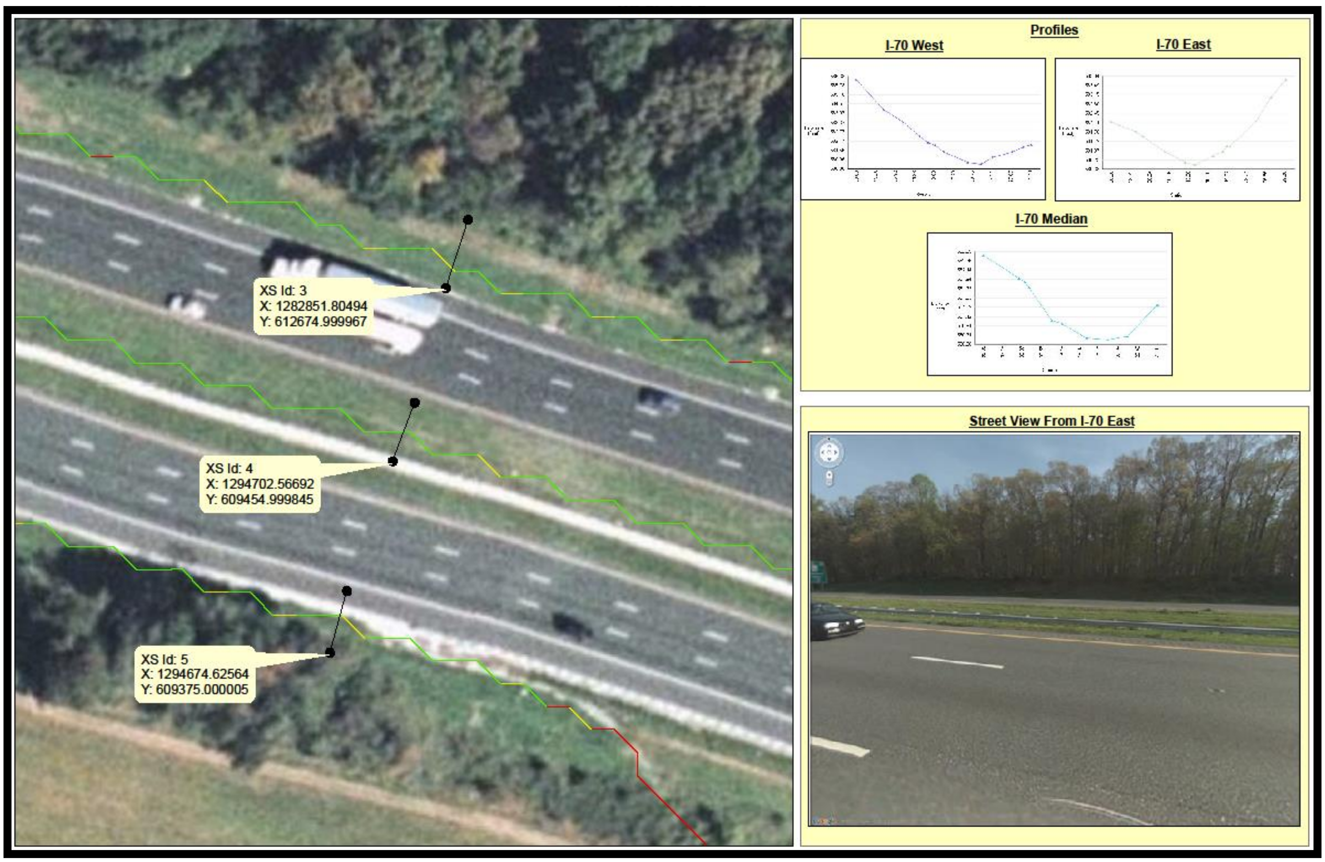
Existing Water Quality Grass Swale Identification Protocol



Highway Hydraulics Division
707 N. Calvert Street
Baltimore, MD

August 2014
December 2015 - Updated
May 2016 - Approved by MDE

Published: April 13, 2016

Prepared by: AECOM

Maryland Department of the Environment

Larry Hogan
Governor

Boyd Rutherford
Lieutenant Governor

Ben Grumbles
Secretary

May 18, 2016

Ms. Sonal Sanghavi, Director
Office of Environmental Design
Maryland State Highway Administration
707 North Calvert Street
Baltimore, MD 21202

Dear Ms. Sanghavi:

The Maryland Department of the Environment (MDE) acknowledges the receipt of revisions to Maryland State Highway Administration's (SHA) Existing Water Quality Grass Swale Identification Protocol received on April 15, 2016. MDE would like to acknowledge SHA for their good-faith effort in updating the protocol and making MDE's requested modifications.

The SHA's recent revisions meet the documentation required by Section IV.3. of Maryland's "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated". MDE approves of this protocol for determining when and how existing roadway disconnects and grass swales can receive impervious area treatment and load reduction credits. MDE commends SHA for its commitment to improving this assessment program that will aid in restoring the State's water resources. If you have any questions regarding this review, please contact me at 410-537-3545 or Mr. Brian Cooper at 410-537-3583 or brian.cooper@maryland.gov.

Sincerely,

Raymond P. Bahr
Program Review Division Chief
Sediment, Stormwater, and Dam Safety Program

cc: Karen Coffman, SHA

Table of Contents

Versions:		
Date	**Version No.**	**Change**
November 2012	1	Initial Version
December 2013	2	General refinements
August 2014	3	Updated GIS methodology and general refinements
November 2015	4	Revised field procedures to measure all potential 2A swales Revised final analysis to use measured bottom width instead of assumed width in the analysis. Also added ‘V’ ditch analysis to compute equivalent flat bottom width. Updated field forms Provided Analysis Spreadsheets, accuracy spreadsheet and memorandum template Updated GIS Methodology Provided submittal details (data dictionary) Removed reference documents from the appendix Added Appendix F, G and H

Background and Purpose

Maryland State Highway Administration has implemented 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 addressing the requirements in its NPDES Municipal Separate Storm Sewer System (MS4) permit for additional water quality treatment of its legacy impervious areas.

Protocol development is described in the "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated" (MDE, 2014). This guidance states: "Many rural roads and residential subdivisions have open vegetated drainage systems, impervious area disconnections, and sheetflow to conservation areas that filter and infiltrate stormwater runoff". Further the document states that "each jurisdiction should conduct a systematic review of existing rural 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 roadway 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 area 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 highways. 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 in Phase I counties by the end of 2017 by using GIS analysis and input that information into SHA's NPDES database.

Detailed in the following is SHA's ***Existing Water Quality Grass Swale Identification Protocol***. The Protocol is used to identify existing grass swales for impervious area treatment and load reduction credit systems. This protocol will assess and document existing grass channels that approximate the current MDE SWM criteria. By using GIS analysis, topographic data, aerial photography, hydraulic analysis and field verification, the Protocol will determine drainage areas, slopes, ditch lengths, bottom widths, 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.*

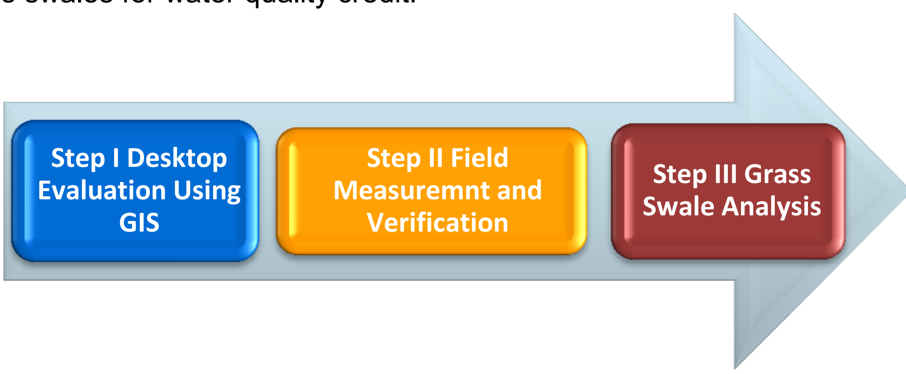
Chapter 5 of the *Manual* provides examples of ESD credits available to SHA. The **Grass Swales (M-8)** is one of these practices.

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 (M-8)**, which most closely resembles grass channel (ditch) drainage design criteria and which has been widely used by SHA as a stormwater conveyance practice.

The 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 in Section 1.1 Evaluation Parameters. These grass channels are used to reduce the volume of runoff and pollutants during smaller storms (e.g., 1 inch per event). The protocol will focus on identifying existing grass swales which satisfy the water quality credit requirements of Grass Swale (M-8) as well existing grass swales that could be retrofitted to obtain water quality credit.

Evaluation Process

For each State Highway controlled roadway, 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 may qualify for water quality credit.
- The second step is conducting field measurements. 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 number of sites are recommended for field validation of the desk top process described above. This minimum number of field accuracy assessment validation will vary from county to county, and will ensure that the LiDAR data used during the desktop analysis is accurate. Additionally, field measurements of potential grass swale parameters will be taken for use in the Analysis stage.

- The third step is a full county analysis and documentation of results. After Step 2, the field accuracy verification and measurement step is completed, the entire county will be evaluated, tabulated and results submitted to MDE.

Step 1: Desktop Evaluation

1.1 Evaluation Parameters

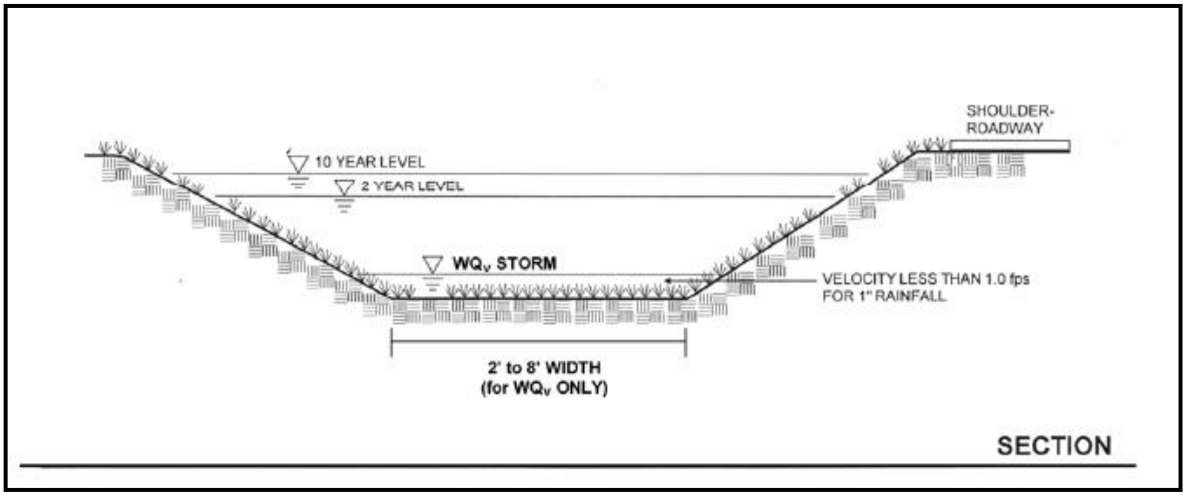
From Chapter 5, of the Manual the MDE stormwater criteria for this Grass Swales include:

- *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 requires a channel bottom between 2 and 8 feet, however the GIS analysis used in this Protocol has an accuracy of 10 feet. Furthermore, v-ditches provide water quality treatment if they meet certain equivalent flat bottom requirements. 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 GIS analysis and the available data used in 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, Field Verification.

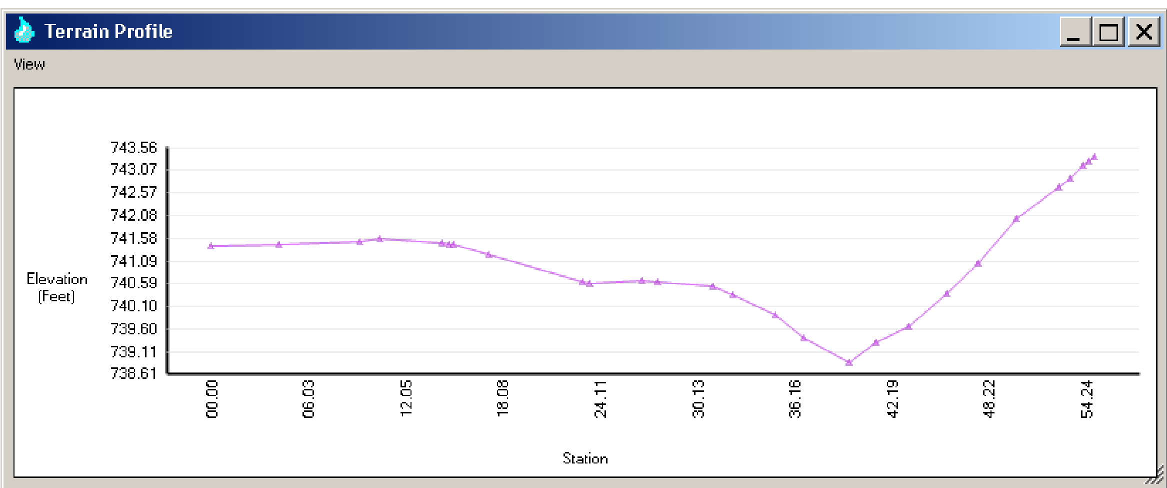
The intent of this evaluation is to find drainage features which approximate the MDE criteria for Grass Swales (M-8) within the tolerances of the data analysis tools, including methodologies for identifying grass swale variants. As shown below, five (5) credit categories will be used in the Grass Swales (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

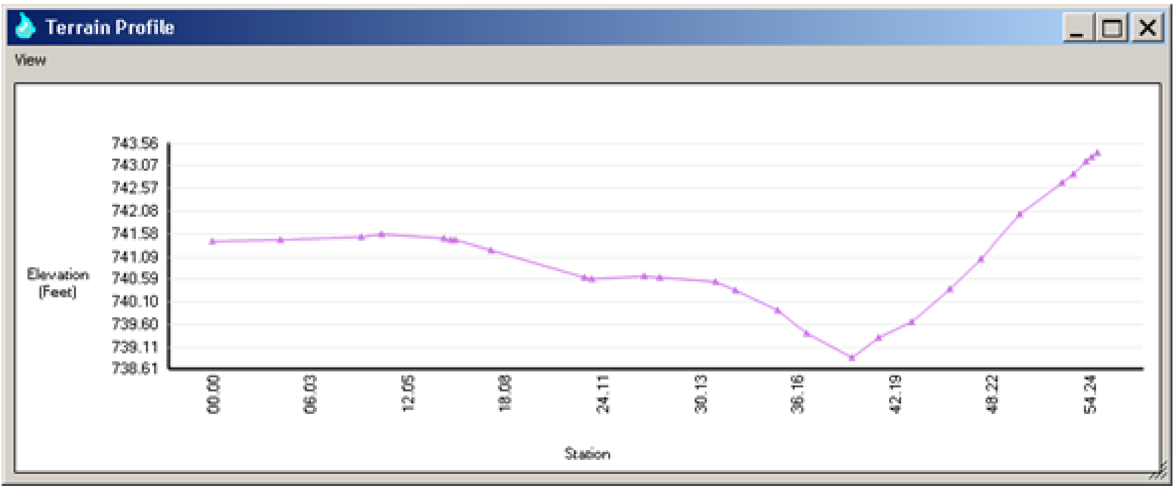


Category 1 – Meets MDE geometric criteria, with bottom width between 2 and 8 ft width, side slopes no greater than 3:1 and longitudinal slope between 0 and 4%.

Category 2 – Approximates MDE geometric criteria within the tolerances of data analysis tools, and with uniform cross-section.

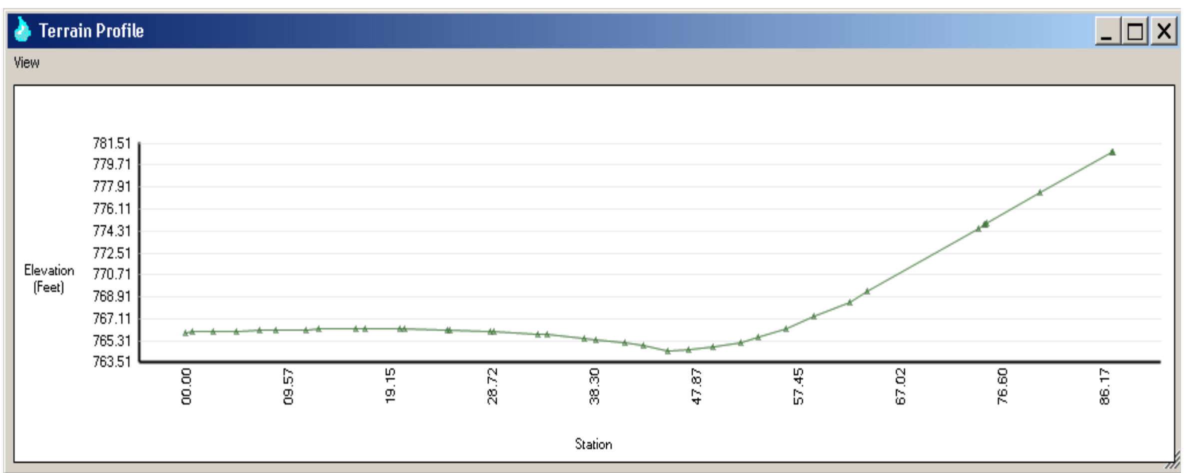


Category 2A – Approximates MDE geometric criteria, with bottom width between 0 and 10 ft width, side slopes no greater than 3:1 and longitudinal slope between **0 and 4%.**

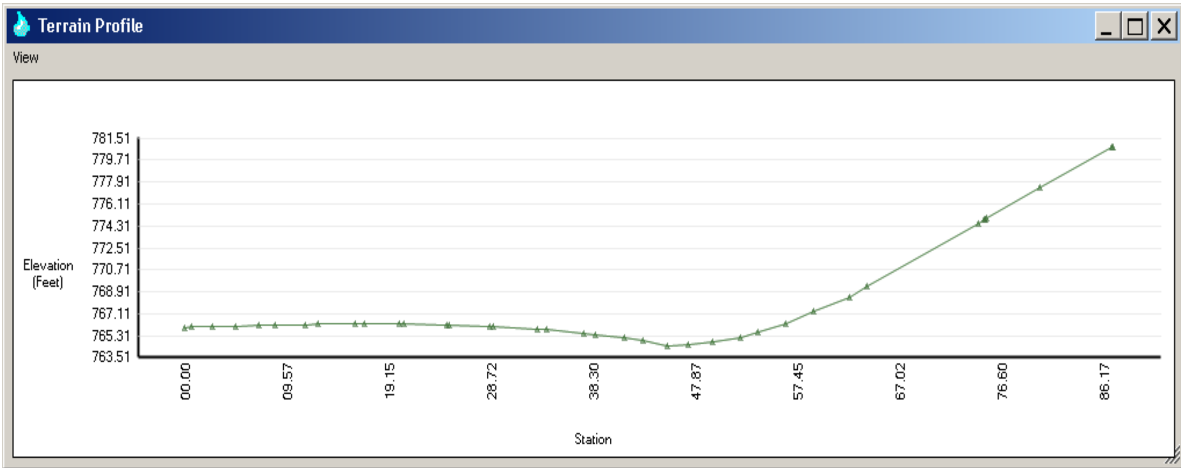


Category 2B – Approximates MDE geometric criteria, with bottom width between 0 and 10 ft width, side slopes no greater than 3:1 and longitudinal slope between **4 and 6%.**

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 side 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 side 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 and 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 various imagery services available on Maryland iMap (Maryland, 2011). Currently 2014 aerial imagery is available for most of the non-eastern shore counties in Maryland. These datasets vary from 0.8-ft vertical accuracy to 1.2-ft vertical accuracy at a 95% confidence level.

Impervious area coverage data can be obtained from SHA's Impervious Surface Account data which has a GIS file of SHA-owned impervious area by contacting the GIS office at MDSHA at GIS@sha.state.md.us. SHA is currently updating its impervious layer, so coordination with SHA should be conducted to utilize the most current impervious layer. Only the impervious area within SHA ROW and within an SHA's BMP drainage area has been delineated. The impervious area that is outside of SHA's right of way and is within a potential grass swale drainage area will need to be digitized so that this area can be used in the analysis of the channel.

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. Refer to Appendix E for a full description of data required.

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.

Appendix E of this protocol describes the step by step process to completing the Desktop Evaluation. Upon completion of the Desktop Evaluation the user will have a list of categorized swales. Only those swale that are categorized as a 2A swale will continue to Step 2 - Field Accuracy Verification process. For the final submittal, all analyzed swales, associated desktop delineated drainage areas, and desktop analysis parameters should be submitted. Refer to Section 3.6 – Submittal Requirements for the required data formats.The Swale ID should be in the format "Category_XX_123_IndX_CountyCode" and should be unique (all duplicate values should be resolved). For example, "Category_2A_30_Ind10_03" would represent a "Category 2A" swale which is number "30" located in the consultant designated "Index 10" in Baltimore County (03). Once the Swale ID is assigned, the Swale ID value will be used as a relational value between tables and will be entered into spreadsheets and forms during the post field processing.

1.3.1 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 auto-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. Delineation of these flow lines is included in **Section B** of the Protocol's Appendix E utilizing ArcHydro in the processing method. From these flow lines, the drainage areas are created in ArcHydro as well, as described in **Section H** of Appendix E. Each swale should be populated with a swale ID as described in Section 1.3.

An H&H Engineer should review the final desktop delineated swales and drainage areas to update the drainage area as needed. If during the desktop review of a potential 2A swale, the engineer sees reason to de-categorize a desktop generated 2A swale, the engineer should change the swale id from "2A" to "XX" and include comments as to the de-categorization.

1.3.2 Longitudinal Slope and Swale Length

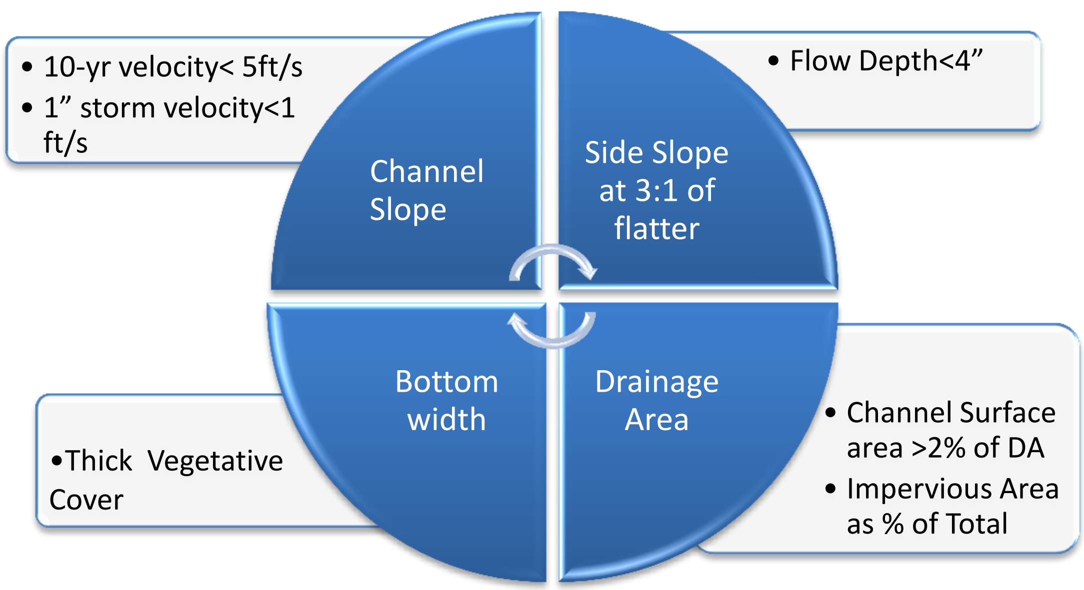
The LiDAR is used to calculate the median longitudinal slope of the delineated drainage features. The median slope is defined as the middle value of the list of slopes. In order to accurately represent the median slope of the drainage features, each line segment is broken at vertices and the slope is calculated then categorized/dissolved utilizing the values of the three slope variables and land category. The slope of all drainage lines is calculated using an automated and manual vertical slope analysis attribution processes using the LiDAR generated DEMs in **Section C** of Appendix E, and then categorized based on MDE defined slope requirements (i.e., 0 to 4%, between 4% and 6% and greater than 6%).

However, to develop continuous drainage feature lines based on longitudinal slopes, while ignoring isolated insignificant slope value in/outlier segments, swale segments of different slopes must be combined with adjacent segments of the same swale. So if a 2A channel is within 30' of another 2A channel, they are to be merged into a longer 2A channel. If a 2A channel sits between other category channels (such two 2B's, or two 3A's, etc.), the 2A is to be merged in with the other category channels. If the 2A channel is not within 30' of another 2A or does not sit between two other category channels, leave it as it is. Any 2A channel less than 20 feet long which has nothing attached to one end is to be deleted. The Engineer's discretion should be used when developing, merging, de-categorizing, or deleting swale flow line.

20 feet was chosen as the cut off length based on the EPA recommendation that the runoff takes 10 minutes to flow from the top to the bottom of the channel. Although the steepest and widest channels we are analyzing requires a length of 50', the flattest and most narrow need only be less than 2' long. The 20' length was chosen to eliminate data noise while keeping those that may qualify should a field review result in a longer swale being evident that what was found in the GIS. Please note that in Step 3, additional length requirements must be met for the 4% (min length is 40') and 3% (min length is 30') sloped swales.

Note: Do not merge any Category 5B with any other categories.

This process of calculating slope percentages 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. This process will also identify and eliminate drainage channels that have a longitudinal slope steeper than 6%. The length of channels will also be determined using GIS via ESRI's native geometry calculation.



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. The side slope attribution process is shown in detail within Appendix E, **Section D**.

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. Additionally, in the past, MDE Sediment and Stormwater Plan Review accepted the idea that triangular channels can qualify for grass channel credit if it can be demonstrated that the wetted perimeter (WP) of the triangular channel is greater than a flat-bottom channel with a 2-foot bottom width and 3:1 side slopes. Therefore the bottom widths of each swale will be measured during Step 2 - Field Accuracy Verification and if the channel is a V-ditch, the equilavent flat bottom width will be determined in Step 3 – Grass Channel Analysis.

1.3.5 Land Cover Determination

Visual review of aerial photography and publicly-available street view imagery such as Bing Maps or Google Maps, 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 and is available in detail at Appendix E, **Section E**. Note that field observations may require the swale bottom material to change.

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. Additionally, the grass channel must be able to carry the ten year storm at a velocity at or below 5 ft/s. Grass Channel requirements in the Manual also dictate the maximum flow depth of 4”. This protocol has developed a procedure to determine the maximum drainage area based on side slope, longitudinal slope and percent impervious described in Step 3 below. This procedure follows the requirements outlined in the Manual and using Manning’s Equation. Please note that swales with longitudinal slope of 4% do not meet the velocity requirements if they have a bottom width greater than 5’ wide.

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. The combining of adjacent ditch segments described in 1.3.2 (Longitudinal Slope) is followed by the auto-generation of drainage areas for potential swales utilizing the ESRI available ArcHydro toolbar/toolbox as explained in Appendix E, **Section H**. The actual drainage area associated to the channels will be evaluated to determine if the swales meet the other criteria for Grass Channel credit (Step 3). Although a drainage area will be auto-delineated for all grass swale categories, only the drainage areas associated to potential 2A swales require updating for further analysis. Each drainage area should be assigned a swale identifier as described in Section 1.3

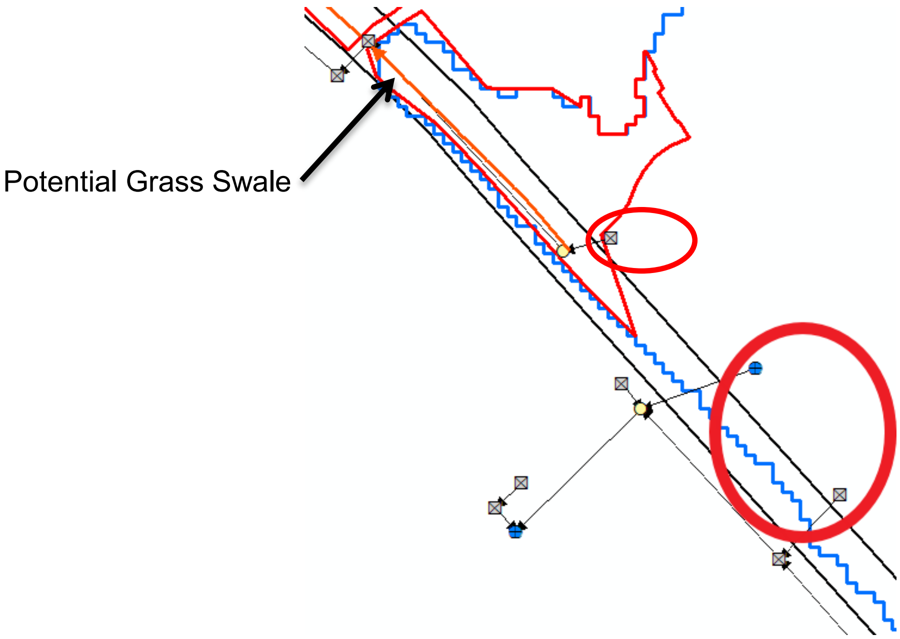
The auto-delineated drainage areas for the potential 2A swales should be reviewed by a qualified H&H engineer prior to field verification. GIS layers to take into consideration during the desktop review include 2-ft elevation contours, SHA and County storm drain layers, and aerial imagery. The review should be conducted by a water resource engineer or someone that has experience delineating drainage areas.

During the desktop review, the reviewer should make the necessary updates to the drainage area boundary. Only major and obvious drainage area boundary errors should be corrected. Only drainage areas for potential 2A grass swales should be modified. Most of the BMP drainage areas in the existing NPDES database have been field verified. If a potential 2A grass swale shares a drainage area boundary with an existing BMP drainage area, the potential 2A grass swale drainage area boundary should match that of the existing BMP drainage area.

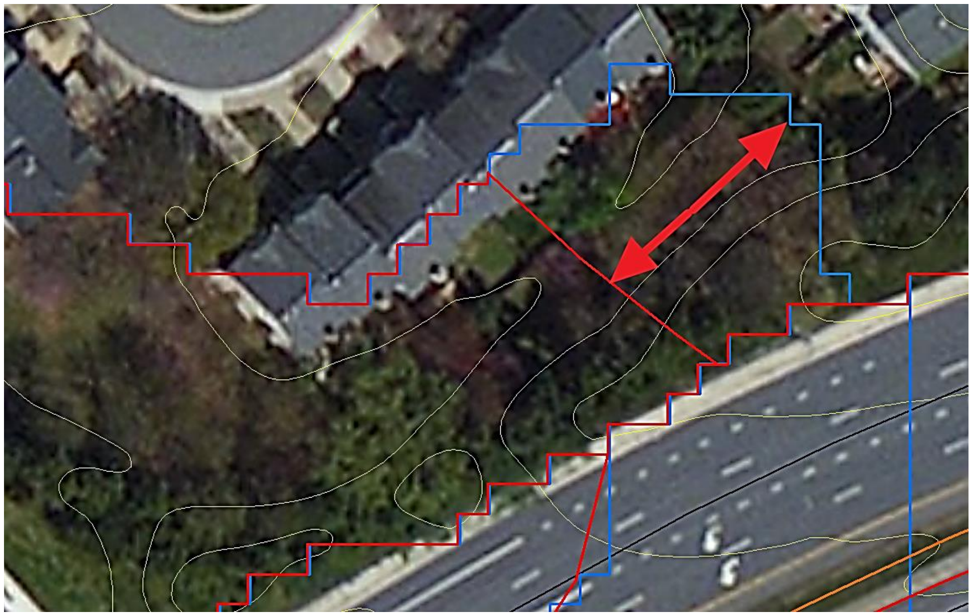
Newly identified swales that have a drainage area that overlaps an existing BMP drainage area will be included in this analysis. It is possible that the swale will provide better pollutant removal than the existing BMP so an analysis of these swales should be completed in Step 2 and Step 3.

Straightening of the jagged lines that mostly follow the 2-ft elevation contours is not considered a major error. Examples of major errors include (blue outline is the auto-delineation; red outline is the desktop corrected boundary):

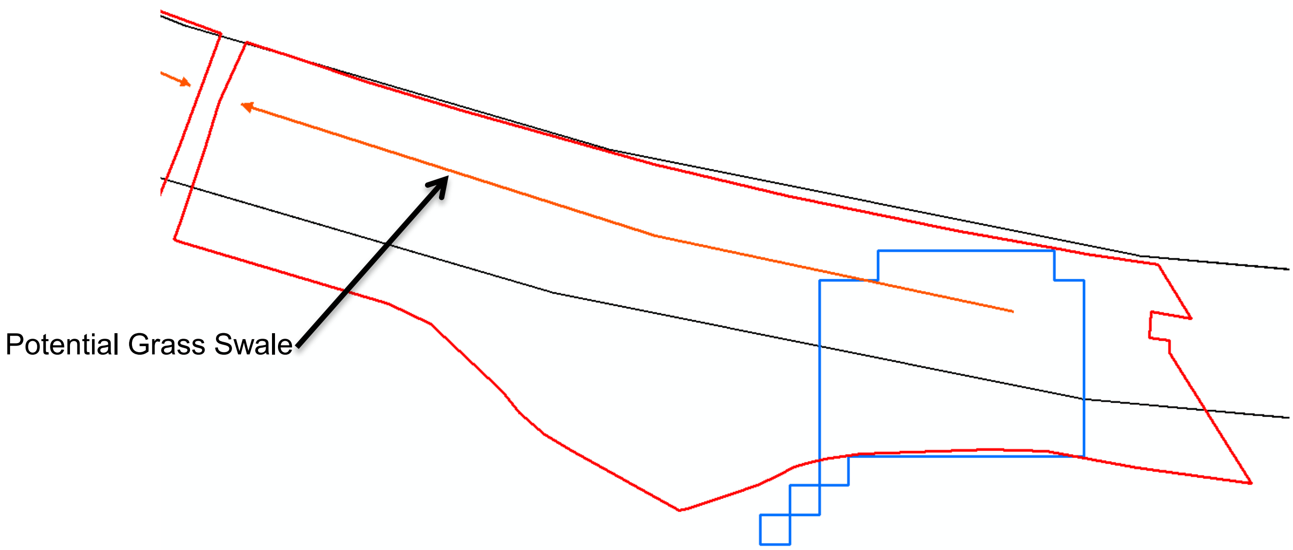
- Storm drain features diverting water to or from the potential swale that effect the drainage area boundary:



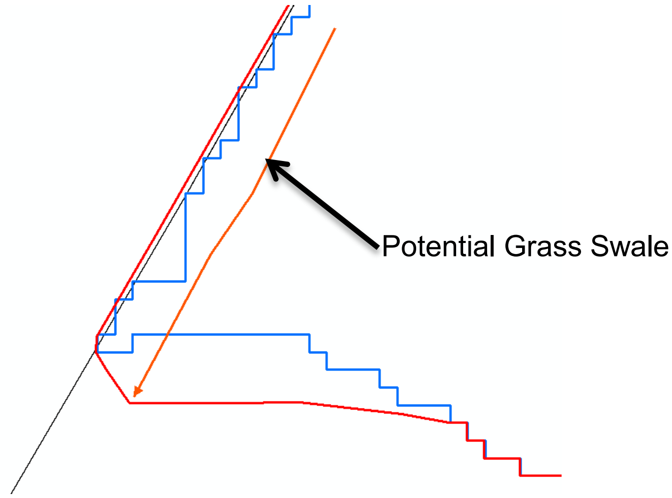
- Drainage area boundaries completely incorrect based on 2-ft elevation contours or engineering judgment:



- Drainage area boundaries that didn't completely delineate during the desktop auto-process:



- Drainage area boundaries that do not incorporate or over-shoot the potential 2A swale limits:



- Corrections can also be made to tighten up the boundaries around SHA's ROW. In the example below, the drainage areas for the swale in the upper left of the photo was very large (blue outline). When reviewed in the desktop environment, it was determined that storm water was being drained by the stormdrain system located throughout the development. Therefore the drainage area to the swale was adjusted to the red outline.

During the desktop review of the drainage areas, the reviewer should make notes as to exact locations along the drainage area boundary that require field verification. These are boundaries that are inconclusive based on the GIS source data review of the drainage area.

1.3.8 Treated Impervious Area

The drainage area boundaries described above will be intersected with the impervious areas. All impervious (within and outside of SHA ROW) should be calculated for each swale drainage area. The percent impervious will be used during the post field data analysis for each swale.

SHA's current impervious GIS layer was created based on SHA ROW and existing BMP drainage areas. There will be impervious area outside of the current impervious GIS layer that will need to be digitized and incorporated into the shape file. This additional impervious area, including all paved surfaces and rooftops, will need to be included for the new potential 2A drainage areas prior to conducting the analysis in Step 3.

1.4 Declassification

Throughout the swale delineation process, swales will be de-categorized based on engineer review, field measurements and observations, and post field analysis. If a potential 2A swale is de-categorized throughout the process, the Swale ID should be changed from "2A" to "XX", and notes should be included that describes the reason for the de-categorization.

2A swales are declassified to an XX swale during the Step 1 process if:

- The swale length is less than 20'.

Step 2: Field Verification

2.1 Introduction

All potential 2A swales must be visited in the field to measure the swale geometry, verify drainage areas limits and ground cover, and to document the swale with photographs. Proper SHA maintenance of traffic for the District you are working in must be followed while conducting field work.

Upon completing the Desktop Analysis, all potential 2A swales will have been identified. A site visit will be made to these potential 2A swales. 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.

If any swale geometry, drainage areas boundary, or ground cover discrepancies are found during the field measurements, GIS modification to swale parameters should be made in the office prior to final water quality calculations done in Step 3

2.2 Field Measurement and Verification

Field measurement of all identified Category 2A swales that potentially meet Grass Channel criteria will be performed to determine the bottom width, to verify the contributing drainage area and be sure the swale exists, and to ensure there is no visible functionality issues that would disqualify the swale from operating as a MDE classified M-8 grass swale. Field verification also includes capturing photographs of each swale. SHA must perform a field measurements/verification of all swales that meet the M-8 criteria so that TMDL reduction credit can be claimed.

For the field verification, the field crews should verify and update the drainage areas within a walkable distance of SHA's ROW and within SHA's impervious coverage. It is not required to go off SHA ROW in most cases. If during the desktop review, the reviewer identifies a drainage area boundary that should be field verified off SHA's ROW, it will be at the field crew's discretion to confirm the boundary in the field, while staying on public property. The overall goal of the drainage area boundary verification should be to produce an accurate drainage area based on water resource engineer approval.

Field crews should attempt to confirm the entire drainage boundary. Where crews can make a confident statement that supports the initial delineation (or justifies a change in the delineation), crews shall provide such a statement and document the change on field forms provided in Appendix A and edit the drainage boundary if appropriate. If field crews cannot verify that flow is entering or being diverted to a swale due to private property restrictions, crews should document that "no opinion" can be made on the validity. In such cases, the swale(s) should be de-categorized and renamed as an "XX" swale with notes included as to the de-categorization reason.

2.3 Field Forms

2.3.1 Grass Channel Identification Cover Page

Standard field forms were created to record data measured and observed during the field Stage. The field teams may also utilize digital forms to capture the information; digital forms have not been developed. If the field teams use hardcopy field forms, the forms should be scanned, renamed accordingly, and submitted. Refer to Section 3.6 – Submittal Requirements for the required data formats.

The Grass Channel BMP Identification Cover Page must be filled out for each grass channel visited. This form will be used to identify and locate the channel by County and Swale ID number. The date, weather (including rainfall events) and crew names must be included. A checklist is included to ensure all aspects of the field review have been completed. 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.

2.3.2 Field Data Input Form

The Field Data Input Form also must be completed. It will be used to identify the cross section elements and to calculate channel slope. At a minimum, the longitudinal slope at the cross-section location will be measured and calculated. Should the H&H engineer determine other locations along the channel should have slope measurements 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 to determine swale bottom width. The vertical changes at these points must also be measured using the level and measuring tapes described in the equipment section, Section 2.4.3 below. This bottom width will be used in Step 3 to validate swale criteria. The swale type must be recorded on the form; i.e. flat-bottom, V-channel, parabolic, or NA in the notes block. The Photograph Log table should be used to record the photographs captured during the field work. Photographs taken at all potential 2A swales during field measurements should be renamed and submitted. Required photograph locations and photograph naming convention is described in Section 2.4.2 below and Section 3.6.

A section for notes on other findings and a section for items that may be identified such as damaged guardrail, erosion problems, damaged pavement, etc. are included. Issues pertaining to public safety and hazards should be conveyed to the SHA project manager within 24 hours of finding the issue, and a report containing a location map, photographs, and issue description should be submitted. The NPDES section is to be filled in should the team identify a stormdrain or BMP not in SHA's current NPDES database. Finally, boxes are included to note changes in either the swale length or drainage area and for noting a category change (i.e. from a 2A to a 2B if the slopes are steeper than 2:1)

Note that all swale field measurements will be recorded in tables and submitted during the final submittal. Be sure to maintain the Swale ID as swales are de-categorized based on field observations. Swale measurements will also be used during Step 3 to perform further evaluation of the swale parameters, so it is important to maintain the field data integrity.

2.3.3 Grass Channel BMP Site Sketch and Additional Photographs Sheet

The team may choose to update swale and drainage area geometry using a hardcopy field map or a digital solution. When more space is needed than available on the field map, this optional sheet is to be utilized as a space to sketch any field changes.

Regardless of the process, the data collected and updated in the field should be available for post field GIS updates and quality control. As well, if a hardcopy solution is utilized, the field teams should mark up the field map with any geometry edits and other information that can be used by the quality controller. Hardcopy field maps must be scanned, renamed accordingly, and submitted. Refer to Section 3.5 – Submittal Requirements for the required data formats.

Also, this sheet can be used should more photos be taken than there is room for on the Field Data Input form.

2.3.4 Inspector's Daily Log

The Inspector's Daily Log form is optional and can be filled out by the field crew leader to record basic information such as the date, weather, crew names, channels inspected, and unusual conditions.

2.4 Field Methodology

2.4.1 Field Measurement Locations

The potential 2A swale field measurements will be reviewed to determine safe access prior to embarking on field measurements. SHA safety procedures will be followed when accessing each site and collecting the data. This includes the use of warning lights, traffic cones, OSHA approved safety vest, and crash protection vehicles as required by the SHA district you are working in. Please coordinate with SHA to determine the proper MOT required in the working District. The field crew will carry SHA's signed Letter of Intent (example in Appendix A) granting permission to access the sites, company identification, and driver's license at all times. Each swale will be field measured in compliance with and per the SHA NPDES Data Management & Editing Tools Manual and SHA's BMP Inventory and Inspection Manuals.

2.4.2 Field Data Parameters

Cross sectional data will be collected at the most represented location within the swale limits while taking safety into consideration. Although the swale parameters were calculated during Step 1, the field measurements will override the desktop values when performing the post field analysis in Step 3. The following information will be collected in the field for each potential 2A swale:

- Channel GIS Geometry – the potential 2A swale GIS geometry and drainage area boundary should be verified in the field and updated as necessary.
- Measured Channel Parameters
  - Bottom width (ft) – measured from bottom of slope to bottom of slope. The value is zero (0) for V-channels.
  - Depth of ditch (ft) – depth from bottom of the swale to the edge of pavement measured from the leveled cross-section tape to the bottom of the channel.
  - Side slopes (Z:1) – both side slopes should be measured
  - Longitudinal slope based on elevation collected 30 feet upstream and 30 feet downstream of each cross-section (ft/ft), for a total length of 60 feet, where possible. There may be instances where this distance is shorter. It may be necessary to take multiple longitudinal slope measurements due to changing slope within the channel limits. When entering the channel slope in the post field analysis spreadsheet, multiple longitudinal slopes should be averaged.
- Land cover description (e.g. grass, brush, stone, concrete) – the field observed bottom material will override the desktop determined value. Maintenance issues, such as lack of grass or erosion, may be observed during the bottom material observations. Maintenance issues do not de-categorize a swale.
- Location and stability of outfall – the field team should identify any maintenance or erosion issues at the outfall
- Photographs – the goal of the photographs is to document the swales current condition and/or any issues related to the potential swale. The photograph naming convention is described in Section 3.6.
  - Photograph of the overall channel; at a minimum one photograph looking upstream and one photograph looking downstream. It is at the field team's discretion as to the number of photographs required to document the swale.
  - Photographs of maintenance issues
  - Photographs of potential public hazards
- GPS location of the cross-section(s) which will be used during the accuracy assessment evaluation of the Z elevation.
- GPS of storm drain structures that are visible on the aerial imagery which will be used during the accuracy assessment of the X and Y coordinates.

2.4.3 Field Equipment

It is at the team's discretion as to the field equipment used to capture the potential 2A swale geometry. The field teams can utilize hard copy forms and maps, or utilize digital solution to capture the data in the field.

GPS units will be used to verify the potential 2A swale location. A measuring tape will be used to measure the bottom width, and a survey level and tape measure will be used to measure side slopes. Equipment required for the field include:

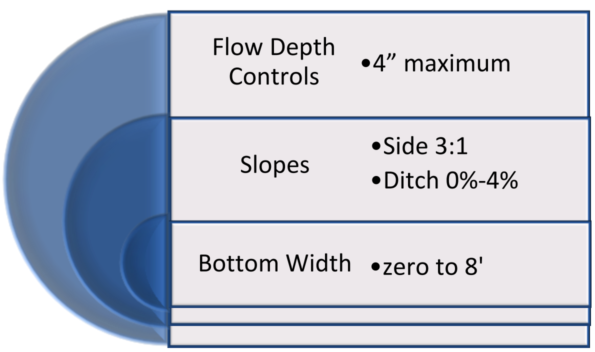
- Safety Gear (safety vests, amber lights, traffic cones, at a minimum. Refer to the Districts MOT requirement for proper safety gear include the use of crash protection vehicles)
- Letter of Intent
- Stakes
- 2-100’ Tapes
- Camera (preferred with GPS photo-tagging)
- Hammers
- Hand Level
- Line Level
- Measurement Wheel
- Flags/Pins
- Truck Magnets
- 25’ measuring tape
- GPS (sub-meter accurate)
- Flashing Light / MOT Cones
- Field maps and forms
- Survey Rod

2.5 Characterization of Field Conditions

The data collected during field measurements will be used to modify drainage areas and swale spatial representations.   The geometry measurements will determine bottom widths and will be used in Section 3.3 to determine water quality treatment provided. 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. All results of the field measurements will be submitted regardless of the final categorization. Refer to Section 3.5 for database submittals.

2.6 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 width between zero for a v-ditch to eight feet.



M-8 Swale Geometry

2.7 Summary of Evaluation Parameters

The evaluation parameters for the 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 steps will collect actual slope measurements in order to assess GIS predictions. To do this, elevations will be taken at locations upstream and downstream of the cross-section site.

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 steps will collect actual slope measurements.

Bottom width:

- The GIS data identifies channels with a bottom width of 10' or less.
- Field evaluation steps will collect actual bottom widths.

Depth of ditch

- Depth from the bottom of the ditch to the edge of shoulder must be at least 4".
- This measurement will be collected in the field.

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 steps will collect land cover descriptions for comparison to the visual classification from aerial imagery.

Impervious and drainage obstruction features:

- Desktop analysis can calculate 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 observations will indicate highway conditions and 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, as needed to determine the presence of an unstable outfall as well as a photograph looking upstream to show the inflow conditions.

2.8 Declassification

Field crews may also identify swales that are not true channels, swales that do not meet the ground cover requirements, or swales that receive concentrated flow from closed storm drain systems. The swales that obviously do not meet the MDE criteria based on field observations should be de-categorized to an "XX" swale and notes must be included that describes the reason for the de-categorization.

Swales are declassified to an XX swale during the Step 2 process if:

- There is no swale based on field observations

- Swale drainage areas cannot be confirmed due to access restrictions
- Field measured depth from the bottom of swale to edge of pavement is less than 4”
- Side slopes at representative cross section are steeper than 3:1
- Field measured bottom width greater than 8.
- Lining material is anything other than grass (eroded swales should be identified for maintenance)

2.9 GIS Analysis Accuracy Assessment

Additionally, a minimum number of coordinates and elevations are needed for determining the accuracy of the LiDAR data. The number of sample locations to be taken is calculated based on the equation :

Sample size = 5.88 * C * (1-C)/ .0025

C= percent share of SHA and County right-of-way in each county

This number will vary from county to county, with a minimum of fifty (50) sample locations. Location accuracy describes the degree to which items on the map are shown in their true location. GIS information must be compared to a sample of field measurements to assess the accuracy of the LiDAR and validate its use in this application. It can then be concluded that all the geometric based calculations and spatial representations are correct. To do this it is recommended that the field measured X and Y coordinates be taken at storm drainage structures and then compared to those identified from the GIS files. The Z elevation shall be gathered at the cross-section location described above in **2.4.2 Field Data Parameters** and then compared to the associated GIS point.

While the academic literature on assessing locational accuracy (sometimes referred to as positional accuracy) is vast, one source most repeatedly cited in the discussion is the Positional Accuracy Handbook which applies to the National Standard for Spatial Data Accuracy.

See Appendix B for a sample of the accuracy assessment report (*Grass Channels GIS Accuracy Memo.docx*) as well as the spreadsheet used to determine the accuracy (Grass Channel Accuracy Analysis.xls)

Step 3 Grass Channel Analysis

3.1 Introduction

After conducting the desktop analysis, field measurement and verification steps, the evaluation of all SHA owned roadway in the County will be done to determine which channels qualify as grass swales. This final step utilizes the modifications to the potential swale lines and drainage area boundaries auto-generated from desktop and adjusted per field observations. The information generated during the Data Analysis step (Section 1.3) 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).

3.2 Post Field Analysis

In order to determine the amount of treatment credit the swales may provide, drainage areas and percent impervious information will be measured and calculated as described below.

Detailed analysis of the grass swale credit criteria has shown that the flow depth is the controlling factor in determining if channels will meet the grass swale credit. Calculations were done as part of the protocol development 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 per percent impervious.

3.2.1 Surface Area of Channel > 2% of Contributing Drainage Area

In order for a grass swale to qualify for credit the surface area of the swale bottom must comprise at least 2% of the overall drainage area flowing into the swale. This parameter comes from the MDE Stormwater Design Manual Chapter 5.4.3. The percentage is calculated using the swale length validated during field measurements and the measured bottom width measured in the field from relative to the overall drainage area size.

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, PE=1” is assumed in the protocol (See Appendix F). However, plugging PE=1” in the equation above will not work, because that would result in (Af/DA)>10% which is too conservative. Instead, it was determined that the equation above represents a design tool and is not relevant to use in this credit analysis and that a simple check of the surface area of the channel being greater than 2% of the contributing drainage area is appropriate. For analysis of v-ditches, the equivalent flat bottom width will be used in the 2% calculation.

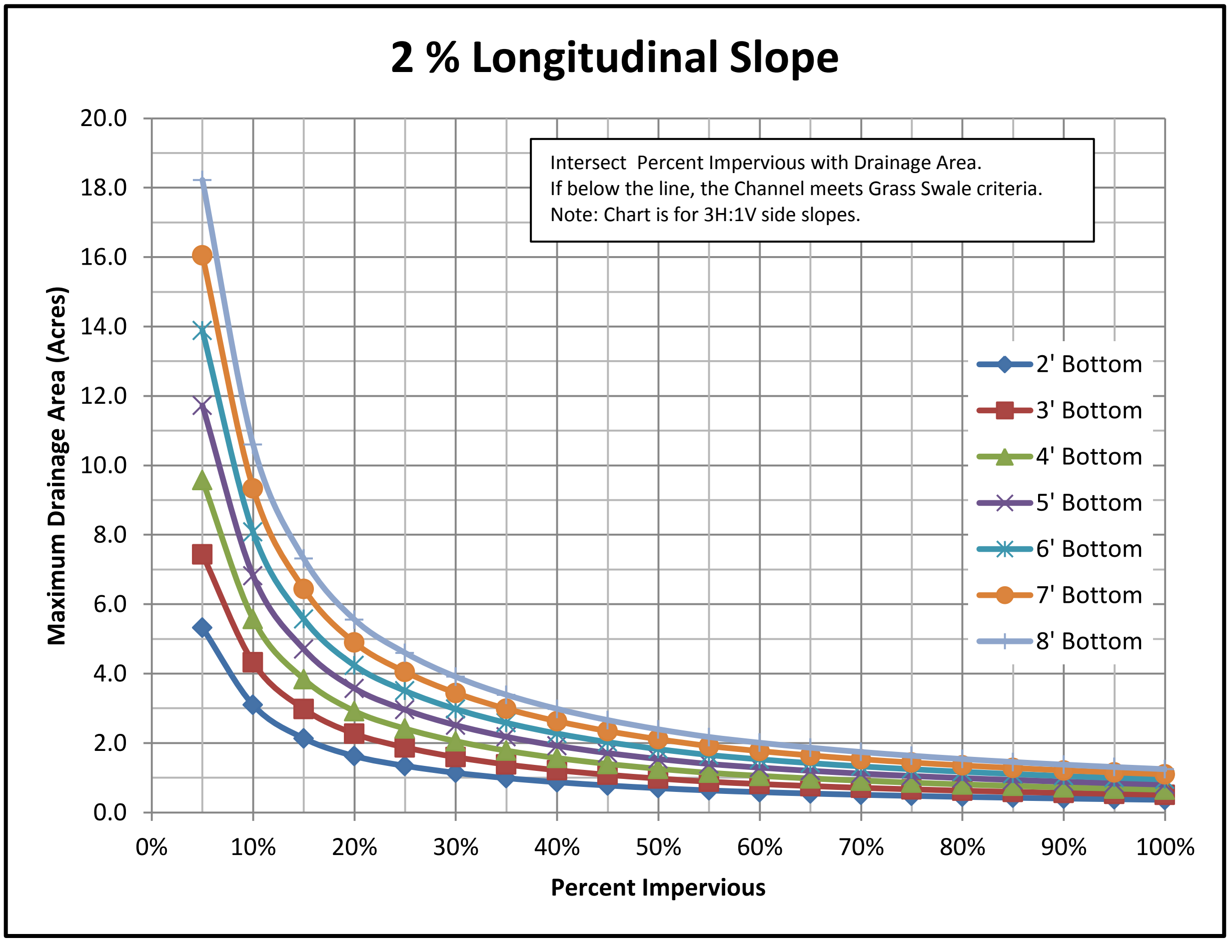
3.2.2 Analysis Spreadsheets

Spreadsheets have been developed for the engineer to use in determining if a ditch will meet Grass Channel Credit criteria. The first is the Grass Swale Data Input sheet (*Grass Swale Data Input.docx*) will be exported from GIS and supplied to the engineer. The Grass Swale Final Analysis sheet (*Grass Swale Final Analysis.docx*) is used to perform the analysis to determine if a swale meets the M-8 Grass Swale criteria. The Engineer will input data from the Grass Swale Data Input sheet generated in Step 1 and from the field measurements taken during Step 2 into the Grass Swale Final Analysis sheet. This spreadsheet is based on the charts contained in Appendix C. The engineer will use a spreadsheets specific to each county.

The methodology uses the charts to intersect the percent of the total impervious draining to the ditch within the drainage area. If the intersection point falls below the relevant line (2’ to 8’ wide ditch) then the ditch meets Grass Channel Criteria. If it falls above the line, it fails, and the swale may be considered a category 2B swale. The Desktop and Field derived parameters are entered into a final analysis spreadsheet (*Grass Swale Final Analysis.xlsx*). The spreadsheets will perform the necessary calculations and will allow the user to identify the swales that meet the MDE criteria based on field measurements.

3.2.3 Grass Swale Charts

Analysis has shown that the flow depth is the controlling characteristic for most 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 except for channels with longitudinal slope of 4% with bottom widths of 6' or greater. For these channels, the velocity criteria are greater than the 1 ft/s and 5 ft/s requirements and therefore are not to be considered qualifying as Grass Swales. 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 channel at a 2% slope. The design methodology for developing these charts and associated equations is outlined in Appendix F and MDE's approval of the Grass Swale methodology can be found in Appendix G.



3.2.4 Equivalent Flat Bottom Width

In the past, MDE Sediment and Stormwater Plan Review accepted the idea that triangular channels can qualify for grass channel credit if it can be demonstrated that the wetted perimeter (WP) of the triangular channel is greater than a flat-bottom channel with a 2-foot bottom width and 3:1 side slopes. This was formalized in the Grass Channel Credit Guidance (2003) prepared by SHA and used on subsequent SHA projects (See Appendix H for a copy of this document). The basis of this idea is the WP, a key factor in grass swale pollutant removal ability. The WP is the length along the edge of the swale cross section where runoff flowing through the swale contacts the vegetated sides and bottom. Increasing the WP slows runoff velocities and provides more contact with vegetation to encourage absorption, filtering, and infiltration.

If the triangular channel has a WP greater than or equal to the minimum-sized trapezoidal channel (based on the same discharge and channel longitudinal slope), then the triangular channel provides equivalent water quality treatment as the trapezoidal channel.

Based on this concept, existing triangular channels (or V-ditches) are analyzed to determine their equivalent flat bottom width based on a trapezoidal channel section. The specific steps involved with this analysis are:

1. Determine the water quality discharge to the existing V-ditch.
2. Based on the existing V-ditch geometry (side and longitudinal slopes), determine flow depth, flow velocity, and WP.
    a. If flow depth and velocity exceed Chapter 5 Grass Swales (M-8) criteria, then the existing V-ditch is automatically eliminated from further analysis. No existing water quality is provided.
    b. If flow depth and velocity meet Chapter 5 Grass Swales (M-8) criteria, then the existing V-ditch is analyzed to find its equivalent bottom width/flow depth/WP based on a trapezoidal channel.
3. Determine the equivalent bottom width/flow depth/WP based on a trapezoidal channel with 3:1 side slopes and the same water quality discharge and longitudinal slope as the existing V-ditch.
    a. If the equivalent bottom width ≥ 2 feet and equivalent WP ≤ the WP of the existing V-ditch, enter the equivalent bottom width value into the Final Analysis spreadsheet and complete the final existing grass swale analysis.
    b. If the equivalent bottom width < 2 feet or equivalent WP < the WP of the existing V-ditch, the existing V-ditch is automatically eliminated from further analysis. No existing water quality is provided.

The equivalent flat bottom width will be used for V-ditch and any flat bottom swale with a bottom width of less than two (2) feet wide. A spreadsheet for determining the equivalent flat bottom width is located in Appendix C (Grass Swale Equivalent.xlsm). Any potential swale that has a field measured bottom width between zero (0) and (two) 2 feet wide is entered into the Equivalent spreadsheet to identify the equivalent bottom width. The user will input the total drainage area, impervious area, swale length and swale slope from the field measurements and GIS desktop analysis. The side slopes will be measured in Step 2 and input into the Equivalent Flat bottom width Spreadsheet for these channels. Any side slope measuring steeper than 3H:1V is disqualified and shall not be analyzed. A time of concentration of equal to 0.1 hour should be used as the standard in the Equivalence spreadsheet. The final equivalent bottom width (Equivalent Bottom Width value) is re-entered into the Final Analysis spreadsheet for the V-channels and the final analysis is complete (Section 3.4). A button exists in the V-channel Equivalence spreadsheet that allows the user to export the calculation to a table that will be submitted upon completion.

3.3 Water Quality Treatment Credits

The results of the post field analysis done in Step 3.2 and field measurements done in Step 2.4 will be used to summarize the impervious area treated and load reductions credited 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 shall be noted if identified during the evaluation.

The grass swales will be tabulated along with pervious and impervious area draining to them and summarized according to location along the roadway (roadside ditch or median ditch), County, MDE Watershed, drainage area and treatment credits (see the example table below). Please note that SHA will populate the 8-digit watershed information in a batch upon submittal of the final grass swales; the consultant can leave the column blank. 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.

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 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 57% Total Nitrogen, 66% Total Phosphorus and 70% 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 table below shows sample load reduction found along a portion of I-70.

					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

3.4 Declassification

Swales will be declassified based on the Analysis process. These swales should be de-categorized to an "XX" swale and notes must be included that describes the reason for the de-categorization.

Swales are declassified to an XX swale during the Step 3 process if:

- **% of Drainage Area** – any swale where the percentage of swale area vs. drainage area is less than 2% is de-categorized to an "XX" swale.
- **Max Drainage Area vs. Existing Drainage Area** – any swale where the existing drainage is greater than area maximum allowable drainage area is de-categorized to an "XX" swale.
- **Swale Length less than the following minimum**:
    - **4%-**40'
    - **3%-**30'

3.5 Submittal Requirements

For the final submittal, all swale analysis results created during the Desktop Analysis through the final post field analysis will be submitted. Associated tables related to the analysis process will be populated and submitted. These tables include the analysis spreadsheet results, final feature classes of the swales and drainage areas, and supporting files and tables (photographs & documents). The submittal requirements are defined below and the data dictionary containing the submittal definitions are in Appendix D. The data dictionaries identify the source of the data and the tabular field definitions. The team should confirm feature classes and tables to match the data dictionaries provided. The databases, feature classes, tables, and spreadsheets have been provided.

- **Grass Swale Database Submittal geodatabase** (*Grass_Swale_Database_Submittal.mdb*) – a personal geodatabase has been created to store the grass swale features, analysis results, final NPDES features, drainage areas, and photograph and document file names.
    - <u>GRASS_SWALE_SS feature class</u> **-** this line feature class contains the desktop analysis results for all of the swales analyzed during the processes, including non-2A and failed 2A swales. Some of the fields may change based on field observations and measurements. Most of the fields in the table represent the desktop generated values but some values may change due to field verification and post field analysis. One example, is the CATEGORY_FINAL field where the value will change as potential 2A swales are de-categorized. This feature class should contain all categories of swales (2A thru 5B). Be sure that the final CATEGORY_NUM is populated correctly.
    - <u>SWMFAC feature class</u> – this polygon feature class contains the final swales that meet the MDE criteria and are assigned a BMP number. The final BMP polygon should be created by using the field measured or V-channel equivalent bottom width and field verified swale length to create the polygon outline.
    - <u>GS_SS_DA feature class</u> – this polygon feature class contains both the raw desktop delineated drainage areas and the final 2A swale drainage areas that are updated throughout the process. Each polygon feature should have an associated CATERGORY_NUM.
    - <u>GS_SS_PHOTOS_DOCS table</u> – this table contains the filenames of any associated photographs, field forms, or mapping. See below for proper file naming conventions.

- **Grass Swale Data Input spreadsheet** (*Grass Swale Data Input.xlsx*) – this Excel spreadsheet contains the field measurements for the potential 2A swales. Be sure that the final CATEGORY_NUM is populated correctly. The spreadsheet can be found in Appendix C.

- **Final Analysis spreadsheet** (*Grass Swale Final Analysis.xlsx*) – this Excel spreadsheet contains the potential 2A swale post field analysis results. Be sure that the final CATEGORY_NUM is populated correctly. If a swale is de-categorized to an "XX" swale based on the parameter analysis, the CATEGORY_NUM field should be changed in this table and in the Grass_Swale feature class. The spreadsheet can be found in Appendix C.

- **V-Channel Equivalence spreadsheet** (*Grass Swale Equivalent.xlsm*) – this Excel spreadsheet contains the potential 2A swales that were identified as V-channels, and therefore entered into the equivalence spreadsheet to determine the equivalent bottom width. Be sure that the final CATEGORY_NUM is populated correctly. The spreadsheet can be found in Appendix C.

3.6 Photographs:

The most efficient and manageable digital photograph format is JPEG (aka .jpg). This format can be generated by most digital cameras and is read by most computer applications. Care must be taken to balance image quality (i.e., low, medium, high resolution) with file size. The lowest resolution should be used that is still sufficient to clearly view the subject. File sizes per image file should be less than one megabyte. Photographs can all be stored in a folder named "*AA*_Co_Swale_Photographs_2015".

Photographs are taken at every Category 2A swale that requires field measurements. The photograph is an attempt to provide an overall view of the site and also any site conditions associated with the verification. At a minimum, field crews should photograph:

- Swale looking upstream
- Swale looking downstream
- Maintenance issues

The field crew should make every attempt to capture photographs in the same location as past inspections. If necessary, the photograph location can be described in the COMMENTS field in the corresponding table.

Field photographs should be labeled with the date and the SMWFAC number (or Category_Num). This label should be imbedded within the image. The labeling on the photograph can be created with any photograph imaging software. Refer to the image below as an example of photograph labeling.

The naming convention of the jpg image and the FILENAME field is as follows

For swales that pass the entire criteria and receive a BMP number:

<SWMFAC>-<Descriptor>-<sequential letter (A-Z), if necessary>-<YYYYMMDD>.jpg

Descriptors:

- OV = Overall (Overall pictures of the swale)
- SP = Specific concern (Pictures of any site concerns/constraints)
- ER = Erosion
- SD = Storm drain structure
- MA = Maintenance
- OTH = Other photograph

Some examples would be:

- 020001-OV-A-20150903.jpg
- 020001-OV-B-20150903.jpg
- 020001-ER-A-20150903.jpg
- 020001-ER-B-20150903.jpg
- 020001-SP-A-20150903.jpg

For swales that do not meet the criteria: *Category_NUM*-OV-A-20150903.jpg, -OV-B, etc.

3.7 Field Map Naming Convention: Please submit the marked up field maps with your submittal. Be sure that the swale CATEGORY_NUM or BMP number is clearly labeled on the map. The field maps should be scanned as a pdf. The pdf files should be individually named to the associated swale; please combine multiple field maps into 1 pdf for the same swale. The field maps can all be stored in a folder named “*AA*_Co_Swale_Field_Maps_2015”. *For teams that did not use a hardcopy map, no records are required.* The naming convention for the field maps are as follows:

- For swales that pass the entire criteria and receive a BMP number: 020123-FieldMap-2015.pdf
- For swales that do not meet the criteria: *Category_NUM*_FieldMap-2015.pdf

3.8 Field Form Naming Convention: Please submit the completed field forms with your submittal. Be sure that the swale CATEGORY_NUM or BMP number is clearly labeled on the map. The field forms should be scanned as pdf. The pdfs should be individually named to the associated swale; please combine multiple field forms into 1 pdf for the same swale. The field maps can all be stored in a folder named “*AA*_Co_Swale_Field_Forms_2015. *For teams that did not use a hardcopy field form, no records are required.* The naming convention for the field forms are as follows:

- For swales that pass the entire criteria and receive a BMP number: 020123-FieldFrom-2015.pdf
- For swales that do not meet the criteria: *Category_NUM*_FieldForm-2015.pdf

References

Maryland, GIO. 2011. MD iMap. *Maryland.gov.* [Online] 2011. http://mdimap.towson.edu/arcgis/services.

MDE. 2009. *Maryland Stormwater Design Manual, May 2009, Chapter 5. Environmental Site Design.* s.l. : Maryland Department of the Environment, 2009. Vol. I.

MDE. 2014. Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated. Guidance for National Pollutant Discharge Elimination System Stormwater Permits. s.l. : Maryland Department of the Environment, August 2014.

Minnesota Planning. 1999. *Positional Accuracy Handbook*. Cialek, Christopher, Don Elwood, Ken Johnson, Mark Kotz, Jay Krathefer, Jim Maxwell, Glenn Radde, Mike Schadauer, and Ron Wencl.

Appendix A - Field Forms

- A-1. Field Work Cover Page.pdf
- A-2. Field Data Input Form.pdf
- A-3. Field Work-Site Sketch (optional).pdf
- A-4. Field Work-Daily log (optional).pdf
- A-5. Grass_Swale_LOI_Sample.pdf

Appendix B – Accuracy Assessment

- B-1. Grass Channel Accuracy Analysis.xlsx
- B-2. Grass Channels GIS Accuracy Memo.docx

Appendix C - Analysis Charts and Spreadsheets

- C-1. Grass Swale Data Input.xlsx
- C-2. Grass Swale Final Analysis.xlsx
- C-3. Grass Swale Equivalent.xlsm
- C-4. Grass Channel Credit Graphs.pdf

Appendix D – Submittal Data Dictionary

- D-1. Appendix_D_Submittal_Data_Dictionary.pdf
- D-2. Grass_Swale_Database_Submittal.mdb
  - GRASS_SWALE_SS feature class
  - SWMFAC feature class
  - GS_SS_DA feature class
  - GS_SS_PHOTOS_DOCS feature class

Appendix E – Desktop Analysis Process

- E-1. Grass Channel Protocol-Appendix E.pdf

Appendix F – Design Standards Memo

- F-1. Design Standard Memo - Grass Swale.pdf

Appendix G – MDE Approval Letter

- G-1. MDE Approval Letter.pdf
  *Dated April 16, 2013

Appendix H – Grass Channel Credit Guidance

- H-1. Grass Channel Credit Guidance.pdf

April 15, 2016

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

Dear Mr. Bahr:

Thank you for the comments dated March 31, 2016 regarding your review of SHA's revised Existing Grass Swale Identification Protocol. Your comments along with our responses to your comments are listed below:

MDE Comment:

The proposal states that triangular-shaped channels (or "V-ditches") can qualify for grass channel credit if the wetted perimeter of the channel is greater than that for a flat bottom channel with a 2-foot bottom width and 3:1 side slopes. The minimum requirement for a grass swale in the Manual is 3:1 side slopes and a flat bottom. V ditches with side slopes that are 2:1 exceed the minimum standard in the Manual and do not qualify for the credit. Thus, for the proposed broad-based application to be acceptable to MDE, the combined profile of the bottom and sides of the ditch need to be at least 3:1. Also, please note that time of concentration (TOC) is expressed in hours. Therefore, the proposed TOC of 0.1 minute (or 0.0017 hour) used in the Grass Swale Equivalent spreadsheet should be 0.1 hours.

Response: In Section 3.2.4 Equivalent Flat Bottom Width, there was an error in the text stating that the time of concentration was expressed in minutes rather than in hours. The text has been revised to state "hours" and some additional text was added to state that any side slope measuring steeper than 3h:1v is disqualified and shall not be analyzed. It was confirmed that the Grass Swale Equivalent spreadsheet does in fact use a time of concentration of 0.1 hours, so a revision to the time of concentration within the spreadsheet is not needed. Also, the side slope input was revised so a user is no longer able to input any value less than 3:1.

Please find attached for your review one hard copy of the revised SHA Existing Water Quality Grass Swale Identification Protocol as well as an electronic copy on the provided CD. If you have any questions or comments about this matter, please contact Mr. Ryan Doran at 410-545-8635 or RDoran@sha.state.md.us, or me at 410-545-8407 or KCoffman@sha.state.md.us.

Sincerely,

Karen M Coffman

Karen Coffman, Chief
Water Programs Division

Attachments

cc: Mr. Rob Shreeve, Deputy Director, SHA
Mr. Ryan Doran, Team Leader, SHA
Mr. Jeff Tirschman, SHA