FINAL

MCBH POST-CONSTRUCTION BMP MANUAL

Storm Water Management Program Plan

Marine Corps Base Hawaii, Oahu, Hawaii

NPDES Permit No. HI S000007

Prepared by:

Marine Corps Base Hawaii

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List of Acronyms and Abbreviations

AMS	Asset Management System
BAT	Best Available Technology
BCT	Best Conventional Technology
BFM	Bonded Fiber Matrix
BMP	Best Management Practice
C&D	Construction and Demolition
CO	Commanding Officer
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CTB	Cement-Treated Base
CWA	Clean Water Act
CWB	State of Hawaii Department of Health, Clean Water Branch
CWRM	State of Hawaii Department of Land and Natural Resources, Commission on Water Resource Management
DLNR	State of Hawaii Department of Land and Natural Resources
DOE	Department of Education
DOH	State of Hawaii Department of Health
EAL	Environmental Action Level
EC	Erosion Control
ECPD	Environmental Compliance and Protection Division
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FEAD	Facilities Engineering and Acquisition Division
GDI	Grated Drop Inlet
GHS	Globally Harmonized System
H:V	Horizontal to Vertical Slope
HAR	Hawaii Administrative Rules
HDOA	State of Hawaii Department of Agriculture
HEER	State of Hawaii Department of Health, Hazard Evaluation and Emergency Response
LBP	Lead-Based Paint

LID	Low Impact Development
L/SD	Length to Settling Depth
LFPE	Logistics Facilities Public Works Engineering
LOS	Lines of Study
MCBH	Marine Corps Base Hawaii
MCCS	Marine Corps Community Services
MCD	Facilities Engineering Maintenance Control Division
MEP	Maximum Extent Practicable
MRO	Facilities Engineering Maintenance Repair Operations
MS4	Municipal Separate Storm Sewer System
NRCS	United States Department of Agriculture, Natural Resource Conservation Service
NGPC	Notice of General Permit Coverage
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Coast Guard National Response Center
OMC	Ohana Military Communities
OSHA	Occupational Safety and Health Administration
PCBs	Polychlorinated Biphenyls
PCC	Portland Cement Concrete
PM	Project Manager
PPE	Personal Protective Equipment
PPV	Public-Private Venture
PS&E	Plan, Specifications, and Estimate Documents for a Plan Submittal
RCRA	Resource Conservation and Recovery Act
SC	Sediment Control
SDS	Safety Data Sheet
SHWB	State of Hawaii Department of Health, Solid and Hazardous Waste Branch
SM	Site Management
SPCC	Spill Prevention Control Countermeasures
SSBMP	Site-Specific Best Management Practice
SWMP	Storm Water Management Plan
SWPPP	Storm Water Pollution Prevention Plan

Tm	Recurrence Interval
TMDL	Total Maximum Daily Load
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WLAs	Waste Load Allocations
WQDV	Water Quality Design Volume
WQFR	Water Quality Flow Rate
WQLS	Water Quality Limited Segments

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1 Introduction

1.1 Purpose and Scope

The purpose of this *Marine Corps Base Hawaii (MCBH) Post-Construction Best Management Practice (BMP) Manual* is to provide guidance on BMP selection, installation, and maintenance procedures that aim to eliminate or reduce the discharge of pollutants to State waters. While this manual does not constitute an exhaustive list of all BMPs available, it does provide guidance suitable for use by a wide range of individuals involved in pollution control. Each user of the manual is responsible for working within their capabilities obtained through training and experience, and for seeking the advice and consultation of appropriate experts at all times. The target audience for this manual includes MCBH personnel, consultants, contractors, and other agencies involved in the planning, design, construction, and maintenance of construction projects at MCBH.

As of the effective date, September 1, 2021, MCBH is required to comply with the conditions of the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit No. HIS000007. In accordance with Part D.1.d.(1) of the MS4 Permit, MCBH is required to develop and implement a Storm Water Permanent BMP Manual (referred to herein as the Post-Construction BMP Manual) to establish MCBH policy for permanent post-construction measures. The Post-Construction BMP Manual is a key element of the MCBH's Post-Construction Storm Water Management Program (Post-Construction Program) to ensure that permanent controls are incorporated into all applicable construction projects and protect the MCBH MS4. Refer to Chapter 5 of the Storm Water Management Program (SWMP) Plan for additional information on the objectives of MCBH's Post-Construction Program.

1.2 Water Quality Impacts Related to Developed Areas

Under natural and undeveloped conditions, surface runoff can range from 10 to 30 percent (%) of the total annual precipitation. Depending on the level of development and the site planning methods used, the alteration of physical conditions can result in a significant increase of surface runoff to over 50 % of the overall precipitation.

Alteration in site runoff characteristics can cause an increase in the volume and frequency of runoff flows (discharge) and flow velocities that cause flooding, accelerated erosion, and reduced groundwater recharge. This contributes to degradation of water quality and the ecological integrity of streams and nearshore ecosystems. Pollutants that are commonly associated with stormwater include sediment, nutrients, bacteria and viruses, oil and grease, metals, organics, pesticides, and trash (floatables).

1.3 Requirements for Post-Construction BMPS

Per Part D.1.e of the MS4 Permit, MCBH is required to implement a Post-Construction Storm Water Management Program. The Post-Construction Program applies to all new development and redevelopment projects that result in a disturbance of one (1) acre or more and smaller projects that have the potential to discharge pollutants to MCBH's MS4. The Post-Construction Program will ensure that permanent controls are in place to prevent or minimize water quality impacts to the Maximum Extent Practicable (MEP).

2 Post-Construction Program Organization

The Post-Construction Program organization is similar to that of the Construction Program as described in Chapter 4 of the MCBH SWMP Plan and the MCBH Construction BMP Field Manual. The main differences are that Post-Construction Program begins in the planning stages and includes a long-term maintenance component which is coordinated by the Environmental Compliance and Protection Division (ECPD) and Facilities Engineering Maintenance Control Division/Maintenance Repair Operations (MCD/MRO). As part of this component there is a required management of the maintenance and associated tracking for each construction project.

Figure 2-1 outlines the organization of the Post-Construction Program. The grey boxes indicate the agency responsible for general oversight of the project. Typically, construction projects at MCBH are categorized as either:

(i) *In-house Maintenance and Construction* – projects are scoped and planned by MCD, and the construction work is completed by MRO. Typically, these projects are less than 5,000 sf and/or related to emergency repair work.

(ii) *Military Construction* – These are projects that would typically be handled as in-house construction, but due to limited manpower have been contracted out. These projects are managed by Logistics Facilities Public Works Engineering (LFPE), with all storm water management managed by ECPD.

(iii) *Contract Maintenance and Construction* – These projects are conducted by an outside contractor, but are managed as follows:

- *Naval Facilities Engineering Systems Command (NAVFAC) Construction Projects* are managed by the Facilities Engineering and Acquisition Division (FEAD).
- *Mokapu Elementary School Projects* are managed by the Department of Education (DOE).
- *Public-Private Venture (PPV) Housing Projects* are managed by Ohana Military Communities (OMC)/Hunt.
- *Commercial Tenant Projects* are managed by Marine Corps Community Services (MCCS).
- *Various other contract maintenance and construction projects* are managed by MCD.

To address the MS4 Permit requirements, construction projects subject to the requirements of the Post-Construction Program are those that disturb one (1) or more acres, or smaller projects that have the potential to discharge pollutants into MCBH's MS4. This Post-Construction Program covers all new development and redevelopment projects.

The following construction activities are *not* considered for classification as "redevelopment" projects:

- Routine maintenance to maintain the original hydraulic capacity, line and grade, or the original purpose of the facility;
- Trenching and pavement resurfacing activities, of the same surfacing material, related only to utility work;
- Resurfacing or replacement of damaged pavement, with the same surfacing material;
- Construction of sidewalks, ramps, or related pedestrian/bicyclist features on existing paved roadways;
- Emergency construction activities required to immediately protect public health and safety;
- Interior remodeling that involves no outside exposure of construction materials/waste to storm water; and
- Exterior building renovation that does not disturb ground or increase the footprint of impermeable surfaces.

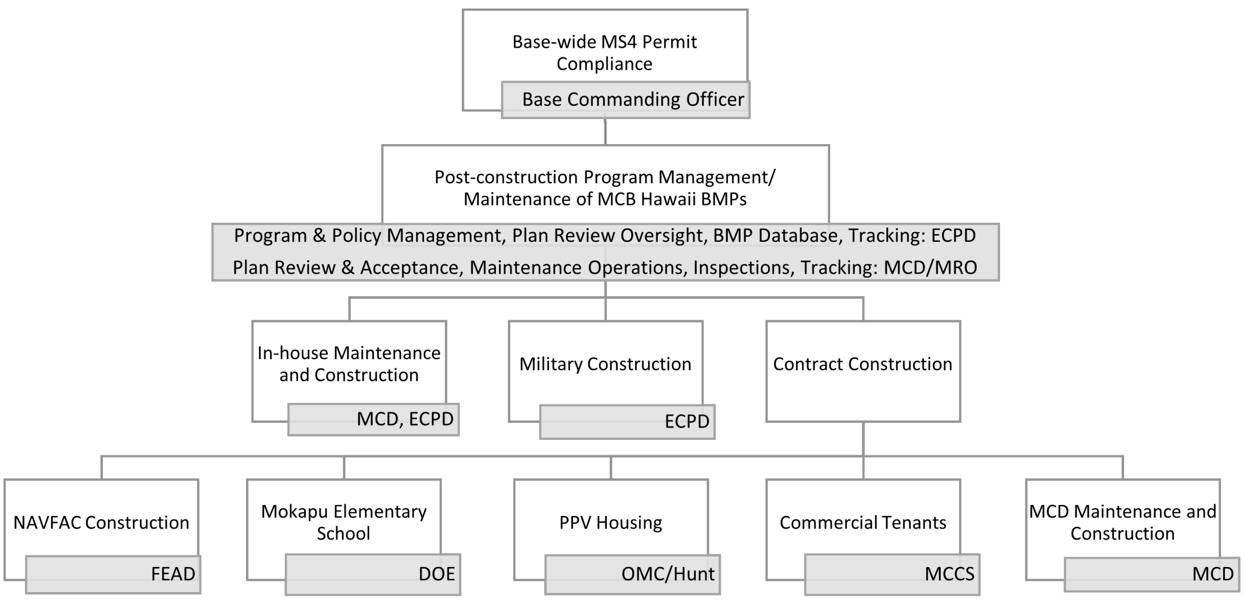

Figure 2-1 Post-Construction Program Organizational Chart

3 New Development and Redevelopment Construction Project Process

A primary goal of the Post-Construction Program is to ensure that no construction project will proceed without the inclusion of the appropriate permanent post-construction BMPs and documentation outlining future BMP maintenance requirements. To achieve this goal, all projects, design-bid-build and design-build alike, must be reviewed and accepted for suitable use of permanent BMPs.

3.1 Project Review Roles and Responsibilities

The review and acceptance process is conducted by the overseeing agency shown in Figure 2-1. All project owners have access to the criteria for requiring Low Impact Development (LID), and the "Low Impact Development Planning and Design Checklist," (Refer to the LID Design Checklist in SWMP Plan Appendix 5-1). Applicants are required to submit this checklist which facilitates the incorporation of BMPs into the initial stages of design development. This review process is intended to assist with the early identification of design conflicts and selection of preferred alternatives. At the time of review, the project owner must also submit documentation of required maintenance activities. These will also be reviewed for long-term feasibility and may require reviewers to collaborate with MCD/MRO.

To guarantee the implementation of adequate permanent BMPs, no construction shall begin or be awarded until the plans have been appropriately reviewed and accepted by the overseeing agency. If it is determined that it is infeasible for a construction project to meet all of the post-construction permanent BMP requirements, the applicant must submit a completed "LID/EISA Constraints and Waiver Request" (SWMP Plan Appendix 5-2). As part of the Plan for Requiring LID (SWMP Plan Appendix 5-1), the applicant must also submit a description of the alternative measures or non-LID BMPs that will be implemented should the LID waiver be granted by MCBH due to technical constraints.

MCBH encourages the collaboration of applicants, reviewers, ECPD, and MCD/MRO, as necessary to meet program requirements, and develop successful solutions for permanent BMP implementation.

ECPD is responsible for general oversight of the Post-Construction Program. This includes revising design checklists/criteria or policies, as needed, to meet program requirements and to facilitate program implementation within the various types of construction projects at MCBH.

For design-bid-build projects, MCBH shall not advertise any construction project nor award any construction contract until the project design has been reviewed and accepted to ensure that appropriate permanent post-construction BMPs.

For design-build projects, MCBH shall review and approve the project design the same as for design-bid-build projects prior to implementation. No project shall proceed without the inclusion of appropriate permanent post-construction BMPs unless a waiver is granted by the Permittee based on specific documentation demonstrating that such post-construction BMPs are not feasible.

Project documents for projects that will include installation of permanent post-construction BMPs shall also include appropriate requirements for their future continued maintenance.

3.2 Stabilization and Project Closure

There is a stabilization period over which the contractor is responsible for maintenance of vegetated BMPs. This stabilization period can be helpful in identifying design problems and/or oversights during installation. Unvegetated, structural BMPs are to be clean when ready to turnover to the base. To facilitate the turnover of BMP ownership to MCBH, the contractor may document any observed maintenance baseline or other information that may be useful to MCD/MRO. The process for a contractor to turn a new or redeveloped facility over to ownership of MCBH includes submittal of:

- As-built plans, with clear distinction of all permanent BMPs (supplemental written documentation may be submitted for additional clarification of any details);
- All relevant documentation outlining permanent BMP/LID specifications and required future maintenance; and
- Proof of BMP stabilization (photos, prior maintenance records, etc.), if applicable.

These documents are to be submitted to MCD/MRO and LFPE. Before the contractor demobilizes, ECPD or a qualified inspector will conduct a post-construction BMP inspection. Once MCD/MRO has accepted the proof of stabilization, the maintenance of applicable BMPs will fall under the responsibility of MCD/MRO. It is up to the project owner/contractor to ensure that all relevant information is provided to MCBH.

A copy of the as-built plans will also be provided to LFPE to be used to update MCBH's existing Geographic Information System (GIS) file and its existing overall storm drain system database, MAXIMO. LFPE will incorporate all structural BMP components into these Asset Management Systems (AMSs), such as inlets, pipes, vaults, etc., within 150 days of the beneficial occupancy date. Notification of MCD/MRO BMP acceptance, along with applicable plans and relevant documentation, showing permanent BMPs, LID features, and required maintenance, will be directed to ECPD for incorporation into an inventory of permanent BMPs (BMP Database within the AMS). To supplement the BMP database, ECPD is working with LFPE to develop a new layer in the MCBH's GIS file which will map vegetated BMPs. When available, this layer will be maintained by ECPD.

4 Post-Construction BMP Selection

To reduce pollution associated with stormwater runoff, new development and redevelopment projects should consider using BMPs that fall within three categories: LID Site Design Strategies, Source Control BMPs, and Post-Construction Treatment Control BMPs. These practices reduce peak runoff and improve water quality by allowing rainwater to infiltrate into the ground, evaporate and transpire, or collect in a storage system for irrigation and other methods of reuse. Rather than moving stormwater off-site through a conveyance system, the goal of LID is to restore the natural ability of a developed site to absorb storm water, resulting in an area more closely resembling pre-development hydrology. Importantly, the LID strategy seeks to control stormwater quality at its source, using a range of small-scale, economical devices such as native landscaping and constructed green spaces, bioretention facilities, vegetated swales, infiltration through permeable pavement, and green roofs to name a few.

4.1 Types of Post-Construction BMPs

Post-construction BMPs such as Site Design Strategies, Source Control, and Treatment Control BMPs should be considered during the planning and design phases of a project.

Table 4-1 LID Site Design Strategies

Element		Description
LID Site Design Strategies		Reducing the hydrologic impact of development and incorporating techniques that maintain or restore the site's hydrologic and hydraulic functions.
Source Control		Preventing pollutants from coming in contact with runoff and preventing polluted runoff from discharging into small MS4.
Treatment Control	**LID Retention**	Retaining runoff on-site with no off-site discharge by infiltration, evapotranspiration, and harvesting/reuse.
	LID Biofiltration	Removing pollutants from runoff by filtering stormwater through vegetation and soils.
	Other Treatment	Removing pollutants from runoff by detention, settling, filtration, and vortex separation.

Projects should be designed to minimize directly connected impervious surfaces, promote infiltration using LID techniques, and minimize the introduction of pollutants generated from site runoff to the stormwater conveyance system. Mimicking a site's natural hydrologic regime can be accomplished by:

- Reducing imperviousness, conserving natural resources and areas, maintaining and using natural drainage courses in the stormwater conveyance system, and minimizing clearing and grading.
- Providing runoff storage measures dispersed throughout a site's landscape with the use of bioretention facilities and detention, retention, and infiltration practices.
- Implementing on-lot hydrologically functional landscape design and management practices.

The following five LID components, should be considered for each applicable project:

4.1.1 Conserve Natural Areas, Soils, and Vegetation

This LID design strategy helps retain numerous functions of predevelopment hydrology including rainfall interception, evapotranspiration, and infiltration. Maximizing these functions reduces the amount of runoff that must be treated. Protection of mature trees and vegetation provides habitat, prevents erosion, captures significant rainfall, provides summer shading, and reduces runoff volume and velocity.

4.1.2 Minimize Disturbances to Natural Drainages

Natural drainages offer a benefit to stormwater management as the soils and habitat already function as a natural filtering/infiltrating swale. Minimizing disturbances to natural drainage patterns preserves the predevelopment timing, rate, and duration of runoff as well as preserving streamside habitats. When determining the development footprint of the site, natural drainages should be avoided. By keeping the development envelope set back from natural drainages, the drainage can retain its water quality benefit to the watershed.

4.1.3 Minimize Soil Compaction

Clearing, grading, and compaction by construction traffic reduces the natural absorption and infiltration capacities of the native soils. Soil compaction damages soil structure, reduces infiltration rates, limits root growth and plant survivability, and destroys soil organisms. Subsequent tilling and/or addition of soil amendments such as compost can help, but may not restore the original infiltration capacity of the soils. By protecting native soils and vegetation in appropriate areas during the clearing and grading phase of development, the site can retain some of its existing beneficial hydrologic function.

4.1.4 Minimize Impervious Surfaces

The increased volume, increased velocity, and discharge-duration of stormwater runoff from developed areas has the potential to accelerate downstream erosion and impair stream habitat in natural drainages. Studies have demonstrated a direct correlation between the degree of imperviousness of an area and the degradation of its receiving waters. Impervious surfaces (such as pavement and concrete) can neither absorb water nor remove pollutants. Reducing impervious surfaces to the minimum amount needed retains the permeability of the project site, allowing natural processes to filter and reduce non-point sources of pollution.

4.1.5 Direct Runoff to Landscaped Areas

Any impervious surface that drains into a catch basin, area drain, or other conveyance structure is a “directly connected impervious area.” As stormwater runoff flows across parking lots, roadways, and paved areas, the oils, sediments, metals, and other pollutants are collected and concentrated. If this runoff is collected by a drainage system and carried directly along impervious gutters or in closed underground pipes, it has no opportunity for filtering by plant material or infiltration into the soil. It also increases in speed and volume, which may cause higher peak flows downstream, and may require larger capacity storm drain systems, increasing flood and erosion potential. Solutions that reduce “directly connected impervious areas” prevent runoff, detain or retain surface water, attenuate peak runoff rates, benefit water quality and convey stormwater.

4.2 Source Control BMPs

Proactively controlling pollutants at their source is fundamental to effective stormwater quality management. Design of BMPs to minimize or prevent pollutant generation is guided by two general principles:

- Prevent stormwater from contacting operation and storage areas. These areas should be designed to prevent stormwater runoff from passing through industrial areas, vehicle maintenance yards, and other workplaces before it reaches storm drains.
- Prevent pollutants from contacting surfaces that come into contact with stormwater runoff or wash-water runoff.

4.3 Treatment Control BMPs

When a site cannot retain all or a portion of the Water Quality Volume on-site, the remaining portions of the water must be treated using Treatment Control BMPs. Treatment Control BMPs are engineered technologies designed to remove pollutants from stormwater runoff prior to discharge to the storm drain system or receiving waters. Details on BMP numeric sizing criteria and general requirements for infiltration BMPs can be found in the following individual fact sheets.

4.4 Maintenance Requirements

The long-term performance of BMPs hinges on ongoing and proper maintenance. Consideration of the time and funding necessary to support long term maintenance should be included as part of the process when selecting BMPs. Maintenance costs will also include disposal of accumulated residuals such as trash, oil and grease, filter media and fine sediments. An effective operation and maintenance (O&M) Plan should contain following major components:

- The designated responsible party to manage the post-construction stormwater BMPs.
- Post-construction operating schedule, maintenance frequency, and specific maintenance activities.
- Any necessary employee training and duties.
- Recordkeeping and reporting on inspection and servicing of all post-construction BMPs (on source/treatment control) at least on an annual basis, which uses a project-specific inspection form submitted with the O&M Plan.

4.5 BMP Selection Summary

Selection of BMPs must be site-specific. No single BMP can be applied to all scenarios. The designer should consider the benefits, pollutant removal efficiency, historical data from other installations, aesthetics, community acceptance, the lifecycle cost, and maintenance factors. Refer to the Department of Defense (DOD) Unified Facilities Criteria (UFC) 3-210-10 document on LID considerations for more in-depth discussion on BMP selection and sizing. Regarding Non-LID methods, this manual does not endorse any particular type of BMP. When selecting treatment control devices, it is recommended that the project designer consults with BMP device manufacturer to obtain independent performance testing data to ensure the device will target the pollutants of concern. For this reason, this manual does not include any proprietary BMPs. Table 9-1 lists BMP Fact Sheets included in this field manual.

5 Post-Construction BMP Inspections and Maintenance

MCBH's maintenance program allocates its resources to prioritize the operation and maintenance of facilities with the maximum potential to affect storm water quality. The BMP Database and AMS will be used by ECPD to collaborate with MCD/MRO, to ensure that annual inspection requirements of all permanent BMPs, and LID features are met. At a minimum, this requires at least one inspection be conducted annually for each permanent BMP, with maintenance performed as necessary to retain its function. Inspections will be conducted using the guidance of the LID and Post-Construction BMP Inspection Checklists.

Routine maintenance activities will also be conducted to the MEP, but priority will be given to BMPs that have been identified by inspection, or public notification, as malfunctioning. Inspection and maintenance records will be tracked via work orders generated by MCBH's current AMS MAXIMO, and by field notes documented by maintenance personnel. All inspection/maintenance records will be maintained by MCD/MRO and made available to ECPD upon request.

Post-Construction BMP Inspection Checklists are included as Attachment 1.

6 Reporting, Documentation, and the Asset Management System

Effectively managing project information and post-construction assets will ensure the long-term effectiveness of LID and other post-construction items. This will enable MCBH to easily identify and correct compliance issues and recognize recurring issues within the Stormwater Pollution Prevention Program or repeat offenders of its MS4 Permit requirements. This AMS allows a user to determine the current performance, likelihood of failure, and the consequences of failure for a particular asset. The ability to easily identify and address current/potential problems will further promote the continual improvement of the MCBH Stormwater Program and facilitate its effectiveness in reducing storm water pollution across MCBH.

The MS4 permit requires that post-construction assets are well documented in the MCBH AMS. At a minimum, the BMP information tracked in the AMS will include:

- General Information: Project name, owner, general location, start/end date of construction, date of acceptance by MCBH (MCD/MRO);
- Type and number of LID practices;
- Type and number of Source Control BMPs;
- Type and number of Treatment Control BMPs;
- Latitude/Longitude coordinates of controls using Global Positioning Systems and NAD83 or other Datum as long as the datum remains consistent;
- Photographs of controls;
- Operation and maintenance requirements;
- Frequency of inspections;
- Frequency of maintenance and entity responsible for maintenance;

- Current performance;
- Likelihood and consequences of failure;
- Records of upsets or malfunctioning of the BMPs.

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8 Disclaimer

The information presented in this Post-Construction BMP Manual was adopted from available and most recent sources that have locally acceptable BMPs and stormwater runoff control measures. This manual has been prepared as a reference guideline, however, due to site-specific conditions, the selection of the BMPs and suggested installation specifications must be made in conjunction with the best professional judgment and sound engineering principles to assure proper function and performance of the BMPs contained herein. The author does not guarantee the accuracy or completeness of this document and will not assume any liability or responsibility for the use of, or for any damages resulting from the use of any information contained herein. The detail and the wording in this manual will not necessarily result in compliance with NPDES permit requirements or other requirements specific to the user's site or construction contract. Application of BMPs should comply with applicable federal, state, and county regulations.

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9 Post-Construction BMP Fact Sheets

Table 9-1 Post-Construction BMP Fact Sheets

Section	BMP Category	BMP Name	MCBH BMP ID
1	LID	Dry Swale	MCBH-PBMP-01
2	LID	Wet Swale	MCBH-PBMP-02
3	LID	Infiltration Trench	MCBH-PBMP-03
4	LID	Infiltration Basin	MCBH-PBMP-04
5	LID	Bioretention	MCBH-PBMP-05
6	LID	Shallow Wetland	MCBH-PBMP-06
7	LID	Pocket Wetland	MCBH-PBMP-07
8	LID	Wet Extended-Detention Pond	MCBH-PBMP-08
9	LID	Wet Pond	MCBH-PBMP-09
10	Non-LID	Surface Sand Filter	MCBH-PBMP-10
11	Non-LID	Underground Sand Filter	MCBH-PBMP-11
12	Non-LID	Organic Sand Filter	MCBH-PBMP-12
13	LID	Green Roof	MCBH-PBMP-13
14	LID	Dry Wells	MCBH-PBMP-14
15	Non-LID	Downspout Disconnection	MCBH-PBMP-15
16	Non-LID	Rain Harvest and Reuse	MCBH-PBMP-16
17	LID	Permeable Hardscape	MCBH-PBMP-17
18	Non-LID	Proprietary Non-LID BMPs	MCBH-PBMP-18

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ATTACHMENT 1

Post-Construction BMP Inspection Example Checklists

Example Inspection Checklist	Applicable BMPs	MCBH BMP IDs
Bioretention	Dry Swale Wet Swale Bioretention	MCBH-PBMP-01 MCBH-PBMP-02 MCBH-PBMP-05
Hydrodynamic Separator	Hydrodynamic Devices	MCBH-PBMP-18
Underground Detention	Underground Sand Filter Dry Wells	MCBH-PBMP-11 MCBH-PBMP-14

BIORETENTION INSPECTION CHECKLIST

BMP ID Number: ___________ Installation: __________Location: ______________________________

Date: ____________________ Inspector: ____

Code Key:

NP = No Problem Observed	WN = Work Needed	N/A = Not Applicable

ASSESSMENT	CODE	COMMENTS
Inlet / Outlet		
Structural condition		
Debris accumulation		
Overflow catch basin debris accumulation		
Erosion control (e.g., rock, mat)		
Pretreatment for Sediment		
Device functioning to trap sediment		
Sediment accumulation		
Bioretention Surface		
Sediment accumulation		
Debris accumulation		
Erosion		
Vegetative cover		
Mulch cover		
Overall Functionality		
Is bioretention area functioning properly (professional landscape architect recommended)		

Additional Comments:

HYDRODYNAMIC SEPARATOR INSPECTION CHECKLIST

BMP ID Number: ___________ Installation: ________ Location: ________________________________
Date: ____________________ Inspector: ____

Code Key:

NP = No Problem Observed   WN = Work Needed   N/A = Not Applicable

ASSESSMENT	CODE	COMMENTS
Inflow Points		
Obstruction: vegetation / debris / sediment		
Structural condition		
Filter condition		
Separator Body		
Sediment / debris accumulation		
Separator structural condition		
Central shaft condition		
Oil accumulation		
Standing water		
Outlet Device		
Obstruction: vegetation / debris / sediment		
Erosion / undercutting		
Joint failure / loss of joint material		
Leaking device		
Emergency bypass condition		
Miscellaneous		
Trash / debris		
Access		
Odors present		
Other (describe)		

Additional Comments:

UNDERGROUND DETENTION STRUCTURE INSPECTION CHECKLIST

BMP ID Number: ____________ Installation: _________ Location: ____________________________________
Date: ______________________ Inspector: ____

Code Key:

NP = No Problem Observed	WN = Work Needed	N/A = Not Applicable

ASSESSMENT	CODE	COMMENTS
Inflow Points		
Obstruction: trash / debris / sediment		
Structural condition		
Pipe condition		
Other (describe)		
Underground Vault		
Sediment / debris accumulation		
Access hatch condition		
Access ladder / steps condition		
Vault structural condition		
Baffles / weir condition		
Oil accumulation		
Blocked / damaged air vents		
Proper drainage		
Other (describe)		
Outlet Device		
Obstruction: vegetation / debris / sediment		
Erosion / undercutting		
Joint failure / loss of joint material		
Leaking device		
Control valve / bottom drain operation		
Emergency bypass condition		
Displacement / blockage of outlet or rock, apron, mat, etc.		
Other (describe)		
Miscellaneous		
Trash / debris		
Access		
Odors present		
Other (describe)		

UNDERGROUND DETENTION STRUCTURE INSPECTION CHECKLIST

Additional Comments:

1 Dry Swale

Image Source – Mark M. Holeman, Inc.

1.1 Description & Purpose

Swales are vegetated open channels that are designed to capture and treat the full water quality volume within dry or wet cells that are formed by check dams or other means. A dry swale, often referred to as a bioswale, receives runoff during rain events but generally does not have ponded or standing water during dry periods.

1.2 Applications

Dry swales are used at low density residential projects or for very small impervious areas. Dry swales are applicable for land uses such as roads, highways, residential development, and pervious areas.

1.3 Suggested Design Criteria

- Volume is based on a rainfall intensity of 0.4 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- Longitudinal slopes shall be less than 4.0% to qualify for water quality volume treatment.
- Channels shall have moderate side slopes (flatter than 3:1) for most conditions and may NOT be steeper than 2:1.
- Peak velocity shall be non-erosive for the soil and vegetative cover provided.
- The maximum allowable ponding time shall be less than 48 hours, and the minimum ponding time shall be 30 minutes is recommended.

- A bottom width of no wider than 8 feet or a meandering drainage pattern shall be established.
- There should be a maximum ponding depth of one foot at the mid-point of the channel profile and a maximum depth of 18 inches at the downstream end of the channel.
- At the water quality flow rate, the swale width should be that which will have a flow depth of no greater than 4 inches and the hydraulic grade line is no greater than 2% between structures.
- The flow length in the swale should be a minimum of 100 feet.

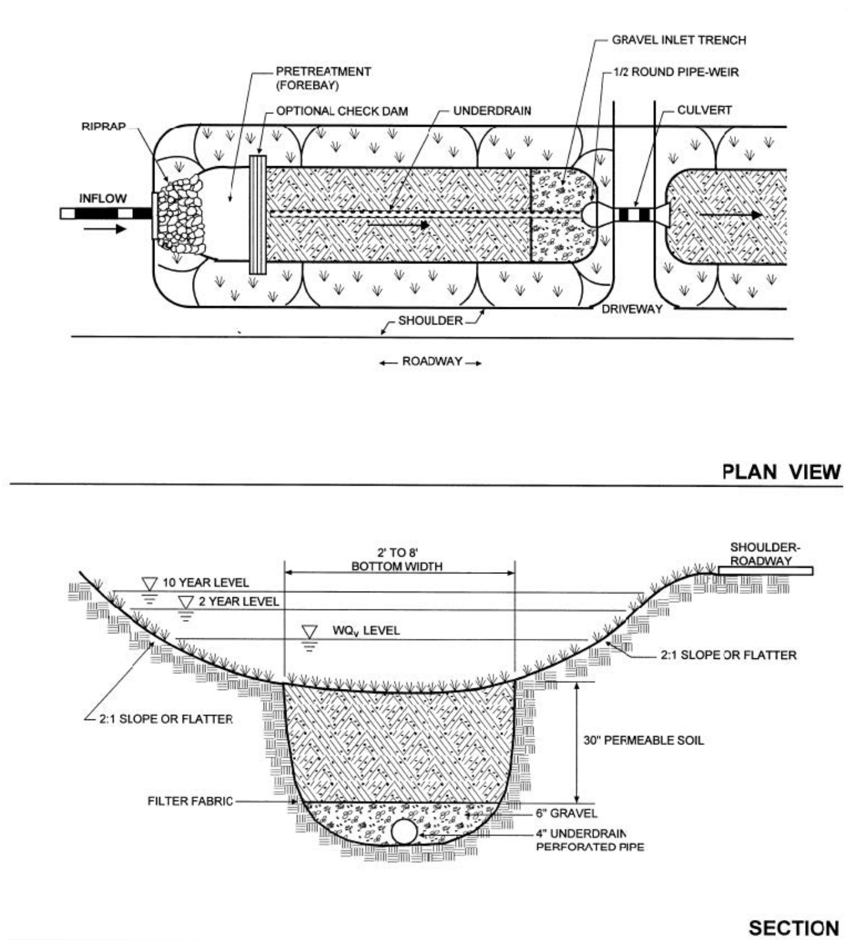

Figure 1. Example of a Dry Swale. Source- Maryland Department of the Environment 2000

1.4 Pretreatment Requirements

- Pretreatment storage of 0.1 inches of runoff per impervious acre storage shall be provided, which is usually obtained by check dams at pipe inlets and/or driveway crossings.
- A diaphragm of pea gravel and gentle side slopes should be provided along the top of channels to accommodate pretreatment for lateral sheet flows.
- Direct discharge of concentrated flow shall be pretreated.

1.5 Construction Considerations

- The inflow should be directed towards the upstream end of the swale but should occur evenly over the swale.
- Swales that directly receive runoff from impervious surfaces may have a six inch drop onto a protected shelf of pea gravel to minimizing the clogging of the inlet.
- An underdrain shall be provided to ensure maximum ponding time of 48 hours.

1.6 Landscaping Requirements

- Landscape design should specify proper grass species and wetland plants based on the specific site, soils and hydric conditions present along the channel.
- A permeable soil mixture 30”-30” deep should meet the bioretention “planting” soil specifications listed in the Bioretention section.
- Seed should be flood and drought resistant grasses.

1.7 Maintenance And Inspections

- Swales should be mowed as required during the growing season to maintain heights in the 4-6 inch range.
- Sediment buildup in the bottom of the swale shall be removed when 25% of the original water quality volume has been exceeded.

1.8 Limitations

- The bottom of the facility shall be above the seasonally high water table.
- No gravel or perforated pipe shall be placed under driveways.

2 Wet Swale

Image Source -limno.com

2.1 Description & Purpose

Swales are vegetated open channels that are designed to capture and treat the full water quality volume within dry or wet cells that are formed by check dams or other means. Wet swales are differentiated from dry swales in that they function with the likely presence of moist or wet conditions. A wet swale functions similarly to stormwater wetlands and is designed to fit into linear environments.

2.2 Applications

Wet swales are ideal for treating highway runoff in low lying or flat areas. Wet swales are applicable for land uses such as roads, highways, and pervious areas.

2.3 Suggested Design Criteria

- Volume is based on a rainfall intensity of 0.4 inches per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- Longitudinal slopes shall be less than 4.0% to qualify for water quality volume treatment.
- Channels shall have moderate side slopes (flatter than 3:1) for most conditions and may NOT be steeper than 2:1.
- Peak velocity shall be non-erosive for the soil and vegetative cover provided.
- The maximum allowable ponding time shall be less than 48 hours, and the minimum ponding time shall be 30 minutes is recommended.
- A bottom width of no wider than 8 feet or a meandering drainage pattern shall be

established.

- There should be a maximum ponding depth of one foot at the mid-point of the channel profile and a maximum depth of 18 inches at the downstream end of the channel.
- At the water quality flow rate, the swale width should be that which will have a flow depth of no greater than 4 inches and the hydraulic grade line is no greater than 2% between structures.
- The flow length in the swale should be a minimum of 100 feet.

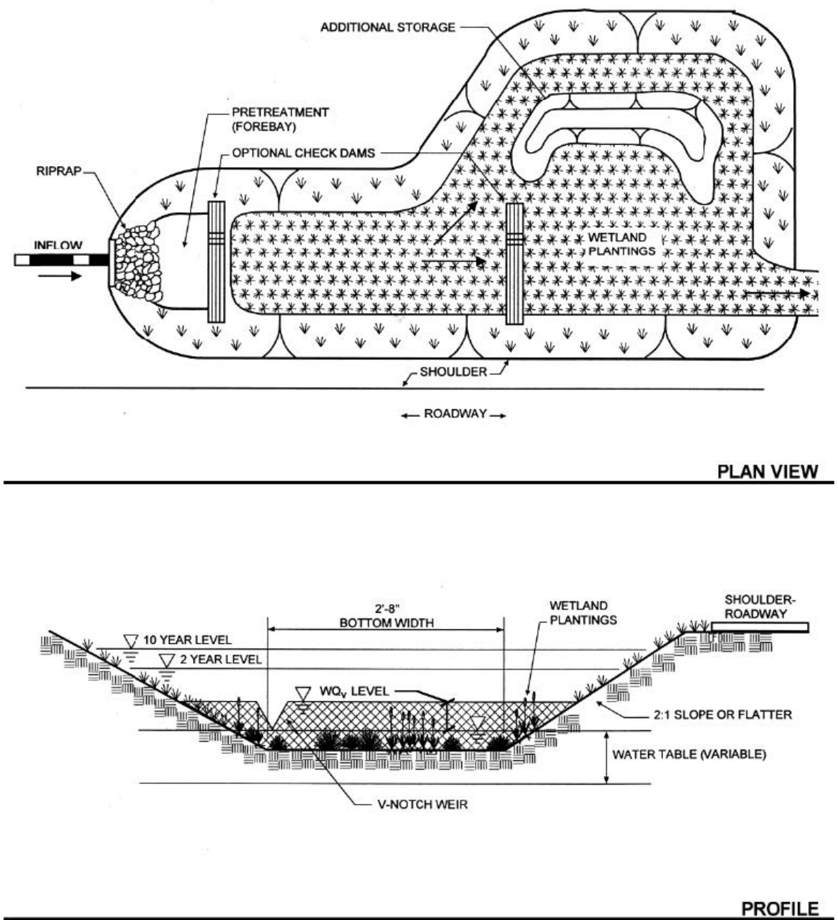

Figure 2. Example of a Wet Swale. Source- Maryland Department of the Environment 2000

2.4 Pretreatment Requirements

- Pretreatment storage of 0.1 inches of runoff per impervious acre storage shall be provided, which is usually obtained by check dams at pipe inlets and/or driveway crossings.
- A diaphragm of pea gravel and gentle side slopes should be provided along the top of channels to accommodate pretreatment for lateral sheet flows.
- Direct discharge of concentrated flow shall be pretreated.

2.5 Construction Considerations

- The inflow should be directed towards the upstream end of the swale but should occur evenly over the swale.
- Swales that directly receive runoff from impervious surfaces may have a six inch drop onto a protected shelf of pea gravel to minimizing the clogging of the inlet.
- Excavation should be performed in undisturbed areas.
- No underdrain system should be used.

2.6 Landscaping Requirements

- Landscape design should specify proper grass species and wetland plants based on the specific site, soils and hydric conditions present along the channel.
- A permeable soil mixture 30”-30” deep should meet the bioretention “planting” soil specifications listed in the Bioretention section.
- Seed should be flood and drought resistant grasses.

2.7 Maintenance and Inspections

- Swales should be mowed as required during the growing season to maintain heights in the 4-6 inch range.
- Sediment buildup in the bottom of the swale shall be removed when 25% of the original water quality volume has been exceeded.
- Swales with wetland vegetation or other low maintenance ground cover do not require frequent mowing of the channel.

2.8 Limitations

- The seasonally high-water table may inundate the swale, but not above the bottom of the channel.
- No gravel or perforated pipe shall be placed under driveways.
- Not recommended for residential developments since they can create potential nuisance or mosquito breeding conditions.

3 Infiltration Trench

Image Source - sudswales.com

3.1 Description & Purpose

Infiltration trenches are linear ditches that collect rainwater from adjacent surfaces, and their highly permeable soils allow the water to quickly seep into the ground.

3.2 Applications

Infiltrated storm water shall be infiltrated through soils capable of filtering prior to entering groundwater. Other suitable media filters pollutants that are accompanied by a certification from a licensed civil engineer that the filter/device will remove 80 percent of total suspended solids from the design flow rate are also acceptable. Infiltration shall only be used where soil conditions and slope stability are suitable.

3.3 Suggested Design Criteria

- A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Volume is based on a rainfall intensity of 0.4 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- Groundwater shall be protected from possible contamination by avoiding potential storm water areas.
- The bottom of the facility shall be separated by at least 4' (vertically) from the seasonally high-water table or bedrock layer.
- Facilities shall be located at least 100 feet from any water supply well.
- Facilities shall have a maximum contributing area of five acres.
- The facility should not be placed in locations that cause water problems to downgrade properties and should be setback (25') downgrade from structures

- All trenches shall be designed to fully de-water the entire water quality volume within 48 hours after the storm event.
- Adequate storm water outfalls shall be provided for the overflow associated with the ten- year design storm event.
- Since the trench will be located “off-line” from the main conveyance system, a flow splitter will be required to divert the water quality volume into the filter.

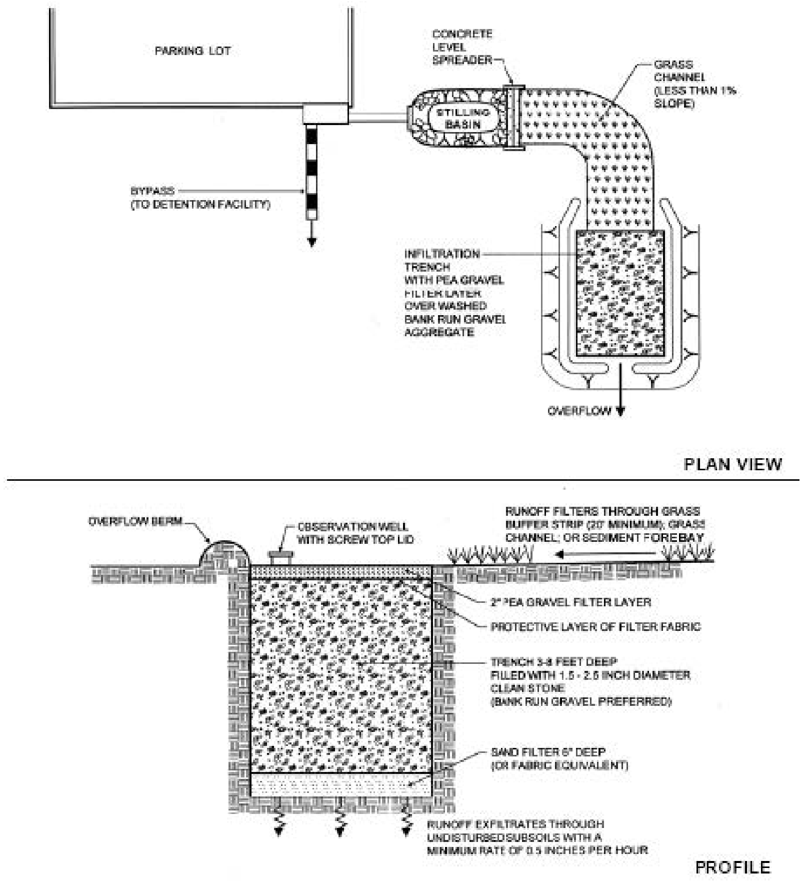

Figure 3. Example of an Infiltration Trench- Maryland Department of the Environment 2000

3.4 Pretreatment Requirements

- A minimum of 25% of the water quality volume is to be pretreated in the stilling basin prior to entering the facility.
- Exit velocities shall be non-erosive during the two-year design storm.
- Long-term techniques for infiltration protection (2 per trench):
  - Grass channel;
  - Grass filter strip (minimum 20 feet and only if sheet flow is established and maintained);
  - Bottom sand layer;
  - Upper sand layer (6 inches minimum) with filter fabric at sand/gravel interface; and
  - Washed bank run gravel used as aggregate.

3.5 Construction Considerations

- Phases of trench construction shall be coordinated with the overall project construction schedule.
- Rough excavation and rough grading phases of construction should be scheduled together to permit the exchange of cut and fill. The partially excavated trench **CANNOT** serve as a sedimentation basin.
- Trench construction specifications should state:
    - The earliest point in progress when storm drainage may be directed to the trench;
    - The means by which the delay will be accomplished.
- Initial trench excavation should be carried to within 2 feet of the final elevation of the trench floor.
- Final excavation to the final grade should be done after all disturbed areas in the watershed area stabilized or protected.
- Final phase excavation should remove all accumulated sediment.
- Light tracked equipment is recommended to avoid compaction in the trench.
- After the completion of final grading, the trench should be well-aerated and have a highly porous surface texture.
- Trenches may be lined with a 6 to 12 inch layer of filter material, such as coarse sand to help prevent the buildup of impervious deposits. The filter layer can be replaced or cleaned when clogged.
- Establish dense vegetation on trench side slopes and floor, preventing erosion, sloughing, and a natural means of maintaining high infiltration rates.
- Use NRCS requirements for vegetative materials for side slopes and other areas to be vegetated.
- Fescue family grasses are recommended for seeding.

3.6 Landscaping Requirements

- Dense and vigorous vegetative cover is to be established over the contributing pervious drainage areas before runoff can be accepted into the facility. Infiltration trenches are not to be constructed until all of the contributing drainage areas have been completely stabilized.

3.7 Maintenance and Inspections

- Are not to serve as a sediment control device during site construction.
- Erosion and sediment plans for the site must clearly indicate methods that will prevent sediment from entering the infiltration device.
- Recommended that infiltration designs include dewatering methods such as underdrain pipe systems to accommodate drawdown in the event of a failure.
- Direct access provided to all infiltration practices for maintenance and rehabilitation.
- Should not be covered by an impermeable surface.

3.8 Limitations

- Often best used with other BMPs downstream.
- Underlying soils shall have specific infiltration rates to be tested with geotechnical borings.
- Soils shall have a clay content of less than 20% and a silt/clay content of less than 40%.
- Infiltration cannot be located on slopes greater than 15% or within fill soils.

4 Infiltration Basin

Image Source - trianglepondmanagement.com

4.1 Description & Purpose

Water quality volume is retained in an infiltration basin, where it percolates through the basin in a 2-day period. The facility must be able to completely treat the flow rate as determined from storm water quality control flow rate charts. Flows above this rate can either be by-passed or routed through the facility if it can be demonstrated that velocities will not re-entrain captured pollutants.

4.2 Applications

Infiltrated storm water shall be infiltrated through soils capable of filtering prior to entering groundwater. Other suitable media filters pollutants that are accompanied by a certification from a licensed civil engineer that the filter/device will remove 80 percent of total suspended solids from the design flow rate are also acceptable. Infiltration shall only be used where soil conditions and slope stability are suitable.

4.3 Limitations

- Often best used with other BMPs downstream.
- Underlying soils shall have specific infiltration rates to be tested with geotechnical borings.
- Soils shall have a clay content of less than 20% and a silt/clay content of less than 40%.
- Infiltration cannot be located on slopes greater than 15% or within fill soils.

4.4 Suggested Design Criteria

- A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Volume is based on a rainfall intensity of 0.4 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- Groundwater shall be protected from possible contamination by avoiding potential storm water areas.
- The bottom of the facility shall be separated by at least 4' (vertically) from the seasonally high-water table or bedrock layer.
- Facilities shall be located at least 100 feet from any water supply well.
- Facilities shall have a maximum contributing area of five acres.
- The facility should not be placed in locations that cause water problems to downgrade properties and should be setback 25' downgrade from structures.
- All basins shall be designed to fully de-water the entire water quality volume within 48 hours after the storm event.
- Adequate storm water outfalls shall be provided for the overflow associated with the ten- year design storm event.

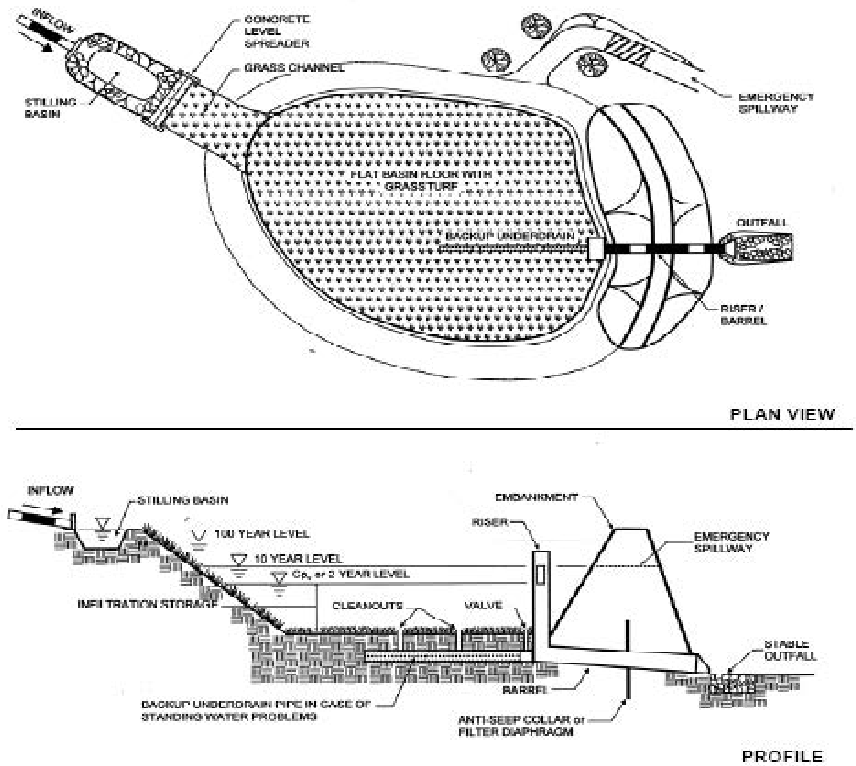

Figure 4. Example of an Infiltration Basin- Maryland Department of the Environment 2000

4.5 Pretreatment Requirements

- A minimum of 25% of the water quality volume is to be pretreated in the stilling basin prior to entering the facility.
- Exit velocities shall be non-erosive during the two-year design storm.
- Long-term techniques for infiltration protection (2 per basin)
    - Grass channel;
    - Grass filter strip (minimum 20 feet and only if sheet flow is established and maintained);
    - Bottom sand layer;
    - Upper sand layer (6 inches minimum) with filter fabric at sand/gravel interface; and
    - Washed bank run gravel used as aggregate.

4.6 Construction Considerations

- Phases of basin construction shall be coordinated with the overall project construction schedule.
- Rough excavation and rough grading phases of construction should be scheduled together to permit the exchange of cut and fill. The partially excavated basin **CANNOT** serve as a sedimentation basin.
- Basin construction specifications should state:

  - The earliest point in progress when storm drainage may be directed to the basin; and
  - The means by which the delay will be accomplished.
- Initial basin excavation should be carried to within 2 feet of the final elevation of the basin floor.
- Final excavation to the final grade should be done after all disturbed areas in the watershed area stabilized or protected.
- Final phase excavation should remove all accumulated sediment.
- Light tracked equipment is recommended to avoid compaction in the basin.
- After the completion of final grading, the basin should be well-aerated and have a highly porous surface texture.
- Basins may be lined with a 6 to 12 inch layer of filter material, such as coarse sand to help prevent the buildup of impervious deposits. The filter layer can be replaced or cleaned when clogged.
- Establish dense vegetation on basin side slopes and floor, preventing erosion, sloughing, and a natural means of maintaining high infiltration rates.
- Use NRCS requirements for vegetative materials for side slopes and other areas to be vegetated.
- Fescue family grasses are recommended for seeding.

4.7 Landscaping Requirements

- Dense and vigorous vegetative cover is to be established over the contributing pervious drainage areas before runoff can be accepted into the facility. Infiltration trenches are not to be constructed until all of the contributing drainage areas have been completely stabilized.

4.8 Maintenance and Inspections

- Are not to serve as a sediment control device during site construction.
- Erosion and sediment plans for the site must clearly indicate methods that will prevent sediment from entering the infiltration device.
- Recommended that infiltration designs include dewatering methods such as underdrain pipe systems to accommodate drawdown in the event of a failure.
- Direct access provided to all infiltration practices for maintenance and rehabilitation.
- Should not be covered by an impermeable surface.

5 Bioretention

Image Source - owp.csus.edu/lid/

5.1 Description & Purpose

Bioretention combines open space with storm water treatment in vegetated areas where runoff is directed through vegetation and soils for filtration. It captures and temporarily stores the water quality volume and passes it through a filter bed of sand, organic matter, soil, or other media.

5.2 Applications

Filtered runoff may be collected and returned to the conveyance system or allowed to partially exfiltrate into the soil.

5.3 Suggested Design Criteria

- A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Volume is based on a rainfall intensity of 0.4 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- The required filter bed area (Af) is computed using the following equation: Af= (WQv) (df) / [(k) (hf+df) (tf)]
    - WQv is the water quality volume (cu. ft);
    - df is the filter bed depth (ft);
    - k is the coefficient pf permeability of the filter bed (ft/day);
    - hf is the height of water above the filter bed (ft); and

- o tf is the design filter bed drain time (days)- 2 days recommended.

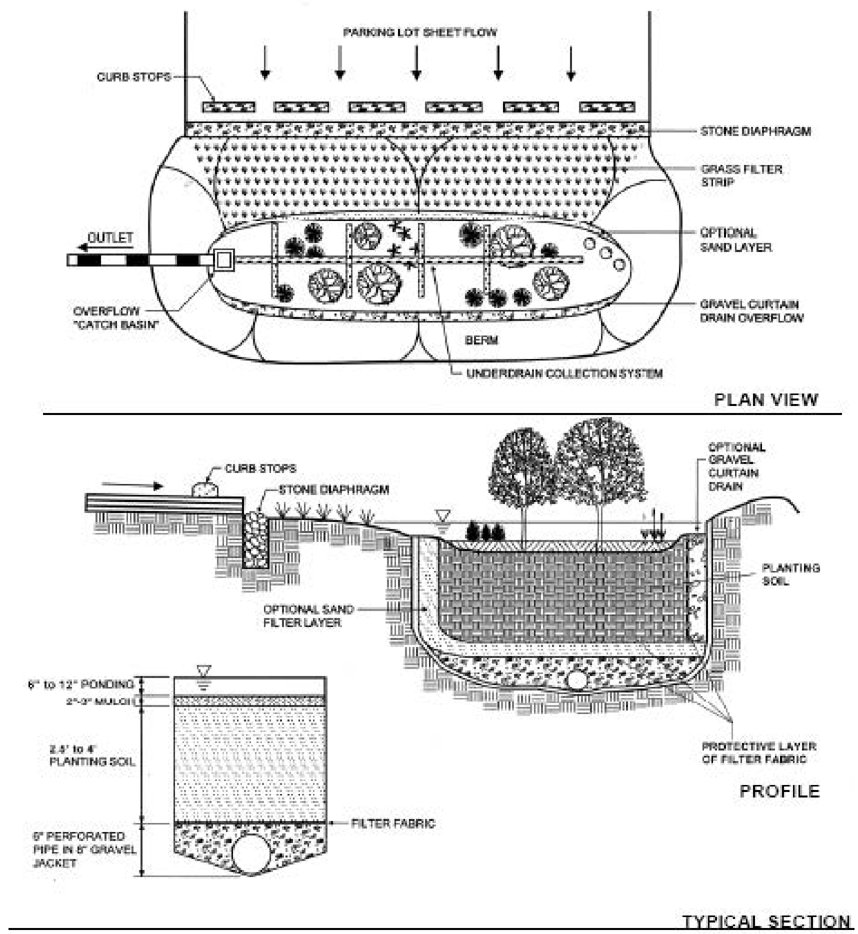

Figure 5. Example of a Bioretention Plan. Source- Maryland Department of the Environment 2000

5.4 Pretreatment Requirements

- Pretreatment is provided when all of the following are provided:
  - o 20’ grass filter strip below a level spreader or sand filter layer;
  - o Gravel diaphragm; and
  - o Mulch layer.
- Treatment components shall include:
  - o 2 ½ to 4 foot deep planting soil bed;
  - o Surface mulch layer; and
  - o 12 inches deep surface ponding area.

5.5 Construction Considerations

- Overflow for the ten-year storm event shall be provided to a non-erosive outlet point and non-erosive velocities shall result.
- A flow regulator shall be provided to divert the water quality volume to the filtering practice.
- The filters shall have a 6-inch perforated underdrain pipe in a gravel layer.

- A permeable filter fabric shall be places between the gravel layer and the filter media.

5.6 Landscaping Requirements

- Landscaping is critical to the function and performance of the bioretention areas. A landscaping plan shall be provided for these areas.
- Planting recommendations:
    - Native plant species;
    - Select vegetation based on the zone of hydric tolerance;
    - Trees with an understory of shrubs and herbaceous materials should be selected; and
    - Woody vegetation should not be used at inflow locations.
- The ponding depth should be 6 inches or less with a mulch layer of 2 to 3 inches.
- A sandy planting soil of 2 to 3 inches should be used.
- Dense and vigorous vegetation should be established over the contributing drainage area before accepting runoff into the facility.

5.7 Maintenance and Inspections

- Direct maintenance access is to be provided to the pretreatment area and the filter bed.
- At least a six-inch drop shall be provided at the inlet of the facility (stone diaphragm).
- Dead or diseased plants shall be replaced.
- Areas with mulch that has been washed out should be re-mulched annually.

5.8 Limitations

- Unless there is adequate infiltration capacity, underdrains and overflow drains should be included to collect and discharge filtered runoff to the storm drainage system.

6 Shallow Wetland

Image Source – Maryland DOT State Highway Administration

6.1 Description & Purpose

Shallow wetlands provide water quality volume in a shallow pool that has a large surface area.

6.2 Applications

Practices that create shallow wetland areas to treat urban storm water and often incorporate small permanent pools and/or extended detention storage to achieve the full water quality volume.

6.3 Suggested Design Criteria

- Volume based on the 1-inch storm.
- C=0.05+0.009*IMP is the runoff coefficient.
- IMP is the percentage of impervious area.
- WQDV=C*1"*A*3630 (Water Quality Design Volume (cf)).
- C is the runoff coefficient.
- 1 inches is the 1-inch storm.
- A is the area of the site in acres.
- 3630 is a conversion factor.
- The volume must meet minimum detention times.
- Flowpaths from inflow points to outflow points within storm water wetlands shall be maximized.
- Flowpaths of 1.5:1 (L:W) and irregular shapes are recommended and achieved by constructing internal berms.
- Microtopography is encouraged to enhance diversity in the wetland.
- Surface area shall be at least 1.5 percent of the total drainage area to the facility.

- At least 25% of the total water quality volume shall be in deepwater zones with a minimum depth of four feet. This may be reduced if the wetland is located where thermal impacts area a primary concern.
- A minimum of 35% of the total surface area shall have a depth of 6 inches or less.
- At least 65% of the total surface area shall be shallower than 18 inches.
- If using extended detention, the extended detention volume shall not comprise more than 50% of the total wetland design. Maximum surface elevation shall not extend more than 3 feet above the normal pool.
- In order to promote greater nitrogen removal, rock beds may be used as a medium for growth of wetland plants. Rock should be 1-3 inches in diameter and placed up to the normal pool elevation. Rock beds should be open to flow-through from either direction.

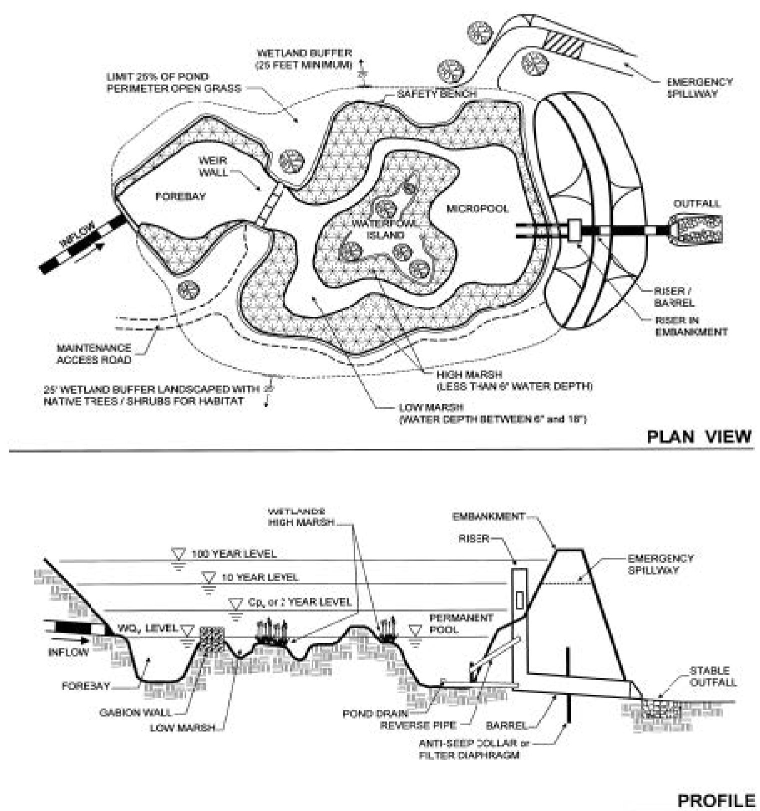

Figure 6. Example of a Shallow Wetland. Source- Maryland Department of the Environment 2000

6.4 Pretreatment Requirements

- Sediment regulation is critical for sustaining storm water wetlands.
- Sediment forebay:
  - o Located at the inlet and the micropool shall be located at the inlet;
  - o Micropool located at the outlet; and
  - o Forebay shall be sized to contain 0.1 inches per impervious acre of contributing drainage. The storage in the forebay counts toward the total amount of water

quality volume required to be treated.

- Micropool is a 3-6 foot deep pool used to protect the low flow pipe from clogging and prevent sediment resuspension.
- Exit velocities shall be non-erosive.

6.5 Construction Considerations

- The wetland bed should be graded to create maximum internal flowpaths and microtopography.

6.6 Landscaping Requirements

- Landscaping plans shall be provided that indicate methods used to establish and maintain wetland coverage.
- Minimum plan elements include:
  - Delineation of pondscaping zones;
  - Selection of corresponding plant species;
  - Planting configuration; and
  - Sequence for preparing wetland bed.
- Landscaping plans for Use III and IV watersheds should incorporate plant species and plants found in wooded wetlands.
- Fascines, coconut rolls, or straw bales can be used in high energy areas of the storm water wetland to create shallow marsh cells.
- Landscaping plans should promote greater wildlife and waterfowl use within the watershed.
- A wetland buffer should extend 25 feet outward from the maximum water surface elevation with an additional 15 foot setback to structures.

6.7 Maintenance and Inspections

- If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required.
- Storm water wetlands are created in upland areas and away from jurisdictional wetlands and are not regulated by state and federal laws as long as regular maintenance is performed.

6.8 Limitations

- A water balance must be performed to demonstrate that a wetland can withstand a thirty-day drought at summer evaporation rates without completely drawing down.
- Storm water wetlands may not be located within jurisdictional waters, including wetlands without obtaining a wetlands and waterways permit from the state.
- Use III watersheds may require a small pond review and approval from dam safety in wetlands that include permanent ponds as design components.

7 Pocket Wetland

Image Source – Center for Watershed Protection, Inc.

7.1 Description & Purpose

A high-water table or groundwater interception helps maintain the shallow wetland pool in the pocket wetland.

7.2 Applications

Practices that create wetland areas to treat urban storm water and often incorporate small permanent pools and/or extended detention storage to achieve the full water quality volume.

7.3 Suggested Design Criteria

- Volume based on the 1-inch storm.
- C=0.05+0.009*IMP is the runoff coefficient.
- IMP is the percentage of impervious area.
- WQDV=C*1”*A*3630 (Water Quality Design Volume (cf)).
- C is the runoff coefficient.
- 1 inches is the 1-inch storm.
- A is the area of the site in acres.
- 3630 is a conversion factor.
- The volume must meet minimum detention times.
- Flowpaths from inflow points to outflow points within storm water wetlands shall be maximized.
- Flowpaths of 1.5:1 (L:W) and irregular shapes are recommended and achieved by constructing internal berms.
- Microtopography is encouraged to enhance diversity in the wetland.

- Surface area shall be at least one percent of the total drainage area to the facility.
- At least 25% of the total water quality volume shall be in deepwater zones with a minimum depth of four feet. This may be reduced if the wetland is located where thermal impacts area a primary concern.
- A minimum of 35% of the total surface area shall have a depth of 6 inches or less.
- At least 65% of the total surface area shall be shallower than 18 inches.
- If using extended detention, the extended detention volume shall not comprise more than 50% of the total wetland design. Maximum surface elevation shall not extend more than 3 feet above the normal pool.
- In order to promote greater nitrogen removal, rock beds may be used as a medium for growth of wetland plants. Rock should be 1-3 inches in diameter and placed up to the normal pool elevation. Rock beds should be open to flow-through from either direction.

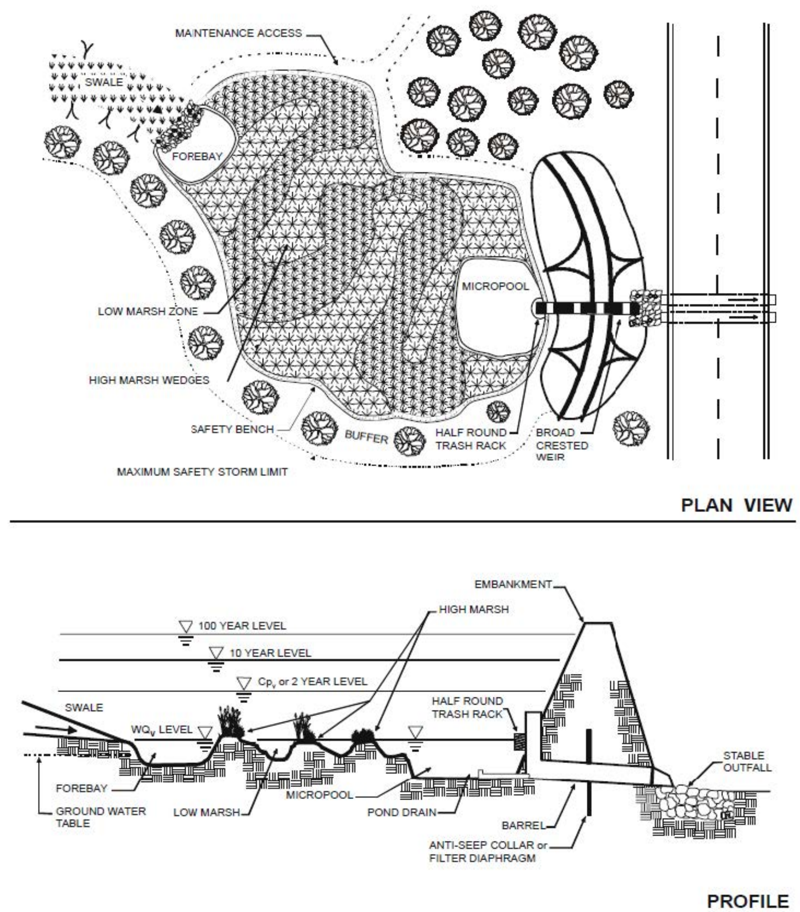

Figure 7. Example of a Pocket Wetland. Source- Maryland Department of the Environment 2000

7.4 Pretreatment Requirements

- Sediment regulation is critical for sustaining storm water wetlands.
- Sediment forebay:

    - Located at the inlet and the micropool shall be located at the inlet;
    - Micropool located at the outlet; and
    - Forebay shall be sized to contain 0.1 inches per impervious acre of contributing drainage. The storage in the forebay counts toward the total amount of water quality volume required to be treated.
- Micropool is a 3-6 foot deep pool used to protect the low flow pipe from clogging and prevent sediment resuspension.
- Exit velocities shall be non-erosive.

7.5 Construction Considerations

- The wetland bed should be graded to create maximum internal flowpaths and microtopography.

7.6 Landscaping Requirements

- Landscaping plans shall be provided that indicate methods used to establish and maintain wetland coverage.
- Minimum plan elements include:
    - Delineation of pondscaping zones;
    - Selection of corresponding plant species;
    - Planting configuration; and
    - Sequence for preparing wetland bed.
- Landscaping plans for Use III and IV watersheds should incorporate plant species and plants found in wooded wetlands.
- Fascines, coconut rolls, or straw bales can be used in high energy areas of the storm water wetland to create shallow marsh cells.
- Landscaping plans should promote greater wildlife and waterfowl use within the watershed.
- A wetland buffer should extend 25 feet outward from the maximum water surface elevation with an additional 15 foot setback to structures.

7.7 Maintenance and Inspections

- If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required.
- Storm water wetlands are created in upland areas and away from jurisdictional wetlands and are not regulated by state and federal laws as long as regular maintenance is performed

7.8 Limitations

- A water balance must be performed to demonstrate that a wetland can withstand a thirty-day drought at summer evaporation rates without completely drawing down.
- Storm water wetlands may not be located within jurisdictional waters, including wetlands without obtaining a wetlands and waterways permit from the state.
- Use III watersheds may require a small pond review and approval from dam safety in wetlands that include permanent ponds as design components.

8 Wet Extended Detention Pond

Image Source – Highpointnc.gov

8.1 Description & Purpose

Water quality storage is provided through a combination of permanent pool and extended detention storage.

8.2 Applications

Detention of storm water runoff allows for the settling of fine particles and pollutants that are associated with these particles.

8.3 Suggested Design Criteria

- Volume based on the 1-inch storm.
- C=0.05+0.009*IMP is the runoff coefficient.
- IMP is the percentage of impervious area.
- WQDV=C*1"*A*3630 (Water Quality Design Volume (cf))
    - C is the runoff coefficient;
    - 1 inches is the 1-inch storm;
    - A is the area of the site in acres; and
    - 3630 is a conversion factor
- The volume must meet minimum detention times.
- The draw-down time for the detention volume shall be greater than or equal to 48 hours. For the bottom half of the detention volume, the draw-down time shall be greater than or equal to 36 hours.
- The detention system shall be designed to maximize the distance between the inlet and outlet, and to minimize "dead spaces" (areas with little or no exchange occurs

during a storm event), limiting short-circuiting. A minimum flow path length to width ratio of 3 should be utilized.

- The outlet shall be sized to achieve the above required detention times. It shall also be large enough that clogging is unlikely to occur. It should be 4 inches or larger in diameter. If this is not possible, the use of flow-through based measures should be considered, unless it can be demonstrated that clogging can be avoided.
- There shall be a minimum contributing drainage area of ten acres or more unless groundwater ground water is the primary water source.
- The ten-year design storm is to be used to design for a stable outfall.
- Dams shall meet class A dam safety hazard classification.
- The principal spillway/riser shall provide anti-floatation, anti-vortex, and trash-rack designs.
- One foot of freeboard shall be provided above the design high water for the 10-year storm.
- Woody vegetation is prohibited on the embankment.
- Pond benches:
  - The safety bench extends outward from the normal water edge to the toe of the pond side slope. Maximum slope=6%; and
  - Aquatic bench extends inward from the normal shoreline and has a maximum depth of 18 inches below normal pool water surface elevation. Not required in forebays.
- Pond buffers and setbacks:
  - Buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond and should be contiguous with other required buffer areas; and
  - Existing trees should be preserved during construction and forest conservation areas should be located.
- Non-clogging low flow orifice:
  - Shall have a minimum diameter of 3 inches and shall be adequately protected from clogging by an external trash rack;
  - Orifice diameter can be reduced to 1 inch if using an internal orifice;
  - Submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below normal pool elevation is preferred;
  - Alternatives include broad crested rectangular, v-notch, or proportional weird, protected by half-round CMP that extends 12 inches below permanent pool;
  - Horizontal perforated pipe protected by geotextile and gravel not recommended; and
  - Vertical pipes can be used if a permanent pool is present.
- Riser:
  - Shall be located within the embankment for maintenance access, safety and aesthetics;
  - Access to riser to be provided by lockable manhole covers and steps within reach of valves and controls; and
  - Openings should be fenced with pipe or rebar to prevent trash accumulation.

- Pond Drain:
  - Ponds shall have a drain pipe that can drain the pond within 24 hours;
  - Prevent downstream discharge of sediment and slope instability caused by drawdown by exercising care during these processes; and
  - Appropriate jurisdictions shall be notified before draining a pond.
- Valves:
  - Drain shall be equipped with adjustable valve;
  - Drain should be sized one pipe size larger than the calculated design diameter;
  - Controls should be located inside of the riser they will not be inundated and can be operated safely; and
  - Handwheel shall be chained to a ringbolt or manhole step to prevent vandalism.

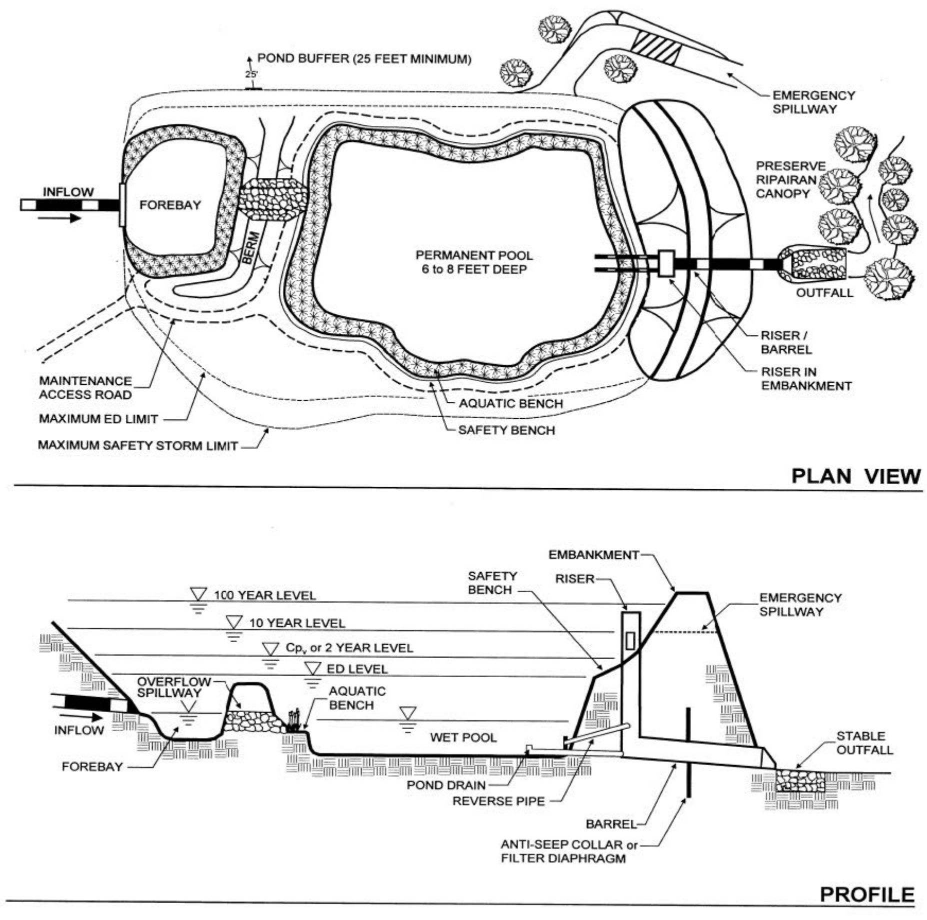

Figure 8. Example of a Wet Extended Detention Pond. Source- Maryland Department of the Environment 2000

8.4 Pretreatment Requirements

- Sediment forebay:
  - Each pond shall have a sediment forebay or equivalent upstream treatment and shall consist of a separate cell, formed by an adequate barrier; and
  - Forebay shall be sized to contain 0.1 inches per impervious acre of contributing drainage. The storage in the forebay counts toward the total amount of water quality volume required to be treated.

- Exit velocities shall be non-erosive.
- The bottom may be hardened to make sediment removal easier.
- The fixed vertical sediment depth marker should be installed to measure sediment deposition over time.

8.5 Construction Considerations

- Inlet protection shall not be fully submerged at normal pool elevations.
- A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond.
- Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement should be used at the spillway outlet.
- The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, usually by the use of large riprap over filter cloth.
- A stilling basin or other outlet protection should be used to reduce flow velocities form the principal spillway to non-erosive.
- In ponds that daylight to channels with dry weather flow, tree clearing should be minimized along the downstream channel. Avoiding the excessive use of riprap is important to prevent stream warming.
- Pond liners should be used in areas of karst topography, gravelly sands or fractured bedrock.

8.6 Landscaping Requirements

- The landscaping plan for storm water ponds and its buffer shall indicate how aquatic and terrestrial areas will be vegetatively stabilized and established.
- Wetland plants are encouraged either along the aquatic bench, safety bench and side slopes, or within shallow areas of the pool. The best elevations for establishing these plants are within six inches of the normal pool.
- It is advised to excavate large and deep holes around the proposed planting sites and backfill with uncompacted topsoil.
- Planting holes should be at least six inches larger than the diameter of the rootball (balled and burlap stock) and three inches wider for container grown stock.
- Avoid species requiring full shade which are prone to wind damage.
- Extra mulching around the base is strongly recommended to conserve moisture and prevent weeds.

8.7 Maintenance and Inspections

- Maintenance responsibility for the pond and its buffer shall be given to a responsible party by means of a legally binding and enforceable maintenance agreement.
- The principal spillway shall be equipped with a trash rack that has maintenance access.
- Sediment removal in the forebay shall take place when 50% of the forebay capacity is lost.
- Sediment removed from ponds shall be disposed of according to current erosion

and sediment control regulations.

- A maintenance right-of-way or easement at least 12 feet wide and a maximum slope of 15% and stabilized shall extend to a pond from a public or private road.
- Maintenance access should extend to the forebay, safety bench, riser, and outlet and should allow vehicles to turn around.
- Annual mowing of the buffer is only required on maintenance rights-of-way.

8.8 Limitations

- Although a detention system for water quality could be combined with a flood control system, the volume assigned for water quality control must meet minimum detention times. This volume will typically not be available for peak rate volume control.
- Ponds cannot be located within jurisdictional waters such as wetlands without obtaining proper permits.

9 Wet Pond

Image Source – charlottenc.gov

9.1 Description & Purpose

A wet pond provides all of the water quality volume storage in a permanent pool.

9.2 Applications

Detention of storm water runoff allows for the settling of fine particles and pollutants that are associated with these particles. The wet pond volume is equal to the water quality design volume and is entirely a permanent wet pond, where storm water exchanges with the pond water to achieve treatment.

9.3 Suggested Design Criteria

- Volume based on the 1-inch storm.
- C=0.05+0.009*IMP is the runoff coefficient.
- IMP is the percentage of impervious area.
- WQDV=C*1"*A*3630 (Water Quality Design Volume (cf))
    - C is the runoff coefficient;
    - 1 inch is the 1-inch storm;
    - A is the area of the site in acres; and
    - 3630 is a conversion factor.
- Detention time requirements do not apply.
- The draw-down time for the detention volume shall be greater than or equal to 48 hours. For the bottom half of the detention volume, the draw-down time shall be greater than or equal to 36 hours.
- The detention system shall be designed to maximize the distance between the inlet and outlet, and to minimize "dead spaces" (areas with little or no exchange occurs

during a storm event), limiting short-circuiting. A minimum flow path length to width ratio of 3 should be utilized.

- The outlet shall be sized to achieve the above required detention times. It shall also be large enough that clogging is unlikely to occur. It should be 4 inches or larger in diameter. If this is not possible, the use of flow-through based measures should be considered, unless it can be demonstrated that clogging can be avoided.
- There shall be a minimum contributing drainage area of ten acres or more unless groundwater ground water is the primary water source.
- The ten-year design storm is to be used to design for a stable outfall.
- Dams shall meet class A dam safety hazard classification.
- The principal spillway/riser shall provide anti-floatation, anti-vortex, and trash-rack designs.
- One foot of freeboard shall be provided above the design high water for the 10-year storm.
- Woody vegetation is prohibited on the embankment.
- Pond benches:
  - The safety bench extends outward from the normal water edge to the toe of the pond side slope. Maximum slope=6%; and
  - Aquatic bench extends inward from the normal shoreline and has a maximum depth of 18 inches below normal pool water surface elevation. Not required in forebays.
- Pond buffers and setbacks:
  - Buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond and should be contiguous with other required buffer areas; and
  - Existing trees should be preserved during construction and forest conservation areas should be located.
- Non-clogging low flow orifice:
  - Shall have a minimum diameter of 3 inches and shall be adequately protected from clogging by an external trash rack;
  - Orifice diameter can be reduced to 1 inch if using an internal orifice;
  - Submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below normal pool elevation is preferred;
  - Alternatives include broad crested rectangular, v-notch, or proportional weir, protected by half-round CMP that extends 12 inches below permanent pool;
  - Horizontal perforated pipe protected by geotextile and gravel not recommended; and
  - Vertical pipes can be used if a permanent pool is present.
- Riser:
  - Shall be located within the embankment for maintenance access, safety and aesthetics;
  - Access to riser to be provided by lockable manhole covers and steps within reach of valves and controls; and
  - Openings should be fenced with pipe or rebar to prevent trash accumulation.

- Pond Drain:
  - o Ponds shall have a drain pipe that can drain the pond within 24 hours;
  - o Prevent downstream discharge of sediment and slope instability caused by drawdown by exercising care during these processes; and
  - o Appropriate jurisdictions shall be notified before draining a pond.
- Valves:
  - o Drain shall be equipped with adjustable valve;
  - o Drain should be sized one pipe size larger than the calculated design diameter;
  - o Controls should be located inside of the riser they will not be inundated and can be operated safely;
  - o Handwheel shall be chained to a ringbolt or manhole step to prevent vandalism; and
  - o Applicant must show a water balance that demonstrates that there will be sufficient dry weather flows to maintain the planned pool volume, without creating stagnant conditions.

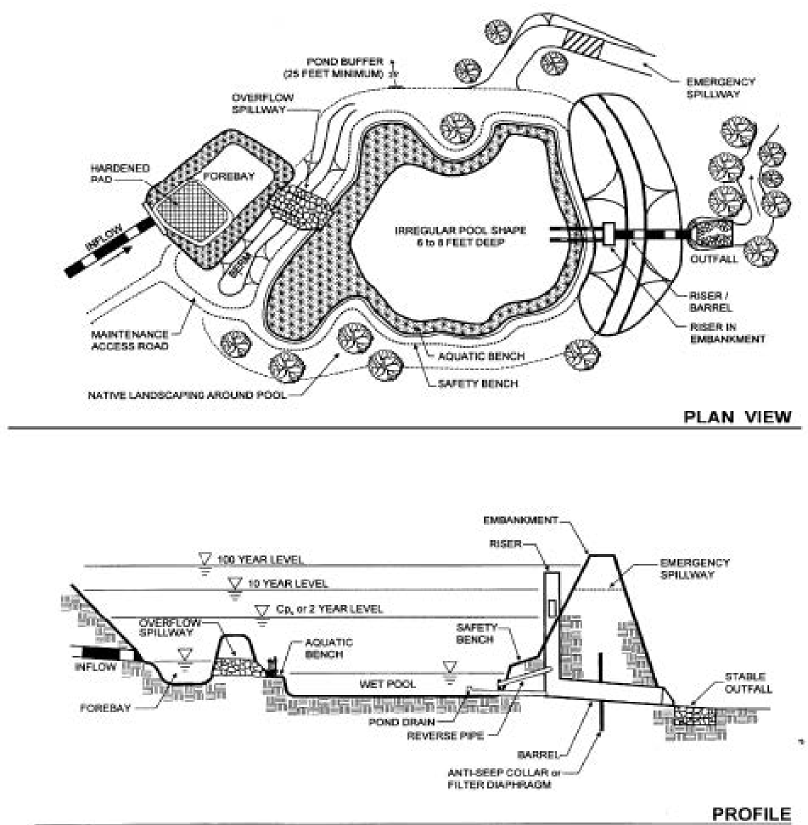

Figure 9. Example of a Wet Pond. Source- Maryland Department of the Environment 2000

9.4 Pretreatment Requirements

- Sediment forebay:
  - Each pond shall have a sediment forebay or equivalent upstream treatment and shall consist of a separate cell, formed by an adequate barrier; and
  - Forebay shall be sized to contain 0.1 inches per impervious acre of contributing drainage. The storage in the forebay counts toward the total amount of water quality volume required to be treated.
- Exit velocities shall be non-erosive.
- The bottom may be hardened to make sediment removal easier.
- The fixed vertical sediment depth marker should be installed to measure sediment deposition over time.

9.5 Construction Considerations

- Inlet protection shall not be fully submerged at normal pool elevations.
- A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond.
- Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement should be used at the spillway outlet.
- The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, usually by the use of large riprap over filter cloth.
- A stilling basin or other outlet protection should be used to reduce flow velocities form the principal spillway to non-erosive.
- In ponds that daylight to channels with dry weather flow, tree clearing should be minimized along the downstream channel. Avoiding the excessive use of riprap is important to prevent stream warming.
- Pond liners should be used in areas of karst topography, gravelly sands or fractured bedrock.

9.6 Landscaping Requirements

- The landscaping plan for storm water ponds and its buffer shall indicate how aquatic and terrestrial areas will be vegetatively stabilized and established.
- Wetland plants are encouraged either along the aquatic bench, safety bench and side slopes, or within shallow areas of the pool. The best elevations for establishing these plants are within six inches of the normal pool.
- It is advised to excavate large and deep holes around the proposed planting sites and backfill with uncompacted topsoil.
- Planting holes should be at least six inches larger than the diameter of the rootball (balled and burlap stock) and three inches wider for container grown stock.
- Avoid species requiring full shade which are prone to wind damage.
- Extra mulching around the base is strongly recommended to conserve moisture and prevent weeds.

9.7 Maintenance And Inspections

- Maintenance responsibility for the pond and its buffer shall be given to a responsible party by means of a legally binding and enforceable maintenance agreement.
- The principal spillway shall be equipped with a trash rack that has maintenance access.
- Sediment removal in the forebay shall take place when 50% of the forebay capacity is lost.
- Sediment removed from ponds shall be disposed of according to current erosion and sediment control regulations.
- A maintenance right-of-way or easement at least 12 feet wide and a maximum slope of 15% and stabilized shall extend to a pond from a public or private road.
- Maintenance access should extend to the forebay, safety bench, riser, and outlet and should allow vehicles to turn around.
- Annual mowing of the buffer is only required on maintenance rights-of-way.

9.8 Limitations

- Although a detention system for water quality could be combined with a flood control system, the volume assigned for water quality control must meet minimum detention times. This volume will typically not be available for peak rate volume control.
- Ponds cannot be located within jurisdictional waters such as wetlands without obtaining proper permits.

10 Surface Sand Filter

Image Source – Montgomerycountymd.gov

10.1 Description & Purpose

Surface sand filters can treat the largest drainage area of all the filtering systems. It captures and temporarily stores the water quality volume and passes it through a filter bed of sand, organic matter, soil, or other media.

10.2 Applications

Filtered runoff may be collected and returned to the conveyance system or allowed to partially exfiltrate into the soil. Applied to land uses with a high percentage of impervious surfaces.

Drainage areas with imperviousness less than 75% discharging to a filtering practice shall require full sedimentation pretreatment techniques.

10.3 Suggested Design Criteria

- A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Volume is based on a rainfall intensity of 0.4 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- The required filter bed area (Af) is computed using the following equation: Af= (WQv) (df) / [(k) (hf+df) (tf)]
    - WQv is the water quality volume (cu. ft);
    - df is the filter bed depth (ft);
    - k is the coefficient pf permeability of the filter bed (ft/day);
    - hf is the height of water above the filter bed (ft); and
    - tf is the design filter bed drain time (days)- 2 days recommended.
- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.

- Filter bed has a minimum depth of 12".

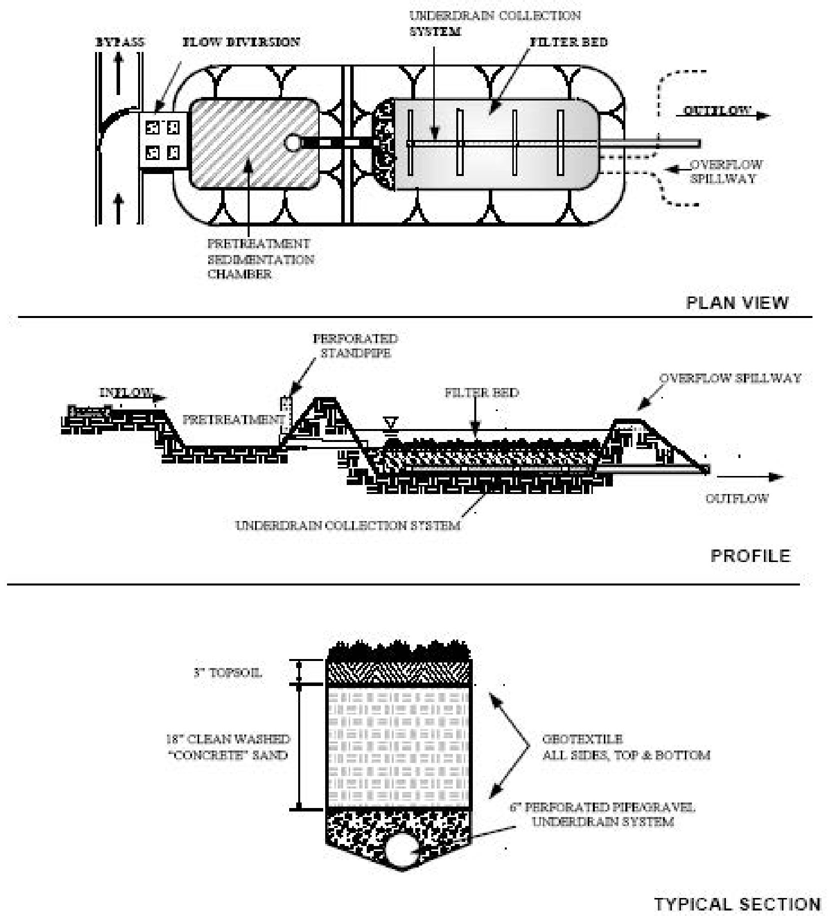

Figure 10. Example of a Surface Sand Filter. Source- Maryland Department of the Environment 2000

10.4 Pretreatment Requirements

- Dry or wet pretreatment equivalent to at least 25% of the computed water quality volume shall be provided prior to the filter media.
- Typically, sedimentation basins with a length to width ratio of 2:1 are used.
- Pretreatment is provided when all of the following are provided:
    - 20' grass filter strip below a level spreader or sand filter layer;
    - Gravel diaphragm; and
    - Mulch layer.
- Treatment components shall include:
    - 2 ½ to 4 foot deep planting soil bed;
    - Surface mulch layer; and
    - 12 inches deep surface ponding area.

10.5 Construction Considerations

- Overflow for the ten-year storm event shall be provided to a non-erosive outlet point

and non-erosive velocities shall result.
- A flow regulator shall be provided to divert the water quality volume to the filtering practice.
- The filters shall have a 6-inch perforated underdrain pipe in a gravel layer.
- A permeable filter fabric shall be places between the gravel layer and the filter media.

10.6 Landscaping Requirements

- The ponding depth should be 6 inches or less with a mulch layer of 2 to 3 inches.
- A sandy planting soil of 2 to 3 inches should be used.
- Dense and vigorous should be established over the contributing drainage area before accepting runoff into the facility.
- A grass cover is permitted to aid in pollutant adsorption and should be cable of withstanding frequent periods of inundation and drought.

10.7 Maintenance and Inspections

- Direct maintenance access is to be provided to the pretreatment area and the filter bed.
- Dead or diseased plants shall be replaced.
- Areas with mulch that has been washed out should be re-mulched annually.
- The sediment chamber outlet devices shall be cleaned/repaired when drawdown times within the chamber exceed 36 hours. Trash and debris shall be removed as necessary.
- Sediment shall be cleaned out of the sedimentation chamber when it accumulates to a depth of more than 6 inches.
- Vegetation in the sediment chamber should be no greater than 18 inches in height.
- When water ponds on the surface of the filter for more than 72 hours, the top few inches of the discolored material shall be replaced with fresh material, and the removed sediment should be disposed of (landfill).
- When silt and sediment accumulation exceeds one inch, it should be removed from the filter bed.
- Filters with a grass cover should be mowed at least 3 times per growing season to maintain grass heights of less than 12 inches.

10.8 Limitations

Unless there is adequate infiltration capacity, underdrains and overflow drains should be included to collect and discharge filtered runoff to the storm drainage system.

11 Underground Sand Filter

Image Source – rotondo-es.com

11.1 Description & Purpose

The underground sand filter is an option for providing water quality volume where space is limited.

11.2 Applications

Filtered runoff may be collected and returned to the conveyance system or allowed to partially exfiltrate into the soil. Applied to land uses with a high percentage of impervious surfaces. Drainage areas with imperviousness less than 75% discharging to a filtering practice shall require full sedimentation pretreatment techniques.

11.3 Suggested Design Criteria

- A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Volume is based on a rainfall intensity of 0.4 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- The required filter bed area (Af) is computed using the following equation: Af= (WQv) (df) / [(k) (hf+df) (tf)]
    - WQv is the water quality volume (cu. ft);
    - df is the filter bed depth (ft);
    - k is the coefficient pf permeability of the filter bed (ft/day);
    - hf is the height of water above the filter bed (ft); and

  - o tf is the design filter bed drain time (days)- 2 days recommended
- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.
- Filter bed has a minimum depth of 12”.

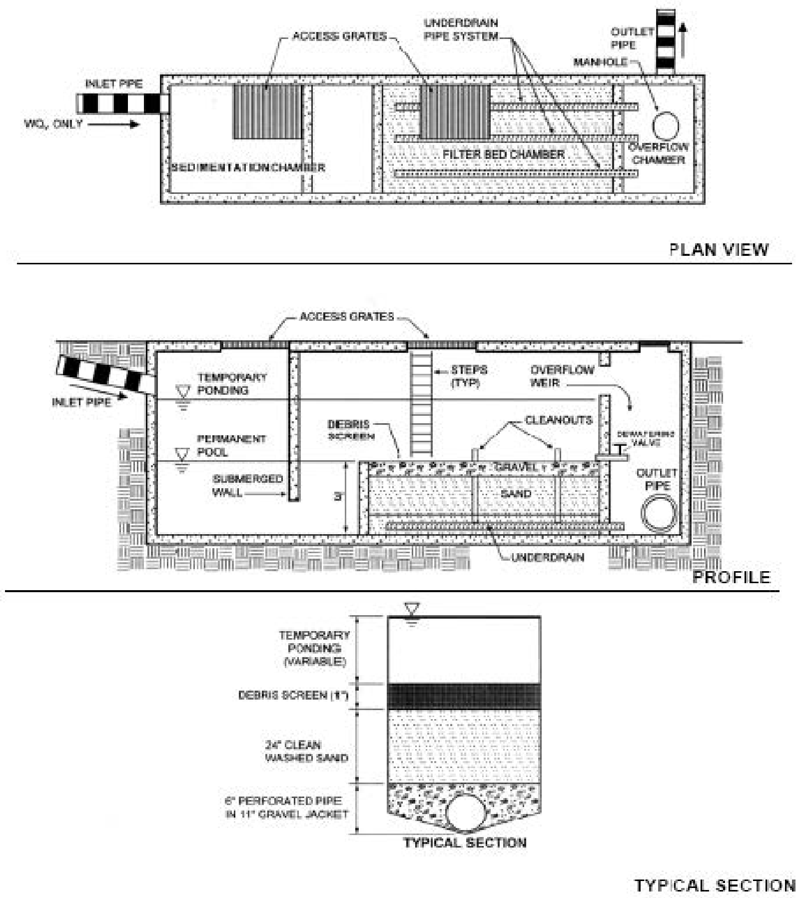

Figure 11. Example of an Underground Sand Filter. Source- Maryland Department of the Environment 2000

11.4 Pretreatment Requirements

- Dry or wet pretreatment equivalent to at least 25% of the computed water quality volume shall be provided prior to the filter media.
- Typically, sedimentation basins with a length to width ratio of 2:1 are used.
- Pretreatment is provided when all of the following are provided:
  - o 20’ grass filter strip below a level spreader or sand filter layer;
  - o Gravel diaphragm; and
  - o Mulch layer.
- Treatment components shall include:
  - o 2 ½ to 4 foot deep planting soil bed;
  - o Surface mulch layer; and
  - o 12 inches deep surface ponding area.

11.5 Construction Considerations

- Overflow for the ten-year storm event shall be provided to a non-erosive outlet point and non-erosive velocities shall result.
- A flow regulator shall be provided to divert the water quality volume to the filtering practice.
- The filters shall have a 6-inch perforated underdrain pipe in a gravel layer.
- A permeable filter fabric shall be places between the gravel layer and the filter media.

11.6 Landscaping Requirements

- The ponding depth should be 6 inches or less with a mulch layer of 2 to 3 inches.
- A sandy planting soil of 2 to 3 inches should be used.
- Dense and vigorous should be established over the contributing drainage area before accepting runoff into the facility.

11.7 Maintenance and Inspections

- Direct maintenance access is to be provided to the pretreatment area and the filter bed.
- Dead or diseased plants shall be replaced.
- Areas with mulch that has been washed out should be re-mulched annually.
- The sediment chamber outlet devices shall be cleaned/repaired when drawdown times within the chamber exceed 36 hours. Trash and debris shall be removed as necessary.
- Sediment shall be cleaned out of the sedimentation chamber when it accumulates to a depth of more than 6 inches.
- Vegetation in the sediment chamber should be no greater than 18 inches in height.
- When water ponds on the surface of the filter for more than 72 hours, the top few inches of the discolored material shall be replaced with fresh material, and the removed sediment should be disposed of (landfill).
- When silt and sediment accumulation exceed one inch, it should be removed from the filter bed.

11.8 Limitations

- Unless there is adequate infiltration capacity, underdrains and overflow drains should be included to collect and discharge filtered runoff to the storm drainage system.

12 Organic Sand Filter

12.1 Description & Purpose

The organic filter is used when maximum nutrient or trace metal removals are desired.

12.2 Applications

Filtered runoff may be collected and returned to the conveyance system or allowed to partially exfiltrate into the soil. Applied to land uses with a high percentage of impervious surfaces. Drainage areas with imperviousness less than 75% discharging to a filtering practice shall require full sedimentation pretreatment techniques.

12.3 Suggested Design Criteria

- A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Volume is based on a rainfall intensity of 0.4 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- The required filter bed area (Af) is computed using the following equation: Af= (WQv) (df) / [(k) (hf+df) (tf)]
    - WQv is the water quality volume (cu. ft);
    - df is the filter bed depth (ft);
    - k is the coefficient pf permeability of the filter bed (ft/day);
    - hf is the height of water above the filter bed (ft); and
    - tf is the design filter bed drain time (days)- 2 days recommended.

- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.
- Filter bed has a minimum depth of 12”.

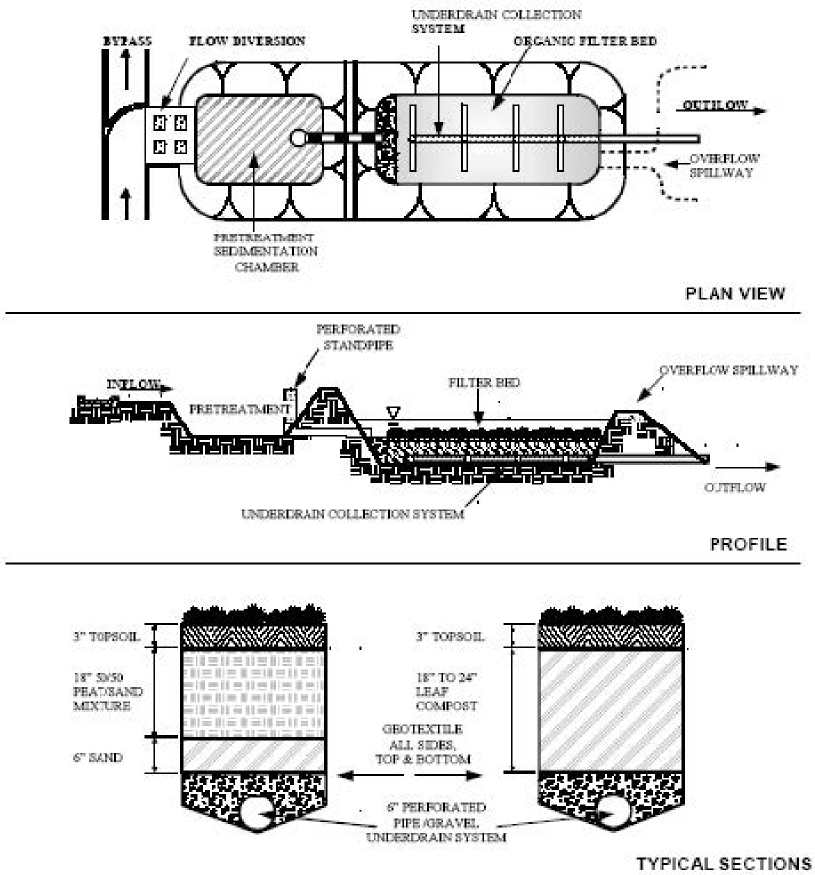

Figure 12. Example of an Organic Sand Filter. Source- Maryland Department of the Environment 2000

12.4 Pretreatment Requirements

- Dry or wet pretreatment equivalent to at least 25% of the computed water quality volume shall be provided prior to the filter media.
- Typically, sedimentation basins with a length to width ratio of 2:1 are used.
- Pretreatment is provided when all of the following are provided:
    - 20’ grass filter strip below a level spreader or sand filter layer;
    - Gravel diaphragm; and
    - Mulch layer.
- Treatment components shall include:
    - 2 ½ to 4 foot deep planting soil bed;
    - Surface mulch layer; and
    - 12 inches deep surface ponding area.

12.5 Construction Considerations

- Overflow for the ten-year storm event shall be provided to a non-erosive outlet point and non-erosive velocities shall result.
- A flow regulator shall be provided to divert the water quality volume to the filtering practice.
- The filters shall have a 6-inch perforated underdrain pipe in a gravel layer.
- A permeable filter fabric shall be places between the gravel layer and the filter media.

12.6 Landscaping Requirements

- The ponding depth should be 6 inches or less with a mulch layer of 2 to 3 inches.
- A sandy planting soil of 2 to 3 inches should be used.
- Dense and vigorous should be established over the contributing drainage area before accepting runoff into the facility.
- A grass cover is permitted to aid in pollutant adsorption and should be cable of withstanding frequent periods of inundation and drought.

12.7 Maintenance and Inspections

- Direct maintenance access is to be provided to the pretreatment area and the filter bed.
- Dead or diseased plants shall be replaced.
- Areas with mulch that has been washed out should be re-mulched annually.
- The sediment chamber outlet devices shall be cleaned/repaired when drawdown times within the chamber exceed 36 hours. Trash and debris shall be removed as necessary.
- Sediment shall be cleaned out of the sedimentation chamber when it accumulates to a depth of more than 6 inches.
- Vegetation in the sediment chamber should be no greater than 18 inches in height.
- When water ponds on the surface of the filter for more than 72 hours, the top few inches of the discolored material shall be replaced with fresh material, and the removed sediment should be disposed of (landfill).
- When silt and sediment accumulation exceed one inch, it should be removed from the filter bed.
- Filters with a grass cover should be mowed at least 3 times per growing season to maintain grass heights of less than 12 inches.

12.8 Limitations

- Unless there is adequate infiltration capacity, underdrains and overflow drains should be included to collect and discharge filtered runoff to the storm drainage system.

13 Green Roof

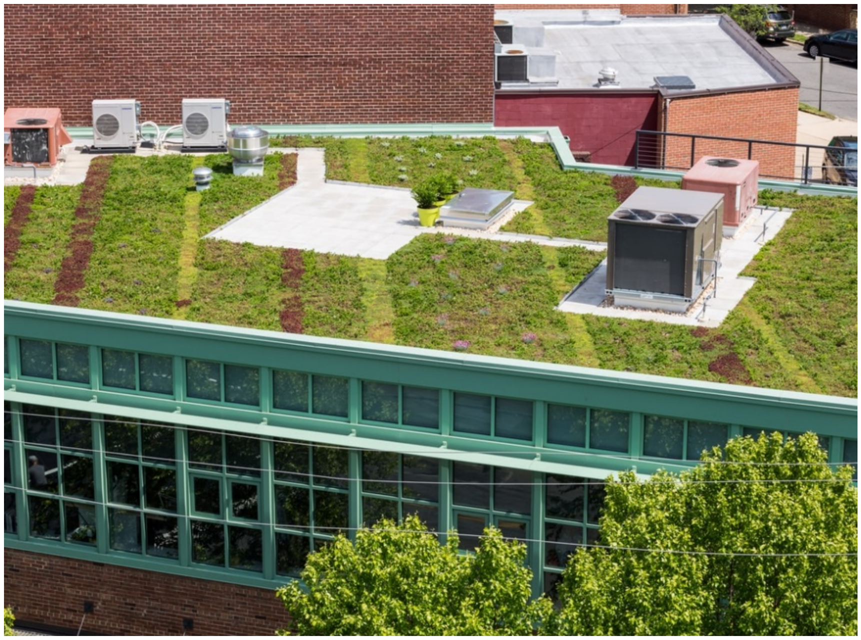

Image Source – Landdesign.com

13.1 Description & Purpose

Sometimes referred to as a vegetated roof or eco-roof, a green roof is a roof that is entirely or partially covered with vegetation and soils. It is a vegetative layer grown on top of an elevated impervious surface.

13.2 Applications

Green Roofs assist in the filtering, absorbing, evapotranspirating, and retaining/detaining of rain that lands on structural roofs. Green roofs offer additional benefits including the reduction of urban heat island effects, increased thermal insulation and energy efficiency, increased acoustic insulation, and increased durability and lifespan compared to conventional roofs. Green roofs can be applied to new or existing structures of residential, commercial, or industrial buildings.

13.3 Suggested Design Criteria

- Minimum depth of soil media = 2 inches
- Minimum depth of drainage layer = 2 inches
- Maximum slope of roof = 20%
- The design must include adequate roof access for delivery of construction materials and for routine maintenance.

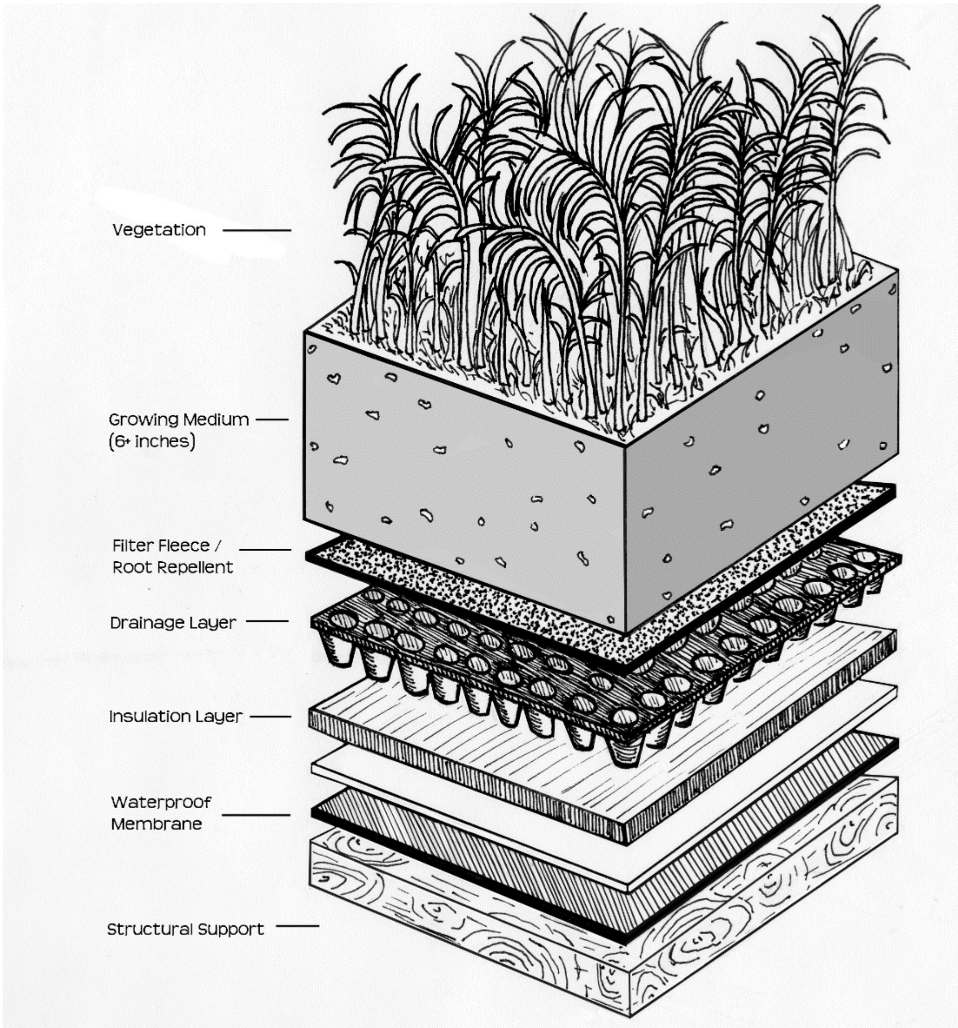

Figure 13. Example of an Extensive Green Roof Design. – Source: Greenroofplan.com

13.4 Pretreatment Requirements

- Green roofs do not require pretreatment.

13.5 Construction Considerations

- Safety measures against wind uplift must be taken into account during design, especially for areas susceptible to high winds.
- The maximum load bearing capacity of the roof construction must be considered. The water saturated weight of the green roof system, including vegetation must be calculated as permanent load. Generally, vegetated roofs weigh between 15 and 30 lb/ sqft depending on the thickness of the vegetated roof system. In addition, construction elements such as pergolas and walkways cause high point loads and, therefore, have to be calculated accordingly.
- The drainage layer below the growth media should be designed to convey the flood design storm without backing water up to into the growing media. The drainage layer should convey flow to an outlet or overflow system such as a traditional rooftop

drainage system with inlets set slightly above the elevation of the vegetated roof surface.

- Green roofs can be designed to be either intensive, semi-intensive, or extensive green roofs. The type of design chosen will depend upon loading capacity, budget, design goals, and stormwater retention desired. There will also be variations in the type of green roof selected depending upon climate, types of plants chosen, soil layer depth desired and feasibility and other design considerations. Green roofs can be constructed layer by layer or can be purchased as a system. Some vendors offer modular trays containing the green roof components.
- Generally, extensive green roofs have six inches or less of growing medium, whereas intensive green roofs have greater than 6 inches of substrate. Semi-intensive green roofs can be defined as a hybrid between intensive and extensive green roofs, where at least 25 percent of the roof square footage is above or below the 6-inch threshold.
- Extensive green roofs provide many of the environmental benefits of intensive green roofs, but they are designed to be very low-maintenance and are not typically designed for public access. Semi-intensive and intensive green roofs are designed to be used by the public or building tenants as a park or relaxation area. However, they also require greater capital and maintenance investments than extensive green roofs. Intensive green roofs are particularly attractive for developers, property owners, and municipalities, in areas where land prices command a premium, but property owners want to provide some of the amenities associated with parks.
- Extensive green roofs range in price from approximately 5 dollars per square foot to 20 dollars per square foot. However, there are significant cost savings associated with reducing energy consumption and longer roof lifespan.
- Intensive green roofs can be considerably more expensive than extensive green roofs. Estimates range from 20 dollars to 80 dollars per square foot. Other benefits should be taken into account, however, such as recreational space provided and costs relative to the price of land in an area.
- All green roof systems should include a waterproofing layer that will prevent stormwater runoff from damaging the underlying rooftop. Waterproofing materials typically used in green roof installations include reinforced thermoplastic and synthetic rubber membranes.
- The waterproofing layer should be protected from root penetration by an impermeable, physical root barrier. Chemical root barriers or physical root barriers that have been impregnated with pesticides, metals or other chemicals that may leach into postconstruction stormwater runoff should not be used.
- To help prevent compaction of the engineered growing media, heavy foot traffic should be kept off green roof surfaces during and after construction.

13.6 Landscaping Requirements

- Plants selected need to be suited for local climatic conditions and can range from sedums, grasses, and wildflowers on extensive roofs to shrubs and small trees on intensive roofs.

- Succulent and other hardy varieties of plants that do not require shade as well as other vegetation general suitable for the environment in Hawaii.
- A landscaping plan should be prepared for all green roofs. The landscaping plan should be reviewed and approved by the local development review authority prior to construction. When developing a landscaping plan, site planning and design teams are encouraged to consult with a botanist, landscape architect or other qualified professional to identify plants that will tolerate the harsh growing conditions found on rooftops in the area.

13.7 Maintenance and Inspections

- Immediately after construction, green roofs need to be monitored regularly to ensure the vegetation thrives.
- During the first season, green roofs may need to be watered periodically if there is not sufficient precipitation. After the first season, extensive green roofs may only need to be inspected and lightly fertilized approximately once per year.
- The roofs may need occasional weeding and may require some watering during exceptionally dry periods.
- Green roofs are less prone to leaking than conventional roofs. In most cases, detecting and fixing a leak under a green roof is no more difficult than doing the same for a conventional roof.
- Intensive green roofs need to be maintained as any other landscaped area. This can involve gardening and irrigation, in addition to other roof maintenance.
- Direct maintenance access is to be provided to the pretreatment area and the filter bed.

13.8 Limitations

- In most climates, green roofs will need to have drought tolerant plant species or an irrigation system to sustain vegetation.
- In new construction, buildings should be designed to manage a potentially increased load associated with the green roof. When designing green roofs for existing structures, engineers must take the load restrictions of the building into account.
- Green roofs can be difficult to install on rooftops with slopes of 10% or greater.
- The amount of rainfall retained by a green roof will depend primarily on the depth of the growing medium and may also be affected by the roof slope.
- Green roofs should only be used to replace traditional impervious roof surfaces. They should not be used to “receive” any stormwater runoff generated elsewhere on the development site.

14 Dry Wells

Image Source- thisoldhouse.com

Description & Purpose

A dry well is a well that is used to transmit surface water underground and is deeper than its width at the surface. They are lined with perforated casings and can be filled with gravel or rock or left empty.

14.1 Applications

Dry wells are used to redirect stormwater and runoff into the subsurface to promote infiltration and temporary storage. This has the added benefit of returning water to aquifers and recharging local groundwater supplies.

14.2 Suggested Design Criteria

- Most drywells are 30 to 70 feet deep and 3 feet wide at the surface.
- Some states provide guidelines for where to install dry wells as part of their permitting process. These guidelines include minimum vertical separation distances between the dry well and groundwater, horizontal separation from municipal wells, the amount of pretreatment required, and appropriate land use surrounding a potential dry well.
- Typically, 10 feet of vertical separation is required between the dry well bottom and the water table, and a vadose zone of sand/gravel and clay is ideal for removing contaminants while still allowing aquifer recharge.

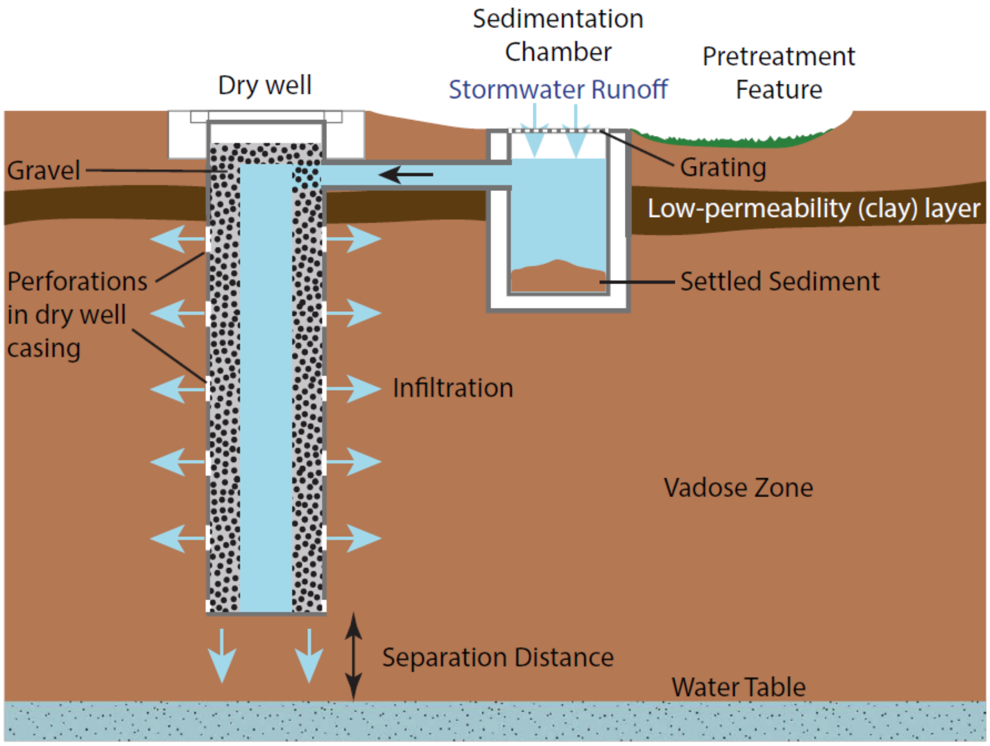

Figure 14. Typical dry well design with pretreatment features. Source – E. Edwards and B. Mandler

14.3 Pretreatment Requirements

- Efficient pretreatment is the key to keeping contaminants out of groundwater.
- Vegetation helps to trap sediment and associated contaminants.

14.4 Construction Considerations

- A percolation test of the soil is suggested to ensure infiltration rates are sufficient.
- Ideally, dry wells should be large enough to collect runoff without overflowing in typical rain events.
- Position the wells near the natural drainage path but at a safe distance from structural foundations.
- Smaller pre-fabricated dry wells are available at some retail stores.
- The size of the well will ultimately depend on the infiltration rate of the soil and the volume of water expected during storm events.

14.5 Maintenance and Inspections

- Many dry wells function for years without problems, but sometimes sediment and debris washed along with runoff can clog the pit walls and reduce the dry well's ability to disperse water.
- Regular inspection and maintenance of pretreatment items is essential to the long-term functionality of dry wells.

14.6 Limitations

- Dry well use has been limited in some places by the concern that dry wells could contaminate groundwater, including drinking water, by reducing the distance contaminated stormwater must travel through sediment in order to reach groundwater. Surface soil and underground sediment remove contaminants by acting as a natural filter, but dry wells allow stormwater contaminants to bypass many underground layers.
- Groundwater contamination has occurred in the past when surface contaminant spills have entered dry wells, or when substances have been illegally dumped into open dry well. However, groundwater contamination is rare when dry wells are used as intended and when appropriate precautions are taken. Contamination risk can be reduced by using dry wells at sites where spills are unlikely or installing emergency shut-off valves to keep out contaminated water.
- Contaminant-rich areas, such as gas stations and many industrial sites, are often unsuitable for dry well installation.

15 Downspout Disconnection

Image Source- stormwater.allianceforthebay.org

15.1 Description & Purpose

Downspout disconnection involves the redirection of stormwater from roof downspouts to permeable surfaces or containers, such as cisterns and rain barrels, for collection and reuse. This directly reduces the amount of stormwater and associated pollutants that reaches sensitive ecosystems. Additional benefits of allowing water to infiltrate into soils include water filtration and increased groundwater supplies.

15.2 Applications

Many industrial, commercial, and residential structures have downspouts that discharge water to paved surfaces or directly to stormwater systems. The redirection of this water to permeable surfaces reduces the volume of stormwater runoff and associated pollutants, flooding, and erosion while increasing groundwater supplies.

15.3 Suggested Design Criteria

- Measure and cut the existing downspout 9 inches from the standpipe if directing water to a permeable surface.
- Cap the standpipe so water cannot continue to enter the storm drain through this entrance.
- Utilize a downspout extension to direct water 5 ft away from structures to a downward sloping area if possible.

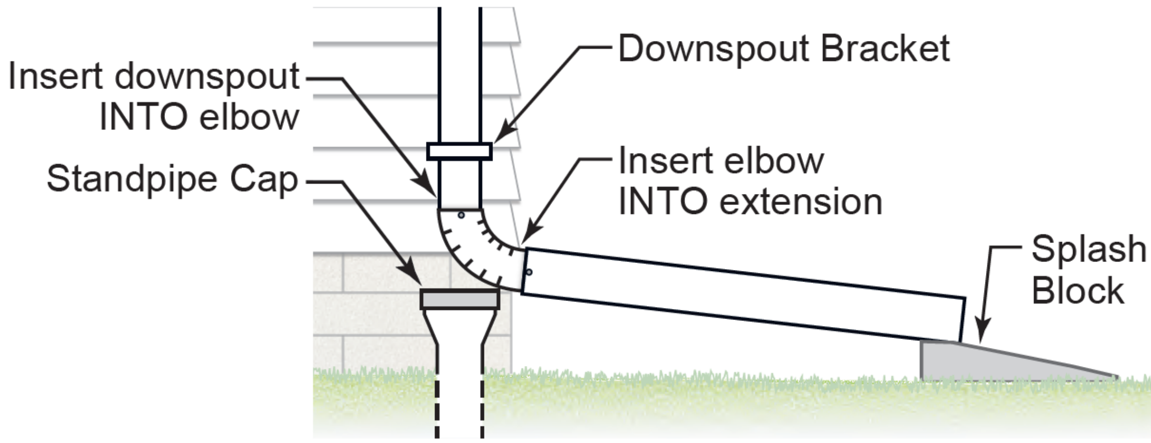

Figure 15. Example of a Downspout Disconnection – Source: City and County of Honolulu

15.4 Pretreatment Requirements

- Pretreatment is typically not required unless roof surfaces are prone to debris.
- Roof gutter guards or leaf gutter screens may be used to keep downspouts from clogging.
- Downspout debris filters can also be installed before the elbow joint to remove debris.

15.5 Construction Considerations

- While downspout water may be discharged directly to vegetated landscapes, consider the velocity of the water and potential erosion issues.
- A splash block should be used to direct water away from buildings.
- A rock or similar velocity dissipator should be considered for concentrated, high velocity discharge.
- A rain chain is decorative feature used in place of a downspout to slow the flow of water from the gutter. The base of the chain should be secured to the ground and surrounded by vegetation or rocks to minimize erosion.
- Consider directing water to cistern or rain barrel for reuse. See fact sheet 16 – Rain Harvest and Reuse.

15.6 Landscaping Requirements

- Thick, well-established grass may be adequate for infrequent, low-velocity flows on relatively level ground that slopes away from the building.
- Shade or sun exposure should be considered when selecting the vegetation.
- Stormwater may also be directed to rain gardens or other vegetated areas.

15.7 Maintenance and Inspections

- Clean gutters and downspouts at the beginning of the rainy season and inspect after severe storms. Use a plumber's or electrician's snake to clean out any obstructions.
- Adjust or replace the outlet protection (splash block, gravel, etc.) as needed to prevent

erosion at the outlet.

- Check for leaks and defects.

15.8 Limitations

- Concentrated, higher velocity flows may result in erosion.

16 Rain Harvest and Reuse

Image Source - doityourself.com

16.1 Description & Purpose

Rain harvest and reuse, sometimes referred to as capture/reuse or rainwater harvesting, is the collection and temporary storage of roof runoff in rain barrels, cisterns, or other tanks for subsequent non-potable outdoor use (i.e., landscape irrigation, vehicle washing).

16.2 Applications

Harvesting of rainwater from roof surfaces prevents water runoff to storm drain systems or sensitive habitats. This resource can then be used onsite in a way that allows for it infiltrate back into the ground or provide plants with irrigation. This has the added benefit of reducing potable water consumption and improved filtration of roof runoff.

16.3 Suggested Design Criteria

- Size storage systems for 80% of average annual (long term) runoff volume and meet 80% of the annual overall demand.
- Storage tank requires an inlet for water to enter and outlet for water to exit.
- Overflow pipe should be as large as inlet pipe.
- Include an air vent or similar to allow air to escape while filling.
- Multiple tanks can be connected to increase storage capacity.

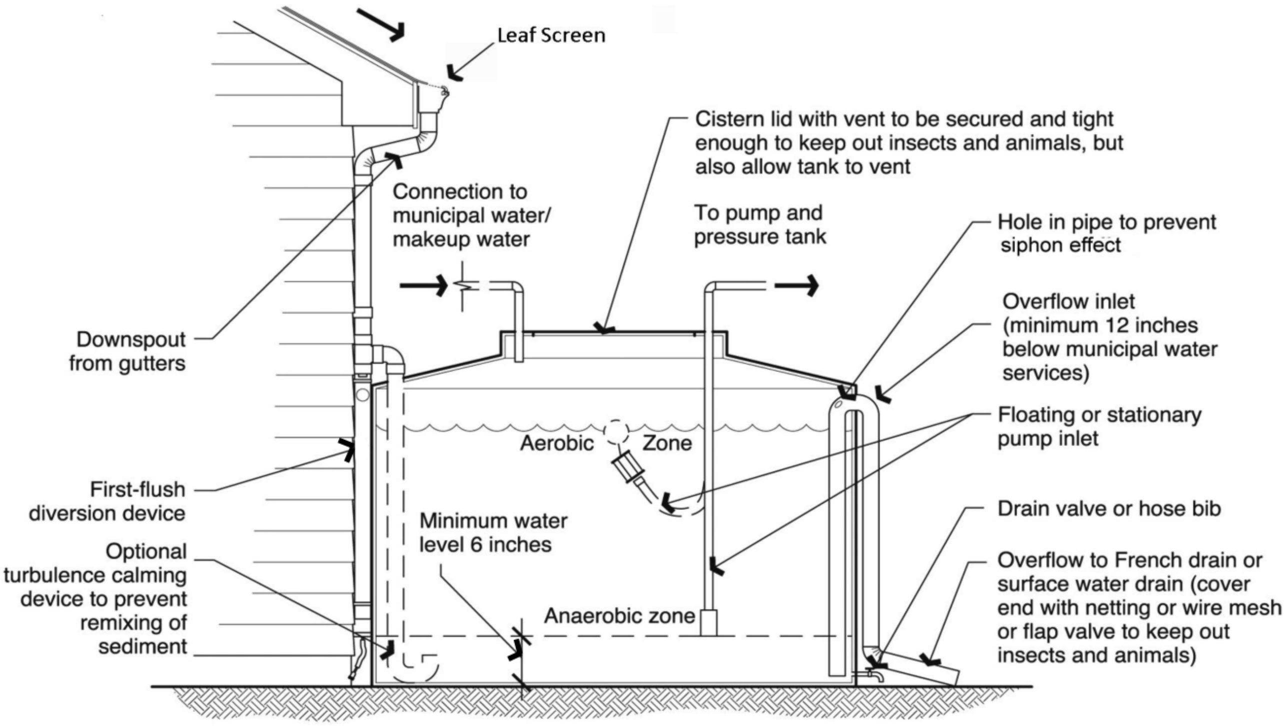

Figure 16. Example of Rainwater Storage System – Source: The University of Arizona Cooperative Extension

16.4 Pretreatment Requirements

- Roof gutter guards or leaf gutter screens are required to keep water clean and prevent clogging.
- A strainer basket or screen at the inlet serves as further protection from debris and animals.

16.5 Construction Considerations

- Rain barrel/cistern sizes can vary greatly depending on the project area, roof size, and irrigation area. The size can be anywhere from less than 1,000 gallons to more than 10,000 gallons per 1,000 sq-ft of roof area.
- Local pan evaporation and rainfall data may be used if available.
- Tanks should have tight fitting covers to exclude contaminants and animals, and above ground tanks should not allow penetration of sunlight to limit algae growth.
- In areas where the tank is to be buried partially below the water table, special design features must be employed to keep it from “floating.”
- Consider installing pumps for irrigation systems and irrigation controllers.
- Gravity-fed discharge of water from the tank is also possible.
- Place tanks at least as far away from foundations as the foundation is deep—usually 10-18 inches, and on a surface such as a cement pad, contained pea gravel, or compacted earth.
- An access hatch or inspection port on a tank eases maintenance.
- Consider a first flush diversion or turbulence calming device or for cleaner water.

16.6 Landscaping Requirements

- Place collection tanks near landscapes that require irrigation.

16.7 Maintenance and Inspections

- Requires frequent cleaning of gutters, filter screens, or basket if installed.
- Tanks do not need to be cleaned unless storing poor quality water.
- Check the system regularly to identify potential problems.

16.8 Limitations

- Stored water should not be used as potable unless further treatment is obtained.
- Mosquito and other insect growth can become a problem if not maintained properly.
- May be an unreliable source of water in areas with infrequent rain.

17 Permeable Hardscape

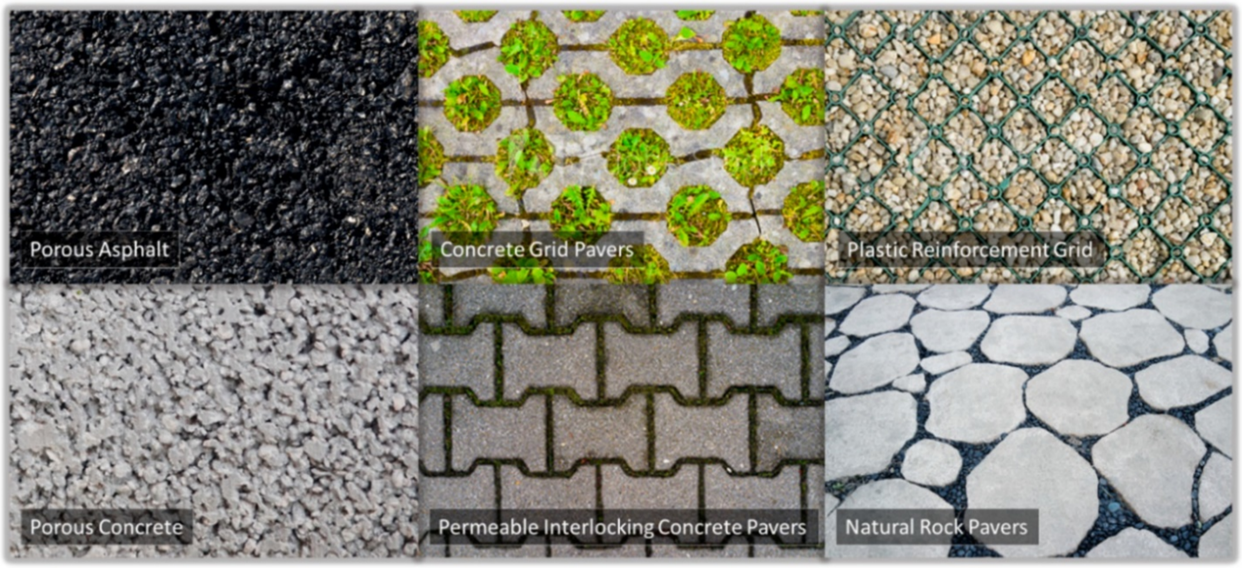

Image Source – Sprouse et al., 2020, doi.org/10.3390/su12187422

17.1 Description & Purpose

A permeable hardscape is a hard surface that allows water to soak into the ground. Permeable hardscapes represent an alternative to traditional impervious paving surfaces. They typically consist of an underlying drainage layer and an overlying permeable surface layer. A permeable pavement system allows stormwater runoff to pass through the surface course (i.e., pavement surface) into an underlying stone reservoir, where it is temporarily stored and allowed to infiltrate into the surrounding soils or conveyed back into the storm drain system through an underdrain. Permeable hardscapes can slow down the flow of runoff from rooftops, sidewalks, and driveways and filter out sediment and nutrients. Slowing down the flow helps to decrease the amount of pollutants washed into streams and the ocean. Permeable hardscapes also increase the amount of rainwater that soaks into the ground, which helps to replenish the ground water supply.

17.2 Applications

Permeable hardscapes can be constructed using various types of traditional pavers, permeable pavers, plastic reinforced grids, and porous asphalt/concrete pavement. Combinations of these materials are used to create terraces, walkways, driveways, and parking areas. Porous asphalt/concrete can replace traditional impervious pavement for most pedestrian and vehicular applications and are often used in the construction of parking lots for office buildings and shopping centers. Other uses include traffic islands, emergency stopping areas, road shoulders, residential driveways, airport parking aprons, and maintenance roads.

17.3 Suggested Design Criteria

- The load-bearing and infiltration capacities of the subgrade soil, the infiltration capacity of the porous material, and the storage capacity of the stone base/subbase are the key stormwater design parameters.
- Porous asphalt should be designed and sited to intercept, contain, filter, and infiltrate stormwater on site.
- Permeable pavement systems should be designed to completely drain within 48 hours of the end of a rainfall event.
- Determine the infiltration rate based on the known storm events and soil type. Soils should have an infiltration rate of 0.5 inches per hour.
- If the infiltration rate of the native soils located beneath a permeable pavement system do not meet or exceed 0.25 in/hr, an underdrain should be included in the design.
- Although permeable pavement systems may be installed on development sites with slopes of up to 6%, they should be designed with slopes that are as close to flat as possible to help ensure that stormwater runoff is evenly distributed throughout the stone reservoir.
- Permeable pavement requires a footprint equivalent to 5% - 18% of its contributing impervious drainage area. The lower value reflects the maximum allowable infiltration rate and minimum allowable factor of safety, while the upper value reflects the minimum allowable infiltration rate and maximum allowable factor of safety.
- For permeable pavers, the openings typically comprise 5% to 15% of the paver surface area and are filled with highly permeable, small-sized aggregates.

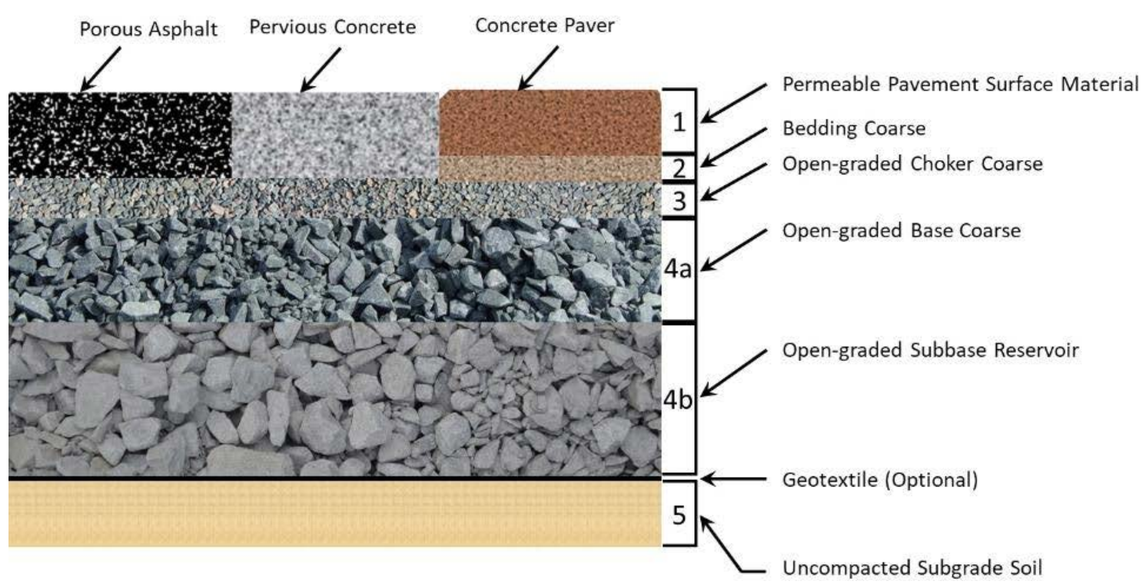

Figure 17. Example of a Permeable Hardscape Cross-section – Source: Eban Bean, University of Florida IFAS Extension

17.4 Pretreatment Requirements

- Pretreatment is not required as long as the permeable pavement does not receive run-on from other surfaces. If it does, pretreatment is necessary to prevent premature failure due to clogging with fine sediment, and may be achieved with gravel filter strips, vegetated buffer strips, or vegetated swales.

17.5 Construction Considerations

- Permeable hardscapes work best over sandy or well-drained soils that are relatively flat.
- Permeable pavement systems should generally not be used to “receive” any stormwater runoff generated elsewhere on the development site.
- All porous paving and permeable paver with storage bed systems must include measures that will allow runoff from the design storm to enter the storage bed in the event that the porous or permeable paver surface course becomes clogged or otherwise incapable of conveying the maximum design storm runoff to the bed.
- Additional design details on specific pavement systems are provided by the National Asphalt Pavement Association, the National Ready Mix Concrete Association, the Interlocking Concrete Pavement Institute, and the American Association of State Highway and Transportation Officials.
- Perforated pipes along the bottom of the bed may be used to evenly distribute runoff over the entire bed bottom. Pipes should lay flat along the bed bottom and provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.
- Flows in excess of the design capacity of the permeable pavement system will require an overflow system connected to a downstream conveyance or other storm water runoff BMP.
- The pavement should be constructed in a single operation, as one of the last items to be built, on a development site.

17.6 Landscaping Requirements

- Landscaping upland of the alternative pavers is important to reduce sediment loads in the runoff.
- Landscape development should be completed before pavement construction to avoid contamination by silt or soil from this source.

17.7 Maintenance and Inspections

- The most prevalent maintenance concern is the potential clogging of the porous surfaces. Fine particles that can clog the pores are deposited from vehicles, the atmosphere, and runoff from adjacent land surfaces. Clogging will increase with age and use.
- Frequent sweeping/vacuum sweeping is important to prevent clogging.
- Inspect pavers for weathering including paver breakage and cracking as well as potential pollutants, such as oil leaks and sediment build-up.
- Respond to oil leaks with absorbent materials and/or remove the contaminated sediment.

- Inspect permeable pavement system for drawdown following rainfall events. Failure to drawdown within 72 hours after the end of a rainfall event may indicate permeable pavement system failure.
- Inspect permeable pavement surface for deterioration or spalling. Repair or replace any damaged areas as needed.

17.8 Limitations

- Permeable hardscapes are not suitable for areas near or downslope of loose or eroded materials, as sediment may clog the soil layers.
- They generally have relatively high construction costs, which are typically offset by savings on stormwater infrastructure (e.g., storm drain system).
- Permeable pavement systems should be installed only by experienced personnel.
- Alternative pavers are not recommended for high traffic volumes.
- Permeable hardscapes are not appropriate for stormwater hotspots where hazardous materials are loaded, unloaded, or stored or where there is a potential for spills and fuel leakage.

18 Proprietary Non-LID BMPs

18.1 Catch Basin Inserts

Catch basin inserts consist of a frame that fits below the inlet grate of a catch basin and can be fitted with various trays that target specific pollutants. The trays may also contain a variety of media. The device is typically designed to accept the design flow rate of the inlet grate with bypasses as the trays become clogged with debris. The media require routine maintenance for replacement and cleaning. Catch basin inserts are typically used for smaller drainage areas.

Image Source – cleanwayusa.com

18.2 Water Quality Inlets

Water quality inlets are underground retention systems designed to remove settleable solids. There are several water quality inlet designs. Some water quality inlets include a second chamber with a sand filter to remove finer suspended solids by filtration.

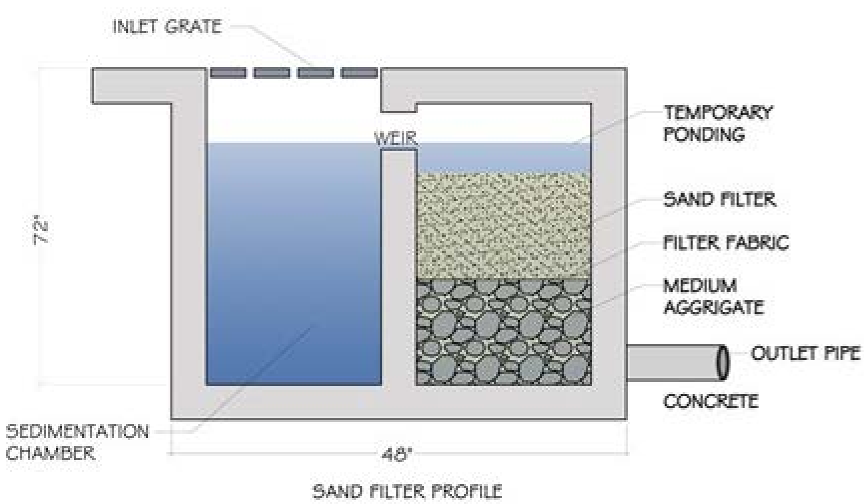

Image Source - psara.com

18.3 Oil/Grit Separators

Typical oil/grit separators consist of three chambers. The first chamber removes coarse material and debris; the second chamber separates oil, grease, and gasoline; and the third chamber provides safety relief if blockage occurs. Similar to water quality inlets, frequent maintenance and disposal of trapped residuals and hydrocarbons are necessary for oil/grit separators.

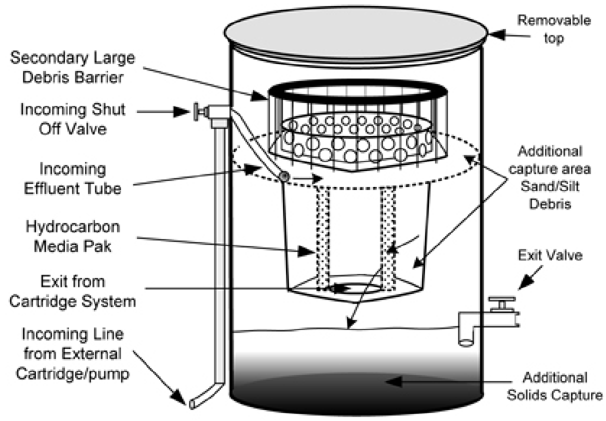

Image Source -remfilters.com

18.4 Hydrodynamic Devices

A variety of manufactured hydrodynamic devices are available for removing pollutants from storm water runoff. The hydrodynamic separation concept these devices are based on involves the settlement of sediment as runoff moves in a swirling path. Typically, these devices are prefabricated in a range of sizes targeted at specific flow rates.

One type of hydrodynamic device is designed to remove suspended particles, oil, and grease during low flow conditions. Higher flows are diverted around the treatment chamber to prevent scour and high velocity from carrying the collected pollutants out of the treatment chamber. Maintenance requirements include the periodic removal of oil/grease and sediments by using a vacuum truck.

A second type of hydrodynamic device utilizes centrifugal motion to remove litter, floatable debris, and larger sediment particles from runoff. Since this technology is designed to capture trash rather than pollutants, these devices are most applicable in coastal areas or areas that receive heavy trash loads. These devices are constructed so that a vacuum truck can regularly remove the floatable and settled debris collected in the treatment chamber.

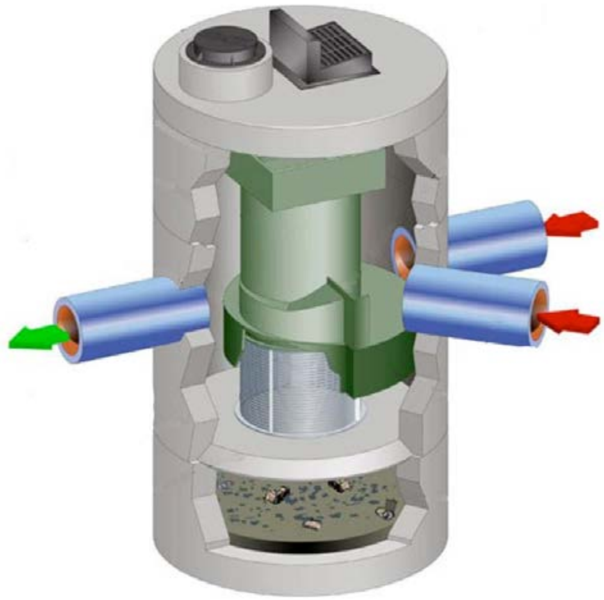

Image Source - cfwep.org

18.5 Recommended Performance Standards

Ultimately, choosing a proprietary BMP will be based on document performance standards. There are numerous performance standards and testing done by third parties for various proprietary BMPs.