Storm Water Permanent Best Management Practices Manual

PROTECT OUR WATER

MĀLAMA I KA WAI

STATE OF HAWAII DEPARTMENT OF TRANSPORTATION

www.stormwaterhawaii.com

Hawaii State Department of Transportation
Highways Division
Storm Water Management Program
NPDES Permit No. HI S000001
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Effective: October 27, 2015

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ACRONYMS AND ABBREVIATIONS

BMPs	Best Management Practices
DOT-HWYS	State of Hawaii Department of Transportation, Highways Division
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
HWY-DE	DOT-HWYS Division, Design Branch, Environmental Permitting and Compliance Section
HWY-DH	DOT-HWYS Division, Design Branch, Hydraulic Design Section
HWY-P	DOT-HWYS Division, Planning Branch
LID	Low Impact Development
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
SWMP	DOT-HWYS' Storm Water Management Plan
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

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'. A permanent BMP shall be maintained in its perpetuity unless the original purpose of the project no longer exists.

CONTRACT PROJECT – A construction project, which is designed either by DOT-HWYS' personnel or by an engineering consultant firm 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.

DISTURBED AREA / DISTURBANCE OF LAND – The penetration, turning, or moving of soil or resurfacing of pavement with exposure of the base course or the exposure of bare soil or ground surface; including the land surface exposed by construction roads, baseyards, staging areas, demolition, headquarters, and parking areas. It includes "grubbing" in its normal meaning of the use of equipment to knock down and push vegetation out of the way, typically uprooting vegetation and disturbing the ground surface. It does not include grass or weed cutting, bush or tree trimming or felling that leaves soil or ground intact.

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-DOT-HWYS entity (i.e. third party) within the DOT-HWYS' right-of-way and requires the issuance by DOT-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.

GRUBBING – The use of equipment to knock down and push vegetation out of the way, typically uprooting vegetation and disturbing the ground surface.

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 DOT-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 DOT-HWYS's right-of-way in a sheet flow fashion.

LOW IMPACT DEVELOPMENT (LID) –A comprehensive land planning and engineering design approach with a goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds.

PERMANENT BMP – A specific practice intended to reduce storm water volume and/or the pollution typically associated with storm water runoff. Such practices may include LID design features, source control methods, or manufactured devices designed to capture pollutants.

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.

PROPRIETARY BMP – A commercially available pre-manufactured or partially manufactured permanent BMP that treats water through filtration or settling methods. Such examples include catch basin inserts, water quality inlets, oil-grit separators, and hydrodynamic devices

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.

SOURCE CONTROL BMP – Appropriate operational or structural measures that prevent or reduce pollutants from entering storm water. Examples of operational source control BMPs include good housekeeping practices, spill prevention, and employee training. Structural source control BMPs consist of enclosures or roofs for working areas where pollutants are present or installing devices that direct contaminated storm water to appropriate treatment BMPs.

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.

WATERS OF THE STATE [ALTERNATIVELY, STATE WATERS] – All waters, fresh, brackish, or salt, around and within the State, including, but not limited to, coastal waters, streams, rivers, drainage ditches, ponds, reservoirs, canals, ground waters, and lakes.

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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1. ENVIRONMENTAL BACKGROUND AND INTRODUCTION

1.1 ENVIRONMENTAL BACKGROUND

Urban development continues to have a profound impact on the quality of Hawaii's state waters. Development, which adds impervious area to watersheds, prevents storm water absorption and creates obstacles in the traditional hydrologic cycle. Storm water runoff generated from impervious areas may carry surface pollutants into Hawaii's state waters and affect natural habitats. With a shift in philosophy, minimizing impervious area and maximizing areas where storm water runoff can infiltrate, evapotranspire, or be reused will provide direct benefits to not only fresh water resources, but also localized and downstream habitats.

Creative use of Permanent Best Management Practices (BMPs) which address storm water runoff volume and quality will be beneficial in keeping Hawaii's state waters clean and help reduce the negative effects of urban development. Permanent BMPs can be activities, prohibitions, procedures, or design projects which provide a positive impact on water quality or reduce storm water runoff from a site.

1.2 INTRODUCTION TO THIS MANUAL

The State of Hawaii Department of Transportation, Highways Division, Oahu District (DOT-HWYS) operates a Municipal Separate Storm Sewer System (hereinafter referred to as the "MS4") on the Island of Oahu. The operation and discharge of the MS4 is authorized and governed by DOT-HWYS' National Pollutant Discharge Elimination System (NPDES) Permit No. HI S000001 (hereinafter referred to as "MS4 Permit"), which became effective on October 28, 2013.

To fulfill the MS4 Permit requirements and to address storm water pollution associated with highway runoff, DOT-HWYS implements Permanent BMP criteria that apply to the applicable new developments and 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 DOT-HWYS project development, including planning, design, construction, and maintenance.

This updated DOT-HWYS Permanent BMP Manual was created to comply with Part D.1.e. of the MS4 Permit, which requires the inclusion and prioritization of Low Impact Development (LID) practices. LID is a subset of Permanent BMPs where project planning and design focus on maintaining and enhancing pre-development hydrology during development. This version, revised April 2015 supersedes the March 2007 Permanent BMP Manual and is effective on October 27, 2015. Future revisions to this manual will be released through the Annual Report and on the DOT-HWYS storm water website located at the address www.stormwaterhawaii.com. Always consult with DOT-HWYS to ensure that you are incorporating the latest revisions to this manual.

This manual focuses on Permanent BMPs that are most relevant to DOT-HWYS projects, which are typically space-limited to construction within a narrow right-of-way. However, as industry changes and new BMPs are developed, designers should consider new and creative alternatives

and consult with DOT-HWYS on the applicability of such alternatives. Furthermore, for encroachment projects and projects that require a connection permit to the MS4, as long as safety requirements are met, LID permanent BMPs (when applicable), in addition to those covered in this manual may be appropriate (see Chapter 2.3.1 and 2.3.2 for more information on these projects). Examples of BMPs that are not covered in this manual because they are not typically applicable to DOT-HWYS projects include:

- Permeable Pavement and Interlocking Pavers- permeable pavement has been tested by DOT-HWYS lab personnel, but has not been approved for State road surfaces. However, it may be appropriate for use in encroachment projects adjacent to State Routes or projects connecting to the DOT MS4 in order to fulfill PBMP requirements when applicable (see Chapter 6 regarding Treatment Volumes).

- Vegetated Roofs- there are few situations where a vegetated roof would be appropriate for DOT-HWYS structures. However, this solution provides many benefits to a project with roofed structures including a reduction in storm water runoff.

- Dry Wells- utilizing dry wells for treating rooftop storm water runoff is an effective technique. However, in situations where runoff has the potential for high pollutant concentrations, dry wells are not recommended as these pollutants have the potential to reach ground water aquifers.

- Underground Storage- storing storm water as a resource to be used in non-potable applications (e.g. toilets, landscaping) is a good practice with many benefits, but as with dry wells, it is not recommended for projects that receive runoff from industrial facilities.

- Minimal Excavation Foundations- usually used for residential and commercial structures no higher than three stories, no standards currently exist for incorporating this technique into highway structure design.

The remaining BMPs included in this manual provide many viable options for storm water management on DOT-HWYS projects.

2. APPLICABILITY

2.1 SCOPE

All contract construction and in-house and/or encroachment projects that do not qualify for exemptions are subject to DOT-HWYS review to determine if storm water permanent BMPs are required. If applicable according to the criteria set forth herein, the permanent BMPs and measures shall be designed consistent with this manual and constructed according to the project plans approved by DOT-HWYS.

2.2 CRITERIA

The criteria contained herein becomes effective on October 27, 2015.

2.2.1 Unified Criteria

All non-exempt projects (new development or redevelopment) that disturb an area of one (1) acre or more of land are required to be reviewed for storm water controls.

Smaller projects, less than one (1) acre, that have the potential to discharge pollutants to the MS4 may be required to install specific BMPs (see Section 2.3.3 for qualifiers of such smaller projects) at the direction and discretion of DOT-HWYS.

All non-exempt projects (new development or redevelopment) are required to install LID BMP(s) for storm water management if they generate equal to or greater than one (1) acre of new permanent impervious surface. Some projects may qualify for exemptions or variances from this requirement to install LID BMP(s). Projects that qualify for variances from LID may install alternative permanent BMPs approved by DOT-HWYS.

The required permanent BMP(s) 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 volume and/or the pollution created by storm water runoff and shall be selected based on their ability to target pollutants of concern in the project's watershed, particularly those causing water body impairment. Typical pollutants contained in the storm water runoff may include, but are not limited to: phosphorus, nitrogen, sediment, heavy metals, oil, and grease. Unlike temporary construction activity BMPs, permanent BMPs are designed to provide long-term storm water treatment for the completed project and associated site improvements.

The type and size of the permanent BMPs are 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.

2.3 APPLICABLE PROJECTS (STATEWIDE)

2.3.1 Projects within DOT-HWYS's Rights-of-way

- Contract Projects – A construction project, which is designed either by DOT-HWYS' personnel or by an engineering consultant firm and is constructed by a private contractor; and
- Encroachment Projects – A construction project undertaken by a non DOT-HWYS entity (i.e., a third party) within the DOT HWYS' right-of-way and requires issuance by DOT-HWYS of a Permit to Perform Work Upon State Highways.

2.3.2 New Projects Requiring a Connection (to DOT's MS4) Permit

New projects outside of DOT-HWYS' right-of-way that produce storm water runoff that will drain to the MS4 through an authorized connection permit are subject to the unified criteria. Specifically, DOT-HWYS administers a permitting program for any business (industrial or commercial), agency, or project that wishes to establish a permanent connection to the MS4 and release storm water runoff via the MS4. Any new development or redevelopment project that applies for a permit will be subject to this criteria.

2.3.3 Specific Projects with Potential to Discharge Pollutants to the MS4

Retail gasoline outlets, carwashes, automotive repair shops, restaurants, and parking lots with at least 10,000 square feet of total impervious area, will at the minimum apply Source Control BMPs. Such projects that exceed the size of one (1) acre of new impervious area will apply LID BMPs in accordance with the unified criteria.

In addition, any project that DOT-HWYS determines may have the potential to pollute the MS4 through its future industrial or commercial activities may also require BMPs. Furthermore, such 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 DOT-HWYS and may include DOT-HWYS 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 STORM WATER CONTROL DESIGN CHECKLIST TOOL

Prior to commencement of the detailed engineering design of non-exempt Contract Projects, the design consultant or DOT-HWYS project manager shall complete the Storm Water Control Design Checklist Tool (see Figure 2-1).

The Design Checklist Tool shall also be completed by all non-exempt encroachment or connection permit project applicants to the relevant DOT-HWYS district.

STORM WATER CONTROL DESIGN CHECKLIST TOOL

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 and are not a retail gasoline outlet, auto repair shop, restaurant, parking lot with at least 10,000 square feet of total impervious surface area
☐	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 water quality controls

Water Quality Control:

Water quality volume required: _____ cubic feet

Water quality volume provided by LID: _____ cubic feet

Type of BMP used: _____

*** In the event that water quality volume cannot be treated via LID alone for safety concerns, hydrogeological constraints, physical constraints, or operational constraints alternate approved treatment BMPs will be used**

**** For new gasoline outlets, auto repair shops, restaurants, and parking lots, all with at least 10,000 square feet of total impervious surface area, consider LID and apply Source Control BMPs**

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 Treatment used: _____

Description: _____

Signatory:

Figure 2-1. Storm Water Design Checklist Tool

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3. EXEMPTIONS AND VARIANCES

3.1 EXEMPTIONS

Exemptions may be granted for certain types of projects including operations that conduct routine and emergency maintenance, linear projects, and safety, environmental, and public enhancement projects.

3.1.1 Projects that are not Eligible for Exemptions

The following project types are not eligible for exemptions from the requirements in this manual:

- New Roadway Corridors
- Roadway Realignment
- Roadway Widening
- New Commercial Facility Sites
- Specific project types listed in Section 2.3.3 of this manual

3.1.2 Exemptions

The following types of projects are exempt from the provisions contained in this manual:

- Projects that return an area to pre-development hydrologic conditions
- Projects that do not discharge into State waters
- Projects consisting of multiple unconnected areas that do not generate 1 acre or more of new impervious surfaces
- Operations and Maintenance Activities
    - Pavement Resurfacing, Restoration, Rehabilitation
    - Structural Repairs
    - Baseyard Repairs and Improvements
- Linear Projects
    - Guardrail and Shoulder Improvements
    - Utility Installation and Relocation
- Water Quality Improvement or Preservation
    - Shoreline Protection
    - Landscaping
    - Culvert Rehabilitation or Replacement
    - Permanent BMP projects
    - Erosion and Water Pollution Control
- Emergency
- Temporary Projects

3.2 VARIANCES FROM LID

Circumstances exist where a variance from LID requirements is granted by DOT-HWYS due to the impractical nature of attempting to meet the requirement. Specifically, instituting LID requirements could be physically impossible or unsafe. This variance from LID requirements does not nullify requirements to implement other permanent BMPs in accordance with DOT-HWYS standards. A project may be given a partial variance or full variance from LID requirements. In a partial variance, LID is required to the extent possible and other non-LID permanent BMPs will make up the balance of the Water Quality Design Volume (WQDV) (see Chapter 6 regarding the WQDV) once approved by DOT-HWYS. In a full variance scenario, non-LID permanent BMPs will be used to treat the full Water Quality Design Volume (WQDV) by DOT-HWYS.

The criteria for issuing variances is based on:

- Hydrogeological constraints—e.g., permeability; depth top groundwater; slope stability; structural impacts to buildings/roadbed (shown in Table 3-1)
- Physical constraints—e.g., space constraints; site slope; lack of right of way; contaminated subsoil (shown in Table 3-2)
- Operational constraints—e.g., Strength/loading requirements for pavement; no application for water reuse (shown in Table 3-3)
- Other constraints/Non-Applicability—e.g., no discharge to State Waters; multiple, dispersed project locations, projects that return area to pre-development runoff conditions (shown in Table 3-4)

To obtain a variance, designers must evaluate all LID BMP solutions for their project from the LID BMPs listed in Chapter 7 of this manual. If constraints listed in the following tables or a detail is listed in Chapter 7 eliminates all LID BMP solutions an alternative storm water control may be used. Designers will consult with DOT-HWYS citing the corresponding constraints and stating that all LID BMP solutions are not practical and propose alternative permanent BMPs. Failure to provide proper analysis of permanent BMPs for a site could result in delays to the approval of encroachment permits.

Table 3-1. Hydrogeological Constraints

Constraints	Safety Concern
Permeability	Soil under BMP basin invert does not allow for water to permeate less than 0.5 in/hr
Depth to Ground Water	BMP invert is closer than 3 ft depth to seasonally high groundwater table
Distance to Drinking Water	BMP is closer than 50 ft to nearest groundwater well for drinking
Distance to Septic System	BMP is closer than 35 ft to nearest septic system
Slope Stability	BMP and infiltration would destabilize slope or cause landslide
Structural Impacts to Buildings/Roadbed	BMP is close to the nearest building foundation or roadbed. Proximity is dependent on BMP type, but minimum is 10 feet distance
Sensitive Downstream Areas	Instituting BMPs would significantly affect downstream habitats

Table 3-2. Physical Constraints

Constraints	Safety Concern
Space Constraints	Instituting LID BMPs to MEP doesn't yield enough treatment for WQDV
Site Slope	Usable flat area doesn't yield enough treatment for WQDV
Lack of Right of Way	Project is closer than 10 ft to the nearest property line and no memorandum of understanding or joint ownership has been established
Contaminated Subsoil	Project is in the vicinity of industrial contamination
Sensitive Community Site	Excavation for BMP would permanently damage a community resource (e.g. wildlife refuge)
Sensitive Archeological Site	Excavation for BMP would result in disturbance of remains or artifacts

Table 3-3. Operational Constraints

Constraints	Safety Concern
Strength/Loading Requirements for Pavement	BMP is closer than 10 feet to pavement
No Application for Water Reuse	Landscaping or green roof is not an option due to space, energy systems, electrical, or mechanical systems
Hazardous Operations	Nature of site's permanent operations leave potential for mobilizing pollutants via proposed BMPs

Table 3-4. Other Constraints/Non-Applicability

Constraints/Non Applicability	Description
Legality	Implementing a BMP in the project would violate Federal or State Law

4. PERMANENT BMP CONSIDERATION IN PROJECT PLANNING AND DESIGN PHASE

4.1 INTRODUCTION

As DOT-HWYS implements a proactive SWMP and applies unified criteria for all new development and redevelopment projects, it is important for DOT-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 right-of-way needs and costs, potential community impacts, future maintenance costs, and design conflict. All of these factors may lead to incomplete design and project delays. As detailed in various chapters of this manual, DOT-HWYS 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 right-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. Furthermore, as highway settings are typically linear in nature, using some LID techniques may prove difficult. In some cases, using LID and non-LID to satisfy storm water control requirements may be necessary based on constraints.

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 it is 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 DOT-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 6 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 be 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:

Table of Contents

Executive Summary

Introduction

- Description of Project Area
- Location and Vicinity Maps

Design Checklist Tool

- Storm Water Design Checklist Tool

Outfall

- Location and Vicinity Maps
- Description of outfall condition and potential impact

Permanent BMP Description

- Description and intended treatment
- Description of environmental resources
- Regulatory requirements
- 30% Construction Plans with topographic map showing footprints of proposed Permanent BMP(s).
- Location of outfall(s) impacted by the drainage improvements
- Calculations of surface area and volume tabulation
- Right of Way requirements
- Maintenance requirements and cost
- Construction cost estimate

Appendix

- Applicable computations
- Existing and proposed drainage maps
- Photos

References

4.2.5 Review and Approval

The project planner/engineer shall submit the permanent BMP concept report and required information to DOT-HWYS 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 DOT-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 DOT-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 DOT-HWYS rights-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:

Table of Contents

Executive Summary

Introduction

- Description of Project Area
- Location and Vicinity Maps

Design Checklist Tool

- Storm Water Design Checklist Tool

Outfall

- Location and Vicinity Maps
- Description of outfall condition and potential impact

Permanent BMP Description

- Description and intended treatment
- Description of environmental resources
- Regulatory requirements
- 30% Construction Plans with topographic map showing footprints of proposed Permanent BMP(s).
- Location of outfall(s) impacted by the drainage improvements

- Calculations of surface area and volume tabulation
- Right of Way requirements
- Maintenance requirements and cost
- Construction cost estimate

Appendix

- Applicable computations
- Existing and proposed drainage maps
- Photos

References

4.3.3 Future Maintenance and Cost Considerations

Careful and deliberate consideration will be taken with regard to maintenance over the lifespan of the permanent BMP. BMPs that cannot be maintained will not fulfill the original designed treatment volume or designed treatment quality. Accessibility for maintenance personnel, equipment and method of maintenance are among the important considerations during the design process. Furthermore, realistic costs for maintaining the BMP shall also be considered by the designer. Finally, life-cycle and replacement costs shall also be considered for the future of the project.

4.3.4 Review and Approval

Submittals for review and approval include the permanent BMP plans, design report, and other required information. The permanent BMP design shall be made part of the PS&E documents and follow the normal design review process.

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5. SELECTION OF THE QUANTITATVE CRITERIA

5.1 DOT-HWYS HYDRAULIC DESIGN CRITERIA

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 DOT-HWYS hydraulic criteria and standards related to storm water quantity. Follow the current DOT-HWYS Design Criteria for Highway Drainage published by the DOT-HWYS Hydraulic Design Section (HWY-DH). Information is constantly updated and can change periodically.

5.2 THE QUANTITATIVE CRITERIA

DOT-HWYS determined that a 1-inch storm correctly models the volume for permanent BMP treatment. This quantitative criteria is essential in designing and sizing BMPs adequate enough to enhance storm water runoff quality through infiltration, evapotranspiration, harvesting/reuse or other activities that treat and release storm water (for calculation details see Chapter 6). The City and County of Honolulu (CCH) conducted research and analysis of the 85th percentile values for 24-hour cumulative depths over 0.10 inches for the island of Oahu. The resulting research, presented in the CCH Standards Revision Plan (dated December 2011), demonstrated the 24-hour 85th percentile value of one (1) inch equaling or exceeding the total for 89% of the stations analyzed. Consequently, in 2013 DOT-HWYS conducted an independent study to confirm Oahu data and the rest of the counties in the State of Hawaii with 24-hour 85th percentile values for the purpose of storm water quantity control.

DOT-HWYS looked at all rainfall stations within a margin seven (7) miles to the left and right of State routes across all counties. Stations were primarily selected for having 35 years of recent continuous monitoring data. In some cases, stations did not have a complete 35 years of data, but were still useful in providing rainfall information. Through the analysis of these stations, no more than half of the stations in the State exceeded the one (1) inch value with most county averages at or close to the one (1) inch value. This information of averages is presented in Table 5-1. Appendix A of this manual graphically shows station locations analyzed.

Table 5-1. Summary of Statewide 85th Percentile Storm Averages

Island Name	No. of Stations Analyzed	Average From All Stations (in.)
Hawaii	107	1.101
Maui	45	1.059
Lanai	3	1.105
Moloka'i	8	0.989
Oahu	62	0.889
Kauai	38	0.939

It is noted that designers may attempt to exceed the one (1) inch value due to their existing site conditions, safety concerns, or other reasons.

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6. STORM WATER QUALITY BMP DESIGN

6.1 WATER QUALITY DESIGN VOLUME CRITERIA

The water quality design volume for treatment by permanent BMPs (LID and non-LID) is based on the 1" design storm discussed in Chapter 5:

WQDV = C x 1" x A x 3630

WQDV = water quality design volume in cubic feet
C = runoff coefficient (see section 6.2.2)
A = total drainage area in acres
3630 = conversion factor
1" represents the design storm depth

6.1.1 Objectives of Water Quality Design Volume

LID will be the primary treatment for projects that generate one (1) acre or more of impervious area. If a project is subject to a variance and LID cannot be used for some or all of the treatment volume required, the project shall use other permanent BMPs to treat the remaining WQDV such that the total WQDV required is treated by LID and non-LID methods. The purpose of the water quality design volume is to present a unified approach for sizing and selecting storm water permanent BMPs for the applicable projects as listed in Chapter 2 and 3 of this manual. The ultimate goal in this situation is to reduce the pollution associated with storm water runoff discharging into receiving waters to the MEP. The project's remaining volume of water untreated by LID will be treated with water quality as the objective since this water is likely to be discharged directly to State waters.

Since much of the MS4 and the CCH's MS4 are interconnected, it is DOT-HWYS intent to have similar standards for both systems.

6.1.2 Management Practices to Meet Criteria

The quality 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 and Consideration of Performance

These are minimum requirements. If DOT-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 of concern 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 when LID is not feasible is the same as the WQDV discussed in Section 6.1. In the event that LID is partially feasible, treat the untreated WQDV with alternate treatment methods approved by DOT-HWYS.

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:

$C = 0.05 + (0.009) \times (IMP)$
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 Table 6-1. Use the lower values presented in Table 6-2 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.

Table 6-1. 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**

Table 6-2. Values of Runoff Coefficients, C, for alternate conditions

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

See Section 6.2.2.

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.

6.3.3 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 = total drainage area 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 WQDV 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 gradual 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 LID Treatment Upstream of Detention or Flow-Through Based Treatment

LID treatment will be used as the preferred treatment method. In the event that LID practices cannot treat the complete WQDV, excess runoff shall flow to a downstream detention system of flow-through based treatment that is designed to capture and treat the remaining runoff volume. Specifically, the LID treatment will be used where ever possible and any remainder on-site runoff volume will be treated via detention or flow-through systems.

7. STORM WATER PERMANENT BMP OPTIONS

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

- LID Methods (e.g. Swales, Bioretention, Infiltration Trenches, Engineered Wetlands)
- Non-LID Methods (e.g. Filtration and Proprietary BMPs including "Hydrodynamic" type).

Selection of BMPs must be site specific and treat the WQDV. No single BMP can be applied to all scenarios. The designer should consider the benefits, pollutant removal efficiency, historical data from other installations, aesthetics, community acceptance, and the lifecycle cost, and maintenance factors. A summary of BMP limitations and factors to consider is provided in Table 7-1 to aid the project designer in selecting the most appropriate permanent BMPs. Regarding Non-LID methods, DOT-HWYS does not endorse any particular type of BMP and will review its application and performance on a case by case basis. It is the designer's responsibility to consult with manufacturer and obtain independent performance testing data to support the use of each device and demonstrate it will target the pollutants of concern. For this reason, Table 7-1 does not include any proprietary BMPs.

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Table 7-1. LID 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 DRAINAGE AREA)	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	

7.1 LID METHODS COVERED IN THIS MANUAL

VEGETATED SWALES
- Dry Swales
- Wet Swales

INFILTRATION FACILITIES
- Infiltration Trenches
- Infiltration Basins
- Bioretention

STORM WATER WETLANDS
- Shallow Wetland
- Pond Wetland
- Pocket Wetland

STORM WATER PONDS
- Extended-Detention Ponds
- Wet Ponds
- Pocket Ponds

Note that not all of the most current BMPs will be covered in this Manual. The most appropriate LID BMP may not be listed. Industry standards change and new unlisted BMPs may be proposed to DOT-HWYS for any given project.

7.1.1 Pretreatment

Pretreatment should be considered for all LID BMPs. Pretreatment extends the life and therefore the replacement frequency of LID BMPs. Sediment, whether it is clogging the media of a BMP or other components (e.g. in a reuse project), is one of the biggest reasons for premature failure of LID BMPs. Designers should plan for necessary space to accommodate pretreatment in the form of filters or sediment forebays along with the space that will be required for the main LID BMP. Designers can also consider utilizing proprietary BMPs to filter sediment or reduce flow velocities upstream of LID BMPs even if the LID BMPs alone are sufficient to treat the WQDV. Finally, utilizing pretreatment will add complexity to the long-term maintenance of the project site and should be planned for and documented in operations accordingly. See Appendix B regarding various techniques which may extend the life of LID BMPs or encourage maximum treatment of design volumes.

7.1.2 Preserving Existing Vegetation

Preserving existing vegetation is one of the strongest assets in project site development. Non-invasive or acceptable vegetation that is appropriate to the subclimate will, on the average, have a higher success in bio-remediating storm water. Emphasizing the preservation of existing vegetation will also reduce the amount of disturbed area and could be leveraged to prevent the need for instituting additional LID BMPs. More information on preserving existing vegetation is found in chapter 7.2.

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DRY SWALE

DESCRIPTION & PURPOSE

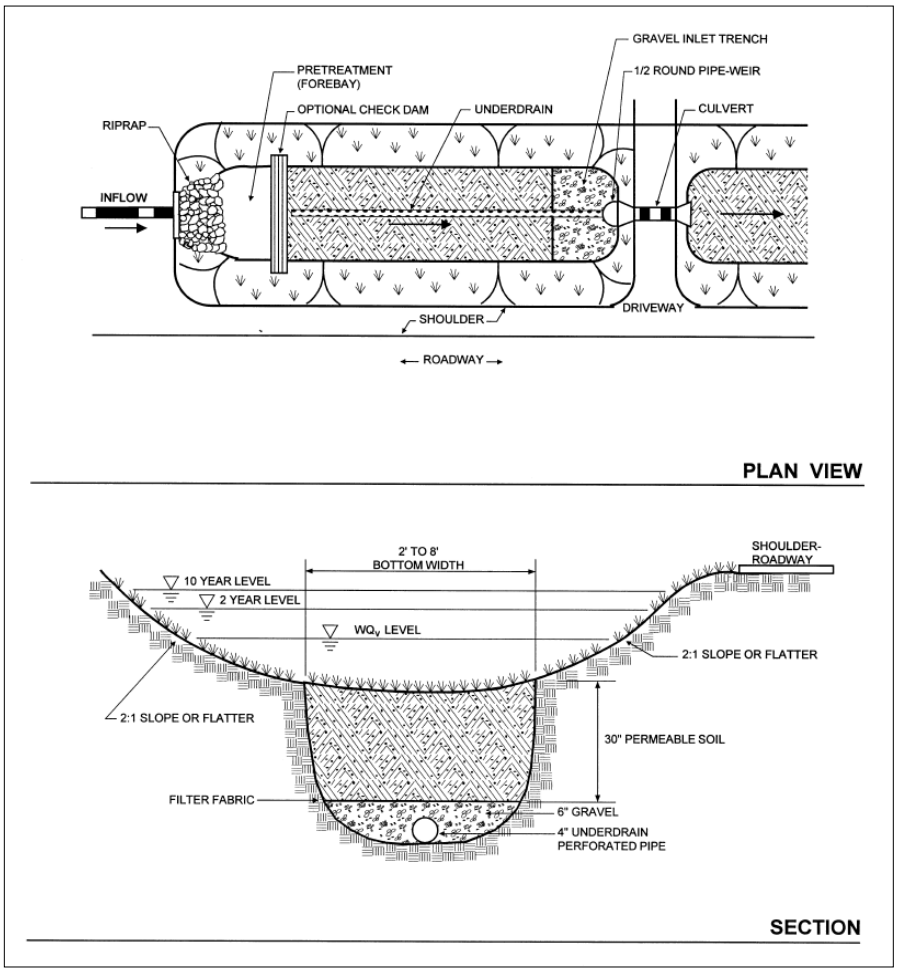
Swales are vegetated open channels that are designed to capture and treat the full water quality volume within dry or wet cells that are formed by check dams or other means.

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 inches per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- Longitudinal slopes shall be less than 4.0% to qualify for water quality volume treatment.
- Channels shall have moderate side slopes (flatter than 3:1) for most conditions and may NOT be steeper than 2:1.
- Peak velocity shall be non-erosive for the soil and vegetative cover provided.
- The maximum allowable ponding time shall be less than 48 hours, and the minimum ponding time shall be 30 minutes is recommended.
- A bottom width of no wider than 8 feet or a meandering drainage pattern shall be established.
- There should be a maximum ponding depth of one foot at the mid-point of the channel profile and a maximum depth of 18 inches at the downstream end of the channel.
- At the water quality flow rate, the swale width should be that which will have a flow depth of no greater than 4 inches and the hydraulic grade line is no greater than 2% between structures.
- The flow length in the swale should be a minimum of 100 feet.



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.
- 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

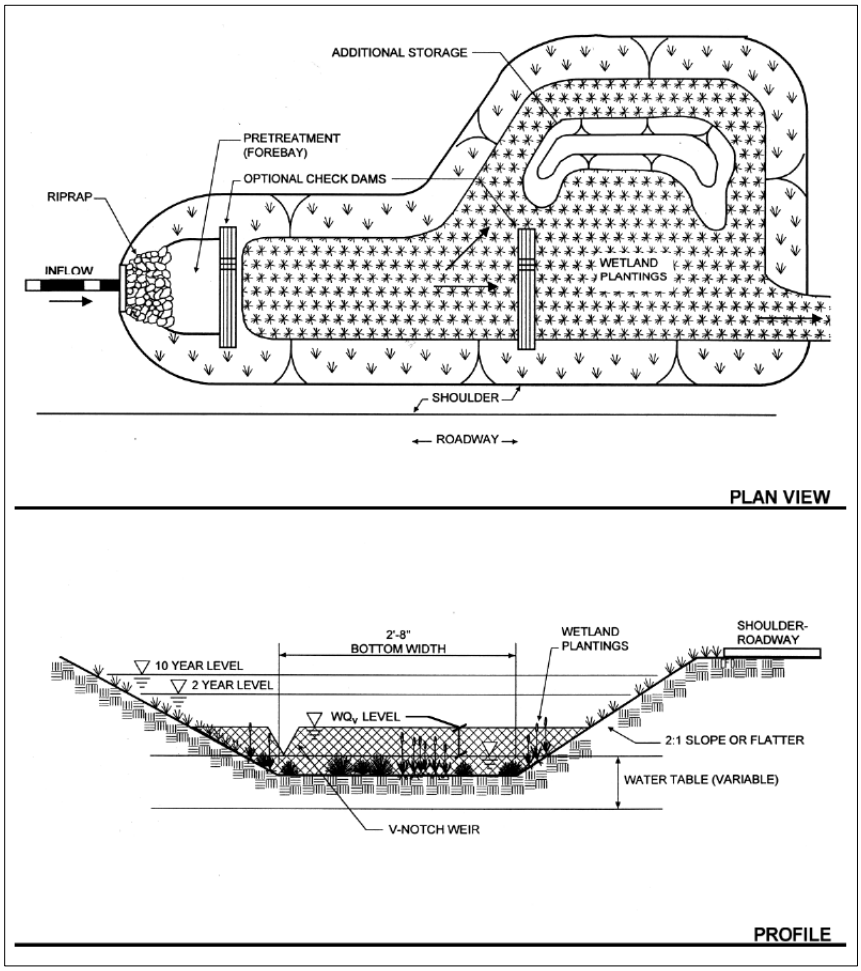
Swales are vegetated open channels that are designed to capture and treat the full water quality volume within dry or wet cells that are formed by check dams or other means.

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 inches per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- Longitudinal slopes shall be less than 4.0% to qualify for water quality volume treatment.
- Channels shall have moderate side slopes (flatter than 3:1) for most conditions and may NOT be steeper than 2:1.
- Peak velocity shall be non-erosive for the soil and vegetative cover provided.
- The maximum allowable ponding time shall be less than 48 hours, and the minimum ponding time shall be 30 minutes is recommended.
- A bottom width of no wider than 8 feet or a meandering drainage pattern shall be established.
- There should be a maximum ponding depth of one foot at the mid-point of the channel profile and a maximum depth of 18 inches at the downstream end of the channel.
- At the water quality flow rate, the swale width should be that which will have a flow depth of no greater than 4 inches and the hydraulic grade line is no greater than 2% between structures.
- The flow length in the swale should be a minimum of 100 feet.



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

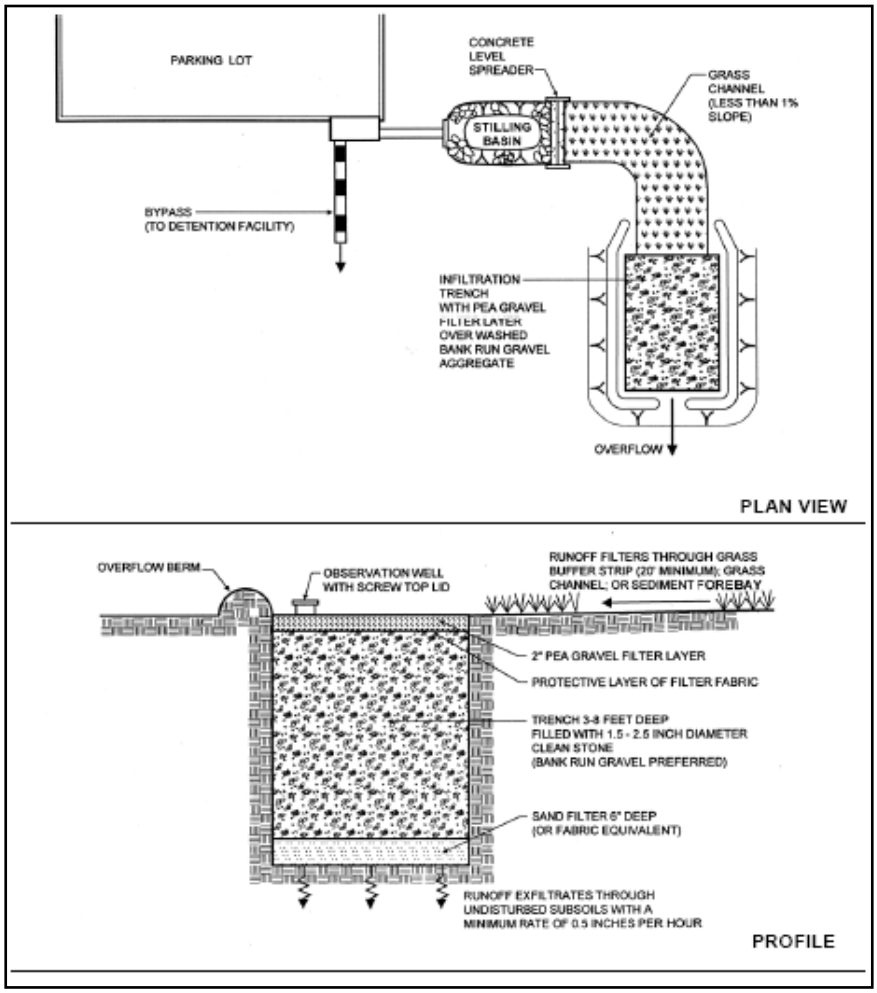
The infiltration trench provides recharge and water quality volume in one location.

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 inches per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- Groundwater shall be protected from possible contamination by avoiding potential storm water areas.
- The bottom of the facility shall be separated by at least 4’ (vertically) from the seasonally high water table or bedrock layer.
- Facilities shall be located at least 100 feet from any water supply well.
- Facilities shall have a maximum contributing area of five acres.
- The facility should not be placed in locations that cause water problems to downgrade properties and should be setback (25’) downgrade from structures
- All trenches shall be designed to fully de-water the entire water quality volume within 48 hours after the storm event.
- Adequate storm water outfalls shall be provided for the overflow associated with the ten-year design storm event.
- Since the trench will be located “off-line” from the main conveyance system, a flow splitter will be required to divert the water quality volume into the filter



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 inches 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.

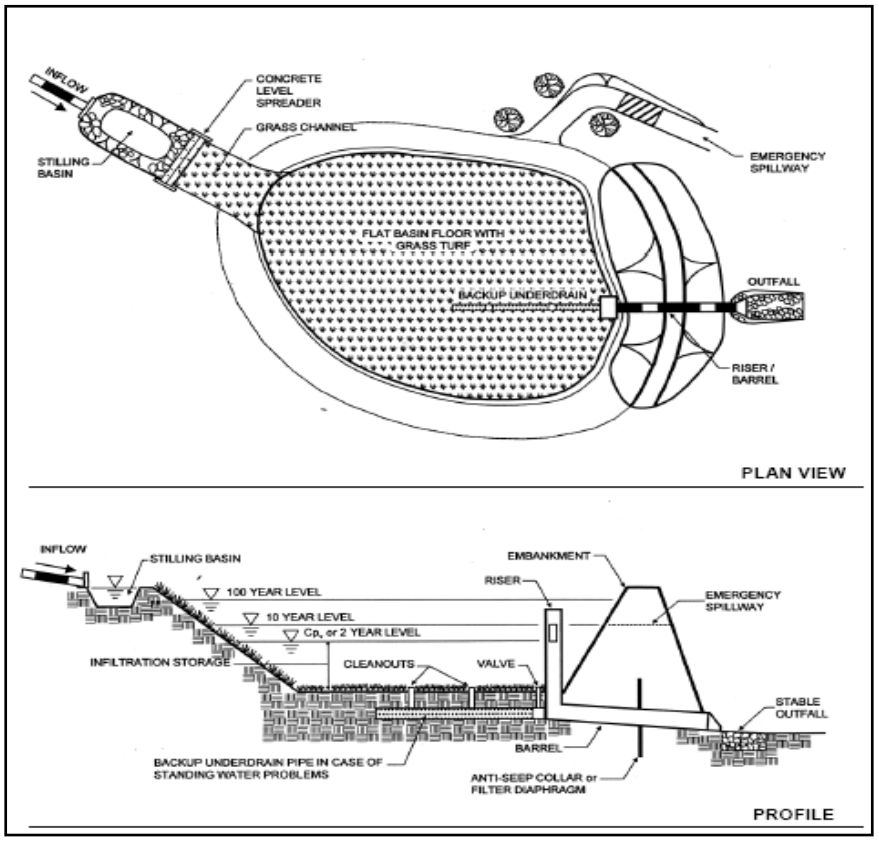
LIMITATIONS

- 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 inches per hour.
- WQFR: C*0.4”*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.

- Groundwater shall be protected from possible contamination by avoiding potential storm water areas.
- The bottom of the facility shall be separated by at least 4’ (vertically) from the seasonally high water table or bedrock layer.
- Facilities shall be located at least 100 feet from any water supply well.
- Facilities shall have a maximum contributing area of five acres.
- The facility should not be placed in locations that cause water problems to downgrade properties and should be setback 25’ downgrade from structures.
- All basins shall be designed to fully de-water the entire water quality volume within 48 hours after the storm event.
- Adequate storm water outfalls shall be provided for the overflow associated with the ten-year design storm event.



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 inches 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

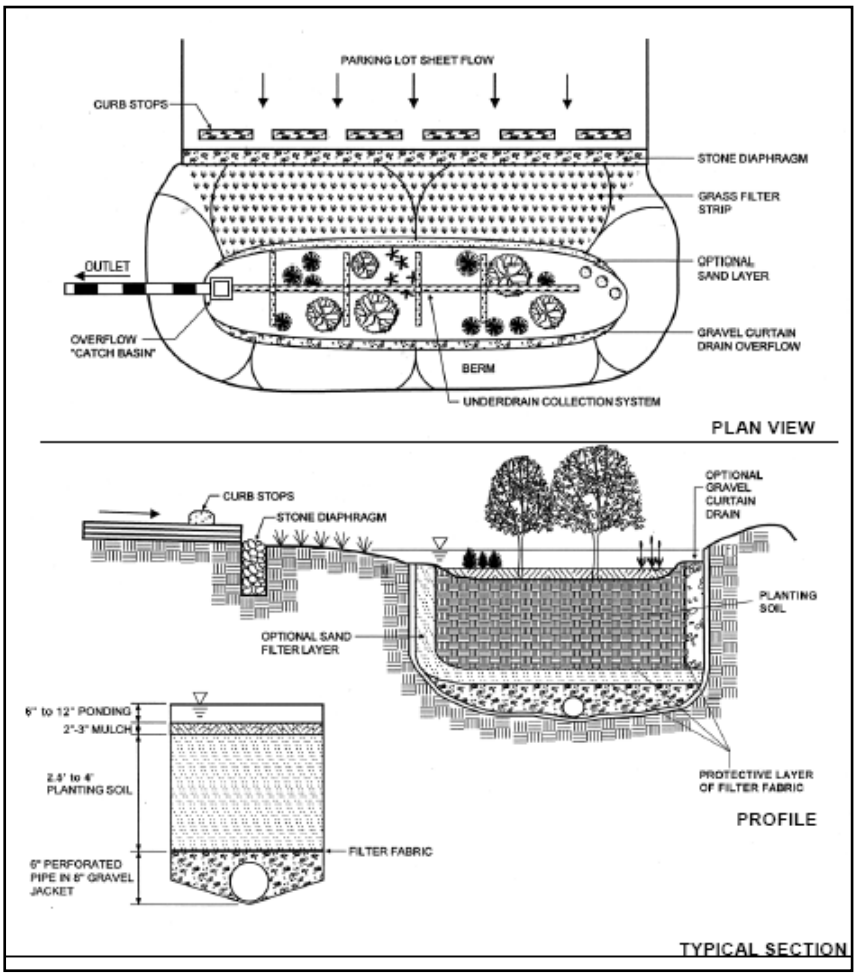
Bioretention combines open space with storm water treatment in vegetated areas where runoff is directed through vegetation and soils for filtration. It captures and temporarily stores the water quality volume and passes it through a filter bed of sand, organic matter, soil, or other media.

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



SOURCE: Maryland Department of the Environment 2000.

PRETREATMENT REQUIREMENTS

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

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.

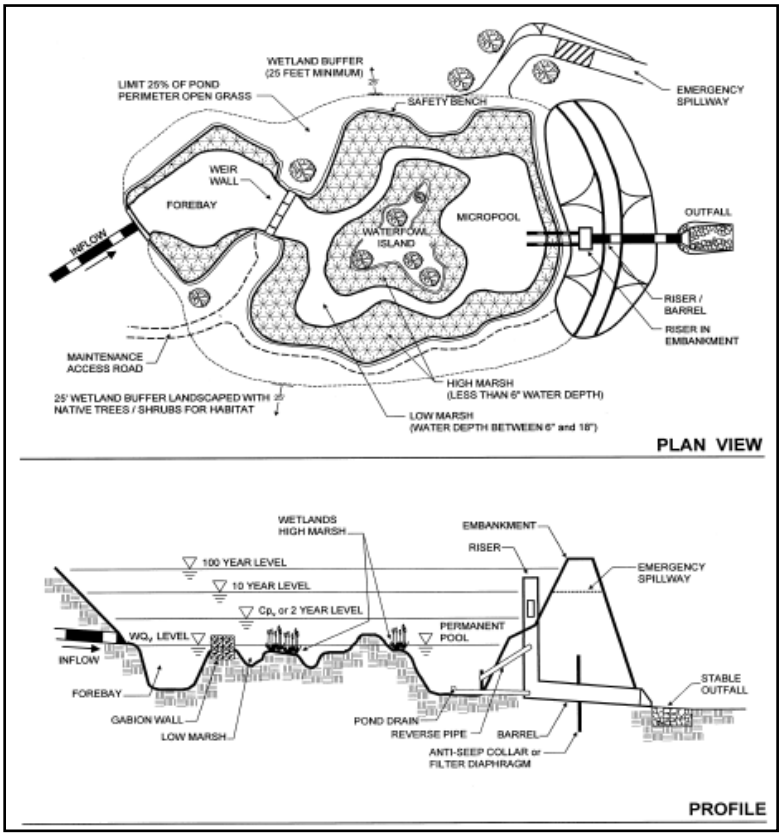
APPLICATIONS

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 inches is the 1-inch storm.
- A is the area of the site in acres.
- 3630 is a conversion factor.
- The volume must meet minimum detention times.
- Flowpaths from inflow points to outflow points within storm water wetlands shall be maximized.
- Flowpaths of 1.5:1 (L:W) and irregular shapes are recommended and achieved by constructing internal berms.
- Microtopography is encouraged to enhance diversity in the wetland.
- Surface area shall be at least 1.5 percent of the total drainage area to the facility.
- At least 25% of the total water quality volume shall be in deepwater zones with a minimum depth of four feet. This may be reduced if the wetland is located where thermal impacts area a primary concern.
- A minimum of 35% of the total surface area shall have a depth of 6 inches or less.
- At least 65% of the total surface area shall be shallower than 18 inches.
- If using extended detention, the extended detention volume shall not comprise more than 50% of the total wetland design. Maximum surface elevation shall not extend more than 3 feet above the normal pool.

- In order to promote greater nitrogen removal, rock beds may be used as a medium for growth of wetland plants. Rock should be 1-3 inches in diameter and placed up to the normal pool elevation. Rock beds should be open to flow-through from either direction.



SOURCE: Maryland Department of the Environment 2000.

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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POCKET WETLAND

DESCRIPTION & PURPOSE

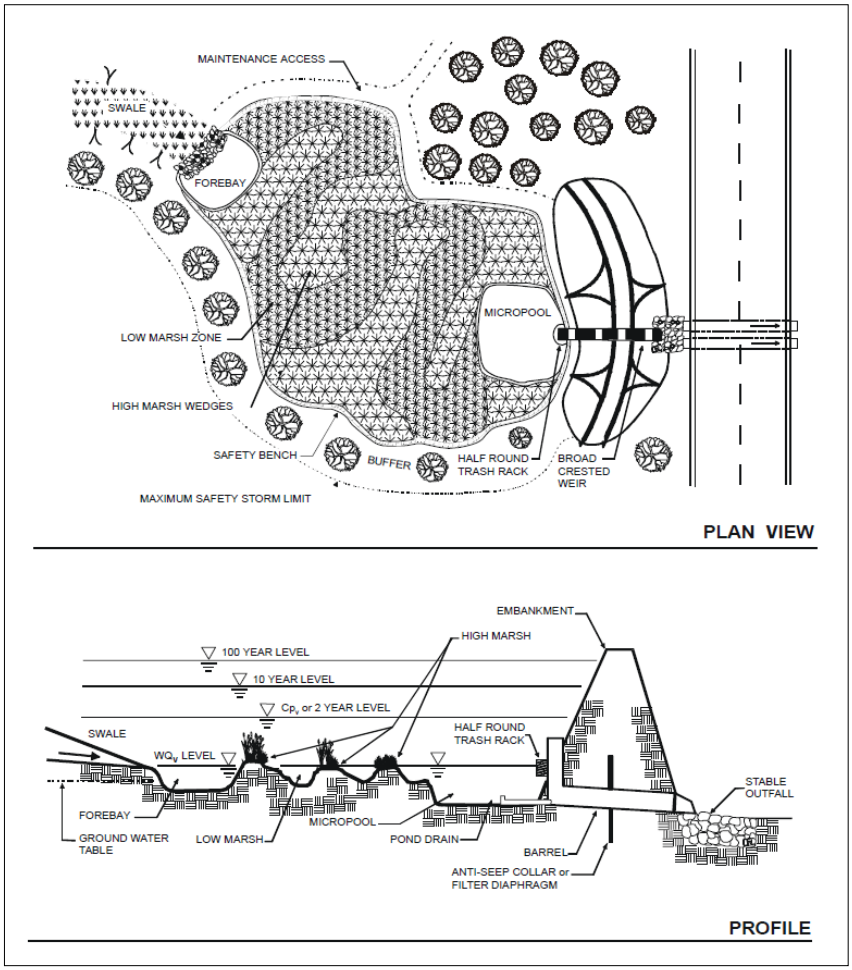
A high water table or groundwater interception helps maintain the shallow wetland pool in the pocket wetland.

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 inches is the 1-inch storm.
- A is the area of the site in acres.
- 3630 is a conversion factor.
- The volume must meet minimum detention times.
- Flowpaths from inflow points to outflow points within storm water wetlands shall be maximized.
- Flowpaths of 1.5:1 (L:W) and irregular shapes are recommended and achieved by constructing internal berms.
- Microtopography is encouraged to enhance diversity in the wetland.
- Surface area shall be at least one percent of the total drainage area to the facility.
- At least 25% of the total water quality volume shall be in deepwater zones with a minimum depth of four feet. This may be reduced if the wetland is located where thermal impacts area a primary concern.
- A minimum of 35% of the total surface area shall have a depth of 6 inches or less.
- At least 65% of the total surface area shall be shallower than 18 inches.
- If using extended detention, the extended detention volume shall not comprise more than 50% of the total wetland design. Maximum surface elevation shall not extend more than 3 feet above the normal pool.
- In order to promote greater nitrogen removal, rock beds may be used as a medium for growth of wetland plants. Rock should be 1-3 inches in diameter and placed up to the normal pool elevation. Rock beds should be open to flow-through from either direction.



SOURCE: Maryland Department of the Environment 2000.

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.

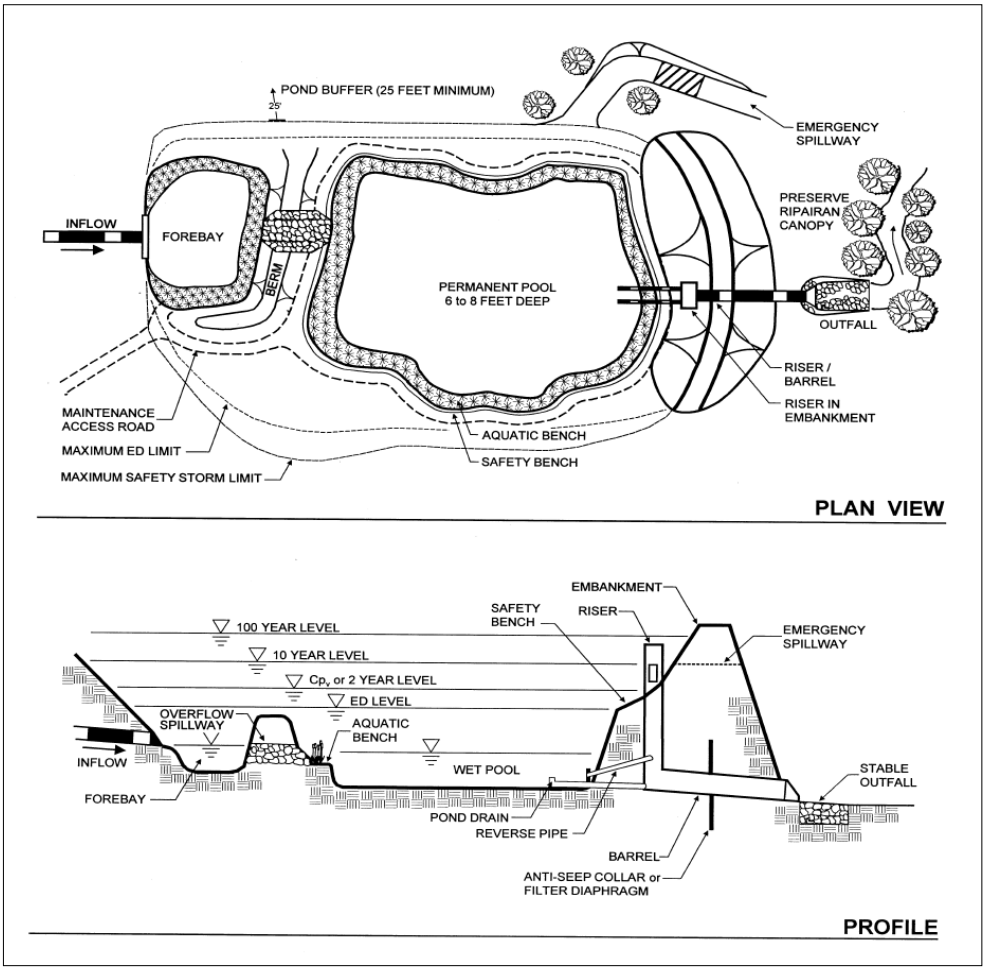
APPLICATIONS

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 inches is the 1-inch storm;
    - A is the area of the site in acres; and
    - 3630 is a conversion factor
- The volume must meet minimum detention times.
- The draw-down time for the detention volume shall be greater than or equal to 48 hours. For the bottom half of the detention volume, the draw-down time shall be greater than or equal to 36 hours.
- The detention system shall be designed to maximize the distance between the inlet and outlet, and to minimize “dead spaces” (areas with little or no exchange occurs during a storm event), limiting short-circuiting. A minimum flow path length to width ratio of 3 should be utilized.
- The outlet shall be sized to achieve the above required detention times. It shall also be large enough that clogging is unlikely to occur. It should be 4 inches or larger in diameter. If this is not possible, the use of flow-through based measures should be considered, unless it can be demonstrated that clogging can be avoided.
- There shall be a minimum contributing drainage area of ten acres or more unless groundwater ground water is the primary water source.
- The ten year design storm is to be used to design for a stable outfall.
- Dams shall meet class A dam safety hazard classification.
- The principal spillway/riser shall provide anti-floatation, anti-vortex, and trash-rack designs.

- One foot of freeboard shall be provided above the design high water for the 10 year storm.
- Woody vegetation is prohibited on the embankment.
- Pond benches:
    - The safety bench extends outward from the normal water edge to the toe of the pond side slope. Maximum slope=6%; and
    - Aquatic bench extends inward from the normal shoreline and has a maximum depth of 18 inches below normal pool water surface elevation. Not required in forebays.
- Pond buffers and setbacks:
    - Buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond and should be contiguous with other required buffer areas; and
    - Existing trees should be preserved during construction and forest conservation areas should be located.
- Non-clogging low flow orifice:
    - Shall have a minimum diameter of 3 inches and shall be adequately protected from clogging by an external trash rack;
    - Orifice diameter can be reduced to 1 inch if using an internal orifice;
    - Submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below normal pool elevation is preferred;
    - Alternatives include broad crested rectangular, v-notch, or proportional weird, protected by half-round CMP that extends 12 inches below permanent pool;
    - Horizontal perforated pipe protected by geotextile and gravel not recommended; and
    - Vertical pipes can be used if a permanent pool is present.
- Riser:
    - Shall be located within the embankment for maintenance access, safety and aesthetics;
    - Access to riser to be provided by lockable manhole covers and steps within reach of valves and controls; and
    - Openings should be fenced with pipe or rebar to prevent trash accumulation.
- Pond Drain:
    - Ponds shall have a drain pipe that can drain the pond within 24 hours;
    - Prevent downstream discharge of sediment and slope instability caused by drawdown by exercising care during these processes; and
    - Appropriate jurisdictions shall be notified before draining a pond.
- Valves:
    - Drain shall be equipped with adjustable valve;
    - Drain should be sized one pipe size larger than the calculated design diameter;
    - Controls should be located inside of the riser they will not be inundated and can be operated safely; and
    - Handwheel shall be chained to a ringbolt or manhole step to prevent vandalism.



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.

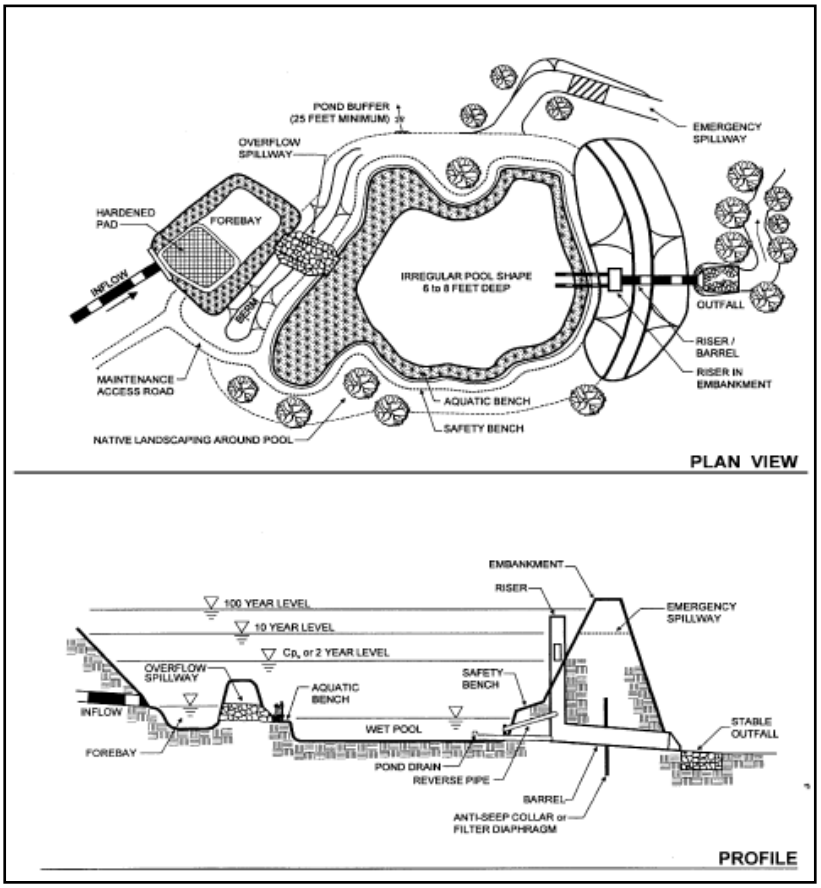
The wet pond volume is equal to the water quality design volume and is entirely a permanent wet pond, where storm water exchanges with the pond water to achieve treatment.

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 inch is the 1-inch storm;
    - A is the area of the site in acres; and
    - 3630 is a conversion factor.
- Detention time requirements do not apply.
- The draw-down time for the detention volume shall be greater than or equal to 48 hours. For the bottom half of the detention volume, the draw-down time shall be greater than or equal to 36 hours.
- The detention system shall be designed to maximize the distance between the inlet and outlet, and to minimize “dead spaces” (areas with little or no exchange occurs during a storm event), limiting short-circuiting. A minimum flow path length to width ratio of 3 should be utilized.
- The outlet shall be sized to achieve the above required detention times. It shall also be large enough that clogging is unlikely to occur. It should be 4 inches or larger in diameter. If this is not possible, the use of flow-through based measures should be considered, unless it can be demonstrated that clogging can be avoided.
- There shall be a minimum contributing drainage area of ten acres or more unless groundwater ground water is the primary water source.
- The ten year design storm is to be used to design for a stable outfall.
- Dams shall meet class A dam safety hazard classification.

- The principal spillway/riser shall provide anti-floatation, anti-vortex, and trash-rack designs.
- One foot of freeboard shall be provided above the design high water for the 10 year storm.
- Woody vegetation is prohibited on the embankment.
- Pond benches:
    - The safety bench extends outward from the normal water edge to the toe of the pond side slope. Maximum slope=6%; and
    - Aquatic bench extends inward from the normal shoreline and has a maximum depth of 18 inches below normal pool water surface elevation. Not required in forebays.
- Pond buffers and setbacks:
    - Buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond and should be contiguous with other required buffer areas; and
    - Existing trees should be preserved during construction and forest conservation areas should be located.
- Non-clogging low flow orifice:
    - Shall have a minimum diameter of 3 inches and shall be adequately protected from clogging by an external trash rack;
    - Orifice diameter can be reduced to 1 inch if using an internal orifice;
    - Submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below normal pool elevation is preferred;
    - Alternatives include broad crested rectangular, v-notch, or proportional weir, protected by half-round CMP that extends 12 inches below permanent pool;
    - Horizontal perforated pipe protected by geotextile and gravel not recommended; and
    - Vertical pipes can be used if a permanent pool is present.
- Riser:
    - Shall be located within the embankment for maintenance access, safety and aesthetics;
    - Access to riser to be provided by lockable manhole covers and steps within reach of valves and controls; and
    - Openings should be fenced with pipe or rebar to prevent trash accumulation.
- Pond Drain:
    - 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;

- Handwheel shall be chained to a ringbolt or manhole step to prevent vandalism; and
- 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:
  - 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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7.2 NON-LID MANAGEMENT METHODS

Non-LID management methods for storm water control include many current proprietary and non-proprietary BMPs These BMPs include:

- Sand filters; and
- Proprietary BMPs:
  - 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 trash 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 other LID practices.

DOT-HWYS does not endorse any specific Proprietary BMP described in this section. Designers working on DOT-HWYS 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.

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SURFACE SAND FILTER

DESCRIPTION & PURPOSE

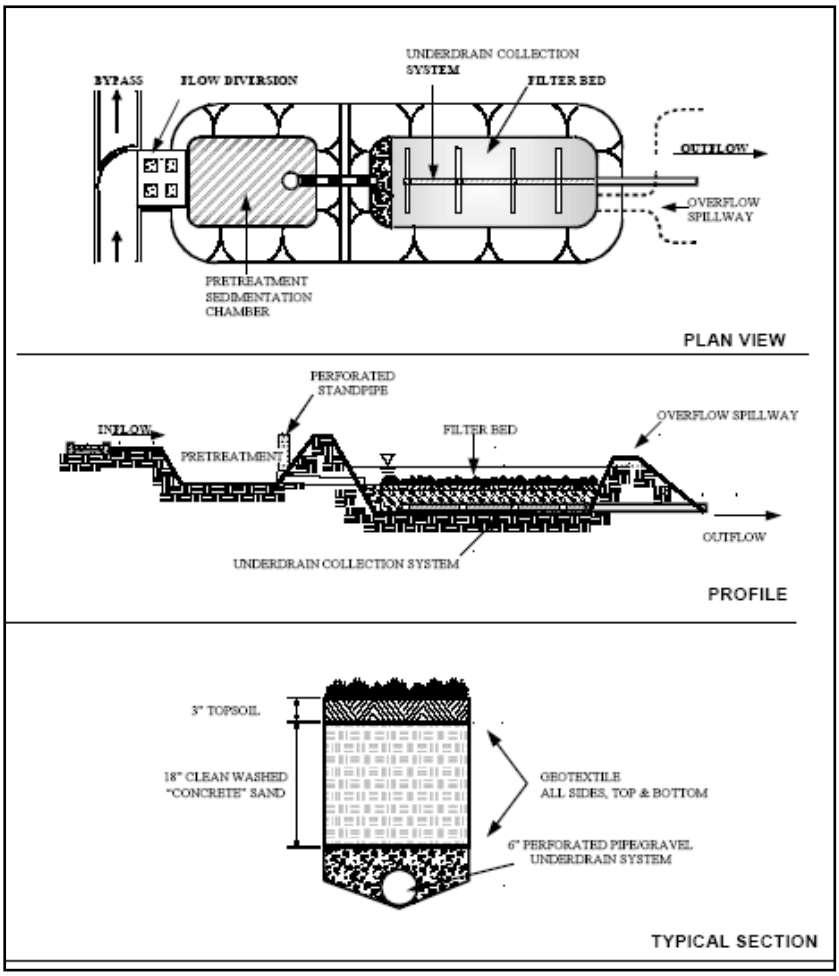
Surface sand filters can treat the largest drainage area of all the filtering systems. It captures and temporarily stores the water quality volume and passes it through a filter bed of sand, organic matter, soil, or other media.

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 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- The required filter bed area (Af) is computed using the following equation:
  Af= (WQv) (df) / [(k) (hf+df) (tf)]
  - WQv is the water quality volume (cu. ft);
  - df is the filter bed depth (ft);
  - k is the coefficient pf permeability of the filter bed (ft/day);
  - hf is the height of water above the filter bed (ft); and
  - tf is the design filter bed drain time (days)- 2 days recommended.
- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.
- Filter bed has a minimum depth of 12".



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 inches 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 than 72 hours, the top few inches of the discolored material shall be replaced with fresh material, and the removed sediment should be disposed of (landfill).
- When silt and sediment accumulation exceeds one inch, it should be removed from the filter bed.
- Filters with a grass cover should be mowed at least 3 times per growing season to maintain grass heights of less than 12 inches.

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

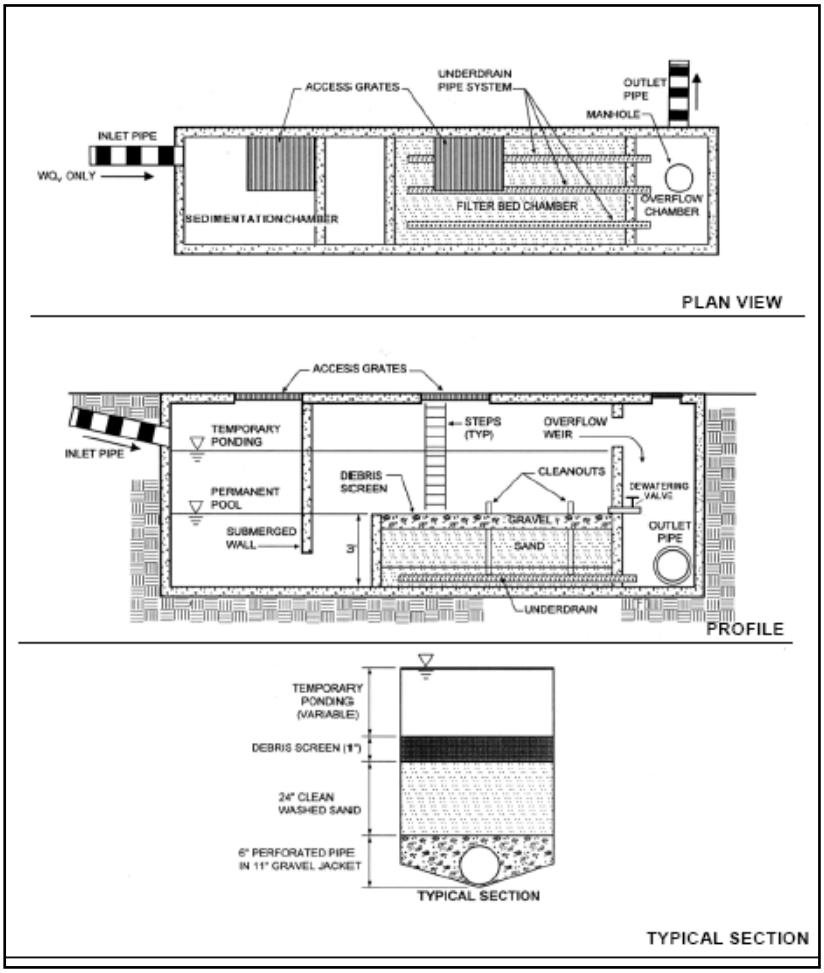
The underground sand filter is an option for providing water quality volume where space is limited.

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 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- The required filter bed area (Af) is computed using the following equation:
  Af= (WQv) (df) / [(k) (hf+df) (tf)]
  - WQv is the water quality volume (cu. ft);
  - df is the filter bed depth (ft);
  - k is the coefficient pf permeability of the filter bed (ft/day);
  - hf is the height of water above the filter bed (ft); and
  - tf is the design filter bed drain time (days)- 2 days recommended
- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.
- Filter bed has a minimum depth of 12".



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 inches 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 than 72 hours, the top few inches of the discolored material shall be replaced with fresh material, and the removed sediment should be disposed of (landfill).
- When silt and sediment accumulation exceeds one inch, it should be removed from the filter bed.

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

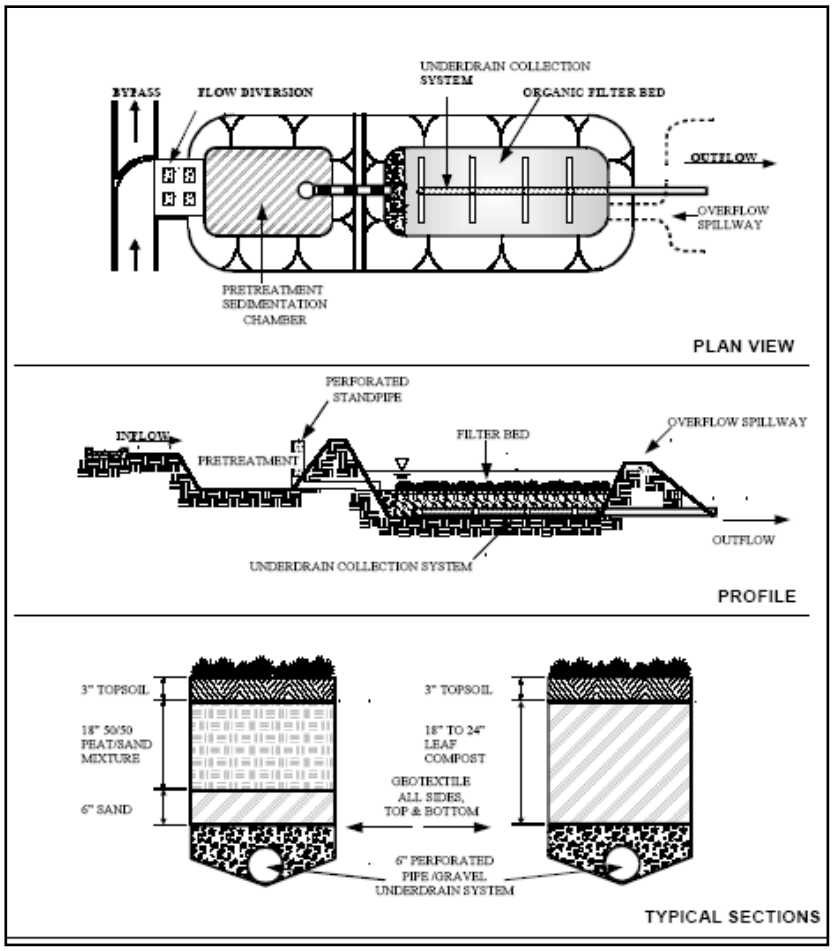
The organic filter is used when maximum nutrient or trace metal removals are desired.

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=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 inches per hour.
- WQFR: C*0.4"*A is the Water Quality Flow Rate (cfs).
- C is the runoff coefficient, calculated using tables.
- 0.4 inches is the hourly rainfall intensity.
- A is the site area in acres.
- The required filter bed area (Af) is computed using the following equation:
  Af= (WQv) (df) / [(k) (hf+df) (tf)]
  - WQv is the water quality volume (cu. ft);
  - df is the filter bed depth (ft);
  - k is the coefficient pf permeability of the filter bed (ft/day);
  - hf is the height of water above the filter bed (ft); and
  - tf is the design filter bed drain time (days)- 2 days recommended.
- If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.
- Filter bed has a minimum depth of 12".



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 inches 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 than 72 hours, the top few inches of the discolored material shall be replaced with fresh material, and the removed sediment should be disposed of (landfill).
- When silt and sediment accumulation exceeds one inch, it should be removed from the filter bed.
- Filters with a grass cover should be mowed at least 3 times per growing season to maintain grass heights of less than 12 inches.

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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PROPRIETARY NON-LID BMPS

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.

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

RECOMMENDED PERFORMANCE STANDARDS

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

proprietary BMPs. Any proposed BMPs for projects submitted to DOT-HWYS or new projects that will connect to the DOT-HWYS MS4 must have evidence of documented third party testing for the pollutants of concern.

7.3 TRASH MANAGEMENT PRACTICES

Trash reduction will be done in accordance with a focused trash reduction plan completed by DOT-HWYS. All BMPs, whether LID or non-LID will address trash as a pollutant of concern and have the adequate maintenance procedures to remove trash from the BMP. Most of the BMPs prescribed in this manual will prevent trash from entering the MS4.

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8. INSPECTION, MAINTENANCE, AND RECORD KEEPING

This section outlines the inspections and maintenance procedures for DOT-HWYS permanent BMPs. To ensure that the performance of BMP meets the design criteria and they serve the intended purpose, the following activities are essential during construction and after construction:

- 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 Table 8-1. The table is to be used as a tool for helping inspectors understand the appropriate times inspection of BMPs during the construction process is necessary:

Table 8-1 Inspection Events during Construction of Permanent BMPs

Recommended Inspection Events During Construction of Permanent BMPs **If applicable, inspections will occur:**
- During excavation to subgrade or sub-foundation
- During placement of underdrain systems and observation wells
- During backfill for foundations, trenches, underdrain systems and observation wells
- During placement of geotextile and filter media
- During construction of appurtenant conveyance systems such as diversion structures, pre-filters and filters, inlets, outlets, catch basins, piping, anti-seep collars, diaphragms, watertight connectors on pipes, and flow distribution structures
- During wetland reservoir area planting
- During the placement of structural fill and concrete
- Upon completion structural supports or reinforcement for structures, to include core trenches for structural embankments
- Upon completion of embankments
- Upon completion of enclosed trenches for storm water facilities
- Upon completion of wetland reservoir area planting
- Upon completion of final grading
- Upon establishment of permanent stabilization
- At any construction stage highlighted on the fact sheet for the relevant LID BMP or filtration BMP listed in Chapter 7
- At any critical construction stage highlighted by the manufacturer for proprietary BMPs

8.2 AS-BUILT CERTIFICATION & ACCEPTANCE OF PERMANENT BMPs

Once construction is complete, as-built plan certification shall be submitted to DOT-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. DOT-HWYS may require additional information.

8.3 BMP INSPECTIONS AFTER CONSTRUCTION

Contract construction projects requiring Permanent BMPs based on the Unified Criteria are to be inspected at least once a year after construction and within fourteen (14) days after the first storm event that produces one inch or more precipitation after construction of the BMP. 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 aids in identifying maintenance activities needed. Annual inspections are important to determine if vegetation has survived past the growing season. The result of the inspection and evaluation for DOT-HWYS BMPs must be written in the latest inspection form as provided by DOT-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 OPERATIONS AND 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.

A maintenance schedule shall be developed for the life of the permanent BMP 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. This information will be used to update or augment the current DOT-HWYS Permanent BMP Operations and Maintenance manual (if applicable)

8.5 RECORD KEEPING

Records of all inspections and follow-up activities for deficiencies in the conditions of DOT-HWYS 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 for DOT-HWYS BMPs 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. Furthermore, should the BMPs be owned on a private parcel but connect to the MS4, not maintaining proper records is evidence of improperly maintained BMPs and a potential violation of polluted discharge to the MS4. Finally, this information is important to ensure DOT-HWYS can maintain its database of permanent BMPs. The database shall include the BMP type and location, as well as all inspection and maintenance records of DOT-HWYS BMPs. The database is part of the DOT-HWYS' storm water asset management system.

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Storm Water Permanent BMP Manual

APPENDIX A: RAIN STATIONS ANALYZED FOR QUANTITATIVE CRITERIA

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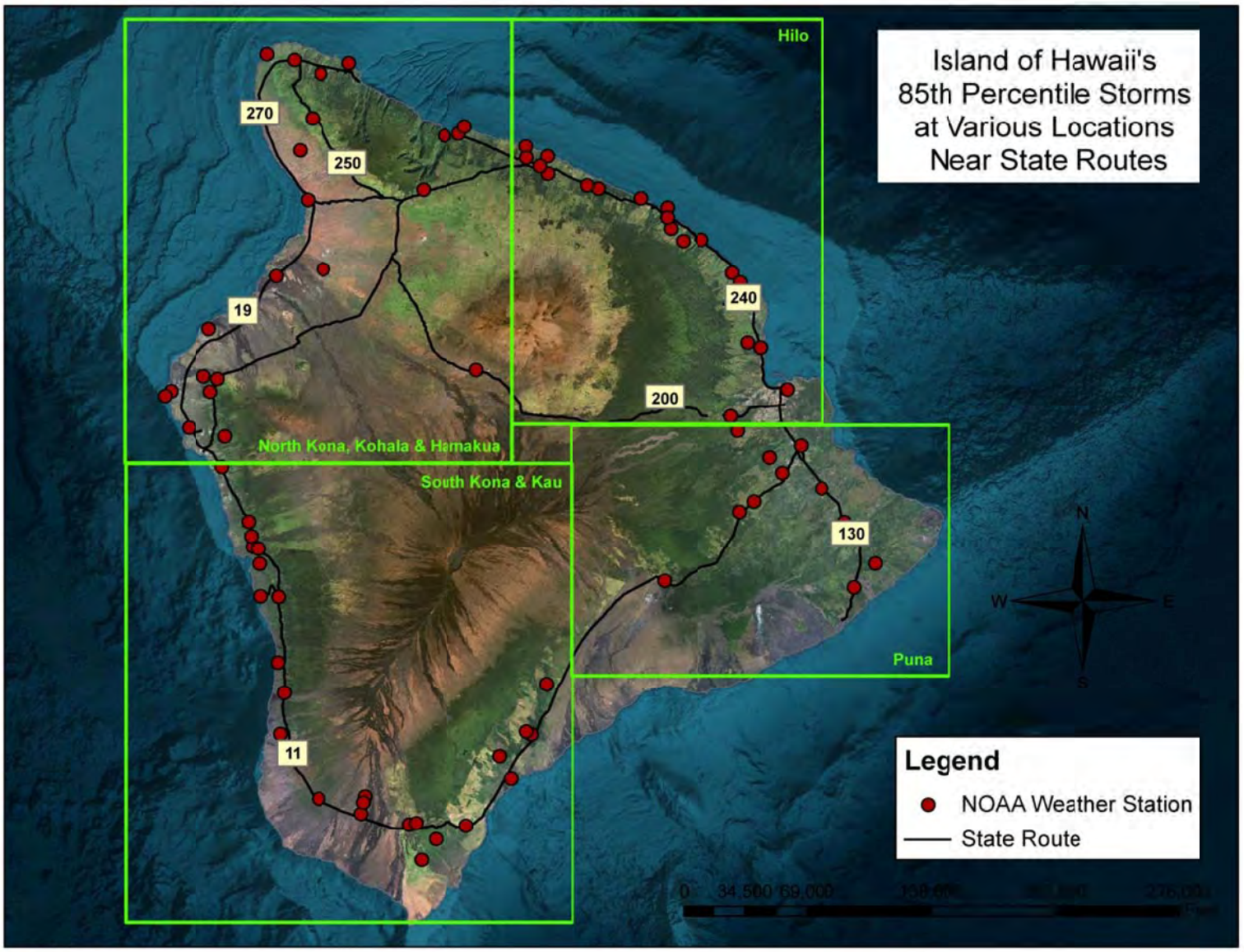
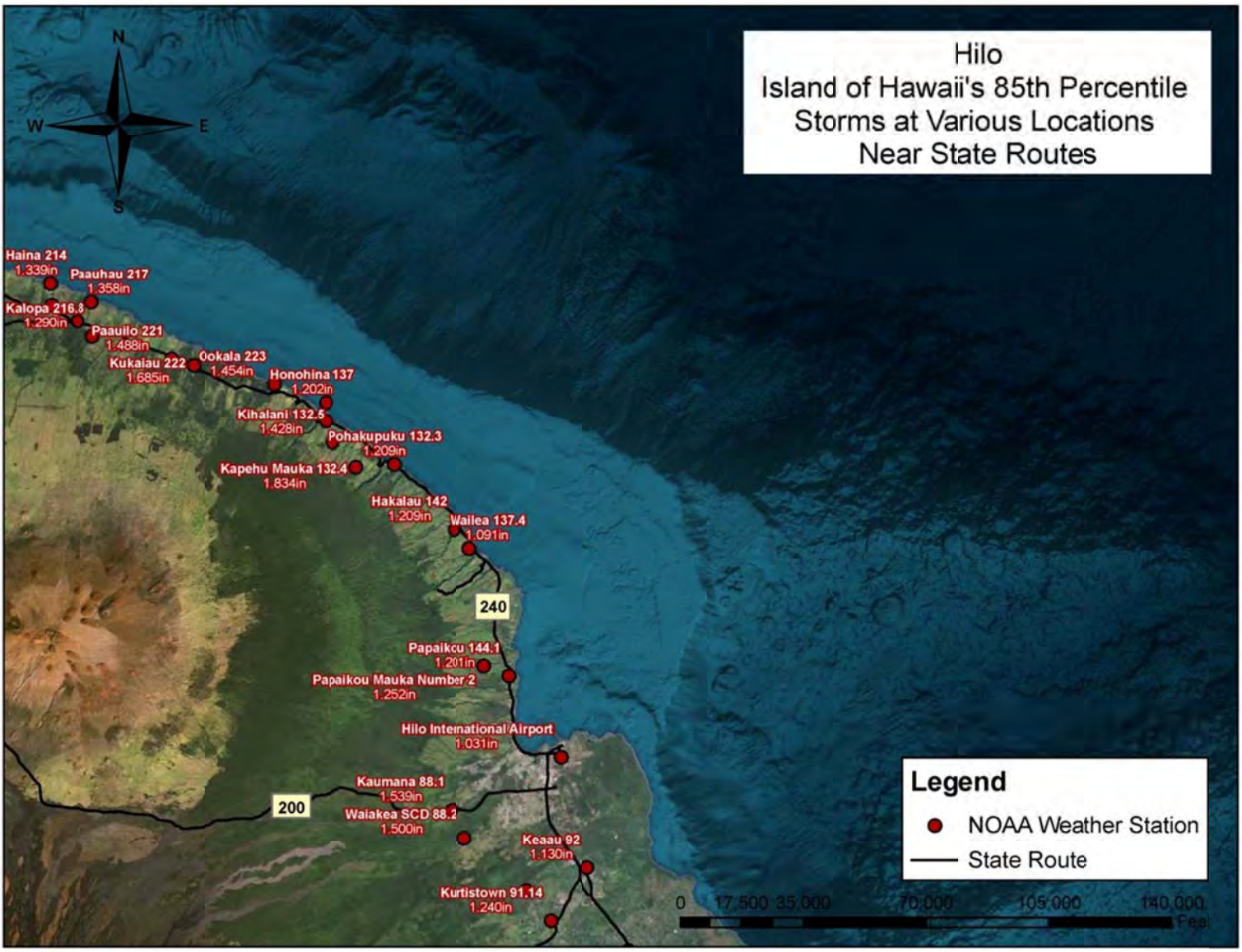
Introduction

This appendix provides graphical references regarding the rain gauge stations used in determining the quantitative criteria. These references are not to be used in local estimation of reducing the water quality design volume.

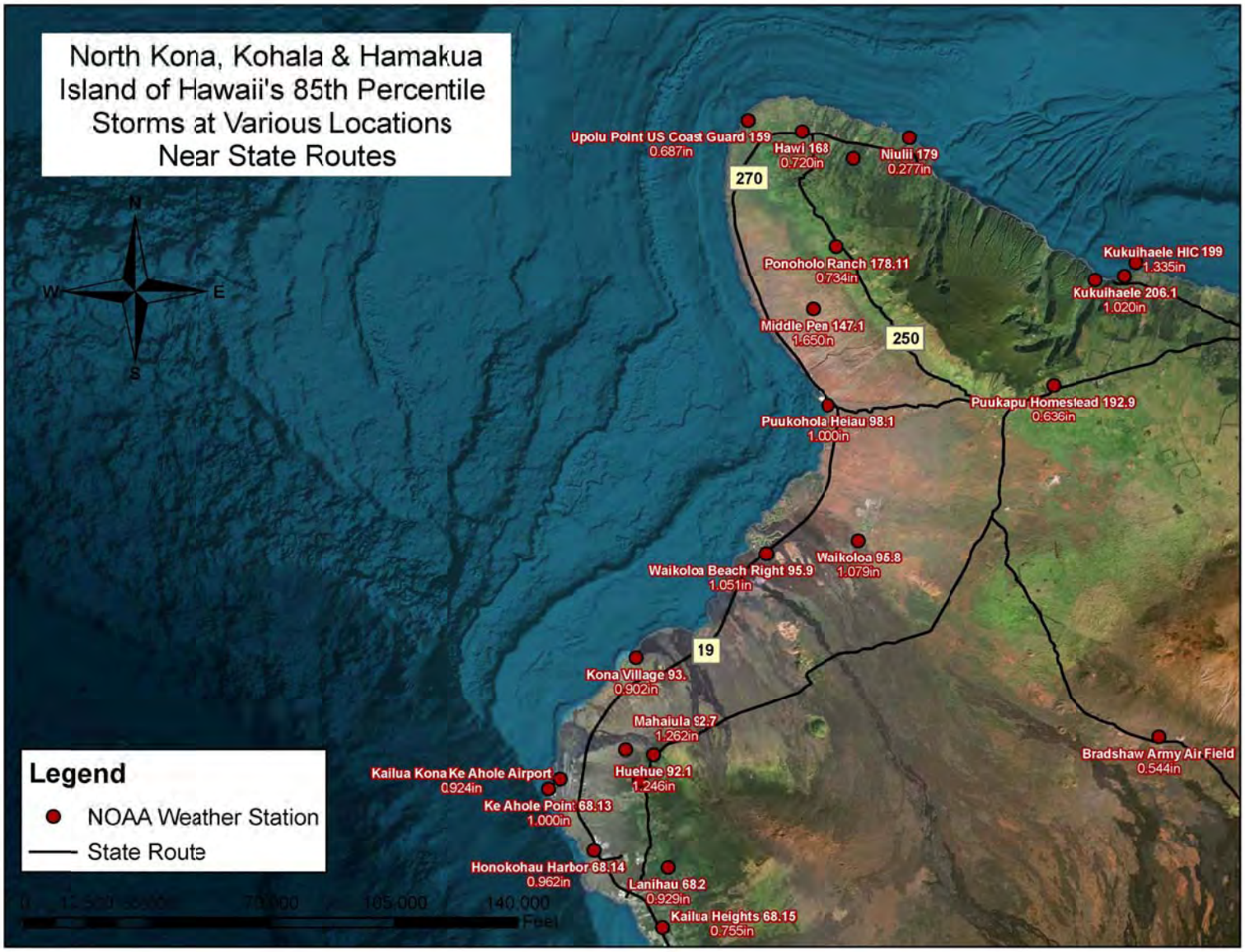
Hawaii County



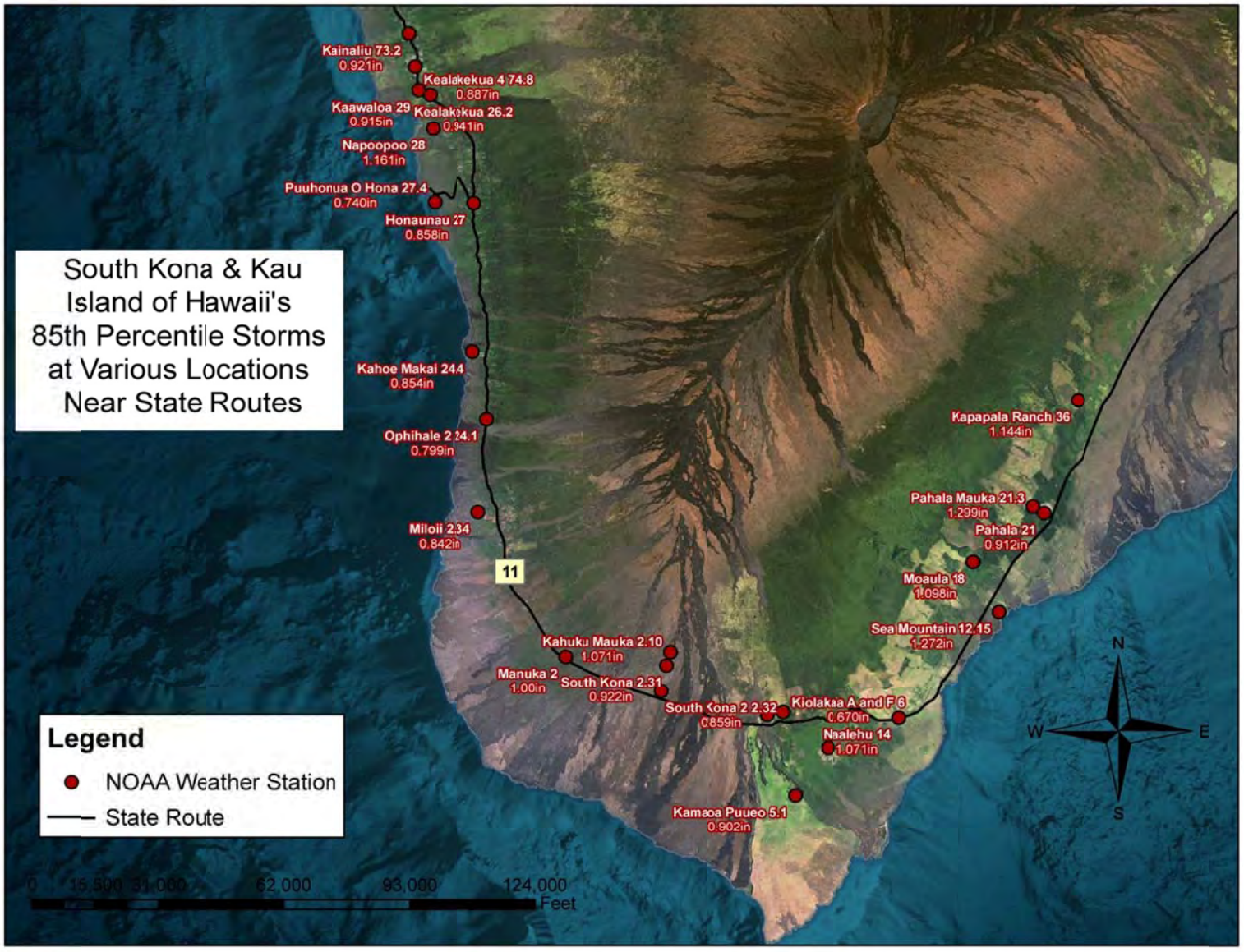
Hawaii County (Hilo Area)



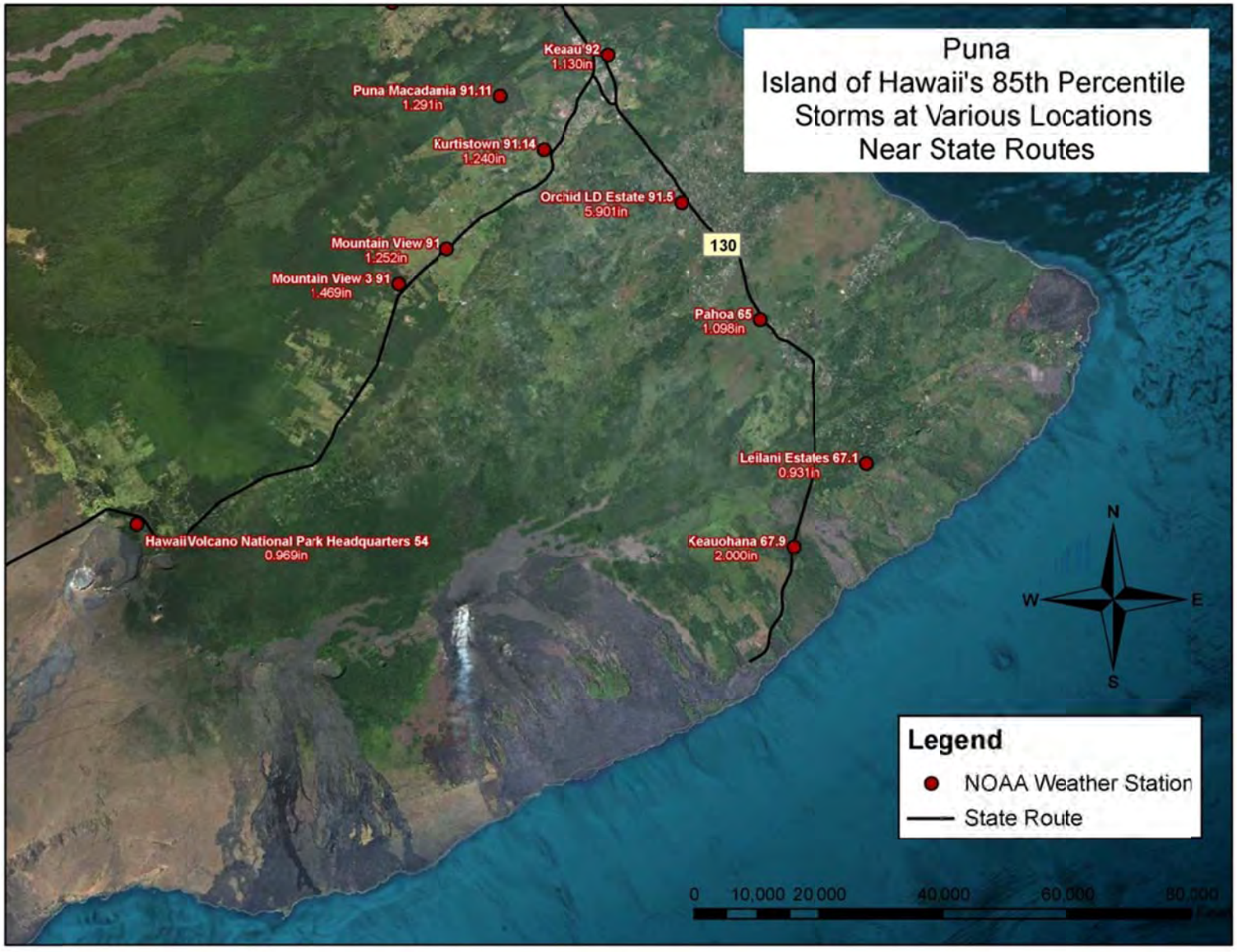
Hawaii County (North Kona, Kohala, & Hamakua Area)



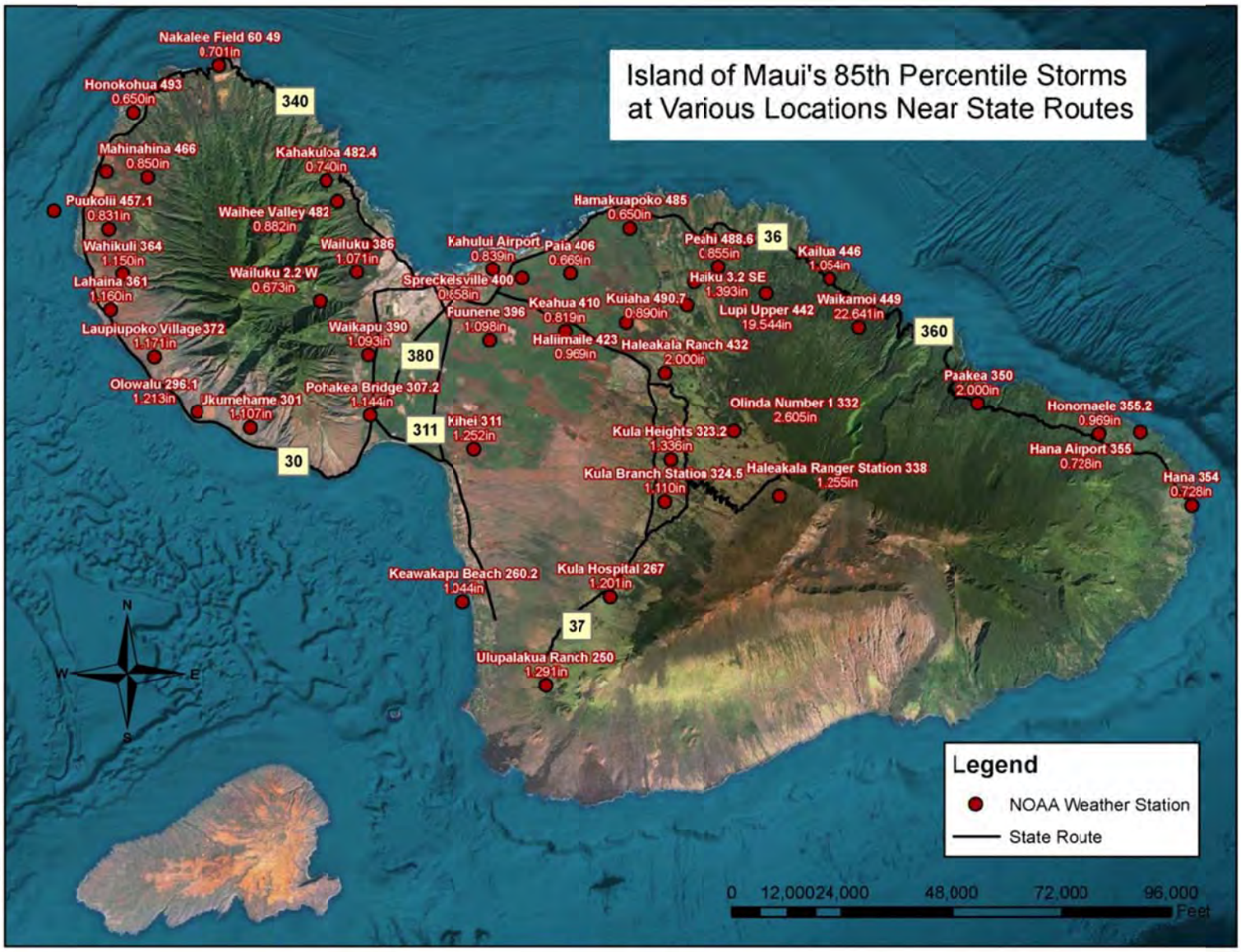
Hawaii County (South Kona & Ka'u Area)



Hawaii County (Puna Area)



Maui County (Maui)



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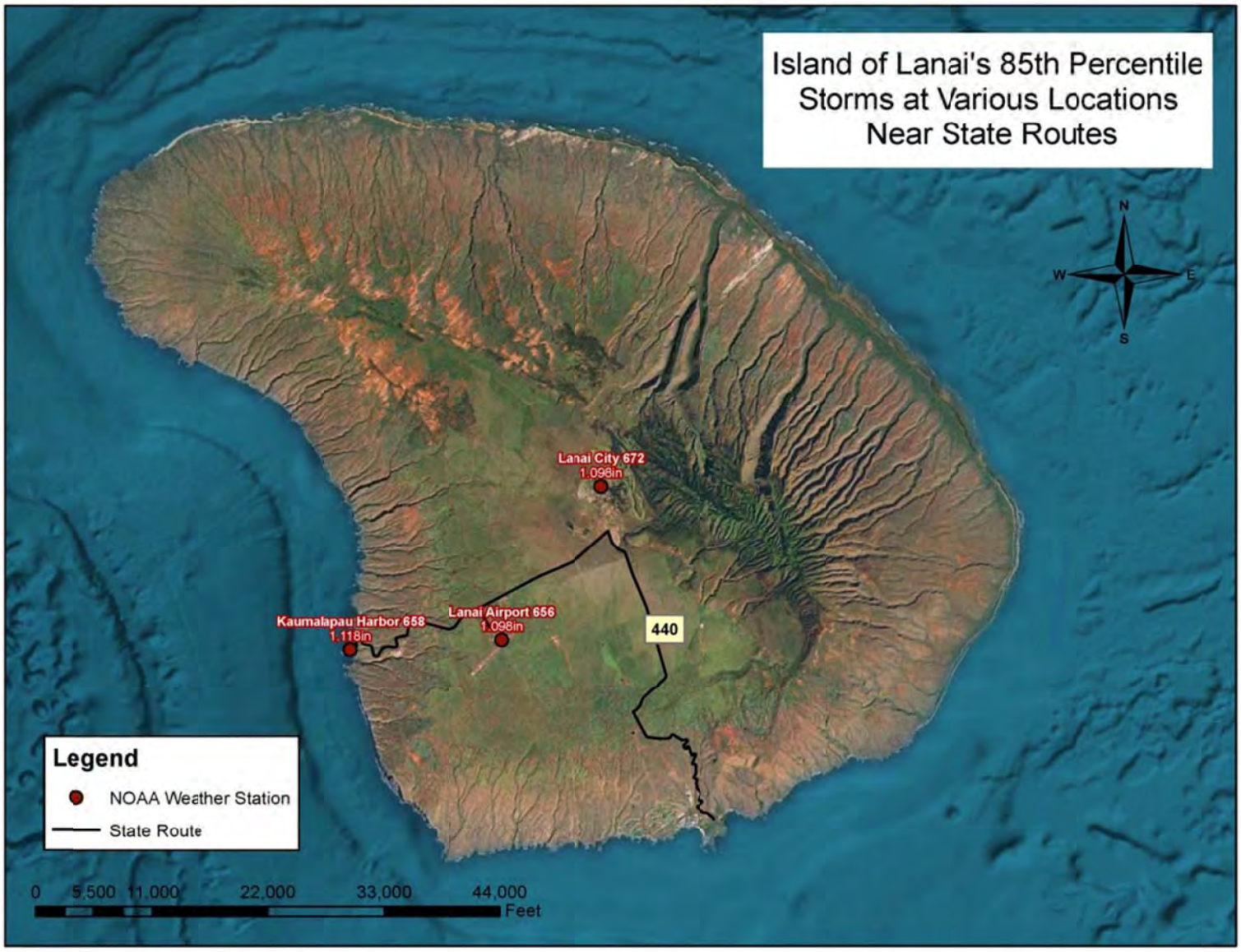

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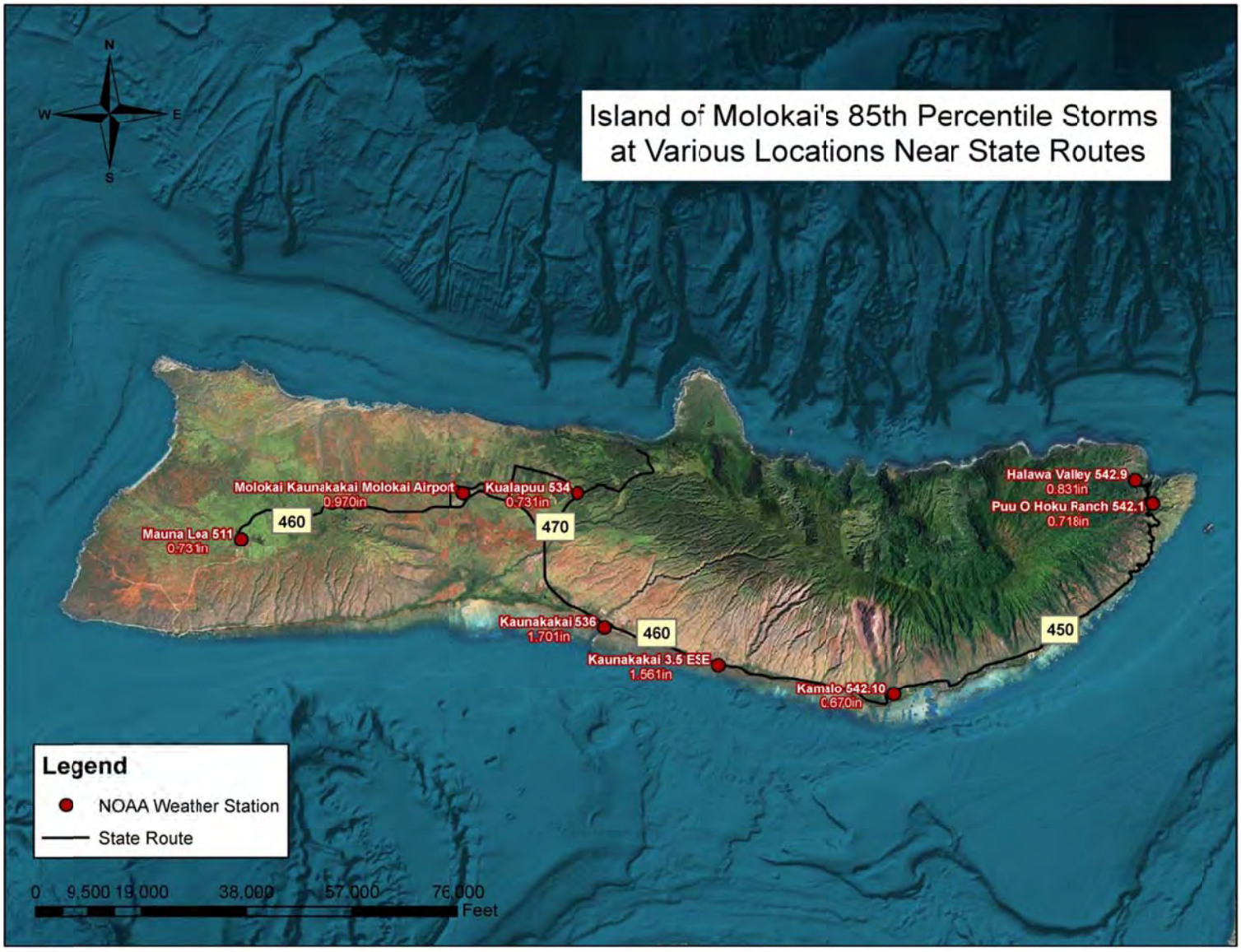
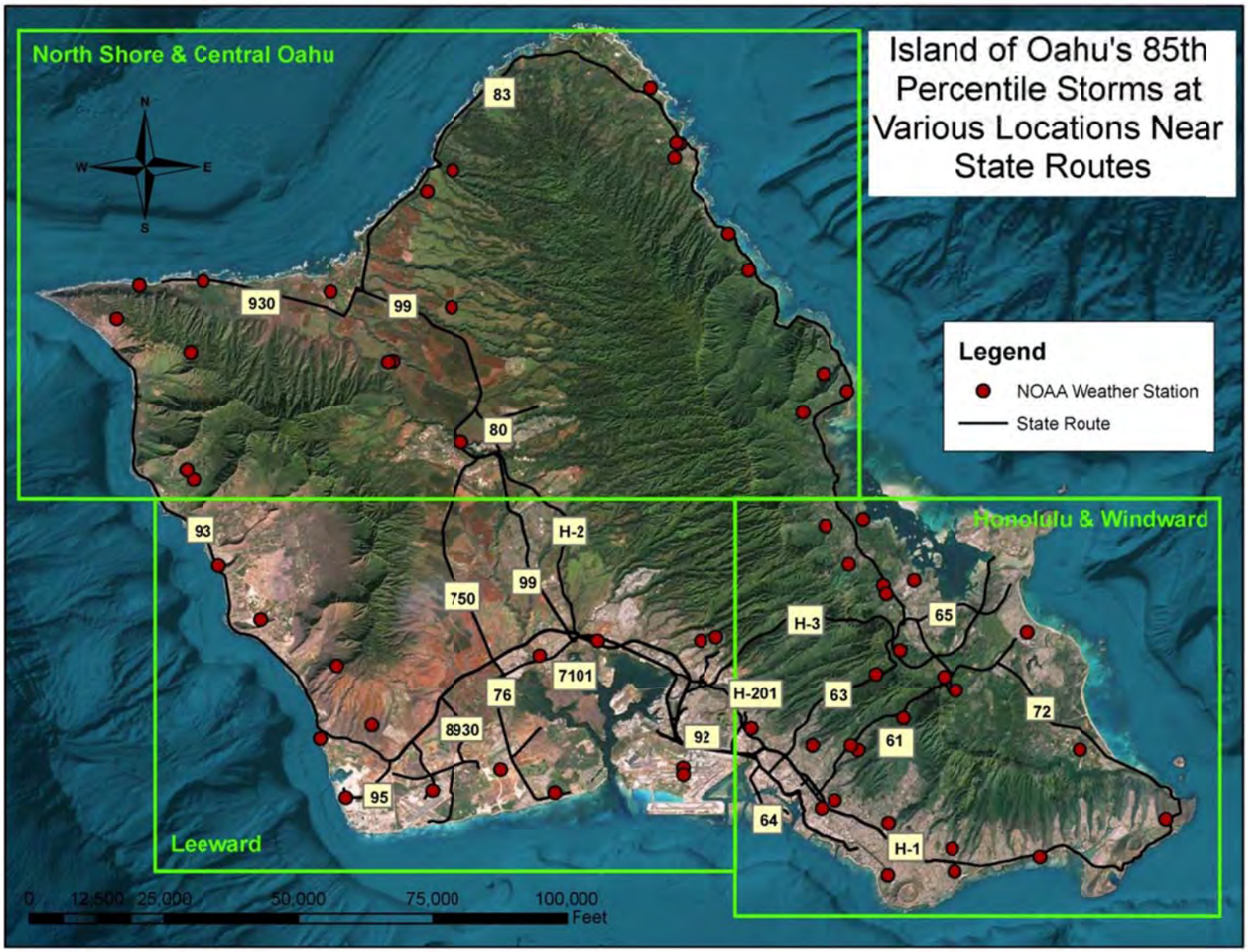
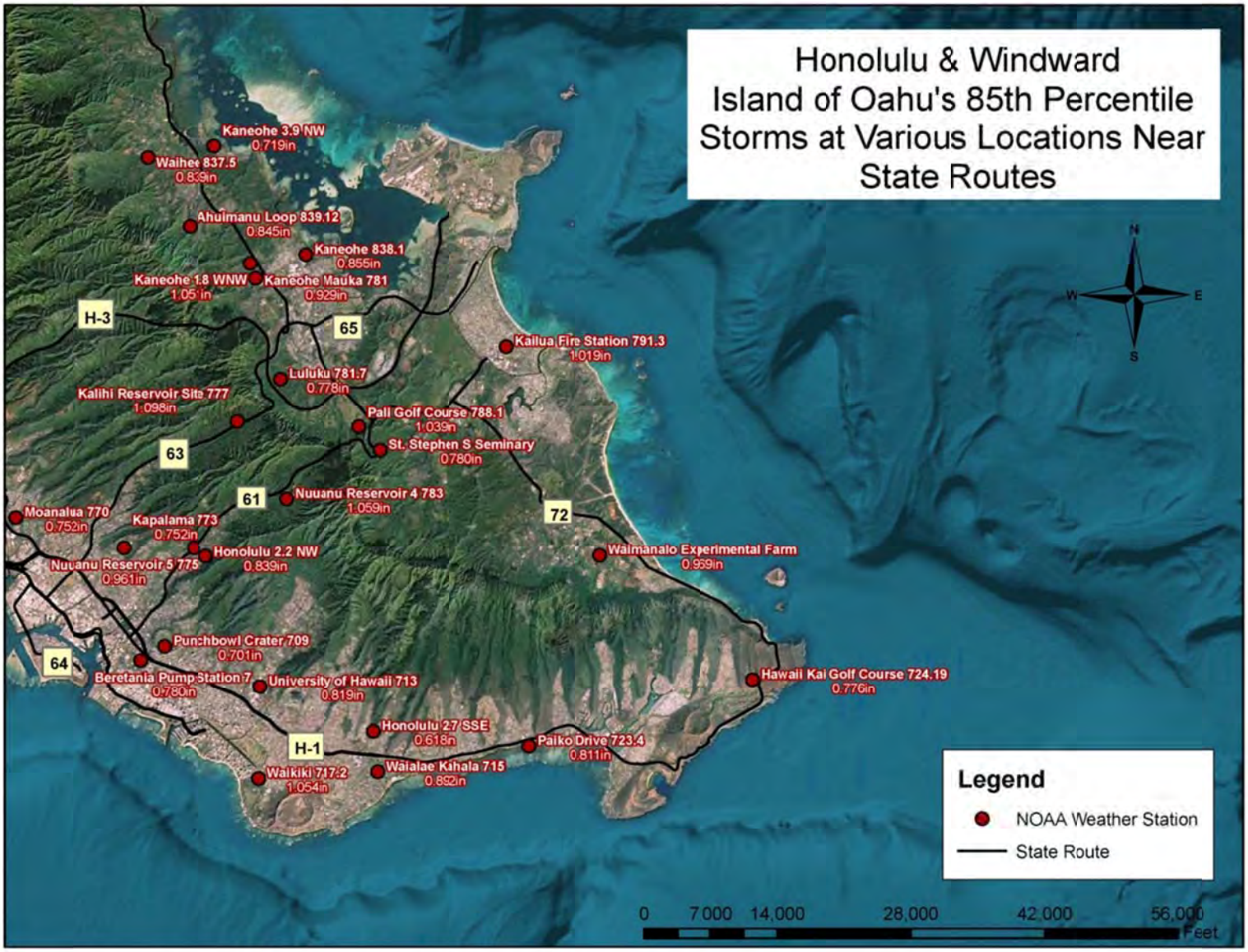


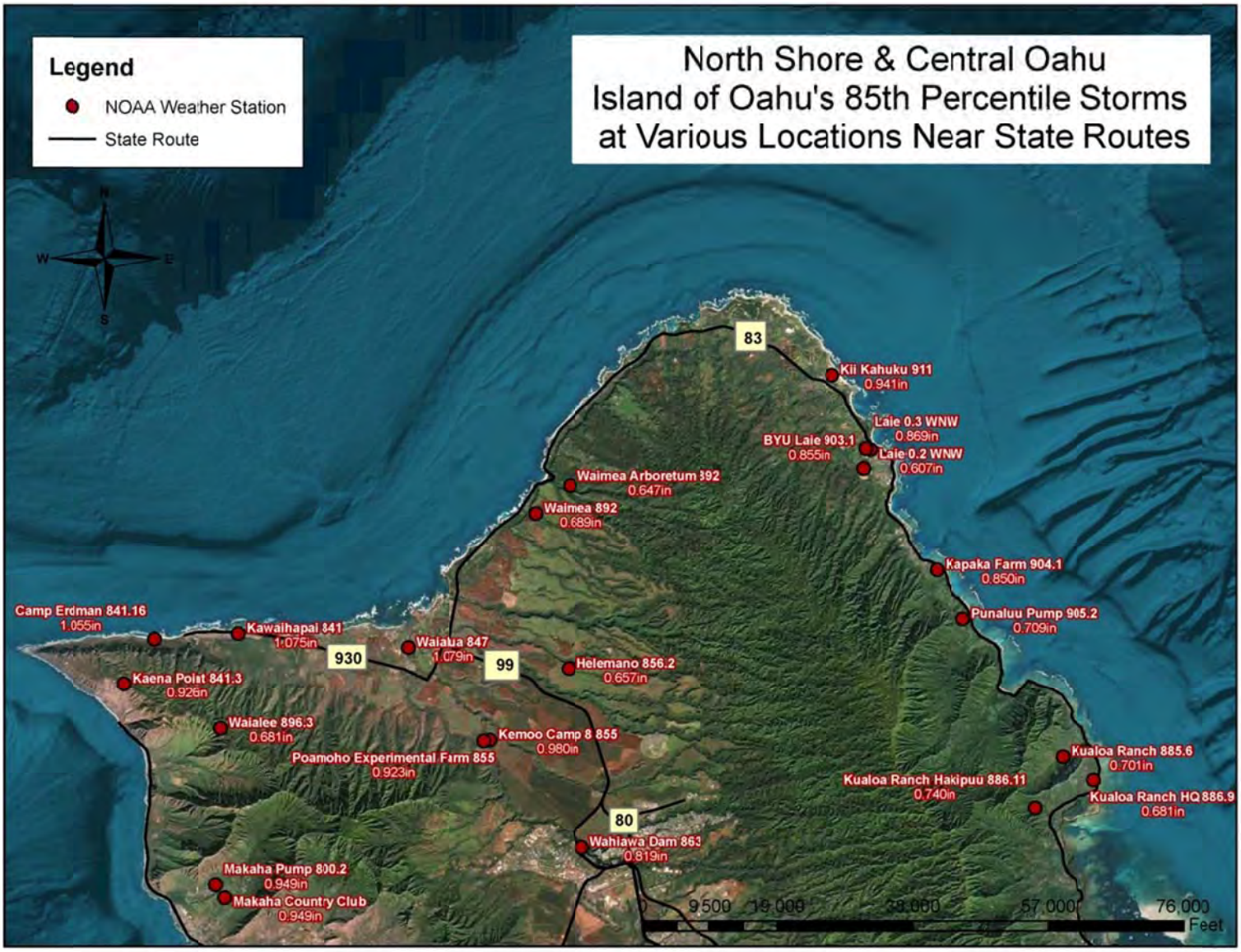
Honolulu County



Honolulu County (Honolulu & Windward Area)



Honolulu County (North Shore & Central Oahu)



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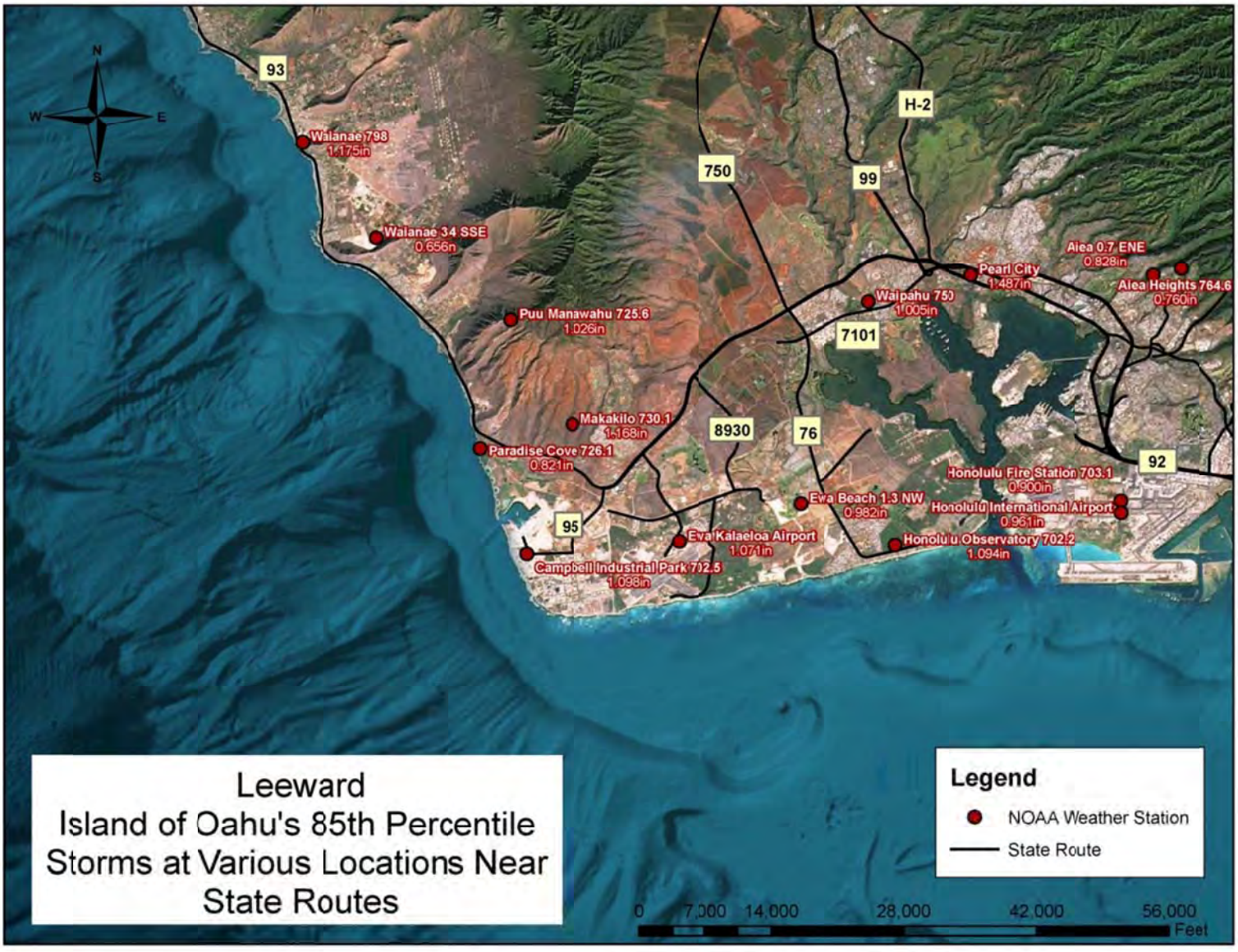
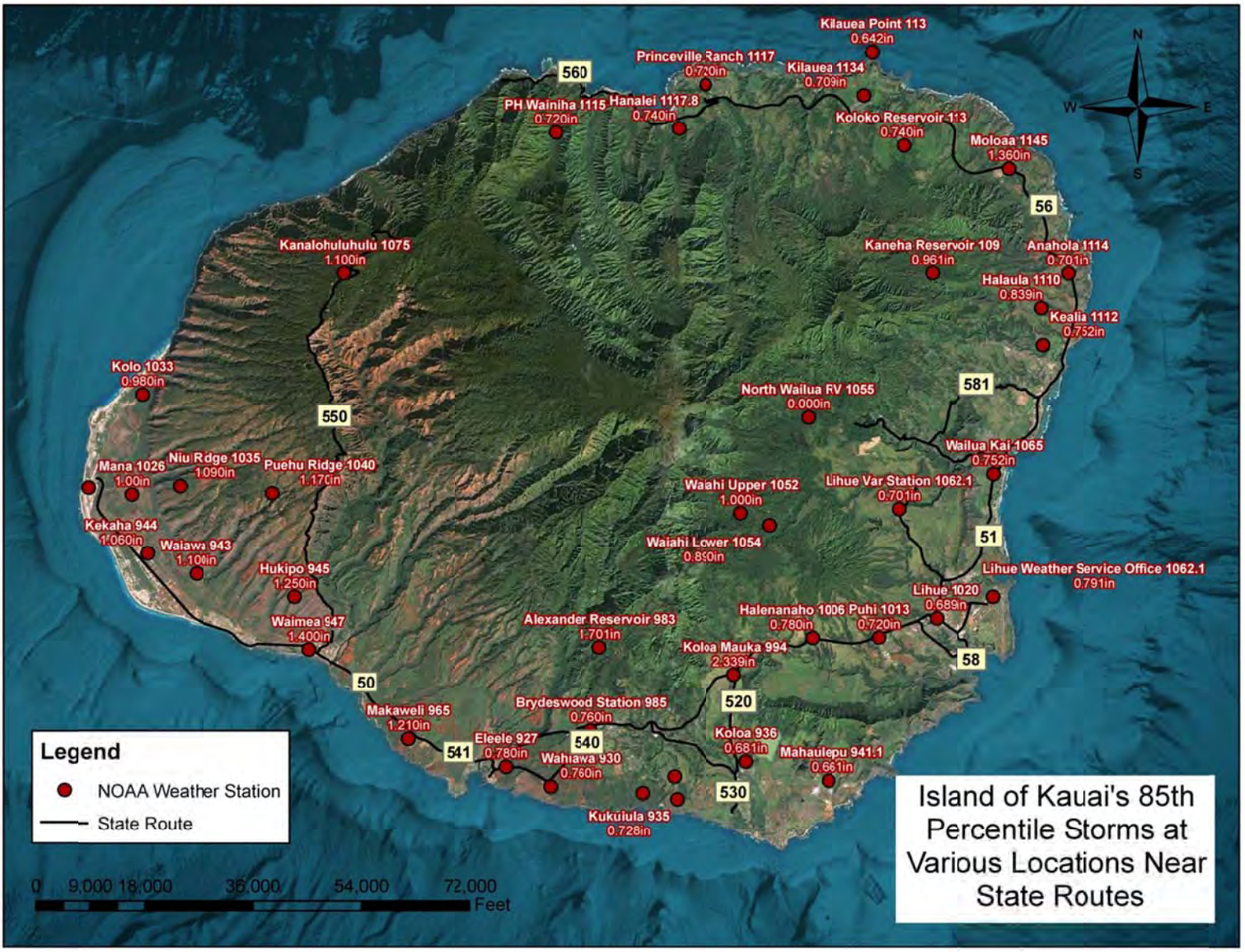


Kauai County



Storm Water Permanent BMP Manual

APPENDIX B: SOIL STABILIZATION AND STORM WATER CONTROL TECHNIQUES

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Introduction

The purpose of this appendix is to provide the designer with ideas for site management and tools that will be helpful in storm water control. These tools will not fulfill the requirement of providing required BMPs under the unified criteria, but should be used at a site in order to reduce the maintenance and increase the longevity of permanent BMPs used for LID Design Volume or for Storm Water Quality Control.

B.1 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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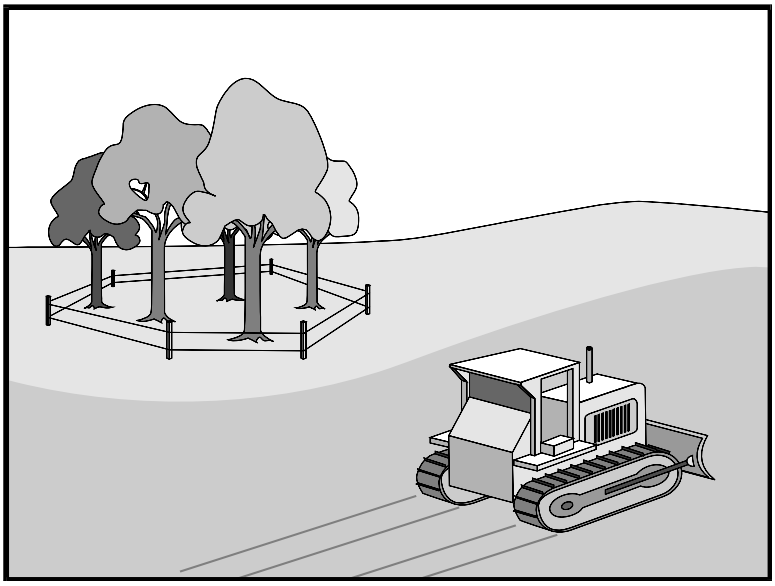
PRESERVATION OF EXISTING VEGETATION

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:
    - Mark, flag, or fence areas of vegetation to be preserved;
    - Designate limits of root system (tree drip line);
    - Tree wells and retaining walls which are large enough to protect the root system;
    - 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.

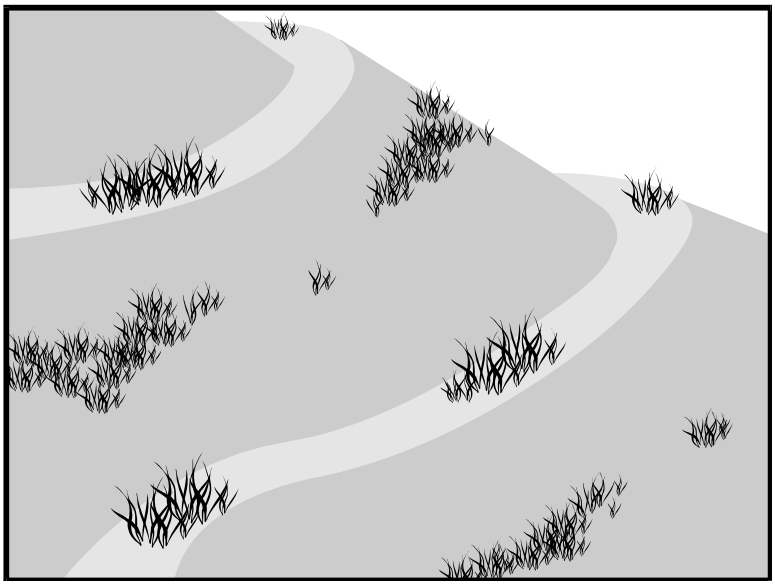
LIMITATIONS

- 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.

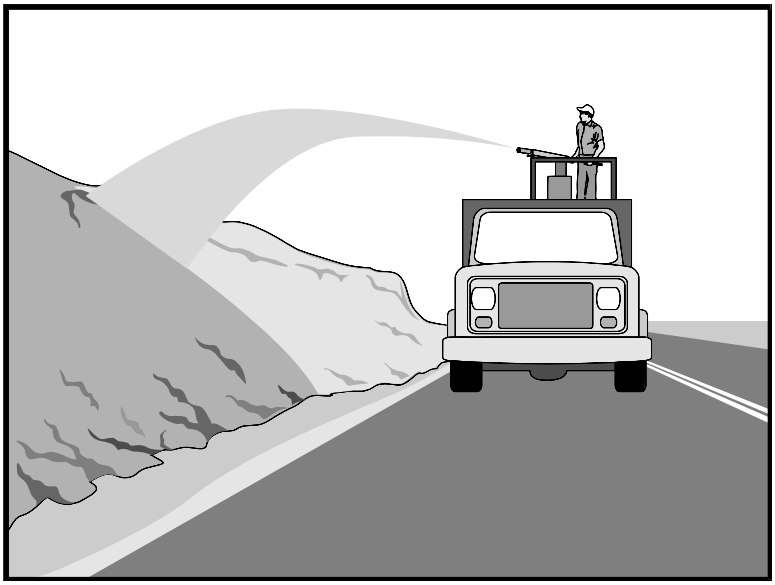
LIMITATIONS

- 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;
    - 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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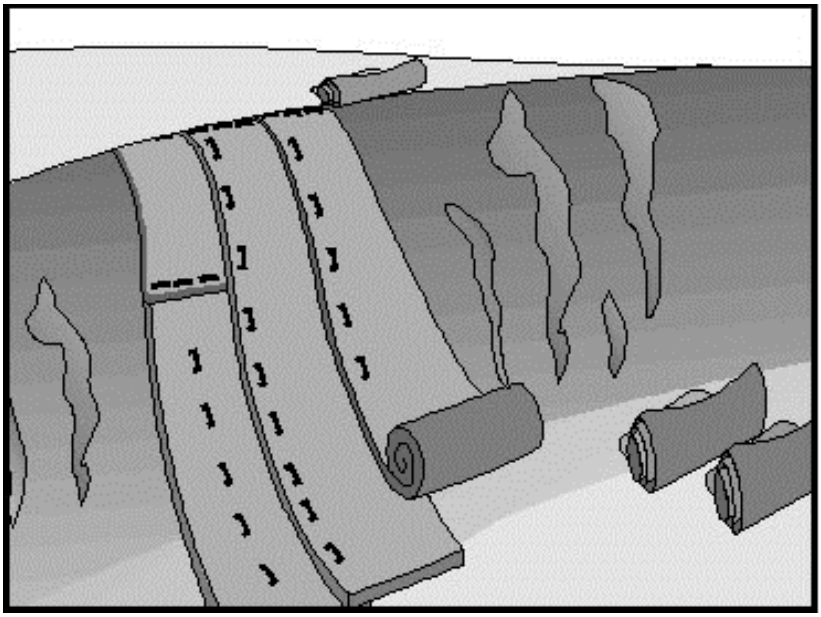
GEOTEXTILES AND MATS

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:
    - Jute matting; and
    - Straw matting.
- Synthetic matting provides temporary or post-construction soil stabilization in both vegetated and non-vegetated areas. Synthetic matting materials include the following:
    - Excelsior™ matting;
    - Glass fiber matting;
    - Staples; and
    - 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;
    - Vehicular traffic passing through vegetated buffer strips or channels shall be avoided to protect vegetation from damage and maximize its effectiveness;

- Comply with applicable regulations and manufacturers' instructions when applying fertilizers, pesticides, soil amendments, or chemicals;
- 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
- 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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B.2 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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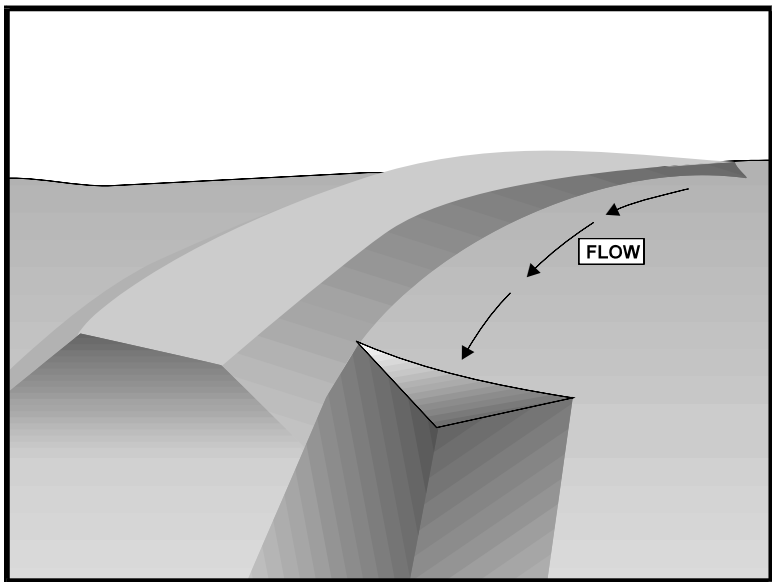
EARTH DIKES, DRAINAGE SWALES, AND LINED DITCHES

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.

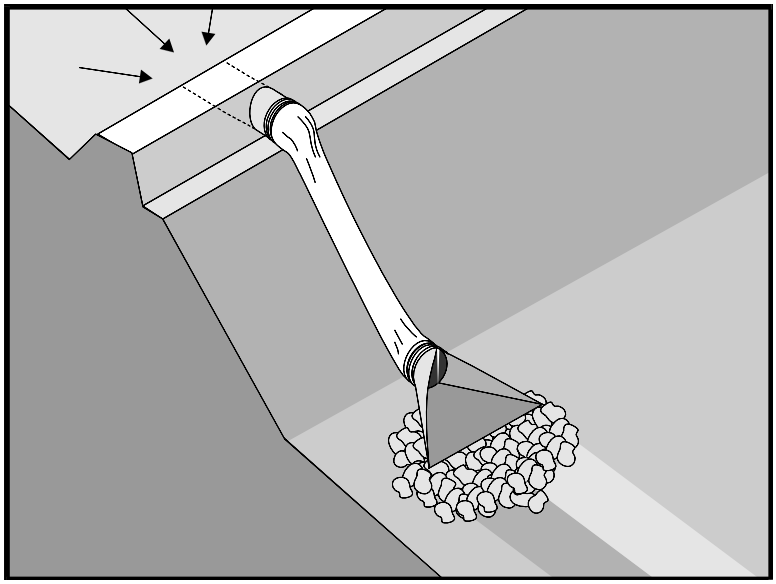
LIMITATIONS

- 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

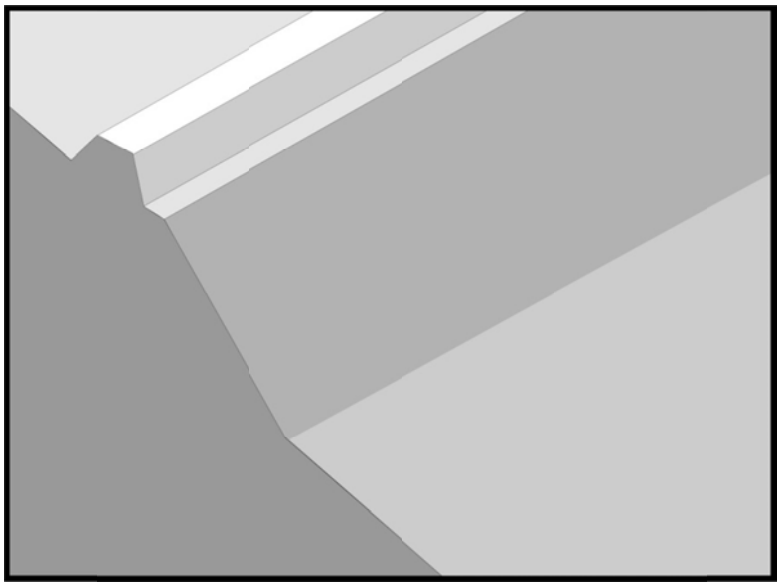
- Inspect regularly and after significant rainfall events for erosion at outlet and downstream scour. Repair damage and install energy dissipation devices as necessary.
- Inspect slope drains for debris and sediment accumulation. Remove sediment and debris from entrances, outlets, and within drains.
- 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.

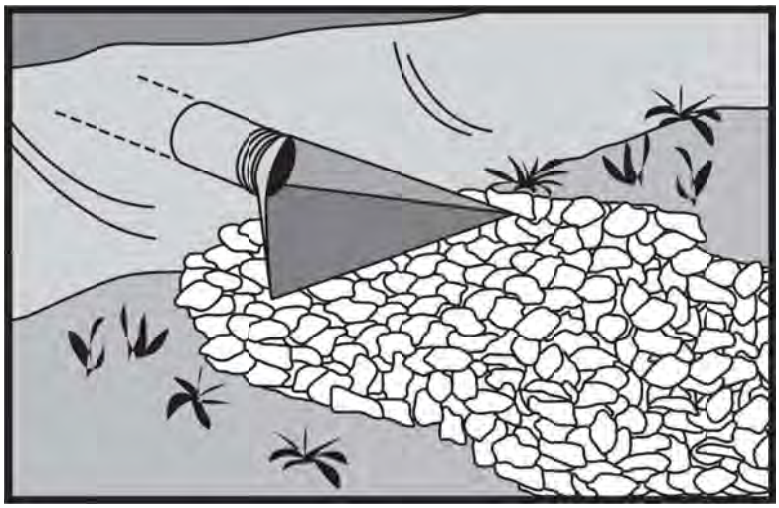
LIMITATIONS

- 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.

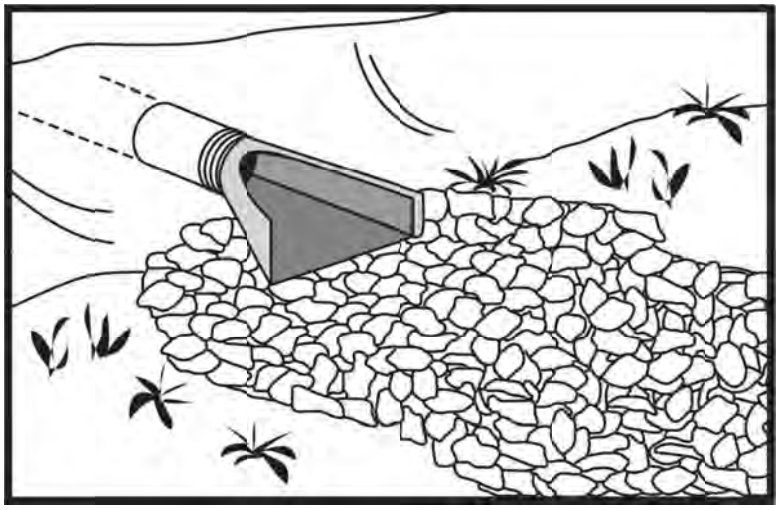
LIMITATIONS

- 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.

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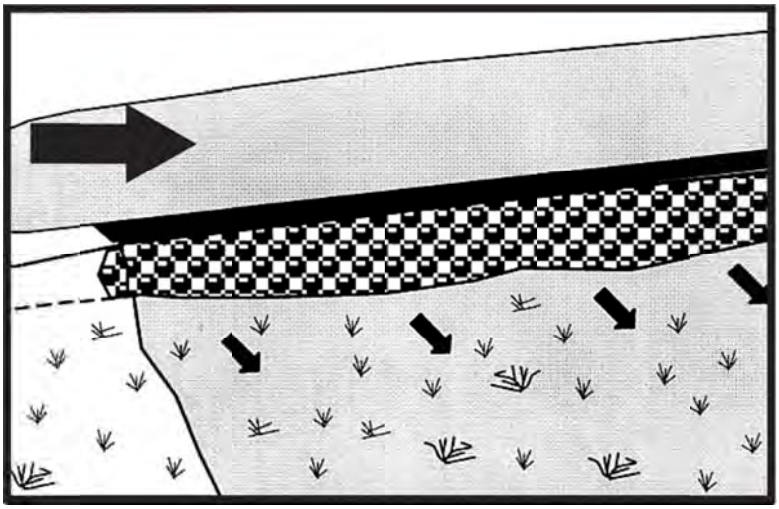
LEVEL SPREADER



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.