2015-ORIL 7
Storm Water Best Management Practices for Local Roadways

Prepared by:

Gresham, Smith and Partners
In collaboration with Geosyntec Consultants

Prepared for:
Ohio's Research Initiative for Locals
The Ohio Department of Transportation,
Office of Statewide Planning & Research

State Job Number 134990

September 2015

Final Report

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/OH-2015/31		
4. Title and Subtitle		5. Report Date
Storm Water Best Management Practices for Local Roadways		**September 2015**
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
Gresham, Smith & Partners **in collaboration with Geosyntec Consultants**		
9. Performing Organization Name and Address		10. Work Unit No. (TRAIS)
Gresham, Smith and Partners **155 E. Broad Street, Suite 900** **Columbus, OH 43215**		11. Contract or Grant No. **SJN 134990**
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered
Ohio Department of Transportation **1980 West Broad Street, MS 3280** **Columbus, Ohio 43223**		**09/09/2014 -09/092015** 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Local communities and the Ohio Department of Transportation (ODOT) are required by the Ohio Environmental Protection Agency's (Ohio EPA) statewide Construction General Permit for Storm Water Discharges OHC000004 (CGP) to select, design, construct, operate and maintain post-construction storm water best management practices (BMPs) for new and redevelopment roadway projects statewide. Through the research conducted, a BMP selection tool, BMP case studies, and an annotated bibliography were developed to assist Locals with identification and BMP selection. The BMP tool is intended to facilitate the understanding of BMP requirements and considerations so Locals and designers can select, plan, and construct appropriate post-construction storm water BMPs. These research products will help Locals improve implementation of appropriate BMPs by providing resources to understand BMP characteristics with regard to limited space requirements, on-going maintenance, aesthetics, safety considerations, and other potential impacts associated with project delivery.

17. Keywords		18. Distribution Statement	
post-construction storm water, storm water best management practice (BMP), local roadways, BMP selection tool		**No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161**	
19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	**Unclassified**	**106**	

Form DOT F 1700.7 (8-72) **Reproduction of completed pages authorized**

2015-ORIL 7
Storm Water Best Management Practices for Local Roadways

Prepared by:
Gresham, Smith and Partners
In collaboration with Geosyntec Consultants

September 2015

Prepared in cooperation with the Ohio Department of Transportation
and the U.S. Department of Transportation, Federal Highway Administration

ACKNOWLEDGMENTS

Technical Advisory Committee

Jeff Agricola, City of Springdale
Greg Butcher, P.E., Violet Township Engineer/ORIL Board
Jennifer Eismeier, Mill Creek Watershed Council
Tim Gilday, P.E., P.S., Hamilton County
Hans Gucker, P.E., ODOT – Construction Administration
Becky Humphreys, P.E., ODOT – Hydraulic Engineering
Terry Huxel, City of Wyoming
Christine Jonke, P.E., City of Akron
Bruce Koehler, OKI Regional Council
Rui Liu, Ph.D. P.E., Kent State University
Todd Long, P.E., Hamilton County
Michael Miller, Ph.D, University of Cincinnati
Jon Prier, P.E., ODNR
Michael Toedecki, P.E., City of Akron
Hassan Zahran, P.E., City of Columbus/ORIL Board

Additional Contributors

Tim Burkert, P.E., Mahoning County
Justin Czekaj, P.E., City of Aurora
Kirby Date, AICP, Cleveland State University / Ohio Lake Erie Commission
Kathy Dorman, P.E., City of Mason
Cyndee Gruden, Ph.D, P.E., University of Toledo
Doug Gruver, P.E., ODOT – District 8
Kathryn Gruver, P.E., HDR Inc.
Kent Halloran, P.E., Ohio State University
Jennifer Heard, City of Cleveland, DPC
Katherine Holmok, ASLA, EDG Consultants
Tom Komlanc, P.E., Ohio State University
Sandra Kosek-Sills, Ph.D, Ohio Lake Erie Commission
Chuck Petty, P.E., Warren County
Eric Pottenger, Butler County Storm Water District
Dave Ritter, NE Ohio Regional Sewer District
Robert Rosen, P.E., ODOT – District 4
Jason Sanson, P.E., City of Columbus
Marilyn Sferra Kenner, P.E., Boardman Township
Christopher Sherk, P.E., CH2M Hill
Jason Sisco, P.E., City of Bowling Green
Nick Smith, P.E., Boardman Township
Andy Stepnick, P.E., City of Toledo
Tom Tucker, P.E., City of Wadsworth
Doug Turney, P.E., EMH&T Inc.
John Woolard, Mahoning County
Glen Yoder, P.E., Ohio State University

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

BMP	Best Management Practice
CGP	Construction General Permit
EPA	Environmental Protection Agency
GS&P	Gresham, Smith and Partners
L&D	Location and Design Manual
MS4	Municipal Separate Storm Sewer System
O&M	Operations and Maintenance
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
ORIL	Ohio Research Initiative for Locals
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids

1 INTRODUCTION

Local communities and the Ohio Department of Transportation (ODOT) are required by the Ohio Environmental Protection Agency's (Ohio EPA) statewide Construction General Permit for Storm Water Discharges *OHC000004* (CGP) to select, design, construct, operate and maintain post-construction storm water best management practices (BMPs) for new and redevelopment roadway projects statewide. In addition to these requirements, ODOT and the local communities may be affected by regulatory trends that require or encourage the implementation of BMPs to reduce the volume of runoff through infiltration practices (e.g., match predevelopment runoff volumes), control peak flow rates or provide flood control for large storm events (e.g., match post-development peak flow rates to predevelopment peak flow rates), and address storm water quality impacts from existing development (e.g., retrofit projects to improve water quality associated with redevelopment projects).

A challenge facing many Ohio municipal, county and state roadway engineers is the lack of sufficient Ohio-specific guidance on post-construction storm water BMPs for linear roadway projects that considers the constraints faced by local jurisdictions, urbanized and rural areas. The Ohio Department of Natural Resources (Ohio DNR) Rainwater and Land Development Manual, which the Ohio EPA CGP references, includes design guidance for post-construction water quality controls but does not provide guidance focused specifically towards linear roadway applications.

ODOT's Location and Design (L&D) Manual, Volume 2 serves as the primary in-state guidance for selecting and designing post-construction BMPs that are specific to roadway applications. The need for state-specific BMP guidance for linear roadway projects, particularly for local that can be easily accessed by local transportation officials, was the driving force behind this research project.

The research products, particularly the BMP selection tool, facilitate early planning and discussion to consider the pros and cons of each BMP type. Beyond BMP selection, the BMP tool is intended to facilitate the understanding of BMP requirements and considerations so Locals and designers can plan accordingly. Standardizing documentation through use of Ohio-specific tools (i.e., within the BMP selection tool) will help address potential roadblocks and work towards improved post-construction BMP design, implementation, and maintenance. These research products will help Locals facilitate successful implementation of BMPs by providing resources to understand BMP characteristics with regard to footprint requirements, on-going maintenance, aesthetics, safety considerations, and other potential impacts to the construction project.

2 RESEARCH OBJECTIVES

The primary technical objectives of this research are listed below followed by the tasks to accomplish the objectives:

1. Identify and screen literature highly applicable to research products, both national and Ohio-specific sources
    - Identify the potentially applicable literature sources
    - Conduct a high level review to screen the sources down to a list of 20 highly relevant documents
    - Use these references as the primary source of information for developing the BMP selection tool
    - Provide an annotated bibliography of these references
    - Provide a summary of key findings used in developing the BMP selection tool
2. Gather information from Ohio roadway BMP stakeholders and apply to research products
    - Identify list of potential interviewees who are involved with local roadway BMPs

- Develop list of questions for the interviews
- Conduct 20 to 30 interviews to acquire Ohio-specific issues and concerns related to local roadway BMPs
- Incorporate results from interviews into BMP selection tool and BMP Case studies
- Provide summary of results from the interviews

3. Develop and provide a BMP selection tool for Locals
    - Review literature sources to identify potential BMPs for inclusion in BMP selection tool
    - Provide list of proposed applicable BMPs
    - Use research information to develop a draft BMP selection tool, including a matrix of applicable BMPs and their characteristics
    - Provide final BMP selection tool based on comments from the TAC
4. Develop and provide five BMP case studies as reference documents
    - Identify list of potential BMPs which are widely representative and useful as case studies
    - Use results from stakeholder interviews to develop list of potential case studies
    - Provide proposed list of case studies for TAC approval
    - Provide draft format of case studies for TAC approval
    - Gather data through correspondence and interviews
    - Write five draft and final BMP case studies

3 GENERAL DESCRIPTION OF THE RESEARCH

The primary goal of the research was to develop a post-construction storm water BMP selection tool based on the outcomes of the research, accompanied by five BMP case studies. The tool is primarily intended to support local municipal, township or county agencies (Locals) through the process of identifying and selecting storm water BMPs for local roadway systems. To that end, the GS&P Team conducted a literature review to identify relevant and current research and guidance on storm water BMPs applicable to local Ohio roadways. Interviews were also conducted with representatives from Ohio municipalities, county engineers and other Ohio storm water BMP stakeholders to gather feedback on Ohio-specific issues and identify potential BMP case studies. Follow up interviews and correspondence were conducted to gather the information needed to develop the BMP case studies.

The key findings on BMP design characteristics, functions, and limitations from the literature review and interviews were used to help develop the BMP selection tool and shape the tool's screening process. The resulting BMP selection tool is a multi-step spreadsheet screening tool, designed to assist the user with identifying potentially applicable BMPs based on user-defined site and project characteristics. The tool also includes supplemental information from the research, including cost and maintenance data.

4 RESULTS

4.1 <u>Literature Review</u>

The GS&P Team conducted a literature review to identify relevant and current research and guidance on post-construction storm water BMPs applicable to local Ohio roadways. The literature review helped to establish the current state of the practice with regard to BMP selection, design, performance, and maintenance, and thereby provide a foundation for the development of the BMP selection tool.

Five "baseline" references were identified as essential to this project, as described in the Annotated Bibliography Memo (Appendix A):

- International Stormwater BMP Database
- ODOT Location and Design (L&D) Manual, Volume 2
- Ohio EPA Construction General Permit for Storm Water Discharges (*OHC000004)*
- Ohio Small MS4 General Permit
- Ohio DNR Rainwater and Land Development Manual

Additionally, the GS&P Team identified over 100 additional documents for possible use in this research. This list was ultimately screened down to 20 highly applicable references based on a variety of factors, including applicability to local roadways, local design standards, and Ohio-relevant BMPs. These documents were reviewed, and an annotated bibliography was developed to summarize the relevance of these documents to the research (Appendix A).

The first focus of the literature review was to define a set of BMPs to be included in the tool, based on their ability to meet Ohio roadway needs. These 24 BMPs were researched to identify BMP selection considerations for local Ohio roadways, including compliance with Ohio regulations, right-of-way considerations, site feasibility, pollutant performance, capital and operations and maintenance costs, and the Local's specific needs. These selection considerations were used to develop a set of BMP screening factors to be used by the tool logic in determining BMP compatibility with site and project characteristics entered by the user.

Many of the national BMP references reviewed included more stringent storm water treatment requirements than those in the Ohio EPA CGP. Total suspended solids (TSS) is the primary pollutant of concern in the Ohio EPA CGP, unless the project is within a watershed with a total maximum daily load (TMDL). The BMP tool was developed with pollutant removal information for various constituents, allowing users the flexibility to screen for more than TSS removal.

During the course of BMP selection tool development, some additional highly applicable references were identified to support the development of screening factors. These additional references are listed below and summarized in the Key Literature Findings and Basis for BMP Screening Criteria Memo (Appendix B):

- Minnesota Stormwater Manual (MPCA, n.d.)
- Mn/DOT Decision Tree for Stormwater BMPs (Marti, 2011)
- NCHRP 25-25 Task 83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways (Venner et. al, 2013)
- NCHRP Project 25-25 Task 85: Nutrient (Nitrogen/Phosphorus) Management and Source Control (Leisenring et al., 2014)
- NCHRP Report 565: Evaluation of Best Management Practices for Highway Runoff Control (Huber et al., 2006)
- NCHRP Report 792: Long-Term Performance and Life-Cycle Costs of Stormwater Best Management Practices (Taylor et al., 2014)
- Port of Portland Stormwater Design Standards Manual (GS&P et al., 2014)
- WERF Critical Assessment of Stormwater Treatment and Control Selection Issues (Strecker et al., 2005)

An all-inclusive list of documents used in the research is provided in the References section (Section 7) of this final report, including the essential baseline documents, 20 documents from the annotated bibliography, and additional references used to develop screening factors.

4.2 Outreach to Local Roadway BMP Stakeholders

The GS&P Team conducted a series of interviews with 23 individuals involved in BMP implementation across the state of Ohio. The interviews were intended to key in on frequent challenges, constraints, success factors, and other lessons learned related to BMP implementation on local roadway projects. The lessons learned from the interviews were used to refine the research objectives for the ongoing literature review, as well as to shape the content and features of the BMP tool. The interview outreach and results are summarized below. Refer to Appendix C for the complete memo, including interviewees contacted, interview content, significant lessons learned, and applicability toward tool development.

4.2.1 Key Findings from Interviews

Based on interview findings and lessons learned, the GS&P Team identified a series of functions and features to be incorporated into the BMP selection tool. The following considerations for the tool were identified to address user needs and to facilitate the process of BMP selection for local roadway projects:

- Educate users with respect to post-construction applicability and requirements, as well as other considerations related to the post-construction BMP implementation process.
- Incorporate flexibility into the tool to allow it to be used by entities whether they are following the ODOT L&D Manual or the Ohio EPA CGP. Allow for users to specify if they are willing to consider alternative BMPs (those not pre-approved by Ohio EPA).
- Incorporate questions regarding BMP aesthetic preferences as part of the BMP screening process, while recognizing that aesthetic preferences may vary between users.
- Provide high level information to inform tool users during the BMP selection process about potential operations and maintenance (O&M) burdens associated with particular BMPs, recognizing that users may have limited resources for O&M.
- Encourage consideration of BMP siting early in project planning.
- Include BMPs that are practical for roadway applications, reflecting Ohio-specific O&M needs and site conditions.

These results were key to better understand the Locals' needs and perspectives, guiding the direction of the BMP selection tool development. While Locals' needs vary widely, requiring the tool to be flexible, the interviews made clear that very specific information should be incorporated into the BMP tool as much as possible to assist in the selection process. So, the GS&P Team set out to strike a balance between detail and flexibility in the BMP selection tool to make it applicable for the greatest number of users statewide.

4.3 BMP Case Studies

Suggested contacts from the ORIL TAC along with the stakeholder interviews helped identify potential BMP projects which could be used as case studies. Five projects were selected with input from the TAC, representing an array of typical local roadway BMPs:

- Bioretention with underdrain
- Manufactured device (also known as hydrodynamic separator)
- Permeable pavement with extended underground detention
- Vegetated biofilter/swale
- Constructed wetland (also known as extended detention wetland)

Through interviews and other correspondence, the GS&P Team gathered the data from stakeholders to develop the case studies (Appendix D). Each case study provides information specific to the particular BMP to help identify some of the key factors to consider during BMP selection. The following sections outline each case study:

- Project Background
    - Brief description of the project, location, and need for a post-construction storm water BMP
- BMP Functional Description
    - Explains the types of pollutants treated and mechanism(s) for treatment
- Design Constraints and BMP Selection
    - Project-specific limitations that led to the particular BMP chosen for the site
- Construction Lessons Learned
    - BMP-specific information and suggestions to consider during construction
- General Operations and Maintenance Considerations
    - Operations and maintenance tasks to understand before selecting a BMP
- Cost Considerations
    - Common issues which drive the costs of the specific BMP
- Figures
    - Site photographs during or after construction
    - Excerpts from the design drawings

4.4 BMP Selection Tool

4.4.1 Background

The BMP selection tool is intended to help Locals confirm the applicability of post-construction requirements and identify a list of potentially applicable BMPs, based on site and project-specific data. Using the results from the interviews and literature review, the GS&P Team created a step-wise work flow to organize the BMP selection tool. A spreadsheet-based software was selected as the platform for the tool to facilitate ease of use by a broad range of users.

4.4.2 Organization and Layout

There are two types of worksheets in the tool—steps and reference tabs. The steps walk the user through the central BMP screening process. The steps alternate between posing questions to the user and reporting output from sequential screening phases, culminating in the final list of screened BMPs. Reference tabs provide guidance, supplemental information, or allow the user to document project information. Figure 1 displays an excerpt from the Main Menu of the tool, which provides an overview of the sequence of steps and references in the tool.

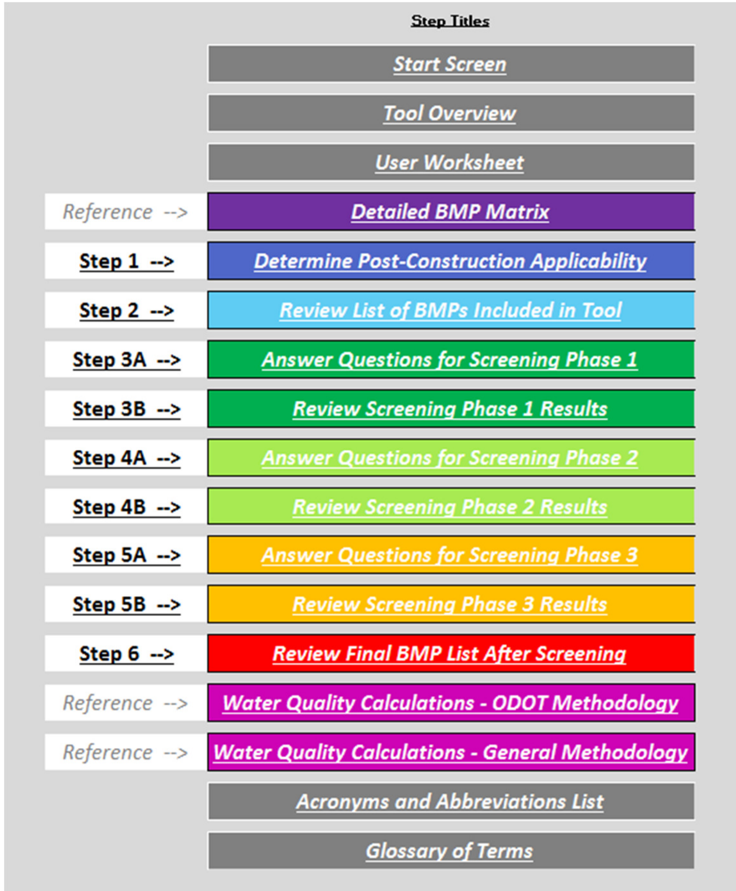


Figure 1. List from the Main Menu in the BMP Selection Tool

The tool selection process begins in Step 1, which asks questions to confirm if the project being evaluated requires post-construction BMPs. Once BMPs are known to be required, the user can review the list of BMPs included in the tool (Step 2) before proceeding to the three screening phases (Steps 3-5). Each screening phase is followed by a table of screening results based on compatibility with the project data entered up through that step. After the third screening phase, the user can review the final results in Step 6. This final step summarizes the fully screened list of compatible BMPs, along with the corresponding operations and maintenance level of effort and anticipated range of construction costs for each remaining BMP.

The following list describes the screening factors applied in each screening phase:

Phase 1 BMP methodology and quantity/quality functions
  a. What is the basis of design?
  b. Will the user adhere strictly to the ODOT L&D Manual?
  c. What BMP functions are required?

Phase 2 Site and design constraints
  a. What are the space constraints?
  b. What are the hydraulic/hydrologic limitations?
  c. Are there any safety considerations?

Phase 3 Local BMP preferences
  a. Are there any aesthetics preferences?
  b. Are there any operations and maintenance limitations?

4.4.3 Basic Functions and Use

The tool steps are organized with the intent to progressively narrow the field of potentially applicable BMPs. If a single screening decision indicates that a particular BMP's characteristics are incompatible with the user's responses, that BMP is ruled out. At the end of multiple consecutive screening steps, the user is left with a reduced set of BMPs that are potentially compatible for their specific project application.

BMP screening decisions were developed for the tool based on a comprehensive review of BMP literature. The Key Literature Findings and Basis for BMP Screening Criteria memo (Appendix B) describes the sources and assumptions used to develop critical screening factors and sources of BMP-specific criteria. Over thirty screening factors were selected including a mix of qualitative criteria (e.g., permit inclusion, BMP inflow types, etc.) and quantitative criteria (e.g., minimum footprint, etc.), falling within the following general categories:

- BMP Inclusion in Ohio EPA CGP or ODOT L&D Manual Volume 2 [Step 1]
- BMP Functions [Step 3]
- Site Conditions/Physical Constraints [Step 4]
- Costs and Maintenance [Step 5]
- Aesthetics [Step 5]

BMP-specific criteria corresponding to the selected screening factors were used to populate the *Detailed BMP Matrix* reference tab, which provides the foundation for the BMP screening process. Each screening step applies logic that compares site and project-specific characteristics entered by the user (in response to questions in each step of the tool) against BMP-specific criteria in the *Detailed BMP Matrix* to determine which BMPs are compatible. These BMP characteristics in the matrix can also be directly referenced to identify ways to overcome site constraints or BMP limitations. For convenience, the *Detailed BMP Matrix* also displays the screening results from each of the screening phases, which allows the user to determine which criteria were incompatible with the BMPs.

4.4.4 Additional Noteworthy Features

Beyond the basic functionality described above, several additional features in the BMP tool are noteworthy:

- **Optional screening for specific water quality parameters:** As mentioned in the literature review discussion, many of the national BMP references reviewed included more stringent storm water treatment requirements than those in the Ohio EPA CGP. Total suspended solids (TSS) is the primary pollutant of concern in the Ohio EPA CGP, unless the project is within a watershed with a total maximum daily load (TMDL). The tool is designed to identify BMPs which simply address TSS, but with the flexibility to add additional requirements, such as nutrients (which are common in the TMDLs).
- **BMP sizing guidance:** Two reference worksheets are provided to help the user calculate the treatment requirements, including the water quality volume, water quality flow, and treatment percentage (if the project is redevelopment). One of the worksheets follows the Ohio EPA CGP methodology for calculating the treatment requirements, while the other is customized to the ODOT methodology described in the L&D Manual,
- **Iterative screening for design flexibility:** The tool can be used in an iterative process to further refine or expand the outputs. If the outputs from the initial data inputs are too limited, the user can examine the screening results indicated after each of the three screening phases or in the summary included in the *Detailed BMP Matrix.* By evaluating the specific reasons for incompatibilities, the user can modify their

design to accommodate the criteria of the desired BMP(s). Conversely, if the list of BMPs is too large, the user can revisit the data inputs and be more selective about certain BMP criteria, such as aesthetics, operations and maintenance, or safety considerations.

4.4.5 Limitations of Use and General Disclaimer

The BMP tool cannot be used for multiple drainage areas within a project simultaneously, as the tool questions are targeted toward a singular BMP installation site. If multiple drainage areas or BMP installations need to be evaluated, the spreadsheet format of the tool allows for multiple copies of the tool to be saved and modified for different installations as needed.

Because the BMP tool performs screening based on site and project-specific data inputs, the user must have knowledge of site and its constraints in order to get value from the tool results. This requires some basic information about the site, similar to what would be available just prior to or early in Stage 1 plan development.

When using the tool, the resulting list of applicable BMPs must be evaluated by the Local and/or designer for practicability and appropriateness. The BMP tool is intended as general guidance, and use of the results is entirely the responsibility of the user. The GS&P Team, the ORIL Board, and ODOT accept no liability for use of the results from the BMP tool and screening process.

The BMP characteristics in the *Detailed BMP Matrix* were defined to assist in the screening process. These values should not be used for design purposes, as they may be overly conservative due to the tool functionality. Use the primary references cited in the literature review for design guidance.

To provide enough flexibility for use throughout the state, the BMP tool cannot address every possible circumstance. As mentioned above, the tool assumes typical and somewhat conservative values for BMP characteristics and constraints to minimize over-screening, but the tool is unable to account for all possible design variations. Even if a specific BMP is eliminated by the screening tool based on conflicts with identified project or site constraints, it may be possible for a designer to overcome these constraints in practice through the use of creative site design practices or BMP modifications. Furthermore, because local storm water regulations vary widely, only statewide storm water requirements are reflected in the screening steps.

The functionality of the tool relies on the user to provide valid data inputs at an early stage in the design process. It is incumbent upon the Local and/or project designer to understand the aspects of the design that will affect the BMP selection, especially if the design significantly changes after the initial use of the tool.

5 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the conclusions and recommendations identified by the GS&P Team as a result of this research.

5.1 Conclusions:

- Locals would benefit from additional guidance materials to support decision-making in BMP selection and design. Many Locals requested additional supporting information to help select a BMP, especially regarding footprint requirements, on-going maintenance, aesthetics, safety considerations, and other potential impacts to the construction project.

- Storm water BMPs occupy space, typically in the right-of-way, and space on local roadway projects is often limited. When BMP planning is incorporated late in the project, BMP options become more limited and additional costs are typically incurred.
- Some engineers reviewing and designing BMPs are not completely aware of Ohio storm water regulatory requirements. It appears that drainage design is well understood, but often storm water management BMPs are considered late in design or not at all.
- Some vendors of storm water BMP products are similarly unaware of Ohio storm water requirements or make generalized claims about product performance which can be misleading to Ohio Locals.
- If the project requires treatment of the water quality volume (i.e., typical for projects unless a water quality flow treatment is allowed), the BMP inherently must be large enough to detain that volume for some time, while releasing flow at a limited rate. Thus, BMPs which treat the water quality volume tend to have larger size footprint requirements.
- Storm water BMPs must be evaluated on a case-by-case basis. Each project site has unique conditions which can be addressed by different BMPs depending on their characteristics.
- Generally, the selection and design of post-construction BMPs could use improvement for local roadway projects.
- All BMPs require regular maintenance to function appropriately, and proper maintenance is a condition of the Ohio EPA CGP and local MS4 permits.
- Stakeholder interviews uncovered that some Locals are not aware of the operations and maintenance requirements of BMPs, which can lead to poor BMP functionality. Also, some Locals attribute lack of maintenance to limited staff, budget, and training. These BMPs when constructed become public infrastructure and need to be managed as such.

5.2 Recommendations:

The products from this research are recommended to be implemented to help local roadway projects in Ohio overcome key roadblocks to successful BMP selection, design and implementation. The BMP selection tool facilitates early planning and discussion to consider the pros and cons of each BMP type. Beyond BMP selection, the tool is intended to facilitate the understanding of BMP requirements and considerations so the Local and/or designer can plan accordingly. Standardizing documentation through use of Ohio-specific tools (i.e., within the BMP selection tool) will help address potential roadblocks and work towards improved post-construction BMP design, implementation, and maintenance. This information also provides context for incorporating project-specific BMPs within proposal requests for professional services. The following specific recommendations are provided.

- Project designers and Locals must understand the regulatory requirements for storm water treatment. The BMP selection tool provides assistance with identifying the applicable regulatory requirements.
- Post-construction BMPs should be considered early in the project planning and design process. ODOT's L&D requires that post-construction calculations be completed by the Stage 1 submittal. The BMP selection tool should be implemented during project planning and prior to completion of Stage 1 design drawings.
- In project planning, Locals must account for budget and space requirements for post-construction BMPs (i.e., assess right-of-way needs associated with BMP characteristics and budget accordingly).

- Locals should engage project designers to discuss BMP selection to better understand the options and implications of BMPs being considered. Using a common tool, like the BMP selection tool provided, will help facilitate that discussion and facilitate understanding of the decision-making process. The BMP case studies are an additional source of information to better understand the BMP options.
- Providing standardized documentation to show the BMP selection process and key design parameters will facilitate project reviews and encourage discussion between the project designer and Locals. The BMP selection tool provides a format for this documentation.
- Locals should be aware of the operations and maintenance requirements of the BMPs during the selection process. The BMP selection tool and case studies provide some guidance, and more information can be found in the sources referenced in this research. Locals need to understand that the BMPs are public infrastructure once they are constructed.
- Locals should become better informed early in the design process to understand BMP characteristics with regard to footprint requirements, on-going maintenance, aesthetics, safety considerations, and other potential impacts to the construction project. Use of the BMP tool will help develop this understanding and improve successful implementation of BMPs.
- In order to offer more BMP options to Locals and other roadway owners, ODOT may want to update the ODOT L&D Manual to add appropriate BMPs included in the BMP tool. It is understood that ODOT would need to allow for Ohio EPA review and comment on revisions to the ODOT L&D Manual since it is referenced in the Ohio EPA CGP. For example, permeable pavement could be implemented, especially for low traffic pavement or non-motorized vehicle pavement; and, shoulder media filter drains could be implemented where nutrient removal is required, such as within watersheds with nitrogen or phosphorus TMDLs.
- The BMP tool will require occasional maintenance and updates over time, as discussed in Section 6.2.

6 RECOMMENDATIONS FOR IMPLEMENTATION OF RESEARCH FINDINGS

This section describes considerations for implementing the research findings. Recommendations for using the tool are provided to explain ways Locals can integrate the research products into their BMP selection and design process. Considerations for future use and ownership of the BMP selection tool are explored to predict potential implementation challenges. Finally, potential data gaps became apparent during the research which are identified as opportunities for additional research.

6.1 Recommendations for Use of the Research Products

To best implement the results of this research project, the GS&P Team has provided the following recommendations.

Utilize the BMP selection tool prior to stage 1 design development, possibly even prior to release of the project request for proposal. Use of the BMP tool will help Locals to understand which regulations are applicable to the project. The research clearly indicated that determining the BMP characteristics early in the project helps increase the likelihood of a successful project by reducing the risk of unnecessary costs, providing more flexibility in design options, and understanding future operations and maintenance requirements. Use of the BMP tool can assist in accomplishing these tasks, even at an early stage in project development. The BMP tool can also be used to prompt the Locals to identify gaps in key data, which may enhance the project's development.

Once the project data has been entered into the BMP selection tool and a list of potential BMPs has been generated, users are encouraged to review the Detailed BMP Matrix to understand the BMP options and project compatibility issues. The project concept and constraints can be revisited in light of the BMP selection criteria and Locals can make informed decisions about the BMP selections associated with the project design. Once the BMP list has been finalized, engineers and locals can employ their experience and use the recommended references to prioritize and rank the potential BMPs for their projects.

One additional area of continued research is advancing this tool from the local roadway system to the primary roads (i.e., Interstate, State, and U.S. routes). What modifications would be needed? What benefits would be anticipated for designers and ODOT? Could this be incorporated into the ODOTs project delivery process and if so, how would this need to be modified? What OEPA-ODOT facilitation would need to be done to modify the current list of BMPs in ODOTs L&D to add other BMPs to the toolbox?

The list of references in Section 7 and the annotated bibliography identify sources for more information. Table 1 provides context for the categories for which each reference might be most useful. Locals are also encouraged to refer to the BMP Case Studies (Appendix D) for additional information regarding the five types of BMPs covered in the case studies.

Table 1. Select References and their Primary Focus for BMPs

Reference	Design	Selection	Costs	Maintenance	Performance	Safety
BMP Performance and Cost-Benefit: Arlington Pascal Project (Capitol Region Watershed District, 2012)	X		X	X	X	
WERF Critical Assessment of Stormwater Treatment and Control Selection Issues (Strecker et al., 2005)	X	X	X		X	
International Stormwater BMP Database (BMPDB)					X	
Mn/DOT Decision Tree for Stormwater BMPs (Marti, 2011)		X	X	X		X
NCHRP Report 565: Evaluation of Best Management Practices for Highway Runoff Control (Huber et al., 2006)	X	X			X	
NCHRP 25-25 Task 83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways (Venner et. al, 2013)	X		X	X	X	X
NCHRP Report 728: Guidelines for Evaluating and Selecting Modifications to Existing Roadway Drainage Infrastructure to Improve Water Quality in Ultra Urban Areas (Strecker et al., 2012)		X	X	X	X	X
NCHRP Project 25-25 Task 85: Nutrient (Nitrogen/Phosphorus) Management and Source Control (Leisenring et al., 2014)		X	X		X	
ODOT Location and Design (L&D) Manual (ODOT, 2014)	X	X				
Philadelphia Green Streets Design Manual (Philadelphia Water Department, 2014)	X	X		X		
Rainwater and Land Development Manual (Ohio DNR, 2014)	X	X				X
San Mateo County sustainable Green Streets and Parking Lots Design Guidebook (San Mateo County, 2009)	X	X				
Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring (FHWA, 2002)		X	X	X	X	
Treatment BMP Technology Report (Caltrans, 2013)		X		X	X	
Minnesota Stormwater Manual (MPCA, n.d.)	X	X		X		
NCHRP Report 792: Long-Term Performance and Life-Cycle Costs of Stormwater Best Management Practices (Taylor et al., 2014)			X	X	X	
Port of Portland Stormwater Design Standards Manual (GS&P et al., 2014)	X	X		X		X

Locals who utilize the research products can expect several benefits as described throughout this document, and summarized below:

- Develop a better understanding of local roadway BMP options.

- Have tools available to compare different BMP options depending on project-specific data and Local's preferences and priorities.
- Create better documentation and quality assurance in the BMP identification and selection process.
- Reduce the risk of unnecessary costs through early planning of BMPs and coordination with overall project design.
- Increase the potential for BMP success by better understanding long term operations and maintenance needs, safety considerations, and aesthetics of potential BMPs.

The following potential risks and obstacles to implementation were identified by the GS&P Team, as well as an associated strategy to overcome the risks and obstacles.

- Risk: Use of the BMP selection tool requires baseline understanding of the project site limitations and of BMP design. If quality data is not input into the tool, then quality data cannot be output.
  - Strategy to overcome: Preliminary project planning will allow the BMP tool user to understand data needed to populate the tool without creating schedule delays to the project.
- Risk: BMPs require space within the project area or right of way and conflicts may arise between interested parties on the project due to space limitations.
  - Strategy to overcome: Use of the BMP selection tool early in project design will help facilitate discussion between interested parties and help to avoid potential conflicts around BMP location. Off-site mitigation can be pursued as an alternative if space is not available.
- Risk: Questions in the BMP tool may be misunderstood by the user.
  - Strategy to overcome: The BMP tool was vetted by the research team and by the TAC to identify and revise issues with wording and language clarity. Furthermore, guidance tips are provided throughout the BMP tool to explain the intent of each question.
- Risk: Locals who are unfamiliar with spreadsheet software may not be willing to use the BMP tool.
  - Strategy to overcome: Provide outreach to Locals to promote the published research products. Offer guidance materials and training to Locals after the research is published.
- Risk: Some projects are governed by local storm water regulations which are not specifically covered in the BMP tool.
  - Strategy to overcome: The BMP tool has been developed to identify BMPs which are compliant with Ohio EPA CGP and the ODOT L&D Manual, but cannot specifically cover all local storm water regulations. Locals may want to customize the tool by modifying the selection criteria to their own requirements and design standards.

The potential users and organizations affected include all Locals (e.g., Ohio counties, townships, and municipalities) as well as ODOT.

The suggested time frame for implementing the research products begins following publication to support implementation and tool maintenance:

- Within one to two months, conduct public outreach to advertise the BMP selection tool, BMP case studies, and literature references.
- Develop and offer training to interested parties within six months of publication.

- One year after publication, conduct a survey of Locals to evaluate the success of the implementation. Adjust as needed based on results of the evaluation.

Potential minor costs may be associated with the implementation recommendations. Primarily the costs are associated with effort related to outreach, training, and evaluation are estimated as follows:

- Public Outreach— 40 hours
- Tool Training— 80 hours
- Evaluation through collection of user feedback— 32 hours
- Document Updates— unknown

Additional costs may be incurred for maintaining and updating the BMP selection tool, but the scope and schedule for those updates are driven by unknown factors, such as changes to storm water regulations, outcomes of other research, or updates to the ODOT L&D Manual, Volume 2.

The GS&P Team recommends the following to evaluate the ongoing performance of the implemented research products:

- Within two months of publication, a process to allow for BMP tool feedback and suggested updates should be developed and made available.
- One year after the research products have been published, a survey should be conducted to evaluate how many Locals are using the BMP tool, how they rate the success of its use, what, if any, standardization of documentation has occurred, and what improvements are suggested.
- As explained in section 6.2, the BMP tool spreadsheet will need to be maintained and updated periodically. Proper maintenance and accessibility may affect the research implementation's success.

6.2 Future Use and Ownership of the BMP Selection Tool

The GS&P Team has identified several questions regarding the future use and ownership of the BMP tool. It is recommended that these questions be answered prior to the completion of the project and release of the final work products, especially the BMP selection tool.

- How will the BMP tool be made available to Locals? Is there a relevant ODOT website where is could be hosted?
- Who will be the document "owner" to maintain the document as updates are needed?
- How frequently will the document be reviewed and updated to incorporate regulatory changes as well as updates to current BMP information?
- The spreadsheet is currently password protected to prevent accidental editing. Will the unprotected spreadsheet be made available to Locals? Will it be available to the general public?
- Will ODOT provide any training or guidance to Locals on using the BMP tool?

6.3 Additional Research Opportunities

During the research project additional questions arose which were outside of the original project scope to answer. These future potential research opportunities are listed below.

- As discussed, the BMP selection tool is broadly applicable to statewide requirements. An opportunity exists to customize the tool for specific agencies, including ODOT, agencies with a local design standards manual, and agencies within a watershed with a TMDL. ODOT may benefit from a modified version of the BMP tool which incorporated Interstate, State, and U.S. route projects. This version of the tool could expedite BMP assessment and selection for ODOT designers, and add continuity in

BMP selection and design process statewide. Other agencies may benefit from customizing the tool to incorporate their specific local requirements.

- Conduct a research synthesis to evaluate linkages with other ODOT research project findings which inform storm water BMP performance. Based on the findings from the synthesis, additional BMPs which better accommodate local roadway projects could be recommended to Ohio EPA to expand the existing list of standard BMPs in Table 2 of the Ohio EPA CGP.
- BMP construction costs ranges were provided in the BMP tool, but more detailed, Ohio-specific cost analysis would help Locals better understand the tradeoffs between BMP options.
- Similarly, comparative costs for BMP operations and maintenance were provided in the BMP tool, but more detailed information would be helpful in BMP selection. The GS&P Team identified several sources for potential follow up, including the ODOT District 4 operations and maintenance records and data being collected by the Toledo Metropolitan Area Council of Governments.
- A methodology for integrating other ODOT research results into the BMP tool is needed (e.g., evaluating particle size distribution of Ohio's roadway runoff).

7 REFERENCES

Abbasi, S., and Koskelo, A. (2013). NCHRP Synthesis 444: Pollutant Load Reductions for Total Maximum Daily Loads for Highways.

Caltrans (2013). Treatment BMP Technology Report. April.

Capitol Region Watershed District (2012). BMP Performance and Cost-Benefit Analysis: Capitol Region Watershed District Arlington Pascal Project, 2007-2010. March.

CDM Smith (2014). Philadelphia Green Streets Design Manual. March.

FHWA (2012). Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring (Web Doc) (May).

Geosyntec Consultants, Oregon State University, Venner Consulting, Low Impact Development Center, and Wright Water Engineers (2012). NCHRP 25-31: Guidelines for Evaluating and Selecting Modifications to Existing Roadway Drainage Infrastructure to Improve Water Quality in Ultra Urban Areas July

Gresham, Smith and Partners and Geosyntec Consultants (GS&P and Gesoyntec). (2014). Memorandum to ORIL Technical Advisory Committee Regarding Task 2 – Annotated Bibliography, Stormwater Best Management Practices for Local Roadways/ 2015-ORIL 7. December.

Gresham, Smith and Partners, Geosyntec Consultants, and HDR (GS&P et al.). (2014). Port of Portland Stormwater Design Standards Manual. May.

Hein, D., Strecker, E., Poresky, A., Roseen, R., and Venner, M. (2013). NCHRP Project 25-25/Task 82: Permeable Shoulders with Stone Reservoirs, White Paper and Decision Tool. October.

Huber, W., Heaney, J., Strecker, E., and Weinstein, N. (2006). NCHRP Report 565: Evaluation of Best Management Practices for Highway Runoff Control. Transportation Research Board of the National Academies.

Leisenring, M., Sahu, S., Poor, C., Zell, C., Mansell, S., and Venner, M. (2014). NCHRP Project 25-25/Task 85: Nutrient (Nitrogen/Phosphorus) Management and Source Control. August.

Marti, M. (2011). Decision Tree for Stormwater BMPs. Minnesota Department of Transportation Research Services Section. MN/RC- 2011R1C01. March.

Marti, M. (2011). Minnesota Department of Transportation Decision Tree for Stormwater BMPs

Minnesota Pollution Control Agency (MPCA). (n.d.). Minnesota Stormwater Manual. Accessed May 2015 from http://stormwater.pca.state.mn.us/index.php/Main_Page.

Moores, J., Gadd, J., Pattinson, P., Hyde, C., and Miselis, P. (2012). Field Evaluation of Media Filtration Stormwater Treatment Devices. August

NC DOT (2010). North Carolina Department of Transportation Stormwater Control Inspection and Maintenance Manual. January.

Nevue Ngan Associates and Sherwood Design Engineers (2009). San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook. October.

Ohio Department of Natural Resources (Ohio DNR). (2006). Rainwater and Land Development, Ohio's Standards for Stormwater Management Land Development and Urban Stream Protection. Division of Soil and Water Conservation. Third Edition.

Ohio Department of Transportation (ODOT). (2014). Location and Design Manual, Volume 2. July.

Ohio EPA. (2013). NPDES Construction General Permit. Permit Number OHC000004. April.

Oregon State University, Geosyntec Consultants, University of Florida, and Low Impact Development Center (2006) NCHRP 25-20-01: Evaluation of Best Management Practices for Highway Runoff Control.

Roseen, R., Houle, J., Avelleneda, P., Wildey, R., and Briggs, J. (2006). Storm Water Low-Impact Development, Conventional Structural, and ManufacturedTreatment Strategies for Parking Lot Runoff.

Seattle Public Utilities (2012). CatchBasin StormFilter Performance Evaluation Report. (March).

Strecker, E., Huber, W., Heaney, J., Bodine, D., Sansalone, J., Quigley, M., Leisenring, M, Pankani, D., Thayumanavan, A. (2005). Critical Assessment of Stormwater Treatment and Control Selection Issues. June.

Strecker, E., Quigley, M., and Leisenring, M. (2005). Critical Assessment of Stormwater Treatment and Control Selection Issues. Water Environment Research Foundation. WERF 02-SW-1.

Taylor, S., Barrett, M., Leisenring, M, Sahu, S., Pankani, D., Poresky, A., Questad, A., Strecker, E., Weinstein, N., and Venner, M. (2014). NCHRP Report 792: Long-Term Performance and Life-Cycle Costs of Stormwater Best Management Practices. Transportation Research Board of the National Academies.

Taylor, S.; Barrett, M.; Leisenring, M.; Weinstein, N.; Venner, M. (2014). NCHRP 25-40: Long-Term Performance and Life-Cycle Costs of Stormwater Best Management Practices-Final Report 792-Tool. October.

Venner, M., Strecker, E., Leisenring, M., Pankani, D., Taylor, S. (2013). NCHRP 25-25/83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways. August.

Venner, M., Strecker, E., Leisenring, M., Pankani, P., and Taylor, S. (2013). NCHRP 25-25 Task 83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways. Transportation Research Board of the National Academies.

Weiss, P., Gulliver, J., and Erickson, A. (2005). The Cost and Effectiveness of Stormwater Management Practices, Minnesota Department of Transportation. June.

Winston, R., Hunt, W., Kennedy, S., and Wright, J. (2012). Evaluation of Permeable Friction Course (PFC), Roadside Filter Strips, Dry Swales, and Wetland Swales for Treatment of Highway Stormwater Runoff. October.

APPENDIX A

ANNOTATED BIBLIOGRAPHY

MEMORANDUM

TO:	ORIL Technical Advisory Committee
FROM:	GS&P Team (GS&P/Geosyntec)
DATE:	December 3, 2014
SUBJECT:	**TASK 2 – ANNOTATED BIBLIOGRAPHY, STORM WATER BEST MANAGEMENT PRACTICES FOR LOCAL ROADWAYS / 2015-ORIL 7** ODOT State Job No. 134990 GS&P Project No. 40399.00

1 INTRODUCTION

As part of the research on ORIL 7- Storm Water Best Management Practices for Local Roadways, the GS&P Team is conducting a literature review to identify relevant and current research and guidance on post-construction storm water best management practices applicable to local Ohio roadways. The literature review is intended to help establish the current state of the practice with regard to BMP selection, design, performance and maintenance and thereby provide a foundation for the development of the BMP matrix and supporting guidance. The attached annotated bibliography has been developed to summarize some of the top priority documents.

The GS&P Team identified an initial pool of over 100 documents for possible use in this research. Five references have been identified as essential to this project, which are briefly described in Section 2. The remaining references were briefly screened to prioritize the documents for applicability. Section 3 describes the approach for prioritizing the top 20 references that are included in the annotated bibliography. The bibliography is intended to summarize the direction of the research, but not to be an all-inclusive list of research documents. Many documents not included in the bibliography are expected to be used to inform the final research product. The memo is concluded in Section 4 with a description of the next steps to be taken for the literature review task.

2 BASELINE REFERENCES

While many references were identified, sorted, and reviewed, the five reference sources listed below are considered foundational to the project. The research team has reviewed these documents for their relevant information and the documents will be utilized throughout the project. A brief summary of the five documents is listed below. They are not included specifically in the annotated bibliography.

- ODOT Location and Design (ODOT L&D) Manual – Establishes current standards for ODOT drainage design and BMPs. The project team will regularly refer to the ODOT L&D Manual to compare contents of the manual to BMP selection criteria, recommended BMP design variations, and alternatives that arise from this project.
- Rainwater and Land Development Manual – Document prepared by Ohio DNR covers a broad scope of storm water management techniques specific to the urban environment from erosion control to post-construction BMP designs. The GS&P Team will identify the BMPs in this manual (and variants thereof) that can be adapted for linear roadway applications.
- Ohio Construction General Permit – The general permit for storm water discharges for construction activities and post-construction storm water control. The GS&P Team will identify how the post-construction storm water management BMPs and other requirements in the permit accommodate or conflict with BMP selection and design recommendations.
- Ohio Small MS4 General Permit – Storm water general permit for small municipal storm water systems that includes construction considerations and thresholds for implementing post-construction BMPs. Requirements of this permit will be evaluated similar to the requirements of the construction general permit.
- International Storm water BMP Database – Largest repository of BMP design and performance information from field monitoring studies. As part of Task 5, the GS&P Team will reference the performance data from the Database with the intent of providing relative guidance on expected effectiveness.

3 BIBLIOGRAPHY REFERENCE SELECTION APPROACH

In addition to the five baseline references described above, the GS&P Team assembled a list of over 100 references related to storm water management, BMP design, and technical research. Approximately half of these were determined to have limited relevance to the project and were quickly screened out. The other half were further evaluated and ranked as having low, medium, or high relevance. Those determined to have high relevance were reviewed in detail and summarized in the attached annotated bibliography. The summaries include basic bibliographic information, key words for project relevance, and identification of document sections that may be particularly useful for the current project. Finally, the summaries identify whether the reference is applicable to highways, urban roads, and/or rural roads. For example, a document on green street designs, such as curb bump-outs, are more relevant to urban roads than to highways and rural roads.

4 NEXT STEPS

During the course of the literature review, the GS&P Team will document the significant findings from all the relevant references (baseline, high, medium, and low priority) and submit a summary of these findings. The Team will use this information to assist in the development of the BMP matrix and supporting guidance for selecting, siting, sizing, and designing BMPs.

Title: *Minnesota Department of Transportation Decision Tree for Stormwater BMPs*

Publisher/Sponsor: MnDOT

Author(s): Marti, M.

Publication Date: March 2011

Target Location Minnesota

Content and Focus: This project's objectives were to create a scoping-level tool that could assist city and county public works staff in the selection of BMPs appropriate for specific projects. The tool steps through a five-step selection process that includes: 1.) Project type selection (site vs. roadway/linear); 2.) Site description (receiving water, soils, etc.); 3.) Regulatory environment (what state or federal requirements apply; determine most stringent criteria); 4.) Create BMP toolbox – select from a matrix of seven BMPs; and 5.) Refine BMP selection based on maintenance, life cycle costs and aesthetics. This document is to be used in conjunction with document 2009RIC12 (Stormwater Maintenance BMP Resource Guide)

Report Sections Relevant to ORIL: Main Body- step-by- step worksheets that walk through first determining space availability/site or linear project type and then using those specific project type worksheets that include a series of project-relevant questions (treatment considerations, soil type, and site considerations based on project setting) to preliminarily screen BMPs using a table. Final screening is based on maintenance considerations, life expectancy, life cycle costs and other factors that may be important such as aesthetics, safety concerns, wildlife nuisance, and spill containment.
Appendices- Cost Benefit Analysis, summary of resources used

Keywords: DOT, methods & tools, selection, site constraints, maintenance

Url: *http://www.lrrb.org/pdf/2011RIC01.pdf*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	High

Title: *Philadelphia Green Streets Design Manual*

Publisher/Sponsor: Philadelphia Water Department

Author(s): CDM Smith

Publication Date: October 2014

Target Location Philadelphia, PA

Content and Focus: This is an urban street greening guidance document that details the green stormwater infrastructure strategies that have been the easiest and most effectively used within Philadelphia to meet stormwater management goals. The document also presents two pilot designs that could be added to the green streets roster. The document includes detailed discussions on sizing, placement, and maintenance issues as well as detailed renderings of each green infrastructure type.

Report Sections Relevant to ORIL:
Chapter 2 Provides design sheets and high-level renderings of urban roadway green street designs; Includes discussion of ROW and maintenance issues.
Chapter 4 Discusses siting within ROW, design considerations and provides example scenarios
Chapter 7 Discusses step-by-step policy and procedures for implementation.
Appendix 6.1 BMP CAD drawings and specifications
Appendix 6.2 design component CAD details and specifications
Appendix 6.3 design component photos/ideas

Keywords: green streets, factsheets, design, CAD drawings, specifications

Url: http://www.phillywatersheds.org/what_were_doing/gsdm

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
Low	High	Low

Title: *San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook*

Publisher/Sponsor: San Mateo County

Author(s): Nevue Ngan Associates and Sherwood Design Engineers

Publication Date: January 2009

Target Location San Mateo County, CA

Content and Focus: Guidebook to design and implement BMPs to manage stormwater runoff and is to be used in conjunction with San Mateo's post-construction stormwater controls technical guidance document (C.3 Technical guidance) for their municipal stormwater permit. Intended to help identify street and parking lot BMP design opportunities, how to overcome common barriers, and offer design, construction, and maintenance guidance.

Report Sections Relevant to ORIL:
Chapter 2 Provides strategies for design on various roadway types, including a matrix associating suitable BMPs to different roadway types (e.g. high density, low density residential, etc.). Includes renderings of BMP placement options
Chapter 4 Design examples for different type of roads
Chapter 5 Design considerations based on road configuration; dealing with utilities, topography, poor soils; curb cut types; overflow options; plant materials
Chapter 6 Demonstration projects

Keywords: green streets, design, case studies, site constraints

Url: http://www.flowstobay.org/files/greenstreets/FirstEdGuidebook2009-01-05.pdf

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
Low	High	Low

Title: *NCHRP Synthesis 444: Pollutant Load Reductions for Total Maximum Daily Loads for Highways*

Publisher/Sponsor: AASHTO, FHWA

Author(s): Abbasi, S., and Koskelo, A.

Publication Date: 2013

Target Location National

Content and Focus: The intent of this synthesis is to collect information on the types of best management practices (BMPs) currently being used by state departments of transportation (DOTs) for meeting total maximum daily load (TMDL) water quality goals for stormwater runoff. The study approach includes two major components: interviews with 12 state DOTs to identify the existing state of the practice as it relates to TMDL implementation, and a review of selected literature sources based on the criteria of highways, TMDLs, BMP performance, and BMP cost to stay consistent with the goals of this synthesis. In particular, detailed quantitative BMP performance and cost data, including life-cycle costs, are presented, which builds significantly on previous studies of this nature.

Report Sections Relevant to ORIL: Chapter 3 Identifies DOTs via literature review and interviews that are addressing TMDLs and which BMPs they are using to meet limits. Substantial literature review info on costs and pollutant removal performance.
Chapter 4 Provides a synthesized matrix/toolbox
Appendix B Includes interview summaries with DOT staff

Keywords: DOT, methods & tools, design, selection, costs

Url: *http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_444.pdf*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	Low

Title: *BMP Performance and Cost-Benefit Analysis: Capitol Region Watershed District Arlington Pascal Project, 2007-2010*

Publisher/Sponsor: Capitol Region Watershed District

Author(s): Capitol Region Watershed District

Publication Date: 3/9/2012

Target Location St. Paul, MN

Content and Focus: The Arlington Pascal Project was the first large-scale capital improvement project ($2.7 million), implemented by CRWD. The goals of the project, which included reducing the frequency of localized flooding and reducing the pollutant loading to Como Lake, were achieved through the construction of eighteen stormwater BMPs in the Como 7 Subwatershed. Construction of the project BMPs commenced in 2005 and was completed in 2007. The BMPs constructed included: an underground stormwater storage and infiltration facility (Arlington-Hamline Underground Stormwater Facility), a regional stormwater pond (Como Park Regional Pond), eight underground infiltration trenches, eight rain gardens.Extensive monitoring and modeling efforts have been conducted by CRWD since the project BMPs became operational, to ascertain and track the overall operation and performance of the individual BMPs and the project as a whole. Specifically, monitoring and modeling activities have aimed to determine BMP performance with regards to volume reduction, total phosphorus (TP) load removal, and total suspended solids (TSS) load removal.

Report Sections Relevant to ORIL:

Section 3 Capital costs in terms of storage area and volume of the BMP
Section 5 Cost-benefit analysis; Volume and pollutant reduction per BMP, $/lb per pollutant removal, and $/cf volume reduction
Section 7-10 Includes detailed info on infiltration trench (in-street) and basin, bioretention, underground storage, wet ponds design and capital and O&M info.

Appendix A detailed cost estimates
Appendix B, Includes CAD drawings (BMP As-Builts); another in-street infiltration trench is on PDF page 168
monitoring methods and data
Appendix D Sump Monitoring Study
Appendix E Gross Solids Accumulation Study has monitored TSS and TP for BMPs

Keywords: green streets, design, case studies, CAD drawings, cost, performance

Url: http://www.capitolregionwd.org/wp-content/uploads/2012/09/2007_2010_BMP_Perfor

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
Low	High	Low

Title: *Critical Assessment of Stormwater Treatment and Control Selection Issues*

Publisher/Sponsor: WERF

Author(s): Strecker, E., Huber, W., Heaney, J., Bodine, D., Sansalone, J., Quigley, M., Leisenring, M, Pankani, D., Thayumanavan, A.

Publication Date: 6/27/2005 **Target Location** National

Content and Focus: The purpose of this guidance document is to provide a framework, or conceptual design methodology, for applying fundamental principles of unit operations and processes (UOPs) to aid in the evaluation and selection of runoff management and treatment control systems for urban and urbanizing areas. The steps of the conceptual design process presented include: 1) problem definition, 2) site characterization, 3) identification of fundamental process categories, 4) selection of treatment system components, 5) practicability assessment, 6) sizing and development of conceptual design, and 7) development of performance monitoring and evaluation plan.

Report Sections Relevant to ORIL:
Chapter 1 Identifies step-by-step procedure for BMP selection
Chapter 3 discusses site conditions and constraints
Chapter 4 Pairs BMPs with UOPs as a means of BMP selection; Table 4.1 includes many BMP types relevant to this project
Chapter 5 discusses treatment systems components including pretreatment, conventional BMP components, and enhancements; includes ranking/discussion of BMP enhancements to the UOPs (Table 5-13);
Chapter 7 discusses flow-based and volume-based sizing approach (including nomographs similar to those created for NCHRP tool)
Appendix A Pollutant Fact Sheets
Appendix B Example applications of method
Appendix C Methodology Worksheet to rank alternatives and assess practicability

Keywords: methods & tools, design, factsheets, site constraints, performance

Url: *http://www.werf.org/a/ka/Search/ResearchProfile.aspx?ReportId=02-SW-1*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
Medium	Medium	Medium

Title: *Field Evaluation of Media Filtration Stormwater Treatment Devices*

Publisher/Sponsor: New Zealand Transport Agency

Author(s): Moores, J., Gadd, J., Pattinson, P., Hyde, C., and Miselis, P.

Publication Date: August 2012 **Target Location** Auckland, New Zealand

Content and Focus: This study evaluated the performance of media filtration stormwater treatment devices for removing suspended solids, copper and zinc from road runoff. Between September 2010 and March 2012, a field program comprising the measurement of runoff volumes and the collection and analysis of influent and effluent samples was conducted using three different commercially available devices installed at sites in the Auckland region. Field conditions were found to have a marked influence on device performance. In particular, low suspended solid concentrations in runoff contributed to each of the three devices achieving lower overall contaminant removal rates than reported previously, although performance varied in relation to differences in influent quality between sites and between storm events. Relatively frequent bypassing of treatment also influenced performance; with contaminant removal rates typically lower during storm events where bypassing occurred. The devices generally achieved only limited removal of dissolved copper and zinc, with export of dissolved zinc occurring in one case and effluent samples from one of the devices routinely exceeding a water quality guideline for dissolved zinc. The results of the study provided the basis for guidance on the use, design, operation and maintenance of media filtration devices and on expectations relating to their performance.

Report Sections Relevant to ORIL:
Section 2 overview of media filtration stormwater treatment devices; indicates evaluation and approval with TARP, TAPE, etc.
Section 3 describes field methodology and has install pictures
Section 4 includes influent/effluent and performance statistics on cartridge-type/proprietary devices- includes Up-Flo filter, StormFilter; Table 4.2 has info on road description, road surface material and last resurfacing, vehicles a day for each BMP
Section 5 discussion of results for each BMP and factors influencing influent/effluent quality; substantial statistical analysis; discusses implications including sizing; Table 5.1 is summary of BMP guidance (device selection, performance, design, O&M)
Section 7 recommendations on design and sizing on these proprietary devices
Appendix B Summary of protocols for field evaluation in comparison to other studies and

Keywords: case studies, design, performance, sizing, maintenance

Url: http://www.nzta.govt.nz/resources/research/reports/493/docs/493.pdf

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	Low

Title: *Storm Water Low-Impact Development, Conventional Structural, and Manufactured Treatment Strategies for Parking Lot Runoff*

Publisher/Sponsor: University of New Hampshire Stormwater Center (UNHSC)

Author(s): Roseen, R., Houle, J., Avelleneda, P., Wildey, R., and Briggs, J.

Publication Date: 2006 **Target Location** New Hampshire

Content and Focus: Eleven storm water treatment strategies were evaluated for water quality performance and storm volume reduction during rainfall–runoff events between September 2004 and August 2005. Evaluated treatment strategies included structural best management practices (BMPs) (swales, retention ponds), low-impact development (LID) designs (treatment wetland, filtration and infiltration designs), and manufactured BMPs (filtration, infiltration, and hydrodynamic separators). Contaminant event mean concentration, performance efficiency, and mass-based first flush were evaluated for storms with varying rainfall–runoff characteristics. The devices were tested in parallel, with a single influent source providing uniform loading to all devices. Treatment strategies were uniformly sized to target 90% of the annual volume of runoff. Infiltration and filtration treatment strategies had the greatest all-around performance characteristics due to combined effects of storage volume and physical-chemical filtration.

Report Sections Relevant to ORIL: Methodology- Site Design uniformly sized, isolated, parallel treatment systems. Rainfall runoff divided to the BMPs by a distribution box and effluent was piped to a central sampling gallery. The 11 BMPs (8 discussed in report) include:
1 . riprap swale
2. retention pond
3. surface sand filter
4. bioretention system
5. subsurface gravel wetland
6-9. hydrodynamic separator (only one of 4 discussed in report)
10. storm filter
11. subsurface infiltration device
Results and Discussion- Hydrologic Data and Basic Water Quality- discussion on how hydrology affects loading/seasonal variation (hurricanes). Discusses design storm (SCS Type III) versus actual storm and storm event effect on routing.
Contaminant Water Quality- discusses performance of BMP with respect to biological activity, influent concentration, hydraulic conductivity, and sediment resuspension.
Mass-Based First Flush Examines first-flush characteristics of pollutants

Keywords: design, case studies, performance, sizing

Url: *http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/bmp_performance_eval_trr1984*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
Low	High	Low

Title: *Evaluation of Permeable Friction Course (PFC), Roadside Filter Strips, Dry Swales, and Wetland Swales for Treatment of Highway Stormwater Runoff*

Publisher/Sponsor: NCDOT

Author(s): Winston, R., Hunt, W., Kennedy, S., and Wright, J.

Publication Date: 10/31/2012

Target Location Johnston, Sampson, and Duplin Counties, North Carolina

Content and Focus: Stormwater runoff from roadways is a source of surface water pollution in North Carolina. The North Carolina Department of Transportation (NCDOT) has specific interest in evaluating pollutant loads from interstate highways and potential stormwater treatment measures. The research presented herein focuses on monitoring of highway runoff at four sites along Interstate 40 (I-40) in Johnston, Sampson, and Duplin counties. Data collection began in September 2008 and continued through May 2010. Results support further use of permeable permeable friction courses (PFCs) as a water quality control. The roadside filter strips were shown to increase sediment and sediment-bound pollutant concentrations, due to relatively high slopes, sparse vegetative cover, and clean influent. The wetland swales produced lower mean effluent concentrations (by approximately 0.4 mg/L) of TN when compared to the dry swales. Similar trends were not observed for TP and TSS. Therefore, there is the potential for significant nitrogen removal by wetland swales. Load reductions of pollutants were generally poor to fair for the roadside filter strips due to substantial measured soil compaction. In fact, TP and TSS loads increased through both filter strips studied. Pollutant loads were generally lowest at the swale outlets, except at site D, where a head cut in the swale caused substantial increases in TP and TSS loads vis-à-vis the edge-of-pavement.

Report Sections Relevant to ORIL: NCDOT research paper; Includes four (4) BMPs that can be used for OH: 1) PFC, 2) filter strip, 3) dry swale, 4) wetland swale; highly pertinent figures and information for roadside application
Introduction- discusses BMP pollutant reductions, life expectancies, design variables,
Description of Sites- Figures of road BMP locations and installation pictures and design details, monitoring setup, vegetation and soil sampling and analysis details
Results and Discussion- details on soil/vegetation analyses (pH, CEC, P-Index, etc.) , particle size distribution, hydrology, water quality (effluent quality, irreducible concentrations, pollutant loads normalized by watershed areas)
Conclusions- good performance for PFC, better TN removal with wetland swales compared with dry swales, filter strips had TP and TSS increases due to irreducible concentrations and high slopes, poor cover quality and/or maintenance; swales may not remove further pollutants than PFC

Keywords: DOT, design, case studies, performance

Url: *http://www.ncdot.gov/doh/preconstruct/tpb/research/download/2007-21finalreport.pdf*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	Medium

Title: *NCHRP 25-40: Long-Term Performance and Life-Cycle Costs of Stormwater Best Management Practices�Final Report 792�Tool*

Publisher/Sponsor: NCHRP

Author(s): Taylor, S.; Barrett, M.; Leisenring, M.; Weinstein, N.; Venner, M.

Publication Date: 10/14/2014

Target Location Natiowide

Content and Focus: The document is intended to be used as guidance and provides a decision support tool to optimize BMP performance within the larger context of a DOT stormwater management program. The report/tool objectives include analysis of structural and non-structural BMP elements to inform professionals on the most efficient BMP selection scenarios. The objectives are focused on treating constituents contained in highway runoff.

Report Sections Relevant to ORIL: Useful information on BMP performance and lifecycle costs. The spreadsheet tools can be customized to Ohio rainfall stations and updated with local cost information. There is useful cost data available within the report (e.g. cost per load for BMP types). The focus for this research is on highway constituents and alternatives and therefore may not be as applicable to local roads.

Keywords: costs, tools, performance, maintenance, non-structural

Url: http://www.trb.org/Main/Blurbs/171471.aspx

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	Medium	Medium

Title: *North Carolina Department of Transportation Stormwater Control Inspection and Maintenance Manual*

Publisher/Sponsor:

Author(s): NC DOT

Publication Date: 1/1/2010

Target Location North Carolina

Content and Focus: This is a guidance document for O&M personnel to help them properly maintain and inspect roadway BMPs. The document was created in partial fulfillment of NCDOT's NPDES permit. The frequency and essential components to check are included within the document, as well as a "how-to" guidance.

Report Sections Relevant to ORIL: Document provides maintenance details by BMP type used by NCDOT.
Chapter 2 provides Inspection information.
Chapter 3 provides maintenance information.
Chapters 5-13 provide O&M details for various BMP types.
Appendix A contains inspection checklists.

Keywords: maintenance, DOT

Url: http://www.ncdot.gov/programs/environment/stormwater/download/swcontrolinspectionmaintjan201

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
Yes	Yes	possible

Title: *NCHRP 25-20-01: Evaluation of Best Management Practices for Highway Runoff Control*

Publisher/Sponsor: AASHTO, FHWA

Author(s): Oregon State University, Geosyntec Consultants, University of Florida, and Low Impact Development Center

Publication Date: 2006 **Target Location** National

Content and Focus: This research examines BMPs for highway runoff control designed to provide a means of avoiding or mitigating the negative impacts of various pollutants that can be carried by rainfall into surface waters and groundwater as well as hydromodification impacts. The research is focused on providing highway practitioners with the scientific and economic information needed for selection and design of conventional BMPs and LID approaches for control of highway runoff. This final report accompanied the following work products: (1) User's Guide for BMP/LID Selection (Guidelines Manual), (2) Appendices to the User's Guide for BMP/LID Selection (Appendices), (3) Low Impact Development Design Manual for Highway Runoff Control (LID Design Manual), and a spreadsheet model that simulates regional hydrologic impacts on BMP performance.

Report Sections Relevant to ORIL: Chapter 8 provides methods and tools to evaluate BMP/LID performance for roadways. Chapter 9 presents a methodology to select the most appropriate BMP/LID for a particular site. Chapter 10 provides design considerations (such as sizing for hydraulic and hydrologic controls, treatment design optimization, and adaptive management) and guidance.

Keywords: methods & tools, selection, sizing, site constraints, design

Url: *http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_565.pdf*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	Medium	Low

Title: *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring (Web Doc)*

Publisher/Sponsor: FHWA

Author(s): FHWA

Publication Date: 5/1/2012

Target Location National

Content and Focus: This document is a general guideline/manual for selecting BMPs for ultra urban environments. It includes site considerations, available BMP technologies and methods, and provides factsheets for each BMP type. It discusses the purpose of structural BMP elements, such as inlets and porous pavement. It documents new innovative technologies and in what scenarios they are most useful.

Report Sections Relevant to ORIL: Report provide guidance on implementation of BMPs in ultra-urban settings defined as :
1. Limited space: less than 1 acre
2. Drainage area imperviousness: greater than 50%
3. Property value: greater than $215 per sq. meter
4. Location of BMP in ROW as only option
5. Existence of build-out conditions

Chapter 5 presents a number of case study locations where various BMPs were monitored. Efficiencies and performance evaluations are provided.
Chapter 6 presents a step-by-step decision making framework (flowchart) to guide the selection process for BMPs in ultra-urban settings.

Keywords: case studies, factsheets, methods & tools, selection, site constraints

Url: *http://environment.fhwa.dot.gov/ecosystems/ultraurb/index.asp*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	Low

Title: *CatchBasin StormFilter Performance Evaluation Report*

Publisher/Sponsor: City of Seattle

Author(s): Seattle Public Utilities

Publication Date: 3/5/2012 **Target Location** Seattle, WA

Content and Focus: From February 2009 through September 2011, Seattle Public Utilities (SPU) conducted a performance evaluation of the Stormwater Management StormFilter® (StormFilter) in two CatchBasin StormFilter™ (CBSFs) stormwater treatment systems configured with zeolite-perlite- granular activated carbon (ZPG™) cartridges installed in West Seattle, Washington. The monitoring work was performed to fulfill a portion of the City of Seattle's monitoring requirements contained in Section S8.F of the 2007 National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permit (Permit) and was performed in accordance with criteria in the Permit and the Department of Ecology's (Ecology) "Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol - Ecology" ("TAPE," Ecology 2008 and revised 2011). This report summarizes findings from this study based on analyses of water quality, rainfall and flow data. A total of 37 stormwater events were sampled between both of the monitored CBSF units, which exceeded the required maximum storm event number of 35 required pursuant to the Permit and TAPE.

Report Sections Relevant to ORIL:
1.1 Summary Water Quality Performance- compared influent/effluent, describes statistical test requirements and removals
1.2 Summary Hydrologic Performance- compares quantity of treated to internally bypassed flow; completed retrospective load-based sizing analysis (in addition to traditional flow-based sizing) and determined one CBSF was undersized by a factor of 2- 3.
2 Introduction- CBSFs are frequently installed by Seattle DOT to treat roadway stormwater runoff, describes CBSF setup, has pictures and figures of install; vehicles/day, sizing details, pictures of bypass
3 Sampling, Monitoring and Maintenance Procedures- indicates qualifying storm event criteria, extensive field sampling/monitoring procedures, description and pictures of maintenance procedures
4 Sampling and Monitoring Results- summary tables (4.1a & b, 4.2a,b, c&d) on hydrology and influent/effluent, particle size distribution, sediment accumulation, sediment data (Table 4.5.1)
5 Data Analysis- discusses compliance with TAPE, treatment efficiency results, pollutant removal as function of flow rate, pictures and analysis of clogging by leaves and grate design factors, retrospective flow- and load- based design analysis details
Section 6 Maintenance and Design Considerations- Maintenance visit cost estimate, design considerations to improve function and acceptance of CBSFs
Appendix A Flow Monitoring Quality Assurance/Quality Control Report
Appendix B Analytical Data Quality Assurance/Quality Control Report
Appendix C Annual and Event Hydrographs
Appendix D Box Plots and Summary Statistics
Appendix E Contech Statement

Keywords: design, case studies, performance

Url: http://www.seattle.gov/util/groups/public/@spu/@drainsew/documents/webcontent/01_016486.pdf

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
Medium	High	Low

Title: *NCHRP Project 25-25/Task 82: Permeable Shoulders with Stone Reservoirs, White Paper and Decision Tool*

Publisher/Sponsor: AASHTO

Author(s): Hein, D., Strecker, E., Poresky, A., Roseen, R., and Venner, M.

Publication Date: 10/4/2013 **Target Location** National

Content and Focus: The report is a evaluation of permeable pavement effectiveness within the context of general roadway design. A literature review focused on identifying the success/failures of applying the permeable pavement for roadway use in other areas is sectioned based on limitations of construction site characteristics, design requirements, long-term benefits and sustainability issues/factors, and design, maintenance, and construction practices (state of the art). A decision matrix to is presented to identify the feasibility of permeable surface implementation at a site is provided. Provides a list of considerations for identifying site suitability for implementation.

Report Sections Relevant to ORIL: Focus is on permeable pavements (PP) for roadway shoulders. In depth research on various types of PP, specifically on the design, benefits, maintenance and costs. Literature review provides additional useful information from other documents/research.
Section 4 Provides a step-by-step decision methodology and decision matrix tool to determine the suitability of PP at a site using criteria prioritized as primary, secondary, and other. Some of these criteria include: 1. Funding, 2. Potential Environmental Approval, 3. Safety, 4. Grading, 5. Water Table Considerations, 6. Geotechnical Risks and Contamination, 7. WQ Standards

Keywords: methods & tools, site constraints, sizing

Url: *http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=3315*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	Low

Title: *NCHRP 25-25/83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways*

Publisher/Sponsor: AASHTO, NCHRP

Author(s): Venner, M., Strecker, E., Leisenring, M., Pankani, D., Taylor, S.

Publication Date: 8/30/2013

Target Location National

Content and Focus: This report included DOT survey information associated with post-construction BMP selection and design, and categorized the collected information into 'frequently and sometimes used' BMPs (e.g., vegetated swales, filter strips, infiltration basins, etc.) and 'rarely and never used' BMPs (e.g., hydrodynamic devices, catch basin inserts, sand filters, etc.). DOTs provided information on the content of their respective design guidance that included BMP objectives, water quality performance, maintenance and life cycle costs. The report provides some initial effluent quality concentration information, as well as a review of 2012 new construction costs vs. retrofit costs for frequently used controls. The report also provides a six-step selection and design process. Inventory and tracking are also covered. The report provides a list of ongoing research needs and includes BMP fact sheets for the more frequently used BMPs. This report will assist with formalizing the content of the matrix tool.

Report Sections Relevant to ORIL: Discusses the types of post-construction BMP in use by DOTs nationwide. Includes design, maintenance, and cost information in the form of factsheets. Document contains many summarizing tables populated with data pertaining to implementation, performance, and summary of state specific BMP guidance manuals.

Keywords: DOT, factsheets, methods & tools, selection, performance, cost

Url: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3316

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	Medium	Low

Title: *NCHRP Project 25-25/Task 85: Nutrient (Nitrogen/Phosphorus) Management and Source Control*

Publisher/Sponsor: AASHTO, NCHRP

Author(s): Leisenring, M., Sahu, S., Poor, C., Zell, C., Mansell, S., and Venner, M.

Publication Date: August 2014

Target Location National

Content and Focus: The focus of this report is summarizing the state of the art in controlling nutrient pollutant loading from DOT facilities, particularly focused on highways. Based on the research, the report presents recommendations for source control, program and policy development, site specific and watershed based approaches, and discussions on appropriate use of BMPs and associated tools.

Report Sections Relevant to ORIL: Discussion is focused on pollutant removal for various types of BMPs and enhancements. Document evaluates the types of processes best suited for removing phosphorus and nitrogen from runoff generated by roadways.

Keywords: selection, design, performance, DOT

Url: http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=3510

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	Low

Title: *NCHRP 25-31: Guidelines for Evaluating and Selecting Modifications to Existing Roadway Drainage Infrastructure to Improve Water Quality in Ultra Urban Areas*

Publisher/Sponsor: AASHTO, FHWA

Author(s): Geosyntec Consultants, Oregon State University, Venner Consulting, Low Impact Development Center, and Wright Water Engineers

Publication Date: 7/4/2012 **Target Location** National

Content and Focus: The guidelines in this recent reference document are directed specifically at roadway facilities in dense urban areas that can be particularly difficult and costly to retrofit because of space limitations, high pollutant loadings, hydrologic flashiness, hydraulic constraints, utility conflicts and legacy contamination. The guidelines will assist transportation agencies in meeting regulatory requirements under the Clean Water Act, National Pollutant Discharge Elimination System, Total Maximum Daily Load allocations, and watershed protection initiatives. A spreadsheet tool was developed as a companion to this work to allow for initial conceptual evaluations of potential retrofit projects. Even though the guidance focuses on drainage retrofit situations, it is applicable to dense urban street reconstruction projects as well.

Report Sections Relevant to ORIL: Section 4 contains a number of discussions on types of post-construction roadway retrofits for the ultra-urban environment.
Section 5 provides discussions on approaches for evaluating BMPs to select as well as effectiveness of various BMP types
Section 6 presents sizing and general design criteria and guidance
Section 7 includes a discussion on maintenance and monitoring issues and requirements. Includes a section on maintenance issue that affect BMP performance
Section 8 presents retrofit costs for BMPs in ultra urban roadway settings
Section 9 provides discussion on general approaches to create a retrofitting strategy
Section 10 presents DOT case studies from across the country

Keywords: case studies, methods & tools, site constraints, DOT

Url: *http://www.trb.org/Main/Blurbs/168015.aspx*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	Low

Title: *The Cost and Effectiveness of Stormwater Management Practices, Minnesota Department of Transportation*

Publisher/Sponsor: MnDOT

Author(s): Weiss, P., Gulliver, J., and Erickson, A.

Publication Date: June 2005

Target Location National

Content and Focus: Evaluation of BMP performance and cost for treating urban runoff to remove phosphorus and TSS using data collected from BMP sites nationwide. Statistical analyses were completed on the O/M costs and added to the capital costs to identify the life-cycle costs. then the pollutant loading over a 20 year period was estimated.

Report Sections Relevant to ORIL: The focus of this research is on type specific BMP pollutant removal performance and cost to build and maintain. The research presents a tool to estimate the cost and performance of various BMP types by WQv size.

Keywords: costs, methods & tools, performance, sizing, maintenance

Url: *http://conservancy.umn.edu/bitstream/handle/11299/986/1/200523.pdf*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	High	Low

Title: *Treatment BMP Technology Report*

Publisher/Sponsor: Caltrans

Author(s): Caltrans

Publication Date: April 2013

Target Location California

Content and Focus: This report consolidates information for Caltrans post-construction technologies in a standardized manner by using a fact sheet format. The BMP fact sheets summarize available design, construction, and performance information. The fact sheets result from a desktop evaluation of BMPs. Usually, a full-scale field evaluation (pilot testing) is required to collect sufficient information to determine if a BMP should be approved and under what conditions (siting constraints). The Department uses the fact sheets as a preliminary screening tool for selection of pilot BMPs when approved BMPs cannot meet project-specific treatment requirements due to siting constraints. BMPs selected for pilot testing are not automatically approved for statewide use.

Report Sections Relevant to ORIL:
Section 4 Provides categorization of BMP by process
Appendix A Provides an overview of fact sheets sections including symbology, pollutants, constituent removal and removal confidence assessment based on statistical analysis for Caltrans unapproved and approved BMPs; every BMP factsheet has sections on maintenance and ROW requirements; approved BMPs include cost effectiveness of the BMP relative to detention basins and a listing of certifications, verifications, or designations (e.g., TAPE, NJDEP)
Appendix B Non-approved BMP fact sheets
Appendix C Caltrans approved BMP fact sheets

Keywords: DOT, factsheets, design, cost, performance, site constraints

Url: *http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-09-239-06.pdf*

Roadway Type Applicability

Highways	Urban Roads	Rural Roads
High	Medium	Low

APPENDIX B

KEY LITERATURE FINDINGS AND BASIS FOR BMP SCREENING CRITERIA

Geosyntec consultants

MEMORANDUM

TO: ORIL Technical Advisory Committee (TAC)

FROM: GS&P Team (GS&P/Geosyntec)

DATE: August 14, 2015

SUBJECT: KEY LITERATURE FINDINGS AND BASIS FOR BMP SCREENING CRITERIA
STORM WATER BEST MANAGEMENT PRACTICES FOR LOCAL ROADWAYS / 2015-ORIL 7
ODOT State Job No. 134990
GS&P Project No. 40399.00

1 INTRODUCTION

The primary goal of the research for ORIL 7 - Storm Water Best Management Practices (BMPs) for Local Roadways was to develop a post-construction BMP selection tool based on the outcomes of the research. To that end, the GS&P Team conducted a literature review to identify relevant and current research and guidance on storm water BMPs applicable to local Ohio roadways. Twenty-three interviews were also conducted with local roadway owners (Locals) and other constituents to gather feedback on Ohio-specific issues. The key findings on BMP design characteristics, performance, and maintenance were then used to help develop the BMP selection tool, including specific screening criteria. This memo provides a summary of the key findings used to develop the BMP tool.

The GS&P Team submitted an annotated bibliography summarizing the key reference materials used in the research (GS&P and Geosyntec, 2014). Those references include the ODOT Location and Design (L&D) Manual, Ohio Department of Natural Resources Rainwater and Land Development Manual, Ohio Construction Storm Water General Permit, International Storm Water BMP Database, and twenty other highly relevant reference documents for BMPs. During development of the BMP tool, some additional reference documents were also identified and documented below.

2 BASIS FOR BMP SCREENING CRITERIA VALUES

The first focus of the literature review in support of BMP selection tool development was the definition of a set of BMPs to be included in the tool, based on their ability to meet Ohio roadway needs. As BMPs were researched, BMP selection considerations for local Ohio roadways were also identified, including compliance with Ohio regulations, right-of-way (ROW) considerations, site feasibility, pollutant performance, capital and operations and maintenance (O&M) costs, and the Local's specific needs. These selection considerations were narrowed down into a common set of BMP screening factors that might be used to differentiate between BMPs and screen out incompatible BMPs in the BMP selection process facilitated by the tool.

The selected screening factors are a mix of qualitative criteria (e.g., permit inclusion, BMP inflow types, etc.) and quantitative criteria (e.g., minimum BMP depth, etc.), and they fall within the following general categories:

- BMP Inclusion in Construction General Permit or ODOT L&D Manual Volume 2
- BMP Functions
- Site Conditions/Physical Constraints
- Costs and Maintenance
- Aesthetics

The Detailed BMP Matrix portion of the tool was created based on the selected BMPs and screening factors, and the matrix was populated with BMP-specific values for each screening factor based on relevant reference documents. Within the tool, multiple screening steps are used to collect user data defining site and project characteristics, and these values are compared to BMP-specific values in the Detailed BMP Matrix for critical selection criteria. If a single screening decision indicates that the BMP characteristics are incompatible with site or project needs, the BMP is ruled out. At the end of multiple consecutive screening steps, the user is left with a set of remaining BMPs that are potentially compatible for their specific project application. The subsections below describe critical screening factors included in the tool based on the findings from the literature review, as well as key assumptions and reference documents used to develop BMP-specific criteria values to facilitate screening.

2.1 REGULATORY INCLUSION SCREENING CRITERIA

Adherence to regulatory guidance documents is typically the primary consideration in BMP selection for Locals. Applicable local roadway projects that are required to follow ODOT's L&D Manual must select and design a BMP in accordance with the ODOT L&D Manual, or otherwise seek approval from ODOT to deviate from the ODOT L&D Manual. If not following the ODOT L&D Manual, projects are required to select a standard BMP from Table 2 of the Ohio Construction General Permit, or otherwise seek approval from Ohio EPA to use an alternative (non-standard) BMP that is not listed in the permit. The process to request and obtain approval for a non-pre-approved (non-standard) BMP from ODOT or Ohio EPA can be lengthy and may require resources that are not available to Locals. The process may present unacceptable levels of risks and impacts to project schedules and budgets. Thus, many projects default to pre-approved BMPs and are unable to consider non-standard BMPs. Although BMP inclusion in regulatory documents is typically a critical consideration for BMP selection, non-standard BMPs have been included in the tool to provide flexibility for BMP selection and design based on site and project-specific considerations.

ODOT L&D Manual BMPs

The Ohio EPA Construction General Permit (CGP, Ohio EPA, 2013) allows for roadway projects to implement post-construction BMPs in compliance with the current version of the ODOT L&D Manual (ODOT, 2014) as an alternative to the conditions of the Permit. The ODOT L&D Manual defines a standard set of BMPs that are classified as providing both water quantity and quality control or water quality control only. It also defines specific applicability criteria for water quantity and quality control requirements based on project and site characteristics. The Detailed BMP Matrix therefore identifies which of the standard ODOT BMPs are appropriate for meeting quantity/quality requirements, and which are appropriate for meeting only quality control requirements, as defined by ODOT. Note that the vegetated biofilter, which is a combination of a filter strip and swale, was included as a unique BMP type in the matrix because the ODOT L&D manual identifies specific design requirements for this multi-component, flow-through BMP that must be met if designing in accordance with the ODOT L&D Manual.

OHIO EPA CGP BMPs

Table 2 of the Ohio EPA CGP defines a list of standard and pre-approved BMPs that may be implemented to meet post-construction permit requirements on projects that are not required to comply with the ODOT L&D Manual. The standard BMPs are pre-approved by the Ohio Environmental Protection Agency (EPA) and will likely take less planning and permitting efforts to implement compared with alternative BMPs (those BMPs not listed in Table 2 of the Ohio EPA CGP). BMPs in the Detailed BMP Matrix are classified as either standard (listed in Table 2 of the Ohio EPA CGP) or alternative (all BMPs other than those listed in Table 2 of the Ohio EPA CGP).

2.2 BMP FUNCTION SCREENING

BMPs may be implemented to provide water quantity and/or quality control functions that may be required for a particular project. In addition to the detention quantity-based (water quality volume) and sediment-focused treatment requirements defined in the Ohio EPA CGP, projects may be required to comply with additional quantity or quality control requirements specified by select local manuals or alternative Ohio EPA CGPs in select watersheds. Additional BMP functions that may be required include peak flow rate control (i.e., limiting post-development flow rates to pre-development flow rates), runoff volume control / recharge requirements (i.e., minimum infiltration requirements), and required treatment for additional pollutants of concern. Proper project planning includes identifying the required storm water functions for a site or project, and then identifying BMPs that can provide one or more of those functions. The criteria in the Detailed BMP Matrix identify water quantity and quality control functions provided by each BMP, and the tool allows users to screen for these functions, as applicable to their project.

Peak Flow Control

Peak flow control screening allows users to identify BMPs that can significantly reduce site peak runoff rates in order to meet a defined flow limit, as specified by local manuals, ordinances, or other requirements outside of the Ohio EPA CGP. This screening factor focuses on peak flow requirements from local manuals or ordinances that go above and beyond the water quality volume treatment and drawdown time requirements of the Ohio EPA CGP, such as requirements to match post-development flows to pre-development flows, or critical storm methodology. Only those BMPs that provide a substantial amount of detention storage where the BMP outflow rate can be controlled via an orifice, weir or other outflow restriction (e.g., the in-situ soil infiltration rate) were considered to be capable of providing peak flow control within the tool. If the user indicates that a peak flow control function is required, BMPs that do not provide peak flow control are screened out by the tool.

Volume Control

Volume control screening allows users to identify BMPs that can provide a required runoff volume control function where applicable, meaning that the BMPs facilitate infiltration into in-situ soils and are capable of reducing the total volume of runoff that is ultimately discharged from the site. Infiltration BMPs that are designed to provide substantial storage and opportunity for infiltration via the bottom and/or walls of the BMP were determined suitable for volume control within the tool. BMPs shown as "No" are unlikely to infiltrate due to an impervious structure (e.g., subsurface bed filter), or because the BMP design characteristics are intended to retain a permanent pool (e.g., constructed wetland). BMPs shown as "Incidental" do not rely on infiltration as a primary means of draining, but they do expose stormwater to a pervious surface, and incidental infiltration may occur if soil conditions allow. BMPs shown as "Limited" also do not rely on infiltration as a primary means of draining, and are not intended to infiltrate large volumes of stormwater, but are designed to encourage infiltration to the extent that soil conditions allow. These BMPs (including bioretention with a raised underdrain) are typically used in applications where groundwater recharge is required despite soil conditions not being conducive to infiltration. BMPs shown as "Yes" are intended to promote infiltration and use infiltration as a primary means of draining. These may be capable of infiltrating large volumes of stormwater, such as the water quality volume, if soil conditions are suitable (e.g., hydrologic soil groups A/B).

Pollutant Removal

Pollutant removal screening within the tool provides an opportunity for users to specify if their projects will require treatment for pollutants of concern beyond the sediment-based water quality volume treatment of the Ohio EPA CGP. Such requirements may be dictated by a local manual or ordinance or alternative Ohio EPA CGP. Tool users may comply with the water quality volume requirements of the Ohio EPA CGP without using this particular optional screening function. The additional pollutants of concern that may be considered in BMP selection are classified in the following six storm water pollutant categories:

- Phosphorus (P)
- Nitrogen (N)
- Metals (M)
- Bacteria (B)
- Oil & Grease (O&G)
- Organics (O)

References used for pollutant removal include a combination of the following primary guidance documents:

- International Stormwater BMP Database (BMPDB)
- NCHRP Report 565: Evaluation of Best Management Practices for Highway Runoff Control (Huber et al., 2006)
- WERF Critical Assessment of Stormwater Treatment and Control Selection Issues (Strecker et al., 2005)
- NCHRP 25-25 Task 83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways (Venner et. al, 2013)
- NCHRP Project 25-25 Task 85: Nutrient (Nitrogen/Phosphorus) Management and Source Control (Leisenring et al., 2014)

The tool screens the list of BMPs, based on user-selected pollutants, to those which will provide a significant level of treatment for the selected pollutants. The treatment level for each pollutant was assigned as low, medium or high. If a user indicates that treatment is required for one or more pollutants, those BMPs providing only low treatment for the selected pollutant(s) are eliminated. The pollutant treatment levels for each BMP were determined using a combination of the following four assessments:

- **BMP Performance Data** – The results of data analysis, which is typically comparing the 95% confidence intervals around the median influent and effluent concentrations of BMPDB data and/or other BMP data, were used to determine the level of treatment for BMPs. Some BMPs did not have known performance data available and therefore treatment effectiveness was based on the other following assessments.
- **BMP Unit Process Quantity** – The number of treatment mechanisms (unit processes) provided by the BMPs that physically, biologically, or chemically prevent pollutants from reaching receiving waters. The BMP performance data paired with the known unit processes for that BMP provides insight into which unit processes provide the greatest removal for various pollutants, or conversely, could result in export of a pollutant.
- **BMP Unit Process Robustness –** The performance level of a certain unit process within a BMP. For example, adsorption may be more robust for one BMP when compared to other BMPs based on the type of media included or not (e.g., sand vs. compost) or biochemical degradation rates may be higher in continuously wet systems (e.g., wetlands) than normally dry systems (e.g., detention basins). Infiltration completely removes a pollutant from receiving waters and therefore is the most effective pollutant control where

space is available and soils are adequate to infiltrate. The amount of infiltration provided per unit drainage area is highly variable between BMPs and affects the treatment level.

- **Relative BMP Performance** – Treatment level assignments are relative to the list of BMPs within the tool per pollutant. Therefore, a BMP that is given a high level of treatment for a certain pollutant may not necessarily provide a high removal rate, but it just outperforms other BMPs included in the tool. For example, very few BMPs are exceptionally effective at removing nitrogen, but infiltration BMPs and wetlands can provide relatively high removal compared to vegetated swales and dry detention basins.

Table B-1 indicates which unit processes are expected to have significant effect on treating the pollutant categories considered within the tool. A value of 3 is used for high relative effectiveness (as compared to other unit processes) and a value of 1 is used for low relative effectiveness. A value of 0 indicates the unit process is not effective for reducing the pollutant category. Table B-2 scores the unit processes among the various BMPs using a similar approach (i.e., a value of 3 indicates the unit process is very significant for the BMP; a value of 0 indicates that unit process is negligible or not provided). Both of these tables were produced based on the unit treatment processes defined and described in Strecker et al. (2005) and Huber et al. (2006) along with performance summaries from the International Storm water BMP Database and best professional judgment. Table B-3 is the final relative effectiveness ranking based on the cross-product score of the unit process effectiveness and robustness scores shown in Tables B-1 and B-2. The rankings of high (H), moderate (M), and low (L) are relative among the BMPs listed for each individual pollutant.

Table B-1. – Relative Effectiveness Score of Unit Processes per Pollutant Category

Unit Process	Pollutant Treated					
	P	N	M	B	O&G	O
Infiltration	3	3	3	3	3	3
Filtration- Vegetative	0	0	1	1	1	1
Filtration- Inert[a]	2	1	2	2	2	1
Adsorption/ Ion Exchange	1	0	3	0	0	2
Sedimentation	1	0	2	1	0	1
Microbially-Mediated Transformations[b]	1	2	1	1	1	2
Biological Uptake	1	1	1	0	0	1
Photodegradation / Disinfection[c]	0	0	0	2	1	1
Skimming	0	0	0	0	2	0

Table Notes:

a. Filtration via inert material such as sand or rock
b. Microbial activity that promote or catalyze redox reactions and transformations including the degradation of organic pollutants as well as the oxidation or reduction of inorganic pollutants (Huber et al., 2006)
c. Breakdown of organics and destruction of pathogens from ultra-violet radiation (sunlight) (Strecker et al., 2005)

Effectiveness Score Definitions

0 – not effective unit treatment process for pollutant category
1 – minimally effective unit treatment process for pollutant category
2 – partially effective unit treatment process for pollutant category
3 – highly effective unit treatment process for pollutant category

Table B-2. – Relative Robustness Score of Unit Processes per BMP

BMP in Tool	Infiltration	Filtration-Vegetative	Filtration- Inert	Adsorption/ Ion Exchange	Sedimentation	Microbially-Mediated Transformations	Biological Uptake	Photo-degradation / Disinfection	Skimming
Hydrodynamic Separator	0	0	0	0	1	0	0	0	2
Underground Detention Vault	0	0	0	0	2	0	0	0	0
Modular Manufactured Filtration Systems	0	0	3	3	2	0	0	0	3
Multi-Chamber Treatment Train	0	0	3	2	2	1	0	0	3
Subsurface Bed Filter	0	0	3	1	1	0	0	0	2
Infiltration Gallery	3	0	3	2	2	1	0	0	0
Subsurface Flow Wetland	0	1	2	2	2	2	2	0	0
Vegetated Filter Strip	2	3	1	1	2	1	2	0	0
Shoulder Media Filter Drain	2	1	3	3	1	2	1	0	0
Infiltration Trench	3	0	3	2	2	1	0	0	0
Vegetated Biofilter/Swale	1	2	0	0	1	1	1	0	0
Wetland Channel	0	2	0	1	2	2	1	2	0
Bioretention With Underdrain	1	2	3	3	2	1	3	0	0
Bioretention Without Underdrain	3	2	2	3	2	2	3	0	0
Constructed Wetland	0	2	0	1	3	3	3	2	0
Wet Extended Detention Basin	0	1	0	0	3	2	2	3	0
Dry Extended Detention Basin	1	1	0	0	2	0	1	1	0
Infiltration Basin	3	0	3	2	2	1	0	1	0
Surface Bed Filter	0	0	3	1	2	0	0	1	2
Permeable Pavement - Infiltration	3	0	3	2	1	0	0	0	0
Permeable Pavement - Extended Detention	1	0	3	0	1	0	0	0	0
Permeable Friction Course (PFC)	0	0	2	0	1	0	0	0	0
Permeable Shoulder	1	0	3	0	1	0	0	0	0

Robustness Score Definitions
0 – unit treatment process not present in BMP
1 – unit treatment process minimally present in BMP (minor unit process)
2 – unit treatment process somewhat significant in BMP
3 – unit treatment process very significant in BMP (major unit process)

Table B-3. – Relative Effectiveness Ranking of BMPs at Reducing Pollutant Loads

BMP in Tool	Pollutant Treated					
	P	**N**	**M**	**B**	**O&G**	**O**
Hydrodynamic Separator	L	L	L	L	L	L
Underground Detention Vault	L	L	L	L	L	L
Modular Manufactured Filtration Systems	M	L	M	L	M	M
Multi-Chamber Treatment Train	M	M	M	M	H	M
Subsurface Bed Filter	M	L	M	L	M	L
Infiltration Gallery	H	H	H	H	H	H
Subsurface Flow Wetland	M	M	M	M	M	M
Vegetated Filter Strip	M	M	M	M	M	M
Shoulder Media Filter Drain	H	H	H	H	H	H
Infiltration Trench	H	H	H	H	H	H
Vegetated Biofilter/Swale	L	M	L	L	L	L
Wetland Channel	L	M	M	M	L	M
Bioretention With Underdrain	H	M	H	M	M	H
Bioretention Without Underdrain	H	H	H	H	H	H
Constructed Wetland	M	M	M	M	M	M
Wet Extended Detention Basin	L	M	M	M	L	M
Dry Extended Detention Basin	L	L	L	L	L	L
Infiltration Basin	H	H	H	H	H	H
Surface Bed Filter	M	L	M	M	M	L
Permeable Pavement - Infiltration	H	H	H	H	H	M
Permeable Pavement - Extended Detention	M	M	M	M	M	L
Permeable Friction Course (PFC)	L	L	L	L	L	L
Permeable Shoulder w/ Stone Reservoir	M	L	M	M	M	L

Relative Effectiveness Ranking Definitions
L – low relative effectiveness at reducing pollutant loads
M – moderate relative effectiveness at reducing pollutant loads
H – high relative effectiveness at reducing pollutant loads

2.3 SITE CONDITIONS/CONSTRAINTS SCREENING CRITERIA

Site conditions and constraints were used to screen BMPs through consideration of BMP dimensions, the available existing infrastructure to serve the implemented BMP, hydrogeological conditions, geotechnical hazards, and safety issues. References used to populate the values for these design criteria, which were based on both written values and those derived from detail drawings, include a combination of the following primary guidance documents:

- ODOT L&D Manual (ODOT, 2014)
- Ohio DNR Rainwater and Land Development Manual (Ohio DNR, 2006)
- NCHRP 25-25 Task 83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways (Venner et al., 2013)
- Mn/DOT Decision Tree for Stormwater BMPs (Marti, 2011)
- Minnesota Stormwater Manual (MPCA, n.d.)
- Port of Portland Stormwater Design Standards Manual (GS&P et al., 2014)

The criteria used in the BMP tool are described in more detail below and the values are summarized in Table B-4. The table indicates where numeric values were available for each criterion, and the values assumed within the tool for each. Note that the values selected for the tool account for roadway design characteristics for tributary areas, which tend to be more impervious with faster hydrologic response than average urban tributary areas.

Hydrologic Soil Group Compatibility

Hydrologic soil group (HSG) compatibility screens out infiltration BMPs if the user indicates that the site has primarily HSG C or D soils based on National Resources Conservation Service (NRCS) soil classification, which indicates a low capacity for infiltration.

BMP Minimum Hydraulic Drop

The minimum hydraulic drop is the depth required between inflow and outflow of the BMP, and the tool will screen out BMPs when the minimum hydraulic drop is not available based on preliminary site assessment or planned project design characteristics (for example, the proposed elevations of drainage systems serving the project). Hydraulic drop is shown as not applicable (“N/A”) for BMPs for which hydraulic drop is not typically a significant factor for BMP selection. These include linear system BMPs (e.g., swales, channels, vegetated filters) that are slope dependent, basin systems (e.g., wet or dry extended detention basins), and infiltration BMPs where there is no underdrain. Additionally, basin BMPs without underdrains were also considered not applicable to avoid over-screening, since the drainage system serving the basin may have a minimal drop. Hydraulic drop is typically more of a limitation for BMPs that require significant differences between inlet and outlet elevations, including subsurface BMPs with underdrains or lowered pipe outlets, and BMPs with vertical flow and filtration processes. Please note that for permeable pavement BMPs that do not rely on infiltration, the hydraulic drop is measured from the top surface of the pavement (where stormwater enters the BMP) to the invert of the outlet pipe.

Minimum Depth to Bedrock/Groundwater from BMP Bottom

The depth to bedrock and groundwater from the bottom of the BMP is primarily a concern for infiltration, where the separation should be at least three feet to facilitate percolation into in-situ soils and lessen the risk of negative groundwater impacts. For non-infiltration BMPs, this depth can be reduced. For constructed wetlands, the depth to bedrock should be at least two feet, but the bottom can be at the groundwater table (no separation required) because wetland BMPs require base flow to maintain their ecological functions.

BMP Minimum Top Width

Minimum top width of BMPs is included as a screening criteria to assess compatibility with site-specific space constraints along the roadside (from shoulder to edge of right-of-way, or within median of divided road). The tool asks the user to define the minimum width of the likely BMP installation area, measured perpendicular to the roadway centerline. This is compared to minimum BMP dimensions to screen out BMPs that will not fit within the allowable space. Based on the references listed above and engineering judgment, a top width was calculated for BMPs that was representative of a constructible bottom, side slopes and a minimal freeboard conditions, based on the assumed orientation of the BMP. For vegetated biofilters/swales, the width was assumed to be the cross-sectional width (perpendicular to the likely direction of flow, assuming the swale is parallel to the road). For filter strips, the width was assumed to be measured from upstream end (roadway shoulder) to downstream end (away from the road), in the direction of flow.

To minimize the potential for over-screening BMPs that might be adapted to fit an application, dimensions are assumed to be as small as possible. Vertical side slopes are assumed if it is typical to construct the BMP P with hardscape materials such as asphalt, concrete, modular block, etc., without significantly impacting the intended BMP functions (e.g., a linear bioretention system with vertical walls installed between the curb and sidewalk in an urban area).

BMP Minimum Depth

The BMP minimum depth is the minimum depth required to incorporate, as applicable, surface ponding, filtration media layers, aggregate, underdrain, and/or base structural materials. While an upturned elbow for an underdrain can minimize the depth required, a standard underdrain was assumed for the BMPs within the tool. The minimum depth of the BMP is used in the tool's screening process for depth to groundwater and depth to bedrock. The user is prompted for total depth to groundwater and bedrock from the surface because those characteristics are site-specific, whereas the required separation distance from the bottom of the BMP to bedrock or groundwater varies based on BMP type. If the user-defined available depth to bedrock (from the surface) is less than the sum of the minimum BMP depth and the minimum required separation distance from the bottom of the BMP to bedrock, the BMP is screened out. A similar methodology is used for screening depth to groundwater.

BMP Maximum Tributary Area

A maximum tributary area to a BMP helps increase the probability that the BMP functions (Section 2.2) will be adequately provided as designed. The tool screens out BMPs if the user-entered tributary area value exceeds the BMP-specific allowable tributary area defined in the Detailed BMP Matrix. BMPs which only receive runoff directly from sheet flow are noted as not applicable for roadway applications.

BMP Minimum Footprint Area as Percentage of Tributary Area

The minimum footprint area of the BMP as a percentage of the tributary area provides a standard rule of thumb as to the area that will be required for BMP implementation. This factor is used to screen BMPs for compatibility with site-specific space constraints. The tool multiplies this BMP-specific factor times the user-defined tributary area to estimate an approximate BMP footprint area required for that application. The tool then screens out BMPs if the maximum area available for BMP installation within the ROW (as defined by the user) is less than the approximate BMP footprint area required for that application.

BMP Inflow Types

BMP inflow types are characterized to allow the tool to screen BMPs based on compatibility with the user-defined available conveyance methods (pipe, curb cut, open channel, and/or overland flow). If the BMP requires an inflow method that is incompatible with the project design or site (e.g., piped inflow), then the BMP is screened out.

BMP Permanent Pools and Temporary Ponding Depth

Some BMPs have exposed permanent pools (a.k.a. dead storage, standing water) and because this feature may raise public safety concerns when the BMP is installed in the clear zone or other critical areas within the ROW, the user has the opportunity to eliminate BMPs that require permanent pools. Additionally, because a temporary ponding depth greater than one foot during a storm event may also pose a safety risk, the user similarly has the option to screen out BMPs that are likely to have temporary ponding exceeding one foot.

Underground BMPs are categorized as not applicable (“N/A”). A value of “No” in the table indicates BMPs do not create ponding of more than one foot, and a value of “Yes” indicates that one foot of ponding is an integral element of the BMP design. Dry extended detention basins, which may incorporate micropools of one foot or more but are otherwise dry between storm events, are characterized in the tool as not having temporary ponding exceeding one foot, such that they do not get screened out for this criteria. This avoids over-screening dry extended detention basins since they are typically not located within the clear zone due to their space requirements.

Page Intentionally Blank

Table B-4. – BMP Site Conditions/Constraints Screening Criteria

BMP in Tool	BMP Screening Criteria													
	Min. Hydraulic Drop (ft)		Min. Depth to Bedrock / GW from Bottom (ft)		Min. Top Width (ft)		Min. Depth (ft)		Max. Tributary Area (ac)		Min. Area as (%) of Tributary Area		Perm./ Temp. Ponding Depth (ft)	
	Range	Tool	Range	Tool	Range	Tool	Range	Tool	Range	Tool	Range	Tool	Range	Tool
Hydrodynamic Separator		1	N/A	N/A	N/A	N/A		5		25	N/A	N/A	N/A	N/A
Underground Detention Vault		2	N/A	N/A	N/A	N/A		4		N/A		1	N/A	N/A
Modular Manufactured Filtration Systems		2	N/A	N/A	N/A	N/A		4		25	N/A	N/A	N/A	N/A
Multi-Chamber Treatment Train		1	N/A	N/A	N/A	N/A		5		2	N/A	N/A	N/A	N/A
Subsurface Bed Filter	2	2		0/2	1.5-2.5	2	2	2	1-5	2	≤1-4	N/A	N/A	N/A
Infiltration Gallery		2	3-5	3		5		3	5	5	≤5	1	N/A	N/A
Subsurface Flow Wetland		1	3	2		6	2	3		25		5	0.25-2	No/Yes
Vegetated Filter Strip	N/A	N/A	2-4	2	15	10	0	0	≤2-10	N/A	5-10	2	N/A	No/No
Shoulder Media Filter Drain	N/A	N/A	3	2		10		1.5	≤10	N/A		2	N/A	No/No
Infiltration Trench	N/A	N/A	3-5	3	3	2	3-6	1.5	5-10	5		2	N/A	No/No
Vegetated Biofilter /Swale	N/A	N/A	3	1		6		1.5	≤5-10	10	≤1	3	N/A	No/No
Wetland Channel	N/A	N/A	0-3	2/0		6		1.5	≥10	25	1-5	3	1-5	Yes/ Yes
Bioretention With Underdrain	≥2-3.5	2	3/0-5	2	10	2	2-5	2.5	≤2-5	5	3-5	3	0.5-1	No/Yes
Bioretention w/o Underdrain	≥3.5	N/A	3/0-5	3	10	2	2.5-5	1.5	≤2-5	5	3-5	5	0.5-1	No/Yes
Constructed Wetland	2	N/A	-/0	2/0		15	1.5-6	3	≥10-25	N/A	1-12	3	0.5-8	Yes/ Yes
Wet Extended Detention Basin	6-10	N/A	0-3	0		15	≤6-8	3	10-25	N/A	1-16	2	3-8	Yes/ Yes
Dry Extended Detention Basin	6-10	N/A	0-5	2		15	3	3	10-25	N/A	1-3	1	≤4	No/Yes
Infiltration Basin	N/A	N/A	3-5	3		15		3	5-50	N/A	5	5	≤3	No/Yes
Surface Bed Filter		3		2		6	2	2.5	≤5-25	25	2-4	5	≤3	No/Yes
Permeable Pavement- Infiltration	N/A	N/A	2-3	3	N/A	N/A	1	1	N/A	N/A	N/A	N/A	N/A	No/No
Permeable Pavement- Extended Detention	2	2	2-3	2	N/A	N/A	2	2	N/A	N/A	N/A	N/A	N/A	No/No
Permeable Friction Course (PFC) Overlay	N/A	N/A		2	N/A	N/A		0	N/A	N/A	N/A	N/A	N/A	No/No
Permeable Shoulder w/Stone Reservoir	2	N/A		2		2		2	N/A	N/A	N/A	N/A	N/A	No/No

Page Intentionally Blank

2.4 MAINTENANCE AND COSTS

Maintenance and cost data are summarized within the tool to provide an understanding of the resources required by Locals (e.g., staff, time, and funding) for long-term BMP implementation. Maintenance efforts and costs are presented at the end of the BMP screening process as guidance, not for BMP screening purposes, to minimize the potential for over-screening BMPs. It is anticipated that these criteria will enhance decision-making between several viable BMP options that remain after the screening process is complete.

Operations and Maintenance Level of Effort

The operations and maintenance (O&M) level of effort ranking (low, medium, or high) reflects the amount of total hours of labor needed for the maintenance tasks to uphold the function of the BMPs, including labor required for both hand tools and heavy equipment. References used for O&M level of effort include the following two primary guidance documents:

- NCHRP Report 792: Long-Term Performance and Life-Cycle Costs of Stormwater Best Management Practices (Taylor et al., 2014)
- Port of Portland Stormwater Design Standards Manual (GS&P et al., 2014)

The basis of selection for the level of effort was based on the following assessments:

- **Maintenance Task Quantity** – The greater number of tasks required to maintain a BMP, the higher the level of effort.
- **Maintenance Task Frequency** – The greater maintenance frequency required for proper BMP function increases the level of effort.
- **Maintenance Task Resource Level** – The more time, people, equipment, and materials certain tasks take increases the overall level of effort. For example, filter systems can take more equipment and time to remove and dispose of sediment and spent filter material than a bioretention system.
- **Relative Maintenance Requirements** – Maintenance levels of effort were relative to the list of BMPs within the tool. Therefore, a BMP that is assigned a level of high requires a greater amount of total hours of maintenance labor in relation to the other BMPs included in the tool.

Table B-5 identifies six major maintenance tasks, as well as the standard frequency and resource level for each task, as required for each BMP. The four individual BMP maintenance assessments were then used collectively to determine the ultimate low, medium, and high level of effort rankings within the tool. The individual assessments were based on the best quantitative and qualitative data available, including evaluation of the Table B-5 information, and the team's engineering judgment of relative maintenance requirements based on access needs, components and complexity of the BMP design.

Table B-5. – BMP Maintenance Tasks, Frequency and Resource Level

BMP in Tool	Maintenance Task Frequency (times/yr or every X years), Resource Level (H,M,L)						
	Remove Trash & Debris	Vegetation Management (height, mulch, repair)	Sediment Management (with haul & disposal)	Filter Media Management	Erosion Inspection & Repair	Pipe Inspection & Repair (underdrain, inlet/outlet)	Overall Rating
Hydrodynamic Separator	1,M		1,M			1,M	M
Underground Detention Vault			1,M			1,M	M
Modular Manufactured Filtration System	1,H		2,H	2,H		1,H	H
Multi-Chamber Treatment Train	1,H		1,H	X5,H		1,H	H
Subsurface Bed Filter			X20,H	X5,H		1,H	H
Infiltration Gallery			1,M			1,M	M
Subsurface Flow Wetland	2,M	2,M	1,H			1,M	M
Vegetated Filter Strip		2,L	X5,L		X5,L		L
Shoulder Media Filter Drain	1,L	2,L	X5,L	X5,M	X5,L	1,L	L
Infiltration Trench	1,L		1,M			1,L	L
Vegetated Biofilter/ Swale	1,L	2,L	X5,L		X5,L		L
Wetland Channel	1,M	2,H	X10,H		X5,H		H
Bioretention With Underdrain	1,M	1,M	X20,M	X20,M	X8,M	1,M	M
Bioretention Without Underdrain	1,M	1,M	X20,M	X20,M	X8,M	1,L	M
Constructed Wetland	1,H	2,H	X20,H		X8,H	1,M	H
Wet Extended Detention Basin	1,M	2,H	X20,H		X8,H	1,M	H
Dry Extended Detention Basin	1,L	2,L	X5,M		X5,M	1,M	M
Infiltration Basin	1,L	2,L	1,L		X5,M	1,L	L
Surface Bed Filter	1,L		X5,M	X5,M		1,L	M
Permeable Pavement - Infiltration	1,L		1,M				L
Permeable Pavement - Extended Detention	1,L		1,M			1,M	L
Permeable Friction Course (PFC) Overlay	1,L		X12,H				L
Permeable Shoulder w/ Stone Reservoir	1,L		1,M			1,M	L

Capital Cost Range per Acre Treated

A capital cost range was assigned to each BMP based on a range of literature review values and the team's cost estimation experience. Costs are summarized in the tool as a generalized cost per acre of tributary area treated, which allows for comparison across different types of BMPs (e.g., linear systems versus basin systems). These costs were broken down into cost range categories in the tool (ranging from $ to $$$$). Capital cost ranges and categories are summarized in Table B-6.

Table B-6. – BMP Capital Cost Range

BMP in Tool	Capital Cost (in $1,000s/ acre treated)	References/ Assumptions	Cost Category
Hydrodynamic Separators	10-20	3	$$
Underground Detention Vault	30-50	2 (a)	$$$$
Modular Manufactured Filtration System	10-30	2 (b)	$$$
Multi-Chamber Treatment Train	10-50	1 (c), 3	$$$$
Subsurface Bed Filters	≤10-30	1, 2, 3 (d)	$$$$
Infiltration Gallery	10-50	1 (e), 2 (f)	$$$$
Subsurface Flow Wetland	10-50	1, 2	$$$$
Vegetated Filter Strip	≤2-10	1, 2, 3	$
Shoulder Media Filter Drain	≤10-20	1	$$$
Infiltration Trench	10-30	1 (e), 2	$$$
Vegetated Swales	≤6	2, 3	$$
Vegetated Biofilter	≤16	1, 2 (g)	$$
Wetland Channels	≤10-20	1	$$$
Bioretention With Underdrain	≤20-30	1, 2, 3	$$$
Bioretention Without Underdrain	≤20-30	1, 2, 3	$$$
Constructed Wetland	≥10-30	1, 2 (h)	$$$$
Wet Extended Detention Basin	≥10-35	1, 2, 3 (i)	$$$$
Dry Extended Detention Basin	10-20	1, 2, 3	$$$
Infiltration Basin	10-20	1 (e)	$$$
Surface Bed Filters	≤10-35	1, 2, 3 (d)	$$$$
Permeable Pavement - Infiltration	≤10-25	1, 2 (j)	$$$
Permeable Pavement - Extended Detention	≤10-30	1, 2 (j)	$$$
Permeable Friction Course (PFC) Overlay	≥5	1, 3	$$
Permeable Shoulders w/ Stone Reservoirs	≤10	1	$$

Table References

1. Leisenring, M. et al., 2014
2. GS&P et al., 2014
3. Taylor et al., 2014

Table Assumptions

a. Assumed same as underground storm water control facilities (detention)
b. Assumed Contech StormFilter vault, 15 gpm per cartridge
c. Depends on components
d. Assumed same as “media (bed) or sand filter,” a stand-alone surface filter system. Subsurface bed filter costs were modified to include vault construction similar to a Delaware Sand Filter. Surface bed filter costs were modified to include an upstream sedimentation chamber similar to an Austin Sand Filter.
e. Assumed same as infiltration facility
f. Assumed same as underground storm water control facilities (infiltration)
g. Assumed same as combined cost for vegetated filter strip and swale
h. Assumed the same as wetland basin
i. Assumed same as wet pond
j. Assumed same as porous/pervious pavement

Capital Cost Range Definitions (in $ per acre treated):
$: Very Low (<$5,000), $$: Low ($5,001-$15,000), $$$: Medium ($15,001-30,000), $$$$: High (>$30,000)

2.5 AESTHETICS

Aesthetics play an important role in public acceptance for BMPs installed in visible locations along local roadways, and are therefore included in the tool as screening criteria. The two key criteria chosen for BMP screening for aesthetics include native vegetation allowance and subsurface placement preference. These criteria were primarily selected based on feedback received during the interview task specific to public acceptance, concerns, and preferences.

Native Vegetation Allowance

Native vegetation is generally used in wetland channels and constructed wetlands for pollutant treatment and habitat creation. If the desired aesthetic is the more groomed or urban appearance of turf grass or sod, the tool provides the user the opportunity to eliminate BMPs which require native vegetation.

Subsurface Placement Preference

If underground BMPs are required for the project for aesthetic reasons, the tool provides the opportunity to screen out aboveground BMPs. In urban environments with a potential for vandalism or where there is an expectation of a curb and gutter and “non-rural” aesthetic, it may be preferable for BMPs to be underground and not exposed to the public.

3 REFERENCES

Gresham, Smith and Partners and Geosyntec Consultants (GS&P and Gesoyntec). (2014). Memorandum to ORIL Technical Advisory Committee Regarding Task 2 – Annotated Bibliography, Stormwater Best Management Practices for Local Roadways/ 2015-ORIL 7. December.

Gresham, Smith and Partners, Geosyntec Consultants, and HDR (GS&P et al.). (2014). Port of Portland Stormwater Design Standards Manual. May.

Huber, W., Heaney, J., Strecker, E., and Weinstein, N. (2006). NCHRP Report 565: Evaluation of Best Management Practices for Highway Runoff Control. Transportation Research Board of the National Academies.

Leisenring, M, Sahu, S., Poor, C., Zell, C., and Mansell, S. (2014). NCHRP 25-25 Task 85: Nutrient (Nitrogen/ Phosphorus) Management and Source Control. Transportation Research Board of the National Academies.

Marti, M. (2011). Decision Tree for Stormwater BMPs. Minnesota Department of Transportation Research Services Section. MN/RC- 2011R1C01. March.

Minnesota Pollution Control Agency (MPCA). (n.d.). Minnesota Stormwater Manual. Accessed May 2015 from http://stormwater.pca.state.mn.us/index.php/Main_Page.

Ohio Department of Natural Resources (Ohio DNR). (2006). Rainwater and Land Development, Ohio’s Standards for Stormwater Management Land Development and Urban Stream Protection. Division of Soil and Water Conservation. Third Edition.

Ohio Department of Transportation (ODOT). (2014). Location and Design Manual, Volume 2. July.

Ohio EPA. (2013). NPDES Construction General Permit. Permit Number OHC000004. April.

Strecker, E., Quigley, M., and Leisenring, M. (2005). Critical Assessment of Stormwater Treatment and Control Selection Issues. Water Environment Research Foundation. WERF 02-SW-1.

Taylor, S., Barrett, M., Leisenring, M, Sahu, S., Pankani, D., Poresky, A., Questad, A., Strecker, E., Weinstein, N., and Venner, M. (2014). NCHRP Report 792: Long-Term Performance and Life-Cycle Costs of Stormwater Best Management Practices. Transportation Research Board of the National Academies.

Venner, M., Strecker, E., Leisenring, M., Pankani, P., and Taylor, S. (2013). NCHRP 25-25 Task 83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways. Transportation Research Board of the National Academies.

APPENDIX C

SUMMARY OF INTERVIEW RESULTS

MEMORANDUM

TO: Technical Advisory Committee (TAC)

FROM: Gresham, Smith, and Partners (GS&P)

DATE: February 25, 2015

SUBJECT: SUMMARY OF INTERVIEW OUTREACH
STORM WATER BEST MANAGEMENT PRACTICES FOR LOCAL ROADWAYS / 2015-ORIL 7
ODOT State Job No. 134990
GS&P Project No. 40399.00

1 INTRODUCTION

As part of the research on 2015-ORIL 7- "Storm Water Best Management Practices for Local Roadways," the GS&P Team has conducted a series of interviews with individuals involved in BMP implementation across the state of Ohio. The interviews were intended to key in on frequent challenges, constraints, success factors, and other lessons learned related to BMP implementation on local roadway projects. The lessons learned from the interviews are being used to refine the research objectives for the ongoing literature review, as well as to shape the content and features of the BMP tool, which is the ultimate work product for this research project. The tool is primarily intended to support local municipal, township or county agencies (Locals) through the process of identification and selection of storm water BMPs for local roadway systems. This memorandum provides a summary of the interview outreach and results, including interviewees contacted, interview content, significant lessons learned, and applicability toward tool development.

SUMMARY OF INTERVIEWEES

The GS&P Team developed a list of potential interviewees to represent a cross section of individuals involved in local roadway BMP implementation across the state and in various roles and organizations. Individuals were identified from GS&P contacts as well as TAC recommendations. The list was reviewed and approved by the TAC.

The GS&P Team reached out to 36 individuals to set up potential interviews, and ultimately completed 23 interviews. Multiple attempts were made to reach out to potential interviewees, but ultimately some interviews were not able be completed based on scheduling conflicts or feedback from interviewees about their experience not aligning with the interview subject matter. By the end of the 23 interviews, patterns of results began to emerge and the GS&P Team was satisfied that a representative sample was achieved. The full list of completed interviews is provided as Attachment 1. Table C-1 and Table C-2 show the number of interviewees broken down by region and organization type.

Table C-1. – Interviewee Pool by Region of Ohio

Interviewee Region	Interview Outreach	Completed Interviews
Central	9	3
Northern	15	11
Southern	12	9
TOTAL	**36**	**23**

Table C-2. – Interviewee Pool by Organization

Interviewee Organization	Interview Outreach	Completed Interviews
City	16	8
County	4	4
Township	2	1
Consultant	3	3
ODOT District	3	1
Other	8	6
TOTAL	**36**	**23**

INTERVIEW SUBJECT MATTER

Before the interview outreach started, an interview questionnaire was developed to document the feedback that was sought from interviewees. This questionnaire was initially reviewed by the TAC, and was then shared with potential interviewees to communicate the focus of the interviews. Specific interview questions are provided below:

- Description of your role (and/or your organization's role) related to projects and ensuring storm water quantity/quality are appropriately addressed.
- Types of roadway projects your office or department implements (or non-roadway, if your work does not include roadway projects). For these types of projects how is storm water runoff addressed?
- Questions or comments on the applicability of post-construction BMP requirements to your projects.
- Description of and/or lessons learned with local roadway projects (or non-roadway, if no roadway projects) in which you have implemented storm water post-construction BMPs.
- Process typically used on the projects to identify, select, design, construct and maintain post-construction BMPs
- Constraints or barriers that have been encountered on your projects related to post-construction BMP implementation (selection, design, construction and O&M).

- Type of guidance that you would find useful from this research, including data gaps you see and would like to see fixed in existing post-construction BMP resources.

KEY LESSONS LEARNED

Interview feedback provided by each interviewee was documented and then reviewed and compiled across all interviews. The findings from various interviews were compared to identify common themes and significant lessons learned to be applied toward the research and BMP tool development. These lessons reflect the limitations and challenges that are sometimes faced by Locals during BMP implementation on local roadway projects, as well as factors impacting BMP selection and decision-making that need to be accounted for in the BMP tool. Key lessons learned are summarized by the bullets below:

- **Inconsistent implementation of BMPs:** Required BMPs are sometimes not implemented for a variety of reasons including lack of understanding of permit requirements and exemptions, physical constraints, public pressure, lack of budget, and political resistance.
- **Space requirements for BMPs are considered late in design:** Space required for BMPs is not considered until after the right-of-way footprint has been set, and BMPs are not considered during conceptual project design or planning. Space constraints are significant barriers, and ability to obtain right-of-way is limited by surrounding development and extent of urbanization.
- **Limited understanding of BMP design requirements:** BMP selection and design is frequently deferred to consultants, yet not all hydraulic engineers have adequate storm water management experience or understanding of water quality BMPs. Designers are frequently using a “cookie-cutter” approach, not considering long-term operations and maintenance (O&M) requirements or site-specific conditions, which sometimes has led to improperly designed BMPs. Additional design guidance was requested to support the Locals in managing BMP selection and design.
- **Limited resources are available for BMP O&M:** Locals are challenged to implement recommended O&M due to costs, access constraints, lack of training/ understanding, public perception, and insufficient manpower/equipment. Locals are not aware of BMP long-term O&M requirements during BMP selection and design, and O&M plans are not typically developed.
- **Insufficient training / understanding may hinder BMP implementation success:** Expanded outreach is needed (within organizations’ staff, management / public officials, general public, contractors, inspectors, and designers) to improve BMP acceptance and understanding, including the need for BMPs, how they function, and keys to success during construction and long-term O&M.
- **Aesthetics of roadway BMPs are important to Locals:** Aesthetics of BMPs are critical to buy-in amongst general public and public officials, particularly in urbanized areas. This encompasses aesthetics directly related to the BMP, as well as aesthetics associated with the integration of the BMP into the Locals’ streetscape vision. Public perception of the

aesthetics is also important. Some Locals may have ordinances requiring aesthetic-driven mowing frequency that conflicts with BMP design criteria. In urban areas, visibility of BMPs may present concerns for vandalism.

- **Safety and liability play a large role in BMP selection:** BMPs with open water surfaces, particularly wet ponds/retention basins, are largely avoided due to safety concerns, in addition to concerns about larger footprints required and potential for increased mosquito breeding. However, open basins are often viewed as having preferable maintenance requirements.

CASE STUDY RECOMMENDATIONS FROM INTERVIEWS

During the course of the interviews, the GS&P Team requested recommendations for potential case study projects. Table C-3 summarizes a list of potential case studies identified through the interview process which will be investigated further.

Table C-3. – Potential Case Studies Identified During Interviews

BMP Project Name	Interviewee
Variety of BMPs in ODOT District 4	Bob Rosen, ODOT District 4
Various Bioretention Facilities in Toledo Area	Kirby Date, Cleveland State University and Katherine Holmok, EDG Consultants (Follow up with Andy Stepnick, City of Toledo)
Tech South Pervious Pavement (Columbus)	Doug Turney, EMH&T
Third Ave Pervious Pavement (New Albany)	Doug Turney, EMH&T

LESSONS APPLIED TOWARD BMP TOOL DEVELOPMENT

Based on interview findings and lessons learned, the GS&P Team has identified a series of functions and features to be incorporated into the BMP tool. The following considerations for the tool were identified to address user needs and to facilitate the process of BMP selection for local roadway projects:

- Educate users with respect to post-construction applicability and requirements, as well as BMP sizing and other considerations related to the post-construction BMP implementation process.

- Incorporate flexibility into the tool to allow it to be used by entities whether they are following the ODOT Location and Design Manual or the Ohio Stormwater Construction General Permit. Allow for users to specify if they are willing to consider alternative BMPs (those not pre-approved by Ohio EPA).

- Incorporate questions regarding BMP aesthetic preferences as part of the BMP screening process, while recognizing that aesthetic preferences may vary between users.

- Provide high level information to inform tool users during the BMP selection process about potential O&M burdens associated with particular BMPs, recognizing that users may have limited resources for O&M.

- Include keys to success for BMP design and implementation as supplemental information and links within the tool.

- Encourage consideration of BMP siting early in project planning.

- Include BMPs that are practical for roadway applications, reflecting Ohio-specific O&M needs and site conditions.

Attachment 1 – List of Stakeholder Interviews Completed

Attachment 1

ORIL7: Storm Water Best Management Practices for Local Roadways

List of Stakeholder Interviewers Completed

Potential Interviewee Contact Name	Organization	Geographic Region in Ohio	Type of Organization
Christopher Sherk, PE	CH2M Hill	Southwest	Consultant
Chuck Petty, PE	Warren County	Southwest	County
Cyndee Gruden	University of Toledo	Northwest	Other
Dave Ritter	NE Ohio Regional Sewer District	Northeast	Other
Doug Gruver, PE	ODOT District 8 (Cincinnati)	Southwest	ODOT
Doug Turney, PE / Shawn Arden, PE	EMH&T Inc.	Central	Consultant
Eric Pottenger	Butler County Storm Water District	Southwest	County
Jason Sanson, PE	City of Columbus	Central	City
Jason Sisco, PE	City of Bowling Green	Northwest	City
Jen Eismeier - TAC	Mill Creek Watershed Council	Southwest	Other
Jennifer Heard	City of Cleveland, DPC	Northeast	City
Justin Czekaj, PE	City of Aurora	Northwest	City
Katherine Holmok	EDG Consultants	Northwest	City
Kathryn Gruver, PE	HDR Inc.	Southeast	Consultant
Kathy Dorman, PE	City of Mason	Southwest	City
Kirby Date	Cleveland State University / Ohio Lake Erie Commission	North	Other
Marilyn Sferra Kenner, PE	Boardman Township	Northeast	Township
Nick Smith, PE	City of Beavercreek	Southwest	City
Sandra Kosek-Sills	Ohio Lake Erie Commission	North	Other
Tim Burkert, PE & John Woolard	Mahoning County	Northeast	County
Tim Gilday, PE - TAC	Hamilton County	Southwest	County
Tom Komlanc, PE, Kent Halloran, PE, Glen Yoder, PE	Ohio State University	Central	Other
Tom Tucker, PE	City of Wadsworth	Northeast	City

APPENDIX D

LOCAL ROADWAY BMP CASE STUDIES

BMP CASE STUDY 1 BIORETENTION WITH UNDERDRAIN

Photo Credit: Kirby Date, Cleveland State University

Basic Project Information	
BMP Functions	Water Quality Treatment*
Drainage Area Treated	7.0 acres
BMP Design Methodology	Ohio DNR Rainwater and Land Development Manual
Location	Northwest Ohio
Cost per Impervious Area Treated	$32,000/acre
Owner	City of Toledo
Designer	City of Toledo
*Water quality treatment not a regulatory requirement for this specific project	

Project Background

The Angola Road Storm Sewer Improvements (Angola Road) Project is a green infrastructure project designed and constructed by the City of Toledo (City). Because the project did not disturb more than one acre, the Construction General Permit for Storm Water *OHC000004* (Ohio EPA CGP) was not applicable. This portion of Angola Road between Reynolds and Wenz Roads is an arterial that runs through residential and commercial/office areas in Toledo. The road is two lanes with additional turning lanes at major intersections. It has a wide shoulder, but no curb and gutter. The project included the installation of approximately 7,678 feet of storm sewer pipe and bioretention cells. A series of bioretention cells were installed in selected locations on both sides of the road in the planting strip behind the shoulder. The plantings were complemented by matching landscape mounded plantings interspersed along the road, which had no water quality functions. The project was completed in 2012 and, in 2014, they finished the two-year vegetation establishment period. The project was funded with general transportation funds, along with a Natural Resources Defense Council grant of $200,000. Refer to Figure D-1 and Figure D-2 for project photographs after completion and Figure D-3 for a typical section view from the project construction plans.

BMP Functional Description

Bioretention facilities are landscaped shallow depressions or basins that are constructed with engineered soil media and vegetation to capture and filter runoff. These facilities may also be referred to as bioretention basins, rain gardens, curb extensions, or infiltration planters. They are volume-based BMPs that are designed to filter out sediment and associated pollutants through a variety of physical, biological, and chemical treatment mechanisms. Where conditions are conducive for infiltration, bioretention facilities can also provide volume reduction and removal of pollutants via physical sorption and exclusion. Where full infiltration of the water quality design volume is not feasible, bioretention facilities can be designed with an underdrain to partially infiltrate runoff or function as a flow-through, media filtration facility with less volume reduction.

Bioretention facilities are typically located directly adjacent to contributing impervious drainage areas, using several small facilities at intervals along a roadway or impervious surface. Although not common for roadway projects, bioretention cells can be used as regional treatment facilities (bioretention basins), where storm water is collected from a larger tributary area and conveyed to a single large facility.

Photo Credit: Kirby Date, Cleveland State University

Figure D-1. Angola Road Project established bioretention area

Photo Credit: Kirby Date, Cleveland State University

Figure D-2. Detail of plantings and outlet for the bioretention area for Angola Road

Design Constraints and BMP Selection

Post-construction water quality treatment was not required for this project. The design was based on the City's desire to implement green infrastructure, improve water quality, and reduce overall project costs. Bioretention is a widely used post-construction BMP, standard in both the Ohio EPA CGP and the Ohio Department of Transportation's *Location and Design Manual, Volume 2*. Since there were no regulatory drivers for the sizing, the designers worked with the City to optimize water quality treatment, storm water conveyance, and construction costs. The plant types were selected because of their landscape appeal and ability to withstand occasional inundation as well dry periods. Bioretention was a practical BMP selection for the following reasons:

- The BMP footprint could be accommodated within the existing right-of-way.
- The City's aesthetic goals meshed with this green infrastructure type BMP.
- Without curbs and gutters, no curb cuts were necessary and runoff could be routed by sheet flow directly into the BMPs.
- Underground utilities did not pose a conflict for installing the bioretention cells and underdrains.

Construction Lessons Learned

Bioretention facilities are similar in many ways to a detention basin or swale, if a linear layout, with some significant differences. The following are lessons learned from this project, which may help ensure the success of other bioretention BMPs.

- Contractor should not allow storm water discharges to the BMP until the contributing drainage areas have been stabilized. Fine sediments from construction will promote clogging and reduce BMP functionality.
- Contractor should avoid compaction of the subgrade during construction by eliminating equipment and foot traffic after trench excavation.
- Establishing vegetation is critical to BMP performance, so a minimum one year (preferably two year) performance specification is recommended for the planting.
- Field verify existing underground utilities early to avoid potential conflicts with BMP installation.
- Some mulch types, such as pine bark, will float and accumulate near the drain. Select mulches that allow adequate infiltration and that tend to stay in place.

General Operations and Maintenance Considerations

Plantings should be weeded and watered the first year to ensure successful establishment. Otherwise, the main operations and maintenance (O&M) requirements are related to simple gardening, such as pruning and weeding (as needed) and adding or replacing mulch (annually). Other bioretention cells in Ohio have been planted with turf grass, which requires mowing to a minimum height of four inches as maintenance.

Since some of the bioretention cells are located on or adjacent to private property, the City has completed education sessions with the residents to provide information on the nine types of vegetation planted. This education generally helps to obtain public acceptance of the plantings as well as specifically teaching how to identify a weed versus the planted vegetation. Bioretention BMPs can lose public support if they become weedy and unsightly.

Removing litter and debris (monthly) is needed to help prevent clogging of the outlet and maintain an attractive appearance. Inspect the facility for salt damage to plants due to pavement deicers (monthly, particularly in late winter and spring). Check for erosion or sediment accumulation in the BMP (semi-annually) and repair as needed. Infrequently (2-10 years as needed) check planting soil and drainage layers for clogging and replace as necessary.

Cost Considerations

The original design of the project utilized 60-inch and 48-inch reinforced concrete pipe (RCP) for storm sewers, with a total project cost of $978,948. By installing the bioretention BMPs at a cost of $215,482, the storm sewer pipe sizes could be reduced to 36-inch and 30-inch RCP respectively. The reduction in pipe size resulted in a 47% cost savings or a new project cost of $518,616. In addition to the upfront cost savings, the bioretention swale maintenance and replacement is far less than the replacement of RCP.

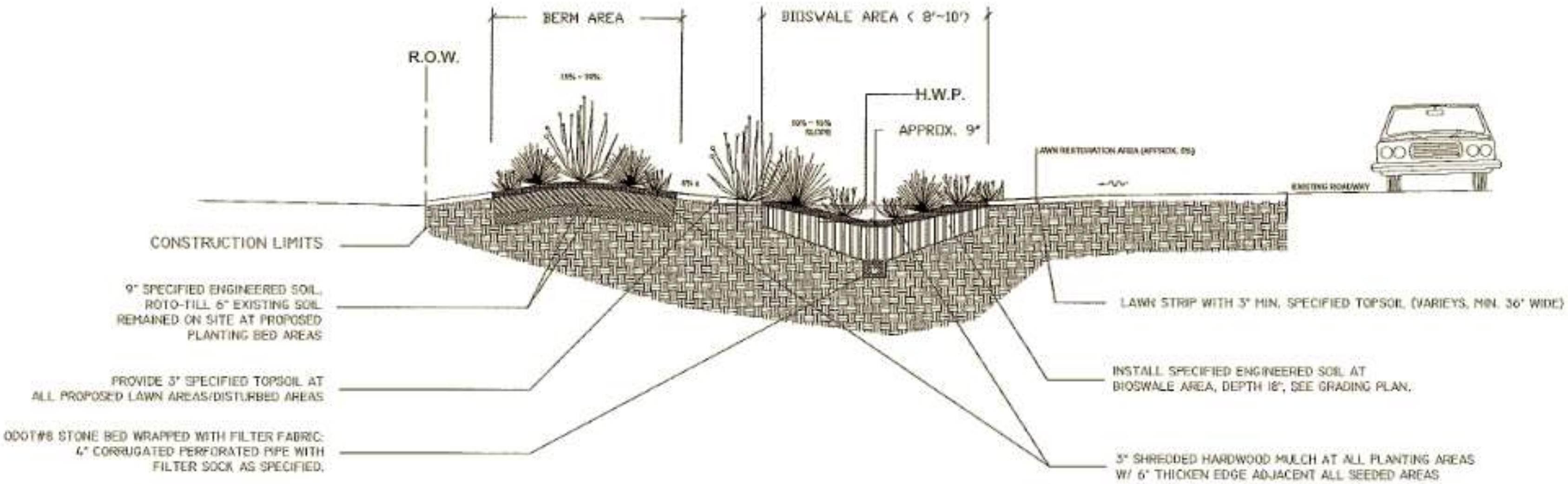


Figure D-3. Typical section of the Angola Road Bioretention facilities

BMP CASE STUDY 2 MANUFACTURED DEVICE

Photo Credit: Robert Rosen, ODOT

Basic Project Information	
BMP Functions	Water Quality Treatment
Drainage Area Treated	15.1 Acres
BMP Design Methodology	ODOT Location and Design Manual, Vol. 2
Location	Northeast Ohio
Cost per Impervious Area Treated	$10,000/acre
Owner	City of Green
Designer	URS

Project Background

The Summit County State Route 619/Arlington Road Improvements (Arlington Road) Project was an urban road full-depth reconstruction and widening project in the City of Green (City) constructed in 2010-2012. The project site is located within a highly developed area of restaurants, shopping strip malls, and car dealerships on Arlington Road near the intersection of East Turkeyfoot Lake Road. The roadway consists of two northbound lanes, two southbound lanes, and one turn lane. Because the project disturbed more than 1 acre, the Construction General Permit for Storm Water *OHC000004* (Ohio EPA CGP) was applicable, requiring post-construction BMPs. The City used the Ohio Department of Transportation's (ODOT) *Location and Design Manual* (ODOT L&D), *Volume 2* to select and design five manufactured devices for the required water quality treatment, four Type 4 and one Type 1 hydrodynamic separators. Refer to Figure D-4 for a project construction photograph and Figure D-5 and Figure D-6 for example cross section and plan views. The project also required water quantity treatment, but that Ohio EPA CGP requirement was addressed by retrofitting an existing detention basin not discussed herein.

BMP Functional Description

The most commonly used manufactured device for storm water quality treatment for Ohio roadways is the hydrodynamic separator (also known as a vortex settler). Hydrodynamic separators are proprietary devices designed with an internal circular flow-through structure that do not require a power source and generally require less space than other BMPs. Hydrodynamic separators treat the water quality flow (WQf) by removing particulate matter through settlement or filtration using centrifugal forces generated from forcing the flow into a circular motion. Many manufacturers have devices on the ODOT qualified products list.

ODOT Supplemental Specifications 895 and 995 cover the material and performance criteria for these devices. They are placed in an off-line configuration with a flow diversion structure to capture the calculated WQf (see Figure D-5). Manholes are required as part of this BMP to allow for routine maintenance procedures.

Photo Credit: Robert Rosen, ODOT

Figure D-4. Arlington Road Project during installation of the manufactured device

Design Constraints and BMP Selection

Water quality treatment was required for post-construction storm water BMPs on this project. Being in a highly developed urban environment, the amount of right-of-way owned by the local agency was extremely limited. Many existing underground utilities were located along and within the right-of-way. The footprint of other BMPs considered for this project would have been cost prohibitive or infeasible to provide equivalent water quality treatment, due to the development density and cost of acquiring new or additional project right-of-way. A manufactured device was a practical BMP selection for the following reasons:

- The smaller footprint required by the BMP reduced potential conflicts with existing underground utilities.
- No additional right-of-way was needed to provide a site for the BMP.
- Smaller footprint allowed for flexibility in locating BMP for maintenance purposes.

The design of manufactured devices should provide access for routine cleanout and maintenance when siting the BMP. It is always preferred to locate a manufactured device near the roadway, but outside of paved areas. Refer to the ODOT's *L&D Volume 2* for more details on design of manufactured systems.

Construction Lessons Learned

Manufactured devices have many benefits in the construction process. The following are lessons learned from this project, which may help ensure the success of other manufactured devices.

- Roadway general contractors are typically aware of the installation methods required for manufactured devices, since they are very similar to the other storm sewer structures' installation.
- Field verify existing underground utilities early to avoid potential conflicts with BMP installation.
- Some contractors have used the manufactured device as a storm water erosion and sediment control during construction. Sizing for erosion and sediment control purposes often requires the BMP to be oversized in comparison to the post-construction requirements. If using for both purposes, ensure contractor performs regular clean out and maintenance, as well as a final clean out at the end of construction.

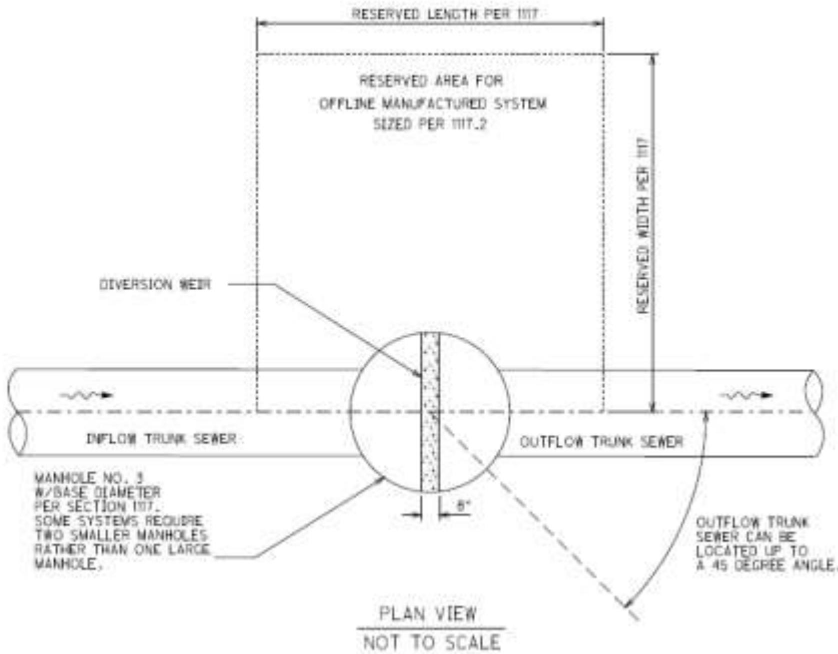
General Operations and Maintenance Considerations

General operations and maintenance (O&M) requirements are related to maintaining the pollutant removal capacity of the hydrodynamic separator. Regular maintenance consists of periodic inspections to check for and remove accumulated sediment, debris, and trash. Major maintenance (repairing or replacing inlet or outlet piping, re-grouting pipes at the vault wall, repairing cracks in the structure) should be needed infrequently.

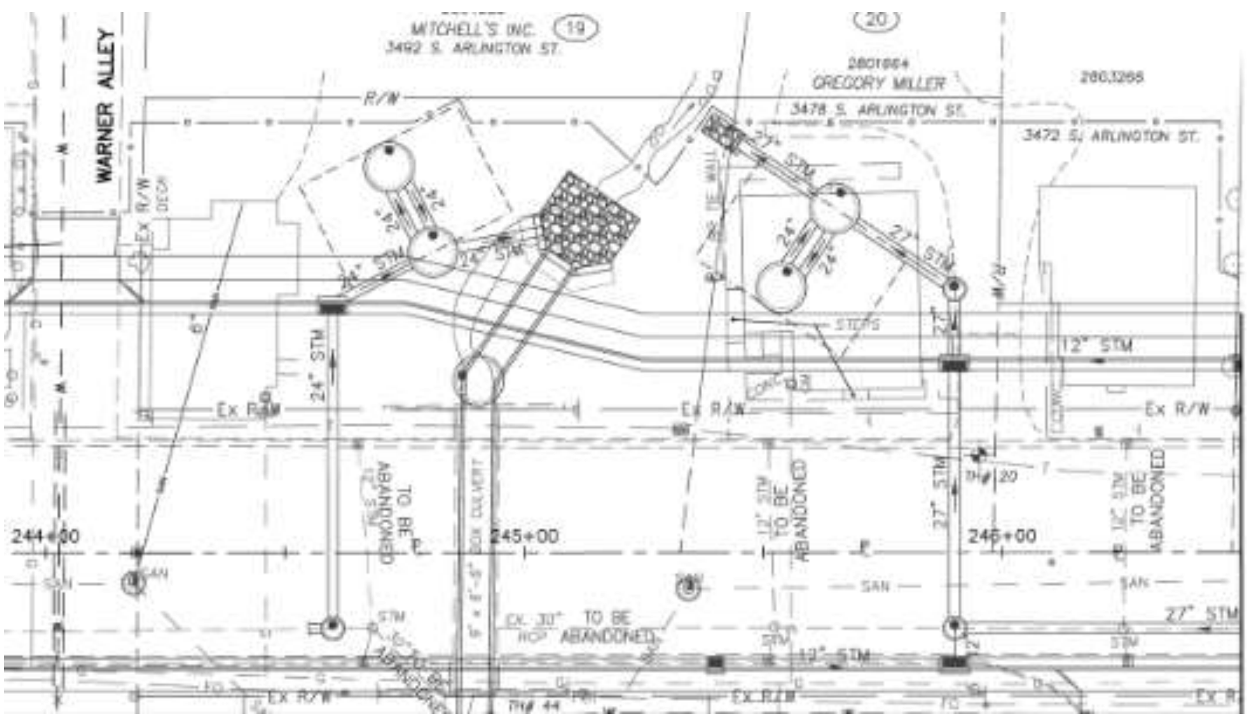
Proper O&M is necessary for hydrodynamic separators to continue to function as designed over time. Re-suspension of sediments and flushing of oil limits effectiveness of the device. Sediment can be removed with a sump vacuum or vactor truck or a professional cleaning contractor can be hired. The removed sediment must be disposed of in accordance with regulatory protocols. Sediment, oil, debris, and water disposal must comply with applicable waste disposal regulations.

Cost Considerations

Typically manufactured systems have relatively low capital costs compared to other BMPs. On the other hand, manufactured devices have relatively high O&M costs. The primary factor influencing capital costs is the basis for sizing and the number of structures needed. Unknown site conditions, such as underground utility conflicts (which may affect location of BMP and diversion piping), is a factor that may influence construction costs. An additional factor used to control costs is to minimize the distance between the diversion manhole and the BMP.



FigureD-5. Manufactured system detail from ODOT L&D Vol. 2 (Figure 1117-2)



FigureD-6. Plan view of two of the manufactured devices in Arlington Road Project

BMP CASE STUDY 3 PERMEABLE PAVEMENT WITH UNDERGROUND EXTENDED DETENTION

Photo Credit: Doug Turney, EMH&T

Basic Project Information	
BMP Functions	Water Quality Treatment
Drainage Area Treated	3.0 Acres
BMP Design Methodology	Ohio DNR Rainwater and Land Development Manual
Location	Central Ohio
Cost per Impervious Area Treated	$58,000/acre*
Owner	City of Columbus
Designer	EMH&T
*Cost includes underground detention, flow control, and paver system, subtracting out standard pavement costs of $3 per square foot.	

Project Background

The Tech Center South Roadway Improvement (Tech South) Project was an urban road full-depth rehabilitation project in the City of Columbus (City) constructed in 2013-2014. The roadways were Gilbert Street between Jenkis and Frebis Avenues and South Ohio Avenue between Jenkis and Markinson Avenues. The project site was constrained by the adjacent properties in this highly developed area. Because the project disturbed more than one acre, the Construction General Permit for Storm Water *OHC000004* (Ohio EPA CGP) was applicable, requiring post-construction BMPs, as well as other criteria specified in the City of Columbus' *Stormwater Drainage Manual*. A concrete brick paver type of permeable pavement was selected as the BMP. Because the soils were not compatible with infiltration, the BMP included an underdrain system, underground detention unit, and outlet flow control structure. Refer to Figure D-7 for a photo and Figure D-8 through D-10 for example design drawings. The design guidance required by both the City and the Ohio EPA CGP is provided in the Ohio Department of Natural Resources' (Ohio DNR) *Rainwater and Land Development Manual*. This BMP design was able to provide both water quality and water quantity treatment, as well as meet the City's peak flow requirements.

BMP Functional Description

Permeable pavement applications are designed to infiltrate or detain storm water while providing a stable load-bearing surface without increasing the amount of effective impervious cover within a project site. Permeable pavements are designed to treat storm water runoff from rain that falls directly on its surface and potentially adjacent impervious areas. Infiltration permeable pavement systems provide water quality through filtration, sorption and hosting microbial organisms known to biodegrade pollutants. Extended detention permeable pavement systems utilize underground storage with a controlled outlet to treat the water quality volume. Concrete pavers were used in this project, but many other types of permeable pavement exist, such as clay pavers, pervious concrete and porous asphalt (more details can be found in the Ohio DNR's *Rainwater and Land Development Manual*, page 93). Underneath the pavement layer lies gravel aggregates for a filter course and choker course. If peak flow control is required (as it was in this project), a reservoir course or manufactured underground detention units can be included. For roadway projects, underdrain systems connected to a storm water outlet are recommended to help ensure long term performance and geotechnical stability.

Photo Credit: Doug Turney, EMH&T

FigureD-7. Tech South permeable pavement project after construction completed

Design Constraints and BMP Selection

Water quality treatment was required for post-construction storm water BMPs on this project. Being in a highly developed urban environment, the amount of right-of-way owned by the local agency was extremely limited. The footprint of other BMPs considered for this project would have been cost prohibitive or infeasible to provide equivalent water quality treatment, due to the density of development and cost of acquiring the right-of-way. Permeable pavement was a practical BMP selection for multiple reasons:

- No additional right-of-way was needed to provide a site for the BMP.
- Vehicle speed and traffic volume are low on the affected roadways, which is recommended for permeable pavement. Typical volume threshold is less than 5,000 vehicles per day.
- Many of the same costs of construction are required in a traditional pavement rehabilitation project, while meeting the water quality treatment requirements. Some additional infrastructure (e.g., underground detention units and outlet control structure) was

incorporated into the subgrade to accommodate the water quality due to poorly infiltrating soils, but the additional costs were relatively minimal because they were integrated into the construction.

- The type of paver product selected for this project can be "machine-installed," which reduced the labor costs.

Construction Lessons Learned

Permeable pavement projects have significant differences when compared to traditional pavement installations. The following are lessons learned from this project, which may help ensure the success of other permeable pavement BMPs.

- The general contractor should be aware of the unique specifications for permeable pavement. The stone aggregate for the base is specified to be "clean, washed" stone without fines to ensure proper drainage. This is not typical sub-base material for traditional pavement projects and may require additional oversight to ensure conformance.
- The construction observation engineer and inspector should have experience with and understanding of permeable pavement installations and specifications. Proper installation is key and construction observation can help avoid future problems.
- Extra care should be taken by the general contractor to keep stone aggregate clean during construction. Common sources of sediment being discharged into the aggregate base during construction are from spills of excavated spoils, erosion of stockpiles, and storm water runoff from sediment-laden areas.

General Operations and Maintenance Considerations

The pavement requires regular inspection to observe proper performance. The surface should be cleaned of fines, which build up on the surface with a typical street sweeper. Occasionally, use of a power washer and vacuum is required to clean the permeable pores of the pavement. Replace aggregate between pavers as needed after cleaning.

Deicing operations differ from traditional pavements. Permeable pavement roads tend to drain and thaw more quickly than traditional pavement, which reduces the need for deicing. The application of grit, such as sand or cinders, is not recommended because it can reduce the infiltration capacity and cause poor performance. Salt application should be done on an "as-needed" basis to avoid the potential for polluting surface water and groundwater.

Proper training on operations and maintenance is essential since the practices significantly differ from traditional roadways, yet the pavement may not appear very different to the untrained eye.

The underground storage and outlet structures also require occasional inspection and maintenance. Manholes were provided for access to the structures. Inspections are planned every three months the first year and annually thereafter to identify blockages and need for cleaning. Maintenance includes removal of accumulated sediment and debris and cleaning of orifices to ensure proper outlet flow.

Cost Considerations

Unknown site conditions, such as underground utility conflicts (which may affect pavement placement), site soil infiltration capacity, reusability of site soils for media mixes, and site slopes are factors that may influence construction costs. Other factors that may influence cost include design factors, such as type of permeable pavement system selected, inclusion or exclusion of media filtration layers, underdrains, underground storage structures, and controlled outlet structures.

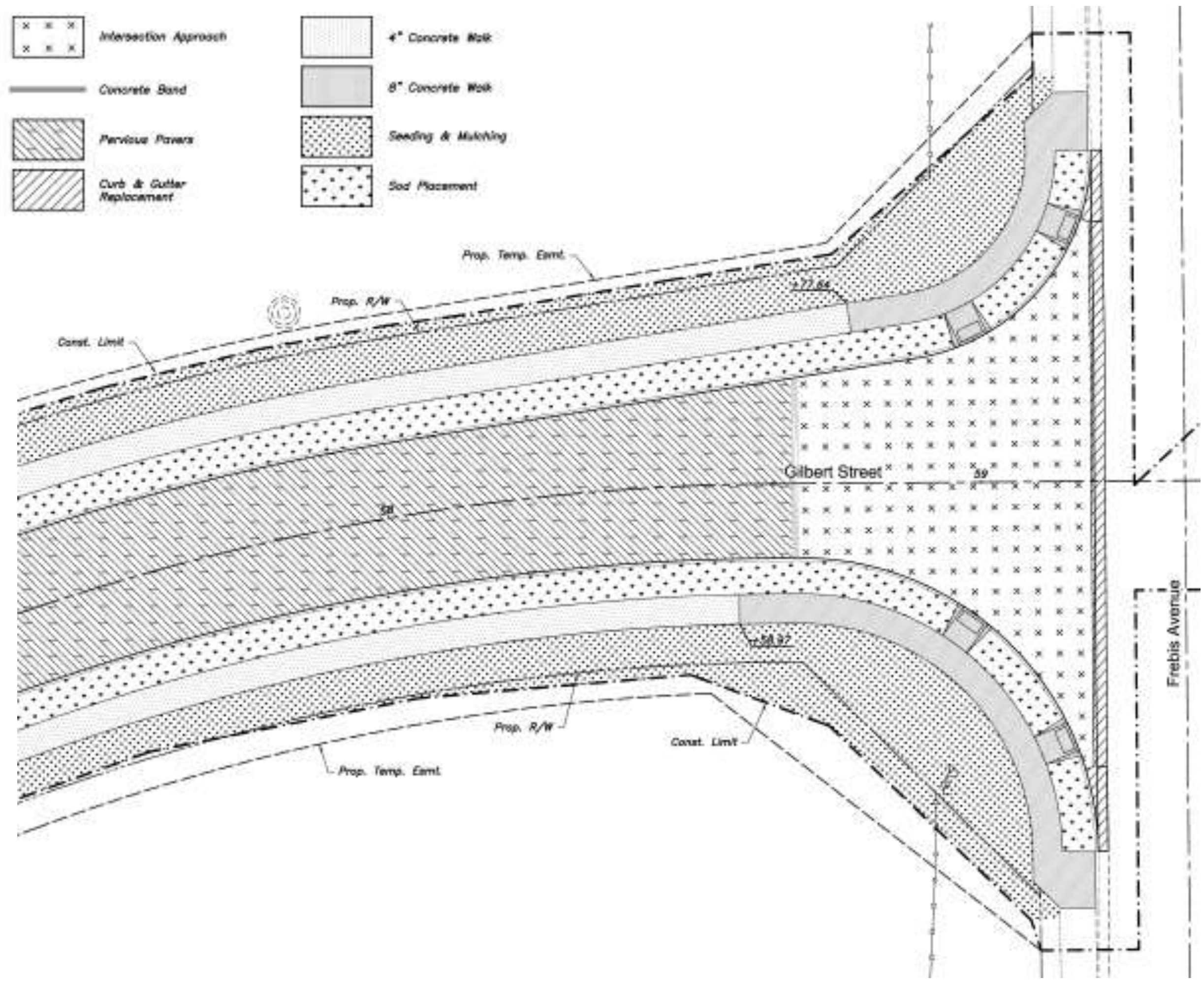


Figure D-8. Plan view of Tech South permeable pavement design

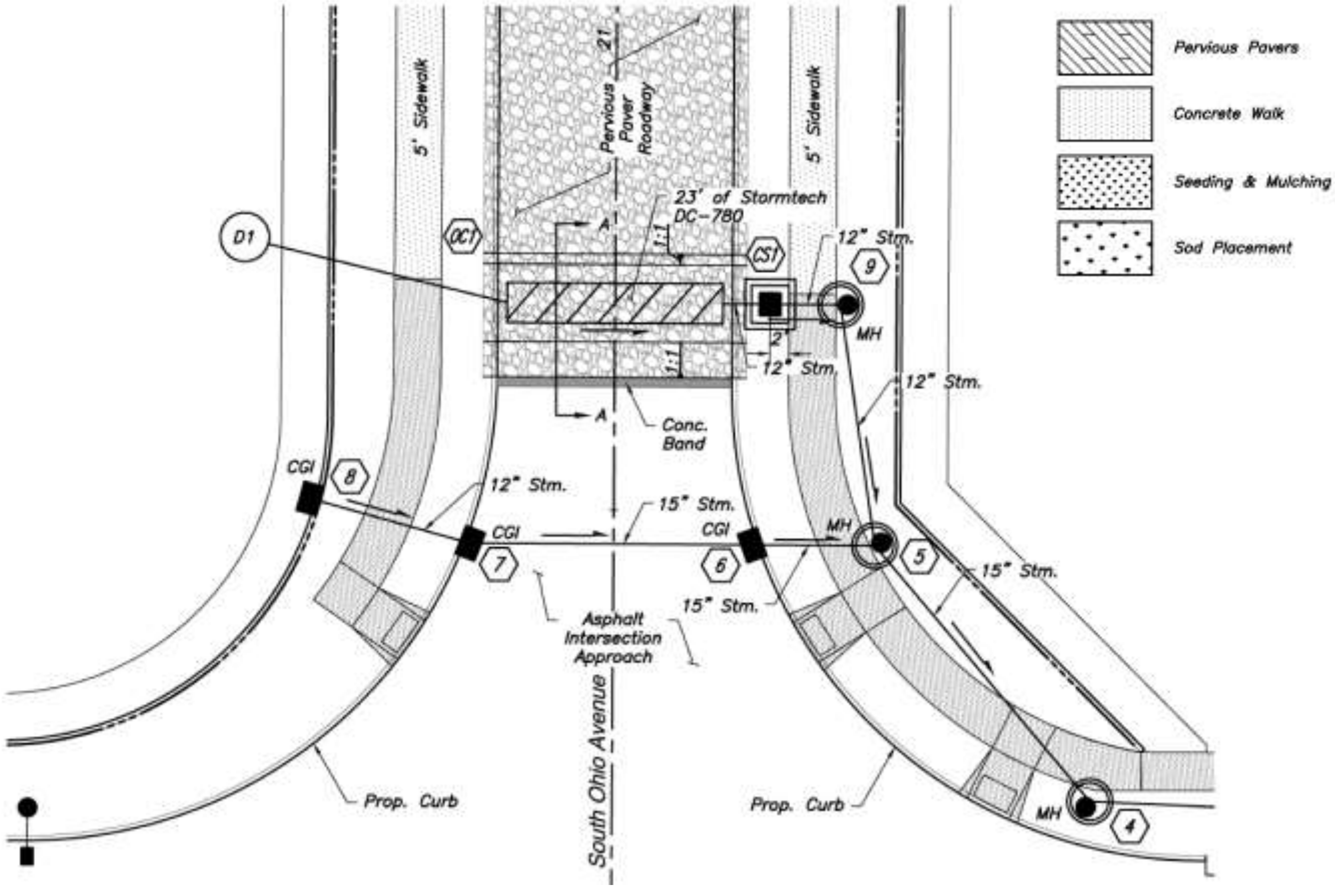


Figure D-9. Plan view of Tech South permeable pavement with detention and outlet structure

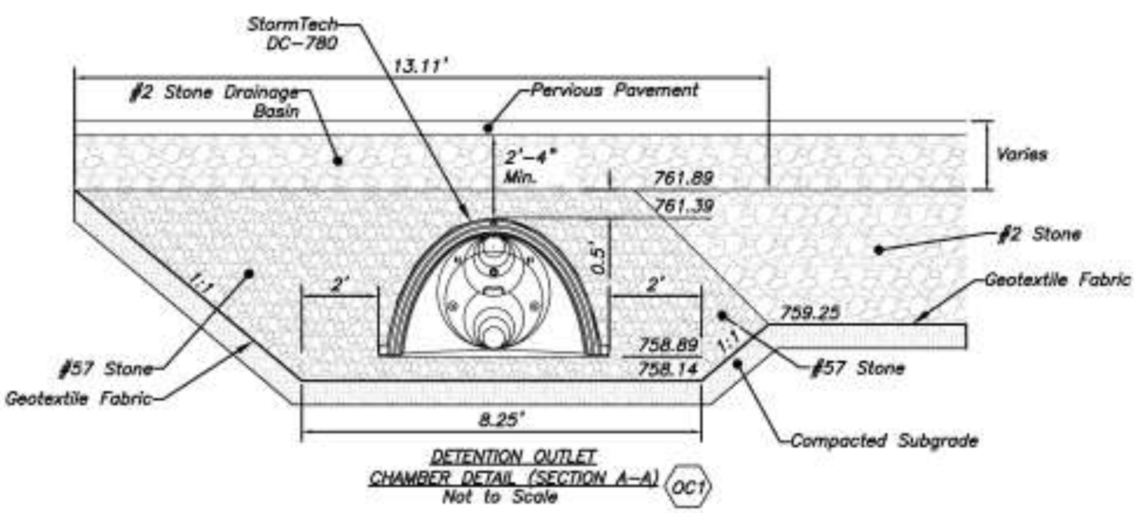


Figure D-10. Section view of Tech South permeable pavement with detention and outlet structure

BMP CASE STUDY 4 VEGETATED BIOFILTER/SWALE

Photo Credit: Robert Rosen, ODOT

Basic Project Information	
BMP Functions	Water Quality Treatment
Drainage Area Treated	6.9 Acres
BMP Design Methodology	ODOT Location and Design Manual, Vol. 2
Location	Northeast Ohio
Cost per Impervious Area Treated	$3,000/acre
Owner	ODOT
Designer	Thomas Fok

Project Background

The Ohio Department of Transportation (DOT) initiated the design and construction of the State Route 45 Sight Distance Improvement (MAH-45) Project. The project was constructed in 2010 and included excavation and regrading to reduce the grade at the intersection of State Route 45 and Leffingwell Road in Ellsworth Township, Mahoning County. Because the project disturbed more than one acre, the Construction General Permit for Storm Water *OHC000004* (Ohio EPA CGP) was applicable, requiring post-construction BMPs for water quality. Water quantity control was not required. ODOT selected a type of vegetated swale as the BMP, using the ODOT Location and Design Manual (L&D), Volume 2 design guidance. In ODOT L&D Volume 2, the BMP is referred to as a vegetated biofilter, which “consists of the vegetated portion of the graded shoulder, vegetated slope, and vegetated ditch.” Throughout this document, vegetated swale and vegetated biofilter are considered equivalent.

Refer to Figure D-11 for a project photograph after completion. Figure D-12 is an example design from the ODOT L&D Volume 2 and Figure D-13 shows an example cross-section from the construction plans. Note that the dimensions in Figure D-13 may not represent current ODOT L&D design requirements.

BMP Functional Description

Vegetated swales are shallow, open channels with dense, low-lying vegetation covering the side slopes and all or most of the bottom area. They receive runoff as concentrated flows at a single inlet and/or as lateral sheet flows. A minimum of six inches of topsoil is required in the ODOT L&D Manual design requirements, and, in general, a porous planting media with organic matter is considered good design practice. Primary treatment mechanisms include settling and filtration of sediment by the vegetation, planting media, and gravel (if present).

In addition to providing primary treatment, swales may be used as pretreatment for other BMPs such as infiltration trenches, bioretention areas and wet basins. Swales are also a green infrastructure alternative to curb and gutter systems, drainage ditches, and storm sewers for runoff conveyance.

Photo Credit: Robert Rosen, ODOT

Figure D-11. The established vegetated swale after construction of the MAH-45 Project

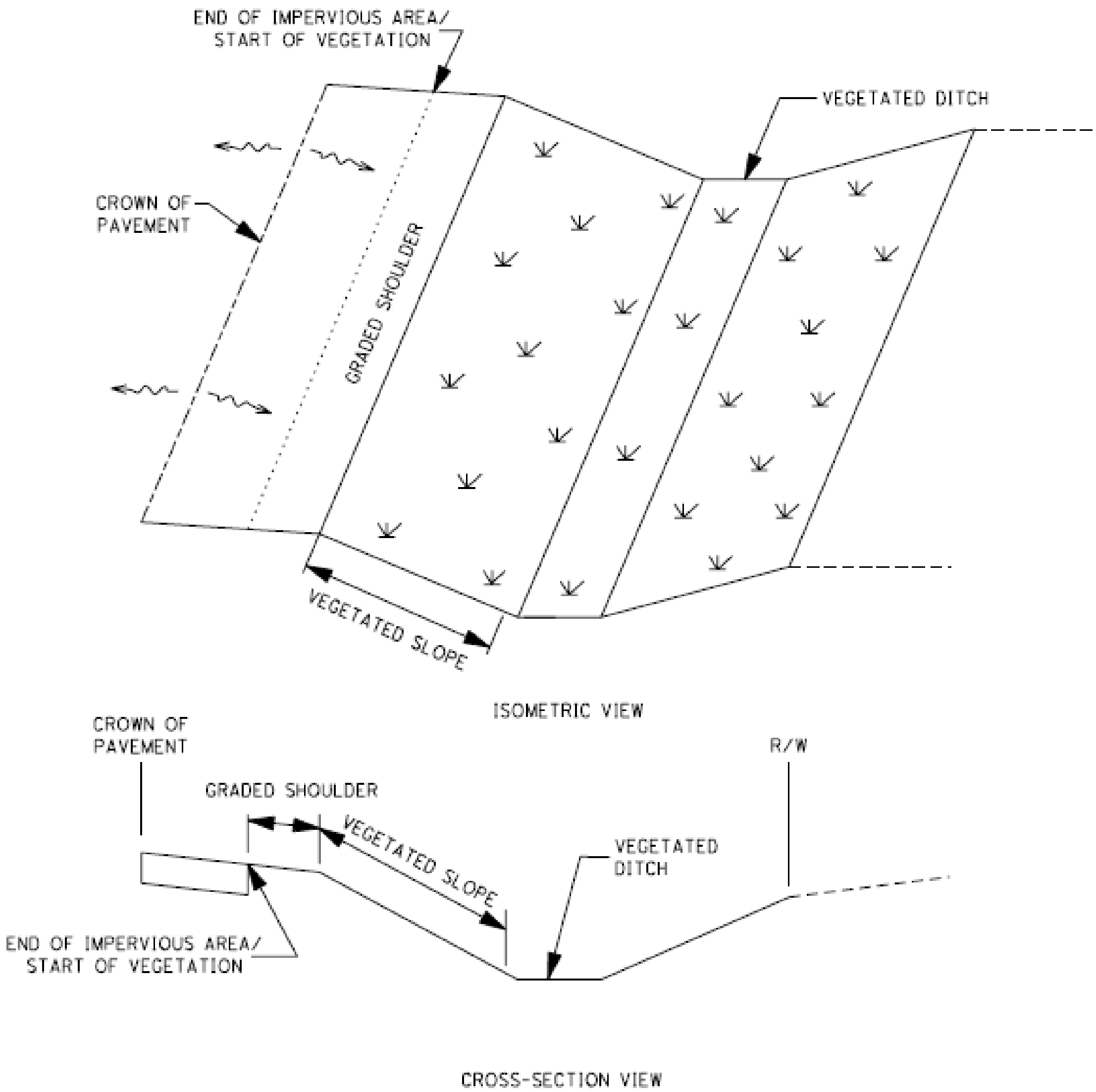


Figure D-12. Vegetated swale detail from ODOT L&D Manual, Vol. 2 (Drawing # 1117-3)

Design Constraints and BMP Selection

Vegetated swales were selected for the required water quality BMP, following the design guidance in the *ODOT L&D Manual*, Volume 2. Swales are very cost effective BMPs and are typically able to fit within the existing right-of-way, especially along rural routes such as this. The swale design is a trapezoidal ditch, with vegetation required per ODOT specification 670, *Ditch Erosion Protection*. A minimum of six inches of topsoil is also required, per ODOT specification 659, *Seeding and Mulching*. Swales should be used as close to the source pavement as possible with the runoff being allowed to sheet flow through grass to the swale. According the Center for Watershed Protection, 1996 as referenced in the *ODOT L&D Manual*, "sheet flow from impervious surfaces will concentrate within a maximum of 75 feet, and 150 feet from pervious surfaces." Side slopes of the swale adjacent to roads shall be as flat as possible to avoid standing water in the swale while not creating a hazard for the motoring public. Another design consideration is to provide maintenance access to the swale to allow for regular mowing.

Construction Lessons Learned

Vegetated swales are easy to construct and designers and contractors alike are quite familiar with them. The following are some lessons learned to help ensure the success of a vegetated swale or biofilter.

- Roadway general contractors are commonly aware of the installation methods required for swales, since it generally entails grading and seeding.
- During construction, the swale and filter strip areas should be protected to minimize compaction of the soil. If not practicable, the site can be disked after construction to loosen the soil prior to seeding.
- If the swale bottom width varies, points of constriction may cause runoff velocities to cause erosion. Use of erosion control matting is generally recommended where design flow velocities are greater than 3.5 feet per second.
- As with other vegetated BMPs, plant establishment is critical to BMP performance, so a minimum one year performance specification is recommended for the planting.

General Operations and Maintenance Considerations

Swales require a relatively small amount of maintenance compared to other BMPs. Mowing to a height of 3 to 4 inches is the primary maintenance task. Inspections (annually) are used to identify accumulations of debris and trash or the development of erosion or gully formation. Trash and debris should be removed as needed to prevent clogging of culverts or outlet structures. Erosion should be corrected immediately with grading and seeding.

Cost Considerations

Unknown site conditions, such as aboveground or underground utility conflicts (which may affect grading or need for guard rails), site soil type (which affects its resistance to erosion), and site slopes are factors that may influence construction costs.

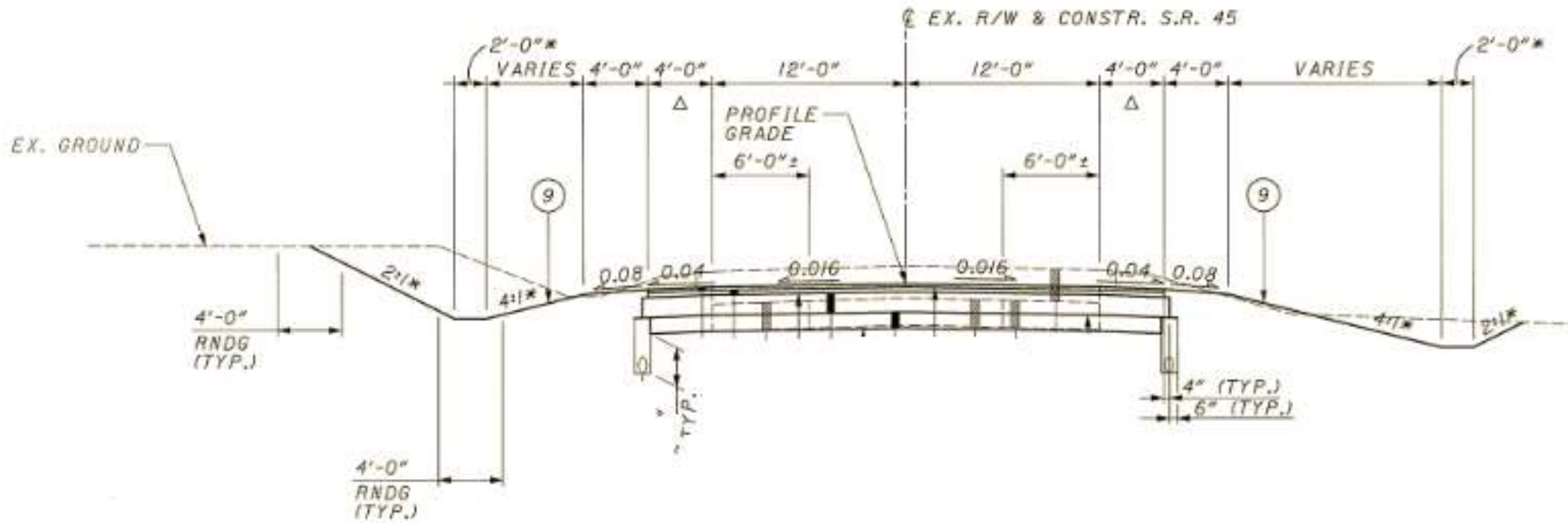


Figure D-13. Vegetated Swale Design Example from Project Plans

BMP CASE STUDY 5 CONSTRUCTED WETLAND

Photo Credit: Robert Rosen, ODOT

Basic Project Information	
BMP Functions	Water Quality Treatment
Drainage Area Treated	11 Acres
BMP Design Methodology	ODOT Location and Design Manual, Vol. 2
Location	Northeast Ohio
Cost per Impervious Area Treated	$3,000/acre
Owner	City of Kent
Designer	Finkbeinner Pettis Inc.

Project Background

The Crain Avenue Roadway and Intersection Improvement (Crain Ave.) Project was an urban roadway project featuring a variety of improvements constructed in 2010-2012. Located near the corner of Fairchild Avenue and North Mantua Street in the City of Kent (City), the project site was constrained by the adjacent properties in this highly developed area. Because the project disturbed more than one acre, the Construction General Permit for Storm Water *OHC000004* (Ohio EPA CGP) was applicable, requiring post-construction BMPs for water quality. Refer to Figure D-14 for a photo of the southern end of the wetland. Figure D-15 is an excerpt of the design drawings showing the constructed wetland in plan view. The design guidance used was the Ohio Department of Transportation's *Location and Design Manual, Volume 2*, providing both water quality and water quantity control.

BMP Functional Description

Constructed wetlands (also known as extended detention wetlands) are designed to function similarly to a wet detention basin with additional features including wetland vegetation. Wetland vegetation promotes settling of sediments and stabilizes the deposited sediment. Wetlands can treat additional storm water pollutants, such as nutrients, metals, bacteria, and organic compounds, in ways most other treatment practices cannot, by plant uptake, adsorption, physical filtration, microbial decomposition and shading. Constructed wetlands must have adequate base flow to maintain a dry weather flow depth ranging between 0.5 to 2 feet. The surface area required for a constructed wetland is typically large compared to other detention BMPs, due to the limited allowable depth and need for benching. The constructed wetland should be sized to slowly draw down the water quality volume over at least 24 hours (above permanent pool) while providing a bypass or overflow for larger discharges. The water depth should be maintained by an outlet structure capable of providing the required water depth with the provision of one foot of freeboard.

Photo Credit: Robert Rosen, ODOT

Figure D-14. Southern end of wetland after Crain Avenue Project construction

Design Constraints and BMP Selection

Water quality treatment and water quantity control was required for the post-construction storm water BMP on this project. Being in a highly developed urban environment, the amount of right-of-way owned by the local agency was extremely limited. However, a building had been torn down, which allowed space for the constructed wetland. The selection of the constructed wetland was largely driven by the City's desire for urban beautification and green space along an existing bike trail. Other BMPs considered were determined not to fit the goals of the area and City officials' requirements.

A constructed wetland was a practical BMP selection for multiple reasons:

- Land was available for the required footprint of the constructed wetland.
- The visual aesthetics of a wetland were desirable for this location, where urban green space was needed.
- The hydrology of the site provided an adequate base flow through the wetland, which helps reduce the risk of nuisance algae and mosquitoes.
- City staff were equipped to provide the needed maintenance.

Construction Lessons Learned

Many similarities, but some significant differences, exist between constructed wetlands and a wet detention basin. The following are lessons learned from this project, which may help ensure the success of other constructed wetland BMPs.

- Due to potential base flow, the contractor should plan to manage flow around the BMP area during construction.
- Contractor should avoid over-compacting the wetland basin floor. Tilling or disking may be required to loosen the soil adequately for planting.
- Establishing the wetland vegetation is critical to the success of the constructed wetland BMP. Typically live plant material is needed for the subaquatic zones and may need to be planted in early spring or fall. Live plant material requires proper handling on site prior to planting to maintain viability.
- A minimum one year warranty period on the planting is recommended.

General Operations and Maintenance Considerations

Operation and maintenance for a constructed wetland are similar to detention basins. Regular trash/debris removal shall occur to prevent clogging of the outlet (as needed). The outlet control structure shall be inspected annually and any damage repaired. Remove sediments at the forebay and/or micro pool as needed (3-7 years). In high sediment loading areas, the main pool should be inspected over the long term (15-20 years) to determine the need to be re-excavated. The basin of a constructed wetlands should not be mowed so that proper wetland vegetation can be maintained, although some of the embankment or surrounding area may be mowed grass. Some vegetation removal is required, so inspect for and remove invasive plants (semi-annually) and unwanted woody vegetation (annually).

Cost Considerations

Unknown site conditions, such as underground utility conflicts (which may affect BMP location), site soil suitability, and site slopes are factors that may influence construction costs. A constructed wetland can be used as a sediment and erosion control BMP during the construction project, yielding a potential construction cost savings. Other factors that may influence cost include design elements such as embankments and spillways, which are largely driven by the site conditions.

Typical maintenance costs are related to inspection and maintenance of the basin at the inlet and outlet structures, including removing vegetation detritus, trash and infrequent sediment removal. Major maintenance (re-excavation of the main pool) is not anticipated for 15-20 years or more.

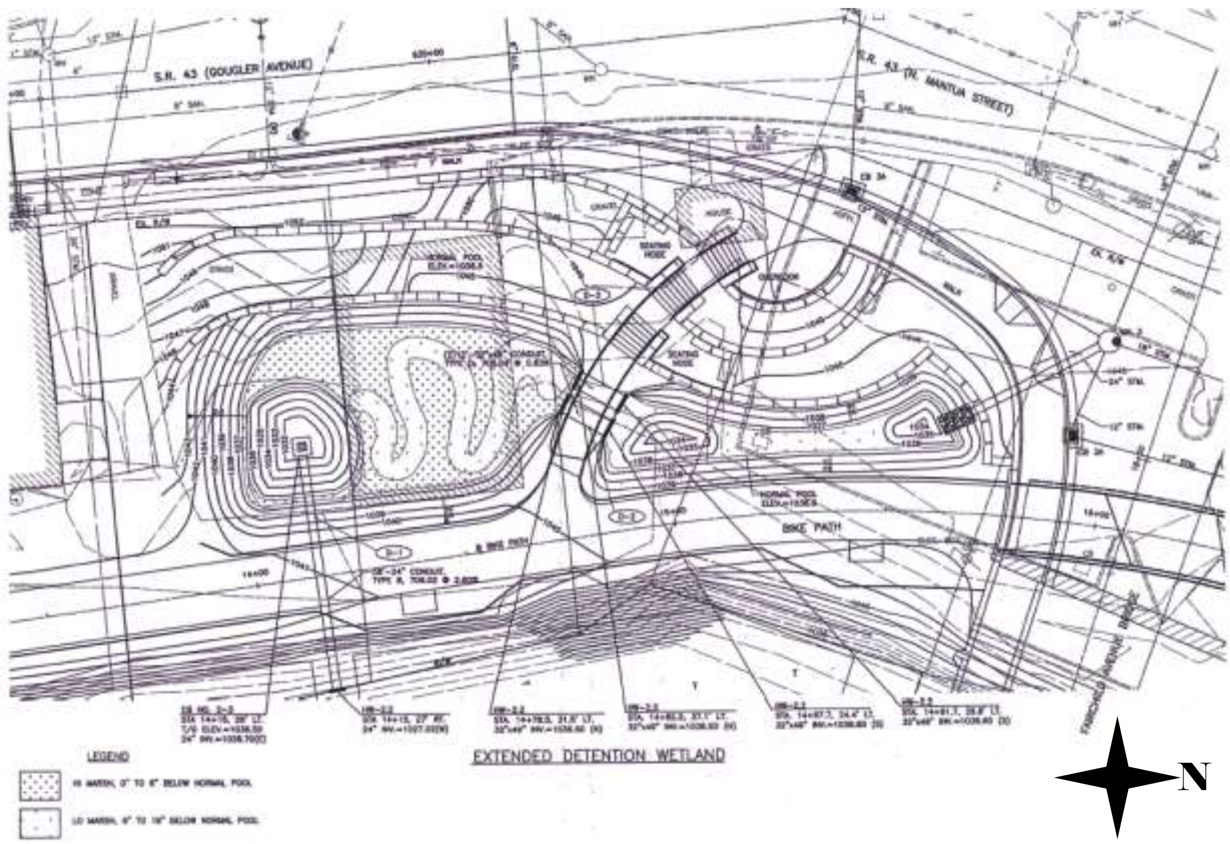


Figure D-15. Plan view of constructed wetland for Crain Avenue Project