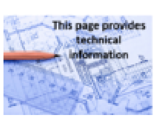
Calculating credits for wet swale (wetland channel)

Download pdf (https://stormwater.pca.state.mn.us/index.php?title=File:Calculating_credits_for_bioretention_-_Minnesota_Stormwater_Manual.pdf_May_2022.pdf)

Page video summary (https://stormwater.pca.state.mn.us/index.php?title=File:Credit_page_descriptions.mp4)



Warning: Models are often selected to calculate credits. The model selected depends on your objectives. For compliance with the Construction Stormwater permit, the model must be based on the assumption that an instantaneous volume is captured by the BMP.
Green Infrastructure: Swales can be an important tool for retention and detention of stormwater runoff. Depending on design and construction, swales may provide additional benefits, including cleaner air, carbon sequestration, improved biological habitat, and aesthetic value. See the section Green Infrastructure for stormwater management.

Recommended pollutant removal efficiencies, in percent, for wet swale BMPs. Sources (http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs#References). NOTE: removal efficiencies are 100 percent for water that is infiltrated.

TSS=total suspended solids; TP=total phosphorus; PP=particulate phosphorus; DP=dissolved phosphorus; TN=total nitrogen

TSS	TP	PP	DP	TN	Metals[2]	Bacteria[3]	Hydrocarbons
35/20[1]	0	0	0	15[4]	35	35	ND[5]

[1] 35 percent credit if a check dam is employed; 20 percent credit if no check dam is employed; [2] Value represents the median removal for total Cd, Cr, Cu, Pb, and Zn using data from the International Stormwater BMP database (http://www.bmpdatabase.org/Docs/03-SW-1COh%20BMP%20Database%202016%20Summary%20Stats.pdf) (2016 summaries); removal for dissolved metal is 0; [3] Data from the International Stormwater BMP database, 2016, for fecal coliform bacteria; [4] From the International Stormwater BMP database, 2016, for total nitrogen; [5] No data found.

Credit (http://stormwater.pca.state.mn.us/index.php/Overview_of_stormwater_credits) refers to the quantity of stormwater or pollutant reduction achieved either by an individual **best management practice** (BMP) or cumulatively with multiple BMPs. Stormwater credits are a tool for local stormwater authorities who are interested in

- providing incentives to site developers to encourage the preservation of natural areas and the reduction of the volume of stormwater runoff being conveyed to a best management practice (BMP);
- complying with permit requirements, including antidegradation (see Construction permit (https://stormwater.pca.state.mn.us/index.php?title=Construction_stormwater_program); Municipal (MS4) permit (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_Program_for_Municipal_Separate_Storm_Sewer_Systems_(MS4)));
- meeting the MIDS performance goal (http://stormwater.pca.state.mn.us/index.php/Performance_goals_for_new_development,_re-development_and_linear_projects); or
- meeting or complying with water quality objectives, including **total maximum daily load** (https://stormwater.pca.state.mn.us/index.php?title=Total_Maximum_Daily_Loads_(TMDLs)) (TMDL) **wasteload allocations** (WLAs).

This page provides a discussion of how wet swales (https://stormwater.pca.state.mn.us/index.php?title=Wet_swale_(wetland_channel)) can achieve stormwater credits.

Contents

Overview

A wet **swale** (https://stormwater.pca.state.mn.us/index.php?title=Dry_swale_(Grass_swale)) acts as a very long and linear shallow **biofiltration** (https://stormwater.pca.state.mn.us/index.php?title=Bioretention) or linear **stormwater wetland (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_wetlands)** system. Wet swales do not provide volume reduction and have limited treatment capability. Incorporation of **check dams** into the design allows treatment of a portion or all of the **Water Quality Volume** (https://stormwater.pca.state.mn.us/index.php?title=Water_quality_criteria) within a series of cells created by the check dams. Wet swales planted with emergent wetland plant species (https://stormwater.pca.state.mn.us/index.php?title=Plants_for_swales) provide improved pollutant removal. Wet swales may be used as **pretreatment** (https://stormwater.pca.state.mn.us/index.php?title=Pretreatment) practices. Wet swales are commonly used for drainage areas less than 5 acres in size.

Pollutant Removal Mechanisms

Wet swales without check dams primarily remove pollutants through **filtration** (https://stormwater.pca.state.mn.us/index.php?title=Filtration) during conveyance of stormwater runoff. Wet swales do not achieve significant volume reduction. Check dams (https://stormwater.pca.state.mn.us/index.php?title=Check_dams_for_stormwater_swales) may be incorporated into wet swale design to enhance settling and filtration of solids.

Location in the Treatment Train

Wet swales provide limited water quality treatment and no volume control and are not recommended practices unless options for other BMPs are limited. Wet swales do however, provide additional **Green infrastructure** benefits because they are vegetated.

Wet swales are designed primarily as in-line systems for stormwater quality and typically are used in conjunction with other structural controls in stormwater **treatment trains** (https://stormwater.pca.state.mn.us/index.php?title=Using_the_treatment_train_approach_to_BMP_selection). Wet swales may be used at various locations within a treatment train] and can be used for pretreatment, conveyance, and/or primary treatment.

Methodology for calculating credits

This section describes the basic concepts and equations used to calculate credits for Total Suspended Solids (TSS).

Wet swale practices generate credits for TSS. Wet swale practices are moderately effective at reducing concentrations of metals. They are somewhat effective at removing bacteria. This article does not provide information on calculating credits for pollutants other than TSS, but references are provided that may be useful for calculating credits for other pollutants.

Assumptions and Approach

In developing the credit calculations, it is assumed the swale is properly designed, constructed, and maintained in accordance with the Minnesota Stormwater Manual. If any of these assumptions is not valid, the BMP may not qualify for credits or credits should be reduced based on reduced ability of the BMP to achieve volume or pollutant reductions. For guidance on design, construction, and maintenance, see the appropriate article within the Manual (https://stormwater.pca.state.mn.us/index.php?title=Wet_swale_(wetland_channel)).

Warning: Pretreatment is required for all filtration and infiltration practices

Unlike other BMPs such as bioretention and permeable pavement, credits for swales are calculated in two ways. First, if check dams are incorporated into the design, the water quality volume (V_{WQ}) is assumed to be delivered as an **instantaneous volume** to the BMP and stored as water ponded behind the check dam, above the soil or filter media, and below the overflow point of the check dam. V_{WQ} can vary depending on the stormwater management objective(s). For construction stormwater, V_{WQ} is 1 inch times new impervious surface area. For MIDS (https://stormwater.pca.state.mn.us/index.php?title=Minimal_Impact_Design_Standards), the V_{WQ} is 1.1 inches times impervious surface area.

Second, if check dams are not incorporated into the swale, water will be filtered as it is conveyed along the swale. Some settling also occurs as the water is conveyed. The extent of filtration is a function of the channel roughness, including vegetation effects, and the slope of the swale, which affects the velocity of the water and thus settling.

Total suspended solids

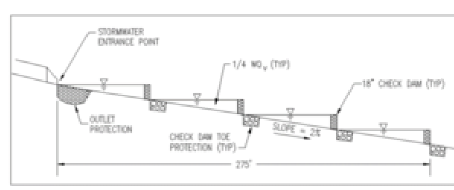
The water quality volume (V_{wq}) achieved behind each check dam (instantaneous volume), in cubic feet, is given by

$$V_{wq} = 1728h^2 * (h * H + B_w)]/(2S)$$

where

h = check dam height (inches)
H = horizontal component of the swale side slope (1 vertical : H horizontal)(inches)
S = slope (unitless); and
Bw = channel bottom width (inches)

Add the V_{wq} for each check dam together to obtain the cumulative water quality volume for the swale.



Profile of swale with structural check dams (not to scale). Source: Virginia DOT BMP Design Manual (http://www.virginiadot.org/business/locdes/bmp_designmanual.asp), Chapter 6. Click on image to enlarge.

TSS reduction credits correspond with the volume captured by swale check dams and is given by

$$M_{TSS} = M_{TSS_f}$$

where

M_{TSS} = TSS removal (pounds); and
M_{TSS_f} = TSS removal from filtered water (pounds).

The event-based mass of pollutant removed through filtration, in pounds, is given by

$$M_{TSS_f} = 0.0000624 V_{total} EMC_{TSS} R_{TSS}$$

where

V_{total} is the total volume of water captured by the BMP (cubic feet);
EMC_{TSS} is the event mean concentration (mg/L); and
R_{TSS} is the TSS pollutant removal percentage for filtered runoff.

The Stormwater Manual (https://stormwater.pca.state.mn.us/index.php?title=Information_on_pollutant_removal_by_BMPs) provides a recommended value for R_{TSS} of 0.35 (35 percent) removal for filtered water. Alternate justified percentages for TSS removal can be used if proven to be applicable to the BMP design.

The above calculations may be applied on an event or annual basis and are given by

$$M_{TSS_f} = 2.72\ F\ V_{F_{annual}}\ EMC_{TSS}\ R_{TSS}$$

where

F is the fraction of annual volume filtered through the BMP; and
V_{annual} is the annual volume treated by the BMP, in acre-feet.

Water not captured by a check dam but conveyed in the swale are assigned a removal value of 0.20 (20 percent).

Total phosphorus

Wet swales do not receive credit for phosphorus removal.

Methods for calculating credits

This section provides specific information on generating and calculating credits from swale BMPs for Total Suspended Solids (TSS). Pollution reductions ("credits") may be calculated using one of the following methods:

- Quantifying pollution reductions based on accepted hydrologic models (https://stormwater.pca.state.mn.us/index.php?title=Available_stormwater_models_and_selecting_a_model)
- MIDS Calculator (https://stormwater.pca.state.mn.us/index.php?title=MIDS_calculator)
- Quantifying pollution reductions based on values reported in literature
- Quantifying pollution reductions based on field monitoring

Credits based on models

Warning: The model selected depends on your objectives. For compliance with the Construction Stormwater permit, the model must be based on the assumption that an instantaneous volume is captured by the BMP.

Users may opt to use a water quality model or calculator to compute TSS pollutant removal for the purpose of determining credits for wet swales. The available models described in the following sections are commonly used by water resource professionals, but are not explicitly endorsed or required by the Minnesota Pollution Control Agency.

Use of models or calculators for the purpose of computing pollutant removal credits should be supported by detailed documentation, including:

1. Model name and version
2. Date of analysis
3. Person or organization conducting analysis
4. Detailed summary of input data
5. Calibration and verification information
6. Detailed summary of output data

The following table lists water quantity and water quality models that are commonly used by water resource professionals to predict the hydrologic, hydraulic, and/or pollutant removal capabilities of a single or multiple stormwater BMPs. The table can be used to guide a user in selecting the most appropriate model for computing volume, TSS, and/or TP removal for constructed basin BMPs. In using this table to identify models appropriate for constructed ponds and wetlands, use the sort arrow on the table and sort by *Constructed Basin BMPs*. Models identified with an *X* may be appropriate for using with constructed basins.

Comparison of stormwater models and calculators. Additional information and descriptions for some of the models listed in this table can be found at this link (http://stormwater.pca.state.mn.us/index.php/Available_stormwater_models_and_selecting_a_model). Note that the Construction Stormwater General Permit (https://stormwater.pca.state.mn.us/index.php?title=Construction_stormwater_program) requires the water quality volume to be calculated as an instantaneous volume, meaning several of these models cannot be used to determine compliance with the permit.

Link to this table

Access this table as a Microsoft Word document: File:Stormwater Model and Calculator Comparisons table.docx.

Model name	BMP Category						Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
Center for Neighborhood Technology Green Values National Stormwater Management Calculator (https://cnt.org/tools/green-values-calculator)	X	X	X		X		No	No	Yes	Does not compute volume reduction for some BMPs, including cisterns and tree trenches.
CivilStorm (http://www.bentley.com/en-US/Products/CivilStorm/)							Yes	Yes	Yes	CivilStorm has an engineering library with many different types of BMPs to choose from. This list changes as new information becomes available.
EPA National Stormwater Calculator (http://www.epa.gov/nrmrl/wswrd/wq/models/swc/)	X		X		X		No	No	Yes	Primary purpose is to assess reductions in stormwater volume.
EPA SWMM (https://www.epa.gov/water-research/storm-water-management-model-swmm)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
HydroCAD (http://www.hydrocad.net/)	X		X	X			No	No	Yes	Will assess hydraulics, volumes, and pollutant loading, but not pollutant reduction.
infoSWMM (http://www.innovyze.com/products/infoswmm/)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.

Model name	BMP Category						Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
infoWorks ICM (http://www.innovyze.com/products/infoworks_icm/)	X	X	X	X			Yes	Yes	Yes	
i-Tree-Hydro (http://www.itreetools.org/hydro/index.php)			X				No	No	Yes	Includes simple calculator for rain gardens.
i-Tree-Streets (http://www.itreetools.org/streets/index.php)							No	No	Yes	Computes volume reduction for trees, only.
LSPC (https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NERL&dirEntryId=75860&CFID=22884508&CFTOKEN=98267566)	X		X	X			Yes	Yes	Yes	Though developed for HSPF, the USEPA BMP Web Toolkit can be used with LSPC to model structural BMPs such as detention basins, or infiltration BMPs that represent source control facilities, which capture runoff from small impervious areas (e.g., parking lots or rooftops).
MapShed (https://wikiwatershed.org/help/model-help/mapshed/)	X	X	X	X			Yes	Yes	Yes	Region-specific input data not available for Minnesota but user can create this data for any region.
MCWD/MWMO Stormwater Reuse Calculator (http://minnehahacreek.org/sites/minnehahacreek.org/files/Stormwater%20Harvesting%20and%20Reuse%20Model_v2.0.xlsx)					X		Yes	No	Yes	Computes storage volume for stormwater reuse systems

	BMP Category									
Model name	**Constructed basin BMPs**	**Filter BMPs**	**Infiltrator BMPs**	**Swale or strip BMPs**	**Reuse**	**Manu-factured devices**	**Assess TP removal?**	**Assess TSS removal?**	**Assess volume reduction?**	**Comments**
Metropolitan Council Stormwater Reuse Guide Excel Spreadsheet (http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning.aspx)					X		No	No	Yes	Computes storage volume for stormwater reuse systems. Uses 30-year precipitation data specific to Twin Cites region of Minnesota.
MIDS Calculator (http://stormwater.pca.state.mn.us/index.php/MIDS_calculator)	X	X	X	X	X	X	Yes	Yes	Yes	Includes user-defined feature that can be used for manufactured devices and other BMPs.
MIKE URBAN (SWMM or MOUSE) (http://www.mikebydhi.com/Products/Cities/MIKEURBAN.aspx)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
P8 (http://wwwalker.net/p8/)	X		X	X		X	Yes	Yes	Yes	
PCSWMM (http://www.chiwater.com/Software/PCSWMM/)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
PLOAD (http://water.epa.gov/scitech/datait/models/basins/framework.cfm#models)	X	X	X	X		X	Yes	Yes	No	User-defined practices with user-specified removal percentages.
PondNet (http://wwwalker.net/)	X						Yes	No	Yes	Flow and phosphorus routing in pond networks.
PondPack (http://www.bentley.com/en-US/Products/PondPack)	X		[				No	No	Yes	PondPack can calculate first-flush volume, but does not model pollutants. It can be used to calculate pond infiltration.
RECARGA (http://dnr.wi.gov/topic/stormwater/standards/recarga.html)			X				No	No	Yes	

Model name	BMP Category						Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
SHSAM (https://shsam.barr.com/)						X	No	Yes	No	Several flow-through structures including standard sumps, and proprietary systems such as CDS, Stormceptors, and Vortechs systems
SUSTAIN (https://www.epa.gov/water-research/system-urban-stormwater-treatment-and-analysis-integration-sustain)	X	X	X	X	X		Yes	Yes	Yes	Categorizes BMPs into Point BMPs, Linear BMPs, and Area BMPs
SWAT (http://swat.tamu.edu/)	X	X	X				Yes	Yes	Yes	Model offers many agricultural BMPs and practices, but limited urban BMPs at this time.
Virginia Runoff Reduction Method (https://swbmp.vwrrc.vt.edu/vrrm/)	X	X	X	X	X	X	Yes	No	Yes	Users input Event Mean Concentration (EMC) pollutant removal percentages for manufactured devices.
WARMF (https://www.epri.com/research/products/3002011868)	X	X					Yes	Yes	Yes	Includes agriculture BMP assessment tools. Compatible with USEPA Basins

Model name	BMP Category						Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
WinHSPF (https://www.researchgate.net/figure/The-WinHSPF-interface-available-through-BASINS_fig1_274344576)	X		X	X			Yes	Yes	Yes	USEPA BMP Web Toolkit available to assist with implementing structural BMPs such as detention basins, or infiltration BMPs that represent source control facilities, which capture runoff from small impervious areas (e.g., parking lots or rooftops).
WinSLAMM (http://www.winslamm.com/default.html)	X	X	X	X			Yes	Yes	Yes	
XPSWMM (https://www.innovyze.com/en-us/products/xpswmm)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.

MIDS Calculator

Users should refer to the MIDS Calculator section of the WIKI for additional information and guidance on credit calculation using this approach.

Credits Based on Reported Literature Values

A simplified approach to computing a credit would be to apply a reduction value found in literature to the pollutant mass load or event mean concentration (EMC) of the wet swale. A more detailed explanation of the differences between mass load reductions and EMC reductions can be found here.

Designers may use the pollutant reduction values reported here or may research values from other databases and published literature.

Designers who opt for this approach should:

- Select the median value from pollutant reduction databases that report a range of reductions, such as from the International BMP Database (https://bmpdatabase.org/).
- Select a pollutant removal reduction from literature that studied a wet swale device with site characteristics and climate similar to the device being considered for credits.
- When using data from an individual study, review the article to determine that the design principles of the studied wet swale are close to the design recommendations for Minnesota, as described here, and/or by a local permitting agency.
- Preference should be given to literature that has been published in a peer-reviewed publication.

The following references summarize pollutant reduction values from multiple studies or sources that could be used to determine credits. Users should note that there is a wide range of monitored pollutant removal effectiveness in the literature. Before selecting a literature value, users should compare the characteristics of the monitored site in the literature against the characteristics of the proposed wet swale, considering such conditions as watershed characteristics, swale sizing, and climate factors.

- International Stormwater Best Management Practices (BMP) Database Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals (https://bmpdatabase.org/)
    - Compilation of BMP performance studies published through 2011

- Provides values for TSS, Bacteria, Nutrients, and Metals
- Applicable to grass strips, bioretention, bioswales, detention basins, green roofs, manufactured devices, media filters, porous pavements, wetland basins, and wetland channels

- Updated BMP Removal Efficiencies from the National Pollutant Removal Database (2007) & Acceptable BMP Table for Virginia (http://lshs.tamu.edu/docs/lshs/end-notes/updated%20bmp%20removal%20efficiencies%20from%20the%20national%20pollutant%20re-2854375963/updated%20bmp%20removal%20efficiencies%20from%20the%20national%20pollutant%20removal%20database.pdf)
  - Provides data for several structural and non-structural BMP performance evaluations
- The Illinois Green Infrastructure Study (http://www.epa.state.il.us/green-infrastructure/docs/draft-final-report.pdf)
  - Figure ES-1 summarizes BMP effectiveness
  - Provides values for TN, TSS, peak flows / runoff volumes
  - Applicable to Permeable Pavements, Constructed Wetlands, Infiltration, Detention, Filtration, and Green Roofs
- New Hampshire Stormwater Manual (https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/wd-08-20b.pdf)
  - Volume 2, Appendix B summarizes BMP effectiveness
  - Provides values for TSS, TN, and TP removal
  - Applicable to basins and wetlands, stormwater wetlands, infiltration practices, filtering practices, treatment swales, vegetated buffers, and pre-treatment practices
- BMP Performance Analysis (https://www3.epa.gov/region1/npdes/stormwater/tools/BMP-Performance-Analysis-Report.pdf). Prepared for US EPA Region 1, Boston MA.
  - Appendix B provides pollutant removal performance curves
  - Provides values for TP, TSS, and zinc
  - Pollutant removal broken down according to land use
  - Applicable to infiltration trench, infiltration basin, bioretention, grass swale, wet pond, and porous pavement
- Weiss, P.T., J.S. Gulliver and A.J. Erickson. 2005. The Cost and Effectiveness of Stormwater Management Practices: Final Report (http://www.lrrb.org/media/reports/200523.pdf)
  - Table 8 and Appendix B provides pollutant removal efficiencies for TSS and P
  - Applicable to Wet Basins, Stormwater Wetlands, Bioretention Filter, Sand Filter, Infiltration Trench, and Filter Strips/Grass Swales

Credits Based on Field Monitoring

Field monitoring may be made in lieu of desktop calculations or models/calculators as described. Careful planning is HIGHLY RECOMMENDED before commencing a program to monitor the performance of a BMP. The general steps involved in planning and implementing BMP monitoring include the following.

1. Establish the objectives and goals of the monitoring. When monitoring BMP performance, typical objectives may include the following.
   1. Which pollutants will be measured?
   2. Will the monitoring study the performance of a single BMP or multiple BMPs?
   3. Are there any variables that will affect the BMP performance? Variables could include design approaches, maintenance activities, rainfall events, rainfall intensity, etc.
   4. Will the results be compared to other BMP performance studies?
   5. What should be the duration of the monitoring period? Is there a need to look at the annual performance vs the performance during a single rain event? Is there a need to assess the seasonal variation of BMP performance?
2. Plan the field activities. Field considerations include
   1. equipment selection and placement;
   2. sampling protocols including selection, storage, and delivery to the laboratory;
   3. laboratory services;
   4. health and Safety plans for field personnel;
   5. record keeping protocols and forms; and
   6. quality control and quality assurance protocols
3. Execute the field monitoring
4. Analyze the results

This manual contains the following guidance for monitoring.

- Recommendations and guidance for utilizing monitoring to meet TMDL permit requirements
- Recommendations and guidance for utilizing lake monitoring to meet TMDL permit requirements
- Recommendations and guidance for utilizing stream monitoring to meet TMDL permit requirements
- Recommendations and guidance for utilizing major stormwater outfall monitoring to meet TMDL permit requirements
- Recommendations and guidance for utilizing stormwater best management practice monitoring to meet TMDL permit requirements

The following guidance manuals have been developed to assist BMP owners and operators on how to plan and implement BMP performance monitoring.

Urban Stormwater BMP Performance Monitoring (https://www3.epa.gov/npdes/pubs/montcomplete.pdf)

Geosyntec Consultants and Wright Water Engineers prepared this guide in 2009 with support from the USEPA, Water Environment Research Foundation, Federal Highway Administration, and the Environment and Water Resource Institute of the American Society of Civil Engineers. This guide was developed to improve and standardize the protocols for all BMP monitoring and to provide additional guidance for Low Impact Development (LID) BMP monitoring. Highlighted chapters in this manual include:

- Chapter 2: Developing a monitoring plan. Describes a seven-step approach for developing a monitoring plan for collection of data to evaluate BMP effectiveness.

- Chapter 3: Methods and Equipment for hydrologic and hydraulic monitoring
- Chapter 4: Methods and equipment for water quality monitoring
- Chapters 5 (Implementation) and 6 (Data Management, Evaluation and Reporting)
- Chapter 7: BMP Performance Analysis
- Chapters 8 (LID Monitoring), 9 (LID data interpretation]), and 10 (Case studies).

Evaluation of Best Management Practices for Highway Runoff Control (NCHRP Report 565) (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_565.pdf)

AASHTO (American Association of State Highway and Transportation Officials) and the FHWA (Federal Highway Administration) sponsored this 2006 research report, which was authored by Oregon State University, Geosyntec Consultants, the University of Florida, and the Low Impact Development Center. The primary purpose of this report is to advise on the selection and design of BMPs that are best suited for highway runoff. The document includes chapters on performance monitoring that may be a useful reference for BMP performance monitoring, especially for the performance assessment of a highway BMP.

- Chapter 4: Stormwater Characterization
  - 4.2: General Characteristics and Pollutant Sources
  - 4.3: Sources of Stormwater Quality data
- Chapter 8: Performance Evaluation
  - 8.1: Methodology Options
  - 8.5: Evaluation of Quality Performance for Individual BMPs
  - 8.6: Overall Hydrologic and Water Quality Performance Evaluation
- Chapter 10: Hydrologic Evaluation
  - 10.5: Performance Verification and Design Optimization

Investigation into the Feasibility of a National Testing and Evaluation Program for Stormwater Products and Practices (https://www.wef.org/globalassets/assets-wef/3---resources/topics/o-z/stormwater/stormwater-institute/wef-stepp-white-paper_final_02-06-14.pdf)

- In 2014 the Water Environment Federation released this White Paper that investigates the feasibility of a national program for the testing of stormwater products and practices. The report does not include any specific guidance on the monitoring of a BMP, but it does include a summary of the existing technical evaluation programs that could be consulted for testing results for specific products (see Table 1 on page 8).

Caltrans Stormwater Monitoring Guidance Manual (Document No. CTSW-OT-13-999.43.01)]

The most current version of this manual was released by the State of California, Department of Transportation in November 2013. As with the other monitoring manuals described, this manual does include guidance on planning a stormwater monitoring program. However, this manual is among the most thorough for field activities. Relevant chapters include.

- Chapter 4: Monitoring Methods and Equipment
- Chapter 5: Analytical Methods and Laboratory Selection
- Chapter 6: Monitoring Site Selection
- Chapter 8: Equipment Installation and Maintenance
- Chapter 10: Pre-Storm Preparation
- Chapter 11: Sample Collection and Handling
- Chapter 12: Quality Assurance / Quality Control
- Chapter 13: Laboratory Reports and Data Review
- Chapter 15: Gross Solids Monitoring

Optimizing Stormwater Treatment Practices: A Handbook of Assessment and Maintenance (http://stormwaterbook.safl.umn.edu/)

This online manual was developed in 2010 by Andrew Erickson, Peter Weiss, and John Gulliver from the University of Minnesota and St. Anthony Falls Hydraulic Laboratory with funding provided by the Minnesota Pollution Control Agency. The manual advises on a four-level process to assess the performance of a Best Management Practice.

- Level 1: Visual Inspection (https://stormwaterbook.safl.umn.edu/assessment-programs/visual-inspection)
- Level 2: Capacity Testing (https://stormwaterbook.safl.umn.edu/assessment-programs/capacity-testing)
- Level 3: Synthetic Runoff Testing (http://stormwaterbook.safl.umn.edu/assessment-programs/synthetic-runoff-testing)
- Level 4: Monitoring (https://stormwaterbook.safl.umn.edu/assessment-programs/monitoring)

Level 1 activities do not produce numerical performance data that could be used to obtain a stormwater management credit. BMP owners and operators who are interested in using data obtained from Levels 2 and 3 should consult with the MPCA or other regulatory agency to determine if the results are appropriate for credit calculations. Level 4, Monitoring, is the method most frequently used for assessment of the performance of a BMP.

Use these links to obtain detailed information on the following topics related to BMP performance monitoring:

- Water Budget Measurement (https://stormwaterbook.safl.umn.edu/water-budget-measurement)
- Sampling Methods (https://stormwaterbook.safl.umn.edu/sampling-methods)
- Analysis of Water and Soils (https://stormwaterbook.safl.umn.edu/analysis-water-and-soils)
- Data Analysis for Monitoring (https://stormwaterbook.safl.umn.edu/data-analysis)

Other pollutants

According to the International BMP Database (http://bmpdatabase.org/index.htm), studies have shown wet swales are somewhat effective at reducing concentrations of bacteria, metals, and nitrogen. This database provides an overview of BMP performance in relation to various pollutant categories and constituents that were monitored in BMP studies within the database. The report notes that effectiveness and range of unit treatment processes can vary greatly depending on BMP design and location. The following table shows a list of the constituents and associated pollutant category for the monitored "media filters" data. The constituents shown all had data representing decreases in effluent pollutant loads for the median of the data points and the 95% confidence interval about the median.

Wet swale pollutant load reduction
Link to this table

Pollutant Category	Constituent	Treatment Capabilities (Low = < 30%; Medium = 30-65%; High = 65 -100%)
Metals[1]	Cd, Pb, Zn	Medium
	Cu, Cr	Low
Nutrients	Total Nitrogen, TKN	Low
Bacteria	Fecal Coliform, E. coli	Medium

[1]Results are for total metals only

References and suggested reading

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Related articles

- Wet swales
  - Terminology for swales
  - Overview for wet swale (wetland channel)
  - Types of filtration
  - Design criteria for wet swale (wetland channel)
  - Construction specifications for wet swale (wetland channel)
  - Operation and maintenance of wet swale (wetland channel)
  - Assessing the performance of wet swale (wetland channel)
  - Plants for swales
  - Check dams for stormwater swales
  - Calculating credits for wet swale (wetland channel)
  - Cost considerations (https://stormwater.pca.state.mn.us/index.php?title=Cost_considerations_for_dry_swale_(grass_swale))
  - External resources for wet swale (wetland channel)
  - References for wet swale (wetland channel)
  - Requirements, recommendations and information for using wet swale in the MIDS calculator (https://stormwater.pca.state.mn.us/index.php?title=Requirements,_recommendations_and_information_for_using_wet_swale_as_a_BMP_in_the_MIDS_calculator)
  - Requirements, recommendations and information for using swale side slope as a BMP in the MIDS calculator
- Calculating credits
  - Calculating credits for bioretention
  - Calculating credits for infiltration basin
  - Calculating credits for infiltration trench
  - Calculating credits for permeable pavement
  - Calculating credits for green roofs
  - Calculating credits for sand filter
  - Calculating credits for stormwater ponds
  - Calculating credits for stormwater wetlands
  - Calculating credits for iron enhanced sand filter
  - Calculating credits for dry swale (grass swale)
  - Calculating credits for wet swale (wetland channel)
  - Calculating credits for tree trenches and tree boxes
  - Calculating credits for stormwater and rainwater harvest and use/reuse

/* Manually replaced by abbott Aug 6 '21 */