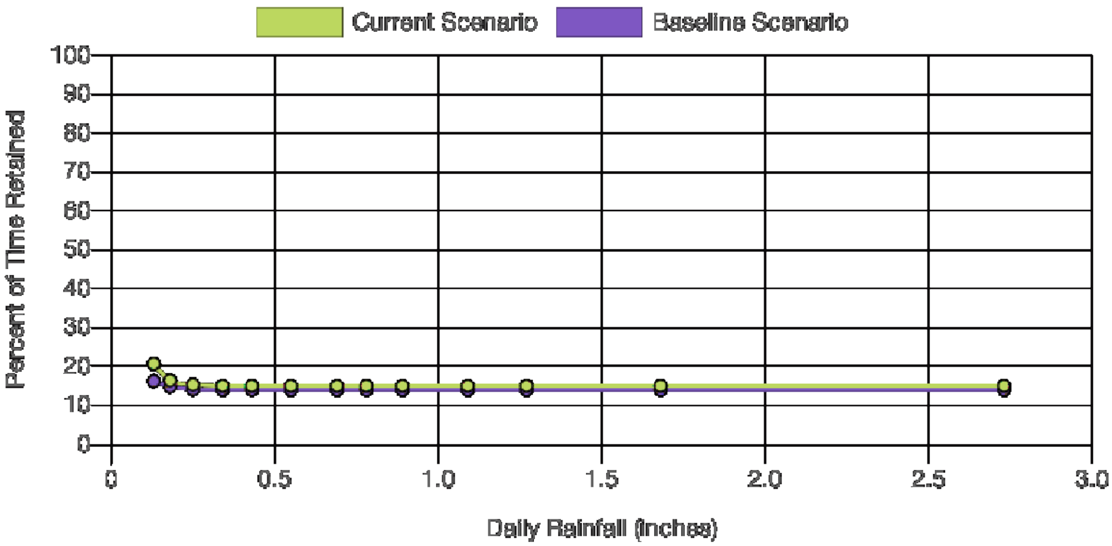


National Stormwater Calculator Report

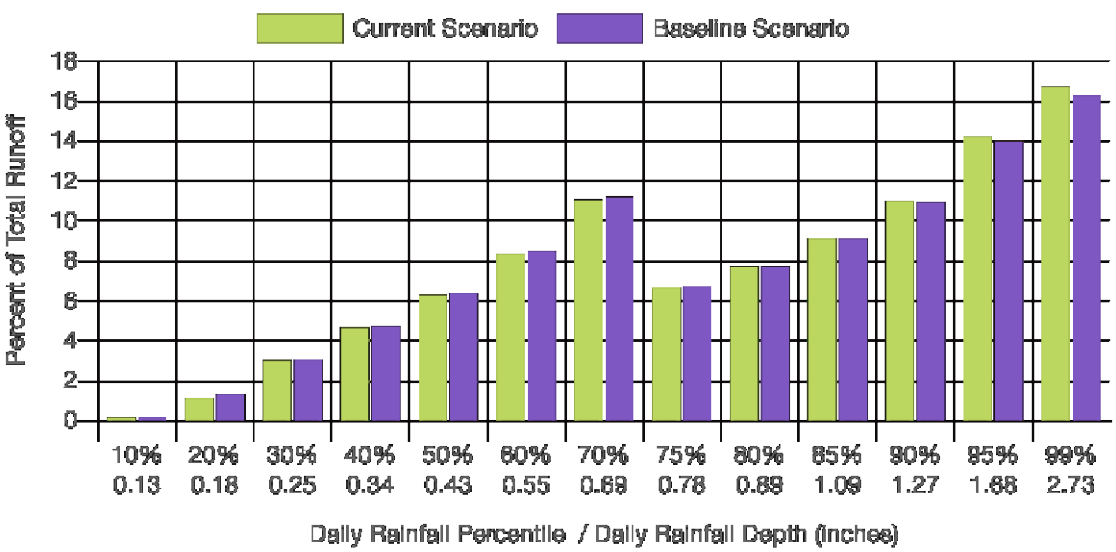
Results

Capstone

Rainfall Retention Frequency



Runoff Contribution by Rainfall Percentile

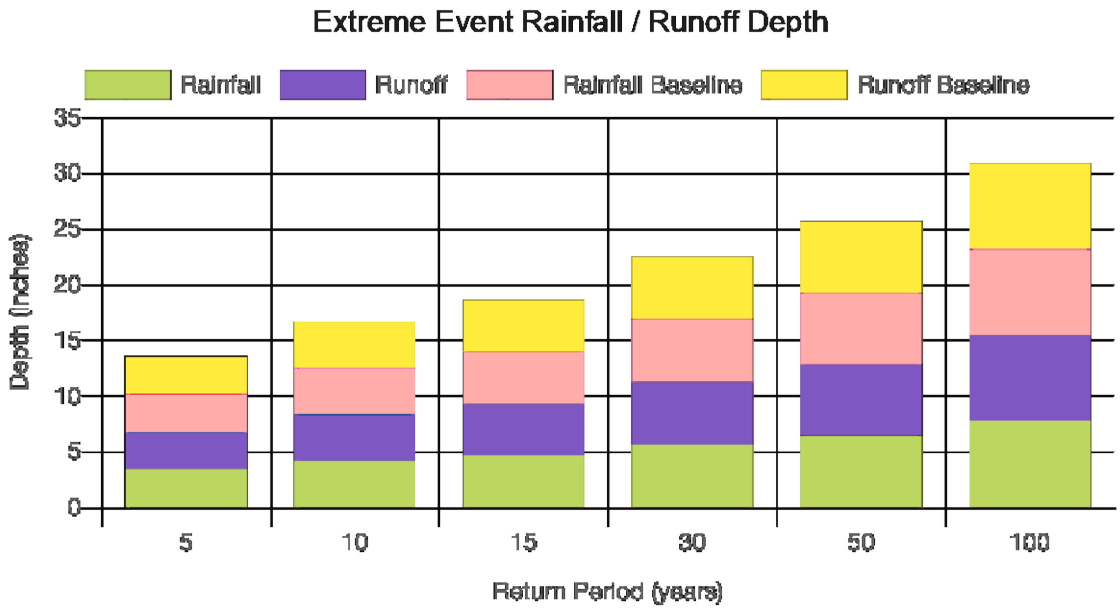


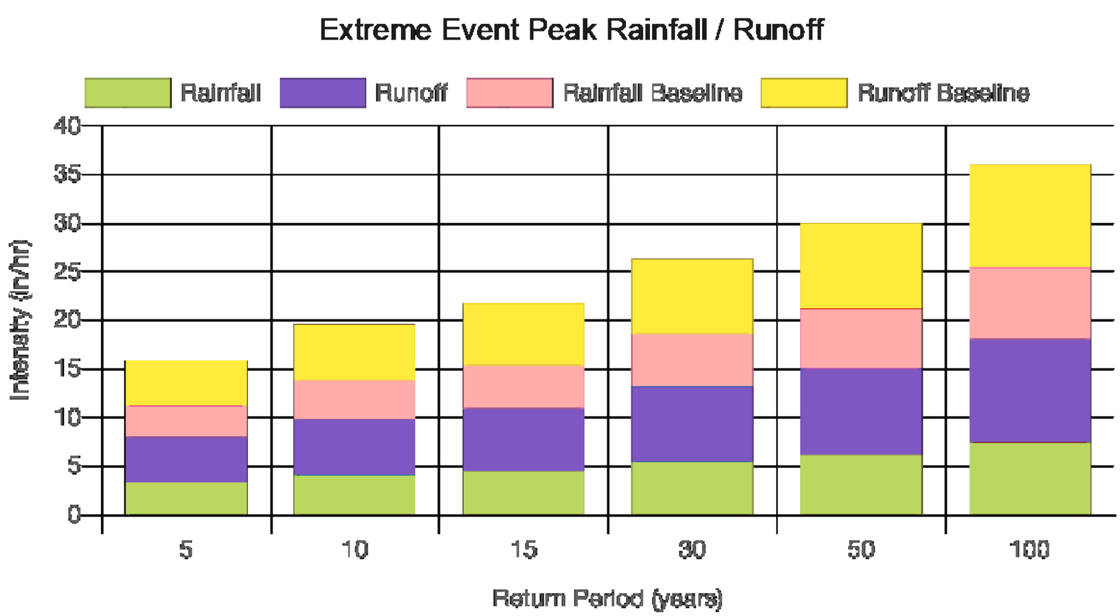
National Stormwater Calculator Report

Results

Capstone

Extreme Event Rainfall / Runoff





National Stormwater Calculator Report

Results

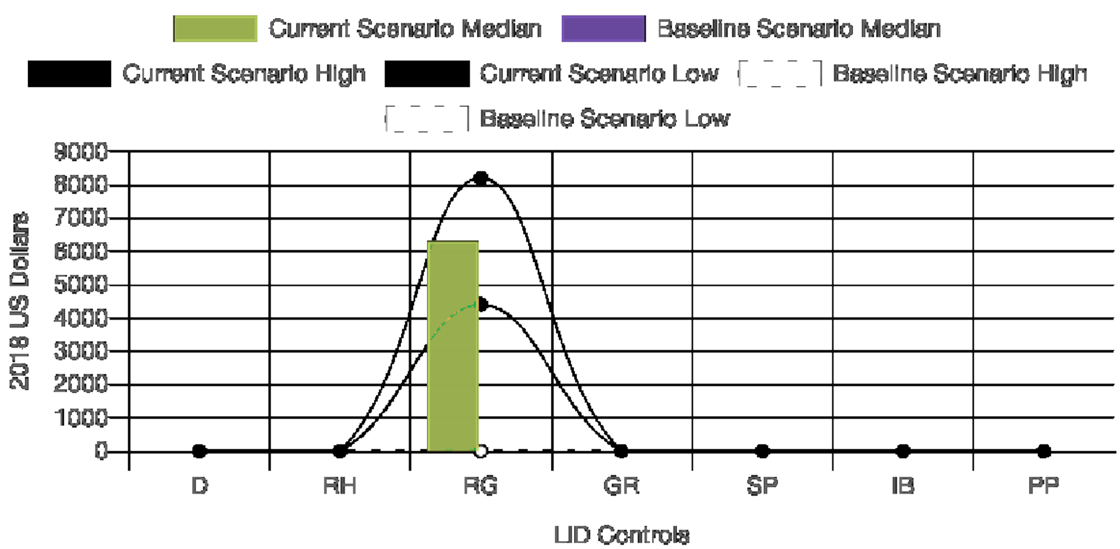
Capstone

Cost Summary

Estimate of Probable Capital Costs (estimates in 2018 US.$)

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	6 (C) / 0 (B)	NA (C) / NA (B)	$4404.51 - $8205.92	$0.00 - $0.00	$4404.51 - $8205.92
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report

Results

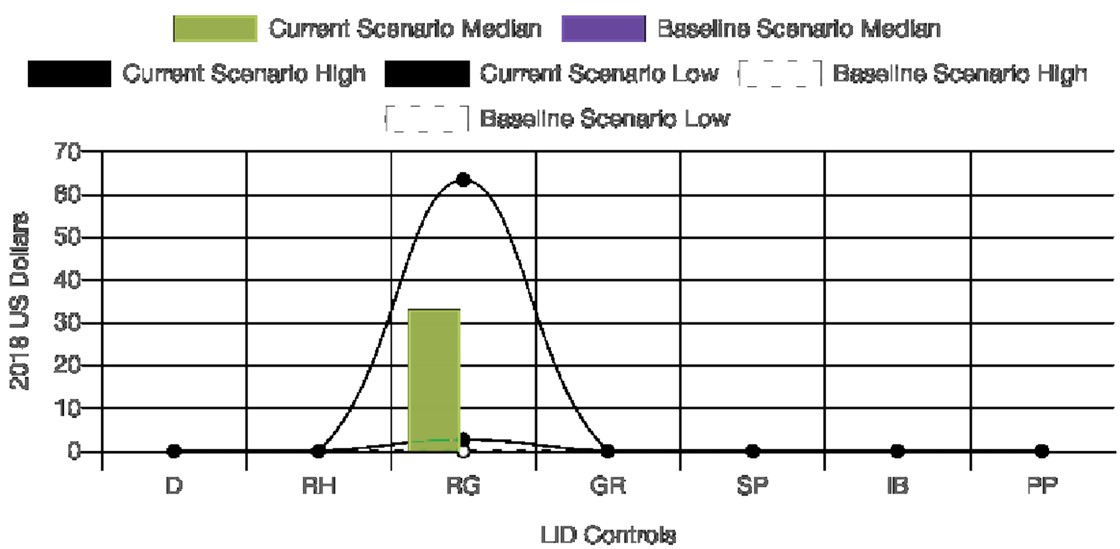
Capstone

Cost Summary

Estimate of Annual Probable Maintenance Costs

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	6 (C) / 0 (B)	NA (C) / NA (B)	$2.62 - $63.41	$0.00 - $0.00	$2.62 - $63.41
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report

Results

Site Description

Capstone

Parameter	Current Scenario	Baseline Scenario
Site Characteristics		
Site Area (acres)	1.377	2.41
Hydrologic Soil Group	B	B
Hydraulic Conductivity (in/hr)	0.4	0.4
Surface Slope (%)	2	Flat (2% Slope)
Precip. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Evap. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Climate Change Scenario	None	None
Land Cover		
% Forest	0	0
% Meadow	0	0
% Lawn	36	0
% Desert	0	0
% Impervious	64	100
LID Controls		
% Disconnection	0	0
% Rain Harvesting	0	0
% Rain Gardens	2 / 5	0
% Green Roofs	0	0
% Street Planters	0	0
% Infiltration Basins	0	0
% Permeable Pavement	0	0
Analysis Options		
Years Analyzed	20	20
Ignore Consecutive Wet Days	False	False
Wet Day Threshold (inches)	0.1	0.1

National Stormwater Calculator Report

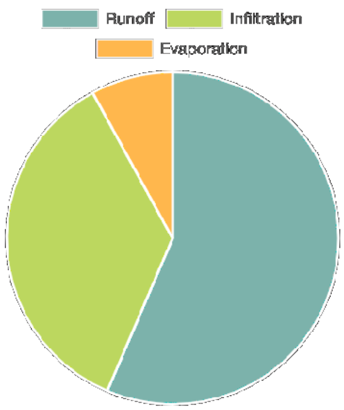
Results

Site Summary

Capstone

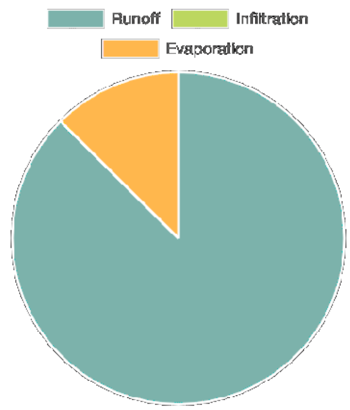
Current Scenario

Annual Rainfall: 50.18 in.



Baseline Scenario

Annual Rainfall: 50.18 in.



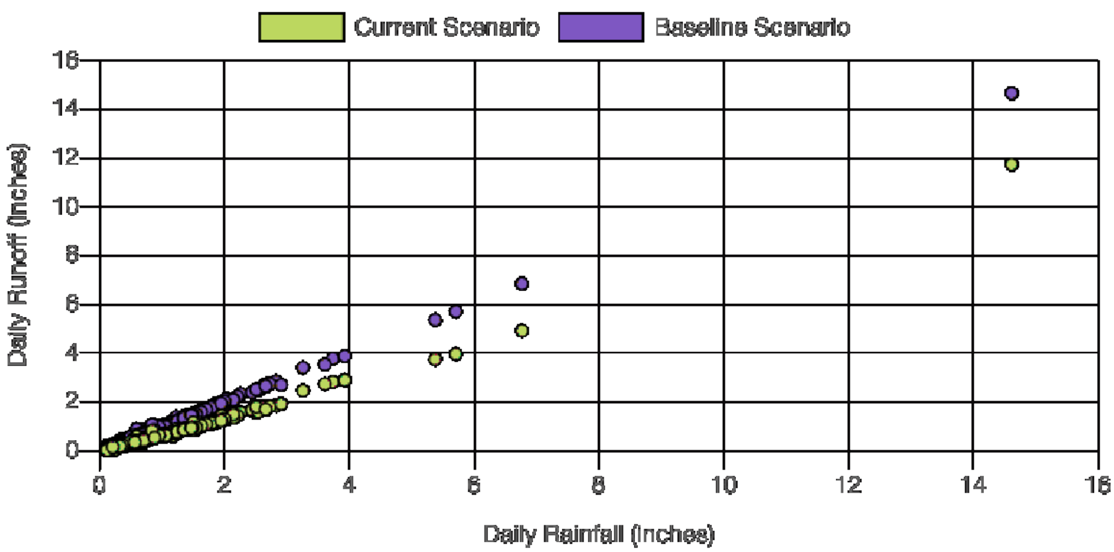
Statisic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	50.18	50.18
Average Annual Runoff (inches)	28.41	44.05
Days per Year with Rainfall	77.34	77.34
Days per Year with Runoff	58.66	66.50
Percent of Wet Days Retained	24.16	14.02
Smallest Rainfall w/ Runoff (inches)	0.12	0.11
Largest Rainfall w/o Runoff (inches)	0.24	0.21
Max Rainfall Retained (inches)	2.90	0.30

National Stormwater Calculator Report

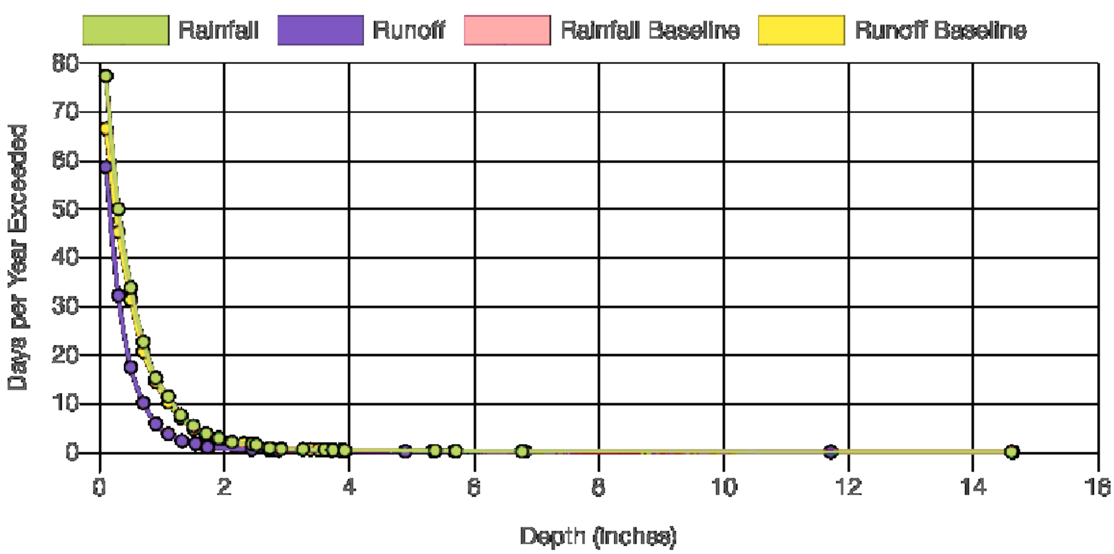
Results

Capstone

Rainfall / Runoff Events



Rainfall / Runoff Exceedance Frequency

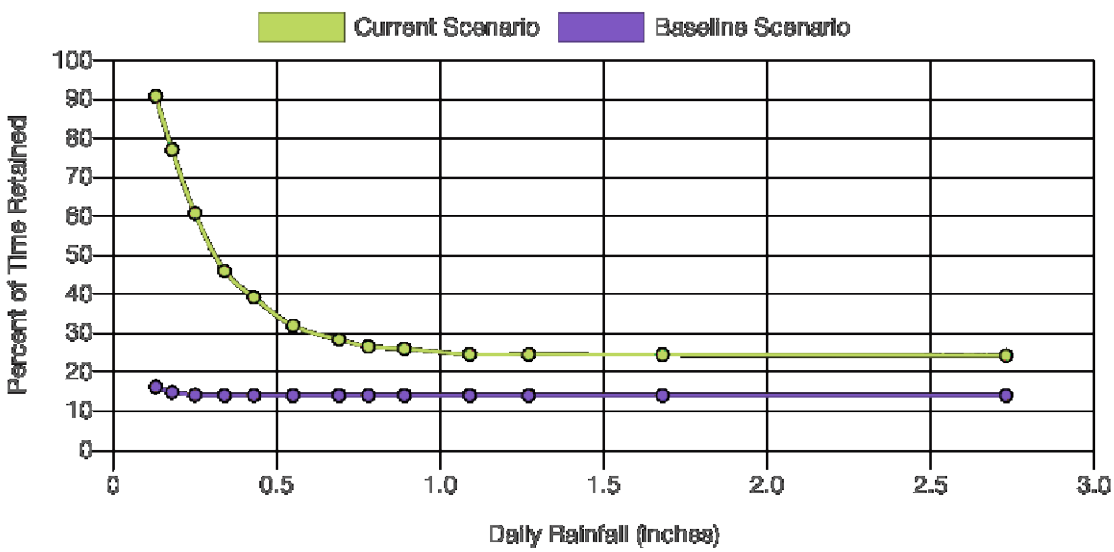


National Stormwater Calculator Report

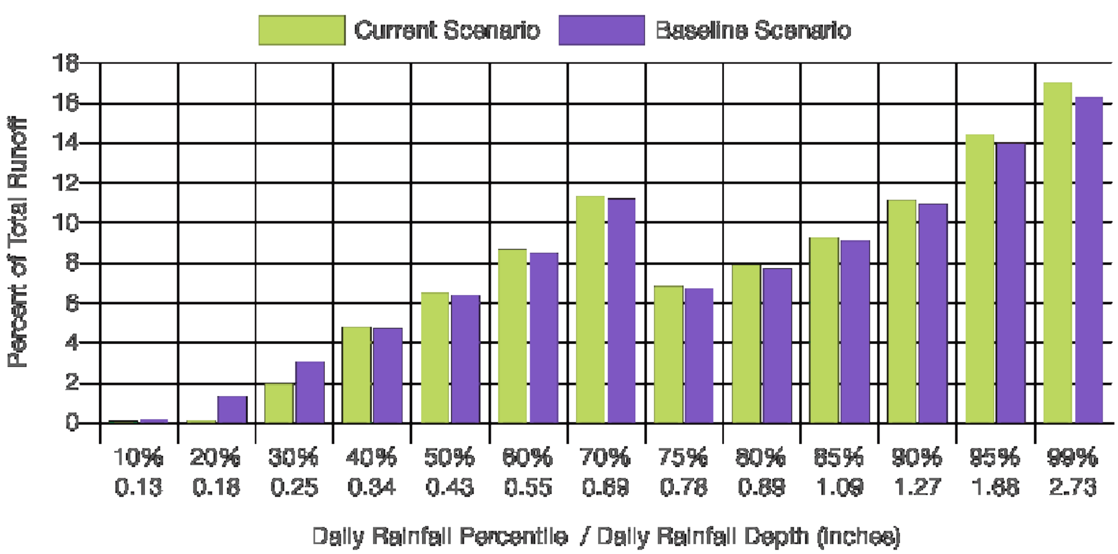
Results

Capstone

Rainfall Retention Frequency



Runoff Contribution by Rainfall Percentile

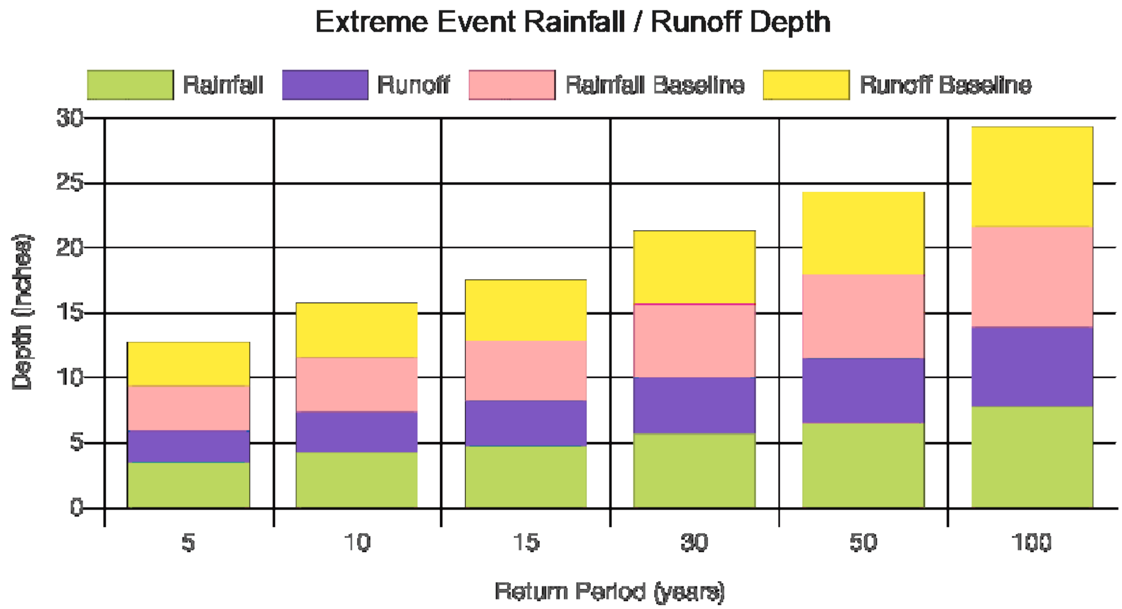


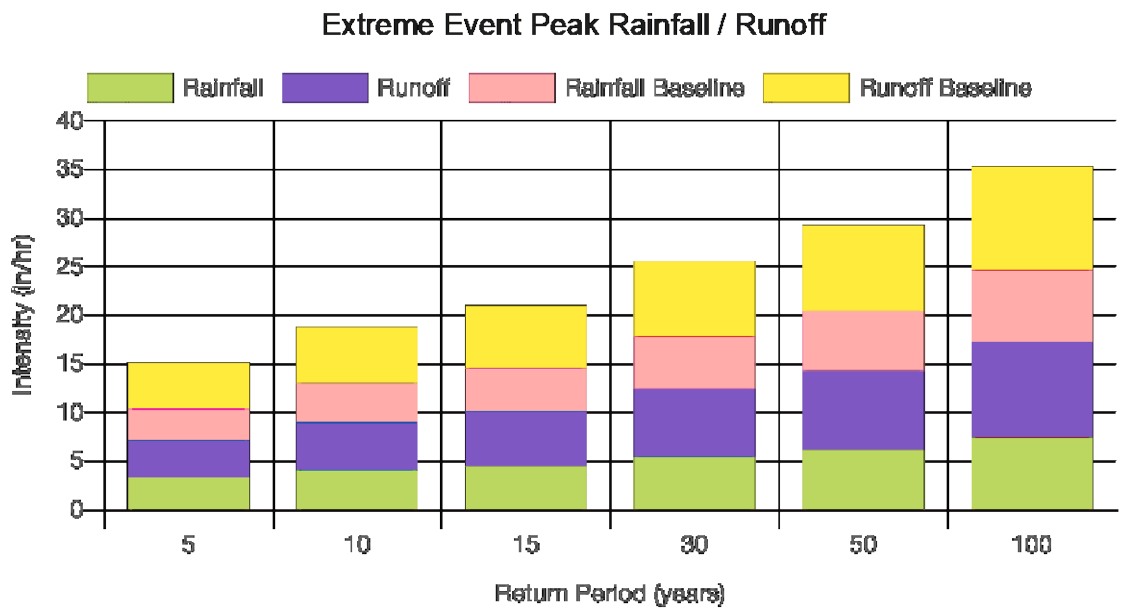
National Stormwater Calculator Report

Results

Capstone

Extreme Event Rainfall / Runoff





National Stormwater Calculator Report

Results

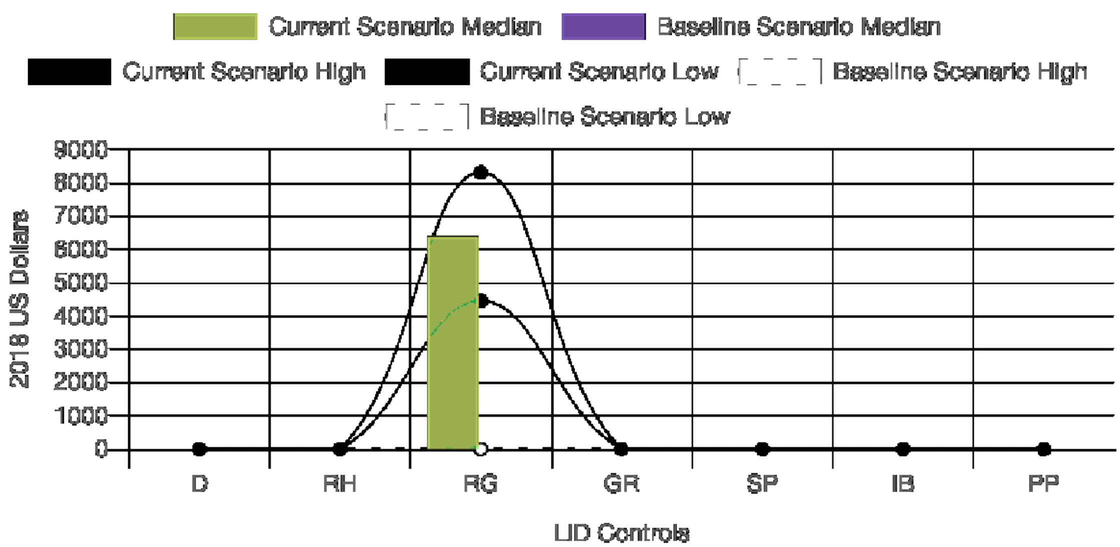
Capstone

Cost Summary

Estimate of Probable Capital Costs (estimates in 2018 US.$)

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	2 (C) / 0 (B)	NA (C) / NA (B)	$4454.15 - $8310.01	$0.00 - $0.00	$4454.15 - $8310.01
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report

Results

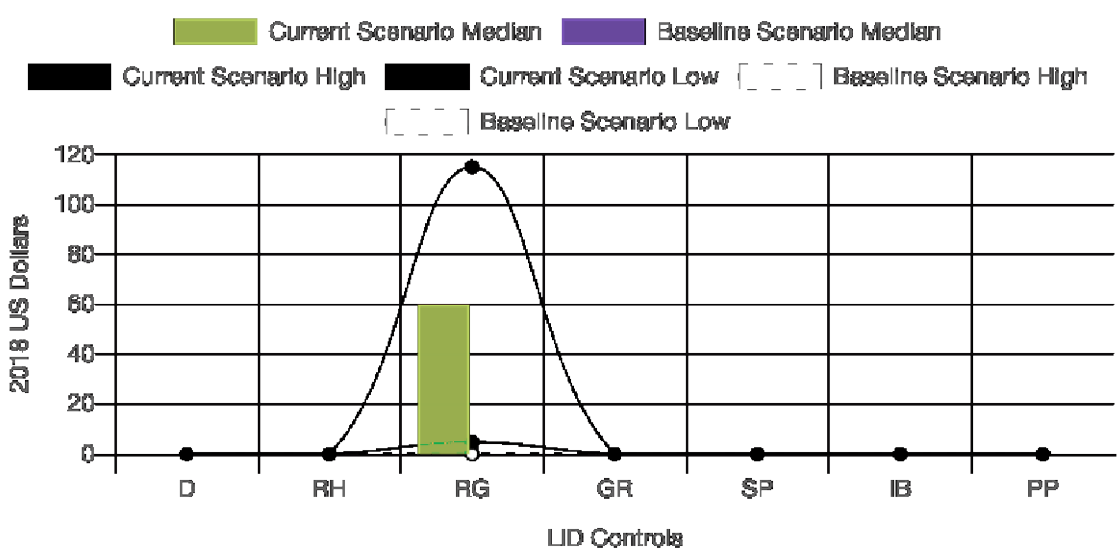
Capstone

Cost Summary

Estimate of Annual Probable Maintenance Costs

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	2 (C) / 0 (B)	NA (C) / NA (B)	$4.76 - $115.04	$0.00 - $0.00	$4.76 - $115.04
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report

Results

Site Description

Capstone

Parameter	Current Scenario	Baseline Scenario
Site Characteristics		
Site Area (acres)	1.951	2.41
Hydrologic Soil Group	B	B
Hydraulic Conductivity (in/hr)	0.4	0.4
Surface Slope (%)	2	Flat (2% Slope)
Precip. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Evap. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Climate Change Scenario	None	None
Land Cover		
% Forest	0	0
% Meadow	0	0
% Lawn	0	0
% Desert	0	0
% Impervious	100	100
LID Controls		
% Disconnection	0	0
% Rain Harvesting	0	0
% Rain Gardens	4 / 5	0
% Green Roofs	0	0
% Street Planters	0	0
% Infiltration Basins	0	0
% Permeable Pavement	0	0
Analysis Options		
Years Analyzed	20	20
Ignore Consecutive Wet Days	False	False
Wet Day Threshold (inches)	0.1	0.1

National Stormwater Calculator Report

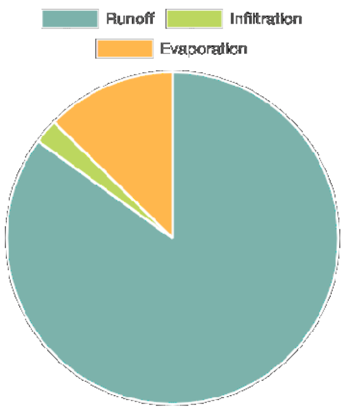
Results

Site Summary

Capstone

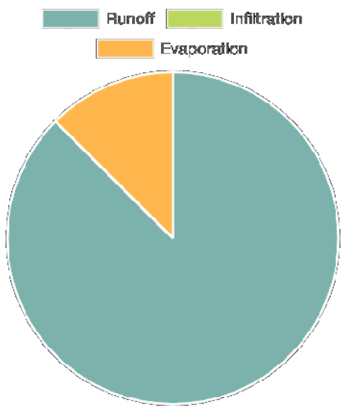
Current Scenario

Annual Rainfall: 50.18 in.



Baseline Scenario

Annual Rainfall: 50.18 in.



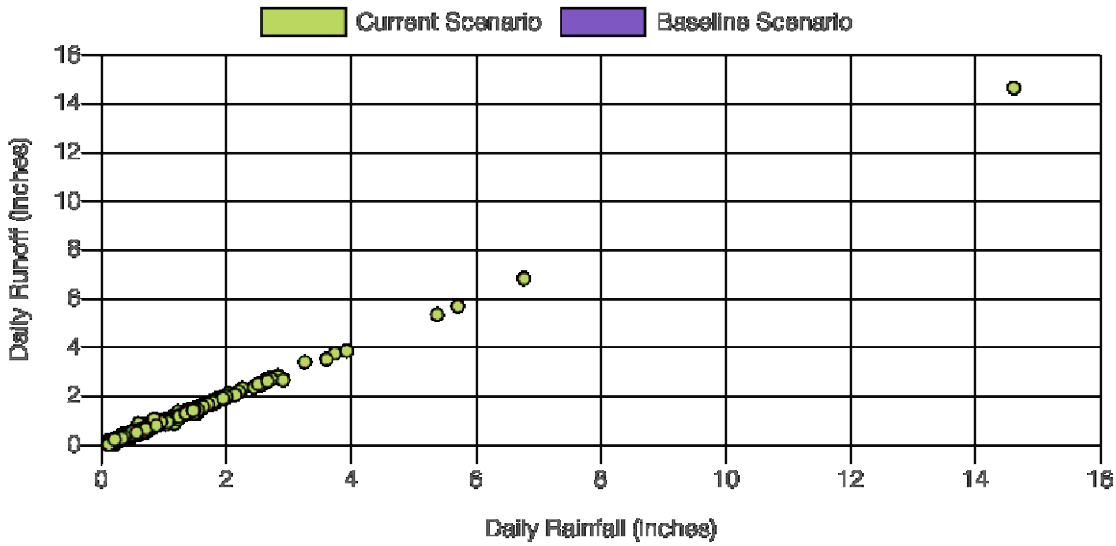
Statisic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	50.18	50.18
Average Annual Runoff (inches)	42.87	44.05
Days per Year with Rainfall	77.34	77.34
Days per Year with Runoff	66.11	66.50
Percent of Wet Days Retained	14.51	14.02
Smallest Rainfall w/ Runoff (inches)	0.11	0.11
Largest Rainfall w/o Runoff (inches)	0.21	0.21
Max Rainfall Retained (inches)	0.32	0.30

National Stormwater Calculator Report

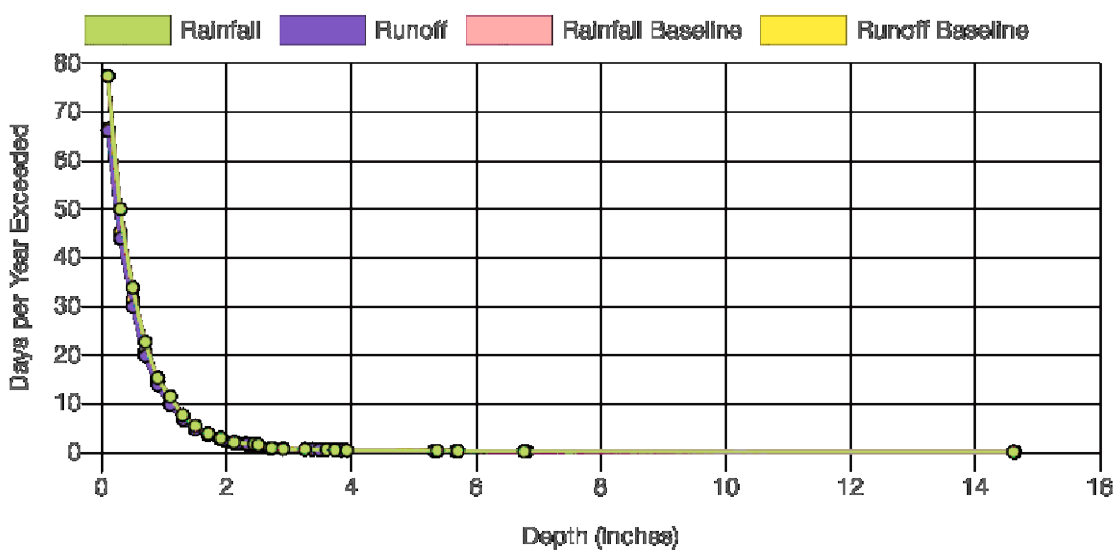
Results

Capstone

Rainfall / Runoff Events



Rainfall / Runoff Exceedance Frequency

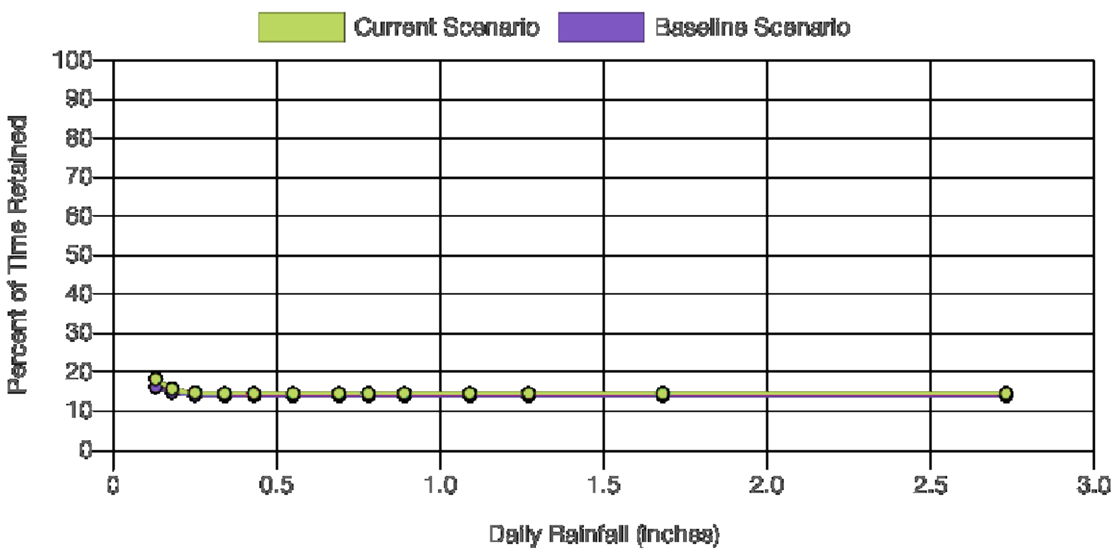


National Stormwater Calculator Report

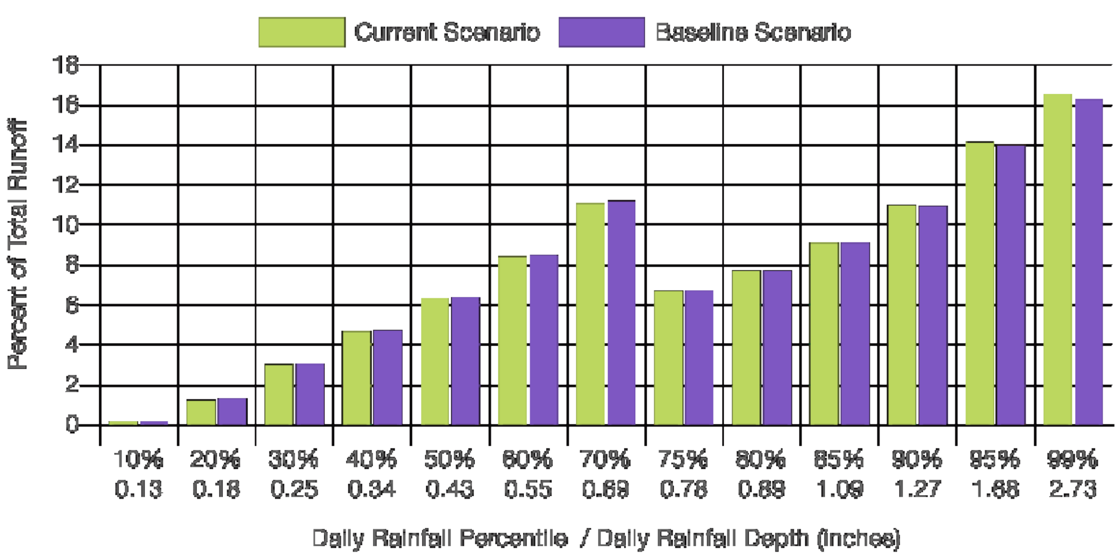
Results

Capstone

Rainfall Retention Frequency



Runoff Contribution by Rainfall Percentile

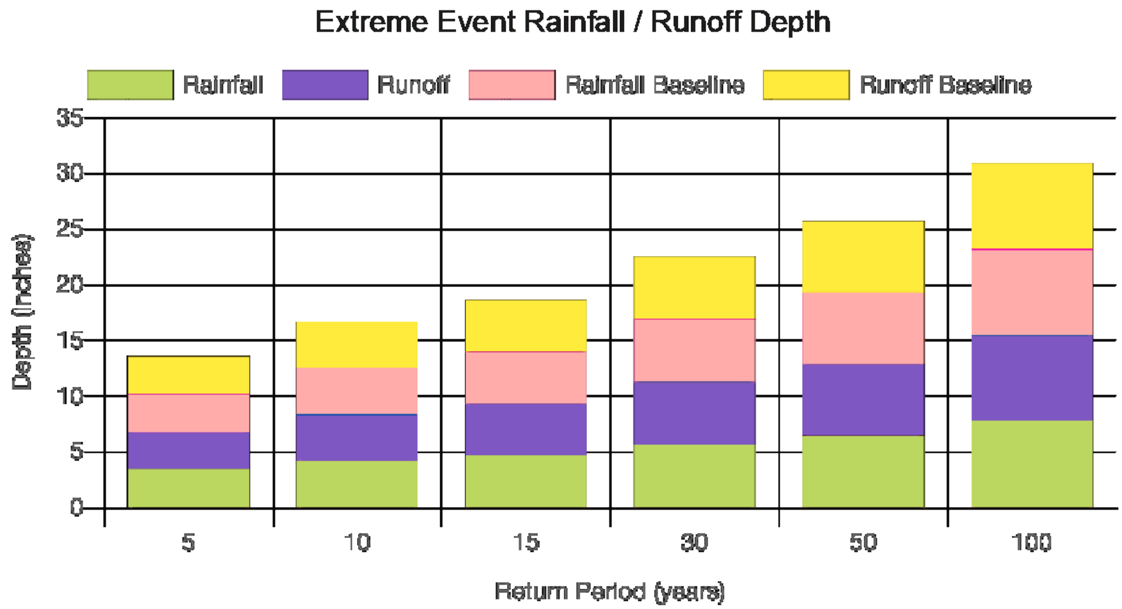


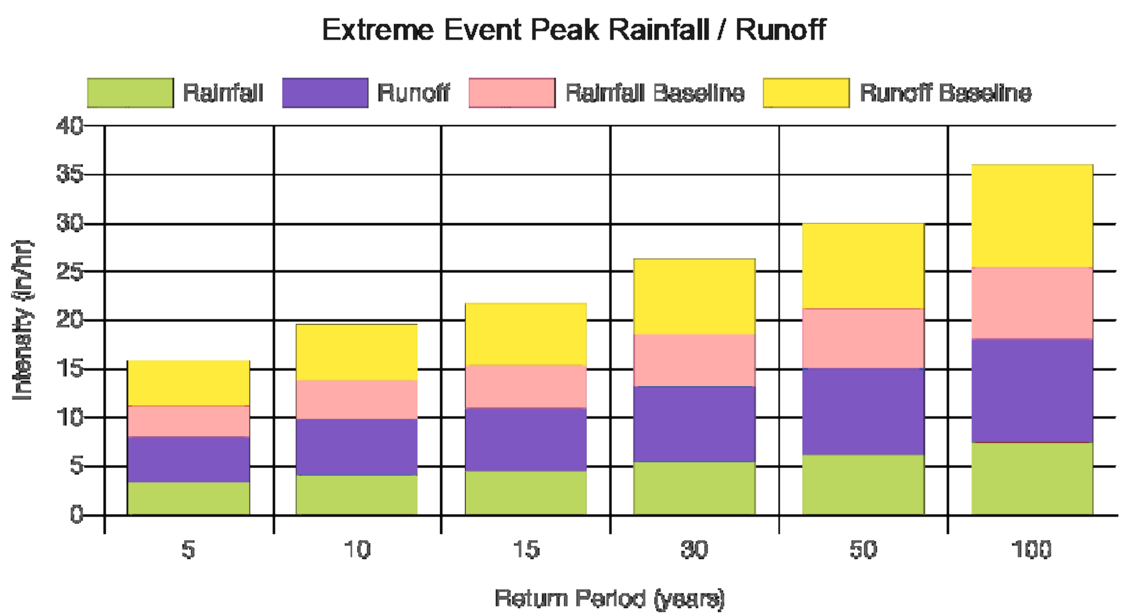
National Stormwater Calculator Report

Results

Capstone

Extreme Event Rainfall / Runoff





National Stormwater Calculator Report

Results

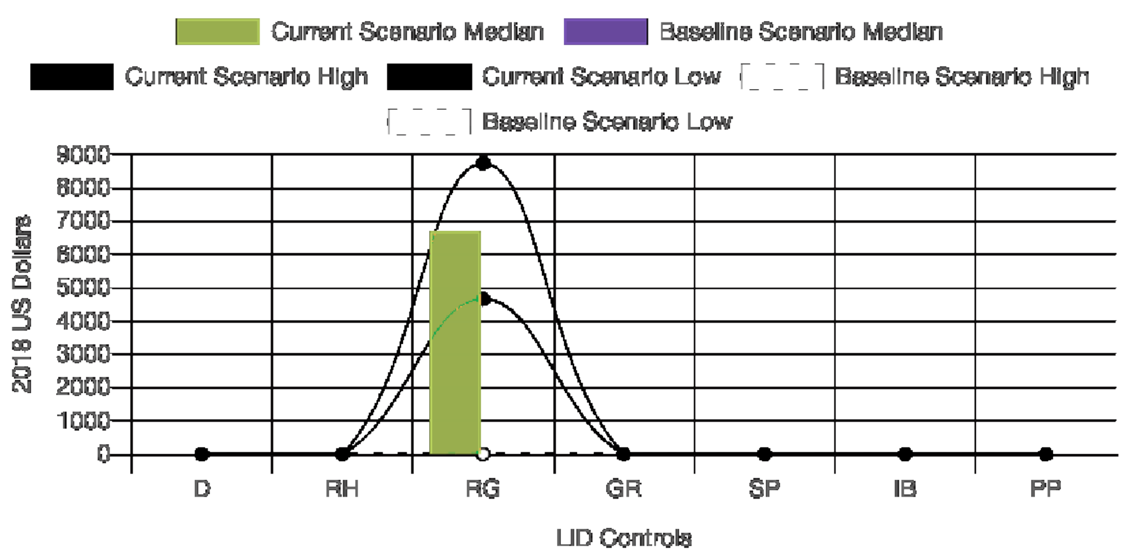
Capstone

Cost Summary

Estimate of Probable Capital Costs (estimates in 2018 US.$)

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	4 (C) / 0 (B)	NA (C) / NA (B)	$4656.97 - $8735.27	$0.00 - $0.00	$4656.97 - $8735.27
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report

Results

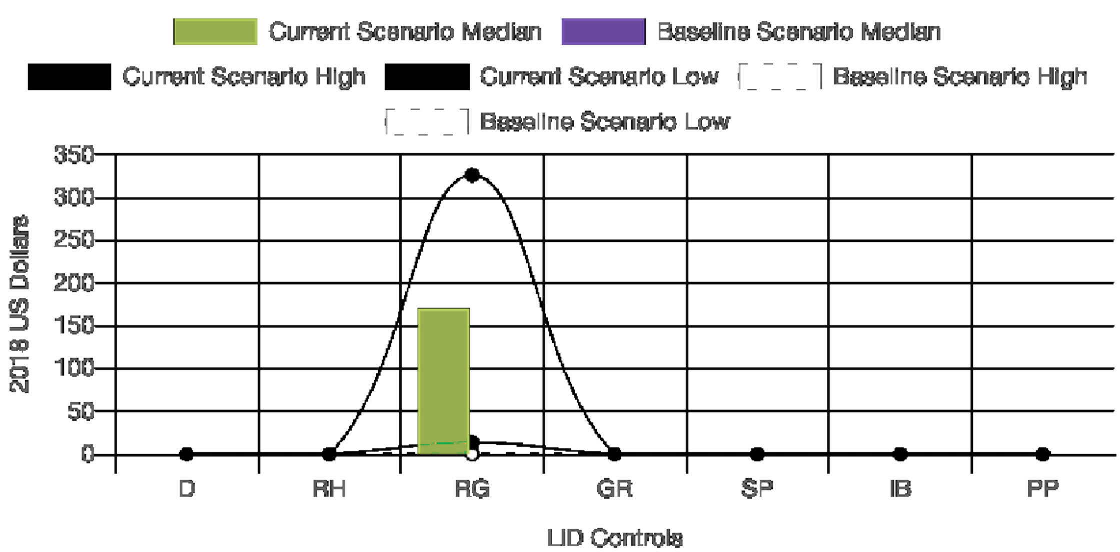
Capstone

Cost Summary

Estimate of Annual Probable Maintenance Costs

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	4 (C) / 0 (B)	NA (C) / NA (B)	$13.48 - $325.99	$0.00 - $0.00	$13.48 - $325.99
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report
Results

Site Description
Capstone

Parameter	Current Scenario	Baseline Scenario
Site Characteristics		
Site Area (acres)	2.41	2.41
Hydrologic Soil Group	B	B
Hydraulic Conductivity (in/hr)	0.4	0.4
Surface Slope (%)	2	Flat (2% Slope)
Precip. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Evap. Data Source	PHILADELPHIA FRANKLIN INSTITUT	PHILADELPHIA FRANKLIN INSTITUT
Climate Change Scenario	None	None
Land Cover		
% Forest	0	0
% Meadow	0	0
% Lawn	0	0
% Desert	0	0
% Impervious	100	100
LID Controls		
% Disconnection	0	0
% Rain Harvesting	0	0
% Rain Gardens	5 / 5	0
% Green Roofs	0	0
% Street Planters	0	0
% Infiltration Basins	0	0
% Permeable Pavement	0	0
Analysis Options		
Years Analyzed	20	20
Ignore Consecutive Wet Days	False	False
Wet Day Threshold (inches)	0.1	0.1

National Stormwater Calculator Report

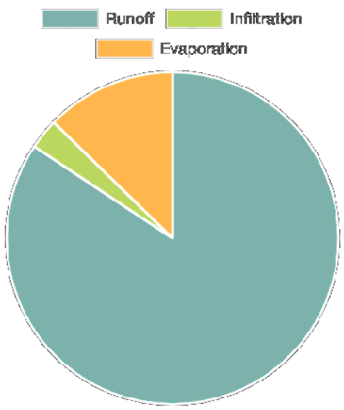
Results

Site Summary

Capstone

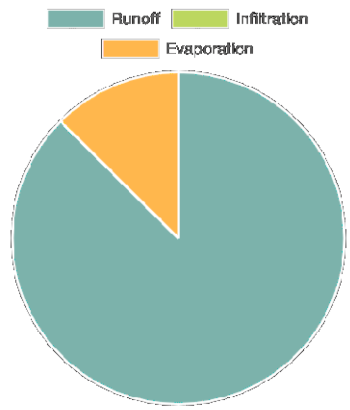
Current Scenario

Annual Rainfall: 50.18 in.



Baseline Scenario

Annual Rainfall: 50.18 in.



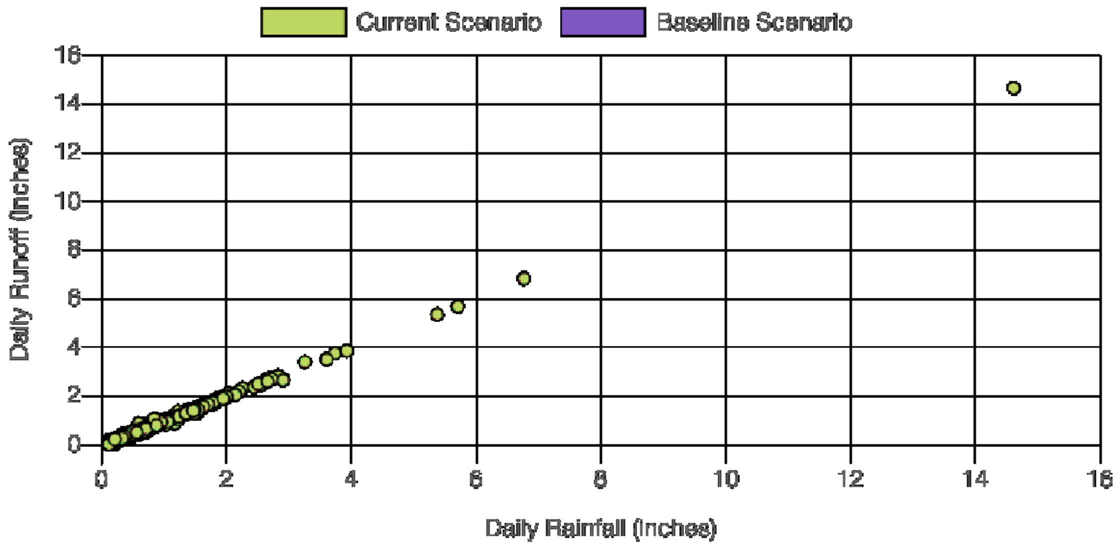
Statisic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	50.18	50.18
Average Annual Runoff (inches)	42.58	44.05
Days per Year with Rainfall	77.34	77.34
Days per Year with Runoff	65.96	66.50
Percent of Wet Days Retained	14.71	14.02
Smallest Rainfall w/ Runoff (inches)	0.11	0.11
Largest Rainfall w/o Runoff (inches)	0.21	0.21
Max Rainfall Retained (inches)	0.32	0.30

National Stormwater Calculator Report

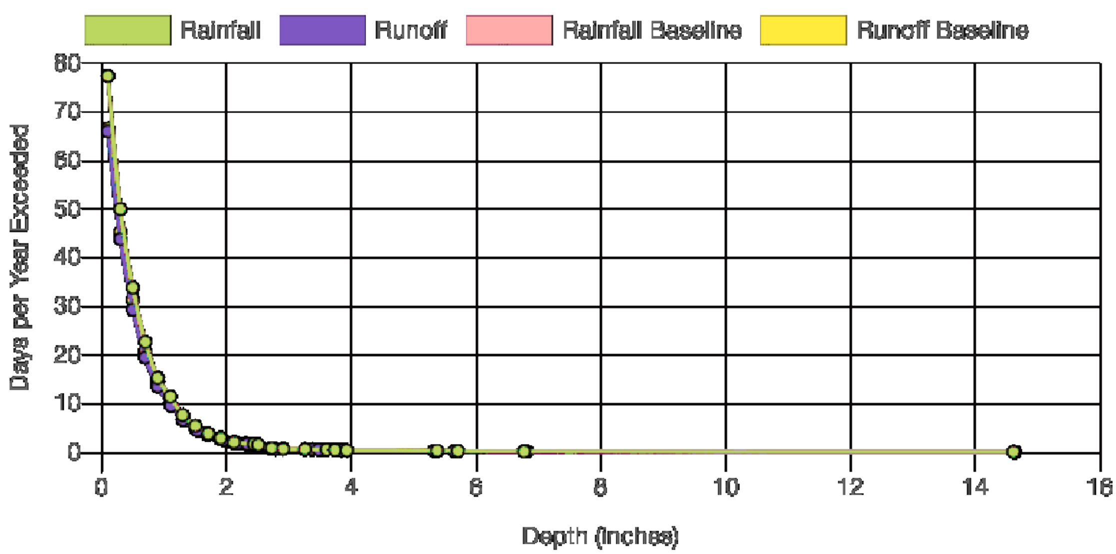
Results

Capstone

Rainfall / Runoff Events



Rainfall / Runoff Exceedance Frequency

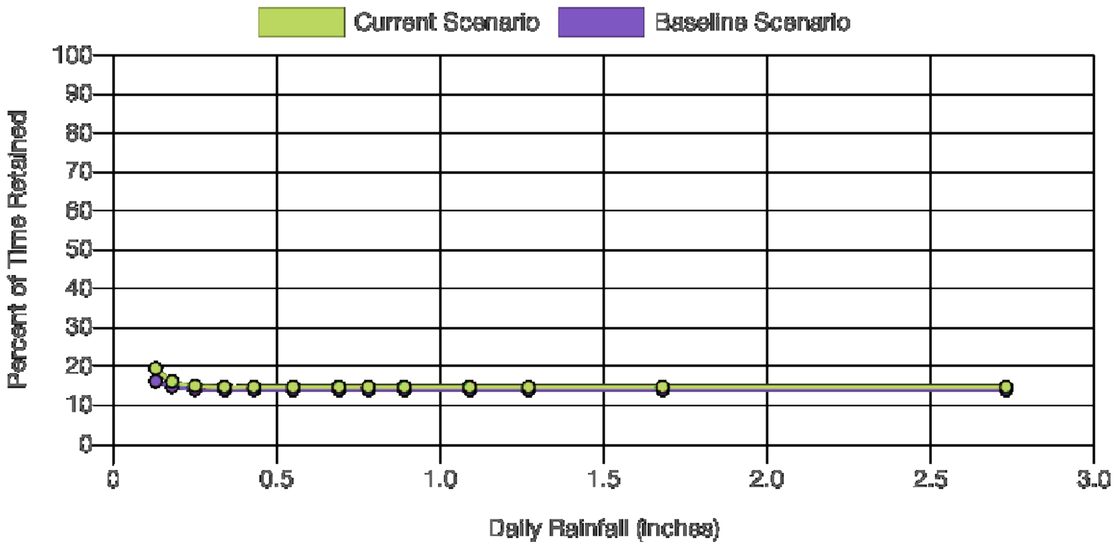


National Stormwater Calculator Report

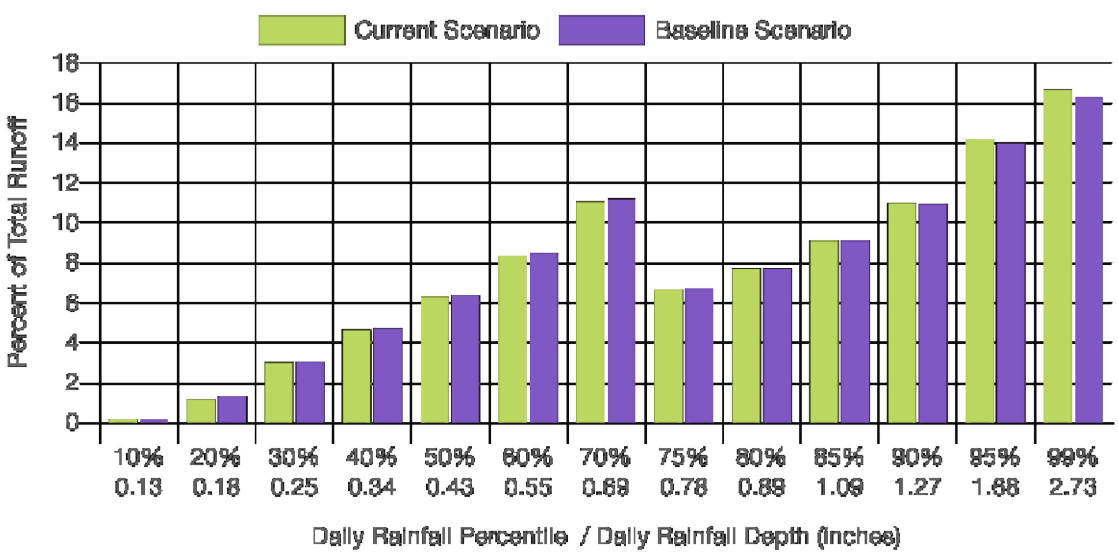
Results

Capstone

Rainfall Retention Frequency



Runoff Contribution by Rainfall Percentile

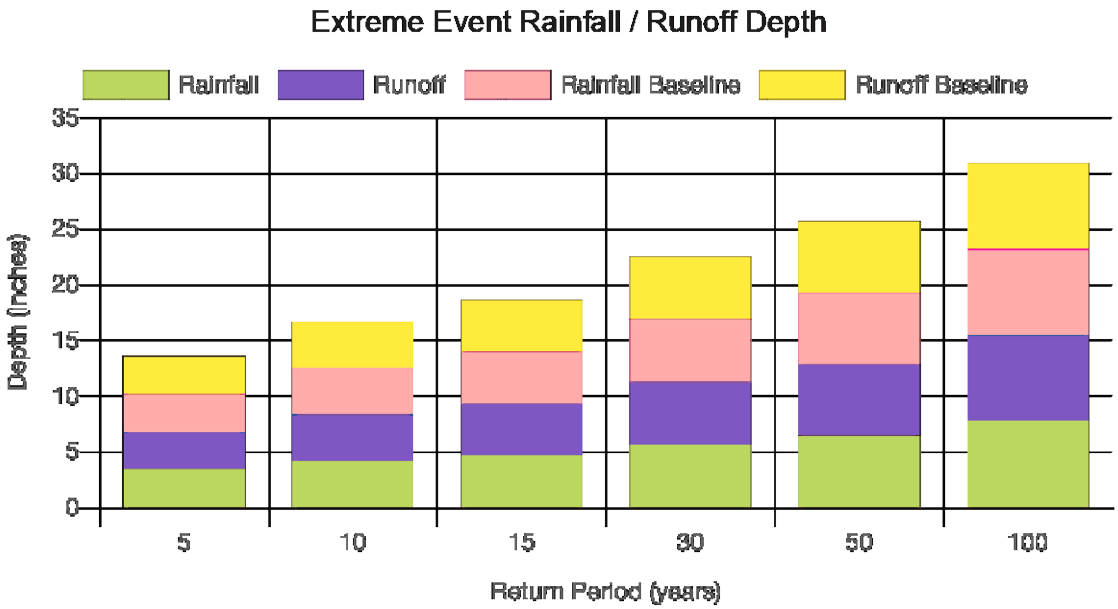


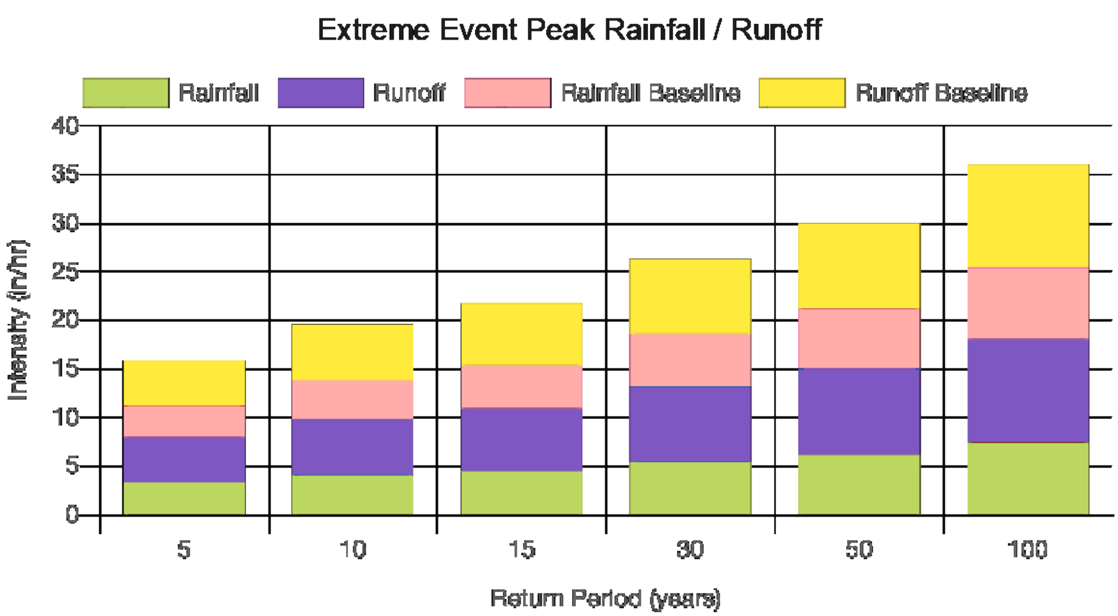
National Stormwater Calculator Report

Results

Capstone

Extreme Event Rainfall / Runoff





National Stormwater Calculator Report

Results

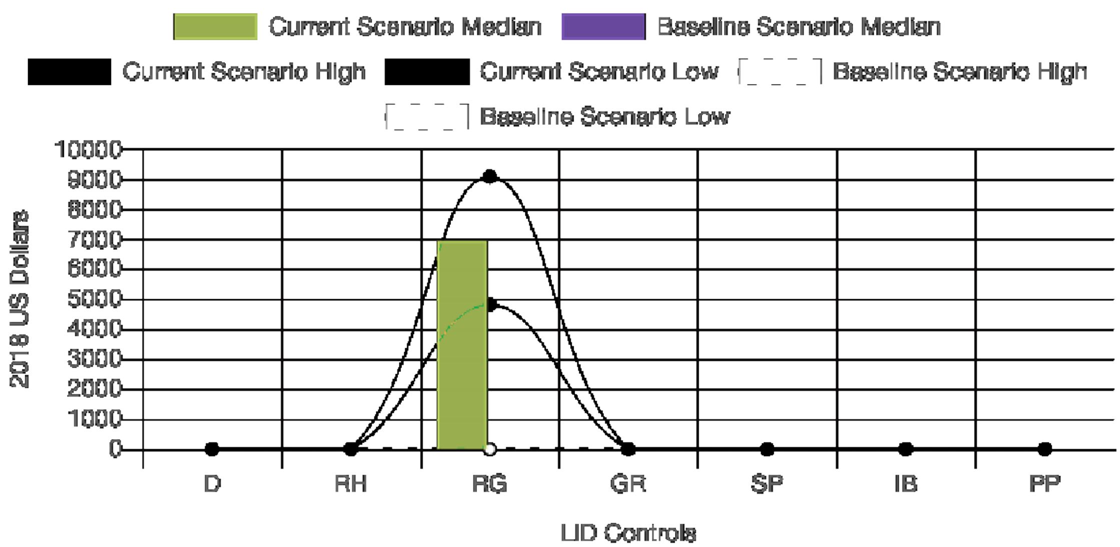
Capstone

Cost Summary

Estimate of Probable Capital Costs (estimates in 2018 US.$)

	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	5 (C) / 0 (B)	NA (C) / NA (B)	$4827.50 - $9092.82	$0.00 - $0.00	$4827.50 - $9092.82
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



National Stormwater Calculator Report

Results

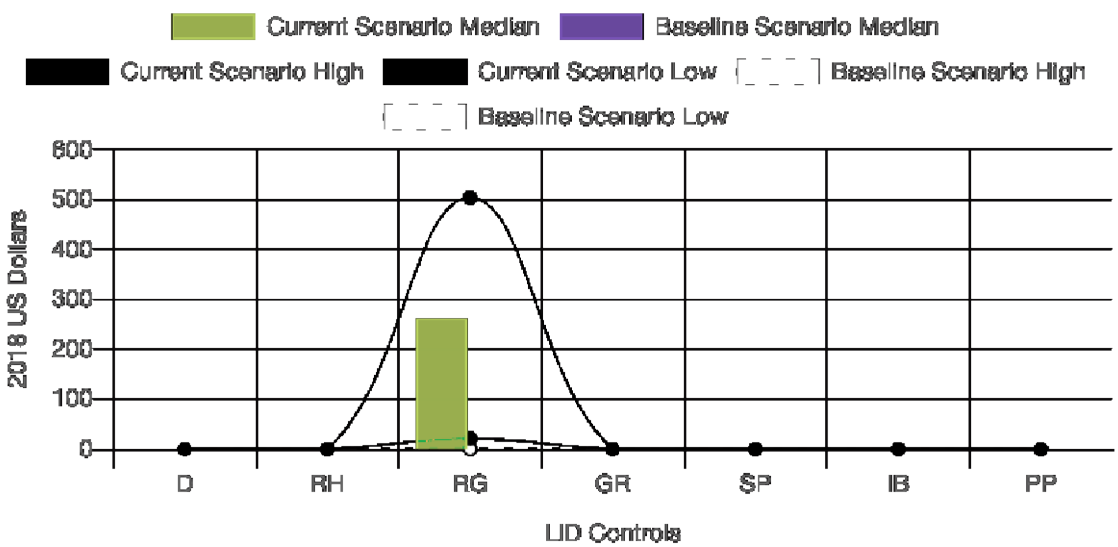
Capstone

Cost Summary

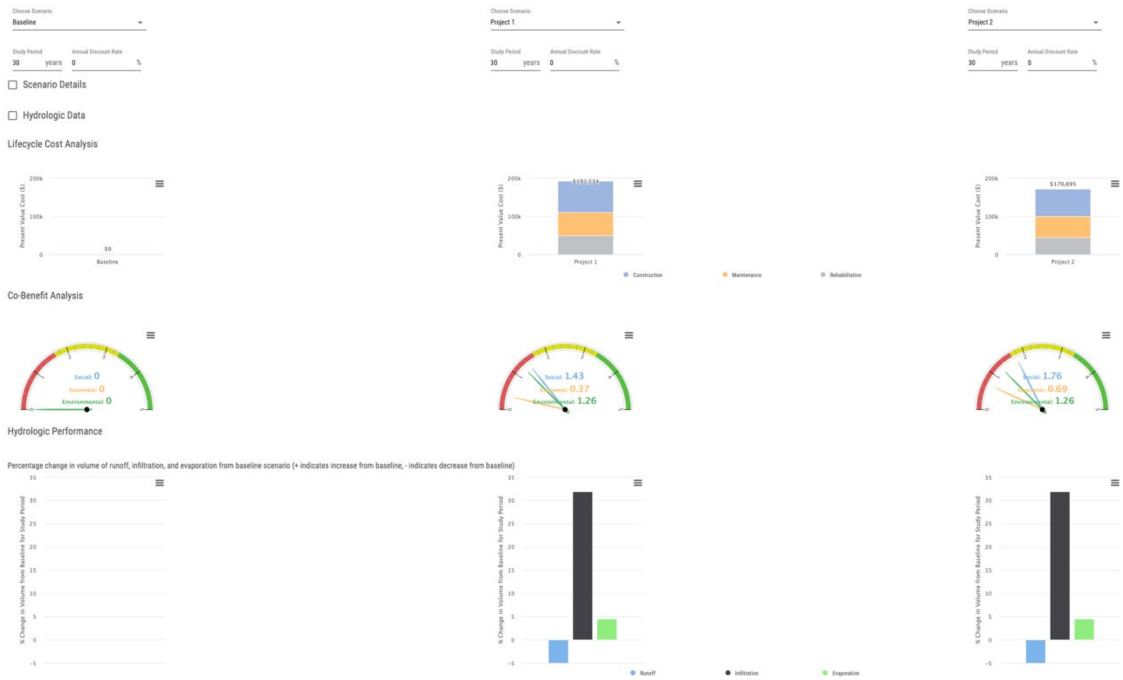
Estimate of Annual Probable Maintenance Costs

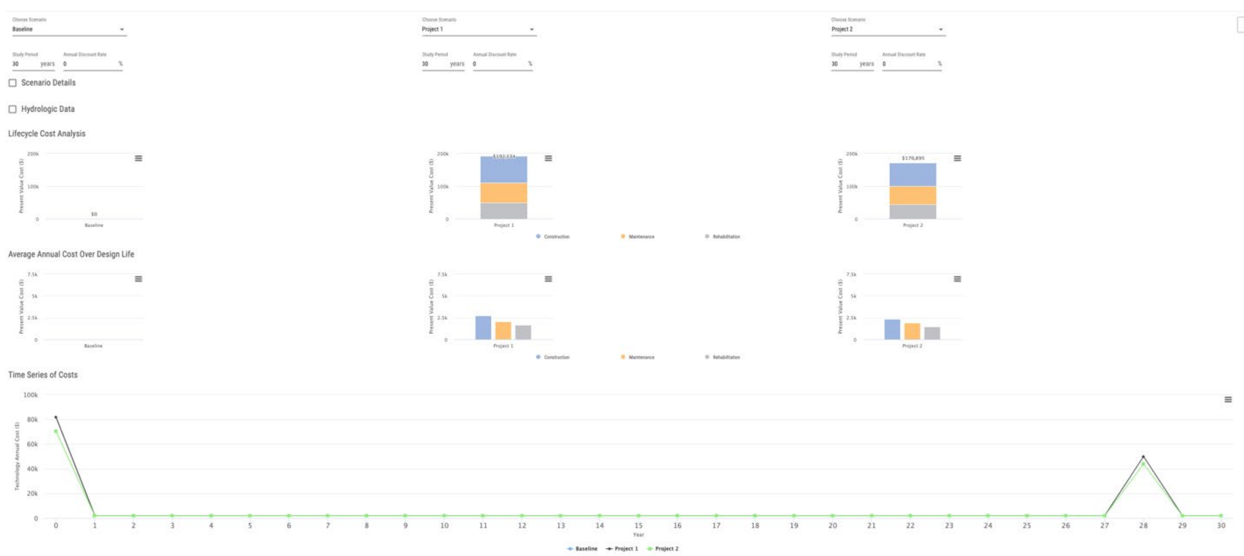
	Drainage Area %	Has Pre-Treatment?	Area Treated (C)	Area Treated (B)	Difference (C-B)
D	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RH	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
RG	5 (C) / 0 (B)	NA (C) / NA (B)	$20.82 - $503.36	$0.00 - $0.00	$20.82 - $503.36
GR	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
SP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
IB	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00
PP	0 (C) / 0 (B)	NA (C) / NA (B)	$0.00 - $0.00	$0.00 - $0.00	$0.00 - $0.00

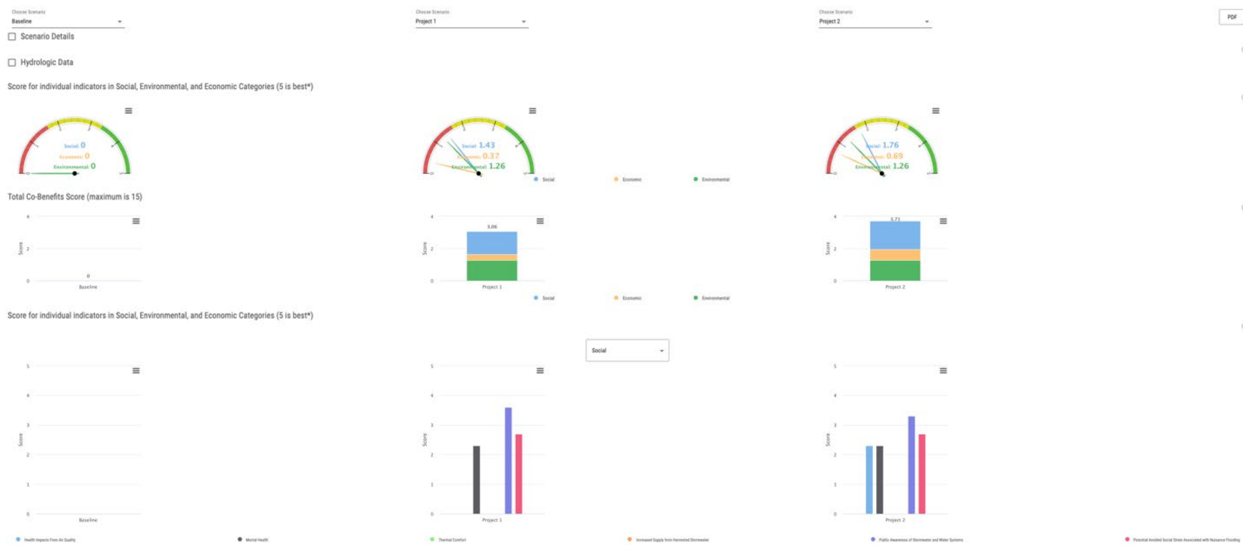
Key	LID Control
D	Disconnection
RH	Rain Harvesting
RG	Rain Gardens
GR	Green Roofs
SP	Street Planters
IB	Infiltration Basins
PP	Permeable Pavement



Appendix C

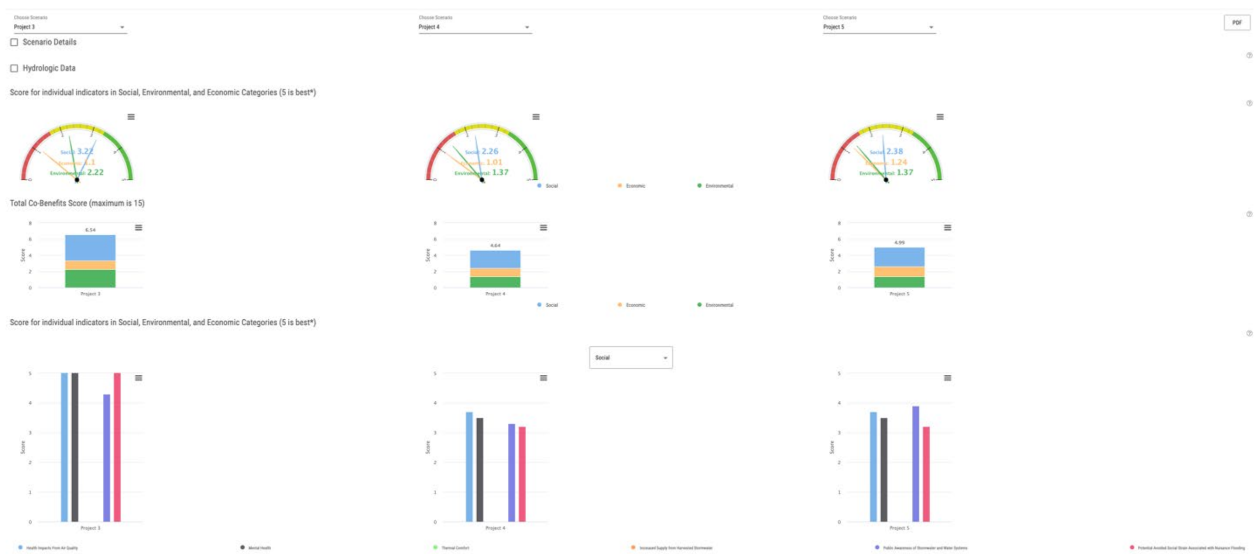

Scenario Details
Hydrologic Data
Lifecycle Cost Analysis
Co-Benefit Analysis
Hydrologic Performance
Percentage change in volume of runoff, infiltration, and evaporation from baseline scenario (+ indicates increase from baseline, - indicates decrease from baseline)

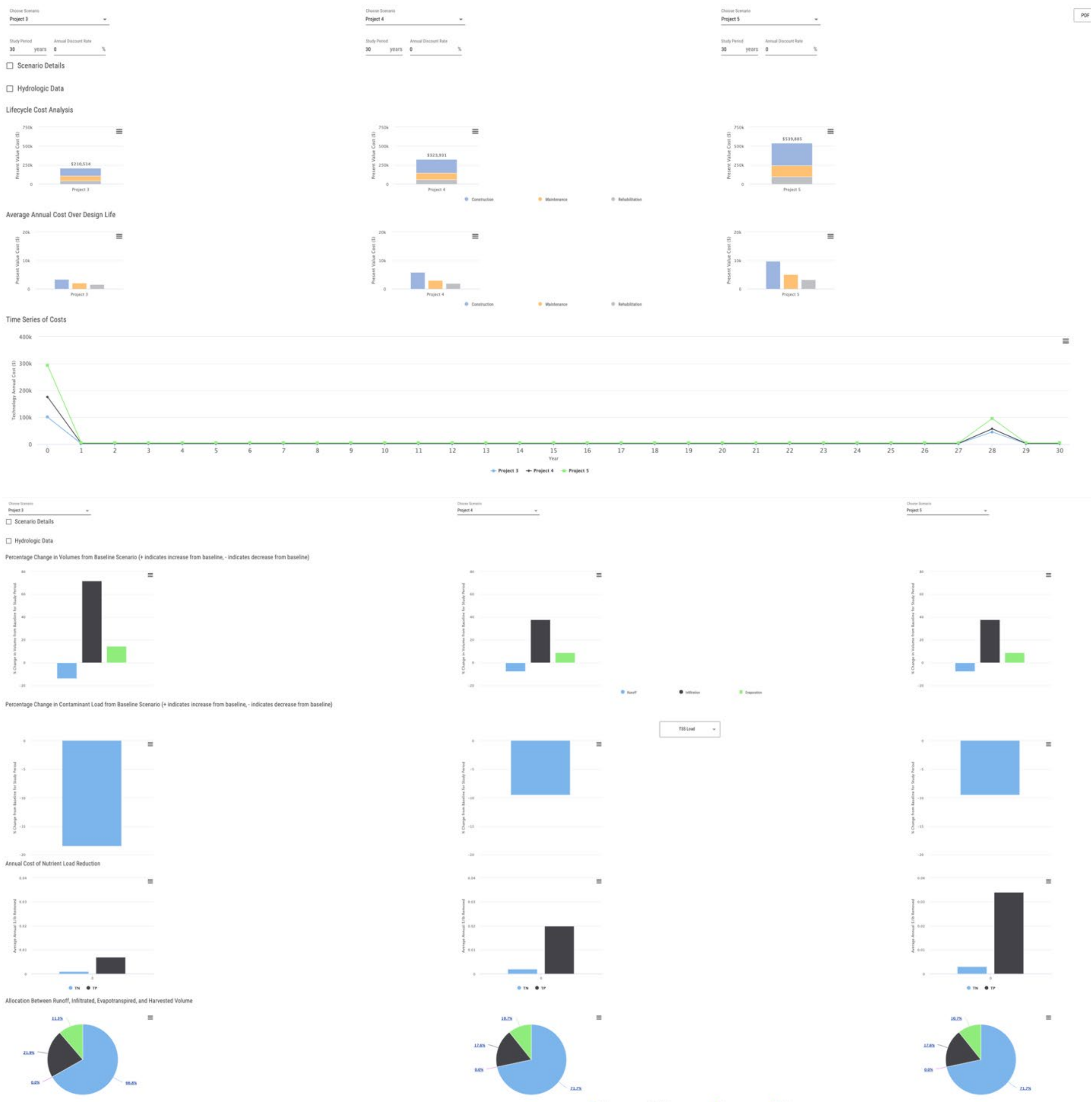

Scenario Details
Hydrologic Data
Lifecycle Cost Analysis
Average Annual Cost Over Design Life
Time Series of Costs


Baseline
Project 1
Project 2
PDF
Scenario Details
Hydrologic Data
Score for individual indicators in Social, Environmental, and Economic Categories (5 is best*)
Social: 0
Economic: 0
Environmental: 0
Social: 1.43
Economic: 0.37
Environmental: 1.26
Social: 1.76
Economic: 0.69
Environmental: 1.26
Total Co-Benefits Score (maximum is 15)
Score for individual indicators in Social, Environmental, and Economic Categories (5 is best*)
Social


Baseline
Project 1
Project 2
Scenario Details
Hydrologic Data
Percentage Change in Volumes from Baseline Scenario (+ indicates increase from baseline, - indicates decrease from baseline)
Percentage Change in Contaminant Load from Baseline Scenario (+ indicates increase from baseline, - indicates decrease from baseline)
TSS Load
Annual Cost of Nutrient Load Reduction
Allocation Between Runoff, Infiltrated, Evapotranspired, and Harvested Volume


Choose Scenario
Project 3
Project 4
Project 5
Study Period
Annual Discount Rate
Scenario Details
Hydrologic Data
Lifecycle Cost Analysis
Present Value Cost ($)
$210,514
$323,931
$539,885
Construction
Maintenance
Rehabilitation
Co-Benefit Analysis
Hydrologic Performance
Percentage change in volume of runoff, infiltration, and evaporation from baseline scenario (+ indicates increase from baseline, - indicates decrease from baseline)
% Change in Volume from Baseline for Study Period
Runoff
Infiltration
Evaporation


Choose Scenario
Project 3
Project 4
Project 5
PDF
Scenario Details
Hydrologic Data
Score for individual indicators in Social, Environmental, and Economic Categories (5 is best*)
Social
Economic
Environmental
Total Co-Benefits Score (maximum is 15)
Score
Score for individual indicators in Social, Environmental, and Economic Categories (5 is best*)
Social


Scenario Details
Hydrologic Data
Lifecycle Cost Analysis
Average Annual Cost Over Design Life
Time Series of Costs
Percentage Change in Volumes from Baseline Scenario (+ indicates increase from baseline, - indicates decrease from baseline)
Percentage Change in Contaminant Load from Baseline Scenario (+ indicates increase from baseline, - indicates decrease from baseline)
Annual Cost of Nutrient Load Reduction
Allocation Between Runoff, Infiltrated, Evapotranspired, and Harvested Volume