Storm Water Permanent Best Management Practices Manual

State of Hawaii
Department of Transportation
Highways Division

February 2007

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DEFINITIONS OF KEY TERMS

303(d) LIST – Under section 303(d) of the Clean Water Act, states are required to compile a list of impaired waters that fail to meet any of their applicable water quality standards or cannot support their designated or existing uses. This list, called a "303(d) list", is submitted to Congress every two years. States are required to develop a Total Maximum Daily Load (TMDL) for each pollutant causing impairment for water bodies on the list.

BEST MANAGEMENT PRACTICE (BMP) – According to CFR § 122.2, schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of 'waters of the Unites States'.

CONTRACT PROJECT – A construction project, which is designed either by HDOT-HWYS personnel or by engineering consultant firms, and is constructed by a private contractor.

DETENTION VOLUME – The volume of runoff that is held and treated in a BMP structure.

DISCHARGE RATE – The rate at which water is discharged out of the BMP after being stored and treated.

DRAINAGE AREA – The specific land area that drains water into a river system or other body of water. Drainage area also refers to the drainage basin or watershed.

ENCROACHMENT PROJECT – A construction project undertaken by a non-HDOT entity (i.e. third party) within the HDOT-HWYS right-of-way and requires the issuance by HDOT-HWYS of a Permit to Perform Work upon State Highways.

FREEBOARD – The vertical distance between the water surface of the design discharge and a point of interest such as a low chord of a bridge or top of a channel bank.

GEOMORPHIC BALANCE – The balance of changes in hydrology and hydraulics that affect stream shape, planform, slope, and sediment transport.

GROUNDWATER RECHARGE – The process of water soaking into the ground to become groundwater.

HYDROLOGIC CYCLE – The cycle of water movement from the atmosphere to the earth and returning to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation.

HYDRAULIC GRADE LINE – A line characterized by a plotted ordinate position, which represents the sum of pressure head plus elevation head for the various positions along a given fluid flow path such as a pipeline or groundwater stream line.

HYDRAULIC GRADIENT – The slope of the water surface. The gradient or slope of a water table or piezometric surface in the direction of the greatest slope, generally expressed in feet per mile or feet per feet. Specifically, the change in static head per unit of distance in a given direction, generally the direction of the maximum rate of decrease in head. The difference in hydraulic heads divided by the distance along the flowpath, or expressed in percentage terms.

IMPERVIOUS SURFACE – Surface area which allows little or no infiltration. Impervious surfaces include pavements and roofs.

IN-HOUSE PROJECT – A construction project that is performed by HDOT-HWYS personnel. These projects are typically small and maintenance related.

LAND USE – The way land is developed and used in relation to the types of allowable activities (agriculture, residences, industries, etc.) and the sizes of buildings and structures permitted. Certain types of pollution problems are often associated with particular land uses such as sedimentation from construction activities.

LINES OF STUDY (LOS) – Line used for drainage calculations where storm water runoff leaving the HDOT's right-of-way in a sheet flow fashion.

PERVIOUS SURFACE – Surface area which allows infiltration of water.

POLLUTANTS – Refer to the waste material that contaminates air, soil, or water. In the context of storm water quality, pollutants often refer to the following:

- Nutrients- phosphorous and nitrogen;
- Suspended solids- sediment suspended in the water;
- Organic carbon and hydrocarbons;
- Bacteria;
- Trace metals;
- Pesticides; and
- Trash and debris.

REDEVELOPMENT PROJECT – A project that consists of reconstruction of or new construction on an existing impervious area exceeding 5,000 square feet.

ROUGHNESS COEFFICIENT – A value based on the material used to construct a channel such as earth, rock, and gravel; the surface irregularity of the side slopes and bottom of the channel, the variations of successive cross sections in size and shape, obstructions which may remain in the channel and affect the channel flow, vegetation effects should be carefully assessed, channel meandering should also be considered.

RUNOFF VOLUME – The volume of water that flows off of a surface during a storm event.

SHEET FLOW- Flow that occurs overland in places without defined channels. The flood water spreads out over a large area at a uniform depth. Also referred to as overland flow.

SHORT-CIRCUITING – The minimizing of "dead spaces" (areas where little or no exchange occurs during a storm event) to minimize the distance between the inlet and outlet.

STORM WATER RUNOFF –Precipitation which flows over the ground.

SWALE – An elongated depression in the land surface that is at least seasonally wet, usually heavily vegetated, and normally without flowing water. Swales discharge storm water into primary drainage channels and may provide some groundwater recharge.

TAILWATER EFFECT – Water located just downstream of a hydraulic structure, such as a dam, culvert, or bridge.

TOPOGRAPHIC MAP – A type of map depicting a limited set of features but including at the minimum information about elevations or landforms. Topographic maps are commonly used for navigation and reference purposes.

WATERS OF THE UNITED STATES – All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide, all interstate waters and wetlands, tributaries of these waters, and the territorial seas.

WETLANDS – Lands where water saturation is the dominant factor determining the nature of soil development and the types of plants and animal communities living in the surrounding environment. Wetlands are also referred to as bogs, ponds, estuaries, or marshes.

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ACRONYMS

BMPs	Best Management Practices
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
HAR	Hawaii Administrative Rules
HDOH	State of Hawaii Department of Health
HDOT	State of Hawaii Department of Transportation
HDOT-HWYS	State of Hawaii Department of Transportation, Highways Division
HWY-DH	HDOT-HWYS Division, Design Branch, Hydraulic Design Section
HWY-P	HDOT-HWYS Division, Planning Branch
LOS	lines of study
MEP	maximum extent practicable
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
PS&E	Plan, specifications, and estimate documents for a plan submittal.
Tm	recurrence interval
TMDL	total maximum daily load
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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CHAPTER 1: ENVIRONMENTAL BACKGROUND AND INTRODUCTION

1.1 Environmental Background

Urban development has a profound influence on the quality of Hawaii's state waters. Site developments result in land use and land cover changes thereby altering the hydrologic cycle. The ability of the ground to absorb rainfall diminishes as pervious surfaces become impervious and ultimately rainfall yields storm water runoff.

Impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles or windblown from adjacent areas. During storm events, these pollutants are washed off impervious surfaces and discharged to downstream waters via surface runoff. Common pollutants contained in urban storm water runoff include nutrients (e.g. phosphorus and nitrogen), suspended solids, organic carbon and hydrocarbons, bacteria, trace metals, pesticides, and trash and debris. These pollutants reduce water quality. In addition, groundwater recharge, which functions as a natural pollution filter diminishes as impervious surfaces increase. Impervious surfaces also increase the rate and velocity of storm water runoff, which may potentially cause severe flooding problems, increase the soil erosion in the receiving channel, and alter the geomorphic balance of the streams. Geomorphic instability causes streams to widen and down cut rapidly thereby causing unbalanced channel erosion, which ultimately results in the degradation of stream habitats.

As part of urban development, highway systems are a potential source of pollution that affects the quality of our state waters. Materials accumulate on highway pavements, median areas, and adjoining right-of-ways as result of highway uses, maintenance, and natural deposition contain most of the pollutants found in the urban development. Therefore, controlling storm water runoff from the highway surface plays a vital role in protecting Hawaii waters from water quality degradation and decline.

1.2 Introduction

State of Hawaii Department of Transportation, Highways Division (HDOT-HWYS) operates a Municipal Separate Storm Sewer System (MS4) on the Island of Oahu. The operation and discharge of its MS4 is authorized and governed by the National Pollutant Discharge Elimination System (NPDES) permit and is subject to permit requirements.

Under this NPDES MS4 permit, HDOT-HWYS is required to implement seven major programs: Public Education and Outreach; Public Involvement and Participation; Illicit Discharge Detection and Elimination; Construction Site Runoff Control; Post-Construction Storm Water Management in New Development and Redevelopment; Pollution Prevention and Good Housekeeping; and Industrial and Commercial Activities Discharge Management program. In addition, HDOT-HWYS is undertaking water quality monitoring task as well as tasks associated with Waste Load Allocations (WLAs). The ultimate goal of these programs is to reduce the amount of pollutants entering and discharged from the HDOT-HWYS Oahu MS4.

To fulfill its Oahu MS4 NPDES Permit requirements and to address storm water pollution associated with highway runoff, HDOT-HWYS implements Permanent Best Management Practices (BMPs) criteria that apply to the applicable new developments and significant redevelopment projects, highway baseyards, and maintenance facilities statewide. The purpose of this manual is to provide procedures and guidelines to ensure that permanent BMPs are being considered and implemented throughout all phases of HDOT-HWYS project development, including planning, design, construction, and maintenance.

CHAPTER 2: APPLICABILITY

2.1 Scope

All contract, in-house and/or encroachment projects are subject to HDOT's review to determine if storm water permanent BMPs are required. If applicable according to the criteria set forth herein, the storm water permanent best management practices and measures shall be designed consistent with this manual and constructed according to the project plans approved by HDOT-HWY.

2.2 Criteria

Criteria contained herein become effective on February 6, 2006.

2.2.1 Unified Criteria

Any project (new or redevelopment) is required to install a permanent BMP(s) for storm water management if it generates equal to or greater than one (1) acre of new permanent impervious surface.

The BMP(s) required shall be designed and installed in accordance with the criteria, guidelines, and design standards described in this manual. The permanent BMP(s) shall be maintained in its perpetuity unless the original purpose of the project no longer exists. The permanent BMPs are intended to reduce storm water pollution typically associated with the increased impervious surfaces. Typical pollutants contained in the storm water runoff may include, but are not limited to, phosphorus, nitrogen, sediment, heavy metals, oil and grease. Unlike construction activities BMPs, the storm water permanent BMPs are designed to remain part of the project features after the site grading operation is completed.

The type and size of the permanent BMPs is dependent on the water quality and water quantity a project is required to control and should be designed in accordance to the sizing rules specified in this manual.

2.2.2 Redevelopment

For the purpose of the Post Construction Storm Water Management in New Development and Redevelopment program, any reconstruction of or new construction on existing impervious area exceeding 5,000 square feet shall be considered redevelopment. New development and redevelopment projects are subject to the same rules and criteria as described in this manual.

Where conditions prevent impervious area reduction or on-site storm water management (quality or quantity), practical alternatives may be considered. Alternatives are subject to HDOT's approval and include but are not limited to:

- Stream restoration (length of restoration subject to HDOT's approval);
- Retrofitting an existing BMP; and
- Other practices approved by HDOT/HDOH.

2.3 Applicable Projects (Statewide)

2.3.1 Projects within HDOT's Rights-of-way

The following types of projects that are constructed within the HDOT-HWY rights-of-way are subject to the rules and criteria contained in this manual:

- Contract project – A construction project designed either by HDOT-HWYS personnel or by engineering consultant firms, and constructed by a private contractor;
- In-house project – A construction project that is performed by HDOT-HWYS personnel; and
- Encroachment (permit) projects – A construction project undertaken by a non-HDOT entity (i.e. third party) within the HDOT-HWYS right-of-way and requires issuance by HDOT-HWYS of a Permit to Perform Work upon State Highways.

2.3.2 Off-site Projects Requiring a Discharge/Connection (to DOT's MS4) Permit

The criteria and rules described in this manual apply to projects outside of HDOT-HWY provided that the project produces storm water runoff from its site and drains to HDOT-HWY MS4, either by a physical connection or surface runoff.

2.3.3 Special Conditions

Projects with special conditions may be subject to the rules and criteria contained in this manual regardless of square footage of the new impervious surface. Special conditions are determined by HDOT and may include HDOT projects which drain to sensitive receiving waters (HDOH Water Quality Limited Segments (WQLS)), projects which drain to Class I Inland Waters, Class AA Marine Waters, and selected 303d listed water bodies.

2.4 Permanent BMP Checklist

Prior to commencement of the detailed engineering design, the design consultant or HDOT project manager shall complete and submit to HWY-DH the Permanent BMP Checklist and Project Record (Checklist) (see Figure 1-1) The Checklist shall be submitted for all contract projects regardless of whether or not the project is exempt.

PERMANENT BMP CHECKLIST AND PROJECT RECORD

Project Name: ______________________________

____

Project Number: ______________ Project Route/Milepost: ______________

Advertise Date: ______________

Exemptions (check all that apply)

☐	Projects that do not generate 1 acre or more of new permanent impervious surface
☐	Project returns the area to pre-development runoff conditions.
☐	Project is a utility project (check applicable type) ☐ Pipeline ☐ Conduit ☐ Traffic Sign/Signal
☐	Projects that are not continuous or involve several locations which may collectively generate 1 acre or more of new permanent impervious surface.
☐	Projects that do not discharge runoff into any waters of the United States.

If none of the above is checked, the project must provide permanent BMPs

Water Quality Control:

Water quality volume required: ______________ cubic feet

Water quality volume provided: ______________ cubic feet

Type of BMP used: ______________

Attach on a separate sheet a detailed description of the Permanent BMPs to be incorporated into the design and the appropriate maintenance requirements.

Water Quality Control:
(Where applicable)

Existing Site Runoff:

10-year: ______________ cubic feet per second
25-year: ______________ cubic feet per second
50-year ______________ cubic feet per second
100-year: ______________ cubic feet per second

Proposed Site Runoff:

10-year: ______________ cubic feet per second
25-year: ______________ cubic feet per second
50-year ______________ cubic feet per second
100-year: ______________ cubic feet per second

Type of BMP used: ______________

Description: ______________

Figure 1-1

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CHAPTER 3:
EXEMPTIONS AND VARIANCES

3.1 Exemptions

The types of projects listed in the following subsections are exempt from the provisions contained in this manual.

3.1.1 Specific Runoff Conditions

Projects that return area to pre-development runoff conditions.

3.1.2 Utility Projects

Utility projects include the following:

- Pipelines;
- Conduits; and
- Traffic sign/signal projects.

3.1.3 Other Projects

Other exempt projects include the following:

- Projects which are not continuous or involve several locations (e.g., Intersection improvements at various locations); and
- Projects which do not discharge runoff into any waters of the United States.

3.2 Variances

The following projects may receive special variances to the permanent BMP requirements:

- Projects which are located within an area with an approved special watershed management plan as approved by HDOT and HDOH; and
- The impervious area created by the project does not exceed six (6) feet in width, is linear in nature such as bike paths, walkways, highway noise barriers etc. and retains the predevelopment drainage patterns.

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CHAPTER 4:
PERMANENT BMP CONSIDERATION IN PROJECT PLANNING AND DESIGN PHASE

4.1 Introduction

As HDOT-HWYS implements a proactive storm water management program and applies unified criteria for all new development and significant redevelopment projects, it is important for HDOT-HWYS personnel, private consultants, and contractors to consider permanent BMPs throughout every phase of a project, including planning, conceptual engineering, and final design. Early consideration of permanent BMPs will help identify sufficient rights-of-way needs and costs, potential community impacts, and design conflict. All of these factors may lead to poor design and project delays. As detailed in various chapters of this manual, HDOT emphasizes the consideration of permanent BMPs throughout the 'Life Cycle" of a project, from the planning phase to the maintenance phase.

4.2 Storm Water Permanent BMP Concepts in Project Planning Phase

4.2.1 Purpose

The Environmental Assessment (EA) and Environmental Impact Statement (EIS) processes require documentation of project impacts, avoidance, minimization and mitigation. As part of these processes, storm water permanent BMPs should be considered in determining impacts to environmental resources such as waters of U.S., wetlands, and groundwater. In certain situations, permanent BMPs can be extremely difficult to accomplish and may affect the feasibility of the highway alternatives being evaluated. The requirements and rights-of-way demands of permanent BMPs can greatly affect the selection of project preferred alternatives. Therefore, it is critical to develop permanent BMPs early during the project planning phase and include them in impact assessment and project cost estimating. Early consideration of storm water permanent BMPs will likely lead to more cost-effective projects.

4.2.2 When to Develop Concept

The storm water permanent BMP concept studies should begin when design alternatives are selected for detailed study.

4.2.3 Concept Development

Once determined that a project is subject to permanent BMP requirements, the concept should be developed by a licensed engineer with support from project planners and landscape architects. The study should be completed prior to the initial public hearing discussing the project location and alternatives.

Certain basic information is needed in order to conduct a concept development study. The information should at minimum include topographic mapping for the entire study area, including adequate area on both sides of all the alignments being considered for the entire length of the project in order to locate permanent BMP facilities. The topographic mapping should identify approximate property lines, existing developments, and publicly owned land. The proposed highway alignment or transportation facility should be superimposed on the mapping.

In order to develop permanent BMP concepts, study points need to be identified where storm water runoff leaves HDOT-HWYS right-of-way. In cases where the drainage pathway indicates sheet flow leaving the right-of-way, determination of the study point should be based on engineering judgment.

Approximate locations of permanent BMPs should be identified on the topographic map. Once study points are identified, the volumetric storage requirements should be estimated. This process requires delineation of approximate drainage areas reaching the study point. Water quality volume should be estimated based on the criteria set forth in Chapter 7 of this manual. Since the required volume and footprint of the permanent BMP may affect the right-of-ways required, which in turn influences the selection of the alternative, additional volumes based on a reasonable estimation should included. This additional volume should be estimated based on site specific conditions.

Surface areas for the permanent BMPs can be estimated using an assumed depth and the volumes computed. In cases where the designer is proposing flow-through based BMPs, the surface areas of the BMPs should be identified based on the flow rate requirement presented in the Chapter 7 and specific BMP type.

Once the surface area required is determined, the BMP footprints can be placed on the topographic maps. Design engineers should consult with environmental scientists, and landscape architects to ensure that terrain, natural resources, and land use are properly considered in the concept development and to avoid unnecessary impacts.

4.2.4 Content of Permanent BMP Planning Concept Report

The storm water permanent BMP planning concept report should include the following:

- Description of the project area;
- Description of the environmental resources such as State Class1 inlands , Class AA Marine waters, wetlands and waters of U.S., FEMA floodplains/floodways etc.;
- Description of the outfalls and how they are identified;
- Regulatory requirements;
- Proposed permanent BMP concept descriptions along with assumptions made. List BMP alternatives with recommended design;
- Surface area and volume tabulation;
- Right-of-way required;
- Preliminary construction cost for the proposed BMPs; and
- Appendices which consist of existing and proposed drainage area maps (including study points), photos, and calculations.

4.2.5 Review and Approval

The project planner/engineer shall submit the permanent BMP concept report and required information to HDOT-HWYS Planning Branch (HWY-P) for review and approval.

4.3 Storm Water Permanent BMP in Project Design Phase

Development of permanent BMP design concepts starts at the initiation of project design. Detailed surveys and design information are necessary to produce conceptual designs which can be refined as the project progresses. For projects that have a planning concept report, the permanent BMP planning concept should be the basis for developing the design concept.

4.3.1 Permanent BMP Conceptual Design Process

For HDOT-HWYS projects, the permanent BMP conceptual design needs to be completed by the 30% plan stage. This requires the engineers to begin the design earlier to identify conflicts, solutions, and cost before a formal 30% cost estimate is generated.

At the design phase, study point identification is similar to the process used for the development of the planning concept. For projects where storm water runoff is discharged from the right-of-way in a sheet flow fashion, lines of study (LOS) should be identified. Care should be taken to follow the drainage patterns within and outside the right-of-way in order to identify correct study points and or lines of study. Field investigation is required to verify study points or lines.

Hydrologic analysis should be conducted in accordance with HDOT-HWYS hydrologic and hydraulic guidelines. Drainage area maps using the best available information should be developed for both existing and proposed conditions.

Outfalls at all study points should be evaluated thoroughly by a licensed engineer. The evaluation should include photographs and channel stability assessment. In some cases, the outfall channel evaluation may be required to extend beyond HDOT's right-of-way. For connections to a closed storm drain system, the evaluation should include the capacity of the downstream drainage system.

If the proposed project reduces existing water quality treatment in the existing grass channels and buffers by adding new curb or reducing existing sheet flow buffer, the pre-construction pavement draining towards such grass channels and buffers must be identified to compensate for the lost water quality treatment. Computations should be made to determine the amount of existing water quality treatment reduced. Means of compensation or mitigation should also be identified in addition to the new water quality treatment required.

4.3.2 Content of Permanent BMP Design Report

The storm water permanent BMP design concept report should include the following:

- Description of the project area;
- Description of the environmental resources;
- Description of the outfalls and how they are identified;

- Outfall condition report;
- Regulatory requirements;
- Preliminary permanent summary and checklist sheet;
- Proposed BMP location;
- Proposed permanent BMP concept descriptions including assumptions, type, and treatment;
- Surface area and volume tabulation;
- Right-of-way needed;
- 30% plans with topographic maps showing footprints of proposed BMPs;
- Preliminary construction cost for the proposed BMPs; and
- Appendices which consist of existing and proposed drainage area maps (including study points), photos, and computations.

4.3.3 Review and Approval

Submittals for review and approval include the permanent BMP plans, design report, and other required information. The review and approval will be performed by HDOT-HWYS Design Branch (HWY-D). The permanent BMP design shall be made part of the PS&E documents and follow the normal design review process.

CHAPTER 5:
STORM WATER QUANTITY CONTROL

While the primary purpose of this permanent BMP manual is to address the management issues associated with water quality of highway runoff and the MS4 system, flood control and preventing channel erosion remain an integral and important part of storm water management. It is essential for planners, engineers, and contractors to be familiar with the HDOT-HWYS hydraulic criteria and standards related to storm water quantity. The information contained in this Chapter are excerpts from the current HDOT-HWYS drainage criteria.

5.1 HDOT-HWYS Hydrologic Design Criteria

5.1.1 Recurrence Interval

5.1.1.1 Bridges and Culverts

- Freeways and Arterial Highways:
  - 50 years to maximum storm of record.
  - 100 years for sites covered by National Flood Insurance Program if practicable.
- Collector Streets and Roads – 25 years
- Local Roads – 10 years.

5.1.1.2 Roadway Drainage

- Travel way at sumps
  - Freeways – 50 years
  - Arterial Highways – 25 years
  - Collector Streets and Roads – 10 years
  - Local roads – 10 years
- Freeways and Arterial Highways – 25 years
- Collector Streets and Roads – 10 years
- Local Roads – 10 years
- The minimum time of concentration shall be 10 minutes.
- Refer to the “Hawaii Statewide Uniform Design Manual for Streets and Highways” for the definitions of the different types of highways.

5.1.2 Design Discharge

5.1.2.1 General Conditions

To strengthen the estimate of runoff and to aid in the selection of the design discharge for watersheds, the use of several appropriate hydrologic methods is recommended. Of the many methods for estimating runoff, there are several which, by experience, have proven convenient and reliable. These include, but are not limited to the following used methods:

- **Rational Method** – The rational method is used to predict peak flows for small drainage areas up to 200 acres, and can be used for culvert design, pavement drainage design, and storm drain design.
- **Published Flow Records** – This method is used to determine peak discharge for large basins. This method is a collection of stream flow data which is done on a regular basis by an agency (primarily the USGS). This data can be used to predict flood flows to design culverts and bridges.
- **USGS Regression Equations** – This method is used to determine peak discharge for medium and large basins. The equations were developed using data from stream flow gauging stations. Regression equations are appropriate for culvert and bridge design but lack the accuracy of published flow records.
- **Soil Conservation Method** – This method is used for large watersheds where gage data are not available. However, the curve numbers, antecedent moisture content factors, and time of concentration curves shall be applicable to the site under consideration.
- **City and County of Honolulu Method** - Plate 6, Design Curves For Peak Discharged Area, From the City and County of Honolulu's Rules Relating To Storm Drainage Standards may be used to determine peak runoff for checking purpose only.

The estimated runoff to be used in design shall be supplemented with field investigation to determine flood marks, amount and type of debris, effect of ponding, streambed evaluation, and size of existing culverts.

New developments shall provide adequate drainage capacity to accommodate the offsite design storm entering the development site.

When downstream drainage systems cannot accommodate peak runoff rates from design storms, runoff rates discharged downstream from new developments will be limited to predevelopment values unless improvements to the downstream system are made.

Runoff volume from the design storm shall be limited to predevelopment values unless it can be shown that the runoff can be safely conveyed through existing or planned conveyances, the increased volume would not have adverse impacts downstream, and provided further that the final receiving waters are open coastal waters.

All hydrologic data and computations shall be submitted and retained in the design files.

5.1.2.2 Design Computations

The following data shall be submitted to HDOT-HWYS Design Branch, Hydraulic Design Section (HWY-DH) for review and approval by the Design Engineer.

5.1.3 Drainage Maps

For each project, a drainage map showing the drainage area for each culvert or structure shall be prepared on suitable map, aerial contour map, U. S. Geological Survey contour map or other specifically prepared contour map.

The information on the drainage map shall include the area of the watershed, the computed runoff, the proposed drainage structure, and the location of the structure referenced to the project station line.

All hydrologic data and computations shall be submitted with the drainage map. All projects shall include a Hydrology and Hydraulic Report conforming to the requirements of the State of Hawaii, Department of Transportation, Highways Division Procedures No. 07-07-03, Hydrology Report and 07-07-04, Hydraulic Report.

5.2 Hydraulic Design Criteria

Computations for runoff, conduit and channel sizes, slopes, losses, hydraulic gradient, and other hydraulic characteristics and information pertinent to the system shall be properly arranged and presented in such a manner that they may be readily checked.

The following data shall be shown on the construction plans:

- Design flow (Q), watershed area (A), roughness coefficient (n), and velocity (v) for all conduits and channels;
- Hydraulic grade lines, including water surface elevation at each manhole and catch basin;
- Building setback lines, where required; and
- Floodway/flood fringe boundary, as applicable.

Where interim drainage measures are required due to restrictions in the downstream drainage systems, the following additional data shall also be provided:

- Runoff rate using the design storm for existing upstream land use conditions;
- Runoff volume using the design storm for existing upstream land use conditions;
- Detention volume and discharge rate; and
- If necessary, capacity of downstream drainage systems.

Backwater will not significantly increase flood damage to property upstream of the crossing. No increase in backwater where possible.

Velocities through the structure will not damage the highway facility or increase damages to adjacent property.

Maintain the existing flow distribution to the extent possible.

Bridge shall be designed to avoid failure by scour.

Where practicable bridge deck drainage shall be designed to avoid discharge directly into streams.

Hydraulic analysis for the location and design of the bridge shall be included in the Hydrology and Hydraulic Report.

Stream stability and scour analysis for the location and design of bridge shall be included in the Hydrology and Hydraulic Report.

5.2.1 Roadway Drainage

5.2.1.1 Catch Basins and Inlets

Design Criteria

- Curb inlets and grated inlets located on continuous slope shall be designed for a minimum of 70% catch and 30% by-pass. The width of flow on the pavements shall not exceed 1/3 the width of the travel lane measured from the edge of pavement adjacent to the gutter or shoulder.
- Catch basins and inlets located at the low or sag points in the gutter profile shall be designed for no encroachment on the travel way. Flanker inlets on each side of the low point inlet shall be installed when in a depressed area that has no outlet except through the system.
- Inlets shall be located at:
  - Upstream corner of intersections;
  - Sag point in the gutter;
  - Immediately upgrade of bridge approaches;
  - Immediately upstream of median breaks and entrance and exit of ramps; and
  - Upgrade of cross slope reversals.

Spacing – Spacing of catch basins, inlets, and manholes shall be based on hydraulic requirements, economy, and ease of maintenance. However, maximum spacing of each catch basin, inlet, and manhole for pipes 36 inches or less in diameter shall be 250 feet. For larger pipe diameters, the maximum spacing shall be 500 feet.

Types

- The standard curb-inlet type of catch basins and grated inlets shall be used in general.
- Where additional capacity is required, the standard catch basin may be modified either by lengthening the inlet or by addition of a gutter grate.
- Bicycle, Pedestrian or ADA type grates shall be provided as required.

Culvert Slope

- The minimum slope for culverts shall be 0.5 percent.
- Exceptions to the above may be made wherever maintenance operations in the culvert can be easily performed and in areas restricted by physical parameters.

Minimum pipe cover shall be 2 feet measured from the crown of the pipe to the finished grade or the pipe shall be beneath the pavement structure, whichever is greater.

5.2.1.2 Roadside Gutters and Ditches

All V-ditches in new construction areas within the clear zone shall be designed with 6:1 side slopes on both slopes.

V-ditches outside of the clear zone may be designed with a 2:1 back slope.

V-ditches in resurfacing projects within the clear zone may remain provided it is not located in a high accident area.

5.2.1.3 Subsurface Drainage

Subsurface drains shall be installed wherever recommended by the Materials Testing and Research Engineer.

5.3 Physical Standards

Physical standards of the storm water appurtenances related to permanent BMPs should follow the latest HDOT design criteria for highway drainage.

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CHAPTER 6:
STORM WATER QUALITY CONTROL

6.1 Water Quality Criteria

6.1.1 Objectives of Water Quality Criteria

The purpose of the water quality criteria is to present a unified approach for sizing and selecting storm water permanent BMPs for the applicable projects as listed in Chapter 2 of this manual. The ultimate goal is to reduce the pollution associated with storm water runoff from new development and significant redevelopment from discharging into receiving waters to the "maximum extent practicable" (MEP).

Since many of HDOT-HWYS MS4 and the City and County of Honolulu's MS4 are interconnected, it is HDOT-HWYS intent to have similar standards for both systems.

6.1.2 Management Practices to Meet Criteria

The criteria can be met by either detaining storm water for a length of time that allows storm water pollutants to settle, referred herein as "detention based treatments" such as storm water wetlands, extended detention pond, wet ponds, and structural underground or above ground vaults/tanks, etc., or by use of flow-through based treatments such as infiltration facilities, filtering systems, and commercially available proprietary BMPs. In addition, a flow-through based treatment system may be used in combination with downstream detention to meet the criteria.

6.1.3 Additional Requirements

These are minimum requirements. If HDOT-HWYS determines that additional controls and/or lower thresholds for developments are required to meet specific water quality needs in watersheds that drain to sensitive receiving waters (as defined by the Hawaii State Department of Health Water Quality Limited Segments (WQLS), Class I Inland Waters, or Class AA Marine Waters), additional requirements may be imposed. These may include design requirements that result in larger facilities as well as additional types of structural or non-structural controls. The design solution will be contingent upon the pollutants that are found to be impacting such water bodies and the regulatory status of the water body.

6.2 Detention Based Water Quality Control

6.2.1 Design Volume

The required design volume for detention based control is equal to the entire runoff volume that would be generated from the drainage area contributing to the detention facility with a 1-inch rainfall.

The volume calculation will be computed as follows:

WQDV = C x 1” x A x 3630

WQDV = water quality design volume in cubic feet
C = runoff coefficient
A = area of the site in acres
3630 = conversion factor

6.2.2 Runoff Coefficient

The runoff coefficient shall be determined from the following equation as developed by EPA for smaller storms in urban areas:

C = 0.05 + (0.009) x (IMP)
C = Runoff coefficient

IMP = Impervious Area (acres) (surface areas which allow little or no infiltration, including pavements, roofs, etc.) for the tributary watershed, expressed as a percentage. It shall be based upon the ultimate use of the drainage area, unless the water quality feature will be re-built/sized during subsequent phases of construction.

The runoff coefficient shall be determined from the table below. Use the lower values for flat slopes and permeable soil; use higher values for steep slopes and impermeable soil. For drainage areas with multiple land uses (e.g. residential area adjacent to a commercial development), a weighted runoff coefficient based upon the individual land uses shall be used.

Values of Runoff Coefficients, C, for use in the Rational Method

Type of Surface	Runoff Coefficient (C)
Rural Areas	
Concrete or asphalt pavement	0.90 - 0.95
Gravel roadways or shoulders	0.4 - 0.6
Bare earth	0.2 - 0.9
Steep grassed areas (2:1)	0.5 - 0.7
Turf meadows	0.1 - 0.4
Forested areas	0.1 - 0.3
Cultivated fields	0.2 - 0.4

Type of Surface	Runoff Coefficient (C)
Urban Areas	
Flat residential, with about 30 percent of area impervious	0.4
Flat residential, with about 60 percent of area impervious	0.55
Moderately steep residential, with about 50 percent of area impervious	0.65
Moderately steep built up area, with about 70 percent of area impervious	0.8
Flat commercial, with about 90 percent of area impervious	0.8

6.2.3 Detention Time

For water quality treatment to be effective, longer detention times are required. The draw-down (or draining) time for the detention volume, which is intended to drain down completely (vs. permanent wet volume), shall be greater than or equal to 48 hours.

6.2.4 Short-circuiting

The detention system shall be designed to maximize the distance between the inlet and outlet, and to minimize "dead spaces" (areas where little or no exchange occurs during a storm event), there-by limiting short-circuiting. A minimum flow-path length to width ratio of 3 should be designed.

6.2.5 Outlet sizing

The outlet shall be sized to achieve the above required detention times. In addition, it shall 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 special measures to prevent clogging are provided.

6.3 Flow-Through Based Water Quality

Flow-through based water quality control measures achieve water quality treatment by either passing the flow through a filtration media or letting the flow be infiltrated. In addition, there are measures (devices) which utilize hydraulic particle separation techniques ("hydrodynamic" BMPs), however, these alone do not typically address the smaller sized fractions of solids (which typically have a higher portion of other pollutants such as copper and zinc attached to them) that are desired to be removed.

6.3.1 Runoff coefficient

Same as in "Detention Based Water Quality Control" section.

6.3.2 Design Storm Size (Hourly Rainfall Intensity)

The required flow rate for treatment is the runoff that would be produced from a rainfall intensity of 0.4 inches per hour. This rate must be maintainable for a minimum of three hours.

6.3.4 Flow Calculation

Flow rate calculation shall be based upon the following:

WQFR = C x 0.4” x A

WQFR = water quality flow rate in cubic feet per second
C = runoff coefficient
A = area of the site in acres

6.4 Water Quality Design Standards

6.4.1 Detention Based Storm Water Quality Control Facilities

Detention facilities can be designed as the following:

- **Wet Ponds** - 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. Detention time requirements do not apply.
- **Wet Extended Detention Ponds** - These are ponds that provide for graduate release of the water quality design volume in order to promote the settling of pollutants. The drawdown time that meets the criteria is required for the extended detention volume.

For wet ponds, the 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.

Detention based water quality systems are recommended to be off-line from flood conveyance. If they are to be on-line or combined with a flood detention facility, then the facility must be designed to pass the appropriate flood without damaging to the facility, as well as to minimize re-entrainment of pollutants.

6.4.2 Flow-Through Based Storm Water Quality Control Facilities

For flow-through treatment, the level of treatment shall be addressed as follows:

- **Infiltration** - Infiltrated storm water shall be infiltrated through soils capable of filtering pollutants (or other suitable media as described below in Other Filters) prior to entering groundwater. Infiltration shall only be used where soil conditions and slope stability are suitable.
- **Vegetated Swales** - Vegetated (wetland/native plants and/or grass) swales shall be designed so that at the water quality flow rate (WQFR), the swale width is

such that the flow depth is no greater than 4 inches and the hydraulic grade line is no greater than 2 percent (unless drop structures are employed) between structures. The inflow should be directed towards the upstream end of the swale as much as possible, but should at a minimum occur evenly over the length of the swale. The length of flow in the swale is a minimum of 100 feet.

- **Bioretention Filters** - Bioretention filters are vegetated (landscaped) areas where runoff is directed through vegetation and soils for filtration. In most cases, unless there is shown to be adequate infiltration capacity, underdrains and overflow drains should be included to collect filtered runoff and discharge runoff to the storm drainage system. 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. Each facility should have no more than 1 acre of tributary area and should be designed to convey larger flows in a manner that does not cause re-entrainment of trapped materials.
- **Other Filters** - Other filters shall be accompanied by a certification from a licensed civil engineer that the filter/device will remove a minimum of 80 percent of the total suspended solids (of the size fractions typical for urban runoff) from the design flow rate.

6.4.3 Flow-Through Based Treatment Upstream of Detention Based Treatment

Flow-through based treatment can be placed upstream of a detention-based treatment to reduce the sizing of each. In this case, the flow-through treatment must be designed to treat the runoff produced from a minimum rainfall intensity of 0.2 inches per hour. The treated runoff shall then flow to a downstream detention system that is designed to capture and treat the entire runoff volume that would occur from the area contributing to the detention facility from a 0.6-inch rain storm. Note that HDOT-HWYS will not consider placing a detention-based treatment upstream of a flow-through based treatment.

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CHAPTER 7:
STORM WATER PERMANENT BMP OPTIONS

Permanent BMPs that control urban runoff and provide storm water quality treatment can be categorized into the following:

- Vegetative Swales;
- Infiltration Facilities;
- Storm Water Wetlands (Created Wetlands);
- Storm Water Ponds;
- Filtering Systems; and
- Proprietary BMPs including "Hydrodynamic" type.

A number of BMPs listed in the previous version of the New Development and Significant Redevelopment BMP Manual (as part of the HDOT-HWYS Oahu District Storm Water Management Program Plan dated December 2003) are considered good site management practices. However, their application is limited to permanent soil stabilization and storm water flow control that dissipates erosive velocities rather than providing effective water quality treatment. Since this manual recognizes the benefits of these BMPs which contribute to good site development and long term environmental stability, they are included in this chapter.

Selection of BMPs must be site specific and applicable to the site conditions. No single BMP can achieve pollutant reduction for every given situation. There are pros and cons for every water quality treatment BMP listed in this chapter. The designer should consider the benefits, costs, pollutant removal efficiency, aesthetical acceptability, and other pertinent factors when selecting BMPs for individual project application. A summary of BMP limitations and factors to consider is provided in Table 1 to aid the project designer in selecting the most appropriate permanent BMP. It is important to note that the selected BMPs should meet the quantity and quality criteria as specified in the previous chapters. There are many proprietary BMP products available on the market. These products were not designed to perform alike and each product is designed to remove certain pollutants. Their performance can vary significantly. HDOT does not endorse any particular type and will review its application and performance on a case by case basis. It is the designer's responsibility to consult with the manufacturer and obtain independent performance testing data to support the use of each device and demonstrate it will meet the water quantity and quality control criteria. For this reason, Table 1 does not include any proprietary BMPs.

Table 1
BMP Selection - Storm Water Treatment Suitability

BMP LIST	SAFETY CONCERNS	SPACE REQUIREMENT	ACCEPT HEAVILY POLLUTED RUNOFF	SOILS	WATER TABLE	DRAINAGE AREA (ACRES)	SLOPE RESTRICTIONS	ULTRA URBAN	EASE OF MAINTENANCE	COMMUNITY ACCEPTANCE	COST (RELATIVE TO DA)	HABITAT QUALITY	OTHER FACTORS
Dry Swale	No	Varies	Yes	Made soil	2 feet	5 max	4% max cross-slope	Not practical	Easy	High	Medium	Low	
Wet Swale	No	Varies	No	OK	Below WT	5 max	4% max cross-slope	Not practical	Easy	High	Low	Low	Mosquitoes possible
Infiltration Trench	No	Low	No	f ≥ 0.52 inch/hour	4 feet	5 max	Installed in no more than 15% slopes	Depends	Difficult	High	Medium	Low	Avoid large stone
Infiltration Basin	No	Varies	No	f ≥ 0.52 inch/hour	5 feet	10 max	None	Not practical	Medium	Low	Medium	Low	Frequent pooling
Bioretention	No	Varies	Yes	Made soil	7 feet	5 max	None	Not practical	Medium	Medium	Medium	Low	Landscaping
Shallow Wetland	No	High	Yes	"A" soils may require liner	4 feet If hotspot or aquifer	25 min	None	Not practical	Medium	High	Medium	High	
ED Wetland	Varies	Varies	Yes	"A" soils may require liner	5 feet If hotspot or aquifer	25 min	None	Not practical	Medium	Medium	Medium	High	Limited ED depth
Pond/Wetland	Yes	High	Yes	"A" soils may require liner	6 feet If hotspot or aquifer	25 min	None	Not practical	Difficult	High	Medium	High	
Pocket Wetland	No	Varies	Yes	OK	Below WT	5 max	None	Depends	Medium	Low	Low	Medium	Drawdowns
Wet ED Pond	Yes	Low	Yes	"A" soils may require pond liner "B" soils may require testing	6 feet If hotspot or aquifer	26 min	None	Not practical	Easy	High	Low	High	
Micropool ED	No	Low	Yes	"A" soils may require pond liner "B" soils may require testing	4 feet If hotspot or aquifer	10 min	None	Not practical	Medium	Medium	Low	Medium	Trash/Debris
Wet Pond	Yes	Varies	Yes	"A" soils may require pond liner "B" soils may require testing	5 feet If hotspot or aquifer	25 min	None	Not practical	Easy	High	Low	High	
Pocket Pond	Varies	Low	Yes	OK	Below WT	5 max	None	OK	Difficult	Medium	Low	Low	Drawdowns
Multiple Pond	Yes	High	Yes	"A" soils may require pond liner "B" soils may require testing	7 feet If hotspot or aquifer	27 min	None	Not practical	Easy	High	Medium	High	
Surface Sand Filter	No	Low	Yes	OK	2 feet	10 max	None	Depends	Medium	Medium	High	Low	
Underground SF	Varies	Low	Yes	OK	3 feet	2 max	None	OK	Difficult	High	High	Low	Underground, out of site
Perimeter SF	No	Low	Yes	OK	4 feet	2 max	None	OK	Difficult	High	High	Low	Traffic bearing
Pocket Sand Filter	No	Low	Yes	OK	6 feet	5 max	None	OK	Medium	Medium	Medium	Low	
Organic Filter	No	Low	Yes	OK	5 feet	5 max	None	OK	Medium	High	High	Low	Filter media replacement

7.1 Storm Water Quality Treatment

VEGETATED SWALES
- Dry Swales
- Wet Swales

INFILTRATION FACILITIES
- Infiltration Trenches
- Infiltration Basins
- Bioretention

STORM WATER WETLANDS

STORM WATER PONDS
- Extended-Detention Ponds
- Wet Ponds

FILTERING SYSTEMS
- Sand Filters
- Organic Filters

"STRUCTURAL", "HYDRODYNAMIC" AND OTHER PROPRIETARY BMPs

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DRY SWALE

DESCRIPTION & PURPOSE

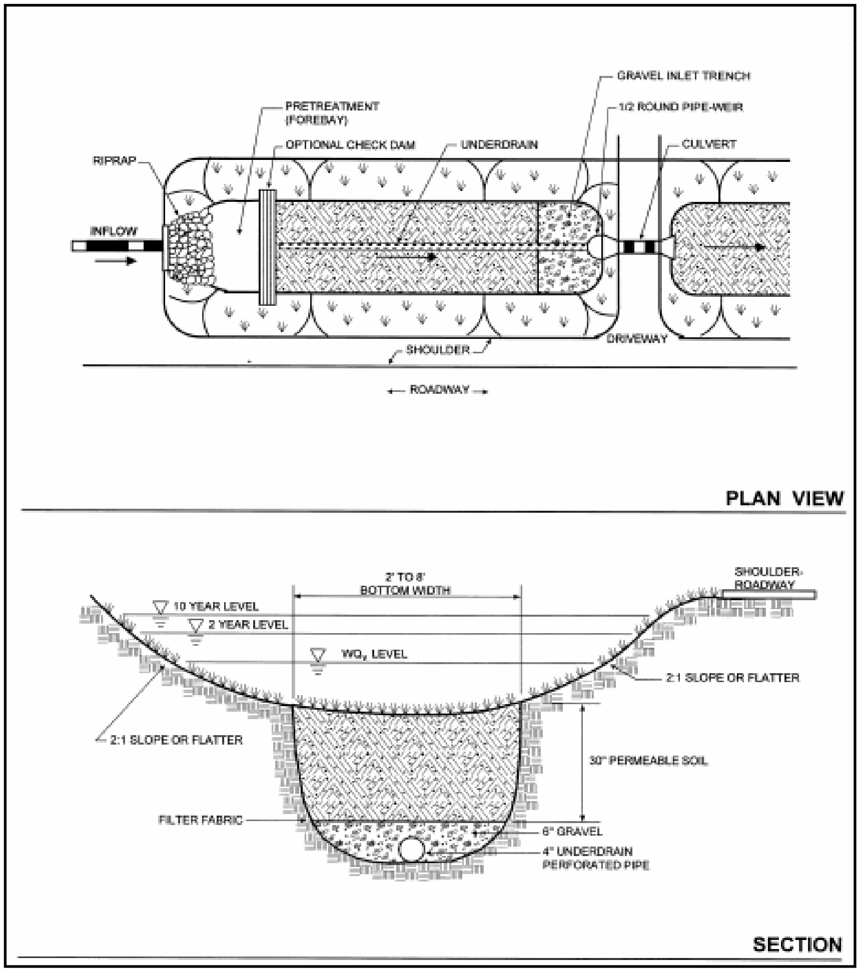
Swales are vegetated open channels that are designed to capture and treat the full water quality volume within dry or wet cells that are formed by check dams or other means.

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.

DESIGN CRITERIA

- Required volume is based on a rainfall intensity of 0.4” per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4” 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.



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.

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.

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.

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.

LIMITATIONS

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

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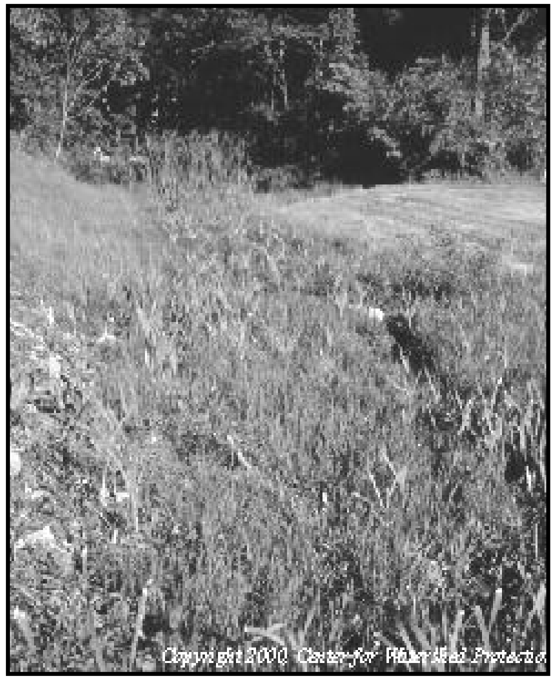
WET SWALE

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.

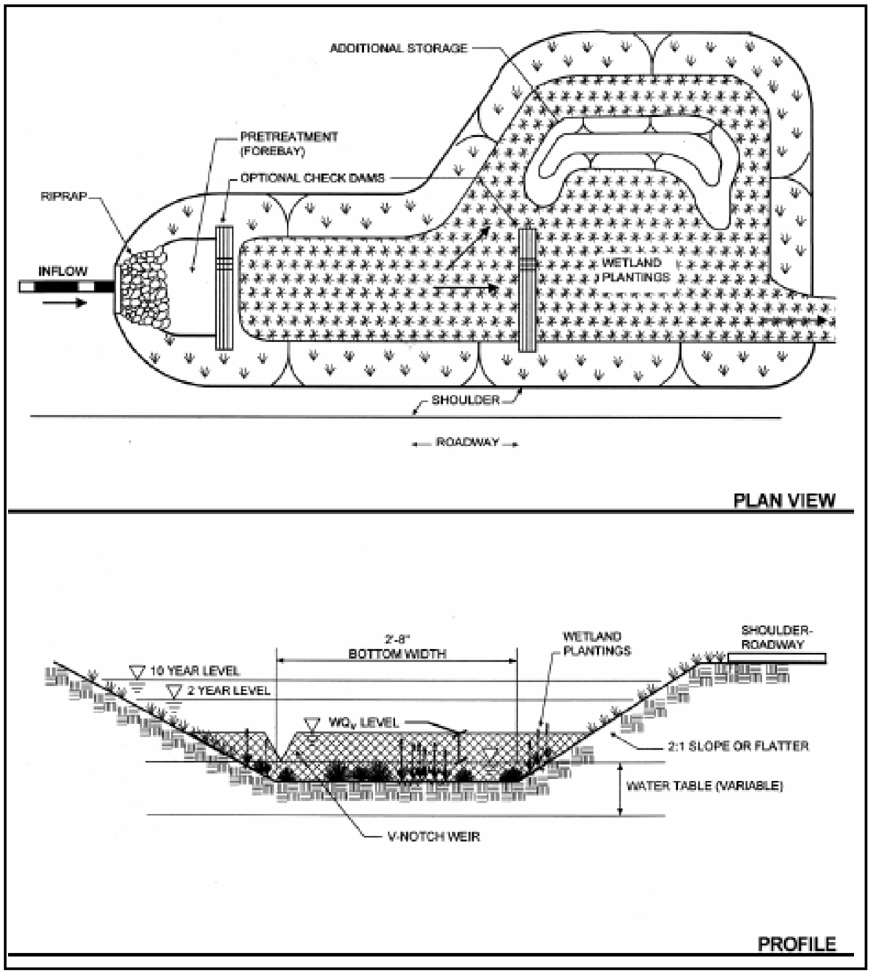


APPLICATIONS

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.

DESIGN CRITERIA

- Required volume is based on a rainfall intensity of 0.4" per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4" 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.



SOURCE: Maryland Department of the Environment 2000.

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.

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.

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.

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.

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.

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INFILTRATION TRENCH

DESCRIPTION & PURPOSE

The infiltration trench provides recharge and water quality volume in one location.

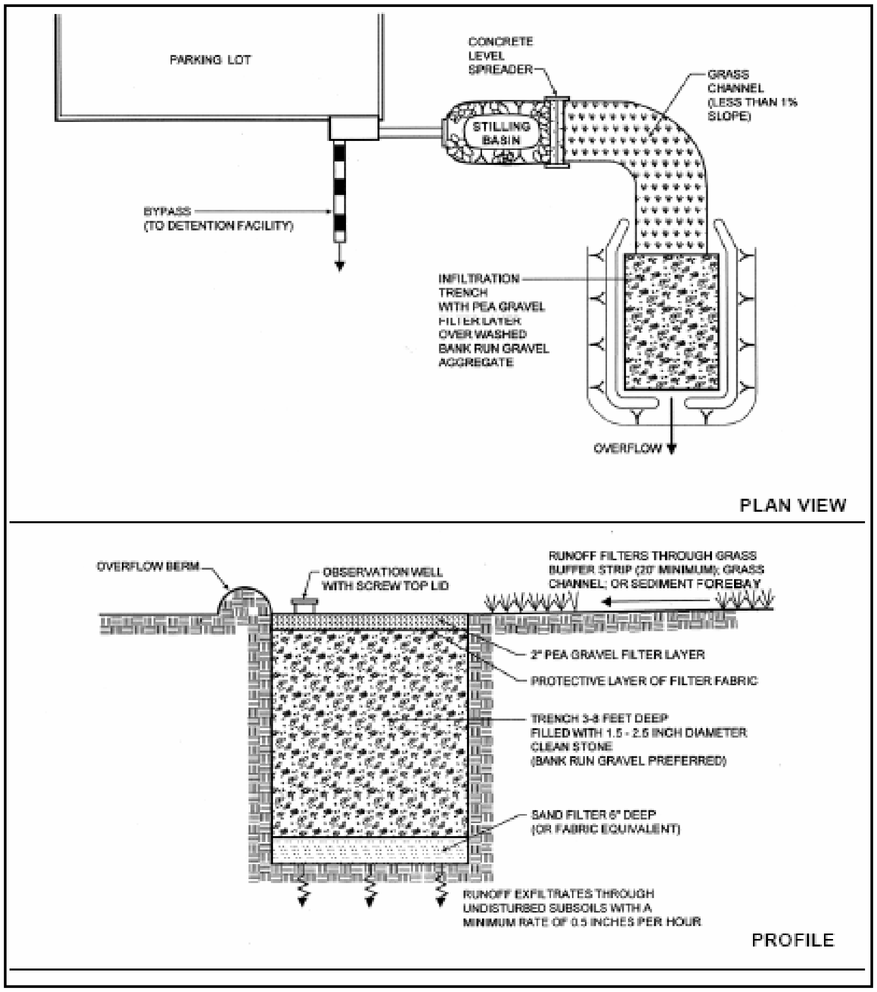
APPLICATIONS

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.

DESIGN CRITERIA

- A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Required volume is based on a rainfall intensity of 0.4" per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4" 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.



SOURCE: Maryland Department of the Environment 2000.

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” minimum) with filter fabric at sand/gravel interface; and
    - Washed bank run gravel used as aggregate.

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; and
  - 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.

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.

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.

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.

INFILTRATION BASIN

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.

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.

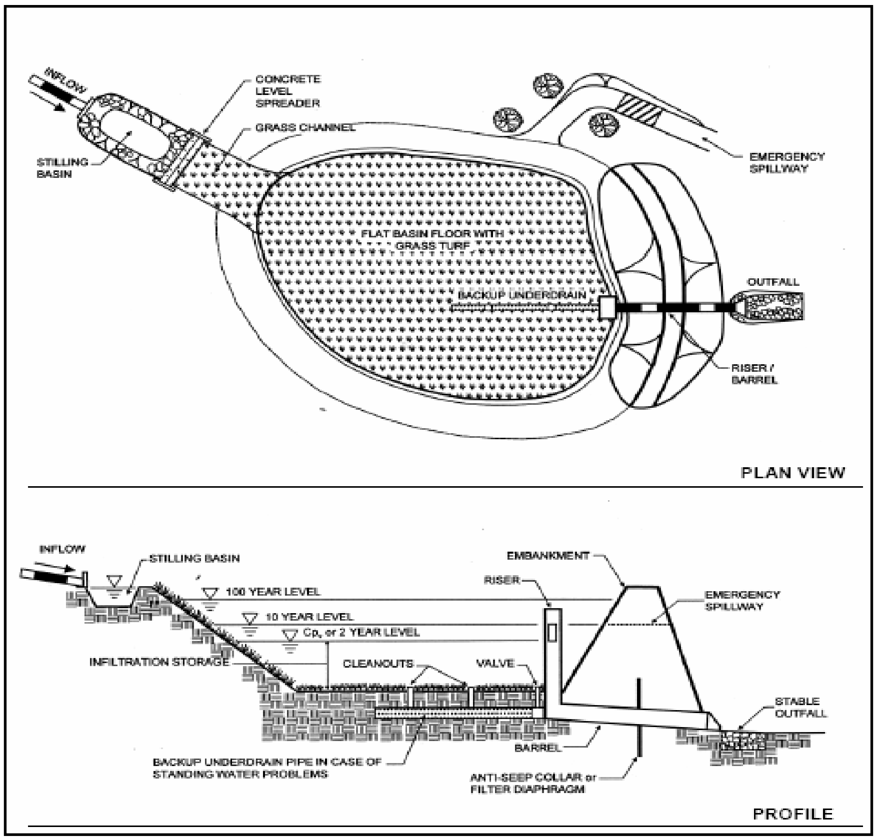
LIMITATIONS

- 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.

DESIGN CRITERIA

- A porosity value “n” (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Required volume is based on a rainfall intensity of 0.4” per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4” 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.



SOURCE: Maryland Department of the Environment 2000.

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" minimum) with filter fabric at sand/gravel interface; and
  - Washed bank run gravel used as aggregate.

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.

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.

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.

BIORETENTION

DESCRIPTION & PURPOSE

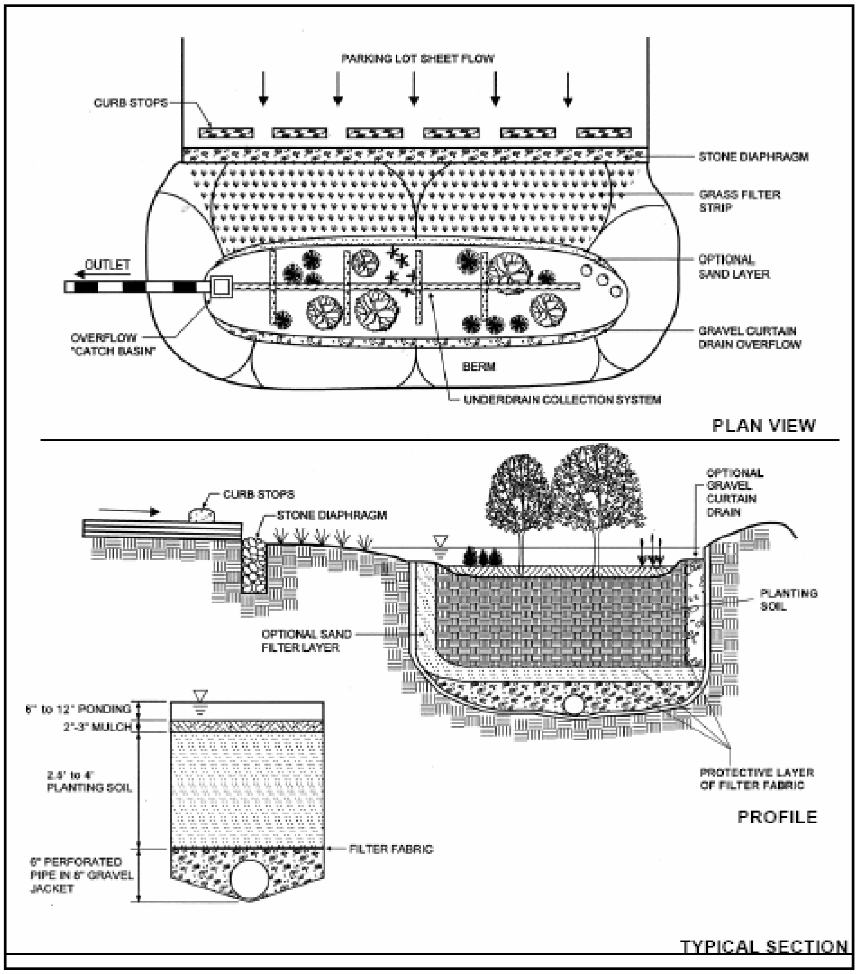
Bioretention combines open space with storm water treatment in vegetated areas where runoff is directed through vegetation and soils for filtration. It captures and temporarily stores the water quality volume and passes it through a filter bed of sand, organic matter, soil, or other media.

APPLICATIONS

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

DESIGN CRITERIA

- A porosity value "n" (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Required volume is based on a rainfall intensity of 0.4" per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4" 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.



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" deep surface ponding area.

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.

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.

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.

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.

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SHALLOW WETLAND

DESCRIPTION & PURPOSE

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

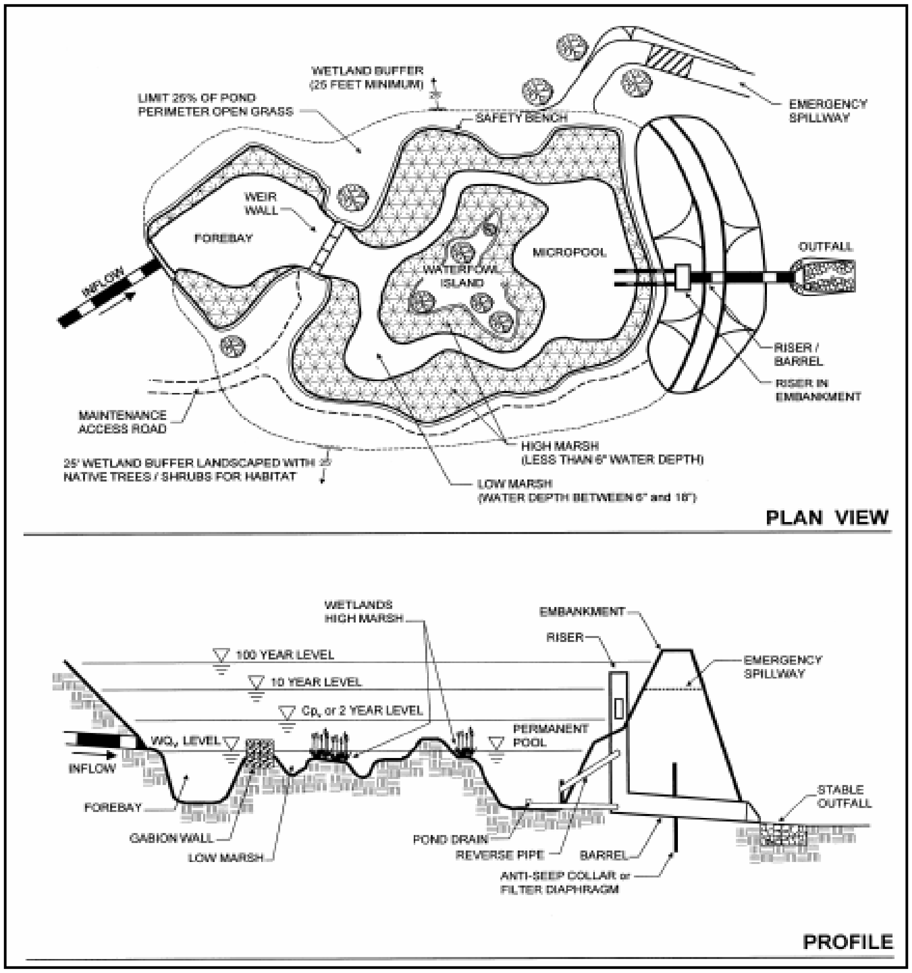
APPLICATIONS

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.

DESIGN CRITERIA

- Required 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" 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.



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.

CONSTRUCTION CONSIDERATIONS

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

LANDSCAPING REQUIREMENTS

- Landscaping plans shall be provided that indicate methods used to establish and maintain wetland coverage.
- Minimum plan elements include:
    - o Delineation of pondscaping zones;
    - o Selection of corresponding plant species;
    - o Planting configuration; and
    - o 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.

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.

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.

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POCKET WETLAND

DESCRIPTION & PURPOSE

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

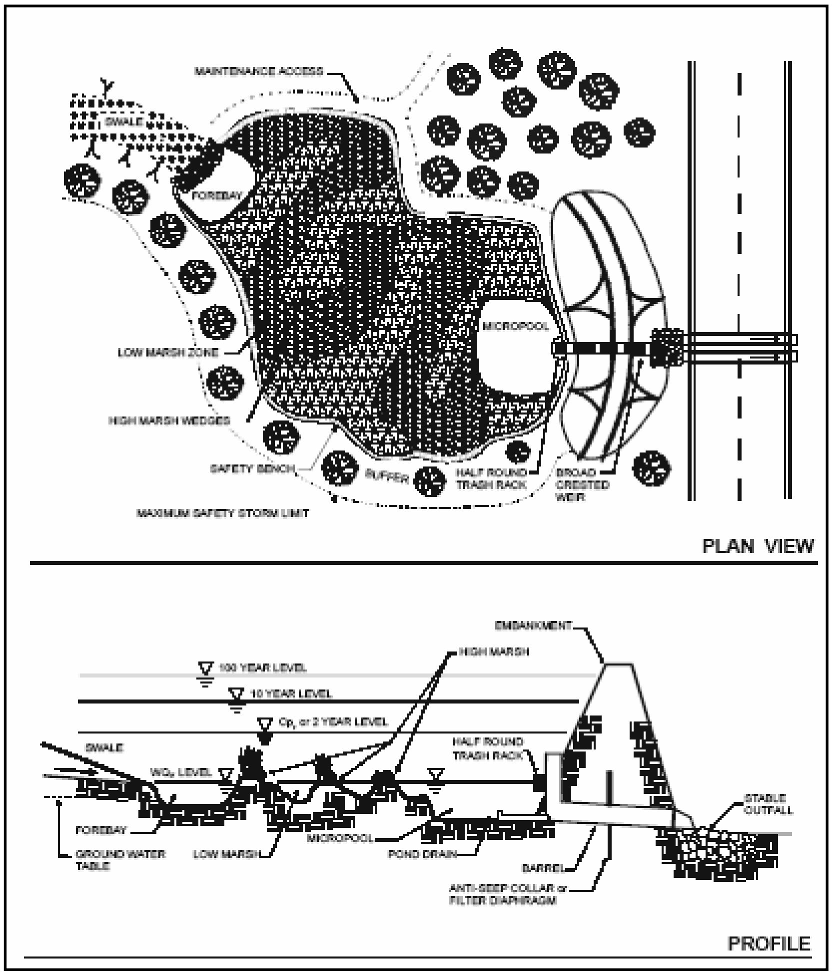
APPLICATIONS

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.

DESIGN CRITERIA

- Required 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" 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.



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.

CONSTRUCTION CONSIDERATIONS

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

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.

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.

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.

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WET EXTENDED DETENTION POND

DESCRIPTION & PURPOSE

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

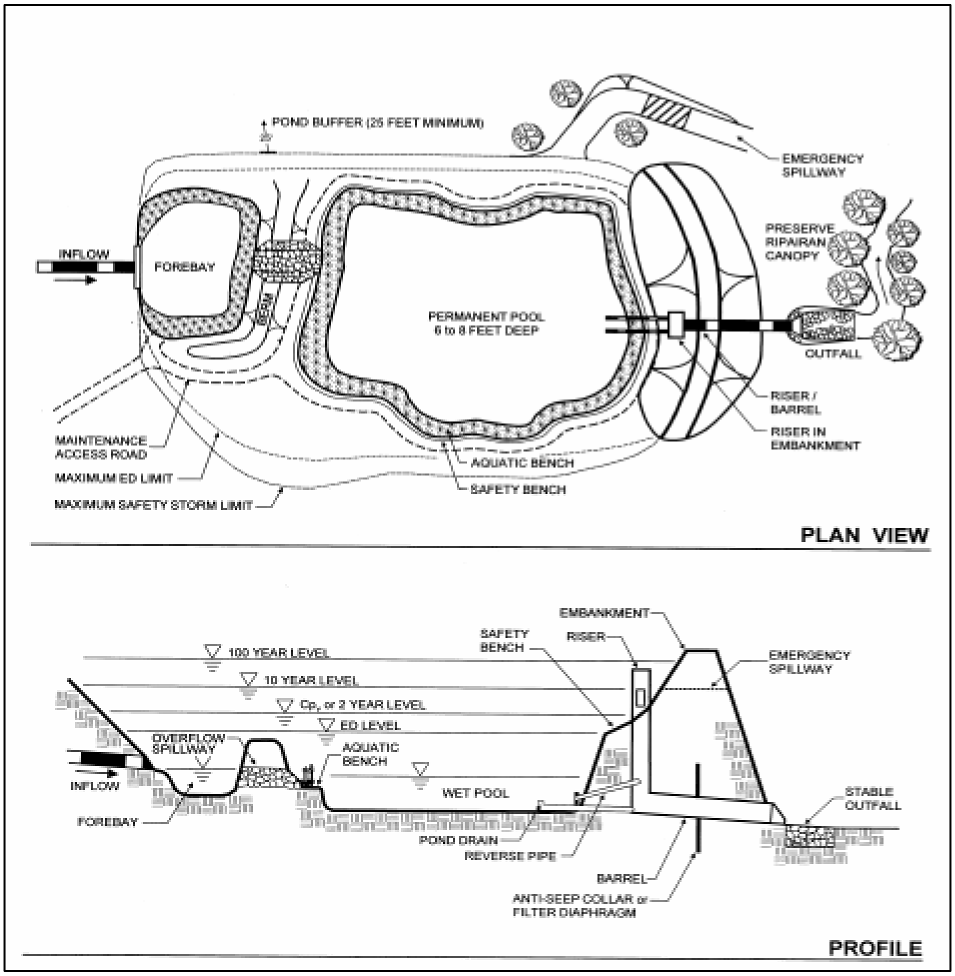
APPLICATIONS

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

DESIGN CRITERIA

- Required 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” 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.



SOURCE: Maryland Department of the Environment 2000.

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.

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.

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.

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.

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.

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WET POND

DESCRIPTION & PURPOSE

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

APPLICATIONS

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

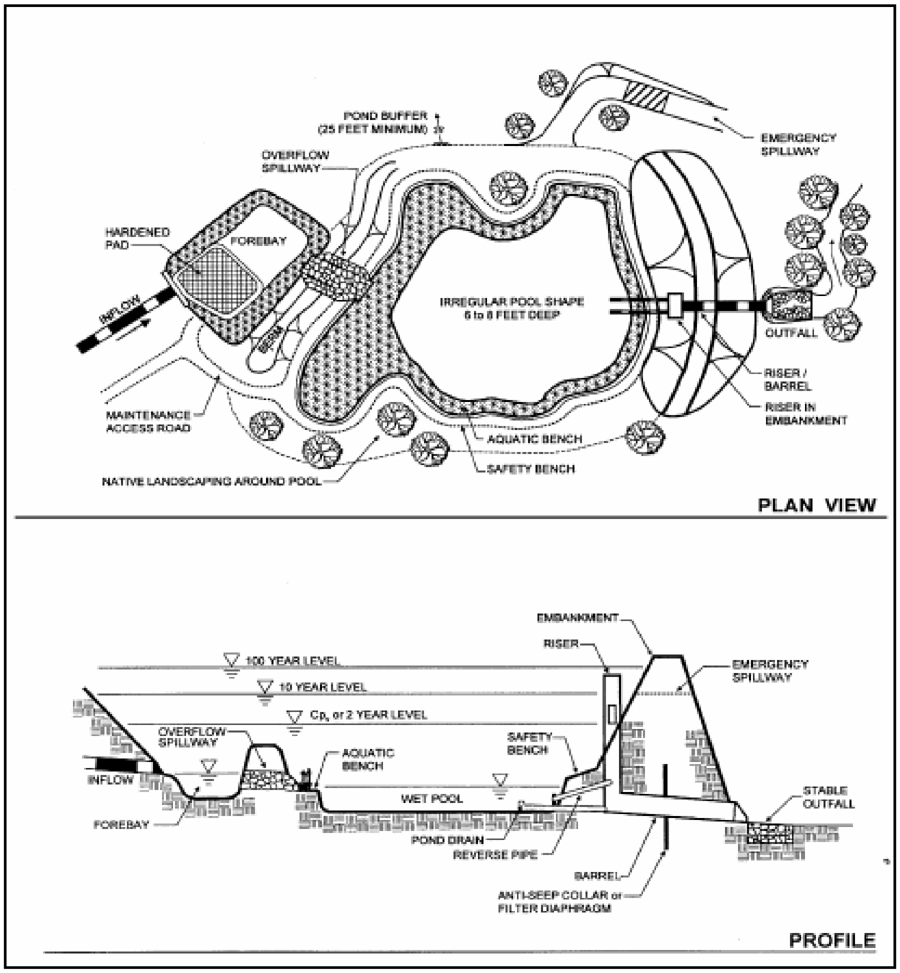
The wet pond volume is equal to the water quality design volume and is entirely a permanent wet pond, where storm water exchanges with the pond water to achieve treatment.

DESIGN CRITERIA

- Required 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" 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:
    - 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;

- 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.



SOURCE: Maryland Department of the Environment 2000.

PRETREATMENT REQUIREMENTS

- Sediment forebay:
  - o Each pond shall have a sediment forebay or equivalent upstream treatment and shall consist of a separate cell, formed by an adequate barrier; 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.
- 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.

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.

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.

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.

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.

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SURFACE SAND FILTER

DESCRIPTION & PURPOSE

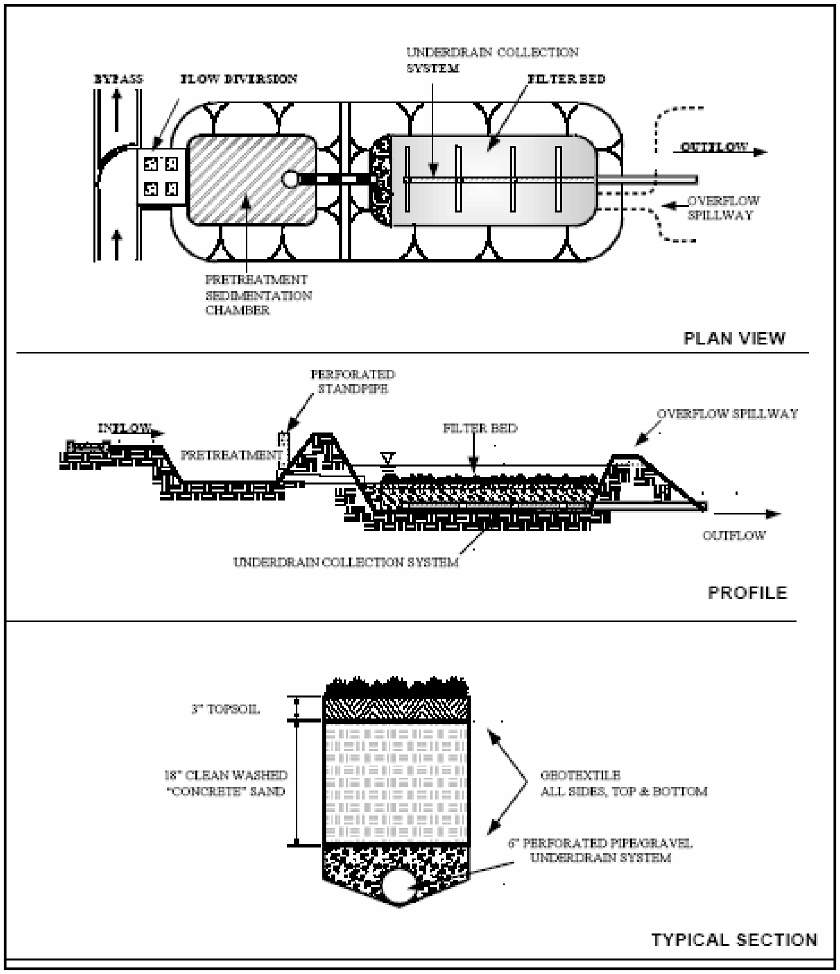
Surface sand filters can treat the largest drainage area of all the filtering systems. It captures and temporarily stores the water quality volume and passes it through a filter bed of sand, organic matter, soil, or other media.

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.

DESIGN CRITERIA

- A porosity value “n” (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Required volume is based on a rainfall intensity of 0.4” per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4” 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”.



SOURCE: Maryland Department of the Environment 2000.

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" deep surface ponding area.

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.

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.

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 than72 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.

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.

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UNDERGROUND SAND FILTER

DESCRIPTION & PURPOSE

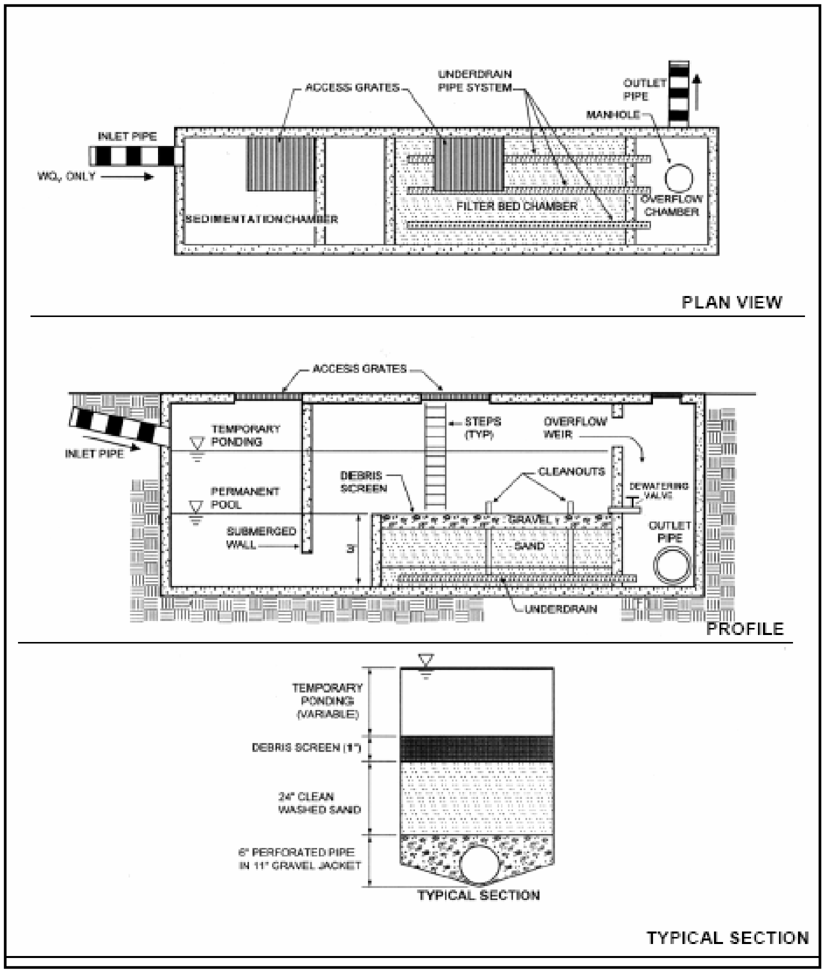
The underground sand filter is an option for providing water quality volume where space is limited.

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.

DESIGN CRITERIA

- A porosity value “n” (n=Vv/Vt) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Required volume is based on a rainfall intensity of 0.4” per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4” 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”.



SOURCE: Maryland Department of the Environment 2000.

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” deep surface ponding area.

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.

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.

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 than72 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.

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.

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ORGANIC SAND FILTER

DESCRIPTION & PURPOSE

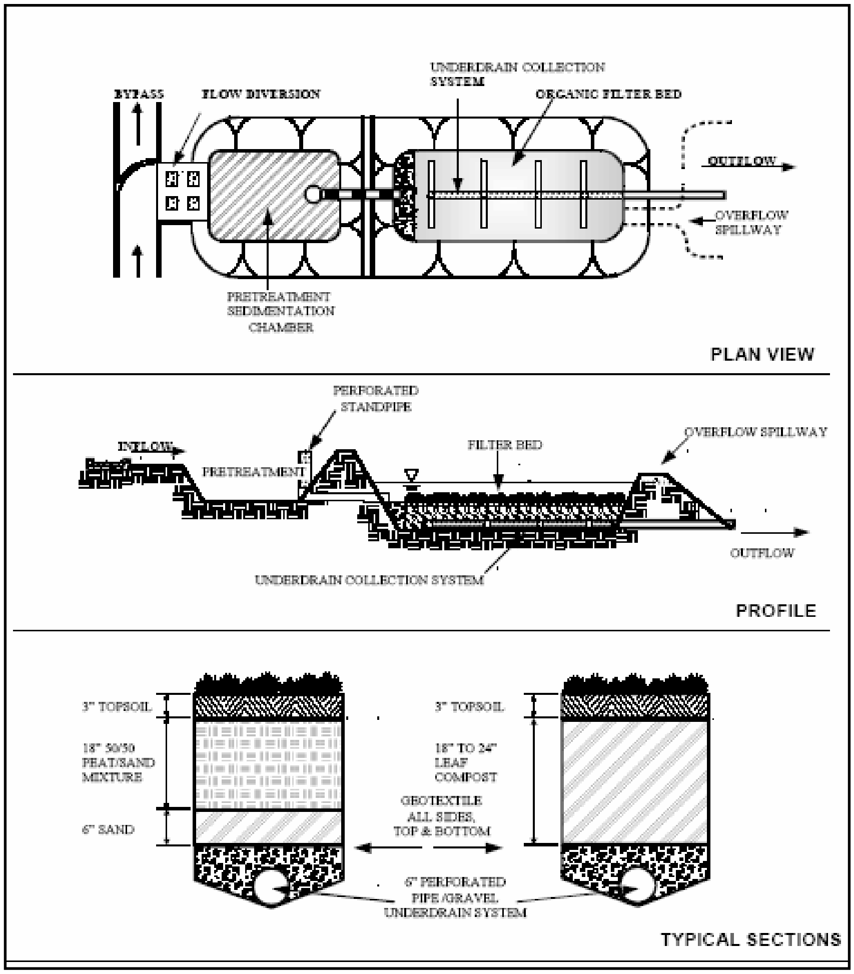
The organic filter is used when maximum nutrient or trace metal removals are desired.

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.

DESIGN CRITERIA

- A porosity value "n" ($n = V_v/V_t$) of 0.40 should be used in the design of stone reservoirs for infiltration methods.
- Required volume is based on a rainfall intensity of 0.4" per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4" 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".



SOURCE: Maryland Department of the Environment 2000.

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" deep surface ponding area.

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.

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.

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 than72 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.

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.

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"STRUCTURAL", "HYDRODYNAMIC" AND OTHER PROPRIETARY BMPS

Many current "structural" BMPs, which are commercially available proprietary products, may not be utilized as stand alone BMPs in meeting the performance criteria specified in the water quality control chapter of this manual. These "structural" BMPs include:

- Catch basin inserts;
- Water quality inlets;
- Oil/grit separators; and
- Hydrodynamic devices.

Structural, hydrodynamic, and proprietary BMPs have not been studied as extensively as other BMPs described in this chapter but have been used with varying degrees of success. The intended functions of these products may vary widely. Some BMPs are designed to primarily remove solid waste and floatable trashes while others use hydrodynamic separation techniques to separate sediment and oil/grease. Many of these BMP devices are not able to decrease Total Suspended Solids (TSS) and/or Total Phosphorus (TP) to meet water quality standards and some lack adequate independent testing data or long-term records. In some cases, these devices are used for pre-treatment or part of an overall storm water quality treatment system ("treatment train"). For example, they may be helpful in removing a portion of the pollutants present in storm water runoff before it enters storm water ponds or filtration practices.

HDOT does not endorse any specific "structural" BMP described in this section. Designers working on HDOT projects are encouraged to consult with manufacturers, obtain independent performance testing data, and demonstrate how these devices will be utilized to meet both quantity and quality criteria.

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.

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.

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.

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. Examples include Stormceptor® and Baysavers®.

A second type of hydrodynamic device utilizes centrifugal motion to remove litter, floatable debris, and larger sediment particles from runoff. Examples include CDS® and various storm water devices manufactured by Contech®. 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.

7.2 Soil Stabilization

PRESERVATION OF EXISTING VEGETATION

PERMANENT SEEDING AND PLANTING

MULCHING

GEOTEXTILES, MATS AND EROSION CONTROL BLANKETS

VEGETATED BUFFER STRIPS AND CHANNELS

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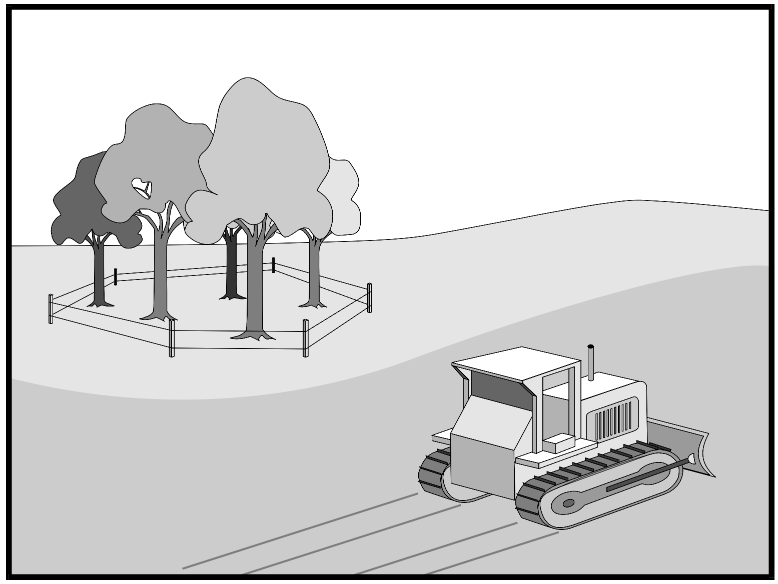
PRESERVATION OF EXISTING VEGETATION



DESCRIPTION AND PURPOSE

Identification of existing vegetation to remain provides erosion and sediment control on a site with future land disturbing activities.

APPLICATIONS

Preservation of existing vegetation practices apply to the following:

- Areas on-site where no construction activity occurs or will occur at a later date.
- Areas where the existing vegetation should be preserved such as steep slopes, watercourses, and building sites in wooded areas.
- Natural resources or environmental protection areas such as wetlands and marshes requiring preservation by local, state, and federal governments.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

- Incorporate existing vegetation into landscaping plans when possible. Proper care of this vegetation before and after construction is required.
- Consider aesthetic and environmental values, tree/plant health, life span, sun exposure limitations, and space requirements when determining which vegetation to preserve.
- When preparing the landscaping plans, avoid using vegetation which competes with the existing vegetation.
- Establish setback distances defined by devices such as berms, fencing, or signs. Setback distances are based on vegetation species, location, size, and age. The type of construction activity in the vicinity of the vegetation shall also be considered. Construction activities are not permitted within the setback.
- Protect existing vegetation using one of the following methods:
    - o Mark, flag, or fence areas of vegetation to be preserved;
    - o Designate limits of root system (tree drip line);
    - o Tree wells and retaining walls which are large enough to protect the root system;
    - o Limit grading to within one foot of the tree drip lines, if grading under the tree is necessary; and

   - Locate construction traffic routes, spoil piles, etc. away from existing vegetation.

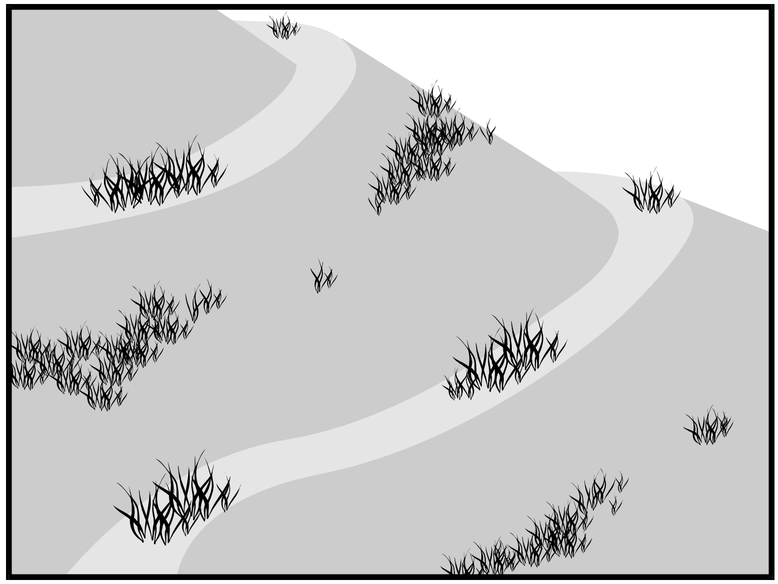
MAINTENANCE AND INSPECTIONS

- Inspect protective measures and immediately repair or replace damaged protection measures.

LIMITATIONS

- Requires advanced planning and coordination between the owner/developer, contractor, and designer.
- Limited use if final site design does not incorporate existing vegetation.
- Diverse site topography may result in additional expenses to satisfy vegetation preservation and the grading required for the site improvements.

SEEDING AND PLANTING



DESCRIPTION AND PURPOSE

Seeding and planting of trees, vines, shrubs, and ground cover for soil stabilization.

APPLICATIONS

Soil stabilization during or after the construction phase applies to the following site conditions:

- Graded/cleared areas;
- Open space and fill areas;
- Steep slopes;
- Vegetated swales;
- Landscape corridors; and
- Stream banks.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

Requirements for each seeding/planting application shall be considered and include:

- Type of vegetation;
- Site and seedbed preparation;
- Seasonal planting times;
- Fertilization; and
- Water.

GRASSES

- Ground preparation requires fertilization and mechanical stabilization of the soil.
- Short-term temperature extremes and waterlogged soil conditions tolerable.
- Appropriate soil conditions include a shallow soil base, good drainage, and 2:1 or flatter slope.
- Quickly develops from seeds.
- Vigorous grass growth dependent on mowing, irrigating, and fertilizing.

TREES AND SHRUBS

- Selection dependent on vigor, species, size, shape, and potential wildlife food source.
- Consider wind/exposure and irrigation requirements.
- Use indigenous species where possible.

VINES AND GROUND COVER

- Lime and fertilizer required for ground preparation.
- Use appropriate seeding rates.
- Consider requirements for drainage, acidity, and ground slope.
- Use indigenous species where possible.
- Avoid species which require irrigation.

MAINTENANCE AND INSPECTIONS

- Monitor vegetation growth
- Water, fertilize, mow, and/or prune the grasses/plants as needed.

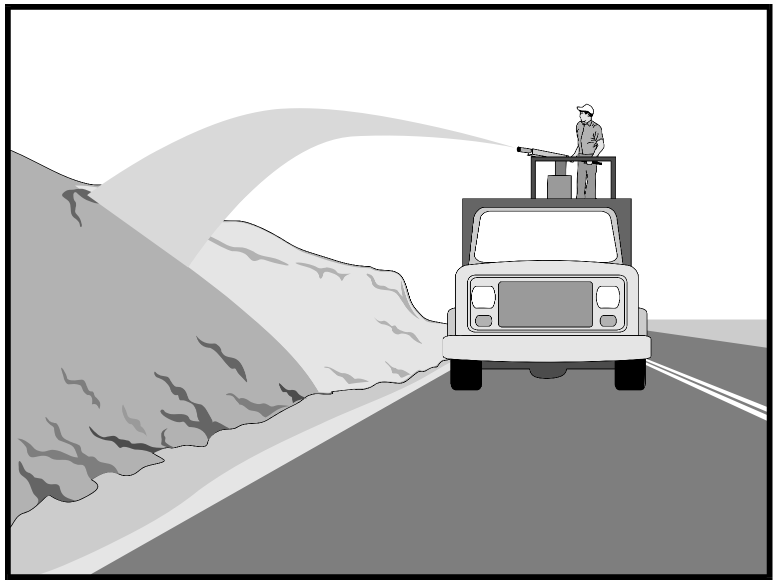
LIMITATIONS

- Vegetation may not be appropriate during dry periods without irrigation.
- Improper application of fertilizer may contribute to storm water pollution.

MULCHING

DESCRIPTION AND PURPOSE

Mulching is the application of loose bulk material to stabilize disturbed soil by protecting bare soil, increasing infiltration, and reducing runoff. Materials used for mulching include green material, hydraulic matrices, hydraulic mulches of recycled paper or wood fiber, stone and aggregate, vegetable fibers (hay or straw), and wood/bark chips.



APPLICATIONS

Mulching BMPs apply to the following:

- Temporary ground cover until permanent vegetation has been established.
- Method used in combination with temporary or permanent seeding to enhance plant growth.
- Areas requiring soil moisture retention to prevent cracking of the soil.
- Ground cover for exposed soil between trees or shrubs.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

The following materials may be used for mulching:

VEGETABLE FIBERS (HAY OR STRAW)

- Loose hay or straw which may be used in combination with seeding. Mulching usually follows seeding and the process is described in the following:
    - Apply seed and fertilizer to bare soil;
    - Apply loose hay or straw over top of seed and fertilizer prior to seed germination. Apply at a rate of 2 tons/acre by machine or hand distribution;
    - Evenly distribute mulch on the soil surface to cover 80% to 90% of the ground;
- Maintain maximum fiber length. Average fiber length shall be greater than 6 inches.
    - Use a tackifier, netting, or mechanical "punching" method to anchor mulch. Method depends on slope steepness, accessibility, soil conditions, and longevity; and

- o "Punching" straw or hay into soil is the preferred method of anchoring mulch for the following conditions:
    - Use a spade or shovel on small areas,
    - Use a knife-blade roller or straight bladed coulter ("crimper") on slopes with soil, which can support construction equipment without undesirable compaction or instability,
    - Use plastic netting or jute on small areas and/or steep slopes. Geotextile pins, wooden stakes, or 11 gauge wire staples shall secure netting in place. This condition warrants consideration of the use of matting rather than mulch, and
    - Use tackifiers on steep slopes unable to support construction equipment or large application areas where use of nettings, straw, or hay is not cost-effective. Tackifiers glue vegetable fibers together and to the soil surface until the establishment of permanent vegetation.

GREEN MATERIAL

- Consists of recycled vegetation trimmings such as grass and shredded shrubs and trees.
- Generally applied by hand.
- Temporary ground cover with or without seeding.
- Evenly distribute green material on soil surface. Depth shall not exceed 4 inches.
- Anchor with a tackifier or netting on steep slopes or for areas with anticipated overland sheet flow. This condition warrants consideration of the use of matting rather than mulch.

WOOD/BARK CHIPS

- Suitable for areas which will not be mowed such as around trees, shrubs, and landscape plantings.
- Test soils prior to application. Add a minimum of 12 pounds of nitrogen per ton of mulch to counteract the effect of decomposing wood-based materials, which extract nitrogen from soil. Use a balanced, slow-release fertilizer or an organic source such as compost.
- Apply mulch by hand.
- Evenly distribute wood/bark chips on soil surface and maintain a mulch depth of 2 to 3 inches.

HYDRAULIC MULCHES OF RECYCLED PAPER

- Consists of recycled newsprint, magazines, and other waste paper sources.
- May be applied with or without tackifiers.
- Hydraulic mulch materials shall conform to *Hawaii Standard Specifications for Road and Bridge Construction (2005)*.
- Mix mulch in a hydraulic application machine (hydroseeder) and apply as a liquid slurry.
- May be sprayed from a cannon up to 200 feet or from a hose up to 1,500 feet away from the application area.
- Mix mulch with seed and fertilizer as specified by the manufacturer. Apply mulch at the manufacturer's recommended rate to ensure uniform, effective coverage.

HYDRAULIC MULCHES OF WOOD FIBER

- Consists of wood waste from lumber mills or urban sources.
- May be manufactured with or without a tackifier.
- Hydraulic mulch shall conform to *Hawaii Standard Specifications for Road and Bridge Construction (2005)* or comply with the following requirements:
  - 100% wood fiber;
  - Maximum moisture content (total weight basis) shall not exceed 12% ±3%;
  - Minimum organic matter content (oven dry weight basis) of 99.3%;
  - Maximum inorganic matter (ash) content (oven dried basis) of 0.7%
  - pH of 4.9±10% for a 3% water slurry; and
  - Minimum water holding capacity (oven dried basis) of 1.2 gallons per pound of fiber.
- Mix mulch in a hydraulic application machine (hydroseeder) and apply as a liquid slurry.
- Mix mulch with seed and fertilizer as specified by the manufacturer. Apply mulch at the manufacturer's recommended rate to ensure uniform, effective coverage.

HYDRAULIC MATRICES

- Hydraulic slurries consisting of wood fiber, paper fiber, or a combination of wood and paper fiber mixed with a binder system.
- Exceeds erosion control performance of blankets due to close contact with soil.
- Apply as an aqueous slurry (with seed) using standard hydroseeding equipment.
- Application rates vary for different combinations of conditions and products.
- A typical mixture based on one acre of treated area includes the following:
  - 500 pounds wood fiber mulch;
  - 1,000 pounds recycled paper mulch; and
  - 55 gallons acrylic copolymer with a minimum solids content of 55%.
- Bonded Fiber Matrix (BFM) consists of premixed fiber and binders.
  - After application and upon drying, BFM shall adhere to soil and form a 100% cover. The cover shall be biodegradable, promote vegetation, and prevent soil erosion.
  - Composed of long strand, thermally produced wood fibers (>88% of total volume by weight), held together by organic tackifiers (10%) and mineral bonding agents (<2%), which become insoluble and non-dispersible upon drying. Composition of BFM varies based on supplier.
  - Perform a free liquid quality control test on the liquid slurry.
  - Binder shall not dissolve or disperse upon watering.
  - Upon application to the soil, holes in the matrix shall not exceed 0.04 inches in size.
  - There shall not be any gaps between the matrix and the soil.
  - Minimum water holding capacity of the matrix shall be 1.2 gallons per pound matrix.
  - The matrix shall be free of germination or growth inhibiting factors and shall not form a water resistant crust.
  - Materials used for the matrix shall be 100% biodegradable and 100% beneficial to plant growth.
  - Testing and evaluation of the matrix by an independent research laboratory shall have been conducted to verify reported erosion control performance.

- A trained and manufacturer certified applicator with knowledge of proper mixing and product application shall install the BFM.
- Typical BFM application rates range from 3,000 to 8,000 pounds per acre per recommendations from various manufacturers.
- BFM shall not be applied immediately before, during, or after a rainfall event to ensure a drying time of 24 hours after installation.

- Mulch used as temporary ground cover shall be reapplied to bare areas until permanent vegetation has been established.
- Avoid spraying mulch onto sidewalk, lined drainage channels, travelway, and existing vegetation.

MAINTENANCE AND INSPECTIONS

- Mulches applied to seeded areas may be disturbed due to wind or runoff. Recover exposed areas until permanent vegetation has been established.
- Mulches applied to areas, which will be regraded and revegetated, shall be inspected once every 2 weeks. Corrective measures shall be initiated within 14 days of inspection.
- Inspect ornamental and landscape mulches of bark or wood chips once every 8 to 10 months. Replace mulch if soil is visible in more than 75% of the area.

LIMITATIONS

VEGETABLE FIBERS (HAY OR STRAW)

- Require three-step machinery.
- Labor intensive installation.
- Weed seeds and undesirable plant material may be introduced to sensitive areas.
- For applications using straw blowers, the applicable area must be located within 150 feet of a road or surface capable of supporting loads from large vehicles. If both hay and straw are available, it is preferable to use straw.

GREEN MATERIAL

- Limited commercial availability.
- Variable quality.
- Weeds or undesirable plant material may be introduced to the mulched area.
- Application primarily uses manual labor.
- Unpredictable effectiveness as an erosion control measure. Requires overspray with a tackifying agent to increase effectiveness.
- Application of fertilizer may be required.
- Limit use to non-critical steep slopes and areas where alternative erosion control measures may be readily applied.

WOOD/BARK CHIPS

- Poor erosion control effectiveness.
- Anchoring of chips onto steep slopes is difficult due to potential movement from high winds.
- Subject to displacement from concentrated flows.
- Use of a fertilizer with high nitrogen content is required to prevent nutrient deficiency in plants due to decomposing wood-based materials, which extract nitrogen from soil. Improper fertilizer use may contribute to water quality pollution.
- Limit use to non-critical steep slopes and areas where alternative erosion control measures may be readily applied.

HYDRAULIC MULCHES OF RECYCLED PAPER

- Limited erosion control effectiveness due to short fiber length and absence of a tackifier.
- Limited moisture and soil temperature moderation.
- Residual inks within mulches may be an undesirable in environmentally sensitive areas.
- Significant decrease in longevity compared with wood fiber mulch.
- Difficulty budgeting for this product due to volatile prices for recycled paper products.

HYDRAULIC MULCHES OF WOOD FIBER

- Limited erosion control effectiveness.
- Short-term use of one growing season.

HYDRAULIC MATRICES

- Avoid application of mulch immediately before, during, or after a rainfall event.
- Requires drying time of 24 hours.

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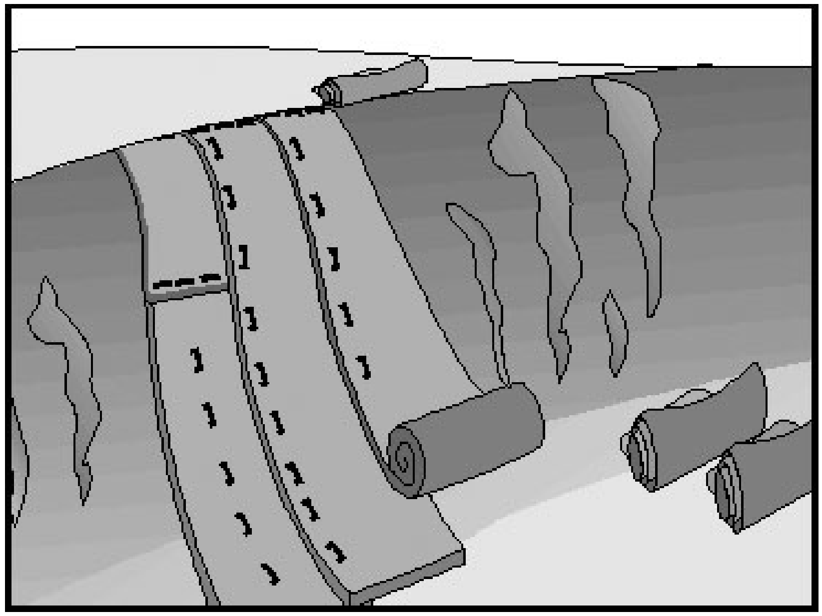
GEOTEXTILES AND MATS

DESCRIPTION AND PURPOSE

Natural or synthetic mats may be used for temporary or permanent soil stabilization.



APPLICATIONS

Geotextiles and mats apply to the following:

- Drainage ditches, channels, and streams.
- Steep slopes.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

- Apply matting to disturbed soils and areas where vegetation has been removed.
- Organic matting provides temporary protection until permanent vegetation has been established, optimal weather conditions occur, or construction delays are resolved. Organic matting materials include the following:
    - o Jute matting; and
    - o Straw matting.
- Synthetic matting provides temporary or post-construction soil stabilization in both vegetated and non-vegetated areas. Synthetic matting materials include the following:
    - o Excelsior™ matting;
    - o Glass fiber matting;
    - o Staples; and
    - o Mulch netting.
- Other proprietary devices may be used and shall be installed per manufacturer's recommendations.

MAINTENANCE AND INSPECTIONS

- Periodically inspect matting after installation.

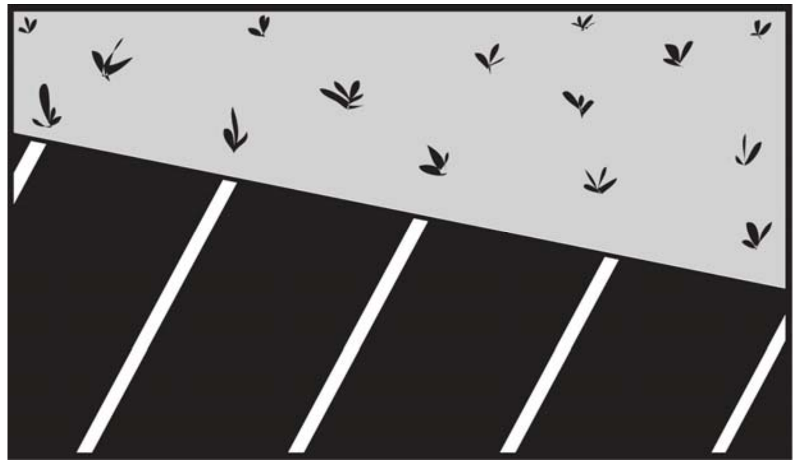
LIMITATIONS

- Minimize use of matting to areas where other erosion control measures are not applicable such as channels or steep slopes since matting is more costly compared to other erosion control measures.
- Seed germination may be delayed due to decreased soil temperature.
- An experienced maintenance engineer is required during installation.

VEGETATED BUFFER STRIPS AND CHANNELS

DESCRIPTION AND PURPOSE

Vegetated buffer strips and channels protect soil from erosion, increase infiltration, and remove sediment from surface runoff. Located adjacent to pollutant sources such as construction sites, vegetated buffer strips also provide protection to downstream receiving inlets or water bodies.



APPLICATIONS

Vegetated buffer strips and channels apply to the following conditions:

- Any site which is suitable for establishment of vegetation.
- Vegetated buffer strips are appropriate for uncurbed, paved areas; steep and potentially unstable slopes; and areas adjacent to sensitive water bodies.
- Vegetated channels are appropriate for surface runoff conveyed by channels to downstream inlets or receiving waters.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

- Refer to the Preservation of Existing Vegetation section in this manual if existing vegetation will be used as a buffer strip.
- Installation of a buffer strip with new vegetation shall comply with the following:
    - Prior to cultivation of the designated buffer strip area, remove and dispose of all weeds and debris in accordance with *Hawaii Standard Specifications for Road and Bridge Construction (2005)*;
    - During construction, strip and stockpile good topsoil for surface preparation purposes prior to planting activities;
    - Plant the area upon completion of grading in the area;
    - Fine grade and roll areas to be planted after cultivating soil and, if applicable, installing the irrigation system;
    - Provide additional watering or irrigation of vegetation to supplement rainfall until vegetation has been established;
    - Fertilize vegetation in accordance with manufacturers' instructions and grass/soil requirements determined by testing of the soil;

- o Vehicular traffic passing through vegetated buffer strips or channels shall be avoided to protect vegetation from damage and maximize its effectiveness;
- o Comply with applicable regulations and manufacturers' instructions when applying fertilizers, pesticides, soil amendments, or chemicals;
- o Comply with the following during seeding activities:
  - Add soil amendments such as fertilizer when preparing seedbed. Apply mulch after seeding to protect vegetation during establishment. Select an appropriate seed mixture based on site conditions. Dense grasses are more effective in reducing flow velocities and removing sediment. Thick root structures are necessary for erosion control,
  - Use proper equipment and methods to ensure uniform distribution and appropriate seed placement, and
  - Overseed, repair bare spots, and apply additional mulch as necessary; and
- o Comply with the following during sodding activities:
  - Protect sod with tarps or other types of protective covering during delivery and do not allow sow to dry between harvesting and placement,
  - Any irregular or uneven areas observed prior to or during the plant establishment period shall be restored to a smooth and even appearance,
  - Prior to placing sod, ground surface shall be smooth and uniform,
  - Areas, which will be planted with sod and are adjacent to paved surfaces such as sidewalks and concrete headers, shall be 1.5±0.25 inches below the top grade of the paved surface after fine grading, rolling, and settlement of the soil,
  - Ends of adjacent strips of sod shall be staggered a minimum of 24 inches,
  - Edges and ends of sod shall be placed firmly against paved borders,
  - After placement of the sod, lightly roll sodded area to eliminate air pockets and ensure close contact with the soil,
  - After rolling, water the sodded area to moisten the soil to a depth of 4 inches,
  - Do not allow sod to dry,
  - Avoid planting sod during extremely hot or wet weather, and
  - Sod shall not be placed on slopes steeper than 3:1 (H:V) if the area will be mowed.

MAINTENANCE AND INSPECTIONS

- Inspect weekly and after significant rain events until vegetation is established. Repair eroded or damaged areas as necessary.

- Maintenance activities include mowing, weeding, and verification of a properly operating irrigation system, if applicable.
- Properly remove and dispose of clippings from mowing and trimming in accordance with *Hawaii Standard Specifications for Road and Bridge Construction (2005).*

LIMITATIONS

- Site conditions such as availability of land.
- Flow depth and vegetative condition determine BMP effectiveness.
- May require irrigation to maintain vegetation.
- High maintenance requirements may exist depending on the design condition of the vegetation.
- Unless existing vegetation is used as a buffer strip, an area will need to be provided specifically for a buffer strip and vegetation will need to be established.
- Maintaining sheet flow in buffer strips may be difficult.
- Vegetated channels require a larger area than lined channels.
- Vegetated channels require gradual slopes since runoff with high flow velocity may flow over grass rather than through it.

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7.3 Storm Water Flow Control

EARTH DIKES, DRAINAGE SWALES, AND LINED DITCHES

SLOPE DRAINS AND SUBSURFACE DRAINS

TOP AND TOE OF SLOPE DIVERSION DITCHES/BERMS

OUTLET PROTECTION/VELOCITY DISSIPATION DEVICES

FLARED CULVERT END SECTIONS

SLOPE ROUGHENING/TERRACING/ROUNDING

LEVEL SPREADER

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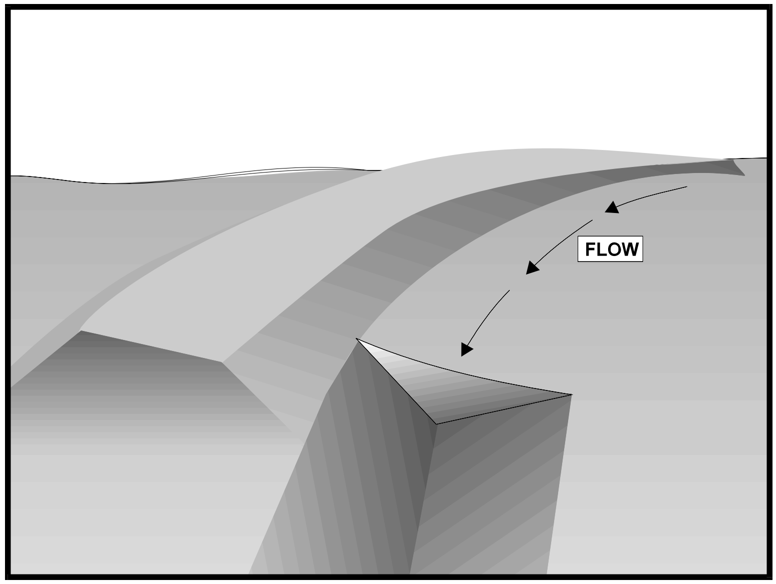
EARTH DIKES, DRAINAGE SWALES, AND LINED DITCHES



DESCRIPTION AND PURPOSE

Earth dikes, drainage swales, and lined ditches are structures that prevent erosion by intercepting, diverting, and conveying surface run-on to a stabilized area or other sediment trapping device.

APPLICATIONS

Earth dikes, drainage swales, and lined ditches may be applied for the following purposes:

- Direct runoff around unstable or disturbed areas to a stabilized water course, drainage pipe, or channel.
- Divert runoff to sediment basins or sediment traps.
- Intercept runoff at the point of concentration.
- Supplement other sediment control measures.
- Intercept and divert runoff to prevent sheet flow over sloped surfaces.
- Convey surface runoff down sloping land.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

- Firmly compact to minimize erosion and prevent unequal settling.
- Drain to a stabilized outlet.
- Drain sediment laden runoff to a sediment trapping device.
- Ensure continuous, positive grade along dike, swale, or ditch to prevent ponding of runoff.
- Stabilize with vegetation, chemicals, or other physical devices.
- Conform to predevelopment drainage patterns and capacities.
- The design of dikes, swales, and ditches shall be submitted to the HWY-OM Engineer or Hydraulic Section staff for review. The review will evaluate structural stability and drainage capacity.
- Design flow and safety factor shall be determined by an evaluation of risks associated with overtopping, flow backups, or washout of structures.
- Evaluate potential run-on from off-site properties.

- Flow velocity limit shall be determined by on-site soil type and drainage flow patterns.
- Establish minimum flow velocity requiring lining (rip-rap, geotextile filter fabric, vegetation, concrete) for earthen diversion devices. Refer to Highways Division's *Hawaii Statewide Uniform Design Manual for Streets and Highways*.
- Incorporate an emergency overflow section or bypass area into the design for storms exceeding the design storm.

MAINTENANCE AND INSPECTIONS

- Inspect dikes, swales, and ditches periodically. Inspections shall include the following:
  - Check for erosion along berms, channel linings, embankments, or beds of ditches. Restore all bare areas with the appropriate lining material;
  - Remove accumulated sediment and debris; and
  - Inspect dike walls, embankments, compacted fills, and earthen channel sidewalls for cracks, washouts, animal habitation, exposed materials, and other signs of potential failure. Restore areas with the appropriate materials. Coordinate restoration with the HWY-OM Engineer or Material Testing and Research Section as necessary. The Hydraulic Section shall also be consulted for problems associated with structural design or runoff flow patterns.

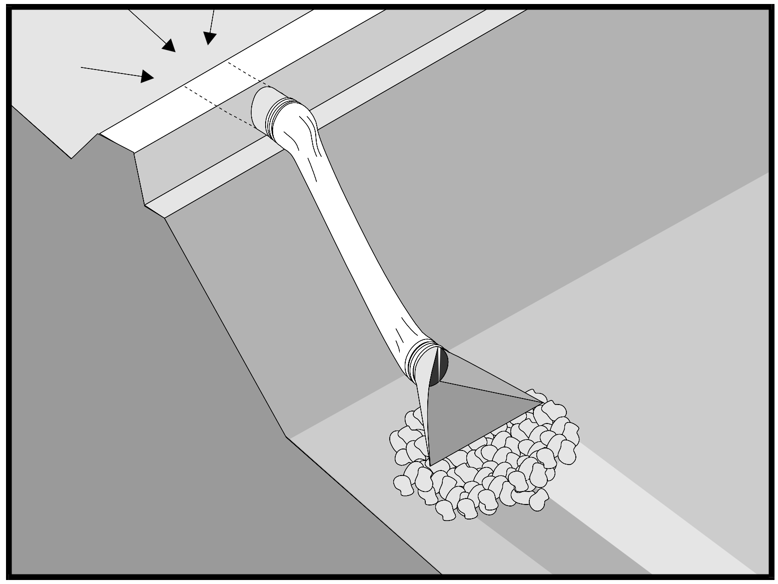
LIMITATIONS

- Unsuitable for use as a sediment trapping device.
- Use of additional sediment and erosion control devices may be required to prevent scour and erosion in recently graded dikes, swales, and ditches.
- Select size and location to prevent unintended consequences such as erosion along steep and unlined ditches and ponding within the travelway or material storage areas. Alteration of existing waterways and clearing of existing vegetation are subject to permit requirements of the U.S. Army Corps of Engineers and state or local agencies.
- Ditches and swales may require check dams or lining to prevent erosion.

SLOPE DRAINS AND SUBSURFACE DRAINS

DESCRIPTION AND PURPOSE

Slope drains and subsurface drains are pipes which prevent erosion along slopes by intercepting and conveying runoff or groundwater from the top of the slope to a stabilized discharge point located at the bottom of the slope. Slope drains are primarily used to convey runoff down cut or fill slopes. Subsurface drains are primarily used to remove water from the soil in sloped areas.



APPLICATIONS

Slope drains and subsurface drains may be used for the following purposes:

- Emergency spillways for sediment basins;
- Use of slope drains apply to the following conditions:
    - Drainage of concentrated runoff from within swales or behind dikes located at the top of slopes, and
    - Drainage of surface runoff to prevent erosion along the slope; and
- Use of subsurface drains applicable to areas where water must be removed from the soil to lower the groundwater table or to prevent excessive soil saturation.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

Design of slope drains shall consider the following:

- Consult with a hydro-geologist or qualified engineer regarding design flows;
- Limit drainage area discharging to slope drain to 5 acres;
- Direct surface runoff into slope drain using interceptor dikes at the top of slope. Refer to Earth Dikes, Drainage Swales, and Lined Ditches in this manual for more information;
- Pipe slope drains exceeding 12 inches in diameter require a standard flared end section or headwall constructed at the inlet and outlet;
- Install lining such as vegetation or geotextile filter fabric to protect area around inlet;
- Install rip-rap or other energy dissipation device at outlets;

- Compact soil under and around inlet, outlet, and along the pipe;
- Slope drains may be installed above ground or buried beneath the slope surface;
- Above ground installation shall utilize pipe anchors to secure pipe to ground;
- Align slope drain perpendicular to contours of slope;
- Generally limit maximum slope to 2:1 (H:V). For slopes exceeding 2:1 (H:V), velocity dissipation is required at the pipe outlet; and
- Direct sediment-laden storm water to a sediment trap or sediment basin.

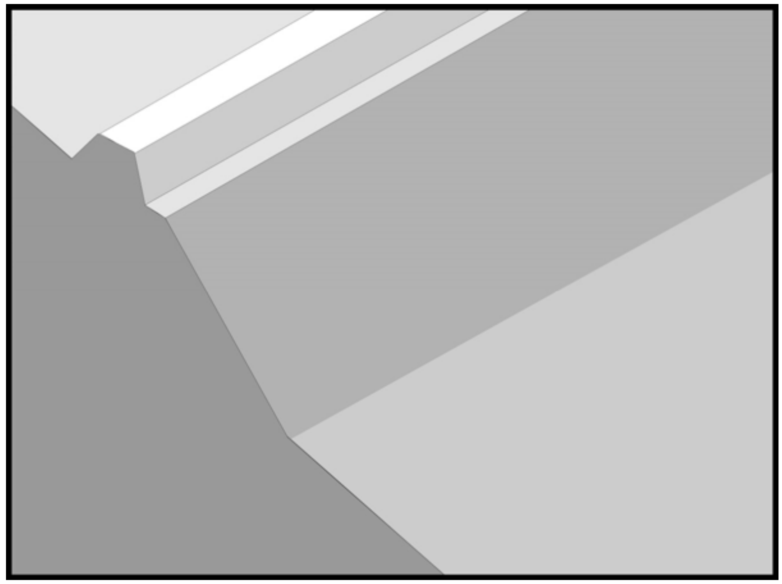
MAINTENANCE AND INSPECTIONS

- Inspect regularly and after significant rainfall events for erosion at outlet and downstream scour. Repair damage and install energy dissipation devices as necessary.
- Inspect slope drains for debris and sediment accumulation. Remove sediment and debris from entrances, outlets, and within drains.
- Inspect pipe anchors to ensure pipe remains anchored to slope.
- Verify ponding does not occur in areas such as active traffic lanes and material storage areas.

LIMITATIONS

- Drainage area discharging to slope drains shall not exceed 5 acres. For larger areas, use multiple pipes, paved chute, or rock lined channel.
- Clogged slope drains direct runoff around pipe which may result in erosion along the slope.
- High flow velocities at the pipe outlet require implementation of velocity dissipation devices to prevent downstream erosion.
- Severe flooding and erosion may result from failure of slope drains.

TOP AND TOE OF SLOPE DIVERSION DITCHES/BERMS



DESCRIPTION AND PURPOSE

Slope diversion ditches and berms are placed along the top and/or toe of slopes to minimize sheet flow over slopes. These devices reduce erosion by intercepting and conveying runoff to sediment removing structures or a protected drainage system.

APPLICATIONS

Top and toe of slope diversion ditches and berms apply to the following:

- Areas which must be protected from runoff flowing down slopes; and
- Areas where runoff must be intercepted at bottom of slope.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

- Design flows and safety factors shall be determined by an evaluation of risks associated with erosion and overtopping, flow backups, or structure washouts. Consult with the HWY-OM Engineer or Hydraulic Section to determine these values.
- Line or stabilize ditches with high flow velocities.
- Direct flows at top of slopes to slope drains. Refer to Slope Drains and Subsurface Drains in this manual for more information.
- Protect outlets from erosion.

MAINTENANCE AND INSPECTIONS

- Inspect prior to the rainy season and after rainfall events exceeding the design storm intensity (25-year recurrence interval, 1-hour duration), unless otherwise directed.
- Inspect ditches/berms for washouts. Repair requirements shall be reported and include replacement of rip-rap, damaged lining, or soil stabilizers and compaction and revegetation of fill berms and ditches.
- Establish a repair schedule with priority assigned to areas with compromised highway safety and Class AA and Class 1 waters (refer to HAR Chapter 11-54

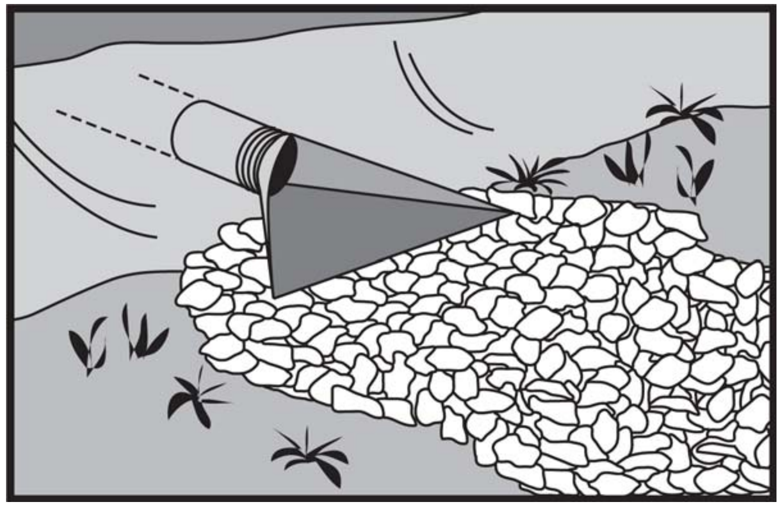
for State water classification). Repair work for remaining areas shall be based on potential erosion, potential habitat damage, and land use of areas located downslope.

- All repairs shall be completed within 1 year of inspection.
- Inspect structures for accumulated sediment and debris and remove as necessary. The schedule for removal of sediment and debris shall be as described in the repair section.

LIMITATIONS

- Additional sediment trapping BMP devices may be necessary for sediment-laden runoff.

OUTLET PROTECTION AND VELOCITY DISSIPATION DEVICES



DESCRIPTION AND PURPOSE

Devices placed at outlets of pipes and channels prevent or minimize scouring and erosion resulting from the high velocity of storm water flows.

APPLICATIONS

Applicable conditions include the following:

- Outlets with continuous flows.
- Outlets located at the bottom of slopes.
- Outlets subject to short, intense flows.
- Discharge points from lined conveyances to unlined conveyances.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

- Apron length shall be determined by outlet flow rate and tailwater level.
- Align apron with direction of flow and avoid curves in apron. If a curve is necessary, place it in the upper section of the apron.
- Protect the underlying geotextile filter fabric with a 4 inch minimum rock blanket if the rip-rap is 12 inches or larger.

MAINTENANCE AND INSPECTIONS

- Establish an inspection schedule and inspect all structures a minimum of once every three years.
- Inspect beneath the rip-rap and around the outlet for scour. Immediately repair damaged slopes or underlying geotextile filter fabric with priorities based on highway safety and protection of Class AA and Class 1 waters, followed by erosion potential and possible damage to down-slope areas.
- Inspect apron for damage to underlying geotextile filter fabric or dislodged rip-rap. Report any damage exceeding 10% of the apron surface area for evaluation by the HWY-OM Engineer or Highway Design Section, as appropriate.

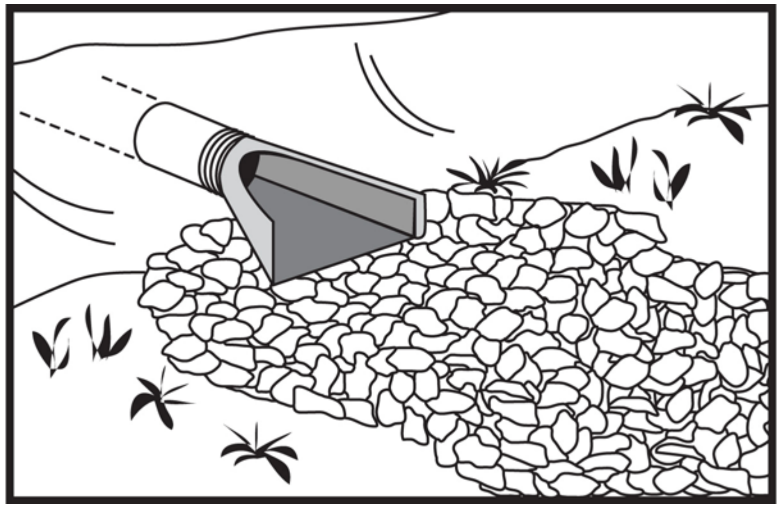
LIMITATIONS

- Potential for stones to wash away.
- Break up of grouted riprap resulting from hydrostatic pressure caused by water accumulation.

FLARED CULVERT END SECTIONS

DESCRIPTION AND PURPOSE

Flared culvert end sections are devices placed at the inlet or outlet of pipes and channels to enhance hydraulic operation while minimizing scour and erosion.



APPLICATIONS

Flared culvert end sections may be placed at inlets and outlets of slope drains and culverts.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

- Construct on level ground where possible.
- Supplement with other outlet protection.
- Protect the transition to the flared end section at inlets to prevent scouring.
- Obtain guidance from the District Maintenance Engineer or Highways Division's Hydraulic Section and refer to Highways Division's Standard Plans.

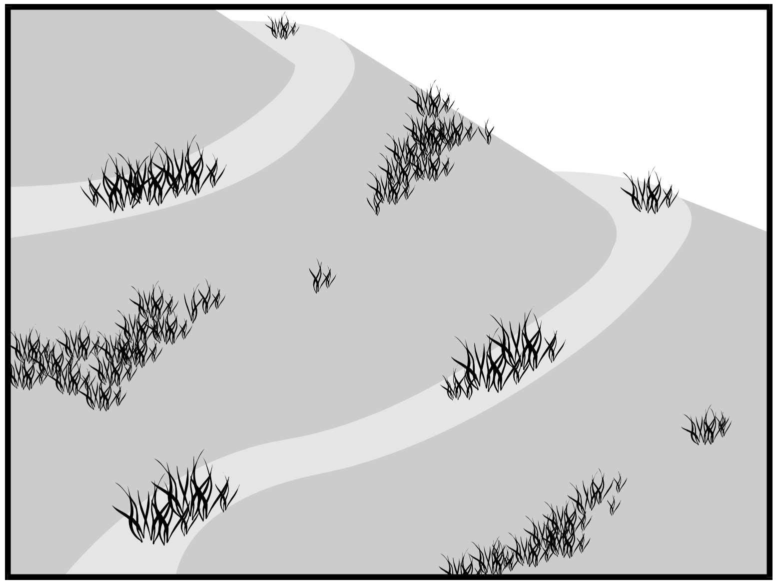
MAINTENANCE AND INSPECTIONS

- Establish an inspection schedule and conduct inspections a minimum of once every three years.
- Monitor accumulation of debris and sediment and remove within 60 days of notification. Immediately clean culverts located where Class AA or Class 1 waters or highway safety may be adversely affected. Refer to HAR Chapter 11-54 for State waters classification.
- Inspect around and beneath flared end sections for scour. Report any scour exceeding 10% of the flared end section area for evaluation by the HWY-OM Engineer or Highway Design Section, as appropriate.
- Establish a repair schedule with priorities based on highway safety and protection of Class AA and Class 1 waters, followed by erosion potential and possible damage to down-slope areas.

LIMITATIONS

- Limited use as an erosion control measure since primarily used to increase hydraulic efficiency.

SLOPE ROUGHENING, TERRACING, AND ROUNDING



DESCRIPTION AND PURPOSE

Methods of slope grading such as slope roughening, terracing, and rounding reduce potential erosion by decreasing runoff velocities, trapping sediment, shortening slope length, and increasing infiltration into the soil.

APPLICATIONS

Slope roughening, terracing, and rounding applies to the following:

- Areas where seeding, planting, and mulching erosion control measures may be enhanced by roughening of the soil surface.
- Graded areas with smooth, hard surfaces.
- Areas requiring terracing to shorten the slope length.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

CUT SLOPE ROUGHENING

- Cut slopes steeper than 3:1 (H:V) shall use stair-step grading or furrows.
- Use stair-step grading on soft soils that may be ripped by a bulldozer. Stair-step grading is particularly suitable for slopes consisting of soft rock with some subsoil.
- The vertical cut distance shall be less than the horizontal distance. The "step" shall drain towards the slope.
- Avoid individual vertical cuts greater than 24 inches high in soft materials or greater than 36 inches high in rocky materials.
- Create ridges and depressions along the slope contours using machinery.

FILL SLOPE ROUGHENING

- Fill slopes steeper than 3:1 (H:V) shall be placed in lifts not exceeding 8 inches. Each lift shall be properly compacted.
- Slope faces shall consist of 4 to 6 inches of loose and uncompacted soil.
- Grooving or tracking shall be used to roughen slope faces as necessary.

- Apply seed, fertilizer, and mulch. Track or punch in the mulch. Refer to Mulching and Seeding and Planting in this manual for additional information.
- The final slope face shall not be bladed or scraped.

CUTS, FILLS, AND GRADED AREAS

- Slopes that will be maintained by mowing shall be no steeper than 3:1 (H:V).
- Create shallow grooves by normal tilling, disking, harrowing, or use of a cultivator-seeder. Final pass of tillage shall be along the contour. Spacing between grooves shall be 10 inches or less. Groove depth shall be a minimum of 1 inch.

ROUGHENING WITH TRACKED MACHINERY

- Roughening with tracked machinery is only applicable to soils with a sandy texture. Other types of soil may be over-compacted by tracked machinery.
- Leave horizontal depressions in the soil by operating tracked machinery up and down the slope. During the final grading operation, do not back blade.
- Roughened areas shall be seeded and mulched for optimum seed germination and growth.

TERRACING

- Slope grades of 4:1 (H:V) shall include terraces or benches when slope heights exceed 30 feet. Steeper slope or highly erosive soil conditions may warrant terraces or benches for slope heights of 15 feet or higher.
- Runoff collected along terraces and benches shall be routed to lined diversion ditches. Install lined diversion ditches at the intersection of the terrace and slope.

ROUNDING

- All slopes shall be rounded with no sharp breaks in plan or profile.

MAINTENANCE AND INSPECTIONS

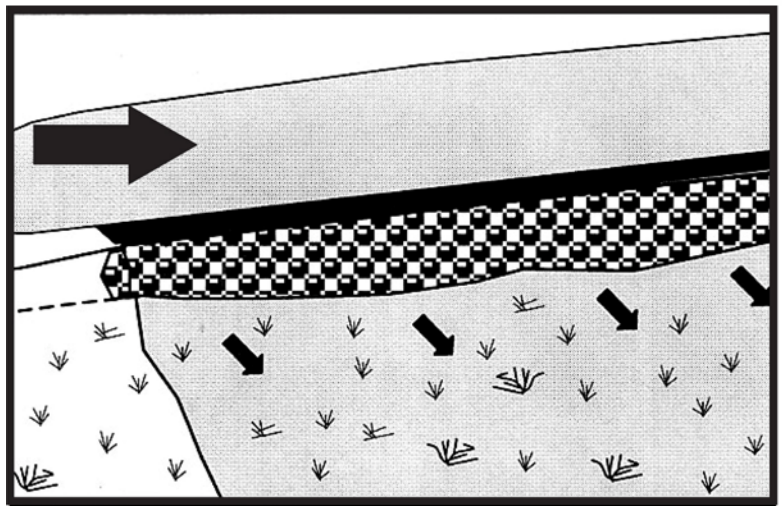
- Inspect slopes after storm events of more than one inch of rain in the area.
- Inspect seeded and planted slopes for rills and gullies.

LIMITATIONS

- Since terracing is permanent, design and approval shall be under the direction of a licensed, qualified engineer.
- Design of terraces shall provide adequate drainage and stabilized outlets.
- Roughening may result in increased grading costs and sloughing in soil.
- Stair-step grading may not be applicable to sandy, steep, or shallow soils.
- During intense rainfall events, roughening may not be an effective temporary erosion control measure.

LEVEL SPREADER

DESCRIPTION AND PURPOSE



Level spreaders are devices used at outlets that convert concentrated flow to sheet flow preventing erosion of the receiving area. Tops of channels, earthen berms, or rigid weir-like structures may function as level spreaders.

APPLICATIONS

Level spreaders may be used for the following:

- Flat or gentle sloping areas.
- Oulets for dikes and diversions.

INSTALLATION AND IMPLEMENTATION REQUIREMENTS

- Construct on undisturbed soil.
- Do not construct on fill material.
- Locate where re-concentration of water will not occur.
- A stabilized and well vegetated slope of less than 10% shall be located below the level spreader.
- Filter runoff containing high sediment loads through a sediment-trapping device prior to release to the level spreader.
- Incorporate a rigid outlet lip design for high discharge flows.
- Zero percent grade on the spreader lip is necessary for uniform sheetflow.
- Avoid operating vehicles and heavy equipment on the level spreader to maintain a smooth level surface for the overflow weir.

MAINTENANCE AND INSPECTIONS

- Conduct inspections of the level spreaders prior to the rainy season and after rain events exceeding the design storm intensity (25 year recurrence interval, 1 hour duration, unless otherwise directed).
- Inspect level spreader channel for accumulation of debris and sediment regularly and remove debris and sediment.
- Verify a slope of zero percent along the spreader lip.

- Inspect the discharge area for signs of erosion or concentrated flow.

LIMITATIONS

- Not applicable to sediment laden runoff.

CHAPTER 8:
INSPECTION, MAINTENANCE, AND RECORD KEEPING

The permanent BMPs are designed to reduce pollutant loadings into receiving waters. To ensure that the performance of BMP meets the design criteria and they serve the intended purpose, the following activities are essential:

- Regular site inspections;
- Acceptance of final BMP construction & As-built certification;
- Proper BMP maintenance; and
- Good record keeping.

8.1 Site Inspection During Construction

Regular inspections shall be conducted and documented at the stages listed in the following subsections:

8.1.1 Vegetative Swales

- During excavation to subgrade;
- During placement and backfill of under drain systems for dry swales; and
- Upon completion of final grading and establishment of permanent stabilization.

8.1.2 Infiltration Facilities

Infiltration Trenches

- During excavation to subgrade;
- During placement and backfill of underdrain systems and observation wells;
- During placement of geotextiles and all filter media; and
- During construction of appurtenant conveyance systems such as diversion structures, pre-filters and filters, inlets, outlets, and flow distribution structures.

Infiltration Basins

- At the stages specified for pond construction in the pond description portion of this section and during placement and backfill of underdrain systems.

8.1.3 Storm Water Wetlands

- At the stages specified for pond construction in the pond description portion of this section;
- During and after wetland reservoir area planting; and
- During the second growing season to verify a vegetation survival rate of at least 50 percent.

8.1.4 Storm Water Ponds

- Upon completion of excavation to sub-foundation and when required, installation of structural supports or reinforcement for structures, including but not limited to:

    - Core trenches for structural embankments,
    - Inlet and outlet structures, anti-seep collars or diaphragms, and watertight connectors on pipes, and
    - Trenches for enclosed storm drainage facilities;
- During placement of structural fill, concrete, and installation of piping and catch basins;
- During backfill of foundations and trenches;
- During embankment construction; and
- Upon completion of final grading and establishment of permanent stabilization.

8.1.5 Filtering Systems

- During excavation to subgrade;
- During placement and backfill of underdrain systems;
- During placement of geotextiles and all filter media;
- During construction of appurtenant conveyance systems such as flow diversion structures, pre-filters and filters, inlets, outlets, orifices, and flow distribution structures; and
- Upon completion of final grading and establishment of permanent stabilization.

8.1.6 Proprietary "Hydrodynamic" Type BMPs

- During excavation to subgrade;
- During placement and backfill of underdrain systems;
- During placement of geotextiles and all filter media;
- During construction of appurtenant conveyance systems such as flow diversion structures, pre-filters and filters, inlets, outlets, orifices, and flow distribution structures;
- Other critical stages as per manufacturer's recommendations; and
- Upon completion of final grading and establishment of permanent stabilization.

8.2 As-Built Certification & Acceptance of Permanent BMPs

Once construction is complete, as-built plan certification shall be submitted to HDOT-HWYS by either a registered professional engineer or professional land surveyor licensed in the State of Hawaii to ensure that constructed BMPs and associated conveyance systems comply with the specifications contained in the approved plans. At a minimum, as-built plan certification shall include a set of drawings comparing the approved permanent BMPs plan with what was constructed. HDOT-HWYS may require additional information.

8.3 BMP Inspections After Construction

Permanent BMPs are to be inspected at least once a year and within fourteen (14) days after each storm event that produces one inch or more precipitation. Inspections after a storm event provide an evaluation of the effectiveness of the BMPs and early detection of potential damages as a result of the storm. The after-storm inspection also aid in identifying maintenance activities needed. The result of the inspection and evaluation must be written in the latest inspection form as provided by HDOT-HWYS. If deficiencies are observed during the inspections, follow-up procedures must be performed to ensure that the required repair, maintenance, or modification activity is completed in a timely manner.

8.4 BMP Maintenance

General maintenance tasks that are to be performed periodically, as specified in the BMP description or determined by site inspection include the following:

- Removal of the sediment and debris;
- Removal of grease and oil;
- Replacement or repair of worn or damaged geotextile fabrics;
- Reseeding or replanting of damaged vegetated areas;
- Re-mulching of damaged stabilized areas; and
- Replacement or repair of damaged flow control structure or devices.

Specific maintenance tasks are identified in the Chapter 7 of this manual for each BMP description. Maintenance related to a storm event must be completed within 14 days of the inspection.

A maintenance schedule shall be developed for the life of the permanent BMP facility and shall state the maintenance to be completed, the time period for completion, and who shall perform the maintenance. This maintenance schedule shall be printed on the approved permanent BMP plan.

8.5 Record Keeping

Records of all inspections and follow-up activities for deficiencies in the conditions of the BMPs are to be retained for a minimum of five years. This record information can be used to improve the BMP performance for future applications. In addition to the inspection form, records of maintenance activities shall also be kept. These records are to indicate specific maintenance activities that have been completed, record observations of maintenance personnel, and provide useful information regarding future maintenance requirements for a particular BMP. It is HDOT-HWYS goal to develop and implement a system to compile a database of permanent BMPs. The database will include the BMP type and location, as well as all inspection and maintenance records. The database will be made part of the HDOT-HWYS' storm water asset management system.

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