A Catalog and the Perceived Effectiveness of Stormwater Best Management Practices BMPs Used on Municipal Sites in Northern Utah

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A CATALOG AND THE PERCEIVED EFFECTIVENESS OF STORMWATER BEST MANAGEMENT PRACTICES (BMPs) USED ON MUNICIPAL SITES IN NORTHERN UTAH

by

Saadia E. Ahmed

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Landscape Architecture and Environmental Planning

Approved:

UTAH STATE UNIVERSITY
Logan, Utah
2007
ABSTRACT

A CATALOG AND THE PERCEIVED EFFECTIVENESS OF STORMWATER BEST MANAGEMENT PRACTICES (BMPs) USED ON MUNICIPAL SITES IN NORTHERN UTAH

by

Saadia E. Ahmed

Utah State University, 2006

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Department: Landscape Architecture and Environmental Planning

Stormwater, as a result of hydrological events and urbanization, has contributed to problems of water quality and flooding. Stormwater picks up pollutants and flows into sewer systems ultimately impacting water sheds and wildlife habitat. The primary method to control stormwater discharge is by the use of best management practices. This research seeks to evaluate the perceived effectiveness of stormwater structural Best Management Practices (BMPs) installed on municipal sites in northern Utah. A representative sample of sites is chosen using a snowballing sampling method. Selected sites are visited and surveys addressing effectiveness and maintenance issues are answered by city engineers and maintenance personnel associated with the site. The results of the survey are catalogued and the perceived effectiveness of the most commonly found BMP types analyzed. Additionally, the results where catalogued according to the respondents’ technical training to highlight whether differences in technical education effected their
perceptions towards the BMP effectiveness and whether managers with similar levels of training hold common perceptions.

This study concludes that after the EPA Phase II Rule (passed in 2000) the rate of installation of BMPs in northern Utah has accelerated and with a dramatic increase in the use of BMP types that improve water quality. Stromwater Wetlands, Extended Dry Detention Basins, Wet Ponds, Infiltration Devices, Sediment Basins, and Grassed Swales are found to be the most common BMP types used in northern Utah. Overall, most of the BMPs are perceived as effective in achieving their intended objectives. The results also indicated that the level of technical training does influence stormwater managers’ perceptions towards BMP effectiveness and managers with similar technical training hold similar perceptions.
ACKNOWLEDGMENTS

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I would like to extend my appreciation to the city engineers of Salt Lake County, Davis County, Utah County, and Weber County who made time for site visits and answer surveys.

I would like to recognize the support of my family in particular my father, who has taught me to believe in myself, and my husband who has supported me and encouraged me to pursue my studies. I am grateful to Allah Almighty for his blessings, without which nothing is possible.

Saadia Ahmed
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Chapter 1

Introduction

Precipitation and snowmelt runoff from roadways, parking lots, and roof drains are a major source of nonpoint source pollution to water bodies. The rapid rate of runoff does not allow sufficient time for natural water treatment and limits recharge to groundwater aquifers. Rapid urbanization in the past few decades is the foremost cause of stormwater runoff as urbanization leads to more impervious surfaces which do not allow water to infiltrate into the ground and increase the amount of stormwater runoff. This stormwater flows through residential, industrial, and commercial areas that ultimately become the cause of surface water pollution in water bodies. A typical city produces five times more runoff than woodland of the same size (U.S. EPA, 2003). This shows the importance of stormwater planning and management, especially in the case of urbanized areas. A primary method for managing stormwater runoff is by the use of on-site stormwater Best Management Practices commonly known as BMPs.

The term 'Best Management Practice' (BMP), in relation to urban runoff, is first adopted in the 1970s (Cormier 2004). Stormwater BMPs are defined by the Environmental Protection Agency (EPA) as: “Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants to waters of the United States. BMPs also include treatment requirements, operating procedures, and practices to control runoff, spills, leakages,

---

1 Nonpoint source pollution (NPS) is generally considered to be a diffuse source of pollution not associated with a specific point of entry into the water body. Nonpoint sources of pollution include sediment from small construction sites, metals and other contaminants washed from streets and/or fertilizers or pesticides washing from lawns.
sludge, waste disposal, and the drainage from raw material storage, at the plant sites.”
(Appendix A General Construction Permit, 2003).

A wide range of BMPs are now available that specifically target the amount of runoff, the quality of runoff, or both. Different BMPs perform different functions. Grasses swales for examples function primarily to remove sediments and often attached phosphorous from surface runoff. This wide range makes the process of selecting BMPs more complicated. Pertinent information regarding performance and effectiveness of BMPs can be hard to attain, or the available information might not be applicable due to various geological and climatic factors. Accurate data regarding BMP effectiveness in removing certain pollutants, costs and maintenance requirements, and their suitability to certain site conditions can be very helpful in their design and selection. It can also facilitate the whole process of stormwater management. This information can also help develop a better understanding of the types of issues that need to be addressed in selecting BMPs. Further, it can help stormwater managers, landscape architects, civil engineers and planners in making informed decisions, remove some of the uncertainty from the process, and help ensure their efforts in improving the quality of water.

To address these questions in northern Utah, the research documented in this thesis surveyed a random sample of sites in a total of 24 cities, in 4 counties in northern Utah, acquired opinions on the perceived effectiveness of the selected BMPs from stormwater managers and analyzed the collected information. The research brings to light the perceptions held by stormwater managers regarding characteristics of BMPs and their effectiveness. It provides information on the types of BMPs being used, estimates what they cost to install, annual maintenance cost, the kind of storm event they are designed
for, comparative analysis of the perceived effectiveness of certain attributes of efficiency. This research can lead to a better understanding of factors influencing BMP performance and help to promote improvements in BMP design, selection and implementation.

1.1. Research objectives

This research aims at providing information on the perceived effectiveness of stormwater BMPs in northern Utah. The three basic objectives of this research are:

- Compilation of a catalog of existing municipal sites in northern Utah with installed stormwater BMPs
- Analysis of the perceived effectiveness of these cataloged BMPs in northern Utah
- Analysis of the respondents' (stormwater managers) perceptions to highlight whether technical education has had any effect on their perceptions towards BMPs effectiveness and whether managers with similar training hold common perceptions

1.2. Importance

The effectiveness of BMP is largely site-specific; therefore every BMP needs to be tailored to its given location. For this reason, the evaluation of BMPs is the most reliable when it is compared to BMPs working in similar site conditions. Eric Livingston (bureau chief for watershed management in the Florida Department of Environmental Protection) stresses the need for stormwater managers to base their decisions regarding the type of BMP they plan to use on data collected as part of testing done within the same state or region (Landers, 2006). This compels the need for the availability of such data particular to northern Utah.
In Utah a cohesive stormwater management program is in the process. A compelling reason for this has been the EPA Phase II Rule\textsuperscript{2} that has redefined the criterion for stormwater management by mandating small "MS4" to obtain NPDES permit. As a result, smaller cities (cities with a population less than 50,000 populations) have started implementing stormwater management programs where previously there were none. Therefore, as these cities progress with their programs there is need for evaluative studies and research on the effectiveness of stormwater BMPs that they have employed. Currently, detailed field tests, evaluation and monitoring have been conducted on only a handful of sites; most located in comparatively bigger cities. Numerous smaller cities in Utah have recently started their stormwater management program (directly in response to the EPA Phase II Rule that came out in December 1999). An evaluation of effectiveness of sample sites encompassed in the majority of effected cities will help present a clearer perspective of the effectiveness of BMPs employed in this region. The results of this research will influence stormwater managers' decisions regarding the selection, design and maintenance of BMPs.

1.3. Limitations of the research

The research studied the perceived effectiveness of BMPs as seen by the stormwater managers who have based their view on their technical training and professional experience. Therefore, the results and findings of this research can not substitute for a detailed scientific exploration into the actual performance testing of BMPs. The intent of the study is to provide some baseline information about the perceptions held by the authorities who manage and operate these BMPs and identify, if possible, any misconceptions. Another limitation inherent in the research is that the

\textsuperscript{2} The EPA Phase II Rule mandated that small "MS4" are also required to obtain NPDES permit.
A representative sample is designed using a snowballing method and therefore there is no possibility of confirmation that the sample sites designed encompass all of the BMP types in northern Utah.

1.4. Benefits

The results of this research can enhance our understanding of the use and perceived effectiveness of BMPs in northern Utah. It may also initiate further research and impact the choice of BMPs to be more site-specific for the intermountain desert climate of northern Utah.

Specific benefits are listed below:

- A compilation of a catalog of the types of BMPs in use in northern Utah
- Identification of the most common BMPs used in northern Utah
- Comparative analysis of the perceived effectiveness of two or more BMPs on any particular aspect such as their ability to remove pollutants or detain water
- Identification of new BMPs that are increasingly being introduced after the EPA Phase II Rule
- Bring to light those criterions of efficiency of BMPs on which the stormwater managers hold conflicting or consenting opinions
- Serve as a basis for further research

1.5. Problem statement

The implementation of BMPs has been suggested as a key strategy to combat the negative impacts of stormwater runoff infiltrating municipal water systems. In order to identify the suitable BMP and to make efficient use of that chosen BMP, there is need for
the availability of analytical studies pertinent to BMPs particular to northern Utah's geology and climate.

First, there has been little work done on measuring the effectiveness of stormwater BMPs in northern Utah. Secondly, the studies that have been commenced particularly in Utah have been focused on BMPs in only a few cities and on only a few types of BMPs. The Majority of the cities have just stated installing their stormwater BMPs since 2000 after Phase II Rule was established in 1999. Additionally these Phase II regulations have propagated the use of a wide variety in stormwater BMPs that were not common in Utah previously.

1.6. Research

There are five chapters in this thesis. The current chapter provides a brief introduction to the problem statement and the need for this research. Chapter two gives a background of literature review, justification of the research focused in Utah, a summary of the stormwater management regulations, and the rational for a perceived effectiveness study for stormwater BMPs. Chapter three dwells in detail into the Research design and methods used. Chapter four focuses on the results and discusses the findings; Chapter 5 presents conclusions and direction for future research.
Chapter 2

Literature review

The purpose of this chapter is to present literature review pertinent to stormwater management. The objectives for conducting this literature review are to develop a better understanding of the importance of stormwater management, why it is critical for northern Utah, and to develop an insight into the laws and regulations governing stormwater management in the U.S. Further, it intends to explore research studies that apply the concept of perceived effectiveness and develop a rational for applying this strategy to the evaluation of stormwater BMPs.

2.1. Importance of Managing Stormwater Runoff

Research conducted on water quality and pollutants highlights the negative aspects of stormwater runoff. High levels of heavy metals, lead, hydrocarbons, nitrogen, and phosphorus concentrations have been detected in urban stormwater runoff (Barrett et al. 1998). Research also shows that stormwater runoff is responsible for scouring stream channels and causing downstream flooding. This has led to the loss of habitat for aquatic life and contributed to water pollution in streams, rivers, and estuaries (GESAMP, 1990). It is estimated that stormwater is responsible for almost 50% of pollutant inputs to the marine environment (GESAMP, 1990) and major habitat alterations in estuaries (Kennish, 2002). With the growing awareness of such negative effects of stormwater runoff, more efforts are being initiated to manage stormwater on-site. The rapid rate of urbanization and land clearing has been identified as the two basic causes of stormwater runoff.
Literature review also brought to light examples of large scale destruction caused by stormwater in the U.S. Stormwater runoff produced as a result of land clearing and development has been the cause of constant flooding of the Mississippi River, including the historic 1993 flood. The two major causes of this flood are identified to be urbanization of the flood plain (resulting in reduced rate of infiltration) and excessive channelisation of the river (BBHS, 2006). Another profound effect of stormwater runoff is the degradation of habitat in the Gulf of Mexico. Runoff from two-thirds of the U.S. drains into the Gulf of Mexico (Burrage, 2006). This adds excessive levels of nitrogen, phosphorus, and other nutrients collected from city sewage treatment plants, industrial operations, septic tanks, lawns, gardens, and agricultural areas. An overdose of nitrogen and phosphorus has led to large patches of algae blooms that are responsible for depleting the dissolved oxygen in water, making it unsuitable for marine life. As a result nearly 3.5 million acres of shellfish growing areas in the Gulf here permanently or conditionally closed (Burrage, 2006).

2.2. Importance of Stormwater Management in northern Utah

Stormwater management has become an increasingly important issue for Utah for a number of geological, social, and climatic factors. Utah has three distinct geological regions; the Rocky Mountains, the Great Basin, and the Colorado Plateau. A great diversity exists in the climate, geology and geography of these three regions, each affecting the rate and amount of stormwater runoff. The Utah Rocky Mountains receive in excess of 350 inches (900 cm) of snowfall each year and our study area, the Wasatch Front, receives up to 500 inches of snow (Utah Centre for Weather and Climate, 2006). In spring the snow melts and produces large amounts of runoff. Steep slopes further
accelerate the rate of flow and put added pressure on municipal stormwater systems. This rapid rate of runoff creates potential for flooding and does not recharge the groundwater system.

The Rapid rate of urbanization in Utah is also a major cause of stormwater runoff. Saint George and Heber City are both ranked the second-fastest growing cities in the country (Bulkeley and Deborah, 2005). The U.S. Department of Interiors' (DOI) *Water 2025: Preventing Crisis in the West* report states that large areas in northern Utah are highly likely to have potential conflict between population growth and finite water resources. As stated above, rapid urbanization increases the amount of impervious surfaces causing higher amounts of runoff. If this continues, regional watersheds will not be able to withstand the projected increase in stormwater runoff, resulting in the degradation of the watershed ecosystem. Additionally, the State of Utah is ranked second in water consumption (Division of Water Resources, 2005) and future water use needs cannot be met with current population growth trends. Furthermore, northern Utah faces another critical issue that is the rising trend for non-native vegetation, which requires more water than native species.

### 2.3. Stormwater Management Regulations in U.S.

To better understand why certain BMPs are being adopted in Utah and to support the results of this perceived effectiveness study it is important to review stormwater management regulations in the U.S. For similar reasons it is also considered important to track the evolution of these regulations over the last two decades.

In the U.S. stormwater management is regulated by the Environmental Protection Agency (EPA) under the Clean Water Act (CWA). The CWA established the basic
structure for regulating discharge of pollutants into U.S. waters in 1987 by establishing the National Pollution Discharge Elimination System (NPDES). The NPDES is a set of federal regulations that address surface water protection and treatment. The EPA has since published two sets of regulations. The first set of regulations, titled Stormwater Phase I Rule, was established in 1990.

The Phase I Rule of the NPDES required operators of “medium” and “large” municipal sites to have separate storm sewer systems (MS4s), to obtain a NPDES permit, and to develop a stormwater management program. The stormwater Phase I Rule was intended to improve the overall quality of the nation’s water. However, later research showed that despite the progress made with the Phase I Rule, degraded water bodies still existed. According to the National Water Quality Inventory of year 2000 (a biennial summary of surveys of states’ water quality) approximately 40 percent of surveyed U.S. water bodies are impaired by pollutants and did not meet water quality standards (National Water Quality Inventory, 2000). Polluted stormwater is found to be a significant factor in degrading water quality. In fact, according to the inventory, 13 percent of impaired rivers, 18 percent of impaired lake acres, and 32 percent of impaired estuaries are affected by urban/suburban stormwater runoff (U.S. EPA, 2005a). These findings indicated a need to strengthen the stormwater management regulations of the Phase I Rule. This led to the establishment of EPA Phase II Rule that came out in December 1999. The Phase II Rule expands on the Phase I Rule, by requiring operators

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3 “Medium” and “large” municipal separate storm sewer systems (MS4s) affect cities with populations of 100,000 or greater, construction activity disturbing 5 acres of land or greater, and ten categories of industrial activity.
of smaller municipal sites (addressed as “small MS4s”) in urbanized areas (UA) and small construction sites under development to obtain NPDES permits. Additionally, it requires them to implement programs and practices to control and manage stormwater (U.S. EPA., 2005c). The Phase II Rule is therefore applicable to a larger extent of urbanized areas. In Utah, the Phase II Rule is a turning point in stormwater management as a lot of smaller cities are now required to implement stormwater management strategies under the Phase II Rule which previously had none.

2.4. Rational for the perceived effectiveness study for BMPs

Extensive literature review is conducted to develop a better understanding of the benefits of this type of study and to become acquainted with the research methods adopted in them. Due to lack of available perceived effectiveness studies in stormwater management, literature review is focused on studies done in other fields. Examples of perceived effectiveness studies are found in medicine, computer programming, social sciences, etc.

Edlund and Harris (2006) investigated patterns of use of psychiatric medication and perceived effectiveness of mental health treatment among users of mental health care with and without alcohol dependence. In another study Karamouzis (2004) assessed the

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4 A small MS4 is any MS4 not already covered by the Phase I program as a medium or large MS4. The Phase II Rule automatically covers on a nationwide basis all small MS4s located in “urbanized areas” (UAs) as defined by the Bureau of the Census (unless waived by the NPDES permitting authority), and on a case-by-case basis those small MS4s located outside of UAs that the NPDES permitting authority designates. Small municipal separate storm sewer systems (MS4s) affect cities with 50,000 populations and construction sites over 1 acre. (U.S. EPA.2005c).

5 An urbanized area is a land area comprising one or more places — central place(s) — and the adjacent densely settled surrounding area — urban fringe — that together have a residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile.
effectiveness of the growing trends of on-line education with emphasis on the evaluation of teaching methods for computer education.

In all the perceived effectiveness studies reviewed the survey is found to be the most efficient tool for extracting the desired information. Fienberg et al. (2004) used personal interviews to examine a community coalition model and the perceived effectiveness of the community functioning with and without outside linkages. The benefits of the perceived effectiveness studies identified are:

- It brings to light the commonly held perceptions by a particular focus group on a specific subject
- It highlights the misconceptions related to the effectiveness held by the focus group
Chapter 3

Research Methods

This chapter outlines the research methods used to evaluate the perceived effectiveness of stormwater BMPs in northern Utah. The process included the selection of sample sites, survey questionnaire design, site visits, and obtaining the survey questionnaires from the stormwater managers. Each of these steps is described in the following sections.

3.1. Study area

The initial step in the sample selection is the demarcation of the limits of our study area. Six counties in northern Utah Morgan County, Rich County, Weber County, Salt Lake County, Davis County and Utah County are selected. Of these six, two counties (Morgan and Rich) are later excluded from the study area on the basis that they did not have enough population required to implement stormwater management as discussed later in the chapter. The resulting study area is therefore limited to Weber, Salt Lake, Davis and Utah counties with a specific focus on the Wasatch front. The Wasatch front houses 80% of northern Utah's population and most of the urbanized areas in northern Utah are located here.

The second step is identifying urbanized areas in the four selected counties that are required by EPA to implement stormwater management. For this purpose, a detailed literature review on the Phase II Rule is conducted. This provides insight into its regulations and their application to northern Utah. Some important facts of the Phase II Rule pertaining to our study are described below.
EPA has two approaches to its stormwater management program. First, it authorizes some states to implement their stormwater NPDES permitting program, or secondly, the EPA itself holds the permitting authority (NPDES, 2006a). Further, exploration into this arrangement revealed that the state of Utah is authorized to implement its own stormwater management program. EPA assists the state by providing detailed directions specifically regarding which areas are required to have stormwater management and how the program should be implemented. These EPAs’ requirements pertaining to northern Utah and the management techniques suggested by EPA are identified. The following is a brief description:

**Stormwater management techniques required for Utah**

The EPAs’ stormwater management requirements consist of 6 minimum control measures listed below. Cities and towns in Utah that are considered as an “urban area” by the EPA are required to implement these measures.

- Public education and outreach
- Public participation/involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post-Construction Runoff Control *
- Pollution Prevention/Good Housekeeping

*This perceived effectiveness study focuses on only one of these measures: the Post-Construction Runoff Control.

---

6 Urban area: An Urban Area is a town or city that houses industrial, commercial, or residential activity or is in close proximity to a metropolitan city. For this research an urban area in Utah is defined as a town or city that has a population greater than 10,000.
Who is required to implement stormwater management in Utah?

In Utah, EPA requires urban areas to implement stormwater management. The EPA has published documents that list the current population figures of all the urbanized areas in each state and has also developed maps of the designated urbanized areas. These maps outline the areas that require coverage under the NPDES permit. The maps relevant to our study area are obtained from the EPA website (refer to appendix B). Using the current population figures and the urbanized area maps, the study area is analyzed and a specific list (Table 3.1) is developed encompassing the urbanized areas in the 4 selected counties.

The EPA provides flexibility to designated urban areas to be exempt from the required stormwater management regulation under certain conditions. One basic condition, outlined in this respect, allows urban areas with less than 10,000 people to obtain a waiver from these requirements. As a result urbanized areas with a population less than 10,000 are not included in our list. Our specific list consisted of 24 cities that are listed in Table 3.1.

<table>
<thead>
<tr>
<th>Salt Lake county</th>
<th>Davis county</th>
<th>Weber county</th>
<th>Utah county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cottonwood Heights</td>
<td>Bountiful</td>
<td>Ogden</td>
<td>Provo</td>
</tr>
<tr>
<td>Draper</td>
<td>Centerville</td>
<td>Roy</td>
<td>Orem</td>
</tr>
<tr>
<td>Harriman</td>
<td>Clearfield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holladay</td>
<td>Clinton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murray</td>
<td>Farmington</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riverton</td>
<td>Keysville</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt lake City</td>
<td>Layton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Jordan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taylorsville</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Jordan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Valley City</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midvale</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1: Cities included in the perceived effectiveness study of stormwater BMPs
3.2. Site selection

Selection of the sample sites to be included in the perceived effectiveness survey of stormwater BMPs, is one of the most crucial steps in the research. The first step is identifying municipal sites in our study area with installed BMPs. The second step is choosing among these to be included in the research.

A non-probability sampling method called “snowballing” is used for identifying possible sites. Snowballing is defined by Berg (2004: 36) as “a non-probability sampling strategy used to locate a network of subjects (in this case site) with certain attributes necessary in a study, when a list is otherwise unavailable.”

Professionals in the public works departments of the selected cities and the Utah Stormwater Advisory Committee are asked to provide a list of known stormwater BMPs. Additionally, some cities have developed maps of their municipal stormwater management facilities. These maps show the installed stormwater post construction BMPs in that city. When possible, these maps are obtained and used in identifying possible sites for our study. Once all the possible sites are identified, a set of criteria is developed as a basis for selecting the specific sites to be included in the research.

- First, it is established that in each city at least one example of each type of existing BMP employed would be included in the research. A Stratified Random Sampling (SRS) method is used for this purpose. “Stratified Random Sampling, also sometimes called proportional or quota random sampling, involves dividing your population into homogeneous subgroups and then taking a simple random sample in each subgroup” (Trochim, 2006). Stratified Random Sampling assures the ability to represent not only the overall sample but also key subgroups of the
sample, especially small minority elements such as a BMP that is found in just one or two cities. This is done to help infer the range of different kinds of BMPs being employed in northern Utah.

- The second criterion is to include those sites that the professionals answering the survey questionnaire are affiliated with. Familiarity with sites is important as the respondents evaluated the BMPs on their perceived effectiveness. As stated above, the EPA Phase II Rule is the major driving force in the development of stormwater management programs in most cities. Very few of these BMPs have been tested for effectiveness resulting in little information available regarding their actual or perceived effectiveness.

3.3. Limitations

The survey sample and results possess limitations due to the level of response, knowledge, and conscientiousness of the respondents. Although the sites surveyed are a representative sample of the types of stormwater BMPs used on municipal sites in northern Utah it cannot be considered 100% accurate. Much of the information on the stormwater BMPs is obtained verbally from professionals. In many cases there is no documentation available on the total number and/or types of existing stormwater BMPs. Additionally, in some cities, complete information on the BMPs could not be gathered due to several reasons such as non-availability of stormwater managers in the Stormwater Management Program or the Engineering Department.

3.4. Procedure

The procedure consisted of visiting the selected sites and soliciting responses to survey questionnaires. Each site visit was accompanied by a stormwater manager from
the local municipality from May through August, 2006. The visits consisted of informal conversation about the stormwater BMPs and answering detailed questions of the survey. Additionally, the BMPs were photographed. The survey questionnaire (presented as printed booklets to the participants) was designed to be self-administrative (refer to appendix A). Usually the questionnaires were answered during the site visits but in some cases they remained with the respondents and mailed when completed. This was done either due to time constraints during the visit or because the respondent needed to consult other professionals. In such cases, the survey questionnaires were returned via mail later with comments made by two or more professionals.

3.5. Survey questionnaire design

The survey questionnaire was developed with the help of Assistant Professor Malgorzata Ryczewicz-Borecki, Department of Landscape Architecture and Environmental Planning, Utah State University. A copy of the survey questionnaire is included in appendix A.

As the questionnaire is intended to gather information for both the catalogue and analysis of the perceived effectiveness of BMPs it employed a combination of qualitative and quantitative methods. The open-ended questions in the survey questionnaire constituted the qualitative part, and the close-ended questions constituted the quantitative part. The advantage of the qualitative approach is that it can generate rich, descriptive data (Reichardt and Cook, 1979 in Bulmer, 1986). The positive aspect of quantitative approach is that it is easy to structure to obtain specific information. Further, it involves few variables, employs prescribed procedures and ensures validity and reliability (O’Neill, 2006). They are used together in a complementary “mixed method approach.”
This approach helped by-pass the weaknesses and combine the strengths of the individual methodology approaches (quantitative and qualitative only). This was in-line with the concept that the combination of methodologies can focus on their relevant strengths (Amaratunga, D. et al. 2002). The qualitative questions addressed site characteristics and the respondents' background. Quantitative questions inquired about the perceived effectiveness of the BMPs. The survey was intended to have an expository format and assist in data cataloguing and analysis.

For simplicity, the survey is divided into the following three parts.

- Part 1: General site information
- Part 2: Perceived effectiveness of the stormwater BMP
- Part 3: Background of the respondent

**Part 1: General site information**

Part 1 focused on getting information for the catalogue of BMPs, employing a qualitative approach. There are two types of questions in this section (the beginning questions introduced the site and site characteristics; later questions are aimed at recording the sites’ background and the physical state of the BMP). Questions pertaining to site introduction included site title (where applicable) and site location. The site title is derived from the facility where the BMP is located e.g., High school, Park, Hospital, etc., and site location is identified by the address of the site. Site characteristic questions dealt with percentage of slope and area of the site. These questions gathered information regarding site conditions and the size of the site that the particular BMP serves. Questions regarding the year of installation of the BMP, a sketch of the BMP and its surroundings, and the authorities (city government/ private organization etc.) responsible for
maintaining the site are also included. Questions dwelling into specific details about the types of BMPs used on the site, their surface materials, cost of installation and the annual expenditure on maintenance of BMP are included (these questions are close ended with multiple options to choose from). Further, evaluative questions such as whether or not the use of the stormwater BMP is a voluntary effort by the authorities and the flood event the BMP is designed to sustain are asked.

**Part 2: Perceived effectiveness of stormwater BMP**

Part 2 of the survey asks questions regarding the perceptions of stormwater managers on the effectiveness of BMPs. This part is designed solely with quantitative questions with a range of answers. These questions addressed different criteria of the BMPs' effectiveness and are further grouped into four sub sections. Sub section A evaluated the respondents' general overall perceptions on stormwater BMPs. Questions in this sub section are quite general, such as, do “the benefits of having and maintaining on-site stormwater BMPs outweigh the initial costs”. Sub section B focused exclusively on site-specific efficiency of the particular BMP. It addressed the respondents’ perceptions of several criteria such as the ability of the BMP in reducing the amount of stormwater entering the municipal water system, and in filtering trash/debris from entering into the municipal water system. Sub section C addressed the overall evaluation of the BMP type in its ability to improve the general quality of water leaving the site, how well it achieve its intended objective, etc. Sub section D addressed the general applicability of the stormwater BMPs types to northern Utahs’ climate, slopes, soil conditions, and surrounding surfaces.
In the first three subsections (A, B, and C) a range of effectiveness ratings are presented to the respondents on an eight point nominal scale. The first format of this scale ranged from Strongly Disagree, to Strongly Agree (including “neutral” and “do not know” options), and was used for subsection A (general qualities of stormwater BMPs). An example is shown below.

```
1 2 3 4 5 6 7 0
Strongly Disagree Disagree Slightly Disagree Neutral Slightly Agree Agree Strongly Agree Don't Know
```

The second format also used an eight point nominal scale ranging from Very Poorly to Strongly Well (including “neutral” and “do not know” options). The scale shown below was used in subsection B and C.

```
1 2 3 4 5 6 7 0
Very Poorly Poorly Slightly Poorly Neutral Slightly Well Well Strongly Well Don't Know
```

Subsection D used questions with yes-no response format.

**Part 3: Background of the respondent**

Part 3, background of the respondent, gathered respondents’ qualifications and experience. The questions extracted information about the respondents’ qualifications and technical training, their experience with the design and or maintenance of BMPs, and the
extent of their involvement with BMPs in their everyday jobs. Lastly, there was space provided for the respondent to leave any comments that he/she may have regarding the survey, or the particular BMP under study.
Chapter 4

Survey Results and Discussion

This chapter presents the results and analyses of the perceived effectiveness survey conducted on stormwater BMPs in northern Utah. It contains the BMPs included in the survey, the data collected on them, and the effectiveness of the practices as perceived by the respondents. The results are catalogued to get an overall analysis of the perceived effectiveness of the total sample plus a detailed analysis of each BMP type found in the sample. Further, results are processed and analyzed to illustrate the possible effects of the respondents' technical training towards their perceptions. This chapter has two sections:

- Section 1: Description of data set

  This section describes and presents the data set.

- Section 2: Analysis of the data

  This section catalogues the collected data and describes the various tasks performed during the analysis. For each task, it provides a rationale, describes the methodology developed to facilitate the rationale, and presents and discusses the results.

  The four major tasks performed in Sections 1&2 are:

Task 1: Analysis of BMP type by year of installation

Task 2: Analysis of the perceived effectiveness of each BMP type
  
  - Perceived overall effectiveness
  
  - Perceived effectiveness based on respondents’ technical training

Task 3: Analysis of cost of installation and cost of yearly maintenance
Task 4: Analysis of BMP perceived effectiveness in removing debris and pollutants

4.1. Section 1: Description of data set

Of the 24 cities requested to participate, 23 responded to the data call resulting in a response rate of approximately 96%. The participating cities are listed in Table 3.1 of the previous chapter. The collected dataset consists of a total of 189 BMPs comprising of 20 different types. Table 4.1 lists the different BMP types along with their corresponding abbreviations that will be used throughout this chapter.

<table>
<thead>
<tr>
<th>BMP</th>
<th>Abbreviation</th>
<th>BMP</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-Detention Basin</td>
<td>BD</td>
<td>Oil Water Separator</td>
<td>OWS</td>
</tr>
<tr>
<td>Biosocks</td>
<td>BS</td>
<td>Retention Pond</td>
<td>RP</td>
</tr>
<tr>
<td>Cleanout Box</td>
<td>CB</td>
<td>Rip-Rap</td>
<td>RR</td>
</tr>
<tr>
<td>Creek</td>
<td>Cr</td>
<td>Sand Filter</td>
<td>SF</td>
</tr>
<tr>
<td>Debris Basin</td>
<td>DB</td>
<td>Sediment Basin</td>
<td>SB</td>
</tr>
<tr>
<td>Desilting Structure</td>
<td>De</td>
<td>Snout</td>
<td>Sn</td>
</tr>
<tr>
<td>Extended Dry Detention Basin</td>
<td>EDD</td>
<td>Storm Water Wetland</td>
<td>SWW</td>
</tr>
<tr>
<td>Grass Swales</td>
<td>GS</td>
<td>Sump</td>
<td>Su</td>
</tr>
<tr>
<td>Green Roof</td>
<td>GR</td>
<td>Wet Detention</td>
<td>WD</td>
</tr>
<tr>
<td>Infiltration Devices</td>
<td>ID</td>
<td>Wet Pond</td>
<td>WP</td>
</tr>
</tbody>
</table>

Table 4.1: BMP types and their abbreviations

Table 4.2 and Figure 4.1 illustrate the BMP distribution according to cities. As evident from Table 4.2 there is quite a difference in the number of BMPs included from each city showing 17 from West Valley and Ogden, and only 1 each from Holladay and Centerville. This hierarchy is due to the diversity in the total number and types of BMPs found in each city. Note that from West Valley, Provo, Ogden, Kaysville, Taylorsville, Murray, Orem, and Sandy 10 or more BMPs are included in the sample. As explained earlier in Ch. 3, the sites are selected using stratified random sampling to get a representative sample from each city.
### Table 4.2: BMPs distribution by Cities

<table>
<thead>
<tr>
<th>Cities/BMP Types</th>
<th>BMP Types</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WD</td>
<td>SWW</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>22</td>
</tr>
<tr>
<td>Bountiful</td>
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<tr>
<td>Centreville</td>
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</tr>
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<td>Clinton</td>
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</tr>
<tr>
<td>Cottonwood</td>
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<tr>
<td>Draper</td>
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<tr>
<td>Farmington</td>
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</tr>
<tr>
<td>Herriman</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Holladay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaysville</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Layton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murray</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Ogden</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Orem</td>
<td>1</td>
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</tr>
<tr>
<td>Provo</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Riverton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roy</td>
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</tr>
<tr>
<td>Salt Lake City</td>
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<td></td>
</tr>
<tr>
<td>Sandy</td>
<td>5</td>
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<tr>
<td>South Jordan</td>
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<td>Taylorsville</td>
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<td></td>
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<tr>
<td>West Jordan</td>
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<td></td>
</tr>
<tr>
<td>West Valley</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Legend**

BD: Bio-Detention Basin  
BS: Biosocks  
CB: Cleanout Box  
Cr: Creek  
DB: Debris Basin  
De: Desilting Structure  
EDD: Extended Dry Detention  
GR: Green Roof  
GS: Grasped Swale  
ID: Infiltration Device  
OWS: Oil Water Separator  
RP: Retention Pond  
Su: Sump  
SF: Sand Filter  
Sn: Snout  
SWW: Stormwater Wetland  
WD: Wet Detention  
WP: Wet Pond
Figure 4.1: Numbers/Distribution of BMPs in each City

Figure 4.2: Total number of each BMP by Type

BD: Bio-Detention Basin
BS: Biosocks
CB: Cleanout Box
Cr: Creek
DB: Debris Basin
De: Desilting Structure
EDD: Extended Dry Detention
GR: Green Roof
GS: Grassed Swale
ID: Infiltration Device
OWS: Oil Water Separator
RR: Rip-Rap
RP: Retention Pond
SB: Sediment Basin
SF: Sand Filter
Sn: Snout
Su: Sump
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond
Figure 4.2 presents a graphical representation of the total number of each BMP type found in the sample. Notice that 4 BMP types WD (46), SWW (22), GS (19), and EDD (22) are most common in the sample.

4.2. Section 2: Analysis of the data

4.2.1. Task 1: Analysis of BMPs year of installation

Task 1 catalogues the BMP types according to their year of installation to analyze the effect of stormwater regulations (Phase I & II Rule) in northern Utah. For this particular analysis 148 out of the total 189 BMPs are included in the sample due to the lack of information about the year of installation for the remaining BMPs. Table 4.3 classifies each BMP type by the year it is installed and presents the years grouped into three distinct time periods:

- Pre stormwater regulations or Pre Phase I Rule (up to 1990)
- Post Phase I Rule (1990-1999)
- Post Phase II Rule (2000-2006)

These three time periods are demarked by three red lines in the Table 4.3. Furthermore, to facilitate our analysis, the total number of each type of BMP in a particular time period is summed within the box along its respective red line.

The objectives of this analysis are:

- To see how the numbers of installed BMPs are affected by the presence or absence of stormwater management regulations. Further, to see how the Phase II Rule enhances the rate of installation of BMPs and BMP type.
### Table 4.3: BMP Type by year of installation

<table>
<thead>
<tr>
<th>Yr/BMP</th>
<th>BD</th>
<th>DB</th>
<th>DS</th>
<th>EDD</th>
<th>GS</th>
<th>ID</th>
<th>OWS</th>
<th>RP</th>
<th>RR</th>
<th>SF</th>
<th>SB</th>
<th>WD</th>
<th>SWW</th>
<th>St</th>
<th>WP</th>
<th>GR</th>
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<th>BS</th>
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<tbody>
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<td>6</td>
<td>17</td>
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<tr>
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<td>1</td>
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</tr>
</tbody>
</table>

**Legend**
- BD: Bio-Detention Basin
- DB: Debris Basin
- BS: Biosocks
- CB: Cleanout Box
- Cr: Creek
- DB: Debris Box
- De: Desilting Structure
- EDD: Extended Dry Detention
- GR: Green Roof
- GS: Grasped Swale
- ID: Infiltration Device
- OWS: Oil Water Separator
- RR: Rip-Rap
- RP: Retention Pond
- SB: Sediment Basin
- SF: Sand Filter
- Sn: Snout
- Su: Sump
- SWW: Stormwater Wetland
- WP: Wet Detention
- WP: Wet Pond
• To see which BMP types are more popular in each of the three time periods and if the Phase I and Phase II regulations have had any affect on the popularity of a particular type of BMP.

The first trend that is noticed from this categorization is that, since Phase II the BMP types De, EDD, GS, ID, OWS, and WDD have shown an upward trend of use. Additionally, the comparison between the number of BMPs falling into each time period shows more BMPs are installed in Phase II which is a shorter amount of time (6 years lapse for Phase II, compared to a 10 year time lapse for Phase I). This shows that there is an overall increase in the rate of installation of BMPs. BMP types EDD, GS, ID, OWS, RR, SB, WD, and SWW all showed considerable increase in use as the regulations became stricter.

A second trend noticed is the popularity of BMPs controlling the quantity\(^7\) of water in the pre stormwater regulations and post Phase I regulations period e.g., the BMP types EDD, SB, WD, SWW, and WP retain or detain water and provide flood control. These BMPs minimize the quantity of water entering the municipal system (refer to intended objectives in Appendix C). However, a significant increase is observed in the number of BMPs that improve the water quality\(^8\) in the post Phase II regulations period as seen in the rising trend of the BMP types GR, Sn, SB, OWS, and De. These BMP types improve the water quality by preventing stormwater pollutants and sediments from moving into the municipal system.

---

\(^7\) Quantity: Quantity here refers to the amount of stormwater runoff.

\(^8\) Quality: Quality here refers to the quality of stormwater runoff such as the amount of pollutants, trash, and sediments that it contains.
4.2.2. Task 2. Perceived Effectiveness of BMPs

Task 2 focuses on cataloguing and analyzing the results of the perceived effectiveness of the BMPs in the study. The evaluation of the perceived effectiveness of BMPs is based on the results of section 2B "site specific efficiency" of BMPs and 2C "overall evaluation" of the survey questionnaire (refer to survey questionnaire, Appendix A). The specific questions used in these sections of the questionnaire are shown in Table 4.4.

<table>
<thead>
<tr>
<th>Question #</th>
<th>Site Specific Efficiency (Survey questionnaire part 2B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>How well does this stormwater BMP reduce the amount of stormwater entering the municipal stormwater system?</td>
</tr>
<tr>
<td>19</td>
<td>How well does the stormwater BMP filter trash and debris?</td>
</tr>
<tr>
<td>20</td>
<td>How well does the stormwater BMP remove pollutants?</td>
</tr>
<tr>
<td>21</td>
<td>How well does the stormwater BMP control pollutants from moving into the municipal stormwater system?</td>
</tr>
<tr>
<td>22</td>
<td>How well does the stormwater BMP control erosion?</td>
</tr>
<tr>
<td>27</td>
<td>Overall Evaluation (Survey questionnaire part 2C)</td>
</tr>
<tr>
<td>27</td>
<td>How well does the stormwater BMP improve the general quality of water leaving the site?</td>
</tr>
<tr>
<td>28</td>
<td>How well does the stormwater BMP increase the water quality of the municipal water system?</td>
</tr>
<tr>
<td>29</td>
<td>How well does the stormwater BMP improve the aesthetic quality to the site?</td>
</tr>
<tr>
<td>30</td>
<td>How well does the stormwater BMP achieve its intended objective?</td>
</tr>
</tbody>
</table>

Table 4.4: "Site specific efficiency" and "Overall Evaluation" criterion from survey questionnaire section 2B and 2C

In both sub sections of "site specific efficiency" and "overall evaluation" the respondents are provided an evaluative scale ranging between "very poorly" to "strongly well" (refer to section 4.2.2.4 of this report). For the following evaluation the sample size is limited to include only those BMP types for which a minimum of 8 samples are obtained as a means to avoid bias that could occur due to the smaller size of sample.

The results are evaluated using a goodness-of-fit measure called as Perceived Effectiveness Score (P.E.S.). The P.E.S. is derived by using the equation:

\[ P.E.S.(X) = \frac{1}{n} \sum_{i=1}^{n} [K(X)]_i \]  eq.1
Where:

\[ X = \text{a particular BMP} \]
\[ n = \text{the total number of samples for a particular BMP type} \]
\[ i = \text{the index of the sample and represents the range from sample size 1 to 'n'} \]
\[ K = \text{the score that a particular BMP type ('X') received for a particular criterion (question) on a scale of 1 to 7.} \]

<table>
<thead>
<tr>
<th>( K ) Value</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Strongly Well</td>
</tr>
<tr>
<td>6</td>
<td>Well</td>
</tr>
<tr>
<td>5</td>
<td>Slightly Well</td>
</tr>
<tr>
<td>4</td>
<td>Neutral</td>
</tr>
<tr>
<td>3</td>
<td>Slightly Poor</td>
</tr>
<tr>
<td>2</td>
<td>Poorly</td>
</tr>
<tr>
<td>1</td>
<td>Very Poorly</td>
</tr>
</tbody>
</table>

The P.E.S. equation is a measure of arithmetic mean used specifically for this analysis. The intended objective for using this equation is to drive a single measure of perceived effectiveness for varying BMP samples evaluated on a multiple answer scale. The higher the P.E.S. value the higher is the perceived effectiveness of a particular BMP. The highest P.E.S value that a BMP can receive is 7 and the lowest is 1. The equation does not include the answer option “do not know” while determining the P.E.S. providing no positive or negative effect on the evaluated perceived effectiveness. For more information on “do not know” please see section 3.5 in Ch. 3.

Further, to better serve our objective of bringing to light the perceptions of stormwater managers on the effectiveness of stormwater BMPs in northern Utah, the results are analyzed in two categories.

* Overall evaluation of perceived effectiveness
- Evaluations categorized by respondents level of technical training

The overall evaluation of perceived effectiveness analyzes the P.E.S. of the BMPs in each criterion of "site specific efficiency" and "overall evaluation", compares the percentage of response to each answer option (on a scale of "very poorly" to "strongly well") for each BMP type, and highlights meaningful results. Further, it ranks the BMPs on the basis of cumulative P.E.S., obtained in all 9 criteria addressed in the "site specific efficiency" and "overall evaluation" sections of the questionnaire. The second category presents a comparative analysis of the P.E.S. given to the 9 criteria of "site specific efficiency" and "overall evaluation" by the three major groups of respondents. These three groups are derived based on the level of technical training of the respondents (bachelors' degree, technical classes, and certificates) as found in question #35 of the survey questionnaire (refer to Appendix A). The intent is to analyze whether the respondents' level of training and education has had any affect on the respondents' perceptions towards BMP effectiveness and whether managers classified into any one group hold common perceptions.
4.2.2.1. Perceived effectiveness of BMPs “Overall analysis”

In this section, the results for each BMP type are analyzed for the “site specific efficiency” and “overall evaluation” sections of the survey questionnaire. Tables 4.7 through 4.15 present the results of the perceived effectiveness of the BMPs in tabular form and Figures 4.3 through 4.11 provide a graphical representation. To assist the reader in interpreting the results presented in these Tables and Figures an interpretative guide is provided below.

**Step 1: Familiarity with Answer Options**

The respondents are provided answer options to rate the perceived effectiveness of BMPs for the subsections “site specific efficiency” and “overall evaluation”. Table 4.5 lists these answer options along with the respective abbreviations and the numeric value assigned to them.

<table>
<thead>
<tr>
<th>Answer option</th>
<th>Abbreviation</th>
<th>Numeric value (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Well</td>
<td>stw</td>
<td>7</td>
</tr>
<tr>
<td>Well</td>
<td>w</td>
<td>6</td>
</tr>
<tr>
<td>Slightly Well</td>
<td>sw</td>
<td>5</td>
</tr>
<tr>
<td>Neutral</td>
<td>n</td>
<td>4</td>
</tr>
<tr>
<td>Slightly Poor</td>
<td>sp</td>
<td>3</td>
</tr>
<tr>
<td>Poorly</td>
<td>p</td>
<td>2</td>
</tr>
<tr>
<td>Very Poorly</td>
<td>vp</td>
<td>1</td>
</tr>
<tr>
<td>Don't Know</td>
<td>dk</td>
<td>0</td>
</tr>
</tbody>
</table>

*Table 4.5: Answer options and their abbreviations*

The numeric values associated with each answer option are used to evaluate the P.E.S. These are the ‘K’ values in equation 1. The following analysis employs this P.E.S. For more detail on P.E.S. refer to section 4.2.2.
Step 2: Interpreting the Tables

Answer options

5.1 is the P.E.S. received for the BMP type GS

List BMP types

Perceived effectiveness score

Percentage of “poor” response received by BMP type WP

For each BMP type the green columns represent the percentage of response a particular answer option received for that particular question.

The P.E.S. column represents the perceived effectiveness value that a BMP received for that particular question.

Step 3: Interpreting the figures

Figures 4.3 through 4.14 represent each answer option for a particular BMP type as a bar graph. There are eight bars of different colors used for the eight possible answer options. These are shown in Table 4.6 below.

Answer option | Abbreviation | symbol
---|---|---
Do not Know | dk | ■
Strongly Well | stw | ■
Well | w | ■
Slightly well | sw | ■
Neutral | n | ■
Slightly Poorly | sp | ■
Poorly | p | ■
Very Poorly | vp | ■

Table 4.6: Answer options and their symbols
The figure shown above is an example illustrating the results in a graphical form.

Where

X-axis represents a scale of percentages

Y-axis represents the BMP types

Each bar represents a specific answer option e.g. □ represents the percentage of “well” responses that each BMP type received. The responses for each BMP type total to 100%. In the following, the tables and figures for each criterion along with the discussion are presented.
4.2.2.2. Perceived Effectiveness on "Site Specific Efficiency"

Analysis of Q-18: How well does this stormwater BMP reduce the amount of stormwater entering the municipal stormwater system?

<table>
<thead>
<tr>
<th>Site Specific Efficiency (Q # 18)</th>
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<tbody>
<tr>
<td><strong>BMP Type</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>EDD</td>
</tr>
<tr>
<td>GS</td>
</tr>
<tr>
<td>ID</td>
</tr>
<tr>
<td>SB</td>
</tr>
<tr>
<td>WD</td>
</tr>
<tr>
<td>SWW</td>
</tr>
<tr>
<td>WP</td>
</tr>
</tbody>
</table>

Table 4.7: BMPs perceived effectiveness in reducing the amount of stormwater from entering into municipal systems

Figure 4.3: BMPs perceived effectiveness in reducing the amount of stormwater from entering into municipal systems

- EDD: Extended Dry Detention
- GS: Grassed Swale
- ID: Infiltration Device
- SB: Sediment Basin
- SWW: Stormwater Wetland
- WD: Wet Detention
- WP: Wet Pond

- dk: don’t know
- stw: strongly well
- w: well
- n: neutral
- sp: slightly poorly
- sw: slightly well
- p: poorly
- vp: very poorly

43
Table 4.7 shows that all the 7 BMP types received comparatively high P.E.S. ranging from 5.1-6.1. The highest P.E.S. score is obtained by the BMP type EDD. The BMP type EDD received more than 70% responses as “well” and almost 20% responses as “strongly well”. Similar responses are noticed for SWW which received more than 70% responses as “well” and almost a 15% response as “strongly well”. These results indicate that a comparatively high percentage of EDD and SWW are perceived to be doing a good job of reducing the amount of stormwater from entering into municipal systems. This is consistent with their primary objective; to reduce the quantity of water entering the municipal systems by detention or retention (refer to the intended objectives of BMPs in Appendix C). Second are BMP types WP and WD. The responses for WP show 55% as “well”, 15% as “strongly well” and 8% as “slightly well” indicating that most of the samples surveyed are perceived to be performing positively. The responses for WD are similar to WP with more than 55% perceived as “well”, 12% “strongly well”, and 6% as “slightly well”. However, an 8% response of “slightly poorly” and 12% response of “poorly” shows that almost 20% of this BMP type is not perceived to be functioning positively in this criterion. Reducing the amount of stormwater entering the municipal systems is the primary objectives of WP and WD, which is consistent with the assessment of the respondents.

The remaining three BMP types (GS, ID, and SB) received comparatively lower P.E.S. than SWW, EDD, WP and WD. It is important to note that reducing the amount of stormwater is not the primary function of BMP types GS, ID and SB as these only provide a moderate control (refer to Appendix C). Examining their individual responses, it is noticed that even though it is not their intended objectives to reduce the amount of
stormwater, the performance of a substantial percent of these BMP types are found to be satisfactory. More than 28% of the BMP types ID are perceived as performing “strongly well”, 28% as “well”, and 28% as “slightly well” which totals to 86% of those surveyed as functioning well. This leaves only 14% of the BMP ID perceived to be performing “poorly”. Also, the results for the BMP type SB show that there are 22% samples which are perceived as “strongly well” and 38% are perceived as performing “well”. That leaves approximately 40% perceived as performing below standards. Out of this 40%, 26% are perceived to be performing “slightly poorly”, 4% as “poorly”, and 8% as “do not know”. It concludes that more than 30% of the BMP type SB is not perceived to be effective in reducing stormwater. As stated earlier reducing the amount of stormwater is not the primary objective of the BMP type SB. Yet, depending on the size and location of the facility some SB are perceived to be performing well with regards to reducing the amount of stormwater entering the municipal water systems. For the BMP type GS the responses indicate that 45% are perceived as performing “well”, 10% as “strongly well” but the rest are not perceived effective which is expected considering this is not their primary objective.
Analysis of Q-19: How well does the stormwater BMP filter trash and debris?

<table>
<thead>
<tr>
<th>Site Specific Efficiency (Q # 19)</th>
<th>VP</th>
<th>P</th>
<th>Sp</th>
<th>N</th>
<th>SW</th>
<th>W</th>
<th>Stw</th>
<th>DK</th>
<th>P.E.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>36.36%</td>
<td>40.91%</td>
<td>9.09%</td>
<td>13.64%</td>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>GS</td>
<td>0.00%</td>
<td>15.79%</td>
<td>0.00%</td>
<td>5.26%</td>
<td>36.84%</td>
<td>26.32%</td>
<td>15.79%</td>
<td>0.00%</td>
<td>5.1</td>
</tr>
<tr>
<td>ID</td>
<td>0.00%</td>
<td>0.00%</td>
<td>28.57%</td>
<td>0.00%</td>
<td>14.29%</td>
<td>28.57%</td>
<td>28.57%</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>SB</td>
<td>4.35%</td>
<td>4.35%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>8.70%</td>
<td>34.78%</td>
<td>43.48%</td>
<td>4.35%</td>
<td>6.0</td>
</tr>
<tr>
<td>WD</td>
<td>0.00%</td>
<td>8.70%</td>
<td>4.35%</td>
<td>0.00%</td>
<td>8.70%</td>
<td>50.00%</td>
<td>19.57%</td>
<td>8.70%</td>
<td>5.6</td>
</tr>
<tr>
<td>SWW</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>18.18%</td>
<td>59.09%</td>
<td>13.64%</td>
<td>9.09%</td>
<td>6.0</td>
</tr>
<tr>
<td>WP</td>
<td>7.69%</td>
<td>0.00%</td>
<td>7.69%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>46.15%</td>
<td>23.08%</td>
<td>15.38%</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Table 4.8: BMPs perceived effectiveness in filtering trash and debris

Figure 4.4: BMPs perceived effectiveness in filtering trash and debris

- EDD: Extended Dry Detention
- GS: Grassed Swale
- ID: Infiltration Device
- SB: Sediment Basin
- SWW: Stormwater Wetland
- WP: Wet Pond

- dk: don't know
- stw: strongly well
- w: well
- sp: slightly poorly
- n: neutral
- p: poorly
- vp: very poorly
Overall, all the BMP types are perceived as relatively effective in this criterion (the lowest P.E.S. being 5.1). The following is a detailed analysis of the respondents’ evaluations of the 7 BMP types. Figure 4.4 shows that among all the surveyed BMP types SWW is perceived to be most effective in filtering trash/debris. Of the total SWW, 14% are perceived to be performing “strongly well”, 60% as “well”, 19% as “slightly well” and 9% as “do not know”. These results indicate that a high percentage of the SWW surveyed in northern Utah are doing a good job in removing trash/debris. Removing trash/debris is not the primary objective of SWW but they do provide moderate removal (refer to Appendix C). Similarly, the BMP type EDD is also perceived as performing well in this criterion. There are 10% of BMP type EDD which are evaluated as performing “strongly well”, 41% as “well”, and 37% as “slightly well”. An important observation for EDD is that none of the surveyed EDD sites received an evaluation in the range of “slightly poorly” to “very poorly” even though removing trash/debris is not its primary objective (refer to Appendix C).

A substantial percentage (20% to 30%) of the BMP types WP and WD are not perceived effective when compared to EDD and SWW. The rest of the sample (70% to 80%) received responses in the range of “slightly well” to “strongly well”. For the BMP type WD, responses indicate that almost 23% (9% of “poorly”, 5% of “slightly poorly”, and 9% of “do not know” responses) of this BMP type is either not performing well or the respondents have no clear perceptions on their ability to remove trash/debris. Similarly, the results for the BMP types WP show 8% perceived as performing “very poorly”, 8% as “slightly poorly”. Therefore, 16% of the WP is perceived as ineffective in removing trash/debris. It is also found that 16% of respondents answered as “do not
know” indicating that these respondents did not have any clear perception on BMP type’s performance. Considering the fact that WP and WD remove trash/debris to some extent but it is not their primary objective the surveyed WP and WD are considered to be doing a good job. BMP type SB is intended to remove trash/debris (refer to Appendix C). A high percentage of BMPs surveyed are perceived to be performing well, as 88% of the responses are in the range of “slightly well” to “strongly well”.

The two BMP types that comparatively are not perceived effective in this criterion are ID and GS. BMP type ID for which removing trash/debris is a primary objective (refer to Appendix C) does not show a consistent trend in its perceived effectiveness. Twenty nine percent of ID received “strongly well”, 29% “slightly poorly” and 29% as “do not know” responses. These results indicate an inadequate performance of a substantial percentage (29% evaluated as “slightly poorly”) of the BMP type ID in northern Utah. The BMP type GS received lower perceived effectiveness ratings which is consistent with the primary objective for the BMP type, though it does remove trash/debris in moderation (refer to Appendix C).

Therefore, the BMP types SWW, WP, WD, SB, and EDD are perceived to be performing well in removing trash/debris. However, the ID and GS BMP types did not show a strong trend for performing well. Specifically, a high percentage of “do not know” responses for ID results in an definite trend in its perceived effectiveness in removing trash/debris.
Analysis of Q-20: How well does the stormwater BMP remove pollutants?

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>vp</th>
<th>p</th>
<th>sp</th>
<th>n</th>
<th>sw</th>
<th>w</th>
<th>stw</th>
<th>dk</th>
<th>P.E.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>0.00%</td>
<td>4.55%</td>
<td>0.00%</td>
<td>9.09%</td>
<td>45.45%</td>
<td>31.82%</td>
<td>0.00%</td>
<td>9.09%</td>
<td>5.1</td>
</tr>
<tr>
<td>GS</td>
<td>10.53%</td>
<td>0.00%</td>
<td>5.26%</td>
<td>5.26%</td>
<td>47.37%</td>
<td>15.79%</td>
<td>10.53%</td>
<td>5.26%</td>
<td>4.8</td>
</tr>
<tr>
<td>ID</td>
<td>0.00%</td>
<td>14.29%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>42.86%</td>
<td>14.29%</td>
<td>28.57%</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>SB</td>
<td>4.35%</td>
<td>4.35%</td>
<td>8.70%</td>
<td>0.00%</td>
<td>13.04%</td>
<td>43.48%</td>
<td>8.70%</td>
<td>17.39%</td>
<td>5.2</td>
</tr>
<tr>
<td>WD</td>
<td>4.35%</td>
<td>2.17%</td>
<td>2.17%</td>
<td>0.00%</td>
<td>23.91%</td>
<td>52.17%</td>
<td>10.87%</td>
<td>4.35%</td>
<td>5.5</td>
</tr>
<tr>
<td>SWW</td>
<td>0.00%</td>
<td>9.09%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>31.82%</td>
<td>40.91%</td>
<td>13.64%</td>
<td>4.55%</td>
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</tr>
<tr>
<td>WP</td>
<td>15.38%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>15.38%</td>
<td>30.77%</td>
<td>15.38%</td>
<td>23.08%</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Table 4.9: BMPs perceived effectiveness in removing pollutants

Figure 4.5: BMPs perceived effectiveness in removing pollutants

EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
SB: Sediment Basin
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond
dk: don’t know
stw: strongly well
sw: slightly well
w: well
n: neutral
sp: slightly poorly
p: poorly
vp: very poorly
In this criterion of removing overall pollutants, the P.E.S is lower than the last two criterions. Figure 4.5 shows two prominent trends that are a high percentage of the “well” and “slightly well” responses and a slightly lower percentage of “strongly well” responses. Three BMP types (SWW, WP, and ID) received comparatively higher P.E.S. A high percentage of the responses (91%) for the BMP type SWW are in the range of “slightly well” to “strongly well” except for the 9% of responses which are perceived as “poorly”. Pollutant removal is the primary objective of SWW and they are considered quite efficient in this criterion (refer to Appendix C). The results indicate that a relatively high percentage of the SWW surveyed in northern Utah are doing a fairly good job at removing pollutants. Pollutant removal is considered as an integral function for BMP type WP (refer to Appendix C). The results of the surveyed WP in northern Utah indicate that although a high percentage of these are performing well in this objective there is a substantial percentage of the sample that is either not performing well and/or its performance is not known. The BMP type WD is also intended to remove Pollutants (refer to Appendix C). The results illustrate that a high percentage of WD surveyed in northern Utah, is perceived as performing well. Comparing the three types of retention/detention facilities WP, WD, and EDD, it is known that the pollutant removal is the intended objective of WP and WD but not of EDD (refer to Appendix C). Interestingly, it is observed that the responses for EDD are quite similar to the other two (refer to Figure 4.5) and they are perceived to be performing well in pollutant removal. This may be the result of a common misconception in the effectiveness of EDD. BMP type GS is intended to remove pollutants (refer to Appendix C). However, the performance of the GS surveyed is relatively poor. Forty eight percent of the surveyed
GS are perceived as performing “slightly well”, only 16% as “well” and 11% as “strongly well”. Overall, it can be stated that majority of the BMP type GS are not perceived as performing as well as they should be in removing pollutants. The results for ID show two prominent performance trends, “well” or “strongly well” and “do not know”. It is known that the pollutant removal is not the primary objective of ID but they do remove pollutants to some extent (refer to Appendix C). Overall notice that a high percentage of the BMP type ID is performing well in this criterion which is an added perceived advantage of these BMPs.

The results for question number 19 and 20 which respectively refer to the performance of BMPs in removing trash/debris and pollutants from stormwater are compared side by side in section 4.2.5 (pg. 87). It is important to compare these two criteria (question 19 and 20) in parallel to compare if a BMP is found to have favorable responses\(^9\) in removing trash/debris. Is it also found to have favorable responses in removing pollutants from stormwater?

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\(^9\) favorable is the term employed to refer to the answer options “slightly well”, “well”, and “strongly well”
Analysis of Q-21: How well does the stormwater BMP control pollutants from moving into the municipal stormwater system?

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>vp</th>
<th>p</th>
<th>sp</th>
<th>n</th>
<th>sw</th>
<th>w</th>
<th>stw</th>
<th>dk</th>
<th>P.E.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>4.55%</td>
<td>31.82%</td>
<td>27.27%</td>
<td>22.73%</td>
<td>13.64%</td>
<td>5.8</td>
</tr>
<tr>
<td>GS</td>
<td>5.26%</td>
<td>5.26%</td>
<td>15.79%</td>
<td>0.00%</td>
<td>15.79%</td>
<td>31.58%</td>
<td>21.05%</td>
<td>5.26%</td>
<td>5.1</td>
</tr>
<tr>
<td>ID</td>
<td>0.00%</td>
<td>0.00%</td>
<td>14.29%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>28.57%</td>
<td>28.57%</td>
<td>28.57%</td>
<td>5.8</td>
</tr>
<tr>
<td>SB</td>
<td>13.04%</td>
<td>0.00%</td>
<td>8.70%</td>
<td>4.35%</td>
<td>4.35%</td>
<td>47.83%</td>
<td>17.39%</td>
<td>4.35%</td>
<td>5.1</td>
</tr>
<tr>
<td>WD</td>
<td>4.35%</td>
<td>8.70%</td>
<td>4.35%</td>
<td>4.35%</td>
<td>17.39%</td>
<td>43.48%</td>
<td>15.22%</td>
<td>2.17%</td>
<td>5.2</td>
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<tr>
<td>SWW</td>
<td>4.55%</td>
<td>4.55%</td>
<td>0.00%</td>
<td>9.09%</td>
<td>27.27%</td>
<td>18.18%</td>
<td>36.36%</td>
<td>0.00%</td>
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</tr>
<tr>
<td>WP</td>
<td>15.38%</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>7.69%</td>
<td>38.46%</td>
<td>23.08%</td>
<td>7.69%</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Table 4.10: BMPs perceived effectiveness in controlling pollutants from entering into municipal systems

Figure 4.6: BMPs perceived effectiveness in controlling pollutants from entering into municipal systems

EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
SB: Sediment Basin
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond
dk: don’t know
sw: slightly well
w: well
p: poorly
vp: very poorly
sp: slightly poorly
n: neutral
The results for the ability of the BMP in controlling pollutants from entering into municipal systems are shown in Figure 4.6. The graph shows a larger spread of answer options than the previous three criteria. This indicates that the perceived effectiveness of each BMP type received varying responses in this criterion. The highest P.E.S of 5.8 is received by BMP types EDD and ID. The responses for the BMP type EDD shows almost 86% of the sample to be perceived as performing well (about 32% of the EDD are perceived to be performing “slightly well”, 28% “well” and 23% as “strongly well”). With the exception of 14% of responses for the BMP type EDD that remains unevaluated, the performance of this BMP type in controlling pollutants from moving into the municipal system in northern Utah is satisfactory even though this is not its primary objective (refer to Appendix C). The responses for the BMP type ID show three consistent bars at 29% of responses as “slightly well”, “well”, and “strongly well”. This concludes that 87% of the respondents perceive the BMP type ID as doing a fairly good job in this criterion. The BMP type ID may or may not remove pollutants as this is not its primary objective (refer to Appendix C). The BMP type WP received almost 16% of the responses as “very poorly” and 8% as “poorly” totaling to 24% of the responses as not performing well in this criterion even though this is one of its primary objectives. The performance of 82% of the responses for the BMP type SWW is perceived satisfactory and is found to be in the range of “slightly well” to “strongly well”. One of the primary functions of the BMP type SWW is to control pollutants. The results also show that a high percentage of the BMP type SWW are perceived as achieving this objective. Even though the BMP type GS received a P.E.S. of 5.1, figure 4.6 shows a scattered graph with perceived effectiveness ratings ranging from “very poorly” to “strongly well”. The
dominant response is “well” (32%). Overall, the perceived effectiveness of the BMP type GS varied depending on the site. The intended objective for the BMP types GS is to control pollutants from entering into the municipal system. However, pollutant removing efficiency depends on site design (refer to Appendix C). The results show that a substantial sample (almost 26%) of GS in northern Utah is not perceived effective in this criterion. Similarly the BMP type SB also received responses in the range of “very poorly” to “strongly well” with a comparatively high percentage of “well” (48%) and “strongly well” (18%). Controlling pollutants from moving into the municipal system is not the intended function of SB, therefore, the performance of SB in this criterion is considered satisfactory.
Analysis of Q-22: How well does the stormwater BMP control erosion?

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>vp</th>
<th>p</th>
<th>sp</th>
<th>n</th>
<th>sw</th>
<th>w</th>
<th>stw</th>
<th>dk</th>
<th>P.E.S.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>31.82%</td>
<td>13.64%</td>
<td>27.27%</td>
<td>5.3</td>
</tr>
<tr>
<td>GS</td>
<td>5.26%</td>
<td>10.53%</td>
<td>10.53%</td>
<td>5.26%</td>
<td>10.53%</td>
<td>42.11%</td>
<td>5.26%</td>
<td>10.53%</td>
<td>4.7</td>
</tr>
<tr>
<td>ID</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>28.57%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>42.86%</td>
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</tr>
<tr>
<td>SB</td>
<td>13.04%</td>
<td>26.09%</td>
<td>0.00%</td>
<td>4.35%</td>
<td>8.70%</td>
<td>13.04%</td>
<td>13.04%</td>
<td>21.74%</td>
<td>3.8</td>
</tr>
<tr>
<td>WD</td>
<td>15.22%</td>
<td>15.22%</td>
<td>17.39%</td>
<td>8.70%</td>
<td>6.52%</td>
<td>23.91%</td>
<td>2.17%</td>
<td>10.87%</td>
<td>3.6</td>
</tr>
<tr>
<td>SWW</td>
<td>9.09%</td>
<td>0.00%</td>
<td>9.09%</td>
<td>4.55%</td>
<td>13.64%</td>
<td>40.91%</td>
<td>4.55%</td>
<td>18.18%</td>
<td>4.9</td>
</tr>
<tr>
<td>WP</td>
<td>15.38%</td>
<td>15.38%</td>
<td>0.00%</td>
<td>7.69%</td>
<td>15.38%</td>
<td>15.38%</td>
<td>15.38%</td>
<td>15.38%</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Table 4.11: BMPs perceived effectiveness in controlling erosion

Figure 4.7: BMPs perceived effectiveness in controlling erosion

EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
SB: Sediment Basin
WD: Wet Detention
WP: Wet Pond

dk: don’t know
stw: strongly well
w: well
sw: slightly well
n: neutral
sp: slightly poorly
p: poorly
vp: very poorly
The results from the respondents on the criteria of controlling erosion are presented above. The perceived effectiveness ratings of all the BMP types are lower for this particular criterion than the previous 4. The P.E.S. values are found to be 3.0 for the BMP type ID, where as the highest P.E.S. is at a relatively low 5.3 for the BMP type EDD. Figure 4.7 presents a stratified graph with no clear trend. Further, it is noticed that a significantly high percentage of the 7 BMP types are not evaluated because the respondents chose “do not know” option (more than 40% for the BMP type ID). The reason for such a stratified graph can be that controlling erosion is not the primary objective of any of these 7 BMP types. The BMP type SB controls the sediments from entering the municipal systems (refer to Appendix C), therefore, it does control erosion to some extent. One interesting observation is that the BMP type EDD received the highest P.E.S. and a fairly high percentage of responses as “well”, where as this BMP is not intended to control erosion. This concludes that either the higher ratings received by some of the EDDs are true or there is a misconception among the stormwater managers that BMP types such as EDD actually do control erosion. Another interesting observation is that the BMP type SB, which to some extent controls erosion, received fairly low ratings. This indicates that the BMP type is not perceived as performing well in controlling erosion.

The results of this criterion do not present a strong indicator that any of the analyzed BMP types are perceived as doing a good job in controlling erosion in northern Utah. The high percentage of “do not know” responses also concludes that for a substantial sample of these BMP types, the respondents have no perceptions on their performance.
4.2.2.3. Perceived Effectiveness on “Overall Evaluation”

Analysis of Q-27: How well does the stormwater BMP improve the general quality of water leaving the site?

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>vp</th>
<th>p</th>
<th>sp</th>
<th>n</th>
<th>sw</th>
<th>w</th>
<th>stw</th>
<th>dk</th>
<th>P.E.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>9.09%</td>
<td>54.55%</td>
<td>27.27%</td>
<td>0.00%</td>
<td>9.09%</td>
<td>5.2</td>
</tr>
<tr>
<td>GS</td>
<td>10.53%</td>
<td>0.00%</td>
<td>5.26%</td>
<td>15.79%</td>
<td>36.84%</td>
<td>21.05%</td>
<td>5.26%</td>
<td>5.26%</td>
<td>4.6</td>
</tr>
<tr>
<td>ID</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>28.57%</td>
<td>42.86%</td>
<td>0.00%</td>
<td>28.57%</td>
<td>5.6</td>
</tr>
<tr>
<td>SB</td>
<td>0.00%</td>
<td>0.00%</td>
<td>4.35%</td>
<td>4.35%</td>
<td>8.70%</td>
<td>78.26%</td>
<td>4.35%</td>
<td>0.00%</td>
<td>5.7</td>
</tr>
<tr>
<td>WD</td>
<td>6.52%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>8.70%</td>
<td>15.22%</td>
<td>52.17%</td>
<td>4.35%</td>
<td>13.04%</td>
<td>5.3</td>
</tr>
<tr>
<td>SWW</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>13.64%</td>
<td>54.55%</td>
<td>4.55%</td>
<td>27.27%</td>
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</tr>
<tr>
<td>WP</td>
<td>0.00%</td>
<td>15.38%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>23.08%</td>
<td>53.85%</td>
<td>7.69%</td>
<td>0.00%</td>
<td>5.2</td>
</tr>
</tbody>
</table>

Table 4.12: BMPs evaluation in improving the general quality of water leaving the site

Figure 4.8: BMPs evaluation in improving the general quality of water leaving the site

EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
SB: Sediment Basin
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond
dk: don’t know
stw: strongly well
w: well
sp: slightly poorly
sw: slightly well
n: neutral
p: poorly
vp: very poorly
In this criterion, the BMPs are generally perceived as doing “slightly well” to “strongly well” in judging their ability to improve the general quality of water leaving the site. Figure 4.8 presents two responses “slightly well” and “well” to be dominant. Figure 4.8 also presents comparatively uniform trends indicating that there is a consensus among the stormwater managers regarding the perceived effectiveness of these BMP types in improving the overall quality of the water leaving the site. Generally, all the BMP types received high P.E.S. (the highest being 5.9 for SWW). This indicates that the majority of the BMPs surveyed are perceived to be performing well in improving the general quality of water leaving the site. The exception is BMP type GS which received a comparatively low P.E.S. of 4.6. Although GS received an overall comparatively lower P.E.S., more than 78% of the GS are perceived as performing “well” in this criterion. Therefore, the majority of the GS surveyed are perceived to be doing a fairly good job at improving the overall quality of the water leaving the site, which is consistent with its intended objective (refer to Appendix C). Also notice that the BMP types ID and SWW received more than 25% responses as “do not know”. This shows that for a substantial sample of these BMP types the respondents do not know their performance in this criterion. Overall, the BMPs received high P.E.S. (5.6 for ID and 5.9 for SWW) indicating that the rest of the 75% of these BMPs are perceived to be doing a satisfactory job. Thus it can be said that for all the 7 BMP types included in this analysis, a high percentage are perceived as improving the overall quality of water leaving the site.
Q-28: How well does the stormwater BMP increase the water quality of the municipal water system?

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>vp</th>
<th>p</th>
<th>sp</th>
<th>n</th>
<th>sw</th>
<th>w</th>
<th>stw</th>
<th>dk</th>
<th>P.E.S.</th>
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</thead>
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<td>0.00%</td>
<td>4.55%</td>
<td>27.27%</td>
<td>31.82%</td>
<td>13.64%</td>
<td>0.00%</td>
<td>22.73%</td>
<td>4.7</td>
</tr>
<tr>
<td>GS</td>
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<td>5.26%</td>
<td>5.26%</td>
<td>21.05%</td>
<td>31.58%</td>
<td>15.79%</td>
<td>0.00%</td>
<td>10.53%</td>
<td>4.2</td>
</tr>
<tr>
<td>ID</td>
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<td>0.00%</td>
<td>14.29%</td>
<td>0.00%</td>
<td>14.29%</td>
<td>42.86%</td>
<td>0.00%</td>
<td>28.57%</td>
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</tr>
<tr>
<td>SB</td>
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<td>4.35%</td>
<td>4.35%</td>
<td>0.00%</td>
<td>21.74%</td>
<td>43.48%</td>
<td>4.35%</td>
<td>21.74%</td>
<td>5.4</td>
</tr>
<tr>
<td>WD</td>
<td>6.52%</td>
<td>0.00%</td>
<td>2.17%</td>
<td>8.70%</td>
<td>23.91%</td>
<td>50.00%</td>
<td>6.52%</td>
<td>2.17%</td>
<td>5.2</td>
</tr>
<tr>
<td>SWW</td>
<td>0.00%</td>
<td>0.00%</td>
<td>4.55%</td>
<td>0.00%</td>
<td>31.82%</td>
<td>36.36%</td>
<td>9.09%</td>
<td>18.18%</td>
<td>5.6</td>
</tr>
<tr>
<td>WP</td>
<td>0.00%</td>
<td>15.38%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>46.15%</td>
<td>15.38%</td>
<td>7.69%</td>
<td>15.38%</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Table 4.13: BMPs evaluation in increasing the water quality of municipal water system

![Bar chart showing the evaluation of various BMPs in increasing water quality](image)

Figure 4.9: BMPs evaluation in increasing the water quality of municipal water system

EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
SB: Sediment Basin
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond
dk: don't know
sw: slightly well
w: well
sp: slightly poorly
n: neutral
vp: very poorly
The respondents’ evaluations on the effectiveness of BMPs in increasing the quality of municipal water systems show two common trends. First, majority of BMP types WP, SB, WD, and SWW, are perceived to be performing in the range of “well” to “strongly well”. The results reflect that the BMP types WP, SB, WD, and SWW, surveyed, are perceived to be working well in increasing the water quality of municipal water systems which is one of their primary objectives (refer to the intended objectives of BMPs in Appendix C). A detailed analysis of Figure 4.9 illustrates the following trends for these 4 BMP types. Almost 70% of the BMP types WP are evaluated between “slightly well” and “strongly well”. Of the remaining 30% more than 15% are perceived as performing “poorly” and 15% as “do not know”. The results for the BMP type SWW show that 32% are perceived to be performing “slightly well”, 38% as “well”, and almost 9% as “strongly well”. Therefore, the perceived effectiveness for the BMP type WP surveyed; is satisfactory. The responses for the BMP type SB show about 9% perceived as performing in the range of “slightly poorly” to “poorly” and more than 21% as “do not know”. The remaining 70% are perceived to be doing a fairly good job.

The remaining 3 BMP types, ID, GS, and EDD received a high percentage of responses as “slightly poorly”, “neutral”, and “slightly well”. These also received lower ratings for the P.E.S. The results of the BMP type ID show almost 58% of these BMPs to be performing in the range of “slightly well” to “well” and the remaining 42% as not so well. More than 28% of ID are not evaluated and answered as “do not know”. The BMP type GS are suppose to improve the water quality of the municipal water system (refer to their intended objectives in Appendix C). The results of this survey indicate that only 46% of responses for the BMP type GS surveyed are perceived as effective in this
criterion. Another noticeable trend is comparatively a large percentage of responses are "do not know", e.g., more than 28% of ID, more than 22% of SB, and almost 19% of SWW.
Analysis of Q-29: How well does the stormwater BMP improve the aesthetic quality to the site?

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>vp</th>
<th>p</th>
<th>sp</th>
<th>n</th>
<th>sw</th>
<th>w</th>
<th>stw</th>
<th>dk</th>
<th>P.E.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>4.55%</td>
<td>4.55%</td>
<td>13.64%</td>
<td>40.91%</td>
<td>9.09%</td>
<td>4.55%</td>
<td>18.18%</td>
<td>4.55%</td>
<td>4.4</td>
</tr>
<tr>
<td>GS</td>
<td>0.00%</td>
<td>0.00%</td>
<td>15.79%</td>
<td>21.05%</td>
<td>21.05%</td>
<td>10.53%</td>
<td>31.58%</td>
<td>0.00%</td>
<td>5.2</td>
</tr>
<tr>
<td>ID</td>
<td>28.57%</td>
<td>0.00%</td>
<td>28.57%</td>
<td>28.57%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>14.29%</td>
<td>0.00%</td>
<td>3.3</td>
</tr>
<tr>
<td>SB</td>
<td>21.74%</td>
<td>4.35%</td>
<td>13.04%</td>
<td>13.04%</td>
<td>21.74%</td>
<td>4.35%</td>
<td>21.74%</td>
<td>0.00%</td>
<td>4.1</td>
</tr>
<tr>
<td>WD</td>
<td>8.70%</td>
<td>2.17%</td>
<td>6.52%</td>
<td>45.65%</td>
<td>2.17%</td>
<td>8.70%</td>
<td>19.57%</td>
<td>6.52%</td>
<td>4.4</td>
</tr>
<tr>
<td>SWW</td>
<td>0.00%</td>
<td>9.09%</td>
<td>9.09%</td>
<td>45.45%</td>
<td>4.55%</td>
<td>13.64%</td>
<td>13.64%</td>
<td>4.55%</td>
<td>4.5</td>
</tr>
<tr>
<td>WP</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>7.69%</td>
<td>0.00%</td>
<td>30.77%</td>
<td>53.85%</td>
<td>7.69%</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Table 4.14: BMPs evaluation in its perceived effectiveness for improving the aesthetics of the site

![Figure 4.10: BMPs evaluation in its perceived effectiveness for improving the aesthetics of the site](image)

EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
SB: Sediment Basin
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond
dk: don’t know
sw: slightly well
w: well
n: neutral
sp: slightly poorly
p: poorly
vp: very poorly
The responses to this criterion of "overall evaluation" are quite different than the other 2 criteria discussed above. A high percentage of responses are "neutral". The highest percentage of "neutral" response is for the BMP types SWW, WD, and EDD. SWW are considered to enhance the aesthetic value of the sites (refer to stormwater wetlands in Appendix C). The "neutral" response concludes that in the view of the respondents either these BMPs do not produce any positive or negative effect on the aesthetic quality of the site or aesthetic quality of the BMP is not being considered an important criterion in the choice, design and management of these BMP types. The exception to this is the BMP type WP that obtained the highest P.E.S. and the majority of responses as "strongly well". A relatively high percentage of the WP surveyed is perceived to be improving the "aesthetical quality of the site" as is evident from the 54% of "strongly well" responses. It is noticed that for BMP types SB and ID, the responses of "strongly well", "neutral" and "very poorly" are common. This concludes that the effect of these BMPs on the aesthetical quality of the site varied from site to site and no definite trend could be seen.
Q-30: How well does the stormwater BMP achieve its intended objective?

Table 4.15: BMPs evaluation in achieving its intended objectives

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>vp</th>
<th>p</th>
<th>sp</th>
<th>n</th>
<th>sw</th>
<th>w</th>
<th>stw</th>
<th>dk</th>
<th>P.E.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>36.36%</td>
<td>45.45%</td>
<td>13.64%</td>
<td>4.55%</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>GS</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>42.11%</td>
<td>21.05%</td>
<td>31.58%</td>
<td>5.26%</td>
<td>5.9</td>
</tr>
<tr>
<td>ID</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>14.29%</td>
<td>0.00%</td>
<td>57.14%</td>
<td>28.57%</td>
<td>6.6</td>
</tr>
<tr>
<td>SB</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>8.70%</td>
<td>34.78%</td>
<td>56.52%</td>
<td>0.00%</td>
<td>6.5</td>
</tr>
<tr>
<td>WD</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>17.39%</td>
<td>36.96%</td>
<td>45.65%</td>
<td>0.00%</td>
<td>6.3</td>
</tr>
<tr>
<td>SWW</td>
<td>0.00%</td>
<td>0.00%</td>
<td>4.55%</td>
<td>0.00%</td>
<td>18.18%</td>
<td>31.82%</td>
<td>45.45%</td>
<td>0.00%</td>
<td>6.1</td>
</tr>
<tr>
<td>WP</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>15.38%</td>
<td>46.15%</td>
<td>38.46%</td>
<td>0.00%</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Figure 4.11: BMPs evaluation in achieving its intended objectives

EDD: Extended Dry Detention  
GS: Grassed Swale  
ID: Infiltration Device  
SB: Sediment Basin  
SWW: Stormwater Wetland  
WD: Wet Detention  
WP: Wet Pond  
dk: don’t know  
stw: strongly well  
w: well  
n: neutral  
sp: slightly poorly  
p: poorly  
vp: very poorly
A high percentage of respondents perceived the BMPs as “strongly well” in their ability to achieve their intended objectives. All the BMP types obtained comparatively high P.E.S. Among all the 9 criteria this question received the highest P.E.S. (the lowest being 5.8). It concludes that all the BMP types are perceived as working properly to meet the objectives established for their functionality.

4.2.2.4. Overall observations

A significant trend noticed among all the 9 criterions (questions) of “site specific efficiency” and “overall evaluation” of the BMPs is that the BMP type ID received a significantly high percentage “do not know” responses. It is found to be 42.9% (refer to Table 4.11) for question #22, and 28.6% for questions 18, 19, 27, 28, and 30 (refer to Tables 4.7, 4.8, 4.12, 4.13, 4.15). This shows that at least 25% of the respondents have no significant perceptions on the effectiveness of this BMP type. Second to ID, the BMP type SWW also received a fairly high percentage of “do not know” responses. Otherwise, the BMPs received high P.E.S. However, there is a probability that among the respondents there exist some discrepancies or uncertainties regarding the effectiveness of the BMP type ID, since the P.E.S. does not include the “do not know” responses.

Table 4.16 presents the P.E.S. for all the 9 criterions of “site specific efficiency” and “overall evaluation” side by side for comparative analysis. Figures 4.12 and 4.13 represent a graphical presentation of this P.E.S.
Table 4.16: P.E.S. of BMP types for each of the 9 perceived effectiveness criteria

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>Site Specific Efficiency</th>
<th>Overall Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Question #</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>EDD</td>
<td>6.1</td>
<td>5.7</td>
</tr>
<tr>
<td>GS</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>ID</td>
<td>5.4</td>
<td>5.2</td>
</tr>
<tr>
<td>SB</td>
<td>5.2</td>
<td>6.0</td>
</tr>
<tr>
<td>WD</td>
<td>5.2</td>
<td>5.6</td>
</tr>
<tr>
<td>SWW</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>WP</td>
<td>5.4</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Figure 4.12: BMPs P.E.S. values for “site specific efficiency”

EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
SB: Sediment Basin
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond
The BMPs obtained high P.E.S. scores in almost all the criterions except for question #22. Notice in the figures 4.12 and 4.13 that the P.E.S. values are spread out and there is no clear trend for questions #22 (which dealt with the effectiveness of BMP in controlling erosion) and #29 (which scored the BMPs in improving the overall quality of the site).
A cumulative measure of P.E.S. for all the 9 questions pertaining to the effectiveness and evaluation for each of the BMPs is presented in the Table 4.17 below. The results are also represented in a graphic plot in figure 4.14.

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>Site Specific Efficiency</th>
<th>Overall Evaluation</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>5.6</td>
<td>5.0</td>
<td>5.3</td>
</tr>
<tr>
<td>GS</td>
<td>4.9</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>ID</td>
<td>5.0</td>
<td>5.2</td>
<td>5.1</td>
</tr>
<tr>
<td>SB</td>
<td>5.0</td>
<td>5.4</td>
<td>5.2</td>
</tr>
<tr>
<td>WD</td>
<td>5.0</td>
<td>5.3</td>
<td>5.2</td>
</tr>
<tr>
<td>SWW</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>WP</td>
<td>5.0</td>
<td>5.7</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Table 4.17: Overall BMPs effectiveness (P.E.S.)

There are three lines in Figure 4.14. The pink line with squares is the “site specific efficiency” score and the red line with triangles is the “overall evaluation” score. Looking at the cumulative P.E.S. values, it is observed that higher P.E.S. values are found for all BMP types (except for EDD) in the “overall evaluation” score. The BMP type EDD
received a comparatively lower cumulative P.E.S. than the other BMPs types. The cumulative score for both “overall evaluation” and “site specific efficiency” is averaged and termed as a mean P.E.S. represented in figure 4.13 as a blue line with squares. This provides the overall effectiveness measure for each of the BMPs. The results show that the BMP types EDD, SWW, and WP scored relatively high where as the BMP type GS scored the lowest with a relatively high P.E.S. of 5.0.

4.2.3. Perceived effectiveness of BMPs based on respondents’ technical education:

The Table 4.18 presents the P.E.S. for the 9 criteria of “site specific efficiency” and “overall evaluation” based on the three groups of respondents’ educational level: Bachelor degree (or higher), Technical classes, and Certificates (asked in Question 35 of the survey questionnaire). The results are then plotted by question each in figures 4.15-4.27 to provide a clearer understanding of the difference in responses based on the respondents’ level of technical education.
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>6.0</td>
<td>5.9</td>
<td>3.7</td>
<td>4.9</td>
<td>5.5</td>
<td>4.9</td>
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<td>5.5</td>
<td>4.4</td>
<td>5.5</td>
<td>4.4</td>
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<td>4.3</td>
<td>5.2</td>
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<td>4.6</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>GS</td>
<td>4.6</td>
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<td>5.1</td>
<td>5.1</td>
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<td>4.7</td>
<td>5.3</td>
<td>4.8</td>
<td>5.0</td>
<td>4.9</td>
<td>5.0</td>
<td>5.1</td>
<td>4.9</td>
<td>5.1</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>5.7</td>
<td>5.3</td>
<td>4.1</td>
<td>5.0</td>
<td>4.0</td>
<td>5.0</td>
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<td>5.0</td>
<td></td>
</tr>
<tr>
<td>SB</td>
<td>6.5</td>
<td>5.0</td>
<td>6.3</td>
<td>5.0</td>
<td>4.9</td>
<td>5.0</td>
<td>5.1</td>
<td>5.0</td>
<td>5.1</td>
<td>5.0</td>
<td>5.1</td>
<td>5.0</td>
<td>5.1</td>
<td>5.0</td>
<td>5.1</td>
<td>5.0</td>
<td>5.1</td>
<td>5.0</td>
<td>5.1</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>WD</td>
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<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
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<tr>
<td>SWW</td>
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<td>5.0</td>
<td>4.6</td>
<td>2.0</td>
<td>6.0</td>
<td>4.2</td>
<td>2.7</td>
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<td>1.3</td>
<td>5.5</td>
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<td>WP</td>
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<td>3.0</td>
<td>2.0</td>
<td>6.0</td>
<td>4.2</td>
<td>2.7</td>
<td>6.2</td>
<td>4.3</td>
<td>1.3</td>
<td>5.5</td>
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<td>3.9</td>
<td>1.3</td>
<td>5.5</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Table 4.18: P.E.S. for each question per the respondents' level of technical education

EDD: Extended Dry Detention  
GS: Grassed Swale  
ID: Infiltration Device  
SB: Sediment Basin  
SWW: Stormwater Wetland  
WD: Wet Detention  
WP: Wet Pond
4.2.3.1. Perceived Effectiveness on “Site Specific Efficiency” based on respondents’ technical education

Analysis of Q-18: How well does this stormwater BMP reduce the amount of stormwater entering the municipal stormwater system?

In question number 18 the respondents are asked to judge the ability of BMPs in reducing the amount of stormwater entering the municipal stormwater system. A relative consensus among the three groups of respondents is found for BMP types EDD, GS, and SWW (Figure 4.15). The remaining four BMPs (ID, SB, WD, and WP) show a noticeable difference in P.E.S. given by the bachelors’ degree group and the certificate group. Overall, the respondents with bachelors’ degree gave a considerably higher P.E.S. to all of the BMPs.
Analysis of Q-19: How well does the stormwater BMP filter trash and debris?

Figure 4.16: BMPs effectiveness in filtering trash and debris

EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
SB: Sediment Basin
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond

Figure 4.16 presents P.E.S. results of the BMPs effectiveness in filtering trash/debris. It can be noticed that the P.E.S. results for the bachelors’ group differs with the ones given by the other two groups (certificate and technical classes) for all BMP types except GS and EDD. Notice that the bachelors’ group gave a lowest P.E.S. (4.0) to the BMP type ID while the other two groups gave it a P.E.S. of 6.8 and 7 indicating that they hold a differing opinion on the effectiveness of these BMPs in filtering trash from stormwater. The greatest discrepancy is seen for WP with a range of P.E.S. from 2.0, 4.8, and 6.2.
Analysis of Q-20: How well does the stormwater BMP remove pollutants?

![Figure 4.17: BMPs effectiveness in removing pollutants](image)

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>Extended Dry Detention</td>
</tr>
<tr>
<td>GS</td>
<td>Grassed Swale</td>
</tr>
<tr>
<td>ID</td>
<td>Infiltration Device</td>
</tr>
<tr>
<td>SB</td>
<td>Sediment Basin</td>
</tr>
<tr>
<td>SWW</td>
<td>Stormwater Wetland</td>
</tr>
<tr>
<td>WP</td>
<td>Wet Detention</td>
</tr>
</tbody>
</table>

The P.E.S. values obtained for the BMP types EDD, GS, and WD for their perceived effectiveness in removing pollutants are found to be very similar for the three groups. However, these groups show varying P.E.S. values for the BMP types ID, SB, SWW, and WP (Figure 4.17). Here again, the bachelors’ group gave a high P.E.S. to all the BMPs which differ from the certificates’ group P.E.S., who gave a low P.E.S.
Analysis of Q-21: How well does the stormwater BMP control pollutants from moving into the municipal stormwater system?

Figure 4.18: BMPs effectiveness in controlling pollutants from entering into municipal systems

EDD: Extended Dry Detention  SB: Sediment Basin  WP: Wet Pond
GS: Grassed Swale  SWW: Stormwater Wetland
ID: Infiltration Device  WD: Wet Detention

Question number 21 asks the respondents to rate the BMP types in respect to controlling the pollutants from moving into the municipal stormwater system. Their responses suggest that the P.E.S. for the three groups is quite similar (Figure 4.18). Overall, the perceptions of all the three groups are relatively equal except for BMP type WP which shows a great difference in the P.E.S. among the three groups.
Q-22: How well does the stormwater BMP control erosion?

Figure 4.19: BMPs effectiveness in controlling erosion

<table>
<thead>
<tr>
<th>BMP Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDD</td>
<td>Extended Dry Detention</td>
</tr>
<tr>
<td>GS</td>
<td>Grassed Swale</td>
</tr>
<tr>
<td>ID</td>
<td>Infiltration Device</td>
</tr>
<tr>
<td>SB</td>
<td>Sediment Basin</td>
</tr>
<tr>
<td>SWW</td>
<td>Stormwater Wetland</td>
</tr>
<tr>
<td>WD</td>
<td>Wet Detention</td>
</tr>
<tr>
<td>WP</td>
<td>Wet Pond</td>
</tr>
</tbody>
</table>

It can be noticed that among all the criterions established in the survey questionnaire for evaluating the efficiency of the BMPs question number 22, received the most scattered responses by the three categories of respondents. Figure 4.19 shows that there is consensus in the perceptions for BMP types EDD and GS, but for the rest of the BMPs (ID, SB, WP, WD and SWW) the three respondent groups gave contrasting views. This concludes that either the stormwater managers hold no clear perception on the effectiveness of these BMPs in controlling erosion or their perceptions actually differ from each other.
4.2.3.2. Perceived Effectiveness on “overall evaluation” based on respondents’ technical education

Q-27: How well does the stormwater BMP improve the general quality of water leaving the site?

Figure 4.20: BMPs evaluation in improving the general quality of water leaving the site

EDD: Extended Dry Detention  
GS: Grassed Swale  
ID: Infiltration Device  
SB: Sediment Basin  
SWW: Stormwater Wetland  
WD: Wet Detention  
WP: Wet Pond

Question 27 of the survey asked the respondents to respond to how well the stormwater BMP improves the general quality of water leaving the site. All the BMPs under review received high P.E.S. by the three groups except the BMP type GS that received the lowest P.E.S. from all three. Interestingly in this analysis the certificate group and technical classes group have similar perceptions as the lines for their responses coincide. Also notice that in this criterion again the BMP type WP received varied responses.
Q-28: How well does the stormwater BMP increase the water quality of the municipal water system?

![Graph](image)

**Figure 4.21:** BMPs evaluation in increasing the water quality of municipal water system

EDD: Extended Dry Detention  
GS: Grassed Swale  
ID: Infiltration Device  
SB: Sediment Basin  
SWW: Stormwater Wetland  
WD: Wet Detention  
WP: Wet Pond

There is an overall consensus among the three groups of respondents that the surveyed BMPs help to increase the quality of the water leaving the site (Figures 4.21). The exception is the BMP type WP which is ranked relatively low by the respondents’ with certificates.
Analysis of Q-29: How well does the stormwater BMP improve the aesthetic quality to the site?

Figure 4.22: BMPs evaluation in its effectiveness for improving the aesthetics of the site

EDD: Extended Dry Detention
GS: Grasped Swale
ID: Infiltration Device
SB: Sediment Basin
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond

In question #29 (how well does the stormwater improve the aesthetic quality of the site) the respondents of the three groups held similar perceptions on the effectiveness of the BMP types EDD, GS, and WP (Figure 4.22) and ranked them similarly (P.E.S. ranging between 4.5 to 7). For the remaining four BMPs (ID, SB, WD, and SWW), the P.E.S. given by the respondents of the bachelors degree group and the respondents of certificate group vary quite a lot. The highest P.E.S. value received from the bachelors’ degree group is 5 where as the highest value of P.E.S. from the certificates group is only 3. It can be said that the respondents’ with certificates ranked these BMPs relatively low, concluding that these two groups hold varying perceptions on the effectiveness of these BMP types in improving the aesthetics of the site.
Q-30: How well does the stormwater BMP achieve its intended objective?

![Figure 4.23: BMP's evaluation in achieving its intended objectives](image)

EDD: Extended Dry Detention  
GS: Grassed Swale  
ID: Infiltration Device  
SB: Sediment Basin  
SWW: Stormwater Wetland  
WD: Wet Detention  
WP: Wet Pond

The results in figure 4.23 for the “overall evaluation” criterion regarding the effectiveness of BMP in achieving its intended objectives show that all the three respondents perceived the BMPs similarly and ranked the BMPs high (P.E.S. > 5). In this criterion two uncommon trends are observed. First, the BMP types ID and SB received P.E.S. of 7 (that is 100%) by the respondents with bachelors' degree. Secondly, this is the only criterion for which the BMP type WP received similar P.E.S. values by all the three groups of respondents. The perceived effectiveness ratings for WP are quite different by the 3 groups in all the other 8 criteria of “site specific” and “overall evaluation”.

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Analysis of the BMPs P.E.S. by each group

The P.E.S. results for the seven BMP types for all the 9 criterions of “site specific efficiency” and “overall evaluation” are plotted separately for each group of respondents (See Figures 4.24-4.26). The intent of these groups is to draw comparative analysis between the P.E.S. of a BMP in the 9 criterions judged by respondents with similar technical training, illustrating prominent perceptions per the respondent’s training level.

![Figure 4.24: BMPs Perceived Effectiveness by respondents with Bachelor's degree](image)

Overall respondents with a Bachelor’s degree gave higher P.E.S. to most BMPs in the 9 criterions. The exception to this is the BMP type ID which received lower P.E.S in its ability in removing trash/debris and controlling erosion (receiving an average P.E.S. of 4.0 and 2.2 respectively). BMP type SB received the highest P.E.S. in the 9 criterions by this group. The BMP that received highest P.E.S. is SWW.
The respondents with technical classes also gave high P.E.S. to all BMPs in the 9 criterions. Notice that figure 4.25 and figure 4.24 show similar trends indicating that the Bachelor and technical training groups hold similar perceptions. However, BMP type ID is the exception to this similarity. It received varying responses in questions 19 and 22 which deal with the ability of the BMP to remove “trash/debris” and “control erosion”. The Bachelors group gave low P.E.S. to BMP type ID in these two criterions, where as the technical classes group gave it a high P.E.S. Overall, this group gave the highest P.E.S. to BMP type ID.
Figure 4.26 shows the P.E.S. results of the BMP perception study of the certificate group. Notice that figure presents a graph with a large spread of P.E.S. indicating that the respondents in this group vary in their perceptions. This group gave relatively low P.E.S. to the BMP type WP in almost all criterions which is contrary to the responses given by the other two groups where WP was given a high P.E.S. in most of the 9 criteria.

4.2.3.3. Overall observations:

In evaluating the effectiveness of BMPs with respect to respondents’ technical training, it is noticed that respondents with Bachelors’ degree and Technical classes responded similarly, where as the category of respondents with certificates showed varied and often varying results. Figure 4.26 presents a larger spread indicating that the respondents in this group do not hold similar views on the effectiveness of these BMPs.
where as figure 4.24 and 4.25 illustrated similarity in the perceptions of respondents. Moreover, the results for BMP type WP has the most varied spread (See figures 4.15-4.22), thus making it harder to get a valid effectiveness score. This may indicate that the certificate group maybe misled in their perception of the effectiveness of the BMP type WP. Overall, in the 9 criteria, it is noticed that the three groups hold strong consensus on the P.E.S. for the BMP types EDD, GS, and WD (see Figures 4.15-4.23). Also, notice that the bachelors and certificate groups have varying perceptions about the effectiveness of the BMP types ID and SB (see Figures 4.24-4.26) concluding that the education level of the respondents may have influenced the perceived effectiveness of these BMPs.

4.2.4. Task 3: analysis of cost of installation and yearly maintenance

The estimated installation and annual maintenance costs of BMPs commonly found in northern Utah are shown to analyze their budgetary requirements. This analysis includes only those BMP types for which at least 3 samples are obtained in the survey. Smaller sample sizes (2 and 1) are considered too small to be representative. Further, to establish consistency between our selected BMPs (that ranged from a sample of 3 to a sample of 46) the results are compiled as a percentage response for each cost category, totaling to 100%. This enables us to establish a basis of comparison among the BMPs irrespective of their sample size. The results are illustrated in Figures 4.27-4.28.

The analysis indicates some interesting trends. Figure 4.27 illustrates that the size of the BMP directly affects its estimated cost of installation. BMPs relatively small in size have lower installation costs (e.g. Su), whereas larger BMPs have higher costs of installation (e.g. the BMP type DB). Some BMP types such as EDD, GS, RR, WD,
Figure 4.27: BMPs Installation cost

Figure 4.28: BMPs Maintenance cost

BD: Bio-Detention Basin
DB: Debris Basin
EDD: Extended Dry Detention
GS: Grassed Swale
ID: Infiltration Device
OWS: Oil Water Separator
RR: Rip-Rap
SB: Sediment Basin
SWW: Oil Water Separator
Su: Sump
SWW: Stormwater Wetland
WD: Wet Detention
WP: Wet Pond
SWW, and WP present quite a large range of installation costs (>20K to <100K). This variation can potentially be attributed to two reasons. First, the date of installation could be the cause of this variation, as our BMPs include samples installed as early as the 1970s' to more recent installations in 2006. Costs have, substantially increased over the years (refer to Table 4.3 illustrating the BMPs’ year of installation). Secondly, the varying sizes of the same BMP types can affect the installation costs.

Another observation is that facilities with higher installation costs also require higher maintenance costs. A careful analysis of figures 4.27 and 4.28 shows a similarity between the percentages of installation cost to maintenance cost. However, note that the maintenance cost is the yearly amount the city allocates to maintenance based on their availability of funds. It does not necessarily show the required cost of maintenance that would sufficiently maintain that particular BMP. For example a maintenance cost of $5000/year for the BMP type SWW is substantially low and often results in inadequate performance of the BMP. This is unfortunately found to be a common yearly maintenance cost allocated for this BMP in our research sample.
4.2.5. Task 4: comparative analysis of BMPs ability in removing debris and pollutants

![Bar chart comparing BMP effectiveness in removing trash/debris and pollutants](image)

Figure 4.29: Comparative analysis of BMPs effectiveness in removing trash/debris and pollutants

Task 4 compares the percentage of favorable responses\(^\text{10}\) to BMPs effectiveness in filtering trash/debris and removing pollutants (Q#19 and 20, survey questionnaire, Appendix A). This analysis is a follow up on Figures 4.4 and 4.5 in task 2 where the perceived effectiveness of BMPs in these two criteria is analyzed individually. These two criteria of efficiency are compared together to analyze if a respondents’ perception regarding a BMPs’ ability to that remove debris/trash, is consistent with its ability to remove pollutants. The analysis is limited to include only those BMP types for which a minimum sample of 4 are obtained in the survey. This is done to limit any bias that could arise due to the difference in a lower numbers of samples.

\(^{10}\) The term favorable response is used to refer collectively to the answer options “slightly well”, “well”, and “strongly well"
The first trend evident from the figure 4.29 is that all BMPs received high percentage of favorable responses except BMP type ID, which received the lowest percentages of 43% and 57% for the criterions of trash/debris and pollutants respectively. The second noticeable trend is that all the BMPs show almost equal effectiveness in removing trash/debris and pollutants (e.g., BMP type EDD received 86% of responses in favor of removing trash/debris and 77% of responses in favor of removing pollutants). This trend concludes that the respondents perceive that a BMP that removes trash/debris also removes pollutants and vice versa. In reality, these are two very different tasks. For example, BMP types WP, EDD, and WD all scored high in both criteria but BMP type EDD is intended to retain water and not to remove pollutants or trash (refer to Appendix C). On the other hand, BMP types ID and RR scored low on trash/debris removal, where this is their primary objective (refer to Appendix C). The lower percent score of these BMP types illustrate that they are not perceived to be performing as well as the other BMP types. The BMP type SB is ranked relatively high (87%) for trash/debris removal which corresponds with its design objectives.

This analysis draws two conclusions. First, the majority of respondents agreed that all the BMPs under review are performing well in removing both trash/debris and pollutants. Secondly, the respondents potentially have misconceptions leading them to view the majority of BMP types as efficient in removing both pollutants and trash/debris from stormwater.
Chapter 5
Summary, Conclusions, and Future directions

This chapter draws conclusions on the perceived effectiveness of stormwater Best Management Practices employed in northern Utah. Additionally, it presents a summary and direction for future research.

5.1. Summary

Stormwater runoff is identified as a critical issue for urbanized areas. On-site, structural BMPs are found to be one of the primary methods for managing this stormwater runoff. With the growing rate of urbanization in northern Utah this research cataloged and evaluated the perceived effectiveness of structural BMPs. The study is based on site visits and a survey answered by stormwater managers responsible for designing, maintaining and/or monitoring the sampled sites. The study included 23 cities in northern Utah that have been required to implement stormwater management by the EPA Phase I or II Rule. The results and analysis of the perceived effectiveness of different BMP types are discussed in depth in chapter 4.

5.2. Primary Findings by objective

As stated in the introduction (chapter 1), the objectives of this research are:

1. Compilation of a catalog of existing municipal sites in northern Utah with installed stormwater BMPs chosen through a random sampling method.
2. Analysis of the perceived effectiveness of the catalogued BMPs.
3. Analysis of the respondents’ (stormwater managers) perceptions to highlight whether technical education has an effect on their perceptions towards BMPs effectiveness and whether managers with similar training held common perceptions.
The following sections present the conclusions related to the last two objectives (2 & 3).

5.2.1. Overall Perceived Effectiveness

In the 23 cities researched, the following seven BMP types are found to be installed most in numbers: Wet Pond, Stormwater Wetland, Infiltration Device, Sediment Basin, Extended Dry Detention, Grass Swales, and Wet Detention. The BMP type Storm Water Wetland is perceived to be the most effective in all the criteria of the perceived effectiveness survey. Second to this are Wet Ponds and Extended Dry Detentions. Grass Swales received the lowest perceived effectiveness ratings among the seven commonly found BMP types. Infiltration Devices showed differing trends in its perceived effectiveness. The perceived effectiveness rating for the BMP type Infiltration Devices (ID) showed two dominant trends. Thirty percent of the respondents did not evaluate this BMP type (and answered as “do not know”) and 70% ranked its perceived effectiveness as high in all criteria. Because a substantial percentage (30%) of the sample is not evaluated, this concluded that a generalization on the perceived effectiveness of BMP type Infiltration Device for northern Utah should not be made.

Overall, it is observed that all the BMP types evaluated are perceived effective in seven of the nine criteria addressed. The two criteria in which they are not perceived effective are “controlling erosion” and in “improving the aesthetic of the site”. The criterion “controlling erosion” received fairly low perceived effectiveness ratings for all the seven BMP types. The results for the criterion “improving the aesthetic of the site” did not present a distinct trend because a high percentage (20-45%) of respondents opted to answer as “neutral”. The criterion that received the highest perceived effectiveness ratings for all the seven BMP types is “how well the BMP achieves its intended objectives”.

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5.2.2. Perceived effectiveness of BMPs in light of respondents’ technical training:

The comparative analysis of the perceived effectiveness ratings of each BMP type by the three common groups of respondents (grouped on the basis of their technical training) illustrated interesting trends.

The results showed that the respondents with similar technical training evaluated BMPs similarly. On the other hand, results showed differences in the perceived effectiveness among the three groups. In all the responses, the strongest difference is in the perceived effectiveness ratings given by the group with “Bachelors degree” and the group with “certificate”. Overall, the group with “Bachelors degree” perceived the BMPs to be performing better overall than the group with “certificate” level trainings. The group with “technical training” showed similar trends in their responses to the group with “bachelors’ degree”. Overall, in all the 9 criteria (questions) the three groups held a relative consensus on the perceived effectiveness of BMP types Extended Dry Detention, Grassed Swales, and Wet Detention and assigned them similar P.E.S. The three groups showed the strongest difference in the perceived effectiveness of Wet Ponds. The group with the “Bachelors degree” gave it the highest P.E.S of 4.9 the group with “Technical Training” 3.7 and the group with certificate the lowest score of 2.5. The results conclude that the respondents’ education level does influence their perceived effectiveness of the BMP types.

5.2.3. Overall conclusions for the study:

The perceived effectiveness results indicate that the future progress of stormwater BMPs in northern Utah is promising, particularly after the EPA Phase II Rule. Results showed a significant increase in the rate of installation of BMPs after the year 2000 (EPA Phase II came out in December 1999). A diverse sample size (20 types of structural stormwater BMPs) indicated that a variety of stormwater BMPs are being employed in
northern Utah. This may also be an indicator that the awareness towards stormwater BMPs is increasing. It is further noticed that BMP types that improve water quality (such as Oil Water Separators, Infiltration Devices, Green Roofs, Snouts, and Sediment Basins) are becoming more popular.

The study also compared and analyzed the cost of installation and the annual maintenance cost of the surveyed BMPs in Section 4.2.4. The first conclusion is that the BMPs with a higher cost of installation also showed higher maintenance cost. Second, it is noticed that the size of BMPs directly affected their cost of installation. Additionally, the maintenance costs are usually constrained due to the lack of available funds. On some BMP types, such as Storm Water Wetlands, the expenditure on maintenance is often far less than what is required for proper performance.

Lastly, a comparative analysis of the perceived effectiveness of BMPs in removing debris/trash and pollutants concluded that the majority of the respondents perceived that a BMP which removed debris/trash also removed pollutants and vice versa. Unfortunately, this is often a misconception.

5.3. Direction for future research

Based on the findings of this research, the following possibilities for future work are proposed. Future research studies can conduct quantitative actual effectiveness tests on each of these BMP types identified in this study. This would allow comparisons to be drawn among the actual effectiveness results of these BMP types and analyze which BMP types achieve higher effectiveness ratings in those tests. Quantitative effectiveness is the effectiveness determined based on actual performance and site data rather than their perceived performance. The results of these quantitative effectiveness tests can also be compared to the perceived effectiveness results. This will help in determining how close
the perceived effectiveness is to the quantitative effectiveness and disclose any misconceptions held by stormwater managers.

Secondly, a similar perceived effectiveness study can be focused on stormwater BMPs on commercial sites. This will show the BMP types which are popular on commercial sites, their cost of installation and maintenance, and their perceived effectiveness. These findings can also be compared with the current study to see how stormwater managers evaluate the perceived effectiveness of commercial sites versus municipal sites.
References


Appendix A: General construction permit, (2003), Environmental Protection Agency (EPA), National Pollutant Discharge Elimination System (NPDES), NPDES Glossary, Best Management Practices (BMPs). Accessed online date: 07/30/06 (http://cfpub1.epa.gov/npdes/glossary.cfm?program_id=0)


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U.S. EPA., (2005c), Stormwater Phase II Final Rule: Small MS4 Stormwater Program Overview Environmental Protection Agency, Office of Water. Fact Sheet2-0 EPA 833-F-00-002.

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Appendix A
Questionnaire
This survey is funded by the USU New Faculty Research grant. Its objective is two fold. Both objectives deal with exploratory research of on-site stormwater Best Management Practices (BMPs) in North Eastern Utah: first, to compile a catalog of implementation of stormwater Best Management Practices (BMPs), and secondly, to survey their perceived effectiveness.

This survey consists of three parts.

Part 1: General information.

Part 2: Perceived Effectiveness

Part 3: Your background

Your opinions are very important and we encourage you to respond to all of the questions. *Your responses will be kept completely confidential, therefore, please do not write your name on the survey.*

Thank you so very much for your valuable time!

PART 1
GENERAL SITE INFORMATION

Site Name: ________________________________

Address: ________________________________

Date BMP installed or built: ________________________________

Today’s date: ________________________________

BMP maintained by: ________________________________

Estimated area of the BMP site: ________________________________
1. Draw a quick sketch of the layout of the site and its approximate size:

Please choose the answer set that best answers the following questions pertaining to the above site. Example: 0% - 5% 

2. What is the approximate slope (in percentage) of the site?

- 0% - 5%  
- 6% - 20%  
- 20% - 40%  
- Over 40%  

3. What is the predominant soil texture of the site?

- Clay  
- Sand  
- Loam  
- Clay loam  
- Sand loam  
- Silt soil  
- Other:  

4. What type(s) of stormwater BMP(s) are located on the site? (Mark all that apply)

- a) Wet detention basin  
- b) Storm water wetland  
- c) Sand filter  
- d) Bio-retention basin  
- e) Grassed swales  
- f) Extended dry detention basin  
- g) Filter strips  
- h) Infiltration devices  
- i) Oil/water separators  
- j) Rip-rap  
- k) Sediment basin  
- l) Surface sand filter system  
- m) Wet pond  
- Other (s):  

- o):
5. What is the surface material of the stormwater BMP(s)?

<table>
<thead>
<tr>
<th>BMP</th>
<th>BMP</th>
<th>BMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian vegetation</td>
<td>Riparian vegetation</td>
<td>Riparian vegetation</td>
</tr>
<tr>
<td>Grass</td>
<td>Grass</td>
<td>Grass</td>
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<tr>
<td>Phragmites</td>
<td>Phragmites</td>
<td>Phragmites</td>
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<tr>
<td>Concrete</td>
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<td>Concrete</td>
</tr>
<tr>
<td>Sand</td>
<td>Sand</td>
<td>Sand</td>
</tr>
<tr>
<td>Pebble stone</td>
<td>Pebble stone</td>
<td>Pebble stone</td>
</tr>
</tbody>
</table>

Other: ________________

6. What is the primary purpose of the on-site stormwater BMP(s)?

<table>
<thead>
<tr>
<th>BMP</th>
<th>BMP</th>
<th>BMP</th>
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</thead>
<tbody>
<tr>
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<td>Pollutant removal</td>
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</tr>
<tr>
<td>Retain water</td>
<td>Retain water</td>
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</tr>
<tr>
<td>Detain water</td>
<td>Detain water</td>
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</tr>
<tr>
<td>Decrease runoff</td>
<td>Decrease runoff</td>
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</tr>
<tr>
<td>Erosion</td>
<td>Erosion</td>
<td>Erosion</td>
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<tr>
<td>Sediment control</td>
<td>Sediment control</td>
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</tbody>
</table>

Other: ________________

7. What do you believe it would have cost to build this stormwater BMP(s)?

<table>
<thead>
<tr>
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<th>BMP</th>
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<tbody>
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<td>&gt; 100 K</td>
</tr>
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<td>61 - 100 K</td>
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<td>41 - 60 K</td>
<td>41 - 60 K</td>
</tr>
<tr>
<td>21 - 40 K</td>
<td>21 - 40 K</td>
<td>21 - 40 K</td>
</tr>
<tr>
<td>&lt; 20 K</td>
<td>&lt; 20 K</td>
<td>&lt; 20 K</td>
</tr>
</tbody>
</table>

Other: ________________

Other: ________________

Other: ________________
8. How much do you believe it costs to maintain this stormwater BMP(s) annually?

<table>
<thead>
<tr>
<th>BMP</th>
<th>BMP</th>
<th>BMP</th>
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</thead>
<tbody>
<tr>
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<td>&gt; 20K</td>
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<td>O</td>
<td>16-19 K</td>
</tr>
<tr>
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<td>O</td>
<td>11-15 K</td>
</tr>
<tr>
<td>6-10 K</td>
<td>O</td>
<td>6-10 K</td>
</tr>
<tr>
<td>&lt; 5 K</td>
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<td>&lt; 5 K</td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td>Other:</td>
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</tbody>
</table>

9. What type of flood event is the stormwater BMP(s) designed for?

<table>
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<tr>
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<th>BMP</th>
<th>BMP</th>
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<tr>
<td>50-yr storm</td>
<td>O</td>
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<tr>
<td>100-yr storm</td>
<td>O</td>
<td>100-yr storm</td>
</tr>
<tr>
<td>300-yr storm</td>
<td>O</td>
<td>300-yr storm</td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td>Other:</td>
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</tbody>
</table>

Please circle the appropriate Yes/No response:

10. Was this particular stormwater BMP required by state and/or local laws and regulations?

<table>
<thead>
<tr>
<th>BMP</th>
<th>BMP</th>
<th>BMP</th>
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<tbody>
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<td>O</td>
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</tr>
<tr>
<td>No</td>
<td>O</td>
<td>No</td>
</tr>
</tbody>
</table>

PART 2
PERCEIVED EFFECTIVENESS OF STORMWATER BMP

The purpose of this section of the survey is to develop a better understanding of the perception of stormwater Best Management Practices (BMPs), including effectiveness and applicability considerations.

Stormwater Best Management Practice (BMPs) are defined by the City of Poway, California (2004) as any schedule of activities, prohibitions of practices, general good housekeeping practices, pollution prevention and educational practices, maintenance procedures, structural treatment BMPs, and other management practices to prevent or reduce to the maximum extent practicable the discharge of pollutants directly or indirectly to receiving waters.
Based on your knowledge or beliefs, please answer the following questions as best as you can by marking the appropriate number along the scale. If you are not sure, you may check the box "Don't know".

A. General qualities of stormwater BMPs

11. "The cost of redirecting stormwater OFF-site into municipal stormwater systems is becoming progressively higher in northern Utah."

12. "When properly done, stormwater BMPs require expensive maintenance programs to maintain their effectiveness in retaining water on-site."

13. "Properly done, stormwater BMPs require relatively inexpensive maintenance programs to maintain their effectiveness in filtering dirty water."

14. "Properly done, stormwater BMPs require expensive maintenance programs to maintain an aesthetically pleasing appearance."

15. "The use of stormwater BMPs requires more maintenance time than directing stormwater off-site with conventional methods."

16. "The use of stormwater BMPs requires less maintenance cost than directing stormwater off-site with conventional methods."

17. "The benefits of having and maintaining on-site stormwater BMPs out-weigh the initial costs?"
B. Efficiency of the stormwater BMP(s) on THIS site

<table>
<thead>
<tr>
<th>BMP</th>
<th>BMP</th>
<th>BMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Poorly</td>
<td>Poorly</td>
<td>Slightly Poorly</td>
</tr>
<tr>
<td>Very Poorly</td>
<td>Poorly</td>
<td>Slightly Poorly</td>
</tr>
<tr>
<td>Don't Know</td>
<td>Don't Know</td>
<td>Don't Know</td>
</tr>
</tbody>
</table>

18. How well does this stormwater BMP reduce the amount of stormwater entering the municipal stormwater system?

19. How well does the stormwater BMP filter trash and debris?

20. How well does the stormwater BMP remove pollutants?

21. How well does the stormwater BMP control pollutants from moving into the municipal stormwater system?

22. How well does the stormwater BMP control erosion?
C. Evaluation of stormwater BMP

<table>
<thead>
<tr>
<th>Very Poorly</th>
<th>Poorly</th>
<th>Slightly Poorly</th>
<th>Neutral</th>
<th>Slightly Well</th>
<th>Well</th>
<th>Strongly Well</th>
<th>Don't Know</th>
</tr>
</thead>
</table>

27. How well does the stormwater BMP improve the general quality of water leaving the site?

28. How well does the stormwater BMP increase the water quality of the municipal water system?

29. How well does the stormwater BMP improve the aesthetic quality to the site?

30. How well does the stormwater BMP achieve its intended objective?

D. The applicability of the stormwater BMP(s) within Northern Utah.

<table>
<thead>
<tr>
<th>Very Poorly</th>
<th>Poorly</th>
<th>Slightly Poorly</th>
<th>Neutral</th>
<th>Slightly Well</th>
<th>Well</th>
<th>Strongly Well</th>
<th>Don't Know</th>
</tr>
</thead>
</table>

23. Is the stormwater BMP appropriate for the **climate** of the region?

24. Is the stormwater BMP appropriate for the **existing slope** of the site?

25. Is the stormwater BMP appropriate for the **soil conditions** of the site?

26. Is the stormwater BMP appropriate for the **surrounding surface material** of the site?
Part 3
Background:

A. Familiarity with stormwater Stormwater BMP design

Please mark all that apply:

31. Other than the site(s) surveyed today, have you been involved in the design and/or maintenance of other stormwater BMPs?

   Yes  ☐
   No   ☐

   If yes please give location and explain involvement__________________________

32. What is your level of involvement with this (these) stormwater BMP(s)?

   It is a large part of my full time job  ☐
   It is a small part of my full time job  ☐
   It is one part of my job                ☐
   Other__________________________

33. What is your training with regards to stormwater BMPs?

   It was part of a bachelor’s degree  ☐
   It was part of a master’s degree    ☐
   I have taken technical classes      ☐
   I have a certificate                ☐
   Other__________________________

34. Please feel free to write any additional comments you would like to make about this research survey, the subject of perceived effectiveness, and/or stormwater Best Management Practices (BMPs) in general.

__________________________________________________________
__________________________________________________________
__________________________________________________________
__________________________________________________________

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You are now finished with this survey.

Thank you very much, once again, for participating in this study!

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Appendix B
Urbanized area Maps for Utah
A.1. Urbanized area map for Salt Lake City, UT
(Urbanized Area Map Results for Utah, United States Environmental Protection Agency (USEPA), Accessed online (06/06/06)
A.2. Urbanized area map for Ogden-Layton, UT
(Urbanized Area Map Results for Utah, United States Environmental Protection Agency (U.S.EPA), Accessed online (06/06/06)
A.3. Urbanized area map for Logan, UT
(Urbanized Area Map Results for Utah, United States Environmental Protection Agency (U.S.EPA), Accessed online (06/06/06)
Appendix C
BMP Objectives
Extended Dry Detention

Description:

Extended Dry Detention are basins whose outlets have been designed to detain stormwater runoff for some minimum time (e.g., 24 hours) to allow particles and associated pollutants to settle. Unlike wet ponds or wet detention, these facilities do not have a large permanent pool of water.

Intended objectives:

Structural stormwater management practices achieve four broad resource protection goals. These are flood control, channel protection, ground water recharge, and pollutant removal. Dry detention basins can provide flood control and channel protection, as well as some pollutant removal. They reduce peak flows to downstream drainage systems and allow pollutants to settle out of the water column (Tichy, J., 2006).

Effectiveness:

Dry ponds provide moderate but variable removal of particulate pollutants, such as sediment, phosphorous, and organic carbon, but provide negligible removal of soluble pollutants. (U.S. EPA., 1999).

A few studies are available on the effectiveness of dry detention ponds. Typical removal rates, as reported by Schueler (1997), are as follows:

Total suspended solids: 61%
Total phosphorus: 19%
Total nitrogen: 31%
Nitrate nitrogen: 9%
Metals: 26%-54%
(U.S. EPA., 1999).

Flood control

Prevent increased flooding downstream of pond, and therefore help to prevent channel erosion and downstream sedimentation (U.S. EPA., 1999).
Ground water recharge

Dry detention ponds can provide infiltration to groundwater, thus creating a more natural water balance in a developed area (i.e. maintenance of base flows) (U.S. EPA., 1999).

Limitations:

Dry detention ponds have only moderate pollutant removal when compared to other structural stormwater practices, and they are ineffective at removing soluble pollutants. (U.S. EPA., 1999).

**Grassed Swales**

**Description**

Grassed swale are vegetated, open-channel management practices designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows along these channels, it is treated through vegetation slowing the water to allow sedimentation, filtering through a subsoil matrix, and/or infiltration into the underlying soils (U.S. EPA., 1999).

**Intended objective:**

Structural stormwater management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Grassed swales perform two of these functions ground water recharge and pollutant removal (U.S. EPA., 1999).

**Ground Water Recharge**

Grassed channels and dry swales can provide some ground water recharge as infiltration is achieved within the practice. Wet swales, however, generally make little, if any, contributions to ground water recharge. Infiltration is impeded by the accumulation of debris on the bottom of the swale (U.S. EPA., 1999).

**Pollutant Removal**

Few studies are available regarding the effectiveness of grassed channels (Table 2). The data suggest relatively high removal rates for some pollutants, negative removals for some bacteria, and fair performance for phosphorous. One study of available performance data (Schueler, 1997) estimates the removal rates for grassed channels as:
<table>
<thead>
<tr>
<th>Total Suspended Solids:</th>
<th>81%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphorous:</td>
<td>29%</td>
</tr>
<tr>
<td>Nitrate Nitrogen:</td>
<td>38%</td>
</tr>
<tr>
<td>Metals:</td>
<td>14% to 55%</td>
</tr>
<tr>
<td>Bacteria:</td>
<td>-50%</td>
</tr>
</tbody>
</table>

(U.S. EPA., 1999).

Limitations

Grassed swales have some limitations.

- Grassed swales cannot treat a very large drainage area.
- Wet swales may become a nuisance due to mosquito breeding.
- If designed improperly (e.g., if proper slope is not achieved), grassed channels will have very little pollutant removal.

(U.S. EPA., 1999).

Stormwater Wetland

Description

Stormwater wetlands are structural practices that incorporate wetland plants into the design. As stormwater runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake within the practice. Wetlands are among the most effective stormwater practices in terms of pollutant removal. They also offer aesthetic and habitat value (U.S. EPA., 1999).

Intended objective:

Structural stormwater management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Wetlands can provide flood control, channel protection, and pollutant removal (U.S. EPA., 1999).

Flood Control

One objective of stormwater management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Wetlands can easily be designed for flood control by providing flood storage above the level of the permanent pool (U.S. EPA., 1999).
Channel Protection

When used for channel protection, wetlands have traditionally controlled the 2-year storm. It appears that this control has been relatively ineffective, and research suggests that control of a smaller storm may be more appropriate (MacRae, 1996).

Ground Water Recharge

Wetlands cannot provide ground water recharge. The build-up of debris at the bottom of the wetland prevents the movement of water into the subsoil (U.S. EPA., 1999).

Pollutant Removal

Wetlands are among the most effective stormwater management practices at removing stormwater pollutants. A wide range of research is available to estimate the effectiveness of wetlands. Wetlands have high pollutant removal rates, and are articularly effective at removing nitrate and bacteria. Table 2 provides pollutant removal data derived from the Center for Watershed Protections's National Pollutant Removal Database for Stormwater Treatment Practices (Winer, 2000) (U.S. EPA., 1999).

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Stormwater Treatment Practice Design Variation</th>
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<tbody>
<tr>
<td></td>
<td>Shallow Marsh</td>
</tr>
<tr>
<td>TSS</td>
<td>83±51</td>
</tr>
<tr>
<td>TP</td>
<td>43±40</td>
</tr>
<tr>
<td>TN</td>
<td>26±49</td>
</tr>
<tr>
<td>NOx</td>
<td>73±49</td>
</tr>
<tr>
<td>Metals</td>
<td>36-85</td>
</tr>
<tr>
<td>Bacteria</td>
<td>76±1</td>
</tr>
</tbody>
</table>

Limitations

Some features of stormwater wetlands that may make the design challenging include the following: Each wetland consumes a relatively large amount of space, making it an impractical option on some sites.

- Improperly designed wetlands might become a breeding area for mosquitoes if improperly designed.
- Wetlands require careful design and planning to ensure that wetland plants are sustained after the practice is in place.
- It is possible that stormwater wetlands may release nutrients during the non-growing season.
- Designers need to ensure that wetlands do not negatively impact natural wetlands or forest during the design phase.
- Wetland vegetation must be properly managed to remain effective. Often it must be harvested.
(U.S. EPA., 1999).

**Wet ponds & Wet Detention:**

**Description**

Wet ponds & Wet Detention are constructed basins that have a permanent pool of water throughout the year. Ponds treat incoming stormwater runoff by allowing particles to settle and algae to take up nutrients. The primary removal mechanism is settling as stormwater runoff resides in this pool, and pollutant uptake, particularly of nutrients, also occurs through biological activity in the pond. Traditionally, these have been widely used as stormwater best management practices (U.S. EPA., 1999).

**Intended objective:**

Structural stormwater management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Wet ponds and wet detention can provide flood control, channel protection, and pollutant removal (U.S. EPA., 1999).

By capturing and retaining runoff during storm events, wet ponds control both stormwater quantity and quality. The pond’s natural physical, biological, and chemical processes then work to remove pollutants. Sedimentation processes remove particulates, organic matter, and metals, while dissolved metals and nutrients are removed through biological uptake. In general, a higher level of nutrient removal and better stormwater quantity control can be achieved in wet detention ponds than can be achieved with other Best Management Practices (BMPs), such as dry ponds, infiltration trenches, or sand filters (U.S. EPA., 1999).

**Pollutant Removal**

Wet ponds are among the most effective stormwater management practices at removing stormwater pollutants. A wide range of research is available to estimate the effectiveness of wet ponds. Table 2 summarizes some of the research completed on wet pond removal efficiency. Typical removal rates, as reported by Schueler (1997a) are:

- Total Suspended Solids: 67%
- Total Phosphorous: 48%
- Total Nitrogen: 31%
- Nitrate Nitrogen: 24%
- Metals: 24.73%
Bacteria: 65%

Limitations:

- If improperly located, their construction may cause loss of wetlands or forest.
- They are often inappropriate in dense urban areas because each pond is generally quite large.
- Their use is restricted in arid and semi-arid regions due to the need to supplement the permanent pool.

(U.S. EPA., 1999).

Infiltration Device:

Description

An infiltration device captures a volume of runoff and infiltrates it into the ground. Infiltration devices can be designed to infiltrate this captured water into the ground over a period of several hours or several days (U.S. EPA., 1999).

Intended objective:

Structural management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Infiltration basins can provide ground water recharge and pollutant removal (U.S. EPA., 1999).

Ground Water Recharge

Infiltration basins recharge the ground water because runoff is treated for water quality by filtering through the soil and discharging to ground water.

Pollutant Removal

Very little data are available regarding the pollutant removal associated with infiltration devices. It is generally assumed that they have very high pollutant removal because none of the stormwater entering the practice remains on the surface. Schueler (1987) estimated pollutant removal for infiltration basins based on data from land disposal of wastewater. The average pollutant removal, assuming the infiltration basin is sized to treat the runoff from a 1-inch storm, is:

TSS 75%

Phosphorous 60-70%

Nitrogen 55-60%
Metals 85-90%

Bacteria 90%

These removal efficiencies assume that the infiltration basin is well designed and maintained (U.S. EPA., 1999).

Limitations

Although infiltration devices can be useful practices, they have several limitations. Infiltration devices are not generally aesthetic practices, particularly if they clog. If infiltration basins are designed and maintained so that standing water is left for no more than 3 days, mosquitoes should not be a problem. However, if an infiltration basin becomes clogged and takes 4 or more days to drain, the basin could become a source for mosquitoes. In addition, these practices are challenging to apply because of concerns over ground water contamination and sufficient soil infiltration. Finally, maintenance of infiltration practices can be burdensome, and they have a relatively high rate of failure.

Sedimentation Basin

Description

Sediment basins are man-made depressions in the ground where runoff water is collected and stored to allow suspended solids to settle out. They are used in conjunction with erosion control measures to prevent off-site sedimentation. They may consist of a dam, barrier or excavation, a principal and emergency outlet structure, and water storage space. Their primary purpose is to trap sediment and other course material. Secondary benefits can include runoff control and preserving the capacity of downstream reservoirs, ditches, canals, diversions, waterways and streams.

Intended objectives:

Properly designed and maintained sediment basins can be very effective in preventing sedimentation of downstream areas. Coarse and medium size particles and associated pollutants will settle out in the basin. Suspended solids, attached nutrients, and absorbed non-persistent pesticides may break down before proceeding downstream. Because sediment basins also retain water, they may help recharge the ground water. Sediment basins are not as effective in controlling fine particles (i.e. silt, clay) as sand and other coarse particles.
Reference:

MacRae, C. 1996. Experience from morphological research on canadian streams: Is control of the two-year frequency runoff event the best basis for stream channel protection? In Effects of Watershed Development and Management on Aquatic Ecosystems. American Society of Civil Engineers, Snowbird, UT


