Expanding Stormwater Solutions: An Inventory of Projects Reducing Polluted Runoff in Massachusetts

An Interactive Qualifying Project Report
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Submitted By:
Hyungseok Lee
Nicolette Yee
Zachary Johnson
Zhaoyu Zheng

Submitted To:
Mr. Ed Himlan, Sponsor Liaison

Project Advisors:
Professor Corey Dehner
Professor Melissa Belz

Abstract

Stormwater Best Management Practices (BMPs) are principal techniques and structures used to mitigate the effects of polluted stormwater runoff. The goal of this project was to expand the Massachusetts Watershed Coalition's inventory of stormwater BMPs, which were used to educate the public on BMP projects across the state. We reviewed numerous annual stormwater reports and contacted over 300 municipalities. As a result, we gathered information on more than 100 projects. During the data collecting process, we collected information on the catalog's utility and subsequently made recommendations.

Acknowledgements

From the very beginning of our project, we have been supported and guided by many people throughout the course of completing our research. We are very thankful for the amount of time, encouragement, and support we received. Our project would not have been possible without many of these people.

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Acronym Definitions

BGY:	Billion Gallons a Year
BMP:	Best Management Practice
CMRSWC:	Central Massachusetts Regional Stormwater Coalition
CMSWS:	Charlotte-Mecklenburg Storm Water Service
CWA:	Clean Water Act
DPW:	Department of Public Works
FGC:	Fitchburg Greenway Committee
IDDE:	Illicit Discharge Detection and Elimination
IQP:	Interactive Qualifying Project
LID:	Low Impact Development
MassDEP:	Massachusetts Department of Environmental Protection
MS4:	Municipal Separate Storm Sewer Systems
MWC:	Massachusetts Watershed Coalition
NPDES:	National Pollutant Discharge Elimination System
PDF:	Portable Document Format
PRWC:	Pomperaug River Watershed Coalition
SSIA:	Stormwater Solutions In Action
TSS:	Total Suspended Solids
US EPA:	United States Environmental Protection Agency
WPI:	Worcester Polytechnic Institute

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Executive Summary

Normally, stormwater is not a problem by itself. It is the development and urbanization of natural lands that results in stormwater runoff. From this runoff, pollutants accumulate and flow directly into natural water bodies. In order to mitigate the effects caused by polluted stormwater runoff across the state of Massachusetts, best management practices (BMPs) can be implemented. BMPs include any activity, practice, maintenance procedures, and other management practices intended to prevent or reduce the discharge of pollutants to waters of Massachusetts. The "Stormwater Solutions in Action" (SSIA) catalog published by the Massachusetts Watershed Coalition (MWC) includes an inventory of structural BMPs implemented across the state. These BMPs are very important to the reduction of stormwater runoff generated due to increased urbanization. The MWC hopes to educate communities on the damage stormwater runoff can cause and alert them to the many BMPs used in project sites across the state.

For our Interactive Qualifying Project (IQP), we worked to expand an existing catalog of stormwater runoff mitigation projects published by the MWC. We also formulated multiple recommendations for improvements that could be made to the catalog in order to increase its utility. One of the main goals of the MWC is to assist municipalities in preventing and reversing the harmful impacts of stormwater runoff. The creation of their SSIA catalog is one way the MWC hopes to achieve that goal.

Methodology

To accomplish the goals of our project, we worked to achieve the following objectives: (1) become well versed on the variety and utility of BMPs used for managing stormwater runoff; (2)

identify various stormwater BMP catalogs nationwide; (3) determine the primary target audience for the MWC catalog; (4) identify and evaluate stormwater mitigation BMPs being used in Massachusetts towns not included in the MWC's catalog; (5) assess the utility of the MWC's catalog; and (6) provide recommendations for an improved and expanded catalog of stormwater BMPs.

During the early stages of our project, we researched various BMPs and their relative effectiveness at treating stormwater runoff. Specifically, we surveyed stormwater professionals, such as town planners and town engineers to get information on the effectiveness of each BMP. We analyzed catalogs created by other states, watershed associations, and the Massachusetts Department of Environmental Protection (MassDEP), to formulate structural changes to be made to the catalog and gather additional information.

To gather information on BMPs implemented in Massachusetts, we sent emails to over 500 Department of Public Works (DPW) employees and conservation commissions from central Massachusetts municipalities. In addition to requesting information on new projects, we also distributed a survey to these DPW employees and conservation commissions, along with town engineers and planners. We intended that these surveys find what aspects of the catalog were useful and which could be improved. Due to a low response rate of approximately 10-20%, we increased the scope of our outreach to include municipalities across the state and not just in central Massachusetts. Initially, we contacted municipalities that started with the letters A through D to test how active this target group was at responding to requests for information on BMPs implemented in their respective municipality. After obtaining a higher response rate, we sent emails requesting information to the remaining municipalities with letters starting with E through Y. We sent follow up emails to municipalities on a weekly basis. The majority of responses received were from town engineers, planners, and conservation commissions, but a few were from watershed associations.

In the last three weeks of our research, we distributed a survey seeking suggestions to improve the utility of the MWC catalog, to the municipal contacts that responded to our initial emails. The survey response rate turned out to be much higher than the email response rate (approximately 88% from 84 responses from the 96 surveys sent).

While email responses yielded a fair amount of information, our project team also reviewed annual stormwater reports and 319 projects (BMP projects partially funded by federal grants) at the MassDEP. We then compiled the BMP project data in a spreadsheet for the MWC and used the survey responses to make recommendations for MWC on improving their SSIA catalog.

Findings

During this seven week project, we identified the appropriate target audience for the SSIA catalog, scope of municipal awareness of the MWC in Massachusetts, factors affecting BMP selection and implementation, methods used for estimating data within the catalog, and challenges associated with improving different aspects of the catalog.

The SSIA Catalog is Designed for Use by Conservation Commissions, DPW Employees, Town Planners

Our team considered that the primary target audience of the MWC's SSIA catalog consists of conservation commissions, DPW employees, town planners, urban planners, angling groups, members of municipal stormwater committees, developers, and engineering consultants. We considered these people over others, because the MWC's catalog is a tool used for determining stormwater runoff issues and BMPs suited to reducing or preventing stormwater runoff. Additionally, these primary audiences replied that they would like to see photos added to the MWC's catalog as well as more information about each BMP's cost details, pollutant removal, and appropriate geography for siting the different BMPs. At the same time, our team found that municipal engineers and urban planners were more likely to understand the term "contributing area", which is essential to estimate the annual volume of total stormwater runoff. Lastly, we identified a secondary target audience to be any group not listed under the primary target audience, such as residents and businesses, which may find this tool useful.

The Majority of Surveyed Municipalities Know About the MWC

From survey responses, we found that a large percentage of contacts from different municipalities were aware of the MWC and its Billion Gallons a Year (BGY) campaign. However, the percentage of people aware of the MWC's SSIA catalog was substantially lower.

Project Site Location is the Most Important Factor When Developing a Stormwater Management System

We determined what factors engineers, urban planners, and stormwater municipal workers take into consideration when implementing a BMP. We considered factors like the locations used to install BMPs, the costs of construction and maintenance, the volume of stormwater runoff treated or removed, and the efficiency at which stormwater runoff is treated, during the course of this project. Responses from our project's survey determined that the location site of a BMP was the most prominent consideration when implementing a BMP and should be highlighted more in the SSIA catalog.

There are Different Methods for Calculating Annual Stormwater Runoff Treated or Removed

In the inventory section of the SSIA catalog there is a column of estimated annual volume of stormwater treated or removed. During the gathering of BMP projects in Massachusetts, we strived to understand how the MWC calculated the value for annual volume of stormwater treated or removed. We found that the current method used by the MWC is the Simple Method, which is easier to use over its alternate, the Rational Method. The Rational Method contains more variables and is therefore more accurate. Both methods produce flawed results due to estimating variables based on factors such as site conditions and local weather patterns. Figure 1 below summarizes the positives and negatives of both methods.

	Benefits	**Difficulties**
Simple Method	• Stormwater runoff easier to calculate • Less expertise required for calculations • Faster to complete estimations	• More inaccurate than other methods
Rational Method	• More accurate estimations due to larger number of variables	• Contains more variables that require calculation • Higher costs due to time and labor spent on gathering information

Figure 1: Comparison of Estimating Stormwater Volume Calculation Methods

Target Audience Members had Difficulties with Organization and Accessibility of Catalog

From further research into the utility of the SSIA catalog, we found that additional data for BMP projects listed within the catalog would be helpful, but would pose organizational challenges. Of the 96 survey responses we received, 75 respondents found the current catalog easy to navigate. However, 19 respondents lamented that the catalog was difficult to navigate because of a lack of a clear roadmap or table of contents. To ensure that the MWC is capable of providing an efficient way for people to use their resources, future changes both to the catalog's layout and interactivity would have to be made.

It is Difficult to get Government Funding for Best Management Practices

A meeting with the Fitchburg Greenway Committee (FGC), who advocate for the protection, preservation, restoration and responsible use of Fitchburg's water resources, open space, natural habitat, riverfront lands, and recreational trails, brought us to an additional finding. The FGC contemplated the difficulty the member towns faced in acquiring funds for potential/scheduled BMP projects. This committee claimed the difficulty obtaining federal grants for the implementation of stormwater BMPs was due to higher priorities set to address flooding issues in municipalities. For this reason, they suggested combining stormwater runoff issues with flooding issues in future grant applications with the hope of increasing their grant approval rate. These priorities were assumed to be a result of recent flooding events brought on by Hurricane Sandy in early 2012. It was from discussions and meetings with organizations similar to the FGC that we found strategic processes of developing stormwater BMPs to be a vital resource provided by the MWC.

Recommendations/Conclusions

Fortunately our outreach efforts were successful in expanding the quantity of BMP projects included in the MWC SSIA catalog and the number of contacts the MWC can use for further project research. From our findings, we formulated the following recommendations.

1. Add additional columns to the catalog for information on project funding costs, annual loads of pollutants removed.
2. Link certain “How To” guides for specific projects listed in the catalog.
3. Compile fact sheets for each BMP to provide descriptions, limitations for construction sites, design and maintenance considerations, pollutant removal efficiencies, etc. on concise documents for public education purposes.
4. Inform municipalities on how to be compliant with MS4 permits.
5. Continue education efforts and inform audiences more about the resources available such as, the SSIA catalog.
6. Rain gardens are one of the most preferred BMPs used in communities and therefore, should be showcased more prominently in MWC documents and programs.
7. The Simple Method used for estimations of annual stormwater volumes treated or removed due to BMP projects should continue to be used instead of more complex methods.
8. A more interactive catalog needs to be included on the MWC website to ensure people can more easily access the information included in the catalog.

Stormwater runoff continues to be a major source of pollution that compromises the future of aquatic ecosystems in Massachusetts. Throughout the course of this project, we provided information for additional BMP projects and changes the MWC can make to their catalog to improve its utility for use by many municipal, state, and possibly federal government agencies. Future editions of the SSIA catalog will serve as an invaluable tool for organizations, agencies, and committees as they continue to develop their own stormwater BMP projects.

1.0 Introduction

“Access to safe water is a fundamental human need and, therefore, a basic human right. Contaminated water jeopardizes both the physical and social health of all people. It is an affront to human dignity” (Annan, 2001). This quote, by former United Nations Secretary General, Kofi Annan, wholly describes the importance of water to mankind.

At this time, clean drinking water is still in high demand for most of the world (Knight, 2003). The world’s freshwater sources are in short supply. Earth contains approximately 330 million cubic miles of water. Roughly 8 million cubic miles of that water is freshwater and about 6 million cubic miles of that is trapped in glaciers, ice caps, and permanent snow. Therefore, only 2 million of the 330 cubic miles of Earth’s water is fresh and accessible (United States Geological Survey, 2012).

The United States Environmental Protection Agency estimates that a billion gallons of stormwater pollution occurs each year, nationwide. Stormwater runoff is generated when precipitation from rain and snowmelt flows over land or impervious surfaces (paved streets, parking lots, and building rooftops) and does not percolate into the ground. As the runoff flows over the land or impervious surfaces, it accumulates debris, chemicals, sediment, or other pollutants that could adversely affect water quality. Stormwater runoff pollutes our rivers, streams, and lakes, often making them unsuitable for use (EPA, 2012). The major concern regarding polluted stormwater runoff lies in the fact that freshwater is a scarce resource, and that many people do not know they can easily prevent this pollution from spreading.

For these reasons, various organizations have developed Best Management Practices (BMPs) to mitigate the effects of stormwater runoff. These BMPs include various strategies from promoting public awareness, to implementing physical stormwater systems to both filter and divert stormwater runoff to surface water bodies. The Massachusetts Watershed Coalition (MWC) is a non-profit organization dedicated to educating the public on the effects of stormwater runoff and the various BMPs which could be implemented to alleviate these effects. The MWC has developed a catalog of BMPs used by municipalities in Massachusetts. The catalog gives detailed information on the specific BMPs used in each included municipality, as well as, information on alternate strategies and a few guidelines on implementing these strategies.

While the MWC's stormwater BMP catalog provides vast amounts of information, there is room for expansion since the MWC has not yet included all BMPs being utilized in Massachusetts. Consequently, our project goal was to expand the breadth of MWC's BMP catalog. Improvements included adding new BMPs to the catalog, improving the explanations of the BMPs already present in the catalog, reorganizing the content and structure of the catalog, and presenting this information in an easy to understand format for the reader.

In chapter 2, we discuss the background information associated with stormwater runoff pollution. We provide definitions for relevant stormwater terminologies, information on efforts made by agencies and organizations to mitigate stormwater runoff, and an initial analysis of the MWC stormwater catalog. In Chapter 3 we describe our methodological approach to the project. Our team developed six objectives that were necessary to complete in order to achieve our project goal. Our project objectives were: (1) Become well versed on the variety and utility of BMPs for stormwater runoff mitigation; (2) Identify the various types of stormwater BMP catalogs nationwide; (3) Determine the primary target audience for the MWC's catalog; (4) Identify and evaluate stormwater mitigation BMPs being used in the Central Massachusetts towns currently not included in the MWC's catalog; (5) Assess the utility of the MWC's catalog and how it can be improved; and (6) Provide recommendations for an improved and expanded catalog of stormwater BMPs.

In order to achieve the aforementioned objectives we performed email correspondence with, conducted interviews with and distributed surveys to a variety of stormwater professionals from Massachusetts towns including, town engineers, urban planners, and Department of Public Works (DPW) employees. We describe our project methodology in Chapter 4. In Chapter 5, we present our findings and recommendations for the improvement of the MWC catalog. In Chapter 6, we provide our project findings, recommendations, and conclusions.

2.0 Background

Stormwater runoff is generated when precipitation from rain and snowmelt flows over land or impervious surfaces (paved streets, parking lots and building rooftops) and does not infiltrate the ground. As this stormwater runoff flows over the land or impervious surfaces, it accumulates debris, chemicals, sediment, or other pollutants. This once fresh stormwater continues flowing over impervious surfaces until it is discharged into nearby freshwater supplies, such as, lakes and streams. The contaminants therefore pollute the freshwater supplies, hence the issue surrounding stormwater runoff. Stormwater provides vast amounts of freshwater to the Earth's surface; however, polluted stormwater runoff is an important environmental issue since it transfers pollutants to these freshwater bodies. If the stormwater pollution issue could be better controlled by finding and implementing various methods to avoid the contamination of stormwater, the positive environmental impacts would be boundless.

The Massachusetts Watershed Coalition (MWC), a non-profit organization established in 1991, is committed to educating Massachusetts municipalities and residents on the severity of stormwater runoff and the various mitigation strategies available. The MWC currently has a catalog of best management practices (BMPs) for mitigating stormwater runoff which they use to educate these municipalities. The catalog also includes an inventory of BMPs that reduce polluted stormwater runoff already implemented in Massachusetts. Our goal was to expand and improve the MWC's catalog of stormwater BMPs and the inventory of stormwater projects. Our project group also aimed to provide recommendations regarding the accessibility and utility of the MWC's catalog.

In this chapter, we discuss the issue of stormwater runoff and pollution, the laws and regulations put in place to control pollution and runoff, and the different organizations that assist in mitigating the effects caused by polluted stormwater runoff. In section 2.1, we define stormwater runoff along with complementary terms and address the issue of polluted stormwater runoff. In section 2.2, we describe the environmental, social, and economic effects of stormwater runoff. In section 2.3, we examine the laws and regulations regarding stormwater and the agencies appointed to handle this issue. In section 2.4, we introduce some of the more popular mitigation strategies and comment on the impact of these strategies. In section 2.5, we introduce our sponsor and state their goals. In section 2.6, we analyze stormwater mitigation catalogs, including that of the MWC.

2.1 What is Stormwater?

Stormwater is essentially any rainwater, ice and snow melt, or any type of precipitation that falls on a variety of surfaces, such as roadways, parking lots, rooftops, forests, and grasslands. All of these surfaces are contained within watersheds, which are large areas of land that drain to the same water body. Watersheds can vary in size depending on how much land surrounds the rivers and streams that transport groundwater. For instance, the Mississippi River watershed is over 1 million square miles (2.6 million square kilometers) and empties into the Gulf of Mexico (Watersheds, 2009). Man-made surfaces, like roads, parking lots, sidewalks, and rooftops, prevent stormwater from infiltrating back into the ground where it is naturally filtered. Figure 2 illustrates how different types of surfaces impact where stormwater goes. In less urbanized areas, stormwater is able to infiltrate the ground more easily because fewer impervious surfaces exist and therefore, less runoff is produced. Conversely, in more urbanized areas, there is an increase in impervious surfaces resulting in little infiltration of stormwater. Low levels of infiltration result in higher amounts of stormwater runoff.

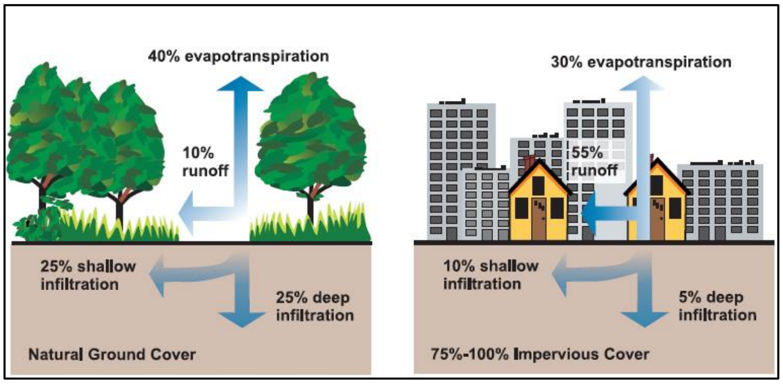


Figure 2: How Stormwater Reacts in Different Environments ("Urban nonpoint source," 2013)

Stormwater runoff occurs when the rate of rainfall exceeds the rate at which rainfall is being absorbed by the ground (infiltration rate). Stormwater runoff gathers countless pollutants while flowing above the ground. Trash, sediment, microscopic organisms and chemicals are a few examples of stormwater runoff pollutants. Polluted stormwater runoff negatively impacts the overall health of the existing water bodies and natural habitats. Pollutants found in stormwater may also cause interruptions or blockages in drainage systems built to control stormwater runoff. These blockages can result in flooding of impervious roadways and further increases the amount of pollutants in runoff, which flow into streams and rivers. If stormwater cannot be properly diverted to drainage systems or the necessary treatment facilities, the potential environmental, health, and economic effects can be damaging to the environment.

2.2 Effects of Stormwater

Only 2.5 percent of the world’s freshwater is accessible, and is made up of freshwater found in rivers, lakes, and groundwater aquifers (United States Geological Survey, 2012). Polluted stormwater runoff flows into these already scarce freshwater resources making them unsuitable for use. Stormwater runoff directly influences the water quality of the receiving surface water. There are many impacts of stormwater runoff that affect the environment, society, and economy. Reducing the amount of stormwater runoff entering watersheds is fundamental to alleviating the negative environmental, health, and economic effects of stormwater.

2.2.1 Environmental Effects of Stormwater

Polluted stormwater runoff can have detrimental effects on land, water bodies, and living organisms. All of these effects are ultimately the result of stormwater runoff pollution. Runoff accumulates various pollutants including soil particles, chemicals, heavy metals, and pathogens. The Oregon Environmental Council claims that when about 10 percent of a watershed is built with impervious surfaces, environmental damage has already occurred in the watershed (Oregon Environmental Council, 2007.) Polluted stormwater accumulates in drainage systems which in turn releases polluted runoff into local surface water bodies.

The term “total suspended solids” (TSS) is part of water quality assessment tests that look for the amount of organic or inorganic materials found in water bodies (Bilotta & Brazier, 2008). These include pollutants that are often too hard to see, such as lead and mercury, which accumulate and further damage the health of ecosystems. It is the collection of all these different pollutants that affect the sustainability of aquatic environments (Krejci, Rossi, Rauch, Kreikenbaum, Fankhauser & Gujuer, 2005).

One specific pollutant present during the winter months is road salt commonly used to melt snow and ice. Dissolved road salt in runoff reduces dissolved oxygen in streams and lakes, causing adverse effects in the health of aquatic life such as fish kills (Wegner & Yaggi, 2001). Dissolved road salt also reacts with chemical pollutants present in runoff such as chlorine, resulting in the breakdown of naturally present minerals and nutrients in freshwater ecosystems necessary for healthy aquatic life (Wegner & Yaggi, 2001).

Some fish, such as New England brook trout, act as biological indicators of the health of receiving water because their presence indicates that water bodies have enough food and oxygen to support large species of aquatic life (Burton & Pitt, 2001). Fish kills, when localized populations of fish die off, are one of the most obvious ways people identify water quality issues in water bodies. Surveys by the United States Environmental Protection Agency (US EPA) have shown that 30% of fish kills are directly linked to polluted water bodies caused by polluted runoff; however, the remaining 70% of fish kills are caused by a combination of problems that could have been worsened by runoff (Burton & Pitt, 2001). Such problems include elevated sediment loadings which increase the growth of aquatic plants causing a dissolved oxygen deficit and ultimately a fish kill (Burton & Pitt, 2001).

2.2.2 Health Effects from Stormwater

The health of a community can also be affected by stormwater runoff. Before freshwater is distributed for human use, it goes through processes that filter or remove various pollutants. Often drinking water suppliers use both filtration and disinfection, with chemicals such as chlorine, to eliminate sediment and disease-causing microorganisms. Despite treatment systems, about 100 million people in the United States suffer gastrointestinal illnesses as a result of poorly treated water annually. Studies by the US EPA show increasing land development as a main reason for the higher concentrations of pollutants in drinking water (Gaffield, Goo, Richards & Jackson, 2003).

2.2.3 Economic Impact of Stormwater Mitigation

Not only does stormwater affect the environment and health of our communities, but it has the potential to put economic strain on governments, businesses, and residents. In the past, more traditional techniques were used to manage stormwater and focused on redirecting stormwater runoff to pre-existing drainage systems. While this strategy does prevent stormwater from picking up pollutants, the cost of installing such large drainage systems puts economic pressure on municipalities. For example, the stormwater drainage system in Framingham, Massachusetts is made up of about 200 miles of drainage pipe that connects to 8,000 storm drains and 2,000 access points (manholes) (*Stormwater management*, 2013). By limiting the number of new pipes, drains, and pumps that are put into managing stormwater runoff, communities decrease the overall costs for installing and maintaining their stormwater drainage infrastructure. Strategically placing BMPs plays an important role in how effective these BMPs function.

The issue of polluted stormwater runoff is disastrous to the earth. For this reason, the United States government has implemented several laws and regulations that aim to protect water bodies from pollutants.

2.3 Federal Regulations to Combat Polluted Stormwater Runoff

The United States government has acknowledged the gravity of the consequences posed by polluted stormwater runoff. Over the past 60 years, they have implemented various laws and regulations which not only address polluted stormwater runoff, but also combat issues related to poor water quality. In this section, we address some of the laws and regulations regarding polluted stormwater runoff

2.3.1 Clean Water Act and the United States Environmental Protection Agency

The Clean Water Act (CWA), originally passed in 1948 as the Federal Water Pollution Control Act, came to its present form following the 1972 amendments (Clean Water Act, 1972). The major goal of the CWA is to limit the release of pollutants (including toxins, total suspended solids, and oil) from a point source into a surface water bodies in the United States (Clean Water Act, 1972). A point source is defined as "any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete, fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged (United States Environmental Protection Agency, 2003)." The National Pollutant Discharge Elimination System (NPDES) program, introduced by the 1972 amendments to the Clean Water Act Amendments regulates discharges of pollutants from a point source into a surface water body. The US EPA, in partnership with numerous state environmental agencies, manages the NPDES program. However, Massachusetts does not have federal Clean Water Act enforcement authority (for a detailed list of which states have CWA and NPDES permitting authority, see Appendix A) (United States Environmental Protection Agency, 2003).

Though water quality has been seriously impaired by non-point source pollution, like stormwater runoff, the US EPA historically did not include stormwater runoff in the NPDES permit program. Originally, the CWA considered stormwater runoff to be an unregulated non-point source of pollution. However, in 1987, the United States Congress passed amendments to the Federal Clean Water Act which mandated that the US EPA address stormwater runoff from municipal separate storm sewer systems and industrial stormwater dischargers. The US EPA in turn, redefined urban stormwater as a point source that is thereby required to obtain a discharge permit (United States Environmental Protection Agency, 1997).

The Massachusetts Department of Environmental Protection (MassDEP) encourages state municipalities to be in compliance with their Municipal Separate Storm Sewer Systems (MS4) permits. The MS4 permit was created by the US EPA to ensure the prevention and control of stormwater runoff. The US EPA also manages MS4 permits and their conditions (Murphy & Haas, 2003). MS4s are defined as public conveyances or systems of conveyance ranging from ditches, curbs, or underground pipes, which transport stormwater into surface water (Gentile, Tinger, Kosco, Ganter & Collines, 2013).

The MS4 permits have six minimum control measures that incorporate public education, outfall mapping, and detection of the presence of illicit discharges in catch basins (for additional detail on the six minimum control measures. Each control measure requires effort on the part of the municipality. Municipalities can comply with control measures by using Best Management Practices.

2.4 Best Management Practices (BMPs)

The US EPA defines Best Management Practices as any activity, prohibition of practices, maintenance procedures, or other management practice intended to prevent or reduce the discharge of pollutants to waters of the Commonwealth. Stormwater BMPs include treatment requirements, operating procedures, structures, devices, and/or practices to control or prevent polluted runoff, spillage, leaks, sludge or waste disposal, or drainage from raw material storage (United States Environmental Protection Agency, 2010).

Stormwater BMPs are important because they allow for natural methods to reduce water pollutants, which minimize man-made damage to natural aquatic habitat. These BMPs aim to both filter or treat polluted stormwater runoff, and also prevent precipitation from becoming runoff, by diverting or conveying precipitation to groundwater flow, treatment structures, or back to water bodies. BMPs are also recognized by the NPDES permitting process to prevent the discharge of toxic and hazardous chemicals. Generally, BMPs have the potential to mitigate the effects of stormwater runoff as well as subsequent water pollution problems. BMPs assist in reducing stormwater volume and peak flows through evapotranspiration, infiltration, detention, and filtration or biological and chemical actions (Debo & Reese, 2003).

Case studies done on different water treatment plants that utilize these BMPs have demonstrated that BMPs are quite successful and flexible in controlling releases of pollutants to receiving waters (United States Environmental Protection Agency, 1993).

BMPs can be categorized into two classifications: nonstructural and structural BMPs. Structural BMPs are man-made innovations that assist in diverting and cleansing stormwater runoff. Nonstructural BMPs include behavioral changes in the mitigation of stormwater runoff (Commonwealth of Massachusetts, 2013). This is further explained in Figure 3 below.

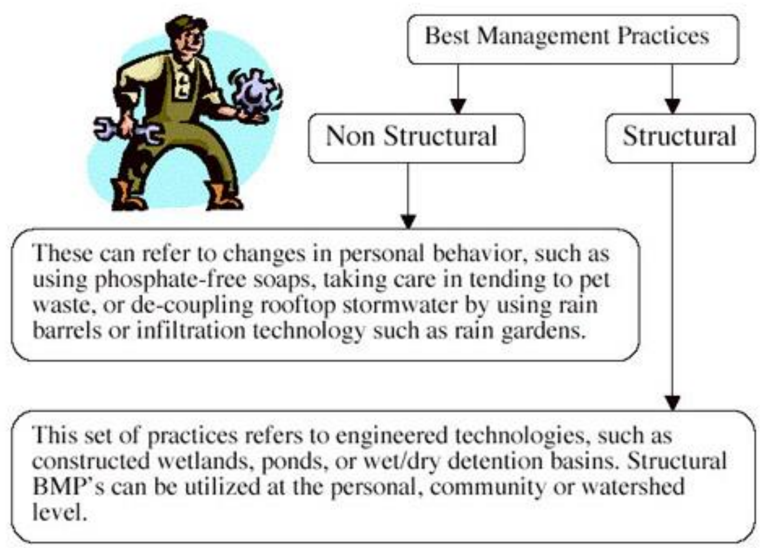


Figure 3: Definition of Structural and Nonstructural BMPs (University of Vermont, 2013)

2.4.1 Nonstructural BMPs

Nonstructural BMPs include intangible efforts made by persons, organizations, or agencies, such as public education and human behavioral changes. Stormwater organizations and agencies can plan interactive and educational events that inform individuals on the effects of stormwater runoff. Additionally, these organizations can offer informational handbooks or pamphlets containing stormwater facts, questions, answers, or resources.

Behavioral changes can be made by anyone who recognizes a stormwater runoff problem and consequently makes efforts to reduce pollutant discharges. For example, residents can properly dispose of pet droppings, clean up trash on streets, or choose to reduce harmful pollutants like phosphorus in backyard lakes by treating it with copper sulfate. However, to actually treat, filter and/or divert polluted runoff, more tangible methods need to be implemented. These methods are structural BMPs.

2.4.2 Structural BMPs

There are four classified types of structural BMPs. These include pretreatment, treatment, conveyance, and infiltration BMPs (Commonwealth of Massachusetts, 2013).

Pretreatment BMPs accumulate stormwater. They are often a necessary step to the utilization of treatment, conveyance and/or infiltration BMPs. Examples of BMPs that require the use of pretreatment BMPs are gravel wetlands, grass channels, and dry wells. Figure 4 below identifies the various BMPs that require the use of pretreatment.

BMPs for Controlling Stormwater Quantity		
	Pretreatment BMP	BMP that requires pretreatment
Pretreatment		
Deep Sump Catch Basin	Yes	No
Oil Grit Separators	Yes	No
Proprietary Separators	Yes	No
Sediment Forebays	Yes	No
Vegetated Filter Strips	Yes	No
Treatment		
Bioretention areas/rain gardens	No	Yes
Constructed stormwater wetlands	No	Yes
Extended Dry Detention Basins	No	Yes
Gravel Wetlands	No	Yes
Proprietary Media Filters	No	Yes
Sand/Organic Filters	No	Yes
Tree Box filters	No	Yes
Wet basins	No	Yes
Conveyance		
Grass Channels	No	Yes
Water Quality Swales – Dry	No	Yes
Water Quality Swales – wet	No	Yes
Infiltration BMPs		
Dry Wells	No	No pretreatment required for runoff from non-metal roofs and metal roofs outside Zone II, IWPA and industrial site.
Infiltration Basins	No	Yes
Infiltration Trenches	No	Yes
Leaching Catch Basins	No	Yes
Subsurface Structures	No	Yes
Other BMPs		
Dry Detention Basins	No	No
Green Roofs	No	No
Porous Pavements	No	No
Rain Barrels & Cisterns	No	No

Figure 4: Figure Showing BMPs That Require Pretreatment (Boston Water and Sewage Commission, 2013)

In order to accumulate stormwater in both high and low population areas, most pretreatment BMPs are designed as underground structures, connected to manholes that divert runoff to a common location. While pretreatment BMPs solely aim to collect runoff, pollutants can settle out of suspension and accumulate at the bottom of the structure. The maximum TSS removal rate of pretreatment BMPs is 45 percent (Commonwealth of Massachusetts, 2013). This means that 45 percent of all TSS present in the accumulated stormwater runoff is removed by the accumulation process alone. After stormwater runoff is accumulated and some pollutants are removed by pretreatment BMPs, stormwater is ready to go through treatment, conveyance, or infiltration processes.

Treatment BMPs are used to filter stormwater runoff by trapping contaminants in filtration mediums such as sand or soil. Biological and chemical reactions between microscopic pollutants, such as phosphates, and the filtration material being used is another function of treatment BMPs. Treatment BMPs utilize man-made, natural filtration methods, such as, rain gardens. Rain gardens are shallow depressions, filled with sandy soil and a thick layer of vegetation (filters) that direct stormwater into the ground and discharge filtered water into groundwater aquifers (Commonwealth of Massachusetts, 2013). If runoff is previously pretreated, treatment BMPs can filter up to 90 percent of TSS found in runoff, in addition to pollutants like nitrogen, phosphorus, metals, and pathogens (Massachusetts Department of Environmental Protection, 2012).

Conveyance BMPs act both as a channel for stormwater runoff, and a means of removing pollutants by sedimentation (settling out of suspension). The average TSS removal rate for conveyance BMPs is approximately 50 percent (Commonwealth of Massachusetts, 2013). This TSS removal rate is substantially lower than that of treatment BMPs since sedimentation is not as effective as filtration. To compensate for the limited effectiveness of conveyance BMPs, these BMPs have the ability to transport partially treated stormwater to open drainage systems. (Commonwealth of Massachusetts, 2013)

Infiltration BMPs first utilize treatment BMPs, then directly discharge this filtered stormwater into groundwater aquifers where the runoff enters natural filtration processes by sand and soil.

Infiltration BMPs are as efficient as treatment BMPs for collecting TSS; however, infiltration BMPs filter far more microscopic pollutants than any other structural BMP (Commonwealth of Massachusetts, 2013). While there are many benefits of infiltration BMPs, the construction and maintenance required by these BMPs tend to be very difficult since infiltration BMPs directly recharge groundwater flow. Special care needs to be taken when constructing infiltration BMPs to ensure that runoff is properly treated before runoff is discharged into groundwater flow. If runoff is not properly treated, the consequences can be detrimental to the health of receiving waters and aquatic life.

Utilizing these pretreatment, treatment, conveyance, and infiltration BMPs assist in both diverting stormwater off of impervious surfaces, and filtering or treating polluted runoff. While all of the above BMPs succeed at diverting or filtering polluted runoff, some are more effective than others.

2.4.3 Impact of BMPs

The effectiveness of structural BMPs can be measured in numerous ways. Some examples include the volume of stormwater treated, the amount of pollutants removed, and the volume of stormwater reduced.

One measure of the effectiveness of various BMPs is the annual volume of stormwater treated (MWC, 2013). This method utilizes variables such as, the contributing area and runoff coefficient which are both based on the size, terrain and permeability of the land (MWC, 2013). Figure 5 on the next page is a detailed explanation of the calculation used to obtain this volume.

Gallons of Stormwater Treated Annually = 45 inches X 1/12 (to convert inches of rainfall to feet) X Contributing area (sq. ft.) X 7.48 (gallons per cubic foot) X runoff coefficient.

For example: Riverfront Park in Orange uses a rain garden, bioretention swales and permeable pavers to treat stormwater runoff. The project drains about 31,363 sq. ft. and was assigned a runoff coefficient of 0.5. The annual treated runoff volume is calculated as follows:

45 x 1/12 x 31,363 x 7.48 x 0.5 = 439,868 gallons --rounded of in the table to 0.44 million gallons per year

Figure 5: Calculation of the Annual Volume of Stormwater Treated (MWC, 2013)

Another measure of the effectiveness of a structural BMP is the concentration of pollutants removed. As previously stated in Section 2.2, there are TSS, pathogens and chemicals like phosphorous in polluted stormwater. Figure 6 shows the concentration of TSS in various water samples before and after the implementation of several BMPs.

BMP Type	Count of Studies and EMCs		25th Percentile		Median (95% Conf. Interval)*		75th Percentile	
	In	Out	In	Out	In	Out	In	Out
Grass Strip	19, 350	20, 286	19.3	10.0	43.1 (36.0, 45.0)	**19.1 (16.0, 21.5)****	88.0	35.0
Bioretention	14, 202	14, 193	18.0	3.8	37.5 (29.2, 45.0)	**8.3 (5.0, 9.0)****	87.8	16.0
Bioswale	21, 338	23, 354	8.00	5.12	21.7 (16.2, 26.0)	**13.6 (11.8, 15.3)****	56.0	33.0
Composite	10, 201	10, 163	40.3	8.0	94.0 (76.2, 107)	**17.4 (12.4, 18.8)****	184.0	34.0
Detention Basin	20, 278	21, 299	24.2	11.3	66.8 (52.3, 76.1)	**24.2 (19.0, 26.0)****	121.0	46.5
Green Roof	2, 20	4, 51	1.44	0.89	10.5 (1.13, 14.5)	2.9 (1.0, 3.5)	20.5	8.0
Manufactured Device	55, 923	63, 904	12.0	6.0	34.5 (30.0, 36.8)	**18.4 (15.0, 19.9)****	93.0	45.0
Media Filter	28, 442	29, 409	26.2	4.0	52.7 (45.9, 58.2)	**8.7 (7.4, 10.0)****	112.0	22.0
Porous Pavement	14, 246	23, 406	18.3	7.08	65.3 (45.0, 80.3)	**13.2 (11.0, 14.4)****	186.7	27.0
Retention Pond	47, 725	48, 723	20.7	5.72	70.7 (59.0, 79.0)	**13.5 (12.0, 15.0)****	180.0	33.0
Wetland Basin	15, 301	17, 305	9.4	2.36	20.4 (16.6, 24.4)	**9.06 (7.0, 10.9)****	54.4	19.5
Wetland Channel	8, 189	8, 154	12.0	8.0	20.0 (17.0, 22.0)	**14.3 (10.0, 16.0)****	66.0	27.0

Figure 6: Table Comparing TSS Concentration for Various BMPs Before and After BMP Use (Leisenring, Clary &Hobson, 2012)

The final measure of the effectiveness of structural BMPs is the annual volume of stormwater runoff reduced. This is measured in terms of watershed-centimeters, which is essentially the annual average height of stormwater produced over the respective watershed area. Figure 7 shows the results of a study done by the Water Environment Research Foundation (WERF), an independent scientific research foundation that specializes in wastewater and stormwater issues (WERF, 2013). Their results illustrate the volume of stormwater runoff reduced by bioretentions (rain gardens) and grass swales. The line shown in the diagram indicates that the volume of rainfall remains the same (Inflow = Outflow). When a point occurs below this line, outflow is less than inflow which means that the BMP has reduced the volume of runoff within that respective watershed.

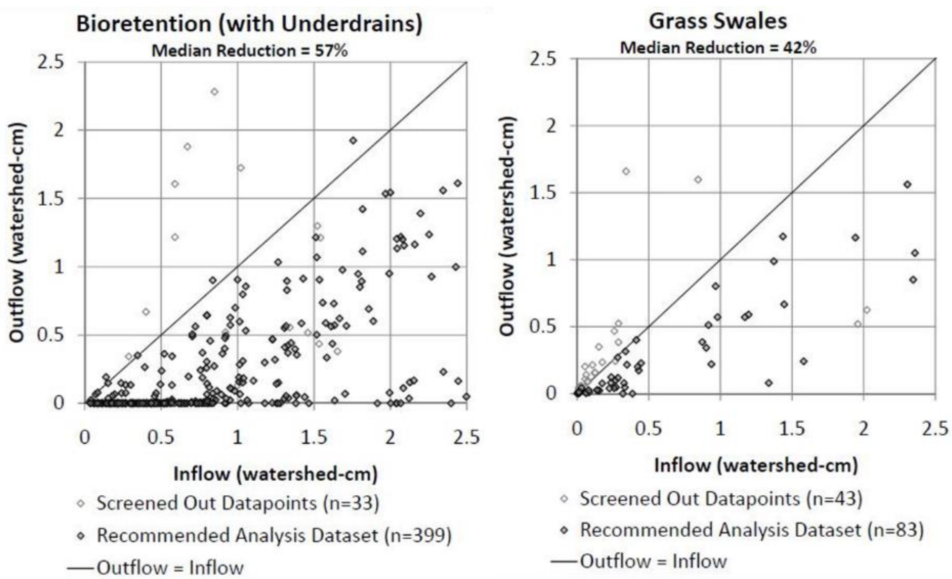


Figure 7: Volume of Stormwater Runoff Reduced (Watershed-cm) by Bioretentions and Grass Swales (Moeller, Clary & Strecker, 2011)

2.5 Massachusetts Watershed Coalition (MWC)

The MWC is a non-profit organization focused on educating the public on stormwater runoff and the effects caused my polluted runoff. They serve as an educational resource; offering workshops, municipal assistance and educational materials. Stormwater runoff is one of the leading environmental problems affecting the health of local water supplies in urban communities across the state (MWC, 2013).The MWC's mission is to "Strengthen the work and knowledge of community groups; raise public awareness of land and water management issues and; improve policies and decisions affecting rivers and their watersheds (“About the Massachusetts Watershed Coalition,” 2013).

The MWC works with numerous government agencies and not for profit organizations to achieve their goal of educating the public on stormwater and the various stormwater mitigation strategies. Some of the organizations the MWC works with include the Nashua River Watershed Association, Massachusetts Audubon Society, and the Wachusett Greenways Project. Some of the government agencies the MWC works with include the MassDEP, US EPA, and the Massachusetts Water Resources Authority (“About the Massachusetts Watershed Coalition,” 2013). By working with these organizations and agencies, the MWC has developed multiple methods for increasing public knowledge on the effects of stormwater runoff and strategies to mitigate those impacts. The MWC accomplishes this through various campaigns, programs, guides, and catalogs.

The MWC has developed a campaign to assist homeowners, cities, towns, schools and local businesses to cleanse one billion gallons of stormwater each year, also known as their “Billion Gallons a Year Campaign”. This campaign aims to educate residents, business owners, and school districts on stormwater pollution and the importance of protecting surface water. They accomplish this by encouraging individual and community actions such as the construction of rain gardens, which absorb and filter stormwater runoff (“Project: Billion Gallons,” 2013).

The MWC hosts numerous workshops and conferences yearly to educate Massachusetts municipalities on how they can mitigate the effects stormwater. These workshops include information on the effects of stormwater, guidance on how to build a rain garden, the benefits of permeable pavements along with other strategies ("Library Hosts Program," 2011). The MWC also participates in the Wachusett Watershed Fair where they educate children on water pollution and how stormwater can affect local water supplies. They have interactive presentations and activities that demonstrate stormwater effects hopefully resulting in a more aware and involved generation (Himlan, 2013).

The MWC offers many resources for residents, officials and organizations on stormwater mitigations strategies including guidebooks on how to implement particular strategies, guides to a 'greener' lifestyle, tutorials and conferences educating the public of the effects of stormwater and how they can help. The MWC assists municipal boards, community organizations, and individuals by providing a huge database of information and technical assistance services. A few of the services offered by the MWC include water supply protection and management plans, open space and recreation plans, community development and education plans (workshops, public forums and conference planning), grant writing assistance and land owners and home builders assistance (Community Services, 2013).

The MWC has created a catalog of several stormwater mitigation strategies. This is the catalog our group worked to improve and expand on. The name of this catalog is "Stormwater Solutions: An Inventory of Projects Reducing Polluted Runoff in Massachusetts." (MWC, 2013) The first part of the catalog contains actual solutions or mitigation strategies implemented throughout the Commonwealth of Massachusetts. It is organized alphabetically by major watershed and then by town. More detailed information about the various Best Management Practices (BMPs), the volume of stormwater treated or reduced, and whether or not stormwater is returned back to the various freshwater sources (infiltration) is also available in this catalog.

The second part of the inventory contains a ‘Resources Section.’ This section houses valuable information about a multitude of already implemented stormwater BMPs, brief descriptions of each, a link to a number of guides created by the MWC, and a list of all the watershed organizations in Massachusetts and their website addresses. In this ‘Resources Sections’, guides are provided to assist residents on the implementation of some of the BMPs. They are step-by-step instructions, with materials needs, a timeframe and costs of such projects. Some of the guides provided are a Rain Garden Guide, Stream Care Guide, and a Community Guide to Growing Greener (Community Guide to Greener Living, 2013).

2.6 Stormwater Mitigation Catalogs

Organizations other than the MWC have recognized the gravity of stormwater runoff and have produced similar stormwater BMP catalogs to increase the awareness of polluted stormwater issues in their respective towns. Some of these organizations include the Charlotte-Mecklenburg Storm Water Service (CMSWS) and the Pomperaug River Watershed Coalition (PRWC). The CMSWS was founded in 1993 created by both Charlotte County Government in Charlotte, North Carolina and Mecklenburg County Government in Mecklenburg, North Carolina. This service department targeted the elimination of sources of water pollution and management of stormwater runoff in its catalog. The PRWC was founded in Woodbury, Connecticut in 1999. Residents of Bethlehem, Woodbury, and Southbury in Connecticut created the coalition aiming to protect the quality of water resources in the Pomperaug Watershed. An assessment of these catalogs is below.

Charlotte-Mecklenburg Storm Water Service (CMSWS) Catalog

Since both the city of Charlotte and Mecklenburg County are aware that stormwater runoff poses a water quality problem in urban areas, they created a catalog that contains detailed and technical information about the BMPs implemented in these counties, with tutorials on how to implement BMPs. The CMSWS catalog is designed for state agencies, engineers, developers, and any resident, who have responsibility or interest in the stormwater management program for the city of Charlotte and Mecklenburg County (Charlotte-Mecklenburg Storm Water Services, 2013a). Based on the catalog, the CMSWS designed many stormwater projects to either reduce water pollution or reduce flood risks by implementing different BMPs and presented pictures of project sites before, during, and after implementing the BMPs. (Charlotte-Mecklenburg Storm Water Services, 2013b).

Figure 8: Upper McDowell Creek Water Quality Improvement pictures (Charlotte-Mecklenburg Storm Water Services, 2011)

The CMSWS manual as part of the CMSWS catalog details three categories of BMP implementation (Charlotte-Mecklenburg Storm Water Services, 2013). These are 1) specific procedures and pollutant removal efficiency calculations for each BMP; 2) BMP structure diagrams and dimension calculations and; 3) vegetation selection and planting zone considerations for different site conditions.

Pomperaug River Watershed Coalition (PRWC) Catalog

The PRWC created the "State of the Watershed Report" to increase people's awareness on the effects of polluted stormwater runoff. The report included four sections: 1) the geologic structure of the Pomperaug River watershed; 2) the investigation of sufficient and qualitative water supplies related to stormwater problem; 3) the protection of wastewater treatment facilities to ensure the quality of treated wastewater and; 4) the summary of land and habitat conditions along the Pomperaug River Watershed (Pomperaug River Watershed Coalition, 2013).

2.6.1 Analysis of the Catalogs

CMSWS's, PRWC's and MWC's catalogs have different content about BMPs, but each are intended to accomplish the same goal; to increase public awareness of stormwater runoff and to be a useful tool for implementing stormwater BMPs. Since each of them have unique structures and content, a table of comparing all three catalogs is shown below to differentiate between each one.

	Charlotte-Mecklenburg Storm Water Service Catalog	Pomperaug River Watershed Coalition Catalog	Massachusetts Watershed Coalition Catalog
Table of contents	Yes	Yes	No
Designated population	Yes	No	No
Roadmap	Clear	Not clear	Not included
Project goal	Clear	Not clear	Not clear
Project cost	Yes	No	No
Project effectiveness	Yes	No	Only BGY
Mitigation strategy	More detailed	More detailed	Less detailed
How to guides for mitigation strategy	Yes	Yes	Yes
Information of Partnerships	No	No	Yes
Conclusion	Yes	Yes	No

Figure 9: Catalog comparison charts of CMSWS, PRWC and MWC

While the MWC catalog is not finished yet, it has a wide variety of content that includes valuable information and resources. The MWC wants the public to be more aware of stormwater issues and works to facilitate this by providing resources in the form of catalogs, “How To” guides, and contacts with other organizations. In order to further this goal, the MWC asked our project group to assess the current MWC BMP catalog and offer new ideas for improving it. The goal of this project is to expand the breadth of the MWC’s current catalog. Our project team accomplished this by accomplishing the following goals: 1) Become well versed on the variety and utility of BMPs used for managing stormwater runoff; 2)Identify various types of stormwater BMP catalogs nationwide; 3)Determine the primary target audience for the catalog; Identify and evaluate stormwater mitigation BMPs in towns not included the he catalog; 5) Assess the utility of the MWC’s catalog and how it can be improved and; 6) Provide recommendations for the improvement and expansion of the catalog.

3.0 Methodology

The goal of our project was to expand the Massachusetts Watershed Coalition's (MWC) catalog of Best Management Practices (BMPs) for mitigating stormwater runoff. The purpose of this catalog is to provide Massachusetts municipalities with applicable information on stormwater BMPs. In order to successfully complete this goal, our project team developed six objectives. These objectives include:

1. Become well versed on the variety and utility of BMPs for stormwater runoff mitigation
2. Identify the various types of stormwater BMP catalogs nationwide
3. Determine the primary target audience for the MWC's catalog
4. Identify and evaluate stormwater mitigation BMPs being used in the Central Massachusetts towns currently not included in the MWC's catalog
5. Assess the utility of the MWC's catalog and how it can be improved
6. Provide recommendations for an improved and expanded catalog of stormwater BMPs

In order to satisfy these objectives we gathered information from various agencies and organizations both in and out of Massachusetts. We then utilized this information to expand the breadth of the MWC's stormwater mitigation catalog by adding new projects and formulating recommendations for the betterment of the catalog.

In this chapter, we describe our methodological approach to accomplishing the aforementioned objectives. Under each objective, we detail the method of data collection we used along with the justification for its use.

Objective 1: Become Well Versed on the Variety and Utility of BMPs for Stormwater Runoff Mitigation

Our first objective was to become well versed on the variety and utility of BMPs for stormwater runoff mitigation. We satisfied this objective by conducting interviews and document analysis.

Our project group conducted a semi-structured interview with our sponsor, Ed Himlan, Executive Director of the MWC, along with other stormwater professionals which included Department of Public Works (DPW) employees, environmental engineers, stormwater project managers, and conservation commissions. These individuals were found working individually, in watershed associations, such as, the Central Massachusetts Regional Stormwater Coalition (CMRSWC), or government agencies like the United States Environmental Protection Agency (US EPA) and the Massachusetts Department of Environmental Protection (MassDEP). These individuals were chosen for interviews because of their vast knowledge and experience in the field of stormwater. These stormwater professionals work with municipalities, organizations, and agencies to implement various stormwater BMPs, and therefore have great knowledge on the matter. Ed Himlan, for example, has over 18 years of experience working with both the Nashua Watershed Association and, presently, the MWC.

Our project group also conducted document analysis on research journals, and stormwater reports produced by civil and environmental engineers, town planners, members of local stormwater management teams and employees of local, state, and national stormwater organizations and agencies, such as the US EPA, MassDEP, and MWC. These documents, found in the MassDEP archives and on the internet, provided vital information on the various kinds of stormwater BMPs, as well as, their effectiveness. The effectiveness of BMPs refers to how well these mitigation strategies divert, filter, and manage stormwater runoff. According to the Stormwater Handbook produced by the DEP, the effectiveness of BMPs can be measured by the annual stormwater volume treated, the volume of pollutants removed or, the cost of implementation and maintenance.

We referred to the MWC's catalog to compare the effectiveness of various BMPs by the measure of annual stormwater volume treated in units of million gallons per year. We also referred to the equation given in the MWC's catalog and applied it to information obtained from various municipal and 319 reports found online and in the MassDEP archives. To compare BMPs by the volume of pollutants removed, we utilized the MassDEP's catalog of BMPs which gave approximate figures for the volume of pollutants removed such as, Total Suspended Solids (TSS) and phosphorous in units of pounds per year (lbs/yr). We utilized past 319 reports and annual municipal stormwater management plans written for various projects found in the MassDEP archives. In addition to these reports, we used the MassDEP's Stormwater Handbook to get approximate figures to compare costs for the implementation and maintenance of several BMPs.

Objective 2: Identify the Various Types of Stormwater Best Management Practice Catalogs Nationwide

In order to expand the current catalog for the MWC, our project group analyzed additional stormwater catalogs and compared them to the MWC's catalog. This served to both identify additional BMPs, and gather information on how to develop a stormwater BMP catalog. To satisfy this objective, our project group conducted document analysis on a number of stormwater BMP catalogs. Some of these included the Charlotte-Mecklenburg Stormwater Service (CMSWS) catalog, Pomperaug River Watershed Coalition (PRWC) catalog, Pennsylvania Stormwater BMP Manual, Stormwater Best Management Practices: Guidance Document, and the Massachusetts Stormwater Handbook.

Two members of our project group went through the various catalogs individually and constructed notes on each. Then, the two members met and compared notes on the structure, quantity and quality of information included, measure of BMP efficiency, organization of information, resources, and user friendliness and compatibility. From these discussions, we began to draw outlines for survey questions to ask about the utility of the MWC's catalog.

Objective 3: Determine the Primary Target Audience for the MWC's Catalog

It was important to determine the primary target audience for this catalog to maximize the catalog's functionality. Our approach for this objective was to use both document analysis and interview-based methodologies. Our project group interviewed our sponsor, Ed Himlan. Also, we conducted a document analysis on the MWC's catalog. By expanding the expected scope of readers to include secondary users who may find this document useful, the MWC's catalog could be more versatile.

Since Ed Himlan is the originator of the MWC's stormwater BMP catalog, he was a fundamental source in retrieving information on the primary target audience as well as secondary users. This interview allowed our project group to ask specific questions on who the catalog was originally intended for (primary users), the explicit target audience at the beginning of our research, as well as, persons who are not included in the aforementioned groups, but may find the information useful (secondary users).

The MWC's catalog was a major contributor in identifying the primary target audience. Our project group conducted a document analysis on the existing catalog to identify the level of knowledge expected from the reader. For this document analysis, our project group looked for a broad spectrum of predetermined components necessary for improvements. These components included: (1) terminologies used, (2) categorization of BMPs, (3) simplicity of calculations, and (4) research accessibility to the general public.

We summarized and categorized notes from the interview for the ease of referencing during the discussion and recommendation stages of our project. The analysis of the MWC's catalog was also summarized to organize thoughts on the concepts and ideas presented. A detailed description of the primary target audience and possible secondary users is stated in the Findings Chapter.

Objective 4: Identify & Evaluate Stormwater BMPs Being Used in Central Massachusetts Towns Currently Not Included in the MWC's Catalog

Our project group's methodologies for this objective included personal communication via emails, document analysis, and surveys. Our plan for accomplishing this objective consisted of four rounds which utilized document analysis and personal communication. A survey was also distributed to get ideas from a select group on the effectiveness of certain BMPs. A survey sample can be found in Appendix C.

Round one included contacting the Central Massachusetts municipalities that were currently included in the MWC's catalog, via email, asking for any updated information on both existing and new projects. The contact information was provided by our sponsor, Ed Himlan. This yielded a low response rate, therefore, our project group decided to expand our search to the entire state of Massachusetts which consists of 351 municipalities. We then collected contact information for as many Department of Public Works (DPW) employees and conservation commissions from using sources from the MassDEP archives employees and search engines such as Google. The contacts for these municipalities were organized in a Microsoft Excel spreadsheet. After these contacts were compiled, our project group continued with rounds two and three. Round two included sending out emails to all the DPW employees and conservation commissions for the municipalities with names beginning with A through D. Round three included sending out emails to the remaining DPW employees and conservation commissions.

For these three rounds, each group member sent standardized emails asking for specific information and a sample of these emails can be found in Appendix D. If contacts did not respond in a timely manner, follow up emails were sent weekly. Some responses included referrals; therefore, a standardized email was also sent to the person the original contact referred us to. These new contacts were also added to the Microsoft Excel spreadsheet of contacts. Round four included three trips to the Massachusetts DEP Office in Worcester, Massachusetts to go through electronic and hard copies of several 319 project reports (Government Funded) and municipal and watershed stormwater management plans. All responses from emails sent in rounds one, two and three, along with the information gathered from the document analysis done in round four, were all compiled into a Microsoft Excel spreadsheet.

To keep track of the status of information gathered for all 351 municipalities, our project group posted a municipal map of Massachusetts in our office and placed color-coded stickers on each municipality based on the amount of information we gathered from emails and document analysis. Blue stickers indicated that a member from our project group attempted to gather information but got no responses from contacts or did not find any reports from the DEP Library. Yellow stickers indicated that the contact person responded with partial information or reports provided some of the specific information we needed. Green stickers indicated the municipalities that our project group had close communication with due to WPI alliances. Red stickers indicated that complete or updated information was collected.

The last research method used to accomplish this objective was the distribution of a 14-question survey using Qualtrics, which is a surveying software to approximately 40 persons. The respondents included all of the contacts who responded showing interest in our project, regardless if they provided partial or complete information. These persons were seen as reliable and our project group could anticipate a high response rate. The respondents also included persons we met over the course of our project at various meetings and field trips. Some of the places our project group went to include: the Fitchburg Greenway Committee monthly meeting; a tour of the Upper Monoosnoc Brook with DPW employees and Nashua Watershed Association representatives where we collected samples for water quality testing; our three trips to the Massachusetts DEP Office; a Central Massachusetts Regional Stormwater Coalition (CMRSC)

Seminar in Holden, MA where we got information on how to use Leica technology to map stormwater outfalls; and tour of the Granite Stormwater Park outside of Leomister, MA where team members visited project sites and saw infiltration trenches, rain gardens, stormwater wetlands and infiltration basins. After the surveys were filled out, our project group utilized Qualtrics and had open discussions to analyze the data and draw conclusions and recommendations.

Objective 5: Assess the Utility of the MWC Catalog and How it Can be Improved

Objective 5 was achieved by interviews, document analysis, participant studies, and surveys. An interactive document analysis and participant study was conducted on the MWC's present catalog. We also conducted an interview with our sponsor Ed Himlan to gather ideas on the how the catalog should be used as a useful tool for the primary and secondary audiences. Survey questions regarding this objective were included in the survey discussed in Objective 4 which can be found in Appendix C.

Our project group conducted a semi structured interview with Ed Himlan to get ideas on his desired utility of the catalog and the different ways the catalog can be used as a versatile tool for primary and secondary users. The interview questions can be found in Appendix E. From this interview our project group decided the best method of executing this objective was to evaluate the MWC's catalog individually using document analysis then gathering to have open discussions among our project group about our individual opinions and findings. We also saw fit to survey the primary target audience so we could best meet their needs for the catalog.

Since our group is well informed on stormwater issues, the breadth of existing BMPs, and the content and use of various BMP catalogs used nationwide from Objectives 1 and 2, each member went through the MWC's catalog individually and constructed notes on the same categories from Objective 2: structure, quantity and quality of information included, measure of BMP efficiency, organization of information, resources, and user friendliness and compatibility. Our project group then formulated survey questions based on ideas from our open discussions which took place after individual document analyses where we obtain a broad spectrum of ideas and thoughts on the different ways the catalog could be improved.

The survey respondent group consists of primary target audience members based on the findings from Objective 3. Conducting surveys was very helpful in determining how the respondents presently utilize the MWC's catalog and allowed for their suggestions and recommendations based on their needs. Surveys also provided a quick and effective method of collecting our primary target audiences' ideas and thoughts on the MWC's catalog utility.

Objective 6: Provide Recommendations for an Improved and Expanded Catalog of Stormwater BMPs

This objective is the last step to our research project. All the information gathered from objectives one through five was analyzed for our project group to develop recommendations on how the MWC stormwater catalog can be improved. Information regarding the content of the catalog, that is, the variety of BMPs available is covered in Objectives 1 and 4. Information regarding the organization and structure of the catalog is covered in Objectives 2, 3, and 5. The additional projects found from our research and the recommendations formed from the previous objectives were used to produce a prototype for the expanded and improve MWC catalog. The prototype embodies all the recommendations posed by our project group through specific examples on catalog layout and content.

3.1 Project Limitations

During the course of this research there were limitations that hindered our data collection. These included low response rates, inability of our project group to visit local watershed associations, lack of resources, time constraints, and insufficient information in 319 reports and municipal stormwater management plans.

In the initial stages of our project, we focused on the Central Massachusetts municipalities. Shortly after we began sending emails to our list of contacts, we noticed that there were not many responses. Since much of our research was dependent on the information provided by these sources, our project group decided to expand our search to the entire state of Massachusetts to yield a larger number of responses. This process was tedious since there are 351 municipalities in Massachusetts and it was difficult to locate contact information for the necessary persons.

Another limitation included the difficulty of finding the appropriate contact or source for the specific information that our project required given such a large target. We contacted watershed associations, DPW employees, and conservation commissions. Many of these persons referred us to town planners or town engineers or simply said that they did not have the information our project group needed. Few contacts said they had hard copies of reports which may contain the information that our project group desired at their office; however, it was not feasible for our project group to venture to these towns.

Both of these limitations were exaggerated by time constraints. Persons were slow to respond with referrals and, the person who we were referred to at times took many days to respond or did not respond at all. For the municipalities who invited us to go through their archives, the time it would take to visit their offices and go through numerous reports made the venture undesirable and unfeasible for our project group.

While we did not visit these individual offices, our project group opted to visit the Massachusetts DEP Office which was a closer destination. We found several 319 reports and municipal stormwater management plans in both hard and soft copies. This research method was difficult since there were so many documents to go through page-by-page with no guarantee of sufficient information. We were also not allowed in the office unattended and had to schedule meetings based on the availability of a DEP employee.

4.0 Findings, Discussion and Recommendations

During the course of our research, we had email conversations and conducted interviews with our sponsor, Ed Himlan, Executive Director of the Massachusetts Watershed Coalition (MWC), as well as, members of the Fitchburg Greenway Committee and the Nashua River Watershed Association. These communications provided our project team with useful information on the Best Management Practices (BMPs) implemented across Massachusetts, the impact these BMPs have on the environment, and permitting and grant application processes.

The data collected through email conversations with conservation commissions, Department of Public Works (DPW) employees, town planners, and urban planners, along with document analyses conducted on various reports at the Massachusetts Department of Environmental Protection (MassDEP) were our primary sources of information for expanding the breadth of the catalog, that is, adding more projects to the catalog. The data collected from surveys and additional interviews provided our project team with secondary data which was used to formulate recommendations for the improvement of the MWC's catalog. From these interviews and surveys, target audience members found the MWC's "Stormwater Solutions In Action" (SSIA) catalog to be a useful tool. However, survey respondents commented that the SSIA catalog would be much more useful if it included information regarding each project, specific BMPs, and permitting and grant application processes. In this chapter, we discuss our findings from our interviews, surveys, and document analysis. After each finding, we suggest recommendations for the respective finding.

Finding 1: The SSIA Catalog is Designed for Use by Conservation Commissions, DPW Employees, Town Planners etc.

The primary target audience consists of a wide ranging group including conservation commissions, Department of Public Works employees, town planners, urban planners, angling groups, members of municipal stormwater committees, developers, and engineering consultants. Members of the primary target audience work in government agencies on the national, state, and local levels, like the United States Environmental Protection Agency (US EPA) and the Massachusetts Department of Environmental Protection (MassDEP). Members of the primary target audience also include private and public sector engineers who design BMP structures. We obtained the identification of the primary target audience through interviews with Ed Himlan of the Massachusetts Watershed Coalition (MWC). During these interviews we discussed the persons who the catalog was intended for during its original production and how they would utilize this catalog. We also determined a group of potential additional users or secondary users. From these interviews, we deduced that the primary target audience previously identified would find the MWC's catalog the most useful since they need the specific information on: the variety of existing BMPs; how effective they are (based on pollutant removal and volume treated estimations); how to create these BMPs; the cost to implement and maintain these projects; the different design considerations; and site constraints. Town planners and engineering consultants could use this catalog as a resource for information on which BMP would be best suited based on site location or annual rainfall volumes. The US EPA and MassDEP can refer municipalities to the SSIA catalog for informational purposes because the catalog includes a summary of reports written by town planners and engineers. From conducting a document analysis on the SSIA catalog, we were also able to deduce and justify the specific target audience previously described. We noted the terminologies used and content of the catalog to comprehend the level of knowledge the originator of the catalog intended the reader to have. After we did this, we were able to support our definition of the primary target audience from our interviews since the members listed should be familiar with the information and terminologies based on their job positions.

While all of this information is most useful to the members of the primary target audience, it could also be useful to persons on a smaller or more residential level. These persons would be considered secondary users since they may not be the target of the SSIA catalog, but could find the information provided in it useful. Secondary users of the MWC's catalog include Massachusetts residents, local business owners, and school districts. From interviews with our sponsor, Ed Himlan, along with a document analysis on the MWC's catalog, we concluded that this group of secondary users may use the catalog to find out what their respective town is doing to alleviate the effects of stormwater runoff or possibly get information on what BMPs they could implement for their personal use given cost, site conditions, maintenance, and ease of implementation.

Finding 2: Members of the Target Audience Want Additional Information to be Added to the Catalog

Members from the primary target audience would appreciate additional information to be added to the MWC's catalog including: (1) cost breakdown of each BMP type; (2) levels of pollutant removal; (3), best site/topography for types of BMPs; (4) installation guidelines, site/project photos and links to more detailed information on each BMP project. From the distribution of surveys, we found that the approximately 70% of the 96 respondents wanted information on one of the above listed fields added to the catalog. Respondents of our survey included conservation commissions, Department of Public Works representatives, town engineers and urban planners.

This information would make the catalog a more useful tool for the primary target audience by giving them insight into which BMPs could be used when developing stormwater management plans for each municipality. This additional information would also be a useful resource for secondary users of the catalog. Residents can find information on which BMPs best suits their neighborhoods, along with details on implementation including cost and guides for construction. Figure 10 on the following page shows the preference of informational fields that members of the primary target audience wanted in future editions of the SSIA catalog. Members of the primary target audience voiced that they want information mostly on cost, project site location/topography and the BMPs which best treat or filter runoff.

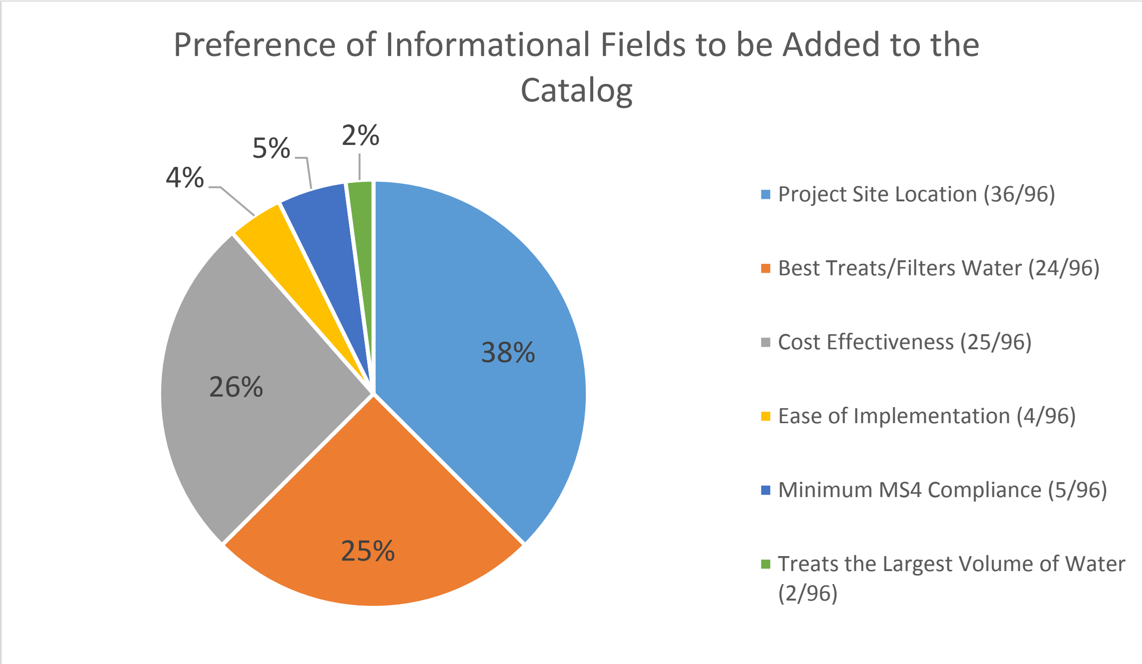


Figure 10: Survey Response Results on Additional Information to be Included in SSIA Catalog

Recommendation 1: Add Columns for Cost, Pollutant Removal, and "Additional Information"

Based on the findings that the primary target audience consists of a group of people who are well informed on stormwater runoff issues and solutions, our team recommends that columns for cost, pollutant removal, and additional information be added to the inventory section of the MWC's catalog. These additional data fields may assist members of the target audience in making decisions about which BMPs would be best suited for their municipality. We recommend that the cost column include information on the cost of each project, along with a breakdown of government and town funding options for the respective project. This cost information would include the cost to implement the project and also information on how much it costs to maintain this project on an annual basis.

Similar to the explanation of the equation for annual volume of stormwater treated, there could also be an explanation of the equation used for the volume of Total Suspended Solids (TSS) removed. We recommend that the MWC add this information to the inventory along with the amount of other pollutants that are also removed from further research. Such pollutants could include phosphorous and iron. Since one of the objectives for the MWC's catalog is to let towns know which BMPs neighboring municipalities are utilizing, contact information or links to municipal reports from which the information was sourced could also be added to the inventory under a column entitled "Additional Information."

Recommendation 2: Incorporate BMP "How To" Guides into the SSIA Catalog

We recommend that "How To" guides be added to the catalog. "How To" guides are small booklets that contain detailed information on how to construct a BMP. These guides would include information on the materials needed, where to find these materials, step-by-step instructions for implementation, and possibly tips on maintenance. "How To" guides would be developed as a complementary tool for the catalog. Developing detailed "How To" guides for the most popular BMPs would assist both the primary and secondary users. Primary users could use these guides to assist in seminars, conferences, or workshops held by local stormwater associations to be in compliance with the Public Education control measure of the MS4 permit. If "How To" guides are detailed enough, residents will be able to construct BMPs on their own or at least have a good idea on how to implement the respective BMP. If not, they may refer to the "Additional Information" section of the catalog described in the previous recommendation where contact information and project links could be found.

Recommendation 3: Incorporate Fact Sheets into the Catalog

A fact sheet is a sheet of paper giving useful information about a particular BMP. While this sheet may not contain an extensive amount of information, it would still be able to provide the most important facts on the respective BMP. Instead of giving brief descriptions of each BMP in the "Resources" section of the current catalog, our project team recommends that a fact sheet for each BMP be developed. These fact sheets could include: brief descriptions, site constraints, design considerations, suitable applications, maintenance, advantages, disadvantages, pollutant removal efficiencies, and groundwater recharge capabilities. These fact sheets can be placed in the resources section of the catalog. The information on this fact sheet should be as clear and concise as possible so that all of this information can fit on one letter size sheet of paper. Similarly to the "How To" guides, facts sheets may assist municipal officials to educate the public on different BMPs by utilizing this tool. Fact sheets could also benefit residents who do not work to construct stormwater BMPs, but would allow them to make decisions on what BMPs fit their needs.

Finding 3: "Contributing Area" is a Term Used by Town Engineers and Urban Planners

Our project team found that conservation commissions, DPW employees, and watershed organizations were confused by the term "contributing area." When our project group sent emails to DPW employees and conservation commissions, about 60 percent of respondents were not sure of what this term meant. From constant communication with these contacts, we found that the persons who designed these BMP projects were the ones who knew this information. Stormwater BMP project designers include civil and environmental engineers, private engineering consultants, or urban planners since they need to take this figure into consideration for their designs.

According to the upcoming draft of the MS4 permit in Massachusetts, municipalities will be required to include contributing area for each BMP, which is a key factor in calculating annual stormwater treated volume and the most lacked informational field during our research project. In order to obtain accurate value for contributing area, municipalities need to measure the site area using Leica GPS devices with network antennas and PeopleGIS systems. These technologies are costly and are difficult to learn and use. Current annual reports do not require any information on contributing area, but the new MS4 permit will require each municipality to list BMP projects with their contributing area. Requesting contributing area can be good for both SSIA inventory and municipalities for early notification of what they are lacking for upcoming MS4 requirements.

Finding 4: The Majority of Surveyed Municipalities Know About the MWC

The MWC itself is already well known in each municipality, but the MWC's SSIA catalog still needs more publicity. From online survey feedback, our project team found that 97% (93 out of 96) of respondents are aware of the MWC as an organization. Additionally, approximately 65% (62 out of 96) of respondents recognized the Billion Gallons a Year (BGY) campaign that was developed by the MWC. However, only 42.8% (41 out of 96) of respondents knew that the

MWC's "Stormwater Solution in Action" (SSIA) catalog exists. Since the catalog contains valuable information on the BMPs implemented in Massachusetts, it is very important to increase public awareness of this catalog. In Figure 11 below, blue represents the percentage of people who know of the MWC. The different shades of blue represent those who are aware of only MWC, MWC and BGY, and MWC, BGY and SSIA catalog.

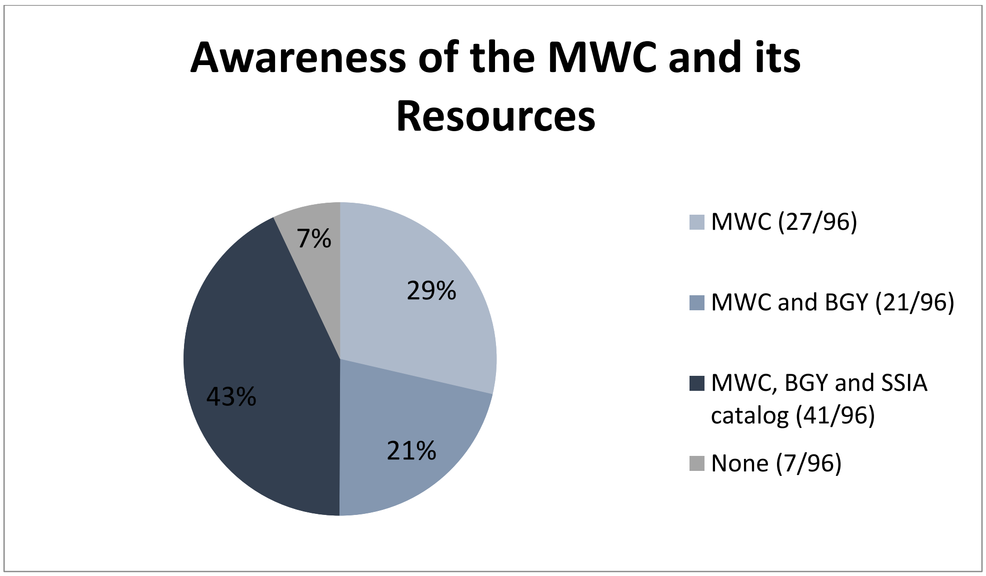


Figure 11: Pie Chart of Survey Questions regarding Awareness of MWC, BGY, and SSIA catalog

Recommendation 4: Continue Public Education Efforts and Present Audiences More About the MWC's Catalog

The data presented in Figure 11 shows that the MWC is effective at educating the public of its existence and resources through its SSIA catalog, conferences, and seminars. However, from our findings, we see that about 50% (48 out of 96) of respondents were aware of the SSIA catalog. This catalog contains valuable information that is useful to the groups of people previously listed as the primary and secondary target audiences. To increase awareness of the catalog, hard and soft copies should be distributed to all watershed associations, conservation commissions, and

DPW employees. This would be a relatively easy task since contact information for the majority of the conservation commissions and DPW employees were obtained through our research. A hard copy could also be placed in the MassDEP Office that we went to for gathering information on municipal stormwater BMP projects. Their archives had extensive information on the BMPs implemented across Massachusetts and the SSIA catalog would be a good addition since it summarizes these projects into a relatively small document.

Finding 5: Project Site Location is the Most Important Factor When Developing a Stormwater Management System

Members of the primary target audience considered project site location the most when developing a stormwater management system. In our team's online survey, a multiple-choice question asked respondents what factor they considered most important while developing a stormwater management system. The seven choices from this survey included: cost effectiveness, the largest volume of water treated, best treatment or filtration of stormwater, project site location, minimum MS4 compliance and, the easiest to implement and maintain. Of these choices, project site location yielded 37.5% (36 out of 96 responses) of responses. This information can be found in Figure 12 on the next page.

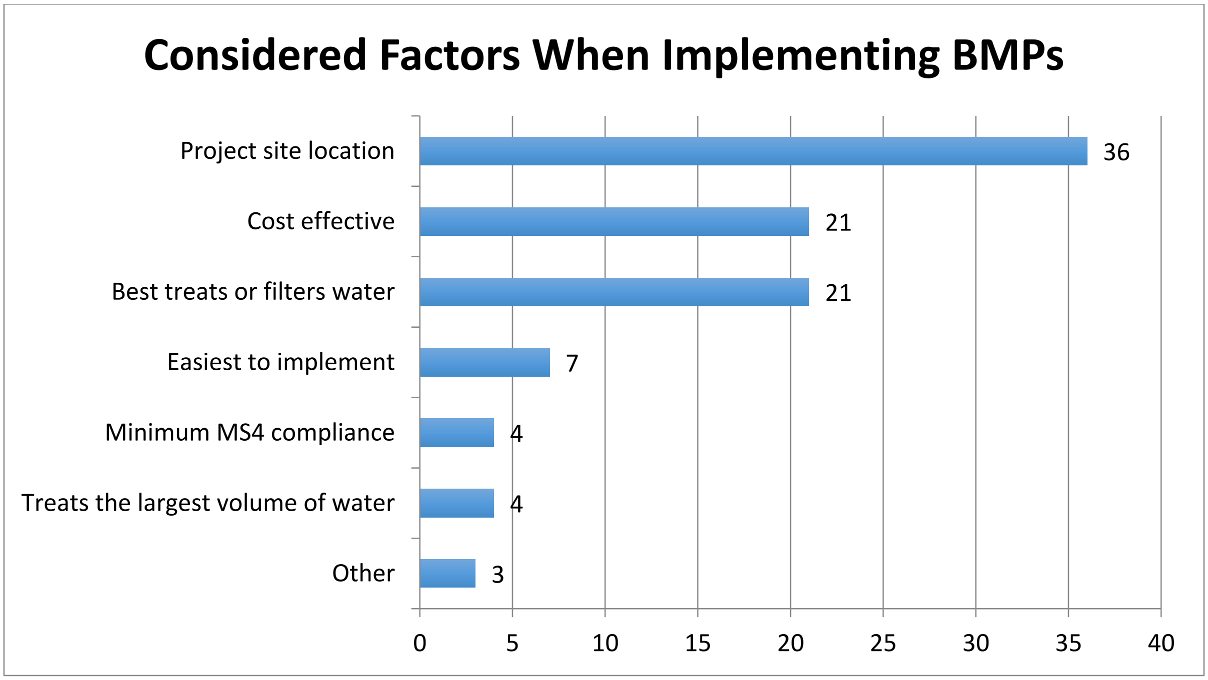


Figure 12: Responses from Survey Questions Regarding Important Factors When Developing BMPs

From discussions with DPW employees who experienced implementing and maintaining BMPs such as, catch basins and infiltration trenches, we learned that they have witnessed difficulties when installing BMPs in inappropriate site locations. They voiced that certain BMPs would be more effective in specific locations based on the terrain, soil quality, level of urbanization, and the size of the project site. Martha Morgan from the Nashua River Watershed Association discussed the importance of the placement of rain gardens. She stated that rain gardens would be most efficient in lower lying areas and should contain depressions in order to maximize the volume of water collected for filtration. Another example showing the importance of project site location, given by DPW employees, would be the placement of catch basins at the bottom of slopes or on street corners. This strategic placement maximizes the volume of water collected based on the expected direction of the runoff flow over surfaces.

The second most important factor to our survey respondents when deciding which BMP to implement was the BMP’s ability to treat/filter stormwater. These survey results can be found in Figure 12 above. Over the course of our project, we found that government funding is very difficult to obtain. Most watershed associations rely on private donations or limited state funds. For this reason, cost is an important factor when deciding if the implementation of BMP is feasible. The other popular factor used for developing stormwater management plans is how effective a BMP is in treating or filtering polluted runoff. The main goal for implementing a BMP is to improve water quality; therefore, it is important to consider exactly how many pollutants are removed from stormwater runoff. From a tour of the Monoosnoc Brook over the course of our project, we found that extensive water quality tests were done to find the location of pollutant outfalls so that BMPs could be implemented at those sites.

Finding 6: Rain Gardens are the Most Cost Effective BMP and the BMP that Best Treats Stormwater Runoff

Rain gardens were favored as the most cost effective BMP and the BMP that best treats or filters stormwater runoff by members of our primary target audience. Fortyithree percent of respondents (41 out of 96 respondents) chose rain gardens as the most cost efficient BMP in our survey. Rain gardens utilize affordable materials such as, sandy soils and plants to filter water. These materials are relatively cheap and along with design, construction and labor cost, a rain garden may cost $3,000 to $5,000 to implement. This is relatively affordable in comparison to more expensive alternatives, such as catch basins systems, which may cost up to $90,000. While implementing rain gardens in suburban areas is affordable, implementing rain gardens in highly urbanized areas is extremely expensive due to excavation costs and the use of more expensive materials. Constructed wetlands, such as swamps or marshes, are another affordable BMP. Wetlands function similarly to rain gardens since they utilize soils and plants; however, they differ from rain gardens since they require a larger site and more expensive soils, such as clay, for their construction. Information comparing cost effectiveness and actual costs for these BMPs are shown in Figures 13 and 14.

Practice	*Wet pond*	*Wetland*	*Bioretention in clay soils*	*Bioretention in sandy soils*
Construction cost	65,357	11,740	124,445	7,843
Annual maintenance cost	4,411	752	583	583
Opportunity cost of land ($217,800/acre)	43,560	65,340	65,340	65,340
Present value of total cost	146,474	83,486	194,751	78,137
Annualized cost per acre watershed	1,721	981	2,288	918

Figure 13: Actual Costs for Implementing Wet Pond, Wetland, Bioretention (Rain Garden) in Clay Soils and Bioretention (Rain Garden) in Sandy Soils (North Carolina Cooperative Extension Service, 2003)

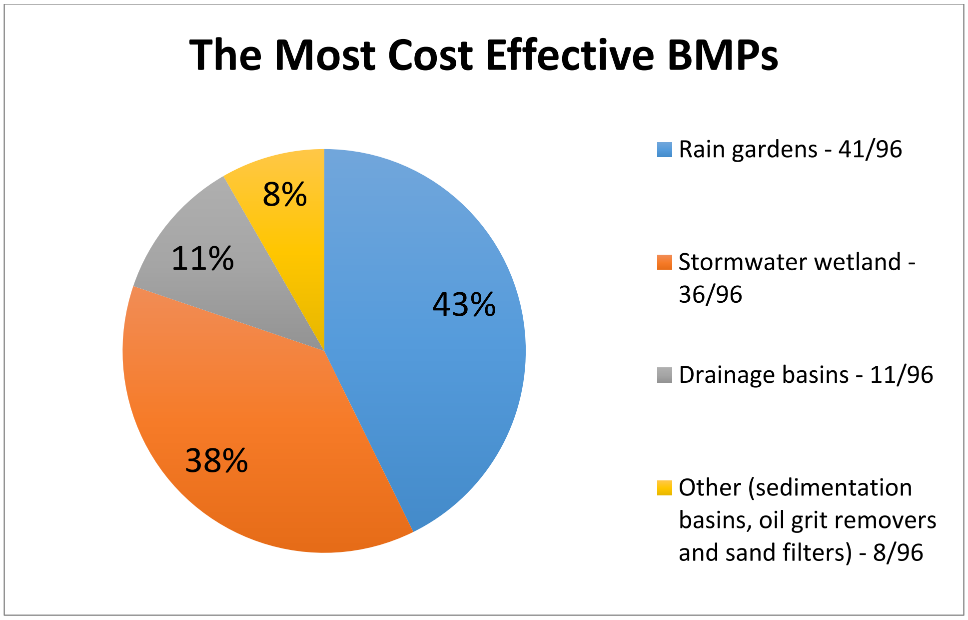


Figure 14: Pie Chart of Survey Questions Regarding the Most Cost Effective BMPs

The collected data from surveys also showed that rain gardens best treat or filter the stormwater runoff. From further document analysis, we found that the total suspended solid (TSS) removal rate for rain garden is 90 percent, which is extremely high compared to other kinds of BMPs, such as drainage basins and stormwater wetlands, which have removal rates of 25 percent and 80 percent respectively. More comparisons on TSS removal rates are shown in Figure 15 below.

TSS Removal Efficiencies for Best Management Practices	
Best Management Practice (BMP)	**TSS Removal Efficiency**
Non-Structural Pretreatment BMPs	
Street Sweeping	0-10%, See Volume 2, Chapter 1.
Structural Pretreatment BMPs	
Deep Sump Catch Basins	25% only if used for pretreatment and only if off-line
Oil Grit Separator	25% only if used for pretreatment and only if off-line
Proprietary Separators	Varies – see Volume 2, Chapter 4.
Sediment Forebays	25% if used for pretreatment
Vegetated filter strips	10% if at least 25 feet wide, 45% if at least 50 feet wide
Treatment BMPs	
Bioretention Areas including rain gardens	90% provided it is combined with adequate pretreatment
Constructed Stormwater Wetlands	80% provided it is combined with a sediment forebay
Extended Dry Detention Basins	50% provided it is combined with a sediment forebay
Gravel Wetlands	80% provided it is combined with a sediment forebay
Proprietary Media Filters	Varies – see Volume 2, Chapter 4
Sand/Organic Filters	80% provided it is combined with sediment forebay
Treebox filter	80% provided it is combined with adequate pretreatment
Wet Basins	80% provided it is combined with sediment forebay
Conveyance	
Drainage Channels	For conveyance only. No TSS Removal credit.
Grass Channels (formerly biofilter swales)	50% if combined with sediment forebay or equivalent
Water Quality Swale – wet & dry	70% provided it is combined with sediment forebay or equivalent
Infiltration BMPs	
Dry Wells	80% for runoff from non-metal roofs; may also be used for runoff from metal roofs but only if metal roof is not located within a Zone II, or IWPA or at an industrial site
Infiltration Basins & Infiltration Trenches	80% provided it is combined with adequate pretreatment (sediment forebay or vegetated filter strip, grass channel, water quality swale) prior to infiltration
Leaching Catch Basins	80% provided a deep sump catch basin is used for pretreatment
Subsurface Structure	80% provided they are combined with one or more pretreatment BMPs prior to infiltration.
Other BMPs	
Dry Detention Basins	For peak rate attenuation only. No TSS Removal credit.
Green Roofs	See Volume 2. Chapter 2. May reduce required water quality volume. No TSS Removal Credit.
Porous Pavement	80% if designed to prevent runon and with adequate storage capacity. Limited to uses identified in Volume 2, Chapter 2.
Rain Barrels and Cisterns	May reduce required water quality volume. No TSS Removal Credit.

Figure 15: Total Suspended Solid Removal Rate of Various Stormwater BMPs (Boston Water and Sewer Commission, 2013)

While rain gardens were found to have the greatest ability to treat/filter stormwater runoff and be the most cost efficient BMP, survey results showed that drainage basins are the most effective in treating the largest volume of stormwater runoff. This data is show in Figure 16 below. Drainage basins are found in areas with large amounts of impervious surfaces such as, parking lots and roadways. These impervious surfaces produce a lot of runoff and; therefore, drainage basins are placed in these areas to collect and treat this excessive amount of runoff.

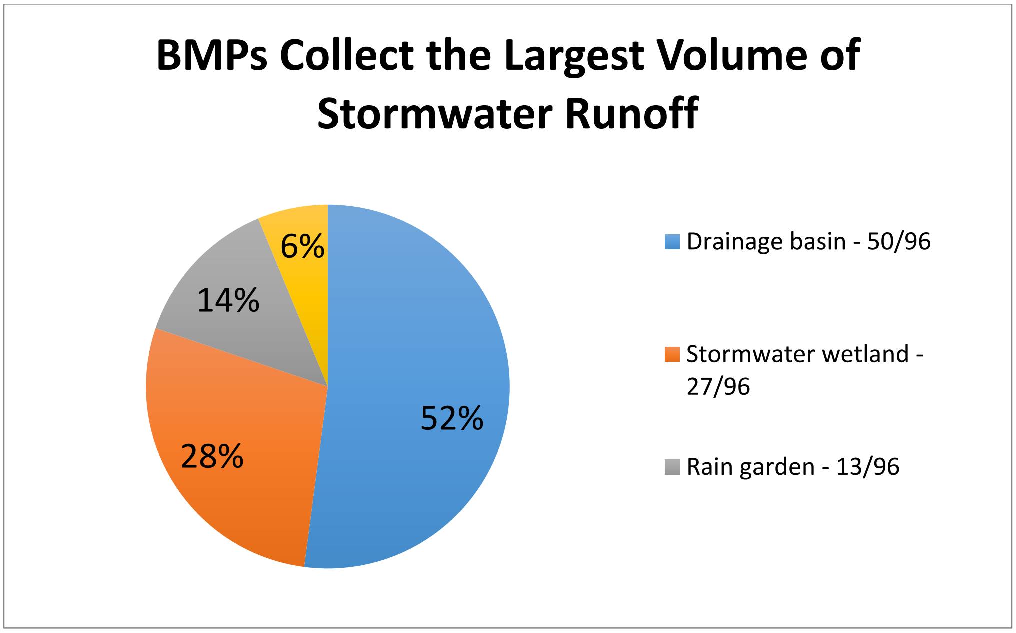


Figure 16: Pie Chart of Survey Questions regarding BMPs that Treat the Largest Volume of Stormwater Runoff

Recommendation 5: Better Utilize Rain Garden "How To" Guides

As suggested in Recommendation 2, "How To" guides are great resources for implementation guidance. The MWC currently has a "How To" guide for rain gardens which could be utilized more by the MWC, other watershed associations, or even individual municipal committees. More conferences and seminars should be held to demonstrate the construction of rain gardens by using the "How To" guide as a primary tool. Also, the construction of a rain garden could be used as a fun and educational event for residents. This could be done as a community effort which can account for municipal compliance in the public education and public participation control measures for current MS4 permits.

Finding 7: There are Different Methods for Calculating Annual Stormwater Runoff Treated or Removed

There are two primary methods for calculating the annual volume of stormwater treated or removed by structural BMPs: the Rational Method and the Simple Method. This finding was determined from interviews and document analysis. During the course of our project, we corresponded with Suzanne LePage, a civil engineering professor at WPI and a member of the MWC Board of Directors, who is knowledgeable on runoff calculations. We utilized hydrology textbooks which contained information on runoff calculations (Bendient, Huber & Vieux, 2013; Shammas & Wang, 2011).

The current method used in the MWC's "Stormwater Solutions in Action" catalog is called the Simple Method, which estimates annual stormwater by assuming variables such as annual rainfall, runoff coefficients, and contributing areas draining to the BMP project site. The second calculation method is called the Rational Method and includes many other factors like soil type and land use values. In addition to these values, determining runoff coefficients and contributing areas require physical assessments of the BMP project site before an estimation can be carried out. A comparison chart for both methods of estimation are shown in Figure 17.

	Benefits	**Difficulties**
Simple Method	• Stormwater runoff easier to calculate • Less expertise required for calculations • Faster to complete estimations	• More inaccurate than other methods
Rational Method	• More accurate estimations due to larger number of variables	• Contains more variables that require calculation • Higher costs due to time and labor spent on gathering information

Figure 17: Comparison of Simple and Rational Method for Estimating Annual Stormwater Runoff Volumes

Recommendation 6: Simple Method Should Continue to be Used in Calculations

Since the MWC is currently using the Simple Method to calculate the volume of stormwater runoff BMP projects have treated or removed, it is our group's recommendation that they continue to maintain their stormwater BMPs catalog under that same method. While the Rational Method provides more accurate representations of annual stormwater volumes treated or removed, it requires additional expertise and therefore, addition costs to update the current catalog. The Rational Method would require field surveying and experienced GIS mapping analysis, which is potentially beyond the scope of the MWC. The Simple Method is a more streamlined process that appears to work effectively with the MWC's goals.

Finding 8: It is Difficult to get Government Funding for Best Management Practices

Obtaining a federal grant for specifically implementing stormwater BMPs is very difficult since the effects of stormwater do not appear to be as disastrous as other environmental issues such as, flooding. Our team attended a monthly meeting with the Fitchburg Greenway Committee (FCG) during the course of our project. The FCG is a non-profit organization composed of local environmental professionals who support many organizations and government representatives focused on solving local stormwater runoff issues. The FGC also assists in starting the initial procedures for implementing BMPs, which include obtaining government permits and grants. A civil engineer from the City of Fitchburg Department of Public Works (DPW) attended the meeting to retrieve suggestions on 319 funding for BMPs along the North Nashua River near Fitchburg State University. 319 grants are federal funding from the US EPA. Since most BMPs are costly, cities and town boards usually take most of the financial burden to install BMPs with little to no financial support from federal organizations like the US EPA or the Federal Emergency Management Agency (FEMA). During the meeting, one of the environmental professionals from FGC suggested applying for a 604B grant, which is a small preparatory research federal grant. Obtaining this grant also gives applicants higher priority when approving 319 grants. According to FGC representatives, there is very limited funding available for stormwater BMPs in the New England area.

This is due to Hurricane Sandy, the most destructive and deadliest storm in the Eastern United States in 2012, which reprioritized federal funding agendas for financing municipal projects (Blake, Kimberlain, Berg, Cangialosi & Beven II, 2013). Therefore, one of the suggestions from the FGC was combining the project's purpose into both flooding and stormwater runoff prevention practices, even though the originally planned BMP addresses few effects caused by flooding (Delpapa, 2013). Since current BMP projects being funded are focused on the issue of flooding, there is a lack of direct stormwater BMP funding (Delpapa, 2013). This might result in fewer numbers of BMP projects being funded solely on the basis of reducing stormwater runoff (Delpapa, 2013).

Finding 9: Target Audience Members had Difficulties with Organization and Accessibility of Catalog

Members of the primary target audience claimed to have difficulties with finding the catalog on the MWC's website, as well as, difficulties finding information within the catalog. Respondents were provided with a link to the catalog when they received the link to our survey; therefore, they did not have any difficulties finding the catalog. However, from email correspondence with various conservation commissions and DPW employees, we received several responses saying that they were unable to find the catalog given the link we provided to the MWC's website homepage. From survey respondents, we found that target audience members had difficulties finding the information they desired using the Portable Document Format (PDF) version of the catalog provided on the MWC's website. General written responses from our project survey included requests for a navigation panel with a table of contents, reordering the sections in the catalog, and providing a link to the catalog on the MWC's homepage.

Recommendation 7: Produce Interactive Online and PDF Versions of the Catalog

We recommend that two versions of the catalog be produced, an online version and a PDF version. The online version can utilize links and prompts to provide a more interactive and easily navigable catalog. The PDF version, which can be printed out for distribution, could be adjusted to allow readers to easily find information.

The online version of the catalog can contain some of the following attributes.

1. The addition of drop down menus – Drop down menus can be utilized in several different ways. A drop down menu can be placed on the homepage of the MWC's website under "Resources" where a list of all "How To" guides, fact sheets, information packets, and the catalog can be shown. Drop down menus can be used to sort the inventory section of the catalog by watershed, town, and the type of BMP. See Appendix G for visuals.
2. Various Links – Clickable link can be used to jump to webpages which contain additional information. For example, for each watershed or town, a link can be embedded to divert the user to the respective website for the watershed association or municipal board/committee. Also, links can be embedded to jump from different sections of the catalog such as, fact sheets, "How To" guides, and additional information on each project. See Appendix G for visuals.

For the PDF version of the catalog, we recommend that a table of contents be added. This addition would allow readers to easily find the information they are looking for and also provides a point-based outline of the catalog. See Appendix F and H for a visual representations.

Recommendation 8: Reorganize the Catalog for Smoother Transitions Between Sections

We recommend that definitions of each BMP be placed before the inventory section of the SSIA catalog. This allows the reader to have a general idea of each BMP before embarking on the complicated inventory section.

5.0 Summary and Conclusion

Stormwater runoff can have devastating impacts on natural environments. Environmental agencies and organizations on the national, state, and municipal level are aware of these effects and have decided to implement Best Management Practices (BMPs) to assist in the alleviation of these stormwater runoff effects. The Massachusetts Watershed Coalition (MWC) has developed a catalog of stormwater BMPs, entitled "Stormwater Solutions in Action: An Inventory of Projects Reducing Stormwater in Massachusetts" (SSIA). Our project goal was to expand this catalog by finding additional BMPs to be included in the catalog.

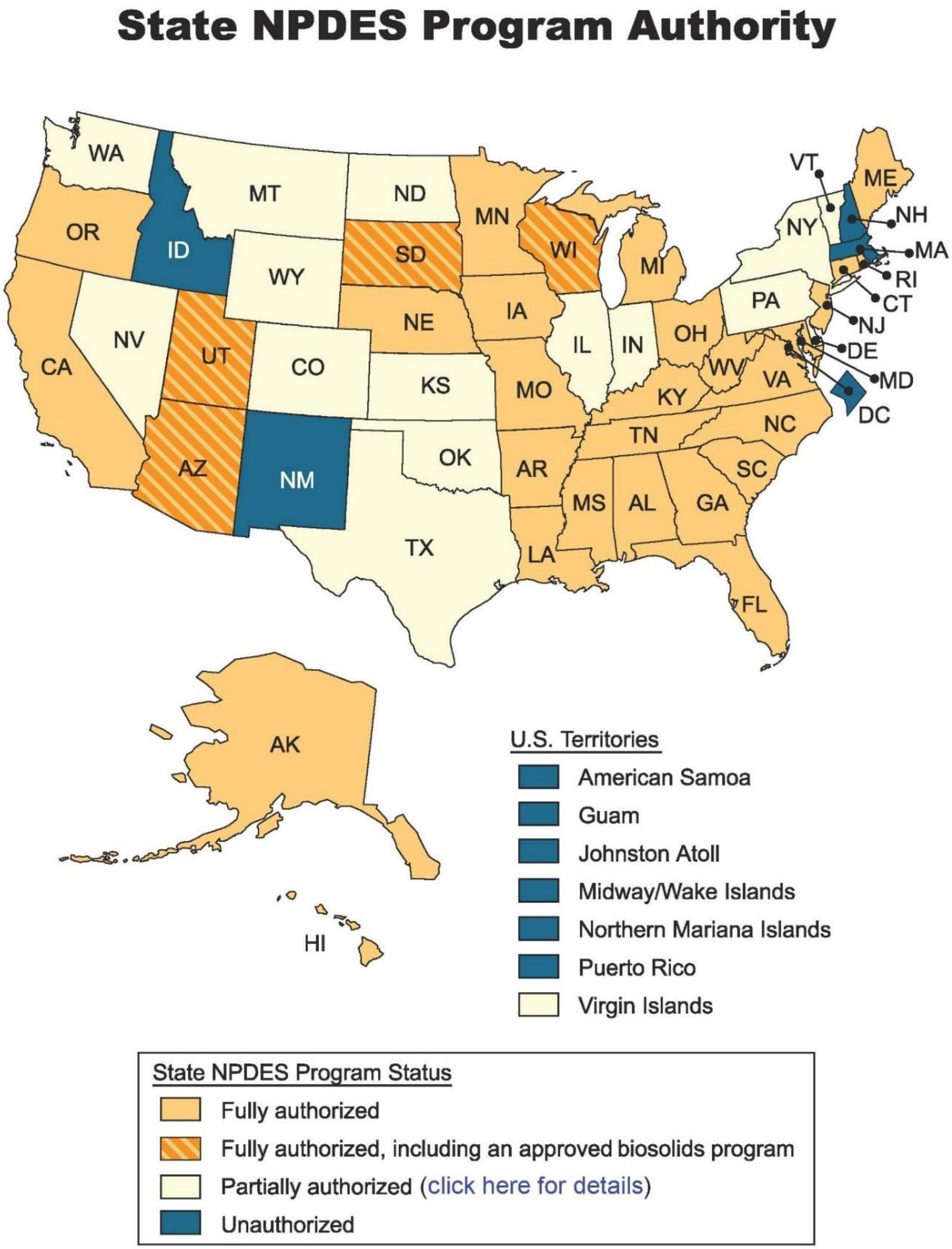
To complete this research, our project team utilized several methodologies to gather information on the various projects implemented across the state of Massachusetts. We obtained information on over 100 BMP projects to be added to the current SSIA catalog as listed in Appendix I. The expansion of this catalog increases municipalities' awareness on existing BMPs and where they are implemented in neighboring municipalities. This additional information on implemented BMP projects is also important to government officials since it gives a summary of each municipality's stormwater mitigation plan.

In addition to the projects we added to the catalog, our project team produced several deliverables. These included an extensive list of contact information for over 500 conservation commissions, Department of Public Works (DPW) employees, town engineers and urban planners for about 315 municipalities. We also included prototypes for the layout of recommended online and Portable Document File (PDF) versions of the catalog.

The recommendations formulated at the end of our data collection aimed to improve the usability, accessibility, and versatility of the catalog. If these aspects were improved, the useful information provided by this catalog could reach a larger audience who could then utilize this information to improve stormwater plans in their respective municipalities. The recommendations were based on a compilation of findings from our research. The findings were related to the comprehension and content of the catalog, permitting processes relating to funding and MS4 compliance, as well as, data collection and analysis methods for water quality reports.

We recognize the gravity of the stormwater runoff issue in Massachusetts, and have become aware of the various BMPs which could be easily implemented to mitigate the effects posed by stormwater runoff. While these solutions are simple, the main hindrance to the complete control of stormwater runoff is insufficient public education. Most municipalities rely on volunteers who sometimes do not have the necessary experience or education on stormwater runoff issues. The SSIA catalog is an instrumental step in educating the public on stormwater runoff issues and providing stormwater agencies, organizations, and committees with help on directing their respective stormwater management plans. The SSIA catalog could also be a useful BMP catalog template for environmental organizations and agencies for other states, or possibly the entire nation since it does not focus on a specific municipality, but rather a larger target area.

Appendix A: State NPDES Program Authority Map



(United States Environmental Protection Agency, 2010)

Appendix B: Six Control Measures of Municipal Separate Storm Sewer Systems (MS4) permits

There are six minimum control measures that separate each control measure by its purpose in order to reduce pollutants that are significantly discharged into receiving waters. The control measures need to be fulfilled by municipalities in order to be in compliance with MS4 permits. The control measures are:

Public education and outreach - inform citizens about the impact of polluted stormwater on water quality by providing educational materials and other outreach programs. (Murphy & Haas, 2003).

Public participation/involvement - requires residents of all economic and ethnic groups to become involved in developing and implementing the stormwater management program. (Murphy & Haas, 2003).

Illicit discharge detection and elimination - An illicit discharge is any discharge to the storm sewer system that is not composed entirely of stormwater, except discharges that have a NPDES permit and discharges resulting from fire-fighting activities. This measure controls street wash water development and puts into action plans to detect and eliminate illicit discharges to storm sewer systems. It also develops a system map and informs residents of hazards associated with illegal discharges and improper wastewater disposal (Murphy & Haas, 2003).

Construction site runoff control - develops and enforces erosion and sediment control programs for construction sites. This control measure also requires the development, implementation, and enforcement of a program to reduce pollutants in stormwater runoff originating from the construction site (Murphy & Haas, 2003).

Post-construction runoff control - develops and implements programs to address discharge from post-construction stormwater runoff from new constructions and redevelopments. (Murphy & Haas, 2003).

Pollution prevention/good housekeeping – refers to preventing or reducing runoff from municipal operations with municipal staff training. Equipment, facility operations, and maintenance should be integral components of all stormwater management programs. (Murphy & Haas, 2003).

Appendix C: Survey Question Sample

To whom it may concern:

We are a group of students from Worcester Polytechnic Institute working with the Massachusetts Watershed Coalition (MWC), a non-profit organization dedicated to educating the public on the problem of stormwater runoff and best management practices (BMPs) that can be used to mitigate this problem. Our team will be working to expand the MWC's catalog of stormwater mitigation practices for use by municipalities. We would appreciate if you spent a few minutes to complete the stormwater-related survey.

This survey is entirely voluntary, confidential, and will be used for research purposes only. You may skip certain questions if they are not applicable to you or you do not feel comfortable responding.

Survey for Residents

1. What town do you currently live in? (please do not disclose full address)

2. Are you familiar with stormwater/watershed associations in your municipality?
    a. If yes, please list:

3. Are you aware of any strategies for mitigating or reducing stormwater runoff used in your municipality?
    a. If yes, please list these strategies:
    b. If yes, please this where you got this information from:

4. Are you familiar with the Massachusetts Watershed Coalition?
    a. If yes, did you know that they have a catalog filled with these mitigation practices?

5. After reviewing the MWC's catalog, did you have any difficulties understanding it?
    a. If yes, please describe your difficulties and how you think this can be fixed:

Survey for stormwater professionals

1. In which municipality have you assisted in implementing stormwater best management practices? (Please state the municipality and the BMP implemented)

2. What BMPs did you find to be most effective?

3. How do you measure the effectiveness of a BMP?

4. After reviewing the MWC's catalog, did you have any difficulties understanding it?
    a. If yes, please explain

5. Part of our goal is to improve the utility of the catalog. How do you think we can make this catalog more user-friendly?

6. The other part of our goal is to expand the inventory section of the catalog. Are there any additions you think that would benefit the inventory section?

7. Please comment on the structure of the entire catalog.

8. Please suggest groups that you think will most benefit from this catalog.

9. Are you aware of the campaigns and programs developed by the MWC?
    a. If yes, how useful do you think they are? And what can be done to improve them?

Appendix D: Email Correspondence Email Sample

Dear [Name of Contact],

We are a group of students from Worcester Polytechnic Institute (WPI) who are collecting information about stormwater management practices in Massachusetts communities. This information will be used to expand a catalog of local projects that was prepared by the Massachusetts Watershed Coalition (MWC). The purpose of this catalog is to inform people about the varied stormwater improvements in communities across the state. To expand this catalog, we would greatly appreciate information on the stormwater runoff mitigation projects currently implemented in [Name of Municipality Here].

Your contact information was provided by Ed Himlan, Executive Director of the MWC (978-534-0379; email: mwc@commonwaters.org) The MWC may have previously contacted you and requested information regarding stormwater runoff mitigation projects. Please check that the information listed below is current and, if possible, please fill in any missing pieces.

- Project Name
- Project Address
- Best Management Practice (BMP) or Low Impact Development (LID) techniques used
- The contributing area that flows into the BMP or LID project site(s)
- Assumed runoff coefficient (If this is not known for annual volume calculations, a coefficient will be assumed.)
- Estimated annual volume of stormwater runoff mitigated by project site(s) (if known)
- Cost of project (if known)
- Photo of project site(s) (if available)

A map showing the local projects is attached. Additionally, you can visit the following link – http://commonwaters.org/resources/bgy-resources - to download the report titled "Stormwater Solutions in Action: An Inventory of Projects Reducing Polluted Runoff in Massachusetts" to see what projects are already included.

Once again, we greatly appreciate any information you are able to provide and we look forward to hearing back from you. Please do not hesitate to contact us with any questions

Thank you.

--[Team Member]

Worcester Polytechnic Institute
Worcester Community Project Center
44 Portland Street
Worcester, MA 01608

Appendix E: Ed Himlan Interview Questions

<u>Sponsor Interview Questions</u>

1. What motivated you to begin working on stormwater issues?
2. What stormwater agencies/organizations do you work with within Massachusetts? Please share some of your shared efforts with these organizations/agencies. Shared efforts include campaigns and programs
3. We have gone through the MWC's inventory of stormwater solutions and a few clarifications need to be made.
    a. Why was the word 'inventory' used to describe this document? As opposed to using 'catalog' or 'report'.
    b. If the word 'inventory' remains as is, how would you like us to expand this inventory?
        i. Add more municipalities?
        ii. Add additional information on the municipalities already listed?
        iii. Focus on the water quality in municipalities more than BMPs?
    c. Would you like us to just focus on select municipalities or all listed in the inventory?
4. Since you are the originator of the 'inventory', please describe the primary target audience for the 'inventory'
    a. Who is currently using it?
    b. What other groups or individuals do you think could also benefit from this inventory?
5. What is the purpose of the stormwater 'inventory'?
    a. What did you wish to accomplish when you developed this inventory?
6. How do you think we can best cater to the primary target audience that we just defined?
7. What do you presently wish to see in the revised inventory?
    a. More qualitative or quantitative data?
    b. More information on BMPs as opposed to numerical data on water quality?
    c. Use more as a tool to assist in public education
    d. How do you want the inventory to function?
8. What final deliverable do you wish to get at the end of this project?
    a. A completed inventory?
    b. A list of recommendations?
    c. A prototype to give an example of what the expanded inventory should be like?
9. Are there any specific requirements you have for the final deliverable?
    a. Organization?
    b. Page limit?
10. Has any other group made edits or recommendations for your inventory prior to us? If so:

    a. What recommendations were made?
    b. Can we get their contact information?

11. Can you provide any additional sources of information regarding BMPs and their effectiveness, efficiency, government assistance and implementation in various municipalities?
    a. Is there a database that you can recommend?
    b. Who/where do you think we can go to gather this information?

Appendix F: Recommended MWC Table of Contents

STORMWATER SOLUTIONS IN ACTION

Table of Content

- South Coastal
    - SuAsCo
    - Taunton
    - Ten Mile
    - Westfield
- Inventory of Cost fact sheet of BMP Projects in Massachusetts
    - Cost cheapest to most expensive

SECTION III: BEST MANAGEMENT PRACTICE "HOW TO" GUIDE

- Instruction of Building Your Own BMP
    - Rain Garden
    - Rain Barrels
    - Individual Catch Basins
    - Bio swells
- Where to Get Materials

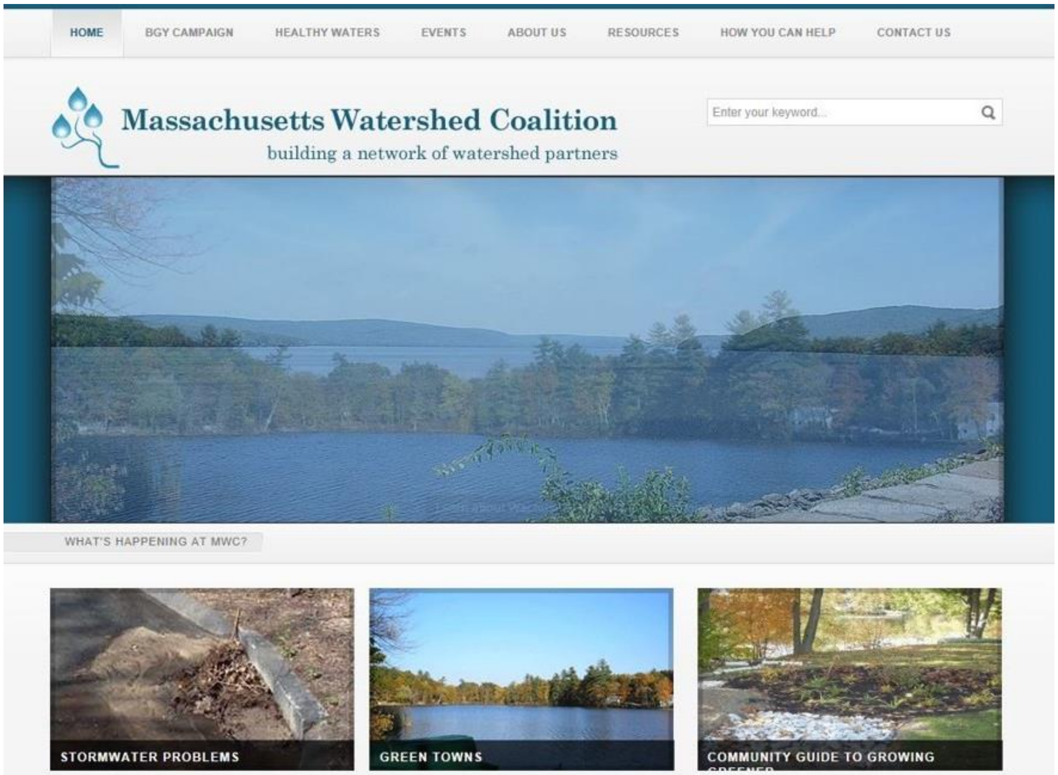
SECTION IV: RESOURCES

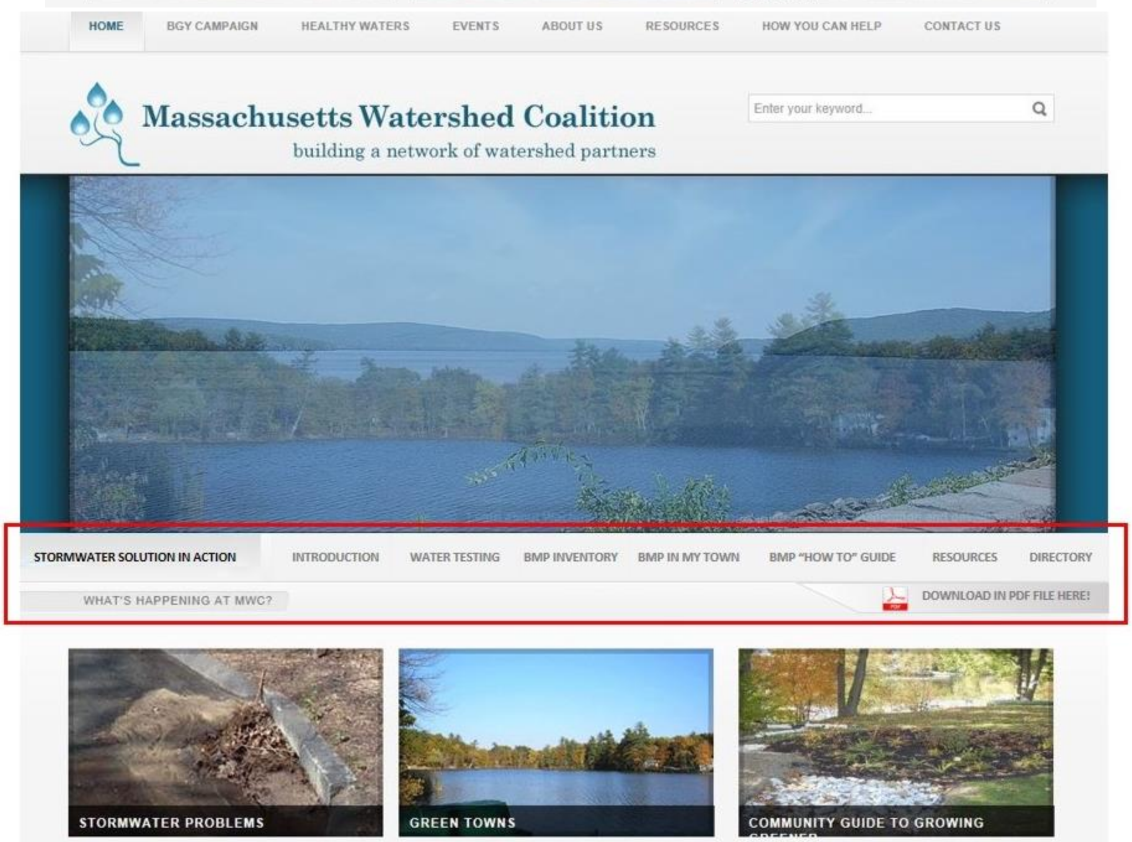
- Event Day
    - Events on 2014
    - Information on Annual Events
- Details Information of BMPs (Chart type)
    - Vegetated Swales (Dry & Wet)
    - Vegetated Filter Strips
    - Constructed Wetlands
    - Bio retention Cells (Rain Gardens)
    - Porous Pavement
    - Tree Box Filter
    - Green Roofs
    - Infiltration Basins
    - Wet Basins (Wet Retention Ponds)
    - Dry Basins (Dry detention basin)
    - Deep-Sump Catch Basins
- References on each BMP information
- US EPA – Soak Up the Rain Campaign

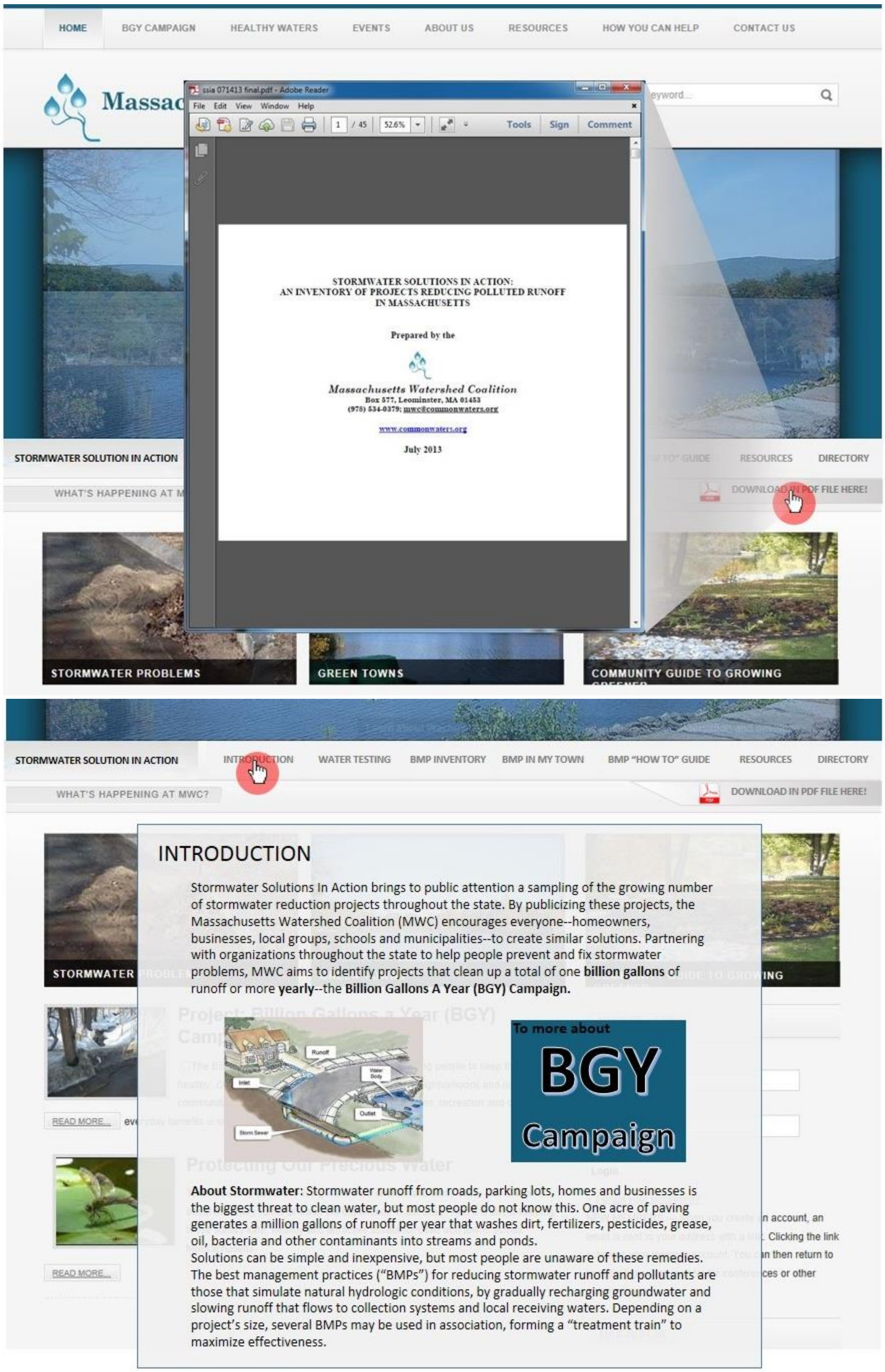
SECTION V: DIRECTORY

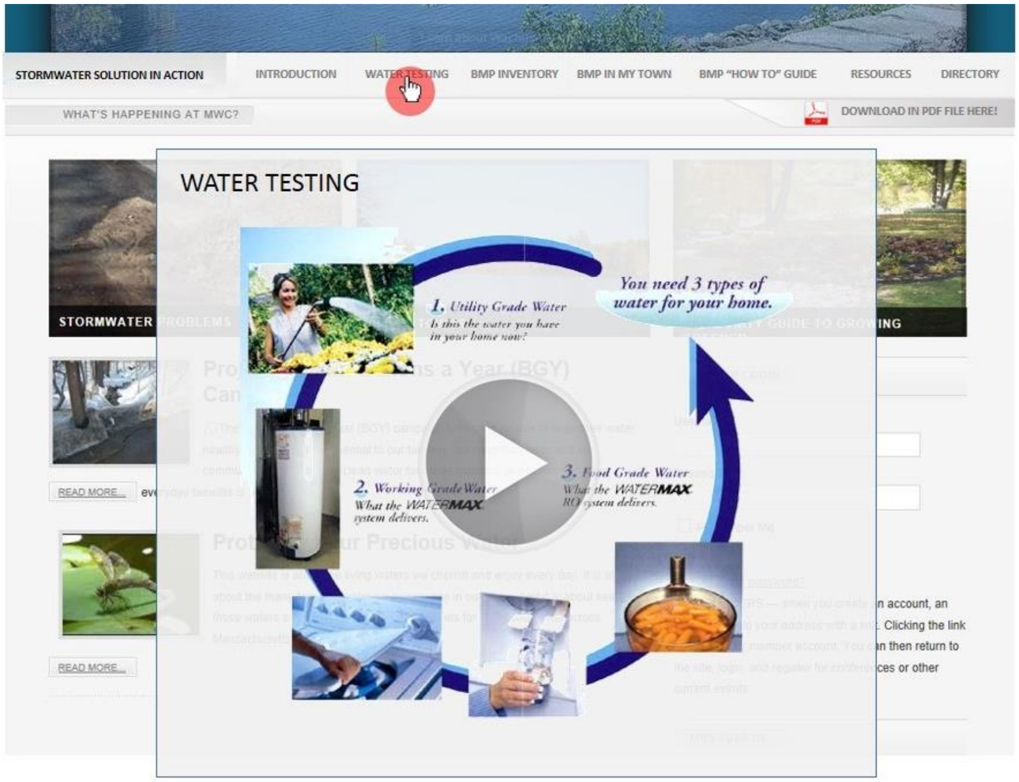
- Municipalities' Department of Public Work/Conservation Commission/Town Designer/Contractor's contact information list

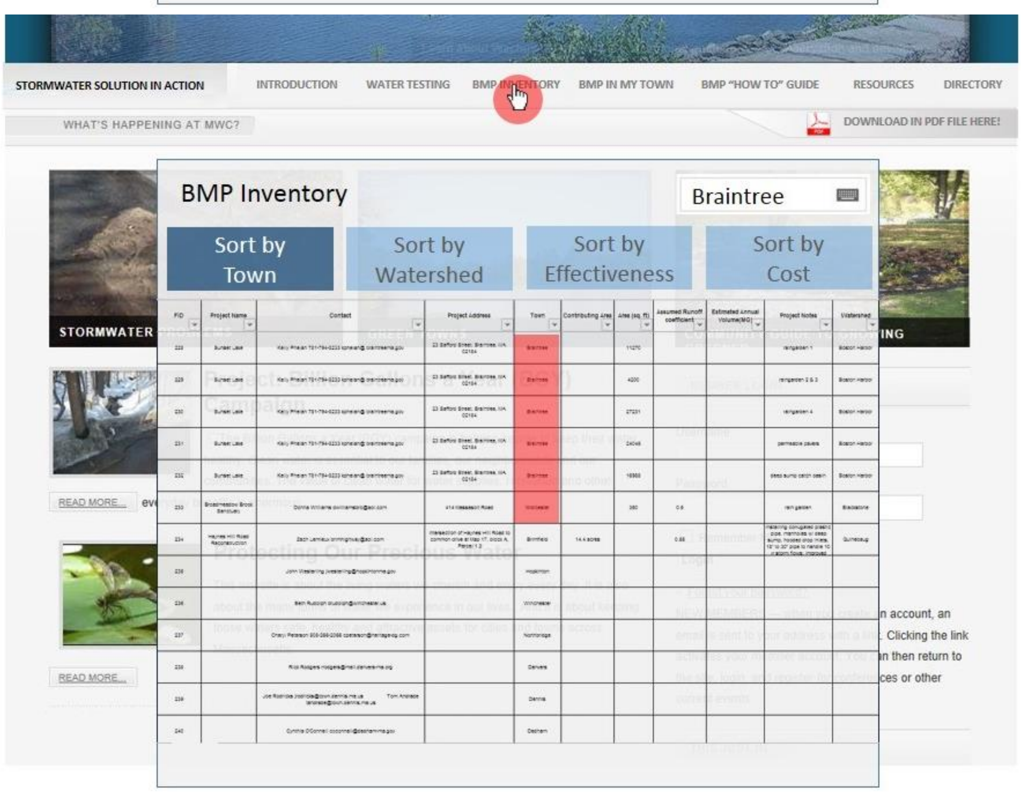
Appendix G: Web SSIA Catalog Recommendations






HOME
BGY CAMPAIGN
HEALTHY WATERS
EVENTS
ABOUT US
RESOURCES
HOW YOU CAN HELP
CONTACT US
STORMWATER SOLUTIONS IN ACTION:
AN INVENTORY OF PROJECTS REDUCING POLLUTED RUNOFF
IN MASSACHUSETTS
Prepared by the
Massachusetts Watershed Coalition
Box 577, Leominster, MA 01453
www.commonwaters.org
July 2013
STORMWATER SOLUTION IN ACTION
RESOURCES
DIRECTORY
DOWNLOAD IN PDF FILE HERE!
STORMWATER PROBLEMS
GREEN TOWNS
COMMUNITY GUIDE TO GROWING
STORMWATER SOLUTION IN ACTION
INTRODUCTION
WATER TESTING
BMP INVENTORY
BMP IN MY TOWN
BMP "HOW TO" GUIDE
RESOURCES
DIRECTORY
WHAT'S HAPPENING AT MWC?
DOWNLOAD IN PDF FILE HERE!
INTRODUCTION
Stormwater Solutions In Action brings to public attention a sampling of the growing number of stormwater reduction projects throughout the state. By publicizing these projects, the Massachusetts Watershed Coalition (MWC) encourages everyone--homeowners, businesses, local groups, schools and municipalities--to create similar solutions. Partnering with organizations throughout the state to help people prevent and fix stormwater problems, MWC aims to identify projects that clean up a total of one billion gallons of runoff or more yearly--the Billion Gallons A Year (BGY) Campaign.
Runoff
Inlet
Water Body
Outlet
Storm Sewer
To more about
BGY
Campaign
About Stormwater: Stormwater runoff from roads, parking lots, homes and businesses is the biggest threat to clean water, but most people do not know this. One acre of paving generates a million gallons of runoff per year that washes dirt, fertilizers, pesticides, grease, oil, bacteria and other contaminants into streams and ponds.
Solutions can be simple and inexpensive, but most people are unaware of these remedies. The best management practices ("BMPs") for reducing stormwater runoff and pollutants are those that simulate natural hydrologic conditions, by gradually recharging groundwater and slowing runoff that flows to collection systems and local receiving waters. Depending on a project's size, several BMPs may be used in association, forming a "treatment train" to maximize effectiveness.


STORMWATER SOLUTION IN ACTION
INTRODUCTION
WATER TESTING
BMP INVENTORY
BMP IN MY TOWN
BMP "HOW TO" GUIDE
RESOURCES
DIRECTORY
WHAT'S HAPPENING AT MWC?
DOWNLOAD IN PDF FILE HERE!
WATER TESTING
You need 3 types of water for your home.
1. Utility Grade Water
Is this the water you have in your home now?
2. Working Grade Water
What the WATERMAX system delivers.
3. Food Grade Water
What the WATERMAX RO system delivers.
STORMWATER
READ MORE...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BMP "HOW TO" GUIDE
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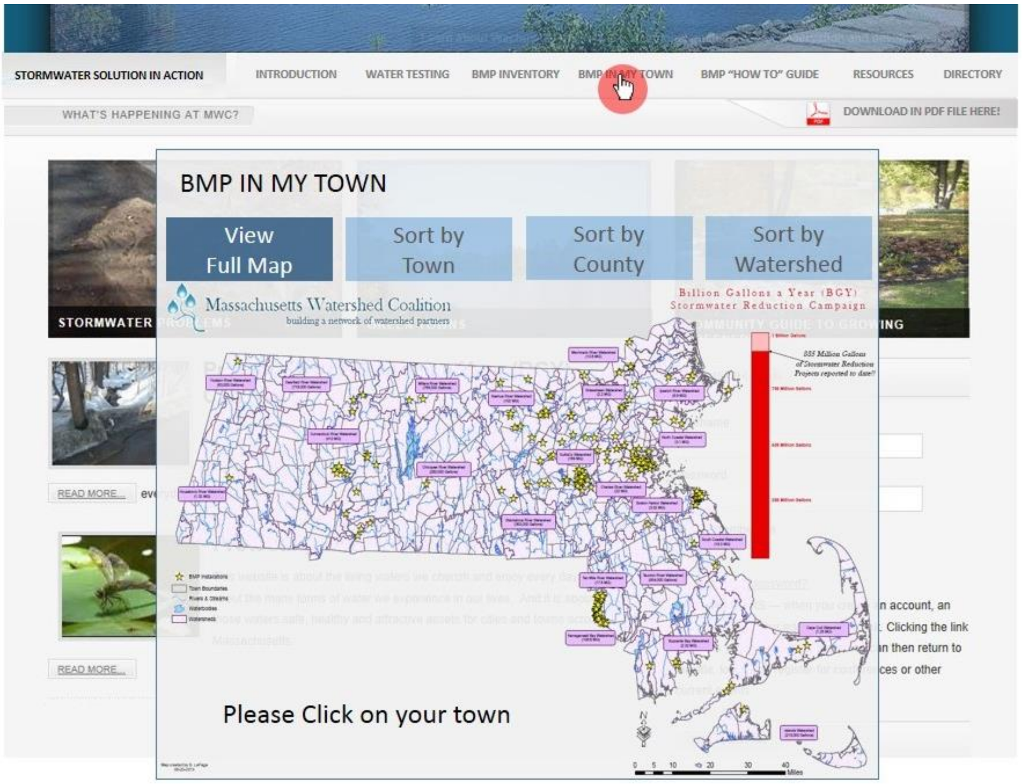
BMP Inventory
Braintree
Sort by Town
Sort by Watershed
Sort by Effectiveness
Sort by Cost
STORMWATER
READ MORE...



STORMWATER SOLUTION IN ACTION
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BMP "HOW TO" GUIDE
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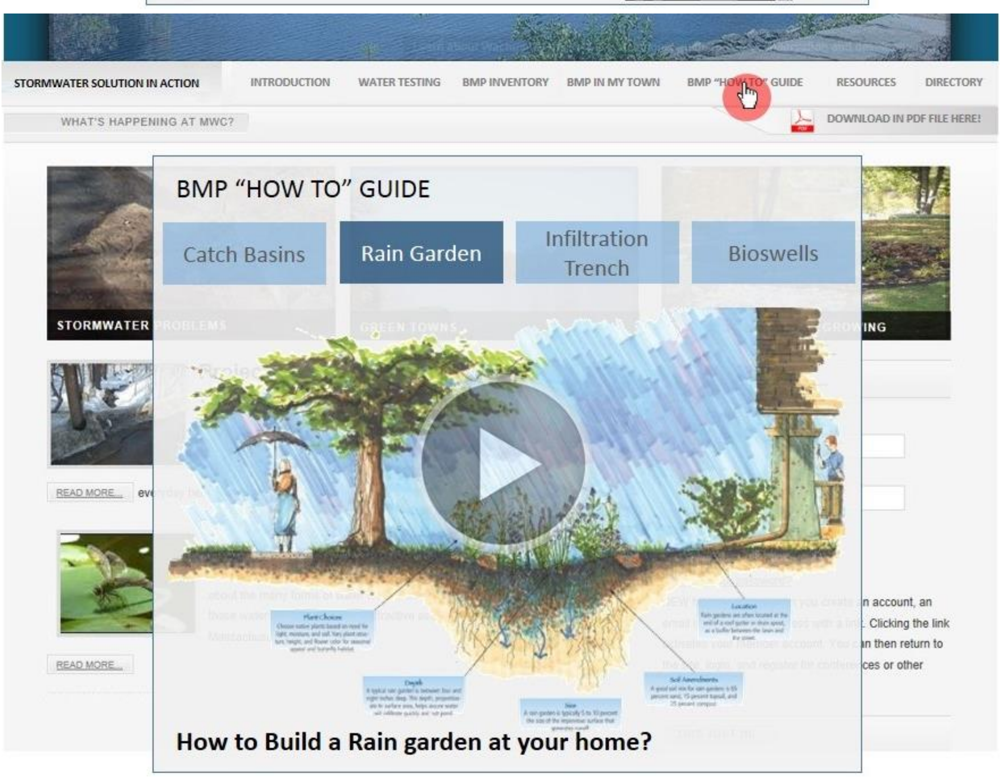
WHAT'S HAPPENING AT MWC?
DOWNLOAD IN PDF FILE HERE!
BMP IN MY TOWN
View Full Map
Sort by Town
Sort by County
Sort by Watershed
Massachusetts Watershed Coalition
building a network of watershed partners
Billion Gallons a Year (BGY)
Stormwater Reduction Campaign
Please Click on your town



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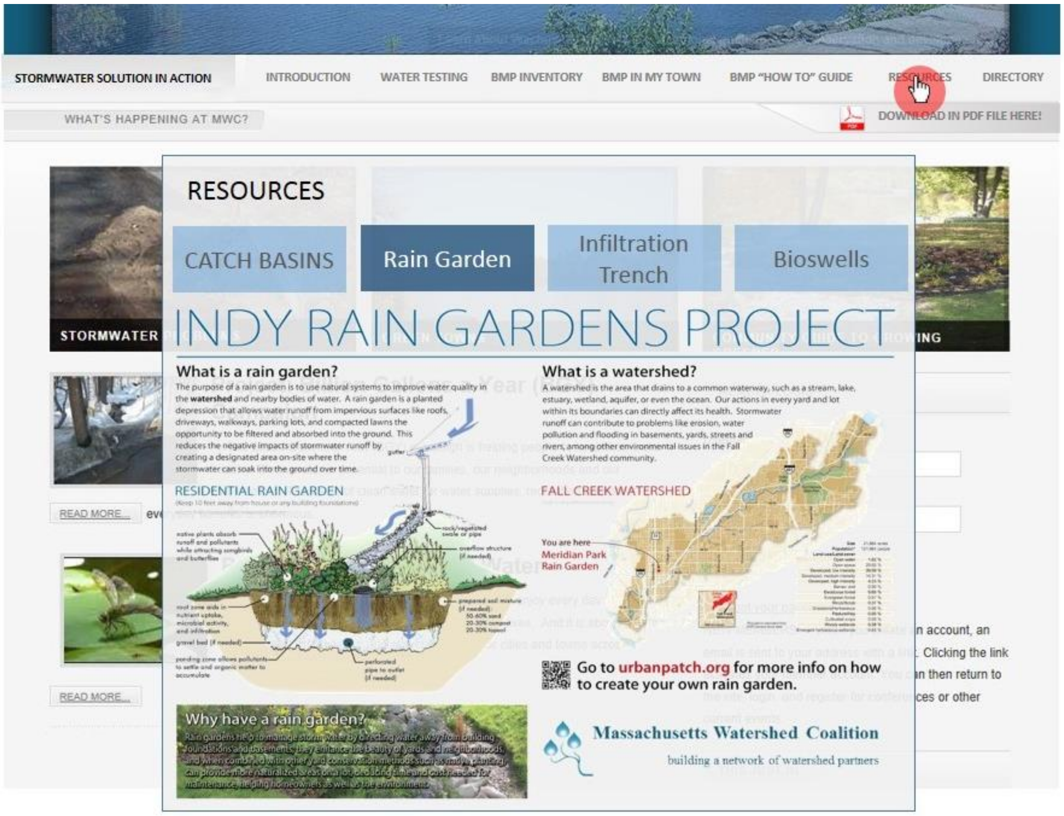
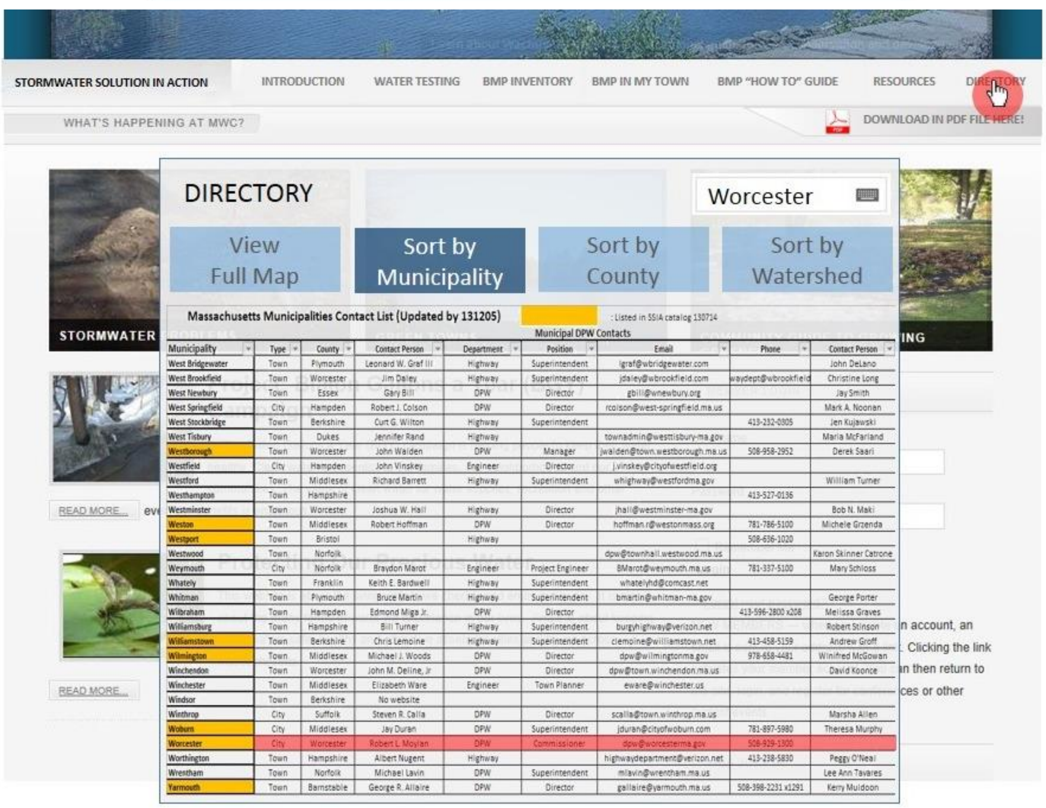
BMP "HOW TO" GUIDE
Catch Basins
Rain Garden
Infiltration Trench
Bioswells
How to Build a Rain garden at your home?



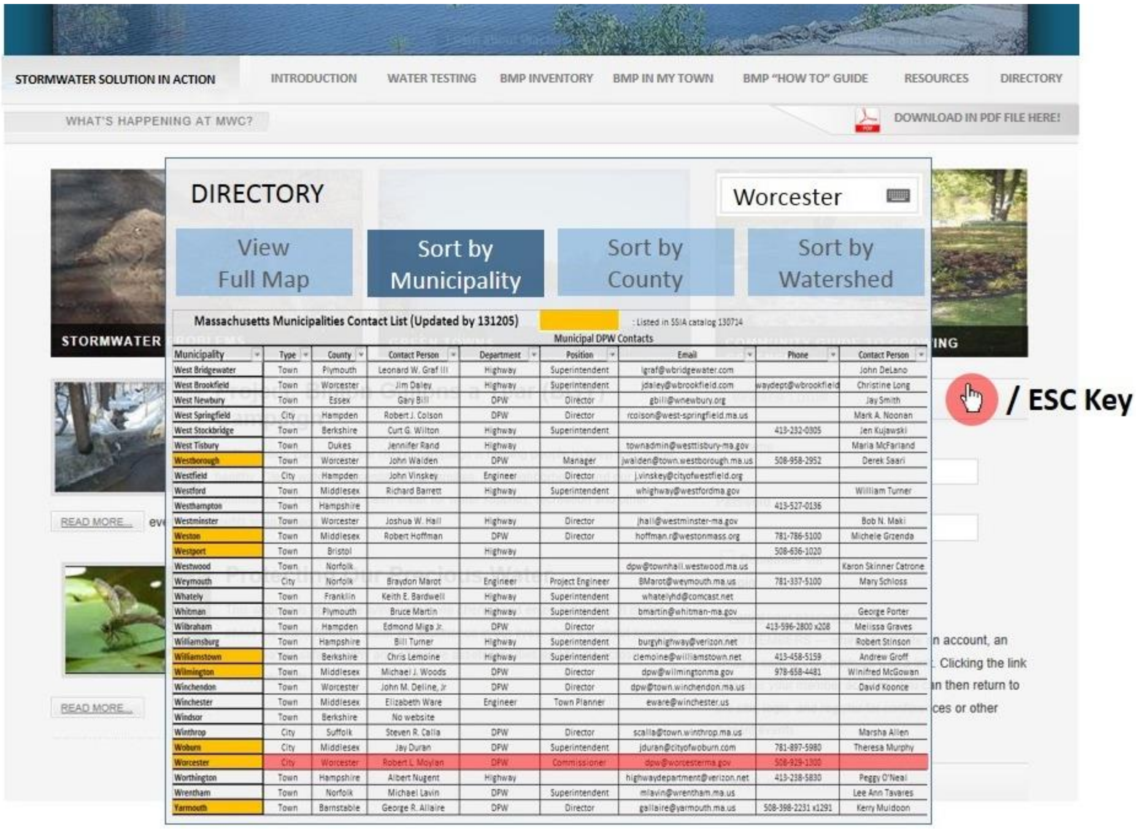


Massachusetts Municipalities Contact List (Updated by 131205)

: Listed in SSIA catalog 130714

Municipal DPW Contacts

Municipality	Type	County	Contact Person	Department	Position	Email	Phone	Contact Person
West Bridgewater	Town	Plymouth	Leonard W. Graf III	Highway	Superintendent	lgraf@wbridgewater.com		John DeLano
West Brookfield	Town	Worcester	Jim Daley	Highway	Superintendent	jdaley@wbrookfield.com	waydept@wbrookfield	Christine Long
West Newbury	Town	Essex	Gary Bill	DPW	Director	gbill@wnewbury.org		Jay Smith
West Springfield	City	Hampden	Robert J. Colson	DPW	Director	rcolson@west-springfield.ma.us		Mark A. Noonan
West Stockbridge	Town	Berkshire	Curt G. Wilton	Highway	Superintendent		413-232-0305	Jen Kujawski
West Tisbury	Town	Dukes	Jennifer Rand	Highway		townadmin@westtisbury-ma.gov		Maria McFarland
Westborough	Town	Worcester	John Walden	DPW	Manager	jwalden@town.westborough.ma.us	508-958-2952	Derek Saari
Westfield	City	Hampden	John Vinskey	Engineer	Director	j.vinskey@cityofwestfield.org		
Westford	Town	Middlesex	Richard Barrett	Highway	Superintendent	whighway@westfordma.gov		William Turner
Westhampton	Town	Hampshire					413-527-0136	
Westminster	Town	Worcester	Joshua W. Hall	Highway	Director	jhall@westminster-ma.gov		Bob N. Maki
Weston	Town	Middlesex	Robert Hoffman	DPW	Director	hoffman.r@westonmass.org	781-786-5100	Michele Grzenda
Westport	Town	Bristol		Highway			508-636-1020	
Westwood	Town	Norfolk				dpw@townhall.westwood.ma.us		Karon Skinner Catrone
Weymouth	City	Norfolk	Braydon Marot	Engineer	Project Engineer	BMarot@weymouth.ma.us	781-337-5100	Mary Schloss
Whately	Town	Franklin	Keith E. Bardwell	Highway	Superintendent	whatelyhd@comcast.net		
Whitman	Town	Plymouth	Bruce Martin	Highway	Superintendent	bmartin@whitman-ma.gov		George Porter
Wilbraham	Town	Hampden	Edmond Miga Jr.	DPW	Director		413-596-2800 x208	Melissa Graves
Williamsburg	Town	Hampshire	Bill Turner	Highway	Superintendent	burgyhighway@verizon.net		Robert Stinson
Williamstown	Town	Berkshire	Chris Lemoine	Highway	Superintendent	clemoine@williamstown.net	413-458-5159	Andrew Groff
Wilmington	Town	Middlesex	Michael J. Woods	DPW	Director	dpw@wilmingtonma.gov	978-658-4481	Winifred McGowan
Winchendon	Town	Worcester	John M. Deline, Jr	DPW	Director	dpw@town.winchendon.ma.us		David Koonce
Winchester	Town	Middlesex	Elizabeth Ware	Engineer	Town Planner	eware@winchester.us		
Windsor	Town	Berkshire	No website					
Winthrop	City	Suffolk	Steven R. Calla	DPW	Director	scalla@town.winthrop.ma.us		Marsha Allen
Woburn	City	Middlesex	Jay Duran	DPW	Superintendent	jduran@cityofwoburn.com	781-897-5980	Theresa Murphy
Worcester	City	Worcester	Robert L. Moylan	DPW	Commissioner	dpw@worcesterma.gov	508-929-1300	
Worthington	Town	Hampshire	Albert Nugent	Highway		highwaydepartment@verizon.net	413-238-5830	Peggy O'Neal
Wrentham	Town	Norfolk	Michael Lavin	DPW	Superintendent	mlavin@wrentham.ma.us		Lee Ann Tavares
Yarmouth	Town	Barnstable	George R. Allaire	DPW	Director	gallaire@yarmouth.ma.us	508-398-2231 x1291	Kerry Muldoon



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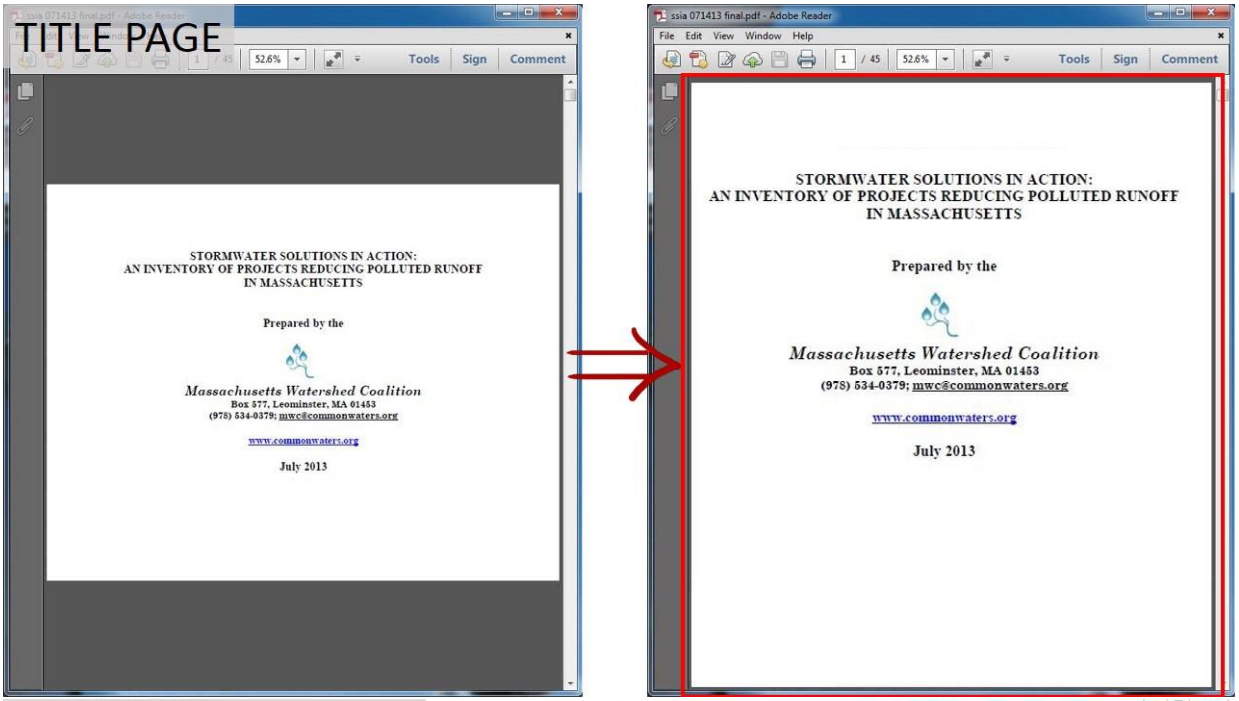
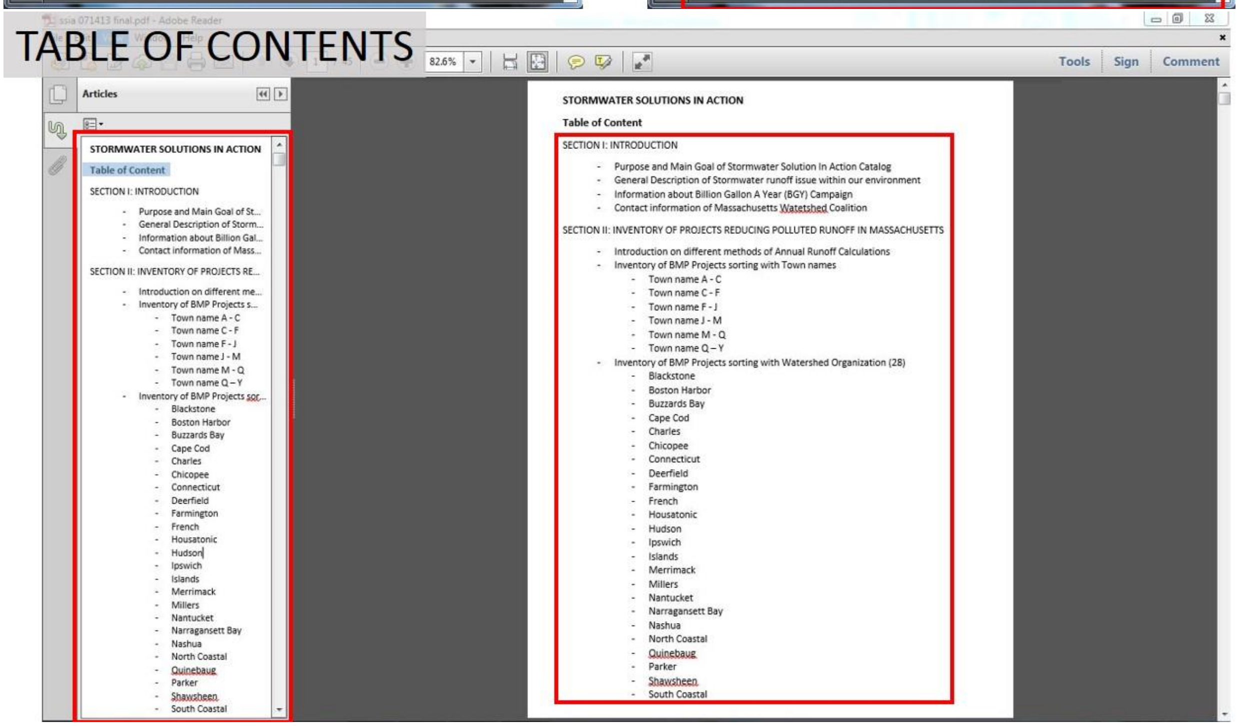
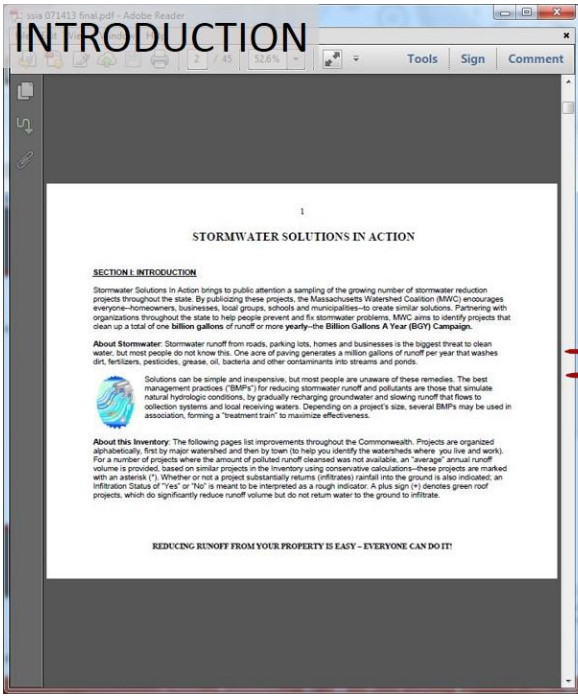
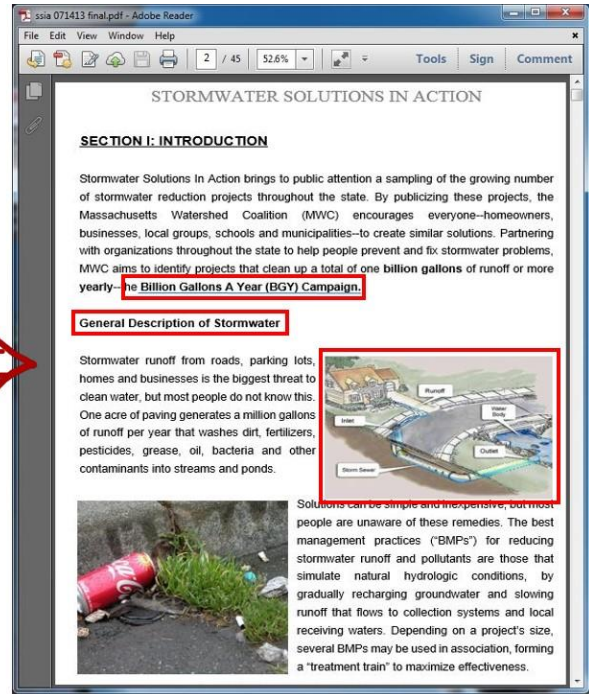
Yarmouth	Town	Barnstable	George R. Allaire	DPW	Director	gallaire@yarmouth.ma.us	508-398-2231 x1291	Kerry Muldoon

Appendix H: PDF SSIA Catalog Recommendations









STORMWATER SOLUTIONS IN ACTION

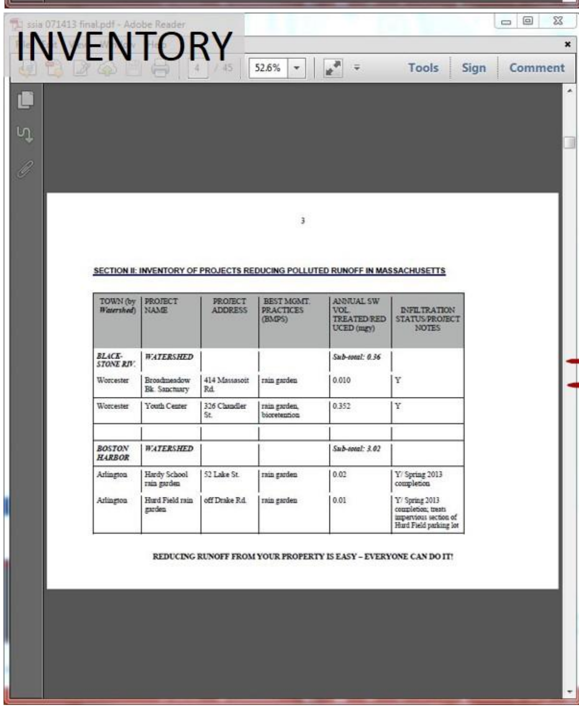
SECTION I: INTRODUCTION

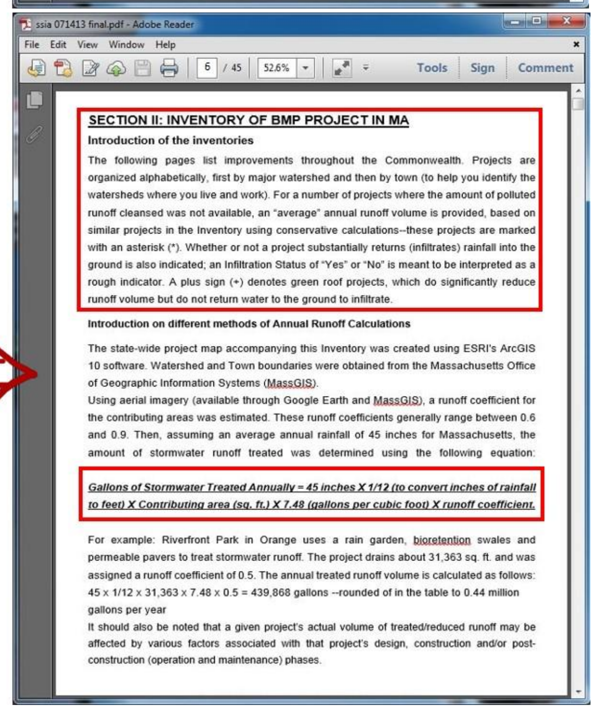
Stormwater Solutions In Action brings to public attention a sampling of the growing number of stormwater reduction projects throughout the state. By publicizing these projects, the Massachusetts Watershed Coalition (MWC) encourages everyone--homeowners, businesses, local groups, schools and municipalities--to create similar solutions. Partnering with organizations throughout the state to help people prevent and fix stormwater problems, MWC aims to identify projects that clean up a total of one **billion gallons** of runoff or more **yearly**--the **Billion Gallons A Year (BGY) Campaign.**

General Description of Stormwater

Stormwater runoff from roads, parking lots, homes and businesses is the biggest threat to clean water, but most people do not know this. One acre of paving generates a million gallons of runoff per year that washes dirt, fertilizers, pesticides, grease, oil, bacteria and other contaminants into streams and ponds.

Solutions can be simple and inexpensive, but most people are unaware of these remedies. The best management practices ("BMPs") for reducing stormwater runoff and pollutants are those that simulate natural hydrologic conditions, by gradually recharging groundwater and slowing runoff that flows to collection systems and local receiving waters. Depending on a project's size, several BMPs may be used in association, forming a "treatment train" to maximize effectiveness.





SECTION II: INVENTORY OF BMP PROJECT IN MA

Introduction of the inventories

The following pages list improvements throughout the Commonwealth. Projects are organized alphabetically, first by major watershed and then by town (to help you identify the watersheds where you live and work). For a number of projects where the amount of polluted runoff cleansed was not available, an "average" annual runoff volume is provided, based on similar projects in the Inventory using conservative calculations--these projects are marked with an asterisk (*). Whether or not a project substantially returns (infiltrates) rainfall into the ground is also indicated; an Infiltration Status of "Yes" or "No" is meant to be interpreted as a rough indicator. A plus sign (+) denotes green roof projects, which do significantly reduce runoff volume but do not return water to the ground to infiltrate.

Introduction on different methods of Annual Runoff Calculations

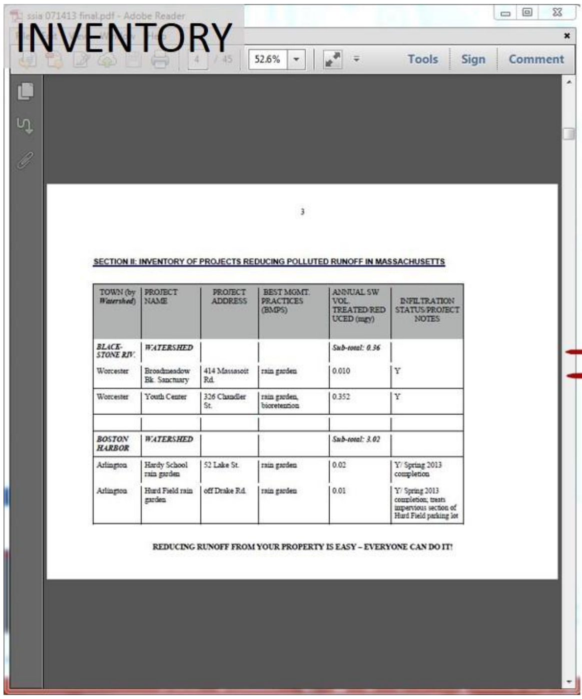
The state-wide project map accompanying this Inventory was created using ESRI's ArcGIS 10 software. Watershed and Town boundaries were obtained from the Massachusetts Office of Geographic Information Systems (MassGIS).

Using aerial imagery (available through Google Earth and MassGIS), a runoff coefficient for the contributing areas was estimated. These runoff coefficients generally range between 0.6 and 0.9. Then, assuming an average annual rainfall of 45 inches for Massachusetts, the amount of stormwater runoff treated was determined using the following equation:

Gallons of Stormwater Treated Annually = 45 inches X 1/12 (to convert inches of rainfall to feet) X Contributing area (sq. ft.) X 7.48 (gallons per cubic foot) X runoff coefficient.

For example: Riverfront Park in Orange uses a rain garden, bioretention swales and permeable pavers to treat stormwater runoff. The project drains about 31,363 sq. ft. and was assigned a runoff coefficient of 0.5. The annual treated runoff volume is calculated as follows: 45 x 1/12 x 31,363 x 7.48 x 0.5 = 439,868 gallons --rounded of in the table to 0.44 million gallons per year

It should also be noted that a given project's actual volume of treated/reduced runoff may be affected by various factors associated with that project's design, construction and/or post-construction (operation and maintenance) phases.



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SECTION II: INVENTORY OF PROJECTS REDUCING POLLUTED RUNOFF IN MASSACHUSETTS

TOWN (by *Watershed*)	PROJECT NAME	PROJECT ADDRESS	BEST MGMT. PRACTICES (BMPS)	ANNUAL SW VOL. TREATED/REDUCED (mgy)	INFILTRATION STATUS/PROJECT NOTES
BLACK-STONE RIV.	*WATERSHED*			*Sub-total: 0.36*	
Worcester	Broadmeadow Bk. Sanctuary	414 Massasoit Rd.	rain garden	0.010	Y
Worcester	Youth Center	326 Chandler St.	rain garden, bioretention	0.352	Y
BOSTON HARBOR	*WATERSHED*			*Sub-total: 3.02*	
Arlington	Hardy School rain garden	52 Lake St.	rain garden	0.02	Y/ Spring 2013 completion
Arlington	Hurd Field rain garden	off Drake Rd.	rain garden	0.01	Y/ Spring 2013 completion; treats impervious section of Hurd Field parking lot

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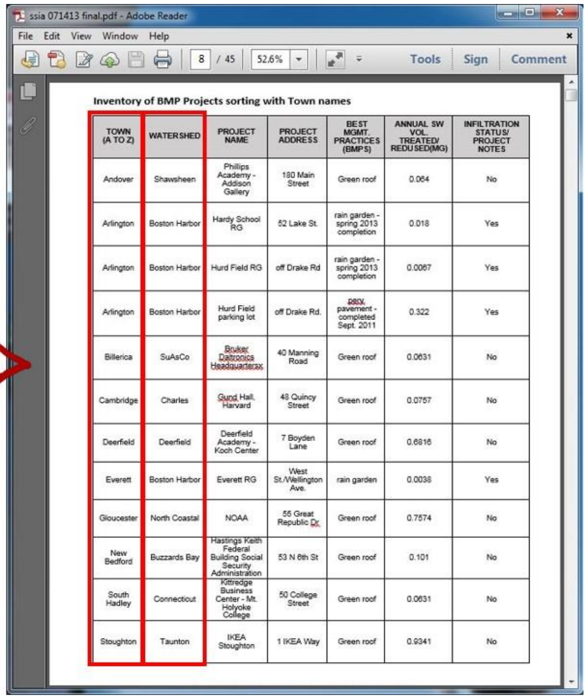
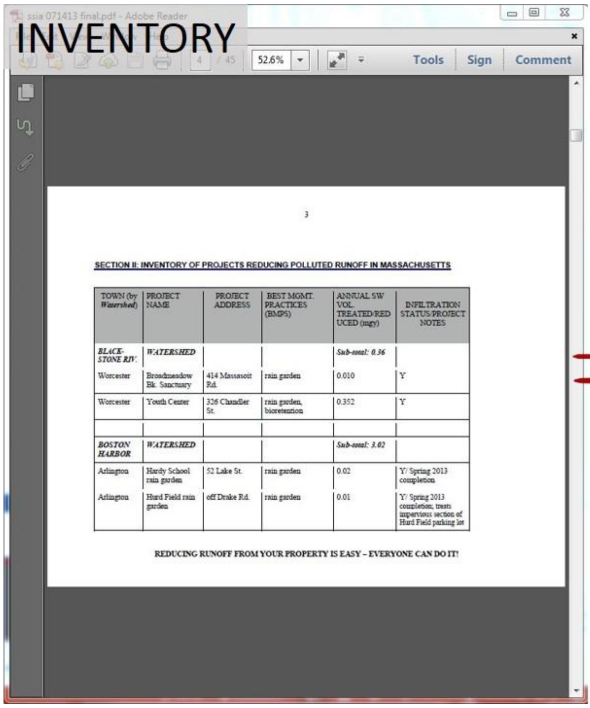


Inventory of BMP Projects sorting with Town names

TOWN (A TO Z)	WATERSHED	PROJECT NAME	PROJECT ADDRESS	BEST MGMT. PRACTICES (BMPS)	ANNUAL SW VOL. TREATED/ REDUSED(MG)	INFILTRATION STATUS/ PROJECT NOTES
Andover	Shawsheen	Phillips Academy - Addison Gallery	180 Main Street	Green roof	0.064	No
Arlington	Boston Harbor	Hardy School RG	52 Lake St.	rain garden - spring 2013 completion	0.018	Yes
Arlington	Boston Harbor	Hurd Field RG	off Drake Rd	rain garden - spring 2013 completion	0.0067	Yes
Arlington	Boston Harbor	Hurd Field parking lot	off Drake Rd.	perv. pavement - completed Sept. 2011	0.322	Yes
Billerica	SuAsCo	Bruker Daltronics Headquartersx	40 Manning Road	Green roof	0.0631	No
Cambridge	Charles	Gund Hall, Harvard	48 Quincy Street	Green roof	0.0757	No
Deerfield	Deerfield	Deerfield Academy - Koch Center	7 Boyden Lane	Green roof	0.6816	No
Everett	Boston Harbor	Everett RG	West St./Wellington Ave.	rain garden	0.0038	Yes
Gloucester	North Coastal	NOAA	55 Great Republic Dr.	Green roof	0.7574	No
New Bedford	Buzzards Bay	Hastings Keith Federal Building Social Security Administration	53 N 6th St	Green roof	0.101	No
South Hadley	Connecticut	Kittredge Business Center - Mt. Holyoke College	50 College Street	Green roof	0.0631	No
Stoughton	Taunton	IKEA Stoughton	1 IKEA Way	Green roof	0.9341	No



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SECTION II: INVENTORY OF PROJECTS REDUCING POLLUTED RUNOFF IN MASSACHUSETTS

TOWN (by *Watershed*)	PROJECT NAME	PROJECT ADDRESS	BEST MGMT. PRACTICES (BMPS)	ANNUAL SW VOL. TREATED/REDUCED (mgy)	INFILTRATION STATUS/PROJECT NOTES
BLACK-STONE RIV.	*WATERSHED*			*Sub-total: 0.36*	
Worcester	Broadmeadow Bk. Sanctuary	414 Massasoit Rd.	rain garden	0.010	Y
Worcester	Youth Center	326 Chandler St.	rain garden, bioretention	0.352	Y
BOSTON HARBOR	*WATERSHED*			*Sub-total: 3.02*	
Arlington	Hardy School rain garden	52 Lake St.	rain garden	0.02	Y/ Spring 2013 completion
Arlington	Hurd Field rain garden	off Drake Rd.	rain garden	0.01	Y/ Spring 2013 completion; treats impervious section of Hurd Field parking lot

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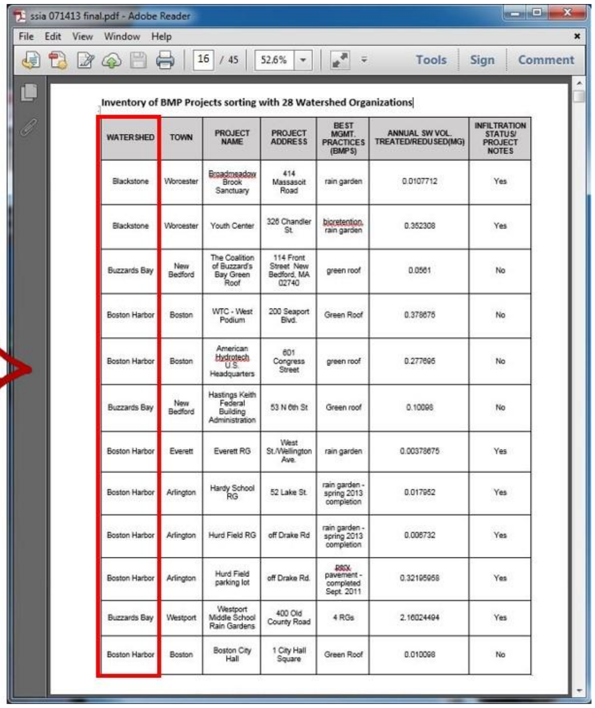
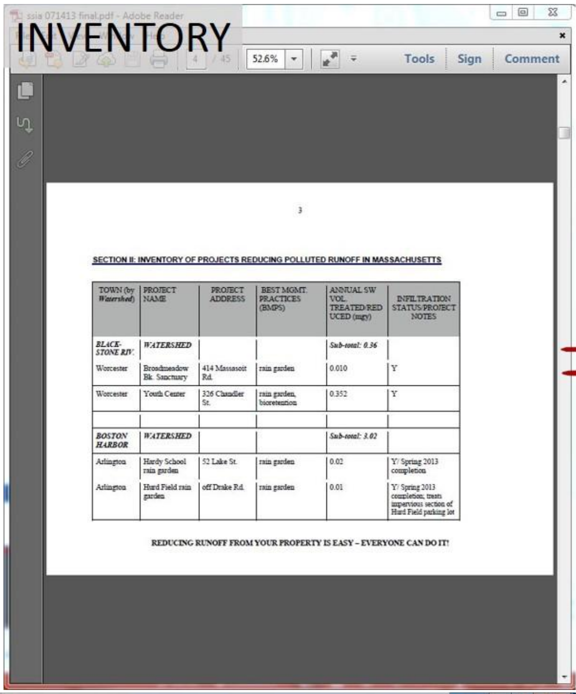


Inventory of BMP Projects sorting with 28 Watershed Organizations

WATERSHED	TOWN	PROJECT NAME	PROJECT ADDRESS	BEST MGMT. PRACTICES (BMPS)	ANNUAL SW VOL. TREATED/REDUSED(MG)	INFILTRATION STATUS/ PROJECT NOTES
Blackstone	Worcester	Broadmeadow Brook Sanctuary	414 Massasoit Road	rain garden	0.0107712	Yes
Blackstone	Worcester	Youth Center	326 Chandler St.	bioretention, rain garden	0.352308	Yes
Buzzards Bay	New Bedford	The Coalition of Buzzard's Bay Green Roof	114 Front Street New Bedford, MA 02740	green roof	0.0561	No
Boston Harbor	Boston	WTC - West Podium	200 Seaport Blvd.	Green Roof	0.378675	No
Boston Harbor	Boston	American Hydrotech U.S. Headquarters	601 Congress Street	green roof	0.277695	No
Buzzards Bay	New Bedford	Hastings Keith Federal Building Administration	53 N 6th St	Green roof	0.10098	No
Boston Harbor	Everett	Everett RG	West St./Wellington Ave.	rain garden	0.00378675	Yes
Boston Harbor	Arlington	Hardy School RG	52 Lake St.	rain garden - spring 2013 completion	0.017952	Yes
Boston Harbor	Arlington	Hurd Field RG	off Drake Rd	rain garden - spring 2013 completion	0.006732	Yes
Boston Harbor	Arlington	Hurd Field parking lot	off Drake Rd.	perv. pavement - completed Sept. 2011	0.32195958	Yes
Buzzards Bay	Westport	Westport Middle School Rain Gardens	400 Old County Road	4 RGs	2.16024494	Yes
Boston Harbor	Boston	Boston City Hall	1 City Hall Square	Green Roof	0.010098	No



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SECTION II: INVENTORY OF PROJECTS REDUCING POLLUTED RUNOFF IN MASSACHUSETTS

TOWN (by *Watershed*)	PROJECT NAME	PROJECT ADDRESS	BEST MGMT. PRACTICES (BMPS)	ANNUAL SW VOL. TREATED/REDUCED (mgy)	INFILTRATION STATUS/PROJECT NOTES
BLACK-STONE RIV.	***WATERSHED***			*Sub-total: 0.36*	
Worcester	Broadmeadow Bk. Sanctuary	414 Massasoit Rd.	rain garden	0.010	Y
Worcester	Youth Center	326 Chandler St.	rain garden, bioretention	0.352	Y
BOSTON HARBOR	***WATERSHED***			*Sub-total: 3.02*	
Arlington	Hardy School rain garden	52 Lake St.	rain garden	0.02	Y/ Spring 2013 completion
Arlington	Hurd Field rain garden	off Drake Rd.	rain garden	0.01	Y/ Spring 2013 completion; treats impervious section of Hurd Field parking lot

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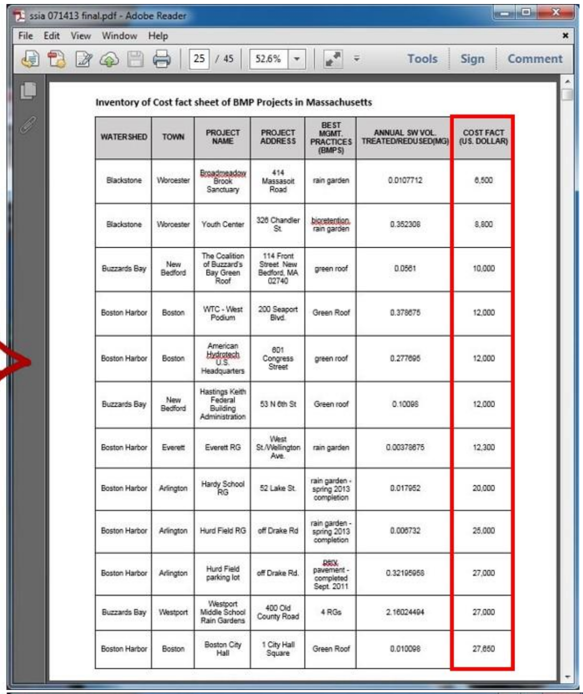
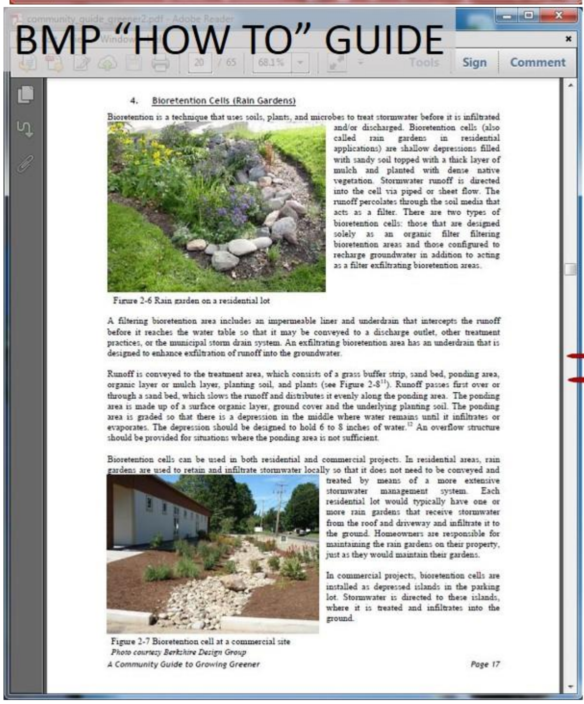


Inventory of Cost fact sheet of BMP Projects in Massachusetts

WATERSHED	TOWN	PROJECT NAME	PROJECT ADDRESS	BEST MGMT. PRACTICES (BMPS)	ANNUAL SW VOL. TREATED/REDUSED(MG)	COST FACT (US. DOLLAR)
Blackstone	Worcester	Broadmeadow Brook Sanctuary	414 Massasoit Road	rain garden	0.0107712	6,500
Blackstone	Worcester	Youth Center	326 Chandler St.	bioretention, rain garden	0.352308	8,800
Buzzards Bay	New Bedford	The Coalition of Buzzard's Bay Green Roof	114 Front Street New Bedford, MA 02740	green roof	0.0561	10,000
Boston Harbor	Boston	WTC - West Podium	200 Seaport Blvd.	Green Roof	0.378675	12,000
Boston Harbor	Boston	American Hydrotech U.S. Headquarters	601 Congress Street	green roof	0.277695	12,000
Buzzards Bay	New Bedford	Hastings Keith Federal Building Administration	53 N 6th St	Green roof	0.10098	12,000
Boston Harbor	Everett	Everett RG	West St./Wellington Ave.	rain garden	0.00378675	12,300
Boston Harbor	Arlington	Hardy School RG	52 Lake St.	rain garden - spring 2013 completion	0.017952	20,000
Boston Harbor	Arlington	Hurd Field RG	off Drake Rd	rain garden - spring 2013 completion	0.006732	25,000
Boston Harbor	Arlington	Hurd Field parking lot	off Drake Rd.	perv. pavement - completed Sept. 2011	0.32195958	27,000
Buzzards Bay	Westport	Westport Middle School Rain Gardens	400 Old County Road	4 RGs	2.16024494	27,000
Boston Harbor	Boston	Boston City Hall	1 City Hall Square	Green Roof	0.010098	27,650



4. Bioretention Cells (Rain Gardens)

Bioretention is a technique that uses soils, plants, and microbes to treat stormwater before it is infiltrated and/or discharged. Bioretention cells (also called rain gardens in residential applications) are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter. There are two types of bioretention cells: those that are designed solely as an organic filter filtering bioretention areas and those configured to recharge groundwater in addition to acting as a filter exfiltrating bioretention areas.

Figure 2-6 Rain garden on a residential lot

A filtering bioretention area includes an impermeable liner and underdrain that intercepts the runoff before it reaches the water table so that it may be conveyed to a discharge outlet, other treatment practices, or the municipal storm drain system. An exfiltrating bioretention area has an underdrain that is designed to enhance exfiltration of runoff into the groundwater.

Runoff is conveyed to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants (see Figure 2-8[11]). Runoff passes first over or through a sand bed, which slows the runoff and distributes it evenly along the ponding area. The ponding area is made up of a surface organic layer, ground cover and the underlying planting soil. The ponding area is graded so that there is a depression in the middle where water remains until it infiltrates or evaporates. The depression should be designed to hold 6 to 8 inches of water.[12] An overflow structure should be provided for situations where the ponding area is not sufficient.

Bioretention cells can be used in both residential and commercial projects. In residential areas, rain gardens are used to retain and infiltrate stormwater locally so that it does not need to be conveyed and treated by means of a more extensive stormwater management system. Each residential lot would typically have one or more rain gardens that receive stormwater from the roof and driveway and infiltrate it to the ground. Homeowners are responsible for maintaining the rain gardens on their property, just as they would maintain their gardens.

In commercial projects, bioretention cells are installed as depressed islands in the parking lot. Stormwater is directed to these islands, where it is treated and infiltrates into the ground.

Figure 2-7 Bioretention cell at a commercial site
Photo courtesy Berkshire Design Group

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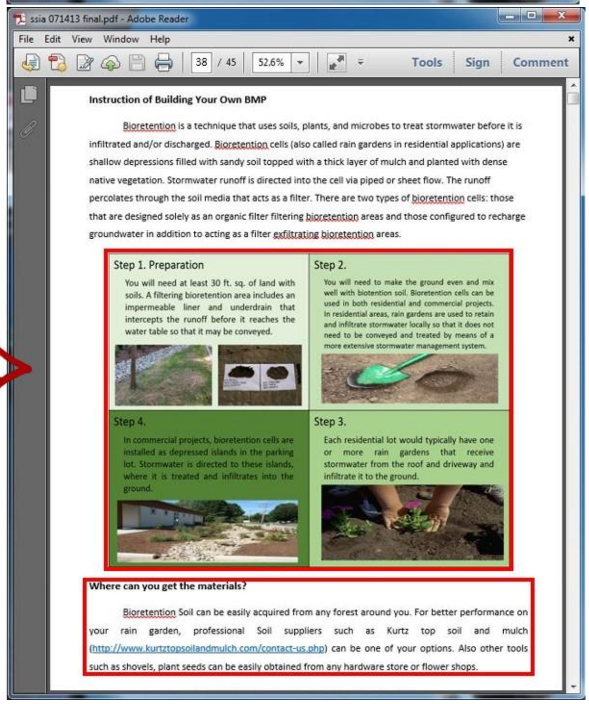


Instruction of Building Your Own BMP

Bioretention is a technique that uses soils, plants, and microbes to treat stormwater before it is infiltrated and/or discharged. Bioretention cells (also called rain gardens in residential applications) are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter. There are two types of bioretention cells: those that are designed solely as an organic filter filtering bioretention areas and those configured to recharge groundwater in addition to acting as a filter exfiltrating bioretention areas.

Step 1. Preparation

You will need at least 30 ft. sq. of land with soils. A filtering bioretention area includes an impermeable liner and underdrain that intercepts the runoff before it reaches the water table so that it may be conveyed.

Step 2.

You will need to make the ground even and mix well with biotention soil. Bioretention cells can be used in both residential and commercial projects. In residential areas, rain gardens are used to retain and infiltrate stormwater locally so that it does not need to be conveyed and treated by means of a more extensive stormwater management system.

Step 4.

In commercial projects, bioretention cells are installed as depressed islands in the parking lot. Stormwater is directed to these islands, where it is treated and infiltrates into the ground.

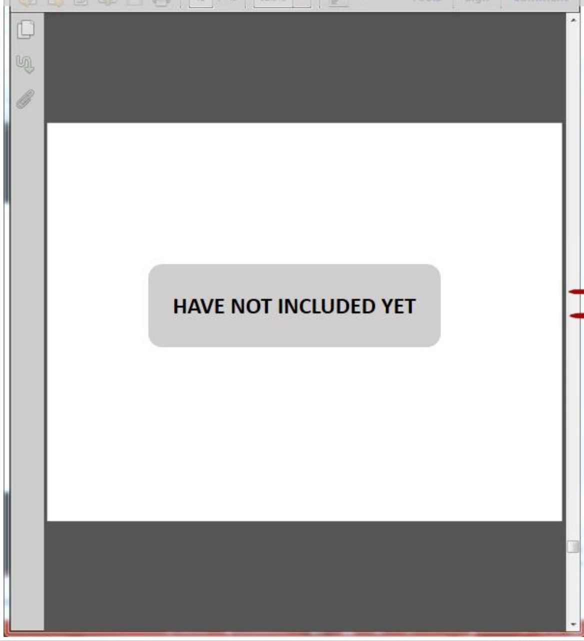
Step 3.

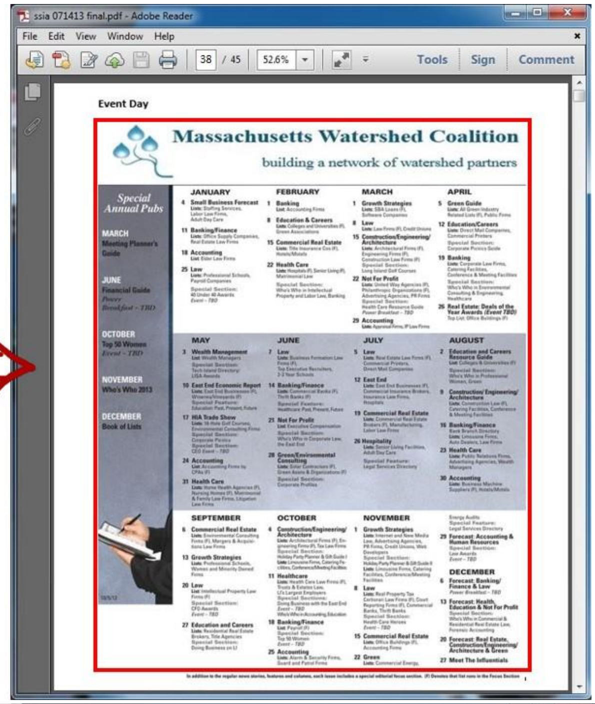
Each residential lot would typically have one or more rain gardens that receive stormwater from the roof and driveway and infiltrate it to the ground.

Where can you get the materials?

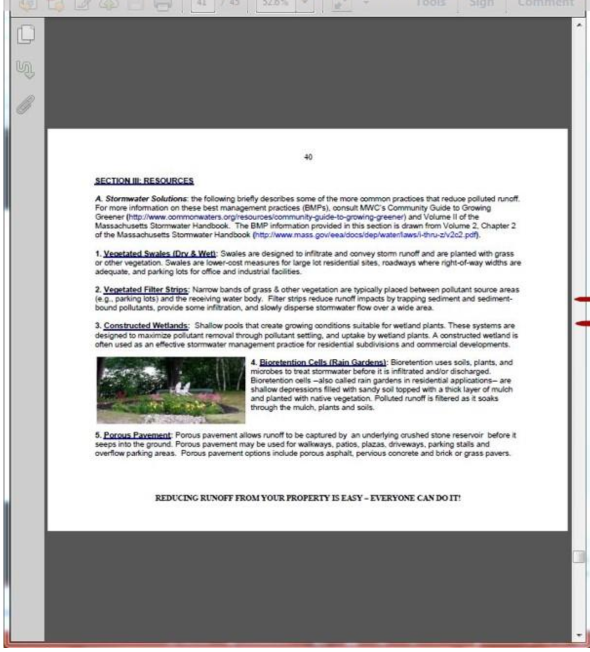
Bioretention Soil can be easily acquired from any forest around you. For better performance on your rain garden, professional Soil suppliers such as Kurtz top soil and mulch (http://www.kurtztopsoilandmulch.com/contact-us.php) can be one of your options. Also other tools such as shovels, plant seeds can be easily obtained from any hardware store or flower shops.

RESOURCES – EVENT CALENDAR





RESOURCES – BMP INFORMATION



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SECTION III: RESOURCES

A. Stormwater Solutions: the following briefly describes some of the more common practices that reduce polluted runoff. For more information on these best management practices (BMPs), consult MWC's Community Guide to Growing Greener (http://www.commonwaters.org/resources/community-guide-to-growing-greener) and Volume II of the Massachusetts Stormwater Handbook. The BMP information provided in this section is drawn from Volume 2, Chapter 2 of the Massachusetts Stormwater Handbook (http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/v2c2.pdf).

1. Vegetated Swales (Dry & Wet): Swales are designed to infiltrate and convey storm runoff and are planted with grass or other vegetation. Swales are lower-cost measures for large lot residential sites, roadways where right-of-way widths are adequate, and parking lots for office and industrial facilities.

2. Vegetated Filter Strips: Narrow bands of grass & other vegetation are typically placed between pollutant source areas (e.g., parking lots) and the receiving water body. Filter strips reduce runoff impacts by trapping sediment and sediment-bound pollutants, provide some infiltration, and slowly disperse stormwater flow over a wide area.

3. Constructed Wetlands: Shallow pools that create growing conditions suitable for wetland plants. These systems are designed to maximize pollutant removal through pollutant settling, and uptake by wetland plants. A constructed wetland is often used as an effective stormwater management practice for residential subdivisions and commercial developments.

4. Bioretention Cells (Rain Gardens): Bioretention uses soils, plants, and microbes to treat stormwater before it is infiltrated and/or discharged. Bioretention cells –also called rain gardens in residential applications– are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with native vegetation. Polluted runoff is filtered as it soaks through the mulch, plants and soils.

5. Porous Pavement: Porous pavement allows runoff to be captured by an underlying crushed stone reservoir before it seeps into the ground. Porous pavement may be used for walkways, patios, plazas, driveways, parking stalls and overflow parking areas. Porous pavement options include porous asphalt, pervious concrete and brick or grass pavers.

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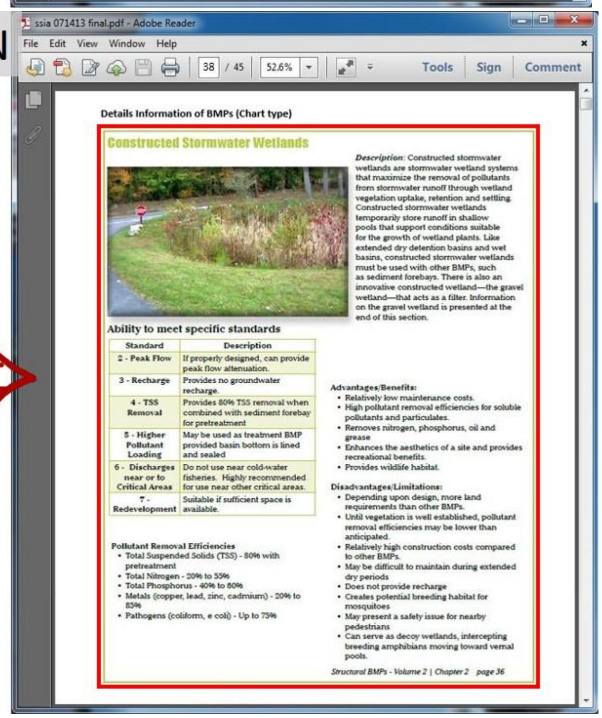

Details Information of BMPs (Chart type)

Constructed Stormwater Wetlands

Description: Constructed stormwater wetlands are stormwater wetland systems that maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling. Constructed stormwater wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Like extended dry detention basins and wet basins, constructed stormwater wetlands must be used with other BMPs, such as sediment forebays. There is also an innovative constructed wetland—the gravel wetland—that acts as a filter. Information on the gravel wetland is presented at the end of this section.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	If properly designed, can provide peak flow attenuation.
3 - Recharge	Provides no groundwater recharge.
4 - TSS Removal	Provides 80% TSS removal when combined with sediment forebay for pretreatment
5 - Higher Pollutant Loading	May be used as treatment BMP provided basin bottom is lined and sealed
6 - Discharges near or to Critical Areas	Do not use near cold-water fisheries. Highly recommended for use near other critical areas.
7 - Redevelopment	Suitable if sufficient space is available.

Pollutant Removal Efficiencies
- Total Suspended Solids (TSS) - 80% with pretreatment
- Total Nitrogen - 20% to 55%
- Total Phosphorus - 40% to 60%
- Metals (copper, lead, zinc, cadmium) - 20% to 85%
- Pathogens (coliform, e coli) - Up to 75%

Advantages/Benefits:
- Relatively low maintenance costs.
- High pollutant removal efficiencies for soluble pollutants and particulates.
- Removes nitrogen, phosphorus, oil and grease
- Enhances the aesthetics of a site and provides recreational benefits.
- Provides wildlife habitat.

Disadvantages/Limitations:
- Depending upon design, more land requirements than other BMPs.
- Until vegetation is well established, pollutant removal efficiencies may be lower than anticipated.
- Relatively high construction costs compared to other BMPs.
- May be difficult to maintain during extended dry periods
- Does not provide recharge
- Creates potential breeding habitat for mosquitoes
- May present a safety issue for nearby pedestrians
- Can serve as decoy wetlands, intercepting breeding amphibians moving toward vernal pools.

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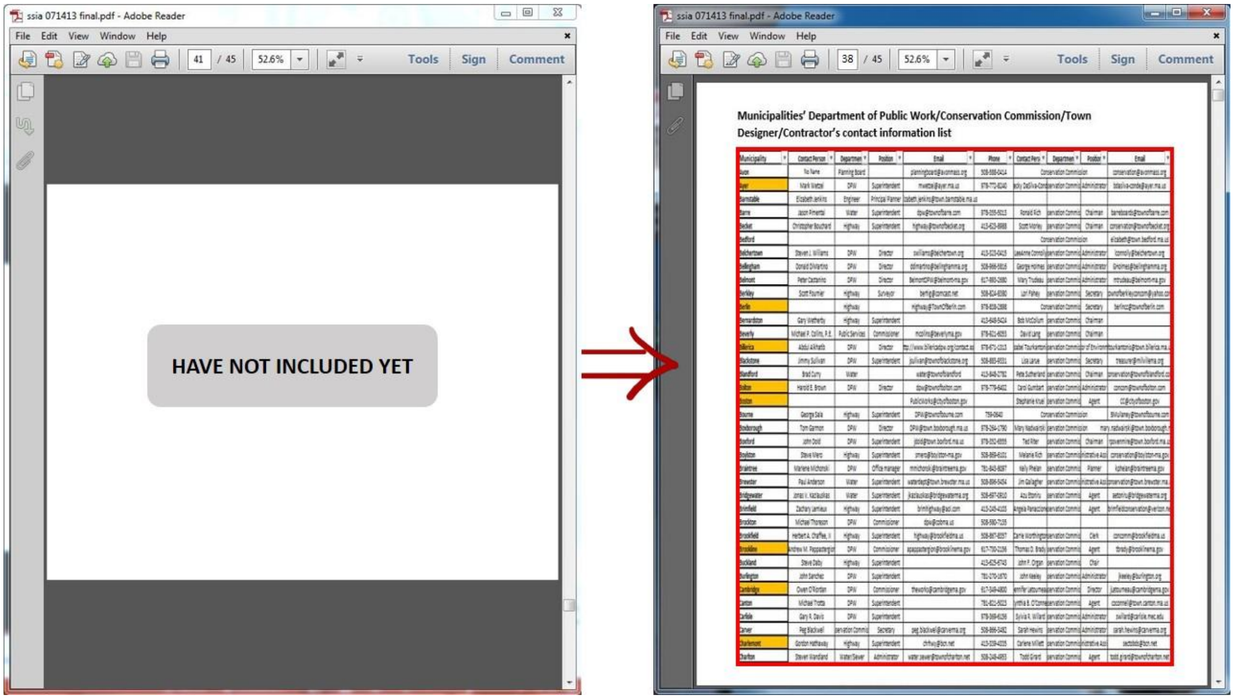
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Tools Sign Comment
Municipalities' Department of Public Work/Conservation Commission/Town Designer/Contractor's contact information list

Appendix I: New Project Information for MWC

Project Name	Contact	Project Address	Town	Contributing Area	Area (sq. ft)	Assumed Runoff coefficient	Estimated Annual Volume(MG)	Type of BMPs	Watershed	Infiltration Status
Castle Hill Avenue Stormwater Improvements	Christopher Rembold, AICP; Town Planner crembold@townofgb.org (413)-528-1619, ext. 7	Castle Hill Ave.	Great Barrington	17.35 acres	755766			deep sump catch basins, stormwater treatment unit	Housatonic	
Pond Street	Joseph Stigliani, DPW Director; jstigliani@town.hull.ma.us		Hull		11135	0.8	0.005552653	rain garden with precast sediment forebay	Boston Harbor	
Cultec Recharger	Joseph Stigliani, DPW Director; jstigliani@town.hull.ma.us		Hull	9.75 acres	424710	0.8	0.21178872	subsurface recharge system	Boston Harbor	
North Street	Michael Soraghan 978-664-6026 msoraghan@northreadingma.gov		North Reading		13670	0.8	0.006816773	6 deep sump catch basins with 3 infiltratior structures	Ipswich	Yes
Hood School	Michael Soraghan 978-664-6026 msoraghan@northreadingma.gov		North Reading		248290	0.9	0.13929069	water quality swales with check dams	Ipswich	
Hood School	Michael Soraghan 978-664-6026 msoraghan@northreadingma.gov		North Reading		3750	0.9	0.00210375	rain garden and infiltration structures	Ipswich	Yes
Town Wide Locations	Michael Soraghan 978-664-6026 msoraghan@northreadingma.gov		North Reading		4000	0.7	0.001745333	small rain garden	Ipswich	Yes
Clark Park	Michael Soraghan 978-664-6026 msoraghan@northreadingma.gov		North Reading		12000	0.6	0.004488	porous pavement	Ipswich	
Culvert Replacement	Paul Shea 781-383-4182 paulshea@cape.com	Border Street	Cohasset	16 sq. miles	446054400	0.75	208.530432	culvert replacement	South Coastal	

Project Name	Contact	Project Address	Town	Contributing Area	Area (sq. ft)	Assumed Runoff coefficient	Estimated Annual Volume(MG)	Type of BMPs	Watershed	Infiltration Status
Jerusalem Road at Atlantic Avenue	Paul Shea 781-383-4182 paulshea@cape.com	Jerusalem Rd. at Atlantic Ave.	Cohasset	8.2 acres	357192	0.75	0.16698726	stormceptor basin and infiltration basin / swale	South Coastal	Yes
Bancroft Hall	Paul Shea 781-383-4182 paulshea@cape.com	15 Lighthouse Lane	Cohasset		19370	0.6	0.00724438	rain garden	South Coastal	
Cushing Road and Norfolk Road	Paul Shea 781-383-4182 paulshea@cape.com	Cushing Rd. and Norfolk Rd.	Cohasset	15.5 acres	675180	0.8	0.33668976	concrete sediment	South Coastal	
Norfolk Road	Paul Shea 781-383-4182 paulshea@cape.com	Norfolk Rd.	Cohasset	6.2 acres	270072	0.8	0.134675904	catch basins	South Coastal	
Sunset Lake	Kelly Phelan 781-794-8233 kphelan@braintreema.gov	23 Safford Street, Braintree, MA 02184	Braintree		52542	0.75	0.024563385	infiltration trench, water quality swale	Boston Harbor	Yes
Sunset Lake	Kelly Phelan 781-794-8233 kphelan@braintreema.gov	23 Safford Street, Braintree, MA 02184	Braintree		11270	0.75	0.005268725	raingarden 1	Boston Harbor	Yes
Sunset Lake	Kelly Phelan 781-794-8233 kphelan@braintreema.gov	23 Safford Street, Braintree, MA 02184	Braintree		4200	0.75	0.0019635	raingarden 2 & 3	Boston Harbor	Yes
Sunset Lake	Kelly Phelan 781-794-8233 kphelan@braintreema.gov	23 Safford Street, Braintree, MA 02184	Braintree		27231	0.75	0.012730493	raingarden 4	Boston Harbor	Yes
Sunset Lake	Kelly Phelan 781-794-8233 kphelan@braintreema.gov	23 Safford Street, Braintree, MA 02184	Braintree		24045	0.75	0.011241038	permeable pavers	Boston Harbor	

Project Name	Contact	Project Address	Town	Contributing Area	Area (sq. ft)	Assumed Runoff coefficient	Estimated Annual Volume(MG)	Type of BMPs	Watershed	Infiltration Status
Sunset Lake	Kelly Phelan 781-794-8233 kphelan@braintreema.gov	23 Safford Street, Braintree, MA 02184	Braintree		16988	0.75	0.00794189	deep sump catch basin	Boston Harbor	
Broadmeadow Brook Sanctuary	Donna Williams dwilliamsbrc@aol.com	414 Massasoit Road	Worcester		350	0.5	0.000109083	rain garden	Blackstone	Yes
Haynes Hill Road Reconstruction	Zach Lemieux brimhighway@aol.com	Intersection of Haynes Hill Road to common drive at Map 17, block A, Parcel 1.3	Brimfield	14.4 acres	627,264	0.55	0.215047008	installing corrugated plastic pipe, manholes w/ deep sump, hooded drop inlets, 18" to 30" pipe to handle 10 yr storm flows; improved sediment removal prior to discharge to wetlands and Wales Road storm drain system	Quinebaug	
Summer Street Drainage Improvements	Kristin Dowdy kdowdy@bedfordma.gov	Intersection of Summer St. and Wiggins Ave.	Bedford	6.5 acres	283,140	0.5	0.0882453	deep sump hooded catch basins and water quality device (Vortechs Model 2000)	Shawsheen	
Cedar Ridge Drive	Kristin Dowdy kdowdy@bedfordma.gov	Cedar Ridege Drive cul-de-sac	Bedford	2 acres	87,120	0.5	0.0271524	rain garden	Shawsheen	
Porous Asphalt Sidewalks	Kristin Dowdy kdowdy@bedfordma.gov	Abbott Lane and section of Hartwell Road	Bedford		5000	0.6	0.00187	porpous asphalt pavement	Shawsheen	Yes
Household Roof Runoff Management	Kristin Dowdy kdowdy@bedfordma.gov	multiple developments	Bedford	25 houses per year	45,000	0.9	0.025245	drywells and infiltration chambers; reduction of runoff from new single family homes	Shawsheen	Yes
Peppermint Brook & Lilly Pond	Mr. Glenn Pratt		Cohasset	521,124 sqft	521,124	0.75	0.24362547	32 raingarden; vegetated grassed swales; oil/water separator		

Project Name	Contact	Project Address	Town	Contributing Area	Area (sq. ft)	Assumed Runoff coefficient	Estimated Annual Volume(MG)	Type of BMPs	Watershed	Infiltration Status
CT River watershed restoration	Kimberly Noake MacPhee		Greenfield	29,400 sf	29,400	0.8	0.0146608	bioengineering bank stbilization techniques; stone toe		
Ashmere Lake work area#1	Carolyn W. Sibner		Hinsdale	0.6 acres	26,136	0.75	0.01221858	grassed swale; 2-sided drop inlet catch basin; riprap discharge apron		
Ashmere Lake work area#2	Carolyn W. Sibner		Hinsdale	0.91 acres	39,639.60	0.5	0.012354342	grassed swale; drop inlet catch basin; rock discharge apron		
Ashmere Lake work area#3	Carolyn W. Sibner		Hinsdale	0.85 acres	37,026	0.5	0.01153977	grassed swale; water quality basin; riprap discharge apron		
Ashmere Lake work area#4	Carolyn W. Sibner		Hinsdale	2.52 acres	109,771.20	0.5	0.034212024	grassed swale; catch basin;		
Ashmere Lake work area#5	Carolyn W. Sibner		Hinsdale	1.76 acres	76,665.60	0.5	0.023894112	catch basin; grassed swale; riprap discharge apron		
Hammond pond	Maria Pologruto Rose		Newton	8124 sf	8124	0.5	0.00253198	catch basin; inlet swale; perimeter sand filter		

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