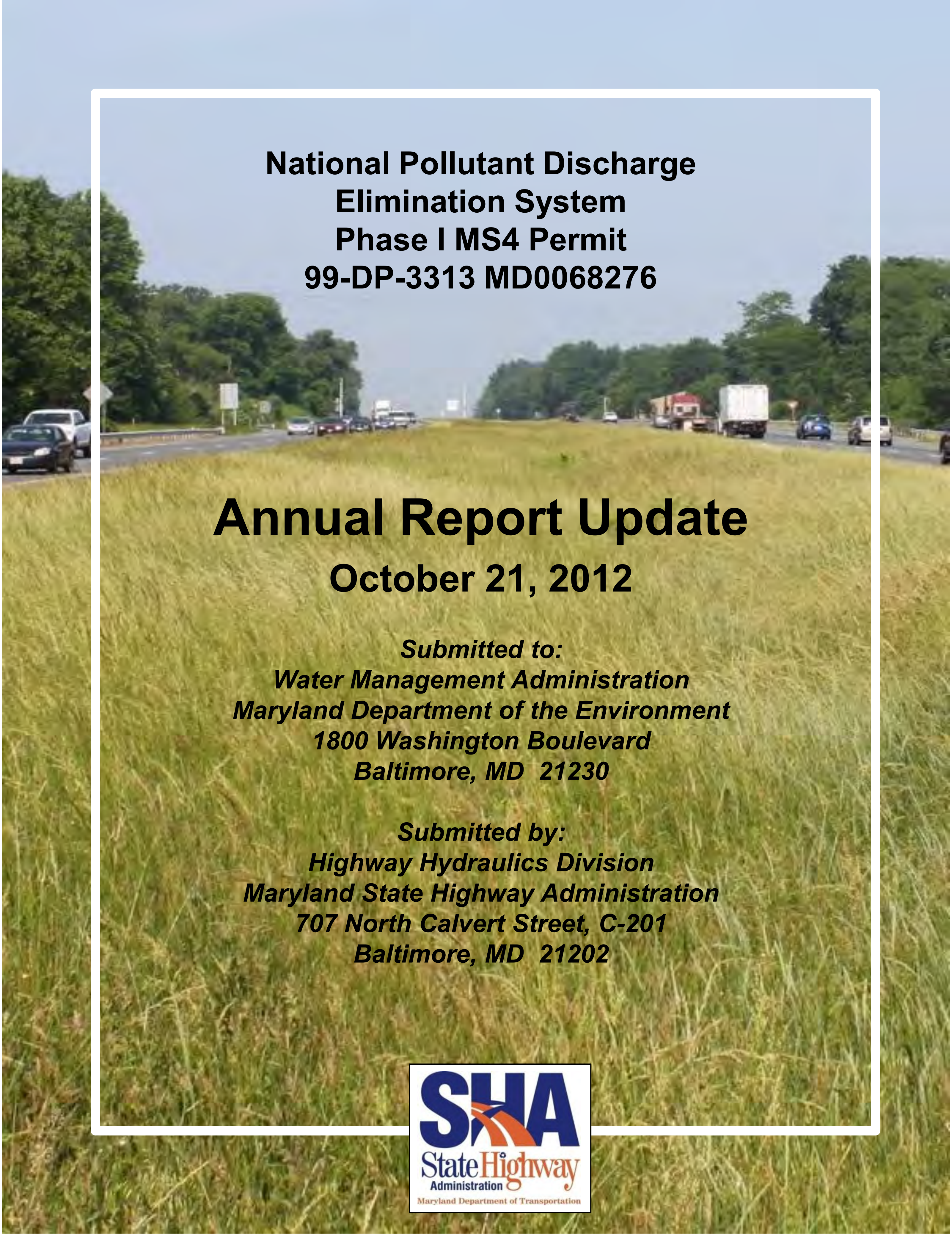

National Pollutant Discharge Elimination System Phase I MS4 Permit 99-DP-3313 MD0068276

Annual Report Update

October 21, 2012

Submitted to:
Water Management Administration
Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230

Submitted by:
Highway Hydraulics Division
Maryland State Highway Administration
707 North Calvert Street, C-201
Baltimore, MD 21202

SHA State Highway Administration
Maryland Department of Transportation

Martin O'Malley, *Governor*
Anthony G. Brown, *Lt. Governor*

SHA State Highway Administration
MARYLAND DEPARTMENT OF TRANSPORTATION

Darrell B. Mobley, *Acting Secretary*
Melinda B. Peters, *Administrator*

Date: October 21, 2012

RE: Annual NPDES MS 4 Phase I Report Update
Permit term 10/2005 to 10/2010
Permit No. 99-DP-3313 MD0068276
Continuation

Mr. Raymond Bahr
Sediment, Stormwater and Dam Safety Program
Water Management Administration
Maryland Department of the Environment
1800 Washington Boulevard, Suite 440
Baltimore, MD 21230

Dear Mr. Bahr:

We are pleased to submit this updated report for the NPDES Phase I MS4 permit as a continuation of coverage under the expired permit. The updated report covers the time period of October 2011 through September 2012. SHA remains committed to the environmental compliance and stewardship even in this difficult budgetary time for furthering the goals of this state towards the preservation and restoration of the Chesapeake Bay as well as local watersheds and streams. We hope that you find this report presenting the hard work of many individuals throughout the organization and the work achieved through the commitment and leadership at much higher levels. We submitted a re-application for the NPDES Phase I Municipal Separate Storm Sewer System (MS4) permit on October 21 2009. SHA will continue to comply with the existing permit until the new permit is received from MDE.

SHA has continued its progress this past year in fulfilling the requirements and the purposes of this permit. SHA has worked closely with the MDE over the last year to coordinate efforts with the Bay TMDL and Maryland Watershed Improvement Plan development.

As the State of Maryland has recognized the value in source control of stormwater by implementing the requirements of Environmental Site Design, SHA has fully adopted the change for integration of Environmental Site Designs into its new highway program. While recognizing the value of non-structural stormwater practices towards the water quality SHA has realized the value of numerous stormwater credits built over the years for which no accounting exists.

SHA will continue its efforts to account for those non-structural practices in truly quantifying the impervious surface that is not treated by any management practice. SHA is in the process of quantifying its current capacity for pollutant load reductions by structural non-structural BMPs, and other strategies with a strong interest in quantifying the benefits of pavement disconnection and grass swales.

An electronic file of the report and the MDE database tables is be supplied on a CD and included with this report. We look forward to the coming year and continued growth of our program as well as partnership between our agencies. If you have any questions or need any additional information regarding the SHA NPDES MS 4 program, please contact me at 410-545-8390 or at kpujara@sha.state.md.us.

Sincerely

Karuna

Karuna Pujara, Chief
Highway Hydraulics Division

Attachment

CC: Karen Coffman
Dana Havlik
Kirk McClelland
Sonal Sanghavi
Doug Simmons
Greg Welker

Phase I National Pollutant Discharge Elimination System
Permit No. 99-DP-3313 MD0068276
Permit Term October 2005 to October 2010

Annual Report Update
October 21, 2012

Submitted to:

Water Management Administration
Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230

Submitted by:

Maryland State Highway Administration
Highway Hydraulics Division
707 North Calvert Street, C-201
Baltimore, MD 21202

Executive Summary

The Maryland State Highway Administration (SHA) is submitting this updated annual report for the NPDES Phase I Municipal Separate Storm Sewer System (MS4) permit that was issued in October 2005 by the Maryland Department of the Environment (MDE) Water Management Administration (WMA). This annual report covers the time period October 2011 to September 2012.

A general overview that highlights significant achievements over the last report period is provided below.

Source Identification

The impervious accounting condition has been completed for the nine Phase I counties, however the SHA is reexamining drainage area related data and accounting procedures. Some updates to the impervious layers have been preformed. Updates to the databases for each NPDES county are on-going. Work has begun to incorporate NPDES related data in the overall SHA workflows

Discharge Characterization

We continue to investigate and research topics in order to maximize water quality in our construction methods, permanent stormwater runoff controls, decisions in design, and location of roadways and maintenance techniques. Previous reports have included reports for research projects completed in the past. One current study seeks to optimize denitrification in bioretention soil mix by investigating treatment time and carbon source material and another seeks to evaluate the function of infiltration facilities that have transitioned to wetlands in terms of quality and quantity stormwater treatment.

Management Program

Our program continues to effectively incorporate all permit components. We have successfully integrated the stormwater environmental site design (ESD) regulations into roadway design and construction projects and continued to measure our performance in the areas of erosion and sediment control (ESC) during construction and our internal business goal of maximizing the number of functionally adequate stormwater facilities statewide.

The ESC Program developed and implemented the ESC Quality Assurance Toolkit (QA Toolkit). This tool allows field inspectors to enter inspection results directly into a field that is connected to the general ESC inspection database through the internet. This improves efficiency, accuracy of data entry and reporting.

The Design Build Operate and Maintain (DBOM) pilot to place the operations and maintenance responsibilities for permanent stormwater management facilities with a private company continues. The contract is in its last year and SHA plans to use a similar but modified contracting format in the near future. Upcoming contracts are expected for Anne Arundel and Prince George's counties pending confirmation of funds.

Watershed Assessment

Coordination with local NPDES jurisdictions continues. We are also moving forward with watershed restoration sites within the Patuxent

River Watershed. Construction of Phase I project is complete. The Phase II project is in the advanced engineering stage. With the EPA Green Highway grant, SHA is nearing the completion of formalizing an implementation framework for watershed-based stormwater design within SHA which could be applicable to any transportation agency.

Watershed Restoration

SHA met the requirement for 25 restoration projects and looks forward to the next permit with increased watershed restoration goals. As the Bay TMDL efforts are underway, SHA has increased its coordination efforts with local MS4s to integrate its watershed assessments and needs to SHA's prioritization of projects and site selection.

Assessment of Controls

The Long Draught Branch stream restoration project has been re-initiated but with delayed funding until 2014. We will continue the project with the post-construction monitoring when the project is completed. The Wet Infiltration Basin Transitional Performance Study will augment data on assessment of controls.

Program Funding

In this tough economic climate, the NDPES remains a top funding priority. Our NPDES program remains fully funded. Also, despite the challenging economic situation, SHA and MDOT have begun funding Bay TMDL efforts and also supported procurement of NPDES engineering contracts.

Total Maximum Daily Loads

SHA has worked closely with the MDE over the last year to coordinate SHA efforts with the Bay TMDL and Maryland Watershed Implementation Plan (WIP) development. We have developed a strategic plan and dedicated funding and engineering resources. While we face fiscal and organizational challenges to compliance with the desire to improve the Bay water quality and demonstrate the SHA commitment to natural resource preservation and Bay restoration.

MDE support and leadership during preparation of WIP I and II for all MS4s including SHA has laid a solid foundation for the state's progress towards meeting the Bay TMDL. SHA appreciates MDEs outreach and participative process.

Table of Contents

List of Tables

List of Figures

PART ONE

Standard Permit Conditions and Responses

Introduction

The Maryland State Highway Administration (SHA) is committed to continuing our National Pollutant Discharge Elimination System (NPDES) Program efforts and is pleased to partner with the Maryland Department of the Environment (MDE), the Environmental Protection Agency (EPA) and other NPDES jurisdictions in order to achieve the program goals.

The original NPDES phase one permit guided SHA through establishing our NPDES program. (The permit, MS-SH-99-011, was issued on January 8, 1999 and expired in 2004.) The current permit (99-DP-3313, MD0068276, issued October 21, 2005 and expired on October 21, 2010) focused on improving water quality benefits, developing an impervious accounting database and developing a watershed-based outlook for stormwater management and NPDES program elements. We submitted a re-application for the NPDES Phase I Municipal Separate Storm Sewer System (MS4) permit on October 21 2009 and are aanticipating a draft permit from MDE. SHA will continue to comply with the existing permit until the new permit is received.

This is the second update to the final annual report that was submitted October 2010 for the expired permit. The report covers the period from October 2011 through September 2012. Part One lists permit conditions and explains SHA activities over the last year to comply with each one. Wherever possible, future activities and schedules for completion are provided. Part Two of this report discusses the SHA Stormwater Management (SWM) Facility Program in depth. Appendices are included at the end of the report that contain research reports, examples of data and other detailed information.

A CD is also included that contains portable document format (PDF) files of the entire report and delivery of database updates in the new MDE Attachment A formats. We have included updated database tables and spatial files according to the recently revised Attachment A, Annual Report Databases. Some data was not available for the newer fields and a document is included on the attached CD that explains any assumptions or unresolved data issues for these tables. New tables for all the SHA NPDES MS4 Phase I data are included even records that were delivered in the past as the data requirements have changed (except where noted on the document included on the CD).

A Administration of Permit

Administration responsibilities of the NPDES MS4 permit for SHA is listed below and an organizational chart is attached as Figure 1-1.

Ms. Karuna Pujara
Division Chief
Highway Hydraulics Division
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NPDES Industrial Permits and associated activities are coordinated by:

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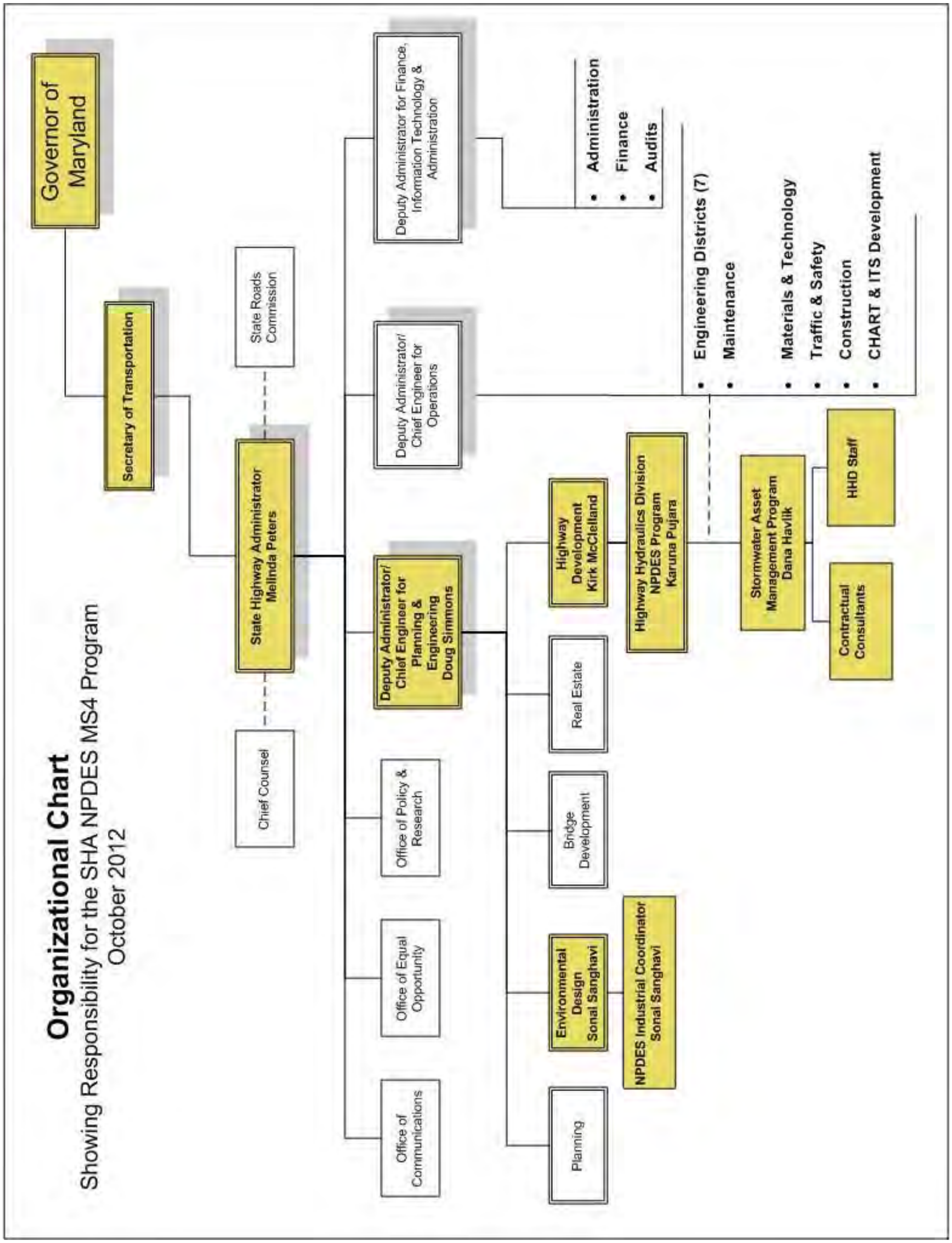

Figure 1-1 Organizational Chart for SHA NPDES MS4 Permit Administration

B Legal Authority

A description of the legal authority maintained by SHA was restated in the fourth annual report dated October 21, 2009 and remains unchanged.

C Source Identification

According to the permit language, source identification deals with identifying sources of pollutants and linking those sources to specific water quality impacts on a highway district basis. Source identification is also tied to impervious surfaces and land uses.

For this permit term, MDE has defined the source identification effort as completing the description of the SHA storm drain and BMP system, submitting BMP data to MDE and creating an impervious surface account.

Maryland SHA has successfully completed the GIS development of SHA storm drain systems within the nine Phase I MS4 counties. We are utilizing advances in technology and software improvements to more effectively and efficiently collect and maintain data sets. These process improvements will enhance communication between offices regarding the goals and needs for NPDES.

C.1 Describe Storm Drain System

Requirements under this condition include:

a) *Complete Source identification requirements by October 21, 2009;*

b) *Address source identification data compatibility issues with each jurisdiction where data are collected. Data shall be organized and stored in formats compatible for use by all governmental entities involved;*

c) *Continually update its source identification data for new projects and from data gathered during routine inspection and repair of its municipal separate storm sewer system; and*

d) *Submit an example of source identification for each jurisdiction where source identification is being* compiled.

C.1.a Complete Source Identification

SHA completed the identification and GIS development for our storm drain systems and stormwater management facilities in 2008, well before the October 21, 2009 deadline. Our focus has shifted to updating our source identification information for the nine MS4 counties and updating our current data structure to integrate new data standards provided in the latest version of Attachment A. Information on source identification updates and updates to the data structure is included under section C.1.c, Update Source ID Data.

C.1.b Data Compatibility

SHA continues to provide data to the other NPDES jurisdictions and MDE as well as acquire data from them. The NPDES data generated by SHA is deployed using the ESRI Geodatabase data format in an ArcSDE enterprise environment and is either natively compatible with other jurisdictions, or can be exported to ESRI shape file format.

MDE is currently in the process of updating their NPDES data requirements and SHA has coordinated with their consultant, Maryland Environmental Services (MES) by providing our TMDL data standards, NPDES Standard Procedures and geodatabase structure to them. SHA intends to continue involvement in this process with MDE.

Geospatial Database Development

SHA has developed a geospatial database for our source identification and inspection data. This database will be expanded to include other components of the program as they are brought together and as we update our standard procedures and inspection manuals. All of the SHA NPDES data including source identification, SWM facility inspections, outfall screening, outfall inspections, and impervious area acre amounts are currently housed in the database.

A SHA-wide web-based application, known as eGIS, was developed to display content themes for decision making purposes. Content themes allow the user to overlay datasets without extensive knowledge of the ESRI tool sets. NPDES data has been included as a content theme in eGIS. See Figure 1-2 for an example.

Google Earth is an alternative method to present and communicate NPDES asset information to parties outside of the SHA network firewall. It provides a discrete and user-friendly framework for which information may be communicated to SHA Districts and the consultant community through the distribution of KML and KMZ files that open directly in Google Earth. Refer to Figure 1-3 for a screenshot of information displayed in Google Earth.

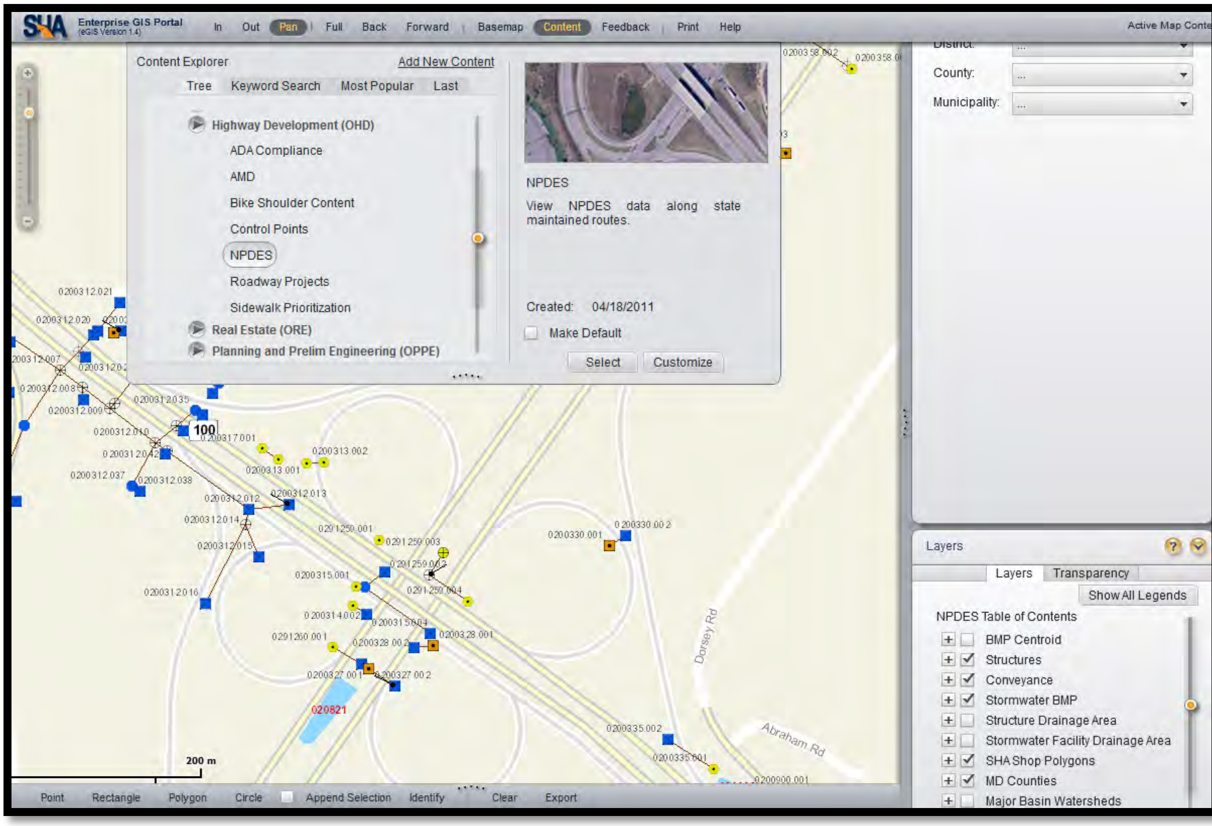

Figure 1-2 eGIS Viewer Screenshot of SHA NPDES Dataset

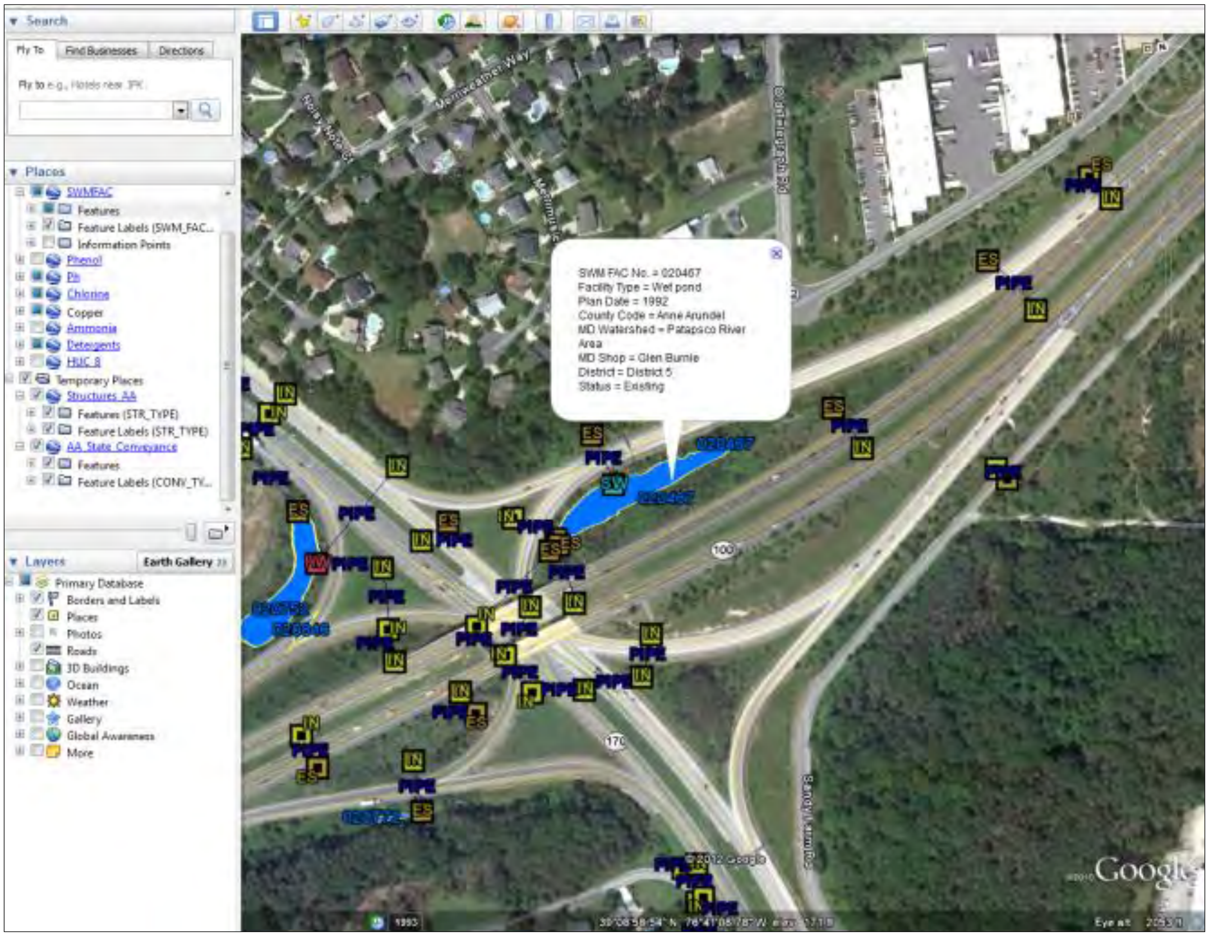

Figure 1-3 Google Earth Screenshot of SHA NPDES Data Uploaded as KML

NPDES Software Development

Descriptions of GIS software application development underway were included in the 2010 Annual Report. Application updates are performed using available resources and employing new technological advances. Table 1-1 represents the upgrade status.

Data Management and Editing Tools Manual

A new addition to SHA standardized procedures for the NPDES program is the SHA *Data Management and Editing Tools Manual*. This manual outlines the data management workflow, discusses office and field editing applications that are used to assist in data collection and discusses the procedures and process for quality control of the stormwater database. SHA data managers and editors will utilize the procedures outlined in the manual to manage all the data and GIS needs for the SHA NPDES program.

Table 1-1 Status GIS Applications

Phase of Development	% Complete
SWM Program Module	100
SWM Facility Numbering Module (eGIS)	65
WQ Bank/Imperviousness Accounting Module	65
eGIS Integration	85

C.1.c Update Source Identification Data

Since the initial source identification has been completed for all the NPDES MS4 Phase I counties, the permit activity requirement for this condition now focuses on updating the source data. During the past year, SHA completed full MS4 updates in Anne Arundel and Baltimore counties, and updates to Howard County have been initiated. These updates include an improved procedure for delineating drainage areas to SWM facilities. In addition, SHA is taking steps to develop the necessary skill set to have the database management performed by SHA in-house staff rather than use more costly consultant services.

Source identification updates are performed with the goal to meet the required three-year cycle and we have improved our processes in order to target this update cycle timeframe. Future updates have been scheduled to meet this goal and or once the maintenance and remediation efforts have been completed for a particular county. Also, SHA will be expanding efforts in Baltimore and Howard counties (which were abbreviated to target 150 outfalls and only new stormwater facilities due to budget constraints) to complete the full MS4 update. The work is anticipated to be completed by the end of CY 2013.

Future updates will be performed as specified in Table 1-2. The latest data collected is as follows:

Anne Arundel County – Updated identifications of the separate storm water system and outfall and BMP inspections were completed during this reporting period and are included in this report.

Baltimore County – Updated identifications of the separate storm water system and outfall and BMP inspections were completed during this reporting period and are included in this report.

Carroll County – Identifications of the separate storm water system were included in the 2009 report. SHA is commencing update this data with completion anticipated for the 2013 Report.

Charles County – Identifications of the separate storm water system is nearing completion and inspections of SWM BMPs are in-progress.

Frederick County – Updated identifications of the separate storm water system and outfall and BMP inspections were completed and included in the 2011 Report.

Harford County Updated identifications of the separate storm water system and outfall and BMP inspections were completed and included in the 2011 Report.

Howard County – Identifications of the separate storm water system are underway and routine outfall and SWM BMP inspections are on-going. Initial identifications and inspections were included in the 2010 report. Updates of this data are anticipated by CY 2013.

Montgomery County – Updated identifications of the separate storm water system and outfall and BMP inspections were included in the 2011 Report.

Prince George's County – Updated identifications of the separate storm water system and outfall and BMP inspections were completed during this reporting period and are included in this report.

Table 1-2 Source ID Schedule

County	Source ID Complete	1st Update	2nd Update
Howard	1/2001 - C	1/2005 - C	6/2011– G 12/2012 - A
Montgomery	1/2001 - C	9/2006 - C	5/2011 - C
Anne Arundel	8/2003 - C	6/2012 – C	10/2015 - A
Prince George's	3/2003 - C	6/2011 - C	6/2014 - A
Baltimore	3/2004 - C	6/2011 – G 10/2012 - C	2/2015 - A
Harford	8/2005 - C	2/2011 - C	1/2014 - A
Frederick	9/2006 - C	1/2011 - C	5/2014 - A
Carroll	5/2008 - C	9/2012 - P 12/2012 - A	7/2015 - A
Charles	6/2008 - C	8/2012- G 1/2013- A	10/2012-P 9/2015 - A
Note: **C** = Completion date **P** = Project Initiation date **A** = Anticipated Completion Date **G** = Partial Update Completed			

C.2 Submit BMP Data

Database tables are included on the attached CD as noted in the Introduction.

C.3 Create Impervious Surface Account

This condition requires that SHA provide a detailed account of impervious surfaces owned by SHA and an account of those acres of impervious surface controlled by stormwater management, broken out by SHA engineering district. This account will be used to identify potential areas for implementing restoration activities.

We completed the impervious accounting requirement and the baseline accounting numbers were reflected in the 2010 report. Table 1-3 displays the baseline untreated impervious numbers for SHA by county and the progress of the restoration based on the requirement for twenty-five restoration projects (permit condition G.1) and Figure 1-4 provides a graphic illustration of the progress.

Table 1-3 SHA Pavement Restoration Accounting by County

County	Baseline Untreated Impervious (AC)	Impervious Acres Restored by Permit Condition (AC)	Impervious Acres Restored by Permit Condition (%)	Adjusted Untreated Impervious (AC)	Total Impervious (AC)	Total Impervious Treated (%)
Anne Arundel	3,162	93	3.0%	3,068	3,796	19.1%
Baltimore	3,718	513	7.2%	3,449	3,954	19.0%
Carroll	1,286	0	0%	1,286	1,330	3.3%
Charles	1,364	2	0.1%	1,362	1,421	4.1%
Frederick	2,166	2	0.1%	2,164	2,353	8.0%
Harford	1,949	21	1.1%	1,928	2,078	7.2%
Howard	1,982	15	0.8%	1,967	2,211	11.0%
Montgomery	2,882	247	8.5%	2,636	3,428	23.1%
Prince George's	3,792	26	0.7%	3,766	4,187	10.1%
Totals	**22,301**	**919**	**4%**	**21,382**	**24,758**	**13.6%**

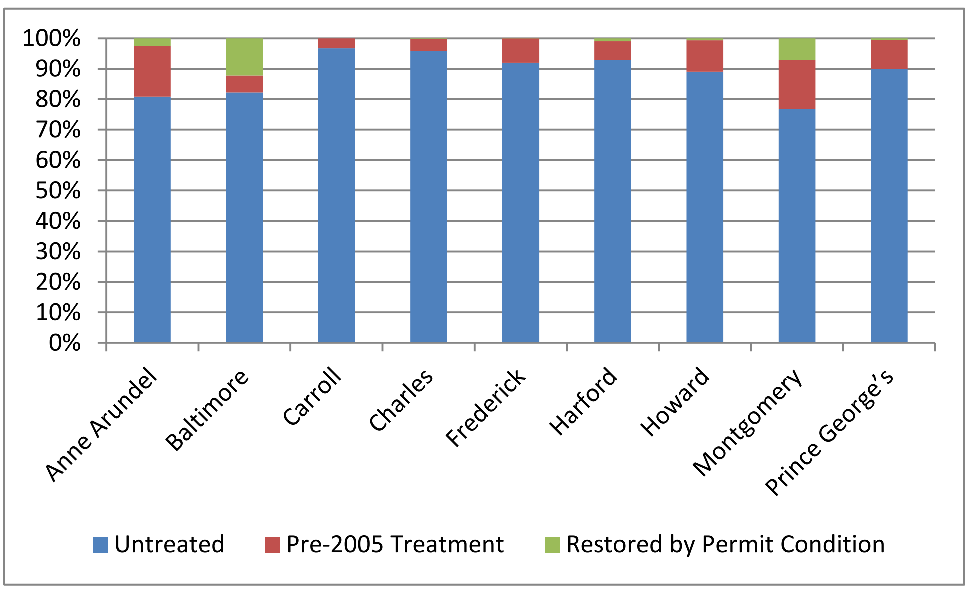

Figure 1-4 SHA Impervious Restoration Progress by County

Impervious Layer Updates

The SHA impervious layer depicting impervious surfaces owned by SHA in Baltimore County was updated this past reporting period. As part of this update, we refined our method for delineating drainage areas to stormwater BMPs in order to provide more accurate data of SHA and non-SHA impervious surfaces draining to each BMP. Future updates to the remaining SHA Phase I MS4 impervious layers are planned.

D Discharge Characterization

This current permit term looks at scrutinizing the available MDE dataset compiled from eleven NPDES jurisdictions and other research performed nationally to improve stormwater management programs and develop watershed restoration projects. We are continuing our efforts to understand stormwater runoff associated with highways by reviewing available literature and studies on the subject and by conducting studies to further our understanding.

The following studies have been sponsored by SHA and progress reports were included in the following, previous annual reports for this permit term:

First Annual Report (October 2006):

Low impact Development Implementation Studies at Mt. Rainier, MD, October 2006.

Grassed Swale Pollutant Removal Efficiency Studies (Part II – MDE/SHA Swale Comparison), October 2006.

Second Annual Report (October 2007):

Grassed Swale Pollutant Removal Efficiency Studies (Part III – Grass Check Dams), Progress Report, Progress Report, August 2007.

Literature Review: BMP Efficiencies for Highway and Urban Stormwater Runoff, September 2007.

Third Annual Report (October 2008):

Grassed Swale Pollutant Removal Efficiency Studies: Field Evaluation of Hydrologic and Water Quality Benefits of Grass Swales with Check Dams for Managing Highway Runoff (Part III – Grass Check Dams), Progress Report, October 2008.

Fourth Annual Report (October 2009):

Field Evaluation of Water Quality Benefits of Grass Swale for Managing Highway Runoff (Part III – Grass Check Dams), Progress Report, July 2009.

Field Evaluation of Wet Infiltration Basin Transitional Performance, Progress Report, October 2009.

Nutrient Removal Optimization of Bioretention Soil Media, Progress Report, August 2009.

Fifth Annual Report (January 2010):

Field Evaluation of Water Quality Benefits of Grass Swale for Managing Highway Runoff, Final Progress Report, Final Progress Report, July 2009.

Field Evaluation of Wet Infiltration Basin Transitional Performance, Progress Report, October 2010.

Nutrient Removal Optimization of Bioretention Soil Media, Final Progress Report, September 2010.

Reported for Previous Permit Term

The following studies were completed by SHA and reported during the previous permit term:

Pindell School Road Storm Sampling, KCI, March 7, 2000.

National Highway Runoff Study: Comparison to MSHA Sampling Results, KCI, December 2001.

Dulaney Valley Road I-695 Interchange Stream Monitoring at the Tributary to Hampton Branch, KCI, Annual Reports dating 2000 to 2003.

Current Studies

Additional studies are currently underway at the University of Maryland, Department of Civil and Environmental Engineering. Progress reports on several of the on-going studies were included in the 2011 Report or earlier. Further updates, as applicable, are included herewith as well as information on new research that has recently commenced.

Wet Infiltration Basin Transitional Performance Studies

This study was initiated in August 2008 and continues analysis. The purpose of this study is to examine the behavior and efficiency of an infiltration basin that is undergoing a natural transition into another facility type. It is enough of a common occurrence that warrants study since SHA has constructed many infiltration basins over the past three decades, and many of them have gone through, or are currently experiencing, a transition. Inspections have shown that many infiltration basins are no longer functioning as designed as they no longer provide infiltration. Instead, these facilities have gradually transformed into wetland-like facilities that appear to provide some level of water quality improvement and water quantity attenuation. In addition, the facilities are providing habitat areas for several species, and to remove such healthy established flora and fauna is in contrast with overall watershed health enhancement. Thus, rather than declare such facilities failures, SHA initiated a study of one site to determine the level of SWM provided by a wet infiltration facility and better understand how the transitioned facility functions.

Figure 1-5 Discharge Weir at BMP 130348 for Wet Infiltration Study

Target pollutants monitored include total suspended solids (TSS), nitrate, nitrite, total Kjeldahl nitrogen (TKN), total phosphorus, copper, lead, zinc, and chloride. The target pollutants are of greatest concern since they pollutants are targeted by the Bay TMDL and various local TMDLs.

A total of 176 storms have been monitored at the study site and the hydrologic response to these storm events has been examined. Results indicate that the facility remains relatively effective in managing SWM runoff, specifically for the smaller-volume storm events in which all runoff volume contributing to the inflow volume to the facility has been entirely assimilated for 53% of the monitored storm events.

In addition, removal efficiencies of the target pollutants have also been monitored. The overall pollutant mass removal efficiencies for the entire monitoring duration to-date are presented in Table 14 and the latest progress report is included as Appendix A.

Table 1-4 Pollutant Mass Removal Efficiency at Wet Infiltration Facility

Pollutant	Removal Efficiency (%)
TSS	89
Oxidized nitrogen (nitrate and nitrite)	79
TKN	51
Total Phosphorus	61
Copper	73
Lead	63
Zinc	55
Chloride	45

Management of Nitrogen in Stormwater Runoff Using a Modified Conventional Sand Filter

Because of increased focus in nutrient removal from stormwater runoff, a study has been initiated to determine how existing SWM facilities may be amended or reconstructed to better improve nitrogen and phosphorus reduction performance. Surface sand filters have been a prevalent SWM type used by SHA between 2003 and 2010, and therefore this type of facility was chosen for closer examination. For simplicity, only nitrogen is examined, but subsequent research will also explore improving phosphorus removal.

The study is presently investigating reconstruction a conventional surface sand filter. The proposed design divides the sand filter into three zones to facilitate the ammonification, nitrification, and denitrification processes.

First to be examined is the increased adsorption of ammonium so that ammonification may occur. Clay, recycled crushed brick, and sand were selected as the adsorbents of study, specifically aluminosilicate, crushed unpainted brick, and pool sand. The pH has been found to have significant affects on the sorption capacity of these materials.

Small scale column studies for the sorption of ammonium are presently underway, after which nitrification and sorption will be examined. A progress report and associated data has been included in this report as Appendix B.

Denitrification Optimization in Bioretention Using Woodchips as a Primary Organic Carbon Source

Because of increased focus in nutrient removal from stormwater runoff, a study has been initiated to determine how new SWM facilities may be further enhanced to better improve nitrogen and phosphorus reduction performance. Because the greatest potential for improvement appears to be with bioretention facilities, this type of facility has been chosen for closer examination. For simplicity, only nitrogen is examined, but subsequent research will also explore improving phosphorus removal.

The technology of bioretention systems is still in its infancy, and while these facilities have proven effective in removing many stormwater runoff pollutants, they lag in nitrogen removal efficiency. The research focuses on the optimization of the denitrification process of the nitrogen cycle. By creating an anoxic zone and providing a source of organic carbon, denitrifying microorganisms can colonize the media and convert nitrate-N into nitrogen gas, which is then be released into the atmosphere.

The study investigates a proposed bioretention design that divides the bioretention cell into three zones. The first zone will maximize nitrogen removal by providing the optimum conditions to facilitate denitrification. Because nitrogen treatment is a process requiring certain minimum timeframes to be successful, this zone will maximize the storage time and ultimately, nitrogen removal.

Results indicate the proposed system is effectively removing nitrogen when using wood chips as the organic carbon source. Wood chips from five different species of trees are being examined including Willow Oak, Wild Cherry, Virginia Pine, and American Beech. Of the species tested thus far, willow oak has shown the greatest potential to support an increased rate of denitrification within the bioretention system.

The data also shows that the bacteria require a full cycle of saturation and dry period before they become fully established, after which nitrogen removal becomes much more consistent. The amount of woodchips that may be amended in the bioretention filter medium as well as the size of the wood chips will be examined to determine the optimum carbon content and surface area necessary for denitrification. A progress report is included as Appendix C.

E Management Program

A management program is required to limit the discharge of stormwater pollutants to the maximum extent practicable. The idea is to eliminate pollutants before they enter the waterways. This program includes provisions for environmental design, erosion and sediment control, stormwater management, industrial facility maintenance, illicit connection detection and elimination, and personnel and citizen education concerning stormwater and pollutant minimization.

E.1 Environmental Design Practices

This permit condition requires that SHA take necessary steps to minimize adverse impacts to the environment through the roadway planning, design and construction process. Engaging the public in these processes is also required.

The Maryland State Highway Administration has a strong environmental commitment that has only increased as the new Stormwater Management Act of 2007 was implemented in May 2010. Through this legislation, emphasis was placed on the use of environmental site design (ESD) techniques. We are actively working ESD measures into roadway projects.

SHA also continues to adhere to processes that ensure that environmental and cultural resources are evaluated in the planning, design, construction and maintenance of our roadway network. This includes providing opportunity for public involvement and incorporating context sensitive design and solution principles. We also ensure that all environmental permitting requirements are met by providing training to our personnel (see E.6.b below) and creating and utilizing software to track permitting needs on projects as they move through the design, advertisement and construction processes.

NEPA/MEPA Process

Our National Environmental Policy Act/ Maryland Environmental Policy Act (NEPA/MEPA) design and planning process, includes environmental assessments for any project proposed within SHA right-of-way or utilizing state or federal funding. This includes projects granted Transportation Enhancement Program funds that are carried out by other jurisdictions. The environmental assessments determine the direction environmental documentation must take, whether Categorical Exclusion (CE), Finding of No Significant Impact (FONSI) or Environmental Impact Statement (EIS). Environmental assessments include land use considerations, water use considerations, air use considerations, plants and animals, socio-economic, and other considerations.

Increasingly, SHA is evaluating stormwater needs during the NEPA process. This movement to development of stormwater concepts in planning has affected our development process in several ways. Beginning the stormwater process earlier allows us to present more realistic concepts during public meetings and allows us to more accurately assess right-of-way needs. The drawback to this approach, however, can be that assumptions made in terms of the stormwater requirements may not be the final approved requirements. This last effect can have negative impacts on our permit approval process, public expectations, right-of-way acquisitions and design schedules. SHA encourages the stormwater regulatory reviewers to participate in the planning process by attending interagency meetings, reviewing concept plans and providing valid comments and concept approvals at the planning stage in the design.

It should be noted, however, that the planning process for major projects and the project development timeline can be greater than cycles of regulatory changes for water quality. This further introduces complexity in decision making and public perception of accuracies of SHA projects and processes.

Effort is made to avoid or minimize environmental impacts. If impacts are unavoidable, however, mitigation is provided and monitored per regulatory requirements.

E.2 Erosion and Sediment Control

Requirements under this condition include:

a) *Use MDE's 1994 Standards and Specifications for Soil Erosion and Sediment Control, or any subsequent revisions, evaluate new products for erosion and sediment control, and assist MDE in developing new standards; and*

b) *Perform responsible personnel ("green card") certification classes to educate highway construction contractors regarding erosion and sediment control requirements. Program activity shall be recorded on MDE's "green card" database and submitted as required in Part IV of this permit.*

E.2.a MDE ESC Standards

SHA continues to comply with Maryland State and Federal laws and regulations for erosion and sediment control (ESC) as well as MDE requirements for permitting. We continue to implement the new NPDES Stormwater Construction Activity permit for all our construction projects that impact one acre or more in area.

We are maintaining implementation of the current Guidelines for State and Federal Projects Published January 1990 and Revised January 2004 and the *1994 Standards and Specifications for Soil Erosion* for our projects.

SHA has remained in compliance with the NPDES Construction Activity permit and has implemented changes in our construction inspection to adhere to the new inspection requirements. We continue to submit applications for coverage under this general permit for all qualifying roadway projects.

SHA ESC Quality Assurance Ratings

SHA continues to use our improved Quality Assurance rating system for ESC on all roadway projects. This effort improves field implementation of ESC measures by including incentive payments to the contractor for excellent ESC performance or imposing liquidated damages on the contractor for poor ESC performance.

SHA tracks QA inspections and ratings for reporting to our business plan (see Figure 1-6) and StateStat. Increased numbers of inspections and better documentation have improved the overall performance of our ESC program. Incentive payments are made when the contractor receives an ESC rating score of 85% or greater. This incentive payment can be made quarterly (every three months) for projects that continue to receive 85% or greater ratings. A final incentive payment is also made for projects with an overall (average) rating of 85% or better.

As SHA has undertaken a large construction program through the design-build process, most of the contract provisions for those projects include compensation for ESC response action when severe weather is encountered. This compensation is in addition to the incentive for excellent performance as stated above.

Liquidated damages are imposed on the contractor if the project receives a 'D' or 'F' rating. If two ratings of 'F' are received on a project, the ESC certification issued by SHA will be revoked from the contractor project superintendent and the ESC manager for a period of six months and until they complete and pass the certification training. This system of rewarding good performance and penalizing poor performance is improving contractor responsibility for ESC practices and improving water quality associated with construction activities.

In FY 2012, a record number of inspections (3,904) on a record number of projects (293) reviewed, yielded an overall compliance of 99.54 percent (See Figure 1-6).

SHA revised standard forms currently used in ESC construction tracking to include NPDES construction activity permit related issues in an effort to increase compliance with both State and Federal ESC regulations. These forms are listed below and copies are included in Appendix D:

- OOC03 – District Engineer's Certificate of Completion of Work
- OOC60 – Erosion and Sediment Control Field Investigation Report
- OOC61 – Independent Quality Assurance Erosion and Sediment Control Field Investigation Report .

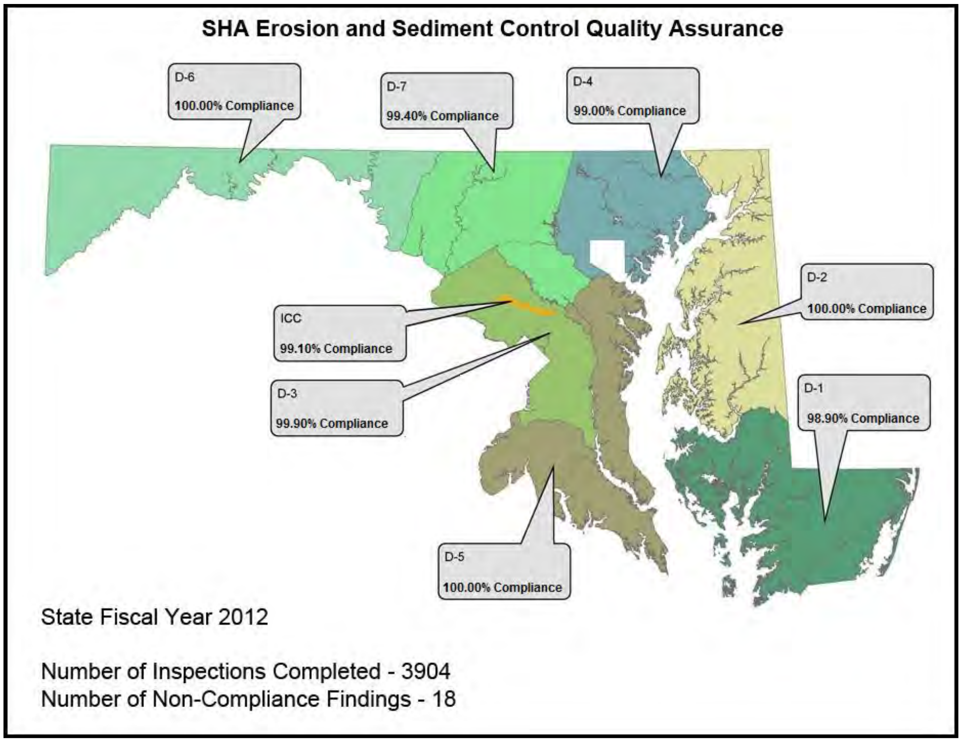

Figure 1-6 Erosion and Sediment Control Quality Assurance for FY2012

E.2.b Responsible Personnel Certification (Green Card Training)

SHA continued to sponsor and perform training for ESC Responsible Personnel Certification Classes over the past year. This training is conducted by SHA for SHA personnel, consultants and contractors.

SHA Basic Erosion and Sediment Control Training (BEST)

In addition to Green Card Training classes, SHA developed and implemented its own ESC Certification Program at two levels. Level I is known as BEST (Basic Erosion and Sediment Control Training). This day and a half training is aimed at contractors and field personnel and focuses on in-depth discussions of ESC design, construction and permitting requirements. This is also a prerequisite for Level II training.

The Level II training is intended for ESC design professionals. The Level II training began in June 2007. Progress in continuing development of this program has been delayed by the release of the new MDE standards. Table 1-5 details the number of personnel certified for each of the training levels for the reporting period.

Table 1-5 SHA ESC Training

Type of Training	No. Certified
Responsible Personnel (Green Card)	644
BEST Level I (Yellow Card)	591
BEST Level I (Yellow Card Recertification)	248
BEST Level II (Designer's Training)	0

E.3 Stormwater Management

The continuance of an effective stormwater management program is the emphasis of this permit condition. Requirements under this condition include:

a) Implement the stormwater management design principles, methods, and practices *found in the 2000 Maryland Stormwater Design Manual, the 2009 update, and COMAR;*

b) *Implement a BMP inspection and maintenance program to inspect all stormwater management facilities at least once every three years and perform all routine maintenance (e.g., mowing, trash removal, tarring risers, etc.) within one year of the inspection; and*

c) *Document BMPs in need of significant maintenance work and prioritize these facilities for repair. The SHA shall provide in its annual reports detailed schedules for performing all significant BMP repair work.*

E.3.a Implement SWM Design Manual and Regulations

SHA continues to comply with Maryland State and Federal laws and regulations for stormwater management (SWM) as well as MDE requirements for permitting. We also continue to implement the practices found in the *2000 Maryland Stormwater Design Manual* and the *Maryland Stormwater Management Guidelines for State and Federal Projects, April 15, 2010* for all projects. We have also implemented the requirements in the revised Chapter 5 of the 2000 Manual for environmental site design (ESD) and the Stormwater Management Act of 2007 for all new projects.

E.3.b Implement BMP Inspection & Maintenance Program

Our continuing Stormwater Management (SWM) Facilities Program inspects, evaluates, maintains, remediates and enhances SHA BMP assets to maintain and improve water quality and protect sensitive water resources. Inspections are conducted on a cyclical basis as part of the NPDES source identification and update effort (see Section C, above). Maintenance and remediation efforts are accomplished after the inspection data has been evaluated and ranked according to SHA rating criteria.

Details of the SWM Facility Program are included as Part 2 of this document. Discussion of inspection results and maintenance, remediation, retrofit and enhancement efforts undertaken over the past year is included in that section.

Stormwater As-Built Certification Process

SHA continues to seek ways to improve our SWM facility as-built certification process. This process requires the design engineer to coordinate with MDE on the completion of as-built checklists and tabulations. The contractor is then required to inspect and certify the facility construction according to the approved design plans. SHA has made the delivery of this certification a separate pay item. As-built certification contract specification was revised in 2010.

Copies of the final approved as-built certifications are retained by SHA and integrated into the storm drain and BMP GIS/database. This information is then used as source identification updates are planned and assigned.

We are finding that completion of this task by contractors is not consistent, and we are re-evaluating our process to determine a more effective means to achieve this requirement. Targeted educational effort is currently under way to improve needed efforts and attention.

E.3.c Document Significant BMP Maintenance

See Part 2 for SWM Facilities Program updates on major maintenance, remediation and BMP retrofits.

E.4 Highway Maintenance

Requirements under this condition include:

a) *Clean inlets and sweep streets;*

b) *Reduce the use of pesticides, herbicides, and fertilizers through the use of integrated pest management (IPM);*

c) *Manage winter weather deicing operations through continual improvement of materials and effective decision making;*

d) *Ensure that all SHA facilities identified by the Clean Water Act (CWA) as being industrial* *activities have NPDES industrial general permit coverage; and*

e) Develop a "Statewide Shop Improvement Plan" for SHA vehicle maintenance facilities to address pollution prevention and treatment requirements.

E.4.a Inlet Cleaning and Street Sweeping

Mechanical sweeping of the roadway is essential in the collection and disposal of loose material, debris and litter into approved landfills. This material, such as dirt and sand, collects along curbs and gutters, bridge parapets/curbs, inlets and outlet pipes. Sweeping prevents buildup along sections of roadway and allows for the free flow of water from the highway, to enter into the highway drainage system.

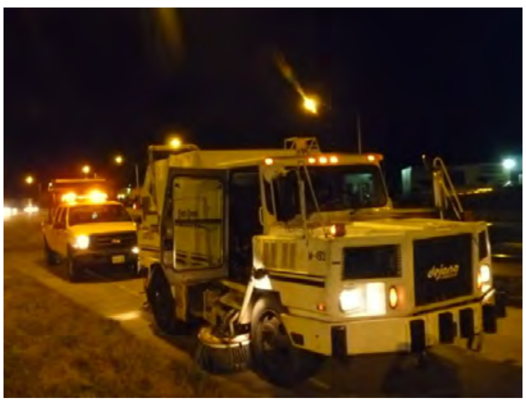

Figure 1-7 Street Sweeping often takes place at Night due to High Traffic Volumes in Urbanized Counties

The SHA desired maintenance condition is 95% of the traveled roadway clear of loose material or debris. In addition, 95% of closed section roadways (curb and gutter) should have less than 1 inch depth of loose material, debris, or excessive vegetation that can capture debris, in the curb and gutter.

In addition to street sweeping, SHA owns and operates four vacuum pump trucks that routinely clean storm drain inlets along roadways. Sediment and trash make up the majority of the material that is removed. The vacuum trucks operate in central Maryland, spanning the following Counties: Anne Arundel, Baltimore, Calvert, Carroll, Charles, Frederick, Harford, Howard, Montgomery, Prince Georges and St. Mary's. This practice ensures safer roadways through maintaining proper drainage and improves water quality in Maryland streams by removing captured sediment and trash before they enter adjacent waterways.

Figure 1-8 SHA Shop Personnel Operating Vacuum Truck to Clean Roadside Debris

Figure 1-9 Inlet Before (Left) and After (Right) Vacuuming

Pollutant Reductions for Inlet Cleaning and Street Sweeping

Sweeping and inlet cleaning are recognized as valid pollutant source reduction BMPs, however the means for crediting reductions is not well defined at this point. We are evaluating appropriate load reductions that can be claimed by SHA in meeting local and Bay TMDLs. This accounting will be added to reports for the next permit term.

The SHA Highway Hydraulics Division (HHD) is working with the SHA Office of Maintenance (OOM) to document current routes, to extend these activities to watershed-based, priority roadways and to characterize and quantify material and debris removed as a result of these activities. The result will be the development of procedures to optimize reporting of reductions associated with each of these activities and to better understand pollutant loads gathered from highways. It is hoped that this understanding will result in additional impervious surfaces treatment.

E.4.b Reduction of Pesticides, Herbicides and Fertilizers

SHA has standards for maintaining the highway system and one of these standards is the *SHA Integrated Vegetation Management Manual for Maryland Highways, October 2003* (IVMM). This manual incorporates the major activities involved in the management of roadside vegetation including application of herbicides, mowing and the management of woody vegetation. In order to maximize the efficiency of funds and to protect the roadside environment, an integration of these activities is employed.

Herbicide Application

The majority of SHA vegetation management is accomplished mechanically, through the use of mowers and brush axes. However, in areas where mechanical control is not practical or feasible, SHA manages vegetation through the use of targeted applications of herbicide.

SHA promotes the safe and responsible use of herbicide for this purpose. All SHA employees and contractors who apply herbicide on SHA rights-of-way must be registered with the Maryland Department of Agriculture (MDA) and operate under the supervision of a MDA-licensed pesticide applicator.

Environmental stewardship is a primary focus of SHA's business plan, and SHA encourages the use of selective herbicides and targeted application, rather than the broad application of non-selective herbicides. The use of herbicide is based on the plant species that is being targeted, so that the effects on other plants are minimized and soil residual activity is limited. Application rates are based on the minimum amount required to control the targeted plant species, so that the potential for runoff and non-point source contamination also is minimized.

Herbicide application equipment is routinely inspected and calibrated to ensure that applications are accurately applied in accordance to the IVMM, Maryland State law and the herbicide label.

Nutrient Management Plans

State law (COMAR 15.20.04-08 – Nutrient Management Regulations) requires SHA to develop a Nutrient Management Plan (NMP) for all fertilizer applications. SHA uses slow-releasing nitrogen based fertilizers with application rates based on soil testing. Topsoil is sampled and tested for major plant nutrients, pH, and organic material. The test results are used to develop a NMP to ensure optimal nutrient levels and growing conditions and to avoid the application of excess fertilizer.

Mowing Reduction & Native Vegetation Establishment

A major initiative at the SHA is to reduce the extent of mowed areas within our right-of-way. The Administration's Turfgrass Management Policy has been revised to provide consistent guidance to decrease the size of mowed areas and the number of mowing cycles per year.

Several projects have been completed throughout the state to install and maintain reforestation and native meadow areas. Reforestation and native meadow areas require no to minimal mowing, preserve native vegetation, and enhance erosion control and nutrient uptake.

E.4.c Winter Deicing Operations

SHA continues to test and evaluate new winter materials, equipment and strategies in an on-going effort to improve the level of service provided to motorists during winter storms while at the same time minimizing the impact of its operations on the environment.

One method employed to decrease the overall application of deicing materials is to increase application of deicing materials prior to and in the early stages of a winter storm (anti-icing). This prevents snow and ice from bonding to the surface of roads and bridges and ultimately leads to lower material usage at the conclusion of storm events, thus lessening the overall usage of deicers.

SHA recently initiated a pilot program using a fairly new product called GEOMELT 55, a de-sugared sugar beet molasses that may be blended with brine. This organic material, also known as beet juice, lowers the freezing point of the brine to -30 degrees. GEOMELT 55 also enables the brine to adhere to bridges and road surfaces better and longer, which extends the effectiveness of the deicer.

In addition, SHA has expanded its 'sensible salting' training of State and hired equipment operators in an on-going effort to decrease the use of deicing materials without jeopardizing the safety and mobility of motorists during and after winter storms.

Table 1-6 lists materials used by SHA in winter deicing operations.

Table 1-6 SHA Deicing Materials

Material	Characteristics
Sodium Chloride (Rock and Solar Salt)	The principle winter material used by SHA. Effective down to 20° F and is relatively inexpensive.
Abrasives	These include sand and crushed stone and are used to increase traction for motorists during storms. Abrasives have no snow melting capability.
Calcium Chloride	A solid (flake) winter material used during extremely cold winter storms. SHA uses limited amounts of calcium chloride.

Material	Characteristics
GEOMELT 55	A de-sugared sugar beet molasses may be blended with the brine. Also known as "beet juice," this organic material lowers the freezing point of the brine to –30º F. The light brown material is environmentally safe and does not stain roadway surfaces
Salt Brine	Liquid sodium chloride or liquefied salt is a solution that can be used as an anti-icer on highways prior to the onset of storms, or as a deicer on highways during a storm. Used extensively by SHA. Freeze point of -6° F.
Magnesium Chloride (Mag)	A liquid winter material used by SHA for deicing operations in its northern and western counties. It has a freeze point of -26° F and has proven cost effective in colder regions.
Potassium Acetate	A costly, environmentally friendly, liquid material used by SHA at its automated bridge anti-icing system in Allegany County

New Road Salt Management

On May 20, 2010 the Governor approved Senate Bill 775, requiring SHA, in consultation with the Department of the Environment (MDE), to develop a best practices road salt management guidance document by October 2011. This document is necessary to reduce the adverse environmental impacts of road salt storage, application and disposal on Maryland's water and land resources.

SHA posted the Statewide Salt Management Plan on its website in October 2011. The plan was subsequently updated on October 1, 2012. The plan provides guidance on snow and ice control operations with an emphasis on lessening the impact of salt on the environment. The plan covers all aspects of winter operations including:

- Safety and mobility of motorists during and after winter storms,
- Defining levels of service provided during winter storms,
- Establishing long-term goals to lessen the usage of salt, and reduce its impact on the environment,
- Salt and other winter materials,
- Material storage and handling,
- Winter storm fighting equipment,
- Training initiatives,
- Winter storm management from pre-storm preparations through post-storm operations,
- Post-storm material and equipment cleanup,
- Post-storm and post-season data analysis,
- Public education and outreach, and
- Testing and evaluation of new materials, equipment, and strategies for continual improvement.

Winter Operations Training

<u>SHA Annual Snow College</u> – This training is offered every fall for new maintenance shop hires as well as 20% of veteran shop forces. The goal is to train all maintenance personnel over a five year period and repeat the process. This ensures that all maintenance personnel are exposed to current trends and technologies. The training presentations are included in the Statewide Salt Management Plan, Appendices II and III and topics covered include all aspects of winter operations with an emphasis on sensible salting. See Table 1-7 for training year and numbers trained.

<u>Annual Maintenance Shop Winter Meetings</u> – Abbreviated salt management training is provided to all SHA maintenance forces annually at winter shop meetings. No data was available for 2011 on numbers trained and we will begin

tracking this training to inclusion in the next report.

Hired Equipment Operator Training – This training is provided to hired equipment contractors and operators every fall. The training presentations are included in the Statewide Salt Management Plan and topics covered include effective plowing, sensible salting and adhering to all pertinent SHA policies and procedures. No data was available for 2011 on numbers trained and we will begin tracking this training to inclusion in the next report.

Table 1-7 SHA 2011 Snow College Training

SHA District (Shops)	No. Participants
1 (D, WI, WO, SO)	20
2 (CE, K, QA, CO, T)	18
3 (MG, MF, PL, PM)	28
4 (BG, BH, BO, HA)	20
5 (AA, AG, CV, CA, CH, SM)	18
6 (G, AL, WA)	24
7 (F, CL, HO)	26
Total Trained	154

E.4.d Industrial Permit Coverage

As discussed in the previous Annual Report, SHA developed and implemented a Compliance Focused Environmental Management System (CFEMS) to ensure multi-media compliance at all maintenance facilities statewide. The CFEMS covers procedures for management of environmental compliance issues, including those related to Industrial NPDES at maintenance facilities, such as spill response, material storage and vehicle washing. It includes the implementation of Standard Operating Procedures (SOPs), routine compliance inspections and environmental training covering a variety of media areas including stormwater management and spill prevention and response.

The CFEMS is being implemented in a phased approach. As stated in previous Annual Reports, Phase I, Phase II and Phase III environmental assessments at 94 SHA facilities were completed by February 2011. In April 2012, SHA began conducting environmental assessments of Phase IV facilities, including movable bridges, communications facilities, rest area/welcome centers, and truck inspection and weighing stations. Recommendations for stormwater improvements at these facilities will be addressed as part of Phase IV.

As shown in Table 1-8 below, certain facilities are currently covered under the General Discharge Permit (02-SW). The SHA Environmental Compliance Division (ECD) is continuing to perform routine inspections at all SHA facilities through its District Environmental Coordinators (DEC) to ensure stormwater pollution prevention BMPs are implemented. The DECs are responsible for ensuring compliance with applicable permits, plans and regulations at facilities in their region.

Table 1-8 Industrial NPDES Permit Status

District	Maintenance Facility	Permit Type
1	Berlin[1]	General
	Cambridge	General
	Princess Anne	General
	Salisbury	General
	Snow Hill	General
2	Centreville	Individual – SW
	Chestertown	General
	Denton	General
	Easton	General
	Elkton	General
3	Fairland	General
	Gaithersburg	General
	Laurel	General
	Marlboro	General
4	Churchville	Individual – SW
	Golden Ring	General
	Hereford	Individual – SW[2]
	Owings Mills	General
5	Annapolis	General
	Glen Burnie	General
	La Plata	General
	Leonardtown	Individual – SW[2]
	Prince Frederick	General
6	Hagerstown	General
	Hancock	General

District	Maintenance Facility	Permit Type
	Keyser's Ridge	Individual – GW
	La Vale	General
	Oakland	General
	Dayton	Individual - SW[2]
7	Frederick	General
	Thurmont[1]	General
	Westminster	General
	Brooklandville Complex[3]	General
Offices/ Other Facilities	Hanover Auto Shop	Individual - SW[3]
Notes: SW = Surface Water, GW = Groundwater 1 Phase II Facility (Satellite / Salt Storage Facility) 2 Currently collecting all wastewater for pump and treat in a storage tank - therefore generating no discharge 3 Vehicle wash discharge connected to sanitary sewer in 2009, SW provisions of individual permit remain in effect		

The SHA ECD also continues to encourage maintenance facilities to present funding requests for stormwater related improvements such as erosion stabilization, material storage improvements, and spill prevention / containment devices.

E.4.e Statewide Shop Improvement Plans

As described above, SHA continues to maintain an effective Industrial Stormwater NPDES Program through ECD to ensure pollution prevention and permit requirements are being met at SHA maintenance facilities. SHA annually updates 85 combined Storm Water Pollution Prevention Plans (SWPPP)/SPCC Plans. As a continuing best management practice SHA has developed SWPPPs for facilities not required to have one (e.g. salt storage facilities). Throughout 2011, SHA continued to address potential stormwater pollution issues by implementing Best Management Practices (BMPs) and designing/constructing capital improvements. BMPs were identified during pollution prevention plan updates and routine inspections facilities. The status of BMP implementation for maintenance facilities is tracked by each District Environmental Coordinator during routine inspections. Potential capital improvements are prioritized based on risk to human health and the environment and funding availability. The following list details the major pollution prevention efforts and maintenance facility improvements since the last annual report.

Completed Projects:

- Annual review and update of SPCCP/SWPPP at 94 SHA facilities
- Petroleum storage tank system upgrades were completed at 36 maintenance facilities
- Upgrade to structures used for inlet cleaning waste dewatering at Glen Burnie and Owings Mills Shops to cover and connect discharge to sanitary sewer system (see photo below)
- Outfall stabilization project at Prince Frederick maintenance facility.
- Grit Chamber assessment and upgrade design at Prince Frederick

Ongoing Projects:

- Statewide oil-water separator maintenance program
- Statewide discharge sampling and reporting program for facilities with Individual Discharge Permits
- Routine compliance inspections at all Phase I facilities (primary maintenance) and Phase II facilities (satellite and salt storage)
- Annual multimedia compliance training provided to maintenance shop personnel

Figure 1-10 Upgrade to Structure used for Inlet Cleaning Waste Dewatering

Figure 1-11 Stormwater Outfall Improvements at SHA Maintenance Shop

Figure 1-12 Installation of Earthen Berm around Soil Stockpile

Table 1-9 shows the SHA capital expenditures towards industrial pollution prevention BMPs from the current and past six fiscal years. Projected expenditures for 2012 are also included.

Table 1-9 Capital Expenditures for Pollution Prevention BMPs

Fiscal Year	Expenditure
2005	$ 613,210 - actual
2006	$ 592,873 - actual
2007	$ 450,608 - actual
2008	$ 590,704 - actual
2009	$ 478,889 – actual
2010	$ 613,766 - actual
2011	$ 595,984 - actual
2012	$ 664,577 - actual
2013	$ 500,000 - projected

E.5 Illicit Discharge Detection and Elimination

Requirements under this condition include:

a) *Conduct visual inspections of stormwater outfalls as part of its source identification and BMP inspection protocols*

b) *Document each outfall's structural, environmental and functional attributes;*

c) *Investigate outfalls suspected of having illicit connections by using storm drain maps, chemical screening, dye testing, and other viable means;*

d) *Use appropriate enforcement procedures for eliminating illicit connections or refer violators to MDE for enforcement and permitting.*

e) *Coordinate with surrounding jurisdictions when illicit connections originate from beyond SHA's rights-of-way; and*

f) *Annually report illicit discharge detection and elimination activities as specified in Part IV of* *this permit. Annual reports shall include any requests and accompanying justifications for proposed modifications to the detection and elimination program.*

E.5.a Visual Inspections of Outfalls

The SHA Storm Drain and Outfall Inspection and Remediation Program (SOIRP) has seen an expansion over the past year from the original focus on the physical conditions and structural functionality of NPDES defined major outfalls which were documented using Chapter 4 of the *SHA NPDES Standard Procedures*, to performing comprehensive inspections of all SHA pipe outfalls. This expansion was initiated in an effort to locate and eliminate significant sources of pollution within the SHA highway drainage systems as well as address issues with degraded drainage infrastructure. In addition to assessing the current structural condition of the pipe and outfall structure, the inspections also identify eroded downstream channels that are contributing to the pollution of Maryland's waterways and the Bay, with the intent to restore these sites to reduce the pollutant loads.

The new outfall channel assessment criteria are being incorporated into the SOIRP through an new protocol and revisions to the SHA NPDES geodatabase structure. A new assessment protocol has been developed as Chapter 8, Rapid Assessment Guidelines for Outfall Channels: Outfall Condition and Restoration Potential, of the *SHA NPDES Standard Procedures* and was tested through a pilot program for several roadway corridors. It has since been deployed as part of the SHA routine inventory and inspections conducted in compliance with permit source identification requirements. This protocol describes the standard data collection and documentation required for performing outfall channel assessments and is used in conjunction with Chapter 4 by targeting outfalls with poor ratings for further assessment for remediation. The record management system is currently under development with the intent to include the collected data within the structure of the SHA NPDES Geodatabase.

The outfall channel inspections have been initiated along seven road corridors within the following NPDES Phase 1 Permit counties:

Anne Arundel County

- MD 2
- MD 4
- I-97 and
- MD 32

Baltimore County

- I-83

Prince Georges County

- MD 210 and
- US 301

As a result of these investigations, several outfall stabilization projects have been initiated as listed in the Table 1-10

Table 1-10 Current Outfall Stabilization Projects

Project Number	Road	County	Location Description	No. of outfalls	Project Status
AA757	MD 2	AA	Between I-695 and US 50	5	Under design
MO637	US 29	MO	At SWM Facility 150173	1	Under design
PG092	MD 216	PG	NB at Patuxet River Bridge	1	Under Design
HO408	MD 100	HO	Behind noisewall between MD 104 and Long Gate Parkway	1	Construction completed 2012
BA712	I-695	BA	Minebank Run at Cromwell Bridge Road	5	Under Design

Project Number	Road	County	Location Description	No. of outfalls	Project Status
BA487	I-83	BA	Gunpowder Falls	2	Construction completed 2012
BA487	MD 147 I-695	BA	Various locations (Phase 2)	4	Under Construction
AW730	I-83	BA	Near Cold Bottom Road	4	Design initiated
PG554	MD 4	PG	At MP 2.6	1	Construction completed 2012
PG712	I-495	PG	400 ft N of Ramp 2 MD 450 WB to I 95 NB	1	Under Design
CH374	US 301	CH	From MD 6 to Glen Albin Road	2	Emergency repair completed 2012
BA144	I-795	BA	Near Red Run Buleward	2	Construction completed 2012
HA365	US 1	HA	Conowingo Road Slope and Outfall Stabilization	1	Construction completed 2012
AA	I-97	AA	North of Benfield Blvd	1	Field Investigation
BA487	Various	BA	5 sites within BA County	5	Under Construction
AW730	MD 202	PG	Near Campus Way	1	Completed
AW 730	Various	PG	Various locations	9	Under design

SHA continues to undertake projects related to outfall stabilization and enhancement. The goal of these projects is to protect the receiving streams and improve the water quality within the watershed. As well as extend the service life of roadway infrastructure.

MD 4 Northbound Outfall Improvement

SHA advertised a contract to stabilize a severely eroded outfall along MD 4 NB in Prince Georges County. The erosion impacted Waters of the US and exposed an underground utility line. The scope of repair included new storm drain construction and scour hole installation. In-ground repair of a corroded 54" CMP under MD 4 was also included. Construction was completed in December 2011. See Figure 1-13 and 1-14for pre- and post-construction photos.

I-795 Southbound: Outfall Repair and Enhancement

SHA advertised a contract to stabilize 2 eroded outfalls that resulted from pipe collapses on I-795 SB. The scope of work included new storm drain construction, E&S controls and outfall stabilization. The southernmost site involved erosion that impacted a timber noisewall. This site also contained wetlands and required permitting through MDE. Construction was completed in April 2012. See Figure 1-15 and 1-16 for pre- and post-construction photos.

US 301 Southbound: Outfall Repair and Enhancement

SHA completed stabilization of 2 severely eroded outfalls caused by pipe collapses on US 301 SB in LaPlata, MD (Charles County). The scope of work included lining the existing culverts, extending the culverts with new storm drain, E&S controls and outfall stabilization. Both sites impacted roadway shoulders and underground utilities. Both sites also contained wetlands and required permitting through MDE. The southernmost site required the use of soil nailing along the slope to ensure stability. Construction was completed in November 2011. See Figure 1-17 and 1-18 for pre- and post-construction photos.

US 1 Southbound Slope Stabilization

SHA advertised a contract to stabilize an eroded slope and replace undermined concrete ditches along US 1 SB in Harford County, about 0.5 miles south of the Conowingo Dam. The Susquehanna River is downstream of the box culvert. The scope of the repair includes new storm drain and riprap construction. Construction was completed in September 2012. See Figure 1-19 and 1-20 for pre- and post-construction photos.

Figure 1-13 Inspected Outfall along MD 4, Pre-Construction

Figure 1-14 Stabilized Outfall along MD 4, Post-Construction

Figure 1-15 Inspected Outfalls along I-795 SB, Pre-Construction. Photo on left is site with existing timber noise barrier.

Figure 1-16 Stabilized Outfalls along I-795 SB, Post-Construction. Photo on left is site with existing timber noise barrier.

Figure 1-17 Eroded Outfalls along US 301 SB, Pre-Construction. Photo on left is southernmost site, with exposed fiber optic line.

Figure 1-18 Stabilized Outfalls along US 301 SB, Post-Construction

Figure 1-19 Undermined Channel and Washout along US 1 SB, Pre-Construction

Figure 1-20 Stabilized slope and Channel along US 1 SB, Post-construction

E.5.b Document each Outfall's Attributes

SOIRP outfall inspections are currently being conducted on outfalls in Frederick, Harford and Montgomery counties. Inspections are conducted using the SHA SOIRP Program outfall inspection protocol, Chapter 4, of the *SHA NPDES Standard.* As discussed above, based on the inspection ratings developed from the Chapter 4 protocol, those with the poorest ratings are assessed for repair or remediation using the newly developed outfall assessment protocol, now Chapter 8 of the SHA standard procedures. Details of each protocol and current work for the report period are discussed below.

SOIRP Pipe and Outfall Inspections (Chapter 4)

The first step in the newly expanded SOIRP process is to perform a visual evaluation of pipe and outfall conditions when pipes connect to headwalls or endwalls, and when pipes terminate at their own outfall locations, such as end sections, projecting pipes, or in some cases, connect directly to culverts. Pipes are rated on a scale of 0 to 5 to identify the overall condition of the pipe and outfall.

The inspection results are based on issues visually identified by the inspection crew. Often it is difficult to evaluate an entire pipe length, so the inspection is based only on what the inspection crew can visually identify. If the upstream end of the pipe is in worse condition than the downstream end, the inspection team assigns the worst rating (5). Photographs are taken for ratings of 3, 4, or 5 which are poor ratings and as deemed necessary. These pipes and outfalls are then subjected to a second assessment (based on Chapter 8 discussed below) to determine the form and level of remediation necessary.

The collage image in Figure 1-21 illustrates examples of the rating system values.

Figure 1-21 Illustrative Examples of Pipe Ratings

New Outfall Channel Rapid Assessment Guidelines (Chapter 8)

The newly created protocol for assessing outfalls is Chapter 8, Rapid Assessment Guidelines for Outfall Channels: Outfall Condition and Restoration Potential, and is included in this report as Appendix F. Use of this protocol is the second step in the SOIRP process and assesses each targeted outfall that was rated 3-5 in step one for remediation potential and urgency. These outfalls may be contributing to channel erosion, thus resulting in sediment transport to downstream receiving channels. SHA has identified two overall goals for these second level assessments. The first goal is for data collection and repair recommendations to augment our efforts in maintaining SHA infrastructure that will include GPS-locating of outfall channels downstream from SHA outfall structures, and completing standard inspection forms to be linked with the spatial outfall features. The GPS and form data will be compiled into an outfall assessment geodatabase that is compatible for future migration into the SHA geodatabase inventory. This data will be used to prioritize the repair of SHA-owned infrastructure.

The second goal is to obtain TMDL credits for repaired outfalls by preventing future erosion and the transportation of sediment loads to downstream receiving channels. Using established and acceptable methods approved by MDE, SHA intends to apply the assessment and evaluation protocol state-wide to prioritize unstable outfalls for repair. Those outfalls with the highest potential for future channel and bank erosion will likely be repaired first in order to prevent this erosion and the transport of sediment downstream. Thus the repairs are intended to prevent future channel erosion and will promote reductions in nitrogen, phosphorus and suspended solids to the receiving waterways. SHA intends to apply for a credit for these reductions in order to meet TMDL goals.

Development of Map Structural and Conveyance Asset Evaluation

Outfall inventory, ratings and remediation assessment data collected as part of this permit condition is being utilized by SHA to publish to our eGIS site. The intent is to allow users to view existing conditions of SHA stormdrain structures statewide including inlets, culverts, manholes and outfall structures that includes these operational ratings and assessments for remediation. Users may also generate maps based on the assessment ratings when developing project scopes leading to improved planning for repair activities.

The image in Figure 1-22 illustrates a map which can be used to help identify areas of need and the type of activities needed.

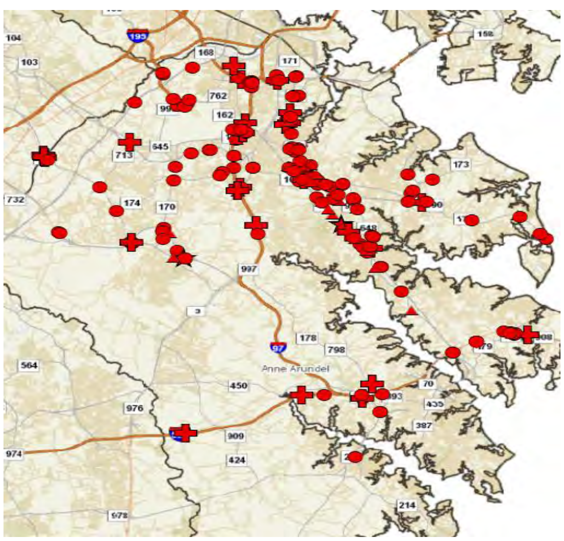

Figure 1-22 Map Created using eGIS Outfall and Conveyance Rating and Evaluation Capability

Immediate Response

In the event of an emergency failure in stormdrain infrastructure, SHA immediately performs work to ensure public safety. SHA also responds to any outfall or SWM facility that requires immediate repair and remediation. Roadways are closed as necessary and detour routes are implemented as needed. Site assessment and investigation occurs at the subject location within hours by a multi-disciplinary team and on-call contractors are mobilized and plans for repairs are initiated within 24-hours.

E.5.c Illicit Connection Investigations

Illicit discharge screenings were completed in Anne Arundel and Baltimore counties. As illicit discharges are found we send the inspection reports to local NPDES coordinators for elimination. Over the past annual reporting period, October 2011 through September 2012, SHA has focused primarily on following up on existing illicit discharges and connections that have been reported in previous annual reports, as well as illicit discharges that were discovered during this reporting period. A consultant team was contracted to visit over forty existing and recently reported illicit discharges and to determine if the connection was properly eliminated by conducting visual inspections and sampling for pollutants. It was determined that out of the 41 reported illicit discharges, 14 will require addition jurisdictional follow-up to eliminate the connections, see the tables below. In addition, the consultant team also performs on-call inspections of illicit discharges that are reported directly to SHA via employees out in the field or the public. SHA continues to remain committed to detecting and eliminating illicit discharges throughout our system.

E.5.d Use Appropriate Enforcement Procedures

Currently, SHA notifies the NPDES coordinator or their IDDE designated contact at the counties or jurisdictions in which the illicit discharges or connections to SHA storm drain system are discovered. In order to achieve better disconnection results and to provide an educational component to the public, SHA is implementing a process to notify adjacent property owners of potential illicit discharges to the SHA MS4 from their property at the same time the jurisdiction NPDES contact is notified. Educational materials on non-stormwater discharges and MS4 permits will be included with the notification.

E.5.f Annual Report Illicit Discharge Detection and Elimination Activities

Over the reporting period from, October 2011 to September 2012, outfalls were screened in two Phase I counties for illicit discharges: Anne Arundel and Baltimore. The geodatabase containing this data is included on the attached CD. Table 1-12 below shows information for the fourteen illicit discharges requiring jurisdictional follow-up. SHA will continue to coordinate with surrounding jurisdictions to get these illicit discharges eliminated.

Table 1-11 Illicit Discharges Investigated from February 2001 to Date

County	Illicit Discharges Investigated	Illicit Discharges requiring Jurisdictional follow-up	Delivered to Jurisdiction	Date Delivered
Anne Arundel	5	3	County NPDES Coordinator	Pending[1]
Baltimore	1	0	-	-
Carroll	7	2	County NPDES Coordinator	Pending[1]
Cecil	7	2	County NPDES Coordinator	Pending[1]
Frederick	16	4	County NPDES Coordinator	Pending[1]
Howard	2	0	-	-
Montgomery	3	3	County NPDES Coordinator	Pending[1]
Totals	**41**	**14**		

[1]SHA is currently in the process of updating our IDDE Notification Protocol and will deliver investigation reports to the appropriate jurisdiction after the process revisions are completed.

Table 1-12 Illicit Discharges Requiring Jurisdictional Follow-up

Number	County	SHA-Structure #	IDDE-Field Inspection Date	Pollutant
1	Anne Arundel	0202689.001	08-16-2012	Copper
2	Anne Arundel	0201478.001	08-17-2012	Ammonia
3	Anne Arundel	0290516.001	08-17-2012	Ammonia and Detergents
4	Carroll	0600412.002	08-31-2012	Sewage
5	Carroll	0600413.004	08-31-2012	Undetermined
6	Cecil	0710170.001	04-17-2012	Copper
7	Cecil	0710169.001	04-12-2012	Copper
8	Frederick	1001515.003	08-31-2012	Sewage

Number	County	SHA-Structure #	IDDE-Field Inspection Date	Pollutant
9	Frederick	1000783.002	08-24-2012	Sewage
10	Frederick	1020959.003	08-24-2012	Laundry Wastewater
11	Frederick	1000146.003	08-24-2012	Sewage
12	Montgomery	1501376.001	04-21-2004	Detergents
13	Montgomery	1500716.001	06-30-2004	Chlorine
14	Montgomery	1500848.001	06-29-2004	Detergents

E.6 Environmental Stewardship

Requirements under this condition include:

a) *Environmental Stewardship by Motorists*
   i) *Provide stream, river, lake, and estuary name signs and environmental stewardship messages where appropriate and safe,*
   ii) *Create opportunities for volunteer roadside litter control and native tree plantings; and*
   iii) *Promote combined vehicle trips, ozone alerts, fueling after dark, mass transit and other pollution reduction actions for motorist participation.*

b) *Environmental Stewardship by Employees*
   i) *Provide classes regarding stormwater management and erosion and sediment control;*
   ii) *Participate in field trips that demonstrate links between highway runoff and stream, river, and Chesapeake Bay health;*
   iii) *Provide an environmental awareness training module for all areas of SHA;*
   iv) *Provide pollution prevention training for vehicle maintenance shop personnel;*
   v) *Ensure Integrated Pest Management instruction and certification by the Maryland Department of Agriculture for personnel responsible for roadside vegetation maintenance; and*
   vi) *Promote pollution prevention by SHA employees by encouraging combined vehicle trips, carpooling, mass transit, and compressed work weeks.*

E.6.a Environmental Stewardship by Motorists

SHA continues many initiatives that encourage or target public involvement and participation in water quality programs. These initiatives cover the areas of litter control, watershed partnerships, community planting efforts and public education.

SHA public involvement and participation initiatives for the past year include:

Annual Earth Day Celebration –To commemorate this year's Annual Earth Day celebration, The SHA Earth Day Team sponsored a series of Lunch and Learn Sessions and activities to promote environmental awareness and stewardship. The lunch and learn sessions were held at SHA Headquarters from April 17-26, 2012. The topics ranged from starting home gardens to creating green-sector jobs. Earth Day participants were able to participate in a service project and lend a hand in giving SHA Headquarters building a landscaping make-over.

Figure1-23 Participants in Earth Day Celebration Service Project

Below is a list of the lunch and learn sessions:

- April 17 – Maintain a Healthy Landscape: A Primer on the Tools and Techniques. Learn tool handling safety, pruning techniques, irrigation systems, plant nutrient requirements and other maintenance practices for grass, perennials and woody plants.

- April 18 - Service Project: Beautification of SHA Headquarters Complex.

- April 19 – Save Energy/ Save Money: A Whole-House Approach. Retrofit Baltimore, a project of the non-profit Civic Works, taught how to reduce energy costs 20-40% while creating local green-sector jobs and minimizing environmental impact. Topics included: the building science of a home, the step-by-step retrofit process, 2012 incentives available, and benefits to the homeowner, community, and world.

- April 24 - Introduction to Vegetable Gardening: Six Easy Steps. Baltimore County Master Gardeners walked participants through the process of selecting a garden site, preparing the soil, and planting and caring for the easiest and most popular vegetables. There were many additional information handouts and other resources for gardening questions.

- April 25- Service Project: Beautification of SHA Headquarters Complex.

- April 26 – Bayscaping. Taught homeowners what to consider when choosing plants, hardscape materials, and overall site design for residential property to enhance the Chesapeake Bay whether planting a single tree, renovating an existing landscape, or starting with a new home. Explored how using the right plant in the right place can benefit the environment and the Bay.

Adopt-a-Highway Program

This program encourages volunteer groups (family, business, school or civic organizations) to pick up litter along one to three mile stretches of non-interstate roadways four times a year for a two year period as a community service. Table 1-13 identifies the participation for the AAH program over the reporting period.

Table 1-13 Adopt-a-Highway Program

County	Groups	No. Bags	Miles Adopted
Anne Arundel	32	133	40.48
Baltimore	100	653	109.87
Carroll	37	314	59.76
Charles	8	126	11.45
Frederick	36	204	35.25
Harford	73	91	129.94
Howard	22	528	26.89
Montgomery	37	187	40.68
Prince George's	21	216	24.57
Totals	366	2452	478.89
Data extracted from the Adopt-A-Highway database for the period 10/01/2011 to 09/30/2012			

Sponsor-a-Highway Program

SHA also has a program that allows corporate sponsors to sponsor one-mile sections of

Maryland roadways. Table 1-14 shows the miles currently being sponsored. The Sponsor enters into an agreement with a maintenance provider for litter and debris removal from the sponsored highway segment.

Table 1-14 Sponsor-a-Highway Programs

County	Available Miles	Miles Sponsored
Anne Arundel	56.92	72.82
Baltimore	27.21	78.72
Carroll	0	0
Charles	22.30	1
Frederick	11.41	12.19
Harford	5.81	3.61
Howard	18.79	29.45
Montgomery	9.22	35.39
Prince George's	58.62	53.07
Totals	210.28	286.25

Partnership Planting Program

SHA develops partnerships with local governments, community organizations and garden clubs for the purpose of beautifying highways and improving the environment. Community gateway plantings, reforestation plantings, streetscapes and highway beautification plantings are examples of the types of projects that have been completed within the Partnership Planting Program. Table 1-15 lists the number of plants, counties or participation and numbers of volunteers for the last reporting period.

Table 1-15 Partnership Planting Program

County	No. Trees/Shrubs	No. Volunteers
Anne Arundel		
Baltimore		
Carroll	2000 Bulbs	16
Charles		
Frederick	2000 Bulbs	14
Harford		
Howard	60 Trees /2000Bulbs	24
Montgomery		
Prince Georges		

Figure 1-24 Recent Partnership Planting at US 29 at MD 216 with Glenelg Country School

Transportation Enhancement Program

SHA Administers the Federal Highway Transportation Enhancement Program (TEP) for the State of Maryland. In this capacity, SHA looks for opportunities to share the potential benefits of applying for funding under this program with projects that fall under the eligible funding categories.

For potential projects that fall under the funding category 'Mitigation of Water Pollution due to Highway Runoff', SHA Office of Highway Development and Office of Environmental Design take the initiative with watershed groups, local municipalities, community groups and counties to encourage their participation in this program. SHA provides assistance to potential project sponsors by advising on proposal content, reviewing drafts and then providing guidance on Federal Aid requirements for construction document preparation and advertisement.

Maryland Quality Initiative (MdQI) 2012 Conference: 'Quality Transportation – A Hybrid Approach'

The mission of MdQI is to provide the Maryland highway industry a forum that fosters coordinated and continuous quality improvement in order to ensure safe, efficient, and environmentally sensitive highways which meet the needs of all transportation stakeholders. This industry conference is held annually each winter and brings together public and private highway design and construction industry professionals in a forum of workshops, round table discussions, exhibits and networking. This year's conference was held February 1-2 at the Sheraton Baltimore City Center Hotel and approximately 667 engineers, consultants and contractors attended the conference which included both public and private industry. The website is 'mdqi.org'.

Two sessions focused on stormwater runoff and surface water quality including 'TMDLs are Here to Stay: What it Means for Operations, Design & Planning' and 'DBOM – Innovative Stormwater Asset Contracting'. Descriptions from the conference website for these two are included below. See Tables 1-16 and 1-17 for a list of all sessions.

<u>TMDLs Are Here to Stay: What it Means for Operations, Design & Planning:</u> Total Maximum Daily Loads (TMDL) have become a focus area in recent years with the Chesapeake Bay restoration and more importantly water quality in general. The implementation of TMDL for the Bay restoration is expected to occur on an accelerated rate and will draw attention to local, small, and large water bodies. This Panel will discuss broad aspects of regulatory drivers, requirements, the financial outlook, and implementation strategies. The Panel will also discuss some more tangible aspects of project design, construction and maintenance. This session is designed for contractors and engineers to listen and discuss topics involving the projects and implementation for TMDL compliance.

<u>DBOM - Innovative Stormwater Asset Contracting:</u> Design, Build, Operate, and Maintain (DBOM) contracting is an innovative procurement method used by the Maryland State Highway Administration (SHA). This contracting method is being used to remediate and perform routine maintenance of SHA's stormwater management facility assets and drainage inventory. SHA has used this method in Charles County and is investigating opportunities to utilize this cost effective method in the future. This session is designed for contractors and engineers to listen and discuss topics involving the technical preparation, procurement, management, and plans for this integrated project delivery process.

Table 1-16 MdQI Conference - Day One Technical Sessions (February 1, 2012)

	Carroll Room	International E Room	Pratt Room	Poe Room	Mencken Room
1:30 p.m. - 2:45 p.m.	Common Contractor Rework Issues - can they be mitigated through design?	Concrete Materials & Recent Technology for Paving in Maryland	Prime/DBE/ MBE Construction Business Opportuni-ties: Building a Successful Relationship	BWI Rail Station and Track Improve-ments	Reviewing Existing Utility Coordination Process
3:15 p.m. -	New	TMDLs Are	Goal Setting	Safety	Follow-up

	Carroll Room	International E Room	Pratt Room	Poe Room	Mencken Room
4:30 p.m.	Technolo-gies: Stakeless Construction and Intelligent Compaction	Here to Stay : What it means for Operations, Design & Planning	For Success	Certification with MTA	round Table Discussion on Utility Coordination Process

Table 1-17 MdQI Conference - Day Two Technical Sessions (February 2, 2012)

	Carroll Room	International E Room	Pratt Room	Poe Room	Mencken Room
10:45 a.m. - 12:00 p.m.	FHWA Everyday Counts – Accelerating Technology: ASC & Safety Edge	Purple Line/Red Line Update	Incentive / Disincentives – Do They Work?	Meetings… who needs them? You do!	Intersection Design Techniques/ MD CATT Lab Discussion
	Carroll Room	Hopkins Room	Pratt Room	Poe Room	Mencken Room
2:00 p.m. - 3:15 p.m.	Warm Mix Asphalt	Pedaling & Peds - Improving Safety and Awareness Along Our Roadways	New envision Sustainability Rating System for Infrastructure Projects	Terminal Concourse B /C Connector Project	FHWA Efforts to Improve Safety/Mobili-ty in Work Zones/Inno-vative Work Zone Safety Operations
	Carroll Room	Hopkins Room	Pratt Room	Poe Room	Mencken Room
3:45 p.m. - 5:00 p.m.	Prefabricated Bridge Elements and Systems for Accelerated Bridge Construction	DBOM - Innovative Stormwater Asset Contracting	Design /Build Risk Minimization	MDTA Facility Inspection Program– An Inside Look	New Noise Policy

E.6.b Environmental Stewardship by Employees

SHA continues to provide environmental awareness training to its personnel and is committed to continuing these efforts in the future. We have provided updated data for these efforts through the following training and awareness programs listed below:

SHA Recycles Campaign

In support of the SHA Business Plan, the Environmental Compliance and Stewardship Key Performance Area launched the SHA Recycles Campaign on April 22, 2008 to raise awareness and encourage change in consumer culture throughout the organization. The goal of this campaign is to reduce waste and litter by making conservation a priority, reusing what we previously discarded, and recycling as much as possible.

The SHA Recycles Campaign is working to build a consortium of stakeholders across the entire SHA organization towards this collective goal. The campaign encourages all employees to give feedback on what can be done to save energy and fuel, reduce or eliminate waste, improve current recycling efforts, or change business practices to conserve resources. It provides education and outreach through displays and presentations at SHA events such as the Annual Earth Day Celebration, and office-wide training and recognition days.

A State-wide Recycling Task Force has also been formed at SHA to examine key issues in recycling and identify ways to improve the SHA Statewide Recycling Program.

Million Tree Initiative

In the fall of 2008, the Maryland State Highway Administration (SHA), the Maryland Department of Natural Resources (MDNR), Federal Highway Administration (FHWA), and the Maryland Department of Safety and Correctional Services (DPSCS) formed a partnership to plant trees along Maryland roadsides and in State right-of-way. The tree-planting program directly supports Governor Martin O'Malley's *Smart, Green and Growing* initiative. SHA is funding the trees and materials; MDNR is funding the labor, which is provided by inmates from DPSCS. On May 4, 2011, Governor O'Malley planted the One Millionth Tree with Inmates.

Environmental Awareness Training (Chesapeake Bay Field Trips)

This training is provided to all new employees. This field trip demonstrates the link between highway runoff and its impacts on streams, rivers and on the health of the Chesapeake Bay. There are two trips scheduled for October 2012, and two trips anticipated for the spring of 2013. Two trips were held during this reporting period on October 5 and 6, 2011, and 50 participants attended.

Graduate Engineers Training Program (GETP)

SHA continues to provide environmental awareness training to its personnel and is committed to continuing these efforts in the future. The three-year GETP provides training to roughly 100 new engineers and includes modules concerning the National Environmental Policy Act (NEPA) and Introduction to the Office of Environmental Design. GETP hosted 18 modules for GETP classes of 2012, 2013 and 2014 where to total of 393 people were trained during the reporting period.

Office of Highway Development (OHD) University

This is an annual, internal training program for the Office of Highway Development that provides technical training for new engineers and others who desire to take refresher courses. In addition to highway engineering and technical issues, detailed information is presented for SWM, ESC and environmental permitting issues, including NPDES concerns. The number of people attending these environmental training sessions during the reporting period was 21.

Statewide Pesticide/Vegetation Manage-ment Training

There are several types of internal training sessions for pesticide management that SHA provides annually. They include registration, re-certification, right-of-way pre-certification preparation, aquatic pre-certification preparation, and herbicide updates. The number of participants at each of these training sessions is listed in Tables 1-18 to 1-21. There was no Aquatic Pesticide Certification Preparation (ENV220) training held in 2012.

Table 1-18 Pesticide Applicator Registration (ENV100)

SHA District	Number Trained
3 (MO, PG)	0
4 (BA. HA)	0
5 (AA, CH)	40
7(CL ,FR, HO)	0
Totals	40

Table 1-19 Pesticide Recertification & Herbicide Update (ENV200)

SHA District	Number Trained
3 (MO, PG)	09
4 (BA. HA)	10
5 (AA, CH)	05
7(CL, FR, HO)	13
Totals	31

Table 1-20 Pesticide Core and Right-of-Way Certification Preparation Class (ENV210)

SHA District	Number Trained
3 (MO, PG)	4
4 (BA. HA)	0
5 (AA, CH)	0
7(CL, FR, HO)	5
Totals	9

Table 1-21 New Aquatic Pesticide Certification

SHA District	Number Trained
3 (MO, PG)	0
4 (BA. HA)	1
5 (AA, CH)	0
7(CL, FR, HO)	0
Totals	1

Maryland Department of Transportation (MDOT) Water Quality Policies and Water Quality Clearing House Web Page

This is a continuing effort that provides information on department-wide water quality policies and other regulations applicable to transportation projects. This webpage is periodically updated with regulatory/policy changes and can be accessed at www.mdot.state.md.us and clicking on the 'Office of Environmental Programs' link on the left-hand panel. The tabs at the top of the page lead to information on state and environmental regulations for transportation facility operations such as storage tanks and spill prevention and response; environmental resources such as Smart, Green & Growing, MDE, MDNR and EPA; MDOT environmental resources such as environmental stewardship in the 2009 MD Transportation Plan and the 2010 Annual Attainment Report on Transportation System Performance; and an information brochure for the MDOT Office of Environment.

SHA Environment and Community Web Page

SHA has developed an environmental awareness web page that is located on the SHA internet site (www.marylandroads.com). A recent addition to this webpage is a page called 'Cleaner, Greener Practices and Initiatives', see Figure 1-25. The webpage includes the following topics:

Innovation and Design

- LEED
- Signal Systemization
- HOV
- Geographic Information System & Environmental Inventory Tool

Initiatives

- Wind Turbine
- Diesel and Biodiesel Fuels
- Recycling
- Litter Education.

Maintenance

- Winter Operations
- Mowing Reduction
- Idling Policy
- Vehicle and Equipment Fleet
- Road Sweeping & Ditch/Culvert Cleanings
- Litter Removal

Descriptions from select links are included below.

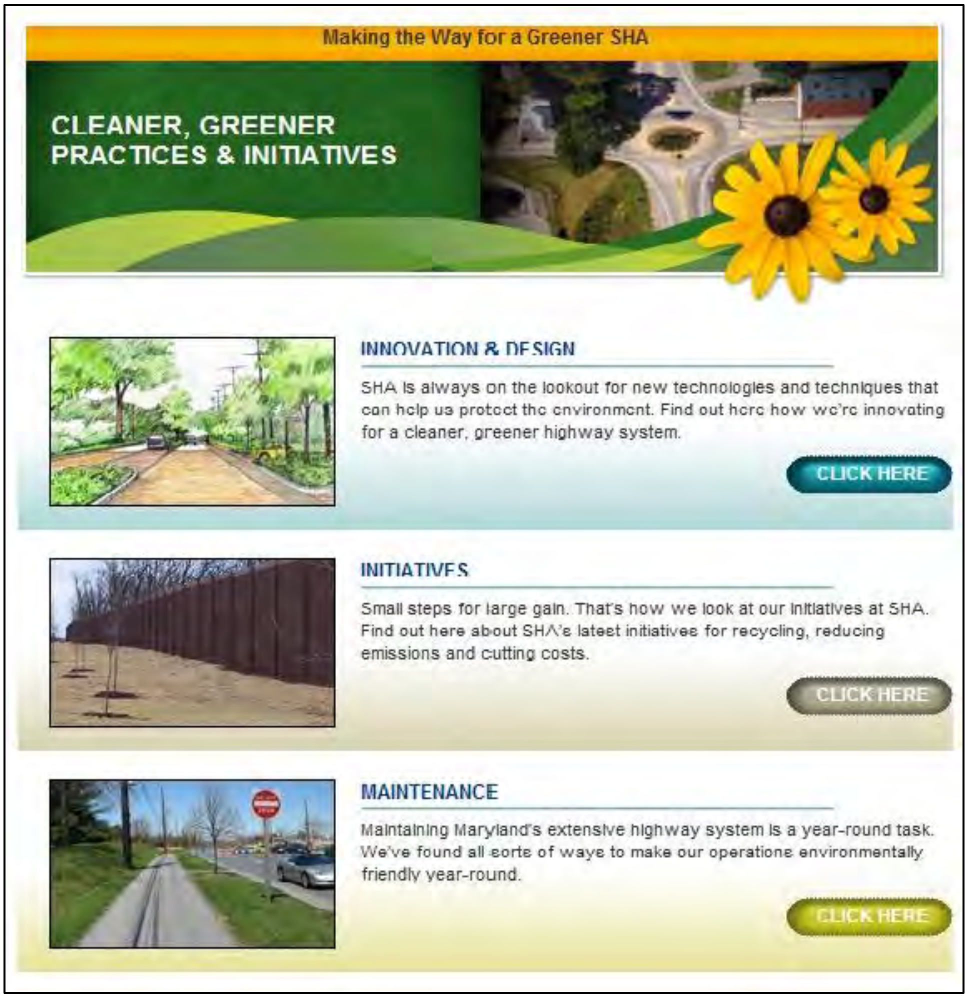

Figure 1-25 - SHA Internet 'Cleaner, Greener Practices & Initiatives' Web Page

Litter Education Link: "As an additional public service, SHA offers support for litter awareness events at schools and civic events. The program can provide materials such as coloring books, brochures, speakers and visits from our Litter Critter characters. Contact information is provided."

Bio-Diesel Fuels Link: "SHA is acting now to reduce the environmental impact of diesel fuel usage. Our first step was to find ways to reduce our overall diesel usage through policies such as our engine idling policy. We also replaced many diesel vehicles with flex-fuel vehicles (which can use more than one type of fuel) and replaced antiquated equipment with newer fuel-efficient equipment. In some cases, we were able to reduce our inventory of equipment.

One of our major changes was to introduce bio-diesel fuels into our supply. Currently, SHA uses a 5% bio-diesel blended fuel (also known as B5) where conventional diesel is blended with a biodegradable, renewable fuel derived from soy beans. Bio-diesel reduces our use of non-renewable fossil fuels and it significantly reduces the amounts of particulates, carbon monoxide and unburned hydrocarbons released into the atmosphere. The B5 blend is also "ultra-low-sulfur." Reducing sulfuric acid emissions into the environment greatly reduces the formation of harmful acid rain and the amount of dry acidic deposits that can accumulate in places such as the ground, buildings, homes or trees.

Finally, all of SHA's pre-2004 dump trucks have been brought up to 2004 emissions standards via Diesel Catalyst Retrofit Technology. This technology reduces emissions by converting harmful diesel exhaust pollutants to carbon dioxide and water via a catalyst. This technology reduces unburned hydrocarbons and carbon monoxide by 90%. Particulate matter (PM) reductions vary from 20-50%. To put it simply, these retrofits turn harmful compounds normally found in our diesel exhaust to safe components."

Recycling Link: "Reusing and recycling is one of the many steps we take to help provide future generations with a cleaner, safer environment. We realize the importance of environmental cleanliness and conservation, and have established several recycling practices to reduce our carbon footprint and protect climate change. (Carbon footprint is the amount of greenhouse gas emissions generated by a person, business, or other type or organization.)

One of our practices is supporting the goals of Maryland's Smart, Green and Growing initiative and using effective recycling programs throughout the community. We remain committed to recycling no less than fifty percent of solid waste each year. For example, we reuse asphalt when possible on our projects, and recycle materials from construction projects.

SHA formed a task force in 2009 to help identify ways to improve our statewide recycling program. Our task force, known to many as a network of "recycling champions", includes members from the University of Maryland, the Maryland Department of the Environment, and the Environmental Protection Agency.

Working with the local construction industry is another important step we take as part of our recycling practices. This partnership helps to generate ideas on environmentally safe ways of recycling pavement for future highway projects. For example, we have worked with a local contractor that produces 100 percent recycled crushed graded aggregate base. (This is a product typically applied to roadways prior to paving.) Over 13,000 tons of natural aggregate have been saved though this program.

In addition to reusing and recycling pavement materials, we are also focusing on reducing emissions and waste from our machinery and equipment. By reducing emissions and waste, we lessen the overall output of substances into the air that could lead to climate change. We are moving forward with using a five percent blend of bio-diesel fuel in equipment as well as recovering and recycling motor oil, filters, and batteries to meet our goals of saving the environment, one step at a time.

We continue to partner with our fellow state agencies, the construction community, and others to successfully implement our recycling practices and keep Maryland healthy and beautiful."

Litter Removal Link: "A critical aspect of year round highway maintenance is the removal of litter from shoulders and drainage systems. SHA uses a multi-pronged approach to litter control utilizing SHA employees, state workers, contractors as well as labor donated through the Sponsor-A-Highway program and partnerships with Adopt-A-Highway volunteers. SHA also continues its public outreach to educate the public about the hazards of littering and its impact on the environment.

The MD SHA has taken several steps to "green" our litter removal efforts. Instead of just picking up litter, we now provide our crews and volunteers with the means to separate recyclables from trash. All seven of our Districts are currently recycling roadway litter in a formal manner. As our recycling efforts increase, the volume of waste taken to landfills continues to decrease."

Employee Commuter Reduction Incentives

SHA offers several incentives to reduce the number of drivers and/or number of commuter days/miles per week by Administration employees. Fewer commuter days and miles mean less vehicle pollutants entering the watershed.

Alternate work schedules include flexible work hours allowing employees to work compressed workweeks reducing the total number of commuting days and miles.

Teleworking allows employees to work from a remote location (presumably at or close to home) and also reduces the number of commuting days and miles per week. Each office has or is developing a teleworking policy.

Car-pooling has been encouraged at SHA for many years and reduces the number of commuters on the road. SHA car-pooling incentives include prioritizing parking space allocation to those in a designated car pool and Administration assistance in locating a carpool within the employee's residential area through parking database.

Finally, employee ID badges allow state employees to acquire a free State Transit Employee Pass (STEP) that allows free access to MTA mass transit including the Baltimore area subway, light rail and buses. This encourages the use of mass transit by SHA employees who live within the Baltimore area.

SHA Vehicle and Equipment Idling Policy

On September 22, 2009, the former SHA Administrator issued a policy regarding reduction in idling of engines for state equipment and vehicles. The purpose is to reduce fuel consumption by state forces, and if adhered to, will result in pollutant load reduction as well.

F Watershed Assessment

The watershed assessment effort described by the permit includes continuing to provide available geographic information system (GIS) highway data to permitted NPDES municipalities and MDE; completing the impervious surface accounting by the fourth annual report; select sites for retrofitting impervious areas with poor or no control infrastructure; and working with NPDES municipalities to maximize water quality improvements in areas of local concern.

F.1 GIS Highway Data to NPDES Jurisdictions and MDE

SHA continues to make the SHA GIS storm drain and BMP data available to NPDES jurisdictions (when requested) and MDE.

We periodically coordinate with the MDE Science Services Administration on data issues for the Bay and local TMDL modeling.

F.2 Complete Impervious Accounting by Fourth Annual Report

SHA completed the impervious accounting requirement for the all Phase I counties, by the fourth annual report, October 2009.

The issue of treatment credit accounting for impervious surfaces treated by entities other than the jurisdiction that has ownership of the surfaces is still not resolved between MDE and the MS4 jurisdictions. SHA has currently taken credit only for SHA-owned surfaces and not included in the accounting any non-SHA impervious surfaces to date. Although it is anticipated that this additional treatment credit will be applied to SHA in the future, thus increasing treatment currently provided.

F.3 Impervious Area Retrofits

SHA continues to identify and develop sites that prove suitable for SWM facilities that provide water quality treatment of existing impervious areas within the SHA controlled R/W.

F.4 Maximize Water Quality Improvements in Areas of Local Concern

As part of this permit condition, MDE required that we not only implement restoration efforts, but that we adhere to the watershed restoration goals and priorities established by local NPDES jurisdictions. Past performance over this permit term concerning this condition was discussed in detail in the last four reports. They include the following activities.

Green Highways Partnership

The Green Highways Partnership (GHP) is an approach intended to provide sustainable transportation infrastructure through improved environmental compliance, protection, and preservation. Formally launched by the U.S. Environmental Protection Agency (EPA) in 2005, the GHP is a voluntary, public/private network that promotes collaboration in developing 'green' transportation solutions.

The GHP provides opportunities to develop and implement transportation plans and projects that not only enhance mobility, but also livability, environmental quality, and resonance between the human-made environment and the natural environment, i.e. sustainability. The three components of green transportation (stewardship, safety, and sustainability) can be met using the three key focus areas identified by the GHP: recycling and beneficial reuse of materials, conservation and ecosystem preservation, and watershed-based stormwater management (WBSM). SHA is involved in all three key focus areas.

Framework to Implement a Watershed-Based Approach for Managing Stormwater

As a key partner in the GHP, SHA was awarded a grant from the EPA to develop a framework to implement a WBSM for transportation projects. Together, the EPA and SHA have observed that conventional approaches to SWM focus solely on project point-discharges and facilities are designed to meet only the minimum regulatory requirements. The present minimum requirements do not require demonstrative watershed assessments or measureable improvements to overall watershed health; water quality function is assumed or calculated based on research models and runoff volume attenuation is calculated on hydrologic and hydraulic models. IN doing so, multiple environmental benefits may be achieved. Overall watershed impacts are rarely, if ever, considered in any phase (planning, design, maintenance, operations) of a transportation project. By looking beyond the project limits and examining immediate and cumulative effects of transportation and development projects in the surrounding area, a holistic and more effective watershed-based approach can be developed since it is based on actual watershed responses which can be used to develop reliable projected responses. Base on the responses appropriate SWM can be implemented. A working draft framework on how to implement WBSM remains under development and includes recommendations regarding how to cultivate partnerships, determine specific watershed needs, establish accountability, optimize budget spending, and promote sustainable systems.

Green Infrastructure Expansion

To help preserve ecosystems, SHA has begun to examine green infrastructure to review hubs and corridors to establish ways of expanding these areas or increasing corridor connections between hubs as part of improvements associated with transportation projects. In addition to providing improved habitat size and providing more corridors for migration or movement routes of wildlife, further benefits may include enhanced SWM via greater green space and reduced runoff. Also, certain SWM facilities may qualify to be considered green infrastructure since some types of facilities provide habitat space and may facilitate wildlife movement within hubs.

Recycled Materials Task Force

SHA created a task force to review, analyze, and implement the use of recycled materials in transportation projects. Pertinent design offices actively participate in routine meetings. Design expertise includes materials, hydrology, environmental regulations, habitats and ecosystems, and highways. Members of regulatory agencies as well as manufacturers and suppliers are also invited and actively participate. As a result of these meetings, SHA has begun using recycled materials in transportation projects. Examples include the use of recovered crushed glass for use in filtration-type SWM facilities and the use of recovered asphalt in the use of sub-base materials. Additional investigations presently underway include finding practical uses for recovered concrete and recycled brick.

Indian Creek Stormwater Management, Water Quality and Stream Improvements

SHA has performed an assessment for environmental stewardship opportunities in the Indian Creek watershed in Prince George's County, Maryland. The assessment was based on a list of sites previously identified by a joint effort of the U.S. Army Corps of Engineers and Prince George's County, as part of the Indian Creek watershed study. This "preferred list" includes opportunities for watershed improvements primarily through implementation of various stormwater management techniques and some wetland creation/enhancement, and stream restoration/enhancement. The original list included 45 sites which have been divided into Upper, Middle and Lower watershed. In addition to this list, we reviewed a 2003 report prepared for SHA by Gannett Fleming titled *Indian Creek Watershed Improvement Study* for additional wetland creation/enhancement and stream restoration opportunities.

After the performing engineering review of the sites, SHA has indentified four (4) sites, listed in Table 1-22, for which preliminary engineering is being conducted.

Table 1-22 Indian Creek Restoration Sites

Study Location and Name	Description of Concept
Ammendale Road Muirkirk Industrial Park SITE IC-U-01-S-47	Increase storage for treatment of the WQv: Excavated long linear deep pool along the existing tributary flow path; Additional deep pool excavation; Shallow marsh areas plantings; Provide pretreatment and debris collection.
Highview Avenue SITE IC-U-01-S-49	Excavate long linear deep pool along the existing tributary flow path; Additional deep pool excavation; Shallow marsh areas plantings;
Greenbelt Metro Station SITE IC-L-01-S-14	Increase storage for treatment of the WQv and temporary storage of the CPv: Modify existing outlet structure to control discharges associated with the WQv and CPv : Pretreatment forebay: Establish a stormwater wetland: low marsh plantings
Regional SWM Facility SITE IC-U-01-S-50 Indian Creek #2	Modify existing pond; Excavate micropool immediately upstream of the pond outlet; Modify the outlet structure to WQv; Disturbed area be planted as a reforestation area following stone removal and soil amendments: invasive vegetation removal

Figure 1-26 Concept Plan for Regional SWM facility retrofit (Site IC-U-01-S-50, Indian Creek #2)

Figure 1-27 Concept Plan for Ammendale Road Muirkirk Industrial Park (Site IC-U-01-S-47)

Local 8-Digit Impairments and TMDLs

With the TMDL requirements anticipated for the next permit term focused on waste load reductions for urban stormwater, our first focus in the future will be on the Chesapeake Bay segmentsheds and local TMDL watersheds where SHA is named as a contributor to the waste load allocation (WLA). This includes setting and meeting the 2-year milestones for the Bay TMDL as well as demonstrating compliance in local TMDL watersheds. SHA is programming and developing policies to coincide with the anticipated load reduction goals.

G Watershed Restoration

Requirements for this permit condition include developing and implementing twenty-five significant stormwater management retrofit projects, contributing to local watershed restoration activities by constructing or funding retrofits within locally targeted watersheds, and submitting annual reports on watershed activities that contain proposals, costs, schedules, implementation status and impervious acres proposed for management.

G.1 Implement 25 Significant SWM Retrofit Projects

The requirement that twenty-five projects be completed was met and reported on in past annual reports. We are continuing our efforts to maximize treatment of our baseline untreated impervious in anticipation of a percentage treatment requirement for our next permit term.

SHA continues to retrofit facilities and use innovative methods to address water quality.

Stormwater Facility Enhancements & Retrofits

These projects were developed outside of roadway development stormwater management requirements and consist of upgrading stormwater BMPs to current regulations, stream stabilization and restoration, and outfall stabilization projects. Table 1-23 lists these projects to date which total 111 and amount to approximately 919 acres (not including the Chester River Area projects which are in Queen Anne's county) of impervious surface treatment. In addition, there are a number of projects for treatment of pre-1985 impervious surfaces in planning and design stages. The progress will be reported in the next reporting period after construction completion. Our current level of treatment by storm water controls alone is 4%.

Table 1-23 Watershed Restoration Projects

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
Lower Susquehanna River – 02-12-02			
BMP 120076	BMP retrofit	Complete	2.82
Chester River Area – 02-13-05			
BMP 170011	BMP retrofit	Complete	0.41
BMP 170012	BMP Retrofit	Complete	0.23
Bush River Area – 02-13-07			
BMP 120069	BMP Retrofit	Complete	4.16
BMP 120072	BMP Retrofit	Complete	4.68
BMP 120073	BMP Retrofit	Complete	3.99
BMP 120075	BMP Retrofit	Complete	1.77
BMP 120081	BMP Retrofit	Complete	2.39
BMP 120082	BMP Retrofit	Complete	1.00

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
	Gunpowder River – 02-13-08		
I-83 Outfall Stabilization of Tributaries to Gunpowder Falls	Stream stabilization	Complete	7.85
Minebank Run Restoration, Drainage and WQ Improvements*	Stream restoration, outfall stabilization, SWM retrofit	Design	236.8
	Patapsco River – 02-13-09		
BMP 020120	BMP Retrofit	Complete	17.73
BMP 020121	BMP Retrofit	Complete	0.96
BMP 020122	BMP Retrofit	Complete	0.92
BMP 020625	BMP Retrofit	Design	2.46
BMP 030281	BMP Retrofit	Complete	8.35
MD 139 Tributary to Towson Run Stabilization	Stream Stabilization	Complete	260.30
BMP 020111	BMP Retrofit	Complete	6.04
BMP 020112	BMP Retrofit	Complete	0.56
BMP 020098	BMP Retrofit	Complete	0.68
BMP 020099	BMP Enhancement	Complete	0.75
BMP 020476	BMP Retrofit	Complete	3.79
BMP 020477	BMP Retrofit	Complete	Combined with 020476
BMP 130197	BMP Retrofit	Complete	0.44
BMP 130207	BMP Retrofit	Complete	1.57
BMP 130221	BMP Retrofit	Complete	0.17
BMP 130210	BMP Retrofit	Complete	0.24
BMP 130217	BMP Retrofit	Complete	0.10
	West Chesapeake Bay – 02-13-10		
BMP 020019	BMP Retrofit	Complete	1.22
BMP 020022	BMP Retrofit	Complete	1.06
BMP 020027	BMP Retrofit	Complete	1.59
BMP 020029	BMP Retrofit	Complete	0.88
BMP 020031	BMP Retrofit	Complete	2.29
BMP 020088	BMP Retrofit	Complete	3.53
BMP 020481	BMP Retrofit	Complete	2.09
BMP 020522	BMP Retrofit	Complete	1.70
BMP 020273	BMP Retrofit	Complete	1.18
BMP 020491	BMP Retrofit	Complete	1.79
BMP 020185	BMP Retrofit	Complete	0.48
BMP 020198	BMP Retrofit	Complete	0.68
BMP 020201	BMP Retrofit	Complete	1.01
BMP 020205	BMP Retrofit	Complete	1.16
BMP 020206	BMP Retrofit	Complete	0.49
BMP 020210	BMP Retrofit	Complete	0.36
BMP 020220	BMP Retrofit	Complete	0.72
BMP 020258	BMP Retrofit	Design	3.27
BMP 020260	BMP Retrofit	Design	1.41
BMP 020268	BMP Retrofit	Design	7.08
BMP 020393	BMP Retrofit	Design	4.35

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
BMP 020394	BMP Retrofit	Design	3.27
BMP 020014	BMP Retrofit	Design	2.20
BMP 020015	BMP Retrofit	Design	1.22
BMP 020016	BMP Retrofit	Design	0.95
BMP 020017	BMP Retrofit	Design	0.44
BMP 020018	BMP Retrofit	Design	0.89
Patuxent River – 02-13-11			
BMP 160059	BMP Retrofit	Complete	3.2
BMP 020488	BMP Retrofit	Complete	5.56
BMP 160217	BMP Retrofit	Complete	0.64
BMP 160219	BMP Retrofit	Complete	0.91
BMP 160380	BMP Retrofit	Complete	3.42
BMP 020301	BMP Retrofit	Complete	2.30
BMP 020311	BMP Retrofit	Complete	0.28
BMP 020437	BMP Retrofit	Complete	4.13
BMP 130149	BMP Retrofit	Complete	0.48
BMP 130150	BMP Retrofit	Complete	1.02
BMP 130154	BMP Retrofit	Complete	0.47
BMP 130159	BMP Retrofit	Complete	0.02
BMP 130160	BMP Retrofit	Complete	0.52
BMP 130162	BMP Retrofit	Complete	0.66
BMP 130179	BMP Retrofit	Complete	2.10
BMP 130180	BMP Retrofit	Complete	0.43
BMP 130187	BMP Retrofit	Complete	0.13
BMP 130188	BMP Retrofit	Complete	0.12
BMP 130189	BMP Retrofit	Complete	0.03
BMP 130190	BMP Retrofit	Complete	0.03
BMP 130191	BMP Retrofit	Complete	0.05
BMP 130192	BMP Retrofit	Complete	0.05
BMP 130193	BMP Retrofit	Complete	0.10
BMP 130194	BMP Retrofit	Complete	0.22
BMP 130232	BMP Retrofit	Complete	0.03
BMP 130242	BMP Retrofit	Complete	0.72
BMP 130243	BMP Retrofit	Complete	3.49
BMP 150228	BMP Retrofit	Complete	0.13
BMP 150331	BMP Retrofit	Complete	0.23
BMP 130047	BMP Retrofit	Complete	1.39
Lower Potomac River – 02-14-01			
BMP 160456	BMP Retrofit	Complete	1.70
BMP 080014	BMP Retrofit	Complete	0.24
BMP 080039	BMP Retrofit	Complete	0.10
BMP 080040	BMP Retrofit	Complete	0.10
BMP 080041	BMP Retrofit	Complete	0.12
BMP 080042	BMP Retrofit	Complete	0.11
BMP 080043	BMP Retrofit	Complete	0.28
BMP 080044	BMP Retrofit	Complete	0.20
BMP 080083	BMP Retrofit	Complete	0.06
BMP 080095	BMP Retrofit	Complete	0.48

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
Washington Metropolitan-02-14-02			
BMP 160607	BMP Retrofit	Complete	0.41
BMP 160609	BMP Retrofit	Complete	Combined with 160607
BMP 160653	BMP Retrofit	Complete	15.80
Long Draught Branch Restoration	Stream Stabilization	Design	228
BMP 150002	BMP Retrofit	Complete	0.31
BMP 150003	BMP Retrofit	Complete	1.69
BMP 150004	BMP Retrofit	Complete	Combined with 150003
BMP 150005	BMP Retrofit	Complete	Combined with 150003
BMP 150172	BMP Retrofit	Design	1.25
BMP 150301	BMP Retrofit	Complete	0.28
BMP 150362	BMP Retrofit	Complete	1.03
BMP 150380	BMP Retrofit	Complete	1.05
BMP 150550	BMP Retrofit	Complete	1.26
BMP 150076	BMP Retrofit	Complete	1.25
BMP 150059	BMP Retrofit	Design	4.67
BMP 150556	BMP Retrofit	Design	5.65
Middle Potomac River – 02-14-03			
Tributary to Tuscarora Creek Stabilization at US 340 and US 15	Stream Stabilization	Complete	1.94
BMP 150270	BMP retrofit	Complete	0.08
*Projects added since last report.			

Pavement Retrofit Projects

SHA worked closely with MDE to determine Bay TMDL requirements for SHA in order to establish funding and resource needs for the future 2-year milestones. As a result, in addition to the stormwater upgrade projects we are currently pursuing, we have established funding sources for the next three years to provide management, design and construction resources to implement new BMPs to meet both the future waste load reductions and impervious treatment requirement. Future projects involve median treatment at existing open section roadways and include sites in all nine Phase I counties.

Stream Project Assessments

In order to assess the success of SHA stream restoration and stabilization projects, SHA continues working with Dr. R. P. Morgan at UMD Center for Environmental Service, Appalachian Laboratory, to perform stream assessments on completed projects. Three assessment protocols are undertaken: benthic macroinvertebrates, fish and habitat. Nutrient sampling is also being undertaken at select sites.

Assessments investigate the presence of benthic macroinvertebrates and the quality of habitats using MBSS sampling protocols for the purpose of quantitatively describing the community composition, determining relative abundance in favorable habitat at each sampling station and assessing habitat categories. Fish are sampled using the Fish Indices of Biotic Integrity (FIBI). The water quality parameters monitored as part of the nutrient sampling include total nitrogen, total phosphorous, conductivity and total suspended solids. This suite of water quality parameters may be expanded in the future as needed. In addition, stable isotope analyses of carbon, nitrogen, and oxygen are concurrently being completed at the selected sites.

SHA will be monitoring the following the sites:

- US 15 Monocracy River/Tuscarora Creek:- Pre-construction
- I-695 at Minebank Run Stream (Lower Site): Pre-construction testing
- MD 117 Long Draught Branch: Post construction monitoring
- Plumtree Run from east of Ring Factory Rd. to north of MD 24: Pre-construction monitoring
- MD 144 Upper Little Patuxent River: Pre-construction monitoring

Figure 1-28 I-695 at MInebank Run (Lower Site) Stream Restoration – Pre-Construction Monitoring Site

Restoration Project Database Delivery

Data related to the retrofit projects was submitted with previous reports and can be made available upon request.

G.2 Contribute to Local NPDES Watershed Restoration Activities

SHA often participates in and supports watershed interest groups and local jurisdictions in their activities. In addition, SHA has participated directly or indirectly in developing watershed plans as well as provided funding. The Maryland Department of Transportation's State Highway Administration oversees the Federal Transportation Enhancement Program (TEP) and encourages the use of these funds by local jurisdictions and interest groups to fund water quality projects associated with roadway runoff.

The following is a summary of watershed activities undertaken during the report period:

I-695 at Minebank Run Stream Restoration, Drainage and Water Quality Improvements – SHA

This project was initiated to address multi outfall stabilization, stream restoration, SWM retrofits and reforestation. Minebank Run is within Gunpowder River watershed that is targeted by Baltimore County for restoration. The topographic survey has been completed, design work on this project has been initiated and project is scheduled for construction in 2015-2016. This project will result in significant pollutant load reductions for the Gunpowder River watershed as well as address local drainage infrastructure issues and adverse impacts of the upstream urbanization.

Westminster SWM Regional Pond – Carroll County

This project is proposed by Carroll County and SHA is sponsoring for TEP funding that has been approved. The project proposes retrofit of a regional stormwater management facility to treat currently untreated impervious surfaces within a 250 acre watershed. SHA will provide technical review and guidance for navigating the Federal Aid approval process. SHA will receive a portion of the water quality credit associated with the treatment of the SHA impervious surfaces within the drainage area. The preliminary estimate indicates SHA credit to be about 25 acres of impervious and 30 acres of pervious surfaces.

Finksburg Industrial Park Regional SWM Facility – Carroll County

This project is proposed by Carroll County within Liberty Reservoir watershed to meet local TMLD reduction goals. It is sponsored by SHA for TEP funding. The project proposes retrofit of regional stormwater management facility to treat currently untreated impervious surfaces within 149 acres drainage area. SHA provides technical review and guidance through the project development and federal funding approval process. SHA will receive a portion of the water quality credit associated with the treatment of MD 91 and MD 140. The preliminary estimate indicates that approximately 4 acres of SHA owned impervious surface will be treated by this facility.

Laurel Lakes Task Force – PG County

The I-95/Contee Road project recently received design funding. Due to procurement and right-of-way challenge, SHA is pursing remediation of the outfall separate from the overall project. The project will be designed in accordance with the Stormwater Management Act of 2007, implementing ESD features.

South River Federation – AA County

The BMP upgrade projects mentioned in the last annual report were delayed to address in-stream issues.

Whitehall Creek Watershed – AA County

This is a Transportation Enhancement Program (TEP) funded project being undertaken by Anne Arundel County. SHA is supporting this project through the TEP review process. The project proposes construction of various stream segments at the head of the watershed as well as significant stabilization from the US 50 interchange at MD 279 up to the point of tidal influence. The project was advertised on September 17 and the Bid opening is scheduled for November 6, 2012

Brampton Hills Stream Stabilization- Howard County

This project is sponsored by TEP and administered by the Howard County Department of Public Works, Environmental Division. The project consists of 2,100 linear feet of stream restoration along with 400 linear feet of SHA drainage outfall channel stabilization. The project construction was been completed in spring 2012.

Dorsey Run Stream Restoration – Howard County

This restoration project is located in Jessup, MD off Dorsey Run Road, west of MD 175. This project was designed to reduce stream channel erosion, to improve floodplain reconnection and to restore adjacent wetlands. The purpose is to enhance/create 12 acres of floodplain wetlands and restore/stabilize 1,970 feet of stream channel by installation of in-stream structures to reduce storm flow energy and create backwater. This is another

SHA sponsored TEP project and it was constructed by MD Department of Natural Resources. The construction started in December 2010 and work was completed in July 2012. Plantings are scheduled for December 2012.

Figure 1-29 Dorsey Run Before (Left) and After (Right) Construction

Figure 1-30 Dorsey Run Before (Left) and After (Right) Construction

Figure 1-31 Dorsey Run Before (Left) and After (Right) Construction

Figure 1-32 Dorsey Run Before (Left) and After (Right) Construction

Figure 1-33 Dorsey Run Before (Left) and After (Right) Construction

Figure 1-34 Dorsey Run Before (Left) and After (Right) Construction

G.3 Report and Submit Annually

SHA completed and submitted information on our twenty-five required watershed restoration projects and other activities to meet the permit requirement in past reports. This included retrofit proposals, costs, schedules, implementation status and impervious acres proposed for management. Documentation in the form of construction plans, cost estimates and schedule for additional projects can be provided to MDE upon request.

H Assessment of Controls

This condition requires that SHA develop a proposal and receive approval for a watershed restoration project by October 21, 2006; develop and receive approval for a monitoring plan that should include chemical, biological and physical monitoring according to parameters specified in the permit and submit data annually.

H.1 Restoration Site Approved by October 21, 2006

The Long Draught Branch restoration project was previously approved as our restoration site. This project has undergone difficulties in obtaining the joint permit approval for construction. SHA has initiated alterations in the previously proposed design in order to address the concerns of multiple agencies and obtain the required permits. The budget for construction funding is allocated for FY 2014 and 2015. Once the project is constructed, SHA plans to continue post-construction monitoring on this project in accordance with the permit requirements and the previous delivered monitoring plan (See SHA First Annual Report, 2006, Appendix K).

H.2 Monitoring Requirements

Based on the previous approval of the Long Draught Branch project by MDE-WMA, significant pre-construction monitoring (physical, chemical and biological) was performed. The final report for the pre-construction monitoring data was included in the SHA Third Annual Report, 2008, Appendix I. Since the project has been delayed, the post-construction monitoring data will not be available until after the construction is completed. In the interim, we are pursuing monitoring of a failed infiltration basin and these monitoring results were summarized in Section D.

H.3 Annual Data Submittal

Monitoring data for Long Draught Branch pre-construction monitoring was included with previous reports. As new monitoring data becomes available, it will be delivered to MDE according to permit database format requirements. Table E and F of the permit Attachment A are included with this report for the latest data associated with the Wet Infiltration Basin Study.

I Program Funding

This condition requires that a fiscal analysis of capital, operation and maintenance expenditures necessary to comply with the conditions of this permit be submitted, and that adequate program funding be made available to ensure compliance.

This report represents end of fiscal responsibility for this permit term. SHA has been able to fund its obligations for the all past years with some adjustments. Fiscal analysis is therefore not needed until a new permit is issued. SHA has seen requirements presented for the Bay TMDL as part of WIP process and also has reviewed MS4 permits issued to others. In near future SHA will perform funding needs as SHA permit is finalized for the next term.

In 2006, SHA had procured open-end consultant contracts in the amount of $9 million in order to accomplish both the current Phase I and Phase II NPDES permits. We are currently in the process of procuring additional open-ended consultant contracts in the amount of $12 million for the next six years to continue our engineering efforts for the future.

SHA utilizes Capital Funds (Fund 74 – Drainage) for engineering and construction related activities associated with the NPDES MS4 Permit. Recently, SHA established an additional fund (Fund 82) category for TMDL related engineering and construction activities. In addition to the funding commitment from these two funds, SHA seeks additional funding from a variety of sources such as the Chesapeake Bay Trust fund, State Planning and Research funds (SPR), Transportation Enhancement Program (TEP) funds and SHA Operations and Maintenance funds in completing NPDES requirements.

Currently, SHA tracks only capital fund spending for the NPDES program as a whole and breaks out a few items such as NPDES Stormwater Facility Program and industrial activities. According to our current records, the total spent for the MS4 NPDES, the Stormwater Facility Program and the Industrial NPDES are listed in Table 1-24 below.

Table 1-24 SHA Capital Expenditures for NPDES (State Fiscal Years)

Fiscal Year	Expenditure (Millions)*
2005	$ 3.40
2006	$ 7.26
2007	$ 5.74
2008	$ 5.73
2009	$ 6.42
2010	$ 8.68
2011	$ 11.62
2012	$ 19.20
* Includes Fund 74, 82, Industrial, SPR and TEP Funds.	

J Total Maximum Daily Loads (TMDLs)

The current SHA NPDES Phase I permit states that MDE has determined that owners of stormdrain systems that implement the requirements of the permit will be controlling stormwater pollution to the maximum extent practicable. However, given the current mandate to restore the Chesapeake Bay by 2025 and the draft MS4 Phase I permits that require that jurisdictions meet assigned waste load allocations (WLAs) for the Bay and local watershed TMDLs, SHA has taken many steps in order to position ourselves to meet these requirements. But while we are looking forward in developing funding and activities, we are not prepared to report on all these activities in detail for this report period, but rather, will include them in milestone progress reports and annual reports for the next permit term. However, expenditures reflected in Table 1-24 reflect this increased activity.

Some of the activities undertaken to provide SHA with the tools to address WLAs and impervious restoration requirements anticipated for the next permit term include:

- Developed SHA Phase II Watershed Implementation Plan (WIP II) milestone strategy and Maryland Assessment Scenario Tool (MAST) scenarios included in the MDE WIP II for Bay TMDL compliance. This SHA strategy identifies a menu of BMPs that will be undertaken in order to meet the SHA Bay TMDL WLAs for sediment and nutrients by the 2025 deadline;

- Through coordination with the Maryland Department of Transportation (MDOT), our parent agency, SHA has developed funding levels to ramp up implementation efforts for designing, constructing and monitoring urban stormwater BMPS;

- Issued multi-million dollar contracts and initiated construction of median bioswale projects along open-section roadways in MS4 counties (see Figures 1-35 to 1-37);

- Working with MDE to develop a protocol to demonstrate that highways with disconnected runoff features such as open channel grassed swales and sheet flow provide water quality benefits by identifying existing channels that can be considered as meeting ESD to the MEP for TMDL and impervious surface restoration credits (see detailed discussion below);

- Developed and in the process of issuing multi-million dollar design build contracts to retrofit existing SHA SWM facilities to add water quality components according to current stormwater design standards and achieve TMDL and impervious surface restoration credits;

- Developed a protocol to assess failing outfalls for remediation in order to reduce pollutant loads resulting from eroding SHA stormdrain outfall channels;

- Developing outfall stabilization projects and contract vehicles in order to reduce erosion and minimize sediment and nutrient transport from SHA right-of-way to receiving waters;
- Expanded impervious surface layers and SHA right-of-way to provide statewide coverage;and
- Engaged interagency discussion to lay groundwork for future project permitting.

Figure 1-35 Bioswale Construction along MD 119 in Montgomery County

Figure 1-36 Bioswale Construction along US 40 in Howard County

Figure 1-37 Bioswale Construction at US 301 in Charles County

Disconnected Roadways Protocol and Assessment

Based on discussion in the MDE document *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for NPDES Stormwater Permits, June (DRAFT) 2011*, under section IV.3, Existing Roads and Subdivisions, SHA has developed a protocol for identifying segments of open-section roadways (disconnected impervious) that can be considered to be providing Environmental Site Design (ESD) to the maximum extent practicable (MEP). Many highways in Maryland are open section roadways with wide medians and gently sloping clear zones on the outer lanes. Due to these roadway characteristics, sheet flow conditions are commonly found. Identifying these sheet flow areas and using the ESD criteria for grass swales found in Chapter 5 of the *2000 Maryland Stormwater Design Manual* (the Manual), SHA will provide evidence that water quality treatment in the form of pollutant load reductions and impervious surface treatment is occurring along these highway corridors. This will allow SHA to both remove untreated impervious surfaces from future treatment requirements and demonstrate waste load reductions for meeting local and the Bay TMDLs.

A protocol, *Existing Water Quality Grass Swale Identification Protocol, July 2012*, (included as Appendix G to this report) has been developed by SHA to standardize the identification of existing grass swales to be credited by using GIS analysis and remote sensing techniques that leverage topographic data, aerial photography, hydraulic analysis and field verification. Drainage areas, slopes, ditch lengths, velocities and lining material (grass, concrete or rip-rap) is determined using these remote sensing technologies and a verification strategy in order to identify swales that currently provide water quality treatment while maximizing efficiency and cost. Channels that do not meet the ESD criteria for grass swales may be candidates for future retrofits.

A three-step process, Figure 1-38, is implemented in the protocol including desktop evaluation using GIS, verification using sample locations and full corridor analysis. This process is currently being used in a pilot study to quantify existing treatment along the I-70 corridor. A recent estimate has revealed that 24% of the existing grass swales along this corridor meet the ESD to the MEP criteria and can be documented as urban BMPs in our NPDES geodatabase. Figure 1-40 shows examples of grassed swales currently under study.

This protocol and results of the I-70 corridor pilot assessment will be presented to MDE for review. The results of the analysis will be included in future annual reports.

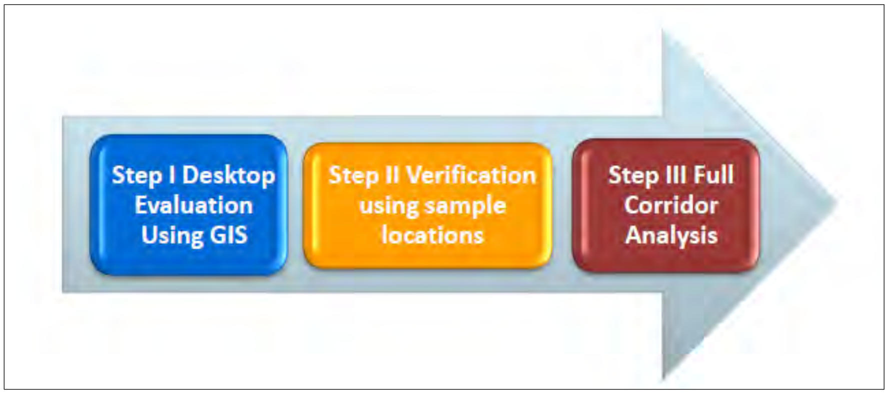

Figure 1-38 Three-Step Grass Swale Protocol Process

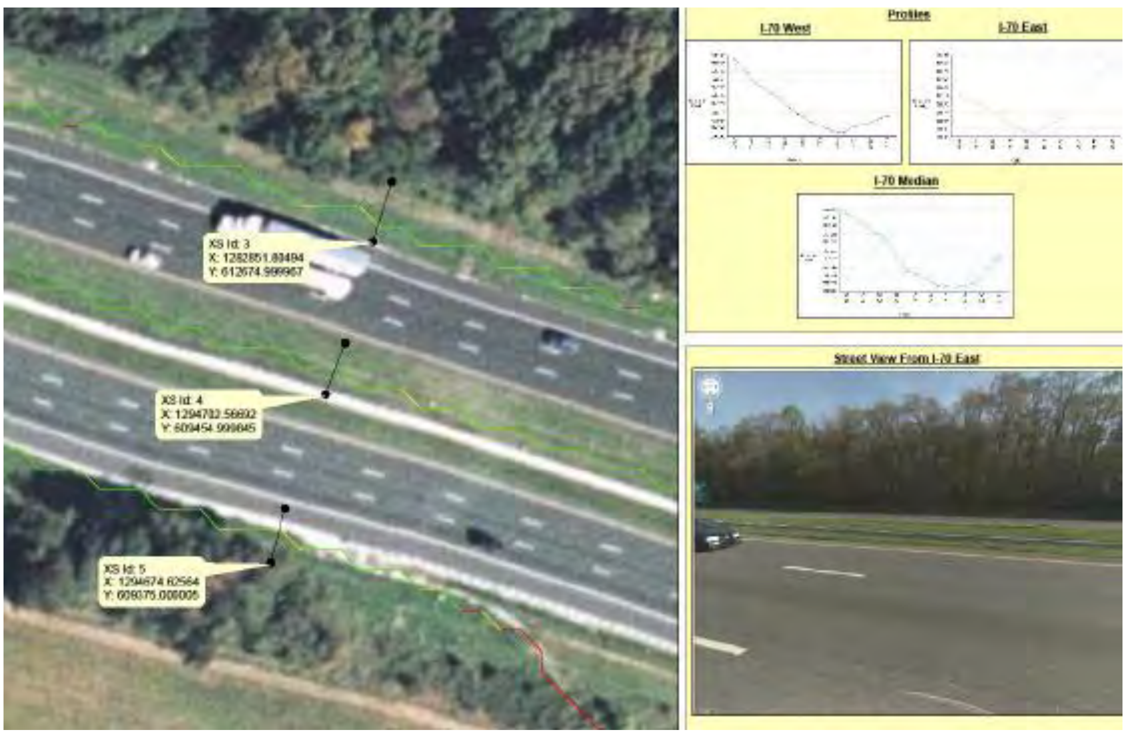

Figure 1-39 Example of Desktop Evaluation

Figure 1-40 Examples of Grassed Swales under Study along I-70

PART TWO

Stormwater Facilities Program

2.1 Introduction

The SHA Stormwater Facilities Program which oversees the inspection, assessment, maintenance and remediation of the SHA stormwater management BMPs and the SHA Stormdrain and Outfall Inspection and Remediation Program (SOIRP) are components of a broader program under the Highway Hydraulics Division (HHD) called the Stormwater Asset Management Program (SWAMP). SWAMP oversees management of SHA stormwater assets as well as the NPDES permit compliance activities for the municipal separate storm sewer system (MS4) permits. This part of the report provides a summary of the Stormwater Facilities Program activities between October 2011 and September 2012.

According to the latest inventory, SHA owns approximately 2550 stormwater management (SWM) facilities statewide. SWM facilities manage highway runoff from qualitative and quantitative aspects. Since 1999, SHA has managed a comprehensive program that provides identification, inspection, evaluation, repair, and remediation of SWM facilities to ensure continued effectiveness in managing water quality and protecting sensitive water resources.

The Program's primary goal, which is tied directly to the SHA Business Plan goal of providing a positive contribution to the water quality of the Chesapeake Bay, is to ensure that SHA's SWM facilities are fully functional and perform as intended. In addition, the Program has a secondary goal to strategically enhance overall SWM facility function of existing facilities to meet or exceed the latest SWM standards.

The Program encompasses four major components:

- Identification, inspection, and database management of SHA's stormwater assets.
- Repair and remediation of SWM facilities.
- Visual, functional, and environmental enhancement, upgrade, and retrofit of SWM facilities, including upgrades related to safety.
- Site and SWM facility monitoring, research, and innovative technology tool development.

2.2 Inventory and Inspections

The following section summarizes the inspection methodology and inventory review to provide a status of all known SWM facilities that manage stormwater runoff from SHA assets.

2.2.1 Inspection Protocol

The inspection protocol is documented in Chapter 3 of *"Maryland State Highway Administration Stormwater NPDES Program, Standard Procedures – Performance Rating."*

During initial field assessments, individual parameters of each SWM facility are scored (on a scale 1 to 5). Scores are used to establish an overall SWM facility performance rating as follows:

A **No Issues.** The SWM facility is functioning as designed with no adverse conditions identified. There are no signs of impending deterioration.

B **Minor Problems.** The SWM facility functions as designed, but minor issues are observed that may worsen to the next rating level if not repaired in a reasonable timeframe.

C **Moderate Problems.** The SWM facility functions as designed, but efficiency, performance and function have been significantly compromised and may worsen to the next rating level if not repaired in a reasonable timeframe.

D **Major Problems.** The SWM facility no longer functions as designed and efficiency has been compromised. Repair or remediation should be performed.

E **Severe Problems.** The SWM facility no longer functions as designed and efficiency as well as several critical parameters have been compromised. The SWM facility shows signs of deterioration and/or failure, requiring immediate remedial action.

The remedial inspection protocol describing field assessment methodologies used for determining the observed functionality of a SWM facility and providing guidance for remedial actions is included in Chapter 7 of the *"Maryland State Highway Administration Stormwater NPDES Program Standard Procedures."* The assessments and recommended action ratings provide consistency that enables SHA to adequately allocate sufficient timing and funding that ensures an appropriate schedule of remediation activities.

SHA Remediation Ratings

Remedial activities are determined by remedial ratings. The rating system is based on the field inspection rating, facility performance, facility function, integrity of key functional components, visual appearance, scope of remedial activities needed, and the complexity of the work. The ratings are as follows:

I **No Response Required.** The SWM facility is functioning as designed. Re-schedule for the next multi-year inspection assessment period.

II **Minor Maintenance.** The SWM facility is functioning as designed, but routine and preventative action should be performed to sustain effective performance. Activities can typically be performed within an 8-hour workday by an average remediation crew.

III **Major Maintenance or Repair.** The SWM facility no longer functions as designed and significant repair is necessary to restore original functionality. The facility is repaired to remain within the existing facility footprint. Activities are more significant than minor remediation and likely require heavy equipment mobilization, construction materials and Maintenance of Traffic (MOT) plans.

IV **Retrofit Design.** The SWM facility no longer functions as designed and cannot be restored to the original function as designed without a complete re-design and construction of a facility with a larger footprint, a different SWM facility type, or additional SWM facilities in the vicinity of the existing facility.

V **Immediate Response.** The SWM facility has catastrophically failed and public safety hazards exist that require immediate corrective action.

VI **Abandonment.** The SWM facility is unsustainable and no longer provides sufficient benefit to warrant remedial design.

2.2.2 Inventory

SHA's SWM facility inventory database is frequently updated as new facilities are brought online. Updates occur statewide for all of SHA's highway and facility infrastructure in each Maryland county, including all Phase I and II MS4 locations as well as those locations not presently covered under the Phase I or II permits. Inventoried SWM facilities include those owned and maintained by SHA as well as those owned and maintained by other jurisdictions, municipalities, or entities because the SWM facilities receive and manage stormwater runoff from the SHA highway network. Table 2-1 summarizes the total number of SWM facilities that intercept and manage stormwater runoff from the SHA highway network and highway-related assets; the information is grouped by county.

The SHA SWM facility inventory includes all SWM facilities that intercept and manage runoff from SHA's highway network and roadway-related assets and includes SWM facilities not owned or maintained by SHA, but by other entities, including but not limited to counties, municipalities, other state agencies, and private entities.

Compared to the previous reporting period, several counties show an increase in the total number of SWM facilities managing runoff from SHA roadway networks and assets. Increases may occur for several reasons, including but not limited to, new developments adjacent to SHA roadways, improvements to the SHA roadway network, and construction of new SWM facilities in areas of the roadway network previously not serviced by adequate SWM facilities. The total number of facilities increased in the past year by over 200 SWM facilities, or 8.6%, with increases in Worcester, Caroline, Montgomery, Prince George's Harford, Anne Arundel, Calvert, St. Mary's, and Frederick counties. The greatest increases occurred in Calvert County (48.3%) and Anne Arundel County (41.8%).

Table 2-1 Total SWM Facilities Intercepting and Managing Stormwater Runoff from SHA's Highway Network and Assets

District	County	SWM Facilities (No.)	District Totals
1	Dorchester	28	174
	Somerset	11	
	Wicomico	50	
	Worcester	85	
2	Caroline	7	137
	Cecil	15	
	Kent	6	
	Queen Anne	102	
	Talbot	7	
3	Montgomery	342	612
	Prince Georges	270	
4	Baltimore	213	358
	Harford	145	
5	Anne Arundel	594	753
	Calvert	46	
	Charles	96	
	Saint Mary's	17	
6	Allegany	41	71
	Garrett	12	
	Washington	18	
7	Carroll	49	444
	Frederick	84	
	Howard	311	
Statewide Total			2,549

2.2.3 Field Inspections

Initial SWM facility field inspections and inventories have been completed for all counties, both MS4 and non-MS4 counties. The information is used to verify existing data in the SHA database as well as determine the SWM facilities functional rating and provide any necessary remedial action recommendations. The statewide inventory is continuously updated on a county-by-county basis.

2.3 Repair and Remediation

This section summarizes the status of SHA repair and remediation activities in response to identified deficiencies of SWM facilities. Since SHA has a goal to ensure complete functionality and efficiency of all SHA owned and maintained SWM facilities, deficiencies are corrected in a timely manner. In addition, SHA seeks to enhance function beyond existing level of service as the need or opportunity arises to increase pollutant removal efficiency or to treat additional impervious surfaces.

Response actions are divided into four major categories of activities: no action, minor or routine upkeep and preventative maintenance, major repair, and retrofit or enhancement. Retrofit projects may include reconstruction of a facility to restore function, or to enhance the facility to deliver improved function, e.g. a non-functional infiltration trench may be retrofitted to a bioretention facility with an enhanced filter to increase pollutant removal efficiency. Table 2-2 shows the remediation ratings within SHA Districts 3, 4, 5 and 7.

Table 2-2 Remediation Ratings of SWM Facilities By County

SHA District	County	No Action (I)	Routine Upkeep (II)	Major Repair (III)	Retrofit (IV)	County Total	District Total
3	Montgomery	58	239	42	3	**342**	**612**
3	Prince Georges	136	103	28	3	**270**	
4	Baltimore	153	40	10	10	**213**	**358**
4	Harford	50	58	26	11	**145**	
5	Anne Arundel	164	280	95	55	**594**	**753**
5	Calvert	6	32	8	0	**46**	
5	Charles	93	3	0	0	**96**	
5	St. Mary's	1	14	1	1	**17**	
7	Carroll	42	6	1	0	**49**	**444**
7	Frederick	64	17	3	0	**84**	
7	Howard	242	41	15	13	**311**	
	Totals	**1009**	**833**	**229**	**96**	**2,167**	

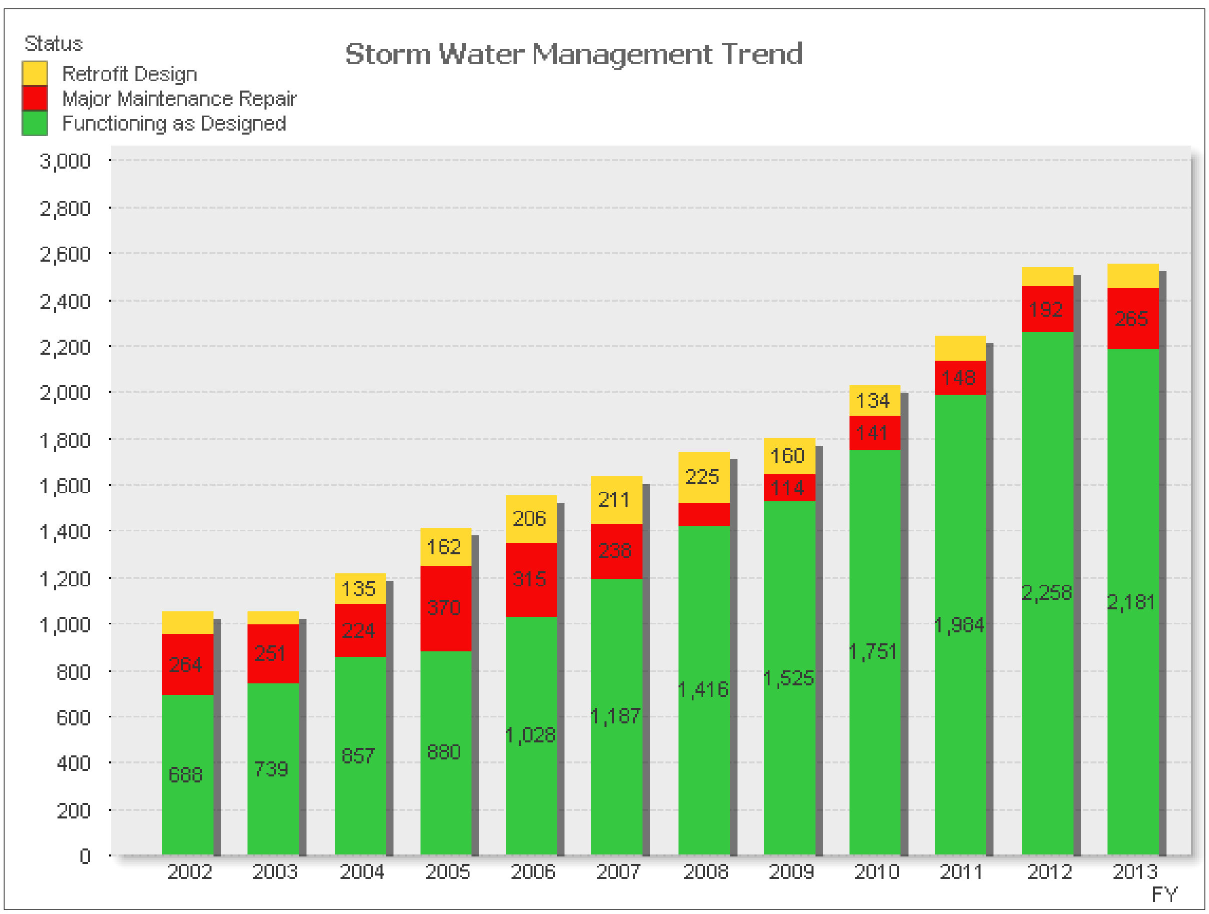

Figure 2-1 Historical Trend for SWM Facility Inventory and Remediation Ratings

2.3.1 Routine Upkeep

Routine upkeep or minor and preventive repairs are generally activities that address minor deficiencies and may include actions such as mowing, brush cutting, vegetative thinning, unwanted woody vegetation removal, invasive weed removal, and trash or debris removal. These activities greatly help to maintain performance of a SWM facility and prevent or eliminate deteriorative conditions of key SWM facility elements. SWM facilities requiring routine upkeep are assigned "II" rating by SHA.

SHA is currently performing most of the work using two (2) open-end asset management construction contracts. An additional contract has been advertised and will be activated by November 2012. Additional coordination is planned with district maintenance departments to better address the routine maintenance needs of the growing inventory. Pilot activities have been conducted in District 7 and District 3 with success.

Activity schedules are based on local needs. In addition, geospatial data is used to assist in combining activities together such that activities can be performed on multiple facilities in proximity to one another and allowing greater efficiency of work completion at lower costs. Entire roadway corridors can often be completed within a few weeks.

2.3.2 Major Repair

Major repair activities are performed to address significant deficiencies of SWM facilities and are also performed through an open-end construction contracts. The purpose of the repair activities is to restore the performance of a SWM facility as well as prevent failure of specific functional elements. Actions may include dredging, sediment removal, and obstruction removal within pipes. Work also may include removal of sediment from facilities to maintain the required water volume. SWM facilities that require major or remedial repair are assigned a "III" rating by SHA. During fiscal year 2012, a total of $5.5million was spent by the Program, with $3.2M in construction costs and $1.8M in preliminary engineering and right-of-way costs.

Figures 2-2, 2-3, and 2-4 show a SWM facility that required sediment removal.

Figure 2-2 SWM Facility 120036 Prior to onstruction

Figure 2-3 Works In Progress on SWM acility 120036

Figure 2-4 Nearing Completion of Work on SWM Facility 120036

2.3.3 Retrofits - Design-Build and Asset Warranty

SHA is presently developing design-build and asset warranty (DBAW) contracts to administer the asset remediation and improvement portion of the NPDES program to include all SHA drainage assets. The contract will use the design-build project framework already developed and implemented by SHA. The scope includes strategically planned activities to preserve functionality and sustain efficiency of SHA SWM facilities, remediate pipe assets that have exceeded the designed lifespan, and replace or enhance hydraulics structures. All of these activities require preliminary engineering. Contracts will cover entire districts but will consist of multiple specific sites. Each site will adhere to NEPA and federal authorization procedures.

Design engineers determine the remedial actions that need to be completed for the targeted SWM facilities to return to the designed intention. This means that the facilities are currently not functioning as originally intended and engineering solutions are needed to return the facilities to their original state. These facilities require a SWM facility type change and retrofit and permit, involving detailed engineering and coordination. Pipe assets deemed to need major remediation must also be addressed. The design-build (DB) team will generate plans and construct the necessary improvements.

All work will require a warranty for function. The warranty will be assed based on the criteria found in the SHA NPDES Standard Procedures Manual. The term of the warranty is 18 months after the completion of construction activities. SWM facilities must be inspected and receive an inspection rating of ‘A’. Conveyance systems will be required to receive an inspection rating of ‘1’. Drainage structures will be required to have no associated structure issues. Any items found to be deficient must be repaired by the DB team contractor at no additional cost to SHA for the duration of the warranty period.

2.3.4 Immediate Response

In the event of an emergency, SHA immediately performs work to ensure public safety. SHA responds to any outfall or SWM facility that requires immediate repair and remediation. Roadways are closed as necessary and detour routes are implemented as needed. Site assessment and investigation occurs at the subject location within hours by a multi-disciplinary team. On-call contractors are mobilized and plans for repairs are initiated within 24-hours.

2.4 SWM Facility Retrofits, Visual and Functional Enhancement Projects

SHA continuously plans, designs and constructs functional enhancements and retrofits for SWM facilities. Projects are funded using state and federal funds.

Site selection for enhancement projects is evaluated using several factors, including feasibility, permitting process complexity, and benefit analysis. SHA often seeks opportunities to improve the efficiencies of older SWM facilities that provide only minimum water quality treatment to achieve greater reduction of pollutant loads from highway runoff. SHA also seeks opportunities to manage greater amounts of untreated roadway areas to existing SWM facilities to increase the amount of highway surfaces being managed for pollutant removal.

As a part of SHA’s greater improvement efforts and gaining increased benefit at smaller costs, projects to improve water quality involve treatment of additional impervious areas as well as provide replacement or upgrade to the existing drainage infrastructure. Projects also include rehabilitation of degraded outfalls, channel restoration, and slope stabilization. The status of SWM facility enhancement, retrofit and water quality improvement projects is summarized in Table 2-3. In addition to improvements included in the table, SHA has begun retrofits of currently untreated pavement. All relevant information will be compiled and reported with the 2013 Bay TMDL milestone progress report.

Table 2-3 Summary of SWM Facility Enhancement, Retrofit and Water Quality Improvement Projects

Project	County	No. of BMPs	Contract Number	Total Cost (PE, R/W, Construction)	Status
1. MD 28 – Retrofit of SWM Facility 150344	MO	1	MO247A21	$120,000	Under Design
2. US 50 –Retrofit of Infiltration Basins	AA	3	AA822A21	Preliminary Estimate $800,000	Survey and concept design completed
3. I-97/ MD100 SWM Facilities Functional Upgrades	AA	12	AA5355174	$1,180,000	Construction completed in May 2011
4. SWM Retrofit and Drainage Improvements at Sawmill Creek	AA	1	AA2735174	$550,000	Construction completed in August 2011
5. MD 4 – Enhancement of SWM Facilities	AA	3	AA5515174	$720,000	Completed in Spring 2012
6. MD 355 – Retrofit of SWM Facility 150012	MO	1	MO410A21	$70,000	Will be constructed through T&M[1] Contract
7. MD 32 Infiltration Basins Retrofit	AA	10	AX931B21	Preliminary $1,500,000	Under Design
8. Enhancement of SWM Facility 150173 and Outfall Stabilization	MO	3	MO637A21	Preliminary $850,000	Survey requested Concept design
9. I-270 SWM Retrofit of BMP 150059 and 150556	MO	2	MO106A21	PI Estimate $510,000	Survey completed, Semi-final review
10. I-695 Minebank Stream Restoration , Drainage and Water Quality Improvements	BA	3	BA712B21	PI Estimate $2,000,000	Survey completed, Concept Development
11. US 29 SWM Retrofit and Outfall Stabilization	MO	1	MO673A21	Est. Cost $600,000	Under Design
Totals		**39**		**$8,300,000**	

Notes:
1. T&M: Time and Materials open end construction contract.

Images show work progression on the enhancement of a SWM facility along MD 4 in Anne Arundel County.

Figure 2-5 MD 4 SWM Facility Enhancement during Construction

Figure 2-6 MD 4 SWM Facility Enhancement during Stabilization

Figure 2-7 MD 4 SWM Facility Enhancement after Completion

2.5 Data Management

SHA has performed an inventory of all SWM drainage infrastructure in each NPDES county and performs SWM facility inspections in all twenty-three counties. The statewide SWM facility inventory database was finalized in 2011. SHA has also proceeded with a second cycle of re-inspection in four counties. This effort involves continuous updates of GIS data for source identification and database records of inspection and remediation activities.

SHA has finalized the structure of the ESRI geodatabase and detailed schema that allows for the establishment and enforcement of topologic and/or network rules and unique data entry. Domain rules are updated as needed. The database format has resulted in improved data intelligence and integrity. SHA plans to integrate the geodatabase with other organizational initiatives such as eGIS and iMAP (discussed below) to improve communication between offices.

SHA uses two custom software programs to collect and store geospatial information: the Office Tool and the Field Tool. The Office Tool is used to input data as well as perform quality assurance (QA) reviews. The Field Tool is used with GPS coordinate units to collect and edit field data.

Along with the database format, the customized data viewer tool known as the NPDES Viewer, has been recently enhanced. The tool allows a user to view the spatial information as well as digital images associated with each SWM facility, such as as-built plans, photographs, inspection reports and other pertinent documents. NPDES Viewer is used to view data at various focus levels, such as highway corridors, SHA districts, counties, or watersheds.

A new component for SWM facility maintenance tracking, called the Remediation Tool, has been added to the NPDES Viewer. The application allows the tracking of routine upkeep and major repair activities, associated costs, retrofit project progress, and current functionality of SWM facilities. It also can output reports of data that can be shared with managers and administrators.

2.6 iMAP

The most recent tool incorporating the SWM facility geodatabase that is used for quick data viewing, reporting and spatial display is a web application named iMap. (Screen captures are shown on Figure 2-8). The application can be found at http://www.mdimap.com/sha/

iMap was developed by SHA primarily for reporting the current status and progress of key SHA Business Plan objectives to the StateStat Committee. The tool has also been used to present the SHA SWM Program to the Lt. Governor's meeting in July 2010.

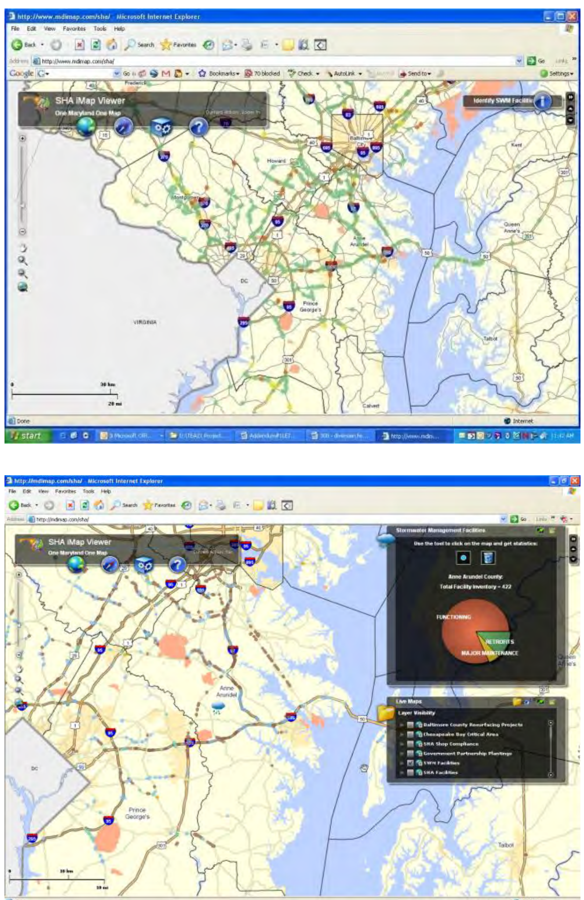

Figure 2-8 Screenshot of iMap.

2.7 eGIS

SHA has developed comprehensive mapping solutions for all internal departments and divisions to view spatial data related to project development and operations. eGIS has contents related to all aspects to highway operations and allows planners and engineers to access asset data on a real-time basis.

Current NPDES drainage and SWM facility information has been integrated into the eGIS platform. With eGIS capability, users who are not experienced or familiar with using GIS software are able to view data in an intuitive format. This greatly enhances cross communication and other business functions.

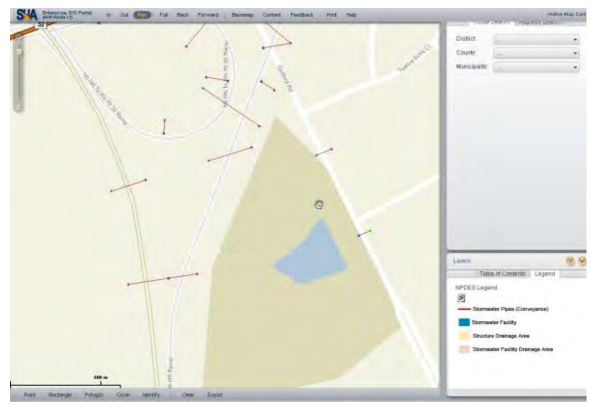

Figure 2-9 Screenshot of eGIS.

2.8 Standard Procedures

Chapter 7 of the *"Maryland State Highway Administration Stormwater NPDES Program Standard Procedures – SWM Maintenance Work Order Development"* has been revised to include knowledge gained over the last few years. The chapter describes the procedure for field assessment of SWM facilities previously designated as requiring remediation after an initial inspection or at any time throughout the inspection cycle. After the preventative cyclical inspections and database updates, final performance ratings and level of functionality are evaluated. SWM facilities with major deficiencies require a detailed Remedial Assessment to determine specific causes of deficiencies, which in turn is used to develop a remedial action plan. The procedures that are outlined in the chapter assist the decision-making process for maintenance, repair, and remediation of SWM facilities. It also provides standardization in the assessment process, instructions for inspection of SWM facilities statewide, as well as examples for identifying and assessing the causes of the deficiencies and recommendations for repairs with relatively consistent results. The intent of the document is not to be an all-inclusive resource manual and other resources are consulted in conjunction with the document. Cost estimating and common causes for facility failure are the updated key portions. Examples of work action are included for common facility types.

2.9 SWM Processor

SHA has developed software, called SWM Processor that facilitates design of SWM facilities for roadway improvements. Figure 2-10 shows a screen capture of the interface. SWM Processor helps with the computational methods as listed in MDE 2000 Stormwater Management Design Manual. The program combines a built-in computation model with a flexible user interface. The software is also able to generate standardized reports. It enables the design engineer to perform calculations efficiently and includes multiple error checking mechanisms. The engineer can save project data, including project information and calculation data, to a centralized database or XML file. The database catalogs all projects that have been entered. External users may install the software and forward computations to be imported into the SHA database system. Consistent computational policies for SWM are needed for long-term success of any comprehensive SWM program.

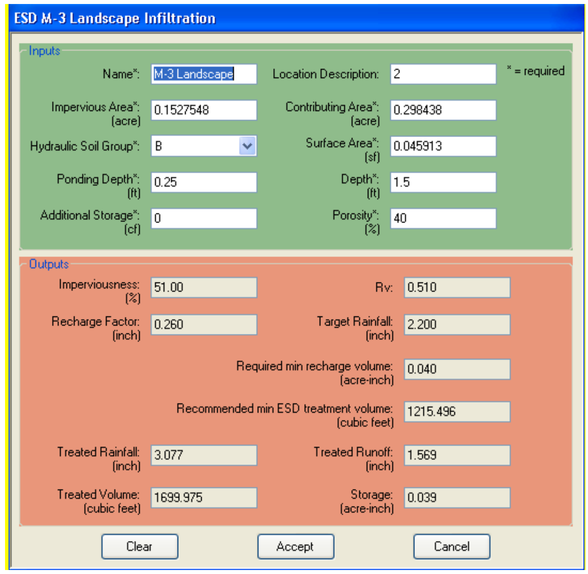

Figure 2-10 Screenshot of SWM Processor

2.10 Qlikview Dashboard

Qlikview is an intelligent business reporting software that allows program managers to make informed and consistent decisions regarding resource allocations. SWM facility upkeep and repair activities are conveniently reported and summarized. Production trends that show current program performance and progress are displayed in formats via a HTML browser. Graphs and charts are updated in real-time as activities are advanced, providing instantaneous decision making support.

Automated queries, based on SWM attributes such as county, watershed, shop, district, and facility type are produced to generate target areas of greater need.

Figure 2-11 Screenshot of Qlikview Dashboard

2.11 Google Earth KML Files

Google Earth KML files are an alternative to eGIS for communicating spatial information specifically for those without connectivity to the SHA intranet such as SHA field personnel. Similar to eGIS, Google Earth KML files enable anyone to view inventory data statewide. However, unlike eGIS, Google Earth KML files are not real-time data, but instead are a snapshot of time based on when the KML was created. KML files have been distributed to each SHA district to aid in locating SWM facilities, drainage structures and conveyances.

Data on Google Earth KML files is presented by type of facility or structure. Users may click on any object to view additional pertinent information, such as structure type, rating, date of last inspection, and contract. Future developments include creating KML files that can be sent to mobile devices and used conveniently in the field without the need for printed hard copies.

Below is an example of a map generated by Google Earth KML:

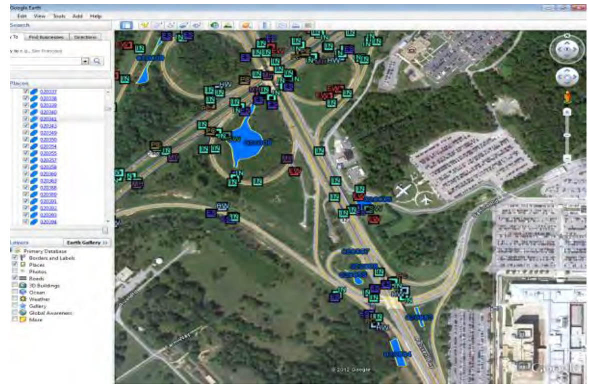

Figure 2-12 KML Coverage View of SHA NPDES Data in Google Earth

2.12 Summary

The NPDES Municipal Separate Storm Sewer System (MS4) permit requires SHA to identify all infrastructure that captures, treats, and conveys stormwater runoff from SHA facilities such as roadways, welcome centers, and park and rides, including hydraulic structures and stormwater management facilities. SHA owns and maintains approximately 2500 SWM facilities. Based on current estimates, SHA also owns and maintains over 130,000 hydraulic structures and 85,000 conveyances statewide. Since 1999, SHA has maintained and managed a comprehensive asset management program to locate, inspect, evaluate, and remediate stormwater facilities to sustain their functionality, improve water quality, and protect sensitive water resources. SHA has developed a comprehensive inspection and rating system to prioritize and plan remedial activities and preventive maintenance to extend the life expectancy of each asset.

The SHA Business Plan goals exceed the NPDES Phase I permit requirements by promoting a complete statewide inventory and maintaining high-efficiency SWM facility performance. A key goal is to maintain 90 percent of all SHA-owned SWM facilities at full functionality. Currently, 85.5% of the SHA-owned and maintained facilities within the inventory meet the functionality goal. At the end of FY12 (June 2012) functionality reached 88.5%, however new inventory data has resulted in a drop of overall program status.

Key program components and structures exemplify a strategic approach to meet NPDES permit requirements, allowing for the enhancement of SWM facility performance efficiency and reducing the pollutant loads contained in highway runoff, significantly improving water quality in the sensitive Chesapeake Bay watershed and the sub-watersheds therein.

APPENDIX A:

Progress Report: Field Evaluation of Wet Infiltration Basin Transitional Performance

Progress Report: Field Evaluation of Infiltration Basin Transitional Performance

Project Duration: June 2009 - July 2012

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Executive Summary

Urban stormwater runoff is a recognized non-point source of pollution of surface waters in the United States. Stormwater runoff washes off pollutants such as suspended solids, nutrients, and heavy metals accumulated on roadways and parking lots which can degrade the water quality of the receiving water bodies. Not only is the water quality impacted, but also the increased runoff volume from impervious surfaces can alter stream hydrology. These modifications can result in the overall degradation of the stream ecosystem. Onsite control of runoff through stormwater control measures (SCMs) such as infiltration basins have been increasingly adopted to slow and treat runoff before it reaches the streams. Infiltration basins provide hydrology and water quality benefits through runoff detention and filtration of pollutants.

While limited performance information is available for stormwater infiltration basins, high failure rates have been reported for these facilities. Over the years, inspections have shown that many infiltration basins constructed in Maryland exhibit inappropriate ponding of water, reduced infiltration rates, and progressive failure. Although the failed basins may not be functioning as originally intended and designed, the failed infiltration basins may possibly be "transforming" into a new ecosystem that possesses both beneficial hydrology and water quality functions.

The purpose of this field-scale research is to fully monitor, research, and document the hydrology and water quality performances of a failed infiltration basin facility that has naturally transformed into a stormwater wet pond or wetland site. The study site receives runoff from a highway and is located in Howard County, Maryland. The flow characteristics and water quality at the infiltration basin were monitored during storm events and periods subsequent to it. Ancillary benefits such as habitat are also being documented.

A total of 176 storm events have been monitored at the study site to date. In general, the hydrology data indicate that the failed infiltration basin is effective in managing runoff flows. The infiltration basin assimilated the entire inflow volume and did not produce any outflow for 53 % of the monitored events. The overall volume reduction achieved through the infiltration basin for the entire monitoring duration was 18 %. Flow delays and peak attenuation (median peak reduction= 43 %) were observed during storm events that produced outflow from the infiltration basin.

Runoff water quality at the study site was monitored during storm events and selected dry-weather periods. Totally, 38 storm events and 54 dry-weather water quality samplings were performed. Levels of total suspended solids (TSS), total phosphorus (TP), nitrate and nitrite nitrogen (NO_x-N), ammonium, total Kjeldahl nitrogen (TKN), total copper, lead, and zinc, and chloride were measured in the samples.

Improvements in water quality were observed during both storm events and dry-weather periods. The event mean concentrations (EMCs) in the outflow were lower than those of inflow in all storm events for all measured pollutants, the exception being one winter event for TKN and six events for chloride. The outflow EMCs of total suspended solids, oxidized nitrogen (nitrite and nitrate), and heavy metals (copper, lead, and zinc) met the selected water quality criteria for majority of the events monitored; only total phosphorus did not meet the selected discharge criterion for any storm event.

From a load perspective, pollutant mass reductions for all pollutants occurred during 35 of the 38 monitored storm events. The poorest performances were observed during two winter events (January 2010, and Dec 8, 2011) and one early spring event (March 2011) that exhibited export of nutrients and heavy metals. The overall pollutant mass removal efficiencies for the entire monitoring duration were TSS 89 %, TP 61 %, NO_x-N 79 %, TKN 51 %, total N 64 %, total Cu 73 %, total Pb 63 %, total Zn 55 %, and chloride 45 %. A significant part of this mass removal is attributed to 30 % volume reduction during the 38 monitored storm events.

Both hydraulics and pollutant removal performances of the infiltration basin exhibited seasonal trends. Factors such as antecedent dry period, rainfall size and duration, and loss of water through evapotranspiration and possibly infiltration can be seasonally important and thus influence the hydrologic behavior of the infiltration basin SCM during a storm event. The water quality performance can be related to the hydrologic behavior of the infiltration basin in addition to factors such as pollutant characteristics and environmental conditions within the basin. The poorest water quality performance was observed during winter due to change in basin hydraulics in the presence of ice, lower loss of water due to evapotranspiration and infiltration, and decreased biological activity in low temperatures.

Ancillary benefits such as habitat to plants and wildlife are also being recorded. The hydrology, water quality, and habitat conditions at the study site will be evaluated jointly to determine the overall ecological value of the failed infiltration basin SCM.

This research study will thus determine the functionality of a failed infiltration basin in managing roadway runoff from a stormwater management perspective. If the “failed” basin is found to provide hydrology benefits and water quality enhancements in its existing condition, similar sites may be classified as functioning, stormwater management practices. The research and performance information obtained from this research will significantly contribute to the knowledge base of innovative stormwater management practices. The research will enable improved understanding of the performances of infiltration-based and similar SCM facilities and will lead to better designs, more widespread, reliable implementation, and ultimately improved environmental quality.

Table of Contents

1.0 Background

Functionality of "failed" infiltration basins in mitigating stormwater runoff flows and treating the runoff is not known. The objective of this research study is to systematically quantify the hydrologic and water quality performances of a failed infiltration basin. The research is based on the hypothesis that a separate ecological function may develop in the failed infiltration basins. The failed infiltration basins can gradually transform into a wet pond or wetland-like practice with abilities to slow runoff as well as provide water quality enhancements.

Monitoring of the study site, located in Columbia, Maryland, began in July 2009. The study site has been monitored continuously for runoff flows, and for water quality during selected storm events. Rainfall depth, water level in the infiltration basin, and temperature, pH, conductivity and oxidation reduction potential of the water column are also continuously monitored. The flora and fauna at the site are also being recorded to assess the ecological value of the site.

This report documents the research progress from February through July 2012. Results from the hydrology and water quality monitoring at the site for this period are presented in this report. This report serves as an addendum to previous progress reports (July 2009 to January 2012). The previous progress reports must be referred to for research background, methodology, and earlier results from this research study.

2.0 Research progress

Totally, 176 rainfall events have been recorded between June 2009 and July 2012. This does not include rainfall events with 0.01 inch rainfall depth. The 0.01 inch rainfall depth corresponds to one rain gauge tip which could be due to equipment malfunction or moisture conditions. Hence, all 0.01 inch rainfall events were ignored. Of the 176 monitored rainfall events, 49 events did not produce any inflow to the site and were excluded, thereby reducing the sample size to 127 rainfall events. Thirty eight rainfall events have been sampled for water quality and 54 dry-weather sampling excursions have been performed to date. Rainfall depths and runoff flows have been continuously monitored for the period Oct 15 to Dec 4, 2009, and from Mar 25, 2010 to July 31, 2012. No hydrology and water quality data are available for winter periods when the infiltration basin was completely frozen (late Dec 2009 through early Mar 2010; late Dec 2010 until early Feb 2011). Details of antecedent dry period, rainfall depth and duration, and inflow and outflow volumes recorded during each storm event are summarized in Table 1.

Table 1. Hydrology data recorded at the study site from June 2009 to July 2012.

Event	**Antecedent dry period (days)**	**Rainfall depth (inches)**	**Rainfall duration (hours)**	**Inflow volume ($\times 10^3 gal$)**	**Outflow volume ($\times 10^3 gal$)**
8/13/2009 [a]	2	0.94	1.13	28	0
8/21/2009 [a]	2	0.64	14.9	11	0
9/26/2009 [a]	1	1.28	16.6	47	21

Event	Antecedent dry period (days)	Rainfall depth (inches)	Rainfall duration (hours)	Inflow volume ($\times 10^3 gal$)	Outflow volume ($\times 10^3 gal$)
10/15/2009	17	2.87	71.6	171	133
10/24/2009	6.3	0.40	8.1	14	12
10/27/2009	2.1	1.82	33.4	125	146
11/1/2009	3.4	0.45	12.3	31	17
11/11/2009	10	1.12	36.6	68	36
11/13/2009	0.7	0.36	1.93	17	10
11/19/2009 [a]	6	0.61	8.5	33	35
11/23/2009	3	0.83	22.1	86[++]	78[++]
11/25/2009	0.7	0.17	10.8		
11/26/2009	0.9	0.12	5.0		
11/30/2009	3.3	0.22	7.1	9	0
12/2/2009	1	0.82	19.3	52	63
1/18/2010 [a]	16	0.63	13.4	52	73
3/26/2010 [a]	3.3	0.31	11.7	9	0
3/28/2010	2.4	0.5	11	26	13
3/30/2010	1.3	0.1	3.5	5	0
4/21/2010	7	0.3	3.0	3	0
4/25/2010 [a]	4	0.96	15.4	40	13
5/3/2010	6	0.23	2.7	2	0
5/11/2010	7	0.20	1.67	0	0
5/12/2010	1	0.47	1.6	15	0
5/18/2010	0.5	0.18	9.83	1	0
5/23/2010 [a]	4	0.40	3.47	7	0
5/27/2010	4	0.37	2.3	6	0
6/3/2010	2	0.25	0.9	0	0
6/6/2010	2	0.12	0.53	0	0
6/9/2010	2	0.09	1.83	0	0
6/28/2010	19	0.48	0.53	0	0
7/10/2010	10	0.32	5.37	0	0
7/12/2010	2	0.55	0.80	3	0
7/12/2010 [a]	0.25	0.96	1.57	14	0
7/13/2010	0.75	1.70	7.37	94[++]	51[++]
7/14/2010	0.29	0.11	1.17		
7/18/2010	4.5	0.17	0.67	0	0
7/25/2010	6.5	0.39	0.33	0.21	0
8/4/2010	9.6	0.71	1.77	10	0
8/5/2010	0.83	0.08	3.67	0	0

Event	Antecedent dry period (days)	Rainfall depth (inches)	Rainfall duration (hours)	Inflow volume ($\times 10^3 gal$)	Outflow volume ($\times 10^3 gal$)
8/12/2010	8.1	1.06	0.93	30	0
8/13/2010 [a]	0.67	1.04	6.37	69	63
8/15/2010	2.2	0.33	3.13	9	8
8/18/2010	2.6	0.96	6.47	50	47
8/22/2010	4.1	0.28	0.47	1	0
8/23/2010	0.79	1.16	2.67	75	71
9/12/2010	19	0.42	11.9	0	0
9/16/2010	4	0.29	14.1	0	0
9/27/2010 [a]	9.8	0.92	25.6	15	0
9/29/2010	2	3.70	25.3	253	223
10/14/2010	9	0.89	6.23	27	24
10/19/2010	4	0.42	5.13	12	14
10/27/2010 [a]	7	0.61	12.0	18	8
11/15/2010	10	0.78	31.7	22	18
11/25/2010	7	0.05	2.57	0	0
11/302010	4	0.06	4.4	0	0
12/1/2010 [a]	12	0.56	6.20	25	18
12/11/2010	10	0.77	22.5	43	31
12/18/2010	6	0.03	1.87	0	0
2/24/2011 [a]	1	0.43	14.2	33	32
2/28/2011	2	0.45	18.7	25	27
3/9/2011 [a]	2	2.21	26.3	203	268
4/5/2011	3	0.28	7.37	8	0.15
4/8/2011	2	0.33	12.1	14	0.072
4/12/2011	3	0.31	6.87	10	0
4/13/2011	-	0.18	11.3	10	0
4/16/2011	2	0.90	12.7	50	38
4/19/2011	2	0.11	5.0	0	0
4/22/2011 [a]	2	0.33	23.5	6	0
5/4/2011	8	0.42	8.00	10	0
5/14/2011 [a]	9	0.38	3.17	5	0
5/17/2011	2	0.26	6.87	20[++]	0
5/17/2011	-	0.17	1.6		
5/18/2011	-	0.24	2.60	11	2
5/19/2011	-	0.14	2.87	4	0
6/9/2011 [a]	20	0.83	0.67	14	0
6/10/2011	-	0.21	0.50	2	0

Event	Antecedent dry period (days)	Rainfall depth (inches)	Rainfall duration (hours)	Inflow volume ($\times 10^3 gal$)	Outflow volume ($\times 10^3 gal$)
6/12/2011	1	0.13	0.17	0	0
6/16/2011	5	0.11	0.37	0	0
6/18/2011	-	0.09	0.67	0	0
6/20/2011	1	0.10	4.90	0	0
6/21/2011	-	0.04	0.17	0	0
7/3/2011	4	0.31	2.87	0	0
7/3/2011	-	0.22	0.30	0	0
7/7/2011 [a]	3	0.34	2.03	12	0
7/8/2011	-	0.44	2.23	10	0
7/11/2011	2	0.08	0.17	0	0
7/19/2011	5	0.16	0.57	0	0
7/25/2011 [a]	5	1.82	2.33	54	0
8/1/2011	6	0.12	0.27	0	0
8/3/2011	1	0.35	0.70	0	0
8/6/2011 [a]	2	0.94	2.03	46	18
8/7/2011	-	0.16	0.27		
8/9/2011	1	0.14	0.17	0	0
8/13/2011	3	0.35	3.53	3	0
8/14/2011	-	0.62	4.37	43++	37++
8/14/2011	-	0.41	3.53		
8/15/2011	-	0.13	4.87		
8/21/2011	5	0.24	0.30	0	0
8/21/2011	-	0.90	0.90	46	49
8/25/2011	3	0.16	2.03	1	0
8/27/2011	1	3.16	28.9	303	378
9/5/2011	7	8.53	91.1	926	971
9/11/2011	1	1.55	9.03	125	146
9/20/2011	8	0.07	4.07	0	0
9/21/2011 [a]	9	0.32	3.70	22	8
9/28/2011	4	0.41	1.73	36++	37++
9/28/2011	-	0.40	2.13		
10/1/2011	2	0.31	10.1	13	2
10/3/2011	0.8	0.06	7.40	0	0
10/12/2011 [a]	8	0.53	21.2	39	0
10/13/2011	-	0.13	0.40		
10/14/2011	-	0.34	4.07		
10/19/2011	4	0.45	5.53	37++	34++

Event	Antecedent dry period (days)	Rainfall depth (inches)	Rainfall duration (hours)	Inflow volume ($\times 10^3 gal$)	Outflow volume ($\times 10^3 gal$)
10/19/2011	-	0.30	7.70		
10/26/2011	6	0.06	0.63	0	0
10/27/2011	-	0.16	4.5	0	0
10/28/2011	-	0.84	19.7	57	47
11/16/2011	17	0.11	1.70	0	0
11/16/2011 [a]	-	0.24	12.3	7	0
11/22/2011	5	1.38	20.8	132	92
11/29/2011	5	0.32	5.63	23	9
12/6/2011	6	0.13	18.6	2	0
12/7/2011 [a]	-	2.14	19.5	194	220
12/22/2011 [a]	14	0.82	7.87	55	31
12/27/2011	3	0.73	10.7	64	56
1/11/2012	10	0.96	16.8	69	56
1/16/2012 [a]	3	0.15	16.3	6	0
1/21/2012 [a]	3	0.22*	0.20*	5	0
1/23/2012 [a]	1	0.06	1.80	10	0
1/27/2012 [a]	3	0.26	2.40	8	2
2/4/2012	7	0.23	18.4	4	0
2/8/2012	3	0.09	8.43	2	0
2/10/2012	2	0.23	7.87	7	0
2/16/2012 [a]	5	0.15	9.03	4	0
2/24/2012	7	0.16	6.83	2	0
2/29/2012 [a]	4	1.79	15.4	141	101
3/2/2012 [a]	1	0.55	15.6	50	36
3/19/2012	16.8	0.04	6.10	0	0
3/24/2012	4	0.37	26.4	5	0
4/1/2012	7	0.08	5.47	0	0
4/18/2012	16.5	0.19	10.6	0	0
4/21/2012	2	0.26	3.73	0	0
4/22/2012 [a]	0.42	1.15	23.3	61	0
4/26/2012	3	0.14	1.13	1	0
4/28/2012	1	0.08	9.37	0	0
5/2/2012	3	0.21	0.30	3	0
5/3/2012	1.7	0.05	0.77	0	0
5/8/2012	7.5	0.08	1.63	0	0
5/8/2012	0.29	0.17	6.23	1	0
5/9/2012	0.5	0.41	8.07	12	0

Event	Antecedent dry period (days)	Rainfall depth (inches)	Rainfall duration (hours)	Inflow volume ($\times 10^3 gal$)	Outflow volume ($\times 10^3 gal$)
5/14/2012 [a]	4	1.04	24.67	42	0
5/20/2012	5.9	0.43	15.20	5	0
5/24/2012	3	0.08	0.47	0	0
5/27/2012	3.8	0.12	2.17	0	0
5/29/2012	1.8	0.37	14.17	3	0
6/1/2012	2	2.24*	8.08*	231	208
6/12/2012 [a]	10	0.62	11.47	5	0
6/22/2012	10	0.05	0.6	0	0
6/25/2012	3	0.05	0.27	0	0
6/29/2012	4	0.47	2.47	0	0
7/2/2012	1	0.08	12	0	0
7/9/2012	6	0.47	5.03	0	0
7/14/2012	4.5	0.84	2.23	19	0
7/15/2012	0.7	0.06	0.47	0	0
7/19/2012	4	1.34	3.5	36	0
7/20/2012 [a]	0.83	2.08	24.2	172	138

[a] Rainfall event sampled for water quality
[++]Flows have been combined since continuous flow occurred during this period.
*Estimated based on weather station near the study site

For the purpose of definition, a new rainfall event is defined as an event occurring six hours after the end of the preceding event. Occasionally, outflow from the infiltration basin continued for extended periods, overlapping the next rainfall event. In such cases, the flow volumes of the two events were combined during all analyses. This resulted in reducing the sample size of rainfall events from 127 to 113 during analysis. In some instances, the rainfall duration exceeded the sampling period. For such events, the hydrology data reported include flows to and from the infiltration basin from the start of the rainfall event until the flows ceased. While performing pollutant mass loading calculations, concentration of the unsampled volume is assumed to be equal to half the concentration of the last sample collected as a conservative estimate. In the event that the duration of flows was much longer than the sampling duration, judgment was used regarding the inclusion of the water quality data towards quantitative determinations.

The hydrology and water quality performances of the infiltration basin were evaluated on an event basis as well as on seasonal basis. The months have been classified as: September to November as fall, December to February as winter, March to May as spring, and June to August as summer.

2.1 Rainfall distribution

Rainfall depth, duration, and frequency analysis was performed for the data recorded at the MD 175 infiltration basin site and the rainfall distribution is shown in Table 2. Also included in Table 2 is the historical rainfall distribution for Maryland (Kreeb 2003) for comparison.

Table 2. Rainfall distribution for MD 175 infiltration basin site and for Maryland (Kreeb 2003). The top most row is the rainfall depth range (in inches), and the left most column is the rainfall duration (in hours).

Total depth (inch)	0.01 -0.10	0.11-0.25	0.26-0.50	0.51-1.00	1.00 <	MD 175 Sum	15 stations MD
0-2 hr	0.0565	0.0791	0.0226	0.0169	0.0056	**0.1808**	**0.3290**
2-3 hr	0.0282	0.0282	0.0169	0.0169	0.0000	**0.0904**	**0.0756**
3-4 hr	0.0169	0.0395	0.0452	0.0113	0.0169	**0.1299**	**0.0627**
4-6 hr	0.0339	0.0282	0.0791	0.0056	0.0056	**0.1525**	**0.1234**
7-12 hr	0.0282	0.0621	0.0621	0.0508	0.0226	**0.2260**	**0.1818**
13-24 hr	0.0000	0.0113	0.0452	0.0621	0.0339	**0.1525**	**0.1616**
24< hr	0.0000	0.0000	0.0056	0.0113	0.0508	**0.0678**	**0.0659**
MD 175 Sum	**0.1638**	**0.2486**	**0.2768**	**0.1751**	**0.1356**	**1.000**	**1.000**
15 stations MD	**0.3287**	**0.1461**	**0.2131**	**0.1741**	**0.1373**	**1.000**	

Overall, the rainfall distribution at the study site are in good agreement with the historical data, especially for rainfall depths (0.26-0.5) and larger (0.5-1.0 and >1.0 inches). The major difference in distribution at the two sites is for the low rainfall depth (0.01-0.1 inch) and durations. Statistical analysis will be performed to determine the similarity of the two rainfall distribution characteristics.

2.2 Hydrology

2.2.1 Hydrologic performance

After eliminating events which did not produce any inflow to the site and then combining events when flows overlapped, the sample size of rainfall events was reduced from 176 to 113 events. The hydrologic performance metrics were computed based on these 113 events.

Figure 1 shows sample inflow and outflow hydrographs recorded during different storm sizes and seasons. The decrease in peak flow, delayed outflow, reduced volume leaving the system, and longer outflow recession limb can be seen in the sample hydrographs presented in Figure 1a. The hydrograph in Figure 1b was recorded during a heavy thunderstorm in summer 2012. During this event, the infiltration basin retained the entire inflow runoff and no discharge was observed.

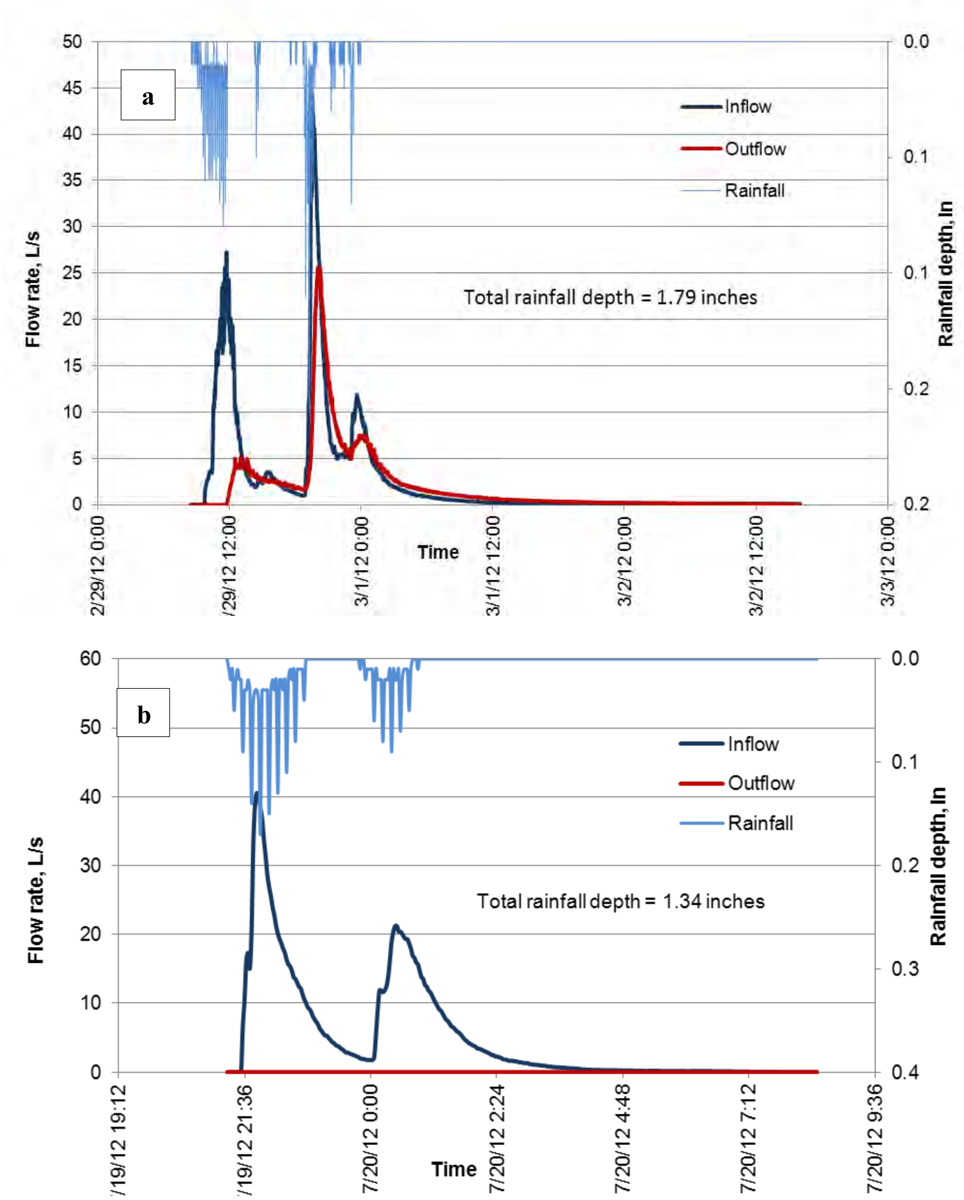

Figure 1. Hydrographs recorded during rainfall events on **a.** Feb 29, 2012 **b.** July 19, 2012 (no outflow) at the MD175 infiltration basin study site.

Peak flow attenuation was observed during most storm events. For each event, the maximum inflow and outflow rates were compared using the flow peak ratio, R_{peak}, computed as:

$$R_{peak} = \frac{Q_{peak-out}}{Q_{peak-in}} \qquad (1)$$

where, $Q_{peak-in}$ and $Q_{peak-out}$ are the measured peak stormwater runoff flow rate at the inlet and outlet, respectively, during the rainfall event (Davis 2008). For the 53 events that produced outflow, the R_{peak} ranged between 0.01 and 1.2; the mean R_{peak} was 0.45 and the median was 0.43.

The infiltration basin assimilated the entire inflow volume and did not produce any outflow (100% volume reduction) for 53% of the events. The infiltration basin is capable of detaining the runoff for a period depending on the pre-event storage volume and the inflow volume. Smaller runoff volumes were thus completely retained in the facility. For the 53 events during which outflow occurred, the outflow volumes were lower than the inflow volume for 40 events. The reduction in volume ranged between 4 and 82% for these events; the mean reduction in volume was 31%. The outflow volumes exceeded the inflow volumes during 13 rainfall events. The additional volume of water can possibly be contributed by direct flow from the banks of the infiltration basin, especially during large rainfall events and extended wet periods.

The total inflow and outflow volumes recorded for 113 events were 5,265,463 and 4,338,951 *gallons*, respectively. Normalizing the runoff volumes over the entire drainage area, this corresponds to total runoff depth of 30 inches of runoff input and 22.2 inches discharged from the infiltration basin. The total runoff volume reduction was 18 % for the entire monitoring duration.

The combined influence of factors such as rainfall intensity and duration, antecedent dry period, and season on the hydrological behavior of the infiltration basin was observed throughout the monitoring period. Figure 1a is a hydrograph of a storm event in winter and Figure 1b is the hydrograph of a storm event in summer. While 28 % volume reduction was observed during the winter storm event, 100% of inflow volume was captured for a similar large rainfall event in summer.

Figure 2 is a plot showing the inflow and outflow volumes recorded during 106 rainfall events at the study site. A 1:1 line is also plotted in the figure. The data are differentiated with different colors and symbols based on seasons.

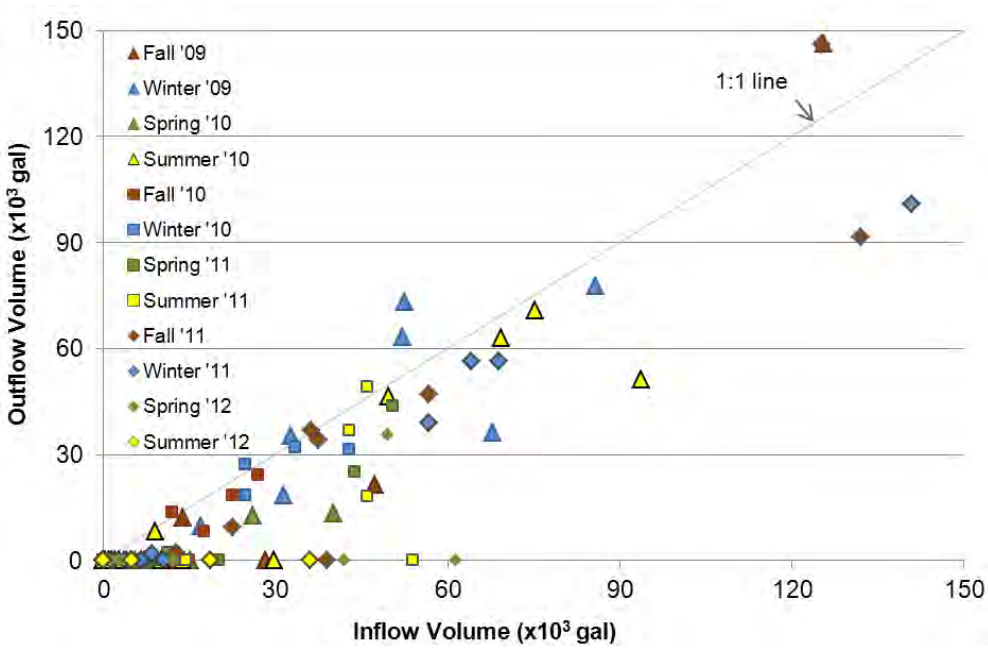

Figure 2. Inflow-outflow characteristics for 106 out of 113 rainfall events recorded at the MD175 infiltration basin site from June 2009 to July 2012. (Seven large storm events were excluded to clearly show the distribution of the data in this plot).

In Figure 2, most of the points lie below the 1:1 line suggesting that reduction of runoff volume was achieved for those events. The antecedent dry period and season influence the volume of runoff to the site. For instance, a few rainfall events, especially in June and July 2010, 2011, and 2012, produced smaller or no runoff flows to the facility owing to long dry periods between the events. The entire runoff volume from most of the smaller rainfall events was detained in the infiltration basin. For the same inflow runoff volume, the reduction in discharge volume achieved in spring and summer was higher than that in late fall or winter. The dry duration between two events, combined with the effects of evapotranspiration and infiltration from the system influenced the volume of water detained in the system and hence the volume reduction achieved through the infiltration basin.

2.2.2 Estimation of evapotranspiration and infiltration

Continuous basin water level data are available from April 2010 through July 2012, except for a brief period in June 2010 and June-July 2011 when the water level in the infiltration basin dropped below the probe until the probe was re-installed at a different location within the basin. The daily water loss rate is calculated as the decrease in water level in 24 hours for a dry day. Figure 3 shows the water loss for April 2012.

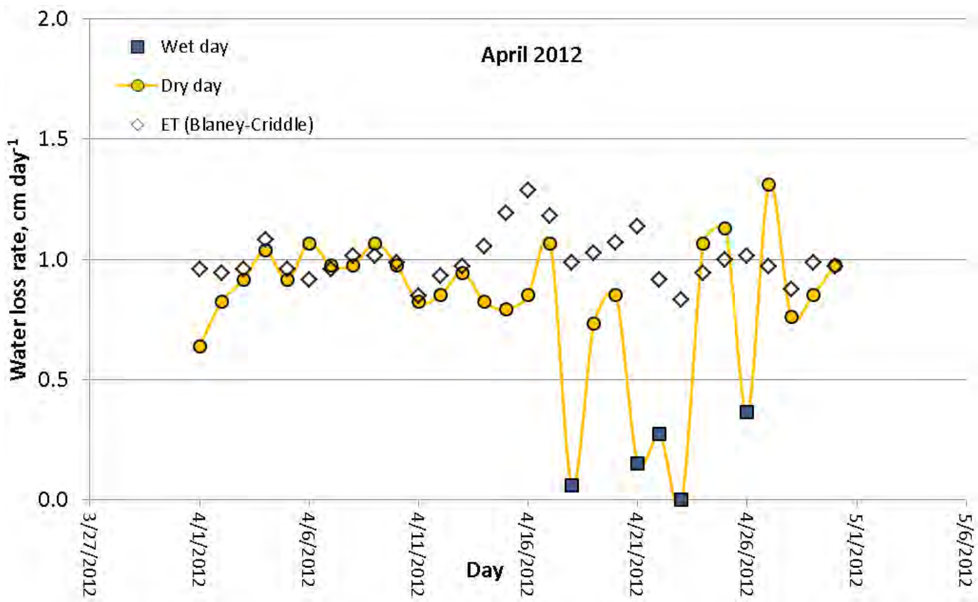

Figure 3. Measured and calculated water loss at the infiltration basin in April 2012.

As a preliminary estimate, the evapotranspiration (ET) has been estimated using the Blaney-Criddle formula for reference crop evapotranspiration (Hargreaves and Samani 1982):

$$ET_0 = p\,(0.46\,T_{mean} + 8) \qquad (2)$$

where, ET_0 (*mm/day*) is reference crop evapotranspiration; p is the mean daily percentage of annual daytime hours, and T_{mean} (°C) is the mean daily temperature. The estimated ET is also plotted Figure 3. The water loss on a wet day has been differentiated from the dry days (darker square markers in the plot). For a wet day, the water loss is computed prior to the event or ignored if inflow and outflow occur during the day. Figure 3 shows that the calculated daily water losses from the infiltration basin match well with the estimated ET for the dry days during April 2012.

The mean daily water loss rate, and monthly water loss and evapotranspiration totals for the dry days from April 2010 through July 2012 are summarized in Table 3. Table 3 shows that the water loss rate was highest in summer and decreased in the following months. The ET (estimated using Blaney-Criddle equation) accounts for most (although sometimes >100%) of the water loss from the infiltration basin during the dry periods. The total dry day water loss and total estimated ET for the entire monitoring duration are also included in Table 3. The total estimated ET accounts for 93 % of the total water loss from the infiltration basin during the dry days for the entire monitoring period. Hence, it appears that evaporation is the major component of water loss from the infiltration basin and infiltration appears to be negligible.

Table 3. Summary of water loss and ET estimates at the site from April 2010 through July 2012.

Column (1)	Column (2)	Column (3)	Column (4)	Column (5)	Col (5) /Col (4)
Month of year	**Number of dry days**	**Mean dry day water loss rate (*in day*$^{-1}$)**	**Dry day water loss total (*in*)**	**Dry day ET* total (*in*)**	$ET/_{Water\ loss}$
April 2010	25	0.45	11.2	10.3	0.92
May 2010	26	0.5	12.9	12.6	0.97
June 2010	24	n/a	n/a	n/a	n/a
July 2010	20	0.57	11.6	11.9	1.02
Aug 2010	19	0.56	10.7	9.8	0.92
Sep 2010	24	0.39	9.92	11.5	1.16
Oct 2010	20	0.45	9.06	8.23	0.91
Nov 2010	24	0.29	7.17	7.95	1.11
Feb 2011	23	0.37	7.33	5.92	0.81
Mar 2011	22	0.52	10.4	6.68	0.64
Apr 2011	17	0.56	8.95	6.86	0.77
May 2011	24	0.5	11.9	11.1	0.93
June+ 2011	22	0.48	9.66	4.45	0.46
July+ 2011	20	0.5	11.0	5.32	0.48
Aug 2011	19	0.6	11.4	9.59	0.84
Sep 2011	18	0.41	7.43	8.33	1.12
Oct 2011	19	0.39	7.39	7.72	1.04
Nov 2011	21	0.30	6.24	7.61	1.22
Dec 2011	22	0.30	6.52	7.20	1.20
Jan 2012	24	0.29	7.01	7.09	1.01
Feb 2012	23	0.25	5.75	7.35	1.28
Mar 2012	25	0.36	8.96	9.69	1.08
Apr 2012	26	0.35	9.14	9.88	1.08
May 2012	24	0.44	10.64	11.14	1.05
June 2012	25	0.53	13.13	12.29	0.94
TOTAL			**225.4**	**210.5**	**0.93**

*ET estimated using Blaney-Criddle equation (Equation 2); n/a: no data; +excluding days on which data was unavailable

The Blaney-Criddle method provides only a rough estimation of ET and can be highly inaccurate for extreme climatic conditions (windy, dry, and sunny vis-à-vis calm, humid, and clouded) (Brouwer and Heibloem 1986). Therefore, it is proposed to employ a more rigorous model such as the modified Penman method to model the ET at the site. The Penman-Monteith model is a combination of mass-transfer and energy balance approaches that has been widely used by several researchers to estimate evapotranspiration (Dingman 1994; Kadlec and Knight 1996; Lott and Hunt 2001; Jacobs *et al.* 2002).

The input data for the Penman-Monteith model include air temperature, wind speed, atmospheric pressure, and humidity and are available at 10-minute intervals at a weather station about 3 miles away from the study site. Solar radiation data are available at hourly resolution for the geographic coordinates of the site (39.193,-76.814) through the GOES Surface and Insolation products database provided by NOAA. The input data extraction and Matlab coding of the model are currently in process.

2.2.3 Flow duration curves

The cumulative duration of runoff flows at the study site can be illustrated using a flow duration curve. The flow rate time series recorded at 2-minute intervals were ranked from the highest to the lowest flow rate values for the duration of interest. The ranked series was plotted against time to develop the flow duration curve. The flow durations were developed for each season: Winter (Dec to Feb); Spring (Mar to May); Summer (June to Aug), and Fall (Sep to Nov).

A study goal is to compare the flow durations at the study site with that of a reference site. For this study, Pond Branch, located in the Gunpowder Falls watershed in Baltimore County in Maryland, serves as the forested reference stream. The catchment area of Pond Branch is 94 *ac* and is 100% forested. Streamflow data for Pond Branch (in 15-minute intervals) are available via USGS and can be accessed at <http://waterdata.usgs.gov/md/nwis/nwisman?site_no=01583570>.

Rainfall data for the reference site are obtained from a rain gauge station located at Oregon Ridge Park. This rain gauge station is about 0.75 miles north of Pond Branch flow gage and about 32 miles from the study site. The precipitation records for this station are managed by the Center for Urban Environmental Research and Education, University of Maryland Baltimore County, and are available at <http://hydro2.umbc.edu/Precip/>.

The rainfall distribution at the MD 175 site and Oregon Ridge Park were compared to determine if the rainfall depths observed at the study site and reference site were comparable. Firstly, the rainfall depths and durations recorded at the two sites were compared for the current monitoring duration. Based on 147 rainfall events, a good agreement (correlation coefficient of 0.66) was observed for the rainfall depths at the two sites. Figure 4 shows the rainfall depth-duration-frequencies at the two sites. While Figure 4 shows that rainfall distributions at the two sites look similar for the most of the rainfall depth and duration ranges, the two distributions will be compared using a statistical test.

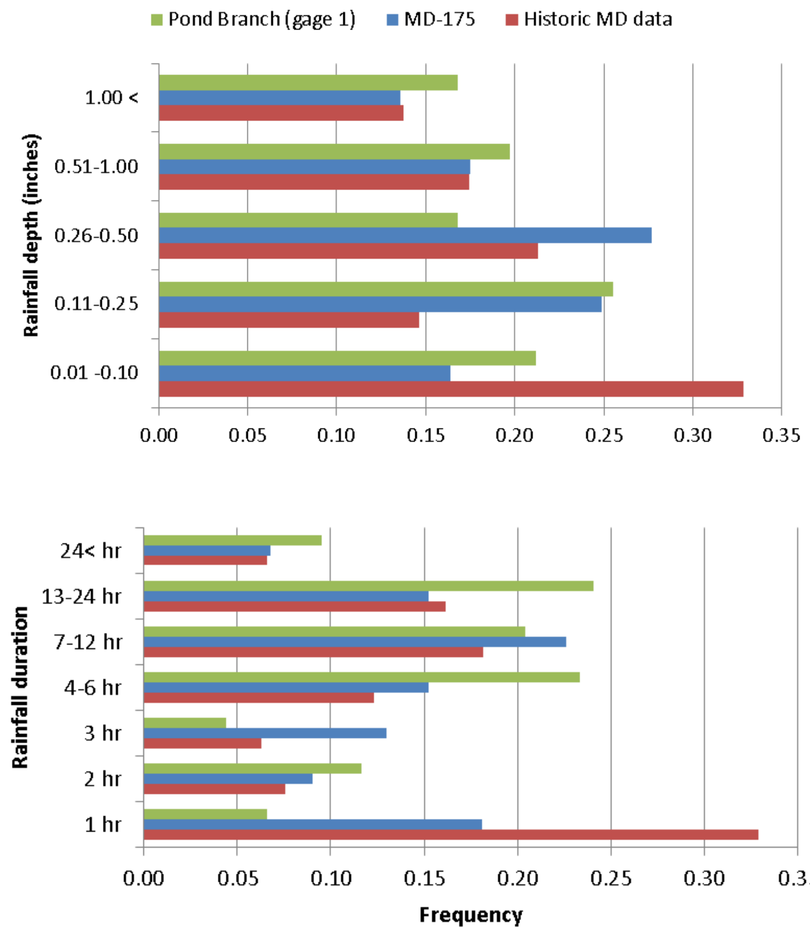

Figure 4. Rainfall depth-duration distributions for the MD 175 study site and Oregon Ridge (reference) site from Aug 2009 to July 2012. The historical rainfall distribution for Maryland (Kreeb 2003) has also been included in the plot.

The flow magnitudes at the sites were normalized by the respective total drainage areas to be expressed in $mm\ day^{-1}$. The Pond Branch stream maintains baseflow between storm events. The mode streamflow rate at Pond Branch was 0.49 $mm\ day^{-1}$ for the period Jan 2009 to July 2012. This mode value was selected as the baseflow and was subtracted from all recorded streamflow values. However, baseflow between storm events were not the same and this method of removing baseflow did not consistently eliminate baseflow. This resulted in very small flow values in the stream during dry periods. The flow durations at the Pond Branch stream were much longer compared to the MD175 infiltration basin site and these small flows were part of the tail end of the curve. Hence, this method was acceptable in the larger context. The reference flow duration curves were developed after removing baseflow from the streamflow data.

Figure 5 illustrates the flow durations observed at the study site along with the reference site Pond Branch (PB) flow durations during two seasons. Based on the flow durations observed since late Fall 2009, differences in flow magnitudes and durations were observed during all seasons.

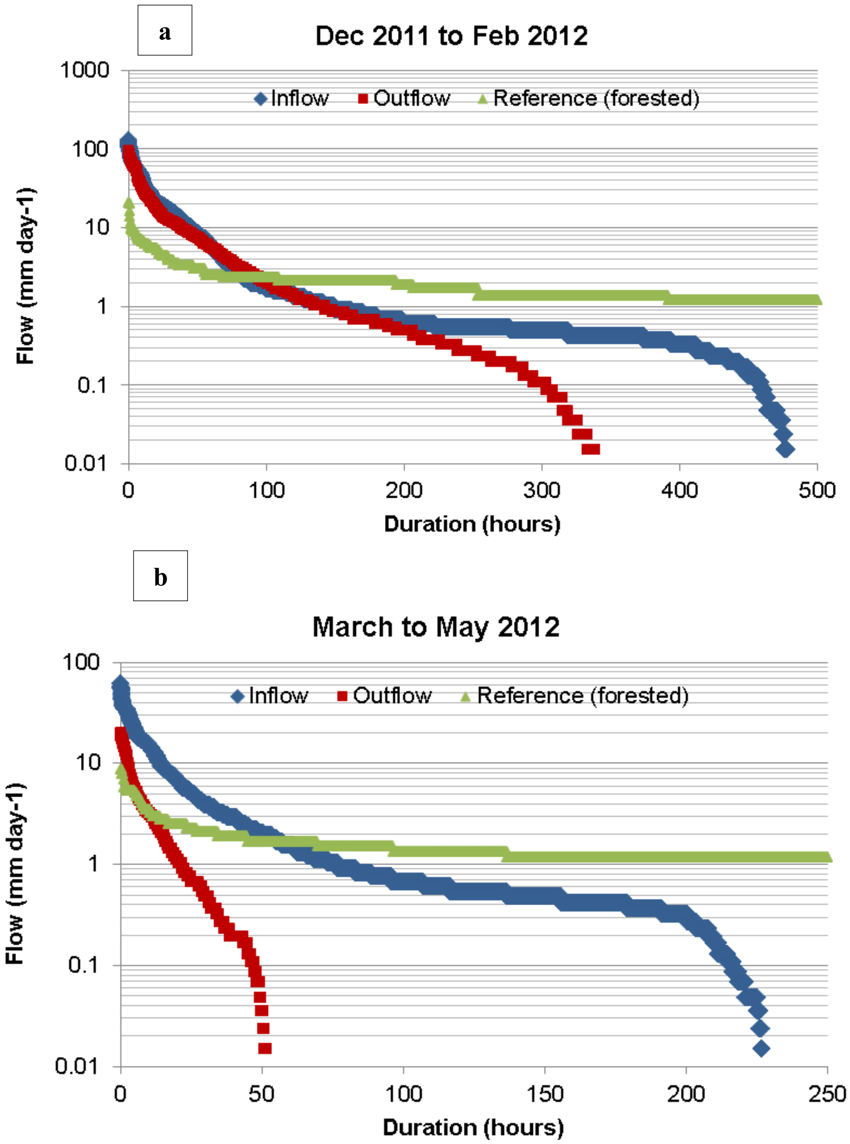

Figure 5. Flow duration curves for **a.** Winter 2011 (Dec 2011 to Feb 2012) **b.** Spring 2012 (Mar to May) at the MD 175 infiltration basin site. The plots also show the flow durations at the Pond Branch (PB) forested stream (reference site).

Firstly, the inflow and outflow durations at the study site were compared. As can be seen in Figure 5, the duration of flow magnitudes exhibit minimal differences during winter 2011 compared to spring 2012. Figure 5a shows that during winter, the inflow and outflow magnitudes are similar for most of the period until the flow magnitude falls below 0.6 $mm\ day^{-1}$. Two storm events recorded rainfall depths close to two inches in Dec 2011 and Feb 2012. Occurrence of such large storm events resulted in high magnitude flow rates and longer flow durations at the study site. During spring 2012, there were fewer storm events and longer intermittent dry periods. Thus the infiltration basin was able to assimilate most of the inflow, resulting in lower outflow magnitudes and much shorter flow duration (Figure 5b).

Shields *et al.* (2008) designated low- to moderate-flow conditions as < 1 *mm day*$^{-1}$ in their study on nitrogen export from urban and rural catchments. Pond Branch was used as the reference watershed in their study. Using the same criterion of < 1 *mm day*$^{-1}$ for low- to moderate flow conditions for the infiltration basin site, outflow magnitudes lower than 1 *mm day*$^{-1}$ can be considered as low flows. Long duration of low flows is acceptable from a pre-development hydrology perspective, as suggested by DeBusk *et al.* (2011). DeBusk *et al.* (2011) compared the bioretention outflows with inter-event flows in a stream draining an undeveloped watershed located in North Carolina. The study results indicated that the bioretention outflow rates mimicked the shallow interflow to streams after a storm event, thereby suggesting that the low outflow rates from a bioretention need not be considered as 'runoff'. The same argument can be applied to the infiltration basin where low discharge flows are observed for extended time periods.

The infiltration basin outflow durations were compared with Pond Branch flow durations to determine the effect of the infiltration basin in mitigating urban runoff flows. Overall, the infiltration basin peak outflow magnitudes (normalized per drainage area) were much higher than the Pond Branch peak flows. Pond Branch flows were at least one order magnitude lower than that of the infiltration basin discharges especially during winter 2011. Given the difference in sizes of the drainage areas and absence of baseflow at the study site, the total flow durations at Pond Branch were much longer compared to the flow durations at the study site. For instance, stream flow sustained for 3 months at Pond Branch (PB) compared to 55 hours for outflow from the infiltration basin in spring 2012. While PB flow magnitudes were below 1 *mm day*$^{-1}$ for two out of the three months during spring 2012, the infiltration basin outflow magnitudes remained lower than 1 *mm day*$^{-1}$ for 33 hours.

Thus, it can be deduced that flow durations in forested streams, although very long, are in low- to moderate- flow condition for majority of the time periods. This is expected for a "natural" hydrologic condition. The discharge flow magnitudes at the infiltration basin were higher than that of Pond Branch during a storm event which suggests that the infiltration basin may not be performing well in comparison to a forested site for high flows. However, the infiltration basin was effective in attenuating the high runoff flows from the highway during storm periods and discharged water at lower flow rate magnitudes that extended over a longer period of time. The storm characteristics combined with seasonal effects played major roles in influencing the discharge flow rate magnitudes and durations.

2.3 Water quality

2.3.1 Water quality performance

Seven storm event and 11 dry-weather samplings were performed during February through July 2012. A total of 38 storm event and 54 dry-weather samplings have been performed for the entire monitoring duration. For 27 storm events, the sampling program was designed to collect multiple samples spread over the entire hydrograph. Composite samples were collected during 11 out of the total 38 sampled storm events. Dry weather samples were collected from different locations in the infiltration basin using a swing sampler before and after a storm event. At each location, the samples were collected from the water column with efforts to not disturb the sediment bottom. All water samples were analyzed for the target pollutants (TSS, TP, nitrate, nitrite, TKN, total Cu, Pb, Zn, and chloride). In some cases, measurements for ammonium and dissolved phosphorus were additionally performed.

Of the 38 sampled storm events, outflow was produced during 15 events only. Water quality improvements during these 15 storm events that produced outflow are discussed in detail. In cases where the entire inflow volume was assimilated by the infiltration basin, the removal efficiency for all target pollutants is 100% for that event. For such events, performance of the infiltration basin was quantified using results of runoff sampling and grab samples collected from the basin after the event.

For each pollutant, the total mass (M) present in each storm event was calculated as:

$$M = \int_0^{T_d} Q\, C\, dt \qquad (3)$$

In Equation 3, Q is the measured runoff flow rate, C is the pollutant concentration, and T_d is the event duration. Substituting corresponding values of Q and C for inflow and outflow, the inflow and outflow mass loadings during an event were obtained, respectively. In cases where the concentration of a pollutant was below the laboratory analytical detection limit, a value equal to one-half of the detection limit was used for calculation and statistical purposes. Mass removal efficiency for a pollutant was calculated as:

$$M_R = \frac{(M_{in} - M_{out})}{M_{in}} \qquad (4)$$

where, M_{in} and M_{out} are the influent and effluent pollutant mass loadings calculated using Equation 3. The total pollutant mass removal through the infiltration basin was evaluated for each storm event.

The event mean concentration (EMC) was calculated as:

$$EMC = \frac{M}{V} = \frac{\int_0^{T_d} C\, Q\, dt}{\int_0^{T_d} Q\, dt} \qquad (5)$$

For composite water sampling, the measured concentration of a pollutant in the composite sample is the event mean concentration of that pollutant. When composite samples were taken, the pollutant mass was obtained by multiplying the measured EMC with the total runoff volume for that storm event.

Table 4 summarizes the water quality criteria for the target water quality parameters. The calculated EMCs and percent pollutant mass removals for all target pollutants are summarized for all events in Table 5. For the dry-weather samples, average concentration in the collected samples, along with the standard deviation is reported in Table 5.

Table 4. Criteria for various water quality parameters. All concentrations are in mg L^{-1}.

Pollutant	TSS	TP	Nitrate (as N)	Nitrite (as N)	TKN (as N)	TN (as N)	Lead	Copper	Zinc	Chloride
Water quality criterion	25[a]	0.05[a]	0.20[a]	1[c]	-	-	0.065[b]	0.013[b]	0.12[b]	250[c]

[a] Criteria for excellent water quality in the Potomac River Basin (Davis and McCuen 2005)
[b] Acute toxicity level (COMAR 2006)
[c] Secondary drinking water regulation (US EPA 2009)

Table 5. Water quality data of the sampled rainfall events and dry-weather samples at the study site from June 2009 to July 2012.

Event	TSS			TP			TKN (as N)			Nitrite + Nitrate (as N)		
	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)
6/24/2009 Dry-weather	65 ± 75			0.32 ± 0.23			2.5 ± 1.7			0.06 ± 0.0		
8/10/2009 Dry-weather	126 ± 107			0.45 ± 0.16			6.6 ± 4.1			0.08 ± 0.06		
8/13/2009 Storm event	181	0*	100	0.52	0*	100	1.5	0*	100	0.58	0*	100
8/21/2009 Storm event	44	0*	100	0.42	0*	100	2.6	0*	100	0.38	0*	100
9/26/2009 Storm event	39	1	98	0.43	0.06	93	1.5	0.93	72	0.96	0.05	97
10/04/2009 Dry-weather	7.6 ± 2.1			0.10 ± 0.06			1.5 ± 0.3			0.06 ± 0.0		
11/19/2009 Storm event	110	9	91	0.25	0.09	60	1.2	0.70	38	0.26	0.06	76
01/18/2010 Storm event	n/a~	n/a~		0.22	0.19	-16	1.3	0.92	-0.32	0.58	0.34	20
3/25/2010 Dry-weather	14 ± 2.1			0.08 ± 0.0			1.19 ± 0.10			0.07 ± 0.02		
3/26/2010 Storm event	72	0*	100	0.22	0*	100	2.1	0*	100	0.46	0*	100
4/24/2010 Dry-weather	16 ± 3.6			0.08 ± 0.0			1.4 ± 0.14			0.11 ± 0.03		
4/25/2010 Storm event	185	29	95	0.28	0.10	91	1.9	1.1	83	0.29	0.14	85
5/2/2010 Dry-weather	9 ± 1.5			0.08 ± 0.0			1.2 ± 0.3			0.22 ± 0.03		
5/22/2010 Dry-weather	15 ± 11			0.11 ± 0.06			0.49 ± 0.3			0.07 ± 0.03		
5/23/2010 Storm event	52	0*	100	0.34	0*	100	1.3	0*	100	0.18	0*	100
5/23/2010 Dry-weather	11 ± 6.6			0.12 ± 0.05			0.98 ± 0.2			0.06 ± 0.0		
6/15/2010 Dry-weather	6 ± 2.5			0.09 ± 0.01			0.89 ± 0.08			0.10 ± 0.05		
6/27/2010 Dry-weather	17 ± 3.3			0.14± 0.03			1.1 ± 0.06			0.06 ± 0.0		
7/9/2010 Dry-weather	44 ± 48			0.19 ± 0.07			2.1 ± 0.43			0.06 ± 0.0		
7/12/2010 Storm event	54	0*	100	0.58	0*	100	0.99	0*	100	0.86	0*	100
8/11/2010 Dry-weather	49 ± 30			0.16 ± 0.09			2.03 ± 0.89			0.06 ± 0.0		
8/12/2010 Storm event	47	0*	100	0.58	0*	100	1.39	0*	100	0.47	0*	100
8/12/2010 Dry-weather	9 ± 6			0.10 ± 0.04			1.33 ± 0.10			0.06 ± 0.0		
9/4/2010 Dry-weather	45 ± 28			0.21 ± 0.05			1.96 ± 0.0			0.05 ± 0.0		
9/26/2010 Dry-weather	45 ± 29			0.22 ± 0.14			2.08 ± 0.93			0.06 ± 0.0		
9/27/2010 Storm event	31	0*	100	0.44	0*	100	1.54	0*	100	0.32	0*	100

Event	TSS			TP			TKN (as N)			Nitrite + Nitrate (as N)		
	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)
9/27/2010 Dry-weather	49 ± 23			0.26 ± 0.10			3.66 ± 0.34			0.06 ± 0.0		
10/27/2010 Storm event	35	0*	100	0.42	0*	100	1.57	0*	100	0.12	0*	100
11/14/2010 Dry-weather	2 ± 0.71			0.13 ± 0.05			0.52 ± 0.05			0.06 ± 0.0		
11/17/2010 Storm event	14	0*	100	0.37	0*	100	1.2	0*	100	0.18	0*	100
11/17/2010 Dry-weather	9 ± 6.8			0.17 ± 0.10			0.98 ± 0.40			0.06 ± 0.0		
11/29/2010 Dry-weather	10			0.16 ± 0.06			0.49 ± 0.30			0.06 ± 0.00		
12/1/2010 Storm event	25	3	92	0.34	0.07	85	1.25	0.64	65	0.08	0.05	60
12/1/2010 Dry-weather	4			0.20 ± 0.10			0.7 ± 0. 0			0.06 ± 0.00		
2/24/2011 Dry-weather	22			0.09			0.98			0.01 ± 0.00$^+$		
2/24/2011 Storm event	58	13	79	0.12	0.08	40	0.97	0.98	5	0.03$^+$	0.004$^+$	87
2/25/2011 Dry-weather	22 ± 19			0.06 ± 0.01			0.77 ± 0.10			0.01 ± 0.00$^+$		
3/9/2011 Dry-weather	23 ± 2.7			0.21 ± 0.02			1.26			0.01 ± 0.00$^+$		
3/9/2011 Storm event	130	32	68	0.23	0.18	-3	1.01	0.86	-11	0.011$^+$	0.009$^+$	-0.37
3/11/2011 Dry-weather	75			0.19 ± 0.03			0.98			0.01 ± 0.00$^+$		
4/21/2011 Dry-weather	13 ± 3.5			0.10 ± 0.02			0.98			0.01 ± 0.00$^+$		
4/22/2011 Storm event	28	0*	100	0.21	0*	100	1.93	0*	100	0.03$^+$	0*	100
4/23/2011 Dry-weather	12 ± 6.2			0.08 ± 0.07			1.12			0.01 ± 0.00$^+$		
5/14/2011 Dry-weather	20 ± 14			0.19 ± 0.02			1.68			0.01 ± 0.00$^+$		
5/14/2011 Storm event	34	0*	100	0.36	0*	100	2.28	0*	100	0.02$^+$	0*	100
5/15/2011 Dry-weather	25 ± 9.9			0.17 ± 0.04			1.82			0.01 ± 0.00$^+$		
6/9/2011 Storm event	134	0*	100	0.60	0*	100	n/a~			n/a~		
7/7/2011 Storm event	48	0*	100	0.55	0*	100	2.18	0*	100	n/a~		
7/25/2011 Storm event	30	0*	100	0.37	0*	100	1.46	0*	100	0.03$^+$	0*	100
8/5/2011 Dry-weather	14 ± 2.8			0.27 ± 0.03			1.49			0.01 ± 0.00$^+$		
8/6/2011 Storm event	38	10	90	0.36	0.14	85	1.6	0.47	89	0.93	0.16	93
8/7/2011 Dry-weather	16 ± 4.9			0.25 ± 0.08			1.68			0.01 ± 0.00$^+$		
9/21/2011 Dry-weather	60 ± 29			0.18 ± 0.03			0.91 ± 0.1			0.13 ± 0.00$^+$		

Event	TSS			TP			TKN (as N)			Nitrite + Nitrate (as N)		
	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)
9/21/2011 Storm event	58	9	91	0.27	0.11	76	1.4	0.81	67	0.4	0.2	58
9/23/2011 Dry-weather	11 ± 1.1			0.16 ± 0.03			0.98 ± 0.0			0.08 ± 0.00		
10/10/2011 Dry-weather	15 ± 4.2			0.11 ± 0.02			0.98			0.06 ± 0.00		
10/12/2011 Storm event	52	0*	100	0.32	0*	100	1.5	0*	100	0.32	0*	100
10/13/2011 Dry-weather	55 ± 27			0.15 ± 0.07			1.82			0.06 ± 0.00		
11/15/2011 Dry-weather	6 ± 3.1			0.15 ± 0.07			0.93			0.06 ± 0.00		
11/16/2011 Storm event	36	0*	100	0.51	0*	100	1.88	0*	100	0.07	0*	100
11/17/2011 Dry-weather	8 ± 1.2			0.15 ± 0.03			1.12			0.06 ± 0.00		
12/06/2011 Dry-weather	8			0.11 ± 0.07			1.31			0.06 ± 0.00		
12/07/2011 Storm event	90	14	82	0.19	0.14	17	1.23	1.22	-13	1.01	0.22	85
12/09/2011 Dry-weather	5 ± 1.5			0.11 ± 0.004			2.24			0.21 ± 0.11		
12/20/2011 Dry-weather	5 ± 2.5			0.11 ± 0.01			0.84 ± 0.2			0.06 ± 0.00		
12/22/2011 Storm event	49	4	94	0.17	0.12	52	1.28	1.00	46	0.25	0.05	85
12/23/2011 Dry-weather	8 ± 2.3			0.11 ± 0.02			0.84 ± 0.2			0.06 ± 0.00		
01/16/2012 Storm event	40	0*	100	0.24	0*	100	1.47	0*	100	1.03	0*	100
01/21/2012 Storm event	33	0*	100	0.04	0*	100	1.26	0*	100	0.65	0*	100
01/23/2012 Storm event	13	0*	100	0.08	0*	100	1.26	0*	100	1.18	0*	100
01/24/2012 Dry-weather	92			0.14			1.12			0.13		
01/27/2012 Storm event	490	0*	100	0.14	0*	100	3.16	0*	100	0.89	0*	100
01/28/2012 Dry-weather	6 ± 1.1			0.12 ± 0.01			0.75			0.08 ± 0.00		
02/27/2012 Dry-weather	7 ± 1.1			0.06 ± 0.02			0.56			0.06 ± 0.00		
02/29/2012 Storm event	510	30	96	0.39	0.11	80	2.43	0.93	72	0.77	0.28	73
03/1/2012 Dry-weather	24 ± 3.5			0.11 ± 0.01			0.75			0.06 ± 0.00		
03/2/2012 Storm event	80	15	86	0.16	0.11	52	1.49	0.93	55	0.24	0.15	55
03/4/2012 Dry-weather	13 ± 0.76			0.09 ± 0.00			0.93			0.08 ± 0.04		
04/22/2012 Storm event	79	0*	100	0.27	0*	100	1.03	0*	100	0.29	0*	100
05/13/2012 Dry-weather	17			0.10			0.56			0.06		

Event	TSS			TP			TKN (as N)			Nitrite + Nitrate (as N)		
	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)
05/14/2012 Storm event	71	0*	100	0.23	0*	100	1.11	0*	100	0.13	0*	100
05/16/2012 Dry-weather	11 ± 0.71			0.10 ± 0.02			0.75			0.06 ± 0.00		
06/10/2012 Dry-weather	21 ± 3.5			0.16 ± 0.05			0.75			0.06 ± 0.00		
06/12/2012 Storm event	32	0*	100	0.30	0*	100	2.37	0*	100	0.15	0*	100
06/13/2012 Dry-weather	23 ± 13			0.26 ± 0.12			1.68			0.06 ± 0.00		
07/20/2012 Dry-weather	41 ± 46			0.36 ± 0.15			2.61			0.08 ± 0.03		
07/20/2012 Storm event	34	14	67	0.21	0.21	18	1.21	1.17	23	0.06	0.06	20
07/23/2012 Dry-weather	11 ± 11			0.25 ± 0.01			1.31			0.06 ± 0.00		

Table 5. (continued)

Event	Total Pb			Total Cu			Total Zn			Chloride		
	EMC_{in} (µg L^{-1})	EMC_{out} (µg L^{-1})	M_R (%)	EMC_{in} (µg L^{-1})	EMC_{out} (µg L^{-1})	M_R (%)	EMC_{in} (µg L^{-1})	EMC_{out} (µg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)
6/24/2009 Dry-weather	7 ± 2.7			6 ± 4			23 ± 13			13 ± 0.1		
8/10/2009 Dry-weather	4 ± 2.1			2 ± 2.8			13 ± 0.0			21 ± 0.14		
8/13/2009 Storm event	7	0*	100	11	0*	100	n/a~	0*		22	0*	100
8/21/2009 Storm event	5	0*	100	13	0*	100	55	0*	100	44	0*	100
9/26/2009 Storm event	2	2	48	10	2	93	47	11	90	79	19	89
10/04/2009 Dry-weather	3 ± 0.0			2 ± 0.0			n/a~			22 ± 0.55		
11/19/2009 Storm event	6	4	29	11	4	64	56	43	18	15	12	10
01/18/2010 Storm event	2	2	-28	5	4	-8	43	35	-13	647	522	-10
3/25/2010 Dry-weather	3 ± 0.0			3 ± 0.72			17 ± 9.1			444 ± 19		
3/26/2010 Storm event	6	0*	100	13	0*	100	58	0*	100	449	0*	100
4/24/2010 Dry-weather	3 ± 0.0			1 ± 0.7			13 ± 0.0			562 ± 86		
4/25/2010 Storm event	6	2	90	20	5	93	54	10	94	120	303	21
5/2/2010 Dry-weather	3 ± 0.0			1 ± 0.7			13 ± 0.0			427 ± 33		
5/22/2010 Dry-weather	3 ± 0.0			1 ± 0.93			21 ± 16			339 ± 14		
5/23/2010 Storm event	3	0*	100	16	0*	100	51	0*	100	113	0*	100

Event	Total Pb			Total Cu			Total Zn			Chloride		
	EMC_{in} ($\mu g\ L^{-1}$)	EMC_{out} ($\mu g\ L^{-1}$)	M_R (%)	EMC_{in} ($\mu g\ L^{-1}$)	EMC_{out} ($\mu g\ L^{-1}$)	M_R (%)	EMC_{in} ($\mu g\ L^{-1}$)	EMC_{out} ($\mu g\ L^{-1}$)	M_R (%)	EMC_{in} ($mg\ L^{-1}$)	EMC_{out} ($mg\ L^{-1}$)	M_R (%)
5/23/2010 Dry-weather	3 ± 0.0			1 ± 0.6			13 ± 0.0			320 ± 20		
6/15/2010 Dry-weather	3 ± 0.0			1 ± 0.7			13 ± 0.0			297 ± 6		
6/27/2010 Dry-weather	3 ± 0.0			2 ± 1.1			13 ± 0.0			392 ± 10		
7/9/2010 Dry-weather	5 ± 3.1			5 ± 3.5			13 ± 0.0			436 ± 13		
7/12/2010 Storm event	4	0*	100	13	0*	100	25	0*	100	42	0*	100
8/11/2010 Dry-weather	3 ± 0.0			3 ± 0.46			13 ± 0.0			106 ± 6		
8/12/2010 Storm event	4	0*	100	12	0*	100	22	0*	100	42	0*	100
8/12/2010 Dry-weather	3 ± 0.0			1 ± 0.67			13 ± 0.0			100 ± 11		
9/4/2010 Dry-weather	3 ± 0.0			3 ± 0.42			13 ± 0.0			25 ± 2.3		
9/26/2010 Dry-weather	3 ± 0.0			3 ± 1.9			13 ± 0.0			35 ± 4.1		
9/27/2010 Storm event	3	0*	100	11	0*	100	15	0*	100	66	0*	100
9/27/2010 Dry-weather	3 ± 0.0			3 ± 1.4			13 ± 0.0			33 ± 6.7		
10/27/2010 Storm event	3	0*	100	8	0*	100	32	0*	100	43	0*	100
11/14/2010 Dry-weather	4 ± 1.9			1.7 ± 1.0			17 ± 8.5			26 ± 0.66		
11/17/2010 Storm event	2	0*	100	7	0*	100	29	0*	100	52	0*	100
11/17/2010 Dry-weather	5 ± 1.9			3 ± 1.6			42 ± 4.9			23 ± 1.7		
11/29/2010 Dry-weather	3 ± 0.0			1.3 ± 0.64			38 ± 7.6			25 ± 1.1		
12/1/2010 Storm event	3	2	39	4	1	82	44	21	67	26	22	42
12/1/2010 Dry-weather	3 ± 0.0			1.7 ± 1.3			34 ± 4.8			23 ± 1.9		
2/24/2011 Dry-weather	3 ± 0.0			1 ± 0.0			13 ± 0.0			655		
2/24/2011 Storm event	3	2	32	6	1	83	38	17	58	1251	702	47
2/25/2011 Dry-weather	3 ± 0.0			1 ± 0.67			26 ± 11			825 ± 51		
3/9/2011 Dry-weather	3 ± 0.0			5 ± 0.63			31 ± 4.4			408 ± 74		
3/9/2011 Storm event	5	2	37	6	4	11	48	38	-1	43	117	-253
3/11/2011 Dry-weather	3 ± 0.0			5 ± 0.83			40 ± 5.9			101 ± 15		
4/21/2011 Dry-weather	3 ± 0.0			1 ± 0.59			13 ± 0.0			229 ± 3.7		
4/22/2011 Storm event	4	0*	100	11	0*	100	41	0*	100	307	0*	100
4/23/2011 Dry-weather	3 ± 0.0			1 ± 0.0			13 ± 0.0			238 ± 3.0		

Event	Total Pb			Total Cu			Total Zn			Chloride		
	EMC_{in} (µg L^{-1})	EMC_{out} (µg L^{-1})	M_R (%)	EMC_{in} (µg L^{-1})	EMC_{out} (µg L^{-1})	M_R (%)	EMC_{in} (µg L^{-1})	EMC_{out} (µg L^{-1})	M_R (%)	EMC_{in} (mg L^{-1})	EMC_{out} (mg L^{-1})	M_R (%)
5/14/2011 Dry-weather	3 ± 0.0			1 ± 0.0			27 ± 0.33			252 ± 12.5		
5/14/2011 Storm event	3	0*	100	13	0*	100	44	0*	100	157	0*	100
5/15/2011 Dry-weather	3 ± 0.0			2 ± 1.3			13 ± 0.0			243 ± 3.8		
6/9/2011 Storm event	4	0*	100	18	0*	100	52	0*	100	n/a~		
7/7/2011 Storm event	4	0*	100	14	0*	100	50	0*	100	37	0*	100
7/25/2011 Storm event	3	0*	100	8	0*	100	28	0*	100	14	0*	100
8/5/2011 Dry-weather	4 ± 2.01			3 ± 0.01			13 ± 0.0			84 ± 5.2		
8/6/2011 Storm event	4	2	80	9	3	89	25	11	84	21	58	-12
8/7/2011 Dry-weather	4 ± 2.2			7 ± 5.3			13 ± 0.0			49 ± 32		
9/21/2011 Dry-weather	4 ± 2.5			6 ± 0.69			13 ± 0.0			8 ± 0.36		
9/21/2011 Storm event	5	6	28	8	3	77	19	12	63	15	6	68
9/23/2011 Dry-weather	3 ± 0.0			5 ± 1.3			13 ± 0.0			19 ± 10		
10/10/2011 Dry-weather	3 ± 0.0			1 ± 0.0			41 ± 0.1			23 ± 0.79		
10/12/2011 Storm event	2	0*	100	8	0*	100	44	0*	100	56	0*	100
10/13/2011 Dry-weather	3 ± 0.0			1 ± 0.0			45 ± 1.7			15 ± 2		
11/15/2011 Dry-weather	3 ± 0.0			2 ± 1.7			13 ± 0.0			18 ± 0.39		
11/16/2011 Storm event	5	0*	100	9	0*	100	15	0*	100	73	0*	100
11/17/2011 Dry-weather	3 ± 0.0			1 ± 0.0			13 ± 0.0			18 ± 2.1		
12/06/2011 Dry-weather	3 ± 0.0			4 ± 1.7			13 ± 0.0			15 ± 1.5		
12/07/2011 Storm event	2	1	-13	5	2	48	44	33	16	5	6	-50
12/09/2011 Dry-weather	3 ± 0.0			2 ± 1.1			30 ± 2.6			7 ± 5.2		
12/20/2011 Dry-weather	3 ± 0.0			1 ± 0.0			18 ± 8.6			6 ± 3.1		
12/22/2011 Storm event	3	3	32	4	2	67	43	33	48	10	7	54
12/23/2011 Dry-weather	3 ± 0.0			2 ± 0.84			33 ± 3.4			8 ± 1.4		
01/16/2012 Storm event	9	0*	100	4	0*	100	46	0*	100	30	0*	100
01/21/2012 Storm event	3	0*	100	1	0*	100	39	0*	100	6423	0*	100
01/23/2012 Storm event	3	0*	100	1	0*	100	33	0*	100	3126	0*	100
01/24/2012 Dry-weather	6			3			13			8		

Event	Total Pb			Total Cu			Total Zn			Chloride		
	EMC_{in} ($\mu g\ L^{-1}$)	EMC_{out} ($\mu g\ L^{-1}$)	M_R (%)	EMC_{in} ($\mu g\ L^{-1}$)	EMC_{out} ($\mu g\ L^{-1}$)	M_R (%)	EMC_{in} ($\mu g\ L^{-1}$)	EMC_{out} ($\mu g\ L^{-1}$)	M_R (%)	EMC_{in} ($mg\ L^{-1}$)	EMC_{out} ($mg\ L^{-1}$)	M_R (%)
01/27/2012 Storm event	13	0*	100	6	0*	100	103	0*	100	979	0*	100
01/28/2012 Dry-weather	3 ± 0.0			1 ± 0.0			13 ± 0.0			18 ± 4.8		
02/27/2012 Dry-weather	3 ± 0.0			1 ± 0.0			13 ± 0.0			286 ± 39		
02/29/2012 Storm event	11	3	84	26	6	84	93	13	90	185	220	15
03/1/2012 Dry-weather	3 ± 1.6			5 ± 0.74			17 ± 8.3			229 ± 41		
03/2/2012 Storm event	7	3	72	8	4	62	28	13	68	118	104	37
03/4/2012 Dry-weather	3 ± 0.0			4 ± 0.27			13 ± 0.0			143 ± 9.1		
04/22/2012 Storm event	9	0*	100	10	0*	100	40	0*	100	81	0*	100
05/13/2012 Dry-weather	5			7			13			117		
05/14/2012 Storm event	8	0*	100	12	0*	100	35	0*	100	42	0*	100
05/16/2012 Dry-weather	4 ± 2.1			3 ± 2.3			20 ± 10			103 ± 8		
06/10/2012 Dry-weather	3 ± 0.0			3 ± 0.56			13 ± 0.0			10 ± 1.9		
06/12/2012 Storm event	22	0*	100	12	0*	100	13	0*	100	18	0*	100
06/13/2012 Dry-weather	3 ± 0.0			2 ± 1.2			13 ± 0.0			11 ± 1.1		
07/20/2012 Dry-weather	6.5 ± 5.7			5 ± 3.7			23 ± 14			17 ± 3.5		
07/20/2012 Storm event	3	3	20	8	5	52	13	13	20	5	7	-11
07/23/2012 Dry-weather	4 ± 2.1			4 ± 0.43			21 ± 11			8 ± 0.88		

EMC = Event mean concentration (as defined in Equation 5); $\mathbf{M_R}$ = Mass removal efficiency (as defined in Equation 4);
*****Entire inflow runoff volume assimilated
$^+$ Nitrite only
n/a Not applicable
n/a~ No data due to lab accident and/or equipment failure
n/a* Yet to perform lab analysis

2.3.1.1 Total suspended solids

Total suspended solids (TSS) are washed into the infiltration basin mainly from the road and by erosion of the surrounding soil. As observed in a majority of the rainfall events, the inflow TSS concentrations and the rainfall intensity profiles correlated (Figure 6). The solids are flushed into the basin when the rainfall intensity and flow rate increase. In all sampled events, the maximum inflow TSS concentration coincided with the peak flow. No notable flushing of solids was observed in the effluent from the SCM; the TSS concentrations were mostly similar in all discharge samples for a storm event.

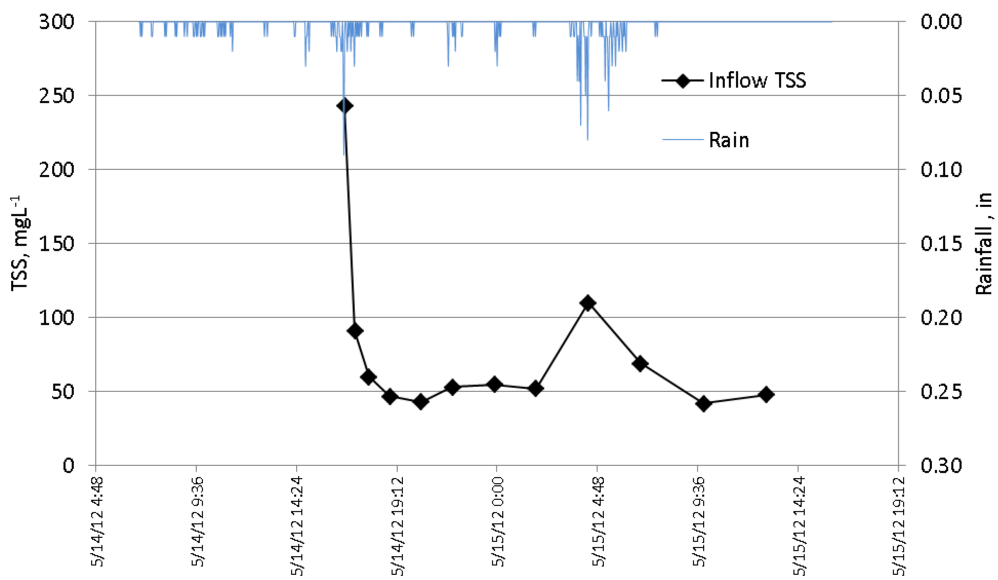

Figure 6. Concentrations of inflow total suspended solids (TSS) recorded during the May 14, 2012 rainfall event at the study site. No outflow was produced during this event.

As an example, during the February 29, 2012 rainfall event, the EMC of the inflow was 510 mg L^{-1} and the outflow EMC was 30 mg L^{-1}. Outflow occurred two hours after the onset of inflow and during this detention period most of the solids in the influent runoff apparently settled, resulting in a total mass removal efficiency of 96% for this event. As can be seen in Table 5, the outflow EMCs were much lower than those of inflow and removal of TSS mass through the infiltration basin was significant, ranging from 67 to 100%, for 38 sampled rainfall events.

The removal of suspended solids from the runoff by sedimentation is supported by the TSS levels in the grab samples. Based on the data collected, water stored in the infiltration basin for a relatively long dry period (~10 days) contained a TSS concentration of about 10 mg L^{-1} (Table 5). The highest inflow EMC of 510 mg L^{-1} was recorded during the February 29, 2012 event. Comparing the pre-event (7 mg L^{-1}), outflow EMC (30 mg L^{-1}), and post-event (24 mg L^{-1}) TSS levels, it can be deduced that some mixing occurred during the event and given enough detention time (one day), the solids settled within the basin.

A probability exceedence plot for TSS was developed using EMC data of all sampled storm events (Figure 7). The water quality target level of 25 mg L^{-1} (Table 4) was used for comparison. Storm events with no outflow were assigned an EMC value of 0.1 mg L^{-1} in order to be plotted on a log scale axis. Figure 7 shows that the median discharge TSS value is zero mg L^{-1}, resulting from no discharge. About 90 % of the discharge TSS concentrations are expected to meet the target value of 25 mg L^{-1}.

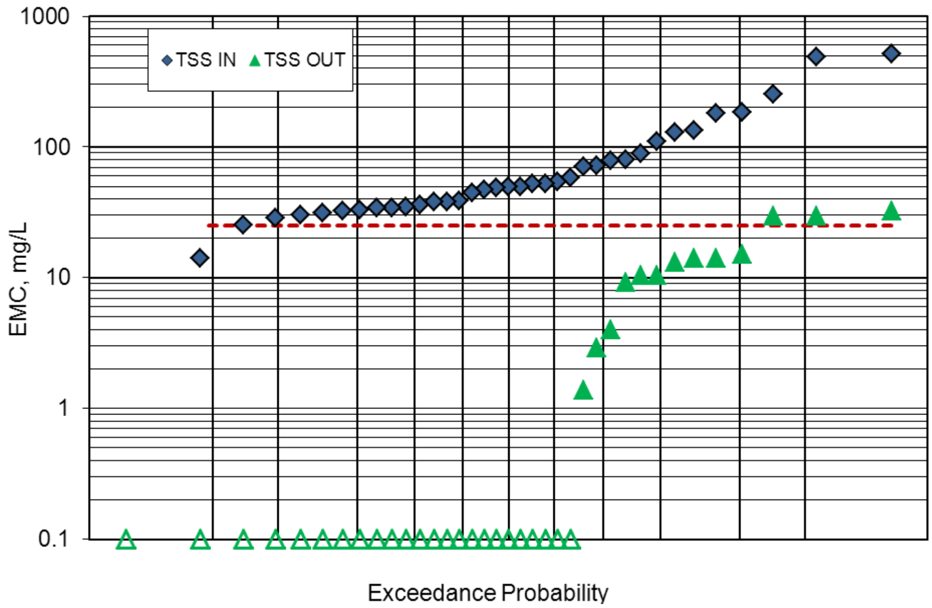

Figure 7. Probability plot for total suspended solids at the MD175 infiltration basin site. Open symbols represent storm events with no outflow. Dashed line represents the water quality target criterion (TSS wq = 25 mg L^{-1}).

2.3.1.2 Nitrogen

Concentrations of TKN, nitrite, and nitrate in the water samples were determined during all storm events. Nine composite sample sets collected were analyzed for ammonium in addition to other nitrogen species. Due to equipment failure, the nitrate-N data are unavailable for the period February through July 2011. Samples collected during this period were analyzed for nitrite-N and TKN only.

In general, concentrations of nitrite-N in the runoff were low in all storm events. In the inflow, individual sample concentrations of nitrite-N ranged between 0.01 and 0.09 mg L^{-1}. Sample outflow nitrite-N levels were around the laboratory detection limit of 0.01 mg L^{-1}. The nitrite-N outflow EMCs were always lower than the inflow EMCs (Table 5). The outflow EMCs of nitrite-N were lower than the water quality criteria of 1 mg L^{-1} in all 15 events that produced outflow. EMCs of nitrate-N in the discharge were lower than that of inflow in 14 events. The discharge nitrate EMCs exceeded the water quality criterion of 0.2 mg L^{-1} during 3 winter events (Jan 18, 2010, Dec 8, 2011, and Feb 29, 2012). The nitrate and nitrite levels in the grab samples were always around or below their respective detection limits (Table 5) (nitrite detection limit = 0.01 mg L^{-1}; nitrate detection limit = 0.1 mg L^{-1}).

The oxidation-reduction potential (ORP) measurements within the water column of the infiltration basin support processing of NO_x during storm events and dry periods. Figure 8 shows the ORP measurements during April 2012. The ORP of the water column remained low positive during dry periods. The low ORP values indicate the presence of anoxic condition within the infiltration basin. This suggests that nitrate removal occurs through denitrification. Removal of nitrate during a storm event could largely be due to dilution.

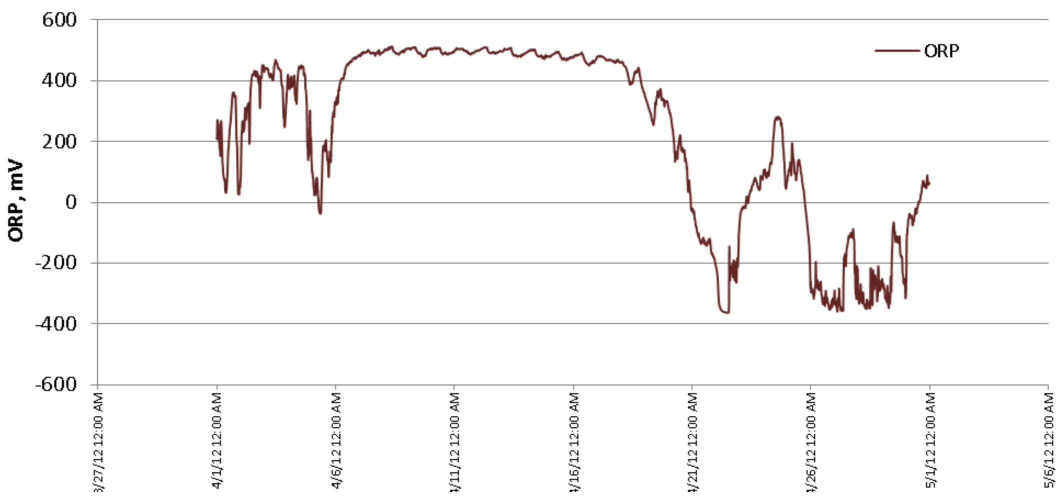

Figure 8. Oxidation-reduction potential measured within the infiltration basin during April 2012.

The inflow TKN EMCs ranged between 3.5 and 0.96 mg L^{-1} and the outflow EMC levels were mostly around 1 mg L^{-1} or less. The TKN outflow EMCs were lower than the inflow EMCs during 37 storm events, the exception being one winter event (Feb 24, 2011) (Table 5). The TKN levels in the water stored in the infiltration basin in between storm events were around the same concentration as well (~1 mg L^{-1}).

Excluding eight storm events with no nitrate data, TKN is the largest portion of TN in both inflow (mean=78%) and outflow (mean=86%) in 30 sampled storm events. Ammonium-N concentrations were determined for nine storm events. Organic nitrogen level was obtained as the difference between TKN and ammonium levels. Comparing the organic nitrogen and ammonium-N concentrations in these samples, organic nitrogen is the dominant fraction of TKN in both inflow and outflow samples. While organic nitrogen concentrations were 54-96% of TKN in inflow, outflow TKN consisted of 70-92% organic-N. These observations are in agreement with the study by Taylor *et al.* (2005) in which TKN was found to be the major constituent (~70%) of total nitrogen in urban stormwater runoff. This is also in agreement with the median concentrations of various nitrogen species observed in stormwater runoff from a variety of urban land uses summarized in Collins *et al.* (2010).

On a pollutant mass removal perspective, the worst removal of the nitrogen species was observed during the winter rainfall events (Jan 18, 2010, Feb 24, 2011, and Dec 8, 2011) and during a large storm event (rainfall depth = 2.21 inches) on March 9, 2011. During these events, export of TKN and NO_x-N masses were observed. The highest outflow EMC of 0.34 mg L^{-1} NO_x-N was recorded during the Jan 18, 2010 storm event. Excluding these four storm event, the percent mass removal efficiencies of TKN ranged between 5 and 100% and that of NO_x-N between 20 and 100%.

2.3.1.3 Phosphorus

Phosphorus loading to the infiltration basin during various rainfall events and efficiency of the basin in reducing the P loads to acceptable levels was investigated for 38 storm events. Similar to TSS, first flush phenomenon was observed in the inflow runoff.

Table 5 shows the computed TP EMCs for all events. In the 38 sampled storm events, the total phosphorus (TP) EMC levels in the inflow runoff were between 0.1 and 0.6 mg L^{-1}. The outflow EMCs were lower than inflow EMCs during all events. However, the outflow TP concentrations exceeded the stringent water quality criterion of 0.05 mg L^{-1} during all 15 storm events. The efficiency of the infiltration basin in removing the TP mass varied between 17 and 100% during 36 sampled storm events. Similar to nitrogen, phosphorus export occurred during a winter storm event (Jan 18, 2010) and the large storm event (rainfall depth = 2.21 inches) in spring (March 9, 2011). Also, these events recorded the highest outflow EMCs of 0.19 mg L^{-1} and 0.18 mg L^{-1}, respectively.

In order to understand the phosphorus removal mechanism in the infiltration basin, selected samples were analyzed for dissolved phosphorus (DP) in addition to total phosphorus (TP). Particulate phosphorus levels were determined as the difference between total and dissolved phosphorus levels for these events. A total of 15 storm events were tested for DP, of which eight storm events produced outflow. The inflow DP concentrations ranged between 14-78 % of inflow TP levels (mean = 49%) and the outflow DP levels ranged between 13-59 % of outflow TP levels (mean = 44%) for these eight events. The discharge DP EMCs were less than the inflow DP EMCs in seven out of the eight events. During the one winter storm event (Dec 8, 2011) when the discharge DP EMC was higher than that of inflow, export of dissolved phosphorus occurred. The DP mass removal ranged between 22-90% for the remaining seven events. The discharge DP EMC exceeded the selected water quality criterion of 0.05 mg L^{-1} during five events. Based on the concentration of DP in the inflow and outflow samples, the decrease in TP concentration through the infiltration basin can be primarily attributed to settling of particulate phosphorus during the course of the storm event.

Figure 9 shows the probability exceedence plot for TP based on EMC data of 38 sampled storm events. Water quality target level of 0.05 mg L^{-1} is included in the plot for comparison. Storm events with no outflow were assigned an EMC value of 0.001 mg L^{-1} in order to be plotted on a log-scale axis. Figure 9 shows that the median discharge TSS value is zero mg L^{-1}, resulting from no discharge. About 40 % of the discharge TP concentrations are expected to exceed the stringent target value of 0.05 mg L^{-1}.

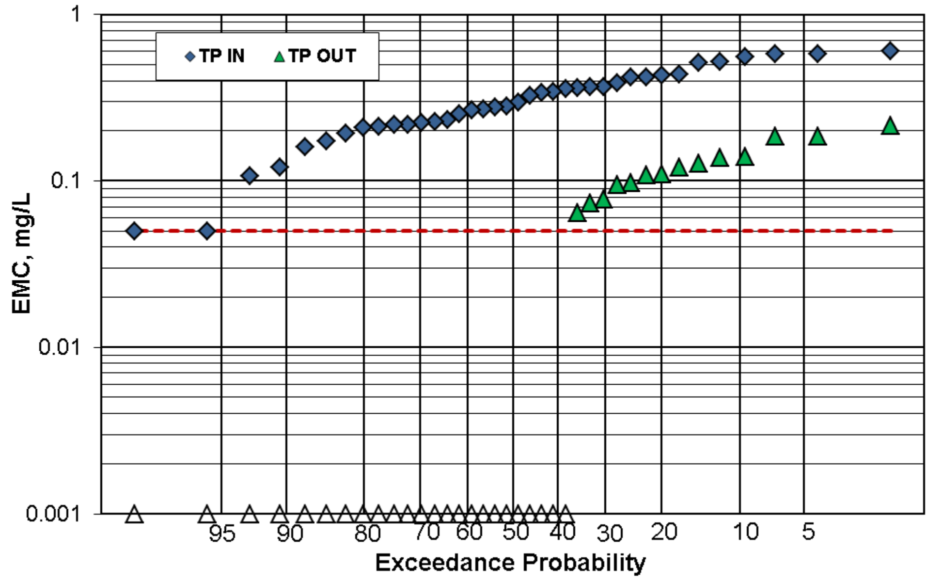

Figure 9. Probability plot for total phosphorus at the MD175 infiltration basin site. Open symbols represent storm events with no outflow. Dashed line represents the water quality target criterion (TP wq = 0.05 mg L^{-1}).

2.3.1.4 Heavy metals Cu, Pb, and Zn

The total concentrations of the heavy metals copper (Cu), lead (Pb), and zinc (Zn) were determined for all storm event and dry weather sampling. The heavy metal concentrations were generally low in the inflow runoff (EMCs of total Cu < 26 µg L^{-1}; total Pb < 13 µg L^{-1}; total Zn < 103 µg L^{-1}). The discharge sample concentrations were usually around or below their detection limits, especially for lead and copper. Zinc was detected in all inflow samples and fewer outflow samples. Runoff sampled during winter contained relatively higher metal concentrations than other events. This can be attributed to the accretion of metals in the snow and their subsequent wash off in the runoff (Sansalone and Glenn 2002; Glenn and Sansalone 2003).

Figure 10 shows the inflow and outflow EMCs recorded for the three heavy metals during 38 storm events. For the15 events that produced outflow, the outflow EMCs were below the inflow EMCs during all 15 events for Cu and Zn, and for 14 events for Pb. In the 38 sampled rainfall events, the inflow and outflow EMCs were lower than the water quality criteria for all three heavy metals, except inflow Cu EMC during five storm events. Mass export of metals was observed during one event for Cu, three events for Pb, and two events for Zn; these events were during winter and large storm events (rainfall depth > 2 inches) (Table 5).

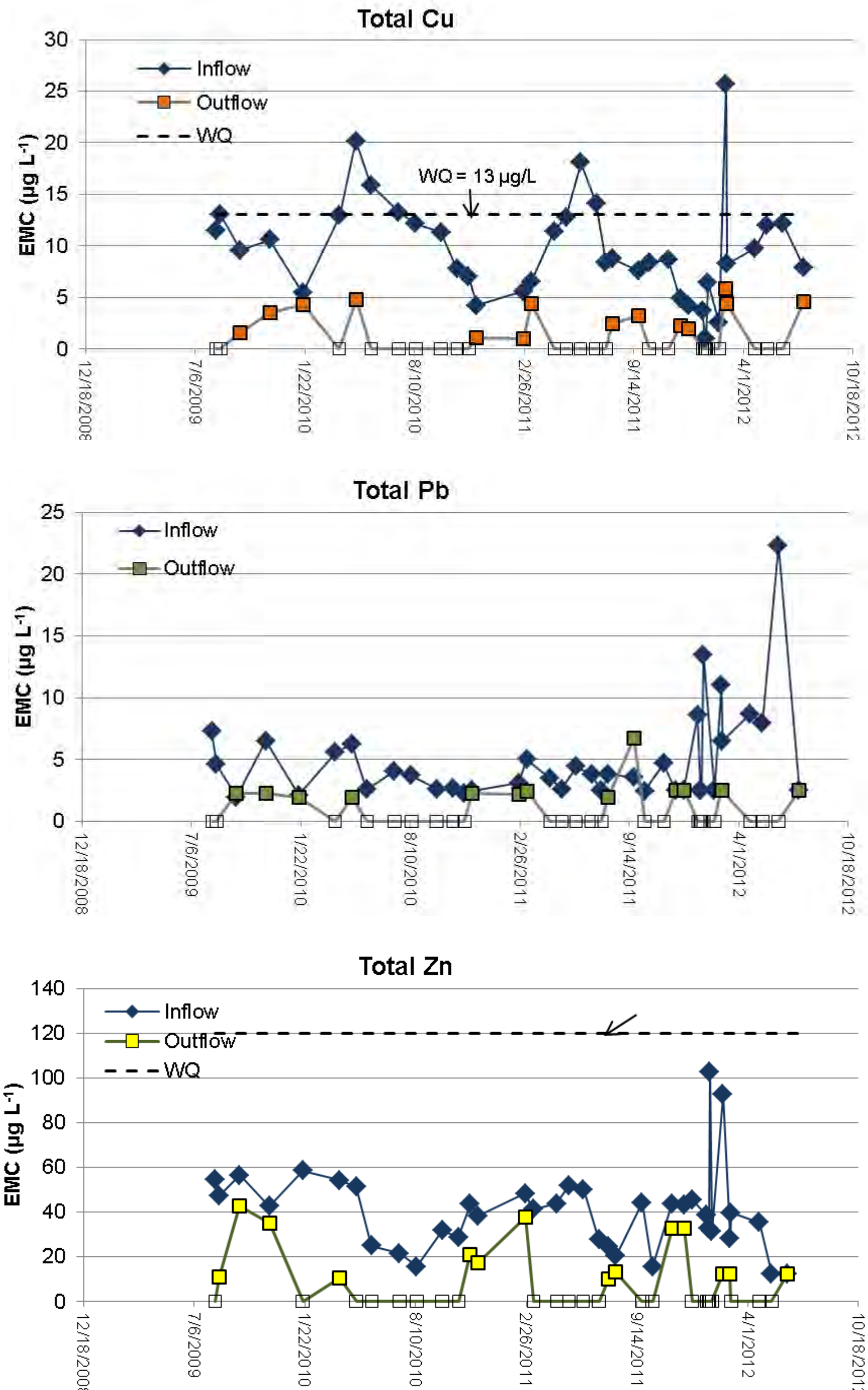

Figure 10. Event mean concentrations of total copper, lead, and zinc during 38 sampled rainfall event at the MD175 infiltration basin site. The dashed line represents the

water quality criteria (denoted by subscript "wq") for each heavy metal (acute; COMAR 2006). Open symbols represent storm events with no outflow.

Figure 11 shows the probability plot for total copper based on the EMC of total copper observed during 38 sampled events. Storm events with no outflow were assigned an EMC value of 0.1 mg L^{-1} in order to be plotted on a log-scale axis. The median discharge value for total copper is zero mg L^{-1}, resulting from no discharge. The discharge total Cu concentrations are never expected to exceed the target value of 13 µg L^{-1}. The discharge total Pb and total Zn concentrations are never expected to exceed their respective target values as well.

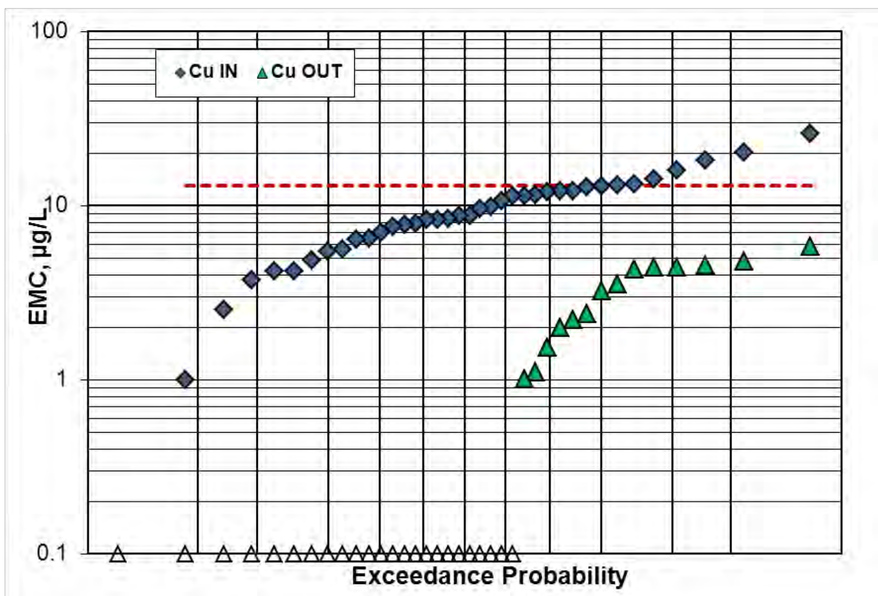

Figure 11. Probability plot for total copper at the MD175 infiltration basin site. Open symbols represent storm events with no outflow. Dashed line represents the water quality target criterion (Copper wq = 13 µg L^{-1}).

2.3.1.5 Chloride

The chloride levels in runoff and grab samples exhibited seasonal trends during the entire monitoring period (Table 5). Figure 12 shows the chloride EMCs for the entire monitoring duration. Stormwater runoff from the road surfaces contained high levels of chloride during winter events when application of road salts for deicing are common. The maximum EMC of 6423 mg L^{-1} observed was for the Jan 21, 2012 event. As seen in Figure 12, the chloride EMCs gradually decreased by dilution and wash off during subsequent storm events. In Figure 12, four inflow EMCs greater than 1000 mg L^{-1} are off the chart (1251 mg

L^{-1} on Feb 24, 2011, 6423 mg L^{-1} on Jan 21, 2012 , 3126 mg L^{-1} on Jan 23, 2012, and 1326 mg L^{-1} on Feb 16, 2012 storm events).

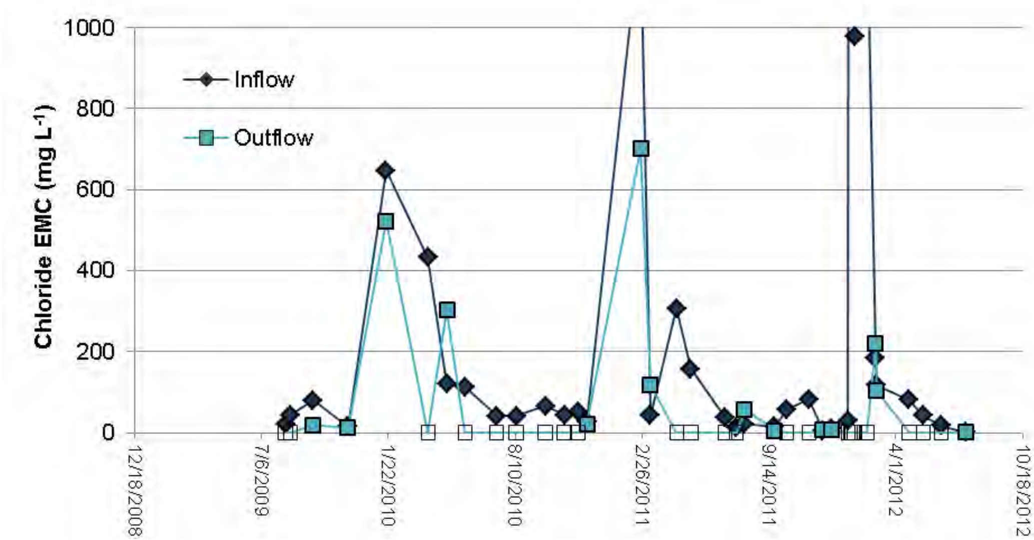

Figure 12. Event mean concentrations of chloride in the inflow and outflow observed at the MD175 infiltration basin site during the monitoring period. Open squares denote storm events with no outflow. In this plot, four inflow EMCs greater than 1000 mg L^{-1} are off the plot scale .

2.3.1.6 Pollutant mass load removal calculations

The pollutant mass input and output to the infiltration basin was computed for each rainfall event using Equation 6:

$$Mass = EMC \times Flow\ volume \tag{6}$$

The cumulative total pollutant mass into and out of the infiltration basin (in *lbs*) during the 38 monitored events are summarized in Table 6. Table 6 shows that the input pollutant loads were reduced by the infiltration basin for all the pollutants. The mass removal efficiencies for the entire monitoring duration are TSS 89%, TP 61%, NO_x-N 79%, TKN 51%, total N 64%, total Cu 73%, total Pb 63%, total Zn 55%, and chloride 45%. Part of this removal is attributed to 30% volume reduction during the 38 monitored storm events.

Table 6. Total pollutant mass loads to the infiltration basin for 38 monitored rainfall events and annual pollutant loads and discharge from June 2009 to July 2012.

Pollutant	TSS	TP	Nitrate + Nitrite (as N)	TKN (as N)	Total N	Lead	Copper	Zinc	Chloride
Mass in (*lb*)	1446	3.34	5.2	16.8	19.8	0.059	0.118	0.51	1874
Mass out (*lb*)	157	1.31	1.1	8.2	7.1	0.022	0.032	0.23	1029

Annual pollutant mass load, L_{in} ($lb\ ac^{-1}\ yr^{-1}$)	288	0.65	1.01	3.3	4.54	0.011	0.023	0.099	365
Annual pollutant mass discharge, L_{out} ($lb\ ac^{-1}\ yr^{-1}$)	31	0.26	0.22	1.6	1.64	0.004	0.006	0.045	201

The annual pollutant mass load per unit drainage area (L, in $lb\ ac^{-1}\ yr^{-1}$) in Table 6 was estimated using Equation 7:

$$L = \frac{M}{A} \times \frac{P_{average}}{P_{observed}} \qquad (7)$$

In Equation 7, M is the overall input pollutant mass (in *lb*), A is the drainage area of the infiltration basin (in *acres*), $P_{average}$ is the average annual precipitation [42 $in\ yr^{-1}$ for the State of Maryland; MDE 2000], and $P_{observed}$ is the observed cumulative precipitation during the monitoring events (in *inches).* $P_{observed}$ for the monitoring duration was 30 *inches*. The annual pollutant input mass L_{in} and discharge L_{out} from the infiltration basin were obtained using the input (M_{in}) and output (M_{out}) masses, respectively, in Equation 7. The difference between annual input and output masses ($L_{in} - L_{out}$) is the effect of the infiltration basin in reducing the annual pollutant loads. Table 6 shows that the annual pollutant mass discharged from the infiltration basin was much lower than the annual pollutant input load for all pollutants.

2.3.1.7 Pollutant duration curves

Pollutant-duration curves were developed for each pollutant based on 27 monitored storm events. Composite sampling was performed during the 11 excluded storm events. The curves illustrate the cumulative duration of a pollutant concentration flowing into, and that discharged from the infiltration basin.

Figures 13, 14, and 15 show the pollutant duration curves for TSS, TP, and nitrogen species (TKN and NO_x-N). The water quality criterion for each pollutant is also shown in each figure. Figure 13 shows that TSS concentration of the runoff flowing into the infiltration basin exceeded the water quality criterion of 25 mg L^{-1} for 199 hours compared to 28 hours only for the discharge from the infiltration basin. While the highest measured input TSS concentration was 1771 mg L^{-1}, the largest discharge concentration was 48 mg L^{-1}.

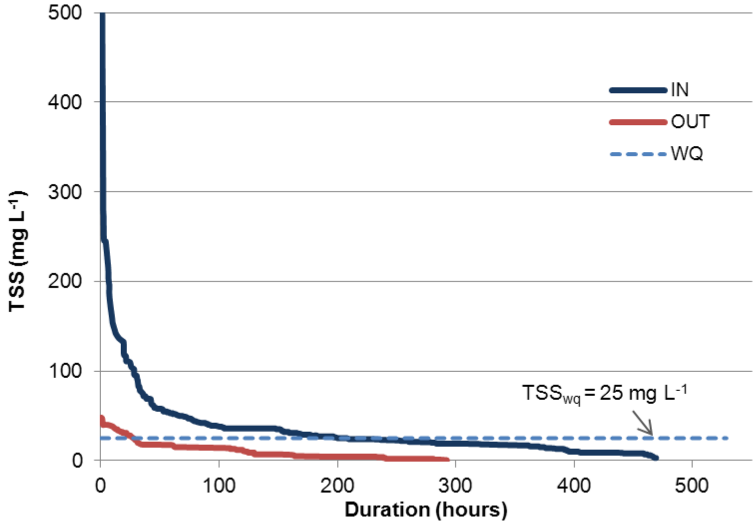

Figure 13. Pollutant duration curves for total suspended solids (TSS) at the infiltration basin for the monitoring duration. Subscript "wq" denotes "water quality". The y-axis has been truncated at 500 mg L^{-1} in order to show the outflow pollutant duration clearly.

Figure 14 shows the duration of total phosphorus input and discharge from the infiltration basin. The TP discharge concentrations were lower than that of the inflow for the entire duration. However, both inflow and outflow TP levels exceeded the stringent water quality criterion of 0.05 mg L^{-1} during most of the period. While the inflow concentration exceeded the water quality criterion for 466 hours, the discharge exceeded the water quality criterion for 284 hours.

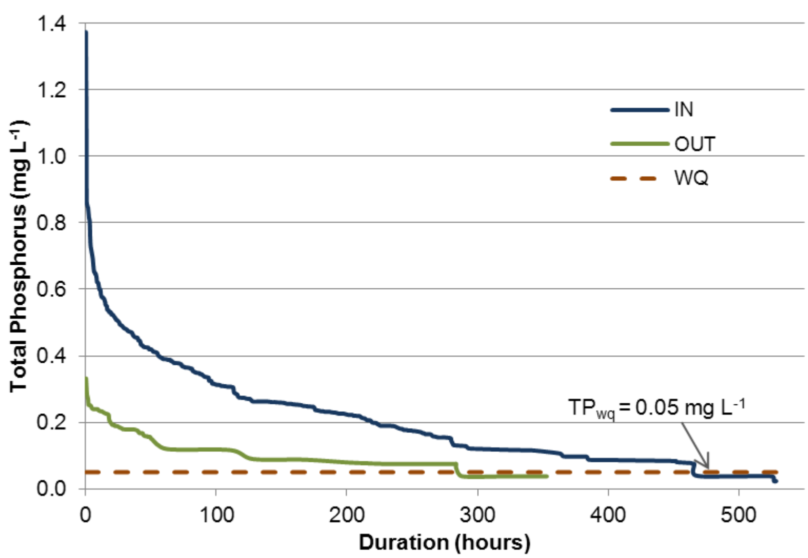

Figure 14. Pollutant duration curves for total phosphorus (TP) at the infiltration basin for the monitoring duration. Subscript "wq" denotes "water quality".

The pollutant duration curves for TKN and NO_x-N species are shown in Figure 15. The concentrations of both TKN and NO_x in the runoff discharged from the infiltration basin were lower than those of the inflow during the entire duration. With respect to the water quality criterion for NO_x-N (1.2 mg L^{-1}), the runoff flowing into the infiltration basin contained NO_x levels greater than 1.2 mg L^{-1} for a duration of 15 hours. However, the runoff discharged met the 1.2 mg L^{-1} water quality criterion for the entire monitoring duration.

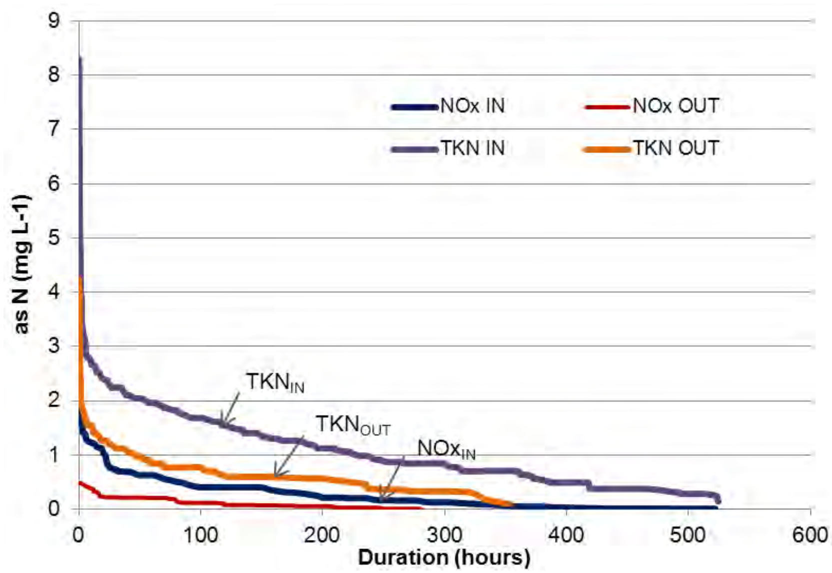

Figure 15. Pollutant duration curves for nitrogen species (TKN and NO_x-N) at the infiltration basin site for the entire monitoring duration.

2.3.1.8 Statistical test on pollutant EMCs

Statistical tests were performed to determine if the runoff pollutant EMCs reductions achieved through the infiltration basin were significant. A non-parametric statistical method, Wilcoxan matched-pairs signed-ranks test, was used to determine if the outflow EMCs were significantly lower than the inflow EMCs for all pollutants (TSS, TP, TKN, Pb, Cu, Zn, and chloride). EMC data from all 38 monitored storm events were used to perform a one-sided test (EMCout < EMCin). The test showed that the outflow EMCs were significantly lower than inflow EMCs at a 0.005% level of significance for all water quality parameters.

2.4 Discussion for completed tasks

The hydrology at the infiltration basin site has been quantified based on 113 monitored rainfall events. Overall, the results indicate that the infiltration basin was capable of mitigating the hydrologic impacts of urban stormwater runoff. The infiltration basin attenuates peak flows, delays outflow, and reduces the discharge volume through detention and water loss. The available hydrology data also suggest that the response of the infiltration basin to a rainfall event is influenced by factors such as the size and duration of the rainfall event, available storage volume in the basin, incoming runoff rate and volume, and loss of water through evapotranspiration and possibly infiltration.

Water quality monitoring at the infiltration basin suggests overall improvements in the runoff water quality during both storm events and dry-weather periods. The event mean concentrations (EMCs) of the measured pollutants in the outflow were significantly lower than those of inflow in all events. Except for total phosphorus, the outflow EMCs of total suspended solids, nitrite and nitrate nitrogen, and heavy metals (copper, lead, and zinc) satisfied the selected water quality criteria for the majority of the events monitored.

The infiltration basin exhibited excellent removal of total suspended solids (TSS) for the monitored events. Based on the observed flow delay in the facility, it can be deduced that most of the suspended solids settle during the period before outflow begins, resulting in high TSS removal. This also explains the observed removal efficiencies of phosphorus and heavy metals which are usually associated with particulates. This is in agreement with the observed similarity in the concentration profiles of TSS, TP, and heavy metals during several monitored events.

The nitrogen water quality data suggest that the infiltration basin is effective in removing the oxidized nitrogen species (NOx) through denitrification. This is supported by the negative oxidation-reduction potential measured in the water column of the infiltration basin, especially during the dry periods between storm events. TKN (ammonia -N + organic-N) is only partially removed. Also, speciation analyses showed that majority of the TKN was in the form of organic-N in both inflow and outflow samples. Based on the concentrations of TKN in the inflow, outflow, and dry-weather samples, it can be deduced that most of the TKN in the infiltration basin water must be organic nitrogen. The predominance of organic-N in the water suggests that conditions in the infiltration basin may be limiting for ammonification and nitrification to occur at a considerable rate compared to denitrification.

With respect to trends in performance, both hydraulics and treatment efficiency of the infiltration basin showed seasonal differences and the trends were common to each seasonal year. One possible explanation is that biological activity is higher during warmer periods compared to colder periods since biological activity tends to slow down as temperature drops. Also, water losses through evapotranspiration and infiltration are lower during winter compared to warmer months. Combined, changes in the physical and biological processes within the infiltration basin can influence its hydrologic and water quality performances. Hence, during the coldest temperatures, the infiltration basin is expected to act as a flow-through system and provide the least benefits. This was evident in the poor pollutant removal, especially for nutrients, in the winter storm event.

3.0 Tasks to be completed

3.1 Hydrology

The water quality monitoring at the infiltration basin site is complete. The site will continue to be monitored for more rainfall events and in-situ measurements (water level, temperature, ORP, pH, conductivity) until the end of summer 2012. The hydrologic data analysis and metrics will be updated as these data become available. Probability exceedence plots for runoff flows and an appropriate target metric will be developed.

As a preliminary step, the evapotranspiration (ET) was estimated using the Blaney-Criddle method. The Penman-Monteith model will be used in for estimating the ET at the site and the model will be evaluated using Matlab. The ET estimate combined with the continuous water level data will be used to estimate the degree of infiltration in the basin. The significance and seasonal importance of ET and infiltration will be established. The water balance computations will be performed.

3.2 Habitat value assessment

An assessment plan to evaluate the ecological value of the infiltration basin will be developed. In this plan, a set of 'indicators of functionality' will be developed so that these indicators can be employed to similar infiltration basin sites to determine their environmental functionality.

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APPENDIX B:

Management of Nitrogen in Stormwater Runoff Using a Modified Conventional Sand Filter

August 15, 2012

Management of Nitrogen in Stormwater Runoff Using a Modified Conventional Sand Filter

Project Duration: August 2011 – August 2012

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Table of Contents

Executive Summary

This work investigates the retrofit of a conventional sand filter for enhanced removal of nitrogen from highway runoff. To reduce the nitrogen loading, the proposed design divides the sand filter into three zones to allow for ammonification, nitrification, and denitrification. In previous works nitrification was observed to take place during low nitrogen loadings and dry periods. In order to achieve adequate retention times for these biological processes to take place, sorptive media need to be incorporated within the filter. The project aims to study the sorption of nitrogen, and the rate at which biological turnover of influent nitrogen takes place.

The first phase of the project focused on selection of adsorbents for the uptake of ammonium. Clay and recycled materials and sand were selected as adsorbents, The time required for the sorption to reach equilibrium was found to be 24 hours. Because of low sorption capacity and instability in the structure of clay agglomerates, studies on the GA Attapulgite and brown montmorillonite were abandoned. The sorption isotherms for the remaining materials (i.e., CA aluminosilicate (CA), crushed brick (BR), and red montmorillonite (MR), and pool sand) were obtained at two different pH ranges. The increase in pH was shown to increase the sorption capacity of the adsorbents, particularly BR although other adsorbents such as CA did not improve dramatically. The sorption capacity of MR was found to be greatest of all adsorbents for both pH ranges. Cation selectivity and competition between other cations and ammonium were also studied, but because of interferences caused by the presence of Na^+ and K^+, the results were not conclusive. New measurements using a standard method (i.e., phenate method) is underway. Current work also focuses on small scale column studies for the sorption of ammonium to allow for more comprehensive judgment on the performance of the adsorbents. Based on the results, the column studies will be expanded to allow for nitrification and sorption to take place simultaneously in order to quantify the rate of nitrification and determine the media thickness required for optimum results.

Introduction

Increasing impervious land area will disrupt the infiltration of water into the soil and raises flooding frequencies. The runoff originating from these land areas carries with it many pollutants, including suspended solids, organic compounds, heavy metals, nitrogen, and phosphorous, and contributes a significant amount of pollutants to receiving water bodies. New management technologies, such as bioretention and sand filters, are emerging to address urban runoff challenges. While these practices have been effective in removal of suspended material, bacteria, and toxic compounds, the efficiency in reducing the nitrogen load in stormwater requires improvement. In this work, optimization of sand filters with respect to removal of nitrogen species is emphasized.

Nitrogen Cycle

Nitrogen in urban runoff can be found in both dissolved and particulate forms. The particulate form tends to be dominated by organic nitrogen (ON), while dissolved nitrogen exists as dissolved organic nitrogen (DON), ammonium, and nitrogen oxide species, predominantly nitrate (NO_3^-) (Duncan, 1999; Collins, et al., 2010) . As in other natural systems, transformation of nitrogen based on its cycle can readily take place (Figure 1). While capture of ammonium, particulate and dissolved organic nitrogen is possible, nitrate is highly mobile; hence the speciation of nitrogen plays an important role in its removal efficiency. Figure 1 illustrates the pathway for conventional nitrification and denitrification while Reactions 1 – 3 give a more detailed overview of the chemical changes taking place in the nitrogen cycle. In natural conditions, nitrogen fixation (i.e., conversion of nitrogen gas to ammonia) occurs through abiotic pathways (sunlight) and biosynthesis. Fixation of nitrogen through biosynthesis often leads to the formation of proteins and nucleotides ($-NH_2$), making the most reduced form of nitrogen its predominant organic form, such as amino acids and amino sugars. Once decomposed, free ammonium/a will be released.

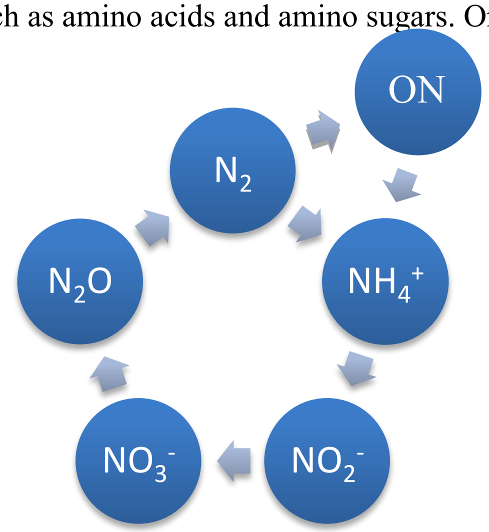


Figure 1. Transformation of nitrogen observed in nitrogen cycle via nitrification/denitrification. NH4+ here represents free ammonia/um.

$N_2 + 3\ H_2 \rightarrow 2\ NH_3$ Ammonification: Equation 1

$2\ NH_4^+ + 3\ O_2 \rightarrow 2\ NO_2^- + 4\ H^+ + 2\ H_2O$

$$2\ NO_2^- + O_2 \rightarrow 2\ NO_3^-$$
$$2\ NH_4^+ + 4\ O_2 \rightarrow 2\ NO_2^- + 4\ H^+ + 2\ H_2O \qquad \text{Nitrification: Equation 2}$$

$$2\ NO_3^- + 5/2\ CH_2O + 2\ H^+ \rightarrow N_2 + 5/2\ CO_2 + 7/2\ H_2O \qquad \text{Denitrification: Equation 3}$$

Organic Nitrogen

The biodegradation/decomposition of organic nitrogen is very complex. Several models can be used to describe the turnover of organic matter in agricultural soils, where ON is found in high concentrations. Biodegradation of ON has been shown to be highly dependent on the microorganism responsible for biosynthesis and the amino acid chains involved, and tends to be slower than that of non-nitrogenous organic compounds, particularly in systems where the concentration of ON is scarce (Jenkinson, 1990; Jones, 1999). The mean half-life of organic-N in top soils at high concentrations (5 mM in soil solution) and at 18^oC was found to be 1.7 ± 0.6 h (Jones, 1998). Quantification of ON is important in stormwater remediation. With decomposition of larger organic molecules, smaller and lighter ON molecules are formed. These molecules are more water soluble, which leads to an increase in the activity (concentration) of ON in stormwater (Thorkild, et al., 2010).

Nitrification

As can be seen from Figure 1, ammonium undergoes nitrification, a two-step process, which takes place under oxic conditions and in the presence of autotrophic bacteria (Equation 2). In the first step, ammonium is oxidized to nitrite. This is an energy-yielding reaction, with ΔG^o_r = -45.79 kJ/e^- equivalent (Rittman and McCarty, 2001). The most common bacteria that are responsible for this step include *Nitrosomonas*, *Nitrosococcus*, *Nitrosopira*, *Nitrosovibrio*, and *Nitrosolobus*. The second step of nitrification is the conversion of nitrite to nitrate with ΔG^o_r = -37.07 kJ/e^- equivalent, and is predominantly carried out by *Nitrobacters* and *Nitrospira*. All of these bacterial genuses are obligate aerobes, and require the use of oxygen in the presence of limited organic carbon.

Nitrifiers are slow growers, and compete with other aerobic bacteria for oxygen. The basic bio-kinetic values for the two steps of nitrification are provided in Tables 1 and 2, where f_s^o is the fraction of electrons from an electron-donor substrate that microorganisms utilize toward cell synthesis, Y corresponds to the yield for cell synthesis, μ is the growth rate of active biomass, $\hat{q}$ is the maximum specific rate of substrate utilization, $\hat{\mu}$ is the maximum specific growth rate, K_i is the concentration of *i* giving one-half the maximum rate, $\theta_x^{\ limiting}$ is the mean cell residence time at which washout begins, and $S_{min,i}$ is the minimum concentration of substrate *i* capable of supporting steady-state biomass (Rittman and McCarty, 2001). As can be seen from the f_s^o values, only a small fraction of the electrons are utilized towards cell synthesis, indicating that the growth of nitrifiers is slow. Furthermore, increasing temperature positively affects nitrification rate.

During nitrification, the nitrifiers almost always have to compete for dissolved oxygen and space with heterotrophic bacteria, and the high K_O and slow growth rate puts them at a disadvantage with respect to other microorganisms. To ensure high nitrification rates, high retention times must be allowed to allow for conversion of ammonium to nitrate. Furthermore, the availability of ammonium within the medium should equal $S_{min,N}$.

Table 1. Basic and Derived Parameter Values for Ammonium Oxidizers at 5 to 25°C at neutral pH; Reproduced from Environmental Biotechnology: Principles and Applications Table 9.1 (Rittman and McCarty, 2001).

	5°C	10°C	15°C	20°C	25°C
f_s^o	0.14	0.14	0.14	0.14	0.14
Y (mg VSS/mg NH_4^+-N)	0.33	0.33	0.33	0.33	0.33
μ (1/d)	0.96	1.3	1.3	2.3	3.1
$\hat{q}_n$ (mg NH_4^+-N/mg VSS_a-d)	2.9	3.8	3.8	6.8	9.2
$\hat{q}_{O_2}$ (mg O_2/mg VSS_a-d)	3.2	0.42	0.42	0.76	1.02
$\hat{\mu}$ (1/d)	0.18	0.32	0.32	1	1.5
K_N	0.5	0.5	0.5	0.5	0.5
K_O	0.045	0.06	0.06	0.11	0.15
$\theta_x^{limiting}$ (d)	3.6	2.8	2.8	1.5	1.2
$S_{min,N}$ (mg NH_4^+-N/l)	0.029	0.053	0.053	0.17	0.26
$S_{min,O}$ (mg O_2/l)	0.081	0.083	0.083	0.085	0.085

Table 2. Basic and Derived Values for Nitrite Oxidizers at 5 to 25°C at neutral pH, Reproduced from Environmental Biotechnology: Principles and Applications Table 9.2 (Rittman and McCarty, 2001)

	5°C	10°C	15°C	20°C	25°C
f_s^o	0.10	0.10	0.10	0.10	0.10
Y (mg VSS/mg NH_4^+-N)	0.083	0.083	0.083	0.083	0.083
μ (1/d)	4.1	5.5	7.3	9.8	13.0
$\hat{q}_n$ (mg NH_4^+-N/mg VSS_a-d)	4.2	5.6	7.5	10.1	13.5
$\hat{q}_{O_2}$ (mg O_2/mg VSS_a-d)	0.34	0.45	0.61	0.81	1.1
$\hat{\mu}$ (1/d)	0.15	0.3	0.62	1.3	2.7
K_N	0.68	0.68	0.68	0.68	0.68
K_O	0.045	0.06	0.082	0.11	0.15
$\theta_x^{limiting}$ (d)	3.5	2.6	1.9	1.4	1.1
$S_{min,N}$ (mg NH_4^+-N/l)	0.024	0.047	0.10	0.20	0.42
$S_{min,O}$ (mg O_2/l)	0.11	0.11	0.12	0.11	0.11

Denitrification

The final step in the nitrogen cycle is denitrification, or the reduction of nitrate to nitrogen gas (Equation 3). Denitrification involves the step-by-step electron reduction of nitrate (NO_3^-) to NO_2^-, NO, N_2O, and finally N_2. Since the oxygen concentration controls whether the facultative aerobes can respire nitrate, anoxic conditions and the presence of organic carbon are needed for denitrification to take place.

The kinetics of nitrification and denitrification are of great importance; at low temperatures, both nitrification and denitrification will slow and for temperatures less than 4^{o}C, both processes will reduce significantly, although denitrification at 8 and 4^{o}C in soil systems has been found to persist (Thompson, 1989) . The nitrification rate at higher temperatures corresponds to a first order reaction with respect to ammonium, while the rate order of denitrification varies with its concentration (Reddy, et al., 1977, Smith, 1978). The reaction rates for both nitrification and denitrification at different concentrations and conditions found in typical urban runoff need to be tested in the laboratory to determine the designs for nitrogen removal.

Fate of Nitrogen in Stormwater Runoff

Previous research has focused on speciation of nitrogen in stormwater runoff by categorizing the total nitrogen as ammonium, nitrate, nitrite, and organic nitrogen, with no detailed information on the speciation of ON. Furthermore, the speciation and concentration of nitrogen in the runoff heavily depends on the land area. For example, the available nitrogen in the runoff from an agricultural area differs from that of industrial land. In roadways, the source of organic nitrogen is likely to be the decomposition of leaves, plant material, and petroleum-based molecules. Table 3 provides a summary of the available data, where TKN is the total Kjeldahl nitrogen (organic N + ammonium), and total nitrogen (TN) is calculated from the summation of TKN, with nitrate (NO_3^-), and nitrite (NO_2^-).

Table 3. Summary of Available Stormwater data included in National Stormwaater Quality Database (Collins, et al., 2010)

Land use	NH_3-N (mg/L)		$NO_{2,3}$-N (mg/L)		TKN (mg/L)		TN (mg/L)
	Median	CoV	Median	CoV	Median	CoV	Median
Freeways (n=185)	1.07	1.3	0.28	1.2	Is 2	1.4	2.3
Mixed Freeways (n=26)			0.9	0.7	2.3	1.3	3.2

In previous research on bioretention, nitrification of ammonium has been witnessed, and since nitrate and nitrite readily dissolve in water, the completion of nitrogen cycle through denitrification is the only effective way for reducing the discharge of nitrogen to the receiving water bodies (Davis et al., 2001). To do this, the decomposition of organic nitrogen and its transformation to ammonium has to take place. The available ammonium will then have to undergo nitrification, so that an anoxic zone and organic carbon could efficiently reduce the nitrate and ensure the return of nitrogen gas to the atmosphere. Therefore, to achieve both nitrification and denitrification, sorption and biological processes should be incorporated into a stormwater treatment system, and different conditions (i.e., oxic and low organic matter and anoxic and high dissolved organic matter concentration) are needed to complete the nitrogen cycle.

Review of Research and Performance of Bioretention and Sand Filter in Nitrogen Removal

Management of stormwater runoff has come a long way from the traditional approach of conveying water downstream from where it falls. Filtration and bioretention technologies have employed precipitation, different sorptive media, and vegetation for treating the runoff. Since nitrogen is one of the primary causes of eutrophication, previous research have focused on the treatment of stormwater runoff with respect to nitrogen. While removal of heavy metals and phosphorous has been successfully observed using vegetation, soils, mulch, compost, and other media, poor nitrate reductions, and at times nitrate production has been observed to take place (Davis et al., 2006). A review of past studies indicates that the incorporation of an anaerobic process for denitrification is required to improve the nitrate removal (Davis et al., 2001). Because of its high solubility, attenuation of nitrate is low, and the addition of an anoxic zone has been shown to greatly enhance nitrate removal (Kim et al., 2003).

Since nitrification can readily take place in the environment, effective treatment of stormwater should also incorporate the kinetics of ammonification and nitrification into the designs. Currently few works have been dedicated to quantify these processes in bioretention and sand filters to optimize nitrogen removal, and study the bioavailability of the nutrients for ammonification and nitrification in the presence of sorptive media.

Design of Filter

The proposed design for the retrofit of an existing sand filter divides the filter into three zones in a treatment train approach. This first zone will ensure the retention of organic nitrogen and its subsequent decomposition into ammonia/um (ammonification), a nitrification zone, and finally the denitrification zone (Figure 2). To ensure adequate retention time in the filter, sorptive material need to be incorporated into the filtering media to prevent the discharge of influent and un-nitrified ammonia.

Ammonia/um Sorption

The sorption of a solute by adsorbent from an aqueous phase is described using the sorption isotherm, which relates the equilibrium concentration of the solute (C_e[=] mg/L) to the sorbed concentration (q[=] mg/g) at constant conditions (i.e., temperature, pH, and ionic strength). Sorption isotherms are often empirical relationships, where q and C_e are related with a constant (K), and can exhibit different forms. When a linear relationship exists between the two, the K value does not depend on the concentration of the solute, which is often seen in partitioning of certain chemicals into another phase. In many cases, however, the isotherms are nonlinear. Two frequently used nonlinear models of adsorption are the Langmuir and the Freundlich isotherms. The Freundlich model

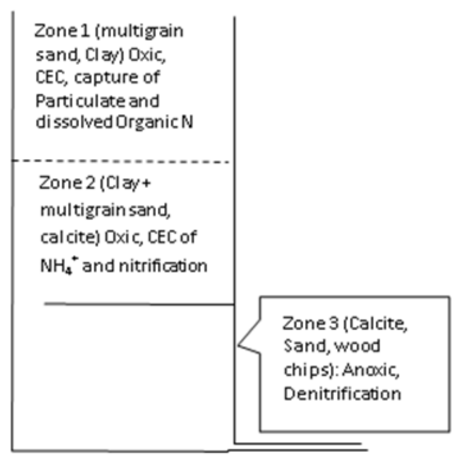


Figure 2. Modified Design of Sand Filter for removal of nitrogen in highway runoff through filtration and nitrification/denitrification processes

is described in Equation 4, where K_f corresponds to the Freundlich sorption coefficient, and 1/n is an empirical exponent, which for n=1, also corresponds to a linear relationship (Grathwohl, 1998).

$$q = K_f C_e^{1/n} \tag{4}$$

The Langmuir isotherm is another non-linear model, which assumes specific homogenous sites and monolayer adsorption (q_{max}). Equation 5 demonstrates the general form of the Langmuir model, in which K_L is the Langmuir sorption coefficient. For very low concentrations and $K_L.C_e$ <<1, Equation 5 also predicts a linear relationship for sorption; however, as $K_L.C_e$>1, q approaches q_{max} (Grathwohl, 1998).

$$q = \frac{K_L q_{max} C_{eq}}{1+K_L C_{eq}} \tag{5}$$

In previous studies, the Freundlich isotherm was observed to describe the adsorption of ammonium to sediment and clay material well (Huang, et al., 2010, Ugurlu, et al., 2011). In addition to adsorption, ion exchange has also been found to be influential in the uptake of ammonium by clay particles, such as Na-bentonite (Rozic et al., 2001). Furthermore, the combined use of clay aggregates for sorption of ammonium and nitrification has also been successfully tested under wastewater conditions. High sorption of ammonium from domestic wastewater using clay-zeolite aggregates was observed during loading of ammonium, which was followed by nitrification during dry periods (Gisvold et al., 2000).

Effect of Environmental Conditions on Adsorption

The sorption of ammonium as well as other compounds is dependent on the pH of the system. At low pH values, H^+ ions compete with cations for sorption sites, and therefore, it is speculated that increasing the pH also increases the adsorption of ammonium. Another factor to be considered, however, is the acid dissociation constant of ammonium. According to Equation 6, at pH values higher than 9.4, ammonium (NH_4^+) will convert to dissolved ammonia (NH_3), and therefore for pH values approaching 9.4, the adsorption is expected to follow a different trend. In a previous study, the adsorption of ammonium onto fly ash and sepiolite clay was found to be maximum at pH of 8 (Ugurlu, et al., 2011).

$$K_a = \frac{(NH_3)(H^+)}{(NH_4^+)} = 10^{9.4} \tag{6}$$

Another important factor that affects the sorption of ammonia/um is the presence of other solutes. Since ammonium is adsorbed as a cation onto the surface of adsorbents, the presence of other cations can inhibit its sorption as these cations are now competing with ammonium for the surface sites. As a general rule, cations of higher valence are preferentially adsorbed to the surface (Stumm and Morgan, 1996). In a previous study, the affinity of ammonium for the zeolite surface was found to decrease in the order: $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$ (Huang et al., 2010). Additionally, the ionic strength or the salinity of the water also affects the sorption of ammonium. Previous findings suggest that the sorption of ammonium in fresh water conditions is higher than that of seawater, but that the ammonium adsorbed onto freshwater sediments was more exchangeable than in seawater sediments (Seitzinger et al., 1991). Since nitrification relies on biologically available ammonia, the lower ionic strength is optimum for biological activity required for nitrification.

Project Goals

Because of the presence of microorganisms, the biodegradation of ON and release of ammonia will takes place in the stormwater runoff and treatment media. As discussed earlier, the conversion of the ammonia to nitrate either within the treatment cell or after discharge is inevitable, and because of the high mobility of nitrate, denitrification is perhaps the only way to effectively reduce the nitrogen in urban runoff. To have an efficient system, the retention time of the sand filter must be sufficiently long to allow the 1) biodegradation of ON, 2) nitrification, and 3) denitrification to take place. To enhance the retention of the nitrogen species in the sand filter, the type of the filtering media as well as the volume and the volumetric outflow will have to be selected and controlled. In this work, the optimum filtering media will be selected, and the kinetics of nitrification will be quantified to enhance the performance of a sand filter with respect to nitrogen species. This study will be coupled with other research results on ammonification, denitrification, and phosphorous removal. Figure 3 maps the different phases of the experimental work of the project before implementing the design to the field.

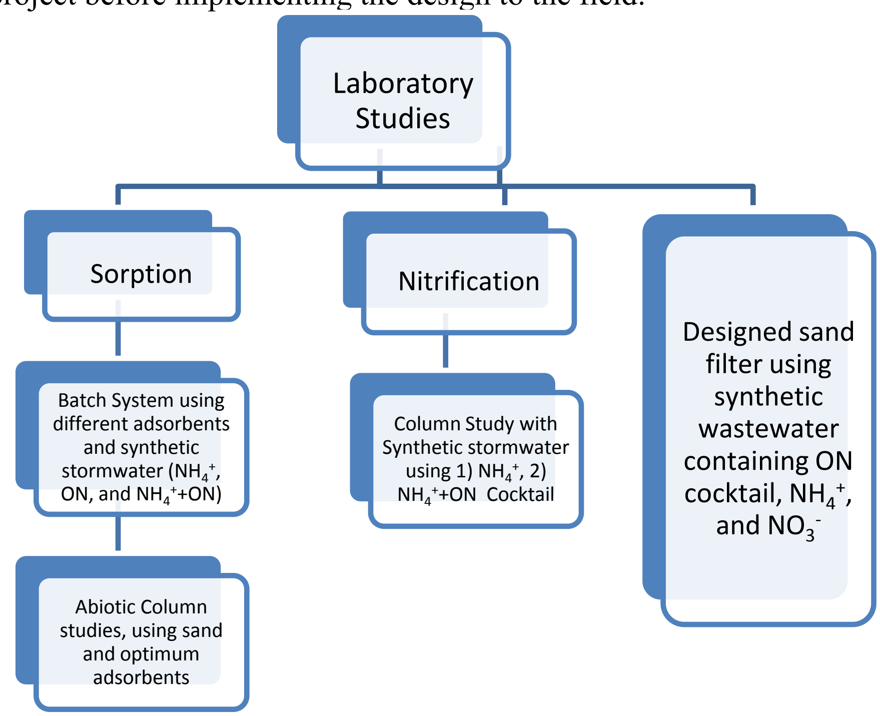


Figure 3. Diagram demonstrating different steps of laboratory studies to be conducted prior to implementation of the findings in field.

Project Goals for Phase I

The first phase of the project concentrated on selecting the media required for maximum adsorption of ammonium. The media tested in this phase included pool filter sand, different clay material, and recycled crushed brick. Since adsorption is affected by acidity of the systems, the influences of pH, within neutral pH ranges expected in stormwater runoff, on uptake of ammonium by the different adsorbents at room temperature is also investigated. After determining the adequate time to reach equilibrium, sorption isotherms were obtained. The breakthrough time for laboratory scale columns can then be estimated, and small-scale column experiments are underway to determine the appropriate combination of adsorbent and sand for the sorptive uptake of ammonium. These results will be compared to large scale biotic column experiments that study the changes in the amount of influent and effluent ammonium from sorption and nitrification. The rate of nitrification and the environmental factors that affect it will then be quantified.

Methodology

Equilibrating Sorption

To determine the time required for equilibrium to be reached in sorption samples, 0.5 g of a specific adsorbent was placed in 6-50 mL centrifuge tubes, and 50 mL of 10 mg/L N-NH_4Cl was added, and the ionic strength was fixed at 0.03 M. Each of the centrifuge tubes was then placed in a tumbler and shaken at 29 rpm for different durations of 0.5, 3, 6, 8, and 24 hours. The pH of the samples was monitored regularly during the test time to ensure neutral pH conditions of 6 – 7. At each duration, the samples were centrifuged at 1100 g, and the solution was decanted and separated, and measurements of soluble ammonium took place using ion chromatography. This procedure was repeated for the six adsorbents tested, and tested in triplicates. The time at which the concentration of the ammonium stopped changing was marked as the time required for the sample to reach equilibrium.

Sorption Capacity of Media

The introductory phase of the experimentation included determining the sorption capacity of different adsorbents as candidates to be used in the filtering media. To do this, each adsorbent listed in Table 4 was sieved through No. 10 and 20 sieves, and the coarse and fine materials were discarded. The selected size of each adsorbent was then washed with deionized water until the water used for washing was clear. At this point the adsorbents were then washed with 0.25 M NaOH for 2 hours and shaken at 32 oscillations/minute using an automatic shaker. The washing NaOH solution was discarded, and after rinsing the adsorbents with DI water for 5 minutes, the rinsing liquid was replaced by 0.25 M HCl and placed in the shaker overnight to increase the surface acidity. The longer exposure time of adsorbents to HCl (approximate exposure to 0.25 M HCl was 12 hours) was required because of the high alkalinity of the adsorbents. Following the acid wash, the adsorbents were then washed with deionized water until clear, and shaken for an additional 2 hours. Subsequently, each adsorbent was dried at 105^{o}C until they reached steady weight.

Table 4. List of Adsorbents Used for Potential Use in Filter Media

List of Adsorbent	Abbreviated Name	Particle Size Selected for this Analysis	Source
Crushed Brick	BR	1-2 mm	BTN Building Salvage Specialists

California Aluminosilicate	CA	1-2 mm	Oil-dri
Georgia Attapulgite	GA	1-2 mm	Oil-dri
Montmorillonite (Red)	MR	1-2 mm	Oil-dri
Montmorillonite (Brown)	MB	1-2 mm	Oil-dri
Pool Sand	Sand	1-2 mm	

Once dried, 0.5 g of each adsorbent was placed in 50 mL centrifuge tubes, and to each sample 50 mL of a specific concentration of NH_4^+ at a fixed ionic strength was added to develop sorption isotherms. Concentrations of 10, 7.5, 5, 2.5, and 1 mg N-NH_4Cl at an ionic strength of 0.03 M were used in this study. To test the potential competition of other commonly encountered cations (i.e., Na^+, K^+, and Ca^{2+}) with NH_4^+, the background electrolyte used in ammonia solutions was prepared using 0.03 M NaCl, 0.03 M KCl, and 0.01 M $CaCl_2$. The pH of each of the samples was neutralized to a pH range of 6 – 6.5, and 7.5 - 8 via the addition of HCl and NaOH as needed. This was achieved for crushed brick (BR), California aluminosilicate (CA), and Georgia Attapulgite (GA) with the addition of 0.2 – 0.3 mL of 1 M HCl. Samples of Montmorillonite required the use of 0.5 – 1 mL 0.1 M NaOH in addition to the 0.2 mL 1 M HCl to achieve the desired pH range. Sorption samples using sand as adsorbent did not require pH adjustment. The samples were placed in a tumbler and mixed at 29 rpm for 24 hours. Upon completion of the 24 hours, the concentration of ammonium and the background electrolyte was tested using ion chromatography immediately. The samples were also frozen to determine the ammonium concentration using the Phenate Method (*Standard Methods for the Examination of Water and Wastewater*, 4500 F) (Eaton and Franson, 2005).

Ammonia/um Measurements

Ion chromatography (Dionex IC-1100) was used to determine the concentration of ammonium as well as other cations in the supernatant solution in the sorption studies. Calibration curves were obtained using standard samples containing specific concentrations of Na^+, NH_4^+, Ca^{2+}, K^+, and Mg^{2+} from standard solutions of NaCl, NH_4Cl, $CaCl_2$, KCl, and $MgCl_2$. Because of overlap of the curves of sodium and potassium with ammonium in the ion chromatography measurements, the concentration of ammonium will be duplicated using Standard Methods 4500F (i.e., the phenate method) (Eaton and Franson, 2005).

Both analytical methods require rigorous calibration using standards in concentrations between 10 and – 0.1 mg N-NH_4^+/L. Standard checks were used every 10 measurements to ensure the accuracy of measurements. In cases where a shift in standard checks (i.e., change in concentration > 5% of standards) was observed, the standard curve was recalibrated. Measurements of the ion chromatograph and the phenate method were made in duplicates and the averages of each of the readings were reported as the concentration. In case of significant variations between the two measurements, the samples were retested.

Results and Discussion

Based on observations, the time required for the samples to reach equilibrium was found to be 24 hours. The results of testing five adsorbents and sand appear in Figure 4, where the initial ammonium concentration of 10 mg N-NH_4^+/L in 0.03 M NaCl at 22-25^oC was exposed to

0.5 g of each material. As can be seen, the concentration of soluble ammonium continues to change until 24 hours. Therefore, for the adsorption isotherms, the samples were shaken for a minimum of 24 hours.

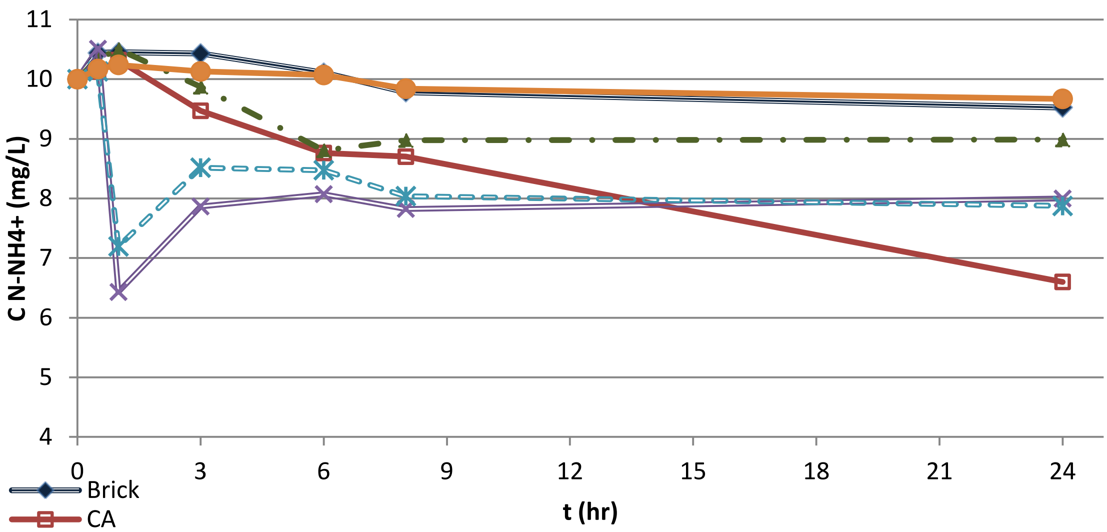
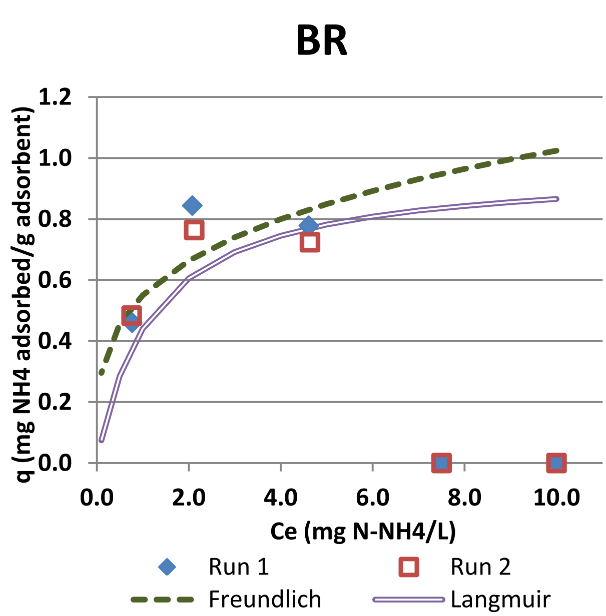


Figure 4. Change of Concentration of ammonium ($C_{initial}$= 10 mg/L) in 0.03 M NaCl, at pH = [6 – 7.2] and room temperature (22 – 25°C) with respect to time.

The initial isotherm studies for the six adsorbents demonstrated poor adsorption for GA, and because of lack of stability of the MB clay aggregates when exposed to sodium hydroxide solutions, further testing of these two adsorbents was discontinued. Adsorption isotherms for the remaining Crushed Brick (CB), California hydro aluminosilicate (CA), red Montmorillonite (MR), and sand for a pH of 6 – 6.7 appear in Figure 5.

(a)



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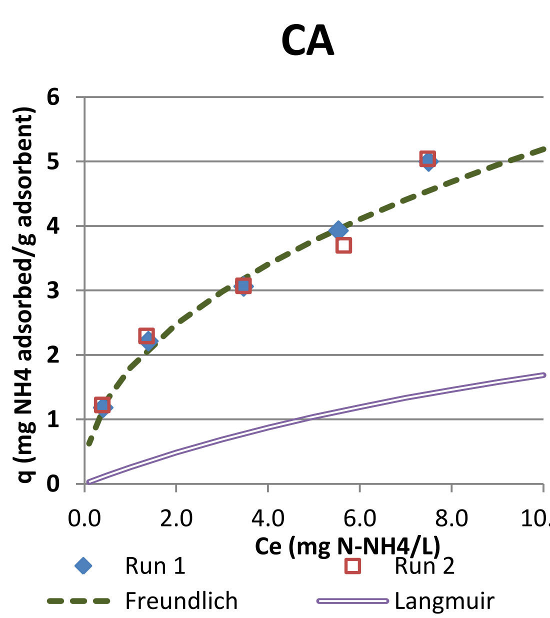

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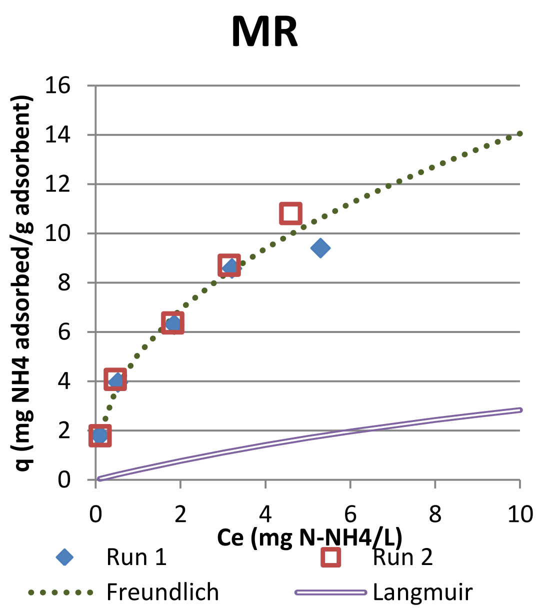


(d)

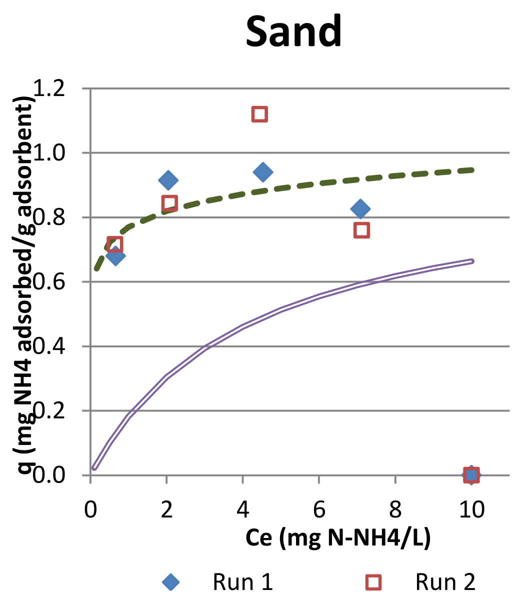


Figure 5. Sorption isotherm for the four feasible adsorbents, obtained after shaking samples for 24 hours at pH = [6–6.7], and in background electrolyte concentration of 0.01 M $CaCl_2$, and T = 22 – 25°C

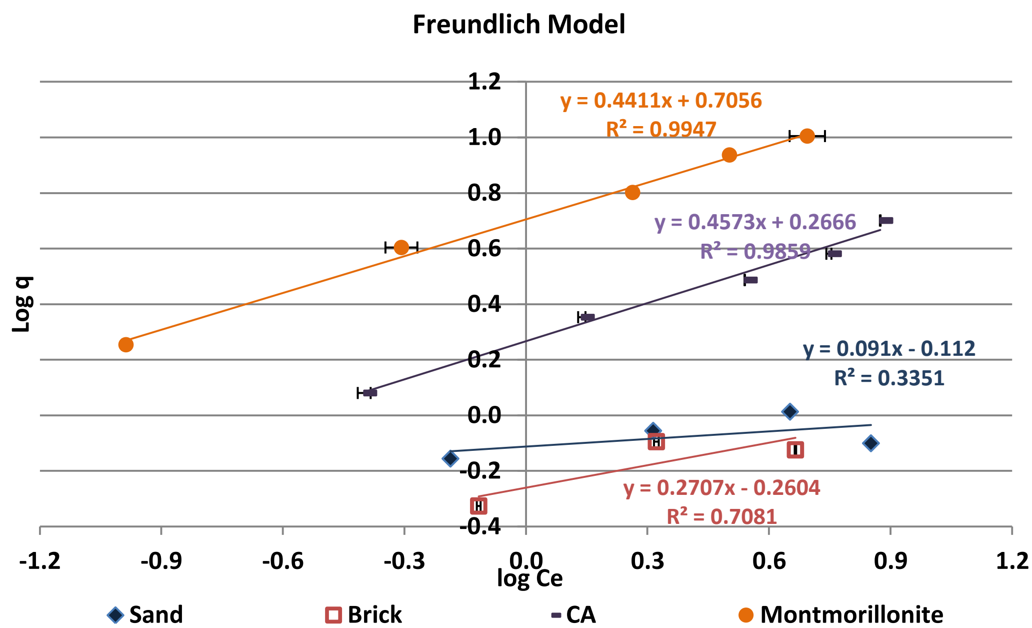
The Langmuir and Freundlich isotherms obtained from these data are also graphed in Figure 5, giving an indication of the most representative model of sorption for each material. As can be seen, MR has the highest sorption capacity, followed by CA. Sand, on the other hand, shows minimal uptake of ammonium, and similar findings were observed for BR. The sorption of ammonium by BR and sand is very small and appears to reach a peak and decrease for higher concentration. The low uptake of the ammonium by these two adsorbents could be responsible for this unusual trend. Additionally, since ion chromatography was used to determine the concentration of ammonium in the supernatant solution, the presence of other cations in the system, particularly Na^+ could have reduced the accuracy of measurements.

The sorption isotherms for the Langmuir and Freundlich models for the adsorbents were obtained and appear in Table 5, and a graphical presentation is summarized in Figure 6. These isotherms were used to predict q for different C_e values and are plotted in Figure 5. As can be seen, the coefficients of determination for MR and CA are highest for the Freundlich isotherm model (r^2=0.99), but also correspond to adequate accuracy for the Langmuir model. BR and sand, on the other hand, are fit by the Langmuir model better (r^2 = 0.9 vis-á-vis 0.71for BR, and 0.56 vis-á-vis 0.34 for sand for the Langmuir and Freundlich, respectively). From Figure 5 and 6, it can also be seen that MR and CA possess the highest sorption capacity q (mg/g) and high correlations for the model fits. Sand and BR, however, show relatively poor fit, particularly sand with the highest coefficient of determination of 0.56, for which a clear trend could not be observed between C_e and q, and as can be seen from Figure 5, both Langmuir and Freundlich models are poor fits for the data obtained for sand. Consequently, MR followed by CA is the strongest adsorbent for ammonium.

Table 5. Langmuir and Freundlich Sorption Isotherm Coefficients for Ammonium in 0.01 M $CaCl_2$ Background Electrolyte - pH= [6-6.7] and T=22 – 25°C

Adsorbent	Langmuir Model			Freundlich Model		
	q_{max}	K_L	r^2	K_f	1/n	r^2
BR	0.97	0.83	0.90	0.55	0.27	0.71
CA	4.5	0.06	0.95	1.8	0.46	0.99
MR	8.5	0.05	0.98	5.1	0.44	0.99
Sand	0.94	0.24	0.56	0.77	0.09	0.34

(a)



(b)

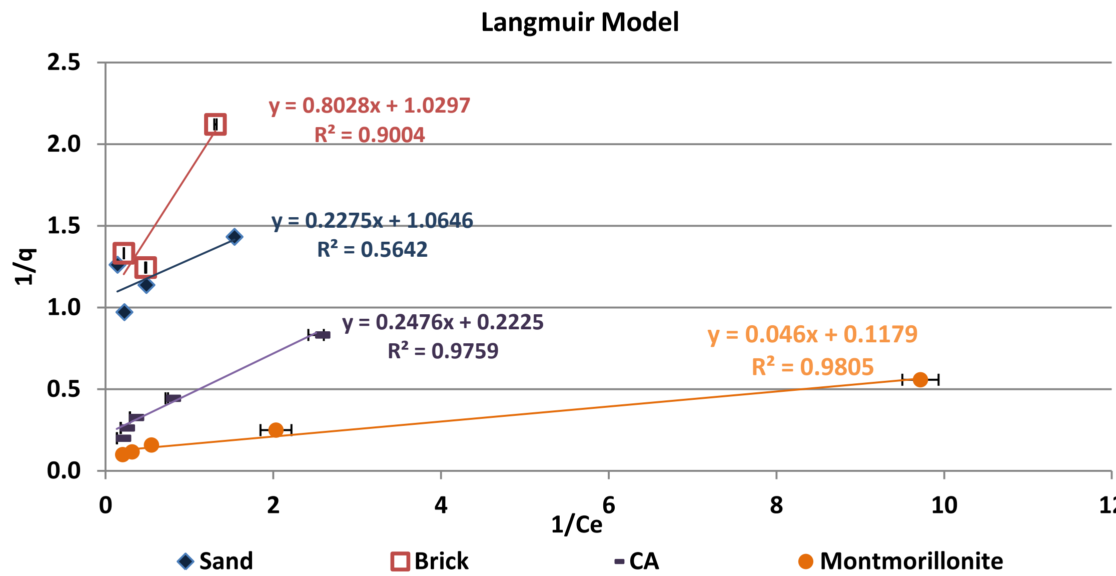
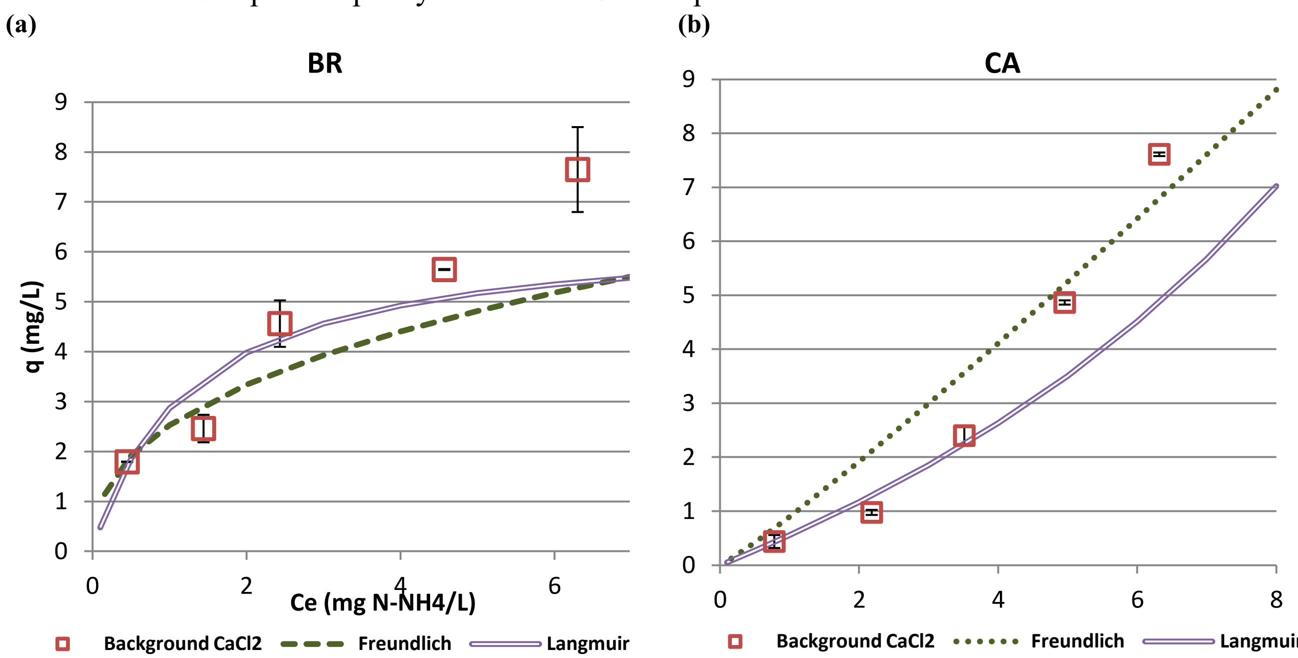


Figure 6. The Freundlich (a) and Langmuir isotherm linearizations for the adsorbents in 0.01 M $CaCl_2$ and pH = [6 – 6.5] at T = 22-25°C.

The effects of pH and competing cations on the sorption of ammonium to BR, CA, and MR were also studied at pH 7.5 – 8 at room temperature (T=22-25°C). The results appear in Figure 7. As can be seen from the figure, ammonium adsorbed more strongly to MR. The overlap of the sodium and potassium curves with that of ammonium during measurements made with ion chromatography caused inaccuracy and overestimation of the ammonium concentration, particularly for the CB and CA. Therefore, these data are not shown. The increase in pH enhanced the adsorption capacity for BR and CA samples.



(c) (d)

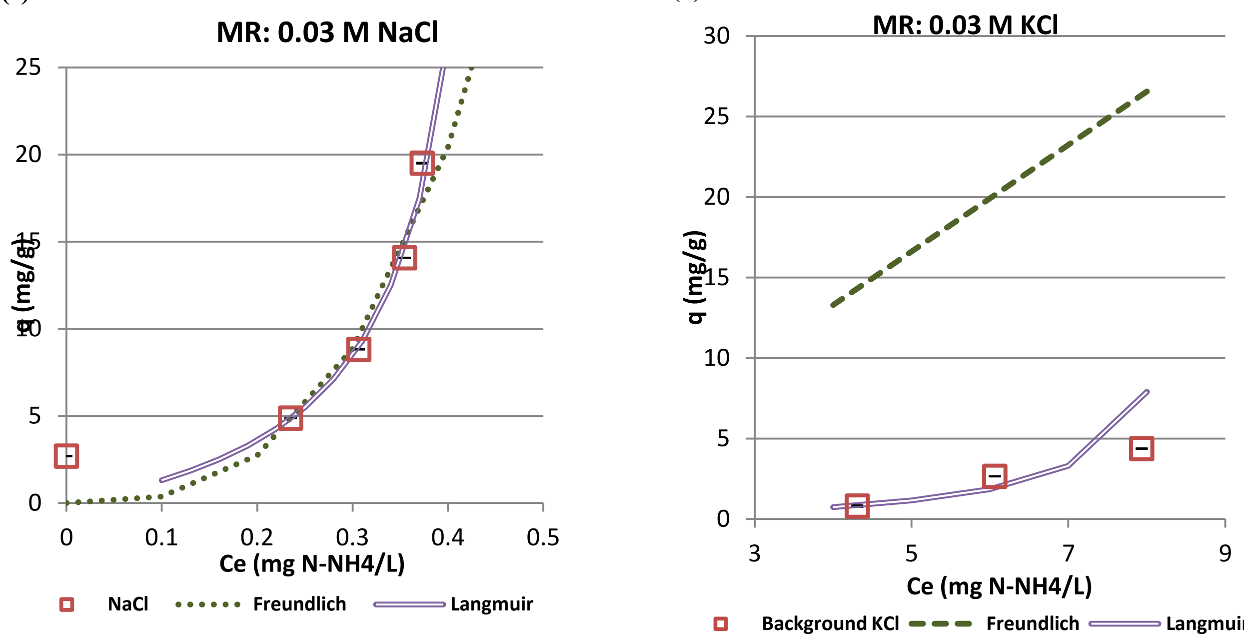


Figure 7. Ammoinum sorption isotherm for the three feasible adsorbents, obtained after shaking samples for 24 hours at pH = [7.5 – 8] tested with 3 different background Electrolytes of 0.03 NaCl, 0.01 $CaCl_2$, and 0.03 KCl. Because of interference of sodium and potassium peaks during IC analysis, the data for 0.01 M NaCl and 0.01 M KCl for CA and BR are not shown.

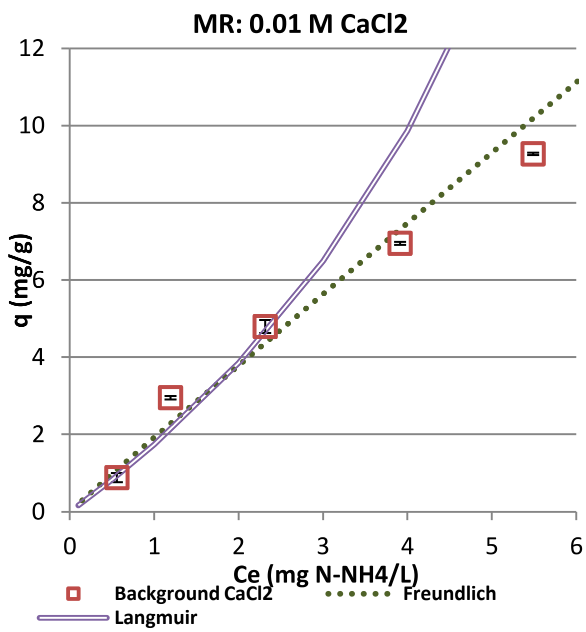


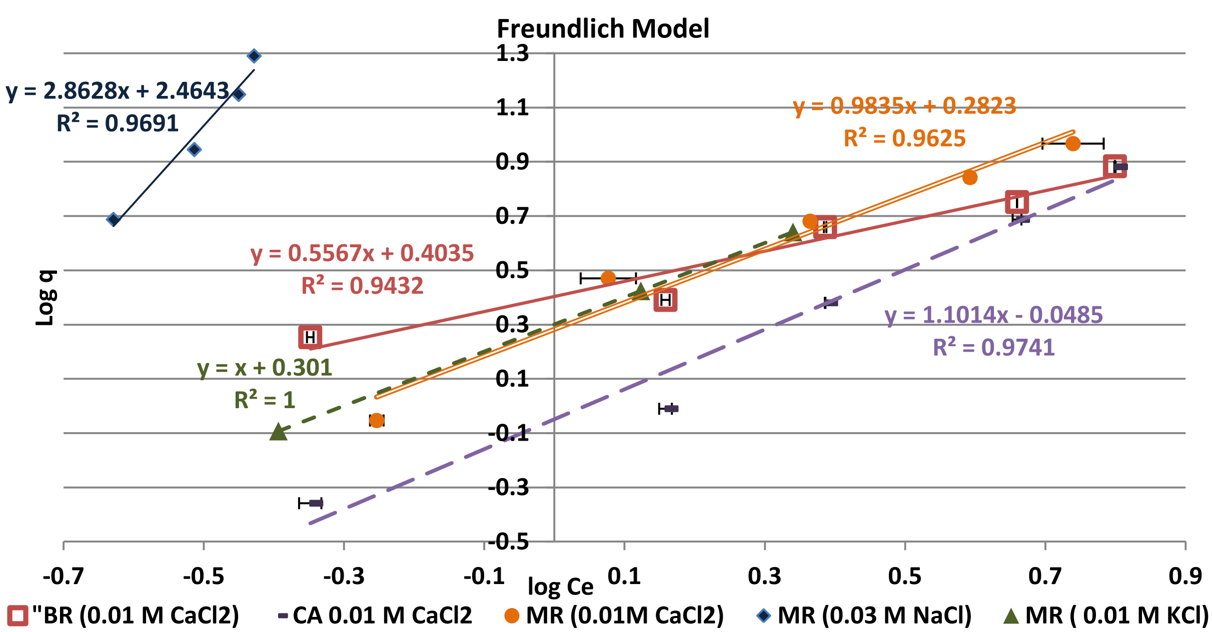
Figure 7 Continued. Sorption isotherm for the three feasible adsorbents, obtained after shaking samples for 24 hours at pH = [7.5 – 8] tested with 3 different background Electrolytes of 0.03 NaCl, 0.01 $CaCl_2$, and 0.03 KCl. Because of interference of sodium and potassium peaks during IC analysis, the data for 0.01 M NaCl and 0.01 M KCl for CA and BR are not shown.

As can be seen from the fit of the two isotherms to the collected data, except for BR and MR in the background electrolyte of 0.03 M KCl, the Freundlich isotherm has a better fit with the data. Comparing the adsorption of ammonium onto MR in 0.01 M $CaCl_2$ at the two different pH ranges, it can be seen that its sorption capacity remains relatively constant. This could be attributed to the presence of the divalent Ca^{2+} cations, which can compete with NH_4^+, and at higher pH range, Ca^{2+} may have a higher affinity to the sorption sites than ammonium. In spite of its monovalent state, potassium has been shown to out-compete and dominate adsorption over ammonium, and in certain cases is used to cause desorption of ammonium from adsorbents (Mamo, et al., 1993, Fitzsimons, 2006). Unlike montmorillonite, the adsorption capacity of CA and particularly BR increases with pH. The Freundlich and Langmuir isotherms at pH = 7.5 – 8 at room temperature for these three adsorbents appears in Table 6, and their fit to the linearized Langmuir and Freundlich models are displayed in Figure 8.

Table 6. Langmuir and Freundlich Sorption Isotherm Coefficients for Ammonium in 0.01 M $CaCl_2$ and 0.03 M NaCl Background Electrolyte - pH= [7.5 - 8] and T=22 – 25°C

Adsorbent	Langmuir Model			Freundlich Model		
	q_{max}	K_L	r^2	K_f	1/n	r^2
BR (0.01 M $CaCl_2$)	6.46	2.99E-02	0.86	2.53	0.40	0.94
CA (0.01 M $CaCl_2$)	-10.5	-1.82E-01	0.98	0.894	1.1	0.97
MR (0.01 M $CaCl_2$)	-17.6	-3.59E-02	0.97	1.92	0.98	0.96
MR (0.03 M NaCl)	-4.94	-1.95E-02	1.00	291	2.9	0.97
MR (0.03 M KCl)	-0.902	-10.9508	0.95	3.32	1.0	1.00

(a)



(b)

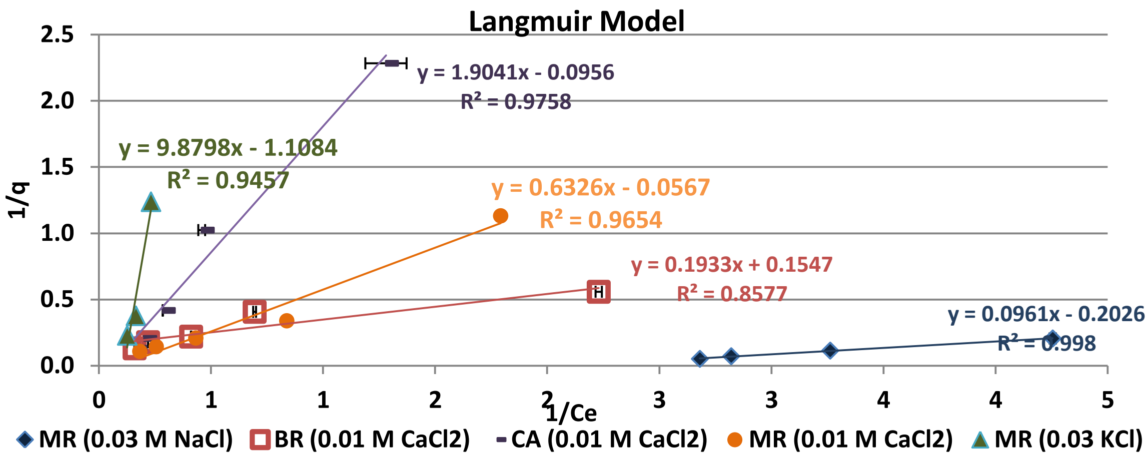


Figure 8. The Freundlich (a) and Langmuir isotherms for the adsorbents in 0.01 M $CaCl_2$ and pH = [7.5 - 8] at T = 22-25°C.

As summarized in Table 5 and displayed in Figures 5 and 6, the Freundlich isotherm produced a higher coefficient of determination for the three adsorbents, and fits the experimental data better than the Langmuir isotherm. MR in 0.03 M KCl and BR are the only exceptions for which the Langmuir model has a better fit. Neither the Langmuir nor the Freundlich quantify the data collected for the CA ammonium adsorption very accurately. Nevertheless, the Freundlich isotherm predicted more representative sorption capacities, and was thus chosen as the sorption model for these adsorbents.

Column Studies

Since the sand filter is a flow-column system, it is important to estimate the life span of the adsorbents used in the filter. To do this, breakthrough curves were estimated using the calibrated Freundlich and Langmuir (BR and MR in KCl for pH range of 7.5-8) isotherms. Equation 7 was used to estimate the breakthrough time (t_B) for the small-scale laboratory columns for an influent concentration of 5 mg-N/L and a volumetric flow rate (Q) of 5 mL/min (49 cm/hr). The mass of adsorbent ($M_{adsorbent}$) used is equal to the mass of each adsorbent required to fill a small-scale column (D=2.8 cm, and H = 23.1 cm). The sorption capacity (q) was calculated from the Freundlich isotherms for MR and CA and BR (pH = 7.5-8), and Langmuir for BR (pH = 6-6.5) and sand. Table 4 summarizes the calculated times.

$$t_B = \frac{q_o M_{adsorbent}}{C_o Q} \quad (7)$$

Table 6. Breakthrough times calculated from best fit isotherms for each adsorbent at room temperature and two different pH ranges of [6 – 6.5], and [7.5-8]

Adsorbent	Madsorbent (g)	pH = [6-6.5]		pH = [7.5 - 8]	
		q (mg/g)	t_B (days)	q (mg/g)	t_B (days)
BR (0.01 M $CaCl_2$)	152.3	0.782	3.3	4.82	20.4
CA (0.01 M $CaCl_2$)	124.5	3.77	13.1	5.25	18.2
MR (0.01 M $CaCl_2$)	107.4	10.4	30.9	9.30	27.7
MR (0.03 M NaCl)	107.4	NA	NA	3.10E+04	9.24E+04
MR (0.03 M KCl)	107.4	NA	NA	16.60	49.5
Sand (0.01 M $CaCl_2$)	179.3	0.51	2.55	NA	NA

As expected, montmorillonite has the longest breakthrough, and is expected to be the most effective media for reduction of ammonium from the stormwater runoff. Crushed brick is also an effective adsorbent at the higher pH range, but at low pH shows similar behavior as that of sand.

Current and Future Work

Abiotic Column Studies

The current work of this project is focusing on experimental determination of the sorption capacities of the adsorbents in small columns (D = 2.8 cm, H = 23.1 cm) containing mixtures of sand and each of the three adsorbents. Four columns are tested at a time with the influent ammonium loading of 5 mg/L at a fixed flow rate of 5 mL/min at neutral pH conditions [7.5-8], room temperature (T=20-25^oC), and with media particle size diameter of 1 – 2 mm. Four columns of sand, adsorbent, and mixtures of sand and adsorbent at 75:25 and 50:50 ratios are prepared. The set-up of this experiment appears in Figure 9. The current work is focusing on continuous flow systems, and the effluent pH, concentration of cations, such as Ca^{2+}, and NH_4^+ are monitored. Additionally, nitrate concentration is also tested to ensure that nitrification is not the cause of ammonium reductions observed in the effluent. Similar work will be conducted to focus on intermittent flow, and the results will be compared. Additionally, sorption capacity and hydraulic conductivity will be recorded for each adsorbent/sand combination in order to determine the ideal ratio of the two for the filter media.

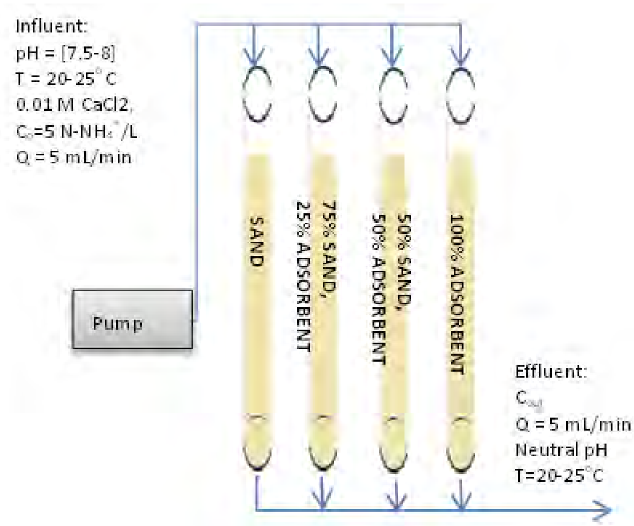


Figure 9. Set-up of introductory column studies

Biotic Column Studies

Once the introductory column studies are performed and the sorption capacities of columns are determined, columns will be employed to investigate the rate of nitrification with respect to sorption. The media will include the ideal combination of adsorbent and sand, and the rate of nitrification will be calculated by subtracting the effluent concentration of ammonium and the adsorbed ammonium from the total influent concentration over time at neutral pH = [7.5-8], and room temperature settings T = [20-25]^{o}C in intermittent flow conditions with a dry period of 2 days. Based on observations, the media thickness that needs to be dedicated to the retention of ammonium via sorption and nitrification will also be calculated based on experimental observations.

Conclusion

In this phase of the project, sorption characteristics of sand and other adsorbents were investigated in batch systems to determine the time required for equilibrium to be reached. Based on observations made, 24 hours is required for the system to equilibrate, and work on two of the adsorbents (GA Attapulgite and one form of montmorillonite) was discontinued because of small sorption characteristics (GA) and instability of the structure of the adsorbent (MB). Sorption isotherms were determined for the remaining adsorbents (BR, CA, MR), and sand as a reference for the sand filter at room temperature and two different pH ranges of [6 – 6.7], and [7.5 -8] in 0.01 M $CaCl_2$. Higher adsorption capacities were observed at the higher pH range, and crushed brick and CA aluminosilicate showed enhanced sorption, while montmorillonite showed little improvement.

Similar studies were conducted to determine competition between the background electrolyte and ammonium for sorption to the surface of adsorbents, which could not be quantified due to interferences of potassium and sodium cations with ammonium measurements. Similar works using a standard method are underway to determine the sorption selectivity. Sorption to the surface of montmorillonite was the highest of the adsorbents evaluated with a background electrolyte of 0.03 M NaCl.

Using sorption isotherms that were developed, breakthrough times were estimated. Montmorillonite is predicted have the longest breakthrough at both pH settings, and the breakthrough curves for BR and CA were found to be similar at the higher pH range of 7.5 – 8 (18 days for BR and 20 days for CA). Overall, the use of BR at higher pH seems suitable as an adsorbent, but pH needs to be adjusted to ensure that the transition from ammonium ions to dissolved ammonia does not take place in the system (i.e., at pH 9.4, 50% of ammonium in the system is converted to dissolved ammonia). The column studies underway will be used to further narrow the recommended adsorbents based on adsorption capacities, and hydraulic conductivity of the media. Once adsorbents are selected, the rates of nitrification will be determined.

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APPENDIX C:

Progress Report: Year 1: Denitrification Optimization in Bioretention using Woodchips as a Primary Organic Carbon Source

July 2012

Progress Report - Year 1: Denitrification Optimization in Bioretention using Woodchips as a Primary Organic Carbon Source

Project Duration: August 2011 – July

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Contents

Executive Summary

As a way of mitigating the impact of urban development, stormwater control measures (SCMs) are employed to increase water quality and decrease the amount of runoff discharged to water bodies. Bioretention systems, an example of an SCM, are shallow sections of very porous media employed for storing and infiltrating stormwater runoff. Although still in its infancy as a technology, bioretention systems have proven effective at removing pollutants from stormwater and increasing infiltration. Bioretention is still lacking in its ability to mitigate nitrogen concentrations in stormwater. These concentrations can cause the eutrophication of surface water bodies. Design options are available that can improve nitrogen removal from stormwater.

One bioretention design splits the typical homogeneous bioretention cell into a treatment train. In so doing the system is able to treat stormwater runoff for nitrogen in the first part of the treatment train. Nitrogen treatment is a time sensitive process which will limit the storage capacity of this first section. Any water that exceeds the storage capacity of the first portion will spill over into the second portion of the treatment train where it will filter quickly removing other pollutants of interest.

By following the nitrogen cycle the first portion of the treatment train can effectively remove nitrogen from the stormwater. The research being conducted focuses on the optimization of the denitrification process of the nitrogen cycle. By creating an anoxic zone and providing a source of organic carbon, denitrifying microorganisms colonize the media and convert nitrate-N into nitrogen gas which is released into the atmosphere.

The results of the research that has been conducted thus far show the system effectively removing nitrogen. Artificial stormwater containing 3 mg/L of nitrate-N is filtered slowly through a column of media designed to mimic a system in the field. Water was drained for a period of 2.3 days. Of the five species of woodchips being evaluated, column studies have shown thus far that Willow Oak woodchips are the most effective source of organic carbon for removing nitrate-N while leaching the least amount of Total Kjeldahl Nitrogen. Using the Willow Oak woodchips 60.3% of the total nitrogen mass is removed from the artificial stormwater. When leaching of Total Kjeldahl Nitrogen from the woodchips is neglected a total of 81.6% of the total nitrate-N mass is removed. Wild Cherry, Virginia Pine, and American Beech show 37.5%, 47.4%, and 34.4% removal of total nitrogen mass respectively and 71.4%, 78.4%, and 87.2% removal of total nitrate-N mass respectively.

The trends in the data show that the bacteria require a full cycle of saturation and dry period before they become fully established. After that time the nitrogen removal becomes much more consistent. When varying the amount of time it takes for the artificial stormwater to drain from the column it is evident that a longer drainage time (2.3 days) produces better overall results than shorter drainage times (1.5 days). More nitrogen is removed when the water is drained over a period of 2.3 days than over 1.5 days. When the drainage time was limited to 1.5 days using Willow Oak woodchips, 6.5% of the total nitrogen mass was removed while 51.5% of the total nitrate-N mass was removed.

More testing is necessary in order to identify the optimum conditions needed to induce denitrification. One of the five selected wood species remains to be tested and compared to the other collected data at a drainage time of 2.3 days. By testing two more experimental durations the optimum drainage time for nitrogen removal can be established as well. The amount of woodchips in the media and size of the woodchips will also be varied in order to determine the optimum carbon content and surface area necessary for denitrification.

Background

Introduction

Increases in pollutant and stormwater loads from urban areas have caused a push for mitigation. As urban areas develop, natural ecosystems, previously conducive to infiltration of stormwater, have become impervious. Roads, parking lots and buildings act as non-point sources of pollution. Larger volumes of water cause erosion while increases in mobilized pollutants cause eutrophication of surface water bodies. This amounts to losses in waterfront property, recreational areas, drinking water supply, and wildlife habitat. As a way of mitigating the impact of urban development, stormwater control measures (SCM) are employed to increase water quality and decrease the amount of runoff discharged to water bodies. Runoff from impervious surfaces is collected and managed in SCMs such as bioretention cells, rain gardens and vegetated swales. Here water is allowed to infiltrate into the ground, naturally filtering out pollutants and returning urban areas closer to pre-development hydrologic conditions. Although effective, these technologies are still somewhat immature and more research is needed to optimize their efforts.

Treatment for nitrogen is one area that needs improvement. Nitrogen is one of the limiting nutrients associated with the eutrophication of lakes and rivers. Eutrophication is the change in the volume and diversity of biomass in an aquatic ecosystem. Increases in nutrients that are usually scarce cause rapid growth of some species, resulting in the death of others. Therefore, a spike in nitrogen can rapidly accelerate eutrophication when left unchecked. Bioretention is a very effective means of mitigating the effects of urban development and has shown some promise in the area of nitrogen treatment. The goal of this research is to design a layered bioretention system that optimizes the efficiency of nitrogen removal from stormwater runoff. This will be achieved by determining the optimum conditions for denitrification.

Literary Review

Bioretention cells are typically shallow (2-4 ft deep) areas of very porous media (Li and Davis 2009). The media is usually topped by a mulch layer to retain moisture and prevent unwanted vegetated species (Li and Davis 2009). Selected vegetation is planted in the bioretention to promote evapotranspiration and uptake of pollutants (Li and Davis 2009). Stormwater from the target watershed is directed into the bioretention where it quickly infiltrates. Pollutants are removed from the water as it passes through the media by means of filtration, adsorption, biological processes, and/or plant uptake (Li and Davis 2009). Clean water can then recharge groundwater by infiltrating further or be taken up by plants (Li and Davis 2009). What remains is usually collected by an underdrain that discharges into surface waters (Li and Davis 2009). Thus hydraulic and pollutant loads are greatly reduced.

Treatment of nitrogen using bioretention has been studied in a few different research endeavors (Kim et al. 2003; Hsieh et al. 2007; Ergas et al. 2010). Different designs have been able to remove anywhere from 70 to 90 percent of the total nitrogen in runoff (Kim et al. 2003; Hsieh et al. 2007; Ergas et al. 2010).

Typical urban stormwater event mean concentrations are approximately 1 to 3 mg/L total nitrogen depending on the land use (Collins et al. 2010). Typically one third of the total nitrogen will be in the form of organic nitrogen, one third will be ammonium, and one third will be oxidized nitrogen (Collins et al. 2010).

A bioretention facility designed to incorporate nitrogen into its treatment processes does so by following the nitrogen cycle. Figure 1 shows how the nitrogen cycle occurs naturally. Organic nitrogen, from decaying plant matter, is converted to ammonium (ammonification). Ammonium is then oxidized to nitrite and then further oxidized to nitrate (nitrification). Finally nitrate is reduced to nitrogen gas which is released into the atmosphere (denitrification). Atmospheric nitrogen can be fixed into usable forms for plants (nitrogen fixation).

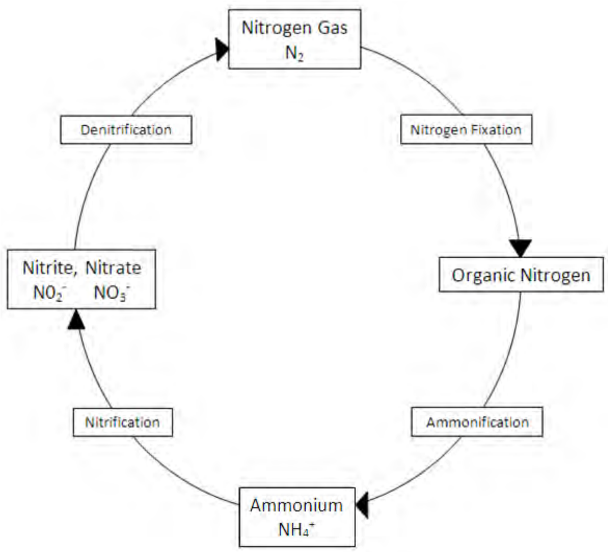

Figure 1: Nitrogen Cycle

These steps naturally occur very slowly but are made more rapid by bacterial processes (Collins et al. 2010). Organic nitrogen is broken down over time and ammonium can then undergo nitrification. Nitrification requires the availability of oxygen. Air from the atmosphere containing oxygen is used by bacteria to oxidize the ammonium. According to Hsieh et al. (2007) the bioretention nitrification process occurs in the time between storm events. In Maryland, on average there are six days between storm events (Hsieh et al. 2007).

Biologically, nitrate reduction can follow assimilatory or dissimilatory pathways (Blowes et al. 1994). Nitrate can be reduced to ammonia and assimilated by the bacterial cell or used as a terminal electron acceptor in respiration (Blowes at al. 1994). Ultimately, respiration will convert nitrate into nitrogen gas which is released into the atmosphere. In stormwater treatment both processes take place to effectively remove nitrogen from aquatic/terrestrial systems.

Denitrifying bacteria require anoxic conditions (the absence of molecular oxygen in the presence of nitrate) in order to reduce nitrate (Kim et al. 2003). This is because most denitrifying bacteria are facultative and will use oxygen as a terminal electron acceptor because it requires less energy (Blowes et al. 1994). After the oxygen is depleted the bacteria will then begin to convert nitrate into nitrogen gas while using the attached oxygen as a terminal electron acceptor

(Blowes et al. 1994). Proper conditions for denitrification can be achieved by saturating the media in the lower layer of a bioretention cell (Kim et al. 2003). This makes oxygen from the atmosphere inaccessible (Kim et al. 2003). Several methods are used to saturate this layer. Some of these methods are using a media with low porosity (Hsieh et al. 2007; Ergas et al. 2010), useing an upturned underdrain (Hunt et al. 2006), or by controlling outflow (Lucas and Greenway 2011a).

Denitrifying bacteria also require a source of organic carbon (Kim et al. 2003). Several studies have been conducted to determine the best carbon source for denitrification in bioretention. Sawdust, woodchips, alfalfa, and newspaper are some of the sources studied (Kim et al. 2003; Leverenz 2009; Robertson 2010). Woodchips appear to provide consistent, reliable and lasting results (Robertson 2010). Kim et al. 2003 determined that the nitrate removal percentage achievable with woodchips, alfalfa and newspaper was near 100%. Sawdust was a bit lower but still showed above 90% removal in a steady state simulation (Kim et al. 2003). Kim et al. 2003 determined that, while woodchips provide adequate and high removal percentages, newspaper provides the most consistent removal results based on fluctuations in hydraulics and nitrate concentrations. Robertson (2010) determined that woodchips had very good longevity approaching 10 years as an effective carbon source. One drawback of using woodchips is they initially cause a spike in organic carbon effluent concentrations which diminishes over time (Robertson 2010).

Given the proper conditions, denitrification using woodchips for an organic carbon source follows first-order kinetics (Leverenz et al. 2010). Denitrification typically has a zero order reaction rate in most SCMs (Leverenz et al. 2010). However, a first-order reaction rate can be used to model denitrification at low temperatures with low nitrate concentrations (Leverenz et al. 2010). Low concentrations were defined as concentrations less than 10 mg/L of nitrate as N (Leverenz et al. 2010). As stated above, typical stormwater concentrations range from 1 to 3 mg/L of total nitrogen (Collins et al. 2010). Fitting these concentrations to the data collected by Leverenz et al. (2010), it is seen that an anoxic environment of woodchips should exhibit a first order denitrification rate constant between 1.41 and 1.30 $days^{-1}$. However, Robertson (2010) found that zero-order kinetics were a better fit to collected data. In that study a zero order denitrification rate was observed at 15.4 to 23.0 mg N L^{-1} Day^{-1} (Robertson 2010). After 7 years that rate was found to be about half of the initial rate (Robertson 2010). Because nitrogen levels in stormwater are typically below the 10 mg/L level identified by Leverenz et al. (2010), first order kinetics may be used. Following a first order model for denitrification, it is estimated that complete removal of nitrate (assuming 1 to 3 mg/L) will be achieved in one to three days.

The effects of woodchip size distribution and wood type on the denitrification process are lacking in the literature. A standard woodchip size distribution from a disc chipper, developed by Hartmann et al. (2006), can be seen in Figure 2. Different types of wood have different carbon contents and vary in hardness. The effect of difference wood types on the denitrification process is also undefined in literature. The carbon content of hardwoods ranges from 46.27 to 49.97 percent (Lamlom and Savidge 2003). Softwoods have slightly higher carbon contents ranging from 48.55 to 55.16 percent (Lamlom and Savidge 2003). These woods are not always easily attainable. Some of the most commonly harvested woods in Maryland are cherry, oak and maple for hardwoods and pine for softwoods (MCAE 2004; USFWS 2001).

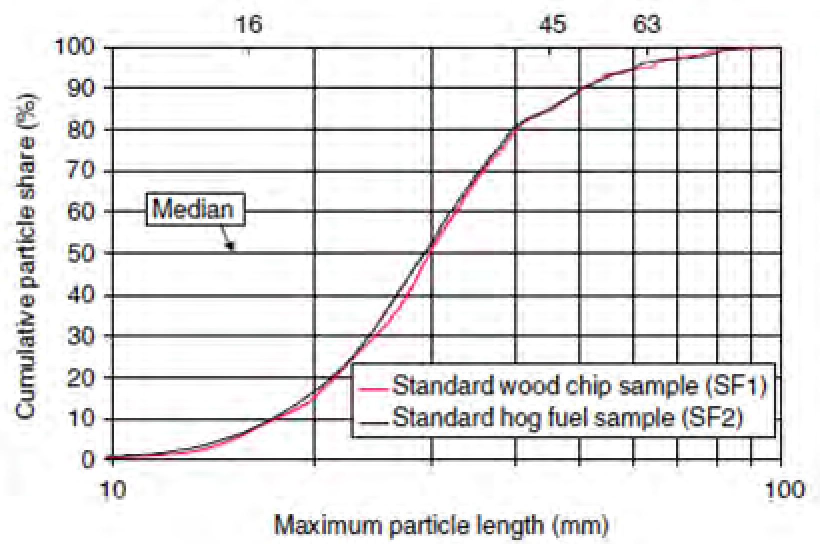

Figure 2: Standard woodchip particle size distribution from a disc chipper (Hartmann et al. 2006)

Research Objectives

Optimizing the denitrification efficiency in a bioretention system will require designing a system that is controlled and sustainable. The effect of several factors involved in the denitrification process will also need to be quantified in order to further optimize the system. The factors to be investigated can be found in Table 1. These factors are evaluated with respect to denitrification in a bioretention system, but when quantified, can be optimized in order to further improve nitrogen removal using a variety of SCMs.

Table 1: These factors are to be investigated in a column study in order to determine the effect they have on denitrification in a bioretention system.

Factor	Description
Carbon Content	Varying the wood species, the availability of organic carbon will fluctuate
Woodchips Size	Smaller particles typically have greater surface areas per unit mass
Media Additive	Adding gravel to maintain structural capacity while decreasing carbon content
Nitrogen Loading	Artificial Stormwater will vary in total nitrogen concentrations
Media Composition	Adjusting the amount of woodchips added to the media

Experimental Plan

In order to further optimize bioretention, a design has been developed that would target concentrations of nitrogen in stormwater and treat runoff nitrogen following the nitrogen cycle.

This design deviates from typical bioretention designs by taking into account a first flush treatment. First flush is considered the first portion of a given storm (usually a half-inch of rainfall) on a watershed. It is widely accepted that the runoff from the first flush contains the majority of contaminants (Bach et al. 2010). If a first flush consideration is applied to runoff collected by a bioretention facility, then it can be assumed that treating the first flush could remove up to 90% of the contaminants it is carrying. Treating the first flush more strictly while allowing whatever remains to be treated normally would effectively optimize the design. Figure 3 shows a design that would facilitate the desired treatment method.

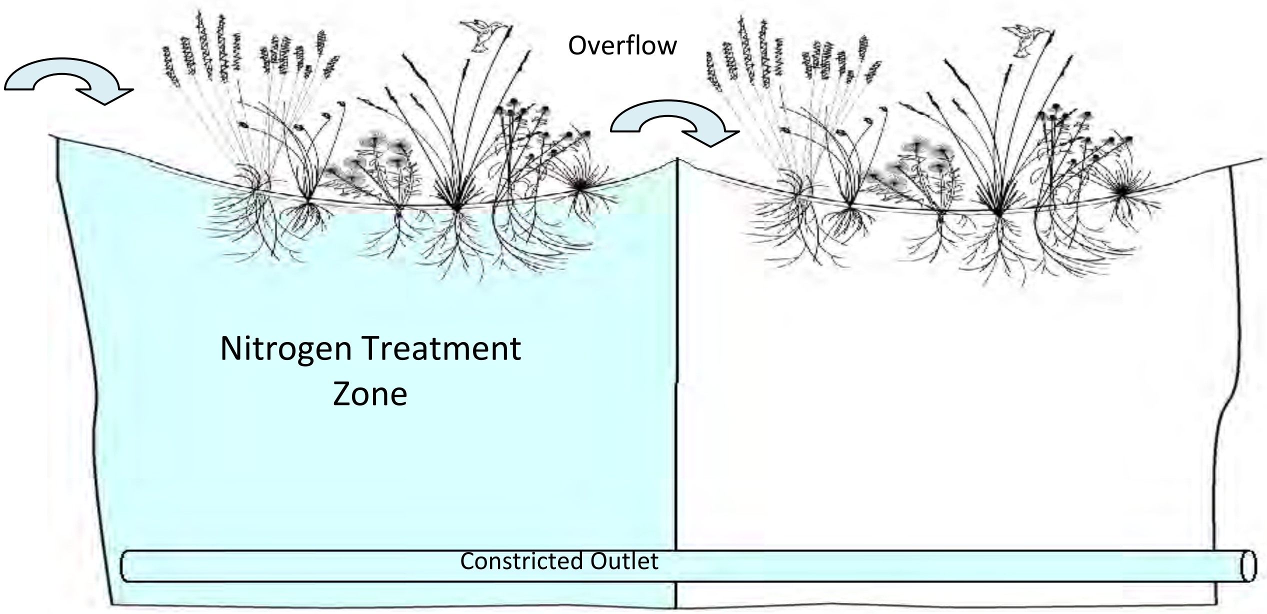

Figure 3: Design alteration to a standard bioretention cell. The cell is split into a treatment train. The first section (Nitrogen Treatment Zone) is meant to remove nitrogen from the first flush of a storm while the second portion filters any overflow that exceeds the storage capacity of the first section.

Typical bioretention is considered one homogenous unit. Water runs in and is infiltrated over the entire surface area. Denitrification, being a time sensitive process, can be optimized by increasing the retention time of runoff. By increasing the retention time, however, the volume of water that can be treated by the bioretention is decreased. One way to achieve large retention times while maintaining the ability to treat large storms is to split the bioretention into two parts or a treatment train. With a split bioretention the first flush of a storm can be treated in a portion of the bioretention cell that is designed to have a large retention time. If a storm is large enough to surpass the available storage volume, overflow would spill into the second portion of the bioretention facility. This portion would filter water quickly and thus allow the entire storm to be treated.

As discussed in the literature review, bioretention designs for treating nitrogen may be constructed in layers to follow the nitrogen cycle (Collins et al. 2010; Hsieh et al. 2007; Ergas et al. 2010). Because oxygen is more available in between storm events nitrification will take place when it is not raining (Hsieh et al. 2007). Organic nitrogen and ammonium are absorbed into the top media layer and later oxidized (Collins et al. 2010). The average amount of time between storm events should be enough to effectively oxidize the organic and ammonium nitrogen to nitrate or nitrite (Hsieh et al. 2007). Therefore, in order to optimize nitrogen treatment in bioretention, denitrification will need to be the focus. Because denitrification requires anoxic conditions, the media in the denitrification layer will be fully saturated during a storm event and allowed to drain slowly. This will allow the media to treat oxidized nitrogen in a large amount of water for a longer duration.

Several studies have looked at woodchips as the primary organic carbon source for the denitrification process in bioretention. Woodchips are able to provide the necessary environment for the denitrifying bacteria and have a longer lifespan than other types of media with comparable results (Kim et al. 2003; Leverenz et al. 2009; Robertson 2010). Lacking in these studies is an understanding of the effects of wood composition on the denitrification process. This study will determine the optimum media composition for denitrification treatment in bioretention.

In order to determine the most ideal media conditions for nitrogen-treating bioretention several factors need to be taken into account. For regional considerations the most available woods in Maryland will be studied for their effects on the denitrification process. As stated in the literature review, three different hard woods, and two different soft woods were chosen for their availability in the region. These woods can be found in Table 1 with their Latin names and corresponding carbon contents.

Also being taken into account is the woodchip size distribution. Using a disc chipper, woodchips will have a size distribution as was displayed in Figure 2. Different size distributions will vary the total surface area of the woodchips as well as the media porosity. In order to determine the most effective size distributions, samples will be sieved and the size distribution will be varied between tests. Initially the woodchip size will be those passing the 0.375 inch

Table 2: Five wood species, available regionally, that will be used to determine the effect of varying woodchip species on the denitrification process in a bioretention cell. Carbon contents for each wood species is identified as it may affect the culturability of denitrifying bacteria (USFWS 2001; Lamlom and Savidge 2003; MCAE 2004).

Wood Type	Species (Scientific Name)	Carbon Content (%)
Cherry	Prunus serotina	49.53 ± 0.18
Oak	Quercus phellos	49.57 ± 0.22
Maple	Acer negundo	49.34 ± 0.53
White Pine	Pinus strobus	49.74 ± 0.16
American Beech	Fagus grandifolia	46.60 ± 0.39

sieve but retained on the No. 4 (0.187 inch) sieve as the majority of the total mass falls within the range. This range will then be used to compare the effect of different size distributions.

In order to optimize the structural capacity of the woodchips, alternative media will be mixed with the woodchips. Pea gravel will be used as an additive. The percentage of the media composed of woodchips will be a final parameter to evaluate. Treatment will be monitored in different media compositions to determine which composition provides optimum treatment efficiency. The woodchip attributes such as carbon content, size, and percent media composition could play a vital role in the ability of denitrifying microorganisms to utilize the available organic carbon.

Experimental Procedures

In order to simulate a field situation, synthetic stormwater is passed through a column similar to the one depicted in Figure 4. The column will be used to determine and optimize the factors pertaining to denitrification of first flush runoff using bioretention (Table 2). For this study no top soil layer will be used because only mechanisms specifically associated with the denitrification layer will be studied. This layer is indicated by the mixed media label.

The column was designed around typical bioretention parameters. Because excavation below 4 feet usually requires some kind of stabilization, bioretention cells are kept shallower than the 4 foot depth (Brown and Hunt 2011). The column constructed is 3 feet high. This will provide enough height for a denitrification layer. The column is wrapped in foil, as shown in Figure 5, in order to prevent light from entering the media. In a field situation light will not penetrate the surface, so it is necessary to mimic that environment.

Wood samples were collected from recently cut trees on University of Maryland campus grounds. Bark from the samples was removed using a hammer and chisel. Samples were then chipped by a Vermeer BC1000 XL 20" drum chipper. In order to reduce the likelihood of contamination, the chipper was allowed to run for 5 minutes in between each species that was chipped. The chips were collected and sealed for storage in large waterproof non-transparent plastic bags. Chips samples were thoroughly rinsed with tap water and air dried for approximately two days. When dry, the samples were sieved through 1 inch, 0.75 inch, 0.5 inch, 0.375 inch, and No. 4 (0.187 inch) sieves. This was done on an automatic shaker for 15 minutes.

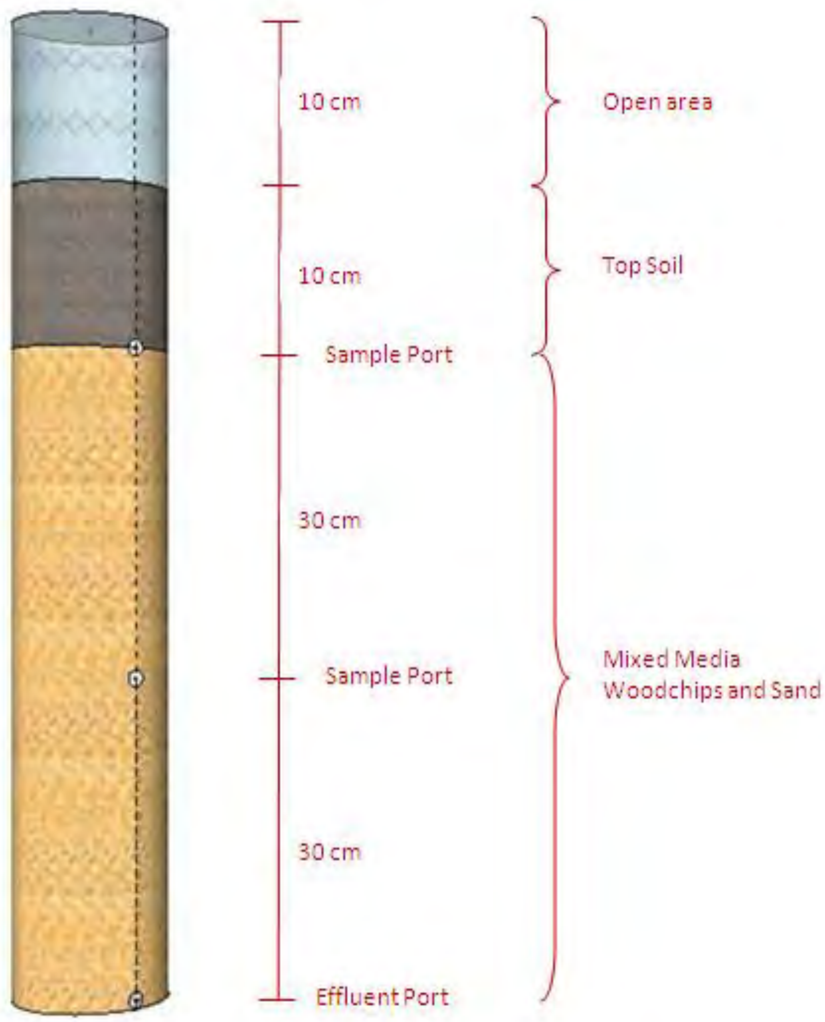

Figure 4: Model bioretention system column design for testing the denitrification process using woodchips as a carbon source.

The samples were soaked for a period of two days prior to being packed in the columns. Chips were completely submerged in the same solution as is used for artificial stormwater which is described below. This soaking has several purposes. Because it will take time to build a bacteria colony in the column it is advantageous to start growth early. Soaking the woodchips will also allow the chips to become fully saturated. Dry chips will absorb water. In order to conduct an accurate water balance it is necessary to have as little water absorbed as possible.

Figure 5: Constructed model bioretention system columns

Immediately after the soaking period the artificial stormwater is drained and the chips are mixed with washed pea gravel. The mixed media is then packed into the column. The media is compacted using a compaction rod at six inch increments. Each layer receives 20 blows from the compaction rod. Media is packed in layers until reaches a height of 2.5 feet. This will provide a freeboard of 6 inches in the column. Tests are conducted with each of the five wood types discussed in Table 1 in order to determine the most effective wood species for denitrification.

Synthetic stormwater is used to represent typical first flush runoff pollutant concentrations of nitrate. Phosphate at urban runoff levels (0.1 mg/L) is added to encourage bacterial growth. Data from Collins et al. 2010 indicate that total nitrogen concentrations in stormwater runoff range from 1 to 3 mg/L as nitrogen. Assuming that all the nitrogen carried by the stormwater is converted to nitrate or nitrite before entering the denitrification layer, the synthetic stormwater contains 3 mg/L nitrate as nitrogen. Sodium chloride is added at 0.01 M in order to fix the ionic strength. The pH of the artificial stormwater is adjusted to be between 7 and 7.2 using either NaOH or HCl.

Synthetic stormwater is pumped into the top of the column at 22.2 mL/min until the column is completely saturated. Pumping stops when the system is completely saturated because in a field setting, at saturation, it is expected that any excess water would overflow into the second portion of the bioretention system.

The column design includes three sampling ports. The bottom port is a valve that is adjusted so that the effluent rate maintains flow for the desired experimental duration. Before the test begins the effluent rate is set. This is done by filling an empty column to the point where media would be fully saturated and setting the flow rate to previously determined rates. The initial flow rate for the 1.5 day and 2.3 day experimental periods are 0.91 mL/min and 1.4 mL/min respectively. A redox/ORP electrode is placed in the middle sampling port in order to monitor the oxidation/reduction potential in the solution during the test (Figure 4).

All of the effluent is collected in order to conduct a water balance and determine the change in water quality parameters. Samples are collected in different time periods during the expected drainage period. Sample volumes are based on the volume needed to conduct different analytical methods. Sample collection times and desired sample volumes can also be found in Table 3 for each of the different experimental durations. For each sample, concentrations of nitrate, nitrite, Total Kjeldahl Nitrogen, phosphorus, and total organic carbon are determined. Oxidation/reduction potential, pH, and temperature are monitored throughout the sampling event.

Table 1: Times (min) at which samples are collected for two different experimental durations.

Sample #	1.5 Days	2.3 Days
1	155	230
2	200	1205
3	665	1865
4	1055	2645
5	1115	3455
6	2105	

Analysis

All collected samples are tested for nitrate using Standard Method 4500-NO_3^- Ion Chromatographic method (APHA, 1992). Nitrite is tested using Standard Method 4500-NO_2^- C - Ion Chromatographic method (APHA, 1992). Nitrite measurements are checked using Standard

Method 4500-NO_2^- B - Colorimetric method (APHA, 1992). TKN is measured using Standard Method 4500-N_{org} B Macro-Kjeldahl method (APHA, 1992). The addition of nitrate, nitrite, and TKN will result in the total nitrogen concentration. Total organic carbon is measured using Standard Method 505 Organic Carbon (Total) (APHA, 1992). Total phosphorus is measured using Standard Method 4500-P phosphorus (APHA, 1992).

Using the data collected from these tests, combined with measurements of pH and oxidation reduction potential, a mass balance can be constructed to show the inflow and outflow characteristics. Detections below the lowest standard are reported as half of the lowest standard. Best practices are followed in regards to quality assurance and quality control. Regular standard checks are conducted and standard procedures are practiced. All machines undergo regular and continued maintenance. Equipment is washed and sterilized before each use.

Research Progress

Column studies were conducted in order to begin assessing the effect of woodchip species and drainage time on the efficiency of denitrification in a bioretention system. Four of the five different wood types discussed in the Methods section have been analyzed for the effect of woodchip species. These woods are Willow Oak (WO), Virginia Pine (VP), Wild Cherry (WC), and American Beech (AB). Artificial stormwater was filtered through the column for an experimental duration of 2.3 day (~3,300 min). Woodchips passing the 3/8" sieve but retained on the No. 4 sieve were used to pack the column at 20% of the total media volume. Pea gravel filled the remaining 80% of the packed column.

For Run 1 of the WO, effluent stormwater remained near or slightly above a pH of 7 (Figure 6). The pH in other runs also remained near 7. The location of the oxidation/reduction probe allows for readings for the first half of each test. The first run shows an initially oxidizing environment with a potential near 250 mV. The potential slowly deceases over time suggesting that the environment is becoming more and more reducing (Figure 7) which is conducive to denitrification. Similar results are seen in the following runs also shown in Figure 7.

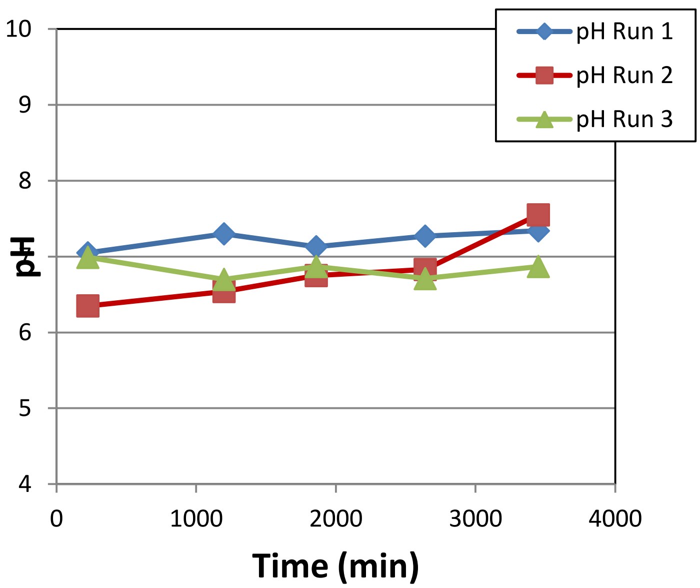

Figure 6: pH over time in a column packed with Willow Oak woodchips. Three different loading events are displayed. Column was loaded at 1.2 L/hr for 2.25 hrs. Input pH was also near 7.

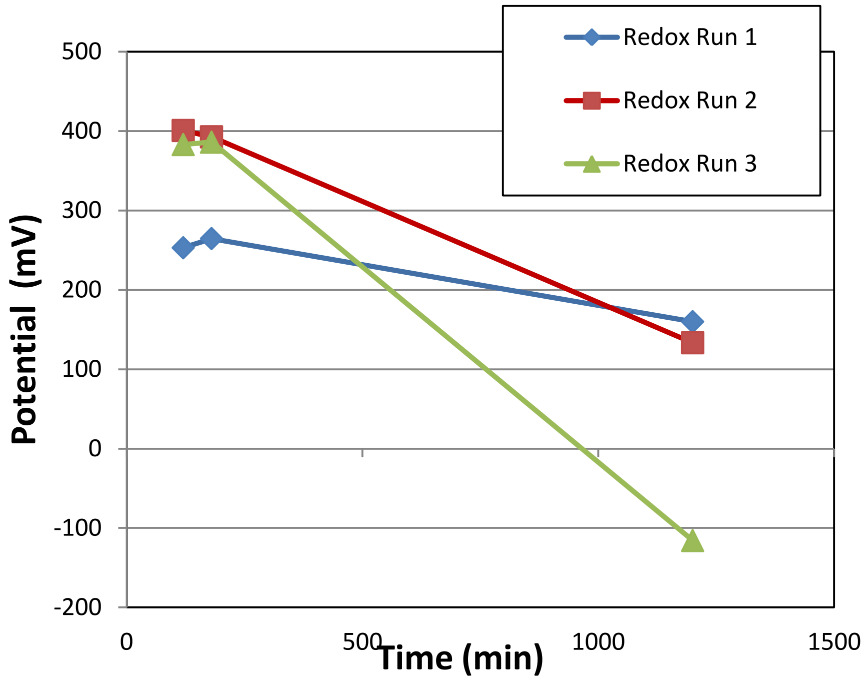

Figure 7: Oxidation Reduction Potential over time in a column packed with Willow Oak woodchips. Three different loading events are displayed. Column was loaded at 1.2 L/hr for 2.25 hrs.

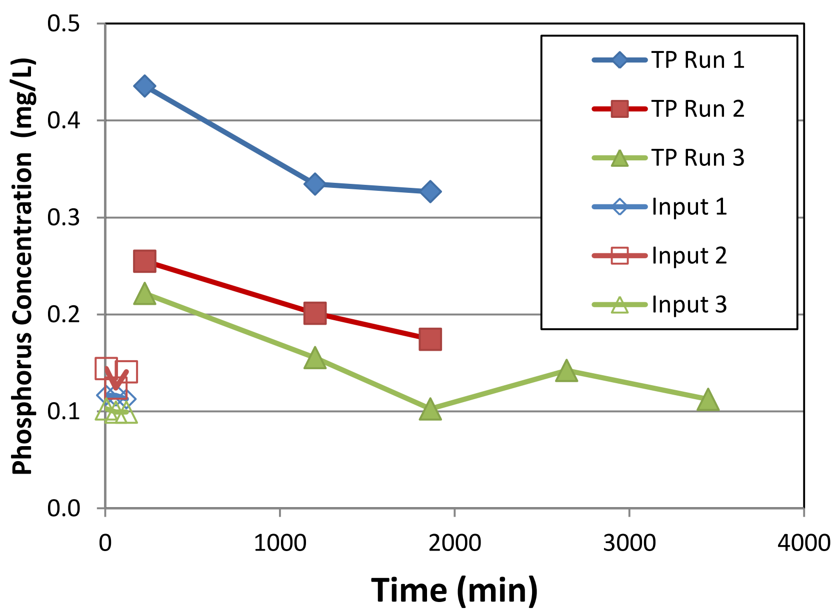

Figure 8: Total phosphorus concentrations over time in a column packed with Willow Oak woodchips. Three different loading events are displayed. Column was loaded at 1.2 L/hr for 2.25 hrs. Input phosphorus concentrations were near 0.1 mg/L.

Effluent total phosphorus concentrations started near 0.45 mg/L for run 1 and slowly decreased over time. Each run had overall lower total phosphorus concentrations compared to the last (Figure 8). Total organic carbon concentrations for Run 1 were at or near 50 mg/L throughout the collection period. The subsequent runs showed lower concentrations with the exception of the first sample of run 2 (Figure 9).

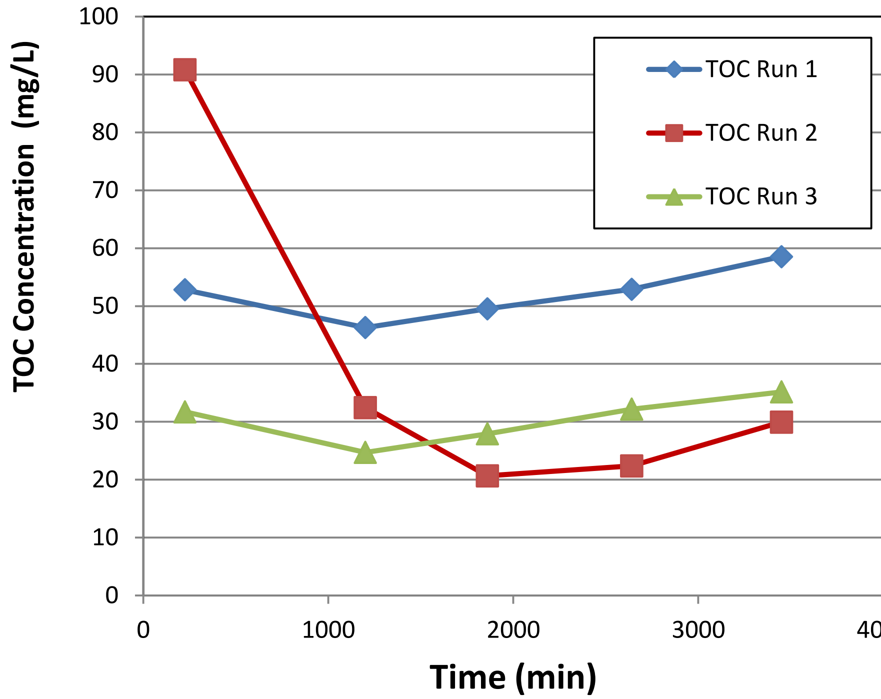

Figure 9: Total organic carbon concentrations in the effluent over time in a column packed with Willow Oak woodchips. Three different loading events are displayed.

Total Kjeldahl Nitrogen for run 1 remained above 1 mg/L for all of the samples tested. The subsequent runs showed much lower concentrations. The Total Kjeldahl Nitrogen trend is similar to that of the total organic carbon, suggesting that the two concentrations are linked or respond similarly to the changing environment. The first run of WO shows a nitrite concentration that starts below the detection limit and increases over time until it peaks at 1 mg/L. This concentration is reached around halfway through the 2.3 day experimental duration. Afterward the concentration decreases until it is below the detection limit in the final sample. The total nitrogen concentrations over time for the WO column can be seen in Figure 10.

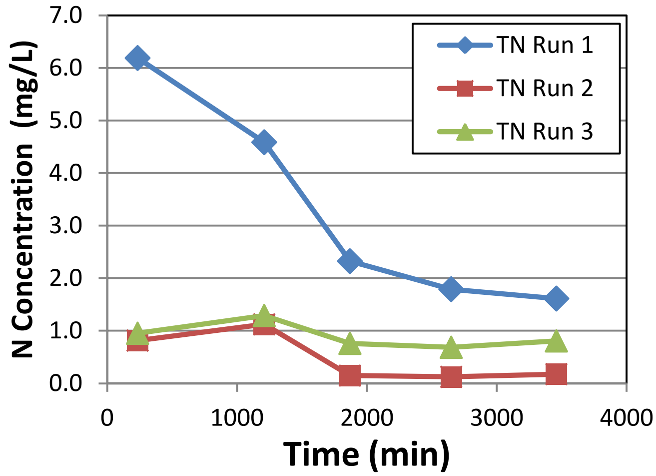

Figure 10: Total nitrogen concentrations in the effluent over time in a column packed with Willow Oak woodchips. Three different loading events are displayed. Column was loaded at 1.2 L/hr for 2.25 hrs. Input contained near 3.0 mg/L Nitrate-N.

Figure 11 shows the nitrate concentration over time for the WO at a 2.3 day experimental duration. The starting nitrate-N concentration in run 1 was higher than in runs 2 and 3. Runs 2 and 3 are also more consistent with one another. The difference between the first run and the later two runs suggests that the denitrifying bacteria require a full cycle to reproduce and become established. After they have colonized the column, the denitrification process is more consistent from one run to the next. Near complete reduction of nitrate is achieved at or near 30 hours (1800 min) as depicted in Figure 11.

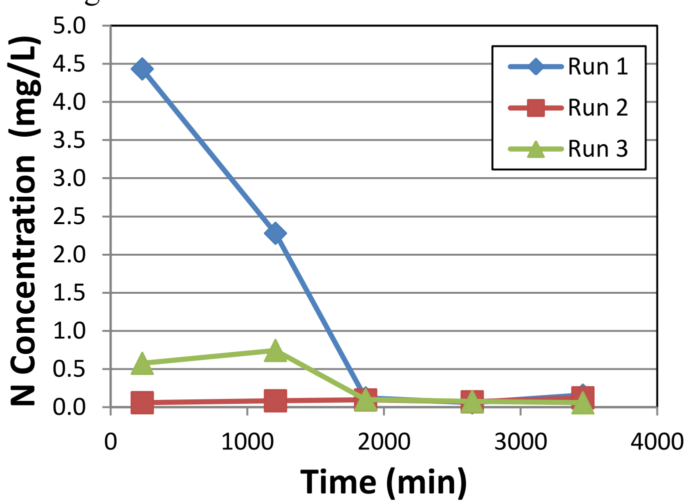

Figure 11: Nitrate-N concentrations over time in a column packed with Willow Oak woodchips. Three different loading events are displayed. Column was loaded at 1.2 L/hr for 2.25 hrs. Input contained near 3.0 mg/L Nitrate-N.

Figure 12 displays the influent and effluent total nitrogen mass for the WO at a 2.3 day experimental duration. Also shown are the different species of nitrogen contained in the samples. As was discussed earlier, run 1 has more nitrate-N in the effluent than runs 2 or 3. This is thought to be due to the time it takes the denitrifying bacteria to colonize. This was observed for all of the different woods tested with the exception of AB. The first run of AB has a greater reduction in nitrate than the second two runs, but had a much larger mass of TKN in the effluent.

This can be seen in Figure 13.

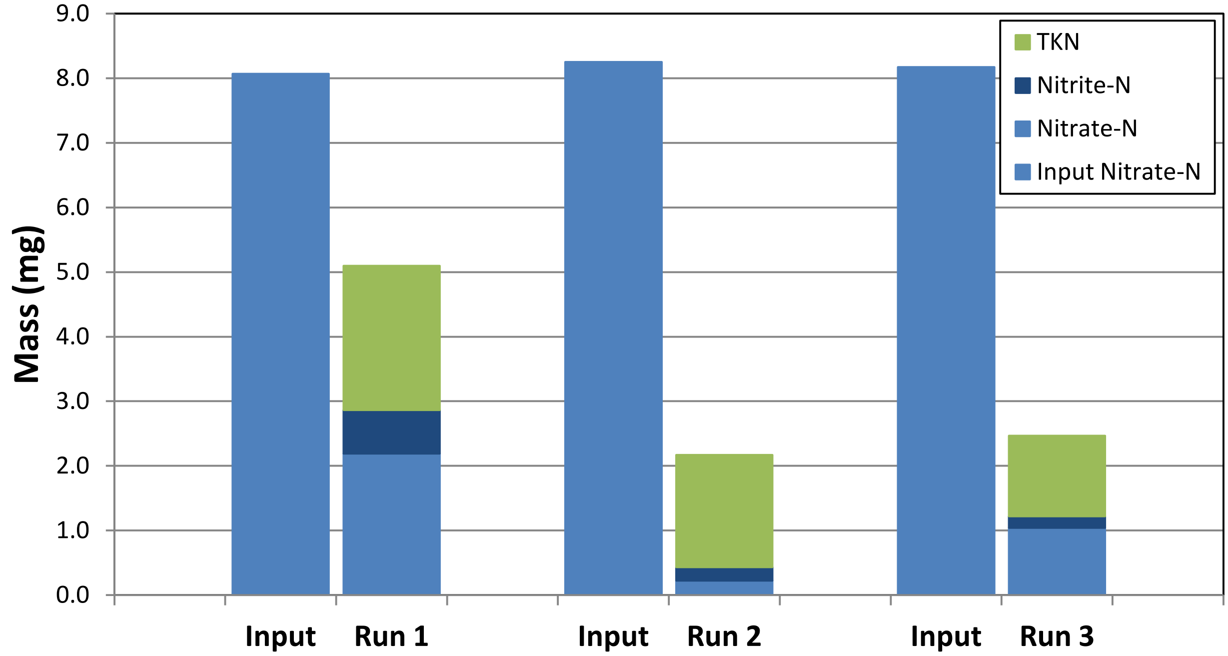

Figure 12: Total nitrogen mass in the effluent (Run #) is compared to its respective input mass from the artificial stormwater for a column packed with Willow Oak woodchips. Three consecutive runs are displayed. The retention time was 2.3 days. Column was loaded at 1.2 L/hr for 2.25 hrs. Input contained near 3.0 mg/L Nitrate-N.

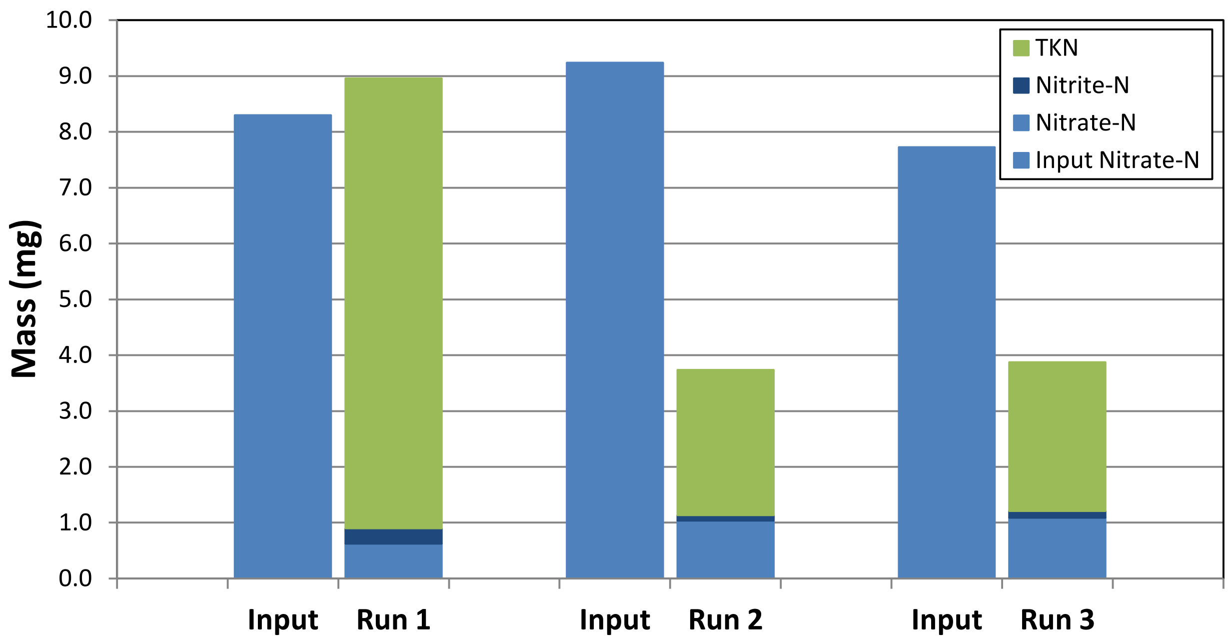

Figure 13: Total nitrogen mass in the effluent (Run #) is compared to its respective input mass from the artificial stormwater for a column packed with American Beech woodchips. Three consecutive runs are displayed. The retention time was 2.3 days. Column was loaded at 1.2 L/hr for 2.25 hrs. Input contained near 3.0 mg/L Nitrate-N.

The nitrate-N concentrations over time for the AB samples can be seen in Figure 14. Again the inconsistency between the first run and the second two runs is evident. The second two runs are again more consistent with one another as was seen with the WO. This trend is repeated with the WC and the VP as well (Figures 15 and 16) with differing degrees. This repeated difference between the first run and those that follow emphasizes the point that the bacteria require a full cycle in order to become established in the media.

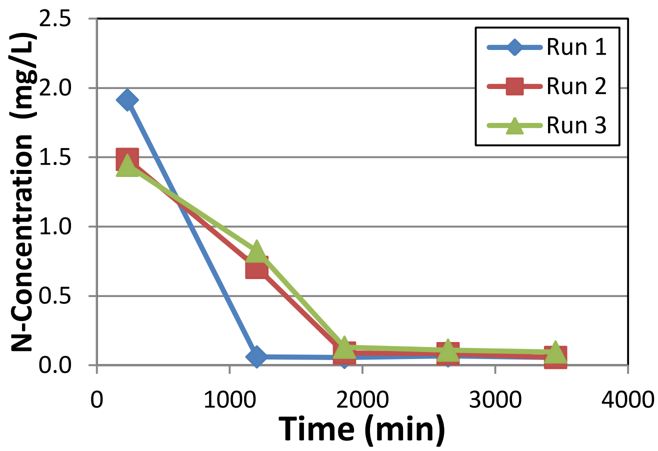

Figure 14: Nitrate-N concentrations over time in a column packed with American Beech woodchips. Three different loading events are displayed. Column was loaded at 1.2 L/hr for 2.25 hrs. Input contained near 3.0 mg/L Nitrate-N.

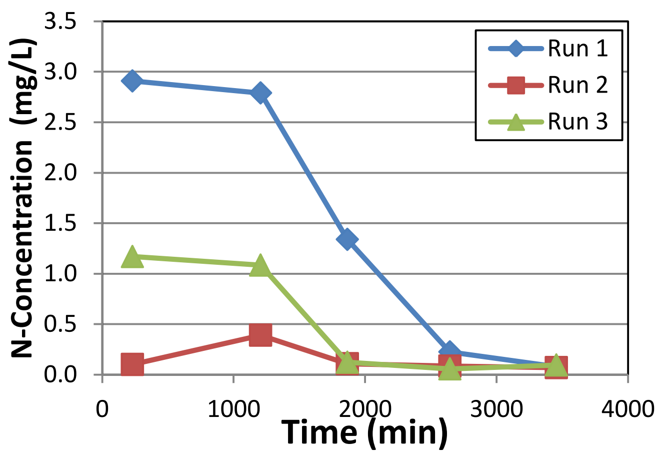

Figure 15: Nitrate-N concentrations over time in a column packed with Virginia Pine woodchips. Three different loading events are displayed. Column was loaded at 1.2 L/hr for 2.25 hrs. Input contained near 3.0 mg/L Nitrate-N.

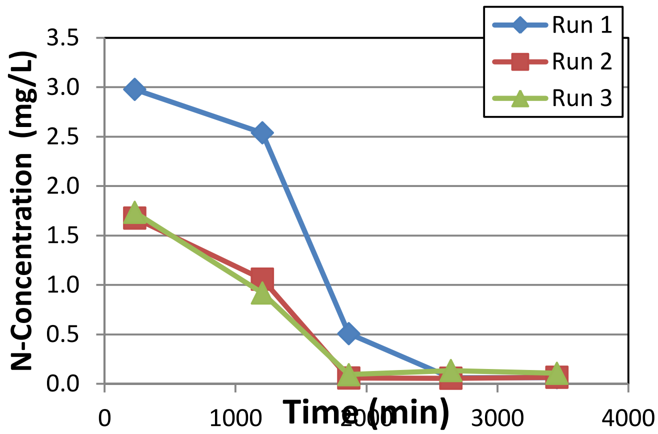

Figure 16: Nitrate-N concentrations over time in a column packed with Wild Cherry woodchips. Three different loading events are displayed. Column was loaded at 1.2 L/hr for 2.25 hrs. Input contained near 3.0 mg/L Nitrate-N.

The second and third runs for WO started at much lower nitrate concentrations in the effluent than do the other species of woods. Run 2 for WO showed near complete removal of nitrate from the start. This suggests that denitrification occurs very quickly for WO after the denitrifying bacteria have been established. VP is the closest to this same trend as seen in Figure 15. It is interesting to note the third run for VP starts with higher nitrate concentrations in the effluent than the second run. This is also evident in the WO.

The total nitrogen mass in and out for three columns for the 2.3 day experimental time is compared in Figure 17 for each wood species. Each column shows the combined mass for the three runs conducted for the identified wood species. While AB is the most effective at nitrate removal, it leaches the largest amount of TKN and it has the highest combined total nitrogen mass in its effluent. Willow Oak is the most effective at reducing the total nitrogen concentration in the effluent by not only substantially reducing nitrate concentrations but also leaching less TKN than the other wood types. No significant variation can be seen between the effluent nitrite mass for each of the wood species.

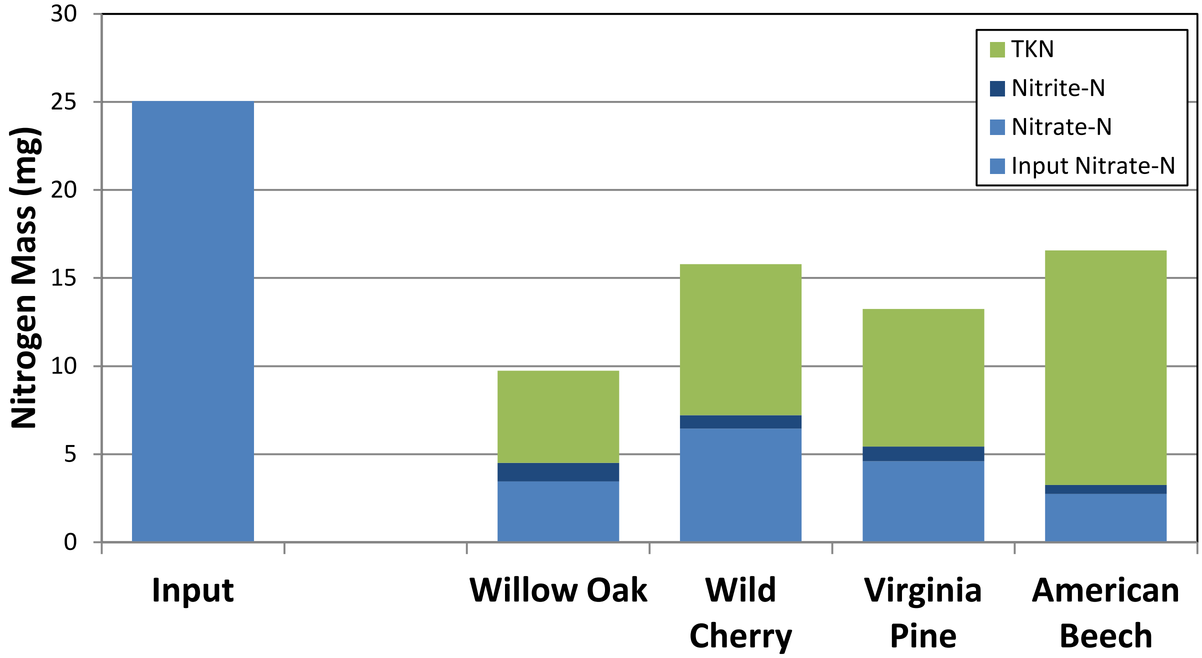

Figure 17: Total nitrogen mass compared for the different wood species at a retention time of 2.3 days. Mass for all three runs is summed for each wood type and compared to the average input nitrogen mass.

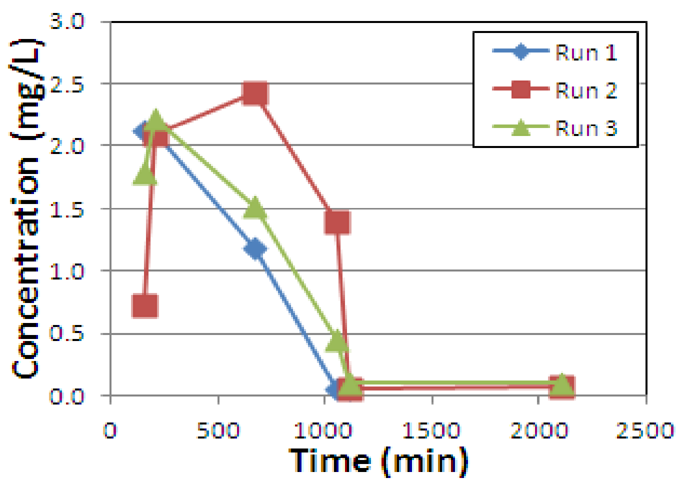

Figure 18: Nitrate concentrations over time in a column packed with Willow Oak woodchips. Three different loading events are displayed at a retention time of 1.5 days.

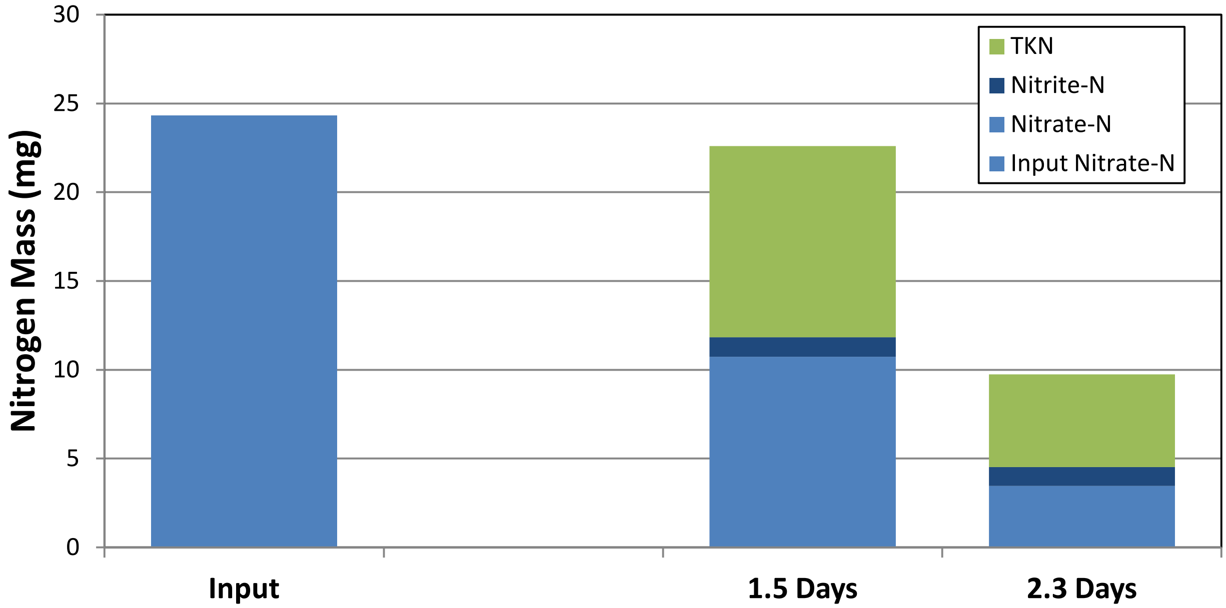

Figure 19: Nitrogen mass compared for different stormwater retention times using Willow Oak woodchips. The columns are labeled by the retention times used and are compared to the average input nitrogen mass.

One column study was also conducted with an experimental duration of 1.5 days. WO woodchips were used in this column in order to compare the effects of different experimental durations. Figure 18 shows the nitrate concentrations over time. The general trend of the three runs in Figure 18 shows a short delay (2-3 hours) before denitrification begins. This is to be expected because the dissolved oxygen in the artificial stormwater must be depleted before the conditions are conducive to denitrification.

Near complete removal of nitrate from solution is achieved at or near 0.75 days (~1100 min) for all three runs. In comparison with the drainage time, shown earlier in Figure 11, the nitrate-N concentration seem to be reduced faster for the shorter drainage time. However, the total nitrogen mass in the effluent for the shorter drainage time is higher than for the longer drainage time as can be seen in Figure 19.

Future Work

Treatment of nitrogen in stormwater using bioretention is a technology in its infancy. Literature review showed several areas of potential improvement. These areas include stormwater drainage time and organic carbon source characteristics which are the focus of this study. Currently only four of the five specified wood species have been tested for comparison. The fifth wood species is Red Maple and will be tested in order to complete the set. After the fifth wood species is tested a full comparison of the effect of wood species on the denitrification process can be made.

Two more tests will also be conducted using varied experimental durations. These, in combination with the two experimental durations already conducted will give a good assessment of the optimum drainage time needed for denitrification in a bioretention system. The new tests will have experimental durations of 1 day and 3.2 days respectively.

Further tests will be conducted by varying the amount of woodchips used in the media. Adjustments in the percent woodchips by volume will allow the system to be optimized for woodchip content. It is expected that as the woodchip volume is decreased the total organic carbon in the effluent will also decrease. Eventually the system will not have enough organic carbon to sustain the denitrifying bacteria.

A similar effect is expected if the size of the woodchips is varied. As the woodchips become larger the available surface area of the woodchips decreases. This reduces the organic carbon that is accessible to the denitrifying bacteria. If this hypothesis is proven true, by testing several different woodchip sizes the ratio of size to percent composition can be optimized as well.

It is expected that this study will produce data which will be used to optimize the denitrification layer of a bioretention system. Different wood species and woodchip sizes are expected to degrade at different rates. As the woodchips degrade the organic carbon will become more available for the denitrifying microorganisms. If these assumptions are true, then a combination of woodchip sizes and species will maintain denitrification rates over a number of years. The data collected from the column studies will guide the combination for an optimized bioretention system. The optimized system can then be used to effectively convert nitrate to nitrogen gas in urban stormwater runoff.

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APPENDIX D:

Revised SHA Standard Construction Forms (ESC Compliance Checks)

OOC60- - ESC Field Investigation Report

OOC61 – Independent QA ESC Control Field Investigation Report

OOC3 – District Engineer Certification of Completion of Work

Revised SHA Standard Construction Forms (ESC Compliance Checks)

OOC60 07/01/2011 Page 1 of 4
CD 07220.300.01

STATE HIGHWAY ADMINISTRATION
EROSION AND SEDIMENT CONTROL FIELD INVESTIGATION REPORT

DISTRICT: ____ COUNTY: ____________ CONTRACT NO: _________________
DATE & TIME OF INSPECTION: ______________________________________
PROJECT DESCRIPTION: ______________________________________
CONTRACTOR: ______________________________________
NOI/PERMIT # __________________________
INSPECTORS NAME AND GC CERTIFICATION # ______________________________________

SITE STATUS: ☐ CURRENTLY ACTIVE ☐ CURRENTLY INACTIVE
PHASE OF CONSTRUCTION ☐ CLEAR & GRUB ☐ GRADING ☐FINAL STABILIZATION
☐ AS-BUILTS SUBMITED ☐ NOT SUBMITED
SITE CONDITION: ☐ COMPLIANCE ☐ NEEDS CORRECTIONS ☐ NON-COMPLIANCE
REASON FOR INSPECTION: ☐ WEEKLY INVESTIGATION ☐ PRE-STORM ☐ POST-STORM ☐ OTHER
STORM EVENT SINCE LAST REPORT ☐ YES ☐ NO
DATE & TIME__________________ DURATION ________ AMOUNT _______

1. IS PROJECT IN SCOPE? *** If No, Project is automatically in non-compliance.**	Y	N	N/A
* 1.1 Have all appropriate permits and approvals been obtained (SHA/Contractor)?	☐	☐	
* 1.2 Are specified LOD, wetlands, buffers, jurisdictional waters, floodplains and/or tree protection areas demarcated and disturbed areas contained within the LOD (active work areas)?	☐	☐	
* 1.3 Is the project in conformance with the E&S plan, schedules and contract documents?	☐	☐	
1.3.1 Are sediment controls in place prior to disturbing areas of intended control?	☐	☐	☐
1.3.2 Are controls removed with MDE approval?	☐	☐	☐
1.4 Have all changes been approved to date including stream crossings/diversions?	☐	☐	☐
1.5 Have approved changes been implemented?	☐	☐	☐
1.6 Are the ESCM duties in compliance with specification 308.03.03	☐	☐	☐
1.7 Are stockpiles/staging/waste areas approved?	☐	☐	☐
1.8 Is grading limited to maximum grading unit?	☐	☐	☐
1.9 Are roadways clear of sediment?	☐	☐	☐
NPDES - The following question are also applicable when the project has 1 acre or more of disturbance			
1.10 Is trash collected and placed in a covered dumpster?	☐	☐	☐
1.11 Are washout facilities (concrete, paint, etc.) clearly marked, maintained and wash water properly contained?	☐	☐	☐
1.12 Are fuel containers and vehicle maintenance areas free of spills, leaks or any other deleterious material?	☐	☐	☐
1.13 Are materials that are potential stormwater contaminants stored inside or under cover?	☐	☐	☐
1.14 Is there evidence of the discharge of significant amounts of sediment (See definitions below) to surface waters, or conveyance systems leading to surface waters?	☐	☐	☐
1.15 Have required notifications (to MDE) been complied with? (Triggering Event, Upset, Bypass)	☐	☐	☐

Definition of significant amount of sediment *A discharge of significant amounts of sediment may be indicated by (but is not limited to) observations of the following. Note whether any are observed during this inspection:*

1. Earth slides or mud flows
2. Concentrated flows of stormwater such as rills, rivulets or channels that cause erosion when such flows are not filtered, settled or otherwise treated to remove sediment
3. Turbid flows of stormwater that are not filtered, settled or otherwise treated to reduce turbidity
4. Deposits of sediment at the construction site in areas that drain to unprotected stormwater inlets or catch basins that discharge directly to surface waters
5. Deposits of sediment from the construction site on public or private streets outside of the permitted construction activity
6. Deposits of sediment from the construction site on any adjacent property outside of the permitted construction activity
7. Discharges from the construction site to municipal conveyances, curbs and gutters, or streams running through or along the site where visual observations show that the discharges differ from ambient conditions in terms of turbidity so as to indicate significant amounts of sediment present in them

Project Engineer / Inspector: ______________________________ DATE: ______________

ORIGINAL: Project Engineer cc: District Engineer Contractor

SHA Construction Form OOC60 – Page 1

The SHA Standard Construction Form OOC60 is a field investigation checklist and report that is filled out by the SHA Construction Engineer to document the condition of project erosion and sediment controls upon installation, weekly to ensure proper maintenance and after-storm events. This form is used in addition to the Standard Inspection Form required by the current NPDES Construction Activity General Permit and includes NPDES compliance checks.

OOC60 07/01/2011 Page 2 of 4
CD 07220.300.01

2. ARE CONTROLS PROPERLY INSTALLED?					3. ARE CONTROLS PROPERLY MAINTAINED?			
Y	**N**	**N/A**	**2.1**	**Water handling**	**3.1**	**Y**	**N**	**N/A**
☐	☐	☐	2.1.1.	Earth Dikes	3.1.1.	☐	☐	☐
☐	☐	☐	2.1.2.	Temporary Swales	3.1.2.	☐	☐	☐
☐	☐	☐	2.1.3.	Perimeter Dike/Swales	3.1.3.	☐	☐	☐
☐	☐	☐	2.1.4.	Diversion Fence	3.1.4.	☐	☐	☐
☐	☐	☐	2.1.5.	Asphalt Berm	3.1.5.	☐	☐	☐
			2.2	**Grade Stabilization Structures**	**3.2**			
☐	☐	☐	2.2.1.	Pipe Slope Drains	3.2.1.	☐	☐	☐
☐	☐	☐	2.2.2.	Rip-rap Inflow Protection	3.2.2.	☐	☐	☐
☐	☐	☐	2.2.3.	Gabion Inflow Protection	3.2.3.	☐	☐	☐
☐	☐	☐	2.2.4.	Stone Check Dams	3.2.4.	☐	☐	☐
			2.3	**Sediment Trapping Devices**	**3.3**			
☐	☐	☐	2.3.1.	Sediment Traps	3.3.1.	☐	☐	☐
☐	☐	☐	2.3.2.	Sediment Basins	3.3.2.	☐	☐	☐
☐	☐	☐	2.3.3.	Stone Outlet Structures	3.3.3.	☐	☐	☐
☐	☐	☐	2.3.4	Gabion Outlet Structure	3.3.4	☐	☐	☐
			2.4	**Dewatering Practices**	**3.4**			
☐	☐	☐	2.4.1.	Removable Pumping Station	3.4.1.	☐	☐	☐
☐	☐	☐	2.4.2.	Sump Pits	3.4.2.	☐	☐	☐
☐	☐	☐	2.4.3.	Portable Sediment Tanks	3.4.3.	☐	☐	☐
☐	☐	☐	2.4.4.	Dewatering Bags	3.4.4.	☐	☐	☐
			2.5	**Filtering Practices**	**3.5**			
☐	☐	☐	2.5.1.	Silt Fence	3.5.1.	☐	☐	☐
☐	☐	☐	2.5.2.	Super Silt Fence	3.5.2.	☐	☐	☐
☐	☐	☐	2.5.3.	Inlet Protection	3.5.3.	☐	☐	☐
☐	☐	☐	2.5.4.	Straw Bale Dike	3.5.4.	☐	☐	☐
☐	☐	☐	2.5.5.	Filter Log	3.5.5.	☐	☐	☐
☐	☐	☐	2.5.6.	Filter Berm	3.5.6.	☐	☐	☐
			2.6	**Land Grading and Structural Stabilization**	**3.6**			
☐	☐	☐	2.6.1.	Stabilized Construction Entrance	3.6.1.	☐	☐	☐
☐	☐	☐	2.6.2.	Rock Outlet Protection	3.6.2.	☐	☐	☐
			2.7	**Miscellaneous Practices**	**3.7**			
☐	☐	☐	2.7.1.	Temp. Access Waterway Crossing	3.7.1.	☐	☐	☐
☐	☐	☐	2.7.2.	Dust Control	3.7.2.	☐	☐	☐
☐	☐	☐	2.7.3.	Onsite Concrete Washout Area	3.7.3.	☐	☐	☐
☐	☐	☐	2.7.4.	Maintenance of Stream Flow	3.7.4.	☐	☐	☐
			2.8	**Special Features**	**3.8**			
☐	☐	☐	2.8.1.		3.8.1.	☐	☐	☐
☐	☐	☐	2.8.2.		3.8.2.	☐	☐	☐
☐	☐	☐	2.8.3.		3.8.3.	☐	☐	☐
☐	☐	☐	2.8.4.		3.8.4.	☐	☐	☐

4. IS STABILIZATION PROVIDED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS?	Y	N	N/A
4.1 Is stabilization provided as specified?			
4.1.1. Temporary mulch	☐	☐	☐
4.1.2. Temporary seed	☐	☐	☐
4.1.3. Permanent seed	☐	☐	☐
4.1.4. Stabilization matting	☐	☐	☐
4.1.5. Sod	☐	☐	☐
4.1.6. Stone	☐	☐	☐
4.1.7. Other	☐	☐	☐
4.2 Is stabilization provided in the specified time frame?			
4.2.1 Same day stabilization	☐	☐	☐
4.2.2. 24 hour stabilization	☐	☐	☐
4.2.3. 72 hours stabilization	☐	☐	☐
4.2.4 7-14 day stabilization	☐	☐	☐
4.2.5 Other	☐	☐	☐
4.3 Is incremental stabilization provided during construction?	☐	☐	☐
4.4 Is the stabilization performing as specified?	☐	☐	☐
4.5 Is vegetation being established?	☐	☐	☐

SHA Construction Form OOC60 – Page 2

OOC60 07/01/2011 Page 3 of 4
CD 07220.300.01

Item No.	Corrective action needed and notes:	Date Correction Completed:

SHA Construction Form OOC60 – Page 3

OOC60 07/01/2011
CD 07220.300.01

Page 4 of 4

Item No.	Corrective action needed and notes:	Date Correction Completed:

SHA Construction Form OOC60 – Page 4

OOC61 07/01/2011
CD 07220.300.01

Page 1 of 4

STATE HIGHWAY ADMINISTRATION
INDEPENDENT QUALITY ASSURANCE
EROSION AND SEDIMENT CONTROL FIELD INVESTIGATION REPORT

DISTRICT: ____ COUNTY: ____________ CONTRACT NO: ____________________ **DATE OF INSPECTION:** _____
PROJECT DESCRIPTION: ____ TIME: _____
____

CONTRACTOR: ____
S.H.A. PROJECT REPRESENTATIVE: ________________________
QUALITY ASSURANCE INSPECTOR: ________________________

SITE STATUS: ☐ CURRENTLY ACTIVE ☐ CURRENTLY INACTIVE
SITE CONDITION: ☐ COMPLIANCE ☐ NEEDS CORRECTIONS ☐ **NON-COMPLIANCE
REASON FOR INSPECTION: ☐ ROUTINE INVESTIGATION ☐ CITIZEN COMPLAINT ☐ M.D.E. COMPLAINT ☐ OTHER
***RECOMMENDED ACTION:** ☐ **NOTIFY CONTRACTOR** ☐ **FOLLOW UP INSPECTION** ☐ **NOTIFY M.D.E.**
☐ ****SHUT DOWN GRADING OPERATIONS** ☐ ****SHUT DOWN ENTIRE PROJECT**
☐ **REFER TO NOTES**
☐ **NO GRADE**

GRADE

Section	Number of points awarded	Number of points available	Percent Awarded for section (X/Y) x 100
1	x	y	
2	x	y	
3	x	y	
4	x	y	
Weighted Average Percentage (Section 1+2+3+4) x 80% / # of graded sections			A
5	x	y	
Section 5 x 20%			B
Total Grade (Add box A and B)			
6	**Bonus area,** Number of points awarded		
TOTAL			

RATING: ☐ A ☐ B ☐ **C ☐ **D ☐ **F

(A = 105 – 90, B = 80-89.9, C = 70-79.9, D = 60-69.9, F = < 60)

QUALITY ASSURANCE INSPECTOR: ________________________ DATE: ________________

CONTRACTOR: ________________________ DATE: ________________

RECEIVED BY: ____
(SHA REPRESENTATIVE)
(SIGNATURE IMPLIES RECEIPT OF THIS REPORT ONLY)

** Follow the **"QA communication Protocol"**

ORIGINAL: Project Engineer
cc : Contractor

SHA Construction Form OOC61 – Page 1

The SHA Standard Construction Form OOC61 is a field investigation checklist and report that is filled out by the SHA Independent ESC QA Inspector and is used to document the condition of project erosion and sediment controls and to assess a grade for the project that will be used in determining incentive payment, liquidated damages or shut-down the project for non-compliance. This form is used in addition to the Standard Inspection Form required by the current NPDES Construction Activity General Permit and includes NPDES compliance checks.

OOC61 07/01/2011
CD 07220.300.01

Point Value	1. IS PROJECT IN SCOPE? * If No, Project is automatically Rated an "F".	Y	N	Pts. Awarded	N/A	Pts. Excluded
*	1.1. Have all appropriate permits and approvals been obtained (SHA/Contractor)?	☐	☐			
*	1.2. Are specified LOD, wetlands, buffers, jurisdictional waters, floodplains and/or tree protection areas demarcated and disturbed areas contained within the LOD (active work areas)?	☐	☐			
*	1.3. Is the project in conformance with the E&S plan, schedules and contract documents?	☐	☐			
4	1.3.1. Are sediment controls in place prior to disturbing areas of intended control?	☐	☐		☐	
2	1.3.2. Are controls removed with MDE approval?	☐	☐		☐	
4	1.4. Have all changes been approved to date including stream crossings/diversions.	☐	☐		☐	
1	1.5. Have approved changes been implemented?	☐	☐		☐	
4	1.6. Are the ESCM duties in compliance with specification 308.03.03	☐	☐		☐	
3	1.7. Are stockpiles/staging/waste areas approved?	☐	☐		☐	
2	1.8. Is grading limited to maximum grading unit?	☐	☐		☐	
2	1.9. Are roadways clear of sediment?	☐	☐		☐	
	NPDES The following question are also applicable when the project has 1 acre or more of disturbance					
2	1.10 Is trash collected and placed in a covered dumpster?	☐	☐		☐	
2	1.11 Are washout facilities (concrete, paint, etc.) clearly marked, maintained and wash water properly contained?	☐	☐		☐	
2	1.12 Are fuel containers and vehicle maintenance areas free of spills, leaks or any other deleterious material?	☐	☐		☐	
2	1.13 Are materials that are potential stormwater contaminants stored inside or under cover?	☐	☐		☐	
31	= Total Possible Points Subtotal =					*

Total Points Available = 31 - ____ * = ____

Y	N	Pts.	N/A	Pts.	2. ARE CONTROLS PROPERLY INSTALLED? 2.1	Pts.	Water handling	Pts.	3. ARE CONTROLS PROPERLY MAINTAINED? 3.1	Y	N	Pts.	N/A	Pts.
☐	☐		☐		2.1.1.	1	Earth Dikes	1	3.1.1.	☐	☐		☐	
☐	☐		☐		2.1.2.	1	Temporary Swales	1	3.1.2.	☐	☐		☐	
☐	☐		☐		2.1.3.	1	Perimeter Dike/Swales	1	3.1.3.	☐	☐		☐	
☐	☐		☐		2.1.4.	1	Diversion Fence	1	3.1.4.	☐	☐		☐	
☐	☐		☐		2.1.5.	1	Asphalt Berm	1	3.1.5.	☐	☐		☐	
					2.2.		**Grade Stabilization Structures**		3.2.					
☐	☐		☐		2.2.1.	2	Pipe Slope Drains	2	3.2.1.	☐	☐		☐	
☐	☐		☐		2.2.2.	1	Rip-rap Inflow Protection	1	3.2.2.	☐	☐		☐	
☐	☐		☐		2.2.3.	1	Gabion Inflow Protection	1	3.2.3.	☐	☐		☐	
☐	☐		☐		2.2.4.	2	Stone Check Dams	2	3.2.4.	☐	☐		☐	
					2.3.		**Sediment Trapping Devices**		3.3.					
☐	☐		☐		2.3.1.	3	Sediment Traps	3	3.3.1.	☐	☐		☐	
☐	☐		☐		2.3.2.	3	Sediment Basins	3	3.3.2.	☐	☐		☐	
☐	☐		☐		2.3.3.	2	Stone Outlet Structures	2	3.3.3.	☐	☐		☐	
☐	☐		☐		2.3.4	3	Gabion Outlet Structure	3	3.3.4	☐	☐		☐	
					2.4.		**Dewatering Practices**		3.4.					
☐	☐		☐		2.4.1.	2	Removable Pumping Station	2	3.4.1.	☐	☐		☐	
☐	☐		☐		2.4.2.	2	Sump Pits	2	3.4.2.	☐	☐		☐	
☐	☐		☐		2.4.3.	2	Portable Sediment Tanks	2	3.4.3.	☐	☐		☐	
☐	☐		☐		2.4.4.	2	Dewatering Bags	2	3.4.4.	☐	☐		☐	
					2.5.		**Filtering Practices**		3.5.					
☐	☐		☐		2.5.1.	2	Silt Fence	2	3.5.1.	☐	☐		☐	
☐	☐		☐		2.5.2.	3	Super Silt Fence	3	3.5.2.	☐	☐		☐	
☐	☐		☐		2.5.3.	1	Inlet Protection	1	3.5.3.	☐	☐		☐	
☐	☐		☐		2.5.4.	1	Straw Bale Dike	1	3.5.4.	☐	☐		☐	
☐	☐		☐		2.5.5.	2	Filter Log	2	3.5.5.	☐	☐		☐	
☐	☐		☐		2.5.6.	2	Filter Berm	2	3.5.6.	☐	☐		☐	
					2.6.		**Land Grading and Structural Stabilization**		3.6.					
☐	☐		☐		2.6.1.	2	Stabilized Construction Entrance	2	3.6.1.	☐	☐		☐	
☐	☐		☐		2.6.2.	1	Rock Outlet Protection	1	3.6.2.	☐	☐		☐	
					2.7.		**Miscellaneous Practices**		3.7.					
☐	☐		☐		2.7.1.	3	Temp. Access Waterway Crossing	3	3.7.1.	☐	☐		☐	
☐	☐		☐		2.7.2.	1	Dust Control	1	3.7.2.	☐	☐		☐	
☐	☐		☐		2.7.3.	2	Onsite Concrete Washout Area	2	3.7.3.	☐	☐		☐	
☐	☐		☐		2.7.4.	3	Maintenance of Stream Flow	3	3.7.4.	☐	☐		☐	
					2.8.		**Special Features**		3.8.					
☐	☐		☐		2.8.1.	1		1	3.8.1.	☐	☐		☐	
☐	☐		☐		2.8.2.	1		1	3.8.2.	☐	☐		☐	
☐	☐		☐		2.8.3.	1		1	3.8.3.	☐	☐		☐	
☐	☐		☐		2.8.4	1		1	3.8.4	☐	☐		☐	
Subtotal =					*	57	= Total Possible Points =	57		Subtotal =				*

Total Points Available = 57 - ____ * = ____ Total Points Available = 57 - ____ * = ____

SHA Construction Form OOC61 – Page 2

OOC61 07/01/2011 Page 3 of 4
CD 07220.300.01

Point Value	4. IS STABILIZATION PROVIDED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS?	Y	N	Pts. Awarded	N/A	Pts. Excluded
	4.1. Is stabilization provided as specified?					
1	4.1.1. Temporary mulch	☐	☐		☐	
1	4.1.2. Temporary seed	☐	☐		☐	
1	4.1.3. Permanent seed	☐	☐		☐	
3	4.1.4. Stabilization matting	☐	☐		☐	
1	4.1.5. Sod	☐	☐		☐	
1	4.1.6. Stone	☐	☐		☐	
1	4.1.7. Other	☐	☐		☐	
	4.2. Is stabilization provided in the specified time frame?					
2	4.2.1. Same day stabilization	☐	☐		☐	
2	4.2.2. 24 hour stabilization	☐	☐		☐	
2	4.2.3. 72 hours stabilization	☐	☐		☐	
2	4.2.4. 7-14 day stabilization	☐	☐		☐	
2	4.2.5. Other	☐	☐		☐	
1	4.3. Is incremental stabilization provided during construction?	☐	☐		☐	
1	4.4. Is the stabilization performing as specified?	☐	☐		☐	
2	4.5. Is vegetation being established?	☐	☐		☐	
23	= Total Possible Points Subtotal =					*

Total Points Available = 23 - ____* = ____

Point Value	5. WAS CORRECTIVE ACTION TIMELY FROM PREVIOUS QA REPORT?	Select one
5	5.1. No corrective action needed.	☐
4	5.2. Action completed < 24 hours.	☐
3	5.3. Action completed within 24 < 48 hours.	☐
2	5.4. Action completed within 48 < 72 hours.	☐
1	5.5. Action completed > 72 hours.	☐
0	5.6. Action not completed.	☐
5	= Total Possible Points Total Points Awarded =	

Point Value	6. IS THE CONTRACTOR PROACTIVE? (Bonus area)	Y	N	Pts. Awarded
1	6.1. Is sole duty of ESCM E&S activities?	☐	☐	
1	6.2. Recognizes and requests changes in a timely manner as warranted by any Changes or Modifications.	☐	☐	
1	6.3. ESCM conducts daily joint inspection with SHA staff.	☐	☐	
1	6.4. Contractor initiates corrective action.	☐	☐	
1	6.5. Contractor practices Environmental Awareness/Stewardship by training employees.	☐	☐	
5	= Total Possible Points Total Awarded			

SHA Construction Form OOC61 – Page 3

OOC61 07/01/2011
CD 07220.300.01

Page 4 of 4

Item No.	Notes:

SHA Construction Form OOC61 – Page 4

OOC3 05/01/12 MARYLAND STATE HIGHWAY ADMINISTRATION

DISTRICT ENGINEER'S CERTIFICATE OF COMPLETION OF WORK

DATE: ______________________

To: Director, Office of Construction

Re: Completion of Contract No.______________________ FAP No: ______________________

Route No / Name: ______________________

Location / Limits of Work: ______________________

Description/Type of Work: ______________________

Contractor: ______________________

An inspection of this project was made on __________ by the following attendees:

Name	Title	Representing

Except for the comments noted below, the work was found to be satisfactorily completed in conformance with the Contract Documents.

Exceptions: ______________________

____

Therefore, in compliance with the requirements of Section GP-5.13 and TC-7.06 of the Standard Specifications, I recommend the acceptance of the work performed under this contract and release the Contractor from any further work, including maintenance, within the limits of this project.

Signed: ______________________; __________

(District Engineer) (Date)

SHA Construction Form OOC03 – Page 1

The SHA Standard Construction Form OOC03 is a checklist used by SHA Project Engineers to close out construction projects. On page 2, it contains a checklist of important activities needed prior to close-out which includes verification of Stormwater As-Built Certification and NPDES Construction Activity Permit compliance and Notice of Termination (NOT) submittal.

OOC3 05/01/12 Page 2 of 2

Date:				Days
Advertised:______	☐ Working ☐ Calendar Days Charged		=	______
Bids Received:______	No Charge Days:			
Notice of Award:______		Sundays	=	______
Execution of Contract:______		Holidays	=	______
Notice to Proceed Letter:______		Bad Weather	=	______
On or Before:______		Other	=	______
*Time Charges Began:______				
Work Started:______	**Total No Charge Days:**		=	______
Surfacing Completed:______				
Opened to Traffic:______	**Complete Work Suspension**			
Accepted for Maintenance:______	From______	to ______	=	______
*Contract Completed:______	From______	to ______	=	______
Project Accepted:______				
	Partial Work Suspension			
Days	From______	to ______	=	______
	From______	to ______	=	______
Allowed:______	**Total Closed Down**		=	______
Charged:______	**Grand Total Elapsed Days**		=	______
Under:______	*Difference in Calendar Dates		=	______
Over:______				
Extended:______	**Total Number of Additional Work Requests:** ______			
Assessed:______				

Total Number of Change Orders: ______
Total Amount of Change Orders: $ ______

Liquidated Damages should be assessed on the following basis:

______ ☐ Work Days ☐ Calendar Days @ $______ per day = $______

A clearance for materials approval dated ______ has been received.

This contract included: ☐ No pavement ☐ Only Rigid pavement
☐ Only Flexible pavement ☐ Flexible and Rigid pavement

- Rigid pavement has been core drilled to check its thickness. ------------------ ☐ Yes ☐ No ☐ N/A
- A certification of drilling results has been received. ☐ Yes/Date ☐ No ☐ N/A
- The rigid pavement meets the thickness requirements of the specifications. ☐ Yes ☐ No ☐ N/A
- Pavement deficient in thickness by more than 1" has been replaced. --------- ☐ Yes ☐ No ☐ N/A
- The penalty for rigid pavement of deficient thickness left in place has been computed to be $______, which amount should be deducted from any amounts due the contractor.

The Initial Bridge Condition Inspection Report from the OOS has been received. ☐ Yes ☐ No ☐ Not Required

The ADA Compliance Report has been received. ☐ Yes ☐ No ☐ Not Required

The Final Inspection Report from OOTS has been received. ☐ Yes ☐ No ☐ Not Required

All weekly payroll statements of compliance as required by the Copeland "Anti-Kickback" Act for Federal Aid projects have been received. ☐ Yes ☐ No

Certified copies of all payrolls and the final wage rate and labor classification certification, as required for Federal Aid projects, have been received. ☐ Yes ☐ No

The MDSPGP Permit Compliance-Self Certification Form has been completed and forwarded to the Office of Environmental Design, Environmental Programs Division. ☐ Yes ☐ No ☐ Not Required

The Stormwater Management As-Built Certification has been submitted to and approved by the Office of Highway Development, Highway Hydraulics Division. ☐ Yes ☐ No ☐ Not Required

The National Pollutant Discharge Elimination System (NPDES) requirements have been met and the Notice of Termination (NOT) has been submitted to OHD Highway Hydraulics Division and confirmed with them that it was submitted to MDE. ☐ Yes ☐ No ☐ Not Required

Remarks: ______

SHA Construction Form OOC03 – Page 2

APPENDIX E:

SHA Statewide Salt Management Plan

October 2012

Statewide Salt Management Plan
Maryland State Highway Administration
October 2012

Preface

The Maryland State Legislature passed two bills in 2010, House Bill 0903 and Senate Bill 0775 that required the establishment of a Statewide Salt Management Plan. The legislature tasked the Maryland State Highway Administration (SHA) in conjunction with the Maryland Department of the Environment (MDE) with developing a road salt management best practices guidance document by October 1, 2011, for use by local jurisdictions and the state to minimize the adverse environmental impacts of road salt runoff in the state. These Best Practices for Salt Management cover the use of salt from its delivery, storage and handling at salt storage locations to its placement on highways during winter storms and to post storm cleanup operations. The following Best Practices should be seen as a starting point in an agency's plan to minimize the impact of salt on the environment in Maryland.

The objective and goal of this Statewide Salt Management Plan is to provide a framework for highway agencies to deliver safe, efficient roadway systems during winter storms in a cost effective manner while recognizing their obligation to do so in the most environmentally sensitive manner practicable.

A secondary objective and goal of this plan is to consolidate SHA's current practices and documents into a comprehensive guidance document.

1.0 Introduction

To be effective, a Salt Management Plan should contain principles that define the basic goals of a jurisdiction in delivering service to the public while meeting agency missions. Common primary goals for all jurisdictions include:

Public Safety
Effective winter storm maintenance has a direct impact on safety of the roadway users and on the personnel performing the maintenance. In the development of this plan, safety will be the primary goal.

Environmental Protection
Since the use of salt in high concentrations can have a negative impact to the roadside environment and to receiving waters of Maryland, the development of Best Management Practices contained in this plan will consider practices that minimize the use of road salt, thereby reducing the environmental impacts.

Efficient Transportation System
Efficient transportation systems are necessary in maintaining the mobility necessary for economic stability and in providing the quality of life expected by a jurisdiction's constituency. Salt Management Plan development should factor in these requirements.

Fiscal Responsibility
State, county and local jurisdictions are bound by budgets determined by their governing bodies. The Salt Management Plan for these jurisdictions must be within their financial capabilities.

Continual Improvement
In order to progress in the reduction of salt usage and the resultant environmental impacts, goals, technologies, practices, materials and equipment need to be revisited on a re-occurring basis to determine if changes can affect salt usage or can bring about reduced environmental impacts. Since these changes may have a fiscal impact on agency budgets, there must be recognition that the changes may be incremental.

Local Development of Salt Management Plans
Because of the variances in state, county and local transportation agency resources and mission objectives, Salt Management Plans for said jurisdictions should be locally developed. The plans should define the key elements of an environmental management program. Commitment to the plan should include accountability, goals, measurement of progress, communication, reporting, and its periodic review. This will assure that the local Salt Management Plan is a living document that provides for continual improvement.

2.0 Safety and Mobility

Agencies, such as SHA, are keenly aware of their goal to provide safety and mobility during winter storms in a cost-effective manner while minimizing environmental impacts to the maximum extent practicable.

In the reality of winter storms these desirable outcomes for this goal are difficult to achieve and at times, in conflict with each other. The principal driving force that often decides the hierarchy in this potential conflict is the defined level of service (LOS) an agency provides its citizens.

The LOS may be different from agency to agency. The SHA, for example, has more resources at its disposal when fighting a storm than do small rural towns. In this case, the LOS on state highways will almost always be higher than the LOS on the rural town roads. In addition, SHA manages most interstate highways in Maryland and these roads are always addressed at a level higher than most other county or city roads.

The LOS is not only different from agency to agency; it is also different on roads maintained by the same agency. The SHA, for example, identifies four different LOS's for following four different classes of highways in its network:

- Interstate highways and major US routes that connect with other states
- Additional highways with high average daily traffic (ADT)
- Additional highways with moderate ADT
- Additional highways with low ADT

These different LOS's generally correspond to the roadway functional classifications as defined by the FHWA.

A high level of service provides the greatest degree of safety and mobility for motorists. It allows emergency responders to provide adequate response times; citizens to carry out their day to day activities; and the business community to remain vibrant, in the worst of times: major winter storms.

3.0 Establishing Goals for Achieving Reduction in the Environmental Impact of Salt

These Best Practices for Salt Management should be seen as tools for managing the impact of winter materials on the environment. Typically, the principal tool most winter maintenance agencies use to achieve a desired level of service is the tried and true operation: plowing and salting. The current scope of this document is not intended to document the properties of salt and the many other deicing materials used in Maryland and elsewhere or the potential damage caused by salt and deicing materials. This document starts with the premise that winter materials can have a negative impact on the environment. It lays out ways that salt and other winter materials can be used in a manner that serves the interest of the citizens and business community of Maryland with the least impact on the environment. The authors of this document share a hope, common throughout the worldwide winter operations community, that other materials or technology are developed in the near future to optimize and reduce the use of salt.

There is an adage that states "that which gets measured, gets done." Best Practices for Salt Management should adhere to this adage. Highway agencies should measure their salt usage along with other related snow and ice control efforts. Agencies should measure the severity of winters and how it relates to salt usage. However, these measurements should be used to recognize, and respond to, trends rather than to develop annual usage reduction percentages.

Setting annual numerical goals in salt reduction is not responsible or desirable due to the dynamic nature of winter storms that vary in number, type, timing, intensity, duration, type of precipitation and roadway riding surface needs in special areas such as bridges and superelevated roadways, a percentage reduction from year to year would be impossible to project. By analyzing trends, and adhering to a responsible plan, long-term goals can be established to lessen the usage of salt and reduce its impact while maintaining the safety and mobility of highway users.

4.0 Equipment and Materials

Winter operations require specific equipment and materials to obtain the desired LOS. The equipment and materials require activities to properly store, handle and maintain.

4.1 Types of Winter Materials

Salt is the primary snow and ice control material used by SHA and by many agencies throughout the state and country. It is used because it is effective for winter storms in Maryland, inexpensive, easily stored, and readily available. Salt is used primarily during storms when precipitation has already begun to fall. With all of the innovations in winter maintenance over the past 20 years, nothing has stepped up to replace salt in benefit/cost effectiveness and reliability. While it will continue to be the most important material for fighting winter storms for the foreseeable future, agencies should look for ways to minimize its use. That is the focus of this Salt Management Plan.

The second most commonly used material by SHA and other agencies across the country is salt brine (liquid sodium chloride). Salt brine is used by SHA and other agencies primarily in anti-icing operations prior to storms. It is sprayed on highways two hours to two days prior to the onset of frozen precipitation to prevent snow and ice from bonding to pavements. It is also used to pre-wet salt as salt is spread on highways in deicing operations. Deicing operations are used when snow or ice has already accumulated or bonded to the surface of the highway. Deicing involves plowing and spreading salt to remove the frozen precipitation from surfaces. Anti-icing and deicing will be explained in greater detail later in this document.

Salt brine has several attributes that explain its rising usage. First, it is easily manufactured using a brine maker. Dry salt is dissolved in fresh water and brought to a concentration of 23% brine, then pumped to storage tanks where it is available for use on roads. Whereas salt begins to lose its effectiveness at 20 degrees, brine, which has a freeze point of -6 degrees, continues to work when salt cannot. SHA, for example, has 11 salt brine makers strategically placed across the state.

SHA and other highway agencies also use liquid magnesium chloride (mag). Mag has a freeze point of -23 degrees and can work in winter storms with very cold pavement temperatures. Mag is usually used to pre-wet salt. SHA, for example, does not spray mag on highways prior to storms. Although mag works well once precipitation begins to fall, SHA and other highway agencies across the country have found that mag can make highway surfaces slippery, under certain atmospheric conditions, during the hours leading up to the start of the storm.

Agencies should explore other materials and see if they produce good results. SHA, for example, is currently evaluating the use of desugared sugar beet molasses. Desugared sugar beet molasses is an organic material that is blended with salt brine. The beet molasses lowers the freezing point of brine, and allows it to remain on bridge and road surfaces for longer periods of time, extending its effectiveness.

Calcium chloride is a solid (flake) winter material used during extremely cold winter storms. SHA uses a limited amount of calcium chloride.

Agencies, including SHA, use abrasives (sand or crushed stone) in their winter operations although these materials have no snow melting characteristics. Abrasives are not normally used when a very high level of service is required. In addition, abrasives can clog drainage structures, contribute to air pollution and be discharged to receiving waters. Agencies should consider using a mix of salt and abrasives to increase traction for motorists during storms with freezing rain or with very cold pavement temperatures when salt becomes less effective. SHA uses these mixes primarily in Western Maryland.

4.2 Material Storage and Handling

Agencies should store salt in salt barns, salt domes, or other permanent structures whenever possible. The SHA, for example, stores all of its material in domes or barns. The structures should be well maintained. Potential problems should be caught during routine operations or through a periodic inspection program. Maintenance should be performed on structures during the off-season. Aging structures that have repeated high repair costs should be replaced when funding is available.

Properly maintained structures along with good housekeeping allow agencies, such as SHA, to safely keep salt in its structures, and avoid environmental impacts. The SHA, for example, uses a variety of methods to prevent salt from spilling out of structures. Maintenance shops place straw bales, aggregates, or wooden gates at the structures' doorways. Agencies should collect salt spilled in the vicinity of salt structures during loading and unloading operations. The material should be returned to the salt structure.

When fixed structures prove to be cost-prohibitive or not feasible, salt should be stored on impervious surfaces, such as asphalt pads, to prevent groundwater contamination. If material is not stored in fixed structures, it should be covered with a secured tarp.

Procedures should be in place for capturing salt spilled on pavements during the loading or unloading of the material. SHA, for example, has a Spill Prevention, Control and Countermeasures Plan for each of its maintenance facilities. Larger spills should be addressed using a piece of equipment such as a loader while small amounts can be addressed with a shovel and broom. In either case, the material should be returned to the salt structure as soon as possible. SHA's Standard Operating Procedures for Salt Stockpile Maintenance, along with other environmental documents, will be contained in appendices to this document.

Liquid deicing materials, such as salt brine or magnesium chloride, should be stored in well-maintained and labeled storage tanks. Because of the corrosive nature of these substances, routine maintenance should be performed on the storage tank fittings, valves and pumps. Any leaking or dripping should be addressed in a timely manner.

4.3 Snow and Ice Control Equipment

SHA purchases a variety of equipment and distributes it across the state to meet the needs of the area.

4.3.1 SHA Equipment

Agencies should purchase and employ the most effective snow fighting equipment they can buy within the confines of their budgets. Dump trucks should be equipped with well-maintained front plows that can mechanically remove as much snow as possible from highways. When appropriate, agencies should use side or "wing" plows to increase the amount of snow that can be mechanically removed from highways. Effective mechanical removal of snow equates to less salt needed to maintain a road in a safe or passable condition.

Dump trucks should also be equipped with well-maintained salt spreaders and spinners that are capable of applying the required amount of salt on roads in an effective pattern that limits material waste.

Agencies should purchase and employ, whenever possible, electronic salt spreading equipment. This equipment can be used to lock-in specific application rates that will prevent operators from using more salt than an agency recommends. It can also provide very exact application rates. Finally, it can be used in salt data collection after winter storms.

Agencies should calibrate all salt spreading equipment, regardless of its type, prior to the start of a winter season and check it for accuracy periodically during the season. This is a critical aspect of effective salt management.

Agencies should use other specialty equipment for removal of snow from highways, when appropriate. Snow blowers are effective in removing a heavy buildup of snow, particularly from highway shoulders. Front end loaders are effective in removing a heavy buildup of snow from sections of roads where plows are not effective such as narrow residential streets with parking on both sides. In this case the snow needs to be placed in dump trucks and hauled away. Motor graders may be needed to mechanically remove snow or ice that has "packed' on highways. Effective use of these specialized pieces of equipment lessens the need for salt to return a highway to a serviceable condition.

SHA, for example, maintains a fleet of dump trucks, the majority of which are single axle units capable of carrying 5 to 6 tons of salt. The remainder of its dump truck fleet consists of tandem and tri-axle trucks capable of carrying 10 to 15 tons of salt. The dump trucks are equipped with well-maintained plows, and electronically controlled spreaders that are capable of applying the required amount of salt on roads in an effective pattern that limits material waste. The equipment is calibrated for accuracy prior to winter. SHA also has a limited fleet of specialty equipment including snow blowers, frontend loaders, and motor graders.

4.3.2 Hired Equipment Contract for Snow Removal Services

Agencies should use hired equipment to supplement its own forces if needed to maintain its prescribed level of service. SHA, for example, uses this approach. Hired equipment should be equipped with well-maintained plows and spreaders to assure effective and efficient snow removal operations in general and salting operations in particular. Poorly equipped hired equipment can lead to excessive salt use.

Agencies should train hired equipment operators in all facets of plowing and salting operations, much as it does its own forces. Poorly trained hired equipment operators can use excessive amounts of salt. SHA, for example, trains its hired equipment operators using a PowerPoint presentation prior to winter.

Agencies must train its frontline supervisors in the effective management of hired equipment. This assures that hired equipment operators are following an agency's policies and procedures, particularly in salt usage. SHA, for example, follows this approach and trains its frontline supervisors prior to winter.

The spreader systems on contracted dump trucks should be calibrated prior to winter. Tests should be performed on the units to assure that the amount of salt physically spread on a highway correlates to a setting on the control knobs in the truck's cab. It is critical that contract trucks are calibrated, and its operators are closely monitored by agency personnel to avoid improper salting. SHA, for example, assures that contractors' trucks are calibrated for quality control prior to signing a contract with them.

5.0 Training Initiatives

Training is a critical component of salt management and a best practice in winter operations in general

Agencies should provide training in salt management to its maintenance managers and frontline forces on a regular basis. Many agencies, including SHA, have a "Snow College" or "Snow Academy" to accomplish this initiative. The focus of the training should be in best practices that stress using the least amount of material without jeopardizing levels of service and safety for motorists. The SHA, for example, provides Snow College every year for all new hires and 20% of its maintenance forces. In this manner, SHA assures that all maintenance personnel receive updated training every five years.

Special training initiatives should target specific audiences. Shop or garage managers and frontline supervisors should receive additional training in the science of snow removal operations, effective winter storm management, winter materials inventory management, the properties of salt and other winter materials, and data collection and analysis. SHA, for example, performs its manager training in the fall.

Special training should also be provided to hired equipment operators and temporary employees that supplement an agency's operation. This training should concentrate on the need to adhere to an agency's snow and ice control policies and procedures. A major focus of this training should be on the proper use of salt and other winter materials. SHA, for example, provides hired equipment operator training prior to bringing the contractors on board.

Examples of SHA's training presentations will be contained in appendices to this document prior to winter. These programs are revised annually to reflect changes in operations that are developed through post storm and season operations reviews, new materials, new equipment and/or new technologies.

6.0 Winter Storm Management

Winter storm management involves effective planning, execution, and review.

6.1 Weather and Pavement Condition Forecast

A key component of effective winter storm management is good weather and pavement condition forecasting. This is true 24 to 72 hours prior to a storm when planning is taking shape, during a storm as forces react to changing conditions and during post-storm operations when effective cleanup actions prevent potential safety issues.

Agencies across the country rely on the National Weather Service (NWS), contracted weather and pavement condition forecasters, and their own network of Road Weather Information System (RWIS) sites as a tool for winter storm management. The NWS provides a strategic forecast, alerting agencies of the potential for storms well in advance of their arrival. As a storm nears, the NWS will provide forecasts for approximate starting times and snowfall amounts over generalized areas of a state. The NWS does not, however, provide localized site specific forecasts, nor does it provide information on pavement temperature or conditions, key components needed by winter storm managers.

Contracted weather and pavement condition forecasters provide the generalized forecasting provided by NWS and enhance it with localized, site specific, information. The contracted services will not only forecast when snow will begin to fall and how much is anticipated to fall, they will also forecast the anticipated pavement temperatures which will play a part on how much snow will actually accumulate on highways.

The RWIS network is a series of strategically located local "weather stations" placed along an agency's highway system. They consist of a weather tower that provides localized data such as type and intensity of precipitation, air temperature, wind direction and speed, dew point, relative humidity, and pavement sensors that detect pavement temperature, surface freeze point, and salinity concentration.

The SHA, for example, relies on these three sources of information at each stage of its winter storm management. It has a close working relationship with the NWS and its contracted weather and pavement condition forecaster, and maintains 62 RWIS stations across the state. Beyond receiving regular reports from the weather sources throughout the winter, SHA engages in conference calls with them prior to and during significant winter events.

6.2 Pre-Storm Planning

Pre-storm planning is an effective tool for managing salt usage in a storm and a best practice in winter operations. Effective planning prior to storms will equate to better performance during a storm including more efficient usage of salt. SHA's statewide pre-storm planning, for example, can begin as far as 72 hours prior to major winter storms. SHA's planning for typical winter storms begins 18 to 24 hours prior to events.

Agencies should begin resource planning well ahead of the starting time of winter storms. Anti-icing should be performed if appropriate for the storm. Agency personnel and hired contractors, if applicable, need to report to their shops or garages with enough lead time to thoroughly inspect their plow trucks and make any needed repairs. If a credible forecast is available early enough, equipment can be prepared 24 hours in advance of the storm. Either way, equipment needs to be working properly and prepared for operations. Agency and hired truck operators should load salt and other deicing materials on their equipment in an environmentally prudent manner.

Agencies should consider pre-storm meetings with its shop or garage personnel. This provides managers with an opportunity to alert personnel about the latest weather and road forecasts, emphasize the need for effective plowing, reiterate the need for sensible salting, identify appropriate salt application rates, and recommend the use for additives such as salt brine or magnesium chloride. It also allows for information exchange and a sharing of opportunities for improvement. Many SHA shops routinely hold pre-storm meetings for all events.

Once the equipment is ready, it should be pre-positioned on its snow route prior to the start of the event. Pre-positioned snow equipment speeds up the response time of an agency. This is particularly important if the forecasted starting time of the storm could impact morning or evening rush hour traffic. If snow fighting equipment becomes trapped by traffic congestion, it might not be able to get to its snow route in an acceptable time. It's important that the equipment is in place because once a storm begins, it must be fought vigorously. Fighting a storm vigorously means remaining proactive throughout a storm in order to manage it in the most effective and efficient manner.

6.3 Anti-icing Operations

Anti-icing, a proven, proactive, nationwide winter strategy, should be practiced by agencies in Maryland whenever appropriate for a storm. The SHA, for example has been anti-icing since the late 1990's. It has intensified the activity over the past two winters, addressing most interstate highways in Maryland. Anti-icing involves placing a material, usually a liquid such as salt brine, on highways anywhere from two hours to two days prior to the onset of precipitation. Anti-icing can also be accomplished with a pre-wetted salt placed on highways immediately before the start of a winter storm. Finally, it can be accomplished with an application of salt as snow is first starting to accumulate on a pavement.

The primary goal of anti-icing is to prevent snow and ice from bonding to a highway or bridge surface, allowing for more effective and efficient plowing and salting operations during the event. This will often lead to lower overall salt usage during storms and perhaps more importantly, increase the safety of motorists at the start of a storm. If snow or ice is allowed to bond to a pavement, heavy plowing and salting is needed to break it.

The SHA's experience has shown that a timely application of brine prior to the start of storms keeps highways in the best condition once frozen precipitation begins to fall. This is particularly important if a storm begins well in advance of its forecasted arrival time, and maintenance forces are not fully mobilized. The anti-icing application of brine becomes, in essence, the first application of salt that can "hold" the road until salting trucks can address the situation.

Highway agencies across the country, including SHA, do not perform anti-icing operations for every forecasted winter event. If a winter storm is forecasted to begin as rain, anti-icing will usually not be performed. The salt brine would simply be washed off of the highway surface, wasting the material and the expense in putting it down. If pavement temperatures are forecasted to be 15° or colder at the onset of the storm, anti-icing is not usually performed. Finally, if a winter storm had recently occurred and salt residue is present on highway surfaces, anti-icing might not be necessary.

6.4 Winter Storm Operations

Once a storm begins and precipitation starts to accumulate on highway surfaces, agencies begin deicing operations. If a typical winter storm begins with light snowfall, an early application of salt needs to be equally light. If a winter storm begins with moderate to heavy snowfall, applications should be adjusted accordingly. Either way, this initial application should be pre-wetted with a liquid deicing material such as salt brine or magnesium chloride. Pre-wetted salt tends to adhere to the pavement surface, reducing the amount of salt that bounces off the highway onto shoulders or roadsides. The pre-wetted salt also begins working quicker.

The key is to get some material on the road as early as possible to prevent snow or ice from bonding to the highway surface. This will allow for effective plowing and lighter salt applications throughout the remainder of a storm. The old adage "an ounce of prevention is worth a pound of cure" rings true when fighting a winter storm. SHA adheres to this adage.

As the storm continues, forces need to react to changing conditions. As the initial application of salt begins to lose its effectiveness and snow continues to build on highways, forces should go into plowing operations. If the initial application was successful, the buildup will be "mealy" and easy to remove with proper plowing techniques. The plow operator should apply just enough salt to keep subsequent snowfall from bonding to the pavement. This process may have to be repeated multiple times during a winter storm.

If a winter storm is associated with very cold pavement temperatures, salt should always be pre-wetted with a liquid deicer to increase its effectiveness. By increasing the effectiveness of salt, less is needed.

On multilane highways, plow trains should be considered in order to remove as much snow as possible in a coordinated sweep. SHA, for example, makes extensive use of plow trains. If a plow train is effective and the surface is swept clean, minimal salt is needed to keep the highway in an acceptable condition until the train comes through again. Every effort must be made by the train to direct the applications of salt into areas where plowing has already occurred. Otherwise, trailing trucks could plow off salt just placed on the road by the lead trucks. Agencies should train their forces in effective plow train operations, a key element in salt management.

Agencies should consider varying the LOS it provides motorists during storms based on type/intensity of storm, location, and time of day. For example, if a storm occurs during the overnight hours, some snow can build up on highways as long as it is not allowed to become snow packed, the highway remains passable, and is in a reasonably safe condition. In this case, an agency can use less salt than it would otherwise. Conversely, if the same amount of snow falls on the same highway prior to or during periods of heavy traffic, more salting will be necessary to keep the road at a higher level of service.

6.5 Severe Winter Storms

Severe winter storms create unique challenges for a salt management plan. Agencies must be prepared to step up their response, from pre-planning operations to final storm cleanup. They will be called upon to provide their LOS, while fighting heavy accumulations of snow, freezing rain, or blizzard conditions. SHA, for example, has fought these severe winter storms over the past several winters and has learned much in the process.

When fighting storms with heavy accumulations of snow, agencies should concentrate on plowing operations and severely limit salt applications. Plow trucks should still spread a small amount of salt to help keep the snow from packing on the road but the emphasis should be on continuous plowing. As the storm begins to wind down and most of the snow has been removed, an appropriate amount of salt will help remove the remaining frozen precipitation from the surface. As in all other events, salt applications should be as little as possible while still accomplishing the task at hand. The SHA adheres to this approach.

Freezing rain storms also present special challenges to agencies. Freezing rain, if left untreated, will coat highways with ice, creating severe safety and mobility issues for motorists. The SHA has found that the best treatment for freezing rain is salt. The salt will prevent ice from forming on pavement surfaces but will also wash away, requiring additional applications. Some agencies use abrasives, such as crushed stone or sand, to provide traction for motorists. Agencies should consider a mix of salt and abrasives to lessen salt usage and still provide a level of safety for motorists. If a salt/abrasive mix is used during a storm, there may be a need for a cleanup of the abrasives from highways once the storm ends and the surfaces dry.

When preparing for freezing rain storms, agencies should preposition trucks, at key locations along highway systems that will assure quick response to likely trouble spots. While trucks are normally bunched together for snow storms where plowing is necessary, they should be scattered using a “shotgun” approach in freezing rain events. SHA, for example, uses this approach which allows it to treat much of the highway system simultaneously.

Winter storms that occur at the start of or during rush hour traffic pose significant challenges to effective salt management. A winter storm that drops one or two inches of snow during rush hour can be more troublesome than a winter storm that drops five or six inches during off-peak travel times. The SHA and other agencies have learned that they must place salt or other winter materials on highways prior to heavy traffic. Once traffic builds up on highways, plow and salt trucks cannot address snow buildup. They are caught in the traffic snarl with other motorists. In addition, snow can be “packed” on the highway surface, requiring very heavy plowing and salting to remedy it. Appropriate salting prior to rush hour is one of an agency’s best tools in limiting total salt usage during this type of event.

Severe winter events such as blizzards or back-to-back storms create unique challenges to agencies and effective salt management. While normal plowing and salting can keep a highway in a passable condition during a typical winter storm, heavy snowfall requires more intensive plowing operations. The cycle times of plow trains are severely challenged. In these events, agencies should still apply salt, at a reduced rate, during each plow train cycle. This is critical if snowpack or icepack is to be avoided. Salting should keep subsequent snowfall in a plowable state so it can be addressed in the next plowing cycle. The SHA has gained much experience from fighting back-to-back blizzards in February 2010.

Agencies do not usually have sufficient equipment and personnel to run plow trains for hours on end. Equipment breakdowns can eventually affect the operation. In addition, it is critical that agencies provide adequate rest for their employees during severe storms. This keeps operators fresh so they can make good choices while plowing and salting. This also keeps repair technicians fresh so they can keep equipment operable. An appropriately rested workforce should translate into effective salt management.

Some winter storms are so severe that the Governor might declare a State of Emergency and order all highway users, with the exception of emergency responders, to stay off of highways. When this occurs, highway agencies are allowed the opportunity to clear roads of snow and ice in a more effective manner. This allows highway agencies to return the network to a safe manner more quickly.

6.6 Stockpiling and Disposal of Removed Snow

During blizzards or back to back storms, snow can build up to a point when it cannot be plowed. There simply is no place to push the plowed snow. Some municipalities also have difficulty plowing snow in heavily populated or congested areas. In these cases, snow needs to be hauled away in dump trucks. Agencies need to coordinate with MDE and the Maryland Department of Natural Resources (DNR) to identify storage locations for the snow in less environmentally sensitive areas. These pre-approved locations can be used to store snow, which may contain salt or other materials, until it melts over time. Another option is to use a snow melter to speed up the operation. This is important if the holding area needs to be cleared in order to accept more snow. The SHA does not possess snow melting equipment.

6.7 Operations in Sensitive Areas

Highway agencies should coordinate with MDE to determine criteria for determining areas sensitive to exposure to salt and salt runoff. While MDE and SHA recognize the importance of all waters in Maryland, areas of high susceptibility were determined to be:

- Wetlands of Special State Concern as defined in COMAR 26.23.06
- Tier II waters as defined in MDE's TMDL Integrated 303D Reports
- Wellhead Protection Program as defined in MDE's program as susceptible areas.

In addition to the areas of high susceptibility, SHA and MDE also agreed that roadside and/or receiving waters exhibiting indicators of salt contamination will be monitored and salt management practices in those areas will be assessed to determine if changes in practices and salt usage should and can be implemented.

Site specific plans in environmentally sensitive areas should be developed. A plan for a sensitive area may include reduced salt usage or no salt usage at all. It may also include the use of another snow and ice control material.

The potential for reduced levels of service exists for motorists when normal plowing and salting operations are not conducted in sensitive areas. Signage alerting motorists about the reduced levels of service may be required to indicate the need to slow down and remain alert.

Agencies should consider developing and testing new strategies in these areas that may lead to improved service without impacting the environment. The SHA, for example, is piloting the Maintenance Decision Support System (MDSS) at several sites in Maryland. The program provides a high resolution weather and pavement forecast for snow routes along with recommended material application rates. The program attempts to find the lowest amount of salt or other winter material application rate while still maintaining an agency's acceptable level of service.

6.8 Automatic Vehicle Location (AVL)

A critical ingredient in effective winter storm management is knowing where snow fighting equipment is at all times. Many agencies across the country have deployed AVL systems to help in this effort. The AVL system tracks the physical location of dump trucks and other snow fighting equipment during winter storms, and displays it on monitors. The AVL system is a tool for managers to track progress during winter storms. It can be used by managers to locate and redeploy the nearest truck to a highway incident, speeding up emergency response.

The AVL system can also be used to determine if a truck is plowing and spreading salt, and if so, determine the material application rate. Data captured through the AVL system can be analyzed after winter storms to identify opportunities to increase the efficiency of winter operations. Finally, and perhaps most importantly, AVL is a tool to increase the safety of the drivers.

The SHA, for example, began installing an AVL system during the summer of 2011. AVL units are being placed on all SHA dump trucks, Team Leader vehicles, and other specialty equipment. Portable AVL units will also be placed on some contracted trucks that perform snow removal for SHA.

7.0 Post Storm Operations

Post Storm Operations include a variety of tasks including cleaning equipment, stockpile maintenance, and operation reviews.

7.1 Equipment Cleaning and Maintenance

Agencies should develop plans for equipment cleanup and maintenance after winter storms. Cleaning of snow plows and trucks should occur, whenever possible, inside the wash bays of a shop's facility. Cleaning of salt spreaders and plow blades that have been removed from vehicles prior to cleaning should occur in a manner whereby wastewater does not discharge from the site and is discharged into a BMP.

The SHA, for example, has developed site specific Pollution Prevention Plans (SWPPP) for its maintenance facilities. While the SHA shop plans are site specific, they all contain consistent requirements for equipment cleaning and maintenance. The shops are required by MDE's National Pollutant Discharge Elimination System (NPDES) Industrial Permit conditions to develop and implement a site specific Pollution Prevention Plan and a Spill Prevention, Control and Countermeasures Plan. These plans address protocols, inspections, documentation and reporting for the features or practices that have potential negative impacts to the environment. Should a plan not already exist, one should be developed.

7.2 Material Cleanup at Storage Facilities

Immediately after winter storm operations have ceased, all unused salt should be returned to a storage facility. All exposed abrasives should either be moved to a covered facility or covered securely with a tarp. If salt/abrasive mixing has occurred in an uncovered area, any remaining stockpile should be returned to the salt storage facility. SHA's SWPPP, for example, include requirements for material storage at the maintenance facilities.

7.3 Operations Review for Continual Improvement

An agency review of operations after winter events is an essential best practice in winter operations in general and salt management in particular. Agencies in Maryland should consider having post storm reviews at their shop or garage level for most winter storms and agency-wide reviews for major storms. The SHA, for example, follows this approach.

Post storm reviews should concentrate on three key elements: what worked well, what didn't work well, and most importantly, opportunities for improvement. The opportunities for improvement lead to best practices. The SHA, for example, used the opportunities for improvement that came from the back-to-back blizzards of February 2010 to make some of the most significant changes to its operations since the turn of the century.

Post storm reviews can also be used to identify "shop champions" who get their snow route cleared with less salt. The "champions" should be encouraged to share their ideas with others at the shop that use more salt for an equivalent snow route.

7.4 Post Storm Data Analysis

Agencies should consider capturing salt usage data by truck, snow route, shop or garage, district, and agency-wide. Shops should consider measuring their salt usage in relation to the number of lane miles served, and inches of snow fought. A good formula for measurement is “pounds of salt used per lane mile per inch of snow.” This is the process SHA has used over the past decade. In this process, agencies can measure the salt usage performance between trucks on a common route, routes within a single shop or garage, and from shop to shop or garage to garage.

Agencies should consider electronic means of collecting salt usage data. Various electronic salt spreader controllers have this capability. At the close of a winter storm, data on salt usage can be downloaded from the spreader and analyzed by shop managers. SHA, for example, uses this approach in some of its shops. Agencies should also consider using AVL technology for salt usage data collection. AVL technology has the capability of identifying salt usage and when each application was made. The SHA, for example, plans to move in this direction over the next several years.

8.0 Spill Prevention and Control Plan for Winter Operations

First and foremost, agencies should make every effort to prevent the uncontrolled release of winter materials into the environment at storage facilities and on highways. SHA, for example, developed and implemented site specific Spill Prevention, Control and Countermeasure Plans (SPCCP) for each of its maintenance facilities. The individual plans consider the site topography, drainage patterns and the locations of all materials with risk of spillage. While the plans are site specific they all contain a common approach to spill management of winter materials.

8.1 Salt Spill Prevention

When loading salt at storage locations, trucks should never be overloaded. If they are, salt can spill from the sides or back of the truck when it's leaving the facility or when it's on route. Overloading trucks with salt is avoidable and a clear violation of best practices for salt management. If spillage occurs, it should be addressed during a storm if time allows or at the close of the event.

Another best practice is the deployment of tailgate flaps that prevent salt from spilling out of the back of dump trucks. These small triangular pieces of metal can be made in house for a few dollars but can save tons of salt over the course of a winter season. The SHA, for example, requires tailgate flaps on all state and hired trucks.

There are times when salt can spill from a truck that was not overloaded. If the auger in a truck's salt spreader box becomes jammed with a large chunk of salt or debris, the operator may have to manually clear the box. At times the jam is cleared but salt falls to the pavement. At other times, a truck operator may have to raise the dump truck bed to move material to the rear of the truck. This occurs when the salt in the bed of the dump truck begins to get low. During this operation material can spill from the rear of the truck.

Whenever salt spills from a truck, either from being overfilled or not, it should be swept up and placed back in the bed of the dump truck. Operators must do this in a safe fashion so as not to endanger themselves or motorists. Effective salt management does not equate with unsafe practices.

8.2 Brine and Magnesium Chloride Mixing and Storage Tanks

To minimize the possibility of leakage and spills from liquid storage tanks, a weekly inspection program should be implemented. Whenever drips/leaks are found, maintenance and/or repairs should be made as quickly as possible. Until such time as the repair can be completed, the leak should be contained.

9.0 Recordkeeping and Annual Reports

Agencies should keep up-to-date records of all of its winter operations, especially records of salting. Records should be kept on all aspects of its winter operations at all levels of an agency. Records should be kept for each winter event, and for each winter season. This will allow for seasonal analysis and the identification of trends. The SHA, for example, maintains up-to-date records on salt usage and other key winter objectives and performance measures and produces quarterly and annual reports for its statewide business plan.

The SHA has been keeping extensive electronic records of its winter operations since 1999. The SHA tracks personnel, equipment and material usage at each of its maintenance shops. It also tracks weather and pavement conditions during winter events. The information is summarized in various reports for real time operations status and is post-processed for operations cost estimates.

Agencies should perform an in-depth analysis of its operations, with an emphasis on salt usage, at the close of each season. This analysis should culminate in an annual report. The annual report should serve as means for learning lessons, identifying opportunities for improvement, identifying trends, and developing recommendations for operations the following winter. The annual report can also be used by an agency's senior management to determine the need for changes in policies, procedures, processes, and expenditures and to determine any budgetary implications of identified needs.

10.0 Annual Winter Wrap-Up Meeting

Agencies should hold an annual meeting to review its winter operations, deepening its understanding of lessons that came out of the post storm reviews, and identifying areas of concern such as salt management, equipment improvements, etc. The annual meeting can be used to identify key opportunities for improvement and set up teams to tackle them over the summer. It is critical that the progress of the teams is tracked closely so that the efforts come to fruition prior to the following winter. The SHA, for example, followed this approach at the close of the 2009 – 2010 winter season and made considerable progress in its subsequent operations.

11. Public Education and Outreach

Agencies should make every effort to provide the public with information concerning its winter operations in general and with information concerning its winter storm activities in particular.

Agencies should consider an annual media briefing to update the radio, television and print media in their area about their winter operations program. Agencies can use this opportunity to review their experiences during the past winter, discuss their plans for the upcoming winter, and highlight new initiatives. This information is then shared, through the media outlets, with the public.

The SHA's Office of Customer Relations and Information, for example, holds an annual "Snow Show" each fall for its outreach to the media and public. During the briefing, SHA stresses the need for motorists to be mindful of the potential dangers of driving during winter storms. They highlight their "Ice and Snow, Take it Slow" campaign. The SHA also stresses the need for motorists to give snow fighting equipment "space" to do its job. This allows SHA and contracted forces the best opportunity to clear roads of snow and ice in a safe and effective manner.

Agencies should consider having their emergency operations centers activated for winter storms, and using them for outreach. The SHA's Office of Customer Relations and Information, for example, provides live interviews with media representatives in a proactive manner. This allows SHA to keep the public, via the media representatives, updated on the current status of its operations and the overall condition of the highway system.

Agencies should also consider providing customer service for its citizens during and after winter storm events via telephone and internet. An agency's maintenance shop or garage personnel or its emergency operations center can respond directly to citizen needs in a real-time manner on a localized basis. After the storm, the agency can respond to citizens' questions or concerns about its operations in their localized areas. General questions about their operations can be handled through the shop or garage managers or by the agency's office personnel. The SHA, for example, follows this format.

12. Testing and Evaluation of New Materials, Equipment, and Strategies for Continual Improvement

Agencies should always be striving to improve their winter operations. One way to improve operations is by trying new ideas that pose minimal risk to operations but have a substantial potential upside. The new ideas can be in the form of different winter materials, tweaking existing equipment, deploying a new spreader plow, or trying out new strategies or tactics for fighting storms. Testing and evaluating new ideas can lead to lower salt usage and is definitely a Best Practice for Salt Management.

The SHA, for example, is testing and evaluating tow plows, a trailer mounted plow that is towed by a dump truck. The tow-behind plow in conjunction with the dump truck's front plow can clear a path 24 feet wide. A standard front plow can clear a section of roadway eight feet wide. With limited resources, the tow plow may help SHA operate with its thinning work force and fleet. The SHA is continuing its evaluation of desugared sugar beet molasses. The hope is that the material will lead to lower salt usage as well as corrosion protection for its equipment. The SHA is also exploring the use of its graphical displays using its GIS program to improve practices in salt management.

As agencies in Maryland strive to improve their winter operations in general and salt management in particular, they need to expand their search beyond our state's borders. There are many organizations across the country that are performing research on new winter strategies, testing new materials in laboratories, and testing and evaluating new products on highways and bridges. Agencies in Maryland should take advantage of these resources, most of which are free of charge to others in the winter maintenance community. The following links are a good start in this direction:

http://www.clearroads.org/
The Clear Roads pooled fund project provides real-world testing in the field of winter highway operations. This ongoing research program has already attracted 20 member states and is funding practical, usable winter maintenance research.

http://www.aurora-program.org/
Aurora is an international partnership of public agencies that work together to perform joint research activities in the area of Road Weather Information Systems (RWIS). This website is designed to introduce the program, the partners, and its collaborative research projects.

http://www.ops.fhwa.dot.gov/weather/index.asp
The Road Weather Management Program, within the FHWA Office of Operations, seeks to better understand the impacts of weather on roadways, and promote strategies and tools to mitigate those impacts.

http://www.meridian-enviro.com/mdss/pfs/
The Maintenance Decision Support System Pooled Fund Study leads the nationwide effort to provide research, development, and application of computer based winter maintenance decision support, including route specific weather and pavement condition forecasting, and suggested responses to the event, based on an agency's rules of practice.

http://maintenance.transportation.org/Pages/default.aspx
The American Association of State Highway and Transportation Officials (AASHTO) advocates transportation-related policies and provides technical services to support states in their efforts to efficiently and safely move people and goods. Its Subcommittee on Maintenance (SCOM) provides technical services to support high level research into preserving and maintaining a world class highway system. Its Winter Maintenance Technical Services Program addresses AASHTO's goals for the snow and ice control community.

http://www.wsdot.wa.gov/partners/pns/
The Pacific Northwest Snowfighters (PNS) Association strives to serve the traveling public by evaluating and establishing specifications for products used in winter maintenance that emphasize safety, environmental preservation, infrastructure protection, cost-effectiveness and performance.

13. Summary

Agencies should view these Best Practices for Salt Management as a starting point in their winter operations. Agencies should adopt whatever parts of the plan works for them, as long as it results in effective salt management and the safety of motorists.

Agencies should also seek opportunities to work together with various regional, county and local organizations to provide seamless operations during winter storms. The agencies need to be cognizant of the differing needs of each other, based upon public safety, geography, weather patterns, environmentally sensitive areas, available resources, budgets and constituency expectations. Maryland's highway agencies should also seek opportunities to consult with each other after major winter storms and after the completion of winter seasons to share lessons learned in Best Practices for Salt Management.

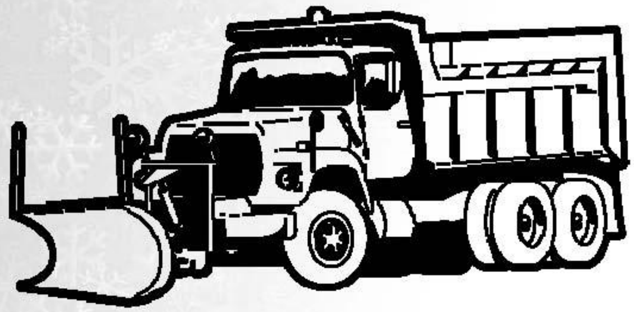
Best Practices for Salt Management should be a living document that is updated on a regular basis. In that regard, SHA will attach a series of appendices to this document. They will address issues such as training, pre-storm checklists, post storm reviews, and material handling. In addition, SHA will continue to attach appendices to this document as new information becomes available. Best

Practices for Salt Management should be seen as a key tool to provide the citizens of Maryland with safety and mobility during winter storms in a cost-effective, environmentally sustainable manner.

Appendix I

Hired Equipment Presentation

State Highway Administration Roadway Winter Operations



-Hired Equipment Presentation –

revised 9/4/12

Winter Operations

- Snow removal is SHA's number one priority regarding highway maintenance operations
- Safety is important to everyone and equally shares first priority in all snow storm activities
- The movement of commerce and people depend on our winter response activities
- SHA and Contract forces are jointly responsible for minimizing impacts to our environment and minimizing Winter Operations Costs

2

Winter Season Operator Guidelines

- SHA's policy states that Winter Operations will continue until all State roads are free of snow and ice

Snow Removal Requirements

- Operator's are required to have all equipment operational prior to check in
- All contract personnel and equipment must be logged in and out of service, and operators must provide their cell phone number.

- ***NO REPAIR DELAYS!***
  All equipment should be ready for work upon arrival
- The Administration will not pay for down time on trucks and equipment that extents beyond one hour

4

Snow Removal Requirements

All CB radios must be in good working condition.

Check with your Snow Supervisor for appropriate channel.

SHA equipment shall not be used for any other work.

5

Snow Removal Requirements Automatic Vehicle Location (AVL)

- SHA has implemented an Automatic Vehicle Location (AVL) tracking system.
- AVL technology is used to track the current and past locations of SHA and hired equipment plow and salting trucks.
- AVL technology increases the efficiency, effectiveness and safety of SHA and contracted equipment operators.

6

Snow Removal Requirements Automatic Vehicle Location (AVL)

- The Contractor's truck shall provide a 12 volt DC Power Port or other similar power source for the plug-in AVL unit.
- The power source shall be in the truck's cab in order to protect the AVL device from damage.
- The Contractor's personnel will be assigned an AVL unit when they report for a storm.
- The Contractor's personnel must sign a form accepting the AVL for the event.

7

Snow Removal Requirements Automatic Vehicle Location (AVL)

- The AVL unit must be kept operational throughout the storm and returned, in working order, at the close of the storm when the operator is logged out.
- Failure to keep the AVL operational will result in a $250 deduction in the season ending retainer. A second occurrence may result in another $250 deduction and contract termination.
- The Contractor will be billed $250 for failure to return the unit in working order.

8

Call-out Phases

- ***Phase 1***- *(0-2 inch forecast)* Includes hired spreader trucks to supplement SHA work forces on designated routes and where there are no assigned SHA trucks
- ***Phase 2*** – *(2-4 inch forecast)* Includes hired spreader trucks to supplement the SHA work forces during heavier snowfalls
- ***Phase 3*** – *(4+ inch forecast)* Includes hired push trucks to support SHA work forces on designated routes as roadway conditions warrant

9

Call-out Phases

- Each storm is evaluated based on the forecasted accumulation and severity
- Report times can be accelerated based on intensity of the storm, timing of the event, and other factors beyond our control

10

Standard Operations

- Show up or commute time, from the designated SHA facility to assigned route, must not be excessive
- Equipment clean-up after storms…

  … all SHA equipment: spreaders, plows, and door signs. (Not for private trucks)

11

Operator Guidelines
- Sensible Salting Practices -

- A well trained operator knows when to apply salt, and when not to.
- Use the correct amount of salt to get the job done.
- Using more salt than necessary actually works against you and damages the environment.

12

Operator Guidelines
- Sensible Salting Practices -

Never Overload Trucks to avoid spillage of salt at SHA facilities and on the road

Travel at a reasonable speed for optimum performance, safety, and to help keep salt on the road and not into the environment

13

Operator Guidelines
- Sensible Salting Practices -

- ONLY apply salt to your designated snow route when directed to by SHA personnel
- Don't salt roads that have already been salted
- Don't apply salt to a undesignated snow route unless directed to by SHA personnel

14

Operator Guidelines
- Sensible Salting Practices -

- SHA captures salt usage by each truck, each snow route, each shop, each district and at the statewide level
- SHA analyzes data after winter storms, looking for opportunities to optimize salt usage
- SHA and hired equipment operators might be asked to capture their salt usage, by loader bucket scoop, on paper forms

15

Operator Guidelines
- Sensible Salting Practices -

What's the big deal? Salt is a naturally occurring substance!

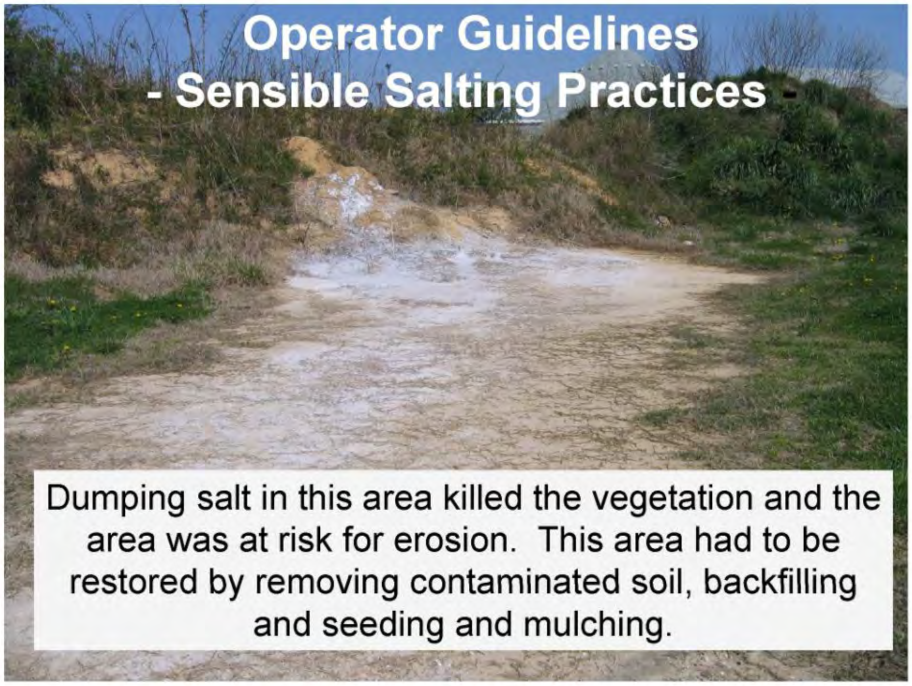
While salt is a naturally occurring substance, high concentrations of salt negatively affect or destroy land based and aquatic habitats and species.

Operator Guidelines - Sensible Salting Practices -

- Once salt goes into solution (melts into the water) it cannot be recovered. It is stored in soil or water and can reach levels that are considered contamination.
- Salt can contaminate drinking water supplies in wells and in reservoirs, inhibit the establishment of vegetation or crops, and eliminate habitat for fish and other aquatic species.

Operator Guidelines - Sensible Salting Practices -

- Excess salt run-off impacts our streams, rivers, lakes, aquatic habitat and our drinking water supplies in wells and reservoirs
- By using *sensible salting practices* you will reduce the amount of materials discharging from the roadway into the environment



Operator Guidelines
- Sensible Salting Practices -

- All unused salt <u>must be</u> returned to the dome or barn that it was loaded from
- <u>Never</u> spread salt just to get rid of it

You play a valuable role in protecting our environment during winter operations by Salting Sensibly.

Operator Guidelines
- Plowing Safety -

Be aware of the weight of heavy snow and the damage it can cause when thrown by a plow

Never plow snow over bridge parapets or Jersey barrier walls - that could endanger traffic and/or pedestrians below

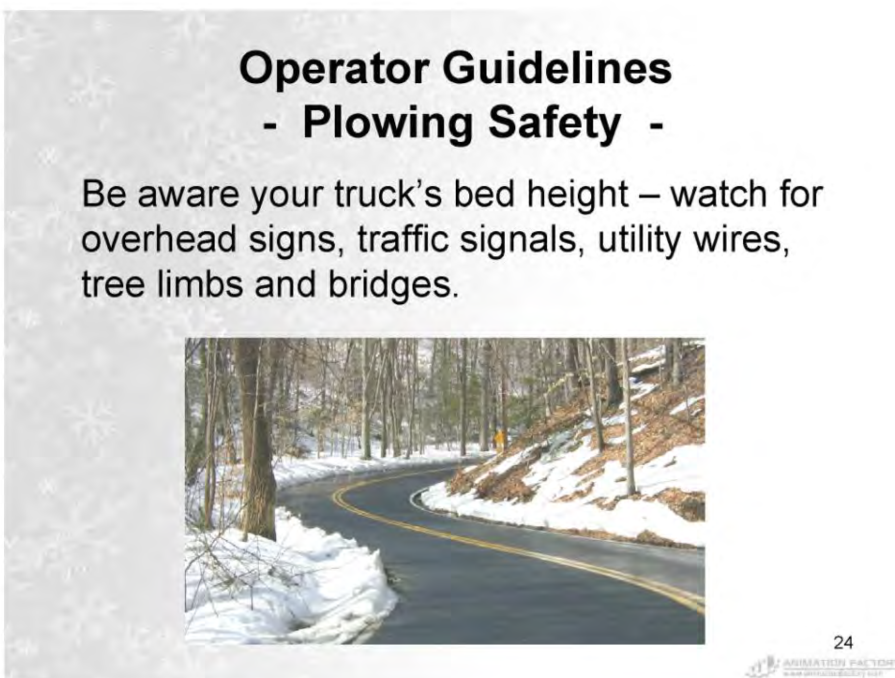
21

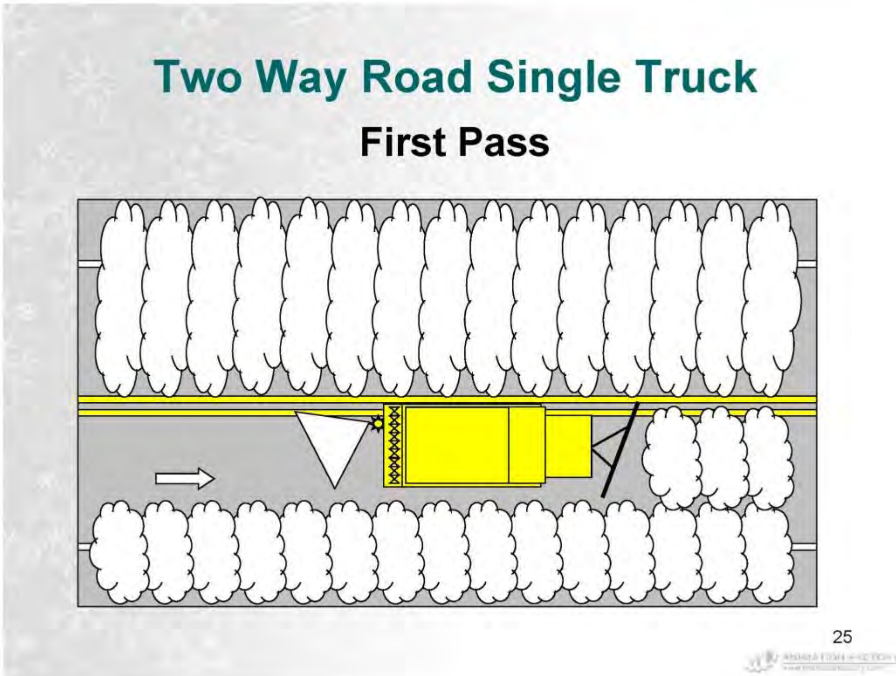
Operator Guidelines
- Plowing Safety -

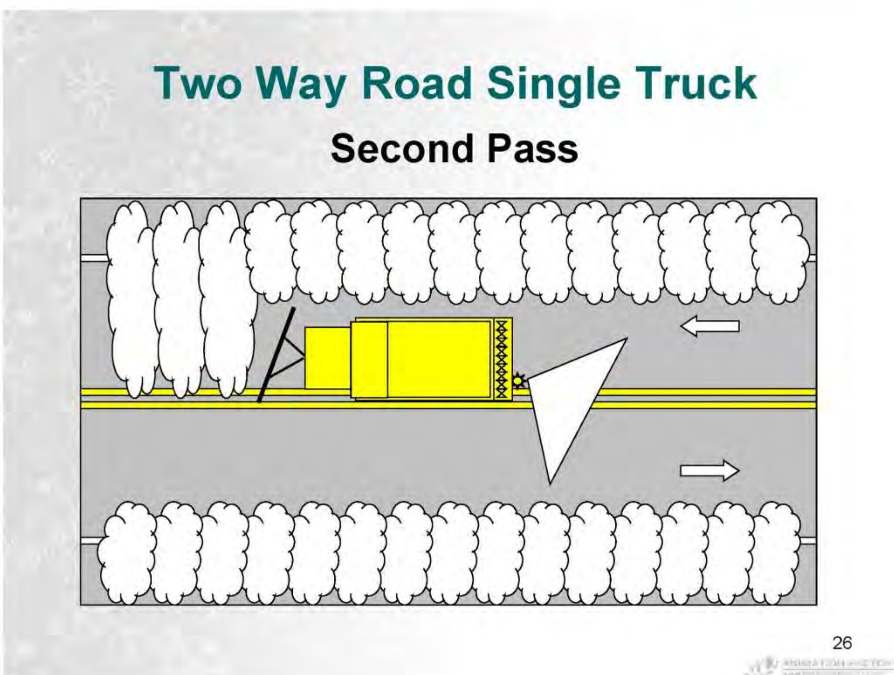
Watch out for manholes, railroad tracks, expansion joints, bridge abutments, utility cuts, mailboxes, etc.

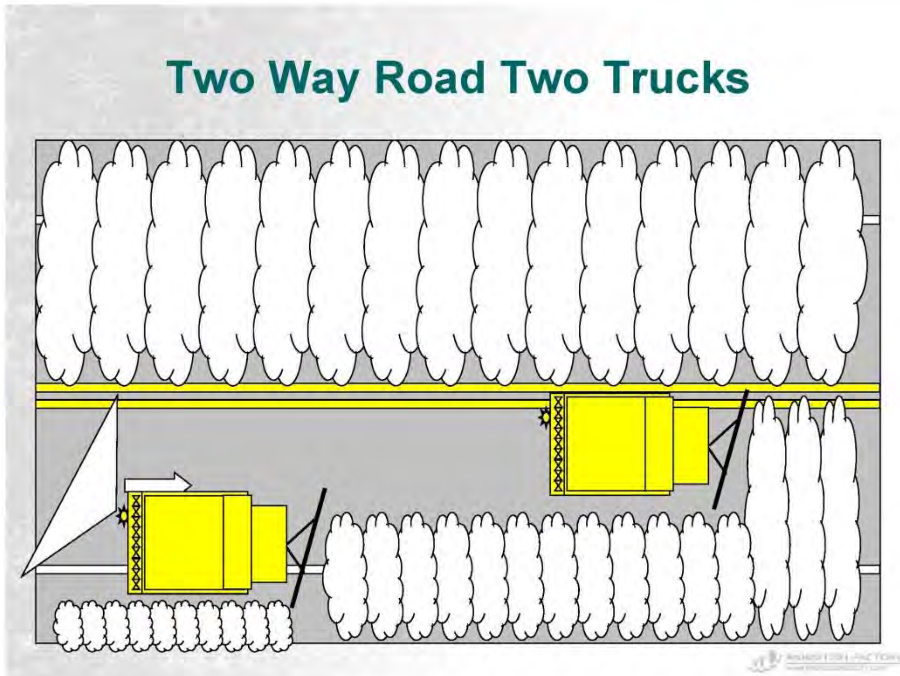
22

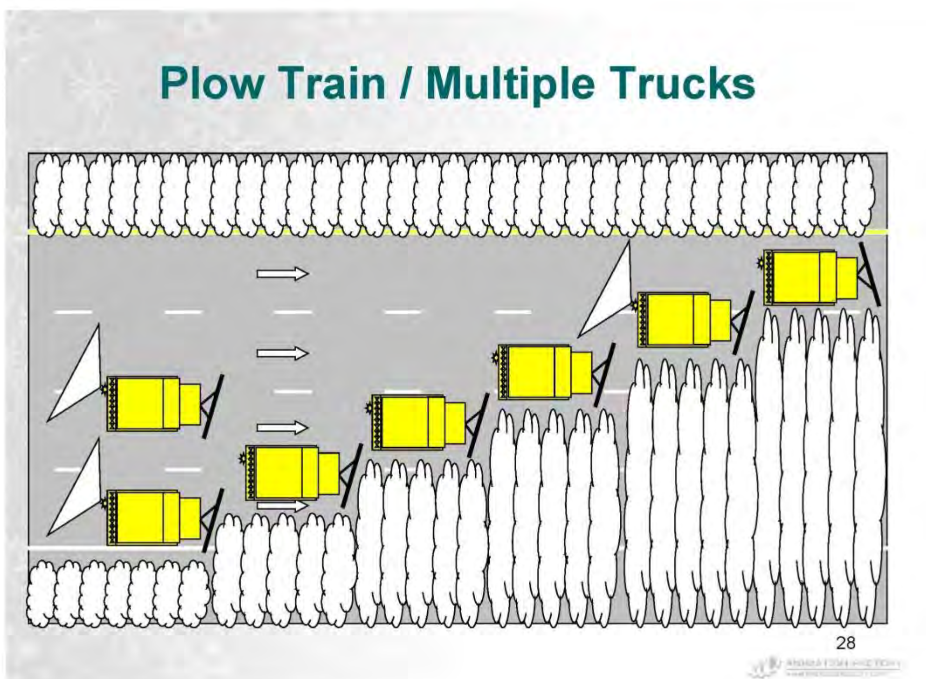

Operator Guidelines
- Plowing Safety -
Watch for Curbs
and Steel Plates ...
23


Operator Guidelines
- Plowing Safety -
Be aware your truck's bed height – watch for
overhead signs, traffic signals, utility wires,
tree limbs and bridges.
24


Two Way Road Single Truck
First Pass
25


Two Way Road Single Truck
Second Pass
26


Two Way Road Two Trucks


Plow Train / Multiple Trucks
28

Operator Guidelines
- Operational Issues -

- Always contact your SHA supervisor prior to leaving your designated snow route or if you get separated from your assigned SHA truck
- Always confirm the need for fuel or meals prior to leaving your assigned route

- All trucks loaded with salt while on standby or just plowing should be covered to avoid freezing

29

Operator Guidelines
- Operational Issues -

- Check the cutting edge of your plow before each event to avoid damage to the plow structure
- When working for SHA, do not plow and salt parking lots, driveways or roads that do not belong to SHA

30

Operator Guidelines
- Accidents and Damage -

- Report all accidents involving SHA equipment or facilities promptly to the snow supervisor and obtain a police report
- SHA will not be held responsible for damage incurred to the Contractor's vehicle while carrying SHA's snow removal equipment
- Upon returning to the shop, the driver will stay with their truck and assist with the repairs of SHA equipment

31

Operator Guidelines
- Accidents and Damage -

- If a repair part is required at the shop, all repair parts must be acquired by a shop mechanic
- All damaged or non-operating equipment must be reported to the snow supervisor, repaired ASAP and/or prior to the next storm

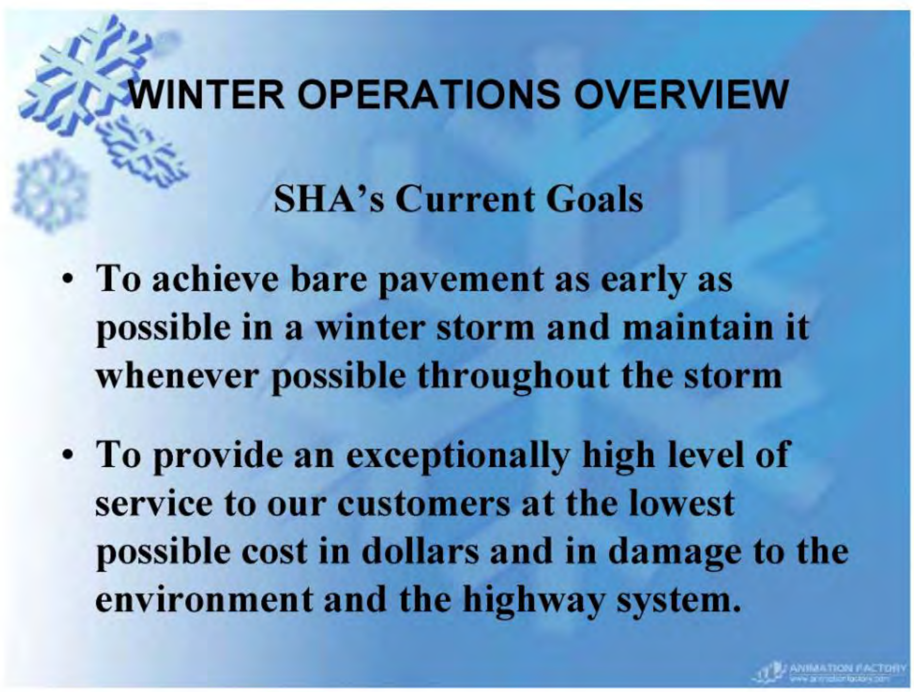
32


Thank You For Your Attendance!
There is no better time than the present to express our appreciation for your support.
The State Highway Administration thanks you for making a difference towards our shop's winter snow removal activities.

Appendix II

Snow College Part I - Roadway Operations


SNOW COLLEGE
ROADWAY WINTER OPERATIONS


WINTER OPERATIONS OVERVIEW
SHA's Current Goals
• To achieve bare pavement as early as possible in a winter storm and maintain it whenever possible throughout the storm
• To provide an exceptionally high level of service to our customers at the lowest possible cost in dollars and in damage to the environment and the highway system.

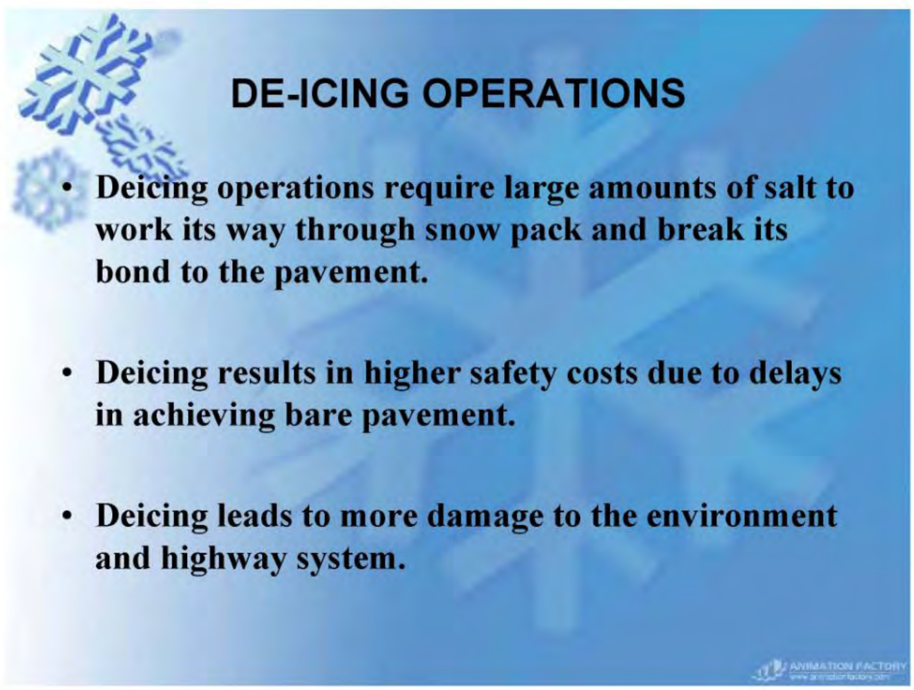
WINTER OPERATIONS STRATEGIES

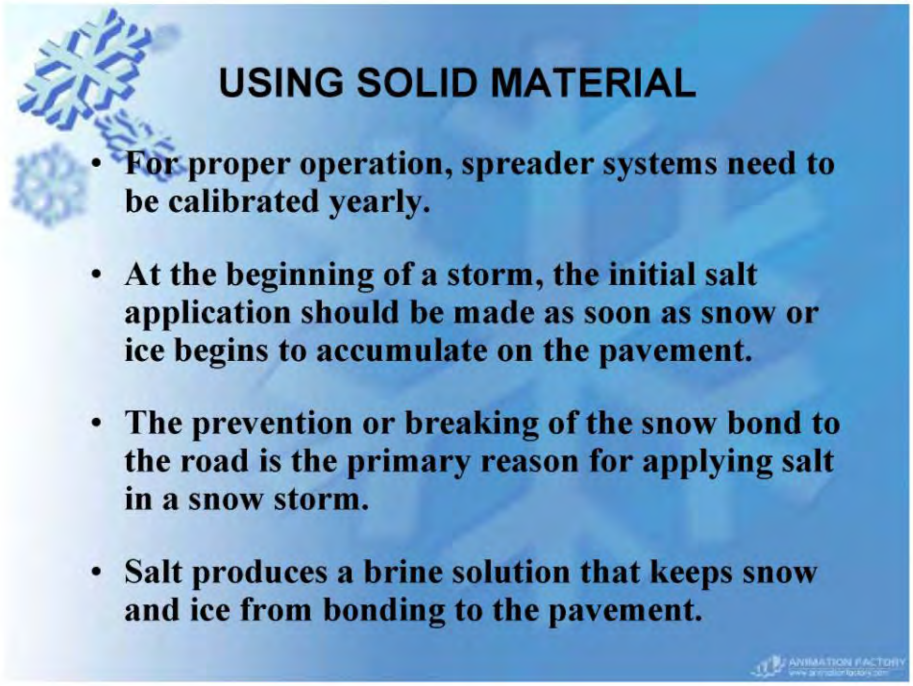
- **<u>Anti-icing</u> is a proactive winter strategy of preventing snow or ice from bonding to the pavement.**
- **<u>Deicing</u> is traditional reactive winter maintenance strategy of breaking the snow/ice and pavement bond once formed.**
- **<u>Both strategies are critical</u> and play roles in SHA's snow and ice control operations.**

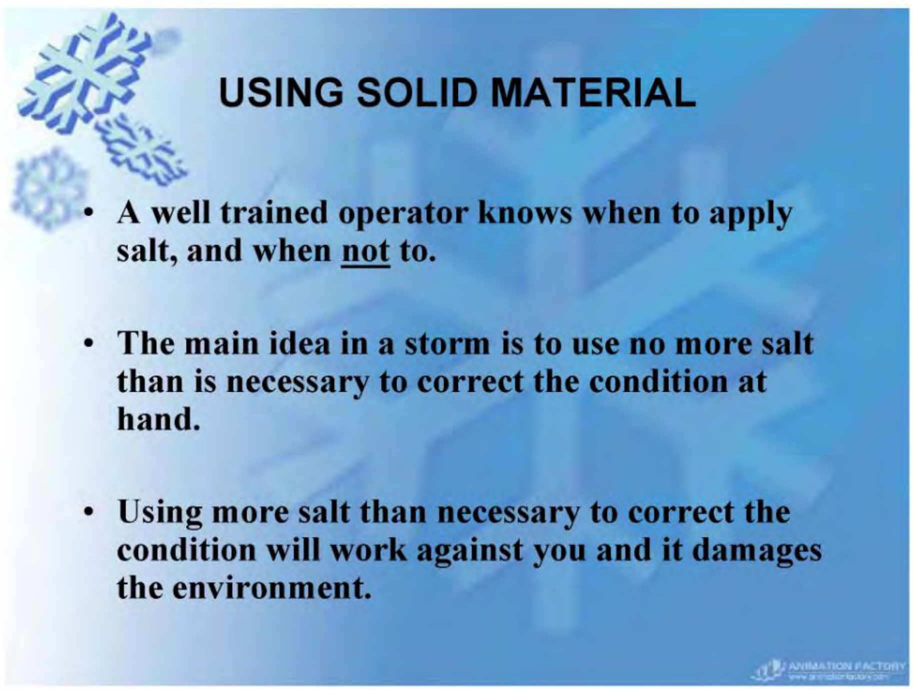
ANTI-ICING OPERATIONS

- **Anti-icing involves a <u>timely</u> application of pre-wetted salt or liquid chemicals on highways usually before start of a storm.**


ANTI-ICING OPERATIONS
• Anti-icing helps SHA maintain highways in the best condition possible throughout a storm.
• Anti-icing lessens the occurrence of snow pack.
• Anti-icing increases traffic safety at a lower cost.
• Anti-icing limits damage to the environment.

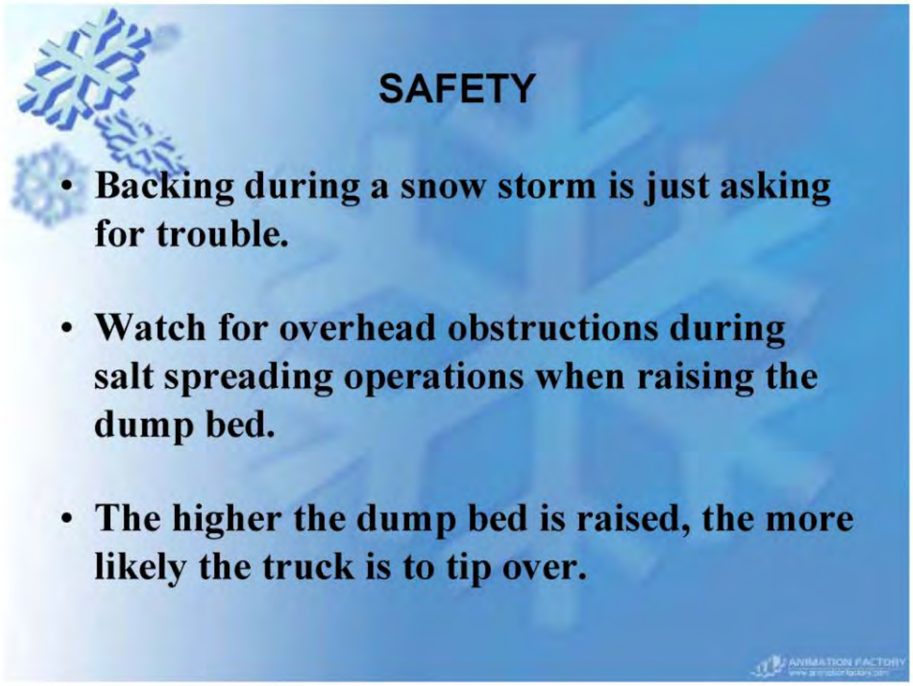

DE-ICING OPERATIONS
• Deicing operations require large amounts of salt to work its way through snow pack and break its bond to the pavement.
• Deicing results in higher safety costs due to delays in achieving bare pavement.
• Deicing leads to more damage to the environment and highway system.


USING SOLID MATERIAL
• For proper operation, spreader systems need to be calibrated yearly.
• At the beginning of a storm, the initial salt application should be made as soon as snow or ice begins to accumulate on the pavement.
• The prevention or breaking of the snow bond to the road is the primary reason for applying salt in a snow storm.
• Salt produces a brine solution that keeps snow and ice from bonding to the pavement.

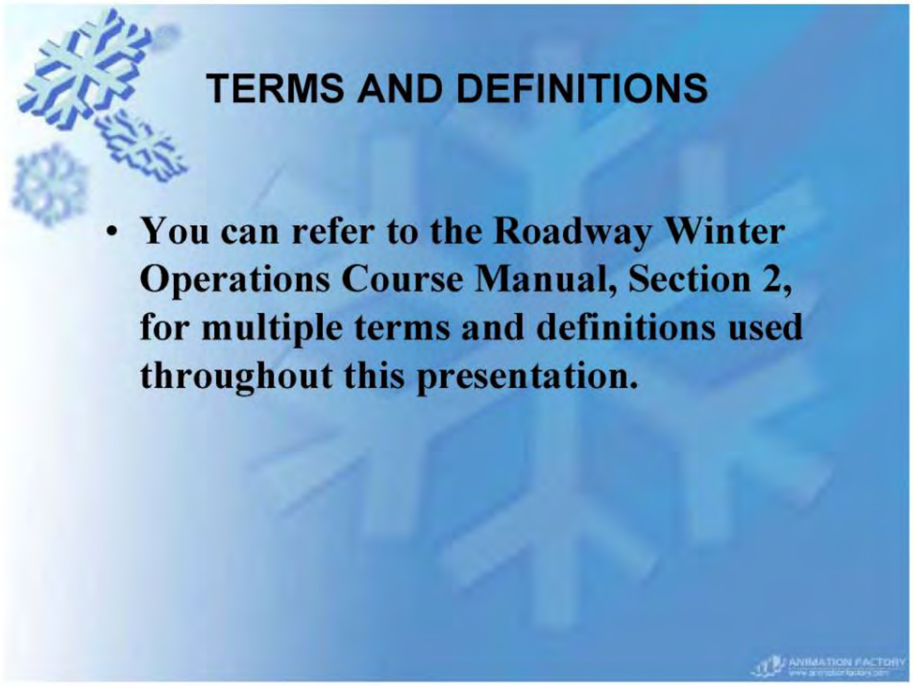

USING SOLID MATERIAL
• A well trained operator knows when to apply salt, and when not to.
• The main idea in a storm is to use no more salt than is necessary to correct the condition at hand.
• Using more salt than necessary to correct the condition will work against you and it damages the environment.

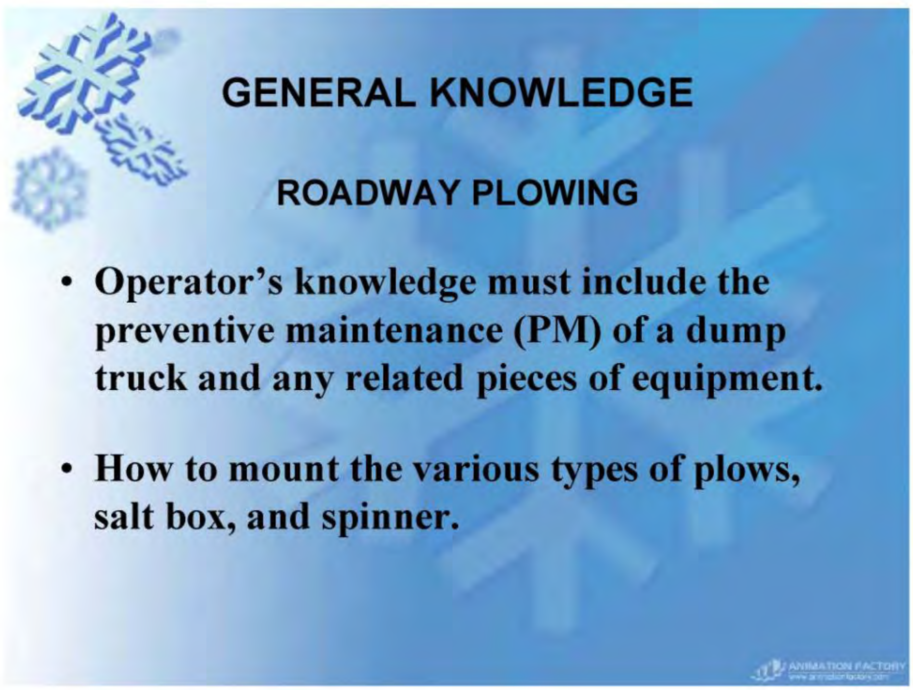

SAFETY
• Snowstorms are the number one hazard to traffic on our roadways.
• Snow removal equipment is the number two hazard to traffic.
• The number two cause of accidents was found to be the snow plow attached to the dump truck.
ANIMATION FACTORY

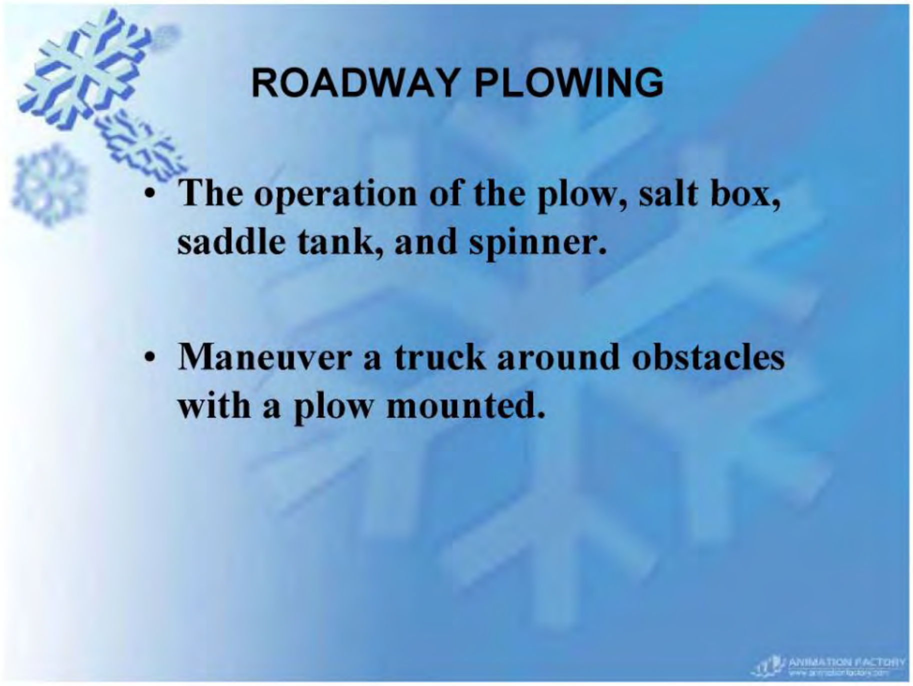

SAFETY
• Remove the plow after completing snow removal operations.
• Remove the plow frame or lower the lift arm to reduce the potential hazard to other vehicles.
• It is never a safe practice to back up a dump truck.
ANIMATION FACTORY


SAFETY
• Backing during a snow storm is just asking for trouble.
• Watch for overhead obstructions during salt spreading operations when raising the dump bed.
• The higher the dump bed is raised, the more likely the truck is to tip over.


SAFETY
• The higher the truck bed, the lower the truck's speed should be.
• Plow trucks are not authorized emergency vehicles.
• Operators must obey the same rules as any other vehicle on the road.


TERMS AND DEFINITIONS
• You can refer to the Roadway Winter Operations Course Manual, Section 2, for multiple terms and definitions used throughout this presentation.


GENERAL KNOWLEDGE
ROADWAY PLOWING
• Operator's knowledge must include the preventive maintenance (PM) of a dump truck and any related pieces of equipment.
• How to mount the various types of plows, salt box, and spinner.


ROADWAY PLOWING
• The operation of the plow, salt box, saddle tank, and spinner.
• Maneuver a truck around obstacles with a plow mounted.


TROUBLE SHOOTING
• Keep an eye on your plow blade for wear and replace when needed.
• Store extra plow pins in truck.
• Keep all truck lights free of snow and ice.
• Keep radiator grill free of obstruction to prevent engine overheating.


TROUBLE SHOOTING
• Carry spare fuses and bulbs.
• Carry windshield cleaner and an ice scraper.
• Be familiar with the type and size of hoses for replacement.

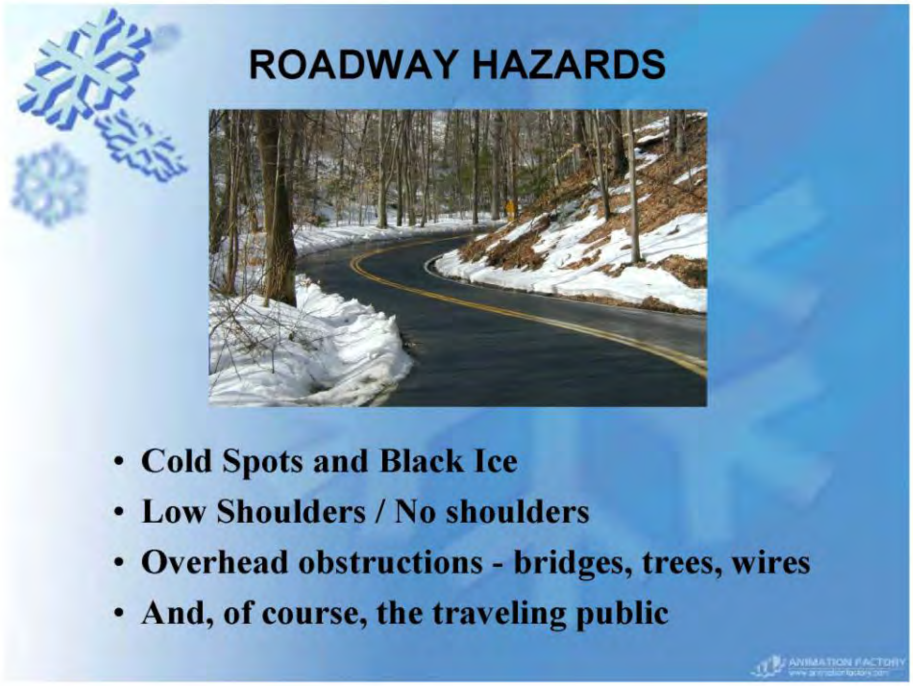

TROUBLE SHOOTING
• Know which hydraulic coupling controls what function.
• Carry a quick link for repairing a broken chain.
• Carry jumper cables.


PRE-SEASON PREPARATION MEETING
• Have a meeting with all personnel involved in snow removal operations before the winter begins.
• Personnel involved are shop personnel, route supervisors, contractors, and EOC representative.

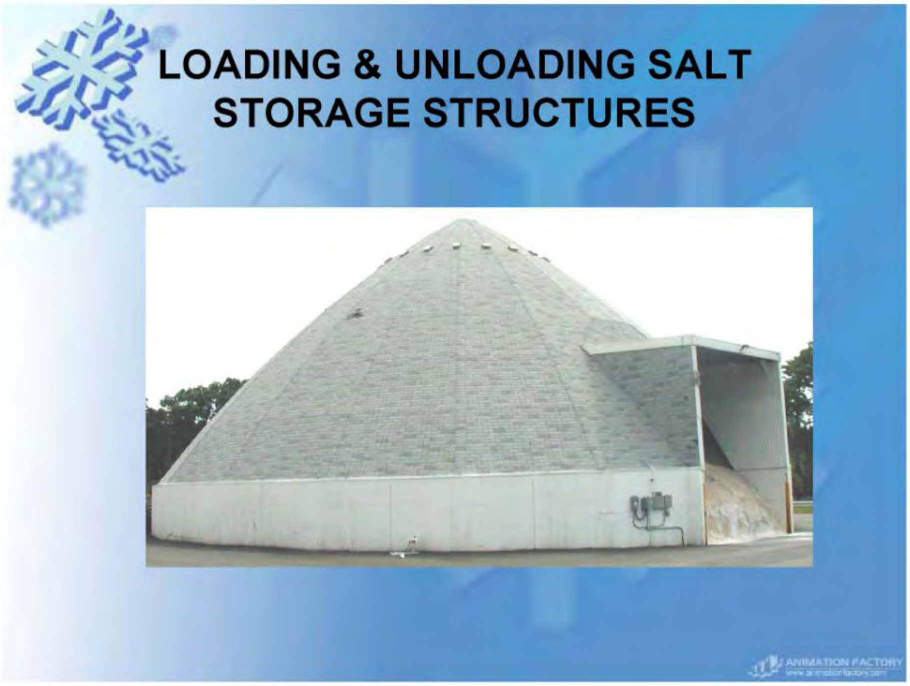

PRE-SEASON PREPARATION MEETING
• Some topics that should be covered:
– Route assignments
– Roadway/Snow hazards
– Turn around points
– Changes in traffic patterns

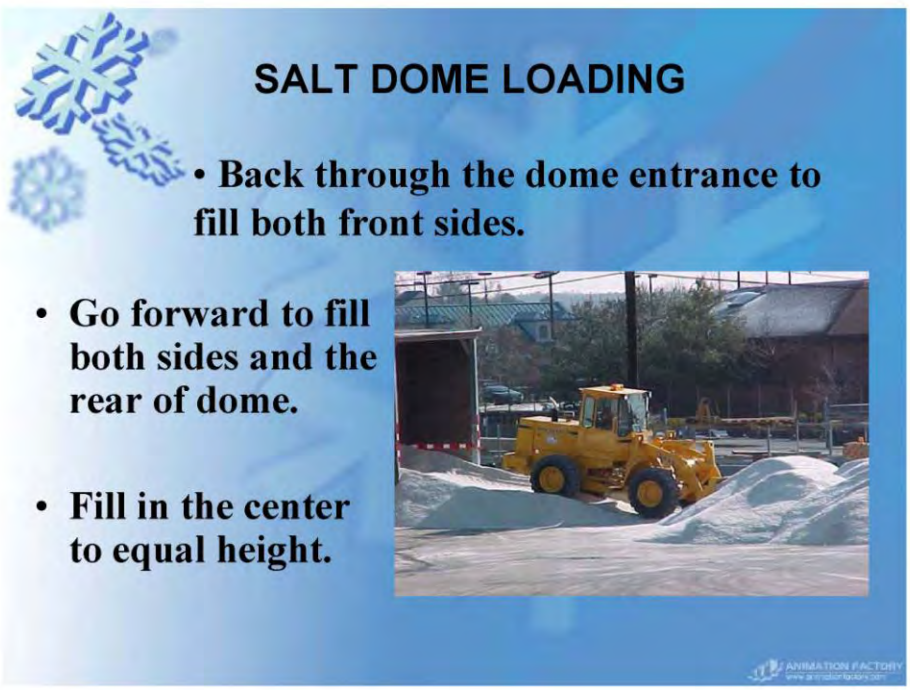

ROADWAY HAZARDS
Always be alert to obstructions to your plowing.
Offset Curbs
Expansion Joints


ROADWAY HAZARDS
Manhole Covers
Steel Plates


ROADWAY HAZARDS
• Cold Spots and Black Ice
• Low Shoulders / No shoulders
• Overhead obstructions - bridges, trees, wires
• And, of course, the traveling public

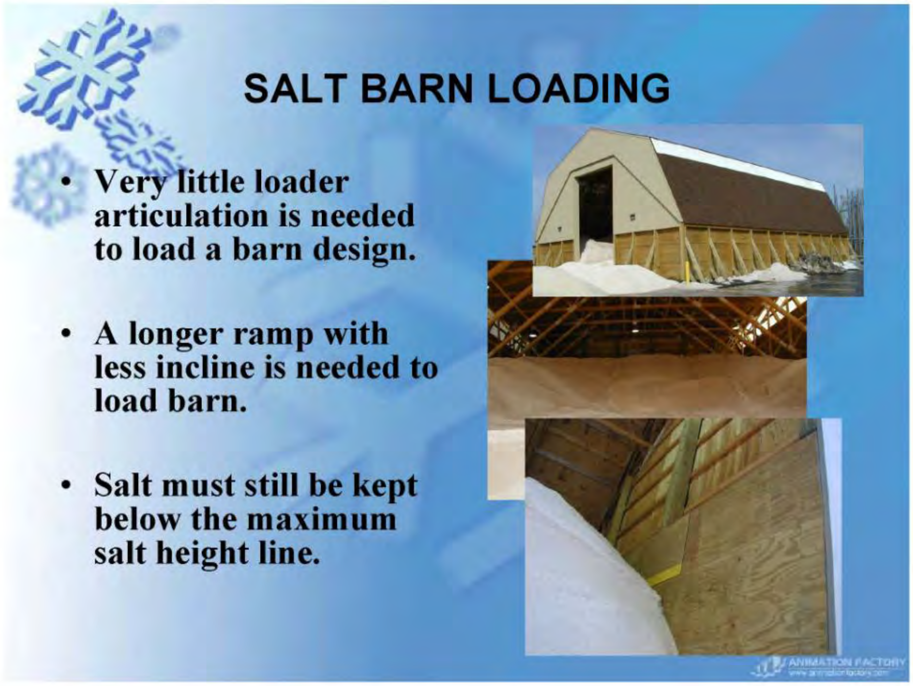

ROADWAY MARKING DEVICES
• Delineating posts
• Stop bars
• Arrows
• Raised pavement markers


LOADING & UNLOADING SALT
STORAGE STRUCTURES
ANIMATION FACTORY


SALT DOME LOADING
• Back through the dome entrance to fill both front sides.
• Go forward to fill both sides and the rear of dome.
• Fill in the center to equal height.
ANIMATION FACTORY

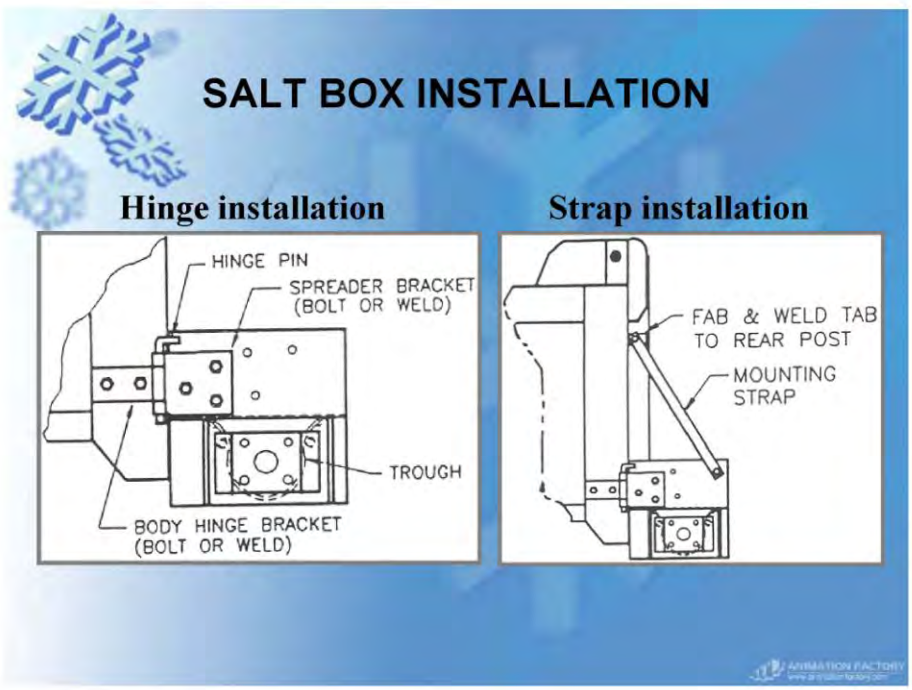

SALT DOME LOADING
• Build a ramp inside of dome.
• Level off top of pile.
• Repeat process over again.
• Fill in the ramp from the back wall to entrance after reaching desired height.


SALT DOME UNLOADING
• Remove salt from the entire face of salt pile.
• Never dig a straight narrow path into a salt pile.


SALT BARN LOADING
• Very little loader articulation is needed to load a barn design.
• A longer ramp with less incline is needed to load barn.
• Salt must still be kept below the maximum salt height line.


PRE-STORM PREPARATION
EQUIPMENT CHECKS
• Match plow number to truck number.
• Mount plow frame and plow to truck.
• Load truck bed with salt, cinders, sand, or mixture.
• Cover the load.


SALT BOX INSTALLATION AND
MAINTENANCE


SALT BOX INSTALLATION
Hinge installation
HINGE PIN
SPREADER BRACKET
(BOLT OR WELD)
TROUGH
BODY HINGE BRACKET
(BOLT OR WELD)
Strap installation
FAB & WELD TAB
TO REAR POST
MOUNTING
STRAP

SALT BOX MAINTENANCE

- Check oil level in Auger motor.
- Lubricate the Auger End Bearing at the beginning of each shift.
- Clean spreader after each storm.

SALT SPREADER SYSTEMS
DICKEY - JOHN
DjGC15


SALT SPREADER SYSTEMS
DICKEY - JOHN ICS2000
SPREAD
RATE SPEED DISTANCE QUANTITY
SALT
SAND
MIX A B
DISPLAY SELECT
CHANGE RATE
DICKEY-john
DJICS2000
SPREAD WIDTH
BLAST
OFF
UNLOAD
AUTOMATIC
SPREADER CONTROL

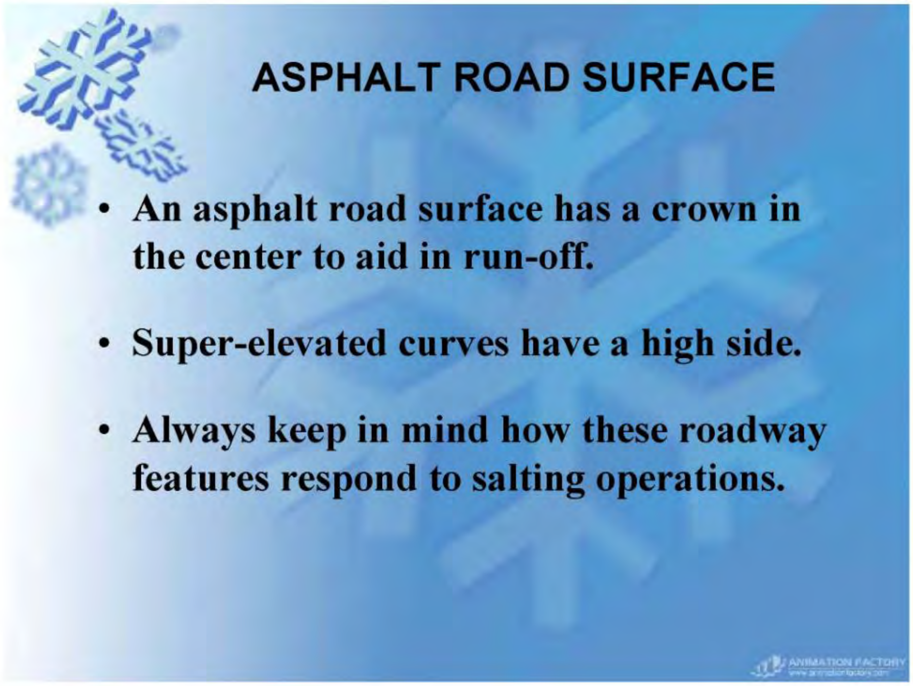

SALT SPREADER SYSTEMS
DICKEY - JOHN CONTROL POINT


ROADWAYS AND SURFACES
TWO-LANE ROADWAYS
• One 12 foot wide lane traveling in each direction.
• The standard plow angled correctly will clear 8 to 9 feet per pass.


ROADWAYS AND SURFACES
TWO-LANE ROADWAYS
• Four passes needed to clear the entire road.
• Clear road shoulders.

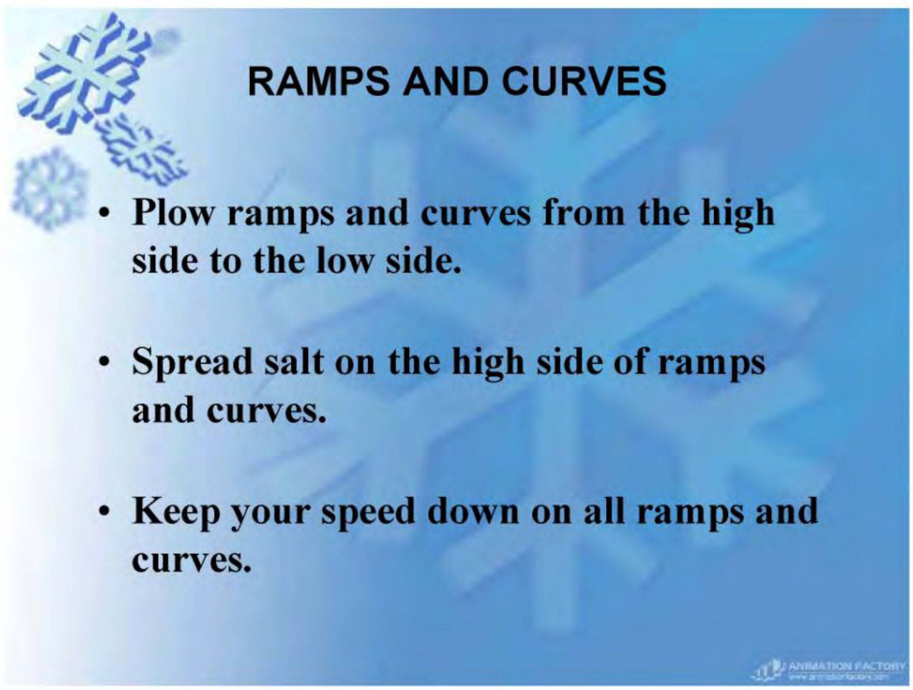

MULTI-LANE HIGHWAYS
• Multiple lanes traveling in both directions.
• Road width determines the number of plow trucks needed.
ANIMATION FACTORY


MULTI-LANE HIGHWAYS
• Factors considered are the median width, shoulders, and Jersey barriers.
• When possible, begin plowing before rush hour traffic.
ANIMATION FACTORY


ASPHALT ROAD SURFACE
• An asphalt road surface has a crown in the center to aid in run-off.
• Super-elevated curves have a high side.
• Always keep in mind how these roadway features respond to salting operations.


CONCRETE ROAD SURFACE
• Reinforced concrete has a contraction joint every 40 feet.
• Reinforced concrete has an expansion joint every 600 feet.
• Bridges have expansion joints at both ends and may have an expansion dam near the middle of the bridge.


ROADWAY CONFIGURATIONS
INTERSECTIONS
• Empty your plow before crossing intersections.
• Reduce the size of the windrow.
• Avoid building snow banks that interfere with sight distance.
• Keep traffic signs unobstructed from view.


RAMPS AND CURVES
• Plow ramps and curves from the high side to the low side.
• Spread salt on the high side of ramps and curves.
• Keep your speed down on all ramps and curves.

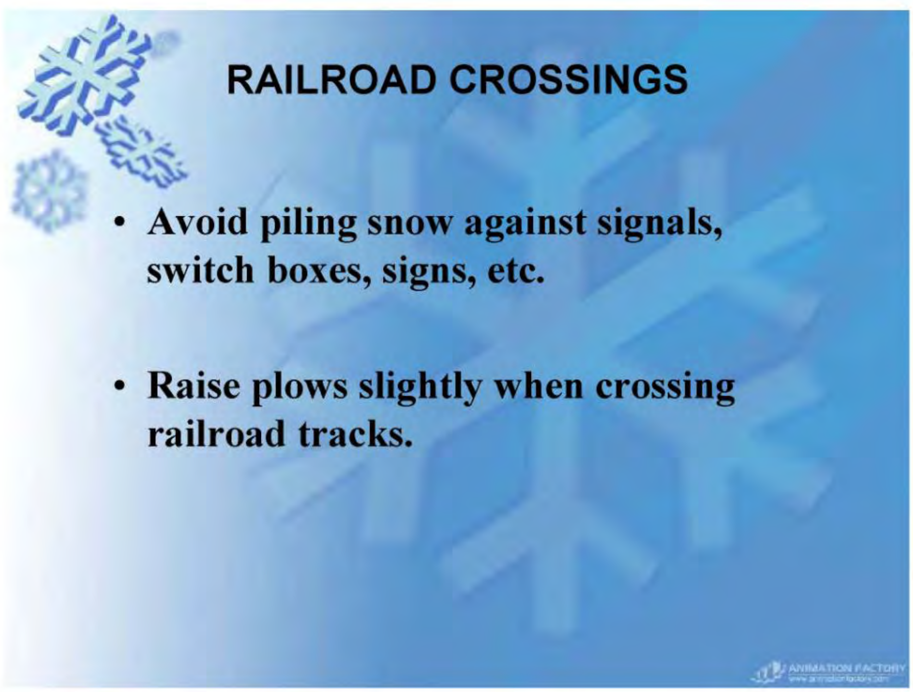
BRIDGES AND OVERPASSES

- Bridge surface may be higher than the road surface due to the bridge freezing and expanding.
- Care must be taken not to throw snow over the bridge to the road below.
- Keep the sidewalks on bridges open for pedestrians.

SHOULDERS, MEDIANS & JERSEY BARRIERS

- Plow away from medians with minimum width shoulder and barrier wall.
- Avoid plowing snow against a Jersey barrier.
- This creates a ramp for vehicles to launch to the other side.


MOUNTAINS AND HILLS
• Traction is limited on hills.
• Stopping can be difficult on hills.
• Watch for melted snow refreezing in the road valley.


RAILROAD CROSSINGS
• Avoid piling snow against signals, switch boxes, signs, etc.
• Raise plows slightly when crossing railroad tracks.

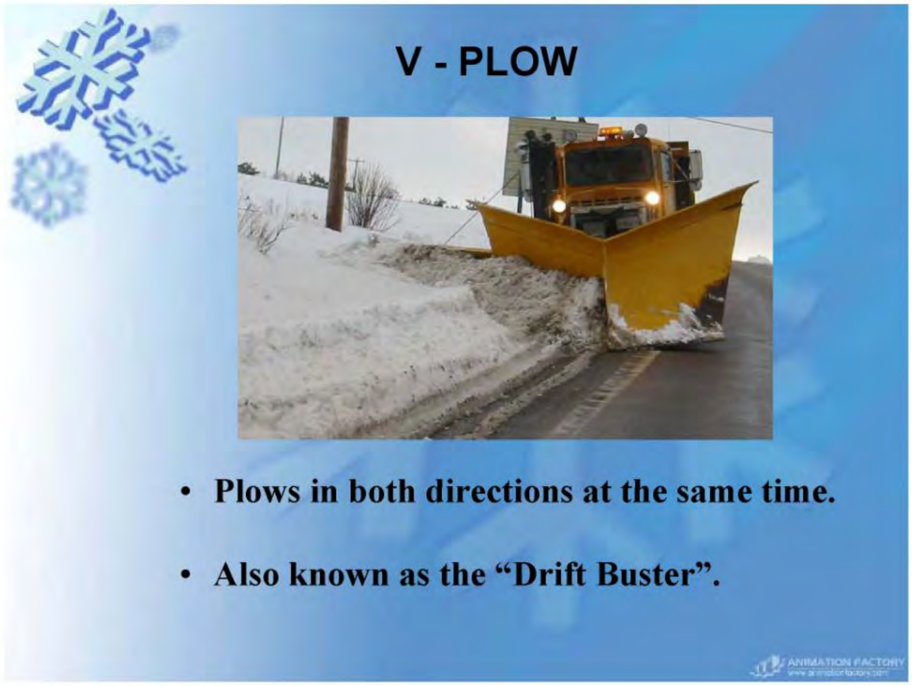
TYPES OF PLOWS

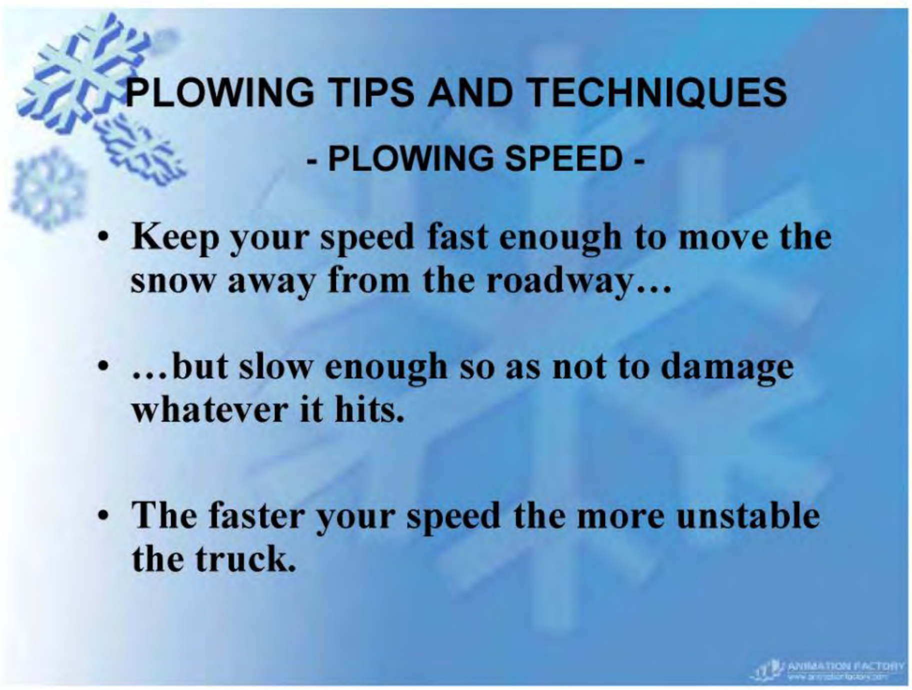
- THE ONE WAY PLOW -

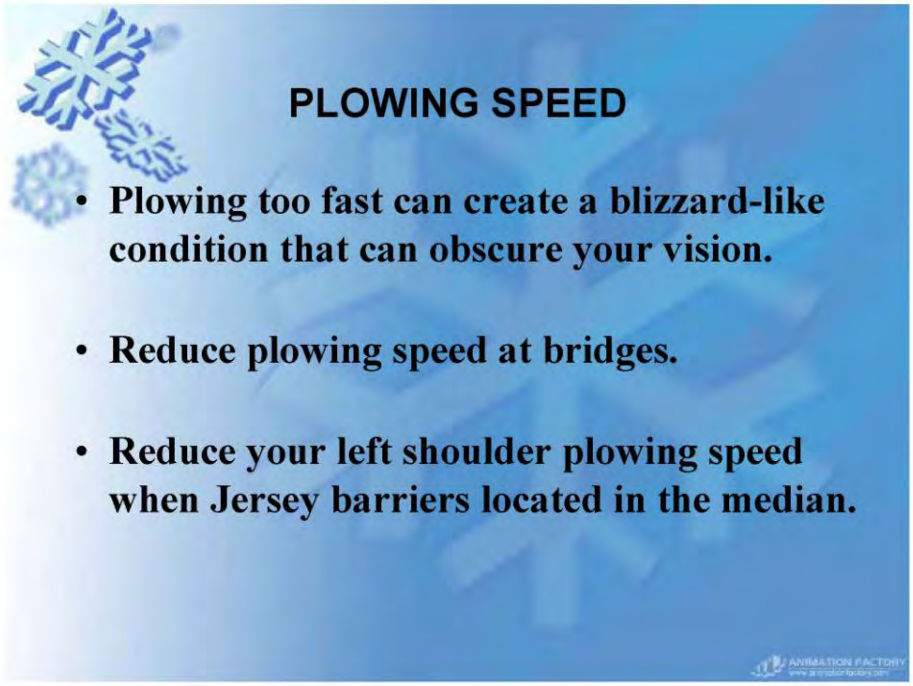
- One way reversible plow (manual adjust).
- One way reversible plow (hydraulic adjust).
- One way non-reversible plow.
- Wing plow.

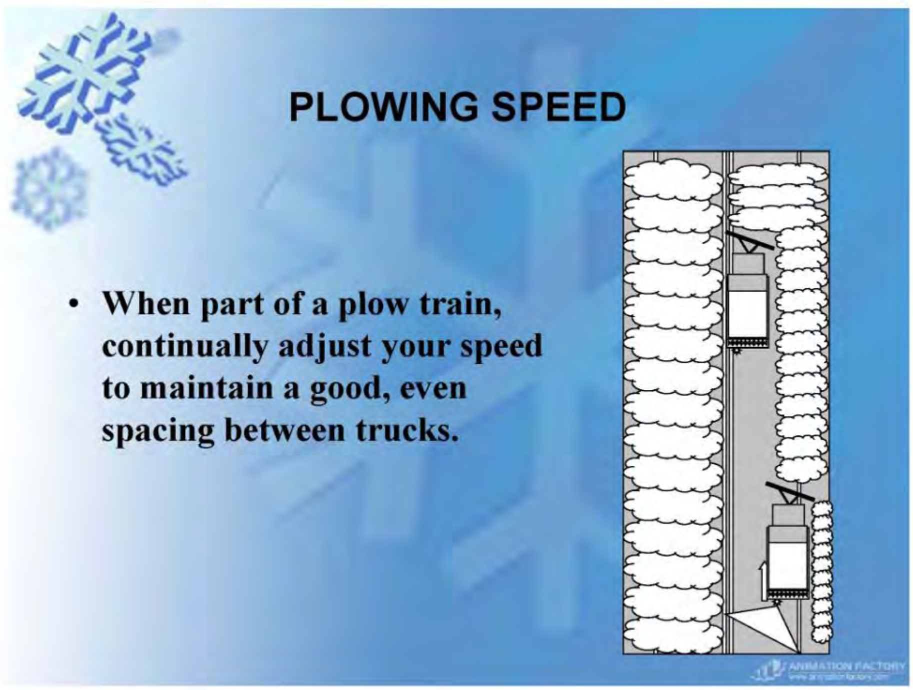
V - PLOW

V-Plows are mounted to a Grader or Oshkosh.


V - PLOW
• Plows in both directions at the same time.
• Also known as the "Drift Buster".

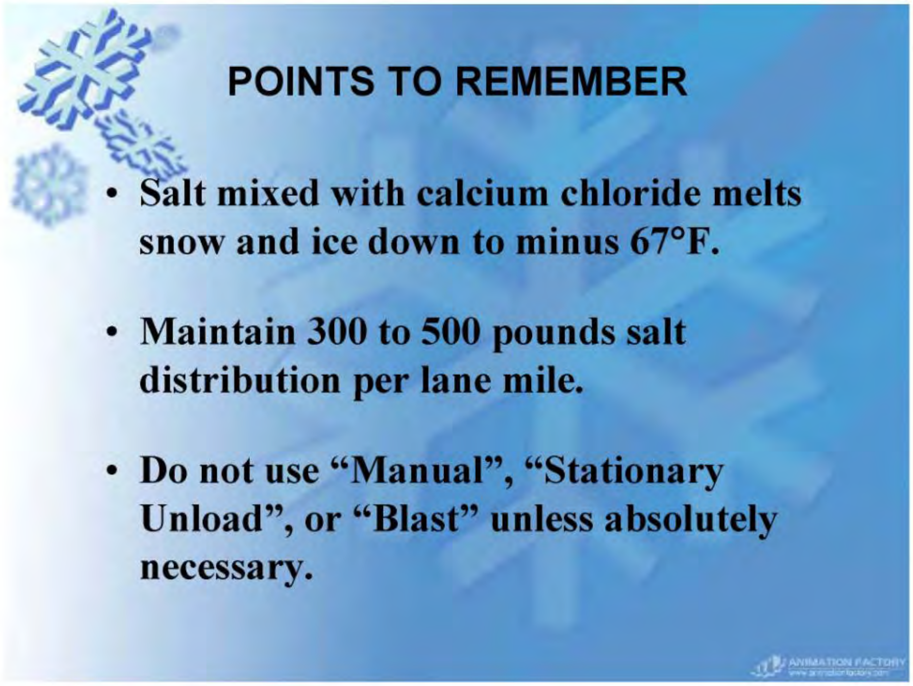

PLOWING TIPS AND TECHNIQUES
- PLOWING SPEED -
• Keep your speed fast enough to move the snow away from the roadway…
• …but slow enough so as not to damage whatever it hits.
• The faster your speed the more unstable the truck.

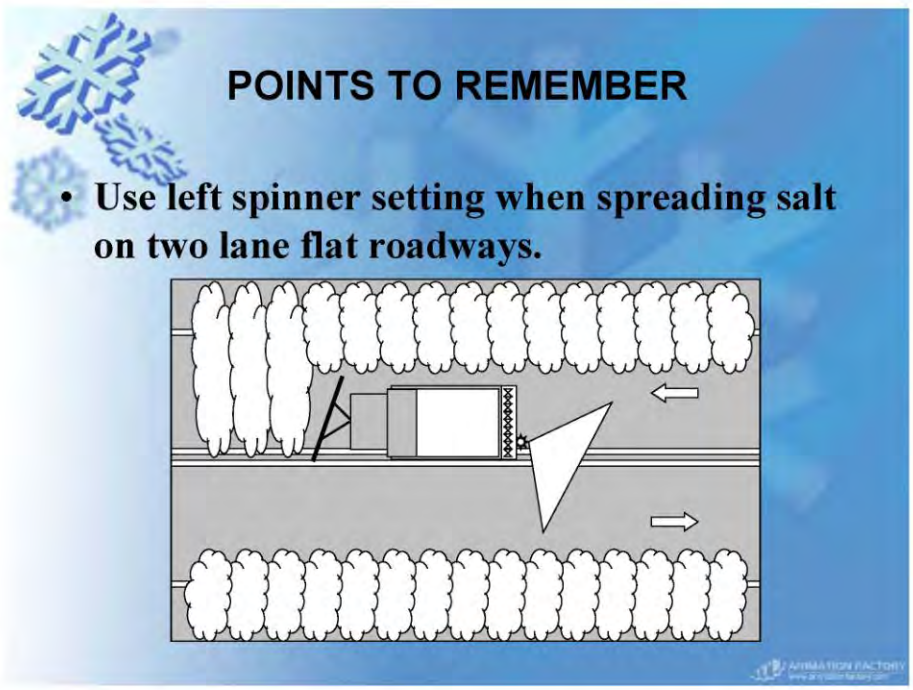

PLOWING SPEED
• Plowing too fast can create a blizzard-like condition that can obscure your vision.
• Reduce plowing speed at bridges.
• Reduce your left shoulder plowing speed when Jersey barriers located in the median.

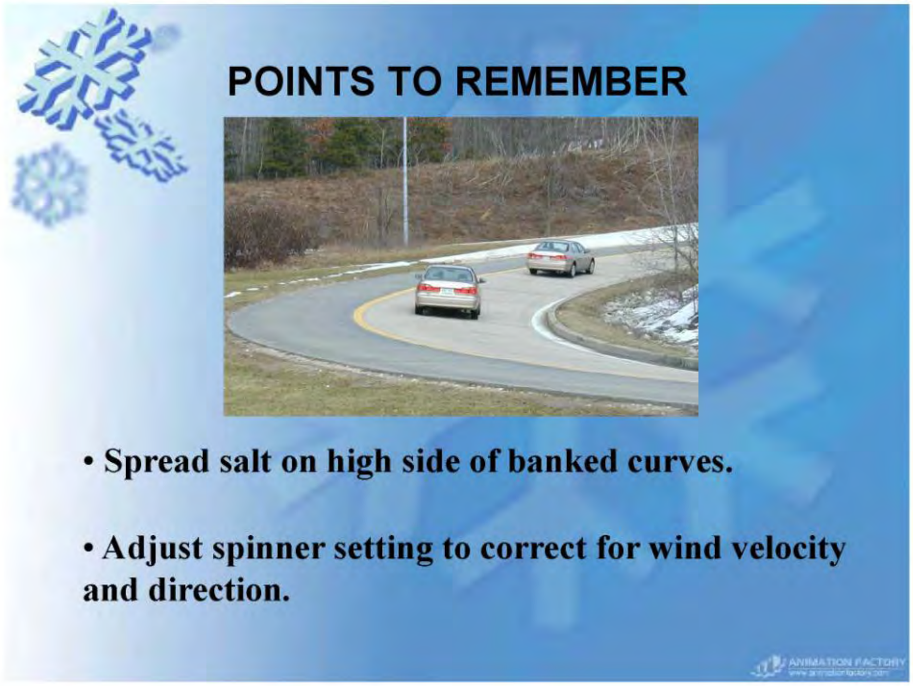

PLOWING SPEED
• When part of a plow train, continually adjust your speed to maintain a good, even spacing between trucks.


POINTS TO REMEMBER
• Always give bridges and ramps special attention.
• Salt the high sides of curves.
• Do not over-use salt.
• Use just enough to get the job done.

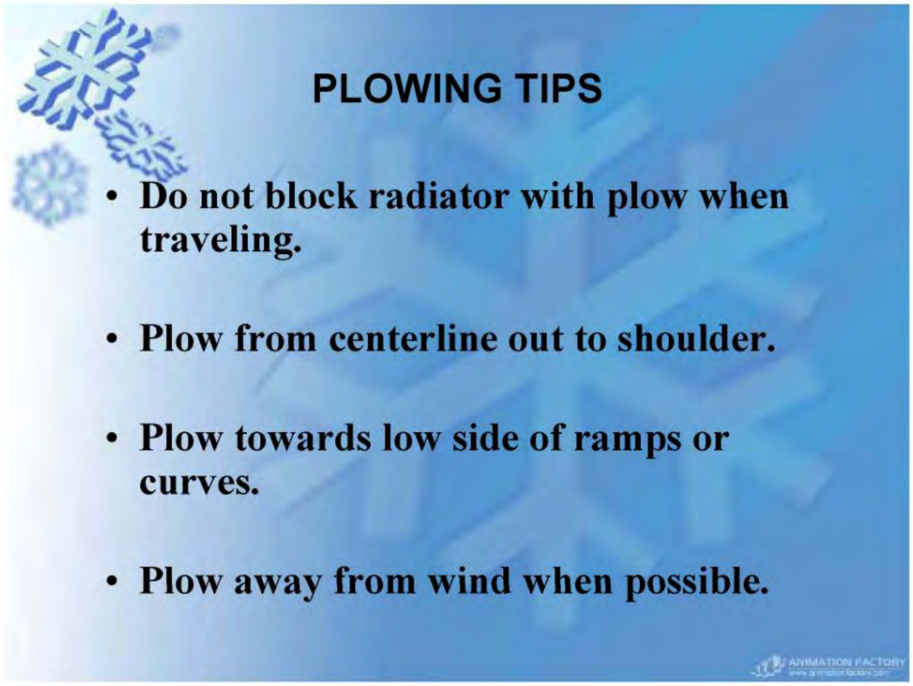

POINTS TO REMEMBER
• Salt loses most of its effectiveness at temperatures below 20°F.
• Salt stops working altogether at - 6°F.
• Adding more salt to an already salted roadway can actually cause the brine solution to freeze.


POINTS TO REMEMBER
• Salt mixed with calcium chloride melts snow and ice down to minus 67°F.
• Maintain 300 to 500 pounds salt distribution per lane mile.
• Do not use "Manual", "Stationary Unload", or "Blast" unless absolutely necessary.

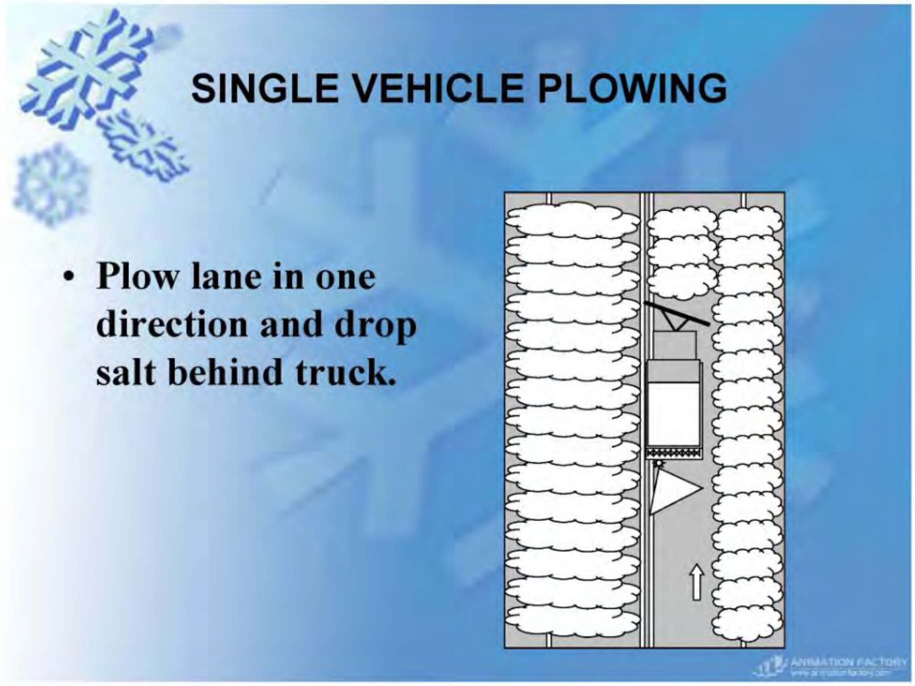

POINTS TO REMEMBER
• Use left spinner setting when spreading salt on two lane flat roadways.

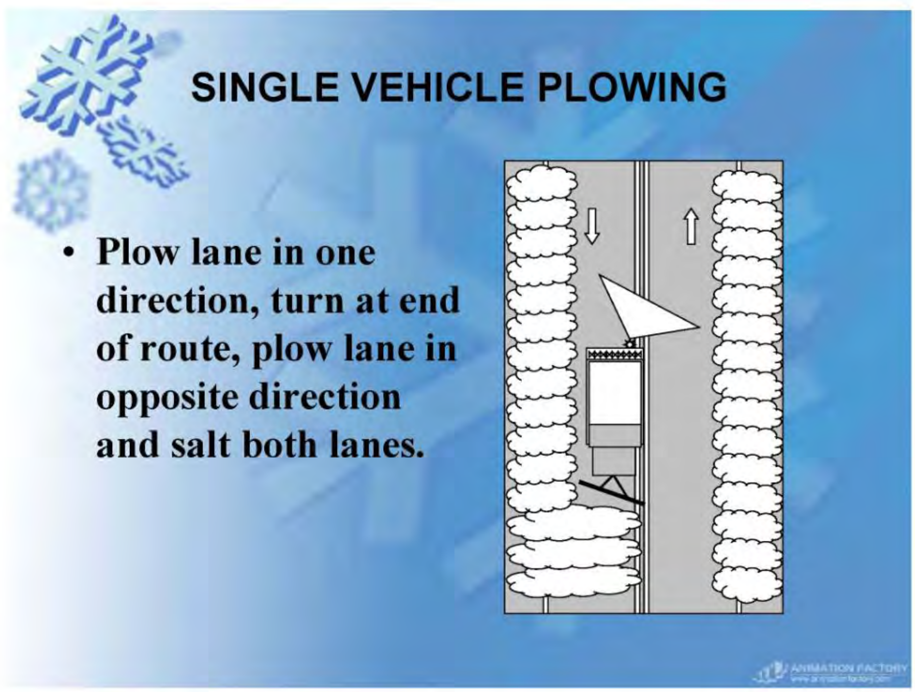

POINTS TO REMEMBER
• Spread salt on high side of banked curves.
• Adjust spinner setting to correct for wind velocity and direction.


PLOWING TIPS
• Never drive faster than speed limit.
• Use a lower gear than normal driving.
• Use extra care plowing curves.
• Plow with direction of traffic.


PLOWING TIPS
• Do not block radiator with plow when traveling.
• Plow from centerline out to shoulder.
• Plow towards low side of ramps or curves.
• Plow away from wind when possible.


PLOWING TIPS
• Raise blade before making sharp turns.
• Don't leave windrow across an intersection.
• Know your turn around points.
• Refuel with meal breaks or reloading.


SINGLE VEHICLE PLOWING
• Plow lane in one direction and drop salt behind truck.

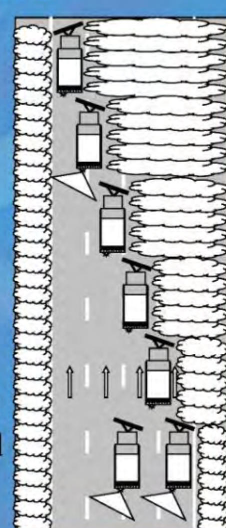

SINGLE VEHICLE PLOWING
• Plow lane in one direction, turn at end of route, plow lane in opposite direction and salt both lanes.

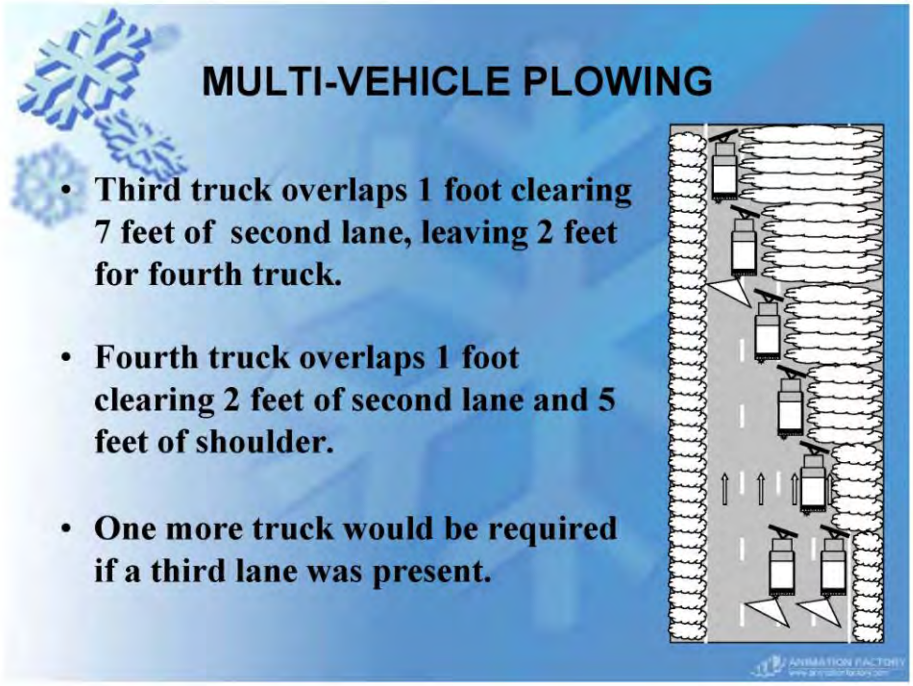
MULTI-VEHICLE PLOWING

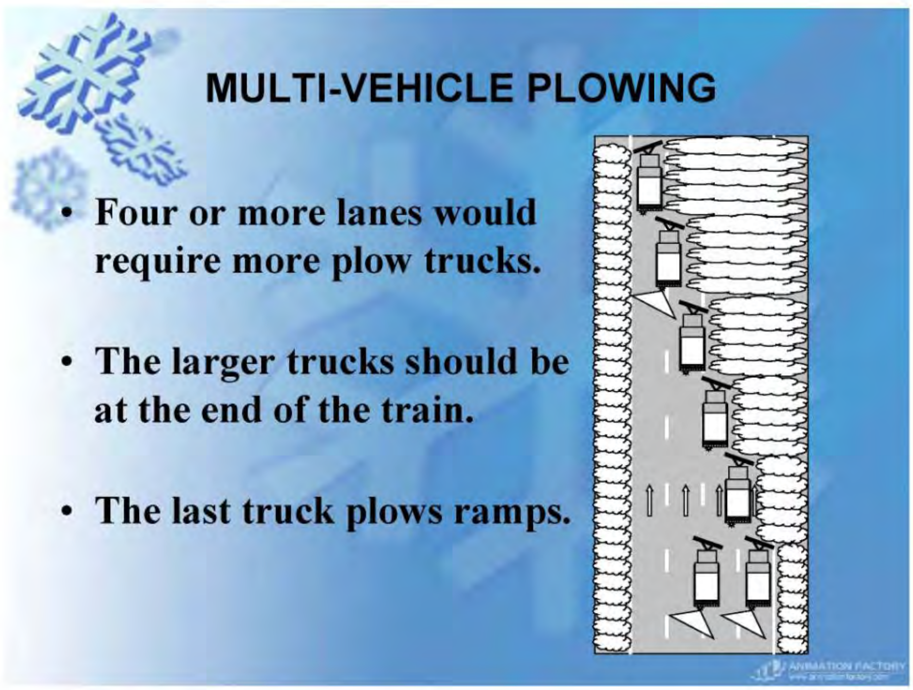
- **The width of the road determines how many plows are needed to clear the snow.**
- **Minimum overlap of any "plow train" should be about 1 foot.**
- **Distance between plow trucks should be around 150 feet.**

MULTI-VEHICLE PLOWING

- **The deeper the snow, the more overlap needed to avoid leaving a windrow.**
- **First truck clears 8 feet of the left traffic lane, leaving 4 feet for second truck.**
- **Second truck overlaps 1 foot clearing 4 feet of first lane and 3 feet of second lane, leaving 9 feet for third truck.**




MULTI-VEHICLE PLOWING
• Third truck overlaps 1 foot clearing 7 feet of second lane, leaving 2 feet for fourth truck.
• Fourth truck overlaps 1 foot clearing 2 feet of second lane and 5 feet of shoulder.
• One more truck would be required if a third lane was present.


MULTI-VEHICLE PLOWING
• Four or more lanes would require more plow trucks.
• The larger trucks should be at the end of the train.
• The last truck plows ramps.

TYPES OF SNOW AND PLOW ANGLE

- **Wet snow requires more plow angle to discharge snow from plow moldboard.**
- **Plow must still clear a path for the truck tires.**

SADDLE TANK OPERATIONS

- **Keep saddle tank filled with salt brine or during winter months.**
- **Spray Mag or salt brine on your salt load at the rate of 10 gallons per ton of salt.**
- **Use saddle tank when applying salt to dry snow.**

SADDLE TANK OPERATIONS

- Use saddle tank when pavement temperatures are 25°F or below.
- Use saddle tank to combat freezing rain, sleet, or black ice.
- Do not use saddle tank on slush or wet snow unless pavement temperatures are below 25°F.

LIQUID APPLICATOR TANK GUIDELINES

- Apply salt brine 2 to 10 hours before storm.
- Spray bridges and cold spots prior to cold weekends to prevent emergencies.


LIQUID APPLICATOR TANK GUIDELINES
CAUTION
• Standard application rate of salt brine is 45 to 80 gallons per lane mile.
• See section 15 charts for correct application.

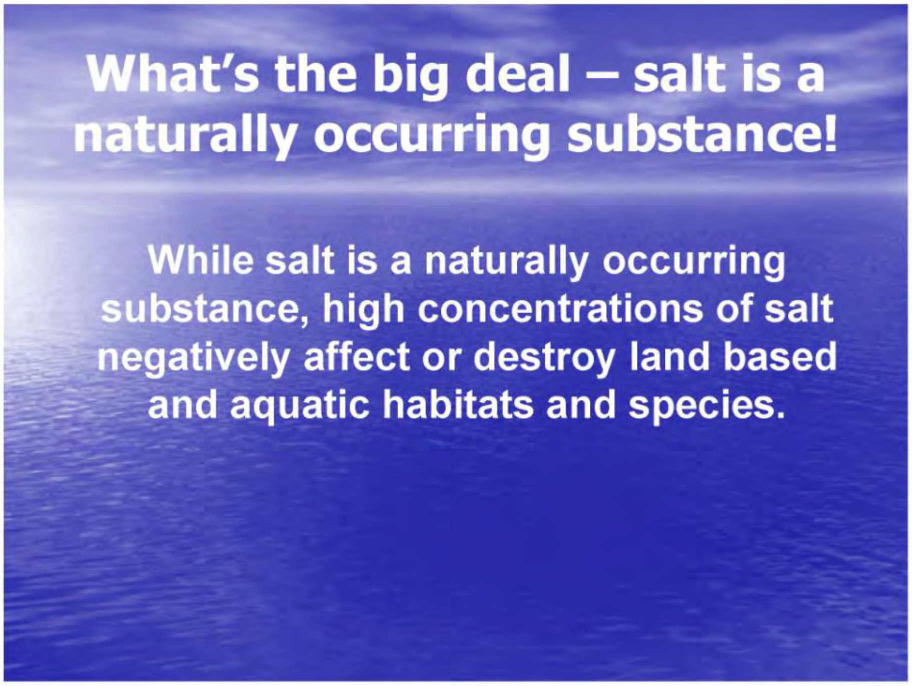

Now let's move on to
Part II of the presentation.
Winter Operations
Environmental
Considerations

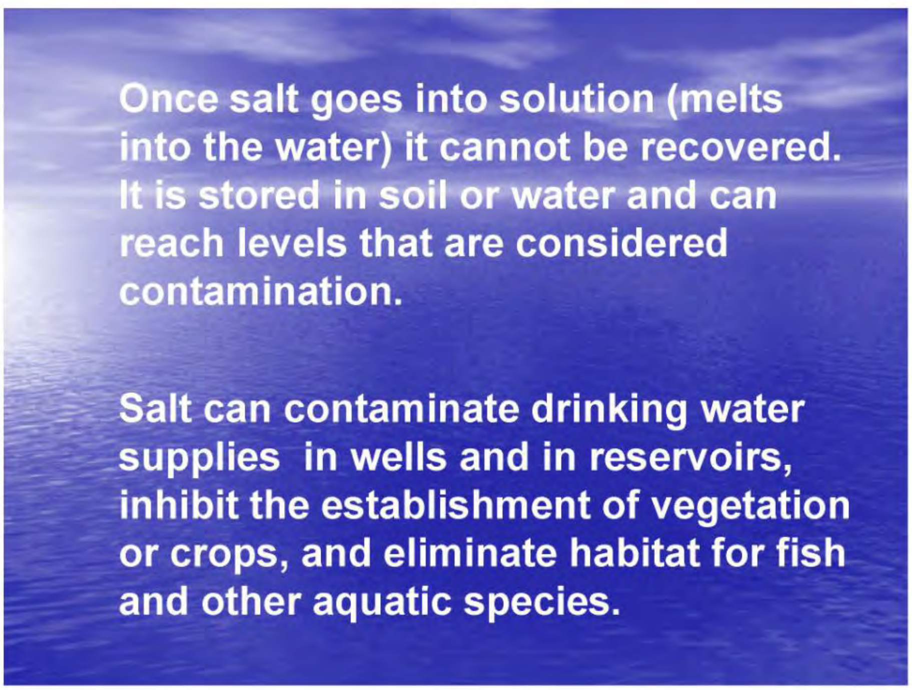
Appendix III

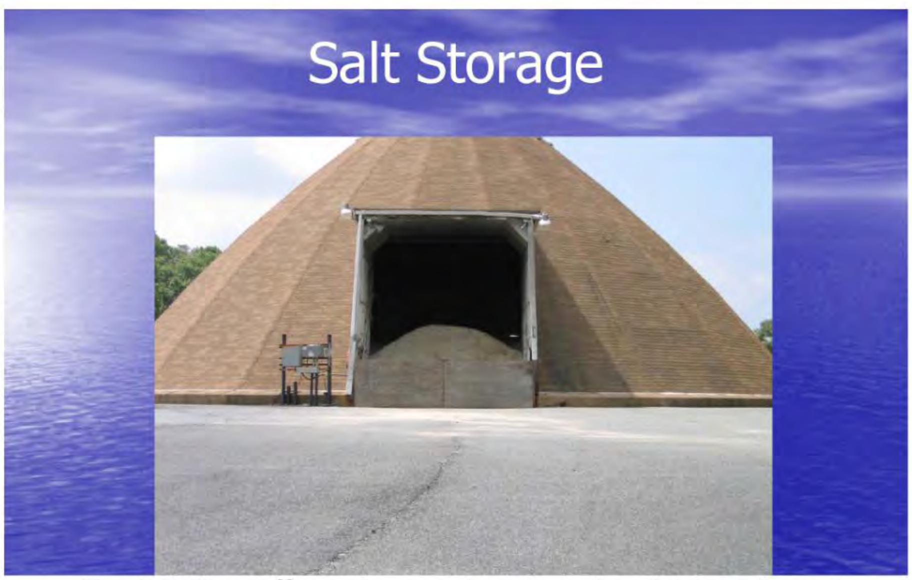
Snow College Part II - Env Considerations


SHA Snow College
Winter Operations
Environmental
Considerations
Winter Materials Storage,
Handling and Spreading

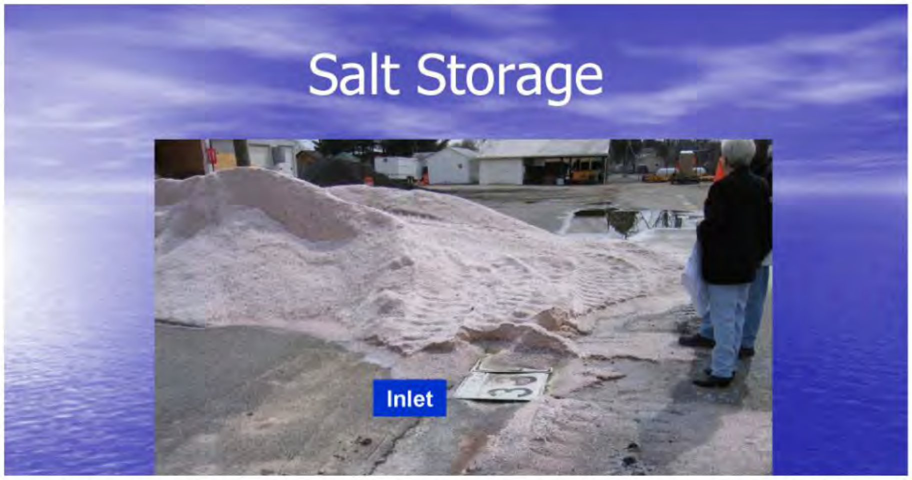

As SHA Employees
you have an important role in
protecting our environment
during winter operations by
Salting Sensibly.


What's the big deal – salt is a naturally occurring substance!
While salt is a naturally occurring substance, high concentrations of salt negatively affect or destroy land based and aquatic habitats and species.


Once salt goes into solution (melts into the water) it cannot be recovered. It is stored in soil or water and can reach levels that are considered contamination.
Salt can contaminate drinking water supplies in wells and in reservoirs, inhibit the establishment of vegetation or crops, and eliminate habitat for fish and other aquatic species.



During the off-season, a barrier should be placed across the structure's opening to prevent salt from contaminating the environment.



Make sure when salt is delivered, that all inlets and drainage structures are protected and all the salt is under covered storage by day's end. Here, an inlet was protected by covering it with sheet signing, but overnight rain washed dissolved salt into the drainage system discharging it off site.

Abrasives stored under cover. Here the material is far enough away from opening that it does not need a barrier across the opening.

Brine and/or MgCl Storage

Inspect tanks monthly paying particular attention to valves and fittings. Place drip pan under leaks and repair immediately.

Salt Handling

- During winter storm events, mixing salt and abrasives on impervious surfaces is allowable.
- Uncovered salt/abrasive stockpiles are allowed during a storm event; however, they must be placed under cover immediately after plowing operations have stopped and the mixing area must then be free of any residual salt and/or abrasives.

Impact of a salt/abrasive mix not being placed under cover. Non-compliant with NPDES permit conditions.

Mixing salt/abrasives on unpaved areas can result in destroying vegetation and causing an erosion problem.

To minimize spillage do not overfill trucks with salt or salt/abrasive mix. After a plowing event, all material on the lot must be swept and returned to covered storage.

All unused salt must be returned to covered salt storage area. Dumping salt in this area killed the vegetation and the area was at risk for erosion. This area had to be restored by removing contaminated soil, backfilling and seeding and mulching.


Materials Spreading
To provide bare pavement in a cost-effective and environmentally responsible manner:
• Use appropriate shop application rates to match specific storm conditions
• Unless otherwise directed, only apply salt to your designated route
• Return unused salt to designated dome or barn. Never spread salt just to get rid of it.


Materials Spreading
By following appropriate Salt Spreading Guidelines you will be performing your job duties in an environmentally sensitive manner, reducing the amount of materials discharging from the roadway environment into the natural environment.
Remember - Excess salt run-off not only impacts aquatic habitat but also impacts drinking water in wells and reservoirs.

Keep your load covered - use the tarp to reduce wind erosion of material

Prior to winter maintenance season, calibrate equipment to ensure maximum efficiency and proper application rates.

Check all fluid systems for leaks to reduce the risk of leaking petroleum based products on roadways and lots.

Clean equipment in the wash bay so that wash water is treated by the grit separator and oil/water separator to minimize the discharge of sediment, salt and heavy metals into the environment.


Do your part in helping to
protect the environment.
Be an Environmental Steward,
Salt Sensibly.

APPENDIX F:

Chapter 8 – Rapid Assessment Guidelines for Outfall Channels: Outfall Condition and Restoration Potential

CHAPTER 8

RAPID ASSESSMENT GUIDELINES FOR OUTFALL CHANNELS: OUTFALL CONDITION AND RESTORATION POTENTIAL

8.1 OUTFALL ASSESSMENT GUIDELINES

INTRODUCTION

This chapter provides guidelines for conducting rapid outfall assessments and evaluation of potential restoration approaches for SHA-owned outfalls. The chapter presents guidance on conducting site investigations and completing the proper data collection forms, along with the methodology for rating and ranking sites for restoration potential. Although this guidance is primarily for the assessment of outfall structures, the methodologies can also be applied to headwall structures where inflow channels can also be assessed for restoration potential. For simplicity, these guidelines will generally refer to headwalls, which is intended to include any type of headwall structure, including upstream end sections. The objectives of this assessment are to:

- Identify outfalls where erosion exists at or immediately downstream of the outfall.
- Recommend and prioritize outfalls for protection or repair to promote stability of the downstream channel

These assessments are intended as rapid and preliminary assessments to effectively evaluate the anticipated need and priority for outfall restoration. At the completion of this process, if an outfall is identified as a strong candidate for restoration, a more extensive assessment will be required to determine the actual restoration design, construction, and cost considerations. Further, these assessments are not intended as maintenance inspections. In some instances, outfall deficiencies may be observed which could require maintenance repairs. For instance, a pipe may be clogged with debris, or an outfall structure may be in need of a structural repair. These maintenance needs will be recorded on the Field Form, but will not affect the prioritization of an outfall for restoration.

The Outfall Channel Assessment Field Form (Field Form) and the Outfall Condition, Restoration and Cost Rating Form (rating Form) are found at the end of Section 8.2 and 8.3, respectively.

8.1.I. FIELD PREPARATION

8.1.I.1. PRE-FIELD INVESTIGATION

The objective of this phase is to gather all available information in preparation for the field investigation. SHA will provide the consultant with all available source information such as as-builts, stormwater management and drainage reports, an inventory and GIS coordinates of outfall locations, existing GIS/database information, and applicable GIS layers. The assessment team should review the provided information, along with base mapping to gain a working understanding of the type of structure, its location, and surrounding area.

Digital or paper field maps should be prepared for reference during the outfall assessments. These maps should include relevant features such as the outfalls selected for assessment, local and state roadways and names, property boundaries, streams and water features, the SHA stormdrain network, and SHA stormwater facilities. Using aerial photography as the base image can supplement the usage of building and edge of pavement GIS layers. If during the field assessment it is determined that the existing stormdrain network database contains outdated, inconsistent, or erroneous data, the questionable data should be identified and reported to SHA.

The following items, in either digital or paper format, are recommended for the field preparation package:

- Outfall Location Maps: field maps (100 or 200 scale mapping) with features located including outfalls identified by number, roads (distinguished between SHA and others, including ramps and interchanges), stormdrain networks, stream networks, parcel boundaries, streets, buildings, and stormwater facilities. Aerial photography is recommended and can be used in place of building and edge of pavement GIS layers. Contours and topographic features are also recommended to prepare the field personnel for steep slopes and to indicate available vehicular access locations.

- Summary Table of Outfall Descriptions: a summary table of outfall descriptions that summarizes the MD-SHA Structure ID, outfall size, and type of structure. This data can be compiled from the SHA inventory of GIS attribute data and as-built plans.

- SHA Authorization Letter (for access to SHA Right-of-Way, letter contains work description)

- SHA Right-of-Entry Letter, if needed (for sites outside SHA owned Right-of-Way).

The pre-field investigation should identify potential safety issues such as road access, traffic hazards, and outfall site conditions. It is imperative that field personnel are familiar with the site locations before heading out to conduct their assessments. Locating the sites ahead of time will allow staff to efficiently plan their travel routes, determine access requirements, plan parking areas, and determine the number of sites to be visited each day.

8.1.I.2. FIELD ASSESSMENT TEAM

Assessment teams should consist of at least two individuals for safety in the field. Individuals on the team should have a good background in water resources engineering, including some experience in outfall assessment, stream restoration concepts and environmental science. In addition to the general engineering knowledge of outfalls, their experience should allow the assessment staff to competently classify the receiving waters based upon flow regime (ephemeral, intermittent, and perennial) and make general assessments for natural resources permitting requirements (forest and wetland identification).

8.1.II. FIELD INVESTIGATIONS

8.1.II.1 EQUIPMENT

The following list of equipment is recommended to perform the outfall site assessments:

- Outfall Location Maps*
- Summary Table of Outfall Descriptions*
- Outfall Channel Assessment Field Forms
- ADC Map Book
- Clip Board, Pens and Pencils
- Field Notebook
- Digital Camera
- Survey Rod or Pocket Rod
- Hand Level
- 100' or 300' tape
- Calculator
- Safety Vests
- Traffic Cones (6)
- First Aid Kit
- Field Attire and Field Boots
- Hip Waders
- Machete for Brush Removal
- Flashlight
- Work ID and Driver's License
- SHA Contact Numbers
- SHA Authorization Letter *(for access to SHA Right-of-Way)*
- As-builts *(optional)*
- SHA Right-of-Entry Letter *(if needed)*

* *see Field Preparation section above for a description of information to be included*

The following equipment is optional and may assist the field crews in completing the field assessments:

- Stormdrain As-builts
- Tablets or Notebooks with pre-loaded Field Forms

8.1.II.2. FIELD PROTOCOL

SHA should be notified immediately if the following conditions are observed:

- The site presents an immediate safety hazard to vehicles or pedestrians.
- Dry weather flows are observed and are indicative of an illicit discharge at the outfall. Illicit discharges are often characterized by the presence of odors or colors. Dry weather flows may also be the result of groundwater interception. If the source of the dry weather flow is unknown, the presence of flow should be noted on the field form and reported to SHA following the outfall assessments. Physical and chemical characteristics of the discharge should be observed and recorded on the Field Form.

8.1.II.3. SAFETY AND TRESPASSING

Safety precautions should always be used while locating and assessing outfalls along roadsides. SHA's s *Safety Manual for Field Survey Personnel* should be reviewed for health and safety requirements along SHA roadways.

Field assessment teams should plan for and be aware of vehicular traffic and road conditions during field investigations. The field equipment list highlights the items required to alert local traffic of the field team's presence and allow for safe inspection of the outfall. <u>Field personnel must wear OSHA approved safety vests and carry work ID, driver's license and SHA field inspection authorization letter at all times during the field investigation.</u> A flashing amber warning light on the field vehicle is also recommended. Where possible use several safety cones to alert oncoming traffic of a stopped field assessment vehicle.

SHA DOES NOT AUTHORIZE TRESPASSING ONTO PRIVATE PROPERTY IN ORDER TO COMPLETE FIELD ASSESSMENTS. If an outfall structure or channel is not accessible from SHA or other public right-of-way and no right-of-entry agreement is available, this should be documented in the Field Form comments. The assessment team should obtain as much information as possible from the public right-of-way and then the field team should move to the next assessment site. If the outfall structure and/or channel are visible from the public right-of-way, the assessment team should take a sufficient number of pictures to document field conditions and then make any additional notes regarding field observations.

SHA should be notified that the outfall needs additional assessment which cannot be accomplished without moving out of SHA right-of-way or easements. An access agreement will need to be obtained in coordination with SHA in order to complete the outfall assessment.

8.2 OUTFALL CHANNEL ASSESSMENT FIELD FORM

The Outfall Channel Assessment Field Form (Field Form) is used to gather information in the field to assess each SHA outfall and to support the Outfall Condition, Restoration & Cost Rating Form in determining a numerical rating for priority of outfall restoration potential.

The Field Form is intended to be completed by individuals with a good background in water resources engineering, including some experience in outfall assessment, stream restoration concepts and environmental science. It is anticipated that the assessment team will inspect between four to six outfalls per day, but this may vary depending on location and field conditions. It is recommended that assessment teams plan out roadway routes prior to the field day. A clear weather day should be selected for site visits. Standard safety protocol should be followed at all times and assessment teams must wear safety vests (See Section 8.1.II.3 above).

The Field Form contains two main sections; Office Data and Field Data. The purpose of collecting the Office Data is to determine some basic data about each outfall that is not easily determined in the field and will help staff plan any necessary restoration efforts. The Field Data section describes the data that will need to be collected in the field by the assessment team in order to assess each outfall according to SHA standard protocols. The Field Data section is sub-divided into the following parts: Outfall Structure, Outfall Protection, Outfall Channel, Miscellaneous, and Overall.

HEADER DATA

Each Field Form includes standard headers to be completed to identify the outfall being assessed and the members and company comprising the assessment team. On each page of the Field Form, the MD SHA Structure ID is provided to properly identify which outfall the form is being completed. The MD SHA Structure ID is a unique identifier provided for each outfall structure by SHA to track in their database. SHA should provide STRUCTURE ID # for all outfall structures to be assessed.

In the header, the Assessment Team is the names of the individuals who perform the field assessment at the outfall and whom SHA can direct questions, if necessary. The Date is the calendar date on which the outfall assessment was performed. The Firm/Agency is the name of the consultant firm that has been assigned to assess the outfall. The Nearest State Roadway is the SHA roadway nearest to the outfall, for example MD 100. The Nearest Cross Road is the nearest roadway crossing the state roadway (whether it's a state, county or local road). An example would be an outfall located near the crossing of MD 100 (Nearest State Roadway) and Coca Cola Drive (Nearest Cross Road).

8.2.I. OFFICE DATA

The purpose of collecting the Office Data is to determine some preliminary information about each outfall, most of which can be collected from commonly available sources such as public websites. The average effort for collecting the Office Data for each outfall should be about 15 to 30 minutes. If the effort requires more than 30 minutes per site, the assessment team should re-evaluate the process being used to obtain the Office Data and should identify options for improving efficiency.

8.2.I.1. SITE INFORMATION

The site information should be collected from the resources as described below. Much of the data can be collected from readily available sources such as public websites, and is anticipated to take no more than 30 minutes to complete.

8.2.I.1.A. DRAINAGE AREA CONDITIONS

The objective of obtaining the Drainage Area Conditions for each outfall channel is to determine the size of the area draining to each outfall, if it is known. The drainage area is an important factor contributing to the amount and type of flow conveyed to an outfall.

There are many potential sources of information to determine the drainage area size, or SHA may provide a drainage area with the information provided for the outfall assessments. Two sources of drainage area information are As-Built Plans or a Stormwater Management Report, if available. SHA may also provide GIS spatial data for the outfall which includes a drainage area delineation which can be used as an estimate of the drainage area size. However, most outfalls will have limited available information and the drainage area size cannot be determined from known sources. For these conditions, the drainage area should be left blank.

The 8-digit watershed number can be determined graphically from the Watershed Profiles Maps developed by Maryland Department of Natural Resources (DNR) or using the Merlin website described in Section 8.2.I.1.E. The DNR maps are organized by watershed and sub-watershed on the following website:

http://mddnr.chesapeakebay.net/wsprofiles/surf/prof/prof.html

To determine the 8-digit watershed number, select the appropriate watershed name and sub-watershed where the outfall site is located. After selecting the appropriate sub-watershed, the 8-digit watershed number will be located in the upper left-hand corner of the Watershed Profile webpage. For example, if watershed Patapsco/Back and sub-watershed Liberty Reservoir is selected, the 8-digit watershed number is 02130907.

Figure 8.2.1: Watershed Profiles

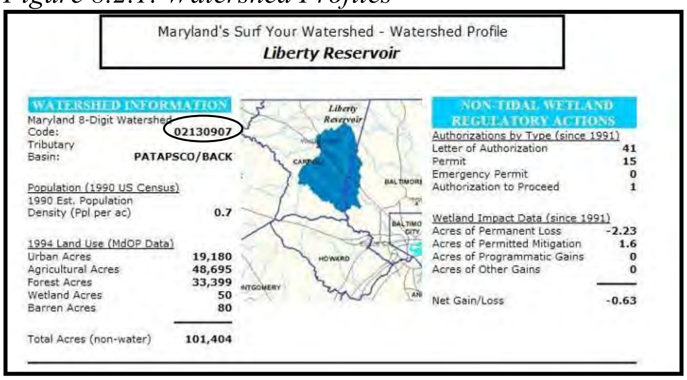


Figure 8.2.2: 8-Digit Watershed Number

8.2.I.1.B. PREVIOUS RAINFALL EVENT

The previous rainfall event is used to determine recent rainfall history at the outfall location which may impact the site assessment. Although there are several sources for recent rainfall data, it is recommended that the following website be used for consistency:

http://www.wunderground.com/wundermap

Once the website is accessed, pan to the general location in Maryland where the outfall is located, choose the station icon closest to the outfall on the map and select it. A pop-up appears and the Station ID is presented in the upper left corner. Click the hyperlinked Station ID to get a Station Data page. Scroll down the page to find the daily rainfall history at the station. Select the monthly history for the station and record the most recent rainfall event that exceeds 0.10 inches. If a rainfall event occurs over consecutive days, then record the cumulative total and note the dates that the event took place.

ID #

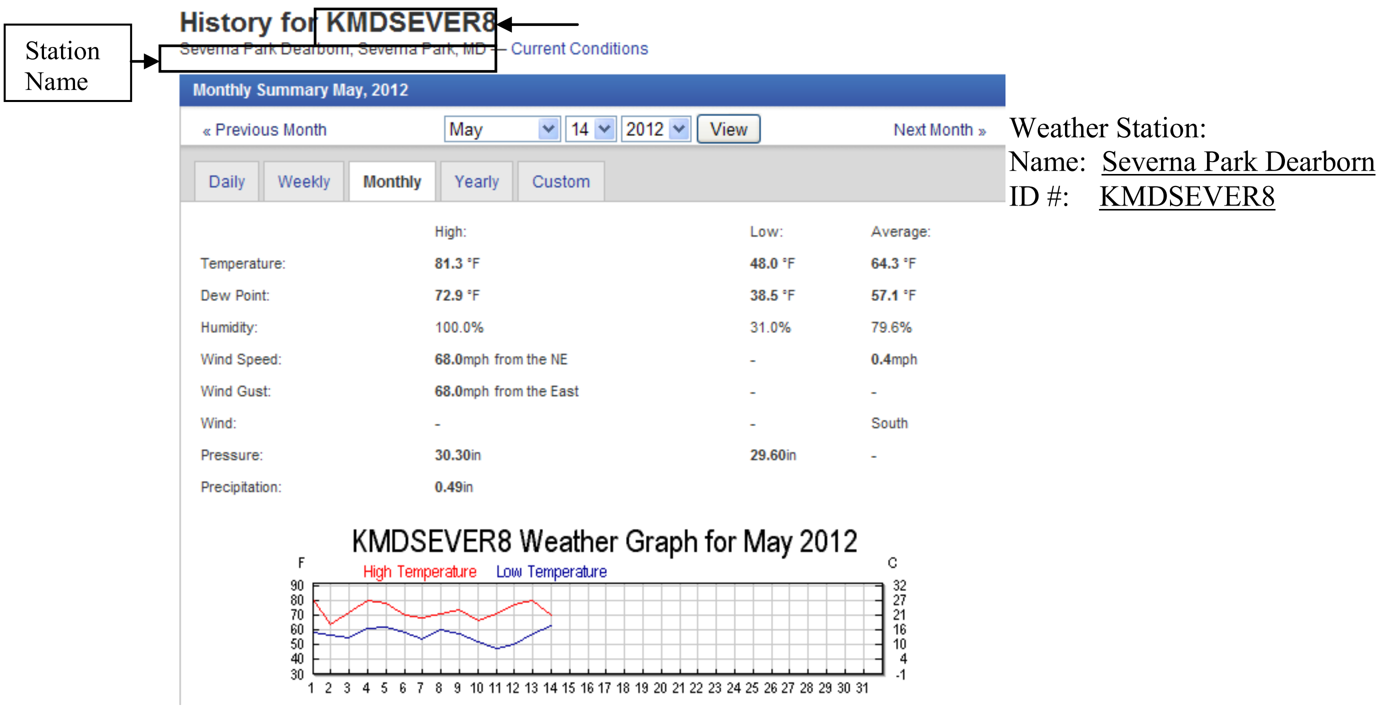


Figure 8.2.3: Real-Time KMDSEVER8 Weather

This Month's Tabular Data

2012	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Pressure (in)			Visibility (mi)			Wind (mph)			Precip (in)
May	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	gust	sum
1	81	68	59	68	61	51	99	80	49	30.13	-	29.97	-	-	-	8	0	8	0.06
2	64	62	56	62	58	54	97	90	82	30.15	-	29.97	-	-	-	7	0	7	0.01
3	72	63	54	64	59	53	96	87	74	30.17	-	30.04	-	-	-	6	0	6	0.03
4	80	68	61	73	65	60	100	92	71	30.06	-	29.85	-	-	-	8	0	8	0.02
5	79	69	62	69	64	61	100	86	65	30.00	-	29.85	-	-	-	68	1	68	0.00
6	70	63	59	61	59	56	96	86	71	30.10	-	29.99	-	-	-	6	0	6	0.00
7	68	62	54	57	53	48	97	75	51	30.12	-	30.04	-	-	-	11	1	11	0.00
8	71	66	60	64	60	52	89	81	70	30.05	-	29.80	-	-	-	9	1	10	0.01
9	74	66	58	68	63	57	100	89	64	29.81	-	29.63	-	-	-	6	0	6	0.29
10	67	59	52	57	48	40	98	70	41	29.94	-	29.60	-	-	-	9	1	10	0.02

Choose this one

Figure 8.2.4: KMDSEVER8 Weather Data – Precipitation Total on May 9, 2012 is 0.29 inches

8.2.I.1.C. Predominant Land Use of Drainage Area

The Predominant Land Use of Drainage Area is used to determine if the drainage area is predominantly developed. The more developed the drainage area, the more likely the instability in the outfall channel is a result of the development. More developed drainage areas have higher restoration potential since there is a lower risk of future development changing outfall discharge conditions in the restored channel. The predominant land use is best determined by looking at recent aerial photography and can be verified during the site field assessment. Below is a brief description of each classification:

Wooded/Open Areas:	The predominant land use is wooded or open areas. Choose when drainage area includes large areas of forest or park.
Agricultural:	The predominant land use is agricultural. This land use should be chosen only occasionally. Agricultural regions in Maryland are located primarily along the Eastern shore, but are also found in other more rural areas of the state.
Residential:	The predominant land use is residential. For most outfalls, residential land use will be the most common chosen. When the drainage area comprises various land uses, residential land would be chosen as development has the biggest impact on an outfall.
Commercial/Industrial:	The predominant land use is commercial or industrial. This category should be chosen rarely.
Roadway/Impervious:	The predominant land use is roadway or impervious. This category should be chosen when most of the drainage area to the outfall is from the adjacent SHA roadway.

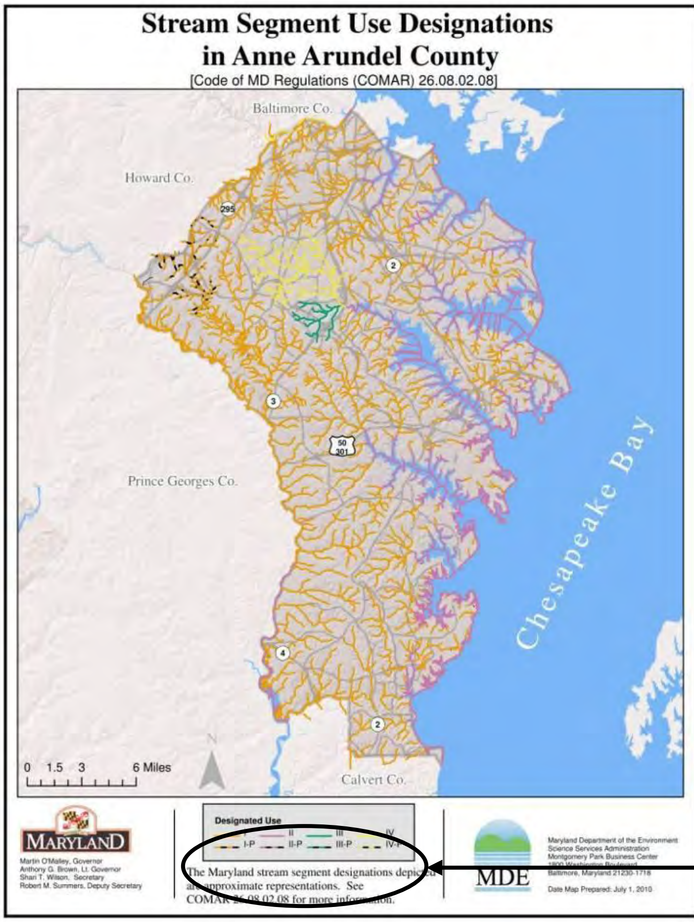
8.2.I.1.D. STREAM USE

The objective of obtaining the Stream Use for each outfall channel (or for receiving streams from the outfall) is to determine any waterway construction permit restrictions associated with restoring the outfall channel. Stream Use can be determined graphically from the Designated Use Maps developed by MDE and organized by County on the following website:

http://www.mde.state.md.us/programs/Water/TMDL/Water%20Quality%20Standards/Pages/programs/waterprograms/tmdl/wqstandards/wqs_designated_uses.aspx

Not all outfalls are located on jurisdictional streams. Outfalls located on ditches or other non-jurisdictional channels should be classified as non-jurisdictional. The Designated Use Maps should only be used as guidance. The assessment team should confirm in the field if the outfall channel is jurisdictional or non-jurisdictional, and should update the Field Form when necessary to correctly identify the channel is jurisdictional or not.

Below is an example of a stream use map, which shows the majority of the streams and tributaries in Anne Arundel County are designated Use I waters.



Stream Use Designation

Figure 8.2.5: Stream Segment Use Designations in Anne Arundel County

8.2.I.1.E. Special Area Designation

The objective of obtaining the Special Area Designation for each outfall channel is to determine any other potential permit restrictions or requirements associated with restoring the outfall channel. Special Area Designations located at a particular outfall can be determined through the MERLIN website maintained by the DNR, at the following address:

http://www.mdmerlin.net/mapper.html

Figure 8.2.6: MERLIN Map and Layer List

Although there are many potential layers which could be used in MERLIN to identify special designation areas, the following table includes those MERLIN layer(s) that should be selected and used for the special area designation categories on the Field Form.

Special Area Designation	**MERLIN Layers**
Wetland	Wetlands-DNR, Wetlands-NWI
Floodplain	Floodplain
Critical Area	Critical Areas, Protected Lands – DNR Programs
Special Protection Area	MD Inventory of Historic Places
Forest	Land Use Land Cover 2010

For Tier II Watersheds, a second source of information will need to be accessed. The website for the County Listing Maps shown below also contains a map (labeled as High Quality Waters Maps) for Tier II Watersheds:

http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/water_quality_maps.aspx

View the County Map to determine if the outfall location is within a watershed that is considered a High Quality (Tier II) Watershed (capacity available). Below is an example of a High Quality (Tier II) Waters map for Anne Arundel County. The areas shaded light green indicate watersheds with Tier II capacity available:

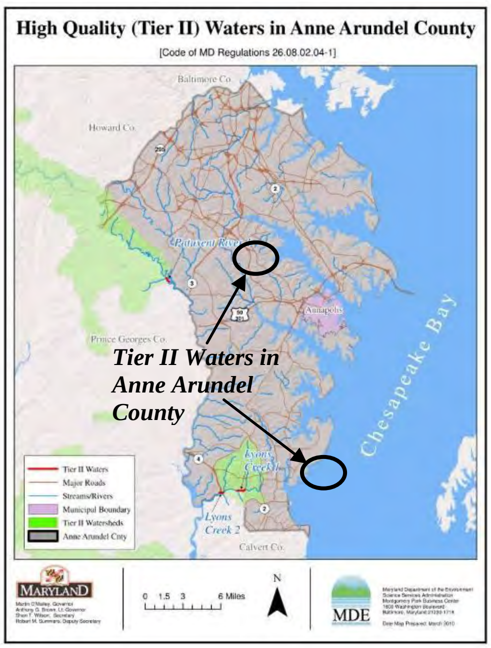


Figure 8.2.7: High Quality (Tier II) Waters Map for Anne Arundel County

8.2.I.1.F. DOWNSTREAM CHANNEL IMPAIRMENT

The objective of obtaining the Channel Impairment for each outfall channel (or for receiving streams from the outfall) is to determine the potential to address the impairment and to quantify ecological benefits that can be gained by restoring the outfall channel. The Channel Impairment can be determined graphically from the Listing Maps developed by MDE and organized by County on the following website:

http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/water_quality_maps.aspx

Once a County is selected, there are seven County Listing Maps. All seven Maps should be viewed and if the project site is within a region labeled as impaired on ANY of the maps, then the outfall should be marked as impaired. If impaired, note each impairment for which the outfall region is labeled as impaired using the abbreviations below:

Impairment	Abbreviation	Impairment	Abbreviation
Bacteria	Bact	pH	pH
Biological	Bio	Sediment	Sed
Metal	M	Toxic	Tox
Nutrients	Nutr		

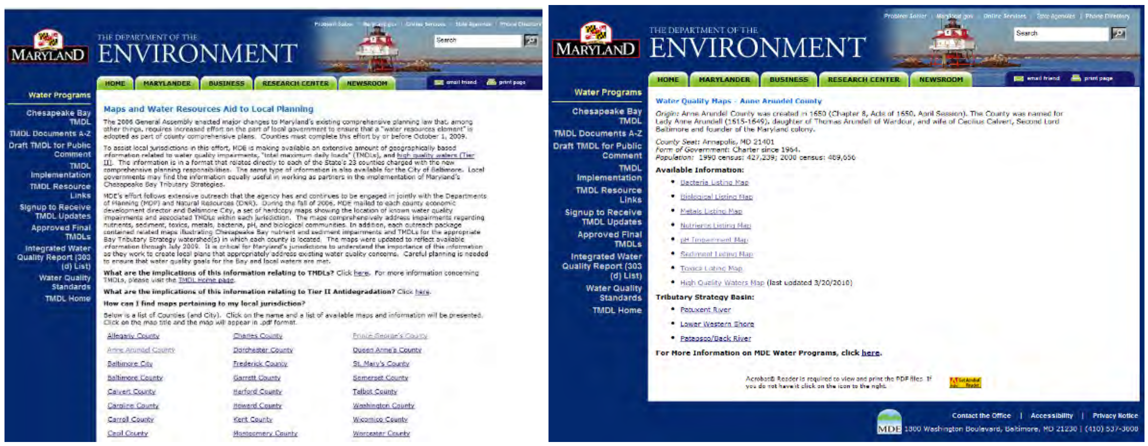


Figure 8.2.8: Maryland Department of the Environment County Listings and Impaired Maps

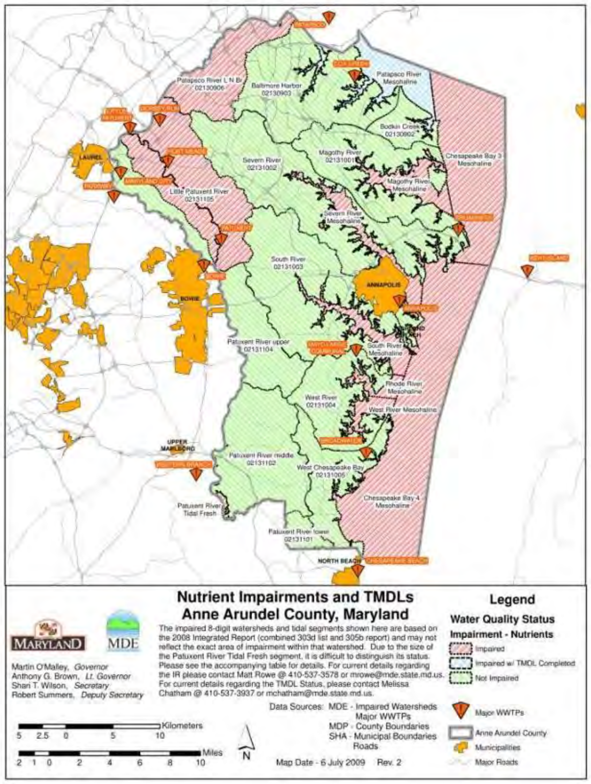


Figure 8.2.9: Nutrient Impairments and TMDLs for Anne Arundel County, Maryland

8.2.I.1.G. LAND OWNERSHIP (AT OUTFALL AND WITHIN 200' DOWNSTREAM)

The objective of obtaining the Land Ownership for each outfall channel is to flag any sites where constructed improvements to the outfall channel will be difficult due to the lack of existing SHA-owned right-of-way. When available, As-built Plans may provide land ownership information. If plans are not available, aerial photos and the MERLIN database may be used (see section 8.2.I.1.E). The MERLIN site provides parcel boundaries that can be reviewed to help determine property ownership. Since most outfall channels at a site will include SHA Right-of-Way and another downstream landowner, choose all categories that apply.

SHA Right-of-Way: The land adjacent to SHA roadway, usually extending from 20 to 50 feet from the edge of roadway. Typically, the outfall structure and a portion of the downstream channel lies within the SHA right-of-way. Land beyond this right-of-way (usually 50 feet or more downstream of the outfall) will usually fall into another category.

Parks: Land with large amounts of forested/wooded acreage is usually within an adjacent Federal, State or County park.

Examples of Maryland State Parks include Seneca Creek State Park and Sandy Point State Park.

Private (Non-residential): Land at outfall or within 200' downstream that is private commercial or industrial property.

Private (Residential): Land at outfall or within 200' downstream that is used for residential purposes and privately owned. Many downstream channels within forested areas may still be residential ownership if the land is part of an adjacent development.

Other: Land that is typically used for transportation or other institutional facilities.

It should be noted that information collected during the field visit can help clarify the land ownership at the outfall and downstream of the outfall. When this occurs, the assessment team should reevaluate and update the information provided in this block.

8.2.I.1.H. PRESENCE OF SWM FACILITY/DAM UPSTREAM OF OUTFALL

The objective of determining the presence of a stormwater management facility or dam upstream of the outfall is to determine any upstream influences which may be impacting the outfall. A stormwater management facility or dam located upstream of an outfall can impact the hydrology to the outfall and also habitat value if fish or other aquatic passage is blocked.

If a stormwater management facility is identified upstream of the outfall, the facility type should be noted on the Field Form in the space provided. Typical facility types include ponds, infiltration trenches or filters. More specific information concerning the facility type would be helpful, but is not necessary to complete this section.

8.2.II FIELD MEASUREMENTS

This section describes the data that will need to be collected in the field by the assessment team in order to assess each outfall according to these SHA standard protocols. Figure 1 on the Field Form illustrates the main components of an outfall structure and an associated channel. By referencing this figure each team can ensure that the same standards are used to identify and describe components of an outfall and its associated channel. These components are assessed in separate sections of the Field Form. Section 1 under Field Measurements is the outfall structure component, Section 2 is the outfall protection component and Section 3 is the outfall channel component. Figure 2 on the Field Form shows a typical channel cross-section and includes illustrations on measurements for the channel bottom width, the left bank and right bank heights.

8.2.II.1 OUTFALL STRUCTURE

The outfall structure (or headwall) includes the components of the SHA infrastructure (pipe, endwall, etc.) for which SHA already inventoried within the stormdrain database. The purpose of this section is to confirm the data that is stored within the database and to assess the condition of the infrastructure if maintenance repairs are necessary. The structure type of some outfalls (or headwalls) may be inconsistent with the information in the SHA storm drain database. Assessment teams should use the pre-field investigation as a first attempt to identify discrepancies, using available as-built information. Ultimately, any discrepancies will be confirmed during the field visits. All outfall structures listed in the SHA database (PP, EW, ES structure types) should be assessed, along with any additional suspected outfall structures. Headwalls (HW) and other upstream structures may also need to be assessed, depending on the scope of the assessment. Field and Rating Forms should be completed using the SHA_STR_NO from the SHA database, even when discrepancies are noted. A list of any database discrepancies should be submitted to SHA.

Beginning in this part of the Field Form, several blocks are shaded grey to better identify data that can be directly transferred to the Rating Form. The grey shading is intended to be a visual aide in reading the form and for transferring the data to the Rating Form.

8.2.II.1.A. OUTFALL STRUCTURE LOCATED

The purpose of this block is to ensure that the assessment team can locate the outfall as assigned by SHA. In some instances field conditions may have changed since the outfall was inventoried by SHA. One example of a changed field condition is when an adjacent development has removed and replaced the outfall with another system, such as a storm drain extension. Another condition may be when the outfall pipe is completely blocked or buried by sediment, and can no longer be located. When there are changed field conditions such that the outfall cannot be located, then the remaining field data cannot be collected. The assessment team should determine the most likely reason that the outfall could not be located, take pictures to document the field conditions, note the observations in the Comments at the end of the section and should notify SHA of the changed field conditions. The assessment team should not complete the form beyond this block.

Another condition is a recent modification to the storm drain system which is inconsistent with the information in the SHA storm drain database. If outfalls are not located in the field, which were likely removed as a result of the recent modification; the assessment team should take pictures to document the new field conditions, should note observations in the Comments and should notify SHA of the changed field conditions. Below are a few pictures showing examples of potential outfalls that could not be located in the field.

Figure 8.2.10: Examples of Problems Associated with Locating Outfalls

If new outfalls are discovered in the field, which are not shown in the SHA database, the assessment team should only complete a Field Form assessment for those outfalls in poor condition. When the outfalls are in good condition and restoration is not needed, a Field Form should not be completed. Instead, the assessment team should notify SHA that the outfall is not recorded in the database, and SHA will include the outfall in the next update to the SHA database inventory. When the outfalls are in poor condition, the assessment team should complete the Field and Rating Forms for this outfall using a temporary unique identifier for the outfall. The completed Field and Rating Forms should be submitted to SHA separately from the remainder of the outfall assessments, since the outfall is not yet inventoried within the SHA database.

If outfalls are located in the field, but appear to be at a different location than shown in the SHA database, the assessment team should use sound engineering judgment to complete the assessment. The team may decide that the field location is in close proximity to the database location and there will be no confusion in assessing the outfall using the database identifier. If the field location and the database location are not in close proximity, the team may consider the field location as a newly discovered outfall and the database location as an outfall not located in the field. The assessment team can then follow the procedures described above.

Finally, some outfalls which are not within SHA right-of-way may be considered as outfalls where the structure is not located, since the assessment team cannot get direct access to the outfall to assess the field conditions. The assessment team should take pictures to document the field conditions, should note observations in the Comments section of the Field Form and should notify SHA of the need for access to the outfall. Below are a few pictures showing an outfall which is outside of SHA's right-of-way.

Figure 8.2.10A: Examples of Outfalls which are beyond SHA Right-of-Way

8.2.II.1.B. PUBLIC SAFETY

Public safety is an important consideration for each outfall assessment as SHA intends to address any significant safety hazard discovered at an outfall during these assessments. Any imminent problems that exist should be flagged for immediate notification to SHA. In order to quantify the extent of the hazard, the field form includes five classifications from immediate safety hazard to no safety hazard. Below is a brief description of each classification:

Immediate Safety Hazard: Existing outfall condition presents an immediate safety hazard to pedestrians or vehicles. One example of an immediate hazard is a mass slope failure adjacent to the roadway which could result in the roadway failing. Another example is missing or extremely damaged guard rail which would fail to protect vehicular traffic from a steep adjacent slope.

High Safety Hazard: Existing outfall condition presents a high safety hazard to pedestrians or motor vehicles. Although the danger is not immediate, there is a high level of danger to pedestrians or vehicles if the hazard is not addressed in the near future. An example would be damaged guard rail adjacent to a steep slope that may or may not withstand a direct impact from vehicle.

Moderate Safety Hazard: Existing outfall condition may present a moderate safety hazard to pedestrians or motor vehicles. This condition represents infrastructure that is damaged, but can be repaired during regular maintenance activity. Examples may include some slope erosion or failure adjacent to a roadway or guard rail that is damaged, but not significantly.

Low Safety Hazard: Existing outfall condition presents a low safety hazard to pedestrians or motor vehicles. This condition represents infrastructure that has some defects or damage, but does not need to be repaired, only monitored. Examples may include minor slope erosion or guard rail that has minor damage.

No Safety Hazard: There is no safety hazard to pedestrians or vehicles due to the existing outfall condition.

Figure 8.2.11: Examples of Different Levels of Public Safety Hazards

8.2.II.1.C. OUTFALL ENDWALL TYPE

This block is used to determine the type of outfall endwall (or headwall) for future hydraulic analysis by SHA. The option for endwall types is based on the descriptions used by hydraulic analysis programs such as HY-8. Below is a brief description of each classification:

Endwall has Square Edge: This is common, especially for smaller outfalls. The connection from the pipe to the endwall is at a 90°, right angle, and there is no grooved transition from endwall to pipe to reduce exit losses.

Grooved/Beveled Edge: This option is more likely to be found on larger pipes where there is a grooved or beveled transition from the endwall to the pipe to reduce exit losses from the pipe.

Projecting from Endwall: This option will be chosen only rarely, when the outfall pipe projects past the endwall. This option should not be confused with the protruding pipe outfall structure type, which is chosen when no endwall exists.

N/A: This option will be chosen only when no endwall exists, such as for an end section or protruding pipe.

Figure 8.2.12: Examples of Outfall Endwall Types

8.2.II.1.D. OUTFALL STRUCTURE TYPE

The purpose of this block is to determine the type of the structure at the outfall to confirm the information within SHA's stormdrain inventory. The outfall structure type is usually an endwall, an end section or a protruding pipe. When performing an assessment on a headwall or upstream end section, the block for Other should be selected and the structure should be described on the line below. If the structure type provided by the SHA database matches that confirmed by the assessment team, then the structure type is confirmed to be correct in the database. Sometimes there is a discrepancy between the structure type listed in the SHA database and the type located in the field by the assessment team. This is an indication that the information in the SHA database may need to be updated, or that the assessment team is not at the correct location. The assessment team should confirm that the location being assessed is correct. If there is a discrepancy between the structure type listed in the SHA database and the type located in the field, the assessment team should note the discrepancy in the Comments at the end of the section and then continue with the assessment.

8.2.II.1.E. OUTFALL STRUCTURE CONDITION

The purpose of this block is to confirm the condition of the outfall or other structure. When there is severe damage to the structure, SHA needs to be notified. Severe damage can include separation between the endwall or end section and the pipe, a broken or deteriorated structure or a structure that has spalling or cracking. In order to quantify the extent of the outfall structure condition, the field form includes five classifications from severe damage to no damage. Below is a brief description of each classification:

Severe Damage: There is severe damage to the existing structure condition which requires significant repairs or replacement. Examples include major cracks and defects in the outfall structure and structural separation between the pipe and outfall structure.

Major Damage: There is major damage to the existing structure condition which may require repairs or replacement. This damage may include significant spalling or cracking of a concrete structure or major deformation of a metal structure.

Moderate Damage: There is moderate damage to the existing structure condition including some spalling or cracking of a concrete structure or moderate deformation of a metal structure.

Minor Damage:	There is minor damage to the existing structure condition including minor cracking, chipping or other defects which do not need to be repaired at this time.
No Damage:	There is no damage to the structure. This classification should also be chosen when there is no outfall structure (ex. protruding pipe) or when the category is not applicable.

Figure 8.2.13: Examples of Outfall Structure Condition

8.2.II.1.F. Pipe Material

The purpose of this block is to confirm the material of the outfall pipe. The outfall pipe is usually concrete, but can also be metal, plastic or another material. If the outfall pipe material provided by the SHA database matches that confirmed by the assessment team, then the outfall pipe material is confirmed to be correct in the database. Sometimes there is a discrepancy between the outfall pipe material listed in the SHA database and the type located in the field by the assessment team. This is an indication that the assessment team may not be at the correct location or the SHA database may need to be updated. The assessment team should confirm that the location being assessed is correct. If there is a discrepancy between the outfall pipe material listed in the SHA database and the type located in the field, the assessment team should note the discrepancy in the Comments at the end of the section and then continue with the assessment.

8.2.II.1.G. Outfall Pipe Type

The purpose of this block is to confirm the type of the outfall pipe. The outfall pipe is usually a circular pipe, but can also be a box culvert, elliptical pipe or a pipe arch. If the outfall pipe type provided by the SHA database matches that confirmed by the assessment team, then the outfall pipe type is confirmed to be correct in the database. Sometimes there is a discrepancy between the outfall pipe type listed in the SHA database and the type located in the field by the assessment team. This is an indication that the assessment team may not be at the correct location or the SHA database may need to be updated. The assessment team should confirm that the location being assessed is correct. If there is a discrepancy between the outfall pipe type listed in the SHA database and the type located in the field, the assessment team should note the discrepancy in the Comments at the end of the section and then continue with the assessment.

8.2.II.1.H. OUTFALL PIPE CONDITION

The purpose of this block is to confirm the condition and type of the outfall. When there is severe damage to the outfall pipe, then SHA needs to be notified. Severe damage can include pipe separation, broken or deteriorated sections of pipe or an undermined pipe that is losing its support as a result of a pipe separation. In order to quantify the extent of the outfall pipe condition, the field form includes five classifications from severe damage to no damage. Below is a brief description of each classification:

Severe Damage: There is severe damage to the existing outfall pipe condition which requires significant repairs or replacement. Examples include a collapsed pipe, a broken pipe or pipe with severe defects, or structural separation between the pipe and outfall structure.

Major Damage: There is major damage to the existing outfall pipe condition which may require repairs or replacement. This damage may include significant spalling or cracking of a concrete pipe or major deformation of a metal pipe.

Moderate Damage: There is moderate damage to the existing outfall pipe condition including some spalling or cracking of a concrete pipe or moderate deformation of a metal pipe. Patching may be required for repair.

Minor Damage: There is minor damage to the existing outfall pipe condition including minor cracking, deformation or other defects which do not need to be repaired at this time.

No Damage: There is no damage to the outfall pipe. This classification should also be chosen when the outfall pipe cannot be observed during the assessment.

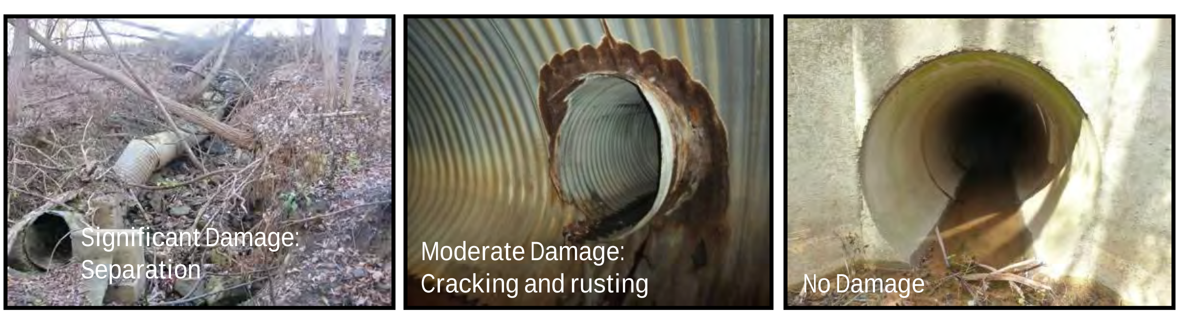


Figure 8.2.14: Examples of Outfall Pipe Condition

8.2.II.1.I. OUTFALL SIZE (CIRCULAR)

The purpose of this block is to confirm the size of the pipe to an outfall or other structure. The outfall pipe is usually a circular pipe and the size can be measured at the outfall. If the outfall is partially blocked, the size can still be measured most times. When the pipe is completely blocked, then a size cannot be measured, and the condition should be noted in the Comments. If the outfall pipe size provided by the SHA database matches that confirmed by the assessment team, then the outfall pipe size is confirmed to be correct in the database. Sometimes there is a discrepancy between the outfall pipe size listed in the SHA database and the size located in the field by the assessment team. This is an indication that the information in the SHA database may need to be updated, or that the assessment team is not at the correct location. The assessment team should confirm that the location being assessed is correct. If there is a discrepancy between the outfall pipe size listed in the SHA database and the type located in the field, the assessment team should note the discrepancy in the Comments at the end of the section and then continue with the assessment.

8.2.II.1.J. OUTFALL SIZE (NON-CIRCULAR)

When the outfall or other conveyance is non-circular, such as box culverts or elliptical pipes, two measurements need to be taken to confirm the size. The width and height of each non-circular pipe should be measured and the assessment team should follow a similar procedure to that described in the Outfall Size (Circular) section above.

8.2.II.1.K. OUTFALL ACCESSIBILITY / MAINTENANCE OF TRAFFIC (MOT) CONSIDERATIONS

The purpose of this block is to confirm the accessibility at each outfall, to determine how difficult construction repair may be. The more difficult the construction access, or the need for more extensive MOT during construction, the lower the priority will be to repair an outfall. In order to quantify the extent of the outfall accessibility and MOT considerations, the field form includes five classifications from good to difficult access. Below is a brief description of each classification:

Good Access/Minimal MOT: Outfall site is in an open area within public ownership and allows for easy access for heavy equipment using existing roads or trails. Minimal MOT requirements are anticipated as adjacent roadways have slower traffic and wider shoulders.

Fair to Good Access: Outfall site has some access limits such as guardrail, moderate slopes from the shoulder to the outfall or adjacent forested areas. No trees or guardrail will need to be removed, but heavy equipment would need to be careful when accessing the site. Minimal to moderate MOT requirements are anticipated as adjacent roadways have moderate speeds and wider shoulders.

Fair Access/Moderate MOT: Outfall site is adjacent to forested or developed areas which may limit access to the site. Access may require tree removal or impacts to landscaped areas. Guard rails are present which may need to be removed for site access. Moderate MOT requirements are anticipated as adjacent roadways have moderate traffic speeds and some shoulder areas.

Difficult to Fair Access: Outfall site is adjacent to heavily forested or developed areas which will limit access to the site. Access will likely require tree removal or impacts to landscaped areas. Guard rails are present which will need to be removed for site access. Moderate to major MOT requirements are anticipated as adjacent roadways have high traffic speeds and some shoulder areas.

Difficult Access/Major MOT: Access is constricted to the outfall site by permanent structures such as fences, traffic barriers, or noise walls. Access may also be restricted by permit requirements if there is a need to cross wetlands, steep slopes, or sensitive areas. Major MOT requirements are anticipated as adjacent roadways have high speed traffic and little to no shoulder area.

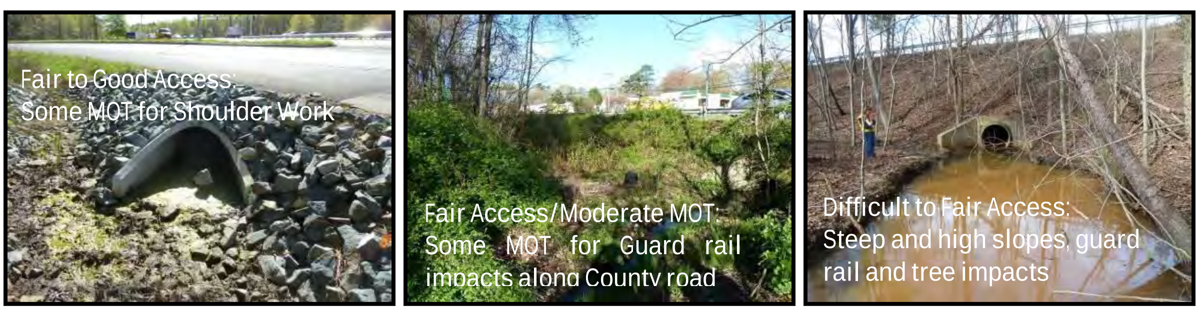


Figure 8.2.15: Examples of Outfall Accessibility/MOT Considerations

8.2.II.1.L. OUTFALL SEDIMENT BLOCKAGE

The objective of obtaining the Sediment Blockage for each outfall channel is to document the conditions at the outfall which may be contributing to poor conditions at the outfall. Below are a few pictures showing the relative degree of blockage for each category.

Figure 8.2.16: Examples of Outfall Sediment Blockage

8.2.II.1.M. PHOTOS TAKEN

The purpose of this is to remind the assessment team to take an adequate number of photos of the outfall structure and to properly document where each photo was taken. During the assessment of the outfall structure, photos should be taken of the outfall structure, outfall pipe, and any other photos deemed necessary by the assessment team. Immediately after photos are taken, photo ID numbers should be recorded. Review the photos prior to departing the site to ensure that all required photos were captured and that they are good quality.

8.2.II.1.N. COMMENTS REGARDING OUTFALL STRUCTURE

The purpose of this block is to provide the assessment team with an area on the form to record pertinent information regarding the outfall structure, including those aspects which require additional description. It is also the part of the form where more specific information can be provided, such as damage at the outfall structure or pipes.

8.2.II.2 OUTFALL PROTECTION

Section 2 of the Field Measurements is the outfall protection component which assesses the conditions of the protection or scour immediately down from the outfall pipe. The purpose of this section is to inventory and assess the measures that have been installed immediately downstream of the outfall to prevent erosion. When assessing a headwall, record the condition of the inflow riprap or other protection in this section. If no inflow protection exists, most of the blocks can be marked as No or N/A. Ultimately, this information will supplement SHA's stormdrain inventory.

8.2.II.2.A. OUTFALL PROTECTION TYPE

The purpose of this block is to determine the type of the protection downstream of the outfall to supplement the information within SHA's stormdrain inventory. The outfall protection type is usually a riprap apron, a concrete apron or a concrete channel. If the outfall protection is a gabion basket, this should be considered as a riprap apron. The following are a few pictures demonstrating the different types of outfall protection.

Figure 8.2.17: Examples of Outfall Protection Types

8.2.II.2.B. OUTFALL PROTECTION SIZE

The purpose of this block is to determine the size of the outfall protection to supplement the information within SHA's stormdrain inventory. The assessment team will measure the extent of the outfall protection by obtaining the length (measured along the direction of the outfall pipe) and the width (measured perpendicular to the pipe). Although the outfall protection is rarely of a uniform length and width, the best representative measurement for the length and width should be obtained. In the photo above, the width of the concrete apron would be at the end of the apron. This width is representative of the protection provided by the apron within the wingwalls of the outfall structure.

8.2.II.2.C. RIPRAP TYPE AT OUTFALL

The purpose of this block is to determine the type of the riprap, when present, at the outfall. Riprap is classified by the median size of the material. Class I riprap (d_{50} = 9.5 in.) is the smallest and most common size of riprap used for outfall protection. Class II (d_{50} = 16 in.) is larger than Class I and is usually found only at the larger outfalls. Class III (d_{50} = 23 in.) is the largest size and is usually only placed at bridges to prevent scour at the abutments. If Class III riprap is encountered, it is anticipated to be only at outfalls near bridges and large streams. Gabion baskets are wire baskets which contain stone and provide extra protection as they can be stacked and provide good erosion protection of banks. The following are a few pictures demonstrating the different sizes of riprap used for outfall protection.

Figure 8.2.18: Examples of Riprap Types at Outfalls

8.2.II.2.D. OUTFALL PROTECTION CONDITION

The purpose of this block is to determine the condition of the outfall protection to supplement the information within SHA's stormdrain inventory. Since the outfall protection type is usually riprap or concrete, there are two ways to characterize the condition of the outfall protection. For concrete outfall protection, the condition is characterized by the damage to the concrete. Damage to concrete includes minor damage such as cracking or chipping and major damage such as broken or displaced concrete. For riprap outfall protection, the condition is characterized by the percentage of the displacement to the concrete.

Severe Damage (>75%): Outfall protection is >75% damaged or displaced. In general, the concrete outfall protection has experienced severe damage including undermining and collapse and the concrete is completely broken into pieces. More than 75% of the riprap outfall protection is displaced further downstream. The outfall protection is not functioning where needed and requires significant repair or replacement.

Major Damage (51-75%): Outfall protection is 51-75% damaged or displaced. Concrete outfall protection has experienced major damage including some undermining and major cracks which result in the concrete being partially broken into pieces. Between 51% and 75% of the riprap outfall protection is displaced further downstream. Repair/replacement is needed.

Moderate Damage (26-50%): Outfall protection is 26-50% damaged or displaced. Concrete outfall protection has experienced moderate damage including erosion along the edges and moderate cracking which may result in the concrete breaking into pieces. Between 26% and 50% of the riprap outfall protection is displaced further downstream. Some repair/replacement is needed.

Minor Damage (6-25%): Outfall protection is 6-25% damaged or displaced. Concrete outfall protection has experienced minor damage including minor cracking or vegetative growth between the joints, which does not impact the function of the outfall protection. Between 6% and 25% of the riprap outfall protection is displaced further downstream. Minor repair/replacement may be needed.

No Damage or N/A (0-5%): Outfall protection is 0-5% damaged or displaced. Concrete outfall protection is in good condition and has negligible damage. Less than 6% of the riprap outfall protection is displaced further downstream. No repair or replacement is needed at this time. This classification should also be chosen when this category is not applicable.

Figure 8.2.19: Examples of Outfall Protection Condition

8.2.II.2.E. INFRASTRUCTURE CONSTRAINTS

The purpose of this block is to determine if any utilities are in close proximity to the outfall protection which may be a constraint for construction of outfall repairs. The assessment team should note any manhole covers, utility markers or other indicators of an underground utility that is within 10 feet of the outfall protection. Any overhead utilities should also be checked. If any underground or overhead utilities are within 10 feet of the outfall protection, the assessment team should describe the utility in the Comments at the end of the Section. The location of utilities can also be included on the plan view sketch on the last page of the form.

8.2.II.2.F. HORIZONTAL PIPE EXPOSURE

The purpose of this block is to determine the erosion which may have occurred around an outfall pipe and to take appropriate measurements. The assessment team will measure the top length of exposed pipe, the bottom length of exposed pipe, the depth of undermining, the distance from the end of the pipe to any scour hole or bed erosion along the downstream channel, and the depth of any bed erosion. In the second photo below, the top length of exposed pipe is about 2.0 feet, with several feet of undermining and about 1.0 feet for the bottom length of exposed pipe. Figure 3 on the Field Form shows a typical channel, including illustrations on measurements for the top and bottom length of exposed pipe, depth of undermining, distance from pipe to scour hole, distance from pipe to bed erosion and the bed erosion depth. Most of the information in this block does not usually apply to headwalls, and can be left blank when it does not apply.

Figure 8.2.20: Examples of Horizontal Pipe Exposure

8.2.II.2.G. PRESENCE OF SCOUR HOLE

The purpose of this block is to determine the presence of a scour hole, at or beyond the outfall protection, which may have occurred due to erosion or may be by design. The assessment team will first need to identify if a scour hole is present. A scour hole is a depression or a hollow hole in the bed of a stream caused by the erosive action of rapidly circulating flow. The scour hole is usually located just beyond the outfall if no outfall protection is present, or beyond the outfall protection where present. Most are naturally occurring, but preformed scour holes are usually designed as a depression with riprap protection at an outfall to mimic natural scour processes to dissipate energy and prevent additional erosion. Preformed scour holes are identified as riprap protected depressions at an outfall where it appears the depression was constructed and not the result of erosion. All other scour holes should be identified as natural. If no erosion or scour is present at the channel outfall just downstream, then the assessment team should check No Scour.

Figure 8.2.21: Examples of Different Types of Scour Holes

8.2.II.2.H. SCOUR HOLE STABILITY

The purpose of this block is to determine the stability of a scour hole. Stable scour holes are those where there is no active erosion. Stable scour holes are usually preformed, but can also be natural if there is no longer any active erosion and the scour hole provides adequate energy dissipation at the outfall. For examples of inactive erosion, refer to Figure 8.2.24 under section 8.2.II.3.J of these guidelines. Unstable scour holes are those where there is active erosion. Unstable scour holes are usually natural, but can also be preformed if there are signs of active erosion within or around the preformed scour hole. If no scour hole is present, then not applicable (N/A) should be checked.

8.2.II.2.I. SCOUR CONDITION

The purpose of this block is to obtain measurements of the degree of scour at a scour hole. Measurements include the depth of the scour hole, which is measured from the natural stream bottom to the depth of the depression. The scour depth to outfall pipe diameter is a ratio that helps determine the degree of the erosion at a scour hole. Ratios greater than 0.5 usually indicate a serious scour condition. The assessment team should also measure the width of the scour hole, which typically is the width of the stream channel, and the length of the scour hole. All measurements should be made to the nearest 0.1 feet. Figure 4 on the Field Form shows a typical scour hole, including illustrations on measurements of scour width and length.

8.2.II.2.J. PHOTOS TAKEN

The purpose of this block is to remind the assessment team to take an adequate number of photos of the outfall protection and to properly document where each photo was taken. During the assessment of the outfall protection photos should be taken of the outfall protection, scour hole, and any other photos deemed necessary by the assessment team. Immediately after photos are taken, photo ID numbers should be recorded.

8.2.II.2.K. COMMENTS REGARDING OUTFALL PROTECTION

This block provides the assessment team with an area on the form to record pertinent information regarding the outfall protection, including those aspects which require additional description. It is also the part of the form where more specific information can be provided, such as damage at the outfall protection or utilities encountered.

8.2.II.3 OUTFALL CHANNEL

Section 3 of the Field Measurements is the outfall channel component which assesses the characteristics of the downstream channel within 200 feet of the outfall. Part of this assessment includes determining the erosive conditions in the channel and other characteristics that influence the restoration potential of the downstream conveyance channel. The primary purpose of this section is to determine which outfall channels exhibit active erosion which can be prevented by a construction repair and which benefits of the repair (such as prevention of future erosion) can be quantified. The assessment team should only account for active erosion that is directly attributed to the outfall. When assessing a headwall, the upstream channel will be evaluated in this section.

8.2.II.3.A. OUTFALL CHANNEL DEFINED

In many cases, although there is a pipe outfall, there is not always a well-defined channel beyond the outfall (or upstream of a headwall). Under these circumstances, the information to be gathered during the field visit will have little value since the outfall channel exhibits minimal to no erosion and there will be minimal quantifiable benefits for improving the outfall. The assessment team should not complete the form beyond this block if the outfall channel cannot be defined. The assessment team should take pictures to document the outfall. It may also be beneficial to sketch the outfall conditions. Below are a few pictures showing examples of outfalls with no defined channel.

Figure 8.2.22: Examples of Outfall Channels

The third picture above illustrates a condition that is encountered when multiple pipes or other conveyances outfall to the same channel. According to SHA database, there are three outfalls in the photo; one is the triple box culvert and the other two are the two 18" pipes which outfall through the wingwalls. It would be redundant to assess the same downstream channel for all three outfalls. Instead, the assessment for the channel should be performed as part of the assessment of the main conveyance, which is the box culvert. The assessment for each of the pipes outfalls at the wingwalls should stop at block II.3.A since there is no defined channel between the outfalls and the main channel. However, a note should be added to the comments at the end of this section which refers to the outfall assessment for the box culvert (the reference should include the SHA Structure ID for the box culvert). This will alert SHA that the outfall shares a common outfall channel with the box culvert**.**

Other instances may be encountered, where the main channel culvert is not included as an outfall structure. Under these circumstances, the downstream channel should still be assessed during the assessment of the more significant or larger of the other pipe outfalls. The other, less significant outfalls should not include a channel assessment, but should refer to the channel assessment for the more significant outfall on the form Comments.

8.2.II.3.B. OUTFALL CHANNEL TYPE

The purpose of this block is to determine the channel type which provides a good indication of restoration potential. Roadside ditches, which are located adjacent and parallel to the roadway, have the lowest potential due to the proximity of the roadway and other constraints; therefore the assessment team should determine if the channel is a roadside ditch. Below are a few pictures typical of roadside ditches.

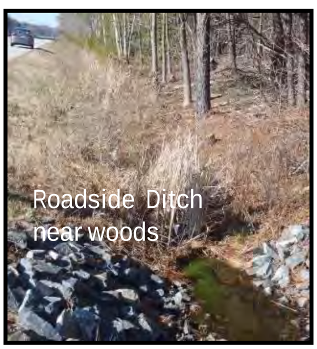


Figure 8.2.23: Examples of Outfall Channel Types

8.2.II.3.C. OUTFALL CONFIGURATION

The purpose of this block is to determine the number of contributing channels to an outfall which helps to characterize the Site Design Considerations on the Ranking Form. Most channels have no additional contributing channels, which is the least restrictive condition for consideration of future restoration designs. If one or more channels are identified as contributing to an outfall channel, the assessment team should make sure that the potential channel(s) is clearly defined and will provide a design constraint. Typically concrete ditches or well-defined natural channels would be included but temporary swales would not be. The number and configuration of contributing channels should be shown on the plan view sketch on the last page of the form.

8.2.II.3.D. CHANNEL SKEW TO CENTERLINE OF OUTFALL PIPE

The purpose of this block is to determine the channel skew at an outfall which helps to characterize the Site Design Considerations on the Ranking Form. Most channels are generally straight and have a low skew (less than 30°), which is the least restrictive condition for consideration of future restoration designs. Greater skews will contribute to more difficult design constraints at these outfalls and will be more difficult to maintain a stable design at the skew. The channel skew should be shown on the plan view sketch on the last page of the form.

8.2.II.3.E. INFRASTRUCTURE CONSTRAINTS (AT OUTFALL CHANNEL)

The purpose of this block is to determine if any utilities are in close proximity to the outfall channel which may be a constraint for construction of outfall repairs. The assessment team should note any manhole covers, utility markers or other indicators of an underground utility that are at or adjacent to the outfall channel. Any overhead utilities should also be checked. If any underground or overhead utilities are at or adjacent to the outfall channel, the assessment team should describe the utility in the Comments at the end of the Section. The location of utilities can also be included on the typical cross section sketch and the plan view sketch on the last page of the form.

8.2.II.3.F. LATERAL ENCROACHMENTS

The purpose of this block is to determine if any lateral encroachments such as structures or bedrock are in close proximity to the outfall channel which may be a constraint for construction of outfall repairs. The assessment team should note any high embankments (over five feet high), any structures or buildings or any valley or bedrock that are at or adjacent to the outfall channel. More than one category can be checked if multiple encroachments exist along the channel. If there are no lateral encroachments, then that block should be checked. The location of lateral encroachments can also be included on the typical cross section sketch and the plan view sketch on the last page of the form.

8.2.II.3.G. OUTFALL CHANNEL BED MATERIAL

The purpose of this block is to determine the channel bed material to supplement the information within SHA's stormdrain inventory. The outfall channel can have a variety of bed material, but the most common is Earth/Mud/Silt/Clay or Vegetated/Grass which cover most natural channels. Other natural channels can be sand or gravel which are less common. Constructed channels can be either Paved/Concrete or Riprap. The assessment team should differentiate between constructed outfall protection and outfall channels. If a paved or riprap channel extends from the pipe outfall to within 100 feet of the outfall and then transitions to a natural channel, this should be considered as outfall protection and not outfall channel.

8.2.II.3.H. OUTFALL CHANNEL DIMENSIONS

The purpose of this block is to determine the dimensions of the outfall channel to supplement the information within SHA's stormdrain inventory. The channel length is measured downstream from the outfall protection to the nearest physical obstruction such as a fence or another stream. Usually there is no obstruction within 200 feet downstream (the downstream limit on the assessment). The channel width is measured at the bottom of the channel, from the toe of the slope at either bank. If the channel has water in it and the bottom is not visible, this dimension can be estimated. The bank heights should be measured from the toe of slope to the natural bank height. The assessment team may take several measurements along the channel to determine the average or representative dimensions.

8.2.II.3.I. OUTFALL CHANNEL BED CONDITION

The purpose of this block is to determine the bed erosion condition of the outfall channel to supplement the information within SHA's stormdrain inventory. The outfall channel bed erosion can be characterized qualitatively as the severity of the erosion along the bed. The assessment team should only account for active erosion that is directly attributed to the outfall. Below are the descriptions of each option:

Severe Bed Erosion: Severe bed erosion (head cutting) occurring along the channel. The bed erosion is highly unstable and is working up the channel. It is also likely the bed erosion has caused a large drop along the channel profile where the bed erosion is active.

Major Bed Erosion: Major bed erosion occurring along the channel. The bed erosion may be unstable but the drop along the channel profile is not very deep (< 6 inches).

Moderate Bed Erosion: Moderate bed erosion occurring along the channel. The bed erosion may be slightly unstable and it is uncertain whether the erosion is active along the channel.

Minor Bed Erosion: Minor bed erosion occurring along the channel. Any erosion that is observed is stable.

No Bed Erosion: No bed erosion is observed. Channel bed is stable.

If there is a headcut along the channel bed, the depth of the headcut should be measured and recorded on the plan view sketch on the last page of the form. A profile of the channel bed may also be provided to better illustrate the channel bed conditions.

8.2.II.3.J. OUTFALL CHANNEL BANK EROSION

The purpose of this block is to determine the bank erosion condition of the outfall channel to supplement the information within SHA's stormdrain inventory. The outfall channel bank erosion can be characterized in two ways: qualitatively (severity of the active erosion) or quantitatively (estimated percentage of the active erosion along the length of the channel). Only active bank erosion should be assessed. Erosion that has occurred in the past but is now stable should not be considered when completing this block. The assessment team should only account for active erosion that is directly attributed to the outfall. Below are the descriptions of each option for the two characterizations. The first defines the type of bank erosion representative for the entire channel length. The second defines the length of the stream bank impacted by erosion.

Severe Bank Erosion:	Areas of severe bank erosion where most to all of the bank is eroded.
Major Bank Erosion:	Areas of major bank erosion where large segments of the bank is eroded.
Moderate Bank Erosion:	Areas of moderate bank erosion where some of the bank is eroded.
Minor Bank Erosion:	Areas of minor bank erosion where small segments of the bank is eroded.
No Bank Erosion:	No bank erosion is observed.

The estimated percentage of active bank erosion is defined by ranges from low (0% to 6%) to high (76% to 100%). Although any active erosion should be considered when characterizing the percentage of the bank that is impacted, minor pockets of erosion along a channel can be disregarded when other areas of more significant erosion are considered for the percentage of active erosion. The photos below are examples of inactive erosion that should not be considered when evaluating bank erosion.

Figure 8.2.24: Inactive Erosion

8.2.II.3.K. OUTFALL CHANNEL BANK MATERIAL

The purpose of this block is to determine the outfall channel bank material to supplement the information within SHA's stormdrain inventory. The outfall channel may contain a variety of bank material, but the most common is Earth/Mud/Silt/Clay or Vegetated/Grass which cover most natural channels. Other natural channels may be sand, which is less common. Constructed channel banks can be Paved/Concrete, Riprap or Gabion/Imbricated Wall. The assessment team should be consistent when identifying bed and bank material, as they are usually of the same material.

8.2.II.3.L. ESTIMATED CHANNEL SLOPE

The purpose of this block is to determine the Estimated Channel Slope along the outfall channel which helps to characterize the Anticipated In-Stream Construction Difficulty on the Ranking Form. An estimate can be determined in the field by taking simple field measurements with an eye level. This measurement should be recorded along locations in the channel, where the bottom elevation can be clearly defined and the distance between the locations can be easily measured. Where there is a headcut along the channel, the channel slope should be measured from upstream to downstream of the headcut, to determine the proposed channel slope necessary for a restoration design.

8.2.II.3.M. OUTFALL CHANNEL HABITAT VALUE

The purpose of this block is to determine the value of the outfall channel habitat which helps to characterize the Outfall Channel Sensitivity on the Ranking Form. Channels with a high aquatic habitat value have perennial flow with deep pools and woody bank debris which offers shelter for fish and macroinvertebrates. Channels with a moderate aquatic habitat value have perennial flow with some woody debris, but few pools or other shelter for aquatic species. Channels with a low aquatic habitat value have no perennial flow and are usually dry drainage swales. Below are a few pictures illustrating the ranges of the aquatic habitat value.

Figure 8.2.25: Examples of Outfall Channel Habitat Values

8.2.II.3.N. OUTFALL CHANNEL MEANDER BENDS

The purpose of this block is to determine the channel meander bends at an outfall which helps to characterize the Site Design Considerations on the Ranking Form. Most channels are generally straight, which is the least restrictive of the condition for consideration of future restoration designs. Greater numbers of meander bends will contribute to greater site design restrictions. The meander bends should be measured in a representative channel section downstream from the outfall and should be measured as true bends and not slight variations in the flow path. The channel meander bends should be well illustrated on the plan view sketch on the last page of the form.

Figure 8.2.26: Example of Channel Meander Bends

8.2.II.3.O. OUTFALL CHANNEL FLOW REGIME

The purpose of this block is to define the flow regime within the outfall channel which supports several of the categories on the Ranking Form. Below are the descriptions of each option.

Ephemeral: Flow that is not present in the channel except after a recent rainfall event.

Intermittent: Flow that is present intermittently throughout the year, as a result of higher groundwater during wetter periods of the year.

Perennial: Flow that is present all year long, usually fed in part by upstream runoff and groundwater.

Tidal: Flow that is present all year long, influenced by tidal waters. Tidal flow is usually characterized by stagnant water.

Unknown: Cannot be determined due to a recent rainfall or time of year. If no flow is present in the channel, the default option is unknown.

8.2.II.3.P. RECORD ANY UNUSUAL COLORS OR SMELLS AT OUTFALL OR DOWNSTREAM CHANNEL

The purpose of this block is to record any unusual colors or odors that are observed in the flow downstream of the outfall. Noticeable water problems are often associated with unusual colors and odors. SHA continues to implement procedures for the detection and control of illicit spills and dumping to its storm drain system by regularly conducting visual inspections of stormwater outfalls as part of the Illicit Discharge Detection and Elimination Program. The assessment team should only record serious issues that will have a significant impact on the water quality of the channel. Minor issues such as trash, isolated oil sheens or a patch of foam should not be recorded.

8.2.II.3.Q. PHOTOS TAKEN

The purpose of this is to remind the assessment team to take an adequate number of photos of the outfall channel and to properly document where each photo was taken. During the assessment of the outfall channel, photos should be taken of the outfall channel bed, outfall channel banks, and any other photos deemed necessary by the assessment team. Immediately after photos are taken, photo ID numbers should be recorded.

8.2.II.3.R. COMMENTS REGARDING OUTFALL CHANNEL

The purpose of this block is to provide the assessment team with an area on the form to record pertinent information regarding the outfall channel, including those aspects which require additional description. It is also the part of the form where more specific information can be provided, such as erosion along the outfall channel or utilities encountered.

8.2.II.4 MISCELLANEOUS

Section 4 of the Field Measurements is the miscellaneous component which assesses the overall characteristics of the outfall, such as riparian conditions and ultimate downstream condition. The primary purpose of this section is to determine the riparian and downstream conditions which may influence the success of a proposed stream restoration.

8.2.II.4.A. PREDOMINANT RIPARIAN VEGETATION

The purpose of this block is to define the predominant riparian vegetation along the outfall channel to better characterize the site. The descriptions of each category are listed below:

Grass: Choose this category primarily for roadside or median channels not in close proximity to wooded areas.

Woods: Choose this category for wooded outfall channels where the majority of the overbank areas have canopy closure.

Brush: Choose this category for overgrown outfall channels where the majority of the overbank area does not have canopy closure.

None: Choose this category only rarely, when the channel overbank areas are bare-earth and non-vegetated.

8.2.II.4.B. RIPARIAN DENSITY

The purpose of this block is to define the density of the riparian vegetation along the outfall channel to better characterize the site. The descriptions of each category are listed below:

Low Density: Minimal vegetative cover with multiple bare spots.

Low to Moderate Density: Choose this category for wooded outfall channels where the majority of the overbank areas have tree cover.

Moderate Density: Moderate vegetative cover with some bare spots, but generally good cover.

High Density: High vegetative cover with few bare spots.

Very High Density or N/A: Very high vegetative cover with no discernable bare spots. This category should also be chosen when the overbank areas are non-vegetated, such as for medians where the adjacent roadway is the overbank area.

8.2.II.4.C. ULTIMATE DOWNSTREAM CONDITIONS

The purpose of this block is to define the ultimate downstream conditions beyond the outfall channel being assessed to better understand potential backwater influence on the channel. When assessing a headwall, Other should be selected and the downstream conveyance (pipe, culvert, etc.) can be provided in the space below. The descriptions of each category are listed below:

Existing Channel Continues: This option should be selected for the majority of the sites, as it is assumed the outfall channel will extend several hundred feet beyond each outfall. Since the limit of these assessments is 200 feet downstream, if the channel continues beyond this limit, this option should be selected.

Pond/Lake: Choose this category when the outfall channel discharges into an existing lake or pond, including a stormwater management pond, within the 200-foot assessment limit. If there is a pond or lake beyond the 200-foot limit, please note in the Comments at the end of this section.

Main Stream Channel: Choose this category when the outfall channel discharges into a larger stream or river within the 200-foot assessment limit. If there is a stream beyond the 200-foot limit, please note in the Comments at the end of this section.

Tidal Waters: Choose this category when the outfall channel discharges into tidal waters within the 200-foot assessment limit. If there are tidal waters beyond the 200-foot limit, please note in the Comments at the end of this section.

Other: There may be other types of outfall channel conveyances within the 200-foot assessment limit that can be noted here, including a downstream culvert, inlet or even no channel if the outfall eventually becomes sheet flow into the woods.

8.2.II.4.D. PHOTOS TAKEN

The purpose of this is to remind the assessment team to take an adequate number of photos of the outfall structure and to properly document where each photo was taken. During the assessment of the miscellaneous features of the channel, photos should be taken of the riparian vegetation, downstream conditions, and any other photos deemed necessary by the assessment team. Immediately after photos are taken, photo ID numbers should be recorded.

8.2.II.4.E. COMMENTS

The purpose of this block is to provide the assessment team with an area on the form to record pertinent information regarding the miscellaneous items on the form, including those aspects which require additional description.

8.2.II.5 OVERALL

Under Section 5 of the Field Measurements the assessment team may recommend removing the outfall site from further restoration consideration.

8.2.II.5.A. RECOMMEND REMOVING SITE FROM FURTHER RESTORATION CONSIDERATION:

The purpose of this block is a final analysis of the outfall channel to determine the need to perform a full restoration analysis. Even after assessing the outfall, if the assessment team feels that the outfall is in very stable condition, has low erosion potential, or that

SHA will not benefit from restoration opportunities, the assessment team should recommend removing the site from further recommendation.

8.2.II.5.B. COMMENTS

The purpose of this block is to provide the assessment team with an area on the form to record pertinent information that may not be included elsewhere on the form.

8.2.II.6 SKETCHES

Section 6 of the Field Measurements provides the assessment team space to provide sketches to better illustrate the channel conditions. Although photographs will provide visual depiction of the channel conditions, excessive vegetation or other factors may limit this information. The channel sketches will supplement the photographs and will allow the assessment team to provide additional measurements and key details as noted along the channel**.**

8.2.II.6.A. SKETCH THE TYPICAL STREAM CROSS-SECTION BELOW:

The purpose of this block is to provide the assessment team a place on the form to develop a more detailed sketch of the channel cross section to better characterize the site conditions. A detailed sketch of a typical channel cross-section should include approximate bank slopes, water level, and any erosion or vegetation directly associated with the banks.

8.2.II.6.B. SKETCH THE PLAN VIEW CHANNEL IN THE BOX BELOW:

The purpose of this block is to provide the assessment team a place on the form to develop a more detailed plan view sketch to better characterize the site conditions. A detailed plan view sketch of the channel should include several features such as scour hole location, outfall protection, nearby vegetation, utilities, and eroded banks. The assessment team should follow the legend provided on the field form. Most trees do not need to be included on the sketch, but significant trees should be shown which would have an impact on any restoration design. Significant trees include those growing adjacent to the outfall structure or outlet protection, or larger trees (greater than 24” diameter) growing along the banks.

8.3 OUTFALL CONDITION, RESTORATION & COST RATING FORM

The Outfall Condition, Restoration & Cost Rating Form (Rating Form) is intended to be completed by individuals with sufficient experience in outfall restoration requirements and techniques. The form is intended to be completed in the office with reference to the site Field Form, photographs, and input from the field crews that assessed the outfall. Field crews can complete the Rating Form if they have a sufficient level of competency and experience. Senior experienced staff will decide who completes the Rating Forms. If the Rating Form is completed in the field concurrently with the Field Form, the results should be reevaluated in the office with reference to all available information for the outfall.

The Rating Form uses information gathered from the Field Form to assign a numerical rating on a 1-5 scale for several specific items that will be used to determine the need and priority for outfall restoration. The Field Form should be used as a reference to complete the Rating Form; however, the rank of some items may be changed based on the ultimate judgment from senior staff. For most rating items, descriptions are provided directly on the Rating Form to assist the user in selecting the appropriate rating. When only three description categories are listed on the Rating Form, a value of 2 or 4 should be selected if the condition has characteristics in between adjacent descriptions. **Note: Higher rating values indicate a greater need or priority for outfall restoration.**

The Rating Form contains four sections: Public Safety, Outfall Condition, Outfall Restoration Potential, and Cost. The first two sections, Public Safety and Outfall Condition, are to be completed for every outfall that is located and assessed. If outfall restoration is recommended, then the last two sections, Outfall Restoration Potential and Cost, are also completed. If an outfall is unable to be located, the Rating Form should not be completed.

The sections of the Rating Form are discussed in detail below.

HEADER DATA

Similar to the Field Form, each Rating Form includes standard headers to be completed to identify the outfall being assessed and the members and company comprising the assessment team. On each page of the Rating Form, the MD SHA Structure ID is provided to properly identify which outfall the form is being completed. The MD SHA Structure ID is a unique identifier provided for each outfall structure by SHA to track in their database. SHA should provide STRUCTURE ID # for all outfall structures to be assessed.

In the header, the Assessment Team is the names of the individuals who complete the rating form and whom SHA can direct questions, if necessary. *The date is the calendar date on which the outfall assessment was performed.* This date should match the date at the top of the corresponding Field Form. The Firm/Agency is the name of the consultant firm that has been assigned to assess the outfall. The Nearest State Roadway is the SHA roadway nearest to the outfall, for example MD 100. The Nearest Cross Road is the nearest roadway crossing the state roadway (whether it's a state, county or local road). An example would be an outfall located near the crossing of MD 100 (Nearest State Roadway) and Coca Cola Drive (Nearest Cross Road).

8.3.I. PUBLIC SAFETY

Items in this category rate the overall threat to public safety. Any imminent problems that exist should be flagged for immediate notification to SHA.

8.3.I. A. PUBLIC SAFETY

Refer to Section II.1.B of the Field Form and pictures included in Section 8.2 of this document. *Any sites that receive a rating of 4 or 5 should be immediately reported to SHA.*

(5) Immediate Safety Hazard: Existing outfall condition presents an immediate safety hazard to pedestrians or vehicles. One example of an immediate hazard is a mass slope failure adjacent to the roadway which could result in the roadway failing. Another example is a missing or extremely damaged guard rail which would fail to protect vehicular traffic from a steep adjacent slope.

(4) High Safety Hazard: Existing outfall condition presents a high safety hazard to pedestrians or motor vehicles. Although the danger is not immediate, there is a high level of danger to pedestrians or vehicles if the hazard is not addressed in the near future. An example would be a damaged guard rail adjacent to a steep slope that may or may not withstand a direct impact from a vehicle.

(3) Moderate Safety Hazard: Existing outfall condition presents a moderate safety hazard to pedestrians or motor vehicles. This condition represents infrastructure that is damaged but can be repaired during regular maintenance activity. Examples include some slope erosion or failure adjacent to a roadway or guard rail that is moderately damaged.

(2) Low Safety Hazard: Existing outfall condition presents a low safety hazard to pedestrians or motor vehicles. This condition represents infrastructure that has some defects or damage, but does not need to be repaired, only monitored. Examples include minor slope erosion or a guard rail that has minor damage.

(1) No Safety Hazard: There is no safety hazard to pedestrians or vehicles due to the existing outfall condition.

Aside from an imminent and easily identifiable hazard, the public safety assessment can be a subjective assessment. Assessment teams should use professional judgment while conducting these assessments, but if unclear or unknown conditions are encountered, a senior staff member should be contacted for assistance. Senior staff should provide a periodic review of all the ratings to ensure an accurate and consistent assessment has been completed.

8.3.II. OUTFALL CONDITION

The Outfall Condition section of the Rating Form rates the condition of the outfall structure, outfall protection, outfall channel, and riparian density to determine the overall need for outfall restoration. When evaluating a headwall, the Rating Form rates the condition of the headwall, inflow channel and inflow channel protection. The rating is taken directly from the Field Form.

8.3.II.1. OUTFALL STRUCTURE

The structural condition of the outfall structure (or headwall) and pipe is rated.

8.3.II.1.A. OUTFALL STRUCTURE CONDITION

Refer to Section II.1.E of the Field Form.

(5) Severe Damage: There is severe damage to the existing outfall structure condition which requires significant repairs or replacement. Examples include major cracks and defects in the outfall structure and structural separation between the pipe and outfall structure.

(4) Major Damage: There is major damage to the existing outfall structure condition which may require repairs or replacement. This damage may include significant spalling or cracking of a concrete structure or major deformation of a metal structure.

(3) Moderate Damage: There is moderate damage to the existing outfall structure condition including some spalling or cracking of a concrete structure or moderate deformation of a metal structure.

(2) Minor Damage: There is minor damage to the existing outfall structure condition including minor cracking, chipping or other defects which do not need to be repaired at this time.

(1) No Damage: There is no damage to the outfall structure. This classification should also be chosen when there is no outfall structure (ex. protruding pipe) or when this category is not applicable.

8.3.II.1.B. OUTFALL PIPE CONDITION

Refer to Section II.1.H of the Field Form.

(5) Severe Damage: There is severe damage to the existing outfall pipe condition which requires significant repairs or replacement. Examples include a collapsed pipe, broken pipe or pipe with significant defects, or structural separation between the pipe and outfall structure.

(4) Major Damage: There is major damage to the existing outfall pipe condition which may require repairs or replacement. This damage may include significant spalling or cracking of a concrete pipe or major deformation of a metal pipe.

(3) Moderate Damage: There is moderate damage to the existing outfall pipe condition including some spalling or cracking of a concrete pipe or moderate deformation of a metal pipe. Patching may be required for repair.

(2) Minor Damage: There is minor damage to the existing outfall pipe condition including minor cracking, chipping, deformation or other defects which do not need to be repaired at this time.

(1) No Damage: There is no damage to the outfall pipe. This classification should also be chosen when the outfall pipe cannot be observed during the assessment.

8.3.II.2. OUTFALL PROTECTION

The condition of the outfall (or inflow) protection material and scour hole is rated.

8.3.II.2.A. OUTFALL PROTECTION CONDITION

Refer to Section II.2.D of the Field Form.

(5) Severe Damage (>75%):	Outfall protection is >75% damaged or displaced. In general, the concrete outfall protection has experienced severe damage including undermining and collapse and the concrete is completely broken into pieces. More than 75% of the riprap outfall protection is displaced further downstream. The outfall protection is not functioning where needed and requires significant repair or replacement.
(4) Major Damage (51-75%):	Outfall protection is 51-75% damaged or displaced. Concrete outfall protection has experienced major damage including some undermining and major cracks which result in the concrete being partially broken into pieces. Between 51% and 75% of the riprap outfall protection is displaced further downstream. Repair/replacement is needed.
(3) Moderate Damage (26-50%):	Outfall protection is 26-50% damaged or displaced. Concrete outfall protection has experienced moderate damage including erosion along the edges and moderate cracking which may result in the concrete breaking into pieces. Between 26% and 50% of the riprap outfall protection is displaced further downstream. Some repair/replacement is needed.
(2) Minor Damage (6-25%):	Outfall protection is 6-25% damaged or displaced. Concrete outfall protection has experienced minor damage including minor cracking or vegetative growth between the joints, which does not impact the function of the outfall protection. Between 6% and 25% of the riprap outfall protection is displaced further downstream. Minor repair/replacement may be needed.
(1) No Damage or N/A (0-5%):	Outfall protection is 0-5% damaged or displaced. Concrete outfall protection is in good condition and has negligible damage. Less than 6% of the riprap outfall protection is displaced further downstream. No repair or replacement is needed at this time. This classification should also be chosen when this category is not applicable.

8.3.II.2.B. SCOUR CONDITION

Refer to Section II.2.H and II.2.I of the Field Form. Preformed or natural scour holes that are stable should receive a rating of 1. Also, sites without a scour hole should receive a rating of 1. Indicators that a scour hole is not stable (i.e. still expanding) include disproportionate depth to pipe size, displacement of stone and/or active erosion within the scour hole that is endangering the banks or bed stability. The percentages included below are given as a rough guideline to assess the degree of instability at the scour hole. If the scour depth exceeds those listed but appears stable, the site should be given a rating of 1.

(5) Scour hole is not stable and the depth of the scour hole is >50% pipe diameter.

(4) Scour hole is not stable and the depth of the scour hole is 36-50% pipe diameter.

(3) Scour hole may be unstable and the depth of the scour hole is 21-35% pipe diameter.

(2) Scour hole may be slightly unstable and the depth of the scour hole is 6-20% pipe diameter.

(1) Scour hole is stable (regardless of depth), preformed, or the depth of the scour hole is >5% pipe diameter. This classification should also be chosen when no scour hole is present and this category is not applicable.

8.3.II.3. OUTFALL CHANNEL

The condition of the outfall (or inflow) channel bed and bank is rated.

8.3.II.3.A. OUTFALL CHANNEL BED CONDITION

Refer to Section II.3.I of the Field Form. This rating is for bed erosion directly attributed to the outfall being evaluated.

(5) Severe Bed Erosion: Severe bed erosion (head cutting) occurring along the channel. The bed erosion is highly unstable and is working up the channel. It is also likely the bed erosion has caused a large drop along the channel profile where the bed erosion is active.

(4) Major Erosion: Major bed erosion occurring along the channel. The bed erosion may be unstable but the drop along the channel profile is not very deep (< 6 inches).

(3) Moderate Bed Erosion: Moderate bed erosion occurring along the channel. The bed erosion may be slightly unstable and it is uncertain whether the erosion is active along the channel.

(2) Minor Bed Erosion: Minor bed erosion occurring along the channel. Any erosion that is observed is stable.

(1) No Bed Erosion: No bed erosion is observed. Channel bed is stable. This rating should also be chosen when there is no defined outfall channel and this category is not applicable.

8.3.II.3.B. OUTFALL CHANNEL BANK CONDITION

Refer to Section II.3.J of the Field Form. Bank erosion attributed to the outfall being evaluated should be rated.

(5) Severe Bank Erosion (>75%): Severe bank erosion is actively occurring along the channel. Bank erosion is highly unstable. In general, erosion is occurring along >75% of the channel banks.

(4) Major Bank Erosion (51-75%): Major bank erosion is actively occurring along the channel. In general, erosion is occurring along 51-75% of the channel banks.

(3) Moderate Bank Erosion (26-50%): Moderate bank erosion is actively occurring along the channel. In general, erosion is occurring along 26-50% of the channel banks.

(2) Minor Bank Erosion (6-25%): Minor bank erosion is actively occurring along the channel. In general, erosion is occurring along 6-25% of the channel banks.

(1) No Bank Erosion (0-5%): No active bank erosion is occurring along the channel. In general, erosion is occurring along <6% of the channel banks. This rating should also be chosen when there is no defined outfall channel and this category is not applicable.

8.3.II.4. MISCELLANEOUS

The condition of the riparian vegetation and density adjacent to the outfall (or inflow) channel is rated.

8.3.II.4.A. RIPARIAN VEGETATION AND DENSITY

Refer to Sections II.4.A and II.4.B of the Field Form.

(5) Low Density:	Low density vegetation, presence of numerous bare spots.
(4) Moderate Density:	Moderate density vegetation, some bare spots observed.
(3) High Density, Grass:	High density vegetation with few or no bare spots. Predominant vegetation is grass.
(2) High Density, Woods or Brush:	High density vegetation with few bare spots. Predominant vegetation is woods or brush.
(1) Very High Density, Woods or Brush:	Very high density vegetation with no observed bare spots. Predominant vegetation is woods or brush. This rating should also be chosen when there is no defined outfall channel and this category is not applicable.

8.3.II. 5. OVERALL

8.3.II.5.A. RECOMMEND REMOVING SITE FROM FURTHER RESTORATION CONSIDERATION?

Not all outfall sites assessed should be recommended for restoration consideration. If an outfall and downstream channel are stable, then restoration is not necessary at the outfall. This section evaluates whether or not a site should be removed from further consideration.

Since the intent of this inspection is to focus only on eroded/scoured outfalls, it should be noted that sites with signs of aggradation or in need of routine maintenance are not to be considered for restoration. Most headwalls and inflow channels would be included under this category, as these sites are usually not eroded to the same degree as outfalls. However, any apparent maintenance needs at a headwall or outfall structure should be noted on the Field Form to alert SHA of the issue(s).

Sites that are removed from further consideration will not be rated for Outfall Restoration Potential or Cost. *If the Yes box is checked, the user stops at this point and Rating Form is considered completed for the site.*

8.3.III. OUTFALL RESTORATION POTENTIAL

The Outfall Restoration section of the Rating Form rates the potential ecological benefit of restoration, design constraints, land use, permitability, and constructability to determine the priority for outfall restoration.

8.3.III.1. ECOLOGICAL BENEFIT OF RESTORATION

The outfall (or inflow) channel sensitivity and downstream channel impairment are rated.

8.3.III.1.A. OUTFALL CHANNEL SENSITIVITY

Refer to Section II.3.M of the Field Form. Channels that are sensitive headwater streams or have a high habitat benefit are prioritized for restoration due to the enhanced ecological benefit that restoration may provide. Therefore, outfall channels with higher sensitivity generate a higher restoration rating.

(5) Channel is a headwater stream or a well defined stream channel. High aquatic habitat characterized by deep pools, stony riffles, woody bank debris, and overhead canopy.

(4) Channel is a defined stream channel with moderate habitat value (some debris, shallow pools, stony riffles).

(3) Channel is a defined stream channel with poor habitat value and debris.

(2) Channel is poorly defined or lacks perennial or intermittent flow. Moderate aquatic habitat value is observed.

(1) Channel is poorly defined or lacks perennial or intermittent flow. Low aquatic habitat value is observed (i.e. channel is a roadside ditch).

8.3.III.1.B. DOWNSTREAM CHANNEL IMPAIRMENT

Refer to Section I.1.F of the Field Form. Channels that are impaired for one or more impairments are prioritized and receive a higher restoration rating.

(5) Downstream channel is an impaired waterbody on the 303d list, listed for more than 3 impairments.

(4) Downstream channel is an impaired waterbody on the 303d list, listed for 1-3 impairments.

(3) Downstream channel is not an impaired waterbody on the 303d list, but is obviously degraded. An example may be the presence of trash, debris, excessive algal growth or unusual odors.

(2) Downstream channel is not an impaired waterbody on the 303d list, but appears slightly degraded. An example may be the presence of sporadic algal growth or unusual odors.

(1) Downstream channel is not impaired or affected by outfall condition.

8.3.III.2. DESIGN CONSTRAINTS

The anticipated design constraints due to site design limitations, infrastructure and utilities are rated. Further, the potential to install a drop structure is evaluated.

8.3.III.2.A. SITE DESIGN LIMITATIONS

There are numerous factors that can present site design limitations, and many of these limitations will not be identified until advanced restoration project design stages. However, some of the data collected on the Field Form can provide broad indications of obvious design limitations that may exist. The fewer design limitations that exist, the easier the anticipated restoration design and therefore the higher the restoration rating.

Users should read the list of bulleted items and circle those that apply in the following categories:

- Outfall Configuration - Refer to Section II.3.C. of the Field Form.
- Channel Skew - Refer to Section II.3.D. of the Field Form.
- Encroachments - Refer to Section II.3.F. of the Field Form.
- Outfall Meanders - Refer to Section II.3.N. of the Field Form.

A total of 4 bullets should be circled. An example is shown below:

2. DESIGN CONSTRAINTS			
A. Site Design Limitations *(See Sections II.3.C,D,F, and N of Field Form)*	Few site design limitations: • No additional channels entering downstream channel area • No/minor skew (<30°) between downstream channel and culvert • No bedrock, unstable soils (e.g. sandy banks, expansive clay soils), or adjacent structures. • Characterized by generally straight flow path	Some site design limitations: • Single channel entering downstream channel area • Downstream channel skew to culvert is 30-60° • Design may be limited by bedrock, unstable soils, or adjacent structures • Characterized by tortuous flow paths (1-2 meanders/100' channel length)	Numerous site design limitations: • Multiple channels coming into downstream channel area • Downstream channel skew to culvert is >60° • Design is constrained due to bedrock, unstable soils, or adjacent structures. • Characterized by highly tortuous flow paths (3+ meanders/100' channel length)
	☐5 ☒4	☐3	☐2 ☐1

The matrix below can be used to assign a numerical rank, depending on the number of items circled in each of the three boxes. For the example shown above, the rank is assigned a value of 4.

Few Limitations	Some Limitations	Numerous Limitations	**Site Design Limitations Ranking**
4	0	0	**5**
3	1	0	**5**
3	0	1	**4**
2	2	0	**4**
2	1	1	**4**
2	0	2	**3**
1	3	0	**3**
0	4	0	**3**
0	3	1	**3**
1	2	1	**3**
0	2	2	**2**
1	1	2	**2**
1	0	3	**2**
0	1	3	**1**
0	0	4	**1**

8.3.III.2.B. INFRASTRUCTURE CONSTRAINTS

Refer to Sections II.2.E and II.3.E of the Field Form. Utility conflicts will generally complicate restoration design, particularly if the utilities are located in close proximity to the outfall or in the downstream channel. Overhead utility conflicts may present fewer constraints. The fewer infrastructure constraints that exist at a site, the easier the anticipated restoration design. Therefore, fewer infrastructure constraints result in a higher restoration rating.

(5) Utility conflicts are not observed in-channel or overhead and present no project constraints.

(4) Utility conflicts are observed overhead or in close proximity to the site and present no project constraints. Utilities located outside potential work area, but location needs to be identified for equipment movement and operation.

(3) Utility conflicts exist overhead or in close proximity to the site and present minor project constraints. Utilities located within work zone, but no direct impact is anticipated.

(2) Utility conflicts exist overhead or in close proximity to the site and present moderate project constraints. Utilities are located within work zone and may be temporarily impacted or only impact one utility. No relocation is anticipated.

(1) Utility conflicts exist in-channel and present major project constraints. Project restoration effort would directly impact one or more utilities and may require relocation of services.

8.3.III.2.C. POTENTIAL TO LOWER OUTFALL TO STREAMBED BY INSTALLING A DROP STRUCTURE?

Refer to Section II.2.F and II.3.O of the Field Form. Due to channel bed erosion, at times the stream channel below an outfall will be several feet lower than the outfall pipe invert. If the downcutting is significant, the result may be a failed outfall structure or an elevated outfall pipe and scouring. To stabilize the outfall requires dissipating the energy in a safe manner. One solution is to construct a drop manhole at the end of the pipe with a lower, and usually flatter, outfall structure. The use of this approach is often limited by whether the receiving channel is jurisdictional Waters of the U.S., as the resources agencies do not favor piping open channels and/or blocking the movement of aquatic species. If, for example, the outfall is a cross culvert with perennial flow, the agencies will most likely require a step pool or similar fish passage structure that represents a more complex and expensive solution.

For headwalls, this category is not applicable. The assessment team should select (5), as a drop structure is not necessary or practical for restorations at headwalls.

Figure 8.3.1: Examples of Outfalls with Potential for Drop Structures

(5) **Not Applicable: the outfall is already at the level of the downstream channel.** A drop structure is not necessary at this site.

(4) **Not Applicable: the outfall has a drop of 1-foot or less to the downstream channel.** A drop structure is likely not necessary at this site.

(3) **Yes: the outfall is located above the downstream channel and comprises a closed stormdrain system.** There is no perennial flow in the outfall. A drop structure could be installed to lower the outfall to the channel elevation.

(2) **Yes, Constrained: the outfall is located >1-foot above the downstream channel but the site is constrained.** The outfall comprises a closed stormdrain system and there is no perennial flow in the outfall. However, the installation of a structure is limited due to utilities, high flows, or other site constraints.

(1) **No: the outfall is located >1-foot above the downstream channel but perennial flow exists through the outfall.** A drop structure cannot be designed at this site. A more complex and expensive solution such as a step pool system is likely required.

8.3.III.3. LAND USE

8.3.III.3.A. LAND OWNERSHIP

Land Ownership refers to the land ownership of the potential restoration impact area. Refer to Section I.1.G of the Field Form. The category of land ownership will likely affect the easement process and it is assumed that the necessity for an easement has the potential to delay construction. Therefore, restoration sites located on privately owned land generate a lower restoration rating.

(5) SHA Right-of-Way:	Restoration area is located on SHA right-of-way and ownership does not present any constraints for project implementation.
(4) Parks or Other Public Lands:	Restoration area is located on public land where ownership presents minor constraints for project implementation.
(3) Unknown or Other:	Land ownership is unknown or fits into a different category than those listed.
(2) Private (Non-residential):	Restoration area is located on private non residential land. Land ownership may present moderate constraints.
(1) Private (Residential):	Restoration area is located on private residential property. Land ownership presents major constraints to implementation.

8.3.III.4. PERMITABILITY

8.3.III.4.A. STREAM USE

Refer to Section I.1.D of the Field Form. Permitability reflects the effort to acquire permit approvals and potential limitations that the agencies may place on the project design. Channels that are non-jurisdictional (i.e. not classified as Waters of the U.S.) will have limited effort and little, if any limitations; especially if a 100-yr floodplain is not present. Jurisdictional channels that are Stream Use I through IV will be subject to permitting requirements and potentially subject to limitations that eliminate or increase the complexity of the design and construction (e.g. fish passage structures).

(5) Stream use of downstream channel is non-jurisdictional.

(1) Stream use of downstream channel is Use I through Use IV.

8.3.III.4.B. ANTICIPATED PERMITTING IMPACTS

Refer to Section I.1.E of the Field Form. Numerous impacts to natural resources and special designation areas will result in a more intensive permitting effort and may affect project construction.

(5) No Impacts: No impacts to wetlands, forest, floodplain, special protection area, critical area or Tier II watershed anticipated.

(4) Minimal Impacts: Minimal impacts to wetlands, forest, floodplain, special protection area, critical area or Tier II watershed anticipated.

(3) Unknown Impacts: Permitting impacts are unknown.

(2) Moderate Impacts: Moderate impacts to wetlands, forest, floodplain, special protection area, critical area or Tier II watershed anticipated.

(1) Major Impacts: Major impacts to wetlands, forest, floodplain, special protection area, critical area or Tier II watershed anticipated.

8.3.III.5. CONSTRUCTABILITY

Potential constructability constraints due to anticipated construction difficulty or accessibility/MOT are rated.

8.3.III.5.A. ANTICIPATED CONSTRUCTION DIFFICULTY

Channel slope, channel incision, and the anticipated maintenance of streamflow can provide broad indications of site construction difficulties that may exist. The fewer construction difficulties that exist, the easier the anticipated restoration design and the higher the restoration rating recieved.

Users should read the list of bulleted items and circle those that apply in the following categories:

- Channel Slope - Refer to Section II.3.L of the Field Form.
- Channel Incision - Refer to Section II.3.H of the Field Form.
- Maintenance of Streamflow Anticipated:
    - Minimal - Restoration project limited to repair or addition of outfall protection. The duration of the project will be less than 2 weeks.
    - Moderate - Restoration project involves more than simple repair or replacement of outfall protection. Duration of the project will likely be more than 2 weeks.
    - Major - Restoration project involves restoration on more than 100-feet of the downstream channel. Duration of the project will be more than 2 weeks.

Figure 8.3.2: Examples of Maintenance of Streamflow

A total of 3 bullets should be circled. An example is shown below:

5. CONSTRUCTABILITY			
A. Anticipated Construction Difficulty	Minimal difficulties anticipated: • Channel slope is < 2% • Channel not incised • Minimal maintenance of streamflow anticipated	Some difficulties anticipated: • Channel slope is 2-4% • Channel moderately incised • Moderate maintenance of streamflow anticipated	Major difficulties anticipated: • Channel slope is >4% • Channel is greatly incised • Major maintenance of streamflow anticipated
	☐5 ☐4	☐3	☐2 ☐1

The matrix below can be used to assign a numerical rank, depending on the number of bullets circled in each of the three boxes. For the example shown above, the rank is assigned a value of 1.

Minimal Difficulties	Some Difficulties	Major Difficulties	**Anticipated Construction Difficulty Ranking**
3	0	0	**5**
2	1	0	**5**
2	0	1	**4**
1	2	0	**4**
1	1	1	**3**
0	3	0	**3**
1	0	2	**2**
0	2	1	**2**
0	1	2	**1**
0	0	3	**1**

8.3.III.5.B. OUTFALL ACCESSIBILITY/MOT CONSIDERATIONS

Refer to Section II.1.K of the Field Form. If a site is difficult to access, construction and mobilization efforts will be further complicated. If sensitive areas are impacted by site access, additional permitting requirements will be triggered. Further, it is assumed that greater MOT requirements have the potential to delay construction. Therefore, the sites with easier access and minimal MOT requirements generate a higher restoration rating.

(5) Good Access/Minimal MOT: Outfall site is in an open area within public ownership and allows for easy access for heavy equipment using existing roads or trails. Minimal MOT requirements are anticipated as adjacent roadways have slower traffic and wider shoulders.

(4) Fair to Good Access: Outfall site has some access limits such as guardrail, moderate slopes from the shoulder to the outfall or adjacent forested areas. No trees or guardrail will need to be removed, but heavy equipment would need to be careful when accessing the site. Minimal to moderate MOT requirements are anticipated as adjacent roadways have moderate speeds and wider shoulders.

(3) Fair Access/Moderate MOT: Outfall site is adjacent to forested or developed areas which may limit access to the site. Access may require tree removal or impacts to landscaped areas. Guard rails are present which may need to be removed for site access. Moderate MOT requirements are anticipated as adjacent roadways have moderate traffic speeds and some shoulder areas.

(2) Difficult to Fair Access: Outfall site is adjacent to heavily forested or developed areas which will limit access to the site. Access will likely require tree removal or impacts to landscaped areas. Guard rails are present which will need to be removed for site access. Moderate to major MOT requirements are anticipated as adjacent roadways have high traffic speeds and some shoulder areas.

(1) Difficult Access/Major MOT: Access is constricted to the outfall site by permanent structures such as fences, traffic barriers, or noise walls. Access may also be restricted by permit requirements if there is a need to cross wetlands, steep slopes, or sensitive areas. Major MOT requirements are anticipated as adjacent roadways have high speed traffic and little to no shoulder area.

8.3. IV. COST

The Cost section of the Rating Form rates several factors that are expected to influence the relative cost of implementing an outfall restoration project. Higher cost rating values indicate a lower anticipated project cost, whereas lower values indicate a higher anticipated project cost. With the exception of the Outfall Energy category, the rating is taken directly from the Field Form and Rating Form and requires no further interpretation. The cost ratings are intended only for comparative purposes to give an approximate indication of which restoration projects will be more costly to implement. The cost factors are listed below.

8.3.IV.A. OUTFALL ENERGY

Refer to Section II.2. of the Field Form. It is assumed that higher energy systems will generally require larger outfall (or inflow) protection or stronger bank stabilization techniques, which will result in a higher restoration costs compared to low energy systems. Therefore, higher energy systems generate a lower rating.

(5) System appears to be low energy, generally characterized by use of no protection or Class I riprap and outfall protection in good condition.

(4) System appears to be low to moderate energy, generally characterized by use of Class I or II riprap and outfall protection in fair condition.

(3) System appears to be moderate energy, generally characterized by use of Class II riprap and outfall protection in moderate condition.

(2) System appears to be moderate to high energy, generally characterized by use of Class II or Class III riprap and outfall protection in poor condition.

(1) System appears to be high energy, generally characterized by use of Class II or III riprap, gabions or concrete, and outfall protection in very poor condition.

8.3.IV.B. SIZE OF OUTFALL PIPE

Refer to Section II.1.I or II.1.J of the Field Form. It is assumed that larger outfalls in need of restoration will generally require more grading, outfall protection materials, maintenance of streamflow, etc. compared to smaller outfalls. The result is a higher anticipated restoration cost. Therefore, larger outfalls generate a lower rating.

(5) Pipe diameter is <18 inches.

(4) Pipe diameter is 18-35 inches.

(2) Pipe diameter is 36-48 inches.

(1) Pipe diameter is >48 inches.

8.3.IV.C. EASEMENT REQUIREMENTS

Refer to Section I.1.G of the Field Form. It is assumed that the necessity for an easement has the potential to delay construction and increase cost. Therefore, the need for an easement generates a lower rating.

(5) Site is located entirely on SHA right of-way. No easement is required for access and construction.

(1) A portion of the site or construction area is located on property other than SHA right-of way. An easement will be required for access and construction.

8.3.IV.D. OUTFALL STRUCTURE CONDITION

Total the rating points from Section II.1 Outfall Structure of the Rating Form. The score will range from 2 to 10 points. It is assumed that outfall structures in poor condition, which should receive a higher outfall structure score, will result in a higher cost associated with repair of the outfall structure. Therefore, an outfall structure in poor condition generates a lower rating.

(5) The total score is 2 points. The anticipated cost associated with repair of the outfall structure condition is minimal.

(4) The total score ranges from 3-4 points. The anticipated cost associated with repair of the outfall structure condition is low.

(3) The total score ranges from 5-6 points. The anticipated cost associated with repair of the outfall structure condition is moderate.

(2) The total score ranges from 7-8 points. The anticipated cost associated with repair of the outfall structure condition is high.

(1) The total score ranges from 9-10 points. The anticipated cost associated with repair of the outfall structure condition is very high.

8.3.IV.E. OUTFALL PROTECTION CONDITION

Total the rating points from Section II.2 Outfall Protection of the Rating Form. The score will range from 2 to 10 points. It is assumed that outfall protection in poor condition, which should receive a higher outfall protection score, will result in a higher cost associated with repair/replacement of the protection material. Therefore, outfall protection in poor condition generates a lower rating.

(5) The total score is 2 points. The anticipated cost associated with repair of the outfall protection is minimal.

(4) The total score ranges from 3-4 points. The anticipated cost associated with repair of the outfall protection is low.

(3) The total score ranges from 5-6 points. The anticipated cost associated with repair of the outfall protection is moderate.

(2) The total score ranges from 7-8 points. The anticipated cost associated with repair of the outfall protection is high.

(1) The total score ranges from 9-10 points. The anticipated cost associated with repair of the outfall protection is very high.

8.3.IV.F. OUTFALL CHANNEL CONDITION

Total the rating points from Section II.3 Outfall Channel of the Rating Form. The score will range from 2 to 10 points. It is assumed that outfall channels in poor condition, which should receive a higher outfall channel score, will result in a higher cost associated with restoration of the channel. Therefore, an outfall channel in poor condition generates a lower rating.

(5) The total score is 2 points. The anticipated cost associated with repair of the outfall channel is minimal.

(4) The total score ranges from 3-4 points. The anticipated cost associated with repair of the outfall channel is low.

(3) The total score ranges from 5-6 points. The anticipated cost associated with repair of the outfall channel is moderate.

(2) The total score ranges from 7-8 points. The anticipated cost associated with repair of the outfall channel is high.

(1) The total score ranges from 9-10 points. The anticipated cost associated with repair of the outfall channel is very high.

8.3.IV.G. ANTICIPATED DESIGN EFFORT

Total the rating points from Section III.2 Design Constraints of the Rating Form. The score will range from 3 to 15 points. It is assumed that less design constraints will result in a lower cost. Therefore, a high design score generates a higher rating.

(5) The total score is 14-15 points. The anticipated cost associated with restoration design is minimal.

(4) The total score ranges from 11-13 points. The anticipated cost associated with restoration design is low.

(3) The total score ranges from 8-10 points. The anticipated cost associated with restoration design is moderate.

(2) The total score ranges from 5-7 points. The anticipated cost associated with restoration design is high.

(1) The total score ranges from 3-4 points. The anticipated cost associated with restoration design is very high.

8.3.IV.H. ANTICIPATED LEVEL OF PERMITTING

Total the rating points from Section III.4 Permitability of the Rating Form. The score will range from 2 to 10 points. It is assumed that less permitting constraints will result in a lower cost. Therefore, a high permitability score generates a higher rating.

(5) The total score ranges from 6-10 points. The anticipated cost associated with permitting is minimal.

(4) The total score is 5 points. The anticipated cost associated with permitting is low.

(3) The total score is 4 points. The anticipated cost associated with permitting is moderate.

(2) The total score is 3 points. The anticipated cost associated with permitting is high.

(1) The total score is 2 points. The anticipated cost associated with permitting is very high.

8.3.IV.I. ANTICIPATED CONSTRUCTION EFFORT

Total the rating points from Section III.5 Constructability of the Rating Form. The score will range from 2 to 10 points. It is assumed that sites that are readily constructable and easier to access will result in a lower cost. Therefore, a high constructability score generates a higher rating.

(5) The total score ranges from 9-10 points. The anticipated cost associated with restoration construction is minimal.

(4) The total score ranges from 7-8 points. The anticipated cost associated with restoration construction is low.

(3) The total score ranges from 5-6 points. The anticipated cost associated with restoration construction is moderate.

(2) The total score ranges from 3-4 points. The anticipated cost associated with restoration construction is high.

(1) The total score is 2 points. The anticipated cost associated with restoration construction is very high.

8.3.V. POTENTIAL DESIGN RECOMMENDATIONS

The final section of the Ranking Form allows users to note potential repair strategies or other alternative restoration opportunities at the outfall. This section is optional for completion and any suggested recommendations will be noted only as comments. Subsequent investigations by SHA at a later project phase will be required before final restoration design concepts are developed.

In some cases, alternative restoration techniques, such as concrete channel removal or end of pipe treatment, may be available at the outfall location. These opportunities are outside the scope of this project, but may be good opportunities for other SHA TMDL initiatives and therefore should be noted. Any recommended strategies should be described under the Notes block.

8.4 SITE RANKING

The final step in the outfall assessment protocol is to rank the sites to determine a priority for restoration. Outfalls and headwalls are evaluated using a tiered approach considering four categories in order of importance: 1. Public Safety, 2. Outfall Channel and Structure Stability, 3. Restoration Potential, and 4. Cost.

The Outfall-Headwall Ranking Summary spreadsheet uses the information from the Rating Form to generate a final ranking for each evaluated site. Since the approach to outfall and headwall restorations will be different, the two types of structures should not be recorded and evaluated within the same tables in the spreadsheet. Instead, separate tabs within the spreadsheet (one for outfall structures and one for headwalls) should be used and each type of structure should have its own priority ranking. The first tab (Weighting Summary) includes the weighted value for each of the items that are scored on the Rating Form. The weighted values are assigned to emphasize the importance of the evaluated items for overall restoration need. The weighting factors may frequently be reevaluated and modified by SHA to ensure that the most appropriate sites are being prioritized.

The second tab (Outfall Score Tally) includes the tabulation sheet which allows the assessment team to input rating data for outfalls to produce final ranking tallies for each of the four categories: Public Safety, Outfall Channel and Structure Stability, Outfall Restoration Potential, and Cost. The fourth tab (Headwall Score Tally) includes a similar tabulation sheet to input rating data for headwalls and inflow channels. The first two categories on these tabulation sheets, Public Safety and Outfall Condition, will be scored for every outfall (and headwall) that is located and assessed. If outfall (or headwall) restoration is recommended, then the last two categories, Outfall Restoration Condition and Cost, are also scored. If an outfall or headwall is unable to be located, the structure should receive zero scores for all four ranking categories.

Figure 8.4.1 shows the Outfall Score Tally tab that has been completed for three example outfalls. The first outfall, Structure No. 1601000.001, was in the worst condition and ranks highest for Channel and Structure Stability. In this example, the outfall was recommended for further restoration consideration; therefore, it was scored for the final two categories, Outfall Restoration Potential and Cost. The second outfall, Structure No. 1601000.002, was in good condition and received a lower ranking for Channel and Structure Stability. This site was not recommended for further restoration consideration; therefore, the ranking did not continue for the last two categories. The final outfall, Structure No. 1601000.003, was unable to be located and received 0 scores for all ranking categories.

A comment box is provided at the bottom of each structure column to summarize key information for the outfall or headwall. If a structure cannot be located, or is not recommended for restoration, this information should be noted in the comment box. Comments can also highlight safety concerns or potential illicit connections that were observed at a particular outfall.

SHA Outfall Inspections
County and Route Number

ACCUMULATED FIELD SCORES FROM OUTFALL ASSESSMENT			GIS ID	001	002	003
			Stru. No.	1600001.001	1600002.001	1600003.01
	Category	Factor	Weight			
I. PUBLIC SAFETY						
I.A	SAFETY	Public Safety	1	1	1	
II. OUTFALL CONDITION						
II.1.A	OUTFALL STRUCTURE	Outfall Structure Condition	2	2	1	
II.1.B	OUTFALL STRUCTURE	Conveyance Pipe Condition	2	1	1	
		Outfall Structure Points Total		**3**	**2**	**0**
II.2.A	OUTFALL PROTECTION	Outfall Protection Condition	5	3	1	
II.2.B	OUTFALL PROTECTION	Scour Condition	5	2	2	
		Outfall Protection Points Total		**5**	**3**	**0**
II.3.A	OUTFALL CHANNEL	Outfall Channel Bed Condition	5	2	1	
II.3.B	OUTFALL CHANNEL	Outfall Channel Bank Erosion	10	4	1	
		Outfall Channel Points Total		**6**	**2**	**0**
II.4.A	MISCELLANEOUS	Riparian Vegetation and Density	1	2	3	
III. OUTFALL RESTORATION POTENTIAL						
III.1.A	ECOLOGICAL BENEFIT	Outfall Channel Sensitivity	2	1		
III.1.B	ECOLOGICAL BENEFIT	Downstream Channel Impairment	6	5		
III.2.A	DESIGN CONSTRAINTS	Site Design Limitations	3	3		
III.2.B	DESIGN CONSTRAINTS	Infrastructure Constraints	4	5		
III.2.C	DESIGN CONSTRAINTS	Potential to Lower Outfall?	1	4		
		Design Points Total		**12**	**0**	**0**
III.3.A	LAND USE	Land Ownership	8	5		
III.4.A	PERMITABILITY	Stream Use	1	5		
III.4.B	PERMITABILITY	Permitting Impacts	5	5		
		Permittability Points Total		**10**	**0**	**0**
III.5.A	CONSTRUCTABILITY	Construction Difficulty	5	3		
III.5.B	CONSTRUCTABILITY	Accessibility/MOT	5	4		
		Constructability Points Total		**7**	**0**	**0**
IV. COST						
IV.A	COST	Outfall Energy	2	3		
IV.B	COST	Size of Outfall	1	2		
IV.C	COST	Easement Requirements	1	5		
IV.D	COST	Outfall Structure Condition	1	4	0	0
IV.E	COST	Outfall Protection Condition	1	3	0	0
IV.F	COST	Outfall Channel Condition	1	3	0	0
IV.G	COST	Anticipated Design Effort	1	4	0	0
IV.H	COST	Anticipated Level of Permitting	1	5	0	0
IV.I	COST	Anticipated Construction Effort	1	4	0	0
		SAFETY TOTAL:		**1**	**1**	**0**
		CHANNEL AND STRUCTURE STABILITY TOTAL:		**83**	**37**	**0**
		OUTFALL RESTORATION POTENTIAL TOTAL:		**170**	**0**	**0**
		COST TOTAL:		**36**	**0**	**0**
				COMMENTS:	**COMMENTS:**	**COMMENTS:**
				Outfall in need of restoration. Stabilize banks, repair outfall protection	Outfall not recommended for restoration.	Outfall not located.

Figure 8.4.1: Outfall Score Tally for three sample outfalls

The third tab (Outfall Prioritization Summary) of the Outfall-Headwall Ranking Summary spreadsheet presents a summary of the outfall site scores. The fifth tab (Headwall Prioritization Summary) of the Outfall-Headwall Ranking Summary spreadsheet presents a summary of the headwall site scores. The scores for outfalls or headwalls can be easily sorted for easy reference and evaluation. A tiered approach is presented to determine priority outfalls/headwalls for restoration:

RAPID ASSESSMENT GUIDELINES FOR OUTFALL CHANNELS: OUTFALL CONDITION AND RESTORATION POTENTIAL

1. Sites are first to be sorted based on the Public Safety hazard. *Any sites that receive a high ranking (5 or 4) in this category should be flagged for immediate notification to SHA.*

2. Sites are then sorted based on the Outfall Channel and Structure Stability. This ranking determines the overall need for restoration. A higher rank indicates a site in poor condition and in need of restoration. Sites that score the highest in this category will be selected for further evaluation in terms of Outfall Restoration Potential and eventually Cost. If a site ranks very low in this category, then it should likely be removed from further consideration and not evaluated for the next two categories. This step can be used as quality control check to ensure that sites are being rated appropriately.

3. Next, sites are sorted based on the Outfall Restoration Potential score. A higher rank in this category indicates that a restoration project will be easier to implement. A lower rank means that the anticipated project implementation will be difficult.

4. Finally, sites are sorted based on the Cost score. A higher rank in this category indicates a lower anticipated project cost. A lower rank in this category means that the anticipated project cost is high.

8.5 OUTFALL CHANNEL ASSESSMENT DELIVERABLES

The Outfall Channel Assessment Deliverables include all forms and other documentation to be submitted to SHA at the completion of the assigned outfall assessment task. The deliverables include copies of all field and ranking forms used for the assessments, a summary memo, a summary spreadsheet of all sites providing a prioritized listing of each outfall for restoration potential and photo documentation from each outfall assessment. The following sections provide a brief description of each deliverable.

8.5.I FIELD FORM AND RANKING FORM

Each completed Field Form and Ranking Form should be scanned and electronic copies (PDF format) of each form should be submitted to SHA.

8.5.II SUMMARY MEMO, OUTFALL-HEADWALL RANKING SUMMARY SPREADSHEET AND PRIORITIZATION LISTS

The Summary Memo is a Word document which summarizes the results of the outfall assessments and provides additional pertinent information to SHA. The Summary Memo should identify the roadway limits where outfalls were assessed. Otherwise, there is no prescribed format for the Summary Memo as it is only meant to supplement the data provided in the spreadsheet and forms. Each assessment team may determine what information is most relevant to highlight in the Summary Memo, such as potential illicit connections or sites where a BMP retrofit may be recommended. It is suggested that the Summary Memo include a listing of all outfalls which are high priority sites recommended for restoration.

The Outfall-Headwall Ranking Summary spreadsheet should include rankings for outfalls and for headwalls. The weighted ranking scores are compiled on the Outfall Score Tally tab (or the Headwall Score Tally tab) of the spreadsheet. The tabs should be populated with outfall data (or headwall data depending on which tab is being compiled) and saved as a PDF. The weighted ranks are summarized on the Outfall and Headwall Prioritization Summary tabs of the spreadsheet. The two lists should be sorted by all four prioritization categories: Public Safety, Outfall Channel and Structure Stability, Outfall Restoration Potential, and Cost. The tabulated scores in the Outfall and Headwall Prioritization Summaries should be sorted with the highest ranking sites listed first followed sequentially by the remaining sites in order of decreasing rank. As the outfall (or headwall) lists are sorted by each of the four categories above, a PDF should be generated to capture the priority ranking for each tier.

One final combined PDF containing the site score tallies and the eight sorted prioritization summaries (four for outfalls and four for headwall) should be compiled and an electronic copy should be submitted to SHA. An excel version of the populated Outfall-Headwall Ranking Summary spreadsheet should also be submitted to SHA.

8.5.III SITE ASSESSMENT PHOTO FORMATTING

The assessment team should download and rename photos immediately following each field day. Photos will be provided in JPEG format. Each photo should have a date stamp in the upper left-hand corner and include a watermark with the SHA Structure ID Number and brief photo description. JPEG files should be renamed using the SHA Structure ID Number, followed by one of the abbreviations listed in the following Table, and the date of the field visit.

Abbreviation	Name	Abbreviation	Name
OS	Outfall Structure	OCB	Outfall Channel Bed
DC	Downstream Channel	OCK	Outfall Channel Banks
IS	Inflow Structure	ICB	Inflow Channel Bed
IC	Inflow Channel	ICK	Inflow Channel Banks
SH	Scour Hole	RV	Riparian Vegetation
OPR	Outfall Protection	OTHER	Other Photos
IPR	Inflow Protection		

When the outfall is not recommended for restoration, a minimum of 2 photographs should be provided depicting the outfall structure (OS) and downstream channel (DC). When the headwall is not recommended for restoration, a minimum of 2 photographs should be also provided depicting the inflow structure (IS) and inflow channel (IC). When the outfall (or headwall) is recommended for restoration, a maximum of 4-8 photographs should be provided including the structure, channel and any additional photographs which emphasize problem conditions or constraints observed at the site.

Labeling should be completed using the following format. If the assessment team takes a photo of an outfall pipe at SHA STRUCTURE ID# 0200580.001 on April 5, 2012, then the photo should be labeled 0200580.001_OS_20120405. If multiple photos are taken of the same outfall feature, then the photos should be labeled: 0200580.001_OS_20120405_1 and 0200580.001_OS_20120405_2.

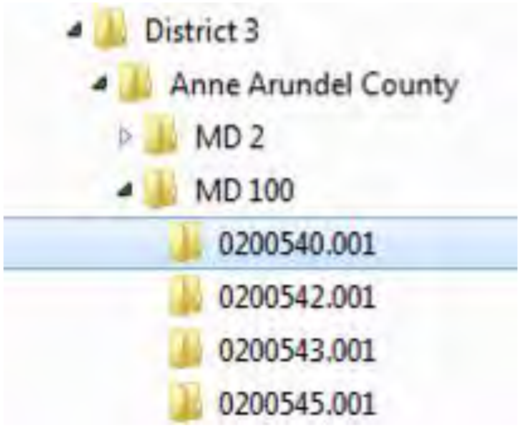
Digital camera resolution settings should be set to reduce image size to 1MB or less. Reducing the image resolution settings will reduce the overall size of the project file and help facilitate electronic submission of the documents and reduce the amount of space required on storage devices. The assessment team can take high resolution photos, but the file size will need to be reduced prior to submission. The photos below show the formatting for the outfall photos.

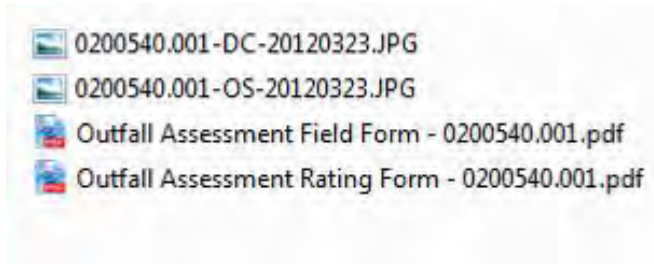
Figure 8.5.1: JPEG file named: 1601059.001_OS-20120403.jpg

Figure 8.5.2: JPEG file named: 1601059.001_OTHER-20120403.jpg

8.5.IV DELIVERY

All deliverables should be submitted to SHA electronically. These deliverables should include the Field Form, Rating Form, Summary Memo, Outfall-Headwall Ranking Summary Spreadsheet and Prioritization Lists, and site photos. The data will be submitted to SHA on Projectwise and will be organized based on SHA Districts, Counties and State Routes or Roadways. Each task should include one roadway corridor, so this organization will be directly compatible. When more than one roadway is included in a task assignment, the information should be uploaded to Projectwise under each of the State Routes. The Summary Memo, Outfall-Headwall Ranking Summary Spreadsheet and Prioritization Lists will be saved directly under the State Route folder which will also include a subfolder for each outfall structure (or headwall) labeled according to the SHA Structure ID Number. Under each structure subfolder, the assessment team will save each of the scanned forms and photographs for that particular outfall or headwall. Below is an example of a typical file directory:


District 3
Anne Arundel County
MD 2
MD 100
0200540.001
0200542.001
0200543.001
0200545.001

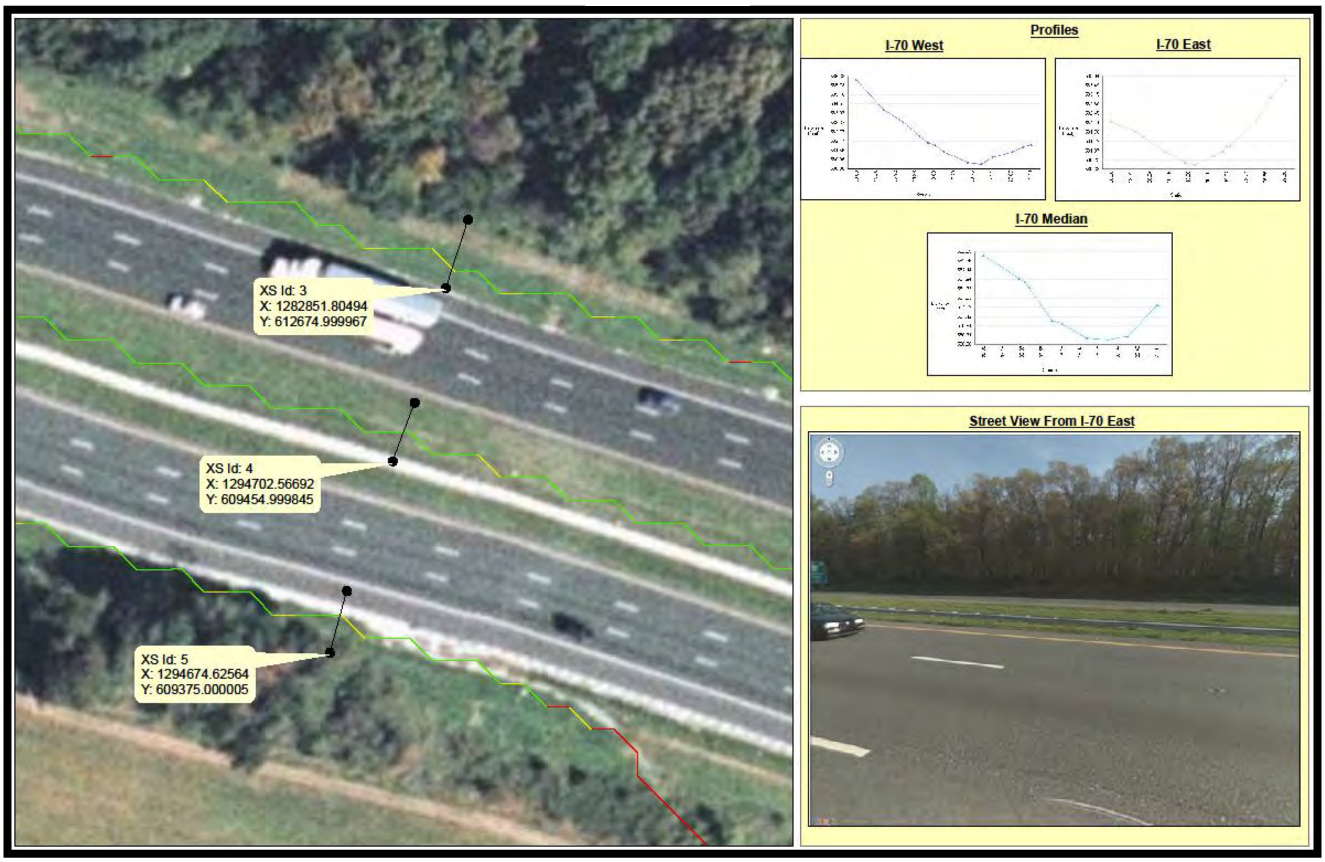

0200540.001-DC-20120323.JPG
0200540.001-OS-20120323.JPG
Outfall Assessment Field Form - 0200540.001.pdf
Outfall Assessment Rating Form - 0200540.001.pdf

APPENDIX G:

Existing Water Quality Grass Swale Identification Protocol

July 2012

Existing Water Quality Grass Swale Identification Protocol



Maryland State Highway Administration
Highway Hydraulics Division
707 N. Calvert Street
Baltimore, MD

July 2012

Table of Contents

Background and Purpose

Maryland State Highway Administration (SHA) is drafting its Watershed Implementation Plan II (WIP II) Action Plan that will focus on a combination of measures to reduce pollution. As part of this process, SHA is anticipating that its future NPDES Municipal Separate Storm Sewer System (MS4) permit will require additional water quality treatment of its legacy impervious areas.

Protocol development is described in the draft Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated (MDE, 2011). This guidance states: "Many roads and subdivisions, including those built before 1985, have <u>vegetated swale systems or sheet flow conditions</u> that filter and treat stormwater runoff. Many of these existing features approximate the ESD designs found in Maryland's Stormwater Design Manual. Each jurisdiction should conduct a systematic review of existing roads and subdivisions to determine the extent of water quality treatment already provided and to identify opportunities for retrofitting."

As part of WIPII Action Plan development, SHA is currently assessing the extent of which existing grass channels are providing water quality treatment, and are un-accounted for in SHA's NPDES database. Many highways in Maryland are open sections roadways with wide median and gentle sloping clear zones on the outer lanes. Due to these roadway characteristics, sheet flow conditions are commonly found. Identifying these sheet flows areas and using the Environmental Site Design Criteria for grass swales found in Chapter 5 of the 2000 MDE Stormwater Design Manual (the Manual), SHA will provide evidence that water quality treatment is occurring along these highway corridors. This effort will support the targeted reduction goals for total nitrogen, total phosphorus, and total suspended solids and to account for acres of legacy impervious area being treated. The SHA's goal is to complete an inventory of grass channels using GIS analysis and input that information into SHA's NPDES database.

SHA has developed a ***Grass Swales Protocol*** (detailed below) to identify existing grass swales along highway corridors to be used in impervious area treatment and load reduction credit systems. This protocol will assess and document existing grass channels that approximate the current MDE SWM criteria. SHA will use GIS analysis, topographic data, aerial photography, hydraulic analysis and field verification to determine drainage areas, slopes, ditch lengths, velocities and lining material (grass, concrete or rip-rap) in order to identify swales that currently provide water quality treatment. The identified impervious acres can be excluded from SHA's baseline quantity of total impervious area requiring management to comply with NPDES permit and will be used to apply credits to MDE's TMDL load reduction requirements. The inventory will also identify channels that do not meet the current criteria but may be candidates for future retrofits.

Description of Water Quality Grass Swales

Chapter 5 of the Maryland Stormwater Design Manual, Volumes I&II, as updated in 2009 (the *Manual*) states:

A comprehensive design strategy for maintaining predevelopment runoff characteristics and protecting natural resources is available. This strategy, known as Environmental Site Design or "ESD," relies on integrating site design, natural hydrology, and smaller controls to capture and treat runoff.

Title 4, Subtitle 201.1(B) of the Act defines ESD as "…using small-scale stormwater management practices, nonstructural techniques, and better site planning to mimic natural hydrologic runoff characteristics and minimize the impact of land development on water resources." Under this definition, ESD includes:

- *Optimizing conservation of natural features (e.g., drainage patterns, soil, and vegetation).*
- *Minimizing impervious surfaces (e.g., pavement, concrete channels, and roofs).*
- *Slowing down runoff to maintain discharge timing and to increase infiltration and evapotranspiration.*
- *Using other nonstructural practices or innovative technologies approved by MDE.*

Chapter 5 of the *Manual* provides examples of ESD credits available to SHA. The **Grass Swales** is one of these practices.

Swales are channels that provide conveyance, water quality treatment, and flow attenuation of stormwater runoff. Swales provide pollutant removal through vegetative filtering, sedimentation, biological uptake, and infiltration into the underlying soil media. The MDE Stormwater Design Manual addresses three design variants including grass swales, wet swales, and bio-swales. The design variant applicable to this protocol is the **Grass Swale**, which most closely resembles grass channel (ditch) drainage design criteria and which has been widely used by SHA as a stormwater conveyance practice.

This protocol will show that impervious area and pollutant load reduction credit is appropriate when open sections of roadway drain to grass channels meeting certain criteria as described below. These grass channels are used to reduce the volume of runoff and pollutants during smaller storms (e.g., ≤ 1 inch per event).

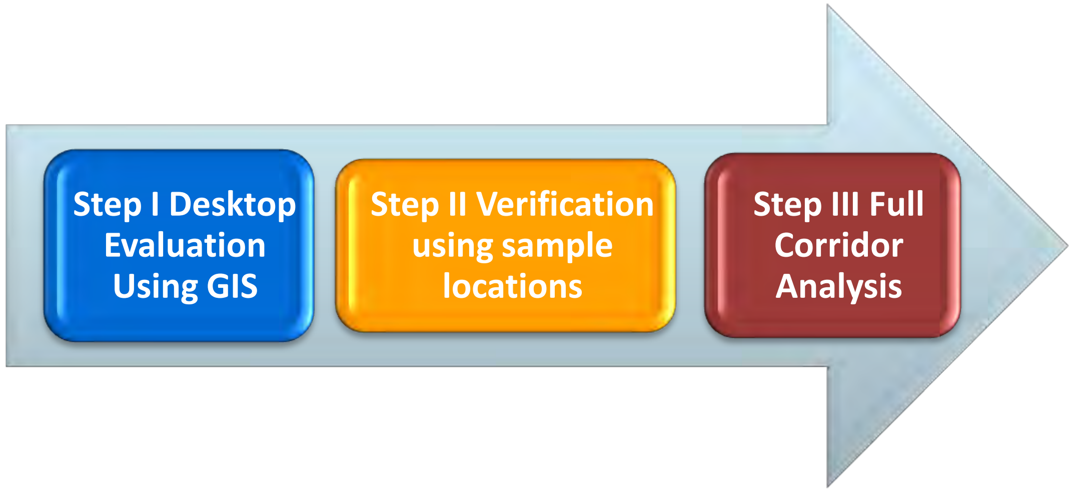
Protocol for identification of existing Grass Swales included below describes methodology to identify and document water quality grass swales within SHA rights-of-way:

- **Grass Swales.** Existing conditions which approximate the geometric criteria and other site conditions described in the *Manual* for the Grass Swales micro-scale practice (M-8), within defined tolerances. These are currently being maintained as highway drainage conveyance areas and are not subject to SWM maintenance. Vegetation in the area may be upgraded and maintained as prescribed for water quality channels to ensure improved water quality treatment.

- **Grass Swale Variants.** Existing conditions which display channel geometry and other site conditions adequate to provide water quality treatment but vary from the criteria described for grass swales. These areas require minor modifications such as the installation of check dams, change in lining material from concrete or riprap to grass or sod and re-grading.

Protocol Development

For each State Highway controlled corridor, this protocol will be a three step process for evaluating existing grass swales for water quality credit:



- The first Step of this protocol is a desktop evaluation using Geographic Information Systems (GIS) which will be used in identifying drainage channels that qualify for water quality credit.
- The second step is verification. The desktop evaluation results will be field verified to assess the accuracy of the GIS analysis results in order to develop a level of confidence for step 3 of the analysis. A minimum of fifty (50) sample locations will be used for the verification stage. More may be needed for corridors longer than 50 miles.
- The third step is a full corridor analysis and documentation of results. After step 2, verification is completed, the entire corridor will be evaluated, tabulated and results submitted to MDE. This final step will include desktop evaluation and field work along the entire corridor.

Step 1: Desktop Evaluation

1.1 Evaluation Parameters

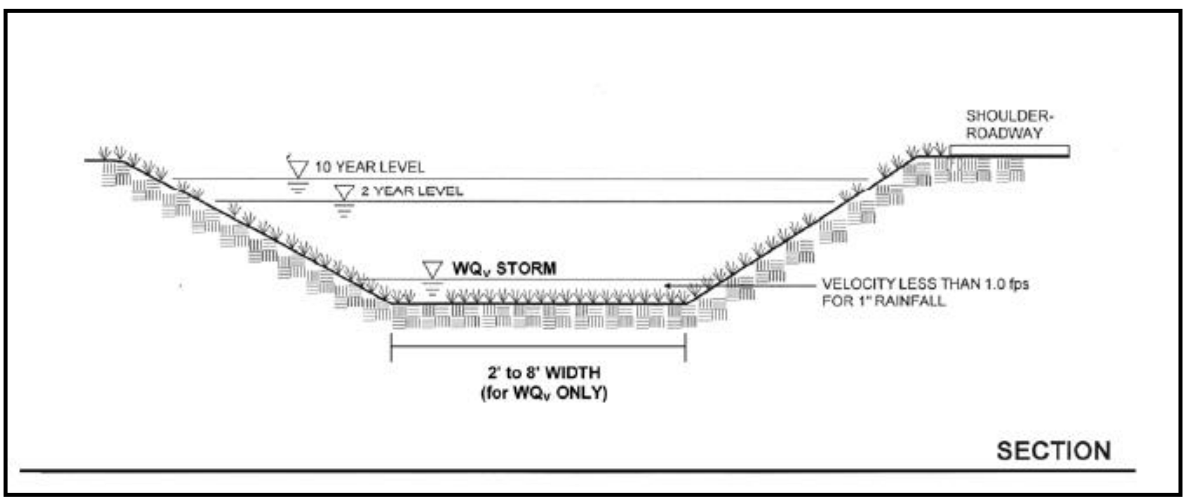
From Chapter 5, of the Manual the MDE stormwater criteria for this Grass Swales include:

- *The bottom width shall be 2 feet minimum and 8 feet maximum,*
- *The channel slope shall be less than or equal to 4.0%, or*
- *The channel slope shall be between 4% and 6% with check dams provided to meet flow depth and velocity criteria*
- *The maximum flow velocity for runoff from the one-inch rainfall (water quality storm) shall be less than or equal to 1.0 fps*
- *The maximum flow velocity for runoff from the ten-year design event shall be non-erosive, less than 5 fps,*
- *The side slopes shall be 3:1 or flatter,*
- *A thick vegetative cover is present*
- *Surface area of the channel is > 2% of the contributing drainage area*
- *The maximum flow depth for the 1" water quality storm is 4" and*
- *n=0.15*

Newly constructed vegetated channels require a flat bottom; however MDE recognizes that vegetated channels will develop a parabolic shape over time. In addition, the precision of the desktop evaluation will be constrained by the resolution of available data and analysis tools, and as described in more detail below, may not be capable of identifying the exact MDE criteria shown above. Specifically, the criteria require a channel bottom between 2 and 8 feet, however the GIS analysis has an accuracy of 10 feet. Therefore the desktop evaluation methodology established in this protocol will identify drainage features which approximate the MDE criteria within the limitations of available data and technology (i.e. less than 10' wide). In the field verification step, data will be collected to assess the ability of the GIS analysis to predict the presence of drainage features approximating MDE grass swale criteria. A thick vegetative cover is assumed for all channels lined with grass. This assumption will be verified in Step 2.

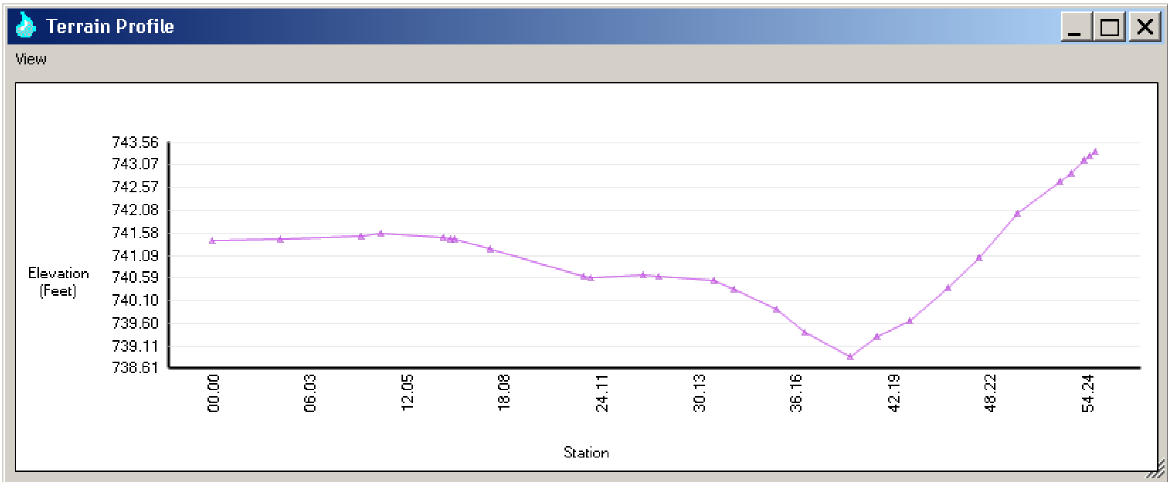
The intent of this evaluation is to find drainage features which approximate the MDE criteria for Grass Swales within the tolerances of the data analysis tools, including methodologies for identifying grass swale variants. As shown below, five (5) credit categories will be used in the Grass Swales (M-8) protocol: Category 1 – Meets MDE geometric criteria; Categories 2A and 2B - Approximates MDE geometric criteria within the tolerances of data analysis tools, with a uniform cross-section; and Categories 3A and 3B - Approximates MDE geometric criteria within the tolerances of data analysis tools, with a non-uniform cross-section. 2A and 3A identify channels with 0-4% longitudinal slope while 2B and 3B represent channels with >4-6% longitudinal slopes.

Category 1 – Meets MDE geometric criteria shown below

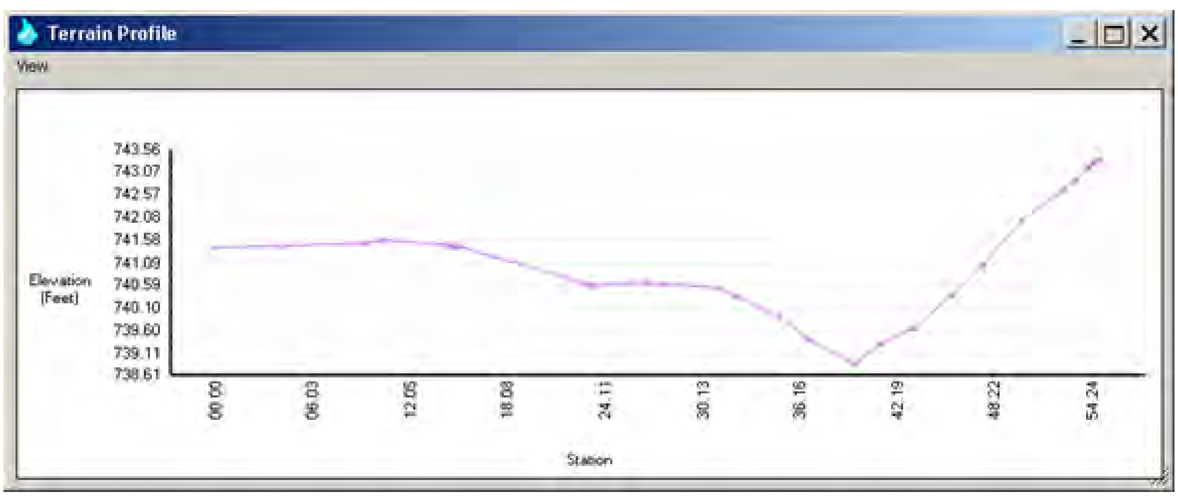


Category 1 – Meets MDE geometric criteria, with bottom width between 2 and 8 ft width, side slopes no greater than 3:1 and longitudinal slope between 0 and 4%.

Category 2 – Approximates MDE geometric criteria within the tolerances of data analysis tools, and with uniform cross-section.

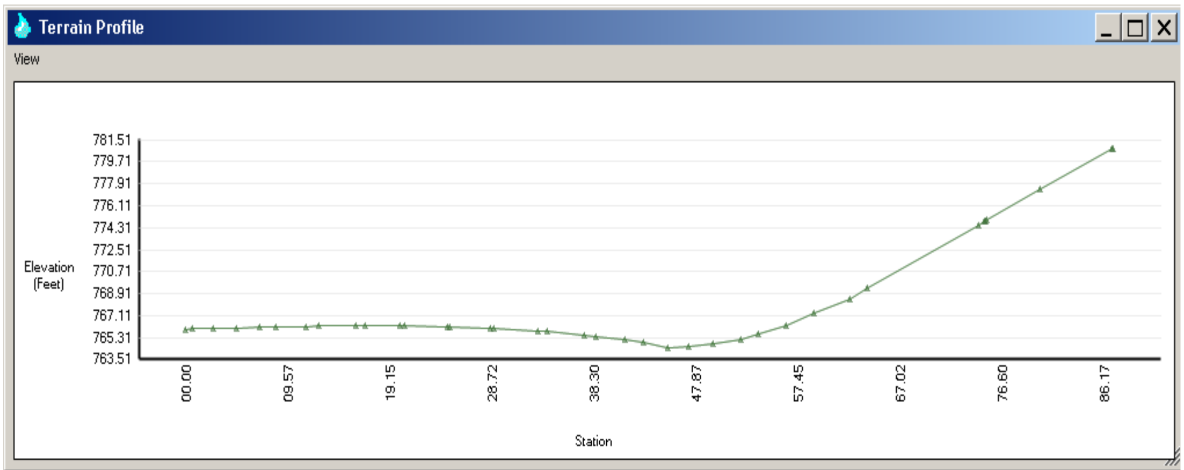


Category 2A – Approximates MDE geometric criteria, with bottom width between 0 and 10 ft width, side slopes no greater than 3:1 and longitudinal slope between **0 and 4%.**

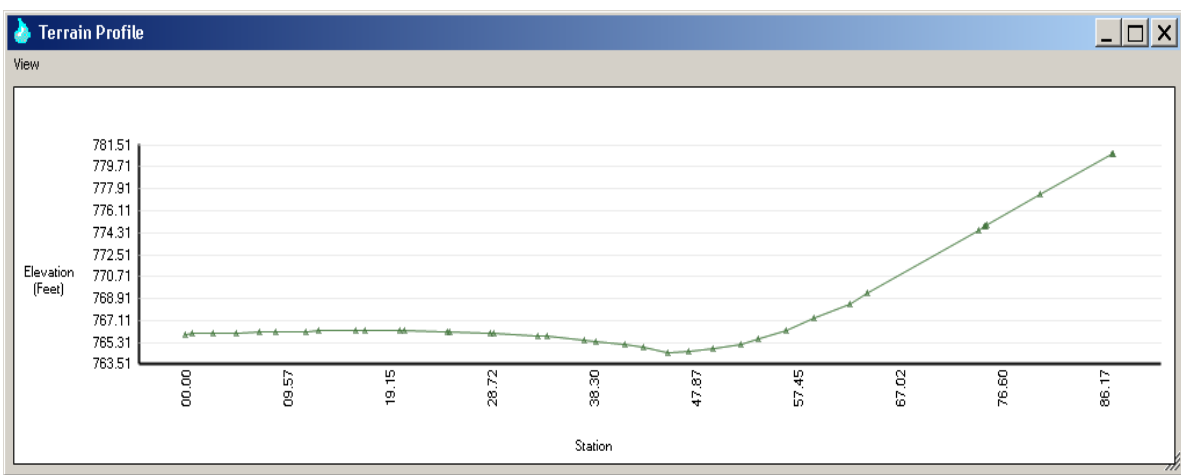


Category 2B – Approximates MDE geometric criteria, with bottom width between 0 and 10 ft width, side slopes no greater than 3:1 and longitudinal slope between **4 and 6%.**

Category 3 – Approximates MDE geometric criteria within the tolerances of data analysis tools, non-uniform cross-section



Category 3A – Approximates MDE geometric criteria, with bottom width between 0 and 10 ft width, one slide slope no greater than 2:1, the other no greater than 3:1 and longitudinal slope between 0 and 4%.



Category 3B – Approximates MDE geometric criteria, with bottom width between 0 and 10 ft width, one slide slope no greater than 2:1, the other no greater than 3:1 and longitudinal slope between **4 and 6%.**

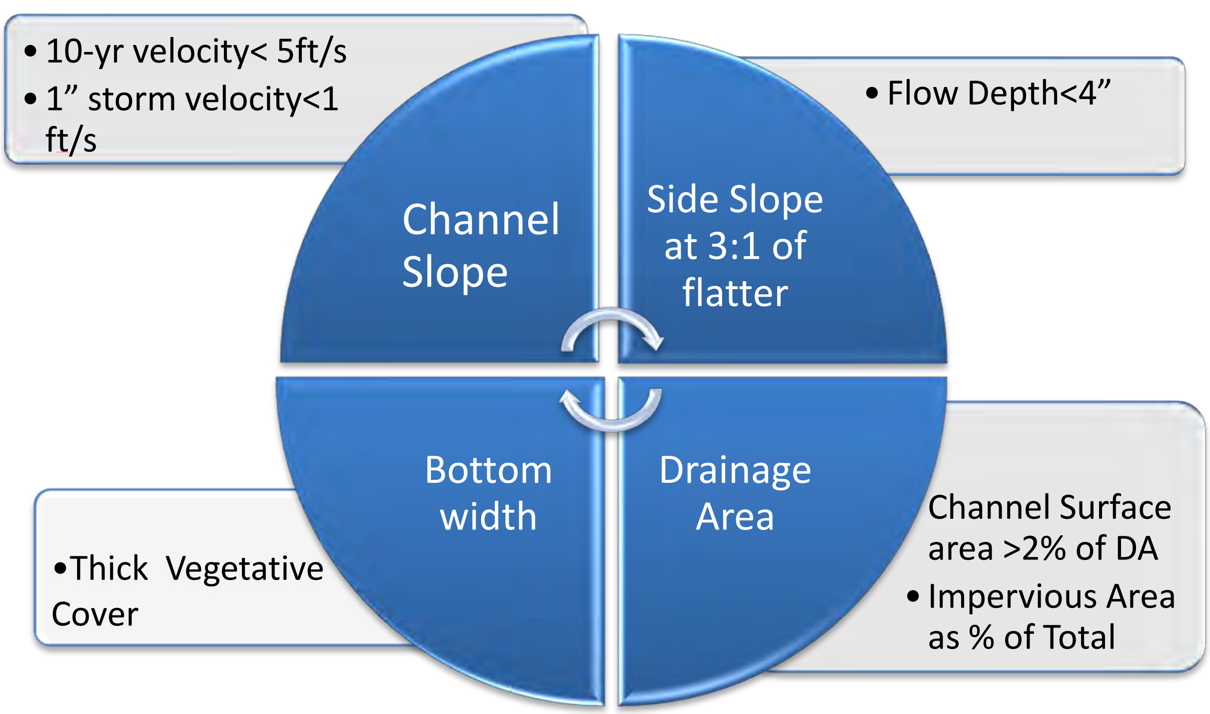
1.2 Available Data

Available GIS data can be used to characterize the above non-structural practices along the State highways based on their potential for water quality credit. Data such as aerial photographs, Light Detection and Ranging (LiDAR) topographic data are available for most highways in Maryland. Aerial photography will be utilized via a data connection to the most current Microsoft Bing maps or the 2007 NAIP imagery available on Maryland iMap (Maryland, 2011). These datasets vary from 0.8-ft vertical accuracy to 1.2-ft vertical accuracy at a 95% confidence level. Overall the topographic data will be able to support the generation of 2-ft contour intervals in order to be used in this process.

Impervious area coverage data can be obtained from SHA's Impervious Surface Account data which has a GIS file of SHA-owned impervious area. The hybrid land cover shapefile used for the Chesapeake Bay Program (CBP) Watershed Model Phase 5.3.2 includes information derived directly from 2005/6 Landsat satellite imagery in combination with secondary road density and institutional and airport boundary information from NAVTEQ (Claggett, 2011), and is available at ftp://ftp.chesapeakebay.net/Gis/p532_lc06.zip. NRCS soils data is available from http://soildatamart.nrcs.usda.gov/ and numerous environmental features including forest buffers from Maryland iMap (Maryland, 2011).

1.3 Data Analysis

As described previously, MDE's design guidelines specify several characteristics that Grass Swales must meet to qualify for water quality credit. The processes below describe GIS methods and hydraulic analysis to help identify those drainage features that may qualify under the noted criteria.



1.3.1 Longitudinal Slope

The LiDAR data can be used to calculate the longitudinal slope of the delineated drainage features. The slope of all drainage lines is calculated using slope analysis processes and then categorized based MDE defined slope requirements (i.e., 0 to 4%). The length of channels will also be determined using GIS measuring tools. This process also allows for the identification of drainage channels that have a longitudinal slope between 4 and 6% which could be retrofitted with check dams to qualify for impervious surface treatment credits.

In order to accurately represent the average slope of the drainage features, each line segment is broken at vertices and the slope is calculated and categorized. To develop continuous drainage feature lines based on longitudinal slopes, while ignoring isolated insignificant slope value in/outlier segments, additional processing is required. This process allows for the identification and elimination of drainage channels that have a longitudinal slope steeper than 6%.

1.3.2 Delineation of Drainage Features (lines and flow accumulation points)

The raw LiDAR points are imported to generate a 10ft x 10ft DEM (Digital Elevation Model) grid dataset. This data set is needed to utilize GIS hydrology tools that allow for the delineation of drainage features to 0.00019 square miles (0.1216 of an acre). The resulting line file shows swales that drain 0.1216 acres or larger of various lengths. This tolerance was chosen after a series of tests runs. Using a higher tolerance as the drainage area value resulted in potentially qualifying drainage features being omitted in the delineation.

These delineated drainage features are identified based on the longitudinal slope segments identified above. They must then be combined with adjacent ditch segments of the same swale. Then, they must then be intersected with SHA's storm drain data to identify the drainage area to be used in the analysis.

1.3.3 Side Slopes

The LiDAR data will be used to identify the side slope of the drainage channels. In general, the side slope should be less steep than 3:1. Slope analysis of the DEM identifies all slope areas within the dataset that fall within the side slope requirements. The resulting slope characteristics can be used to select swales that meet MDE requirements. This process allows for the identification and elimination of drainage channels that have a side slope steeper than the MDE requirements described above for grass channels.

1.3.4 Bottom Width

Based on MDE design requirements, the bottom width should be between two and eight feet. Due to the resolution of the DEM utilized to generate the drainage features (10-ft grid), the bottom width cannot be accurately estimated using the GIS profile tools to less than 10 feet wide. Therefore, Step 2, Field Accuracy Verification step will identify the bottom width to be used in the analysis. Open section highways usually have 2' wide bottom ditches on the outside slopes and 4' wide bottom ditches in the median.

1.3.5 Land Cover Determination

Visual review of aerial photography and publicly-available street view imagery allows for on screen determination of cover material (grass lined, concrete, riprap) for the drainage channel. Swales that meet MDE requirements will have a thick vegetative cover.

1.3.6 Maximum Velocity and Flow Depth in the Channel

The maximum allowable velocity for the 1-inch (Water Quality or Q_w) storm is 1 ft/s. Also, the Grass Channel requirements in the Manual dictate the maximum flow depth of 4". SHA has developed a procedure to determine the maximum drainage area based on side slope, longitudinal slope and percent impervious. This procedure follows the requirements outlined in the Manual and using Manning's Equation. Additionally, the grass channel must be able to carry the ten year storm at a velocity at or below 5 ft/s.

1.3.7 Drainage Area

MDE recommends, but does not require, that the maximum allowable drainage area for a grass channel is 1.0 acres. However, many roadside channels are 0.5 miles or longer and the drainage areas may be larger than 1 acre. A drainage basin delineation tool can use the LiDAR data to delineate the drainage areas to grass channels. The actual drainage area getting to the channels will be evaluated to determine if the swales meet the other criteria for Grass Channel credit and if so, a variance of the maximum drainage area requirement will be requested.

1.3.8 Treated Impervious Area

The drainage area boundaries described above will be intersected with the impervious areas. The drainage areas that drain to ditches that meet the criteria described above for longitudinal slopes, side slopes and bottom widths will be tabulated and impervious area within these drainage areas calculated for input into SHA's NPDES database.

1.3.9 Surface Area of Channel > 2% of Contributing Drainage Area

Equation 5.3 of Chapter 5, MDE's SWM Design Manual states that PE=10"x (Af/DA). This equation has the associated constraint that the bottom area of the swale be at least 2% of the contributing drainage area (Af/DA)> 2%. It also requires PE be dependent on the Af/DA calculation. Doing this calculation to determine PE for each swale is impractical, so instead, we assume PE=1" in the protocol. However, plugging PE=1" in the equation above will not work, because that would result in (Af/DA)>10% which is too conservative. Instead, we have determined that the equation above represents a design tool and is not relevant to use in this credit analysis.

1.3.10 Obstruction Identification

The GIS analysis tools and review of aerial photography will also be used to identify structures or drainage features which may affect the channels' ability to provide treatment. These may include inlets or pipe headwalls.

1.4 Test Site Results

For preliminary verification of the protocol, a minimum of fifty (50) sites are recommended for field verification of the desk top evaluation described above. These 50 locations will be identified by their mile marker designation to the 100^{th} of a mile followed by a letter designation representing the location (M for median, W for west bound and E for eastbound). As an example, several channels along eastbound I-70 in Frederick County are represented as MM60.03 E, MM63.63 E and MM63.83 E. The sites will be selected to represent the ranges in the four groups 2A/2B and 3A/3B that indicate a potential qualifying grass channel. It is recognized that group 1 is an idealized condition and is not expected to be found in the field due to construction limitations and changes over time to these channels.

The information generated will be tabulated and summarized. Drainage channels will be listed based on longitudinal slope and side slope categories and, then further described based on land cover (i.e., vegetated or paved) and the presence of drainage features which may interfere with the function of the swale (i.e., culverts or channels). In order to determine the amount of treatment credit the swales may provide, drainage areas and percent impervious information will be measured and calculated.

Step 2: Field Accuracy Verification

A site visit will be made to the minimum 50 selected locations identified in Step 1 in order to assess the ability of the GIS analysis to identify actual site characteristics, and to collect data needed to characterize the range of variability in the site conditions within the sample survey areas. Each site visit will include channel measurements at the cross-section location of the identified channel. The forms described below and located in Appendix A will be used in the field.

2.1 Field Forms

Grass Channel Identification Report and Cross Section Data Sheets

The Grass Channel Identification report must be filled out for each grass channel visited. This form will be used to identify and locate the channel by County, Grass Channel Number and GIS location (horizontal). The date, weather and crew names must be included. A checklist is included to ensure all aspects of the field review have been completed. There is also a section for notes on other findings including maintenance items that may be identified such as damaged guardrail, erosion problems, damaged pavement, etc. This information will then be immediately conveyed to the SHA project manager. There is a signature block for a qualified H&H engineer to sign and date a determination on the GIS data being a good representation of actual field conditions as well as a section for describing any differences. Finally, if needed, a space for drainage area description is included to verbally describe the observed drainage area.

The Grass Channel Cross Section Data Sheet also must be completed. It will be used to identify the cross section elements and to calculate channel slopes. At a minimum, the slope at the cross-section location will be calculated. Should the H&H engineer determine other locations along the channel should have slopes calculations performed, such as at break points or at the outfall, other slope boxes are included on this sheet. The cross section data table must be filled out with horizontal distances from the edge of pavement to break points and must include two points at the bottom of the channel, with a distance between. If the ditch is 'V' shape instead of flat bottom, this must be noted on the form. The vertical changes at these points must also be measured using the level and measuring tapes described in the equipment section below.

Inspector's Daily Log and Site Map & Photo Log

These two forms are optional and may be used as needed to track your work. The Inspector's Daily Log form will be filled out by the field crew leader. This form includes basic information such as the date, weather, crew names and channels inspected and unusual conditions.

The Site Map and Photo Log form will be completed to identify where the photos taken during the field work have been taken or to sketch the site. Required photo locations are identified in Section 2.2.2 below.

All field forms described above can be found in Appendix A.

2.2 Field methodology

2.2.1 Field Measurement Locations

The minimum of 50 locations will be reviewed to determine that field staff can safely access the segments to take the appropriate measurements and observations. Each segment will be assigned a unique identifier and will follow BMP field data collection standards.

2.2.2 Field Data Parameters

The following information will be collected in the field for each of the sections along the identified channels:

- Geometry
  - Bottom width
  - Side slopes
  - Longitudinal slope based on elevation collected 50 feet upstream and downstream of each cross-section
- Land cover description (e.g. grass, brush, stone, concrete)
- Vegetation condition (good, fair, poor)
- Vegetation height
- Location and stability of outfall
- Is the channel showing signs of erosion (yes, no)
- Photo standing upstream looking downstream (GPS Camera)
- Photo standing downstream looking upstream (GPS Camera)
- The cross section and GIS determined outfall location within the channel will be staked with at least one marker.

The forms that will be used to collect the data can also be found in Appendix A.

2.2.3 Field Procedures

SHA safety procedures will be followed when accessing each site and collecting the data. This includes the use of warning lights, and safety vest while onsite. The appropriate SHA personnel, notable the District ADE for traffic, will be notified 3 days in advance of a field visit. The field crew will carry SHA's approval letter (sample on next page) granting permission to access the sites at all times.

Martin O'Malley, *Governor*
Anthony G. Brown, *Lt. Governor*

SHA State Highway Administration

Beverley K. Swaim-Staley, *Secretary*
Darrell B. Mobley, *Acting Administrator*

MARYLAND DEPARTMENT OF TRANSPORTATION

October 11, 2011

TO: Whom It May Concern

FROM: Karuna Pujara, Chief
Highway Hydraulics Division

SUBJECT: SHA Contract No. AX987B21
NPDES GIS Development and Inspections

RE: **Authorization to Perform Stormwater Facility Inspections on Maryland State Highway Administration Right-of-Way**

The MD State Highway Administration (SHA) is conducting inventory, inspection and maintenance assessments of its drainage system and stormwater management (SWM) facilities located within SHA right-of-way. Administration and consultant personnel under SHA direction are required access to the storm drain and SWM facilities from State or the county roadways in order to assess their condition and to acquire GPS coordinates. They will be conducting a visual inspection, photo documentation, and engineering related data collection for the purpose of State Asset Management.

This letter authorizes individuals from the following consultant firm to access the SHA right-of-way for a period of one year from the date of this letter in order to perform the above mentioned inspections:

AECOM
7 St. Paul Street, 17th Floor
Baltimore, MD 21202
(410) 637-1700

If you have any questions or would like more information about this authorization, please contact Mr. Cornelius C. Barmer, Program Manager, at (410) 545-8629.

My telephone number/toll-free number is ______________________
Maryland Relay Service for Impaired Hearing or Speech 1.800.735.2258 Statewide Toll Free
Street Address: 707 North Calvert Street • Baltimore, Maryland 21202 • *Phone* 410.545.0300 • www.roads.maryland.gov

2.2.4 Field Equipment

GPS units will be used to locate the selected swale segments. A measuring tape will be used to estimate the bottom width, and a survey level and tape measure will be used to measure side slopes. Equipment required for the field include:

- Stakes
- 2-100' Tapes
- Camera (preferred with GPS photo-tagging)
- Hammers
- Smart Level
- Line Level
- Measurement Wheel
- Flags/Pins
- Safety Gear (safety vests and warning lights)
- 25' measuring tape
- GPS (2)
- Flashing Light / MOT Cones

2.3 Characterization of Field Conditions

The data collected during the field step will be used to characterize the geometric and other conditions of the surveyed channels. This information will be used to refine or modify the classification scheme discussed above. Swales providing opportunities for retrofit because they meet configuration criteria, but require land cover change (e.g., concrete removal), flow attenuation (e.g., check dams), grading or vegetation improvements, re-construction of structure or channels interfering with water quality function, or other options will be noted during the field investigation.

2.4 Summary of Evaluation Parameters

The road centerline will be used to place the minimum 50 cross sections. The length of the cross section should cover the left and right channel of the highway as well as the median.

The evaluation parameters for the 50 sites for desktop analysis and field verification steps are based on the considerations discussed above, and summarized below.

Longitudinal slope:

- Desktop analysis will search for and group channels with slopes in the range of 0% to 4%.
- Desktop analysis will search for and group channels with slopes in the range of 4% to 6%.
- Field evaluation step will collect actual slope measurements at the 50 recommended sites in order to assess GIS predictions, and provide data to classify the measured channels. To do this, elevations will be taken at locations upstream and downstream of the cross-section site, GIS determined outfall, and GIS slope change location and overall slope will be calculated.

Side slope:

- Desktop analysis will search for and group channels with sides slopes no steeper than 3:1 for Category 1, 2A and 2B, and with 3:1 to 2:1 side slopes for categories 3A and 3B.
- Field evaluation step will collect actual slope measurements at the 50 recommended sites in order to assess GIS predictions, and provide data to classify the measured channels.

Bottom width:

- The GIS data will allow bottom width less than 10 feet wide to be identified.
- Field evaluation step will collect actual bottom widths at the 50 test sites in order to assess GIS predictions, and provide data to classify the measured channels.

Vegetative cover:

- A visual analysis of aerial imagery will be conducted to provide a description of land cover that can be visually identified.
- Field evaluation step will collect land cover descriptions at the 50 recommended sites for comparison to the visual classification from aerial imagery.

Impervious and drainage obstruction features:

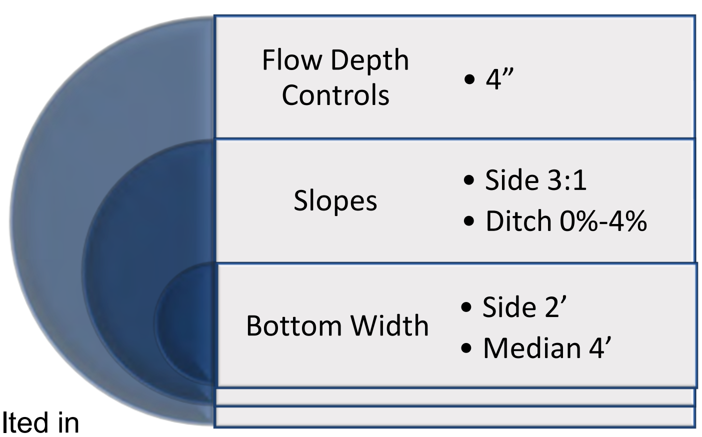
- Desktop analysis can estimate the amount of impervious area based on impervious datasets and will indicate any drainage obstructions which may affect the channels' ability to provide treatment.
- Field evaluation step will indicate highway conditions including number of lanes, roadway classification and approximate lane (and/or shoulder) width, and will indicate the presence of any obstructions which may prevent grass channels from providing adequate treatment within the inspected segments.

Stability downstream:

- A photograph will be taken downstream of the channel to determine the presence of a stable outfall.

2.5 Geometry Assumptions

The flow depth to meet grass channel criteria is 4" as is the side slope of 3:1 required to meet the criteria. Longitudinal slopes can vary from zero to four percent and a bottom with between two and eight feet. The field analysis stage will be used to find the bottom width to be used in the analysis. As an example, field verification of the I-70 corridor resulted in bottom widths shown in the graph on the right.



I-70 Corridor Geometry

2.6 GIS Analysis Accuracy Assessment

Location accuracy describes the degree to which items on the map are shown in their true location. The data generated in GIS will be compared to data collected in the field. GIS information must be compared to a sample of field observations to assess its accuracy and validate its use in this application. While there is a large academic literature on assessing locational (sometimes referred to as positional accuracy), one source most repeatedly cited in the discussion is the Handbook of Positional Accuracy which applies to the National Standard for Spatial Data Accuracy. (See Appendix B)

Application of the Handbook Method

The National Standard for Spatial Data Accuracy describes a way to measure and report positional accuracy of features found within a geographic data set. It is comprised of seven steps as outlined in the Handbook of Positional Accuracy. These are listed below in items 1 through 7:

1. Determine if the test involves horizontal accuracy, vertical accuracy or both. (*Grass Channel analysis for all SHA corridors will involve both horizontal and vertical accuracy assessment.*)
2. Select a set of test points from the data set being evaluated. (*The Handbook recommends a minimum of 20, but SHA requires a minimum of 50 to have 95% confidence in the result. These are the GIS identified data points.*)
3. Select an independent data set of higher accuracy that corresponds to the data set being tested. (*These are the field obtained data points.*)
4. Collect measurements from identical points from each of those two sources.
5. Calculate a positional accuracy statistic. The Handbook recommends calculating the Root Mean Squared Error and using it to calculate the National Standard for Spatial Data Accuracy statistic which is defined as the product of the RMSE and a value that represents the standard error of the mean at the 95 percent confidence level: 1.7308 when calculating horizontal accuracy, and 1.9600 when calculating vertical accuracy.
6. Prepare an accuracy statement in a standardized report form.
7. Include that report in a comprehensive description of the data set called metadata.

Application of this method to SHA:

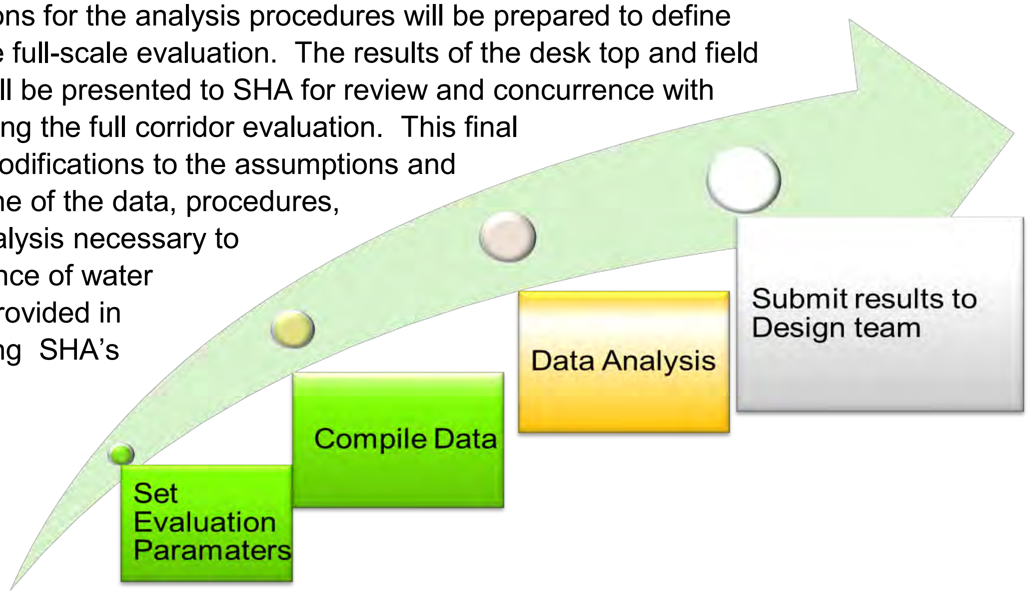
Sample Size: With a field sample of 50 to be used as the comparison to the digital data, the sample size exceeds the recommended 20 observations, even if the sample is divided into two to assess horizontal and vertical accuracy separately.

Accuracy: based on differences of X, Y, and Z coordinates, not statistics generated from the coordinates. They have a spreadsheet to make the calculation simple.

The accuracy assessment report must be submitted to SHA for review prior to moving on to Step 3, Full Corridor Evaluation.

Step 3 Full Corridor Evaluation

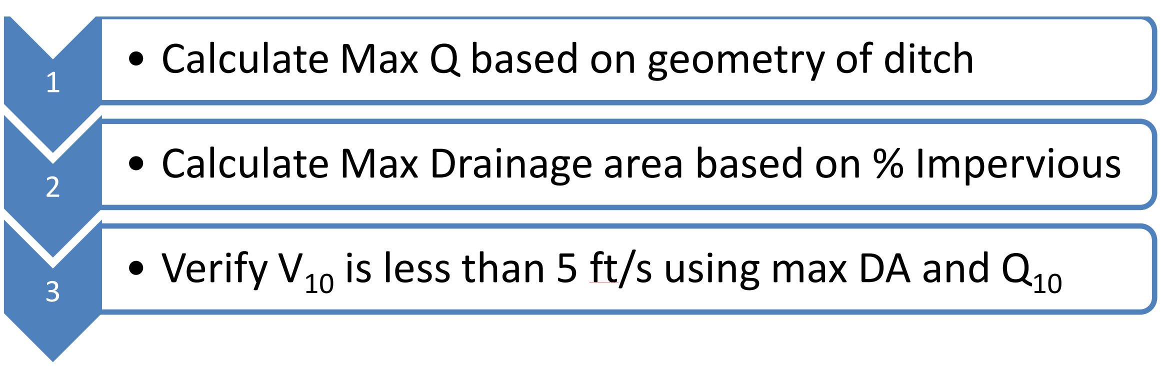
After conducting the desktop analysis and field accuracy verification steps at fifty (50) sample sites, the assumptions for the analysis procedures will be prepared to define methodology for the full-scale evaluation. The results of the desk top and field verification steps will be presented to SHA for review and concurrence with the goal of conducting the full corridor evaluation. This final step may include modifications to the assumptions and will include an outline of the data, procedures, parameters and analysis necessary to present clear evidence of water quality treatment provided in existing swales along SHA's highways.



3.1 Analysis Methodology

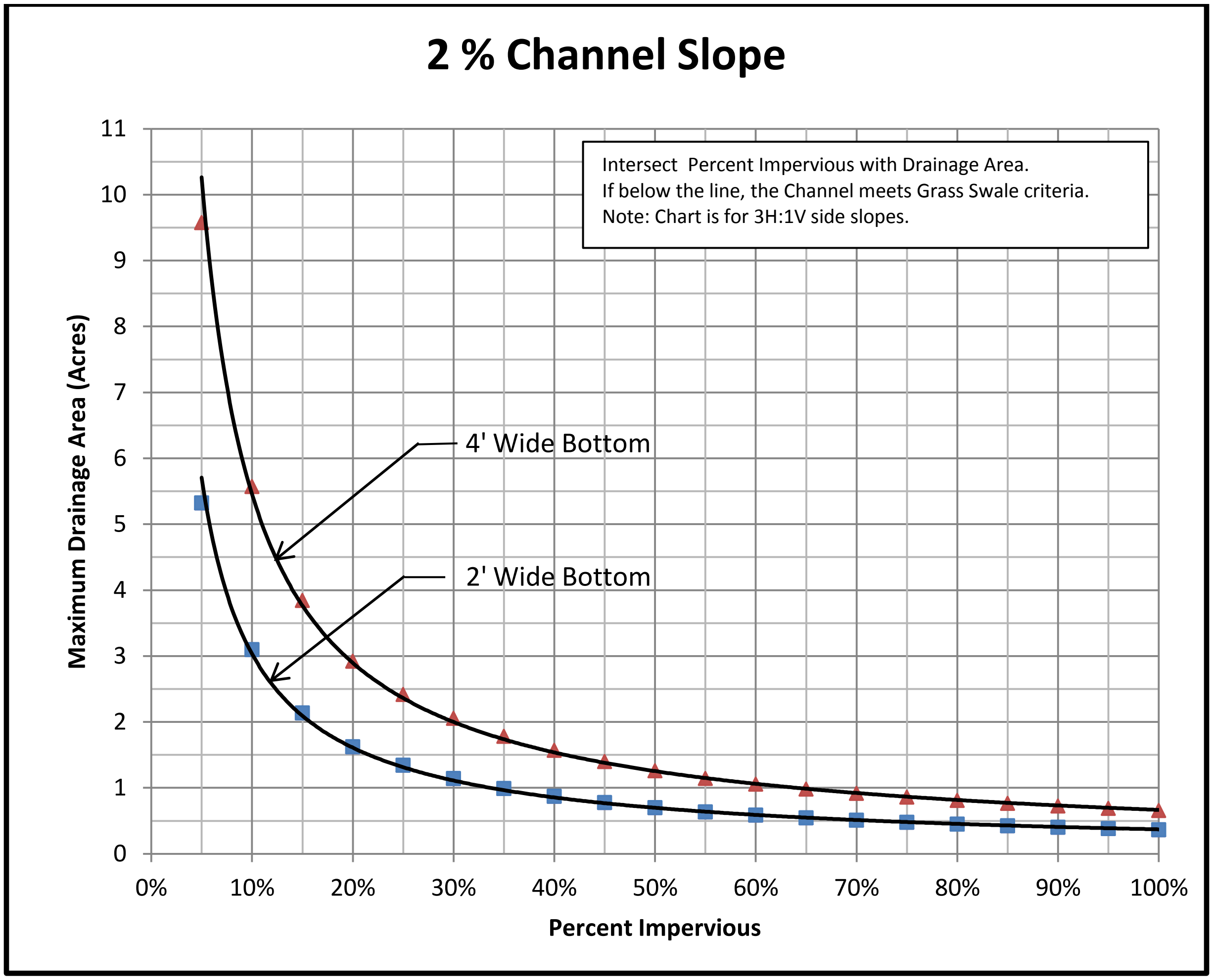
The information generated during the Data Analysis step will be tabulated and summarized. Drainage channels will be listed based on longitudinal slope and side slope categories and, then further described based on bottom width. In order to determine the amount of treatment credit the swales may provide, drainage areas and percent impervious information will be measured and calculated.

Detailed analysis of the grass swale credit criteria has shown that the flow depth is the controlling factor in determining if a channel will meet the grass swale credit. Calculations were done for each bottom width and channel slope configuration to determine a maximum Q that the channel could hold at 4" depth. This maximum Q can be coupled with the Percent Impervious of the channel drainage area to determine a maximum drainage area allowable.



SHA had developed charts for the designer to use in determining if a ditch will meet Grass Channel Credit criteria. The designer will use the charts, an example of which is shown on the next page, to intersect the percent impervious draining to the ditch with the drainage area. If the intersection point falls below the relevant line (for 2' wide or 4' wide ditch) then the ditch meets Grass Channel Criteria. If it falls above the line, it fails.

Analysis has shown that the flow depth is the controlling characteristic for all channel slopes and bottom widths and therefore, it has been determined that each swale meeting the flow depth requirement will meet the 1 ft/s requirement for the 1-inch Q_w storm and will also meet the 5 ft/s requirement for the Q_{10} storm. Appendix C contains the charts for the 0.1%, 1%, 2%, 3% and 4% channel slopes. Below is a sample graph that results from a 2' wide bottom with channel at a 2% slope.



Data generated during the full corridor evaluation step will be compiled and stored in the SHA NPDES database. To the extent possible, data fields will be populated with attributes required by the Maryland Urban BMP Database from MDE's draft Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated (MDE, 2011). Data will be collected following SHA methods and the data table will be generated as result of this data collection. Those attributes are shown in Appendix D.

3.2 Water Quality Treatment Credits

The results of the evaluation will be used to summarize the load reductions by the grass swales identified along the corridor that qualify for water quality credit per the MDE's guidelines. The areas of pervious and impervious surface within the study area that qualify for treatment credits will be tabulated. If SHA impervious surfaces are found to be treated by practices outside the ROW, they will not be eligible for impervious surface or pollutant removal credits. However, SHA may receive credit for impervious surfaces owned by others which are treated within SHA ROWs; therefore either of these cases will be noted if identified during the evaluation.

SHA impervious surface treated within SHA ROW will be subtracted from SHA's baseline quantity of total impervious area requiring management under the NPDES permit requirements. These surfaces are also eligible for nutrient and sediment treatment credit in Maryland's Chesapeake Bay TMDL accounting system. The credits will be calculated to reflect the pollutant removal provided by the existing grass swales. According to the draft MDE guide, grass swales which approximate Environmental Site Design to the Maximum Extent Practicable (ESD to the MEP) per the Maryland Stormwater Design Manual (Manual) are credited with 50% Total Nitrogen, 60% Total Phosphorus and 90% Total Suspended Sediment removal.

The MDE guide also provides annual baseline loading rates used for developing stormwater wasteload allocations (WLA's) for the Chesapeake Bay TMDL. These loading rates will be used along with land use data to calculate SHA's baseline annual load reductions. The baseline loading rates provided by the MDE guide are summarized in the table below.

CBP Annual Urban Runoff Loads per Acre							
	Urban Impervious			**Urban Pervious**			
Parameter	High Density	Low Density	Average	High Density	Low Density	Average	All Urban Weighted Average
Total Nitrogen (TN)	10.48	11.22	10.85	9.10	9.76	9.43	9.96
Total Phosphorous (TP)	2.01	2.06	2.04	0.55	0.58	0.57	0.97
Total Suspended Solids (TSS)	0.44	0.47	0.46	0.07	0.07	0.07	0.18

The grass swales will be tabulated along with pervious and impervious area draining to them. This impervious area will be used to pursue impervious area treatment credit under SHA's MS4 permit. The tabulated area will also be applied to the Chesapeake Bay Program (CBP) Annual Runoff Loads per acre in the table below to calculate annual load reduction credits to EPA's Chesapeake Bay-wide load reduction requirements.

Once a swale is confirmed to meet Grass Channel Credit, a request will be submitted to SHA Highway Hydraulics to have a BMP number assigned to that swale.

The table below will be used to summarize the credits from this analysis. This example is from the I-70 corridor.

					Urban Impervious Credit				Urban Pervious Credit			
Channel No.	Category	County	8-Digit Watershed	DA (ac)	Imp Acres Credit	TN credit (lb/yr)	TP Credit (lb/yr)	TSS Credit (tons/yr)	Pervious DA	TN credit (lb/yr)2	TP Credit (lb/yr)3	TSS Credit (tons/yr)4
2	WB side	Howard	02131108	2.71	**0.19**	**1.03**	**0.23**	**0.08**	**2.52**	**11.90**	**0.86**	**0.16**
4	Median	Howard	02131108	1.10	**0.31**	**1.66**	**0.37**	**0.13**	**0.79**	**3.72**	**0.27**	**0.05**
7	EB side	Howard	02130908	1.28	**0.06**	**0.32**	**0.07**	**0.02**	**1.22**	**5.75**	**0.42**	**0.08**
10	Median	Howard	02130908	1.05	**0.27**	**1.45**	**0.33**	**0.11**	**0.78**	**3.69**	**0.27**	**0.05**
11	EB side	Frederick	02140302	1.94	**0.26**	**1.39**	**0.31**	**0.11**	**1.69**	**7.96**	**0.58**	**0.11**
13	Median	Frederick	02140302	1.18	**0.27**	**1.47**	**0.33**	**0.11**	**0.91**	**4.28**	**0.31**	**0.06**
19	Median	Frederick	02140302	0.99	**0.28**	**1.52**	**0.34**	**0.12**	**0.71**	**3.35**	**0.24**	**0.04**
23	Median	Frederick	02140302	0.75	**0.12**	**0.65**	**0.15**	**0.05**	**0.63**	**2.95**	**0.21**	**0.04**
30	EB side	Frederick	02140302	1.39	**0.06**	**0.32**	**0.07**	**0.02**	**1.33**	**6.29**	**0.46**	**0.08**
33	EB side	Frederick	02140302	0.51	**0.27**	**1.45**	**0.33**	**0.11**	**0.24**	**1.13**	**0.08**	**0.02**
36	EB side	Frederick	02140302	0.90	**0.18**	**1.00**	**0.23**	**0.08**	**0.71**	**3.35**	**0.24**	**0.04**
42	Median	Frederick	02140302	3.24	**0.65**	**3.54**	**0.80**	**0.27**	**2.59**	**12.21**	**0.89**	**0.16**
43	Median	Frederick	02140302	0.42	**0.05**	**0.29**	**0.07**	**0.02**	**0.36**	**1.71**	**0.12**	**0.02**
				17.46	**2.97**	**16.09**	**3.63**	**1.23**	**14.49**	**68.31**	**4.96**	**0.91**

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