FINAL

Post-Construction Stormwater Management in New Development and Redevelopment Honolulu and Kalaeloa Barbers Point Harbors

Small Municipal Separate Storm Sewer Systems File Nos. HI 03KB482 and HI 03KB488

Prepared For:

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PROTECT OUR OCEAN WATER – MĀLAMA I KE KAI

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LIST OF ACRONYMS AND ABBREVIATIONS

%	Percent
ACR	Annual Compliance Report
BMP	Best Management Practice
CASQA	California Stormwater Quality Association
CCH	City and County of Honolulu
DA	Drainage Area
EPA	U.S. Environmental Protection Agency
HAR	Hawaii Administrative Rules
HAR-E	Harbors Division Engineering Branch
HAR-EC	Harbors Division Engineering Branch Construction Section
HAR-ED	Harbors Division Engineering Branch Design Section
HAR-EE	Harbors Division Engineering Branch Environmental Section
HAR-EM	Harbors Division Engineering Branch Maintenance Section
HAR-EP	Harbors Division Engineering Branch Planning Section
HAR-PM	Harbors Division Property Management Section
HDOT	State of Hawaii Department of Transportation
HRS	Hawaii Revised Statutes
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
O&M	Operation and Maintenance
PM	Harbors Division Project Manager
POPC	Pollutants of Potential Concern
PSWP	Post-Construction Stormwater Mitigation Plan
TMDL	Total Maximum Daily Loads
WQF	Water Quality Flow Rate
WQV	Water Quality Volume

DEFINITIONS OF KEY TERMS

Best Management Practices (BMPs): refers to those methods that are the most effective, practical means of preventing or reducing pollution from stormwater runoff. These include schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants to waters of the United States.

Clean Water Act: The Clean Water Act is an act passed by the U.S. Congress to control water pollution. It was formerly referred to as the Federal Water Pollution Control Act of 1972 or Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), 33 U.S.C. 1251 et seq., as amended by Public Law 96-483, Public Law 97-117, and Public Laws 95-217, 97-117, 97-440, and 100-04.

Code of Federal Regulations: The document that codified all rules of the executive departments and agencies of the federal government. It is divided into fifty volumes, known as titles. Title 40 of the CFR (referenced as 40 CFR) lists all environmental regulations.

Disturbance of Land: refers to 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 of roads, buildings, utilities, baseyards, staging areas, demolition, headquarters, and parking areas. It does not include grass or weed cutting, bush or tree trimming or felling that leaves soil or ground intact. 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.

LID Site Design Strategy: combines a hydrologically functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality. They mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff to reduce off-site runoff and ensure adequate groundwater recharge.

MS4: EPA categorizes MS4s as either "small," "medium," or "large." The Phase I Storm Water Rule covers medium and large MS4s. A medium MS4 is an MS4 located in an incorporated place or county with a population of 100,000-249,000 (according to the 1990 Census). A large MS4 is an MS4 located in an incorporated place or county with a population of at least 250,000. A small MS4 is one that is not already defined as medium or large. The Phase II Storm Water Rule covers a subset of small MS4s that are called "regulated small MS4s." Regulated small MS4s are automatically designated if they are located in "urbanized area" (as defined by the Bureau of the Census). Other small MS4s located outside urbanized areas may be designated on a case-by-case basis by the NPDES permitting authority.

New Development: shall mean new construction or installation of a building or structure or the creation of impervious surfaces that disturb greater than or equal to one acre, or less than one acre if it is part of a larger common plan of development or sale that would disturb one acre or more.

Post-Construction BMP: refers to practices or control measures used to mitigate stormwater impacts from new development and redevelopment site. It includes LID site design strategies, source control BMPs, and treatment control BMPs. These practices treat, store, or infiltrate runoff onsite before it can affect water bodies downstream. Innovative site designs that reduce imperviousness and smaller-scale low impact development practices dispersed throughout a site are also ways to achieve the goals of reducing flows and improving water quality.

Redevelopment: shall mean development that would create or add impervious surface area on an already developed site. Redevelopment includes, but is not limited to any construction project that requires demolition or complete removal of existing structures or impervious surfaces at a site and replacement with new impervious surfaces. Maintenance activities such as top-layer grinding, repaving (where all pavement is not removed), and reroofing are not considered to be redevelopment. Interior remodeling projects and improvements are also not considered to be redevelopment.

Source Control: Means measures to prevent pollutants from coming into contact with stormwater runoff or preventing polluted runoff from discharging into small MS4.

Treatment Control: means measures that treat stormwater and non-stormwater that has come into contact with pollutants.

1.0   INTRODUCTION

The Post-Construction Stormwater Management Program is intended for the following audiences: (1) State of Hawaii Department of Transportation [HDOT] Harbors Division (hereinafter referred to as the "Harbors") staff tasked with plan review and approval for Harbors capital projects (hereinafter referred to as the "Harbors Project") and Tenant[1] Improvement projects (hereinafter referred to as the "Tenant Project," (2) Harbors staff tasked with construction oversight, (3) Harbors staff tasked with ongoing inspection and maintenance of post-construction Best Management Practices [BMPs], and (4) the development community including engineers and architects tasked with creating and submitting construction plans for approval.

This program is complementary to Harbors **Construction Site Runoff Control Program** in that post-construction BMPs are required by Harbors National Pollutant Discharge Elimination System [NPDES] permit, and therefore will be incorporated into site-specific construction BMP plans consistent with this manual. This manual defines requirements and provides guidance for the project specific planning, selection, and design of post-construction BMPs to minimize pollutants in post-construction runoff and to minimize the amount of polluted runoff leaving the site.

New development and redevelopment projects (hereinafter referred to as "Regulated Project") that result in a land disturbance of one (1) acre or more, are subject to Harbors **Post-Construction Stormwater Management Program**. All Regulated Projects must implement post-construction BMPs, unless the project is exempted as described in Section 1.2. BMPs shall be designed and installed accordance with the criteria, guidelines, and design standards described in this manual. Harbors has adopted City and County of Honolulu [CCH] **Storm Water BMP Guide** (CCH, 2012; Appendix C) and **Rules Relating to Storm Drainage Standards** (effective June 2013, CCH, 2000; Appendix D) to guide both Harbors and Tenant Projects.

1.1   Component Overview

Sections 2 to 5 of this manual describe the planning, design, construction, inspection, and long-term maintenance requirements for post-construction BMPs. The post-construction general requirements for Harbors and Tenant Projects are depicted in Figure 1-1. General requirements for Harbors reviewers and inspectors are depicted in Attachment 1 of **Construction Site Runoff Control Program** manual.

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[1] "Tenant" shall mean a person, group, partnership, corporation, or any other entity that has an executed lease, revocable permit or disposition instrument under chapter 171, Hawaii Revised Statutes [HRS] to use or occupy land, a building, structure, or other property owned by Harbors. This term also includes Harbors' approved sub-tenants and entities using container or terminal facilities.

Figure 1-1:
General Post-Construction Project Requirements Flow Chart

Total acreage of disturbed land associated with the project

*: Project is also not part of a larger development or sale of one acre or more.

≥ 1 acre   < 1 acre*

Is the project exempted? (Section 1.2)

Yes → No submittal requirements.

No ↓

In Design Phase:
1. Incorporate post-construction BMP into project design – Section 2.0 and **CCH Storm Water BMP Guide**
2. Submit *Permanent Post-Construction BMP Plan Checklist* – Appendix B
3. Apply for necessary permits (consult with appropriate agencies) – Attachments 1 and 2 of **Construction Site Runoff Control Program**
4. Submit plans including PSMP for review – Section 3.0
5. Submit O&M Plan, if applicable, for review – Section 5.1
6. Wait for concurrence and **Notice to Proceed**.

In Construction Phase:
1. Install Post-Construction BMP according to approved PSMP – Section 3.0
2. Monitor installation and inventory – Attachment 4 of **Construction Site Runoff Control Program**
3. Enforcement if necessary – Section 7.0 of **Construction Site Runoff Control Program**
4. Submit O&M Plan for review – Section 5.1

In Post-Construction Phase:
1. Conduct long-term O&M of post-construction BMP, If applicable – Section 5.0
2. Inspect post-construction BMP regularly – Section 5.3
3. For Tenant Project, tenant must submit annual O&M and inspection report to Harbors, if applicable – Section 5.2
4. Enforcement if necessary – Section 6.0

The following lists the major components covered under the Harbors **Post-Construction Stormwater Management Program.**

- BMP requirements for Regulated Projects, including Low Impact Development [LID] Site Design Strategies, Source Control, and Treatment Control BMPs. These BMPs are to be included and described in a required Post-Construction Stormwater Mitigation Plan [PSMP].

- CCH Rules Relating to Storm Drainage Standards (effective June 2013; CCH, 2000).

- Plan and permit application review to ensure that a Regulated Project is incorporating post-construction BMPs in accordance with the program.

- BMP inspections to ensure that post-construction BMPs are installed and maintained properly.

- Enforcement where BMPs are not installed or maintained properly.

- Database and references under development to support and facilitate compliance with the program, including, but not limited to:
  - ***Stormwater BMP Guide*** (CCH, 2012), providing the minimum requirements needed to achieve compliance with LID Site Design Strategies, Source Control BMPs, and Treatment Control BMPs.
  - Post-Construction BMP GIS and database to keep track of all publicly and privately constructed post-construction stormwater BMPs.
  - Training for plan and permit application reviewers, inspectors, maintenance personnel, and Oahu District personnel.
  - Education for project applicants, contractors, developers, designers, and other responsible parties.

1.2   Exemptions

HDOT Harbors may exempt certain types of projects from this program that pose a minimum risk of stormwater pollution, including, but not limited to:

- Maintenance activities such as top-layer grinding, repaving (where all pavement is not removed) and reconfiguring surface parking lots.
- Reroofing.
- Interior remodeling and improvement.
- Routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility.
- Trenching and resurfacing associated with utility work.
- Replacement of damaged pavement.

- Emergency construction activities required to immediately protect public health and safety.

2.0   IMPLEMENTATION PROCESS

All new and redevelopment projects under Harbors jurisdiction undergo an environmental review during planning phase. The project review and approval process is a critical point at which the Harbors can impose conditions or standards that will minimize the impacts of urban runoff on local water resources. Therefore, project developers must address the potential impacts of stormwater discharges associated with development activities early in the project planning and design process. Regulated Projects that have the potential to discharge pollutants to the Honolulu and Kalaeloa Barbers Point Harbors Small MS4s, will be required to identify post-construction BMPs that will be included in the project design, constructed as part of the project, and implemented and maintained in the long-term.

Harbors will not approve construction activities, unless both PSMP and the *Permanent Post-Construction BMP Plan Checklist* (Appendix B) have been included in the submittal package and completed properly for the project during design phase.

Development projects are segregated by two major categories of project proponents – (1) Harbors Projects and (2) Tenant Projects. The Harbors has different project review and approval processes for Harbors Projects (Section 2.1) and Tenant Projects (Section 2.2). Personnel responsibilities for design, plan review, and approval of PSMP are outlined in Section 2.3 (Tables 2-1 and 2-2).

2.1   Harbors Project

Personnel from Harbors Engineering Branch Environmental Section [HAR-EE] initiates the review process by evaluating whether post-construction requirements apply to the projects. The key criteria for determining the need for post-construction BMPs are (a) the acreage of the project and (b) whether it is exempt.

Where post-construction requirements apply, as described in Section 3.1 of the *Construction Site Runoff Control Program* Manual, the Harbors Division Project Manager [PM] shall convene a Pre-Design meeting with HAR-EE at the **Preliminary Design Phase** to discuss the *Construction Site Design Review Checklist* (HDOTa, 2014), as well as the *Permanent Post-Construction BMP Plan Checklist* (include in Attachment B) if applicable. *Construction Design Review Checklist* discussions may also continue into the **Design Phase**. These discussions and meetings will allow the PM and HAR-EE to discuss the project during the design phase for applicable site-specific post-construction BMPs.

HAR-EE will advise PM that a PSMP, describing how the project will meet Harbors **Post-Construction Stormwater Management** program requirements, must be submitted during design phase. At this stage, project environmental mitigation measures are developed and a submittal package (including plans, specifications, designs, and PSMP) is forwarded to HAR-EE for review and comment.

HAR-EE review the PSMP document and final design plans to verify that post-construction program requirements are met. HAR-EE will notify PM when the PSMP is complete and contains proper required BMPs (refer to Sections 3.2 to 3.4), utilizing an interoffice memorandum. Once this memo has been issued (and placed in the project file), Harbors can proceed with putting the project out for bid. This process ensures that Harbors Post-Construction Stormwater Management program requirements are incorporated into the project design and shown on the plans prior to bidding for construction contractors or completion of construction work by Harbors itself. The step-wise process for Harbors plan reviewers is depicted in Attachment 1 of *Construction Site Runoff Control Program* manual.

2.2   Tenant Project

Harbors tenants who wish to perform new construction, reconstruction, modification, or demolition, must submit a request to HDOT or Harbors for review and approval. As described in Section 4.2.2 of the *Construction Site Runoff Control Program* manual, HAR-EE will review the request received from the tenant, and determine whether the tenant project is subject to Harbors **Post-Construction Stormwater Management** program requirements. If post-construction requirements apply, HAR-EE will advise Harbors Property Management Section [HAR-PM] of the determination and require that the tenant prepare and submit a PSMP during the design phase. At this stage, project environmental mitigation measures are developed and submittal package (including plans, specifications, designs, and PSMP) is forwarded to HAR-EE for review and comment.

HAR-EE reviews the PSMP document and final design plans to verify that PSMP requirements are met. HAR-EE will notify the HAR-PM when the PSMP is complete and contains proper required BMPs (refer to Sections 3.2 to 3.4), utilizing an interoffice memorandum. Once this memo has been issued (and placed in the project file), the HAR-PM can notify the tenant the project is approved.

This process ensures that Harbors **Post-Construction Stormwater Management** program requirements are incorporated into the project design and shown on the plans prior to approval. The approval of project becomes part of the lease or revocable permit issued to the tenant. Any mitigation measures required by the environmental review process, such as implementation and maintenance of post-construction BMPs, become part of the lease or revocable permit and are inspected by tenants regularly as outlined in the PSMP.

2.3   Responsibilities

General responsibilities involved in the implementation of Harbors **Post-Construction Stormwater Management** program are listed in Table 2-1 for Harbors Projects and Table 2-2 for Tenant Projects. Harbors Engineering Branch consists of Construction Section [HAR-EC], Design Section [HAR-ED], Environmental Section [HAR-EE], Maintenance Section [HAR-EM],

and Planning Section [HAR-EP]. A *Harbors Environmental Group Organization Chart* is enclosed in Attachment A.

For Harbors Projects, HAR-EP initiates the planning of the project. HAR-ED, HAR-EE, and HAR-EM each review project plans and specifications on different aspects. Additionally, HAR-EE reviews the submitted PSMP. The inspectors from HAR-EC conduct inspections during construction phase to ensure structural post-construction BMPs installed according to approved plans. HAR-EE also verifies that the post-construction BMPs proposed in the PSMP are installed according to approved plans. Harbors Oahu District staff is responsible for the proper operation and maintenance of the installed post-construction BMPs.

For Tenant Projects, HAR-PM will forward construction plans, specifications, and PSMP to HAR-E for review and comment. Each section under HAR-E will provide their comments, if any. During the construction phase, HAR-EE will inspect and verify that the post-construction BMPs proposed in the PSMP are installed properly. Tenants will be responsible for long-term operation and maintenance [O&M] of the installed post-construction BMPs. HAR-EE will inspect these BMPs during regular tenant inspections, at the frequency identified in Harbors *Tenant Inspection Manual* (HDOTc, 2014).

Table 2-1
Responsibilities for Post-Construction Program Implementation
- Harbors Project

| | Harbors Engineering Branch | | | | | Oahu |
	EC	ED	EE	EM	EP	
Harbors Project Planning					X	
Harbors Project Design		X				
Harbors Project Review		X	X	X		X
Harbors Project Approval	X					
PSMP Review and Approval			X			
Inspection during Construction	X		X			
Inspection after Construction			X			
Harbors Project O&M						X
Provide Training			X			
Enforcement	X		X			

Table 2-2
Responsibilities for Post-Construction Implementation
- Tenant Project

	Tenant	Harbors Engineering Branch					PM
		EC	ED	EE	EM	EP	
Tenant Project Planning	X						X
Tenant Project Review			X	X			
PSMP Review and Approval				X			
Tenant Project Approval							X
Inspection during Construction				X			
Inspection after Construction				X			
Tenants Project O&M	X						
Provide Training				X			
Enforcement				X			X

3.0   BMP REQUIREMENTS AND SELECTION PROCEDURE

To comply with its NPDES permit requirements and to minimize water quality impacts from new development and redevelopment, all Regulated Projects shall consider and apply post-construction BMPs, as appropriate.

This section provides a procedure for selecting post-construction BMPs for Regulated Projects. It includes identifying a list of pollutants of potential concern [POPC] and developing a PSMP to minimize water quality impacts through LID Site Design, Source Control, and Treatment Control BMPs. The procedure for determining the combination of these BMPs and their respective sizing is based on the *CCH Rules Relating to Storm Drainage Standards*. It is also recommended that *CCH Storm Water BMP Guide* be used as a guide for post-construction BMP design and implementation (CCH, 2012). A flow chart summarizing the BMP selection procedure is depicted in Figure 3-1.

Figure 3-1
Post-Construction BMP Selection Procedure Flow Chart

3.1   Identifying Pollutants of Potential Concern and Receiving Water Bodies

Two major water bodies within Harbors jurisdiction are Honolulu Harbor and Kalaeloa Barbers Point Harbor. Hawaii Department of Health (HDOH) lists Honolulu Harbor as impaired water for nutrients, trash, turbidity, and NH4 (HDOH, 2013). Kalaeloa Barbers point Harbor has not been fully assessed, yet. No state Total Maximum Daily Loads [TMDL] have been established for either harbor.

Urban runoff from a developed site has the potential to contribute pollutants, including trash, oil and grease, suspended solids, metals, gasoline, pesticides, and pathogens to the stormwater conveyance system and receiving waters. The pollutants that may be generated at a site are related to land use. A list of POPC is provided in Table 3-1. The *CCH Storm Water BMP Guide* provides a general guideline for a list of post-construction BMPs and targeted POPC.

Table 3-1
Pollutants of Potential Concern

Priority Project Categories	General Pollutant Categories								
	Sediment	Trash & Debris	Metals	Organic Compounds	Nutrients	Oxygen Demanding Substances	Oil & Grease	Bacteria & Viruses	Pesticides
Commercial Development > 1 acre	P[1]	P	P	P[2]	P[1]	P[5]	P	P[3]	P[5]
(Heavy) Industry Development	P	P	P	P		P	P		
Automotive Repair Shops		P	P	P[4,5]			P		
Restaurants		P				P	P	P	P[1]
Parking Lots	P[1]	P	P		P[1]	P[1]	P		P[1]
Fueling Facility		P	P	P		P	P		
Driveways	P	P	P	P[4]	P[1]	P[5]	P		P[1]

P: Potential

1: A potential pollutant if landscaping exists on-site.

2: A potential pollutant if the project includes uncovered parking areas.

3: A potential pollutant if land use involves food or animal waste projects.

4: Including petroleum hydrocarbons.

5: Including solvents.

3.2   Drainage Study and Identification of Conditions of Concern

Common impacts to the regional hydrology resulting from development typically include increased runoff volume and velocity; reduced infiltration; increased flow frequency, duration, and peak; faster time to reach peak flow; and water quality degradation. These changes have the potential to permanently impact receiving water bodies, habitat integrity, and downstream channels (if any). A change to Regulated Project site's hydrology would be considered a condition of concern. To mitigate these potential impacts, the project proponent must prepare the following supporting documentation:

- **Evaluate the project's conditions of concern in a drainage study as part of the PSMP**. The drainage study and the PSMP shall be prepared by a registered civil engineer in the State of Hawaii, with experience in drainage design and water resources

management. The report shall consider the project location (from the larger watershed perspective), topography, soil and vegetation conditions, percent impervious area, natural and infrastructure drainage features, wet season groundwater depth, and any other relevant hydrologic and environmental factors to be protected specific to the nearest watershed.

- **Field reconnaissance including observations of the site and upstream and downstream conditions.** Existing conditions, such as undercutting erosion, slope stability, vegetative stress, and areas susceptible to erosion and/or habitat alteration as a result of altered flow regimes should be pointed out.

- **Existing hydrologic conditions** including description of the location, type, and percent cover of onsite vegetation, description of existing impervious features, description of existing stormwater conveyance features, description of distance to downstream water bodies, description of soil type (Natural Resources Conservation Service [NRCS] hydrologic soil classification and types), description of depth to groundwater during the wet season, description of offsite vegetation types, location, and percent cover.

- **Drainage study** information including, at a minimum, existing and post-construction descriptions of impervious area and percentages, rainfall intensities, geotechnical conditions regarding any planned uses of infiltration techniques (slope stability, expansive soils, compressive soils, seepage, groundwater depth, loss of foundation or pavement sub-grade strength), site constraints (impermeable soils, high groundwater, groundwater pollution or contaminated soils, steep slopes, high-intensity land use, vehicular traffic, restricted right-of-way, or safety concerns), flow rates, velocities, and/or durations for a peak rainfall intensity of 0.4 inches per hour and Water Quality Volume of one (1) inch. The drainage study must also include an analysis of proposed post-construction LID Site Design Strategies, Source Control, and/or Treatment Control BMPs to mitigate (downstream) impacts and attempt to maintain or improve pre-project hydrologic conditions.

3.3   Post-Construction Stormwater BMP Selection

Post-construction BMPs shall be considered during the planning and design phases of a project. Each applicable project shall provide an account of how each drainage area's runoff is managed and treated. The entire project area can be divided into individual/discrete Drainage Areas [DA]. Examples of how to account for individual DA on a site is provided in *CCH Examples Illustrating Application of Rules Relating to Storm Drainage Standards* (CCH, 2013).

Post-construction BMPs include LID Site Design Strategies, Source Control, and Treatment Control BMPs.

Table 3-2
Post-Construction Best Management Practices

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

To comply with this manual and be consistent with the *CCH Rules Relating to Storm Drainage Standards*, the criteria shall be met for all Regulated Projects as follow:
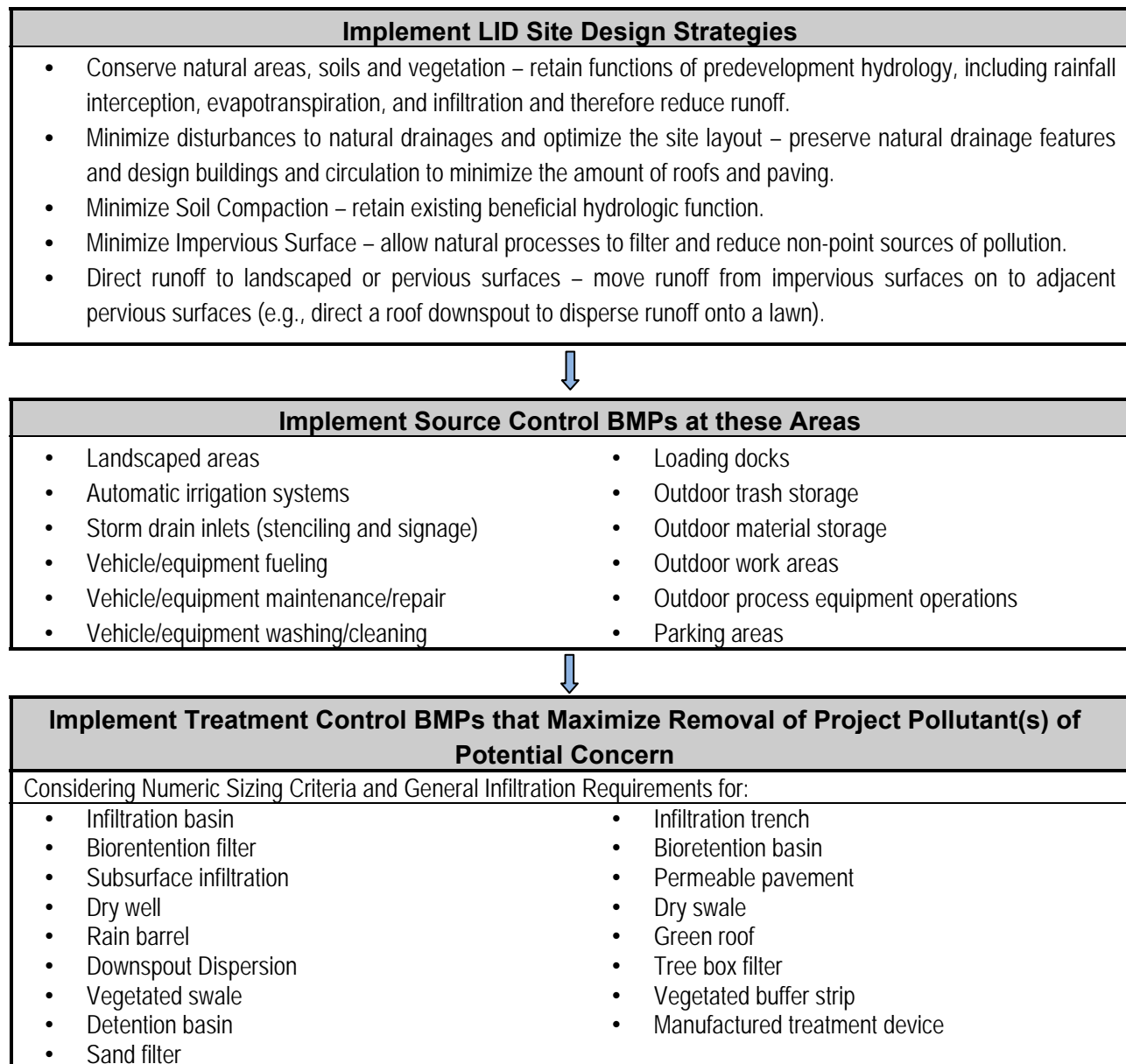
1. Incorporate appropriate LID Site Design Strategies - Either retain on-site the Water Quality Volume with appropriate ID Retention Treatment Control BMPs, or biofilter the Water Quality Volume with appropriate LID Biofiltration Treatment Control BMPs, or a combination of the two, unless determined to be infeasible due to infiltration issues.
2. Incorporate appropriate Source Control BMPs.
3. If it is determined to be infeasible to retain and/or biofilter the Water Quality Volume then treat and discharge with appropriate Treatment Control BMPs any portion of the water that is not retained on-site or biofiltered using the CCH guidance in Section 1-5.2 Part II B of the *Rules Relating to Storm Drainage Standards*, unless a waiver is granted based on the infeasibility of all Treatment Control BMPs.

Consistent with the *CCH Storm Water BMP Guide* and based on collected precipitation data, **1 inch is the depth for all volume-based BMPs and a peak rainfall intensity of 0.4 inches per hour shall be used for flow-based BMPs.** A flow chart summarizing the BMP selection process is provided in Figure 3-2 below.

LID Retention BMPs rely on the soil's ability to infiltrate stormwater runoff. Due to its proximity to ocean water, groundwater underneath Harbors property is relatively shallow and tidally influenced. Therefore, it is recognized that LID Retention BMPs may prove infeasible for majority of Regulated Projects. However, broader LID Site Design Strategies must be considered. For a detailed discussion on infiltration requirements, please refer to General Infiltration Requirements outlined in Section 3 of *CCH Storm Water BMP Guide*.

Selection of Treatment Control BMPs must prioritize and maximize the removal of pollutants of potential concern. Treatment Control BMP design must also consider any impacts caused by tidal influence, which is particularly relevant to subsurface filtration systems, hydrodynamic separator systems, detention or infiltration basins, and wet ponds/wetlands.

Figure 3-2
BMP Selection Process for Pollutants of Potential Concern

Implement LID Site Design Strategies
• Conserve natural areas, soils and vegetation – retain functions of predevelopment hydrology, including rainfall interception, evapotranspiration, and infiltration and therefore reduce runoff.
• Minimize disturbances to natural drainages and optimize the site layout – preserve natural drainage features and design buildings and circulation to minimize the amount of roofs and paving.
• Minimize Soil Compaction – retain existing beneficial hydrologic function.
• Minimize Impervious Surface – allow natural processes to filter and reduce non-point sources of pollution.
• Direct runoff to landscaped or pervious surfaces – move runoff from impervious surfaces on to adjacent pervious surfaces (e.g., direct a roof downspout to disperse runoff onto a lawn).

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Implement Source Control BMPs at these Areas	
• Landscaped areas	• Loading docks
• Automatic irrigation systems	• Outdoor trash storage
• Storm drain inlets (stenciling and signage)	• Outdoor material storage
• Vehicle/equipment fueling	• Outdoor work areas
• Vehicle/equipment maintenance/repair	• Outdoor process equipment operations
• Vehicle/equipment washing/cleaning	• Parking areas

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Implement Treatment Control BMPs that Maximize Removal of Project Pollutant(s) of Potential Concern	
Considering Numeric Sizing Criteria and General Infiltration Requirements for:	
• Infiltration basin	• Infiltration trench
• Biorentention filter	• Bioretention basin
• Subsurface infiltration	• Permeable pavement
• Dry well	• Dry swale
• Rain barrel	• Green roof
• Downspout Dispersion	• Tree box filter
• Vegetated swale	• Vegetated buffer strip
• Detention basin	• Manufactured treatment device
• Sand filter	

3.4   Post-Construction Stormwater Mitigation Plan Development

In order to ensure that a PSMP is adequately designed and integrated into each Regulated Project, project proponents are required to prepare a PSMP by a licensed civil engineer, registered in State of Hawaii. In general, the PSMP must clearly convey the process used to identify pollutants of potential concern, conditions of concern, selected BMPs for the project as well as identifying BMP long-term maintenance requirements. The fundamental steps in preparation of PSMP are provided in Table 3-4. The CCH Storm Water BMP Guide provides a more complete list of LID Site Design Strategies, Source Control BMPs, and Treatment Control BMPs and must be utilized by project proponents. Additionally, project proponents must comply with all applicable requirements by Harbors **Post-Construction Stormwater Management Program** and not rely solely on the outline in Table 3-4.

PSMPs must contain a table of contents to assist reviewers in finding required parts of the document. PSMPs must contain a vicinity map (in scale) containing major roadways, geographic features or landmarks, the project site perimeter, general topography, downstream receiving water body, and north arrow. In addition, PSMPs must also contain a site map (including the entire property on one map or using a key map if multiple sheets are required), scale, north arrow, and legend, impervious features (including location of proposed impervious areas such as paved areas, buildings, covered areas, etc.), potential pollutant source areas (such as fueling area, garage, outdoor storage area, waste container area, wash-rack, potentially hazardous substance storage area). PSMP shall contain the information specified in Table 3-3.

Table 3-3
Required Components of a Post-Construction Stormwater Mitigation Plan
for Regulated Project

Major Components	Descriptions
Organization & Content	• Table of contents • Vicinity map • Project description • Narrative of project activities
Site Map	• Entire property included on one map (use key map if multi-sheets) • Drainage areas and direction of stormwater flow • Private storm drain system(s) • Nearby water bodies and other municipal storm drain inlets • Location of stormwater conveyance systems (ditches, inlets, storm drains, etc.) • Location of existing and proposed stormwater controls • Location of "impervious" areas (i.e., paved areas, buildings, and covered areas) • Locations where materials would be directly exposed to stormwater

Major Components	Descriptions
	• Location of building and activity areas (e.g., fueling area, garages, waste container area, wash racks, potential hazardous substance storage areas, etc.) • Areas of potential soil erosion (including areas downstream of project)
Pollutants of Potential Concern	• Pollutants based upon land use • Impaired water bodies downstream of the project
Drainage Study and Conditions of Concern (refer to ***CCH Rules Relating to Storm Drainage Standards*** and ***CCH Storm Water BMP Guide***)	• Site-specific drainage analysis indicating pre- and post-development runoff calculations. • Impacts to hydrologic regime (hydromodification evaluation, as applicable)
Types of Post-Construction BMPs (refer to ***CCH Rules Relating to Storm Drainage Standards***)	*Example LID and Site Design BMPs* • Conserve natural areas, soils, and vegetation • Minimize impervious surface • Direct runoff to landscaped areas *Example Source Control BMPs* • Covered trash storage • Covered and bermed vehicle wash areas • Automatic irrigation system, timed to prevent discharge *Example Treatment Control BMPs* • Infiltration basin • Subsurface infiltration • Manufactured treatment device
Post-Construction BMP Maintenance	• O&M Plan • Access Agreement

3.4.1 Introduction of Low Impact Development

LID is a stormwater management strategy concerned with maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements (CCH, 2012). It utilizes a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground. By reducing water pollution and increasing groundwater recharge, it helps improve the quality of receiving waters and stabilize the flow rates of nearby surface waters. The goal of LID site design is to reduce the hydrologic impact of development and to incorporate techniques that maintain or restore the site's hydrologic and hydraulic functions. The optimal LID site design minimizes runoff volume and preserves existing flow paths.

LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater **as a resource rather than a waste product**. Many practices have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of developed areas and promotes the natural movement of water within an ecosystem or watershed. The Harbors approach will consist of specific elements that are represented in Table 3-3.

3.4.2   *LID Site Design Strategies*

Consideration of LID Site Design Strategies are required for each Regulated Project. A Regulated Project shall be designed so as to minimize directly connected impervious surfaces and to promote infiltration using LID techniques. A Regulated Project shall minimize the introduction of POPCs generated from site runoff to the stormwater conveyance system. A Regulated Project can address these objectives through the creation of a hydrologically functional project design that attempts to mimic the natural hydrologic regime. These techniques are outlined in Section 1 of **CCH Storm Water BMP Guide**.

Mimicking a site's natural hydrologic regime can be pursued by:

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

These design principles offer an innovative approach to urban stormwater management, one that does not rely on the conventional end-of-pipe or in-the-pipe structural methods but instead uniformly or strategically integrates stormwater controls throughout the urban landscape.

The following five LID components, taken from **CCH Storm Water BMP Guide**, must be considered for each Regulated Project (CCH, 2012).

<u>Conserve Natural Areas, Soils, and Vegetation</u>
> This design strategy helps retain numerous functions of predevelopment hydrology, including rainfall interception, evapotranspiration, and infiltration. Maximizing these functions will thereby reduce the amount of runoff that must be treated. Protection of mature trees and vegetation provides habitat, prevents erosion, captures significant rainfall, provides summer shading, and reduces runoff volume and velocity, which protects and enhances downstream water quality.

Minimize Disturbances to Natural Drainages

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

Minimize Soil Compaction

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

Minimize Impervious Surfaces

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

Direct Runoff to Landscaped Areas

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

3.4.3 Source Control BMPs

Source control BMPs are required for each Regulated Project. Proactively controlling POPC at their source is fundamental to effective stormwater quality management. Design of BMPs to minimize or prevent pollutant generation is guided by two general principles:

- Prevent stormwater from contacting operation and storage areas. These areas should be designed to prevent stormwater runoff from passing through shipping areas, vehicle maintenance yards, and other work places before it reaches storm drains. The objective is to prevent the discharge of water laden with grease, oil, heavy metals and process fluids to surface waters or sensitive resource areas.
- Prevent pollutants from contacting surfaces that come into contact with stormwater runoff. Precautionary measures should be employed to keep POPC from coming into contact with storm or wash water runoff.

In preparation of PSMP, following items need to be provided:

- All potential sources of stormwater pollutants that will be generated at the site.
- Corresponding post-construction BMPs that need to be shown on the site map included in the PSMP.
- A brief narrative description of the source control BMPs to be used including a discussion of the project applicant will ensure their continued operation.

Justification of why a particular source control could not be implemented for this project because of any special condition or situation, shall also be provided. Fact Sheets for applicable source control BMPs may be obtained from Section 2 of the **CCH Storm Water BMP Guide** (CCH, 2012) and/or the **California Stormwater Quality Association [CASQA] Stormwater Quality Handbooks** (CA, 2003). Descriptions of each Source Control Category (taken from CCH **Storm Water BMP Guide**) are summarized in Table 3-4.

Table 3-4
List of Source Control Categories
(taken from CCH Storm Water BMP Guide)

Source Control Category	General Description/Approach
Landscaped Areas	Landscape planning should couple consideration of land suitability for urban uses with consideration of community goals and projected growth. Project plan designs should conserve natural areas to the maximum extent possible, maximize natural water storage and infiltration opportunities, and minimized project slopes and channels.
Automatic Irrigation Systems	Irrigation water provided to landscaped areas may result in excess irrigation water being conveyed into storm water drainage systems.

Source Control Category	General Description/Approach
	Project plan designs for development and redevelopment should include application methods of irrigation water that minimize runoff of excess irrigation water into the storm water conveyance system.
Storm Drain Inlets	Storm drain signs and stencils are highly visible source controls that are placed directly adjacent to storm drain inlets. The stencil or affixed sign contains a brief statement that prohibits dumping of improper materials into the urban runoff conveyance system. Stencils and signs alert the public to the destination of pollutants discharged to the storm drain.
Vehicle/Equipment Fueling	Fueling areas have the potential to discharge oil and grease, solvents, car battery acid, coolant and gasoline to the storm drain. Spills can be a significant source of pollution because fuels contain toxic materials and heavy metals that are not easily removed by storm water treatment devices.
Vehicle/Equipment Repair	Several measures can be taken to prevent operations at maintenance bays from contributing a variety of toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to the storm water conveyance system. In designs for maintenance bays containment is encouraged. Preventive measures include overflow containment structures are dead-end sumps.
Vehicle/Equipment Washing & Cleaning	Vehicle/equipment washing, and steam cleaning may contribute high concentrations of pollutants to wash waters that drain to storm water conveyance systems. Wash water may not be conveyed to a sewer without a sewer connection permit.
Loading Docks	Several measures can be taken to prevent operations at loading docks from contributing a variety of toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to the storm water conveyance system. In designs for loading docks, containment is encouraged. Preventive measures include overflow containment structures and dead-end sumps.
Outdoor Trash Storage	Storm water runoff from areas where trash is stored or disposed of can be polluted. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or streams. Preventive measures including enclosures, containment structures, and impervious pavements to mitigate spills, should be used to reduce the likelihood of contamination.
Outdoor Material Storage	Proper design of outdoor storage areas for materials reduces opportunity for pollutants to enter the storm water conveyance system. Materials may be in the form of raw products, by-products, finished products, and waste products. In outdoor storage areas,

Source Control Category	General Description/Approach
	infiltration is discouraged and containment is encouraged.
Outdoor Work Areas	Proper design of outdoor work areas (grinding, painting, coating, sanding, parts cleaning, etc.) reduces opportunity for pollutants to enter the storm water conveyance system. In outdoor work areas, infiltration and discharge to the storm drain are discouraged; collection and conveyance to the sanitary sewer are encouraged.
Outdoor Process Equipment Operation	Outdoor process equipment operations such as rock grinding or crushing, painting or coating, grinding or sanding, degreasing or parts cleaning, may contribute a variety of pollutants to the storm conveyance system. In outdoor process equipment areas, infiltration is discouraged and containment is encouraged, accompanied by collection and conveyance.
Parking Areas	Parking lots and storage areas can contribute a number of substances, such as trash, suspended solids, hydrocarbons, oil and grease, and heavy metals that can enter receiving waters through storm water runoff or non-storm water discharge. The protocols in this fact sheet are intended to prevent or reduce the discharge of pollutants from parking/storage areas.

3.4.4   Treatment Control BMPs

When a site cannot retain all or portion of the Water Quality Volume on-site, the remaining portions of the water must be treated using Treatment Control BMPs specified in *Section 1-5.2 Part II* B of the **CCH Rules Relating to Storm Drainage Standards**. Treatment Control BMPs are engineered technologies designed to remove pollutants from storm water runoff prior to discharge to the storm drain system or receiving waters. Details on BMP numeric sizing criteria and general requirements for infiltration BMPs are further discussed in Sections 3.4.5. Individual fact sheets for various treatment control BMPs may be obtained from Section 3 of the **CCH Storm Water BMP Guide** and/or **CASQA Stormwater Quality Handbooks**.

Engineering details and specifications shall be included in the PSMP for the selected Treatment Control BMPs. Alternative post-construction BMPs not identified in the **CCH Storm Water BMP Guide** may be approved at the discretion of the Harbors, provided the alternative BMP is as effective in removal of pollutants of concern as other feasible BMPs.

3.4.5   Numeric Sizing Criteria

This section presents the methodology for calculating the Water Quality Volume [WQV] and Water Quality Flow Rate [WQF], which are used to size the majority of the Treatment Control BMPs.

Water Quality Volume

The *WQV* is calculated using this equation: $WQV = PCA \times 3630$, where:

WQV = water quality design volume (in cubic feet)
P = design storm runoff depth (in inches)
C = volumetric runoff coefficient
A = total drainage area (in acres)

As specified in the CCH's Rules (CCH, 2000), a design storm runoff depth of **one inch** shall be used. The volumetric runoff coefficient shall be calculated using the following equation as developed by EPA for smaller storms in urban areas: $C = 0.05 + 0.009I$, where:

C = volumetric runoff coefficient
I = percent of impervious cover (expressed as a percentage)

Water Quality Flow Rate

The *WQF* is calculated using this equation: $WQF = CiA$, where:

WQF = water quality design flow rate (in cubic feet per second)
C = volumetric runoff coefficient
i = peak rainfall intensity (in inches per hour)
A = total drainage area (in acres)

As specified in the CCH's Rules (CCH, 2000), a peak rainfall intensity of **0.4 inches per hour** shall be used. The runoff coefficient shall be determined from Table 3-5 below, based on the drainage area, and shall be, at a minimum, the midpoint of the given range of values. The higher value should be used if soil conditions indicate that pervious areas will have little infiltration/interception potential. For drainage areas containing multiple land uses, the following formula may be used to compute a composite weighted runoff coefficient:

$$C_C = \left(\sum_{i=1}^{n} C_i A_i\right)/A_t, \text{ where:}$$

C_c = composite weighted runoff coefficient
$C_{1,2,...,n}$ = runoff coefficient for each land use cover type
$A_{1,2,...,n}$ = drainage area of each land use cover type (in acres)
A_t = total drainage area (in acres)

Table 3-5
Runoff Coefficients for Water Quality Flow Calculations
(taken from CCH Storm Water BMP Guide)

Type of Drainage Area	Runoff Coefficient (*C*)
Industrial	
Light areas	0.50 ~ 0.80
Heavy areas	0.60 ~ 0.90
Unimproved areas	0.10 ~ 0.30
Lawns	
Sandy soil, flat, ≤ 2%	0.05 ~ 0.10
Sandy soil, average 2~7%	0.10 ~ 0.15
Sandy soil, steep ≥ 7%	0.15 ~ 0.20
Heavy soil, flat, ≤ 2%	0.13 ~ 0.17
Heavy soil, average 2~7%	0.18 ~ 0.22
Heavy soil, steep ≥ 7%	0.25 ~ 0.35
Streets	
Asphaltic	0.70 ~ 0.95
Concrete	0.70 ~ 0.95
Brick	0.75 ~ 0.85
Roofs	0.75 ~ 0.95

Drainage Areas

The entire area of applicable project shall be divided into individual, discrete DAs and clearly presented in a site map. DAs may be defined using grade breaks and roof ridge lines. Separate DAs shall be used for each surface type (e.g., landscaping, pervious paving, or roofs). Each type of DA surface has a unique runoff factor that estimates how much rainfall will produce effective rainfall, or runoff from that drainage area. A list of runoff factors for surfaces draining to BMPs is included in Table 3-5 of this document and Table 4 of the CCH, *Rules Relating to Storm Drainage Standards* (CCH, 2000; Appendix D).

4.0 POST-CONSTRUCTION BMP INSTALLATION

4.1 Installation Inspection during Construction Phase

Inspections will be conducted at multiple stages of construction to ensure the proper installation of all LID Site Design Strategies, Source and Treatment Control BMPs. For Harbors Projects, these inspections shall coincide with the site-specific construction site BMP inspections described in Sections 3.4.1 to 3.4.3 of Harbors **Construction Site Runoff Control Program** manual. For Tenant projects, these inspections shall coincide with the site-specific construction site BMP inspections described in Sections 4.4.1 to 4.4.3 of Harbors **Construction Site Runoff Control Program** manual. In either case, inspections shall include:

- Initial Inspection prior to commencement of construction;
- Recurring BMP Inspection during active construction to ensure construction is occurring in accordance with approved plan; and
- Final Inspection upon completion of construction to ensure proper installation and maintainability.

The inspections may be combined with other inspections provided they will be conducted by trained personnel, as identified in Section 7. The findings of these inspections will be recorded on the *Construction Site Best Management Practices Inspection Checklist* contained in Attachment 4 of the **Construction Site Runoff Control Program**. Each inspection will be reported in the Annual Compliance Report [ACR] and shall be clearly linked to the referenced project and note the stage of the project and the dates of inspections.

5.0 POST-CONSTRUCTION BMP MAINTENANCE, INVENTORY AND RECORDKEEPING

Once built, post-construction stormwater BMPs must be properly maintained to make sure they are operating as designed and managing post-construction runoff as intended.

For Tenant projects, O&M and inspection requirements are documented in an O&M plan that must be submitted to the Harbors prior to completion of construction. All O&M activities will be the responsibility of the tenant and shall be in accordance with the Tenant O&M plan that was submitted and approved as part of the project review and approval process and recorded with the lease, revocable permit, or other contractual document provisions. The tenant O&M plan shall be consistent with the requirements in Section 5.1 below.

For Harbors project, O&M will be provided by Oahu District and/or HAR-EM consistent with the projects O&M plan that was submitted and approved as part of the project review and approval process.

Harbors will verify that appropriate mechanisms, including O&M plans, are in-place for all projects on Harbors' property that have post-construction BMPs. Maintenance requirements identified below are required by Harbors **Post-Construction Stormwater Management Program**.

5.1 Maintenance Requirements

Operation & Maintenance Plan:

For a Regulated Project, Harbors will require that a copy of a satisfactory O&M plan, monitoring plan where applicable (for example, sediment accumulation in a CDS unit; a sample O&M Guideline is enclosed in Appendix E), and a process of verification of ongoing maintenance of installed controls be included in the design submittal package. The O&M Plan must contain following major components:

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

Access Agreement: The Harbors maintains rights to access tenant properties as part of lease or revocable permit provisions. These rights extend to any access required related to

post-construction BMPs. An example of the access agreement is included in Attachment 2 of Harbors *Tenant Inspection Manual*.

5.2 Verification Mechanisms

Annual written verification of effective O&M of each approved post-construction BMP by the responsible party (e.g., contractor, consultant, or tenant) is required to be submitted to Harbors.

- For Harbors Projects, HAR-EC and HAR-EE will verify that post-construction BMPs reflected in the approved PSMP be implemented at the completion of construction. District office will be responsible for long-term O&M of post-construction BMPs and related recordkeeping. Records will be reported in the ACR.
- For Tenant Project, HAR-EE and HAR-PM will verify that post-construction BMPs in the approved PSMP be implemented at the completion of construction. The tenant will be responsible for long-term O&M of post-construction BMPs by conducting routine inspections, documenting all maintenance requirements, submitting annual reports (to Harbors), and retaining records for at least five years. These documents shall be made available to Harbors for inspection upon request at any time.

5.3 Post-Construction BMP Inspection

To ensure that post-construction stormwater BMPs are being operated and maintained in accordance with the approved O&M plan, all LID Site Design, Source and Treatment Control BMPs in the O&M plan will be inspected no less than once a year. Additionally, some BMPs may be inspected more frequently as recommended in *CCH Storm Water BMP Guide* (CCH, 2012; Appendix C) or manufacturer's manual, or because they are located on a tenant site which is inspected more frequently as part of the Tenant Inspection Program. When possible, inspections shall occur after a storm event to allow an evaluation of the effectiveness of the BMPs, identification of any damage that may have occurred, and a determination if any additional maintenance may be required as a result of the storm event. Specifically, O&M inspections shall be performed and documented as following:

- For Harbors Projects, inspectors from the Oahu District will inspect the post-construction stormwater BMPs as specified in the O&M plan but no less than annually.
- For Tenant Projects, the tenant is required to conduct inspections per the approved O&M plan and submit an annual report to Harbors by the annual tenant stormwater awareness training demonstrating proper O&M. HAR-EE inspectors will conduct inspections of post-construction BMP O&M records at a frequency determined by Harbors *Tenant Inspection Program* (i.e., every six months, annually, or every five years).
- Each Harbor and Tenant inspection shall be documented using the Inspection Checklist submitted as part of the O&M plan. HAR-EE will retain copies of all completed inspection reports and the inspection findings will be documented in the electronic Post-

Construction BMP inventory (e.g., database). All deficiencies noted during Harbors and Tenant inspections shall be conveyed to the responsible party in writing and HAR-EE shall conduct timely follow-up to ensure deficiencies are rectified.

5.4   Post-Construction BMP Inventory and Recordkeeping

Harbors has developed an electronic inventory to keep track of post-construction BMPs (i.e., LID Site Design Strategies, Source Control, and Treatment Control BMPs) and the pertinent frequency of inspection and O&M. This inventory includes the BMPs for both Harbors and Tenant projects that discharge into the Honolulu and Kalaeloa Barbers Point Harbors Small Municipal Separate Storm Sewer Systems [MS4s]. Approved Post-Construction BMPs, as identified in the PSMP, will be recorded in the database by HAR-EE. Future records associated with inspection and long-term O&M will be documented in the database. The electronic inventory serves as the basis for the maintenance, inspection, enforcement, and reporting elements of the program.

All existing post-construction BMPs at Honolulu and Kalaeloa Barbers Point Harbors have been logged into the electronic inventory. All new post-construction BMPs, as reflected in the approved PSMP will be logged in the electronic inventory, by HAR-EE during PSMP review and approval phase. The inventory and information for each BMP will be updated at project acceptance, if needed, or based on information obtained from future inspections and maintenance activities. The construction project review, submittal requirements, and procedures, detailed in Section 4.3 of the **Construction Site Runoff Control Program**, provide information about new post-construction BMPs entered into the database. General relevant site information includes:

- Project Identifier, Owner Information
- Project Location (Harbor, Pier Number, Tax Map Key Number, Latitude/Longitude coordinates)
- Acreage
- Control Type and Description of post-construction BMPs
- Photographs of BMPs during construction (if available) and at acceptance
- Date of Acceptance/Construction
- Date of Agreement
- O&M plan
- Maintenance Records
- Inspection Dates and Summary
- Corrective Actions
- Replacement or Repair Date

HAR-EE is responsible for maintaining the post-construction BMP inventory and keeping it current in regards to BMPs, inspections, and maintenance.

6.0   ENFORCEMENT

A detailed discussion on enforcement is presented in the Enforcement Response Plan. Enforcement of tenant construction projects will be undertaken by the HAR-EE and/or other staff who possess enforcement authority through established policies and procedures as described in Harbors Enforcement Response Plan. There are several enforcement mechanisms and penalties to ensure compliance with local ordinances, permits, and contract documents. The enforcement actions proceed along different routes depending upon whether the project is a Harbors Project or a Tenant Project.

The remainder of this Section is focused on enforcement of Tenant Projects during post-construction installation and its long-term O&M by the tenant. When post-construction stormwater BMP inspections reveal improper installation or maintenance, Harbors will undertake appropriate enforcement action. The level of enforcement (summarized in Section 6.2) and associated penalty are typically issued by designated personnel after considering all relevant circumstances regarding the violation. Records of all inspections and follow-up activities for deficiencies are to be retained for a minimum of five years.

6.1   Scope of Authority

The enforcement options available to Harbors range from administrative actions (including verbal/written warnings, eviction notices, and penalties) to the issuance of citations and a criminal fine. Three general areas of the environmental enforcement are listed below:

- Hawaii Revised Statutes [HRS] Chapter 266 authorizes Harbors to issue citations and summons for violations of its rules and have its actions enforced through the district courts by verdict of a misdemeanor or fine.
- Hawaii Administrative Rules [HAR] Title 19 Chapters 41 to 44 establishes uniform safety measures, operational standards and requirements, and the conduct for all tenants at State of Hawaii harbors.
- The tenant lease agreement or revocable permit that provides Harbors with the right of entry to conduct inspection and authority to terminate the permit or lease.

6.2   Enforcement Actions

The levels of enforcement actions to be utilized by inspectors, in order of increasing severity, are as follows:

- Oral or Verbal Warning
- Written Warning (e.g., Tenant Inspection Report or Letter with Tenant Inspection Report)
- Notice of Apparent Violation [NAV]
- Issuance of Summons or Citation
- Notice and Finding of Violation Order ([NFVO], see ERP for detailed description)

Detailed discussion of these enforcement actions could be found at Harbors **Construction Runoff Control Program** (HDOTa, 2014), **Tenant Inspection Manual** (HDOTc, 2014) and the **Enforcement Response Manual** (HDOTb, 2014).

As defined in Harbors **Construction Site Runoff Control Program** and **Tenant Inspection Manual**. There are two types of violations – Class I Violation and Class II Violation, which are based on potential to discharge or cause environmental harm, magnitude of the violation (e.g., failure to apply for Industrial General Permit Coverage), duration of the violation, and violator's compliance history. A range of issues, which could result in enforcement (either informal or formal) in terms of post-construction BMP, includes:

- Failure to maintain a BMP specified in the submitted PSMP,
- Failure to maintain a BMP consistent with O&M Plan,
- Failure to address deficiencies,
- Failure to conduct annual inspection,
- Failure to submit required inspection documentation.

In the event that an enforcement action is required, the designated staff will identify the appropriate enforcement response to achieve compliance. If the tenant cannot achieve compliance by implementing the appropriate corrective action, the designated staff will "escalate" the enforcement response as outlined in Harbors **Enforcement Response Manual**.

7.0   TRAINING

Training is a major component of any successful stormwater program. Harbors will adopt **CCH Rules Relating to Storm Drainage Standards** and **CCH Storm Water BMP Guide** as a reference for those parties who apply for project approvals on selection, design, installation, O&M of stormwater BMPs via the state website and handouts.

Harbors provides training so that employees have the knowledge and skills necessary to perform their functions effectively and efficiently. Training courses provide a comprehensive review of post-construction stormwater BMPs, introduce LID practices, and provide updates on the relevant requirements of the Harbors SWMP.

Appropriate Harbors staff whose job duties are related to implementing post-construction BMPs will be trained to have a clear understanding of their responsibilities. The post-construction BMPs training will consist of overall program goals and implementation. The content of the training will include:

- Post-Construction Technical Standards and use of the *Post-Construction BMP Checklist* including the existing and **CCH Rules Relating to Storm Drainage Standards** and **CCH Storm Water BMP Guide**
- Content and Requirements of PSMP and O&M Plans
- Inspection Procedures
- Implementing the Enforcement Response Plan
- Post-construction BMP Inventory database use and maintenance

Training for Designers and Plans Reviewers
This annual course, required for HAR-ED, HAR-EE, HAR-EM, and HAR-EP and available to other Harbors employees and consulting engineers, will cover planning and design considerations for the proper selection, design, installation, operation, and maintenance of post-construction BMPs. It also includes an introduction to LID stormwater management practices.

Training for Inspectors, Construction Managers, and Contractors
This annual course, required for HAR-EC, HAR-EE, HAR-EM, and HAR-PM and available to other Harbors employees, consultant construction managers, and contractors on Harbors' projects, will cover installation, O&M, and inspection considerations for post-construction stormwater BMPs. It also includes an introduction to LID stormwater management practices.

Training for Operations and Maintenance
This course, required for Oahu District and available to other Harbors employees, will cover proper O&M of post-construction BMPs owned and operated by Harbors.

Training effectiveness will be evaluated through a survey of the participants. All participants will be required to sign in and information regarding how many employees attend the initial training will be reported in the ACR. Input from the survey will be evaluated and used for the development of future training session. The evaluation findings and any necessary program improvements will be included in the ACR.

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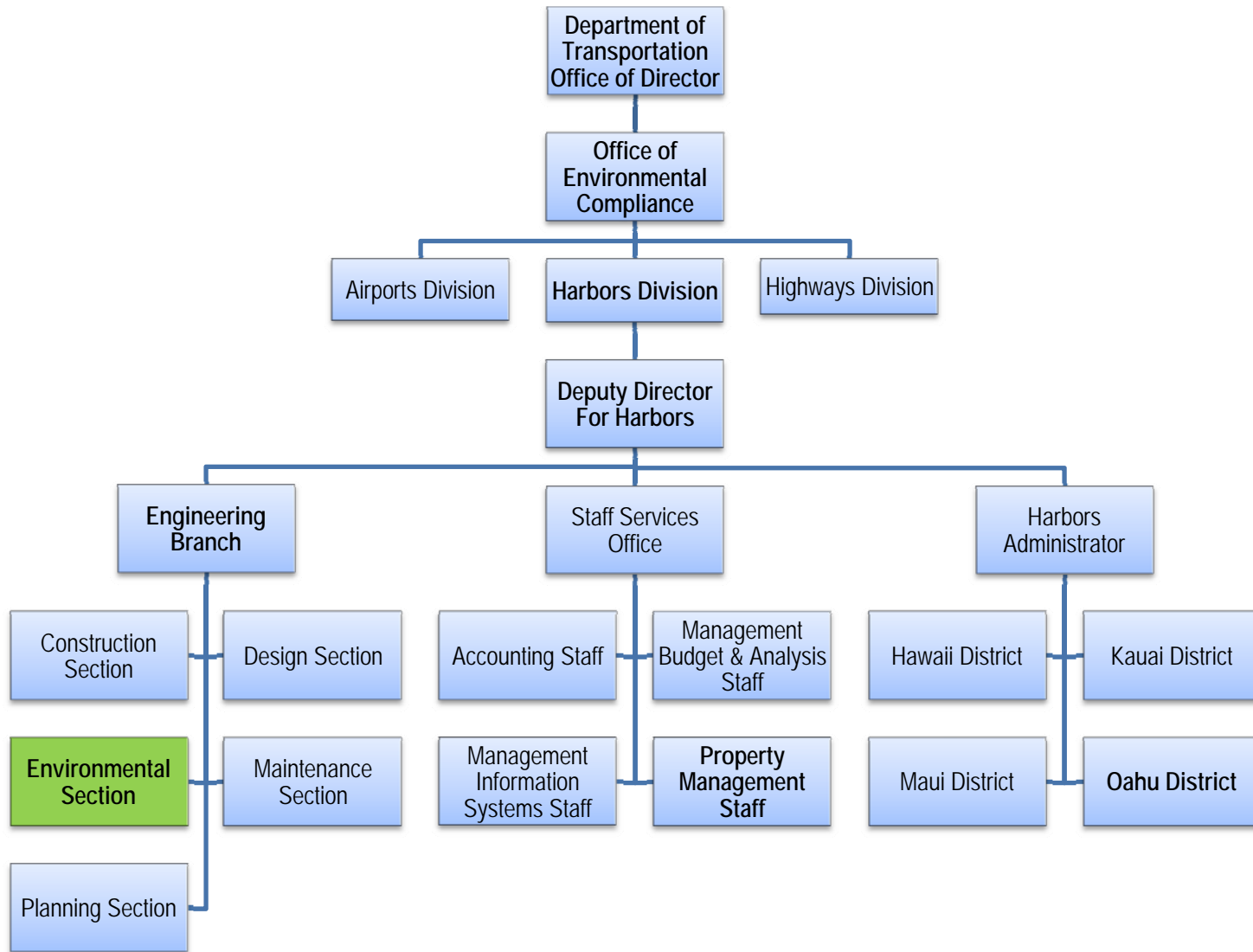
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Appendix A

HDOT Harbors Division Administrative Organizational Chart

State of Hawaii Department of Transportation, Harbors Division Administrative Organizational Chart

- **Department of Transportation Office of Director**
  - **Office of Environmental Compliance**
    - Airports Division
    - **Harbors Division**
      - **Deputy Director For Harbors**
        - **Engineering Branch**
          - Construction Section
          - Design Section
          - Environmental Section
          - Maintenance Section
          - Planning Section
        - Staff Services Office
          - Accounting Staff
          - Management Budget & Analysis Staff
          - Management Information Systems Staff
          - **Property Management Staff**
        - Harbors Administrator
          - Hawaii District
          - Kauai District
          - Maui District
          - **Oahu District**
    - Highways Division

Appendix B

Permanent Post-Construction Best Management Practices Plan Checklist

Permanent Post-Construction Best Management Practice Plan Checklist

For a Harbors Project, please fill in this section	
Project Title:	
Project Location:	
Acreage of Site:	Harbors Project No.:
Name of Design Firm:	
Email:	Phone No.:

For a Tenant Improvement Project, please fill in this section	
Tenant Business Name:	Date:
Project Title:	
Project Location:	
Acreage of Site:	TMK No. (if any):
Applicant Name:	Job Title:
Email:	Phone No.:

Signature and Certifications	
Designer: I certify that the design is complete, accurate, and addresses the items on this checklist to the best of my knowledge. Print Name: Job Title:	
Signature:	Date:
Review: HDOT Harbors Project Manager and Environmental Section.	
Harbors Project Manager Signature:	Print Name:
	Date:
Harbors Environmental Section Signature:	Print Name:
	Date:

Part One - Low Impact Development Site Design Strategies

The following checked strategies will be incorporated and area(s) is denoted on the map:

☐ Conserve natural areas, soils, and vegetation   ☐ Minimize soil compaction

☐ Minimize disturbances to natural drainages   ☐ Minimize impervious surface

☐ Direct Runoff to Landscaped Areas   ☐ None (all infeasible)

If "None" is checked, please provide justification here:

Part Two – Source Control

The following checked Source Control BMP(s) will be incorporated and area(s) is denoted on the map:

☐ Automatic irrigation systems   ☐ Landscaped areas   ☐ Loading docks

☐ Vehicle/Equipment fueling   ☐ Vehicle/Equipment repair   ☐ Vehicle/Equipment washing

☐ Outdoor work areas   ☐ Outdoor material storage   ☐ Outdoor trash storage

☐ Outdoor process operations   ☐ Parking areas   ☐ Others

If "Others" is checked, please describe here (attach separate sheets if needed):

Part Three – Treatment Control

The following checked Treatment Control BMP(s) will be incorporated and area(s) is denoted on the map:

☐ Infiltration basin   ☐ Infiltration trench   ☐ Subsurface Infiltration

☐ Dry well   ☐ Bioretention basin   ☐ Permeable pavement

☐ Green roof   ☐ Bioretention filter   ☐ Dry swale

☐ Downspout dispersion   ☐ Vegetated swale   ☐ Vegetated buffer strip

☐ Tree box filter

Alternative Compliance. The following alternative compliance is proposed and area(s) is denoted on the map:

☐ Incorporate the following alternative Treatment Control BMP(s):

     ☐ Detention basin   ☐ Sand filter   ☐ Rain barrel

     ☐ Manufactured treatment device

☐ Other (specify):

☐ Source Control BMPs are designed with reference to the City and County of Honolulu Storm Water BMP Guide.

☐ Treatment Control BMPs are designed with reference to the City and County of Honolulu Storm Water BMP Guide.

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Appendix C

CCH Storm Water BMP Guide

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Storm Water BMP Guide

DRAFT

June 2012
[Revision date: July 2012]

By:
City and County of Honolulu
Department of Planning and Permitting

Protect our waters...
FOR LIFE

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Acronyms and Abbreviations

BMP	Best Management Practice
cfs	cubic feet per second
cu-ft	cubic feet
ENV	Department of Environmental Services, City and County of Honolulu
EPA	Environmental Protection Agency, United States
ft	feet
hr	hour
in	inches
LID	Low Impact Development
min	minutes
sec	seconds
SPCC	Spill Prevention Control and Countermeasure
sq-ft	square feet
WQF	Water Quality Flow
WQV	Water Quality Volume

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INTRODUCTION

The City and County of Honolulu Rules Relating to Storm Drainage Standards (*Rules*) specifies that regulated new development and redevelopment projects include Low Impact Development (LID) Site Design Strategies, Source Control Best Management Practices (BMPs), and Post-Construction Treatment Control BMPs to meet water quality criteria. This Storm Water BMP Guide provides general guidelines to support their implementation. More detailed information may be found in the *City and County of Honolulu Storm Water BMP Manual, New Development and Redevelopment*, which may be found on the City's website.

Document Organization

Chapter 1 provides descriptions of the five site design strategies that must be considered for regulated projects if applicable

Chapter 2 provides the minimum requirements for the 12 source control BMPs that must be considered for regulated projects if applicable.

Chapter 3 provides design guidelines for those Treatment Control BMPs which are considered most appropriate for the City and County of Honolulu. It includes numeric sizing criteria to calculate the Water Quality Volume (WQV) and Water Quality Flow Rate (WQF), general design requirements for all Treatment Control BMPs that include infiltration as a pollutant removal/treatment mechanism, and specific BMP design and sizing information.

Reference are provided at the end of the document.

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1. SITE DESIGN STRATEGIES

Low Impact Development (LID) is a storm water management strategy concerned with maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements. LID employs a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground. By reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and stabilize the flow rates of nearby streams.

The goal of LID site design is to reduce the hydrologic impact of development and to incorporate techniques that maintain or restore the site's hydrologic and hydraulic functions. The optimal LID site design minimizes runoff volume and preserves existing flow paths. On the following pages are presented the five strategies considered applicable for new development and redevelopment projects.

CONSERVE NATURAL AREAS, SOILS, AND VEGETATION

The conservation of natural areas, soils, and vegetation helps to retain numerous functions of predevelopment hydrology, including rainfall interception, evapotranspiration, and infiltration. Maximizing these functions will thereby reduce the amount of runoff that must be treated. Protection of mature trees and vegetation provides habitat, prevents erosion, captures significant rainfall, provides summer shading, and reduces runoff volume and velocity which protects and enhances downstream water quality. Specific measures are:

- Preserve/protect riparian buffers

- Preserve/protect wetlands

- Preserve/protect natural flow pathways

- Preserve/protect steep slopes

- Preserve/protect sensitive environmental areas.

- Preserve/protect undisturbed vegetated areas/corridors.

- Preserve native trees and restrict disturbance of soils beneath tree canopies.

- Limit construction activities and disturbances to areas with previously disturbed soils.

- Avoid disturbing vegetation and soil on slopes and near surface waters.

- Leave an undisturbed buffer along both sides of natural streams.

Waaloa Way

MINIMIZE DISTURBANCES TO NATURAL DRAINAGES

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

- Limit site disturbance, clearing, and grading to the smallest areas necessary

- Maintain surface flow patterns of undeveloped sites.

- Maintain existing water body alignments, sizes, and shapes.

- Minimize and control construction traffic areas

- Minimize and control construction stockpiling and storage areas

- Use construction fencing to mark where no disturbances will be allowed.

Waimanalo Stream

MINIMIZE SOIL COMPACTION

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

- Protect soils against compaction and rutting in areas where traffic is unavoidable.

- Minimize the size of construction easements and material storage areas.

- Limit areas of heavy equipment

- Prohibit working on wet soils with heavy equipment.

- Restore compacted open space areas with tilling and soil amendments.

- Avoid extensive and unnecessary clearing and stockpiling of topsoil

- Avoid/minimize soil compaction in open space, landscaped, and proposed LID BMP areas

- Prepare soil amendments off-site

???

MINIMIZE IMPERVIOUS SURFACES

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

- Use open space or hybrid street plan instead of grid and curvilinear

- Reduce sidewalk widths

- Maximize utilization of compact car spaces in parking areas

- Reduce parking stalls in areas near Transit Centers

- Incorporate shared parking areas and driveways

- Reduce driveway sizes

- Consider clustering buildings that require less driveways and pathways;

Fasi Municipal Building Green Roof

DIRECT RUNOFF TO LANDSCAPED AREAS

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

- Design roof drains to flow to vegetated areas

- Direct flow from paved areas to stabilized landscaped/vegetated areas

- Grade paved areas to achieve sheet flow to landscaped areas

- Break up flow directions from large paved surfaces

Local Church

2. SOURCE CONTROL BMPS

Proactively controlling pollutants at their source is fundamental to effective stormwater quality management. There are a number of items that can be routinely designed into a project that function as source controls once a project is completed. They include such items as marking new drain inlets and posting informational signs; improving landscape planning and efficient irrigation methods; using water quality friendly building materials; properly designing outdoor material and trash storage areas; and permanently protecting slopes and channels from erosion. They also include design features for specific workplace or other activity areas such as vehicle washing areas, outdoor processing areas, maintenance bays, and fueling areas.

Design of BMPs to control workplace exposure to pollutants is guided by two general principles:

- Prevent storm water from contacting work areas. Work and storage areas should be designed to prevent storm water runoff from passing through shipping areas, vehicle maintenance yards, and other work places before it reaches storm drains. The objective is to prevent the discharge of water laden with grease, oil, heavy metals and process fluids to surface waters or sensitive resource areas.

- Prevent pollutants from contacting surfaces that come into contact with storm water runoff. Precautionary measures should be employed to keep pollutants from contacting surfaces that come into contact with runoff. This means controlling spills and reviewing operational practices and equipment to prevent pollutants from coming into contact with storm or wash water runoff.

The most common Source Control BMPs are the following, and are presented herein:

- Landscaped areas
- Automatic irrigation systems
- Storm drain Inlets
- Vehicle/equipment fueling
- Vehicle/equipment repair
- Vehicle/equipment washing/cleaning

- Loading docks
- Outdoor trash storage
- Outdoor material storage
- Outdoor work areas
- Outdoor process equipment operations
- Parking areas

The following information is provided for each of the above-listed BMPs:

- Brief description/approach
- Minimum (mandatory) design requirements
- Minimum (mandatory) operations and maintenance requirements

LANDSCAPED AREAS

Description / Approach

Landscape planning should couple consideration of land suitability for urban uses with consideration of community goals and projected growth. Project plan designs should conserve natural areas to the maximum extent possible, maximize natural water storage and infiltration opportunities, anMinimumd protect slopes and channels.

Design Guidelines

- Conserve Natural Areas to the extent possible

- Maximize Natural Water Storage and Infiltration Opportunities to the extent possible

- Protect Slopes and Channels

O&M Recommendations

- Do not use pesticides and fertilizers during wet weather or when rain is forecast, and minimize their use during dry weather.

- Do not blow or rake leaves, grass, or garden clippings into the street, gutter, or storm drain.

- Do not apply any chemicals (insecticide, herbicide, or fertilizer) directly to surface waters, unless the application is approved and permitted by the state.

- Dispose of grass clippings, leaves, sticks, or other collected vegetation as garbage, or by composting. Do not dispose of collected vegetation into waterways or storm drainage systems.

- Use mulch or other erosion control measures on exposed soils.

- Check irrigation schedules so pesticides will not be washed away and to minimize non-storm water discharge.

AUTOMATIC IRRIGATION SYSTEMS

Description / Approach

Irrigation water provided to landscaped areas may result in excess irrigation water being conveyed into storm water drainage systems.

Project plan designs for development and redevelopment should include application methods of irrigation water that minimize runoff of excess irrigation water into the storm water conveyance system.

Design Guidelines

- Design irrigation systems to each landscape area's specific water requirements.

- Implement landscape plans consistent with City water conservation resolutions, which may include provision of drip irrigation, water sensors, programmable irrigation times (for short cycles), etc.

- Design timing and application methods of irrigation water to minimize the runoff of excess irrigation water into the storm water drainage system.

- Group plants with similar water requirements in order to reduce excess irrigation runoff and promote surface filtration.

O&M Recommendations

- Inspect irrigation system periodically to ensure that the right amount of water is being applied and that excessive runoff is not occurring.

- Minimize excess watering, and repair leaks in the irrigation system as soon as they are observed.

STORM DRAIN INLETS

Description / Approach

Storm drain signs and stencils are highly visible source controls that are placed directly adjacent to storm drain inlets. The stencil or affixed sign contains a brief statement that prohibits dumping of improper materials into the urban runoff conveyance system. Stencils and signs alert the public to the destination of pollutants discharged to the storm drain.

Design Guidelines

- Provide stenciling or labeling of all storm drain inlets and catch basins, constructed or modified, within the project area with prohibitive language. ENV Storm Water Branch has approved specific signage and/or storm drain message placards for use.

- Place the marker in clear sight facing toward anyone approaching the inlet from either side

- Be aware that signage on face of curbs tends to be worn by contact with vehicle tires and sweeper brooms.

- Post signs with prohibitive language and/or graphical icons, which prohibit illegal dumping at public access points along channels and creeks within the project area.

O&M Recommendations

- Inspect signage regularly and maintain as appropriate to ensure legibility.

- Inspect regularly, at least annually, for structural deterioration or significant build-up of debris or sediment.

VEHICLE/EQUIPMENT FUELING

Description / Approach

Fueling areas have the potential to discharge oil and grease, solvents, car battery acid, coolant and gasoline to the storm drain. Spills can be a significant source of pollution because fuels contain toxic materials and heavy metals that are not easily removed by storm water treatment devices.

Design Guidelines

- *Covering.* Include an overhanging roof structure or canopy over fuel dispensing areas. The cover's minimum dimensions must be equal to or greater than the area within the grade break. The cover must not drain onto the fuel dispensing area and the downspouts must be routed to prevent drainage across the fueling area. If fueling large equipment or vehicles that prohibit the use of covers or roofs, the fueling island should be designed to accommodate the larger vehicles and equipment and to prevent storm water run-on and runoff.

- *Surfacing.* Pave fuel dispensing areas with Portland cement concrete (or equivalent smooth impervious surface). Extend the paved area a minimum of 6.5 ft from the corner of each fuel dispenser, or the length at which the hose and nozzle assembly may be operated plus 1 ft, whichever is less. The use of asphalt concrete is prohibited. Use asphalt sealant to protect asphalt paved areas surrounding the fueling area.

- *Grading/Contouring.* Slope the dispensing areas to prevent ponding, and separate it from the rest of the site by a grade break that prevents run-on. Grade the fueling areas to drain toward a dead-end sump or vegetated/landscaped area. Direct runoff from downspouts/roofs away from fueling areas towards vegetated/landscaped areas if possible.

- *Drains.* Label all drains within facility boundaries using paint or stencil, to indicate whether flow is to the storm drain, sewer, or oil/water separator

O&M Recommendations

- Maintain clean fuel-dispensing areas using dry cleanup methods such as sweeping, or use of rags and absorbents for leaks and spills.

- If you clean by washing, place a temporary plug in the downstream drain and pump out the accumulated water. Properly dispose the water.

- Install vapor recovery nozzles to help control drips as well as air pollution.

- Use secondary containment when transferring fuel from the tank truck to the fuel tank. Cover storm drains in the vicinity during transfer.

- Post signs at the fuel dispenser or fuel island warning vehicle owners/operators against "topping off" of vehicle fuel tanks.

- Develop and implement a Spill Prevention Control and Countermeasure (SPCC) Plan.

VEHICLE/EQUIPMENT REPAIR

Description / Approach

Several measures can be taken to prevent operations at maintenance bays from contributing a variety of toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to the storm water conveyance system. In designs for maintenance bays containment is encouraged. Preventive measures include overflow containment structures and dead-end sumps

Design Guidelines

Design requirements for vehicle maintenance and repair are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design requirements described hereon are meant to enhance and be consistent with these code requirements.

- Locate repair/maintenance bays indoors; or design them to preclude run-on and runoff.

- Pave repair/maintenance floor areas with Portland cement concrete (or equivalent smooth impervious surface).

- Provide impermeable berms, drop inlets, trench catch basins, or overflow containment structures around repair bays to prevent spilled materials and wash-down waters from entering the storm drain system. Connect drains to a sump for collection and disposal. Direct connection of the repair/maintenance bays to the storm drain system is prohibited.

- Label all drains within facility boundaries using paint or stencil, to indicate whether flow is to the storm drain, sewer, or oil/water separator.

O&M Recommendations

- Avoid hosing down work areas. If work areas are washed, collect and direct wash water to sanitary sewer.

- Do not pour liquid waste down floor drains, sinks, outdoor storm drain inlets, or other storm drains or sewer connections.

- Do not dispose of used or leftover cleaning solutions, solvents, and automotive fluids and oil in the sanitary sewer.

- Keep drip pans or containers under vehicles or equipment that may drip during repairs.

- When steam cleaning or pressure washing parts, the wastewater must be discharged to an on-site oil water separator that is connected to a sanitary sewer or blind sump.

- Develop and implement a Spill Prevention Control and Countermeasure (SPCC) Plan.

VEHICLE/EQUIPMENT WASHING & CLEANING

Description / Approach
Vehicle washing, equipment washing, and steam cleaning may contribute high concentrations of pollutants to wash waters that drain to storm water conveyance systems. Wash water may not be conveyed to a sewer without a sewer connection permit.

Design Guidelines

Incorporate at least one of the following features for equipment washing/steam cleaning:

- Be self-contained and/or covered with a roof or overhang

- Be equipped with a clarifier or other pretreatment facility

- Have a proper connection to a sanitary sewer

- Install sumps or drain lines to collect wash water. Divert wash water to the sanitary sewer, an engineered infiltration system, or an equally effective alternative.

- Direct and divert surface water runoff away from the exposed area around the wash pad, and wash pad itself to alternatives other than the sanitary sewer.

- Cover areas used for regular washing of vehicles, trucks, or equipment, surround them with a perimeter berm, and clearly mark them as a designated washing area.

- Label all drains within facility boundaries using paint or stencil, to indicate whether flow is to the storm drain, sewer, or oil/water separator.

O&M Recommendations

- Mark the area clearly as a wash area.

- Post signs stating that only washing is allowed in wash area.

- Provide trash container with lids in wash area.

- Recycle, collect or treat wash water effluent prior to discharge to the sanitary sewer system.

- Do not conduct oil changes and other engine maintenance in the designated washing area. Perform these activities in a place designated for oil change and maintenance activities.

- Cover the wash area when not in use to prevent contact with rain water.

- Do not permit steam cleaning wash water to enter the storm drain.

- Develop and implement a Spill Prevention Control and Countermeasure (SPCC) Plan.

LOADING DOCKS

Description / Approach

Several measures can be taken to prevent operations at loading docks from contributing a variety of toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to the storm water conveyance system. In designs for loading docks, containment is encouraged. Preventive measures include overflow containment structures and dead-end sumps.

Design Guidelines

Design requirements for vehicle maintenance and repair are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design requirements described hereon are meant to enhance and be consistent with these code requirements.

- Cover all loading dock areas, or design them to preclude run-on and runoff.

- Do not allow runoff from depressed loading docks (truck wells) to discharge into storm drains.

- Drain below-grade loading docks from grocery stores and warehouse/distribution centers of fresh food items through water quality inlets, an engineered infiltration system, or an equally effective alternative.

- Grade and/or berm the loading/unloading area to a drain that is connected to a dead-end.

- Pave loading areas with concrete instead of asphalt.

O&M Recommendations

- Develop an operations plan that describes procedures for loading and/or unloading.

- Conduct loading and unloading in dry weather if possible.

- Load and unload all materials and equipment in covered areas if feasible.

- Load/unload only at designated loading areas.

- Check loading and unloading equipment regularly for leaks.

- Look for dust or fumes during loading or unloading operations.

- Develop and implement a Spill Prevention Control and Countermeasure (SPCC) Plan.

OUTDOOR TRASH STORAGE

Description / Approach

Storm water runoff from areas where trash is stored or disposed of can be polluted. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or streams.

Preventive measures including enclosures, containment structures, and impervious pavements to mitigate spills, should be used to reduce the likelihood of contamination.

Design Guidelines

- Hazardous waste must be handled in accordance with legal requirements established in *Hawaii Administrative Rules Title 11 Chapter 58.1 Solid Waste Management Control,* and enforcement by the *State of Hawaii Department of Health solid and Hazardous Waste Branch.*

- Berm trash storage areas to prevent run-on from adjoining roofs and pavement, or grade areas towards vegetated/landscaped areas.

- Reduce/prevent leaking of liquid waste by incorporating at least one of the following:

  – Lined bins or dumpsters

  – Low containment berm around the dumpster area

  – Drip pans underneath dumpsters

- Prevent rainfall from entering containers with roofs, awnings, or attached lids.

- Pave trash storage areas with an impervious surface to mitigate spills.

- Do not locate storm drains in immediate vicinity of the trash storage area.

- Post signs on dumpsters indicating that hazardous material are not to be disposed of therein.

O&M Recommendations

- Spot clean leaks and drips routinely to prevent runoff of spillage

- Post "no littering" signs

- Use only watertight waste receptacle(s) and keep the lid(s) closed

- Do not overfill or fill with any liquid. Keep lid closed at all times.

- Periodically inspect for leaks. If found contact the leasing company immediately.

- Never wash down or rinse with a hose. Contact leasing company for cleaning.

- Develop and implement a Spill Prevention Control and Countermeasure (SPCC) Plan.

OUTDOOR MATERIAL STORAGE

Description / Approach

Proper design of outdoor storage areas for materials reduces opportunity for pollutants to enter the storm water conveyance system. Materials may be in the form of raw products, by-products, finished products, and waste products.

In outdoor storage areas, infiltration is discouraged and containment is encouraged.

Design Guidelines

Design requirements for material storage areas are governed by Building and Fire Codes, and by current City ordinances and zoning requirements. Control measures are site specific, and must meet local agency requirements.

- Materials with the potential to contaminate storm water must either be placed in an enclosure that prevents contact with runoff or spillage to the storm water conveyance system, or protected by secondary containment structures such as berms, dikes, or curbs.

- Pave the storage area with Portland cement concrete (or equivalent smooth impervious surface) to contain leaks and spills.

- Slope the storage area towards a dead-end sump to contain spills.

- Direct runoff from downspouts/roofs away from storage areas.

- Cover the storage area with an awning that extends beyond the storage area to minimize collection of storm water within the secondary containment area. A manufactured storage shed may be used for small containers.

O&M Recommendations

- Protect materials from rainfall, run-on, runoff, and wind dispersal.

- Employ safeguards against accidental releases.

- Inspect storage areas regularly for leaks or spills.

- Keep storage areas clean and dry.

- Keep containers in good condition without corrosion or leaky seams.

- Cover and contain stockpiles of raw materials to prevent storm water run-on. If infeasible, implement erosion control practices around site perimeter and catch basins.

- Develop and implement a Spill Prevention Control and Countermeasure (SPCC) Plan.

OUTDOOR WORK AREAS

Description / Approach

Proper design of outdoor work areas (grinding, painting, coating, sanding, parts cleaning, etc.) reduces opportunity for pollutants to enter the storm water conveyance system.

In outdoor work areas, infiltration and discharge to the storm drain are discouraged; collection and conveyance to the sanitary sewer are encouraged.

Design Guidelines

Design requirements for outdoor work areas are governed by Building and Fire Codes, and by current City ordinances, and zoning requirements.

- Create an impermeable surface such as concrete or asphalt, or a prefabricated metal drip pan, depending on the use.

- Cover the area with a roof to prevent rain from falling on the work area and becoming polluted runoff.

- Berm or perform mounding around the perimeter of the area to prevent water from adjacent areas from flowing on to the surface of the work area.

- Directly connect runoff to the sanitary sewer or other specialized containment system(s). This allows the more highly concentrated pollutants from these areas to receive special treatment that removes particular constituents. Approval for this connection must be obtained from the City.

- Locate the work area away from storm drains or catch basins.

O&M Recommendations

- Dry clean the work area regularly.

- Inspect storage areas regularly for leaks or spills.

- Develop and implement a Spill Prevention Control and Countermeasure (SPCC) Plan.

OUTDOOR PROCESS EQUIPMENT OPERATIONS

Description / Approach

Outdoor process equipment operations such as rock grinding or crushing, painting or coating, grinding or sanding, degreasing or parts cleaning, may contribute a variety of pollutants to the storm conveyance system.

In outdoor process equipment areas, infiltration is discouraged and containment is encouraged, accompanied by collection and conveyance.

Design Guidelines

Design requirements for outdoor processing areas are governed by Building and Fire codes, and by current local agency ordinances, and zoning requirements.

- Cover or enclose areas that would be the most significant source of pollutants; or slope the area toward a dead-end sump; or, discharge to the sanitary sewer system following appropriate treatment in accordance with conditions established by the applicable sewer agency.

- Grade or berm area to prevent run-on from surrounding areas.

- Do not install storm drains in areas of equipment repair.

- Provide secondary containment structures (not double wall containers) where wet material processing occurs (e.g., electroplating), to hold spills resulting from accidents, leaking tanks, or equipment, or any other unplanned releases (Note: if these are plumbed to the sanitary sewer, they must be with the prior approval of the City.)

O&M Recommendations

- Dry clean the work area regularly.

- Inspect storage areas regularly for leaks or spills.

- Develop and implement a Spill Prevention Control and Countermeasure (SPCC) Plan.

PARKING AREAS

Description / Approach

Parking lots and storage areas can contribute a number of substances, such as trash, suspended solids, hydrocarbons, oil and grease, and heavy metals that can enter receiving waters through storm water runoff or non-storm water discharges. The protocols in this fact sheet are intended to prevent or reduce the discharge of pollutants from parking/storage areas.

Design Guidelines

- Direct pavement runoff towards vegetated/landscaped areas if possible.

O&M Recommendations

- Clean leaves, trash, sand, and other debris regularly

- Routinely sweep, shovel, and dispose of litter in the trash. Sweep entire parking lot at least once before the onset of the wet season.

- Provide an adequate number of covered trash receptacles. Clean out frequently.

- Re-seal or pave only on dry days, and stop immediately before rainfall.

- Pre-heat, transfer or load hot bituminous material away from storm drain inlets.

- Do not allow any solids, liquids, or slurries to enter storm drains

- Use dry clean-up methods (absorbents) on auto spills and/or drips.

- Do not hose down unless absolutely necessary. If you must pressure wash, discharge wash water to the sanitary sewer or a vegetated area. Do not allow wash water to enter storm drains.

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3. TREATMENT CONTROL BMPS

Treatment Control BMPs are engineered technologies designed to remove pollutants from storm water runoff prior to discharge to the storm drain system or receiving waters. This chapter addresses BMP numeric sizing criteria, general requirements for infiltration BMPs, and individual BMP fact sheets.

NUMERIC SIZING CRITERIA

This section presents the methodology for calculating the Water Quality Volume (WQV) and Water Quality Flow Rate (WQF), which are used to size the majority of the Treatment Control BMPs.

Water Quality Volume

The Water Quality Volume (WQV) is calculated using the following equation:

$$WQV = PCA \times 3630$$

Where: WQV   = water quality design volume (cubic feet)
                   P   = design storm runoff depth (inches)
                   C   = volumetric runoff coefficient
                   A   = total drainage area (acres)

As specified in the *Rules*, a design storm runoff depth of 1 inch shall be used. The volumetric runoff coefficient shall be calculated using the following equation as developed by EPA for smaller storms in urban areas:

$$C = 0.05 + 0.009I$$

Where: C   = volumetric runoff coefficient
                   I   = percent of impervious cover, expressed as a percentage

A graph presenting the relationship between the percent of impervious cover and the unit water quality design volume for a 1-inch runoff depth is shown in Figure 1.

Water Quality Flow

The design water quality flow rate (WQF) is calculated using the Rational Formula:

$$WQF = CiA$$

Where: WQF   = water quality design flow rate (cubic feet per second)
                   C   = runoff coefficient
                   i   = peak rainfall intensity (inches per hour)
                   A   = total drainage area (acres)

As specified in the *Rules*, a peak rainfall intensity of 0.4 inches per hour shall be used. The runoff coefficient shall be determined from Table 1 below, based on the drainage area, and shall be, at a minimum, the midpoint of the given range of values. The higher value should be used if

soil conditions indicate that pervious areas will have little infiltration/interception potential. For drainage areas containing multiple land uses, the following formula may be used to compute a composite weighted runoff coefficient:

$$C_c = \left(\sum_{i=1}^{n} C_i A_i \right) \Big/ A_t$$

Where: C_c = composite weighted runoff coefficient
          $C_{1,2,...n}$ = runoff coefficient for each land use cover type
          $A_{1,2,...n}$ = drainage area of each land use cover type (acres)
          A_t = total drainage area (acres)

Table 1: Runoff Coefficients for Water Quality Flow Calculations

Type of Drainage Area	Runoff Coefficient
Business	
Downtown areas	0.70 – 0.95
Neighborhood areas	0.50 – 0.70
Residential	
Single-family areas	0.30 – 0.50
Multi-units, detached	0.40 – 0.60
Multi-units, attached	0.60 – 0.75
Suburban	0.25 – 0.40
Apartment dwelling areas	0.50 – 0.70
Industrial	
Light areas	0.50 – 0.80
Heavy areas	0.60 – 0.90
Parks, cemeteries	0.10 – 0.25
Playgrounds	0.20 – 0.40
Railroad yards	0.20 – 0.35
Unimproved areas	0.10 – 0.30
Lawns	
Sandy soil, flat, $\leq 2\%$	0.05 – 0.10
Sandy soil, average 2-7%	0.10 – 0.15
Sandy soil, steep $\geq 7\%$	0.15 – 0.20
Heavy soil, flat, $\leq 2\%$	0.13 – 0.17
Heavy soil, average 2-7%	0.18 – 0.22
Heavy soil, steep $\geq 7\%$	0.25 – 0.35
Streets	
Asphaltic	0.70 – 0.95
Concrete	0.70 – 0.95
Brick	0.75 – 0.85
Drives and walks	0.75 – 0.95
Roofs	0.75 – 0.95

A graph presenting the relationship between the weighted runoff coefficient and the unit water quality design flow rate is shown in Figure 2.
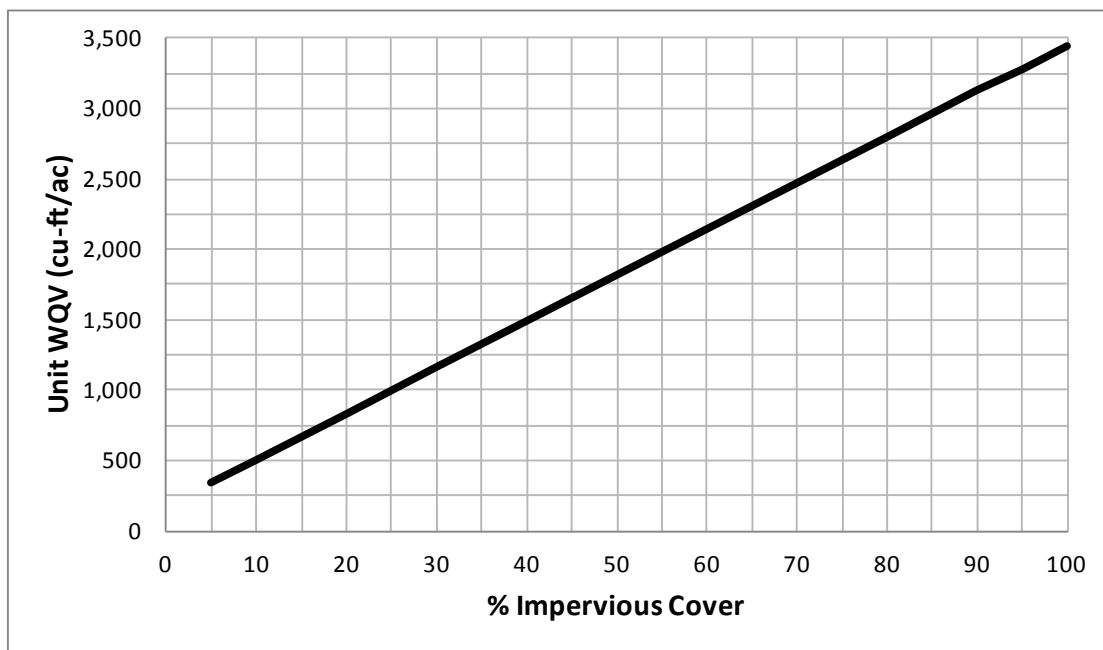
Figure 1: Unit Water Quality Volume for 1 inch Runoff Depth
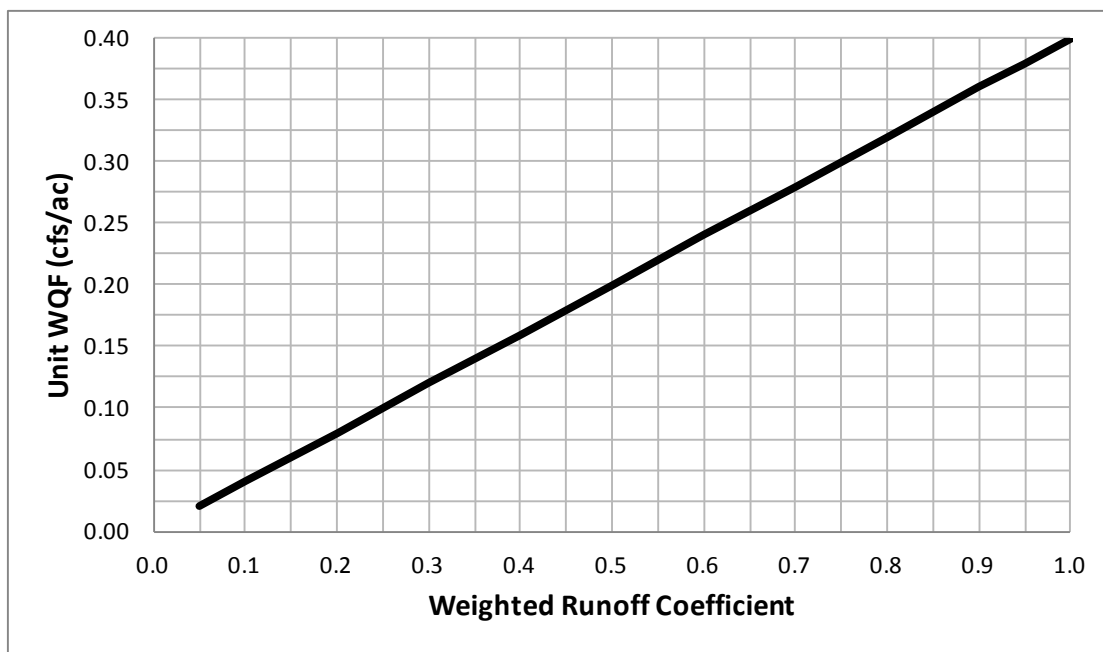
Figure 2: Unit Water Quality Flow

GENERAL INFILTRATION REQUIREMENTS

LID Retention BMPs rely on the soil's ability to infiltrate storm water runoff. This section outlines the design requirements applicable to all infiltration facilities.

Soil Types and Textures

The soil types within the subsoil profile, extending a minimum of 3 feet below the bottom of the proposed facility, should be identified to verify the infiltration rate or permeability of the soil. The infiltration rate, or permeability, measured in inches per hour, is the rate at which water passes through the soil profile during saturated conditions. Although the units of infiltration rate and hydraulic conductivity of soils are similar, there is a distinct difference between these two quantities. They cannot be directly related unless the hydraulic boundary conditions are known, such as hydraulic gradient and the extent of lateral flow of water, or can be reliably estimated. Minimum and maximum infiltration rates establish the suitability of various soil textural classes for infiltration. Each soil texture and corresponding hydrologic properties within the soil profile are identified through analysis of a gradation test of the soil boring material. Table 2 presents a list of the infiltration rates for the soil textures of the U.S. Department of Agriculture Textural Triangle, presented in Figure 3.

Table 2: Typical Soil Infiltration Rates

Texture Class	Hydrologic Soil Group[a]	Infiltration Rate (in/hr)[b]	Infiltration Rate (in/hr)[c]
Sand	A	8.27	8.00
Loamy sand	A	2.41	2.00
Sandy loam	A	1.02	1.00
Loam	B	0.52	0.50
Silt loam	B	0.27	0.25
Sandy clay loam	C	0.17	0.15
Clay loam	D	0.09	0.09
Silty clay loam	D	0.06	0.09
Sandy clay	D	0.05	
Silty clay	D	0.04	
Clay	D	0.02	0.05

[a] Source: U.S. Soil Conservation Service, 1986
[b] Source: Rawls, Brakensiek and Saxton, 1982
[c] Source: ASCE, 1998

Figure 3: USDA Soils Textural Triangle

Percent sand
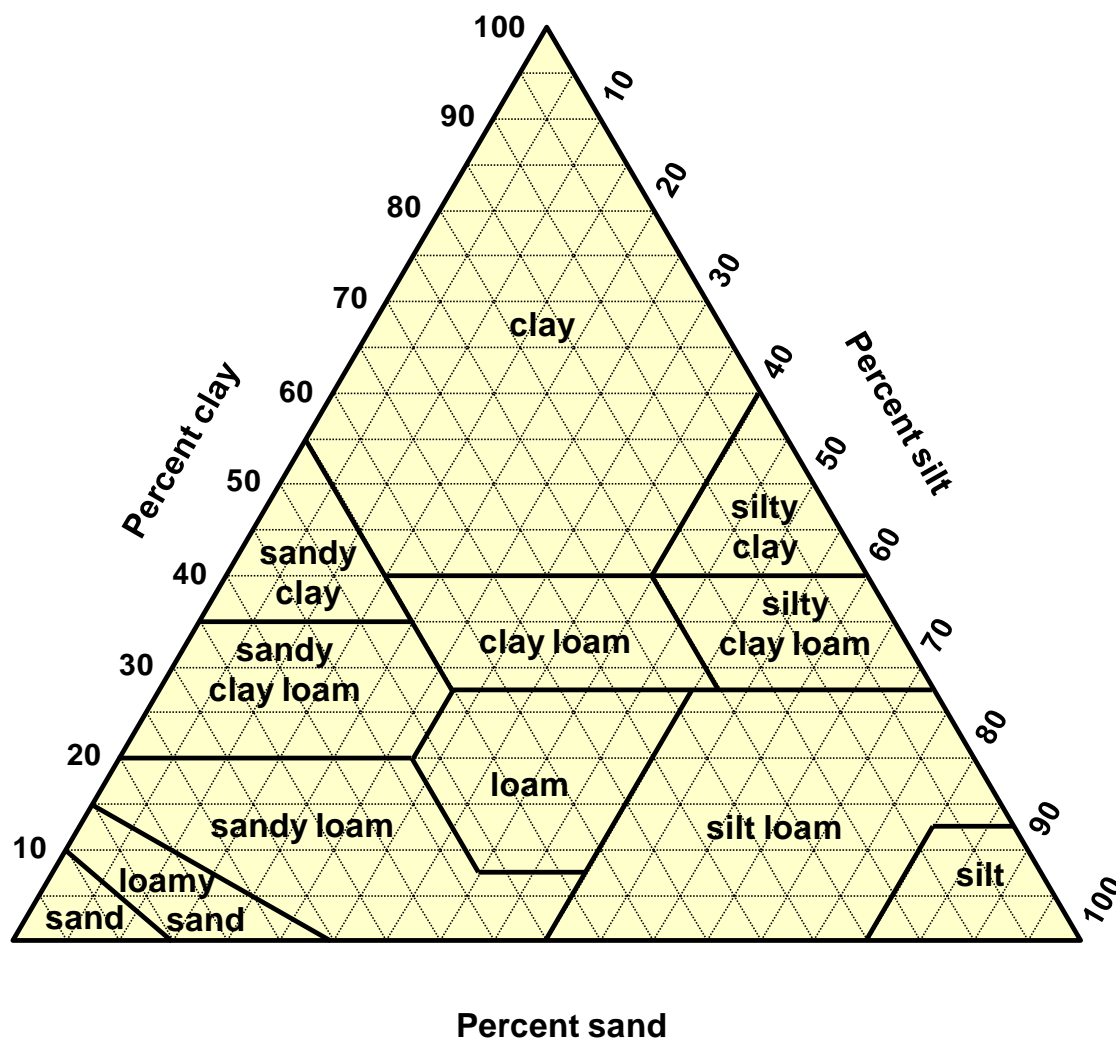
Soil textures acceptable for use with infiltration systems include those with infiltration rates equal to or above 0.50 inches per hour (a soil texture indicative of loam). Soil textures with rates less than 0.50 inches per hour are not suitable as it increases the risk of the BMP not draining properly and creating localized areas of standing water. It is important to note however, that Hydrologic Soil Group (HSG) "D" soils (e.g., clay loam, silty clay loam, and silty clay) in Oahu have been shown to perform better than their counterparts in the Continental United States, as is presented for a representative group of soils in Table 4. As a result, locations with HSG "D" soils should not be prematurely rejected as candidate sites for infiltration BMPs, and field tests should be performed to determine actual infiltration rates.

Table 3: Typical Oahu Soil Infiltration Rates[a]

Soil Name	Depth (in)	USDA Texture	Saturated Hydraulic Conductivity (in/hr)
Kapaa	0 – 14	Silty clay	0.6 – 6.0
	14 – 60	Clay loam	0.2 – 2.0
Kunia	0 – 22	Silty clay	0.2 – 2.0
	22 – 47	Silty clay	0.06 – 0.6
	47 - 74	Silty clay loam	0.2 – 0.6
Waialua	0 – 12	Silty clay	0.2 – 2.0
	12 - 60	Clay, Silty clay	0.2 – 0.6
Waikane	0 – 8	Silty clay	0.6 – 2.0
	8 – 60	Silty clay	0.06 – 0.6

[a] Source: USDA Natural Resources Conservation Service, 2006

Field Investigations

Infiltration testing, soil logs, and the written opinion of a licensed geotechnical engineer are required for the construction of an infiltration facility.

Soil Lithology and Depth to Groundwater

An initial soil investigation should be performed to adequately evaluate soil lithology and determine if there are potential problems in the soil structure that would inhibit the rate or quantity of infiltration desired; or if there are potential adverse impacts to structures, slopes or groundwater that could result from locating the device nearby.

Geotechnical test pits or borings shall be dug to a minimum of 5 ft deep below the proposed device invert. A test pit allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. Although the use of soil borings is permitted at the recommendation of a geotechnical professional, it is discouraged as a substitute for test pits as visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed in-situ, but must be observed from the extracted borings.

The soil profiles should be carefully logged to determine variations in the subsurface profile. The number of requisite test pits/borings is provided in Table 5. Samples should be collected from the soil profiles at different horizons and transported to a laboratory for soil indices testing, plasticity, and chemical testing. In addition, the test pits or samples from borings should be examined for other characteristics that may adversely affect infiltration. These include evidence of significant mottling (indicative of high groundwater), restrictive layer(s), and significant variation in soil types, either horizontally or vertically.

Table 4: Test Pit/Boring Requirements for Infiltration

Facility	Size	Min. No. of Test Pits/Borings
Infiltration Basin, Subsurface Infiltration, Dry Well, Bioretention Basin, Permeable Pavement	< 2,500 sq-ft	1
	2,500 – 20,000 sq-ft	2
	20,000 – 30,000 sq-ft	3
	30,000 – 40,000 sq-ft	4
	> 40,000 sq-ft	1 test per 10,000 sq-ft
Infiltration Trench	< 100 ft	1
	100 – 200 ft	2
	200 – 300 ft	3
	> 300 ft	1 test per 100 ft

An initial indication of the seasonal high groundwater water table elevation shall be determined by using a piezometer or other accepted geotechnical means. The piezometer should be installed to a depth of at least 20 ft below the proposed device invert using the direct push or other suitable method. Initial groundwater levels shall be recorded at least 24 hours after installation. The geotechnical professional will make a determination whether the groundwater elevation determined after 24 hours can be considered to be a reasonable indication of the seasonal high water table for the site.

Permeability Testing

Infiltration rate tests are used to help estimate the maximum sub-surface vertical infiltration rate of the soil below a proposed infiltration facility (e.g., infiltration trench or infiltration basin). The tests are intended to simulate the physical process that will occur when the facility is in operation; therefore a saturation period is required to approximate the soil moisture conditions that may exist prior to the onset of a runoff event. Laboratory tests are strongly discouraged, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Tests should not be conducted in the rain or within 24 hours of significant rainfall events (greater than 0.5 inches).

For the purposes of determining a field infiltration rate, a saturated hydraulic conductivity test should be performed at the bottom of the proposed infiltration facility. The measured infiltration rate of the underlying soil shall be determined using either the Falling Head Percolation Test or the Double-Ring Infiltrometer Test. There are differences between the two methods. A Double-Ring Infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil. A percolation test allows water movement through both the bottom and sides of the test area. For this reason, it is advised that tests for infiltration basins be carried out with an infiltrometer (not percolation test) to determine the saturated hydraulic conductivity rate. This precaution is taken to account for the fact that only the surface of the basin functions to infiltrate, as measured by the test. The number of requisite permeability tests is provided in Table 6.

Table 5: Permeability Test Requirements for Infiltration

Facility	Size	Min. No. of Permeability Tests
Infiltration Basin, Subsurface Infiltration, Dry Well, Bioretention Basin, Permeable Pavement	no manmade soils present	1 test per 2,500 sq-ft
	manmade soils present	1 test per 1,000 sq-ft
Infiltration Trench	no manmade soils present	1 test per 100 ft
	manmade soils present	1 test per 50 ft

Design Infiltration Rates

To account for uncertainties and inaccuracies in testing, a correction (i.e., safety) factor shall be applied to the measured infiltration rate to produce a design infiltration rate for BMP sizing calculations. Minimum safety factors shall be as follows:

Table 6: Infiltration Rate Factors of Safety

Method	Min. Factor (F_s)
Without minimum Test Pits or minimum Permeability Tests	5
With minimum Test Pits only	4
With minimum Permeability Tests only	3
With minimum Test Pits and minimum Permeability Tests	2

On the following pages are fact sheets for each Treatment Control BMP specified in the *Rules*. The following information is provided for each BMP:

- Brief description
- BMP category
- Expected pollutant removals
- Minimum design criteria
- Feasibility criteria
- Step-by-step sizing procedure

- Pretreatment considerations
- Area requirements
- Sizing example
- Other design considerations
- Typical schematic

The sizing procedures are based on simple dynamic and static principles and therefore may result in larger BMPs than are necessary. More rigorous sizing methods (such as detailed routing methods or continuous simulation models) may be used with City approval. Also, the information in the typical schematics may not coincide with the BMP's minimum design criteria. In those instances, the minimum design criteria prevails.

 BMPs not included herein, such as Stormwater Wetlands, Wet Ponds, and proprietary devices, may be used with written City approval.

To facilitate comparison of the BMP characteristics, a summary of the BMP categories and expected pollutant removals is presented in Tables 7 and 8, respectively.

To assist with determining infeasibility, a summary of infeasibility criteria for LID Retention BMPs and LID Biofiltration BMPs is presented in Tables 9 and 10, respectively.

Table 7: Treatment Control BMP Categories

BMP	Retention	Biofiltration	Other
Infiltration Basin	●		
Infiltration Trench	●		
Subsurface Infiltration	●		
Dry Well	●		
Bioretention Basin	●		
Permeable Pavement	●		
Harvesting / Reuse	●		
Green Roof		●	
Bioretention Filter		●	
Dry Swale		●	
Downspout Disconnection		●	
Vegetated Swale		●	
Vegetated Buffer Strip		●	
Tree Box Filter		●	
Detention Basin			●
Manufactured Treatment Device			●
Sand Filter			●

Table 8: Treatment Control BMP Expected Pollutant Removals

BMP	Nutrients	Sediment	Trash	Pathogens	Pesticides	Oil & Grease	Metals	Organic Compounds
Infiltration Basin	H	H	H	H	H	H	H	H
Infiltration Trench	H	H	H	H	H	H	H	H
Subsurface Infiltration	H	H	H	H	H	H	H	H
Dry Well	H	H	H	H	H	H	H	H
Bioretention Basin	H	H	H	H	H	H	H	H
Permeable Pavement	H	H	L	H	H	H	H	H
Harvesting / Reuse	H	H	L	H	H	H	H	H
Green Roof	M	H	H	M	M	H	M	M
Bioretention Filter	M	H	H	M	U	H	H	H
Dry Swale	M	H	H	U	U	M	M	U
Downspout Disconnection	L	M	M	M	U	M	M	U
Vegetated Swale	L	M	L	L	U	M	M	U
Vegetated Buffer Strip	L	M	M	L	U	M	M	M
Tree Box Filter	M	H	H	M	U	H	H	H
Detention Basin	L	M	H	L	U	M	L/M	U
Manufactured Treatment Device	L	M/H	H	L	L	M/H	L	L
Sand Filter	L/M	H	H	M	U	H	M/H	M/H

H = High, M = Medium, L = Low, U = Unknown

Table 9: Infeasibility Criteria for LID Retention BMPs

Exemption Criteria	Infiltration Basin	Infiltration Trench	Subsurface Infiltration	Dry Well	Bioretention Basin	Permeable Pavement	Harvesting Reuse
Soils beneath basin invert have measured infiltration rates less than 0.5 in/hr	●	●	●	●	●	●	
Unable to maintain a distance of at least 3 ft from BMP invert to seasonally high groundwater table	●	●	●	●	●	●	
Site has known man-made plumes or contaminated soils	●	●	●	●	●	●	
Site has high potential for concentrated pollutant/chemical spills	●	●	●	●	●	●	
Site is up-gradient of ephemeral streams (i.e. habitat type change downstream)	●	●	●	●	●	●	
Site is up-gradient of known shallow landslide-prone area	●	●	●	●	●	●	
Unable to maintain a distance of at least 50 ft to the nearest groundwater well used for drinking water	●	●	●	●	●	●	
Unable to maintain a distance of at least 35 ft to the nearest septic system	●	●	●	●	●	●	
Unable to maintain a distance of at least 10 ft from cistern/barrel to the nearest septic tank							●
Unable to maintain a distance of at least 20 ft to the nearest building foundation	●	●	●		●		
Unable to maintain a distance of at least 10 ft to the nearest building foundation				●			
Unable to maintain a distance of at least 5 ft from cistern/barrel to the nearest building foundation							●
Unable to maintain a distance of at least 100 ft to the nearest down-gradient building foundation	●	●	●	●	●		
Unable to maintain a distance of at least 10 ft to the nearest property line	●	●	●	●	●		
Unable to divert flows in excess of WQDS around BMP, and unable to create safe overflow mechanism for flows in excess of WQDS	●	●	●		●		
Excavation would disturb iwi kupuna or other archaeological resources	●	●	●		●		
Unable to maintain a distance of at least 5 ft from cistern/barrel to the nearest property line							●
Site has high potential for oil and/or grease spills						●	
Site has high potential to receive sand and/or sediment loads						●	
Unable to maintain a pavement slope no greater than 5%						●	
Pavement would be above a utility vault						●	
Pavement is expected to receive more than 1,000 average daily trips						●	
Project is for a single family residential dwelling							●
Cistern restricts access to underground utilities							●
Harvested runoff creates a conflict with reclaimed water use							●
Other justification for an exemption proposed by the developer/agent and is acceptable to the City	●	●	●	●	●	●	●

Table 10: Infeasibility Criteria for LID Biofiltration BMPs

Exemption Criteria	Bioretention Filter	Green Roof	Dry Swale	Downspout Disconnect	Vegetated Swale	Vegetated Filter Strip
Unable to divert flows in excess of WQDS around BMP, and unable to create safe overflow mechanism for flows in excess of WQDS	●		●		●	●
Excavation would disturb iwi kupuna or other archaeological resources	●		●		●	●
Invert of underdrain layer is below seasonally high groundwater table	●		●			
Site does not receive enough sunlight to support vegetation	●				●	●
Site lacks sufficient hydraulic head to support BMP operation by gravity	●		●			
Roof is for a single family residential dwelling		●				
Space is unavailable due to renewable energy, electrical, and mechanical systems		●				
Slope on roof exceeds 20% (11 degrees)		●				
Slope of receiving vegetated area exceeds 5%				●		
Diverted runoff drains within 10 feet of a retaining wall				●		
Diverted runoff drains within 10 feet of property line				●		
Concentrated flow cannot be established naturally					●	
Sheet flow cannot be established naturally						●
Other justification for an exemption proposed by the developer/agent and is acceptable to the City	●	●	●	●	●	●

INFILTRATION BASIN

Description

An infiltration basin is a shallow impoundment with no outlet, where storm water runoff is stored and infiltrates through the basin invert and into the soil matrix.

BMP Category	
Retention	●
Biofiltration	○
Other	○

Halawa District Park

Expected Pollutant Removals	
Nutrients	High
Sediment	High
Trash	High
Pathogens	High
Pesticides	High
Oil & Grease	High
Metals	High
Organic Compounds	High

Minimum Design Criteria

Design Parameter	Units	Value
Invert Slope	%	0
Maximum Interior Side Slope (length per unit height)		3:1
Drawdown (drain) Time	hours	48
Minimum Soil Infiltration Rate	inches/hr	0.5
Minimum Freeboard	feet	1.0
Minimum Depth from basin invert to groundwater table	feet	3

Feasibility Criteria
See Table 9.

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Calculate the maximum allowable water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$d_{max} = kt/(F_s \times 12)$$

Where:
- d_{max} = Maximum storage depth (ft)
- k = Soil infiltration rate (in/hr)
- t = Drawdown (drain) time (hrs)
- F_s = Infiltration rate Factor of Safety (see Chapter 4)

3. Select a design ponding depth no greater than the maximum allowable depth calculated in Step 2.

$$d_p \leq d_{max}$$

Where:

d_p	=	Design Ponding Depth (ft)	
d_{max}	=	Maximum storage depth from step 2 (ft)	
k	=	Soil infiltration rate (in/hr)	

4. Calculate the basin bottom surface area (A_b):

$$A_b = WQV / (d_p + kT/12F_s)$$

Where:

A_b	=	Bottom surface area (sq-ft)
WQV	=	Water Quality Volume from Step 1(cu-ft)
d_p	=	Design ponding Depth from Step 3 (ft)
k	=	Soil infiltration rate (in/hr)
T	=	Fill time (time for the BMP to fill with water, hrs)
F_s	=	Infiltration rate Factor of Safety (see Chapter 4)

5. Select a basin bottom width (w_b), and calculate the basin bottom length (l_b):

$$l_b = A_b / w_b$$

Where:

l_b	=	Bottom length (ft)
A_b	=	Bottom surface area from Step 4 (sq-ft)
w_b	=	Bottom width (ft)

6. Calculate the total area occupied by the BMP excluding pretreatment (A_{BMP}) using the basin bottom dimensions, embankment side slopes, and freeboard:

$$A_{BMP} = [w_b + 2z(d_p + f)] \times [l_b + 2z(d_p + f)]$$

Where:

A_{BMP}	=	Area occupied by BMP excluding pretreatment (sq-ft)
w_b	=	Bottom width from Step 5 (ft)
z	=	Basin interior side slope (length per unit height)
d_p	=	Design Ponding Depth from Step 3 (ft)
f	=	Freeboard (ft)
l_b	=	Bottom length from Step 5 (ft)

If the calculated area does not fit in the available space, either reduce the drainage area, increase the ponding depth (if it's not already set to the maximum depth), and/or reduce the Infiltration rate factor of safety (if minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

Pretreatment Considerations

Infiltration facilities are highly susceptible to clogging and premature failure from sediment, trash, and other materials. Suitable pretreatment systems maintain the infiltrate rate of the device without frequent and intensive maintenance. For measured soil infiltration rates below 3 in/hr, pretreatment is strongly recommended, and the pretreatment device should be sized for at least 25% of the WQV. For measured soil infiltration rates greater than 3 in/hr, pretreatment is

mandatory to minimize groundwater contamination risks, and the pretreatment device must be sized for at least 50% of the WQV if the measured soil infiltration rate is below 5 in/hr and 100% of the WQV if the measured soil infiltration rate is greater than 5 in/hr. Pretreatment may be achieved with vegetated swales, vegetated filter strips, sedimentation basins or forebays, sedimentation manholes, and manufactured treatment devices.

Area Requirements
An infiltration basin requires a footprint equivalent to 7% - 20% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the maximum allowable infiltration rate and minimum allowable factor of safety, while the upper value reflects the minimum allowable infiltration rate and maximum allowable factor of safety.

Sizing Example
Calculate the size of an infiltration basin serving a 1-acre residential development. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	70
Design Storm Depth, P	inches	1
Basin Fill Time, T	hours	2
Drawdown (drain) Time, t	hours	48
Basin Interior Side Slope (length per unit height), z		3
Soil Infiltration Rate, k	inches/hr	1.0
Infiltration Rate Factor of Safety, F_s		2
Freeboard, f	ft	1

1. Calculate the volumetric runoff coefficient (C) and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$
$$C = 0.05 + 0.009 \times 70$$
$$C = 0.68$$

$$WQV = PCA \times 3630$$
$$WQV = 1 \times 0.68 \times 1 \times 3630$$
$$WQV = 2,468 \; cubic \; feet$$

2. Calculate the maximum allowable water storage depth in the basin (d_m):

$$d_{max} = kt/12F_s$$
$$d_{max} = 1.0 \times 48/(12 \times 2)$$
$$d_{max} = 2.0 \; feet$$

3. Select a design ponding depth (d_p) no greater than the maximum allowable depth:

    $$d_p = 2.0 \; feet$$

4. Calculate the basin bottom surface area (A_b):

    $$A_b = WQV/(d_d + kT/12F_s)$$
    $$A_b = 2,468/[2.0 + 1.0 \times 2.0/(12 \times 2)]$$
    $$A_b = 1,185 \; square \; feet$$

5. Set the basin bottom width (w_b) to 25 feet, and calculate the basin bottom length (l_b):

    $$l_b = A_b/w_b$$
    $$l_b = 1,185/25$$
    $$l_b = 47.4 \; feet$$

6. Calculate the total area excluding pretreatment (A_{BMP}):

    $$A_{BMP} = \left[w_b + 2z(d_p + f) \right] \times \left[l_b + 2z(d_p + f) \right]$$
    $$A_{BMP} = [25 + 2 \times 3(2+1)] \times [47.4 + 2 \times 3(2+1)]$$
    $$A_{BMP} = 2,812 \; square \; feet$$

Other Design Considerations

- If a temporarily-filled pond creates a potential public safety issue, perimeter fencing may be considered. A vegetative screen around the basin to restrict direct view from adjacent properties may improve the aesthetics of the site and public acceptance of the facility.
- If feasible, include vehicle access to the basin invert for maintenance.
- If the area around the basin has a recreational use, a safety shelf around the perimeter of the basin can be included for times when the basin is flooded.
- The infiltration basin should be designed with an outlet structure to pass peak flows during a range of storm events, as well as with an emergency spillway to pass peak flows around the embankment during extreme storm events that exceed the combined infiltration capacity and outlet structure capacity of the facility.
- To help ensure maintenance of the design permeability rate over time, a 6 inch layer of sand may be placed on the bottom of an infiltration basin. This sand layer can intercept silt, sediment, and debris that could otherwise clog the top layer of the soil below the basin. The sand layer will also facilitate silt, sediment, and debris removal from the basin and can be readily restored following removal operations.
- Observation wells are recommended. They will indicate how quickly the basin dewaters following a storm and it will provide a method of observing how quickly the basin fills up with sediments.

Figure 4: Schematic of an Infiltration Basin
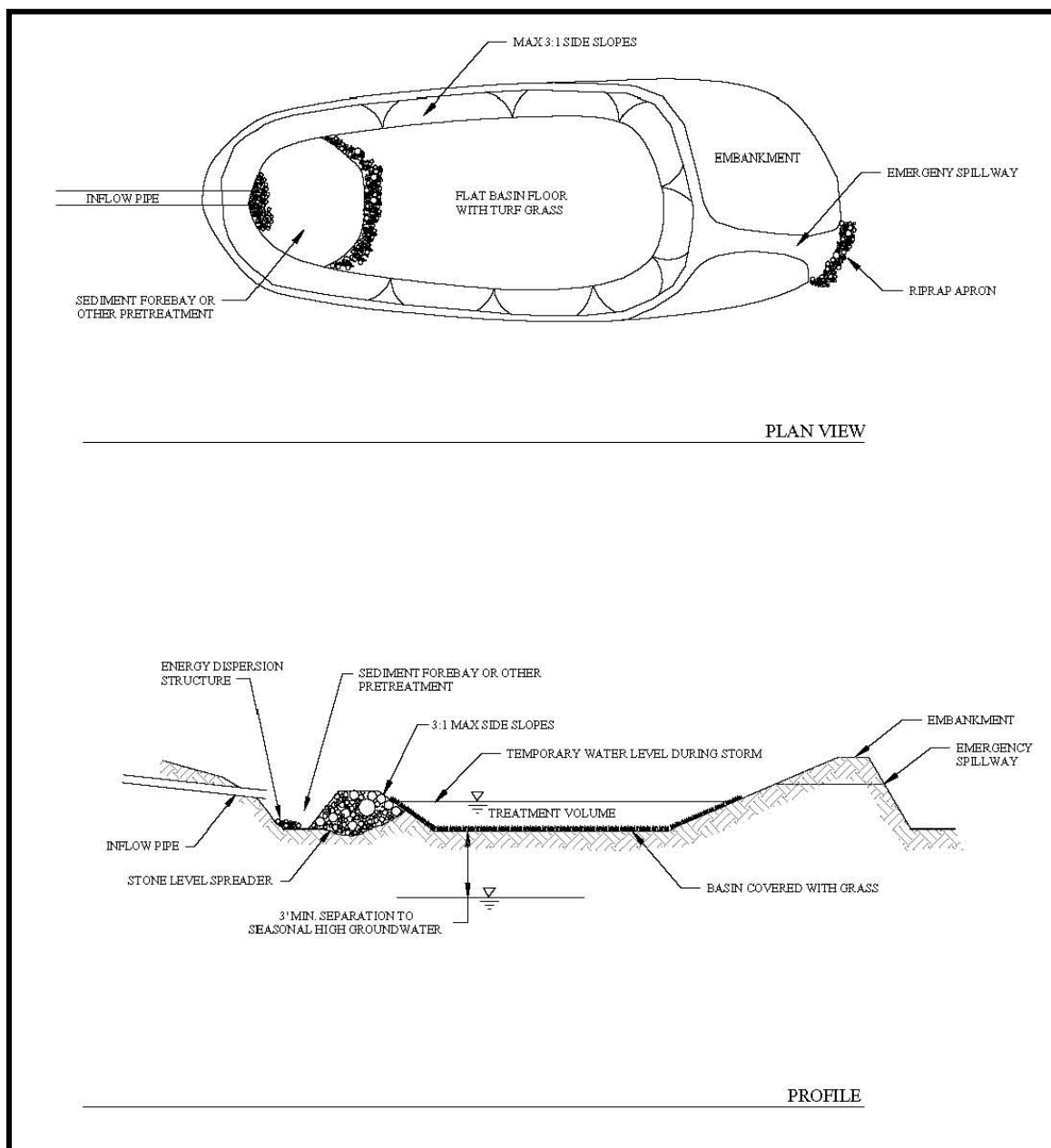
Stormwater Management for Maine, Vol III, BMPs Technical Design Manual. 2006.

INFILTRATION TRENCH

Description

An infiltration trench is a rock-filled trench with no outlet, where storm water runoff is stored in the void space between the rocks and infiltrates through the bottom and into the soil matrix.

BMP Category	
Retention	●
Biofiltration	○
Other	○

Kauai Federal Credit Union (courtesy Group 70)

Expected Pollutant Removals	
Nutrients	High
Sediment	High
Trash	High
Pathogens	High
Pesticides	High
Oil & Grease	High
Metals	High
Organic Compounds	High

Minimum Design Criteria

Design Parameter	Units	Value
Maximum Trench Depth	feet	8
Maximum Trench Width	feet	25
Maximum Top Backfill Layer Thickness	inches	6
Maximum Bottom Sand Layer Thickness	inches	12
Drawdown (drain) Time	hours	48
Minimum Soil Infiltration Rate	inches/hr	0.5
Trench Rock Size	inches	1.5 – 3.0
Minimum Depth from trench invert to Water Table	feet	3

Feasibility Criteria

See Table 9.

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Calculate the maximum allowable water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$d_{max} = kt/(F_s \times 12)$$

Where: d_{max} =   Maximum storage depth (ft)
          k   =   Soil infiltration rate (in/hr)
          t   =   Drawdown (drain) time (hrs)
          F_s =   Infiltration rate Factor of Safety (see Chapter 4)

3. Select a ponding depth (optional), trench rock (or alternative material) depth, and sand layer depth (optional) such that the total effective storage depth is no greater than the maximum allowable depth calculated in Step 2:

$$d_t = d_p + l_b n_b + l_s n_s \le d_{max}$$

Where: d_t =   Total effective water storage depth (ft)
          d_p =   Ponding depth (ft)
          l_b =   Backfill material thickness (depth) (ft)
          n_b =   Backfill material porosity
          l_s =   Sand layer thickness (depth) (ft)
          n_s =   Sand porosity
          d_{max} =   Maximum storage depth from Step 2 (ft)

4. Calculate the trench surface area (A_{BMP}):

$$A_{BMP} = WQV/(d_t + kT/12F_s)$$

Where: A_{BMP} =   BMP surface area excluding pretreatment (sq-ft)
          WQV   =   Water Quality Volume from Step 1(cu-ft)
          d_t =   Total effective water storage depth from Step 3 (ft)
          k   =   Soil infiltration rate (in/hr)
          T   =   Fill time (time for the BMP to fill with water, hrs)
          F_s =   Infiltration rate Factor of Safety (see Chapter 4)

If the calculated area does not fit in the available space, either reduce the drainage area, increase the ponding depth or trench rock depth or sand layer depth (if the total effective depth is not already equal to the maximum depth), and/or reduce the Infiltration rate factor of safety (if minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

Pretreatment Considerations

Infiltration facilities are highly susceptible to clogging and premature failure from sediment, trash, and other materials. Suitable pretreatment systems maintain the infiltrate rate of the device without frequent and intensive maintenance. For measured soil infiltration rates below 3 in/hr, pretreatment is strongly recommended, and the pretreatment device should be sized for at least 25% of the WQV. For measured soil infiltration rates greater than 3 in/hr, pretreatment is mandatory to minimize groundwater contamination risks, and the pretreatment device must be sized for at least 50% of the WQV if the measured soil infiltration rate is below 5 in/hr and 100% of the WQV if the measured soil infiltration rate is greater than 5 in/hr. Pretreatment may

be achieved with vegetated swales, vegetated filter strips, sedimentation basins or forebays, sedimentation manholes, and manufactured treatment devices.

Area Requirements

An infiltration trench requires a footprint equivalent to 2% - 20% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the maximum allowable infiltration rate, minimum allowable factor of safety, and minimal ponding, while the upper value reflects the minimum allowable infiltration rate, maximum allowable factor of safety, and no ponding.

Sizing Example

Calculate the size of an infiltration basin serving a 1-acre residential development. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	70
Design Storm Depth, P	inches	1.0
Trench Fill Time, T	hours	2
Drawdown (drain) Time, t	hours	48
Backfill porosity, n_b		0.35
Sand porosity, n_s		0.40
Soil Infiltration Rate, k	inches/hr	1.0
Infiltration Rate Factor of Safety, F_s		2

1. Calculate the volumetric runoff coefficient (C) and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$
$$C = 0.05 + 0.009 \times 70$$
$$C = 0.68$$

$$WQV = PCA \times 3630$$
$$WQV = 1 \times 0.68 \times 1 \times 3630$$
$$WQV = 2,468 \; cubic \; feet$$

3. Calculate the maximum allowable water storage depth of the infiltration trench (d_m):

$$d_{max} = kt/12F_s$$
$$d_{max} = 1.0 \times 48/(12 \times 2)$$
$$d_{max} = 2.0 \; feet$$

4. Select a ponding depth (d_p), trench rock depth (d_r), and optional sand layer depth (d_s) such that the total effective storage depth (d_t) is no greater than the maximum allowable depth:

$$d_p = 0.0 \ feet$$
$$l_b = 5.0 \ feet$$
$$l_s = 0.5 \ feet$$

$$d_t = d_p + l_b n_b + l_s n_s$$
$$d_t = 0.0 + 5.0 \times 0.35 + 0.5 \times 0.40$$
$$d_t = 1.95 \ feet$$

5. Calculate the BMP surface area excluding pretreatment (A_{BMP}):

$$A_{BMP} = WQV/(d_t + kT/12F_s)$$
$$A_{BMP} = 2,468/[1.95 + 1.0 \times 2.0/(12 \times 2)]$$
$$A_{BMP} = 1,214 \ square \ feet$$

Other Design Considerations

-   Observation wells are recommended at 50 foot intervals over the length of the infiltration trench. They will indicate how quickly the trench dewaters following a storm and it will provide a method of observing how quickly the trench fills up with sediments.

-   Infiltration trenches should not be deeper than the longest surface area dimension. Otherwise, they meet the EPA definition of Class V Injection Wells under the federal Underground Injection Control (UIC) Program, and are subject to applicable federal and state requirements.

-   Vegetation may be planted over the infiltration trench provided that adequate soil media is provided above the trench.

-   There must be an overflow route for storm water flows that overtop the facility or in case the infiltration facility becomes clogged.

Figure 5: Schematic of an Infiltration Trench
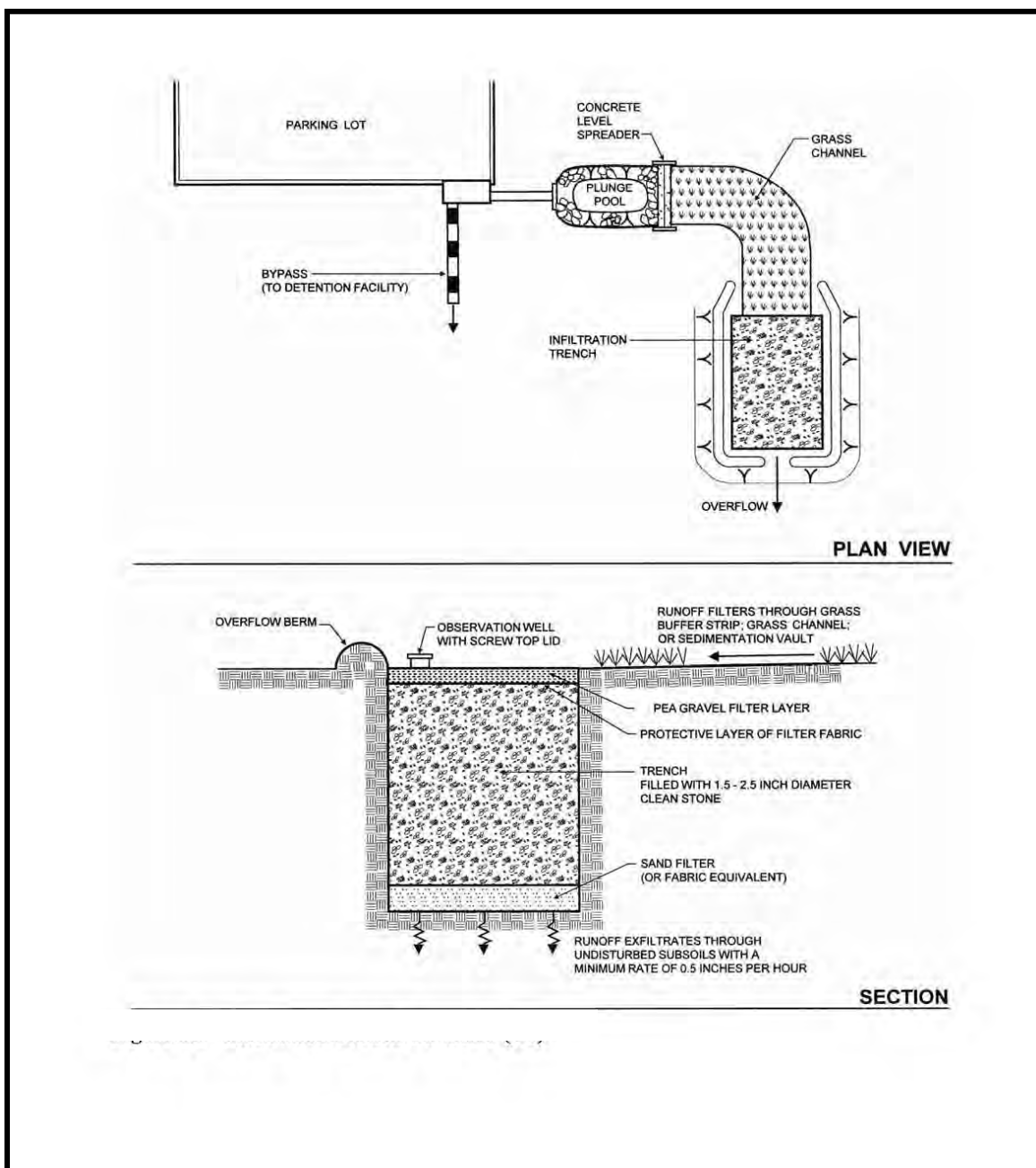
Low Impact Development, A Practitioner's Guide, Hawaii. 2006.

SUBSURFACE INFILTRATION

Description

An subsurface infiltration system is a rock storage (or alternative pre-manufactured material) bed below other surfaces such as parking lots, lawns and playfields for temporary storage and infiltration of runoff.

BMP Category	
Retention	●
Biofiltration	○
Other	○

???

Expected Pollutant Removals	
Nutrients	High
Sediment	High
Trash	High
Pathogens	High
Pesticides	High
Oil & Grease	High
Metals	High
Organic Compounds	High

Minimum Design Criteria

Design Parameter	Units	Value
Drawdown (drain) Time	hours	48
Minimum Soil Infiltration Rate	inches/hr	0.5
Minimum depth from invert to water table	feet	3
Any applicable manufacturer's criteria		

Feasibility Criteria
See Table 9.

Sizing Procedure
Follow the manufacturer's guidelines for appropriate sizing calculations and selection of appropriate device/model.

Pretreatment Considerations
Infiltration facilities are highly susceptible to clogging and premature failure from sediment, trash, and other materials. Suitable pretreatment systems maintain the infiltrate rate of the device without frequent and intensive maintenance. For measured soil infiltration rates below 3 in/hr, pretreatment is strongly recommended, and the pretreatment device should be sized for at least 25% of the WQV. For measured soil infiltration rates greater than 3 in/hr, pretreatment is mandatory to minimize groundwater contamination risks, and the pretreatment device must be sized for at least 50% of the WQV if the measured soil infiltration rate is below 5 in/hr and 100% of the WQV if the measured soil infiltration rate is greater than 5 in/hr. Pretreatment may

be achieved with vegetated swales, vegetated filter strips, sedimentation basins or forebays, sedimentation manholes, and manufactured treatment devices.

Area Requirements
The below-grade footprint requirements for commercially-available infiltration chambers vary by manufacturer. However, similarly to above-grade non-proprietary systems, the space will be minimized for sites with higher infiltration rates and lower infiltration rate factors of safety.

Sizing Example
No example is provided as sizing procedures vary by manufacturer, and presenting any specific product might be interpreted as an endorsement.

Other Design Considerations
Refer to manufacturer guidelines.

DRY WELL

Description

A dry well is a subsurface aggregate-filled or prefabricated perforated storage facility, where roof runoff is stored and infiltrates into the soil matrix.

Courtesy www.brickstoremuseum.org

BMP Category	
Retention	●
Biofiltration	○
Other	○

Expected Pollutant Removals	
Nutrients	High
Sediment	High
Trash	High
Pathogens	High
Pesticides	High
Oil & Grease	High
Metals	High
Organic Compounds	High

Minimum Design Criteria

Design Parameter	Units	Value
Drawdown (drain) Time	hours	48
Minimum Soil Infiltration Rate	inches/hr	0.5
Aggregate Size (if used)	inches	1.0 – 3.0
Minimum Depth from well invert to Water Table	feet	3

Feasibility Criteria

See Table 9.

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Calculate the maximum allowable water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$d_{max} = kt/(F_s \times 12)$$

Where: d_{max} = Maximum storage depth (ft)
  k = Soil infiltration rate (in/hr)
  t = Drawdown (drain) time (hrs)
  F_s = Infiltration rate Factor of Safety (see Chapter 4)

3. Select a ponding depth (optional) and dry well backfill material depth such that the total effective storage depth is no greater than the maximum allowable depth calculated in Step 2:

    $$d_t = d_p + l_b n_b \leq d_{max}$$

    Where: d_t =   Total effective water storage depth (ft)
                       d_p =   Ponding depth (ft)
                       l_b =   Backfill material thickness (depth) (ft)
                       n_b =   Backfill material porosity
                       d_{max} =   Maximum storage depth from Step 2 (ft)

4. Calculate the BMP surface area (A_{BMP}):

    $$A_{BMP} = WQV / (d_t + kT/12F_s)$$

    Where: A_{BMP} =   BMP surface area (sq-ft)
                       WQV   =   Water Quality Volume from Step 1(cu-ft)
                       d_t =   Total effective water storage depth from Step 3 (ft)
                       k   =   Soil infiltration rate (in/hr)
                       T   =   Fill time (time for the BMP to fill with water, hrs)
                       F_s =   Infiltration rate Factor of Safety (see Chapter 4)

    If the calculated area does not fit in the available space, either reduce the drainage area, increase the ponding depth or rock depth (if the total effective depth is not already equal to the maximum depth), and/or reduce the infiltration rate factor of safety (if minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

Pretreatment Considerations

Roof gutter guards or leaf gutter screens are required for roof runoff to reduce dry well clogging from sediment, leaves, and other organic material. If the dry well receives non-roof runoff, pretreatment must be provided by vegetated swales, vegetated filter strips, or manufactured treatment devices.

Area Requirements

A dry well requires a footprint equivalent to 2% - 20% of its contributing impervious drainage area. The lower value reflects the maximum allowable infiltration rate, minimum allowable factor of safety, and minimal ponding, while the upper value reflects the minimum allowable infiltration rate, maximum allowable factor of safety, and no ponding.

Sizing Example

Calculate the size of a dry well serving the roof runoff from a 3,000 square-foot commercial building. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	100
Design Storm Depth, P	inches	1.0
Dry well Fill Time, T	hours	2
Drawdown (drain) Time, t	hours	48
Backfill material porosity, n_b		0.35
Soil Infiltration Rate, k	inches/hr	1.0
Infiltration Rate Factor of Safety, F_s		2

1. Calculate the volumetric runoff coefficient (C) and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$
$$C = 0.05 + 0.009 \times 100$$
$$C = 0.95$$

$$WQV = PCA \times 3630$$
$$WQV = 1 \times 0.95 \times (3,000/43,560) \times 3630$$
$$WQV = 238 \; cubic \; feet$$

3. Calculate the maximum allowable water storage depth of the dry well (d_{max}):

$$d_{max} = kt/12F_s$$
$$d_{max} = 1.0 \times 48/(12 \times 2)$$
$$d_{max} = 2.0 \; feet$$

4. Select a ponding depth (d_p) and backfill material depth (l_b) such that the total effective storage depth (d_t) is no greater than the maximum allowable depth:

$$d_p = 0.0 \; feet$$
$$l_b = 5.5 \; feet$$

$$d_t = d_p + l_b n_b$$
$$d_t = 0.0 + 5.5 \times 0.35$$
$$d_t = 1.925 \; feet$$

5. Calculate the BMP surface area:

$$A_{IMP} = WQV/(d_t + kT/12F_s)$$
$$A_{IMP} = 238/[1.925 + 1.0 \times 2.0/(12 \times 2)]$$
$$A_{IMP} = 118 \; square \; feet$$

Other Design Considerations

- Dry wells are typically deeper than they are wide or long, and therefore meet the EPA definition of Class V Injection Wells under the federal Underground Injection Control (UIC) Program, and are subject to applicable federal and state requirements.

- The dry well must be able to safely convey overflows to either vegetated areas or the storm drain system.

- The design may include an intermediate box with an outflow higher to allow sediments to settle out. Water would then flow through a mesh screen and into the dry well.

- Trees and other large vegetation should be planted away from drywells such that drip lines do not overhang infiltration beds

Figure 6: Schematic of a Dry Well
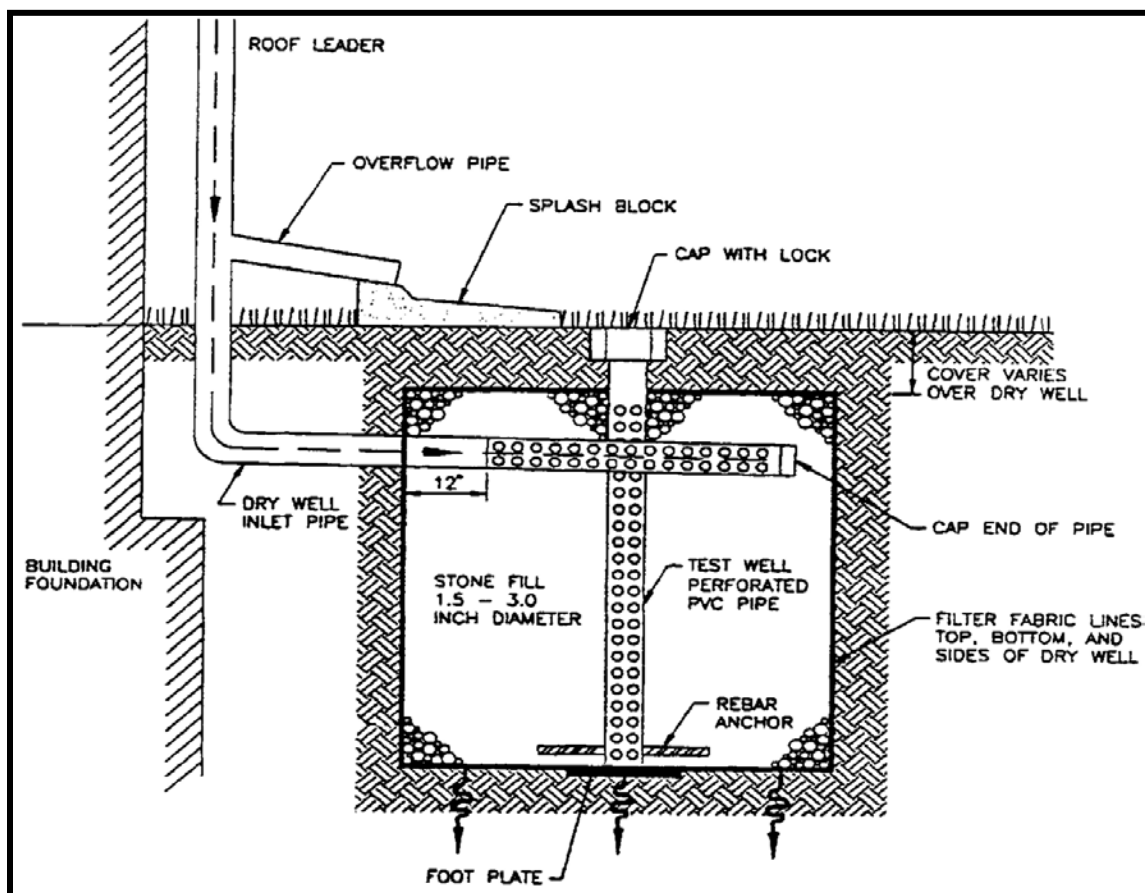
New Jersey Stormwater Best Management Practices Manual. 2004.

BIORETENTION BASIN

Description

Sometimes referred to as a Rain Garden, a Bioretention Basin is an engineered shallow depression that collects and filters storm water runoff using conditioned planting soil beds and vegetation. The filtered runoff infiltrates through the basin invert and into the soil matrix.

BMP Category	
Retention	●
Biofiltration	○
Other	○

Kauai Federal Credit Union (Courtesy Group 70)

Expected Pollutant Removals	
Nutrients	High
Sediment	High
Trash	High
Pathogens	High
Pesticides	High
Oil & Grease	High
Metals	High
Organic Compounds	High

Minimum Design Criteria

Design Parameter	Units	Value
Mulch Thickness	inches	2 – 4
Planting Soil Depth	feet	2 – 4
Drawdown (drain) Time	hours	48
Maximum Interior Side Slope (length per unit height)		3:1
Maximum Ponding Depth	inches	12
Minimum depth from basin invert to water table	feet	3
Minimum Freeboard	feet	1.0
Minimum Soil Infiltration Rate	inches/hr	0.5

Feasibility Criteria

See Table 9.

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Calculate the maximum allowable water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$d_{max} = kt/(F_s \times 12)$$

Where: d_{max} = Maximum storage depth (ft)
          k   = Soil infiltration rate (in/hr)
          t   = Drawdown (drain) time (hrs)
          F_s = Infiltration rate Factor of Safety (see Chapter 4)

3. Select a ponding depth, planting media thickness (depth), and reservoir layer thickness (depth, optional) such that the total effective storage depth is no greater than the maximum allowable depth calculated in Step 2:

$$d_t = d_p + l_m n_m + l_r n_r \leq d_{max}$$

Where: d_t = Total effective water storage depth (ft)
          d_p = Ponding depth (ft)
          l_m = Planting media thickness (depth) (ft)
          n_m = Planting media porosity
          l_r = Reservoir layer thickness (depth) (ft)
          n_r = Reservoir layer porosity
          d_{max} = Maximum storage depth from Step 2 (ft)

4. Calculate the basin bottom surface area (A_b):

$$A_b = WQV/(d_t + kT/12F_s)$$

Where: A_b = Bottom surface area (sq-ft)
          WQV   = Water Quality Volume from Step 1(cu-ft)
          d_t = Total effective water storage depth from Step 3 (ft)
          k   = Soil infiltration rate (in/hr)
          T   = Fill time (time for the BMP to fill with water, hrs)
          F_s = Infiltration rate Factor of Safety (see Chapter 4)

5. Select a basin bottom width (w_b), and calculate the basin bottom length (l_b):

$$l_b = A_b/w_b$$

Where: l_b = Bottom length (ft)
          A_b = Bottom surface area from Step 4 (sq-ft)
          w_b = Bottom width (ft)

6. Calculate the total area occupied by the BMP excluding pretreatment (A_{BMP}) using the basin bottom dimensions, embankment side slopes, and freeboard:

$$A_{BMP} = [w_b + 2z(d_p + f)] \times [l_b + 2z(d_p + f)]$$

Where: A_{BMP} = Area occupied by BMP excluding pretreatment (sq-ft)
          w_b = Bottom width from Step 5 (ft)
          z   = Basin interior side slope (length per unit height)
          d_p = Design Ponding Depth from Step 3 (ft)
          f   = Freeboard (ft)
          l_b = Bottom length from Step 5 (ft)

If the calculated area does not fit in the available space, either reduce the drainage area, increase the ponding depth or planting soil depth or gravel depth (if the total effective depth is not already equal to the maximum depth), and/or reduce the Infiltration rate factor of safety (if minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

Pretreatment Considerations

Infiltration facilities are highly susceptible to clogging and premature failure from sediment, trash, and other materials. Suitable pretreatment systems maintain the infiltrate rate of the device without frequent and intensive maintenance. For measured soil infiltration rates below 3 in/hr, pretreatment is strongly recommended, and the pretreatment device should be sized for at least 25% of the WQV. For measured soil infiltration rates greater than 3 in/hr, pretreatment is mandatory to minimize groundwater contamination risks, and the pretreatment device must be sized for at least 50% of the WQV if the measured soil infiltration rate is below 5 in/hr and 100% of the WQV if the measured soil infiltration rate is greater than 5 in/hr. Pretreatment may be achieved with vegetated swales, vegetated filter strips, sedimentation basins or forebays, sedimentation manholes, and manufactured treatment devices.

Area Requirements

A bioretention basin requires a footprint equivalent to 4% - 13% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the maximum allowable infiltration rate and minimum allowable factor of safety, while the upper value reflects the minimum allowable infiltration rate and maximum allowable factor of safety.

Sizing Example

Calculate the size of a bioretention basin serving a 1-acre residential development. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	70
Design Storm Depth, P	inches	1.0
Basin Fill Time, T	hours	2
Drawdown (drain) Time, t	hours	48
Basin Interior Side Slope (length per unit height), z		3
Planting Media Porosity, n_m		0.25
Reservoir layer porosity, n_r		0.30
Soil Infiltration Rate, k	inches/hr	1.0
Freeboard, f	ft	1.0
Infiltration Rate Factor of Safety, F_s		2

1. Calculate the volumetric runoff coefficient (C) and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$

$C = 0.05 + 0.009 \times 70$
$C = 0.68$

$WQV = PCA \times 3630$
$WQV = 1 \times 0.68 \times 1 \times 3630$
$WQV = 2,468 \; cubic \; feet$

2. Calculate the maximum allowable water storage depth in the basin (d_{max}):

    $d_{max} = kt/12F_s$
    $d_{max} = 1.0 \times 48/(12 \times 2)$
    $d_{max} = 2.0 \; feet$

3. Select a ponding depth (d_p), planting media depth (l_m), and optional reservoir layer depth (l_r) such that the total effective storage depth (d_t) is no greater than the maximum allowable depth:

    $d_p = 0.67 \; feet$
    $l_m = 4.0 \; feet$
    $l_r = 1.0 \; feet$

    $d_t = d_p + l_m n_m + l_r n_r$
    $d_t = 0.67 + 4.0 \times 0.25 + 1.0 \times 0.30$
    $d_t = 1.97 \; feet$

4. Calculate the basin bottom surface area (A_b):

    $A_b = WQV/(d_t + kT/12F_s)$
    $A_b = 2,468/[1.97 + 1.0 \times 2.0/(12 \times 2)]$
    $A_b = 1,204 \; square \; feet$

5. Set the basin bottom width (w_b) to 25 feet, and calculate the basin bottom length (l_b):

    $l_b = A_b/w_b$
    $l_b = 1,204/25$
    $l_b = 48.2 \; feet$

6. Calculate the total area excluding pretreatment (A_{BMP}):

    $A_{BMP} = [w_b + 2z(d_p + f)] \times [l_b + 2z(d_p + f)]$
    $A_{BMP} = [25 + 2 \times 3(0.67 + 1)] \times [48.2 + 2 \times 3(0.67 + 1)]$
    $A_{BMP} = 2,037 \; square \; feet$

Other Design Considerations

- The plantings should emulate a terrestrial forest community ecosystem. Native species that are tolerant to pollutant loads and varying soil moisture should be selected. The trees should be smaller ones similar to those found in the forest understory, since it is more difficult to perform maintenance with the tall trees that are normally part of the forest canopy. Ground cover, such as grasses or legumes, should be planted after the trees and shrubs are in place.

- An overflow device (e.g., domed riser, spillway) must be included to safely convey runoff from large storm events when the surface/subsurface capacity is exceeded.

- If a mulch layer is used on the surface of the planting bed, consideration should be given to problems caused by flotation during storm events.

- Observation wells are recommended. They will indicate how quickly the basin dewaters following a storm and it will provide a method of observing how quickly the basin fills up with sediments.

Figure 7: Schematic of a Bioretention Basin
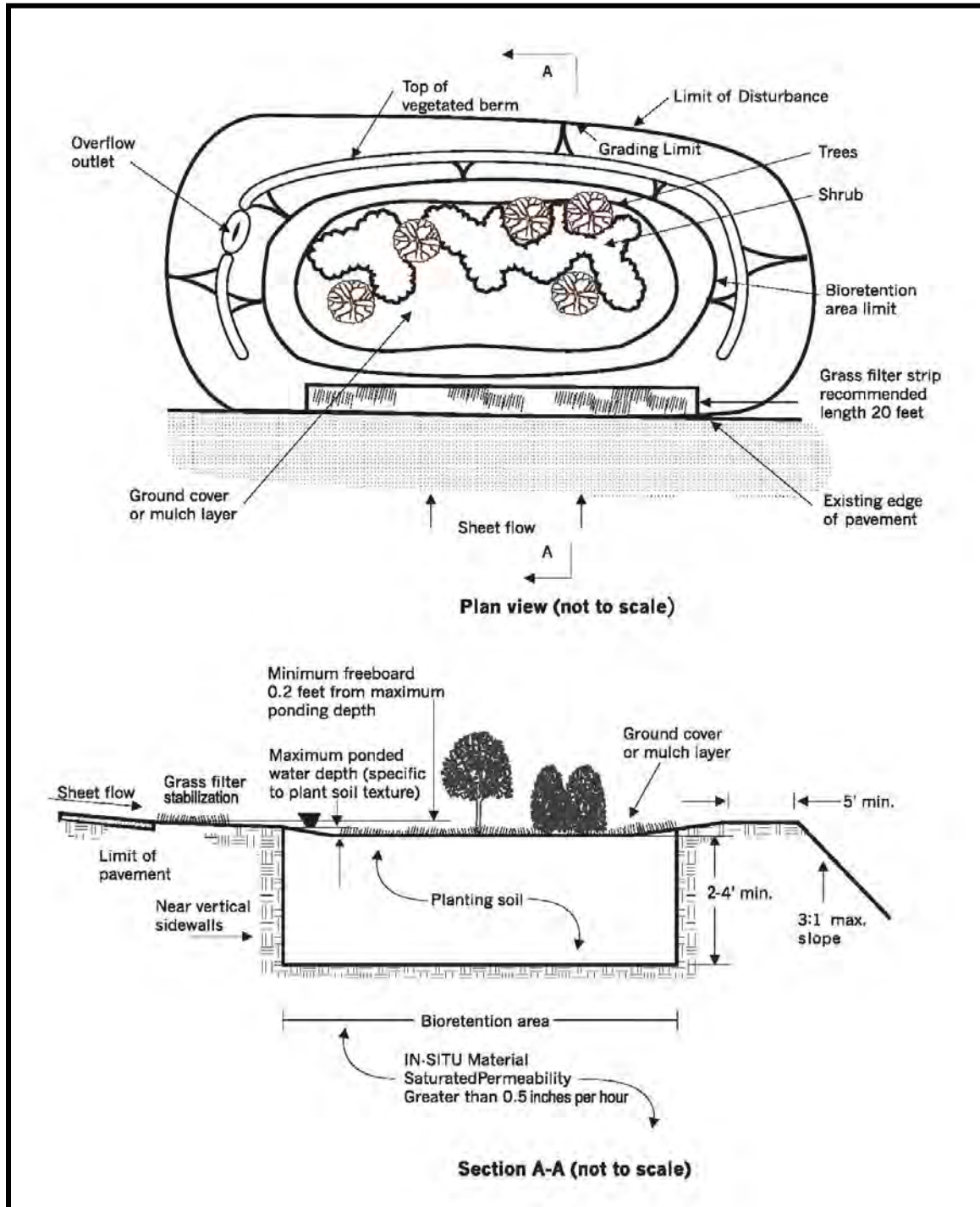
Prince George's County Low Impact Development: An Integrated Design Approach. 1999.

PERMEABLE PAVEMENT

Description

Sometimes referred to as pervious pavement or porous pavement, permeable pavement refers to any porous, load-bearing surface that allows for temporary rainwater storage in an underlying aggregate layer until it infiltrates into the soil matrix. It includes pervious concrete, porous asphalt, interlocking paver blocks, and reinforced turf and gravel filled grids.

BMP Category	
Retention	●
Biofiltration	○
Other	○

Expected Pollutant Removals	
Nutrients	High
Sediment	High
Trash	Low
Pathogens	High
Pesticides	High
Oil & Grease	High
Metals	High
Organic Compounds	High

UH Hale Wainani Dormitory (www.honoluluadvertiser.com)

Minimum Design Criteria

Design Parameter	Units	Value
Maximum Depth of Reservoir Layer	feet	3
Drawdown (drain) Time	hours	48
Minimum depth from reservoir invert to water table	feet	3
Minimum Soil Infiltration Rate	inches/hr	0.5

Feasibility Criteria

See Table 9.

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Calculate the maximum allowable water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$d_{max} = kt/(F_s \times 12)$$

Where: d_{max} = Maximum storage depth (ft)

$\qquad$ k $\quad$ = $\quad$ Soil infiltration rate (in/hr)
$\qquad$ t $\quad$ = $\quad$ Drawdown (drain) time (hrs)
$\qquad$ F_s $\quad$ = $\quad$ Infiltration rate Factor of Safety (see Chapter 4)

3. Select a pavement course thickness (l_p) and reservoir course thickness (l_r) such that the total effective storage depth (d_t) is no greater than the maximum allowable depth:

$$d_t = (l_p n_p + l_r n_r)/12 \le d_{max}$$

Where: $\quad$ d_t $\quad$ = $\quad$ Total effective water storage depth (ft)
$\qquad\qquad$ l_p $\quad$ = $\quad$ Pavement course thickness (in)
$\qquad\qquad$ n_p $\quad$ = $\quad$ Pavement course porosity
$\qquad\qquad$ l_r $\quad$ = $\quad$ Reservoir course thickness (in)
$\qquad\qquad$ n_r $\quad$ = $\quad$ Reservoir course porosity
$\qquad\qquad$ d_{max} $\quad$ = $\quad$ Maximum storage depth from Step 2 (ft)

4. Calculate the BMP surface area (A_{BMP}):

$$A_{BMP} = WQV/(d_t + kT/12F_s)$$

Where: $\quad$ A_{BMP} $\quad$ = $\quad$ BMP surface area (sq-ft)
$\qquad\qquad$ WQV $\quad$ = $\quad$ Water Quality Volume from Step 1(cu-ft)
$\qquad\qquad$ d_t $\quad$ = $\quad$ Total effective water storage depth from Step 3 (ft)
$\qquad\qquad$ k $\quad$ = $\quad$ Soil infiltration rate (in/hr)
$\qquad\qquad$ T $\quad$ = $\quad$ Fill time (time for the BMP to fill with water, hrs)
$\qquad\qquad$ F_s $\quad$ = $\quad$ Infiltration rate Factor of Safety (see Chapter 4)

If the calculated area does not fit in the available space, either reduce the drainage area, increase the pavement course depth or reservoir course depth or gravel depth (if the total effective depth is not already equal to the maximum depth), and/or reduce the Infiltration rate factor of safety (if minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

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

Area Requirements
Permeable pavement requires a footprint equivalent to 5% - 18% of its contributing impervious drainage area. The lower value reflects the maximum allowable infiltration rate and minimum allowable factor of safety, while the upper value reflects the minimum allowable infiltration rate and maximum allowable factor of safety.

Sizing Example
Calculate the size of a section of permeable pavement serving the runoff from a 1-acre parking lot. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	100
Design Storm Depth, P	inches	1.0
Reservoir Layer Fill Time, T	hours	2
Drawdown (drain) Time, t	hours	48
Pavement Course Porosity, n_p		0.15
Reservoir Course Porosity, n_r		0.35
Soil Infiltration Rate, k	inches/hr	1.0
Infiltration Rate Factor of Safety, F_s		2

1. Calculate the volumetric runoff coefficient (C) and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$
$$C = 0.05 + 0.009 \times 100$$
$$C = 0.95$$

$$WQV = PCA \times 3630$$
$$WQV = 1 \times 0.95 \times 1 \times 3630$$
$$WQV = 3,449 \ cubic \ feet$$

2. Calculate the maximum allowable water storage depth (d_{max}):

$$d_{max} = kt/12F_s$$
$$d_{max} = 1.0 \times 48/(12 \times 2)$$
$$d_{max} = 2.0 \ feet$$

3. Select a pavement course thickness (l_p) and reservoir course thickness (l_r) such that the total effective storage depth (d_t) is no greater than the maximum allowable depth:

$$l_p = 12.0 \ inches$$
$$l_r = 24.0 \ inches$$

$$d_t = \left(l_p n_p + l_r n_r\right)/12$$
$$d_t = (12 \times 0.15 + 24 * 0.35)/12$$
$$d_t = 0.85 \ feet$$

4. Calculate the pavement surface area:

$$A_{IMP} = WQV/[d_t + (kT/12F_s)]$$
$$A_{IMP} = 3,449/[0.85 + (1.0 \times 2/12 \times 2)]$$
$$A_{IMP} = 3,695 \ square \ feet$$

Other Design Considerations

- All porous paving and permeable paver with storage bed systems must include measures that will allow runoff from the design storm to enter the storage bed in the event that the porous or permeable paver surface course becomes clogged or otherwise incapable of conveying the maximum design storm runoff to the bed.

- Additional design details on specific pavement systems are provided by the National Asphalt Pavement Association, the National Ready Mix Concrete Association, the Interlocking Concrete Pavement Institute, and the American Association of State Highway and Transportation Officials.

- Perforated pipes along the bottom of the bed may be used to evenly distribute runoff over the entire bed bottom. Pipes should lay flat along the bed bottom and provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

- Flows in excess of the design capacity of the permeable pavement system will require an overflow system connected to a downstream conveyance or other storm water runoff BMP.

Figure 8: Schematic of a Permeable Pavement
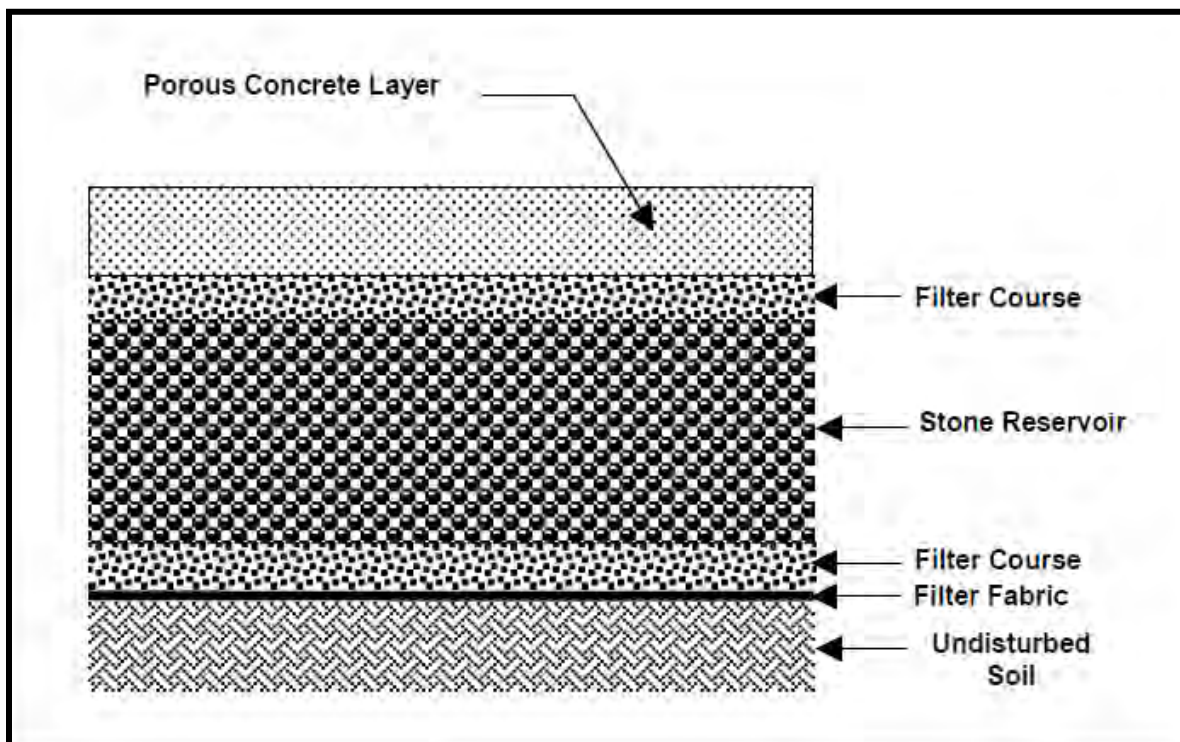
Georgia Stormwater Management Manual. 2001.

HARVESTING / REUSE

Description

Sometimes referred to as Capture/Reuse or Rainwater Harvesting, is the collection and temporary storage of roof runoff in rain barrels or cisterns for subsequent non-potable outdoor use (landscape irrigation, vehicle washing).

BMP Category	
Retention	●
Biofiltration	○
Other	○

Hawaii Baptist Academy (Courtesy Group 70)

Expected Pollutant Removals	
Nutrients	High
Sediment	High
Trash	Low
Pathogens	High
Pesticides	High
Oil & Grease	High
Metals	High
Organic Compounds	High

Minimum Design Criteria

Design Parameter	Units	Value
Minimum overall runoff capture efficiency	%	80
Minimum overall demand met efficiency	%	80

Feasibility Criteria

See Table 9.

Sizing Procedure

1. Define the reuse demand by selecting values for the irrigation area (A_i), pan evaporation coefficient (K_p), landscape coefficient (K_l), irrigation system efficiency (e), and non-irrigation demand (D_o). Unless specific data is available, use a value of 0.80 for K_p (*Guidelines for the Reuse of Gray Water*), 0.60 for K_l (warm season turfgrass, *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California*), and 0.90 for e (well-designed system, *Estimating Irrigation Water Needs of Landscape Plantings in California*).

2. Define the runoff available for reuse by selecting values for the drainage (i.e., roof) area (A_d), percent of impervious cover (I), and cistern size (C).

3. Identify the project's nearest reference point (Makakilo City, Waimanalo, Waialua, Village Park, Waianae, UH Mauka, Mililani, Opaeula, Maunawili, and Kalihi Valley) and use the corresponding monthly rainfall rates and monthly pan evaporation rates (E_{pan}).

4. Perform a month-to-month analysis, starting with January and ending with December. Set the beginning cistern volume in January to 0.

    4a. Calculate the reference evapotranspiration rate for the month using the pan evaporation rate and the pan evaporation coefficient:

    $$ET_0 = E_{pan} \times K_p$$

    Where: ET_0 = Reference evapotranspiration rate for the month (in)
    E_{pan} = Pan evaporation rate for the month (in) from Step 3
    K_p = Pan evaporation coefficient from Step 1

    4b. Calculate the actual evapotranspiration rate for the month using the reference evapotranspiration rate and the landscape coefficient:

    $$ET_a = ET_0 \times K_l$$

    Where: ET_a = Actual evapotranspiration rate for the month (in)
    ET_0 = Reference evapotranspiration rate from Step 4a
    K_l = Landscape coefficient from Step 1

    4c. Calculate the total demand for the month by multiplying the irrigation area by the difference between the actual evapotranspiration rate and the rainfall, and adding the non-irrigation demand:

    $$D_t = 7.48 \times A \times (ET_a - r)/(12 \times e) + D_o$$

    Where: D_t = Total demand for the month (gal)
    A = Irrigation area from Step 1 (sq-ft)
    ET_a = Actual evapotranspiration rate from Step 4b (in)
    r = Total rainfall for the month (in) from Step 3
    e = Irrigation system efficiency from Step 1
    D_o = Other non-irrigation demand for the month (gal) from Step 1

    If the total demand for the month is negative (because the rainfall amount exceeds the evapotranspiration rate and there is no non-irrigation demand), set the total demand to 0.

    4d. Calculate the amount of runoff generated for the month by multiplying the drainage area by the rainfall by the volumetric runoff coefficient:

    $$R_g = 7.48 \times A_d \times r \times (0.05 + 0.009 \times I)/12$$

    Where: R_g = Runoff generated for the month (gal)
    A_d = Drainage area from Step 2 (sq-ft)
    r = Total rainfall for the month (in) from Step 3
    I = Percent of impervious cover from Step 2 (expressed as %)

    4e. Compare the total demand (D_t) to the amount of runoff in the cistern at the beginning of the month (C_b) plus the runoff generated during the month (R). If the monthly demand

is greater, set the amount of runoff reused (R_u) to the sum of C_b and R. If the monthly demand is less, set the amount of runoff reused to D_t.

4f. Compare the Cistern capacity (C) to the amount in the cistern at the beginning of the month (C_b) plus the Runoff generated during the month (R_g) minus the amount of runoff used (R_u). Set the amount of runoff in the cistern at the end of the month (C_e) to the lower of the two values.

4g. Calculate the amount of cistern overflow by the following:

$$O = C_b + R_g - D_t - C_e$$

Where:
O = Total Cistern overflow for the month (gal)
C_b = Amount of runoff in cistern at beginning of month (gal)
R_g = Runoff generated for the month (gal)
D_t = Total demand for the month (gal)
C_e = Amount of runoff in cistern at end of month (gal)

If the overflow is negative (because the amount of runoff in the cistern at the end of the month is less than the cistern capacity), set the overflow to 0.

4h. Calculate the amount of runoff captured in the cistern by subtracting the Overflow from the amount of runoff generated:

$$R_c = R_g - O$$

Where:
R_c = Runoff captured in the cistern for the month (gal)
R_g = Runoff generated for the month (gal)
O = Total cistern overflow for the month (gal)

4i. Set the beginning cistern amount for the next month equal to the ending cistern amount for the current month. Repeat steps 5 through 13 for each subsequent month. Continue on to step 5 after Steps 4a through 4i have been performed for all 12 months.

5. Calculate the overall runoff capture efficiency by dividing the cumulative runoff captured by the cumulative runoff generated:

$$E_c = 100 \times \sum_{1}^{12} R_c \bigg/ \sum_{1}^{12} R_g$$

Where:
E_c = Overall runoff capture efficiency (%)
R_c = Runoff captured from each month (gal)
R_g = Runoff generated from each month (gal)

If the calculated efficiency is below the minimum design criteria value, revise one or more of the following parameters and return to Step 3: drainage area (A_d), cistern size (C), irrigation area (A_i), and other non-irrigation demand (D_o).

6. Calculate the overall demand met efficiency by dividing the cumulative runoff used by the cumulative demand:

$$E_d = 100 \times \sum_{1}^{12} R_u \bigg/ \sum_{1}^{12} D_t$$

Where:
E_d = Overall demand met efficiency (%)
R_u = Runoff used from each month (gal)
D_t = Total demand from each month (gal)

If the calculated efficiency is below the minimum design criteria value, revise one or more of the following parameters and return to Step 3: drainage area (A_d), cistern size (C), irrigation area (A_i), and other non-irrigation demand (D_o).

Pretreatment Considerations
Roof gutter guards or leaf gutter screens are required for roof runoff to reduce dry well clogging from sediment, leaves, and other organic material.

Area Requirements
Rain barrel / cistern sizes can vary greatly depending on the project area, roof size, and irrigation area. The size can be anywhere from less than 1,000 gallons to more than 10,000 gallons per 1,000 square feet of roof area.

Sizing Example
Calculate the size of a cistern serving the roof runoff from an 800 square-foot auto repair shop in Kapolei. Assume the following design parameters:

Design Parameter	Units	Value
Minimum overall runoff capture efficiency, E_c	%	80
Minimum overall demand met efficiency, E_d	%	80

1. Select initial demand values for the Irrigation Area (A_i), pan evaporation coefficient (K_p), landscape coefficient (K_l), irrigation system efficiency (e), and non-irrigation demand (D_o):

$A_i = 115$ *square feet*

$K_p = 0.80$

$K_l = 0.60$

$e = 0.90$

$D_o = 0$

2. Select initial values for the drainage area (A_d), percent of impervious cover (I), and cistern size (C):

$$A_d = 800 \; square \; feet$$

$$I = 100\%$$

$$C = 5,000 \; gal$$

3. The nearest reference point to Kapolei is Makakilo City.

4a. Calculate the monthly reference evapotranspiration rates (ET_0). The calculation for January is as follows, and the results for the entire year are provided in the table below.

$$ET_0 = E_{pan} \times K_p$$

$$ET_0 = 5.46 \times 0.8$$

$$ET_0 = 4.37 \; in$$

4b. Calculate the actual evapotranspiration rates (ET_a). The calculation for January is as follows, and the results for the entire year are provided in the table below.

$$ET_a = ET_0 \times K_l$$

$$ET_a = 4.37 \times 0.6$$

$$ET_a = 2.62 \; in$$

4c. Calculate the total demand (D_t). The calculation for January is as follows, and the results for the entire year are provided in the table below.

$$D_t = 7.48 A_i (ET_a - r)/(12e) + D_o$$

$$D_t = 7.48 \times 115 \times (2.62 - 2.58)/(12 \times 0.9) + 0 = 3$$

$$D_t = 3 \; gal$$

Month	Rainfall (in)	P (in)	ET_0 (in)	ET_a (in)	D_t (gal)
January	2.58	5.46	4.37	2.62	3
February	3.05	5.75	4.60	2.76	0
March	1.87	7.12	5.70	3.42	123
May	1.12	7.75	6.20	3.72	207
May	0.86	8.41	6.73	4.04	253
June	0.55	8.99	7.19	4.32	300
July	0.58	9.74	7.79	4.68	326
August	0.48	9.65	7.72	4.63	331
September	0.74	8.48	6.78	4.07	265
October	2.00	7.54	6.03	3.62	129
November	2.06	6.29	5.03	3.02	76
December	2.69	5.59	4.47	2.68	0

4d. Calculate the generated roof runoff (R_g). The calculation for January is as follows, and the results for the entire year are provided in the table below:

$$R_g = 7.48 A_d r (0.05 + 0.009 I)/12$$
$$R_g = 7.48 \times 800 \times 2.58 \, (0.05 + 0.009 \times 100)/12$$
$$R_g = 1,222 \; gal$$

4e. Calculate the runoff used (R_u) by comparing the total demand (D_t) to the amount of runoff in the cistern at the beginning of the month (C_b) plus the runoff generated during the month (R). The calculation for January is as follows, and the results for the entire year are provided in the table below:

$$C_b = 0 \; gal$$
$$R_u = D_t = 3 \; gal \left[since \; R_g + C_b > D_t \right]$$

4f. Calculate the amount of runoff in the Cistern at the end of the month (C_e) by setting it to the lower value of the amount of runoff in the Cistern at the beginning of the month (C_b) plus the runoff generated (R_g) minus the runoff used (R_u), and the cistern capacity (C). The calculation for January is as follows, and the results for the entire year are provided in the table below:

$$C_e = min(C_b + R_g - R_u \, , C)$$
$$C_e = min(0 + 1222 - 3, 5000)$$
$$C_e = 1,219 \; gal$$

4g. Calculate the Cistern overflow (O). The calculation for January is as follows, and the results for the entire year are provided in the table below:

$$O = C_b + R_g - D_t - C_e$$
$$O = 0 + 1,222 - 3 - 1,219$$
$$O = 0 \; gal$$

4h. Calculate the runoff captured in Cistern (R_c). The calculation for January is as follows, and the results for the entire year are provided in the table below:

$$R_c = R_g - O$$
$$R_c = 1,222 - 0 = 1,222 \; gal$$

4i. Set C_b for the next month equal to C_e of the previous month and repeat the calculations.

Month	r (in)	D_t (gal)	R_g (gal)	C_b (gal)	C_e (gal)	R_u (gal)	O (gal)	R_c (gal)
January	2.58	3	1,222	0	1,219	3	0	1,222
February	3.05	0	1,445	1,219	2,664	0	0	1,445
March	1.87	123	886	2,664	3,426	123	0	886
May	1.12	207	531	3,426	3,750	207	0	531
May	0.86	253	407	3,750	3,904	253	0	407
June	0.55	300	261	3,904	3,865	300	0	261
July	0.58	326	275	3,865	3,814	326	0	275
August	0.48	331	227	3,814	3,710	331	0	227
September	0.74	265	351	3,710	3,796	265	0	351
October	2.00	129	947	3,796	4,614	129	0	947
November	2.06	76	976	4,614	5,000	76	514	462
December	2.69	0	1,274	5,000	5,000	0	1,274	0
Total	**18.58**	**2,014**	**8,802**			**2,014**	**1,788**	**7,014**

5. Calculate the overall runoff capture efficiency (E_c) and overall demand efficiency (E_d):

$$E_c = 100 \times \sum_{1}^{12} R_c \Big/ \sum_{1}^{12} R_g = 100 \times 7,014/8,802 = 80\%$$

$$E_d = 100 \times \sum_{1}^{12} R_u \Big/ \sum_{1}^{12} D_t = 100 \times 2,014/2,014 = 100\%$$

6. Calculate the Water Quality Volume (WQV) for which credit is received:

$$WQV = PCA \times 3630$$
$$WQV = 1 \times (0.05 + 0.009 \times 100) \times (800/43,560) \times 3630$$
$$WQV = 63 \; cubic \; feet$$

Other Design Considerations

- Local pan evaporation and rainfall data may be used if available.

- Tanks should have tight fitting covers to exclude contaminants and animals, and above ground tanks should not allow penetration of sunlight to limit algae growth

- In areas where the tank is to be buried partially below the water table, special design features must be employed to keep it from "floating".

Figure 9: Schematic of a Harvesting / Reuse System
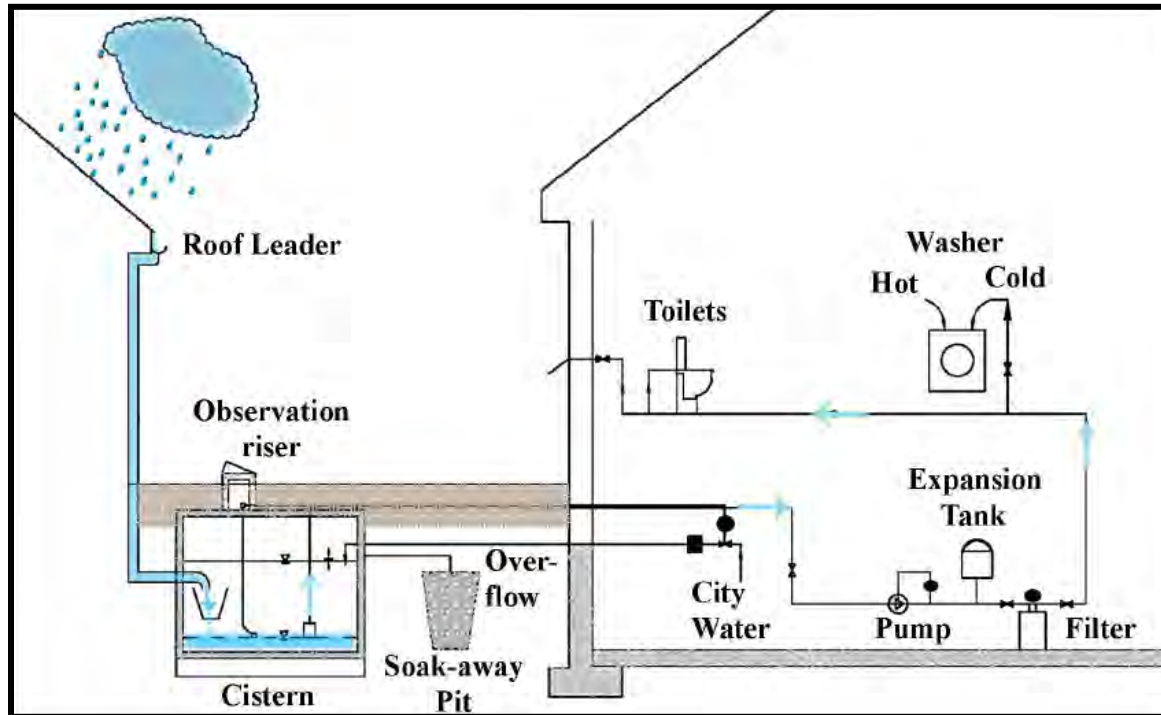
Pennsylvania Stormwater Best Management Practices Manual. 2006.

GREEN ROOF

Description

Sometimes referred to as a Vegetated Roof or Eco-roof, a green roof is a roof that is entirely or partially covered with vegetation and soils for the purpose of filtering, absorbing, evapotranspirating, and retaining/ detaining the rain that falls upon it.

BMP Category	
Retention	○
Biofiltration	●
Other	○

Fasi Municipal Building

Expected Pollutant Removals	
Nutrients	Medium
Sediment	High
Trash	High
Pathogens	Medium
Pesticides	Medium
Oil & Grease	High
Metals	Medium
Organic Compounds	Medium

Minimum Design Criteria

Design Parameter	Units	Value
Minimum Depth of Soil Media	inches	2
Minimum Depth of Drainage Layer	inches	2
Maximum slope on roof	%	25

Feasibility Criteria

See Table 10.

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Select initial values for the soil media thickness (l_m), drainage layer thickness (l_d), and allowable ponding depth (d_p).

3. Calculate the total effective storage depth based on the instantaneous storage capacity using the void space in the soil media and drainage layer, and the allowable ponding:

$$d_t = (d_p + l_m n_m + l_d n_d)/12$$

Where: d_t =   Total effective water storage depth (ft)
                     d_p =   Ponding depth (in)

l_m =   Planting media thickness (in)
n_m =   Planting media porosity
l_d =   Drainage layer thickness (in)
n_d =   Drainage layer porosity

4. Calculate the area required (A_{BMP}) based on the instantaneous storage capacity:

$$A_{BMP} = WQV/d_t$$

Where: A_{BMP} =   BMP area (sq-ft)
                 WQV   =   Water Quality Volume from Step 1 (cu-ft)
                 d_t =   Total effective water storage depth from Step 3 (ft)

If the calculated area does not fit in the available space, either reduce the tributary area and/or increase one or more of the design depths (ponding, soil media, drainage layer), and repeat the calculations.

Pretreatment Considerations
Green roofs do not require pretreatment.

Area Requirements
A green roof requires a footprint equivalent to 11% - 100% of the contributing roof drainage area. The lower value corresponds to 4 inches of ponding and maximum depths for both the planting media and drainage layer depths, while the higher value corresponds to no ponding and minimum planting media and drainage layer depths.

Sizing Example
Calculate the size of a green roof serving the roof runoff from a 1,500 square-foot fast food restaurant. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	100
Design Storm Depth, P	inches	1.0
Soil Media Porosity, n_m		0.20
Drainage Layer Porosity, n_d		0.25

1. Calculate the volumetric runoff coefficient (C) and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$
$$C = 0.05 + 0.009 \times 100$$
$$C = 0.95$$

$$WQV = PCA \times 3630$$
$$WQV = 1 \times 0.95 \times (1,500/43,560) \times 3630$$
$$WQV = 119 \ cubic \ feet$$

2. Select initial values for the soil media depth (d_m), drainage layer depth (d_d), and ponding depth (d_p):

$$d_m = 3\ in$$
$$d_d = 2\ in$$
$$d_p = 0.5\ in$$

3. Calculate the total effective storage depth:

$$d_t = (d_p + l_m n_m + l_d n_d)/12$$
$$d_t = (0.5 + 3 \times 0.20 + 2 \times 0.25)/12$$
$$d_t = 0.133\ feet$$

4. Calculate the area (A_{BMP}):

$$A_{BMP} = WQV/d_t$$
$$A_{BMP} = 119/0.133$$
$$A_{BMP} = 891\ square\ feet$$

$$891\ square\ feet\ is\ available, so\ design\ is\ ok$$

Other Design Considerations

- Safety measures against wind uplift must be taken into account during design, especially for areas susceptible to high winds during the summer trade-wind period.

- The maximum load bearing capacity of the roof construction must be considered when installing vegetated roofs. The water saturated weight of the green roof system, including vegetation must be calculated as permanent load. Generally, vegetated roofs weigh between 15 and 30 lb/sq.ft. depending on the thickness of the vegetated roof system. In addition, construction elements such as pergolas and walkways cause high point loads and, therefore, have to be calculated accordingly.

- The design must include adequate roof access for delivery of construction materials and for routine maintenance.

Figure 10: Schematic of a Green Roof
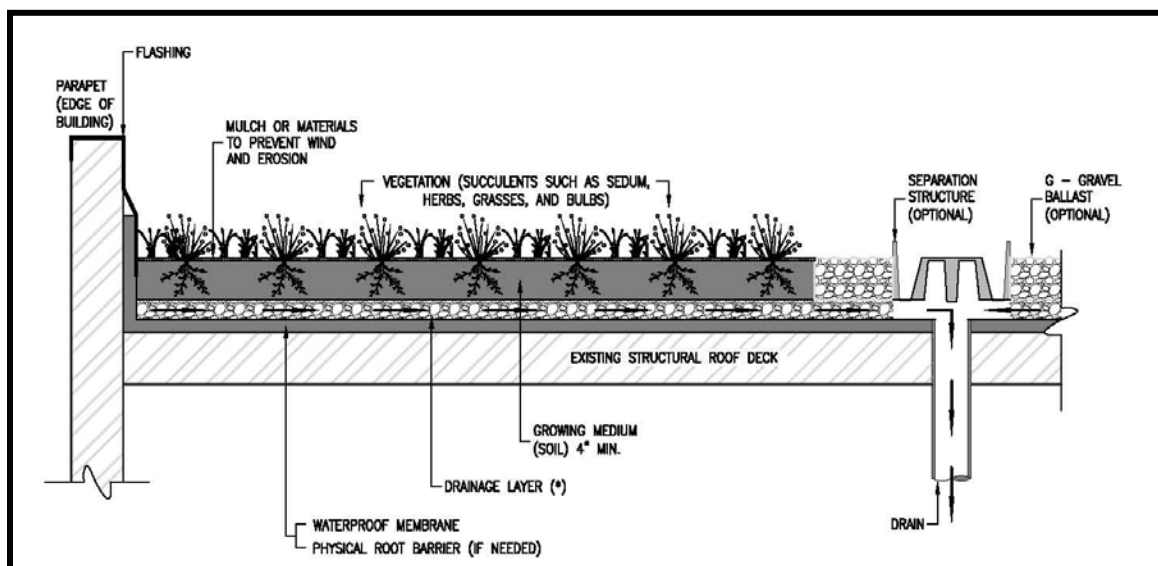
Portland Stormwater Management Manual. 2008.

BIORETENTION FILTER

Description

Sometimes referred to as a Rain Garden or Planter Box, a Bioretention Filter is an engineered shallow depression that collects and filters storm water runoff using conditioned planting soil beds and vegetation. The filtered runoff discharges through an underdrain system.

BMP Category	
Retention	○
Biofiltration	●
Other	○

???

Expected Pollutant Removals	
Nutrients	Medium
Sediment	High
Trash	High
Pathogens	Medium
Pesticides	Unknown
Oil & Grease	High
Metals	High
Organic Compounds	High

Minimum Design Criteria

Design Parameter	Units	Value
Planting Soil Coefficient of Permeability	feet/day	1.0
Mulch Thickness	inches	2 – 4
Planting Soil Depth	feet	2 – 4
Drawdown (drain) Time	hours	48
Maximum Ponding Depth	inches	12
Minimum Underdrain Diameter	inches	6

Feasibility Criteria

See Table 10.

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Select values for the planting media depth (l_m) and maximum ponding depth (d_p).

3. Use Darcy's Law to calculate the required Filter Bed Surface Area:

$$A_b = \frac{WQV \times l_m}{k(l_m + d_p/24)(t/24)}$$

Where:
- A_b = Filter bed surface area (sq-ft)
- WQV = Water Quality Volume from Step 1 (cu-ft)
- l_m = Planting media depth from step 2 (ft)
- k = Planting media permeability coefficient (ft/day)
- d_p = Maximum ponding depth, from Step 2 (in)
- t = Filter bed drain time (hr)

4. Select a filter bed width (w_b), and calculate the filter bed length (l_b):

$$l_b = A_b/w_b$$

Where:
- l_b = Filter bed length (ft)
- A_b = Filter bed surface area from Step 3 (sq-ft)
- w_b = Filter bed width (ft)

5. Calculate the total area occupied by the BMP excluding pretreatment (A_{BMP}) using the filter bed dimensions, embankment side slopes, and freeboard:

$$A_{BMP} = \left[w_b + 2z(d_p + f)\right] \times \left[l_b + 2z(d_p + f)\right]$$

Where:
- A_{BMP} = Area occupied by BMP excluding pretreatment (sq-ft)
- w_b = Filter bed width from Step 4 (ft)
- z = Filter bed interior side slope (length per unit height)
- d_p = Maximum Ponding Depth from Step 2 (ft)
- f = Freeboard (ft)
- l_b = Filter bed length from Step 4 (ft)

If the calculated area does not fit in the available space, either reduce the drainage area, reduce the planting soil depth (if it's not already set to the minimum), and/or increase the ponding depth (if it's not already set to the maximum depth), and repeat the calculations.

Pretreatment Considerations

Pretreatment should be provided where sediments or trash may cause a concern or decreased BMP functionality, and when space permits. Pretreatment may be achieved with vegetated swales, vegetated buffer strips with pea gravel or stone diaphragm, or manufactured treatment device.

Area Requirements

A bioretention filter requires a footprint equivalent to 3.3% - 3.8% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the minimum planting media depth and maximum ponding depth, while the upper value reflects the maximum planting media depth and minimum ponding depth.

Sizing Example

Calculate the size of a bioretention filter serving a 1-acre residential development. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	70
Design Storm Depth, P	inches	1.0
Planting Soil Coefficient of Permeability, k	feet/day	1.0
Drawdown (drain) Time, t	hours	48
Interior Side Slope (length per unit height), z		0
Freeboard, f	ft	0.5

1. Calculate the volumetric runoff coefficient and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$
$$C = 0.05 + 0.0039 \times 70$$
$$C = 0.68$$

$$WQV = PCA \times 3630$$
$$WQV = 1 \times 0.68 \times 1 \times 3630$$
$$WQV = 2,468 \ cubic \ feet$$

2. Select a planting soil depth (d_s) and ponding depth (d_p):

$$d_s = 2.0 \ ft$$
$$d_p = 6 \ in$$

3. Calculate the Filter Bed Surface Area (A_{BMP}):

$$A_{BMP} = WQV \times d_s / \left[k \left(d_s + (d_p/24) \right) (t/24) \right]$$
$$A_{BMP} = 2,468 \times 2 / \left[1 (2 + (6/24))(48/24) \right]$$
$$A_{BMP} = 1,097 \ square \ feet$$

4. Set the bottom width (w_b) to 6 feet, and calculate the bottom length (l_b):

$$l_b = A_b / w_b$$
$$l_b = 1,097/6$$
$$l_b = 182.8 \ feet$$

5. Calculate the total area excluding pretreatment (A_{BMP}):

$$A_{BMP} = \left[w_b + 2z(d_p + f)\right] \times \left[l_b + 2z(d_p + f)\right]$$

$$A_{BMP} = [6 + 2 \times 0(0.5 + 0.5)] \times [182.8 + 2 \times 0(0.5 + 0.5)]$$

$$A_{BMP} = 1,097 \; square \; feet$$

Other Design Considerations

- An overflow device (e.g., domed riser, inlet structure) must be included to safely convey runoff from large storm events when the surface/subsurface capacity is exceeded.

- If a mulch layer is used on the surface of the planting bed, consideration should be given to problems caused by flotation during storm events.

- A cleanout pipe should be tied into the end of all underdrain pipe runs

Figure 11: Schematic of a Bioretention Filter
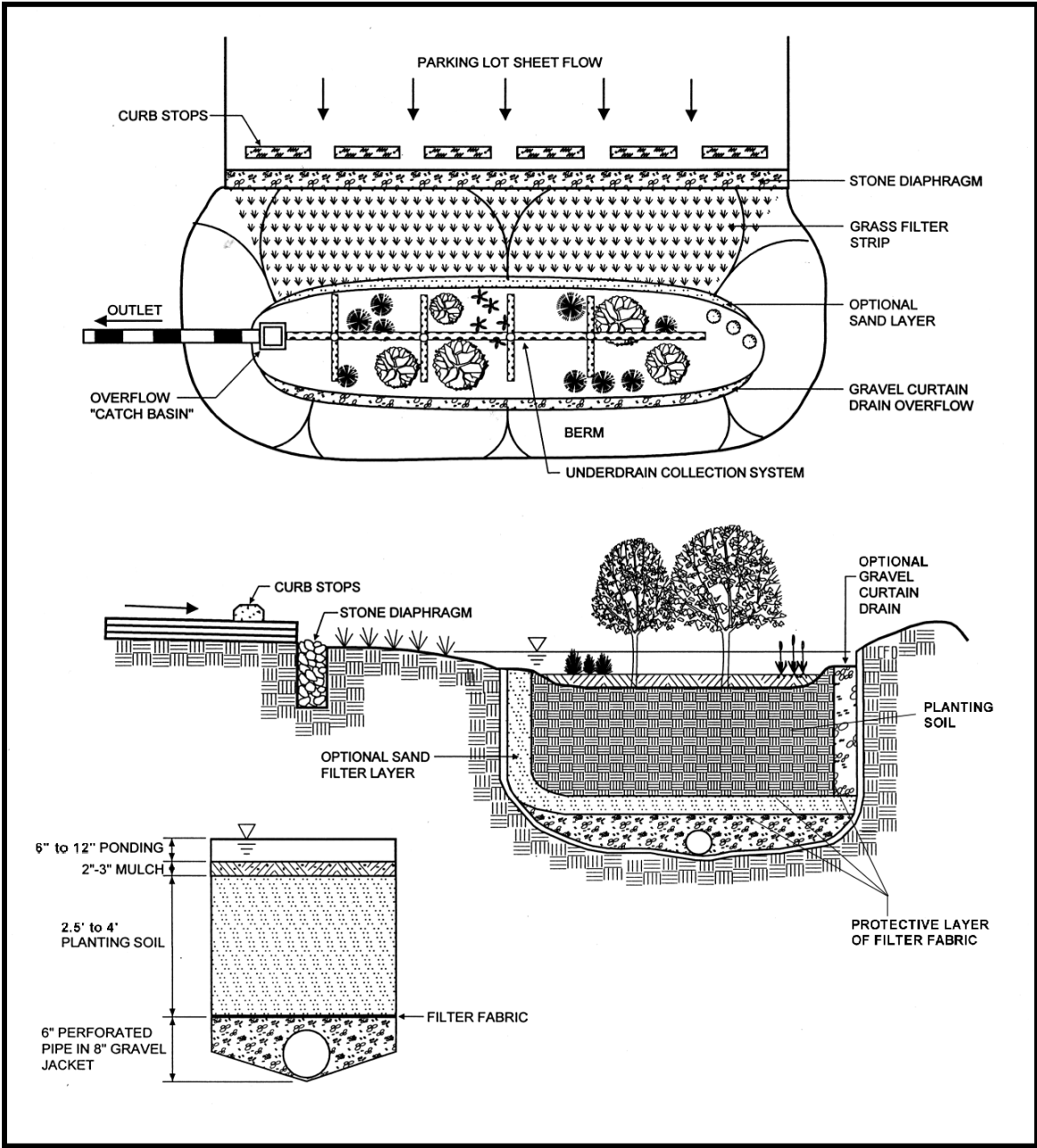
Prince George's County Bioretention Manual. 2007.

DRY SWALE

Description

Sometimes referred to as a Bioretention Swale or Enhanced Swale, a Dry Swale is a shallow linear channel with a planting bed and covered with turf or other surface material (other than mulch or plants). Runoff filters through a planting bed, is collected in an underdrain system, and discharged at the downstream end of the swale.

BMP Category	
Retention	○
Biofiltration	●
Other	○

Expected Pollutant Removals	
Nutrients	Medium
Sediment	High
Trash	High
Pathogens	Unknown
Pesticides	Unknown
Oil & Grease	Medium
Metals	Medium
Organic Compounds	Unknown

Georgia Stormwater Management Manual. 2001.

Minimum Design Criteria

Design Parameter	Units	Value
Maximum Interior Side Slope (length per unit height)		3:1
Bottom width	feet	2 - 8
Maximum Longitudinal Slope w/o check dams	%	2
Maximum Longitudinal Slope w/ check dams	%	5
Maximum check dam height	inches	12
Maximum Ponding Depth at downstream end	inches	18
Media depth	inches	18 - 36
Maximum Velocity	feet/sec	3
Minimum Freeboard	inches	6
Maximum Underdrain Diameter	inches	6

Feasibility Criteria

See Table 10.

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Select values for the planting media thickness, drainage layer thickness, planting media porosity, drainage layer porosity, maximum surface ponding depth (if check dams are used), bottom width, and interior side slope (length per unit height).

3. Calculate the total effective storage depth based on the instantaneous storage capacity using the void space in the planting media and drainage layer, and the average ponding depth (assumed to be one-half the maximum ponding depth):

$$d_t = [(d_p/2) + l_m n_m + l_d n_d]/12$$

Where:
  d_t = Total effective water storage depth (ft)
  d_p = Maximum ponding depth from Step 2 (in)
  l_m = Planting media thickness from Step 2 (in)
  n_m = Planting media porosity, typically around 0.25
  l_d = Drainage layer thickness from Step 2 (in)
  n_d = Drainage layer porosity, typically around 0.40

4. Calculate the swale invert area required (A_b) based on the instantaneous storage capacity (neglecting the additional ponding capacity due to the shape of the swale sides):

$$A_b = WQV/d_t$$

Where:
  A_b = Bottom surface area (sq-ft)
  WQV = Water Quality Volume from Step 1 (cu-ft)
  d_t = Total effective water storage depth from Step 3 (ft)

5. Calculate the total area required (A_{BMP}) taking into account the side slopes along the length of the swale:

$$A_{BMP} = [b + 2 \times z \times (d_p + f)/12] \times (A_b/b)$$

Where:
  A_{BMP} = Total surface area (sq-ft)
  b = Swale bottom width from Step 2 (ft)
  z = Interior swale side slope (length per unit height) from Step 2
  d_p = Ponding depth from Step 2 (in)
  f = Freeboard (in)
  A_b = Bottom surface area from Step 4 (sq-ft)

If the minimum surface area is larger than the available space, reduce the tributary area and/or increase one or more design depths (media, gravel, ponding), and repeat the calculations.

Pretreatment Considerations

Pretreatment for dry swales is provided by a shallow sediment forebay at the initial point of the channel. The volume of this forebay should be equal to at least 0.05 in. per impervious acre of drainage. A pea gravel diaphragm can be used along the top of the channel to provide pretreatment for lateral flows entering the swale.

Area Requirements

A dry swale requires a footprint equivalent to 8% - 40% of its contributing impervious drainage area. The lower value corresponds to the maximum allowable values for the mentioned dependent variables, while the upper value reflects the minimum allowable values for all specified parameters.

Sizing Example

Calculate the size of a dry swale serving a 1-acre residential development. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	70
Design Storm Depth, P	inches	1.0
Media porosity, n_m		0.25
Drainage layer porosity, n_d		0.40
Freeboard, f	inches	6
Drawdown (drain) Time, t	hours	48

1. Calculate the volumetric runoff coefficient and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$
$$C = 0.05 + 0.0039 \times 70$$
$$C = 0.68$$

$$WQV = PCA \times 3630$$
$$WQV = 1 \times 0.68 \times 1 \times 3630$$
$$WQV = 2,468 \; cubic \; feet$$

2. Select a media thickness (l_m), drainage layer thickness (l_d), ponding depth (d_p), bottom width (b), and interior side slope (z):

$$l_m = 18 \; in$$
$$l_d = 6 \; in$$
$$d_p = 12 \; in$$
$$b = 8 \; ft$$
$$z = 3$$

3. Calculate the total effective storage depth:

$$d_t = \left[(d_p/2) + l_m n_m + l_d n_d\right]/12$$
$$d_t = (6 + 18 \times 0.25 + 6 \times 0.40)/12$$
$$d_t = 1.075 \ feet$$

4. Calculate the minimum invert area (A_b) needed for the WQV and depths:

$$A_b = WQV/d_t$$
$$A_b = 2,468/1.075$$
$$A_b = 2,296 \ square \ feet$$

5. Calculate the total area required (A_{BMP}):

$$A_{BMP} = \left[b + 2 \times z \times (d_p + f)/12\right] \times (A_b/b)$$
$$A_{BMP} = [8 + 2 \times 3 \times (12 + 6)/12] \times (2,296/8)$$
$$A_{BMP} = 4,879 \ square \ feet$$

Other Design Considerations
- Landscape design should specify proper grass species based on specific site, soils and hydric conditions present along the channel. Vegetation should be designed for regular mowing, like a typical lawn, or less frequently (annually or semi-annually).
- Dry swales must be adequately designed to safely pass flows that exceed the design storm flows.

Figure 12: Schematic of a Dry Swale
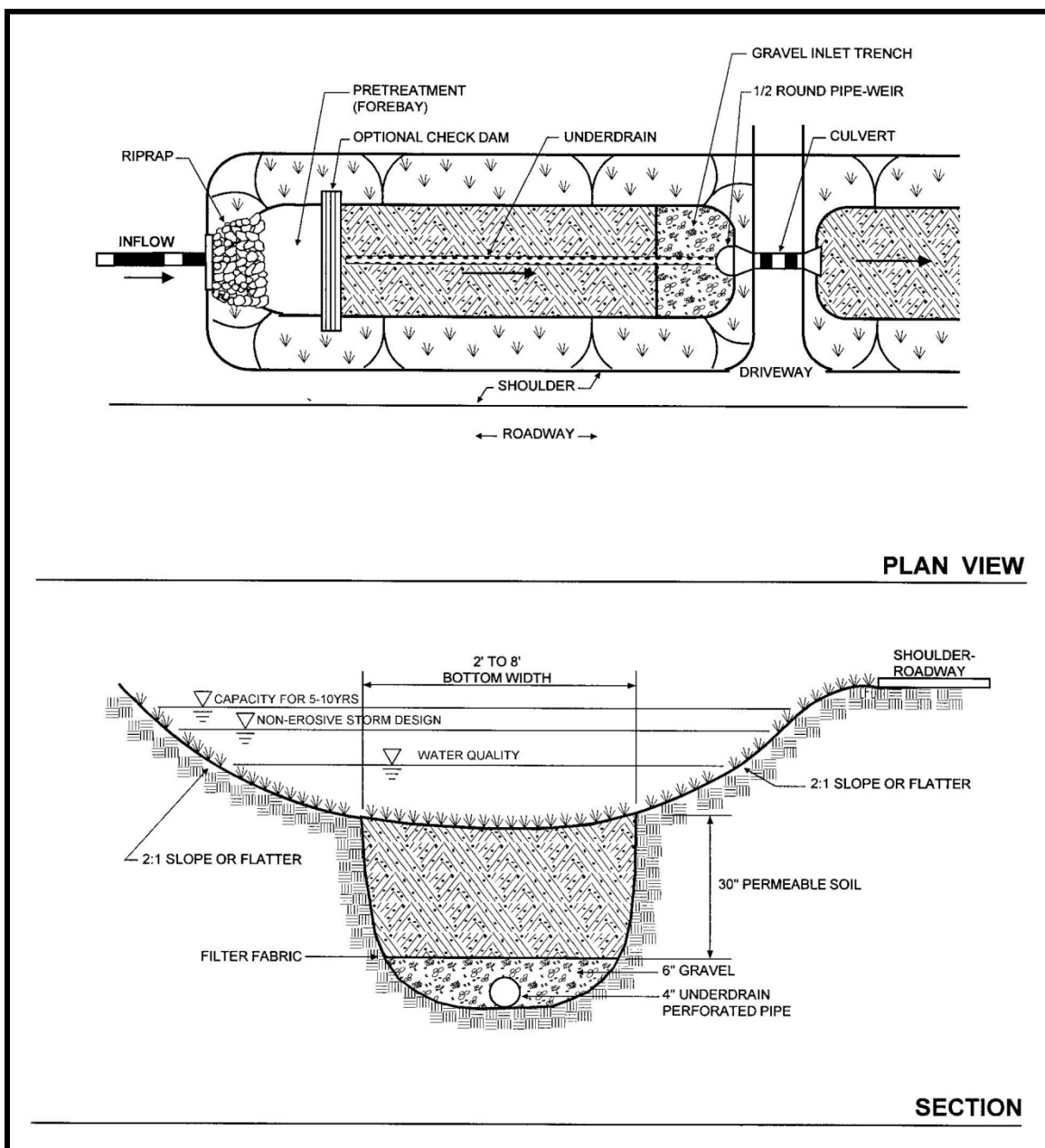
Vermont Stormwater Management Handbook, Technical Support Document, Public Review Draft. 2000.

DOWNSPOUT DISCONNECTION

Description

Sometimes referred to as Rooftop Disconnection or Downspout Dispersion, is the redirection of roof runoff to a vegetated area in a dispersed manner.

BMP Category	
Retention	○
Biofiltration	●
Other	○

Expected Pollutant Removals	
Nutrients	Low
Sediment	Medium
Trash	Low
Pathogens	Low
Pesticides	Unknown
Oil & Grease	Medium
Metals	Medium
Organic Compounds	Unknown

New York State Stormwater Management Design Manual. 2010.

Minimum Design Criteria

Design Parameter	Units	Value
Minimum vegetated area to roof area ratio		0.1:1
Minimum vegetated flow path to roof flow path ratio		1:1

Feasibility Criteria

See Table 10.

Sizing Procedure

1. Calculate size of the vegetated area (A_v) using 10% of the roof drainage area (A_r):

$$A_v = 0.10A_r$$

Where: A_v =   Vegetated area (sq-ft)
              A_r =   Roof drainage area (sq-ft)

2. Use the procedure presented previously to compute the Water Quality Volume (WQV) for which credit is received.

Pretreatment Considerations

Downspout disconnections do not require pretreatment.

Area Requirements

A downspout disconnection requires a footprint equivalent to at least 10% of its contributing impervious drainage area.

Sizing Example

Calculate the size of a vegetated area serving the runoff from a 1,000 square foot roof. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	100
Design Storm Depth, P	inches	1.0

1. Calculate size of the vegetated area (A_v) using 10% of the roof drainage area (A_r):

$$A_v = 0.10 A_r$$
$$A_v = 0.10 \times 1,000$$
$$A_v = 100 \ sq - ft$$

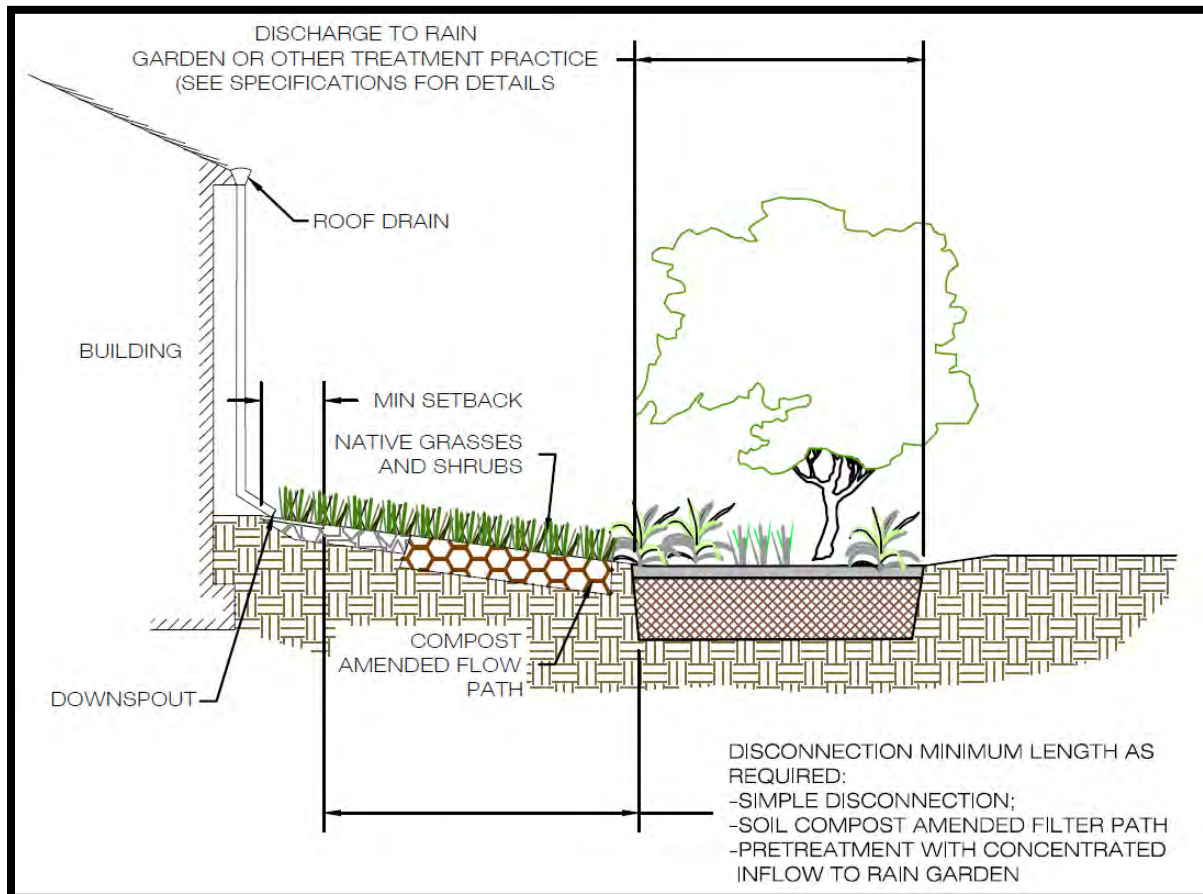2. Calculate the Water Quality Volume (WQV) for which credit is received:

$$WQV = PCA \times 3630$$
$$WQV = 1 \times (0.05 + 0.009 \times 100) \times (1,000/43,560) \times 3630$$
$$WQV = 79 \ cubic \ feet$$

Other Design Considerations

- Disconnected runoff can also be directed to rain barrels, cisterns, rain gardens, dry wells, or other BMPs.

- Disconnections over impervious soils (Hydrologic Soil Group "C" or "D") is discouraged, unless the soil is compost-amended.

- Use splash pads or level spreaders as required to distribute runoff to designated areas with infiltration capacity.

- Runoff must not flow toward building foundations or onto adjacent private property

Figure 13: Schematic of a Downspout Disconnection

DISCHARGE TO RAIN GARDEN OR OTHER TREATMENT PRACTICE (SEE SPECIFICATIONS FOR DETAILS

ROOF DRAIN

BUILDING

MIN SETBACK

NATIVE GRASSES AND SHRUBS

COMPOST AMENDED FLOW PATH

DOWNSPOUT

DISCONNECTION MINIMUM LENGTH AS REQUIRED:
–SIMPLE DISCONNECTION;
–SOIL COMPOST AMENDED FILTER PATH
–PRETREATMENT WITH CONCENTRATED INFLOW TO RAIN GARDEN

Virginia DCR Stormwater Design Specification No. 1. 2011.

VEGETATED SWALE

Description

Sometimes referred to as a Grass Swale, Grass Channel, or Biofiltration Swale, a vegetated swale is a broad shallow earthen channel vegetated with erosion resistant and flood tolerant grasses. Runoff typically enters the swale at one end and exits at the other end.

BMP Category	
Retention	○
Biofiltration	●
Other	○

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Expected Pollutant Removals	
Nutrients	Low
Sediment	Medium
Trash	Low
Pathogens	Low
Pesticides	Unknown
Oil & Grease	Medium
Metals	Medium
Organic Compounds	Unknown

Minimum Design Criteria

Design Parameter	Units	Value
Maximum Interior Side Slope (length per unit height)		3:1
Manning's n value	-	0.20
Maximum Flow Velocity	feet/sec	1
Maximum Water Depth	inches	4
Minimum Hydraulic Residence Time	minutes	7
Maximum Bottom Width	feet	10
Minimum Freeboard	inches	6

Feasibility Criteria

See Table 10.

Sizing Procedure

1. Use the procedure presented previously to compute the Water Quality Flow Rate.

2. Select initial values for swale bottom width (b), depth of flow (y), swale side slope (z), swale longitudinal slope (s), and hydraulic residence time (T):

3. Calculate the cross-sectional area (A), wetted perimeter (WP), and hydraulic radius (R) using the dimensions established in Step 2:

$$A = (by/12) + (zy^2/144)$$

$$WP = b + (2y/12)\sqrt{1 + z^2}$$

$$R = A/WP$$

Where:
	A	=	Cross sectional area (sq-ft)
	WP	=	Wetted perimeter (ft)
	R	=	Hydraulic radius (ft)
	b	=	Swale bottom width from Step 2 (ft)
	y	=	depth of flow for WQF from Step 2 (in)
	z	=	Swale side slope (length per unit height) from Step 2

4. Calculate the design flow rate in the swale using the selected dimensions and Manning's Equation:

$$Q = \frac{1.49AR^{2/3}s^{1/2}}{n}$$

Where:
	Q	=	Design flow rate (cfs)
	A	=	Cross Sectional area from Step 3 (sq-ft)
	R	=	Hydraulic radius from Step 3 (ft)
	s	=	Longitudinal Slope from Step 2 (%)
	n	=	Manning's n value

Note that the Manning's n value for water quality calculations is significantly higher than the Manning's n value typically used for flood control calculations (0.035). If the calculated flow rate is not equal to or greater than the WQF from Step 1, decrease the tributary area and/or increase one or more swale dimensions (bottom width, depth of flow, side slope, or longitudinal slope) and repeat the calculations.

5. Once an appropriate design flow rate is achieved, calculate the design flow velocity using the flow continuity equation:

$$V = Q/A$$

Where:
	V	=	Design flow velocity (ft/sec)
	Q	=	Design flow rate from Step 4 (cfs)
	A	=	Cross sectional area from Step 3 (sq-ft)

If the design flow velocity is greater than the maximum allowed velocity, either include check dams with vertical drops of no more than 12 inches, or revise one or more swale dimensions and repeat the calculations.

6. Multiply the velocity by the hydraulic residence time to determine the length:

$$L = 60VT$$

Where: L   =   Swale length (ft)
                 T   =   Hydraulic residence time from Step 2 (min)
                 V   =   Design flow velocity from Step 5 (ft/sec)

7. Calculate the total area required (A_{BMP}) taking into account the side slopes along the length of the swale and the freeboard:

$$A_{BMP} = [b + 2z\,(y + f)/12] \times L$$

Where: A_{BMP} =   Total surface area (sq-ft)
                 b   =   Swale bottom width from Step 2 (ft)
                 z   =   Interior swale side slope (length per unit height) from Step 2
                 y   =   depth of flow for WQF from Step 2 (in)
                 f   =   Freeboard (in)
                 L   =   Swale length from Step 6 (ft)

If the calculated are does not fit in the available area, reduce the drainage area, reduce the hydraulic residence time (if it is longer than the minimum), and/or revise one or more swale dimensions, and repeat the calculations.

Pretreatment Considerations
Vegetated swales do not require pretreatment.

Area Requirements
A vegetated swale requires a footprint equivalent to 2% - 4% of its contributing impervious drainage area. The lower value corresponds to maximizing the flow depth and slope, while the upper value corresponds to maximizing the bottom width and slope.

Sizing Example
Calculate the size of a grass swale serving the runoff from a one acre parking lot. Assume the following design parameters:

Design Parameter	Units	Value
Weighted Runoff Coefficient, C		0.95
Rainfall Intensity, i	inches/hr	0.4
Interior Side Slope (length per unit height)		3
Manning's n value	-	0.20
Longitudinal Slope, s		0.016
Hydraulic Residence Time, T	minutes	7
Freeboard, f	inches	6

1. Calculate the Water Quality Flow Rate (WQF):

$$WQF = CiA$$
$$WQF = 0.95 \times 0.4 \times 1.0$$
$$WQF = 0.38 \; cubic \; feet \; per \; second$$

2. Select initial values for swale bottom width (b), depth of flow (y), swale side slope length per unit height (z), swale longitudinal slope (s), and hydraulic residence time (T):

$$b = 2.75 \; ft$$
$$y = 3.5 \; in$$
$$z = 3$$
$$s = 0.017$$
$$T = 7 \; min$$

3. Calculate the cross-sectional area (A), wetted perimeter (WP), and hydraulic radius (R):

$$A = (by/12) + (zy^2/144)$$
$$A = (2.75 \times 3.5/12) + (3 \times 3.5 \times 3.5/144)$$
$$A = 1.06 \; square \; feet$$

$$WP = b + (2y/12)\sqrt{1 + z^2}$$
$$WP = 2.75 + (2 \times 3.5/12)\sqrt{1 + 3 \times 3}$$
$$WP = 4.59 \; feet$$

$$R = A/WP$$
$$R = 1.06/4.59$$
$$R = 0.23 \; feet$$

4. Calculate the design flow rate (Q):

$$Q = 1.49AR^{2/3}s^{1/2}/n$$
$$Q = 1.49 \times 1.06 \times 0.23^{0.667} \times 0.017^{0.5}/0.20$$
$$Q = 0.39\ cfs\ [\geq WQF, OK]$$

5. Calculate the velocity in the swale (V):

$$V = Q/A$$
$$V = 0.39/1.06$$
$$V = 0.36\ fps\ [< 1\ fps, OK]$$

6. Calculate the minimum length of the swale (L):

$$L = 60 \times V \times T$$
$$L = 60 \times 0.36 \times 7$$
$$L = 153\ feet$$

7. Calculate the total area required (A_{BMP}):

$$A_{IMP} = [b + 2z\,(y + f)/12] \times L$$
$$A_{IMP} = [2.75 + 2 \times z \times (3.5 + 6)/12] \times 153$$
$$A_{IMP} = 1,148\ square\ feet$$

Other Design Considerations

- Credit for partial infiltration may be given if the soil beneath the BMP is amended by incorporating 6 inches of compost/amendments and tilled up to 8 inches.

- In cases where a vegetated swale is located on-line, it should be sized as a treatment facility and as a conveyance system per the City and County's standards for flood control.

- Vegetate the swale with dense turf grass to promote sedimentation, filtration, and nutrient uptake, and to limit erosion through maintenance of low flow velocities.

- Check dams may be used to achieve flow velocity requirements. They are often employed to enhance infiltration capacity, decrease runoff volume, rate, and velocity, and promote additional filtering and settling of nutrients and other pollutants

Figure 14: Schematic of a Vegetated Swale
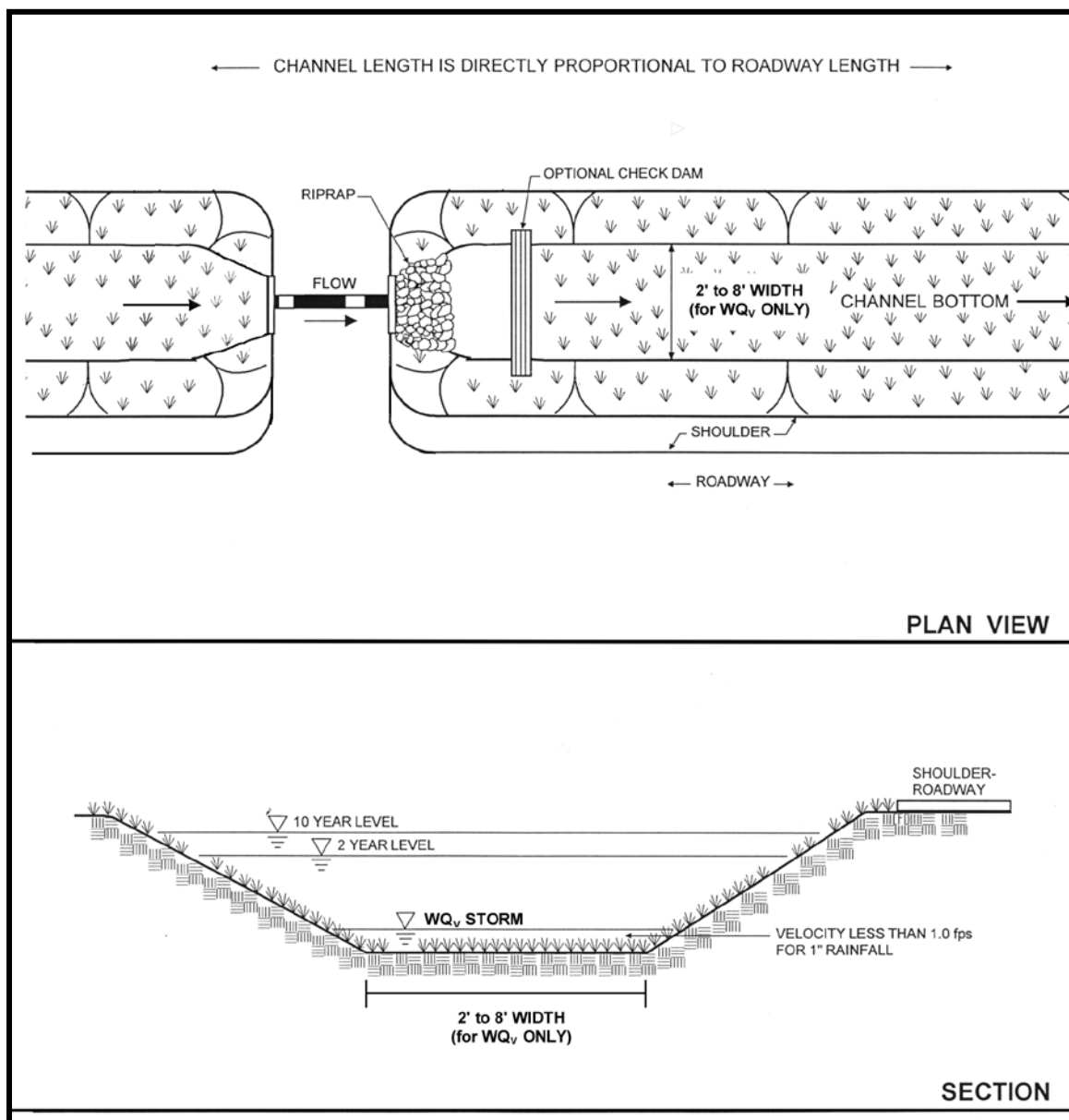
Maryland Stormwater Design Manual. 2000.

VEGETATED BUFFER STRIP

Description

Sometimes referred to as a Vegetated Filter Strip or Biofiltration Strip, a vegetated buffer strip is a grassy slope vegetated with turf grass that is designed to accommodate sheet flow. They may resemble natural ecological communities and remove pollutants by vegetative filtration.

BMP Category	
Retention	○
Biofiltration	●
Other	○

Virginia DCR Stormwater Design Specification No. 2. 2011.

Expected Pollutant Removals	
Nutrients	Low
Sediment	Medium
Trash	Medium
Pathogens	Low
Pesticides	Unknown
Oil & Grease	Medium
Metals	Medium
Organic Compounds	Medium

Minimum Design Criteria

Design Parameter	Units	Value
Manning's n value	-	0.25
Maximum Flow Velocity	feet/sec	1
Maximum Upstream Area Flow Length	feet	75
Minimum Length	feet	15
Maximum Flow Depth	inches	1

Feasibility Criteria

See Table 10.

Sizing Procedure

1. Use the procedure presented previously to compute the Water Quality Flow Rate.

2. Select values for the buffer strip width (w) and buffer strip longitudinal slope (s). Note that if a strip width is selected that is not the same as the width of the upstream flow path, a transition structure will be necessary to capture all the runoff and/or establish uniform sheet flow across the entire strip width.

3. Compute the design flow depth for the WQF using a simplified form of Manning's Equation assuming a shallow flow depth:

$$y = 12 \times \left(\frac{nQ}{1.49w\sqrt{s/100}}\right)^{0.6}$$

Where: y   =   Design flow depth for WQF (in)
          n   =   Manning's n value
          Q   =   Water Quality Flow Rate from Step 1 (cfs)
          w   =   Design width from Step 2 (ft)
          s   =   Longitudinal slope from Step 2 (%)

Note that the Manning's n value for water quality calculations is significantly higher than the Manning's n value typically used for flood control calculations (0.035). If the calculated depth is greater than the maximum allowed depth, reduce the tributary area, increase the design width, or increase the longitudinal slope, and repeat the calculation.

4. Calculate the Design flow velocity across the strip using the flow continuity equation:

$$V = 12Q/wy$$

Where: V   =   Design flow velocity (ft/sec)
          Q   =   Water Quality Flow Rate from Step 1 (cfs)
          w   =   Design width from Step 2 (ft)
          d   =   Design flow depth from Step 3 (in)

If the design flow velocity is greater than the maximum allowed velocity, revise one or more design parameters and repeat the calculations.

5. Select a design buffer strip length (L) equal to or greater than the minimum length, and calculate the total BMP area:

$$L = 20.0 \, ft$$

$$A_{BMP} = L \times w$$

Where: A_{BMP} =   Vegetated buffer strip area (sq-ft)
          L   =   Design length (ft)
          w   =   Design width from Step 2 (ft)

Pretreatment Considerations
Vegetated Buffer Strips do not require pretreatment.

Area Requirements
A vegetated buffer strip requires a footprint equivalent to no less than 0.4% of its contributing impervious drainage area. While there is no upper value because there is no maximum design width or design length, the minimum footprint corresponds to the minimum length and the maximum slope and minimum width combination that provide the maximum allowable design depth.

Sizing Example

Calculate the size of a vegetated buffer strip serving the runoff from a one acre parking lot. Assume the following design parameters:

Design Parameter	Units	Value
Weighted Runoff Coefficient, C		0.95
Rainfall Intensity, i	inches/hr	0.4
Manning's n value	-	0.25
Longitudinal Slope		0.06

1. Calculate the Water Quality Flow Rate (WQF):

$$WQF = CiA$$
$$WQF = 0.95 \times 0.4 \times 1.0$$
$$WQF = 0.38 \; cubic \; feet \; per \; second$$

2. Select a design buffer strip width (w) and longitudinal slope (s):

$$w = 20.0 \; ft$$
$$s = 0.06$$

3. Calculate the depth of flow for the WQF (y):

$$y = 12 \times \left(WQF \times n / 1.49 w \sqrt{s}\right)^{0.6}$$
$$y = 12 \times \left(0.38 \times 0.25 / 1.49 \times 20 \sqrt{0.06}\right)^{0.6}$$
$$y = 0.89 \; inches \; [\leq 1 \; inch, OK]$$

3. Calculate the velocity across the buffer strip (V):

$$V = 12 \times WQF / (y \times w)$$
$$V = 12 \times 0.38 / (0.89 \times 20.0)$$
$$V = 0.26 \; fps \; [\leq 1 \; fps, OK]$$

4. Select a design buffer strip length (L) at least equal to the minimum required length, and calculate the total BMP area (A_{BMP}):

$$L = 20.0 \; ft$$

$$A_{BMP} = L \times W_d$$
$$A_{BMP} = 20 \times 20$$
$$A_{BMP} = 400 \; square \; feet$$

Other Design Considerations

- Credit for partial infiltration may be given if the soil beneath the BMP is amended by incorporating 6 inches of compost/amendments and tilled up to 8 inches.

- A pea gravel diaphragm or engineered level spreader should be provided at the upper edge of the BMP when the width of the contributing drainage area is greater than that of the filter. Level spreader options include porous pavement strips, stabilized turf strips, slotted curbing, rock-filled trench, or concrete sills.

- The selection of plants should be based on their compatibility with climate conditions, soils and topography, and their ability to tolerate urban stresses from pollutants, variable soil moisture conditions and ponding fluctuations.

Figure 15: Schematic of a Vegetated Buffer Strip
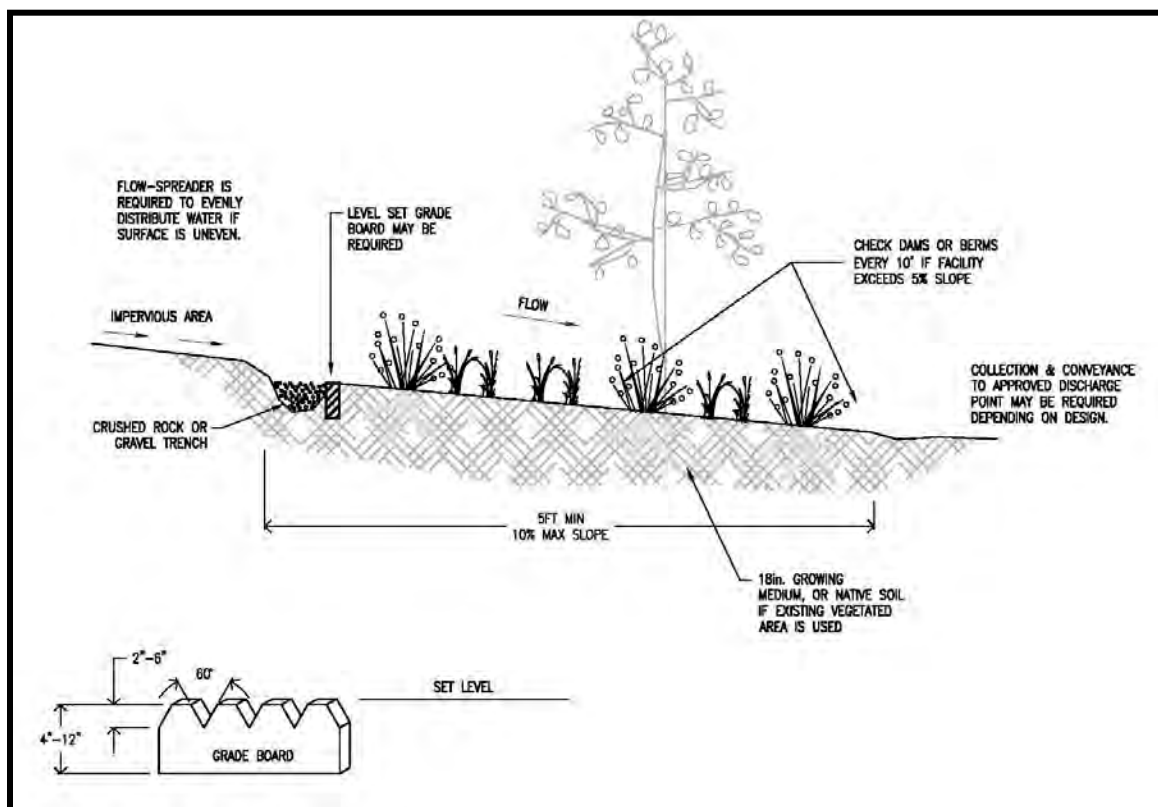
Portland Stormwater Management Manual. 2008.

TREE BOX FILTER

Description

Sometimes referred to as biofiltration boxes, a tree box filter is a proprietary water quality structure utilizing settling, filtration, adsorptive/absorptive materials, vegetative components, or other appropriate technology to remove pollutants from storm water runoff.

BMP Category	
Retention	○
Biofiltration	●
Other	○

www.filterra.com

Expected Pollutant Removals	
Nutrients	Medium
Sediment	High
Trash	High
Pathogens	Medium
Pesticides	Unknown
Oil & Grease	High
Metals	High
Organic Compounds	High

Minimum Design Criteria

Design Parameter	Units	Value
Any applicable manufacturer's criteria		

Feasibility Criteria

See Table 10.

Sizing Procedure

Follow the manufacturer's guidelines for appropriate sizing calculations and selection of appropriate device/model.

Pretreatment Considerations

No pretreatment is required.

Area Requirements

The footprint requirements for proprietary tree box filters vary by manufacturer.

Sizing Example

No example is provided as sizing procedures vary by manufacturer, and presenting any specific product might be interpreted as an endorsement.

Other Design Considerations

- All tree box filters must be able to safely overflow or bypass flows in excess of the storm water quality design storm to downstream drainage systems.

DETENTION BASIN

Description

Sometimes referred to as a Dry Extended Detention Basin, a detention basin is a shallow man-made impoundment intended to provide for the temporary storage of storm water runoff to allow particles to settle. It does not have a permanent pool and is designed to drain between storm events.

BMP Category	
Retention	○
Biofiltration	○
Other	●

Expected Pollutant Removals	
Nutrients	Low
Sediment	Medium
Trash	High
Pathogens	Low
Pesticides	Unknown
Oil & Grease	Medium
Metals	Low/Med
Organic Compounds	Unknown

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Minimum Design Criteria

Design Parameter	Units	Value
Maximum Interior Side Slope (length per unit height)		3:1
Minimum length to width ratio		2:1
Maximum depth	ft	8
Drawdown (drain) time for WQV	hours	48
Drawdown (drain) time for 50% of WQV	hours	24-36
Basin invert slope	%	1-2
Minimum outlet size	inches	4
Minimum freeboard	feet	1

Feasibility Criteria

Detention Basins are considered infeasible for any of the following conditions:

- Basin invert would be below seasonally high groundwater table
- Unable to operate off-line and unable to operate in-line w/ safe overflow mechanism
- Excavation would disturb iwi kupuna or other archaeological resources
- Unable to meet minimum length to width ratio design criteria naturally or artificially

Sizing Procedure

Detention Basins are sized using detailed routing calculations to demonstrate that the storage volume is adequate. However, a reasonable first estimate can be determined using the following simple routing method which assumes triangular hydrographs for the inflow and outflow.

1. Use the procedure presented previously to compute the pre-project (i.e., undeveloped) and post-project (i.e., developed) weighted runoff coefficients.

2. Compute the peak inflow rate using the Rational Method:

$$q_i = C_a iA$$

Where: q_i = Peak inflow rate into basin (cfs)
           C_a = Post-project weighted runoff coefficient
           i = Peak rainfall intensity (in/hr)
           A = Drainage area (ac)

3. Compute the peak outflow rate using the pre-project runoff coefficient, which effectively forces the detention basin to maintain pre-project discharge rates:

$$q_o = C_b iA$$

Where: q_o = Peak outflow rate leaving basin (cfs)
           C_b = Pre-project weighted runoff coefficient
           i = Peak rainfall intensity (in/hr)
           A = Drainage area (ac)

4. Calculate the estimated basin storage volume:

$$s = 3630 \times PA[1 - (q_o/q_i)]$$

Where: s = Storage volume in the basin (cu-ft)
           P = design storm runoff depth (in)
           A = Drainage area (ac)
           q_o = Peak outflow rate from Step 3 (cfs)
           q_i = Peak inflow rate from Step 2 (cfs)

5. Select initial values for the detention basin total width (w_t), total length (l_t), and depth (d) based on space availability, topography and existing drainage facilities. Also select values for the interior side slopes (z) and required freeboard (f). Calculate the basin invert width and invert length:

$$w_b = w_t - 2z(d + f)$$

$$l_b = l_t - 2z(d + f)$$

Where: w_b = Basin bottom width (ft)
           l_b = Basin bottom length (ft)
           w_t = Basin total width (ft)
           l_t = Basin total length (ft)
           z = Basin interior side slope (length per unit height)
           d = Depth of flow for Storage Volume (ft)
           f = Freeboard (ft)

6. Calculate the resulting storage volume using the prismoidal formula for trapezoidal basins:

$$V = w_b l_b d + (w_b + l_b)zd^2 + 4z^2 d^3/3$$

Where:

	V	=	Volume of trapezoidal basin (cu-ft)
	w_b	=	Basin bottom width from Step 5 (ft)
	l_b	=	Basin bottom length from Step 5 (ft)
	d	=	Depth of flow for Storage Volume from Step 5 (ft)
	z	=	Basin interior side slope from Step 5

Compare the calculated volume (V) to the required volume (s) from Step 4. If the calculated volume is greater than or equal to the required volume, the selected dimensions (w_t and l_t) and depth (d) are adequate for preliminary design. If the calculated volume is less than the required volume, increase one or both of the dimensions and/or the depth (d) and repeat Steps 5 and 6. If the footprint area and depth are set to maximum allowable values based on site characteristics and the calculated volume is still less than the required volume, reduce the drainage area (A) and repeat Steps 2 through 6.

Pretreatment Considerations

If significant amounts of sediment or sand are anticipated at the site, sediment forebays should be located at each major inlet to provide pretreatment, preserve the capacity of the basin, and reduce maintenance requirements in the basin. The forebay consists of a separate cell that drains into the main basin, formed by an acceptable barrier, such as an earthen berm or gabion baskets, etc.). If used, the total volume of all forebays should be at least 5% of the total WQV.

Area Requirements

A detention basin requires a footprint equivalent to 1% - 9% of its contributing impervious drainage area. The actual value is dependent on a number of variables, including the drainage area, pre-project and post-project runoff coefficients, and basin depth. Footprints at the lower range reflect deep basins (e.g., 8 feet) serving large drainage areas (e.g., 50 acres), while footprints at the upper range reflect shallow basins (e.g., 1 foot) serving small drainage areas (e.g., 1 acre).

Sizing Example

Calculate the preliminary size of a detention basin serving the runoff from a one acre parking lot. Assume the following design parameters:

Design Parameter	Units	Value
Rainfall Intensity, i	inches/hr	0.4
Runoff Volume, Q	inches	1
Basin Interior Side Slope (length per unit height), z		3
Freeboard, f	ft	1

1. Compute the pre-project (i.e., undeveloped) and post-project (i.e., developed) weighted runoff coefficients:

$$C_b = 0.20$$
$$C_a = 0.95$$

2. Compute the peak inflow rate:

$$q_i = C_a iA$$
$$q_i = 0.95 \times 0.40 \times 1$$
$$q_i = 0.38 \, cfs$$

3. Compute the peak outflow rate:

$$q_o = C_b iA$$
$$q_o = 0.20 \times 0.40 \times 1$$
$$q_o = 0.08 \, cfs$$

4. Calculate the estimated basin storage volume:

$$s = 3630 \times PA[1 - (q_o/q_i)]$$
$$s = 3630 \times 1 \times 1 \times [1 - (0.08/0.38)]$$
$$s = 2,866 \, cubic \, feet$$

5. Select initial values for the detention basin total width (w_t), total length (l_t), depth (d), interior side slopes (z) and required freeboard (f):

$$w_t = 38 \, feet$$
$$l_t = 53 \, feet$$
$$d = 3.5 \, feet$$
$$z = 3$$
$$f = 1.0 \, foot$$

Calculate the basin bottom width and length:

$$w_b = w_t - 2z(d + f)$$
$$w_b = 38 - 2 \times 3(3.5 + 1)$$
$$w_b = 11 \, feet$$

$$l_b = l_t - 2z(d + f)$$
$$l_b = 53 - 2 \times 3(3.5 + 1)$$
$$l_b = 26 \, feet$$

6. Calculate the resulting storage volume using the prismoidal formula for trapezoidal basins:

$$V = w_b l_b d + (w_b + l_b)zd^2 + 4z^2d^3/3$$

$$V = 11 \times 26 \times 3.5 + (11 + 26) \times 3 \times 3.5^2 + 4 \times 3^2 \times 3.5^3/3$$

$$V = 2,875 \; cubic \; feet$$

The calculated volume is greater than the required volume, so the preliminary design is ok.

Other Design Considerations

- Credit for infiltration may be given if the soils beneath the detention basin invert have a measured infiltration rate of at least 0.5 inches per hour and none of the infeasibility criteria for infiltration basins are applicable. However, low flow channels should not be included if infiltration is expected.

- If a temporarily-filled pond creates a potential public safety issue, perimeter fencing may be considered. Warning signs should be used wherever appropriate

- In order to meet designs storm requirements, detention basins should have a multistage outlet structure. Three elements are typically included in this design:

  1. A low-flow outlet that controls the extended detention and functions to slowly release the water quality design storm.
  2. A primary outlet that functions to attenuate the peak of larger design storms.
  3. An emergency overflow outlet/spillway

  Design methodology options are provided in manuals included in the References, including the Georgia Stormwater Management Manual, the Urban Storm Drainage Criteria Manual, and the EPA Stormwater Best Management Practice Design Guide.

Figure 16: Schematic of a Detention Basin
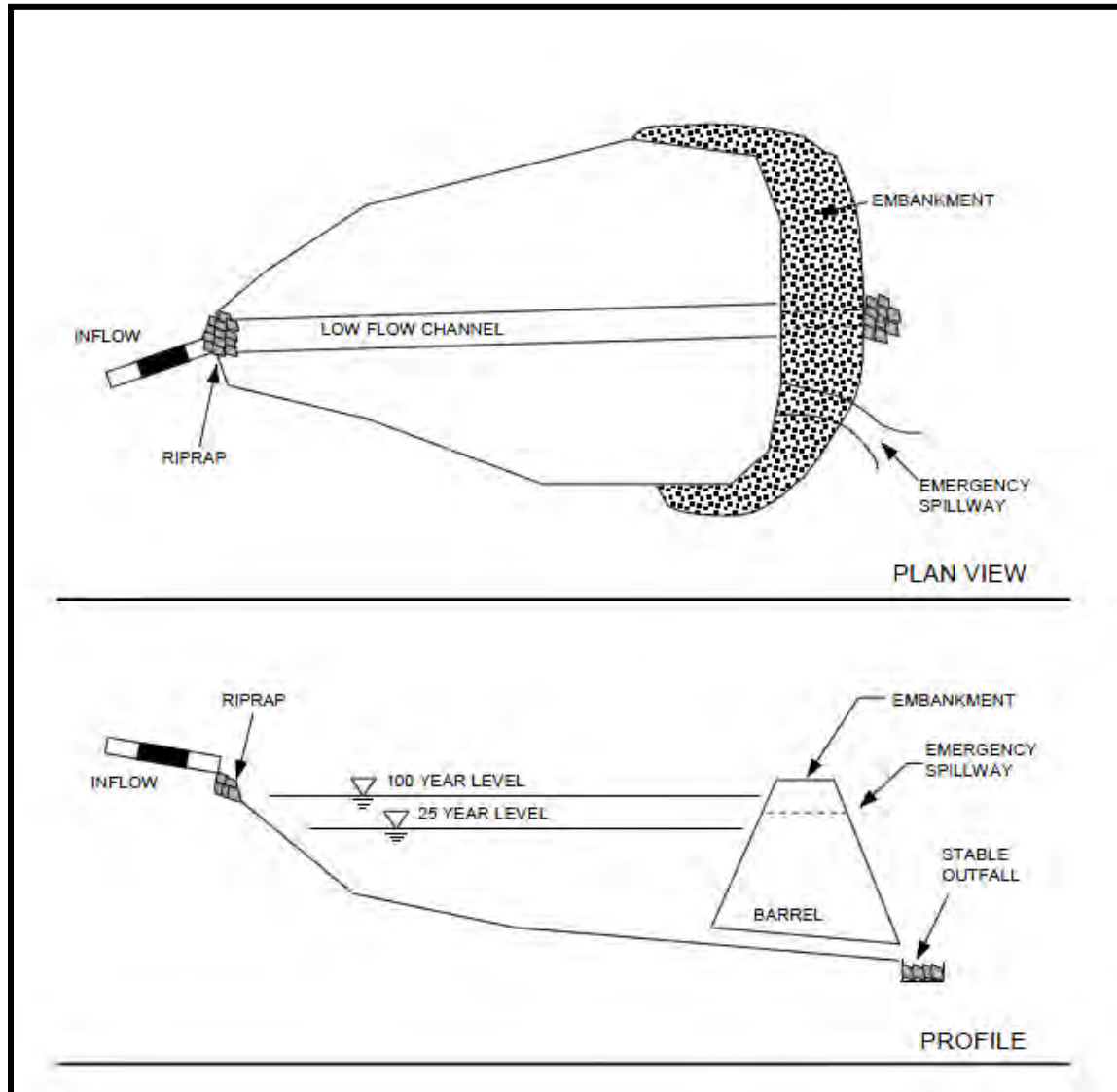
Georgia Stormwater Management Manual. 2001.

MANUFACTURED TREATMENT DEVICE

Description

Sometimes referred to as hydrodynamic or vortex separators, a manufactured treatment device is a proprietary water quality structure utilizing settling, filtration, adsorptive/absorptive materials, vortex separation, vegetative components, or other appropriate technology to remove pollutants from storm water runoff.

BMP Category	
Retention	○
Biofiltration	○
Other	●

Expected Pollutant Removals	
Nutrients	Low
Sediment	Med/High
Trash	High
Pathogens	Low
Pesticides	Low
Oil & Grease	Med/High
Metals	Low
Organic Compounds	Low

???

Minimum Design Criteria

Design Parameter	Units	Value
Minimum TSS Removal	%	80

Feasibility Criteria

Manufactured treatment devices are considered infeasible for any of the following conditions:

- Bottom of BMP is below seasonally high groundwater table
- Unable to operate off-line and unable to operate in-line w/ safe overflow mechanism
- Excavation would disturb iwi kupuna or other archaeological resources

Sizing Procedure

Follow the manufacturer's guidelines for appropriate sizing calculations and selection of appropriate device/model.

Pretreatment Considerations

No pretreatment is required.

Area Requirements

The footprint requirements for proprietary manufactured treatment devices vary by manufacturer.

Sizing Example

No example is provided as sizing procedures vary by manufacturer, and presenting any specific product might be interpreted as an endorsement.

Other Design Considerations

- The device must provide a TSS removal rate of 80%, verified by a Technology Acceptance and Reciprocity Partnership (TARP) state or by other third party testing organizations, provided that such verification is conducted in accordance with the protocol "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity".
- All manufactured treatment devices must be able to safely overflow or bypass flows in excess of the storm water quality design storm to downstream drainage systems.

SAND FILTER

Description

A sand filter is an open chambered structure that captures, temporarily stores, and treats storm water runoff by passing it through an engineered media (e.g., sand).

BMP Category	
Retention	○
Biofiltration	○
Other	●

Portland Stormwater Management Manual. 2004.

Expected Pollutant Removals	
Nutrients	Low/Med
Sediment	High
Trash	High
Pathogens	Med
Pesticides	Unknown
Oil & Grease	High
Metals	Med/High
Organic Compounds	Med/High

Minimum Design Criteria

Design Parameter	Units	Value
Sand Coefficient of Permeability	feet/day	3.5
Filter media depth	inches	18
Drawdown (drain) Time	hours	48
Maximum Interior Side Slope if earthen (length per unit height)		3:1
Minimum Underdrain Diameter	inches	6

Feasibility Criteria

Sand filters are considered infeasible for any of the following conditions:

- Bottom of BMP is below seasonally high groundwater table
- Unable to operate off-line and unable to operate in-line w/ safe overflow mechanism
- Excavation would disturb iwi kupuna or other archaeological resources
- Site lacks sufficient hydraulic head to support BMP operation by gravity

Sizing Procedure

1. Use the procedure presented previously to compute the Volumetric Runoff Coefficient and Water Quality Volume.

2. Select values for the filter media depth (l_m) and maximum ponding depth (d_p).

3. Use Darcy's Law to calculate the required Filter Bed Surface Area:

$$A_{fb} = \frac{WQV \times l_m}{k(l_m + d_p/24)(t/24)}$$

Where:
A_{fb} = Filter bed surface area (sq-ft)
WQV = Water Quality Volume from Step 1 (cu-ft)
l_m = Filter media depth from step 2 (ft)
k = Filter media permeability coefficient (ft/day)
d_p = Maximum ponding depth, from Step 2 (in)
t = Filter bed drain time (hr)

4. Calculate the total area occupied by the BMP (A_{BMP}) using the embankment side slopes and assuming a square basin:

$$A_{BMP} = \left[\sqrt{A_{fb}} + 2z(d_p/12 + f)\right]^2$$

Where:
A_{BMP} = Area occupied by BMP (sq-ft)
Af_b = Filter bed surface area from Step 3 (sq-ft)
z = Filter bed interior side slope (length per unit height)
d_p = Maximum ponding depth from Step 2 (in)
f = Freeboard (ft)

If the calculated area does not fit in the available space, either reduce the drainage area, increase the ponding depth, and/or increase the interior side slope (if it's not already set to the maximum) and repeat the calculations.

Pretreatment Considerations

Pretreatment is required for sand filters in order to reduce the sediment load entering the sand bed, prevent premature clogging, and ensure filter longevity. The pretreatment device must be sized for at least 25% of the WQV, and may be achieved with vegetated swales, vegetated filter strips, sedimentation basins or forebays, sedimentation manholes, and manufactured treatment devices. The typical method is a sedimentation basin that has a length to width ratio of 2:1, and is sized using the Camp-Hazen equation.

Area Requirements

A sand filter requires a footprint equivalent to 1.5% - 3% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects minimum filter media and ponding depths, while the upper value reflects higher filter media and ponding depths.

Sizing Example

Calculate the size of a sand filter serving a 1-acre residential development. Assume the following design parameters:

Design Parameter	Units	Value
Percent Impervious Cover, I	%	70
Design Storm Depth, P	inches	1.0
Sand Coefficient of Permeability, k	feet/day	3.5
Interior Side Slope (length per unit height)		3:1
Freeboard	ft	0.5
Drawdown (drain) Time, t	hours	48

1. Calculate the volumetric runoff coefficient and Water Quality Volume (WQV):

$$C = 0.05 + 0.009I$$
$$C = 0.05 + 0.0039 \times 70$$
$$C = 0.68$$

$$WQV = PCA \times 3630$$
$$WQV = 1 \times 0.68 \times 1 \times 3630$$
$$WQV = 2,468 \ cubic \ feet$$

2. Select a filter media depth (l_m) and maximum ponding depth (d_p):

$$l_m = 1.5 \ ft$$
$$d_p = 24 \ in$$

3. Calculate the Filter Bed Surface Area (A_{fb}):

$$A_{fb} = WQV \times l_m / \left[k \left(l_m + (d_p/24) \right) (t/24) \right]$$
$$A_{BMP} = 2,468 \times 1.5 / \left[3.5(1.5 + (24/24))(48/24) \right]$$
$$A_{BMP} = 212 \ square \ feet$$

4. Calculate the total area occupied by the BMP (A_{BMP}):

$$A_{BMP} = \left[\sqrt{A_{fb}} + 2z(d_p/12 + f) \right]^2$$
$$A_{BMP} = \left[\sqrt{212} + 2 \times 3(24/12 + 0.5) \right]^2$$
$$A_{BMP} = 873 \ square \ feet$$

Other Design Considerations

- A flow spreader should be installed at the inlet along one side of the filter to evenly distribute incoming runoff across the filter and to prevent erosion of the filter device
- A cleanout pipe should be tied into the end of all underdrain pipe runs

Figure 17: Schematic of a Sand Filter
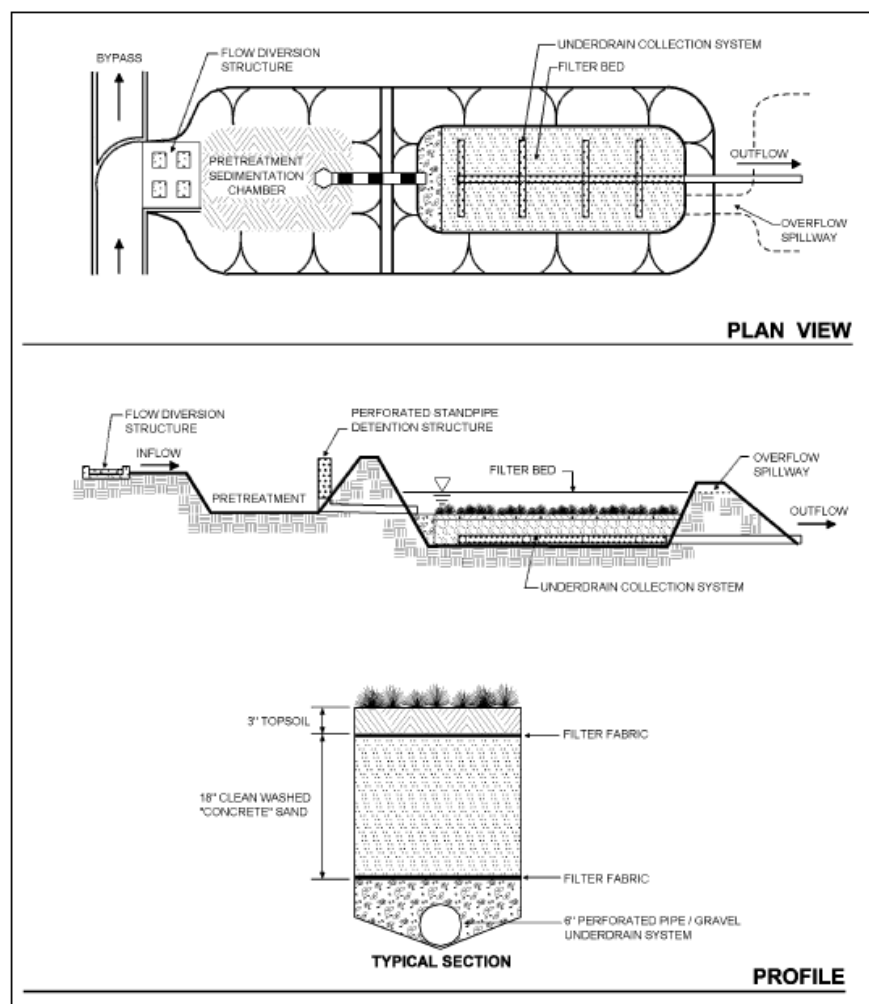
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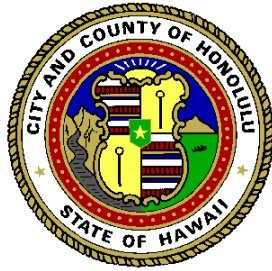
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Appendix D

CCH Rules Relating to Storm Drainage Standards

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RULES RELATING TO
STORM DRAINAGE STANDARDS

JANUARY 2000

Department of Planning and Permitting
City and County of Honolulu
Honolulu, Hawaii

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Department of Planning and Permitting
City and County of Honolulu

RULES RELATING TO

STORM DRAINAGE STANDARDS

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DEPARTMENT OF PLANNING AND PERMITTING
CITY AND COUNTY OF HONOLULU

RULES RELATING TO STORM DRAINAGE STANDARDS

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RULES OF THE DEPARTMENT OF PLANNING AND PERMITTING RELATING TO STORM DRAINAGE STANDARDS

§1-1 <u>PURPOSE</u>

These Rules address requirements for both storm runoff quantities for flood control as well as storm runoff quality and reflect the [most] recent changes to Federal, State, and County requirements related to the quality of storm water discharges. By establishing criteria to address water quality, the City and County of Honolulu continues its efforts in complying with Federal Regulatory requirements to control the discharge of pollutants in storm water as specified in the Clean Water Act as amended by the Water Quality Act of 1987.

These standards are not intended to limit the initiative and resourcefulness [of the engineer] in developing drainage plans, or be viewed as maximum limits in design criteria. More stringent criteria should be used where reasonable.

[Eff: June 1, 2013] (Auth: Sec 14-12.31, ROH) (Imp: Sec14-12.31, ROH)

§1-2   __MODIFICATIONS__

A. The Director may modify provisions of these rules whenever:

    1. Full conformance to these rules is not achievable because of the size and shape, location or geological or topographical conditions, or land uses.

    2. The project provides for adequate storm water controls to mitigate adverse downstream impacts related to runoff flows and water quality; complies with Subdivision Rules and Regulations and the Land Use Ordinance; and covenants or other legal provisions are provided as needed, to ensure continued conformity to and achievement of mitigation measures; and

    3. The modification is reasonably necessary and not contrary to the intent and purpose of these rules.

B. Modification requests must be in writing and substantiated by facts presented with the request.

C. Before granting any modification, the Director may consult with the Departments of Design and Construction, Environmental Services, Facilities Maintenance, Parks and Recreation, Transportation Services, Board of Water Supply or any other appropriate agency for review and recommendation.

[Eff: June 1, 2013] (Auth: Sec 14-12.31, ROH) (Imp: Sec14-12.31, ROH)

§1-3 **DEFINITIONS**

As used in these Rules, the following definitions shall apply unless the context indicates otherwise:

"Best Management Practices" or "BMPs" means pollution control measures, applied to nonpoint sources, on-site or off-site, to control erosion and the transport of sediments and other pollutants, which have an adverse impact on waters of the state. BMPs may include a schedule of activities, the prohibition of practices, maintenance procedures, treatment requirements, operating procedures, and practices to control site runoff, spillage or leaks, or drainage from raw material storage.

"Biofiltration" means the simultaneous process of filtration, adsorption and biological uptake of pollutants in stormwater that takes place when shallow-depth runoff flows slowly over and through vegetated areas.

"City" means the City and County of Honolulu.

"Department" means the Department of Planning and Permitting, City and County of Honolulu.

"Department of Health" or "DOH" means the Clean Water Branch, Department of Health, State of Hawaii, the water pollution regulatory agency of the state.

"Design Engineer" means a licensed civil engineer in the State of Hawaii.

"Development" means land which is being developed or developed lands.

"Director" means the Director of the Department of Planning and Permitting.

"Disturbed Area" means the area of the project that is expected to undergo any disturbance, including, but not limited to excavation, grading, clearing, demolition, uprooting of vegetation, equipment staging, and storage areas. Areas which are cleared, graded, and/or excavated for the sole purpose of landscape renovation or growing crops are not included in the disturbed area quantity. This exemption does not extend to the construction of buildings and roads of agriculture-related operations that disturb one (1) acre or more.

"Engineering Control Facility" means any drainage device such as a basin, well, pond, ditch, dam, or excavation used for the temporary or permanent storage of storm water by means of detention, retention, divergence, or infiltration for the purpose of reducing storm water volume and/or peak storm discharge flows, and which may provide gravity settling of particulate pollutants. It includes, but is not limited to, detention ponds, retention ponds, infiltration wells or ditches, holding tanks, diversion ditches or swales, drainpipes, check dams, and debris basins.

"EPA" means United States Environmental Protection Agency.

"Evapotranspiration" means the combined loss of water into the atmosphere by evaporation (water changing from a liquid to a vapor from soil, water, or plant surfaces) and transpiration (water that is taken up by plant roots and transpired through plant tissue and leaves).

"Flood" or "flooding" means the inundation to a depth of three inches or more of any property not ordinarily covered by water. The terms do not apply to inundation caused by tsunami wave action.

"Impervious Surface" means a surface covering or pavement of a developed parcel of land that prevents the land's natural ability to absorb and infiltrate rainfall/storm water.

"Infiltration" means the downward migration of surface water (i.e., runoff) through the planting soil (if present) and into the surrounding *in situ* soils and ultimately into groundwater.

"Low Impact Development, or LID" means a storm water management strategy that seeks to maintain or restore the natural hydrologic character of the site, reduce off-site runoff, improve water quality, provide groundwater recharge, and mitigate the impacts of increased runoff and storm water pollution. LID comprises a set of site design approaches and integrated management techniques that promote the use of natural systems for infiltration, evapotranspiration, treatment, and use of rainwater.

"Maximum Extent Practicable" or "MEP" means economically achievable measures for the control of the addition of pollutants from existing and new categories of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint source pollution control practices, technologies, processes, siting criteria, operating methods or other alternatives.

"National Pollutant Discharge Elimination System permit" or "NPDES permit" means the permit issued to the City pursuant to *Title 40, Code of Federal Regulations, Part 122,* Subpart B, Section 122.26(a) (1) (iii), for storm water discharge from the City's separate storm sewer systems; or the permit issued to a person or property owner for a storm water discharge associated with industrial activity pursuant to *Title 40, Code of Federal Regulations, Part 122*, Subpart B, Section 122.26(a) (1) (ii), or other applicable section of Part 122; or the permit issued to a person or property owner for the discharge of any pollutant from a point source into the state waters through the City's separate storm sewer system pursuant to *Hawaii Administrative Rules*, Chapter 11-55, "Water Pollution Control".

"New Development" means land disturbing activities; structural development, including construction or installation of a building or structure, the creation of impervious surfaces; and land subdivision.

"Redevelopment" means development that would create or add impervious surface area on an already developed site.

"Site Design Strategies" means LID design techniques that are intended to maintain or restore the site's hydrologic and hydraulic functions with the intent of minimizing runoff volume and preserving existing flow paths.

"Source Control BMPs" means low-technology practices designed to prevent pollutants from contacting storm water runoff or to prevent discharge of contaminated runoff to the storm drainage system.

"Storm water" means storm water runoff, surface runoff, street wash, or drainage and may include discharges from fire fighting activities.

"Treatment Control BMPs" means engineered technologies designed to remove pollutants from storm water runoff prior to discharge to the storm drain system or receiving waters.

[Eff: June 1, 2013] (Auth: Sec 14-12.31, ROH) (Imp: Sec14-12.31, ROH)

§1-4   SECTION I - STANDARDS FOR FLOOD CONTROL

Standards and regulations for flood control are adopted to protect life and property during intense storms. Small storms that occur frequently usually do not cause significant property damages or loss of life, therefore, peak runoff from large storms are regulated for flood control.

The data from *85* U.S. Geological Survey (USGS) *stream flow gauges on the Island of Oahu* form the basis for Plate 6, "Design Curves for Peak Discharge vs. Drainage Area". The rainfall data on Plates 1 and 2 are from the *National Oceanic and Atmospheric Administration (NOAA), National Weather Service, Silver Spring, Maryland, 2009.* Rainfall data on Plates 1, 2 and 6 will be updated periodically and such updates will automatically be incorporated into these rules when the updates are adopted by the Department. *[Eff:] (Auth: Sec 14-12.31,ROH) (Imp: Sec 14-12.31.ROH)*

APR 0 8 2011

§1-4.1 PART I - HYDROLOGIC CRITERIA

A.   RECURRENCE INTERVAL

1.   For drainage areas of 100 acres or less, Tm (recurrence interval) = 10 years, unless otherwise specified.

2.   For drainage areas of 100 acres or less with sump, or tailwater effect and for the design of roadway culverts and bridges, Tm (recurrence interval) = 50 years.

3.   For drainage areas greater than 100 acres and all streams, design curves based upon the U.S. Geological Survey data on flood magnitude and frequency, Tm (recurrence interval) = 100 years.

4.   Interim measures for areas where downstream facilities are inadequate shall be reviewed on a case-by-case basis.

B.   RUNOFF QUANTITY

1.   For drainage areas of 100 acres or less, the rational method shall be used.

2.   For drainage areas greater than 100 acres:

a.   Plate 6 titled, "Design Curves for Peak Discharge vs. Drainage Area" should be used to determine the 100-year peak discharge.

b.   *Modifications from the Plate 6 peak discharge values may be used if the Design Engineer can justify more acceptable values and it is approved by the Director.*

[Eff: APR 0 8 2011 *] (Auth: Sec 14-12.31,ROH) (Imp: Sec 14-12.31.ROH)*

3.   For drainage areas where downstream capacities are inadequate to accommodate runoff quantity identified above, runoff shall be limited to pre-development conditions or as specified in the General Conditions.

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C. RATIONAL METHOD

The formula $Q = CIA$ shall be used to determine quantities of flow rate, in which

Q = flow rate in cubic feet per second;
C = runoff coefficient;
I = rainfall intensity in inches per hour for a duration equal to the time of concentration; and
A = drainage area in acres.

1. RUNOFF COEFFICIENT

The runoff coefficient shall be determined from Table 1 for agricultural and open areas and from Table 2 for built-up areas. It shall be based on the ultimate use of the project drainage area. For distinctive composite drainage areas, a weighted value of runoff coefficient shall be used.

For interim drainage measures, existing upstream land use conditions may be used to size interim measures as long as ultimate drainage requirements can be met when downstream restrictions are removed.

2. TIME OF CONCENTRATION

a. Determine overland flow time from Plate 3 generally for paved, bare soil and grassed areas.

b. Determine flow time over small agricultural areas with well-defined divides and drainage channels from Plate 5.

1) Use upper curve for well-forested areas, representing

$$\textbf{Tc} = \textbf{0.0136 } \textbf{K}^{0.77}$$

2) Use lower curve for areas with little or no cover, representing

$$\textbf{Tc} = \textbf{0.0078 } \textbf{K}^{0.77}$$

c. In case of uncertainty, check the time of concentration by dividing the estimated longest route of runoff by the appropriate runoff velocity from Table 3.

3. RAINFALL INTENSITY

The design rainfall intensity of a drainage area shall be determined by the following procedure:

a. Select the appropriate 1-hour rainfall value from Plate 1 or Plate 2 for the design recurrence interval.

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b.   Enter Plate 4 with the rainfall intensity duration equal to the required time of concentration, select the corresponding correction factor, and multiply the 1-hour rainfall value by the factor to obtain the design rainfall intensity.

D.   HYDROLOGIC STUDIES

Since 1959, the City and County of Honolulu and the U.S. Geological Survey have participated in a cooperative program for the collection of special stream flow data. This program included the installation of additional stream gaging stations and crest-stage gages. With the additional hydrologic data supplementing the data from the existing gaging stations, it was anticipated that more would be known of the effects of exposure, altitude, basin slope, basin shape and degree of urbanization on stream runoff on Oahu.

The U.S. Geological Survey developed flood-frequency curves for 74 gaging stations on Oahu by using the log Pearson Type III distribution (U.S. Water Resources Council, 1977, Bulletin 17A). The length of record for the individual stations ranged from 10 to 60 years. In order to furnish data at ungaged sites, they attempted to regionalize the available data by the use of multiple-regression techniques. In the study, a regional analysis was made by using these techniques to relate floodflows to basin and climatic characteristics. The results are contained in the *U.S. Geological Survey Water-Resources Investigations 80-45 Report, An Analysis of the Magnitude and Frequency of Floods on Oahu, Hawaii*, dated June 1980. The results were subsequently updated.

The U.S. Geological Survey and City have further extended the data to facilitate the determination of peak discharge values for the design of drainage facilities by developing Plate 6, Design Curves for Peak Discharge vs. Drainage Area. The curves are based upon the 100-year recurrence interval data. For clarification, the boundaries between the groups shown on Plate 6 are as follows:

Group Boundary	Location
A and B	Between Oio Stream and Malaekahana Stream and along Koolau Range Ridge.
B and C	Between Honouliuli Stream and Waikele Stream, along Waianae Range Ridge, and between Makaleha Stream and Kaukonahua Stream.

The rainfall data shown on Plates 1 and 2 have been updated from the *Rainfall Frequency Study for Oahu*, Department of Land and Natural Resources, Division of Water and Land Development, State of Hawaii, dated 1984.

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§1-4.2 <u>PART II - DESIGN STANDARDS</u>

A. GENERAL CONDITIONS

The design and capacity of a drainage system shall be predicated on the following conditions:

1. On the basis of the runoff resulting from the selected design storm, the system shall dispose of surface runoff and subsurface water without damage to street facilities, structures or ground and cause no serious interruption of normal vehicular traffic.

2. Runoff exceeding the design storm must be disposed of with the least amount of interruption to normal traffic and minimum amount of damage to surrounding property.

3. System must have maximum reliability of operation with minimum maintenance and upkeep requirements.

4. System must be adaptable to future expansion, if necessary, with minimum additional cost.

5. Where sump conditions exist, a safety measure such as an overflow swale shall be provided to prevent flooding of adjacent lots in the event the design capacity of the closed conduit is exceeded. Floor levels of homes adjoining sumps shall be a minimum of 3 feet above the low point on roadway.

6. Lots abutting streams and open channels may be graded to drain towards the waterway.

7. In general, natural gullies, waterways, streams and tributaries shall not be replaced with a closed system except at roadway crossings.

8. Roadway culverts and bridges shall be designed to pass the design flow under open channel hydraulic analysis with a minimum freeboard as specified in the attached freeboard chart. Multiple span road crossings shall have minimum clear spans of 30 feet, unless otherwise permitted by the Director. Where possible, the roadway shall be designed to form a sag vertical curve with a low point at the waterway crossing with minimum grades to confine and control overflow at the crossing. Whenever the difference in elevations of the roadway and water surface is such that there could be a deep fill, the roadway culvert or bridge shall be designed to include available headroom up to five feet from the water surface to the soffit of the culvert or bridge. After this headroom requirement is fulfilled, fill material may be used to meet roadway elevations.

9. Outlets for enclosed drains emptying into open channels shall be designed to point downstream at an angle of 45 degrees.

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10. Where groundwater is encountered, or may be present during wet weather, subsurface drains shall be installed wherever recommended by the Design Engineer, or the Director.

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

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

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

B. DESIGN COMPUTATIONS

The following data shall be submitted to the Director by the Design Engineer.

1. HYDRAULIC DESIGN DATA

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

b. The following data shall be shown on the construction plans.

1) Design flow (Q), watershed area (A), roughness coefficient (n), and velocity (v), for all conduits and channels.

2) Hydraulic grade lines, including water surface elevation at each manhole and catch basin.

3) Building setback lines, where required.

4) Floodway/flood fringe boundary, as applicable.

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

1) Runoff rate using the design storm for existing upstream land use conditions.

2) Runoff volume using the design storm for existing upstream land use conditions.

3) Detention volume and discharge rate.

4) If necessary, capacity of downstream drainage systems.

2. STRUCTURAL DESIGN DATA

a. Structural design computations for all drainage structures other than pipes used within the limits of current loading tables and structures shown in the *"Standard Details for Public Works Construction"* for the City and County of Honolulu.

b. Information pertinent to the design, such as boring data, soils report, etc.

c. Upon the completion of construction of major structures, submit pertinent data such as pile driving logs, pile tip elevations, etc.

C. CLOSED CONDUITS

1. SIZES AND GRADIENTS

a. The size and gradient will be determined by the Manning Formula:

$$Q = A \frac{1.486}{n} R^{2/3} S^{1/2}$$

Q = flow, in cfs
A = area, in sq. ft.
R = hydraulic radius in ft.
S = slope, in ft./ft.
n = roughness coefficient (Manning)

Charts enabling direct solution of Manning formula are found on Plates 8 to 16.

b. The following limitations apply -

1) Minimum size pipe: 18 inches inside diameter

2) Minimum velocity: 2-1/2 feet per second

3). Pipe sizes should not decrease in the direction of the flow.

2. MATERIALS AND "n" VALUES

The following pipes are acceptable for storm drain construction together with the roughness coefficient to be used in the solution of the Manning Formula.

Materials	n
Concrete	0.013
Cast Iron	0.013
Corrugated metal pipe (CMP) *	
Unpaved	0.024
25% paved invert	0.021
Lower 50% paved	0.018
100% paved	0.013
High Density Polyethylene (HDPE) *	0.015

*Use of CMP or HDPE shall be permitted only when specifically approved for an installation by the Director in writing.

3. LOADING

a. Reinforced Concrete Pipes: Reinforced concrete pipes shall be constructed to American Society for Testing and Materials (ASTM) Specifications.

1) Minimum pipe cover in roadways, driveways and other areas with vehicular traffic shall be two feet.

Should there be a need for a pipe cover of less than 2 feet or should the design or construction method deviate from the Standards of the Department of Planning and Permitting, City and County of Honolulu, the Design Engineer shall submit a structural design for review and approval. The decision to allow such design will be made by the Director.

2) Minimum pipe cover in easement areas without vehicular traffic shall be 1'- 0".

3) Maximum permissible pipe cover will be determined from current loading tables in pipe handbooks for the respective pipes, using 120 lbs. per cu. ft. as the weight of earth.

4) All pipes shall be installed using a first class bedding trench condition. Proper foundations shall be provided for pipes. Pipes on unstable ground or fresh fill shall be supported by a method acceptable to the Director.

5) Drain pipes installed along the longitudinal axis of the roadway shall be located in the pavement area between curbs.

b. Other Closed Conduits. There shall be no minimum cover or maximum permissible depth requirements for closed conduits other than pipes except that such structures, shall be designed to support all loads that it shall be subjected to.

4. MANHOLES AND INLETS

a. Manholes:

1) Location. Manholes shall be located at all changes in pipe size and changes in alignment or grade and at all junction points.

2) Spacing. Maximum manhole spacing shall be 250 feet for pipes 36 inches or less in diameter, or box drains with the smallest dimension less than 36 inches. Maximum manhole spacing for larger pipes and box drains shall be 500 feet.

3) Special Details. Bottoms of manholes and inlets serving as manholes shall be shaped to channelize flow and sloped with slope of pipe as shown in the "Standard Details" of the Department of Planning and Permitting, City and County of Honolulu.

b. Inlets (Catch Basins):

1) Location. Inlets shall be located at the upstream side of intersections, in sumps and where required by quantity of flow.

2) Spacing. Maximum spacing shall be 500 feet.

3) Types. For gutter grades up to 4 percent, standard 10-foot curb inlets with a depressed gutter shall be used. For grades 4 percent and greater, 10-foot long deflector inlets shall be used.

4) Capacity. Inlet capacities as follows, are acceptable:

	Type	Gutter Grade	cfs
a.	Std. depressed	0.4%	6
	gutter inlet	4.0%	4
		sump	10
b.	Deflector inlet	4.0%	4.5
		12.0%	5.5
	Greater than	12.0%	6 max

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5)   Gutter Flow. The gutter flow shall not exceed a width of 8 feet.

5.   PIPE SYSTEM ANALYSIS

Generally speaking, the pipe system shall be analyzed by sections, that is, outlet-to-manhole, manhole-to-manhole or manhole-to-inlet. The analysis shall start at the lowest point of flow and continued upstream. The design flow shall be used in determining whether the pipe will flow full or partially full. Full consideration of the tailwater, entrance and critical flow conditions shall be made.

a.   Pipe Flowing Full. If the conditions show that the pipe section will flow full, the principles of flow of water in closed conduits shall be used. The water surface elevation of the upstream manhole is determined by adding the pipe friction and manhole losses to the water surface elevation of the downstream manhole or the beginning elevation as previously stated.

b.   Pipe Flowing Partially Full. If the conditions show that the pipe section will flow partially full, the principles of flow water in open channels shall be used. The pipe partially full condition may be determined from the *Pipe Flow Charts* on Plates 8 to 16. The tailwater condition must also be considered in this determination.

c.   Manhole Losses.

1.   For junction conditions such as drop manholes, or where the outflow line deflects more than 10 degrees with any inflow line, the hydraulic grade shall be determined by applying the "Entrance Control loss" and "C & D losses" (where applicable), or "A, B, C & D losses", whichever is greater.

2.   For junction conditions where the outflow line deflects 10 degrees or less with the inflow line, the hydraulic grade shall be determined by applying the "A, B, C & D losses".

6.   HYDRAULIC GRADIENT COMPUTATIONS

The hydraulic gradient is: (1) a line connecting points to which water will rise in manholes and inlets throughout the system during the design flow; or (2) the level of flowing water at any point along an open channel.

It shall be determined starting at the downstream end of the proposed drainage system and proceeding upstream by adding the friction losses and manhole losses of the system.

The hydraulic gradient for the design flow shall be at least 1 foot below the top of the manhole cover, or 1 foot below the invert of catch basin inlet opening.

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a.   Beginning Elevation. The elevation of the hydraulic gradient at the downstream end shall be selected according to the following conditions:

    1)   Connection to existing drainage system - determined from the hydraulic gradient computations of the existing drain;

    2)   Discharge into a stream - determined from the flow conditions of the stream;

    3)   Submerged tailwater condition - begin at the tailwater elevation; and

    4)   Freefall condition (conduit) - begin at the crown of the proposed drain.

b.   Friction Loss.

$$h_f = S_f(L), \text{ where:}$$

$$h_f = \text{head loss due to friction}$$

$$S_f = \text{friction slope from Manning Formula}$$

$$= \frac{(nv)^2}{2.208 \, R^{4/3}},$$

$$L = \text{length of pipe or channel}$$

The friction loss shall be calculated for the condition of the design flow, that is, pipe flowing full or partially full.

c.   Manhole Losses.

Manhole losses shall be as shown on the charts, *Head Losses in Manholes* (Plates 17 and 18). The losses shall be evaluated with pipes flowing full in the vicinity of the manholes; and therefore the velocity shall be for the pipe flowing full. The curves on the charts show the various losses:

    1)   A curve - loss due to entrance and exit

    2)   B curve - velocity head

        a.   Where the downstream velocity exceeds the upstream velocity, the head loss shall be difference in velocity heads.

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b. Where the downstream velocity is less than the upstream velocity, the velocity head loss shall be zero.

3) C curve - loss due to change in direction, taking the worst case for branches at a manhole.

4) D curve - loss due to incoming volume.

7. SPECIAL DETAILS

The following structures shall be installed where required:

a. Headwalls, aprons and cut-off walls at drain inlets and outlets.

b. Energy dissipators at outlets.

c. Debris and boulder control structures.

d. Guard rails or fences on channel walls, headwalls and inlets, where they present a hazard to vehicular traffic or pedestrians.

D. OPEN CHANNELS

1. CHANNEL SIZE

Use the Manning Formula to determine the required waterway areas where uniform flow can be assumed.

$$Q = AV \text{ and } V = \frac{1.486 \, R^{2/3} \, S^{1/2}}{n}$$

A = area of flow, in square feet
V = velocity, in feet per second
n = roughness coefficient (Manning)
R = hydraulic radius, in feet
S = slope of the energy gradient, in feet per feet

The channel depth shall include design water depth and minimum freeboard allowances. Design water depth shall include rise in water surface caused by curves and junctions.

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2.   CHANNEL RIGHT-OF-WAY

The channel width shall be sufficient to provide the required waterway area for the design storm as determined by these standards. The total right-of-way shall include a 15-foot wide maintenance road along both banks where the top width of channel exceeds 50 feet, and along one bank where the top width is 50 feet or less. The maintenance road along the channel shall be topped with 6 inches of Asphalt Treated Basecourse (ATB) or Asphalt Concrete (AC). In lieu of a maintenance road, for normally dry channels, access ramps or other suitable alternative measures to facilitate maintenance may be provided.

3.   PERMISSIBLE VELOCITIES AND "n" VALUES

Following is a list of "n" values for open channels and maximum permissible velocities. Maximum velocities shall be based upon design flow quantities.

Unlined Channel	Manning "n"	Maximum Velocity (fps)
Rock	0.030	10
Ledge coral or limestone	0.025	10
Earth with vegetation (grassed)	0.035	5
Lined Channels		
Conc. (trowel finish)	0.013	No limitation
Conc. (smooth wood forms)	0.015	No limitation
Gunite	0.020	20
Grouted Rip-rap & CRM (Cement Rubble Masonry)	0.025	20
Asphaltic Concrete	0.015	20
Corrugated Metal Flumes (Part-circle Sections)	0.021	25

Note: Use of CMP shall be permitted only when specifically approved for an installation by the Director in writing.

a.   Maximum design velocity for channels cut in earth shall not exceed 5 feet per second. The velocity shall be determined by using the natural existing slope of the waterway without utilizing grade transition structures to control the maximum slope for a given unlined channel cross-section and design flow.

b.   Velocities between 5 feet per second and 10 feet per second will be permitted in materials, such as cemented gravel, hard pan, or mud rock, depending upon its hardness and resistance to scouring. Borings and samples shall be submitted for evaluation before velocities exceeding 5 feet per second will be permitted.

4.   CHANNEL LINING

a.   Earth channel shall be fully lined when velocities exceed 5 feet per second, unless otherwise permitted as previously noted above in Section D.3.b of §1-4.2 Part II - Design Standards.

b.   All fill sections shall be lined. This lining shall be a complete lining including side slopes and invert with appropriate cut-off walls. If the invert of the channel is in a cut section, the invert slab may be omitted and appropriate cut-off walls provided at the toe of the side slope lining.

c.   Where linings are required or used, the linings, shall be continuous. Lining of fill sections without continuing the lining out through cut sections in a channel will not be allowed unless adequate provisions are made to reduce the velocity from the lined section to meet the allowable velocity for the unlined section.

d.   Total depth of channel lining will include design water depth and freeboard.

e.   Attention shall be given to construction details of linings, such as thickness, reinforcement, expansion and construction joints, cut-off walls, watertight joints, and placement of reinforcement, etc. Where the channel discharges into streams or other channels outside of the limits of a development, velocity reducing and transition structures shall be constructed to minimize erosion and overtopping of banks and subsequent flooding of downstream areas.

f.   Where velocities are supercritical, rectangular channels shall be used, unless otherwise permitted by the Director.

g.   Earth channels shall be planted with vegetation, such as grass of a species not susceptible to rank growth.

5.   FREEBOARD

In designing open channels, freeboard must be provided to allow for surface roughness, wave action, air bulking, and splash and spray. These phenomena depend on the energy content of flow. For water flowing at velocity v and depth d, the energy per foot of width per second is equal to $(wvd)(v^2/2g) = wdv^3/2g$, where w is the unit weight of water.

Thus, this kinetic energy can be converted to potential energy to lift the water surface when flow is stopped or changing direction as a function of depth and velocity of flow. The U.S. Bureau of Reclamation has developed an empirical expression to express a reasonable indication of desirable freeboard in terms of depth and velocity as follows:

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$$\text{Freeboard in feet} = 2.0 + 0.025 \, v \, (d)^{1/3}$$

where **v** is the velocity in feet per second and **d** is the depth of flow in feet. The velocity of flow can be computed by dividing the design discharge by the cross-sectional area of flow. For convenience of application, the above expression is shown graphically in Plate 7.

6. JUNCTIONS

Junctions shall be designed to channel both flows as nearly parallel as possible to reduce velocity and momentum components, deposition of debris and erosion of banks.

7. BENDS AND SUPERELEVATIONS

Changes in the direction of flow shall be made with smoothly curved channel walls allowing for superelevation in water surface. Curves will nearly always require additional depth. Trapezoidal channels for supercritical velocities are not permitted. Curve radii should be sufficiently great to limit superelevation of the water surface to one foot above computed depth of flow or 10 percent of water surface width, whichever is the least. The amount of superelevation for simple curves may be determined as follows:

a.   Trapezoidal Channels:

Subcritical velocity:

$$e = \frac{V^2(b + 2zd)}{(gR - 2zV^2)}$$

b.   Rectangular Channel:

Subcritical velocity:

$$e = \frac{V^2 b}{gR}$$

Supercritical velocity:

$$e = \frac{2V^2 b}{gR}$$

Supercritical velocity - compound curve:

$$e = \frac{V^2 b}{gR}$$

The compound curve is a simple curve of radius R preceded and followed by a section of simple curve with radius of 2R and length of

$$\frac{b}{\tan \beta} \text{ , where } \sin \beta = \frac{(gd_m)^{\frac{1}{2}}}{V}$$

Where, b   =   channel bottom width (ft)
        d   =   normal depth (ft)
        d_m =   mean depth (ft)
        e   =   maximum difference in elevation of water surface between channel sides (ft)
        g   =   acceleration due to gravity (fps^2)
        R   =   radius of curve to centerline (ft)
        V   =   normal velocity (fps)
        z   =   co-tangent of bank slopes
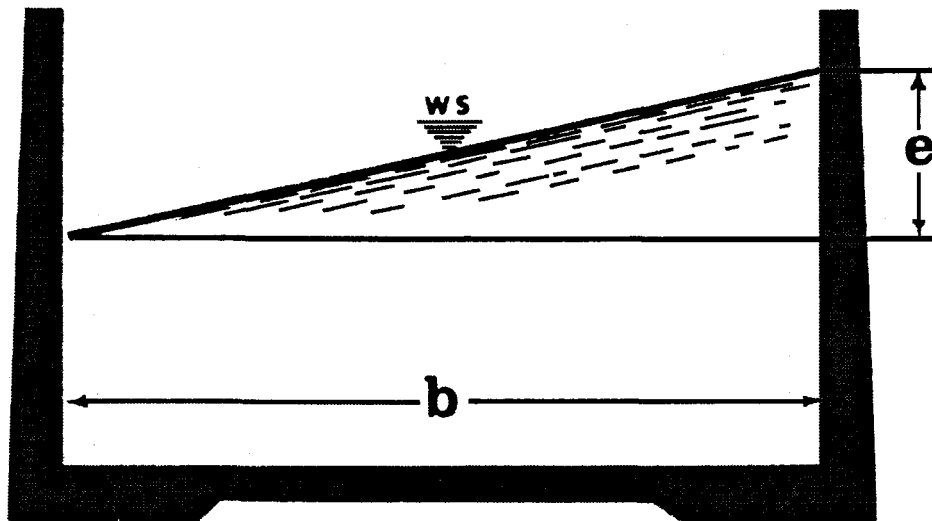
Water Surface Superelevation Showing, "e"

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8. TRANSITIONS

    a. The maximum angle between channel centerline and transition walls should be 12.5 degrees.

    b. Sharp angles in alignment of transition structures should be avoided.

9. DEBRIS BARRIERS

    Debris barriers should be provided upstream of the intake to prevent clogging.

10. DEBRIS BASINS

    Where required by the Director, debris basins shall be provided upstream of the debris barrier. Debris basins shall also be provided at the intake of a drainage system when the upstream drainage area is undeveloped.

    The volume of debris to be impounded shall be estimated based on the existing upstream land uses.

    The basin design shall include an access ramp to the bottom of the basin for maintenance purposes.

11. ENERGY DISSIPATORS

    Energy dissipators shall be used to dissipate energy where necessary, and to transition the flow from a lined channel to a normal flow in an unlined channel.
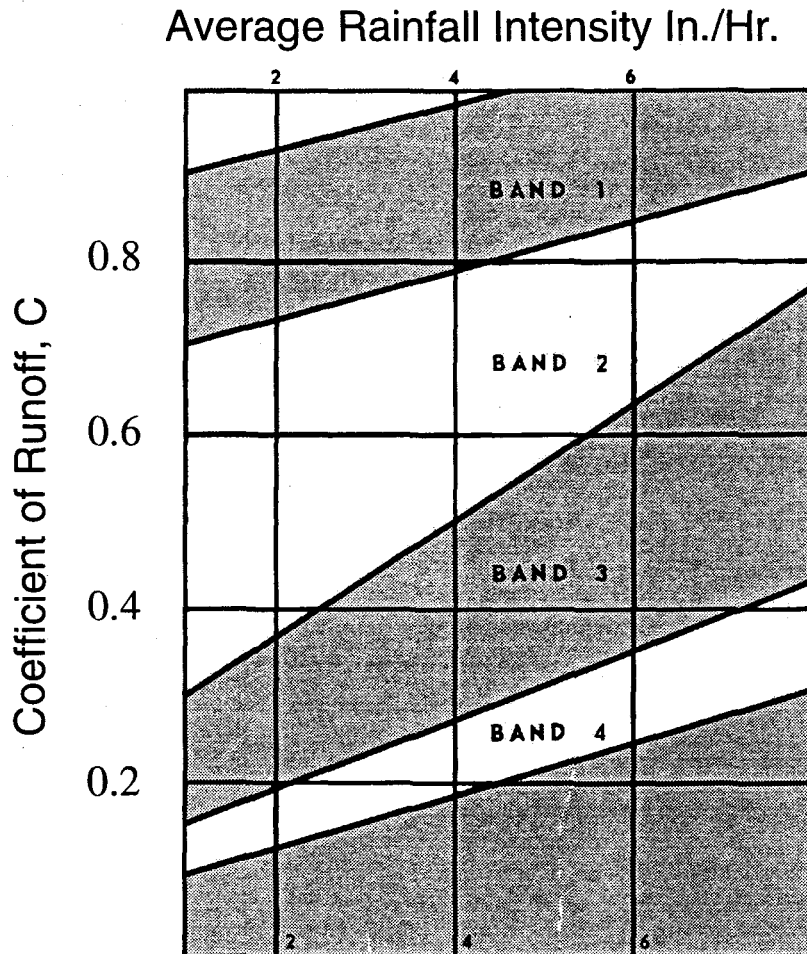
    Energy dissipators may be any of the following types, such as the SAF basin, baffled chute, dentated sills, buckets, impact, hydraulic jump, or other approved designs.

[Eff: **JAN 0 1 2000** *] (Auth: Sec 14-12.31, ROH) (Imp: Sec14-12.31, ROH)*

Table 1

RUNOFF COEFFICIENT FOR AGRICULTRUAL AND OPEN AREAS

Average Rainfall Intensity In./Hr.

Band 1	Steep, barren, impervious surfaces
Band 2	Rolling barren in upper band values, flat barren in lower part of band, steep forested and steep grass meadows
Band 3	Timber lands of moderate to steep slopes, mountainous, farming
Band 4	Flat pervious surface, flat farmlands, wooded areas and meadows

Table 2
MINIMUM RUNOFF COEFFICIENTS FOR BUILT-UP AREAS

RESIDENTIAL AREAS: C = 0.55 to 0.70

HOTEL-APARTMENT AREAS: C = 0.70 to 0.90

BUSINESS AREAS: C = 0.80 to 0.90

INDUSTRIAL AREAS: C = 0.80 to 0.90

The type of soil, the type of open space, and ground cover and the slope of the ground shall be considered in arriving at reasonable and acceptable runoff coefficients.

Table 3

APPROXIMATE AVERAGE VELOCITIES OF RUNOFF
FOR CALCULATING TIME OF CONCENTRATION

TYPE OF FLOW	VELOCITY IN fps FOR SLOPES (in percent) INDICATED			
OVERLAND FLOW:	0-3%	4-7%	8-11%	12-15%
Woodlands	1.0	2.0	3.0	3.5
Pastures	1.5	3.0	4.0	4.5
Cultivated	2.0	4.0	5.0	6.0
Pavements	5.0	12.0	15.0	18.0
OPEN CHANNEL FLOW:				
Improved Channels	Determine Velocity by Manning Formula			
Natural Channel* (not well defined)	1.0	3.0	5.0	8.0

*   These values vary with the channel size and other conditions so that the ones given are averages of a wide range. Wherever possible, more accurate determinations should be made for particular conditions by Manning Formula or from Plate 5.*
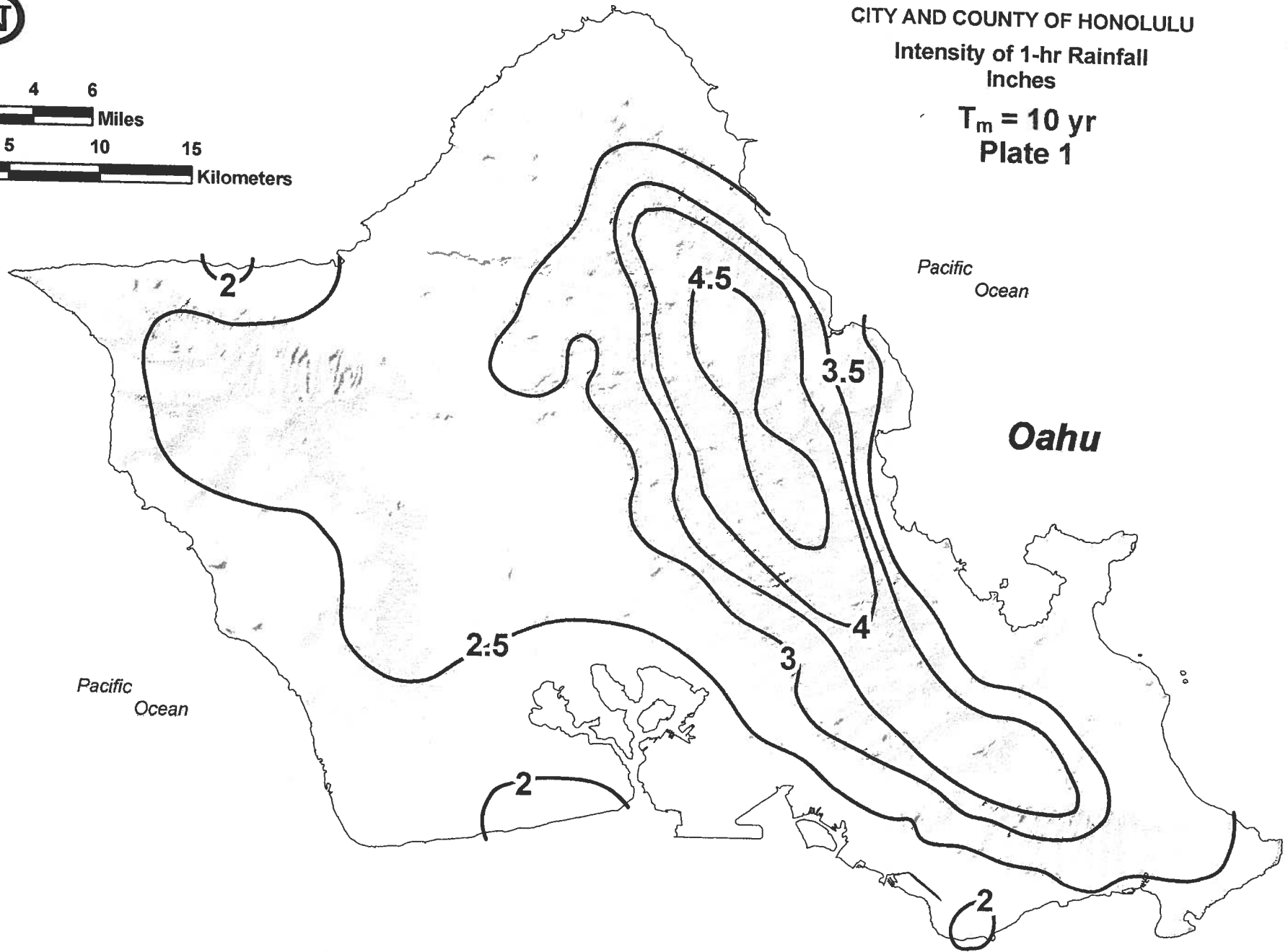
CITY AND COUNTY OF HONOLULU

Intensity of 1-hr Rainfall
Inches

$T_m = 10$ yr
Plate 1

Pacific
Ocean

Oahu

Pacific
Ocean

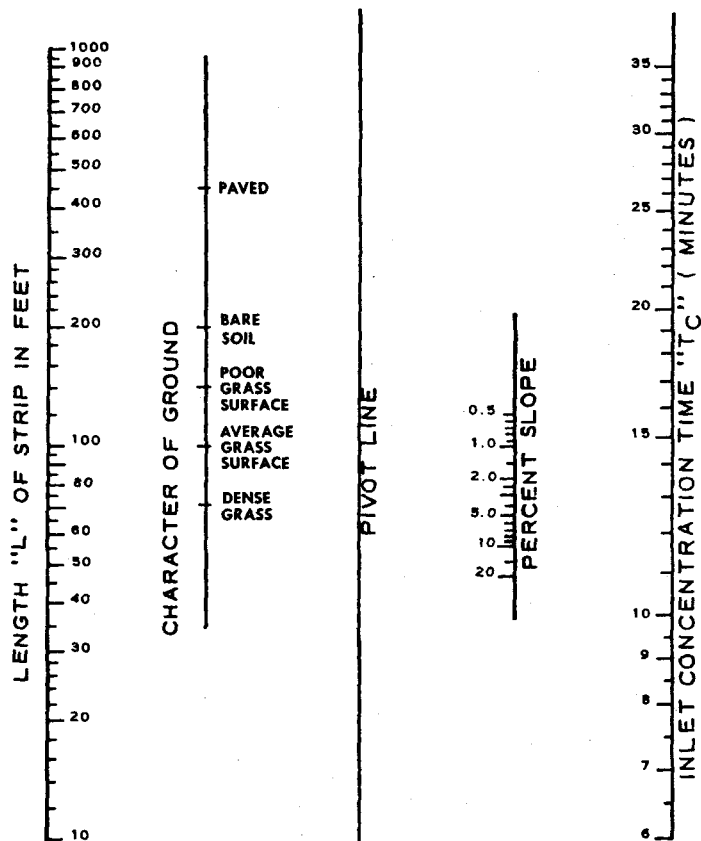[Eff: APR 0 8 2011] (Auth: Sec 14-12.31, ROH) (Imp: Sec 14-12.31, ROH)
Source: National Oceanic and Atmospheric Administration (NOAA), National Weather Service, Silver Spring, Maryland, 2009

CITY AND COUNTY OF HONOLULU

Intensity of 1-hr Rainfall
Inches

$T_m = 50$ yr
Plate 2

Pacific
Ocean

Oahu

6.5

5.5

6

3

3.5

Pacific
Ocean

4 4.5

5

N

0   2   4   6
Miles

0   5   10   15
Kilometers

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Plate 3

Overland Flow Chart

LENGTH "L" OF STRIP IN FEET

— 1000
— 900
— 800
— 700
— 600
— 500
— 400
— 300
— 200
— 100
— 80
— 60
— 50
— 40
— 30
— 20
— 10

CHARACTER OF GROUND

PAVED

BARE SOIL

POOR GRASS SURFACE

AVERAGE GRASS SURFACE

DENSE GRASS

PIVOT LINE

PERCENT SLOPE

0.5
1.0
2.0
5.0
10.0
20.0

INLET CONCENTRATION TIME "Tc" (MINUTES)

35
30
25
20
15
10
9
8
7
6

CORRECTION FACTOR APPLIED TO ONE HOUR RAINFALL IN INCHES TO OBTAIN RAINFALL INTENSITY OF GIVEN DURATION

4.0
3.0
2.0
1.0
0.8
0.6
0.4

DURATION OF RAINFALL INTENSITY IN MINUTES
(ENTER "Tc" FROM PLATE 3 OR 5)

3 3.6 4.8 6 9 12 15 18 24 30 36 48 60 90 120 180
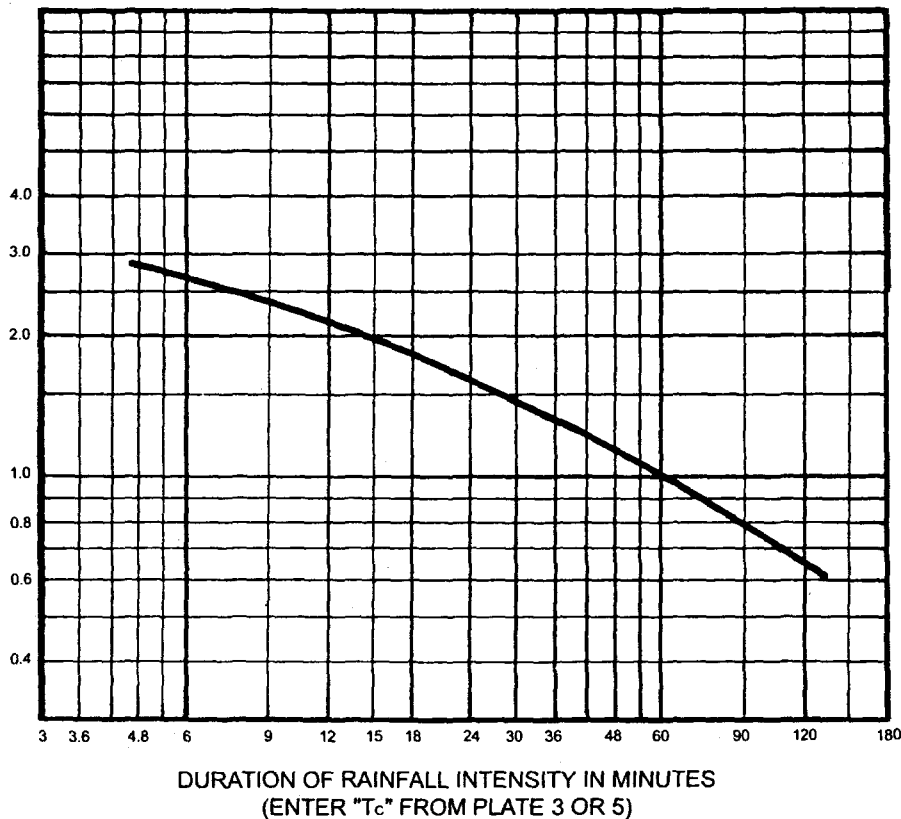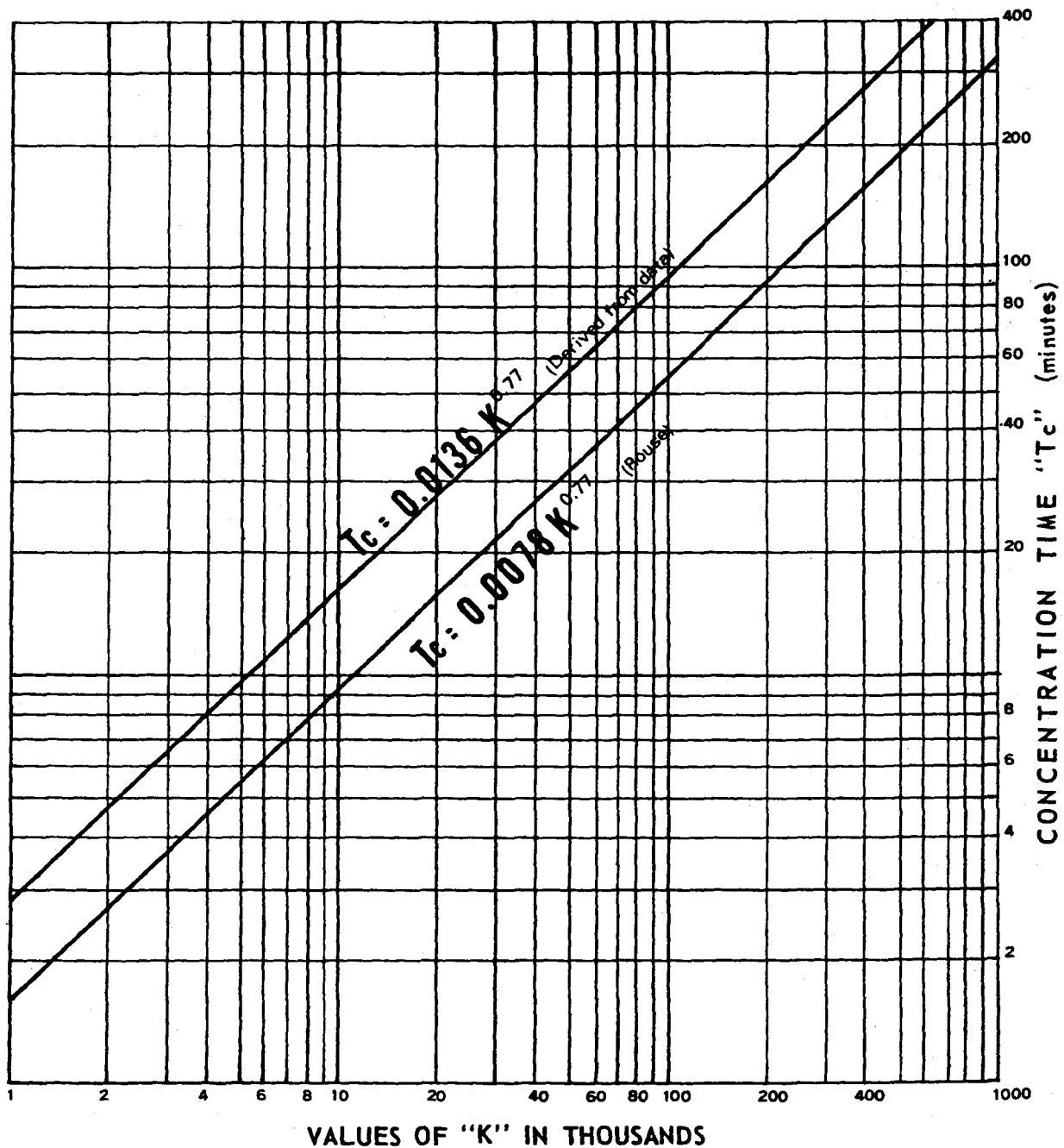
Plate 4

CORRECTION FACTOR

FOR CONVERTING 1 HR. RAINFALL
TO RAINFALL INTENSITY
OF VARIOUS DURATIONS

TO BE USED FOR AREA
LESS THAN 100 ACRES

(See Plate 6 for area
more than 100 acres)

VALUES OF "K" IN THOUSANDS

CONCENTRATION TIME "Tc" (minutes)

$Tc = 0.0136 \, K^{0.77}$ (Derived from data)

$Tc = 0.0078 \, K^{0.77}$ (Rouse)

L = Maximum length of travel in feet
H = Difference in elevation between most remote point and outlet in feet.
S = Slope   H/L

$$K = \frac{L}{\sqrt{S}} = \sqrt{\frac{L^3}{H}}$$

Use upper curve for well forested areas
Use lower curve for areas with little or no cover.

NOTE: Use 5 minutes if Tc is 5 minutes or less.
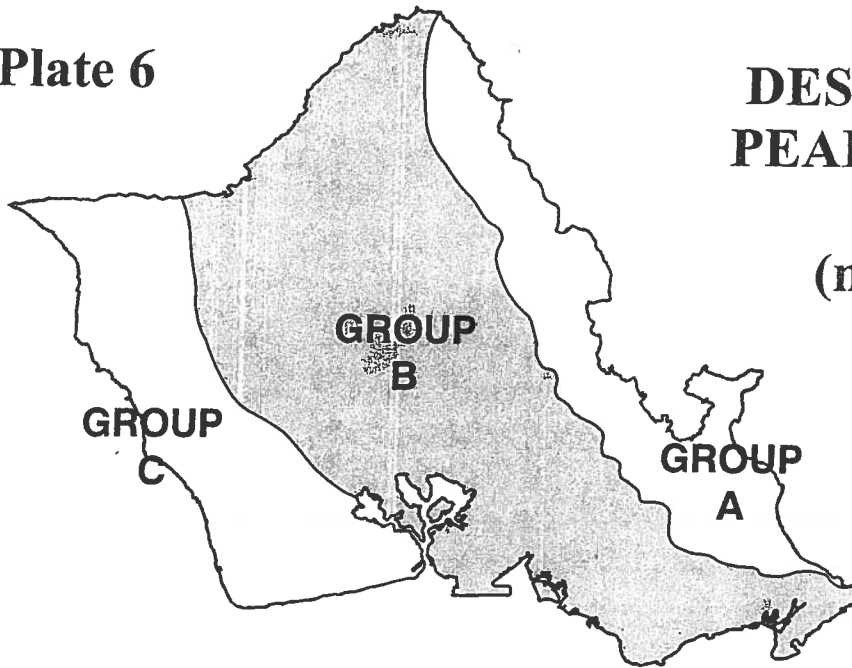
Plate 5

Time of Concentration

(OF SMALL AGRICULTURAL DRAINAGE BASIN)

Plate 6

DESIGN CURVES FOR PEAK DISCHARGE VS. DRAINAGE AREA
(more than 100 acres)

GROUP B

GROUP C

GROUP A

● CURVES ARE FOR STREAM CHANNELS AND DRAINAGE STRUCTURES.

PEAK DISCHARGE IN 100 CFS

GROUP A

GROUP B

GROUP C

DRAINAGE AREA IN 100 ACRES

jsb — D:\PROJECTS\26537218_000B1\DC-DA.DWG — Mon, 21 Jun 2010
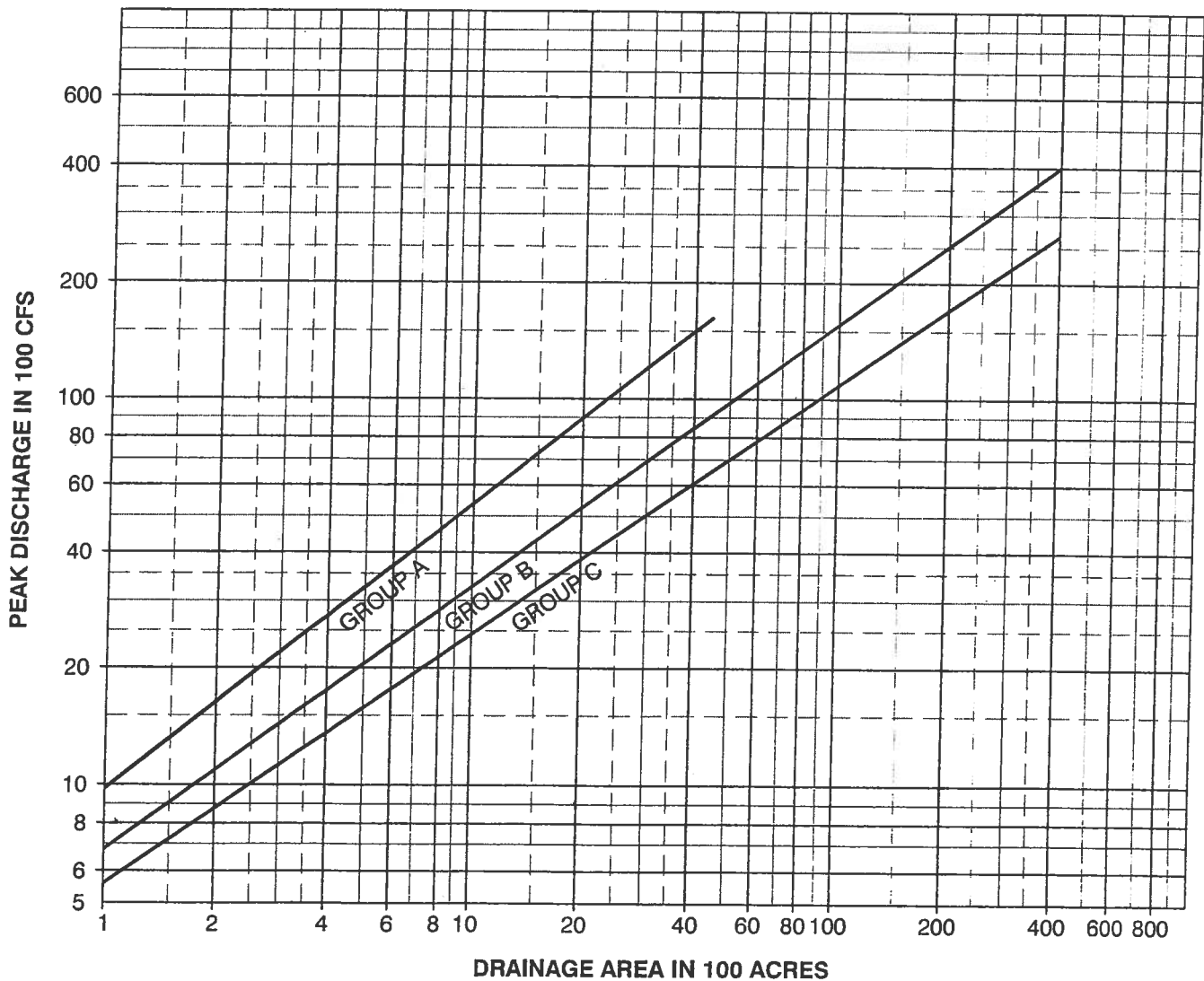
SOURCE: DATA FROM U.S. GEOLOGICAL SURVEY
REV. FEB 2003.

[Eff: APR 0 8 2011] (Auth: Sec 14-12.31, ROH) (Imp: Sec 14-12.31, ROH)

FREEBOARD ALLOWANCES   Plate 7

FREEBOARD IN FEET:

$$2.0 + 0.025 \, V \sqrt[3]{d}$$

Where V = Velocity, in feet per second
d = Depth of flow, in feet

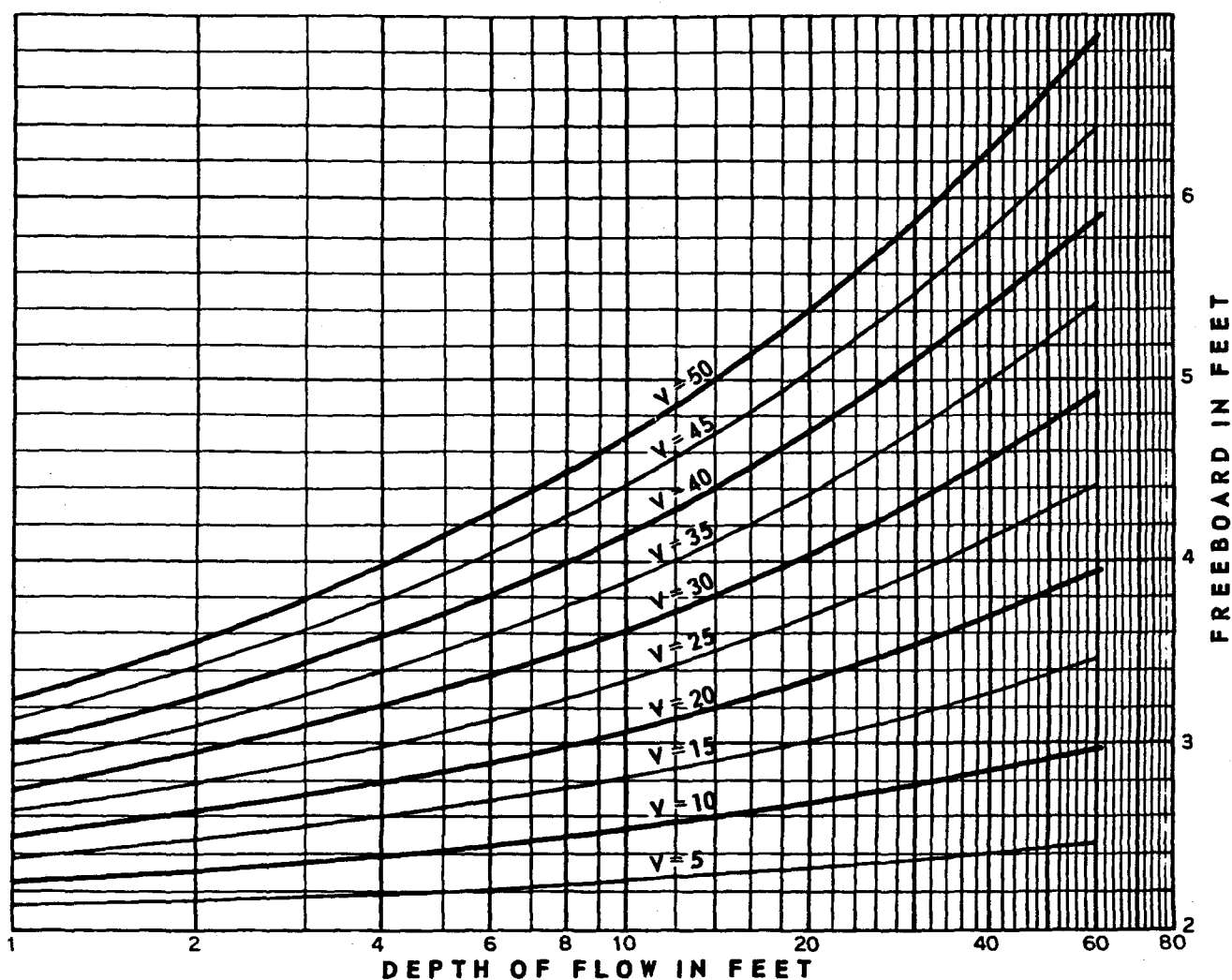DEPTH OF FLOW IN FEET

FREEBOARD IN FEET

Pipe Flow Charts

The following pipe flow charts have been derived by the *U.S. Public Roads Administration, Division Two, Washington, D.C.* These charts are designed to enable direct solution of the Manning formula for circular pipes flowing full and for uniform part-full flow in circular pipes. The "n" scales of 0.013 and 0.024 have been inserted to facilitate the use of these charts for storm drainage systems in Honolulu. The following examples help explain the use of the pipe flow charts.

EXAMPLES

A. Determine the depth and velocity of flow in a long 30-inch pipe, $n = 0.013$, on a 0.5 percent slope ($S_o = 0.005$) discharging 25 cfs. Enter the 30-inch diameter chart at $Q = 25$ on $n = 0.013$ scale, follow up to intersection with the line for slope $S_o = 0.005$, and read normal depth $d_n = 1.8$ feet and normal velocity $V = 6.7$ fps.

To find critical depth, enter chart $Q = 25$ and $n = 0.015$ scale, and read critical depth $d_c = 1.7$ feet at intersection with dotted critical curve. Also critical velocity $V_c = 7.0$ fps. (Note: Critical depth and velocity would be the same, regardless of pipe roughness).

B. Determine friction slope for a 30-inch corrugated metal pipe, $n = 0.024$, on a slope $S_o = 0.008$ ft/ft with a discharge $Q = 25$ cfs. Enter the 30-inch diameter chart at $Q = 25$ on $n = 0.024$ scale. Note that this ordinate falls to the right of the 0.008 slope line, therefore, the pipe will flow full. Read friction slope $S_f = 0.012$ at the line for depth equal to pipe diameter.

$$\text{Note } Q = 25 \times \frac{0.024}{0.015} = 40 \text{ cfs on the Q-scale for } n = 0.015)$$

30

PLATE 8
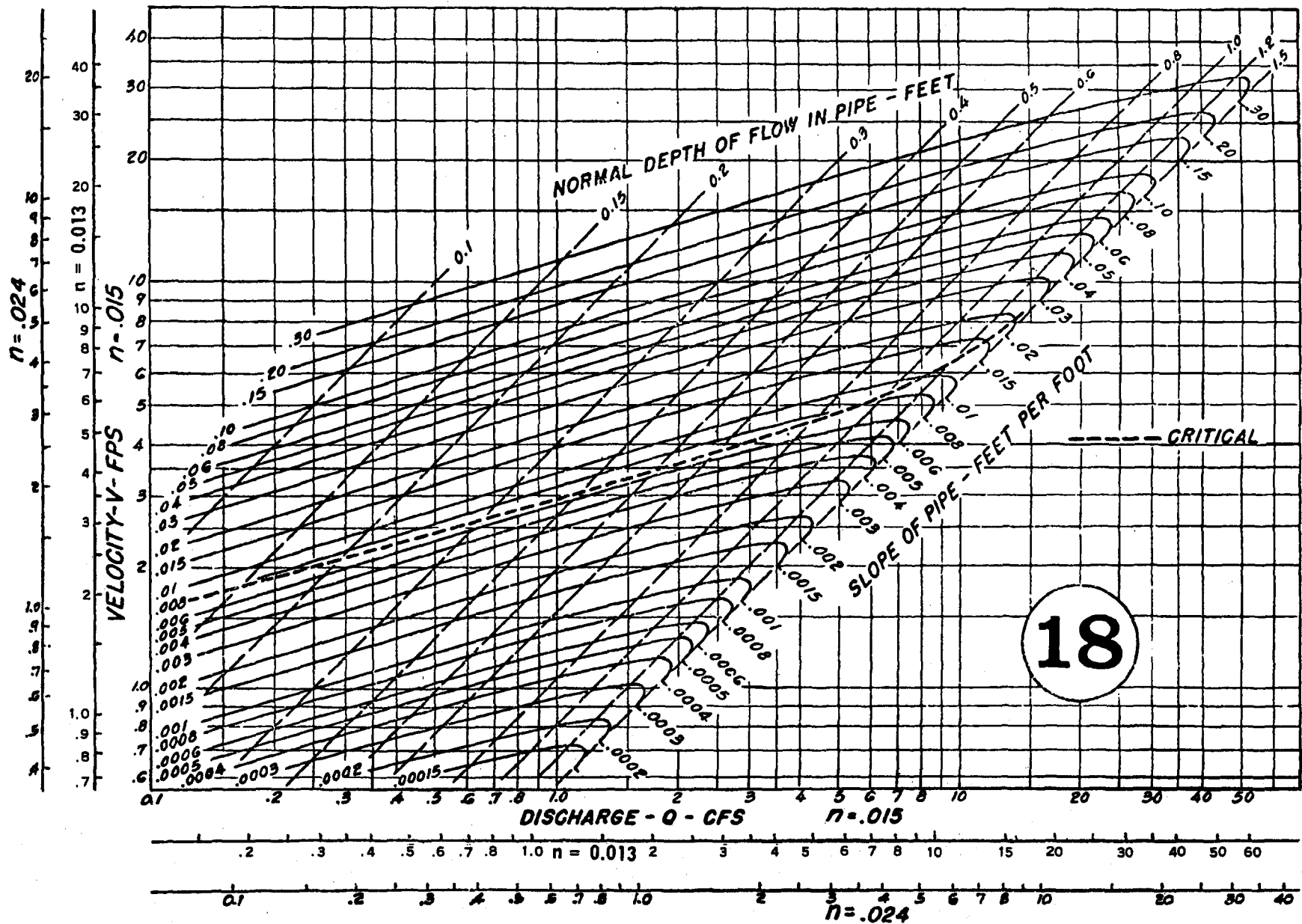
Pipe Flow Chart **18** inch Diameter

PLATE 9
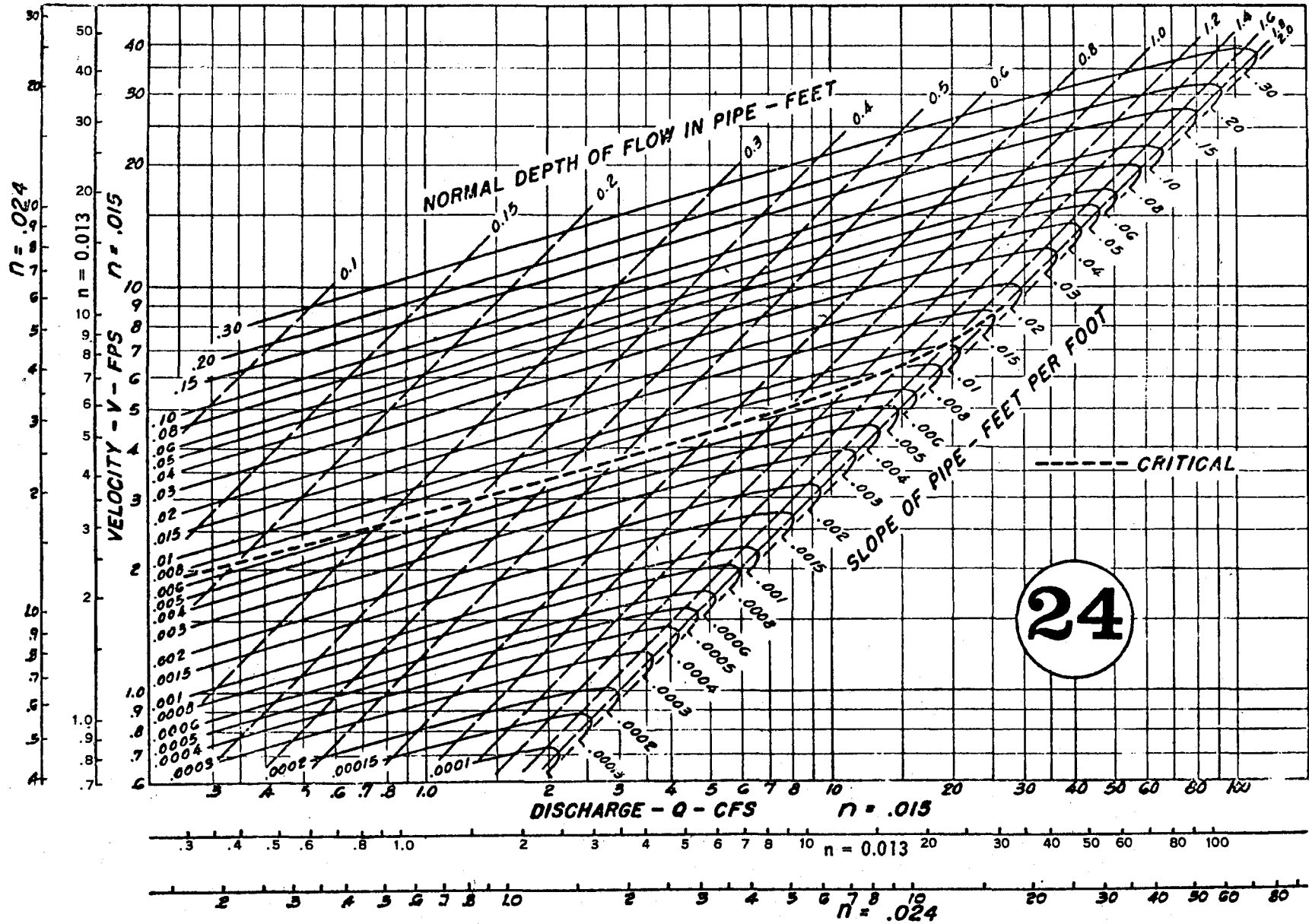
Pipe Flow Chart **24** inch Diameter
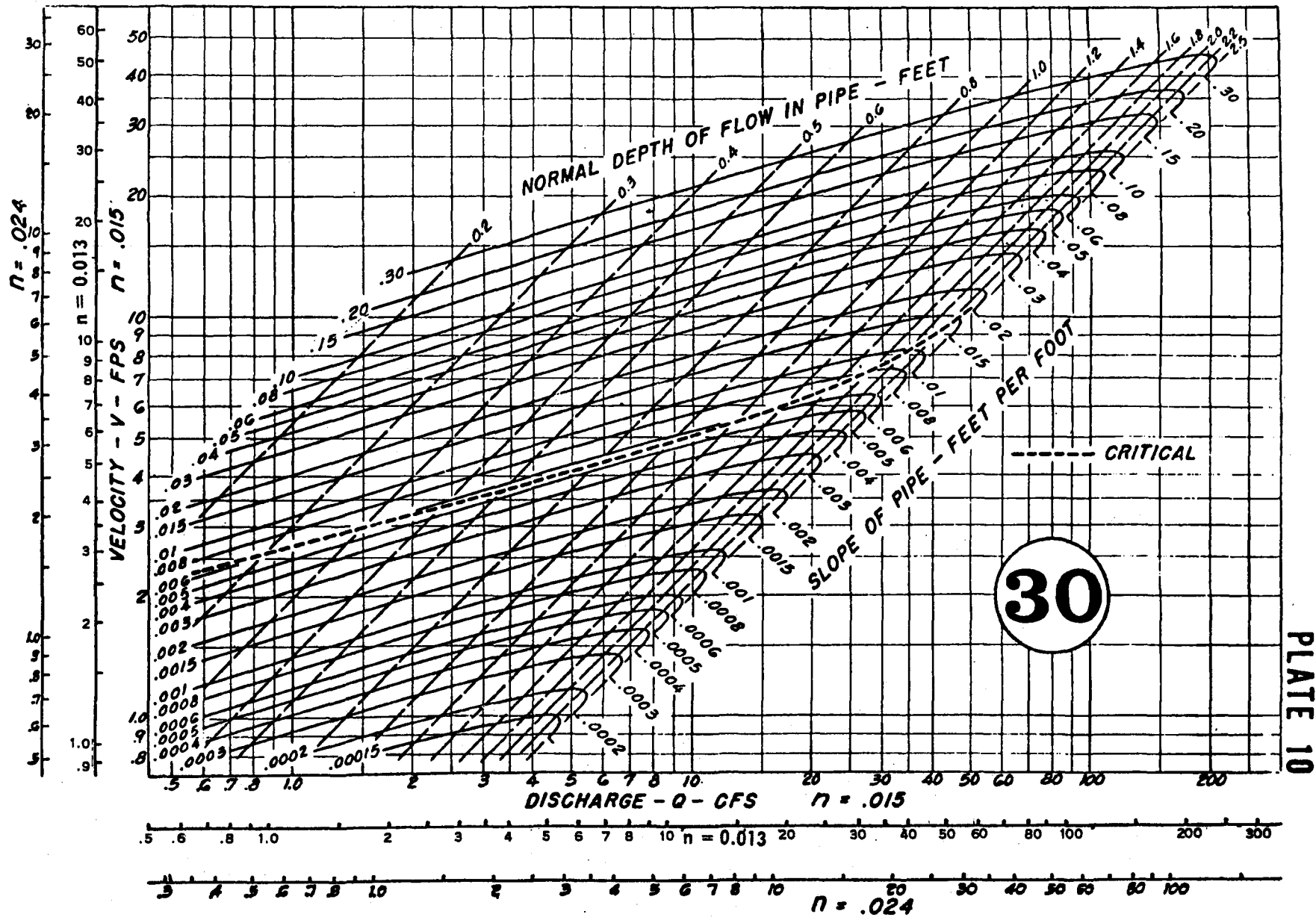
Pipe Flow Chart **30** inch Diameter

PLATE 10

PLATE 11
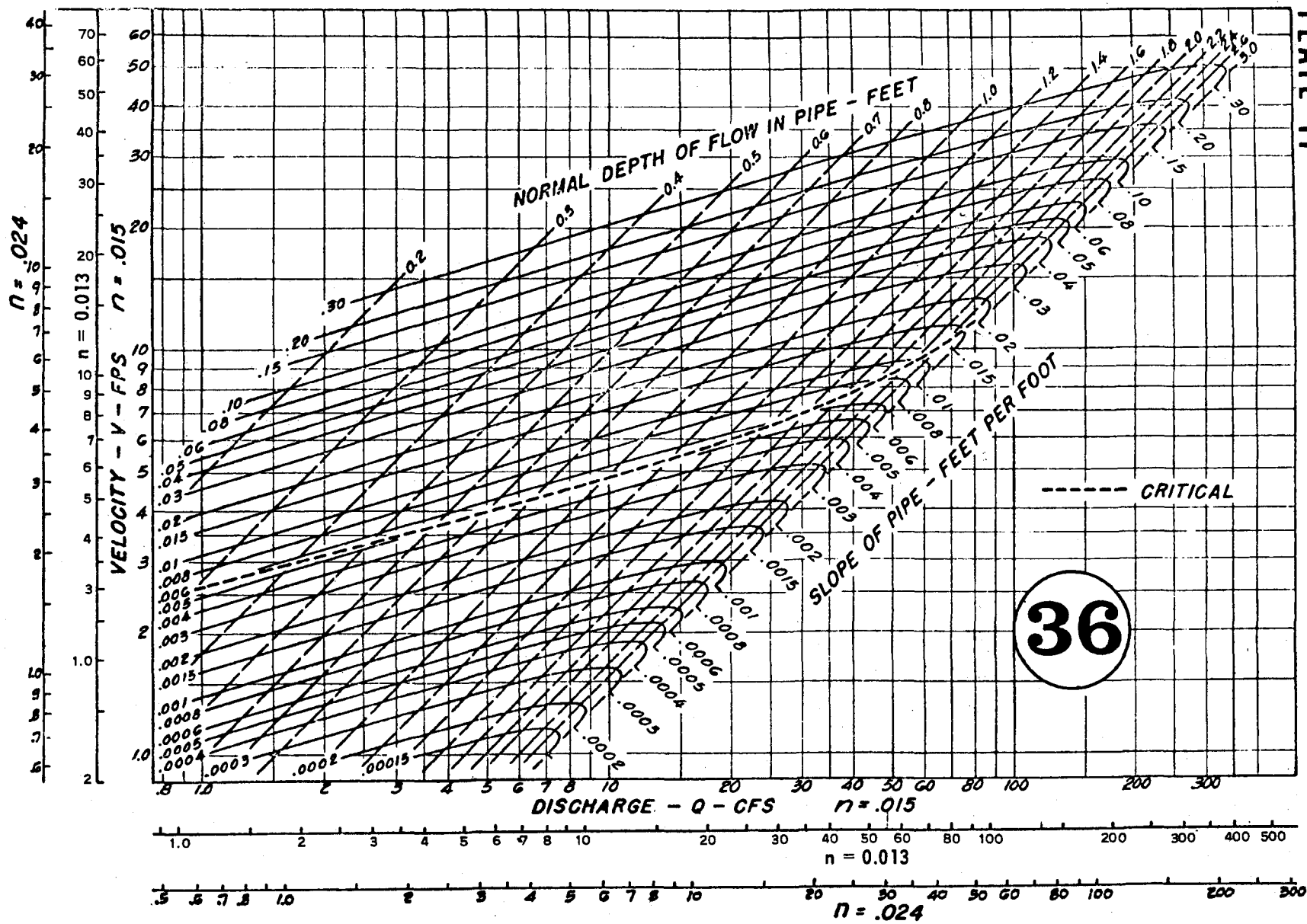
Pipe Flow Chart 36 inch Diameter
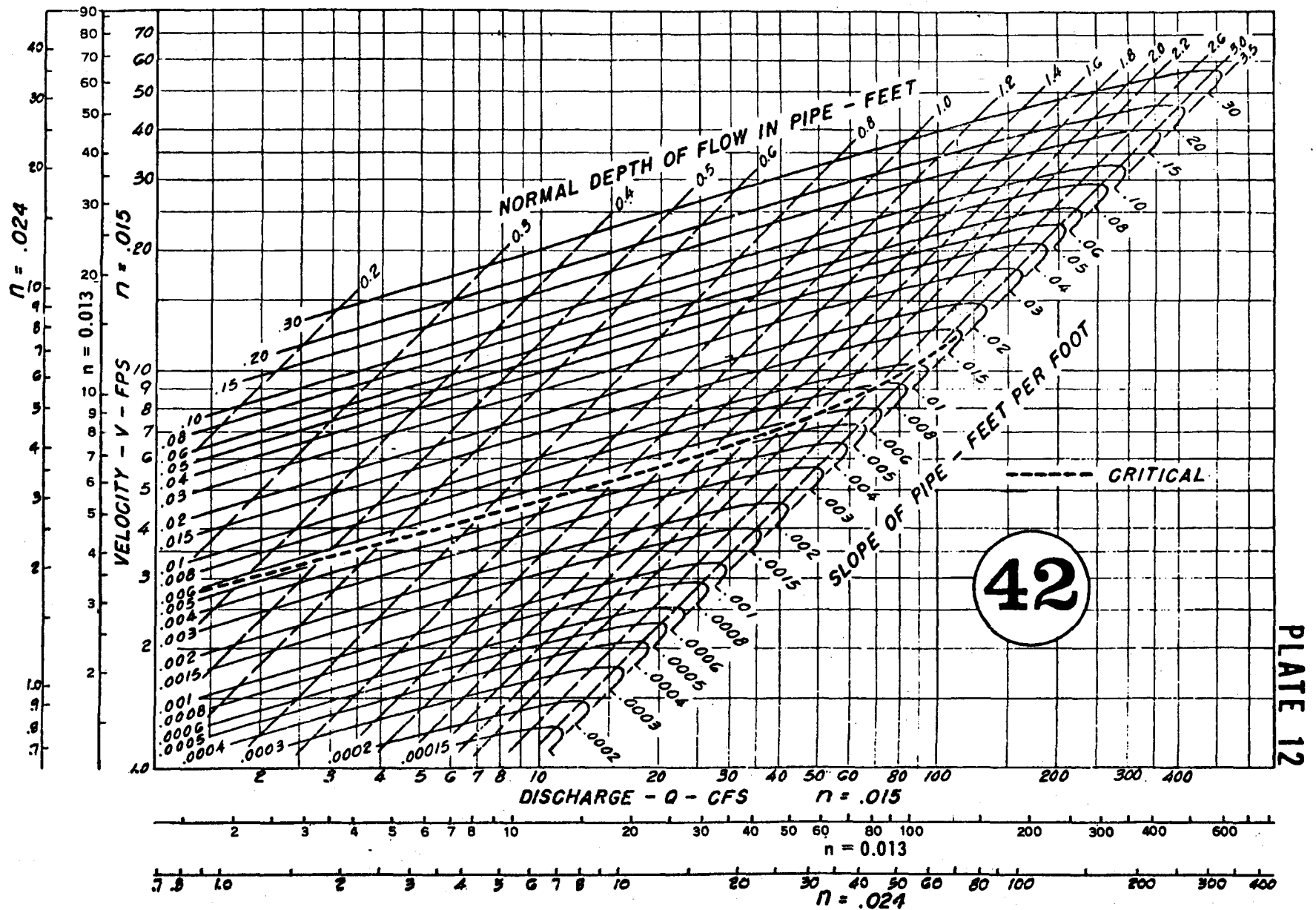
Pipe Flow Chart **42** inch Diameter
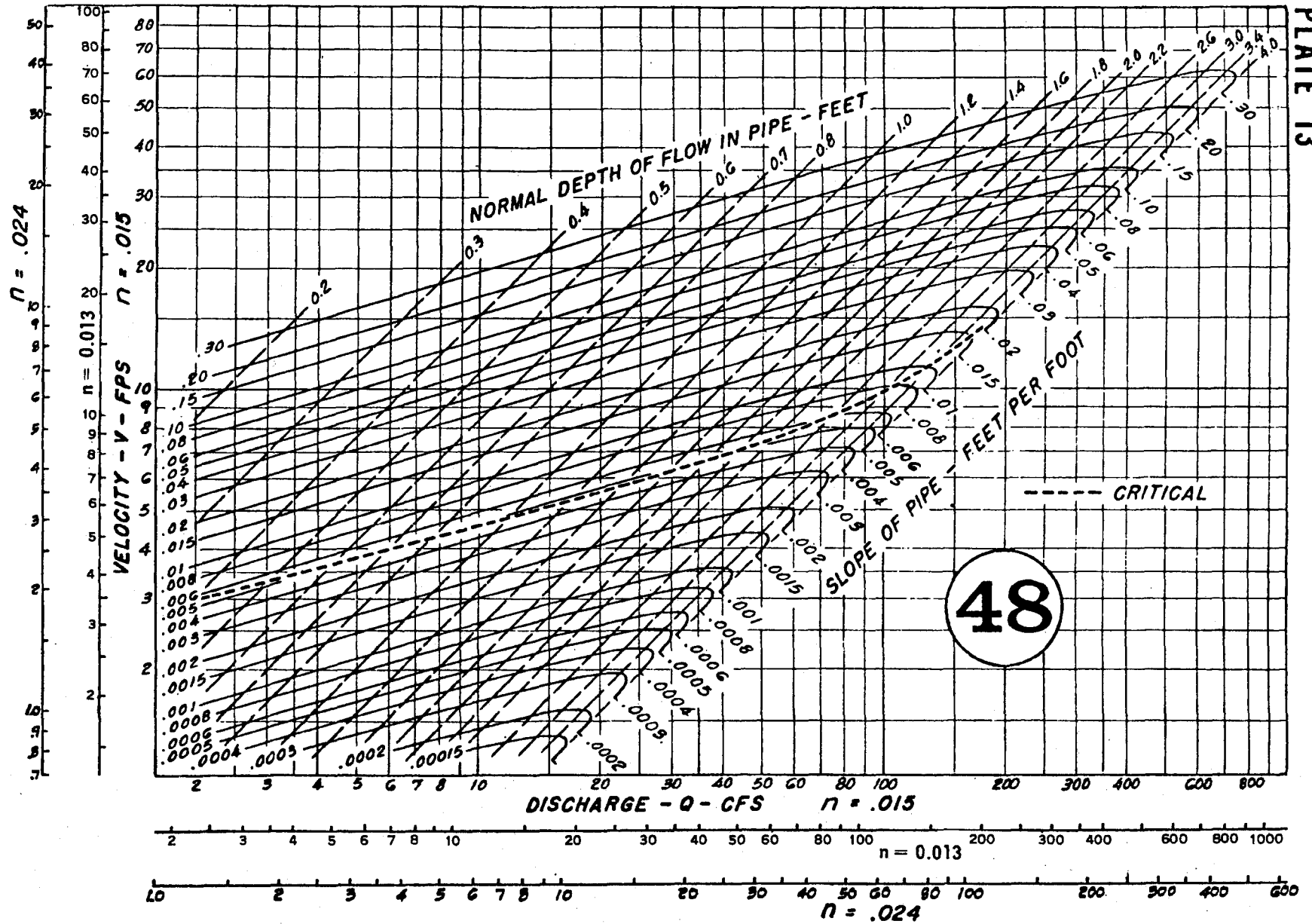
PLATE 12

PLATE 13

Pipe Flow Chart **48** inch Diameter
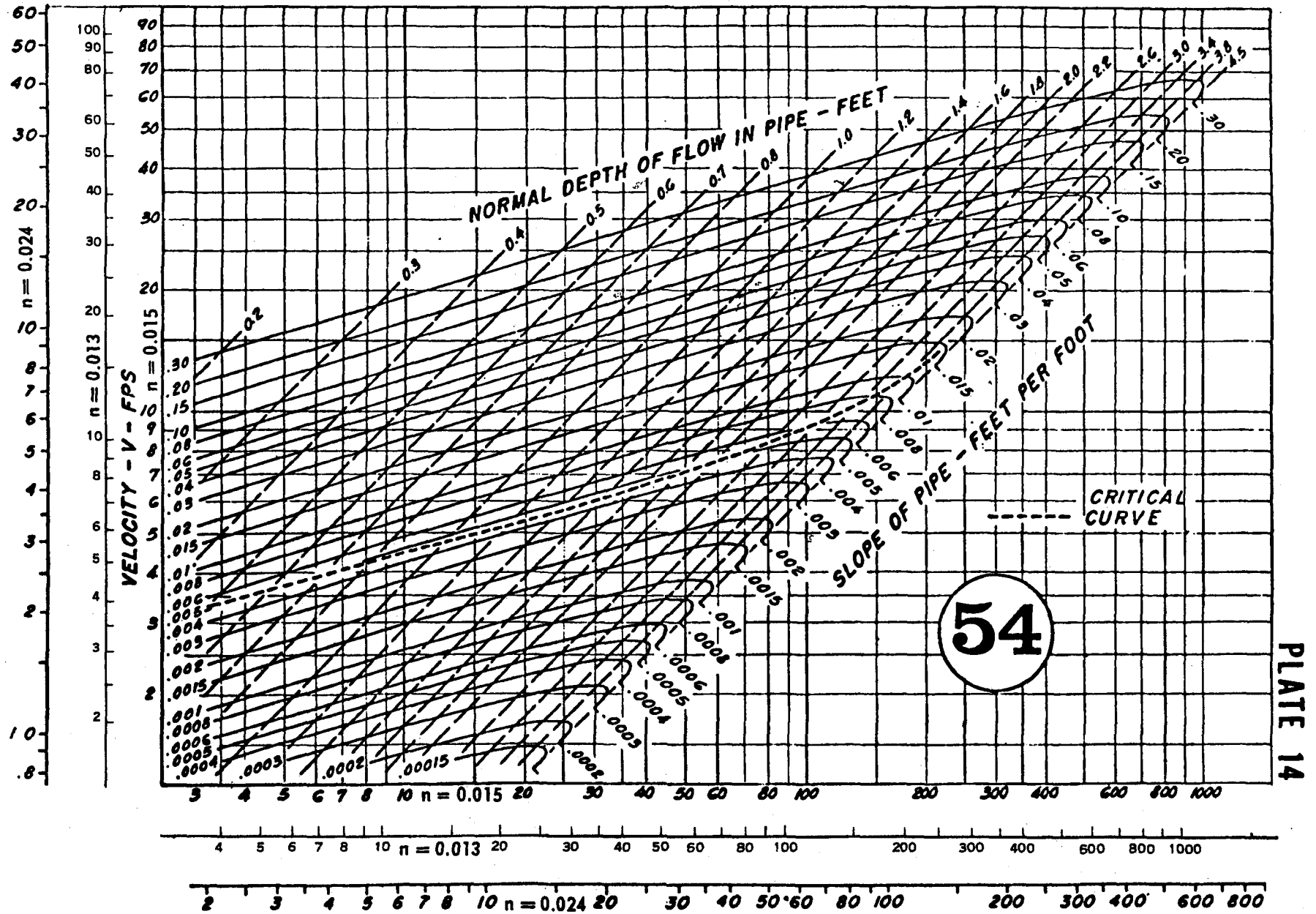
Pipe Flow Chart **54** inch Diameter
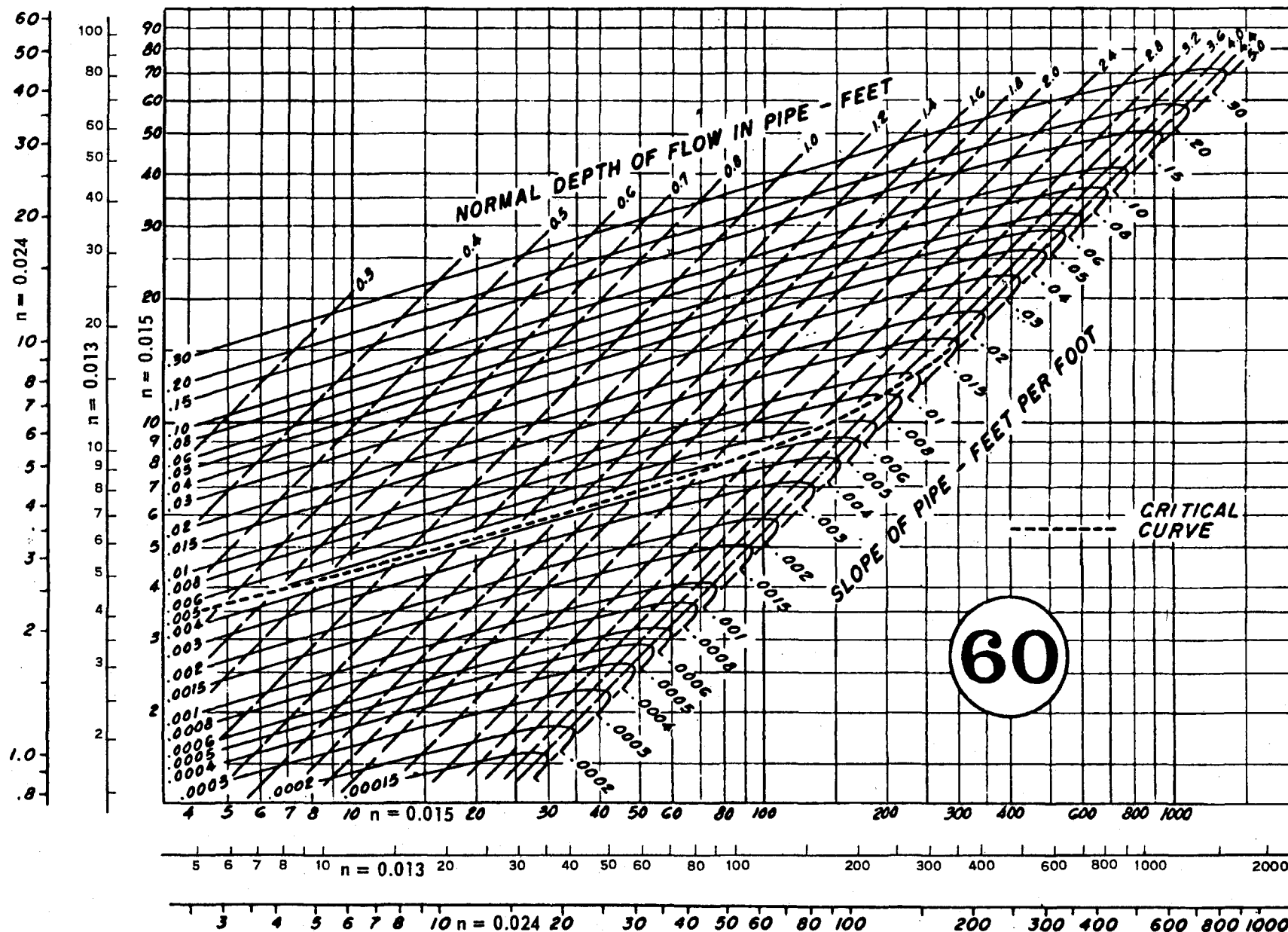
PLATE 14

PLATE 15

Pipe Flow Chart 60 inch Diameter
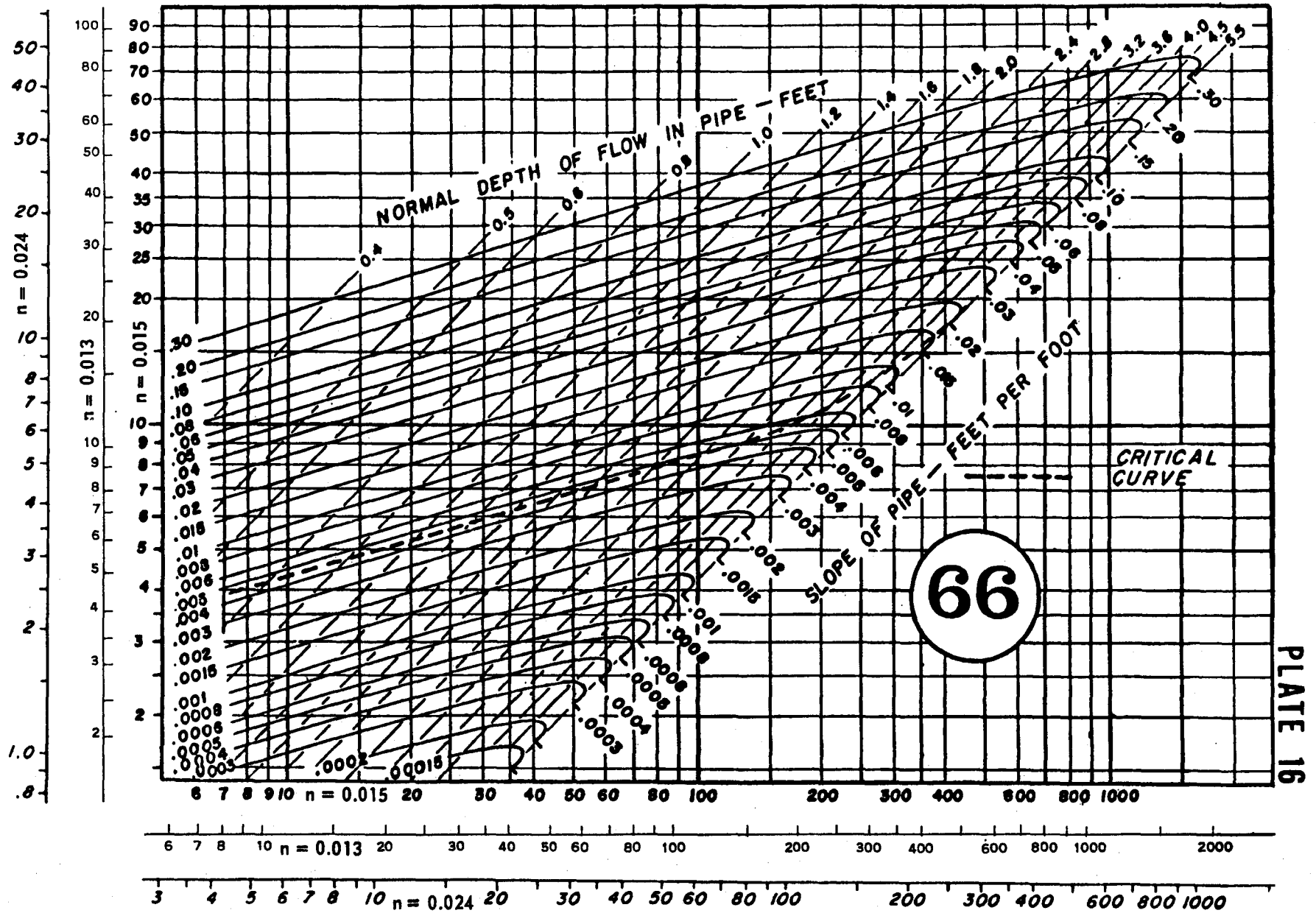
Pipe Flow Chart **66** inch Diameter

PLATE 16

HEAD LOSS IN FEET

Plate 17
A, B & C Losses

Head Losses in Manholes

Plate 18
D Losses

HEAD LOSS IN FEET

R = 0.15 D

D

**ROUNDED-LIP ENTRANCE WITH
RADIUS OF ROUNDING = 0.15 D**

DIAMETER OF CULVERT (D) IN INCHES

180
168
156
144
132
120
108
96
84
72
60
48
36
30
24
18
12

DISCHARGE (Q) IN CFS

4000
3000
2000
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1

$\left(\frac{H}{D}\right)$

HEADWATER DEPTH IN DIAMETERS

5.0
4.5
4.0
3.0
2.0
1.5
1.0
0.9
0.8
0.7
0.6

EXAMPLE

EXAMPLE:

Given: D = 36 inches
         Q = 60 cfs

Read: H/D = 1.34
        H = 48.24 inches (4.0 ft.)

HEIGHT OF CULVERT IN FEET — a

DISCHARGE IN CFS PER FOOT OF WIDTH   Q/b

HEAD ON INLET FLOW LINE PER FOOT OF HEIGHT   H/a

FOR SQUARE EDGED ENTRANCE

EXAMPLE

EXAMPLE
Given: 4' x 2' Box Culvert
         Carrying 40 C.F.S. (Q/b = 10)
Read: H/a
         For Square Edged
Entrance = 1.10, H = 2.2

41

§1-5 SECTION II – STANDARDS FOR STORM WATER QUALITY

In response to the requirements of the City's NPDES permit, the City Council passed Ordinance 96-34 addressing the need to regulate storm runoff design criteria for flood control and water quality. This includes establishing controls on the timing and rate of discharge of storm water runoff to reduce storm water runoff pollution to the maximum extent practicable through the implementation of best management practices and engineering control facilities designed to reduce the generation of pollutants.

Long-term water quality is impacted by the volume and frequency of discharged pollutants.

Water quality is also impacted by the modification of a stream's hydrograph caused by increases in flows and durations that result when land is developed (e.g., made more impervious). This phenomenon known as hydromodification, effectively reduces stream base-flow (groundwater flow into streams) and increases overland or storm-flow which causes reduced groundwater recharge and increased peak discharge rates into streams. Hydromodification may result in stream channel instability, streambank or shoreline erosion, loss of habitat, increased sediment transport and deposition, and increased flooding. Consequently, water quality measures for a development should also be designed to include LID BMPs to manage and control hydromodification.

§1-5.1 PART I - WATER QUALITY CRITERIA

A. OBJECTIVES OF WATER QUALITY CRITERIA

The purpose of the water quality criteria is to reduce the pollution associated with storm water runoff from new development and redevelopment. By establishing these criteria, the City and County of Honolulu is satisfying Federal regulatory requirements to control the discharge of pollutants in storm water as specified in the Clean Water Act Amendments of 1987 and its NPDES permit for discharges from the Municipally Owned and Operated Separate Storm Sewer System issued by the Hawaii Department of Health (DOH) under the authority by the United States Environmental Protection Agency (EPA). Under the NPDES program, the City is required to reduce the discharge of pollutants to receiving waters to the "maximum extent practicable" (MEP).

B. REQUIREMENT APPLICABILITY

1. DEVELOPMENT AND REDEVELOPMENT INCLUDED

Applicable new development and redevelopment projects as defined in B.2a of §1-5.1 Part I Water Quality Criteria must address storm water quality to the MEP through the use of Low Impact Development (LID) Site Design Strategies, Source Control Best Management Practices (BMPs), LID Post-Construction Treatment Control BMPs, and Other Post-Construction Treatment Control BMPs.

For redevelopment projects, the requirements presented in B.6 of §1-5.1 Part I Water Quality Criteria apply only to the addition, and not to the entire development. Redevelopment includes, but is not limited to expansion of a building footprint; addition to or replacement of a structure; replacement of an impervious surface that is

not part of a routine maintenance activity; land disturbing activities related to structural or impervious surfaces. Redevelopment does not include routine maintenance activities that are conducted to maintain original hydraulic capacity, original purpose of facility or emergency redevelopment activity required to protect public health and safety. Impervious surface replacement, such as the reconstruction of parking lots and roadways which does not disturb additional area is considered a routine maintenance activity. Redevelopment does not include the repaving of existing roads.

Projects cannot be subdivided or phased to avoid complying with these requirements. Development and redevelopment of the same or adjacent property (ies) permitted within 5 years may be considered together for purposes of assessing the above criteria. The sizing of water quality facilities and drainageways 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.

2. REGULATED PROJECTS

    For purposes of meeting the objectives presented in A of §1-5.1 Part I Water Quality Criteria, projects shall be regulated as follows[1]:

    a. Priority A Projects. New development and redevelopment projects that disturb at least 1 acre of land and that are not required to obtain a separate industrial NPDES storm water permit from DOH for long term storm water discharges. Projects at least 5 acres in size are classified as A1, and all others are classified as A2.

    b. Priority B Projects. New development and redevelopment projects that do not meet the criteria of a Priority A project but meet any of the following criteria:

        1) Retail Gasoline Outlet with at least 10,000 square feet of total impervious surface area;

        2) Automotive Repair Shop with at least 10,000 square feet of total impervious surface area;

        3) Restaurant with at least 10,000 square feet of total impervious surface area;

        4) Parking lot with at least 10,000 square feet of total impervious surface area

        Impervious surfaces include, but are not limited to, rooftops; walkways; patios; driveways; parking lots; storage areas; impervious concrete and asphalt; and any other continuous watertight pavement or covering. Landscaped soil and pervious pavement, underlain with pervious soil or pervious storage material, are not impervious surfaces.

3. PROJECT APPLICABILITY

    These rules shall be effective as of June 1, 2013. The Director may exempt projects from the application of these rules if projects are determined to have submitted

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[1] **Criteria for Regulated Projects may be revised as necessary by the Department (as described in B.7 of §1-5.1 Part I Water Quality Criteria)**

completed construction drawings and completed site-specific drainage reports prior to June 1, 2013.

4. OFF-SITE RUNOFF APPLICABILITY

These criteria are required to be applied to runoff arising from a site and not from off-site runoff, unless the off-site runoff is entering the site as overland flow, and/or will not be separated from on-site runoff. If off-site runoff is to be conveyed through a water quality facility, then the facility must be designed to meet the requirements as described below for the combined on-site and off-site runoff volumes and/or rates.

5. JURISDICTIONAL APPLICABILITY

These requirements apply to projects that drain to City and County drainage facilities and all natural drainage ways that the City and County has ownership and/or responsibility for. Developments that are located in areas that do not drain to the above facilities may be required to meet other DOH requirements.

6. MANAGEMENT PRACTICES TO MEET CRITERIA

   a. Priority A1 Projects

   The criteria shall be met for Priority A1 projects as follows:

   i.   Incorporate appropriate LID Site Design Strategies to the MEP.

   ii. Incorporate appropriate Source Control BMPs to the MEP.

   iii. Unless determined to be infeasible, retain on-site by infiltration or evapotranspiration, the Water Quality Volume or "WQV" with appropriate LID Retention Post-Construction Treatment Control BMPs. The WQV is defined in A of §1-5.2 Part II, Water Quality Design Standards.

   iv. Unless determined to be infeasible, biofilter any portion of the Water Quality Volume that is not retained on-site with appropriate LID Biofiltration Post-Construction Treatment Control BMPs.

   "Infeasible" means conditions at the site make the implementation of a specific Low Impact Development Best Management Practice technically infeasible. Infeasibility criteria are defined in E of §1-5.2 Part II, Water Quality Design Standards. If it is demonstrated to be infeasible to retain and/or biofilter the Water Quality Volume, one of the following alternative compliance measures is required:

   - Either harvest/reuse, or treat (by detention, filtration, settling, or vortex separation) and discharge with appropriate Other Post-Construction Treatment Control BMPs, any portion of the Water Quality Volume that is not retained on-site or biofiltered.

   - Retain or biofilter at an offsite location, the volume of runoff equivalent to the difference between the project's WQV and the amount retained on-site or biofiltered. Offsite mitigation projects must be submitted for City approval.

b. Priority A2 Projects

The criteria shall be met for Priority A2 projects as follows:

i. Incorporate appropriate LID Site Design Strategies to the MEP.

ii. Incorporate appropriate Source Control BMPs to the MEP.

iii. Unless determined to be infeasible, either retain on-site by infiltration or evapotranspiration, the Water Quality Volume with appropriate LID Retention Post-Construction Treatment Control BMPs, or biofilter the Water Quality Volume with appropriate LID Biofiltration Post-Construction Treatment Control BMPs, or a combination of the two.

Infeasibility criteria are defined in E of §1-5.2 Part II, Water Quality Design Standards. If it is demonstrated to be infeasible to retain and/or biofilter the Water Quality Volume, one of the following alternative compliance measures is required:

- Either harvest/reuse, or treat (by detention, filtration, settling, or vortex separation) and discharge with appropriate Other Post-Construction Treatment Control BMPs, any portion of the Water Quality Volume that is not retained on-site or biofiltered.

- Retain or biofilter at an offsite location, the volume of runoff equivalent to the difference between the project's WQV and the amount retained on-site or biofiltered. Offsite mitigation projects must be submitted for City approval.

c. Priority B Projects

The criteria shall be met for Priority B projects as follows:

i. Consider appropriate LID Site Design Strategies.

ii. Incorporate appropriate Source Control BMPs to the MEP.

Documents providing details and recommendations on LID Site Design Strategies, Source Control BMPs, and Treatment Control BMPs may be found on the City's website.

7. ADDITIONAL REQUIREMENTS

The criteria identified in B.6 of §1-5.1 Part I, Water Quality Criteria are minimum requirements. If the department determines that additional controls and/or lower thresholds for developments are required to meet the 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], or Class 1 Inland Waters, or Class AA Marine Waters), additional requirements may be imposed. These may include design requirements that result in larger facilities as well as additional types of structural or non-structural controls. The design solution will be contingent upon the pollutants that are found to be impacting such water bodies and the regulatory status of the water body.

8. DEDICATION OF FACILITIES TO CITY AND COUNTY

Water Quality facilities may be dedicated to the City. Application for dedication to the City must be approved prior to preparing subdivision maps and construction plans.

9. WATER QUALITY FACILITIES WITHIN PARKS

Parks may be utilized to satisfy water quality facility requirements, with concurrence of the appropriate City agencies, if such parks meet the intent and requirements of the park dedication ordinance and rules.

10. STORM WATER QUALITY FACILITIES REVIEW

The incorporation of storm water quality considerations is encouraged early in the development process as early design considerations will likely lead to more cost-effective projects. Storm water quality management strategies for Priority A1 projects shall be documented in a Storm Water Quality Report (SWQR). Storm water quality management strategies for Priority A2 and Priority B projects shall be documented in a Storm Water Quality Checklist (SWQC). A Storm Water Quality Report Preparation Manual, Storm Water Quality Checklist Preparation Manual, Storm Water Quality Report Template, and Storm Water Quality Checklist Templates may be found on the City's website to assist with and facilitate the preparation of SWQRs and SWQCs.

a. Submittal Requirements

Storm Water Quality Reports or Storm Water Quality Checklists shall be submitted for City review as follows:

1) For Priority A1 and Priority A2 projects, the project's Storm Water Quality Report or Storm Water Quality Checklist shall accompany construction plan approvals.

2) For Priority B projects, the project's Storm Water Quality Checklist shall accompany applications for applicable building and grading permits.

A narrative explaining the project's water quality management strategy must be included in the project's Master Plan, discretionary land use permit, or Environmental Assessment/Environmental Impact Statement.

Storm Water Quality Reports and Storm Water Quality Checklists shall be signed by the owner/developer certifying that the management practices will be implemented and maintained, and signed and stamped by a Professional Engineer licensed and registered to practice in the state of Hawaii, stating that the management practices are in accordance with these Rules and are consistent with the information presented in the construction plans.

11. MAINTENANCE

All storm water quality facilities, including those constructed offsite per B.6 of §1-5.1 Part I, will require regular maintenance by the owner/developer or authorized representative to ensure they operate as designed and to prevent resuspension of previously captured particles. Necessary information, such as inspection/maintenance

frequencies, activities, and responsible individuals shall be documented in the Storm Water Quality Report or Storm Water Quality Checklist as applicable. In addition to regular maintenance, annual inspections must be performed for all Post-Construction BMPs by the owner/developer or authorized representative, including inspection and performance of any required maintenance in the late summer/early fall, prior to the start of the rainy season. A log of inspection and maintenance activities must be kept for a minimum of 5 (five) years and be made available to the City upon request.

For facilities that will be dedicated to the City, the City reserves the right to alter the maintenance plan to conform to its practices.

§1-5.2 PART II - WATER QUALITY DESIGN STANDARDS

A. VOLUME BASED STORM WATER QUALITY CONTROL FACILITIES

Volume based storm water quality facilities include Infiltration Basins, Infiltration Trenches, Subsurface Infiltration Systems, Dry Wells, Bioretention Basins, Permeable Pavement, Green Roofs, Vegetated Bio-Filters, Enhanced Swales, Detention Basins, and Sand Filters.

Volume based storm water quality facilities shall be sized as determined in B.6 of §1-5.1 Part I, Water Quality Criteria. The WQV is calculated as follows:

$$WQV = PCA \times 3630$$

Where: WQV = water quality volume (cubic feet)
                 P   = design storm runoff depth (inches)
                 C   = volumetric runoff coefficient
                 A   = total drainage area (acres)

A design storm runoff depth of 1 inch shall be used. The volumetric runoff coefficient shall be calculated using the following equation as developed by EPA for smaller storms in urban areas:

$$C = 0.05 + 0.009I$$

Where: C   = volumetric runoff coefficient
                 I   = percent of impervious cover, expressed as a percentage

Infiltration Basin. An infiltration basin is a shallow impoundment with no outlet, where storm water runoff is stored and infiltrates through the basin invert and into the soil matrix. Infiltration Basins shall have a flat invert, interior side slopes (length per unit height) no steeper than 3:1 unless approved by a licensed professional engineer with geotechnical expertise, and at least 3 feet from the basin invert to the seasonally high groundwater table. The soil infiltration rate below the basin invert shall be at least 0.5 inches per hour, and drain completely in 48 hours.

Infiltration Trench. An infiltration trench is a rock-filled trench with no outlet, where storm water runoff is stored in the void space between the rocks and infiltrates through the bottom and into the soil matrix. Infiltration Trenches shall have no more than 6 inches of a top backfill layer, no more than 12 inches of a bottom sand layer, and 1.5-3.0 inch diameter trench rock. The soil infiltration rate below the trench invert shall be at least 0.5 inches per hour, the depth from the trench invert to the seasonally high groundwater table shall be at least 3 feet, and the trench shall completely drain in 48 hours. The depth of the infiltration trench shall not exceed the greater of the trench width and trench length to avoid classification as a Class V injection well.

Subsurface Infiltration System. A subsurface infiltration system is a rock (or alternative pre-manufactured material) storage bed below other surfaces such as parking lots, lawns and playfields for temporary storage and infiltration of runoff. In addition to applicable manufacturer's guidelines, the soil infiltration rate below the system invert shall be at least 0.5 inches per hour, the depth from the system invert to the seasonally high groundwater table shall be at least 3 feet, and the system shall completely drain in 48 hours. The depth of the subsurface infiltration system storage bed shall not exceed the greater of the storage bed's width and storage bed's length to avoid classification as a Class V injection well.

Dry Well. A dry well is a subsurface aggregate-filled or prefabricated perforated storage facility, where roof runoff is stored and infiltrates into the soil matrix. The soil infiltration rate below the dry well invert shall be at least 0.5 inches per hour, the depth from the dry well invert to the seasonally high groundwater table shall be at least 3 feet, and the dry well shall completely drain in 48 hours. If the dry well is aggregate-filled, 1.0-3.0 inch aggregate shall be used unless an alternative is approved by a licensed professional engineer with geotechnical expertise. The depth of the dry well shall not exceed the diameter to avoid classification as a Class V injection well.

Bioretention Basin. Sometimes referred to as a Rain Garden, a Bioretention Basin is an engineered shallow depression that collects and filters storm water runoff using conditioned planting soil beds and vegetation. The filtered runoff infiltrates through the basin invert and into the soil matrix. Bioretention Basins shall have a flat invert, interior side slopes (length per unit height) no steeper than 1:1 for single family residential installations and no steeper than 3:1 for all other installations unless approved by a licensed professional engineer with geotechnical expertise, and at least 3 feet from the basin invert to the seasonally high groundwater table. The ponding depth shall be no greater than 12 inches, the mulch thickness shall be 2-4 inches, and the planting soil depth shall be 2-4 feet. The soil infiltration rate below the basin invert shall be at least 0.5 inches per hour, and the basin shall drain completely in 48 hours.

Permeable Pavement. Sometimes referred to as pervious pavement or porous pavement, permeable pavement refers to any porous, load-bearing surface that allows for temporary rainwater storage in an underlying aggregate layer until it infiltrates into the soil matrix. It includes pervious concrete, porous asphalt, interlocking paver blocks, and reinforced turf and gravel filled grids. Permeable pavement shall have a reservoir layer no thicker than 3 feet and have at least 3 feet from the reservoir invert to the seasonally high groundwater table. The soil beneath the reservoir layer invert shall have an infiltration

rate of at least 0.5 inches per hour, and the reservoir layer shall drain completely in 48 hours.

Green Roof. Sometimes referred to as a Vegetated Roof or Eco-roof, a green roof is a roof that is entirely or partially covered with vegetation and soils for the purpose of filtering, absorbing, evapotranspirating, and retaining/ detaining the rain that falls upon it. Green roofs shall have a slope no greater than 20 percent, at least 2 inches of soil media, and at least 2 inches of drainage layer.

Vegetated Bio-Filter. Sometimes referred to as a Bioretention Filter, Stormwater Curb Extension, or Planter Box, a Vegetated Bio-Filter is an engineered shallow depression that collects and filters storm water runoff using conditioned planting soil beds and vegetation. The filtered runoff discharges through an underdrain system. Vegetated Bio-Filters shall have a relatively flat invert, the ponding depth shall be no greater than 12 inches, the mulch thickness shall be 2-4 inches, and the planting soil depth shall be 2-4 feet. The planting soil shall have a coefficient of permeability equal to at least 1.0 foot per day, and the WQV shall drain completely in 48 hours.

Enhanced Swale. Sometimes referred to as a Bioretention Swale or Dry Swale, an Enhanced Swale is a shallow linear channel with a planting bed and covered with turf or other surface material (other than mulch or plants). Runoff filters through a planting bed, is collected in an underdrain system, and discharged at the downstream end of the swale. Enhanced Swales shall have interior side slopes (length per unit height) no steeper than 3:1 unless approved by a licensed professional engineer with geotechnical expertise, a bottom width between 2-8 feet, and a longitudinal slope no greater than 2 percent without check dams or 5 percent with check dams. If used, check dams shall be no higher than 12 inches. The maximum ponding depth is 18 inches and the minimum media depth is 18 inches.

Detention Basin. Sometimes referred to as a Dry Extended Detention Basin, a detention basin is a shallow man-made impoundment intended to provide for the temporary storage of storm water runoff to allow particles to settle. It does not have a permanent pool and is designed to drain between storm events. Detention Basins shall have an invert sloped between 1-2 percent, interior side slopes (length per unit height) no steeper than 3:1 unless approved by a licensed professional engineer with geotechnical expertise, a minimum length to width ratio of 2 to 1, and a maximum depth of 8 feet. With outlets no smaller than 4 inches in diameter, the basin shall drain completely in 48 hours when full and 24-36 hours when half full.

Sand Filter. A sand filter is an open chambered structure that captures, temporarily stores, and treats storm water runoff by passing it through an engineered media (e.g., sand). Sand filter beds shall have at least 18 inches of sand with a coefficient of permeability of at least 3.5 feet per day, and shall drain completely in 48 hours.

B. FLOW BASED STORM WATER QUALITY CONTROL FACILITIES

Flow-through based storm water quality facilities include Vegetated Swales, Vegetated Filter Strips, and Manufactured Treatment Devices.

Flow-through based storm water quality facilities shall be sized for the Water Quality Flow Rate (WQF), which is calculated using the Rational Formula as follows:

$$WQF = CiA$$

Where: WQF = water quality flow rate (cubic feet per second)
                    C   = runoff coefficient
                    i   = peak rainfall intensity (inches per hour)
                    A   = total drainage area (acres)

A peak rainfall intensity of 0.4 inches per hour shall be used. The runoff coefficient shall be determined from Table 4. The runoff coefficient shall be, at a minimum, the midpoint of the given range of values. The higher value shall be used if soil conditions indicate that pervious areas will have little infiltration/interception potential.

For drainage areas containing multiple land uses the following formula may be used to compute a composite weighted runoff coefficient:

$$C_c = \left(\sum_{i=1}^{n} C_i A_i \right) \Big/ A_t$$

Where: C_c = composite weighted runoff coefficient
                    $C_{1,2,...n}$ = runoff coefficient for each land use cover type
                    $A_{1,2,...n}$ = drainage area of each land use cover type (acres)
                    A_t = total drainage area (acres)

The calculated WQF for Vegetated Swales and Vegetated Filter Strips may be reduced by 25% if the soil beneath the BMP is classified as Hydrologic Soils Group (HSG) "A" or "B", as reported by the USDA Natural Resources Conservation Service (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm), or if the soil beneath the BMP is amended by incorporating 6 inches of compost/amendments and tilled up to 8 inches.

Vegetated Swale. Sometimes referred to as a Grass Swale, Grass Channel, or Biofiltration Swale, a vegetated swale is a broad shallow earthen channel vegetated with erosion resistant and flood tolerant grasses. Runoff typically enters the swale at one end and exits at the other end. Vegetated Swales shall have interior side slopes (length per unit height) no steeper than 3:1 unless approved by a licensed professional engineer with geotechnical expertise, a bottom width no greater than 10 feet, and a water depth no greater than 4 inches. The velocity in the swale shall not exceed 1 foot per second, and the hydraulic residence time shall be at least 7 minutes.

Vegetated Buffer Strip. Sometimes referred to as a Vegetated Filter Strip or Biofiltration Strip, a vegetated buffer strip is a grassy slope vegetated with turf grass that is designed to accommodate sheet flow. They may remove pollutants by vegetative filtration. Vegetated Buffer Strips shall have a length (in the direction of flow) no less than 15 feet, the depth of flow shall not exceed 1 inch, and the velocity shall not exceed 1 foot per

second. The flow length of the tributary area discharging onto the strip shall not exceed 75 feet.

Manufactured Treatment Device. Sometimes referred to as hydrodynamic or vortex separators, a manufactured treatment device is a proprietary water quality structure utilizing settling, filtration, adsorptive/absorptive materials, vortex separation, vegetative components, or other appropriate technology to remove pollutants from storm water runoff. These devices must provide a TSS removal rate of 80%, verified by a Technology Acceptance and Reciprocity Partnership (TARP) state or other third party testing organization, provided that such verification is conducted in accordance with the protocol "Stormwater Best Management Practices Demonstration Tier II Protocol for Interstate Reciprocity" (which may be found at http://www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/).

C. AREA BASED STORM WATER QUALITY CONTROL FACILITIES

Area based storm water quality facilities include Downspout Disconnection.

Downspout Disconnection. Sometimes referred to as Rooftop Disconnection or Downspout Dispersion, is the redirection of roof runoff to a vegetated area in a dispersed manner. Downspout disconnection facilities shall be sized such that the size of the vegetated area receiving the roof runoff is at least 10% of the size of the roof area that drains to the downspout, or the flow path of the vegetated area receiving the roof runoff is at least as long as the flow path of the roof area that drains to the downspout.

D. DEMAND BASED STORM WATER QUALITY CONTROL FACILITIES

Demand based storm water quality facilities include Harvesting / Reuse.

Harvesting/Reuse. Sometimes referred to as Capture/Reuse or Rainwater Harvesting, is the collection and temporary storage of roof runoff in rain barrels or cisterns for subsequent non-potable outdoor use (landscape irrigation, vehicle washing). Harvesting / Reuse facilities shall be sized such that at least 80% of the total annual runoff is captured, and at least 80% of the total annual reuse demand is met.

E. INFEASIBILITY CRITERIA

Table 5 lists exemption criteria for Low Impact Development (LID).

[Eff: June 1, 2013] (Auth: Sec 14-12.31, ROH) (Imp: Sec14-12.31, ROH)

TABLE 4: RUNOFF COEFFICIENTS FOR WATER QUALITY FLOW CALCULATIONS

Type of Drainage Area	Runoff Coefficient
Business	
Downtown areas	0.70 – 0.95
Neighborhood areas	0.50 – 0.70
Residential	
Single-family areas	0.30 – 0.50
Multi-units, detached	0.40 – 0.60
Multi-units, attached	0.60 – 0.75
Suburban	0.25 – 0.40
Apartment dwelling areas	0.50 – 0.70
Industrial	
Light areas	0.50 – 0.80
Heavy areas	0.60 – 0.90
Parks, cemeteries	0.10 – 0.25
Playgrounds	0.20 – 0.40
Railroad yards	0.20 – 0.35
Unimproved areas	0.10 – 0.30
Lawns	
Sandy soil, flat, $\leq 2\%$	0.05 – 0.10
Sandy soil, average 2-7%	0.10 – 0.15
Sandy soil, steep $\geq 7\%$	0.15 – 0.20
Heavy soil, flat, $\leq 2\%$	0.13 – 0.17
Heavy soil, average 2-7%	0.18 – 0.22
Heavy soil, steep $\geq 7\%$	0.25 – 0.35
Streets	
Asphaltic	0.70 – 0.95
Concrete	0.70 – 0.95
Brick	0.75 – 0.85
Drives and walks	0.75 – 0.95
Roofs	0.75 – 0.95

TABLE 5: EXEMPTION CRITERIA FOR LOW IMPACT DEVELOPMENT

Exemption Criteria	Infiltration Basin	Infiltration Trench	Subsurface Infiltration	Dry Well	Bioretention Basin	Permeable Pavement
Soils beneath basin invert have measured infiltration rates less than 0.5 in/hr	●	●	●	●	●	●
Unable to maintain a distance of at least 3 ft from BMP invert to seasonally high groundwater table	●	●	●	●	●	●
Site has known man-made plumes or contaminated soils	●	●	●	●	●	●
Site has high potential for concentrated pollutant/chemical spills	●	●	●	●	●	●
Site is up-gradient of ephemeral streams (i.e. habitat type change downstream)	●	●	●	●	●	●
Site is up-gradient of known shallow landslide-prone area	●	●	●	●	●	●
Unable to maintain a distance of at least 50 ft to the nearest groundwater well used for drinking water	●	●	●	●	●	●
Unable to maintain a distance of at least 35 ft to the nearest septic system	●	●	●	●	●	●
Unable to maintain a distance of at least 20 ft to the nearest building foundation	●	●	●		●	
Unable to maintain a distance of at least 10 ft to the nearest building foundation				●		
Unable to maintain a distance of at least 100 ft to the nearest down-gradient building foundation	●	●	●	●	●	
Unable to maintain a distance of at least 10 ft to the nearest property line	●	●	●	●	●	
Unable to divert flows in excess of WQDS around BMP, and unable to create safe overflow mechanism for flows in excess of WQDS	●	●	●		●	
Excavation would disturb iwi kupuna or other archaeological resources	●	●	●		●	
Site has high potential for oil and/or grease spills						●
Site has high potential to receive sand and/or sediment loads						●
Unable to maintain a pavement slope no greater than 5%						●
Pavement would be above a utility vault						●
Pavement is expected to receive more than 1,000 average daily trips						●
Other justification for an exemption proposed by the developer/agent and is acceptable to the City	●	●	●	●	●	●

Exemption Criteria	Vegetated Bio-Filter	Green Roof	Enhanced Swale	Downspout Disconnect	Vegetated Swale	Vegetated Filter Strip	Tree Box Filter
Unable to divert flows in excess of WQDS around BMP, and unable to create safe overflow mechanism for flows in excess of WQDS	●		●		●	●	
Excavation would disturb iwi kupuna or other archaeological resources	●		●		●	●	●
Invert of underdrain layer is below seasonally high groundwater table	●		●				
Site does not receive enough sunlight to support vegetation	●				●	●	
Site lacks sufficient hydraulic head to support BMP operation by gravity	●		●				●
Roof is for a single family residential dwelling		●					
Space is unavailable due to renewable energy, electrical, and mechanical systems		●					
Slope on roof exceeds 20% (11 degrees)		●					
Slope of receiving vegetated area exceeds 5%				●			
Diverted runoff drains within 10 feet of a retaining wall				●			
Diverted runoff drains within 10 feet of property line				●			
Concentrated flow cannot be established naturally					●		
Sheet flow cannot be established naturally						●	
Entrance at surface not possible							●
Residential and no planting strip							●
No curb and gutter							●
Other justification for an exemption proposed by the developer/agent and is acceptable to the City	●	●	●	●	●	●	●

● denotes that the BMP is considered infeasible if the exemption criteria is applicable

[Eff: June 1, 2013] (Auth: Sec 14-12.31, ROH) (Imp: Sec14-12.31, ROH)

§1-6   REPEAL
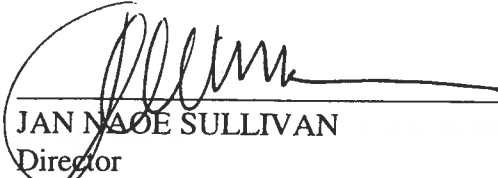
The City and County of Honolulu's Storm Drainage Standards, revised printing dated May 1988, is repealed in its entirety.

[Eff: JAN 01 2000] (Auth: Sec 14-12.31, ROH) (Imp: Sec14-12.31, ROH)

DEPARTMENT OF PLANNING AND PERMITTING
CITY AND COUNTY OF HONOLULU
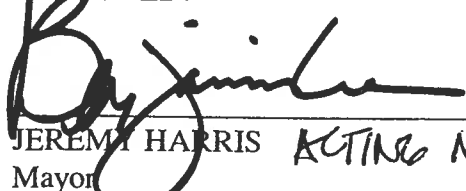
These rules were adopted on ___October 4___, 19_99_, following public hearing held on July 23, 1999, after public notice was given on June 21, 1999, in the Hawaii State and County Public Notices, Honolulu City and County.

These rules shall take effect on January 1, 2000.

_____
JAN NAOE SULLIVAN
Director
Department of Planning and Permitting
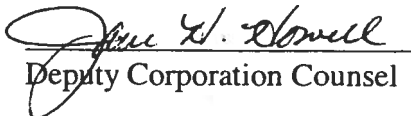
APPROVED:

_____
JEREMY HARRIS *ACTING MAYOR*
Mayor
City and County of Honolulu

Dated: ___October 18, 1999___
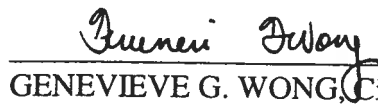
APPROVED AS TO FORM
AND LEGALITY:

_____
Deputy Corporation Counsel

FILED:

Given unto my hand and affixed with the Seal of the City and County of Honolulu this 19th day of _October_, 19_99_.
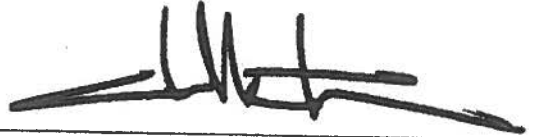
_____
GENEVIEVE G. WONG, City Clerk

56

DEPARTMENT OF PLANNING AND PERMITTING
CITY AND COUNTY OF HONOLULU
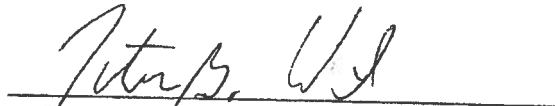
These amendments to the rules were adopted on November 27, 2010, following a public hearing held on November 17, 2010, after public notice was given on October 14, 2010, in the Hawaii State and County Public Notices, Honolulu City and County.

These amendments to the rules shall take effect on May 1, 2011.

DAVID K. TANOUE
Director
Department of Planning and Permitting
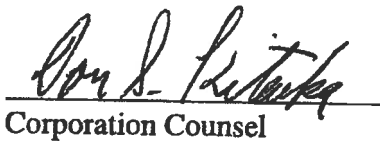
APPROVED:

PETER B. CARLISLE
Mayor
City and County of Honolulu
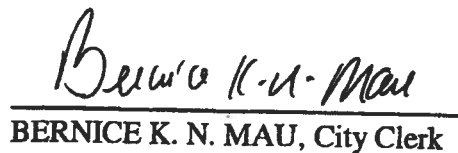
Dated: **MAR 1 6 2011**

APPROVED AS TO FORM
AND LEGALITY:

Corporation Counsel

FILED

Given unto my hand and affixed with the Seal of the City and County of Honolulu this 29 day of March, 2011.

BERNICE K. N. MAU, City Clerk

These amendments to the rules were adopted on December 12, 2012, following a public hearing held on November 27, 2012, after public notice was given on October 26, 2012, in the Hawaii State and County Public Notices, Honolulu City and County.

These amendments to the rules shall take effect on June 1, 2013.

JIRO A. SUMADA
Acting Director
Department of Planning and Permitting

APPROVED:

PETER B. CARLISLE
Mayor
City and County of Honolulu
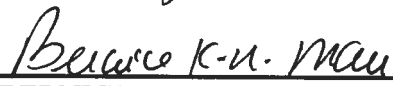
Dated: 12/28/12

APPROVED AS TO FORM
AND LEGALITY:

Deputy Corporation Counsel

FILED:

Given unto my hand and affixed with the Seal of the City and County of Honolulu this 02 day of January , 2013.

BERNICE K.N. MAU, City Clerk

Examples Illustrating Applications of Rules Relating to Storm Drainage Standards

FINAL

December 2012

By:
City and County of Honolulu
Department of Planning and Permitting

E Mālama I Ka Wai Ola
Protect our waters...
FOR LIFE

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TABLE OF CONTENTS

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A. Introduction

This booklet contains examples, which are intended to illustrate some of the more important aspects of the application of the "Rules Relating to Storm Drainage Standards" of the Department of Planning and Permitting, City and County of Honolulu. They are not intended to be complete examples of what must be submitted to the City and County of Honolulu. All designs must be completed per City and County requirements.

The information is brief and subject to change. The user is encouraged and invited to consult with the appropriate staff of the Department of Planning and Permitting for discussions on site-specific best management practices ("BMPs") and to consult with design guidance that has been developed by other agencies on the design of BMPs. For a list of other design guidance manuals, please consult the City and County of Honolulu, Department of Planning and Permitting.

B. Flood Control Design
Example #1: Analysis & Solution for Manhole Losses

NOTE: in lieu of the following analysis, an analysis based upon the Bernoulli's
Energy Theorem, such as the pressure-momentum method, will be acceptable.

GIVEN: Pipe size, Q, pipe flowing full, velocity and direction of flow.

36″
Q_1 = 40.0
V_1 = 5.7

24″
Q_3 = 30.0
V_3 = 9.5

42″
Q_2 = 70.0
V_2 = 7.3
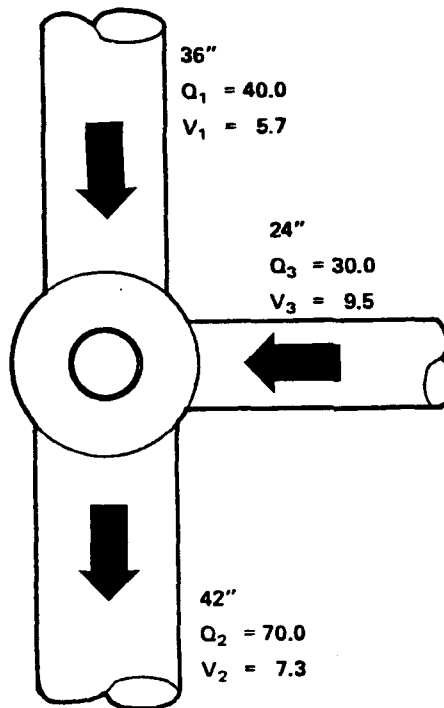
LEGEND

Q_1 = **Upstream Volume, cfs**
Q_2 = **Downstream Volume, cfs**
Q_3 = **Incoming Volume, cfs**
V_1 = **Upstream Velocity, fps**
V_2 = **Downstream Velocity, fps**
V_3 = **Upstream Branch Velocity, fps**
h = **Head Loss, in ft.**

S O L U T I O N

"A" LOSS (ENTRANCE & EXIT LOSS)

1. Determine higher velocity between V_1 and V_2
2. Use Curve **"A"** or **"C"** depending on pipe size and determine h_A (Ex. Prob. h_A = 0.15)

"B" LOSS (VELOCITY HEAD LOSS)

1. Use Curve **"B"** and determine h_V for V_1 and V_2

   a. If V_2 is lower than V_1, then h_B shall be **0**
   b. If V_2 is higher than V_1, then h_B shall be h_{B_2} - h_{B_1}

   Ex. Prob. h_{B_2} = **0.83** and h_{B_1} = **0.50**
   h_B = **0.83** – **0.50** = **0.33**

"C" LOSS (DIRECTIONAL CHANGE LOSS)

1. Use worst case and determine degree of bend.
2. With higher V_1 or V_2, use Curve **"C"** and determine head loss (**h**).

   a. For **0°** to **22½°** bends, h_C shall be **0.67** times **h**.
   b. For **22½°** to **45°** bends, h_C shall be **1.00** times **h**.
   c. For **45°** to **90°** bends, h_C shall be **2.00** times **h**.

   Ex. Prob. **h** = **0.15**
   h_C = **2 x 0.15** = **0.30**

"D" LOSS (LOSS DUE TO INCOMING VOLUME)

1. Add total branch volume and determine ratio of branch volume to upstream volume.
2. Use appropriate curve and determine h_D with higher V_1 or V_3.

   Ex. Prob. Q_3/Q_1 = **30/40** = **75%**,
   h_D = **0.56**

TOTAL LOSS:

1. Add h_A, h_B, h_C, and h_D

   Ex. Prob. h_T = **0.15 + 0.33 + 0.30 + 0.56**
   h_T = **1.34**

Losses
A		=	**0.15**
B	0.83 – 0.50	=	**0.33**
C	2(0.15)	=	**0.30**
D		=	**0.56**

Total Loss = **1.34 ft.**

HEAD LOSS IN FEET

PIPE FLOWING FULL
VELOCITY IN FEET PER SECOND

'C' USE MAX V₁ OR V₂ (LARGER) (33" & OVER)

'A' USE MAX V₁ OR V₂ (30" & SMALLER)

'B' VELOCITY HEAD

Plate 17
A, B & C Losses

Head Losses in Manholes

PIPE FLOWING FULL
VELOCITY IN FEET PER SECOND

$\frac{Q_3}{Q_1}$ = 10%

$\frac{Q_3}{Q_1}$ = 30%

$\frac{Q_3}{Q_1}$ = 50%

INTERPOLATED 75% CURVE

$\frac{Q_3}{Q_1}$ = 100%

Plate 18
D Losses

HEAD LOSS IN FEET

4
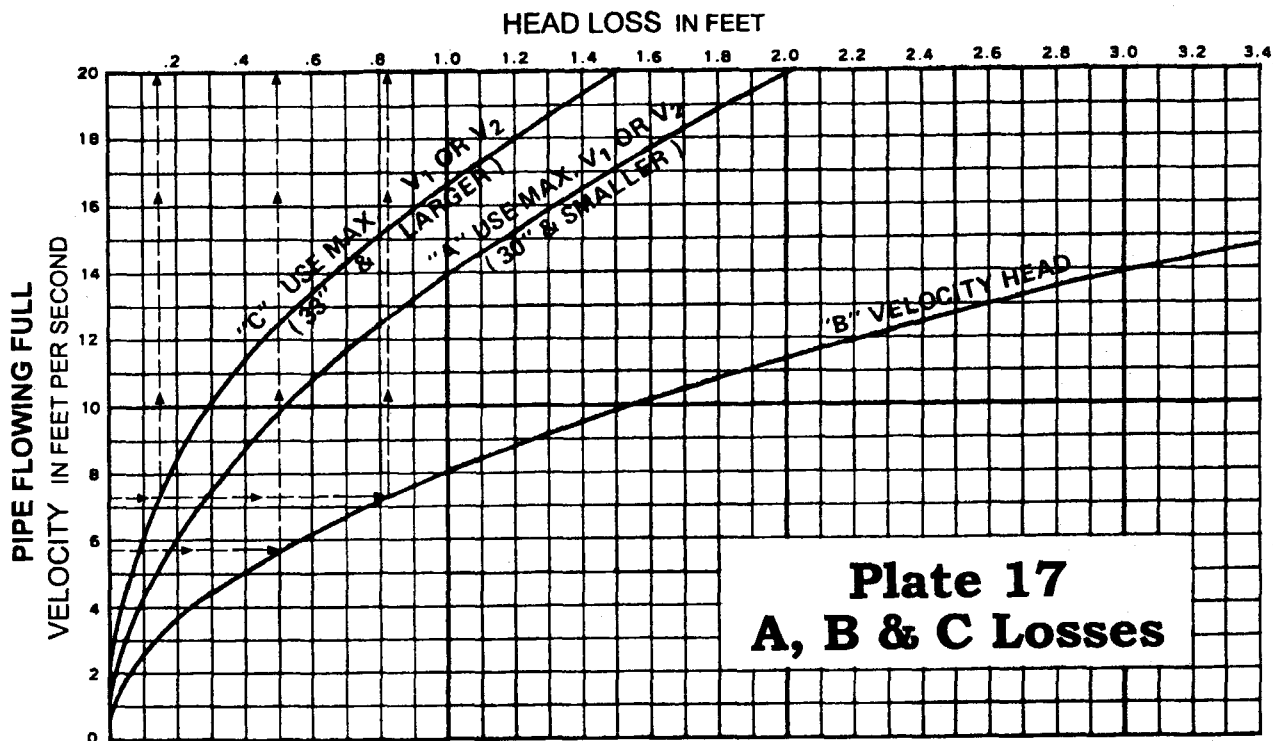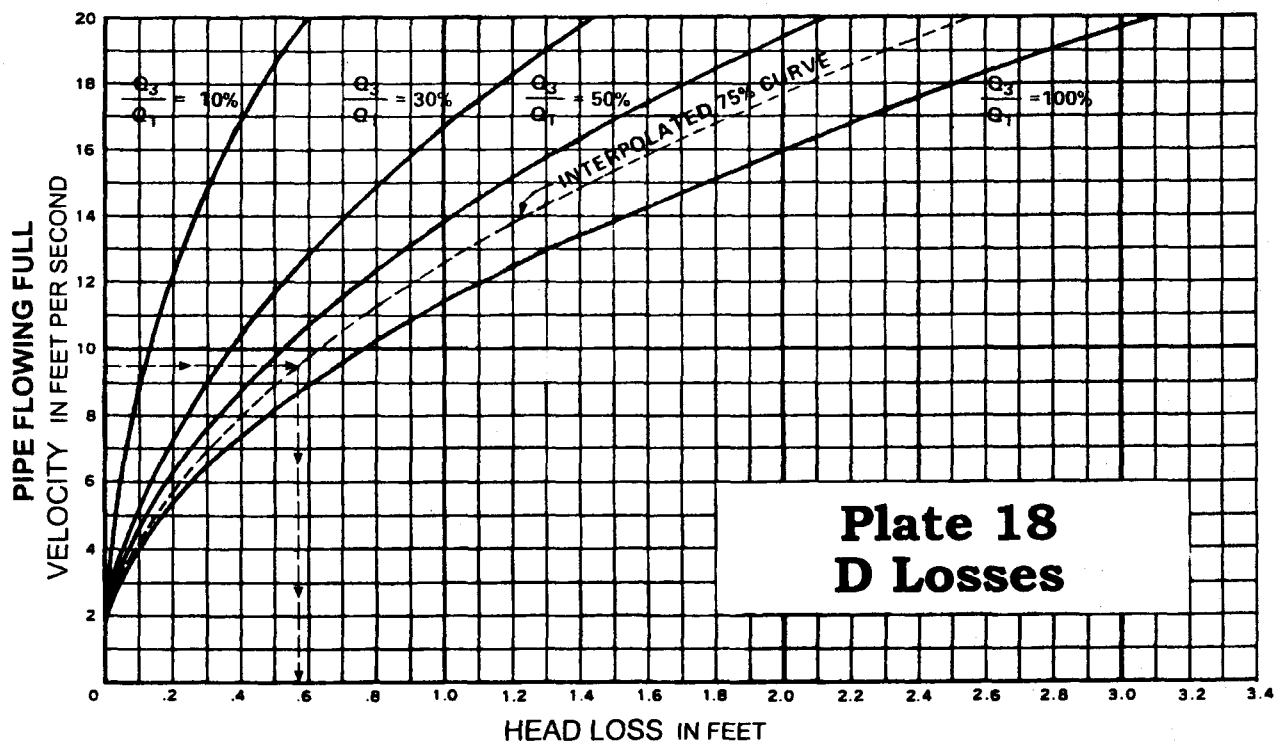
C. Flood Control Design

Example #2: Pipe System Analysis

Figure 1

EXAMPLE OF COMPUTATION

Q = 10 cfs
n = 0.013

Water Surface
Elevation = 100.00

DMH 4   100'   DMH 3   250'   DMH 2   200'   DMH 1

Q = 20 cfs
n = 0.013

Q = 30 cfs
n = 0.013

Q = 30 cfs
n = 0.013

115'

Q = 20 cfs
n = 0.013

INLET

Given: Runoff quantities, n, manholes and outlet condition as shown in Figure 1.

Determine: Pipe sizes and hydraulic gradient.
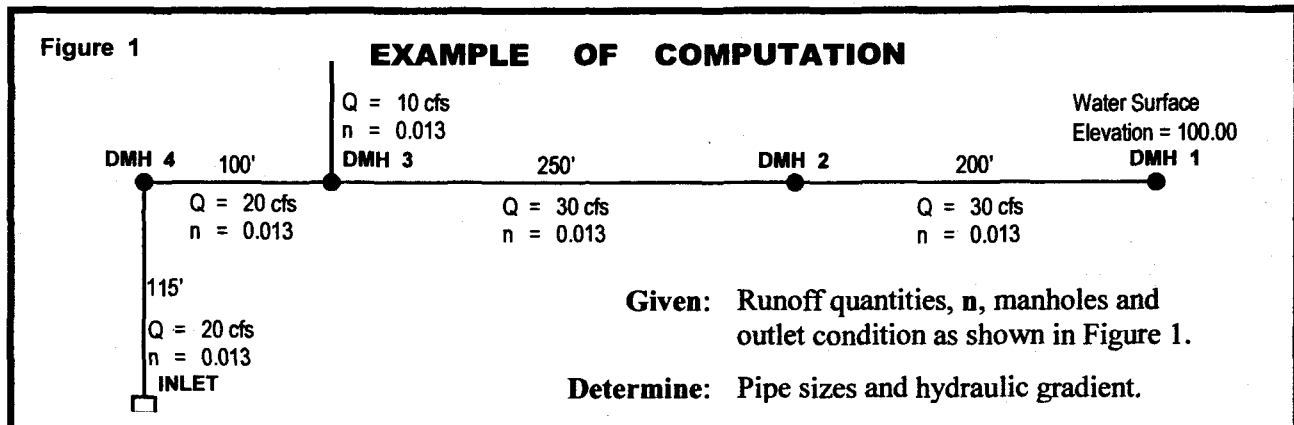
SOLUTION

USE PLATES 8 TO 20 AS AID TO ANALYSIS.

Make preliminary determination of pipe sizes for the data given using pipe flow charts. This is shown in Figure 2.

Using the pipe sizes and slopes of pipes as determined above, compute hydraulic gradient for the system. This is shown in Figure 3.

1. Controlling grade at DMH1 is 100.00 as shown in Figure 3.

   Study conditions of flow between manholes or inlets to determine if entrance control or losses govern hydraulic gradient.

2. With the selected pipe size between DMH 1 and DMH 2, 24" diameter pipe at S = 0.010, compute the head loss in the pipe by the formula h = SL or $h_f = S_f L$, whichever controls.

   h = elevation head loss
   h_f = friction head loss
   S = slope of pipe
   S_f = friction slope (used when pipe flowing full)
   L = length of the pipe or channel

   Since the pipe is flowing full, as determined by the pipe flow chart using 24" diameter, the friction slope 0.018 must be used. The head loss in the pipe is:

   $h_f = S_f L$
   $h_f = (0.018)(200) = 3.60$ feet

5

The downstream hydraulic gradient at DMH 2 is equal to the controlling grade at DMH 1 plus the head loss or

100.00 + 3.60 = 103.60

Figure 2

18" Conc. Pipe
D_n = 1.5 ft.
S = 0.038
V_F = 11.3 fps

DMH 4
INV. 113.80

18" Conc. Pipe
D_n = 1.5 ft.
S = 0.040
V_F = 11.3 fps

INLET
INV. 118.40

18" Conc. Pipe
D_n = 1.2 ft.
S = 0.010
V_F = 5.7 fps

DMH 3
INV. 110.00

24" Conc. Pipe
D_n = 1.2 ft.
S = 0.040
V_F = 9.5 fps

DMH 2
INV. 100.00

24" Conc. Pipe
D_n = 2.0 ft.
S = 0.010
V_F = 9.5 fps

DMH 1
INV. 98.00

NOTE: Velocities (V_F) shown are for pipe flowing full, which are to be used to calculate the manhole losses.
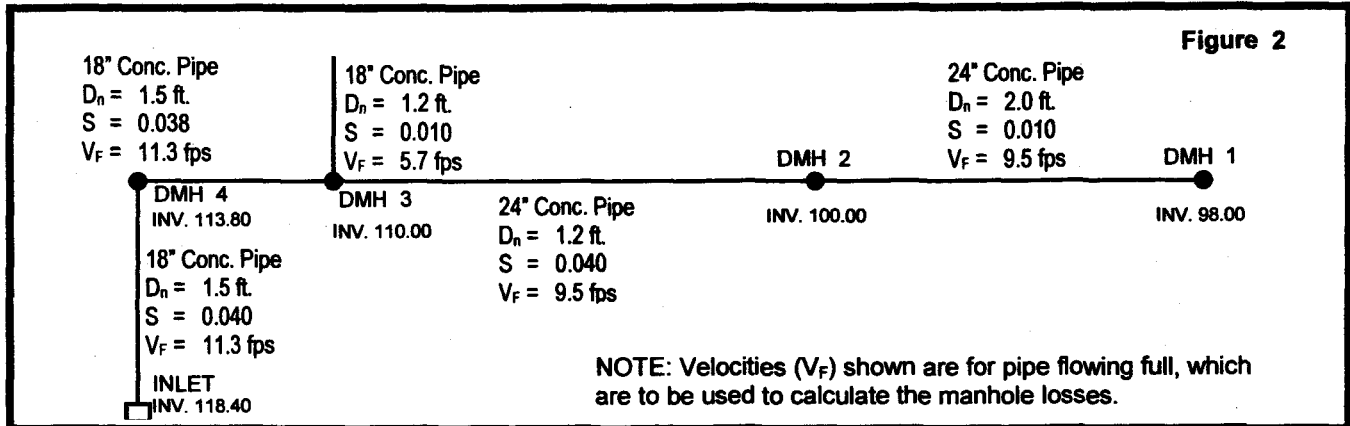
3. Since the pipe is flowing full, and there are no bends or drops, compute the upstream hydraulic gradient at DMH 2 by adding the manhole losses to the downstream hydraulic gradient at DMH 2. These values are obtained from charts on manhole losses. From the charts:

> **A = 0.47**
> **B = 0.00**   (since the velocities are equal)
> **C = 0.00**
> **D = 0.00**
> **0.47 ft. (Total DMH losses)**

The upstream hydraulic gradient at DMH 2 is:

103.60 + 0.47 = 104.07

Figure 3

125.02

120.65

119.19

115.39

INV. 118.40
INLET

INV. 113.80
DMH 4

111.20

INV. 110.00
DMH 3

HYDRAULIC GRADIENT

PIPE INVERT

104.07 103.60

INV. 100.00
DMH 2

100.00

INV. 98.00
DMH 1
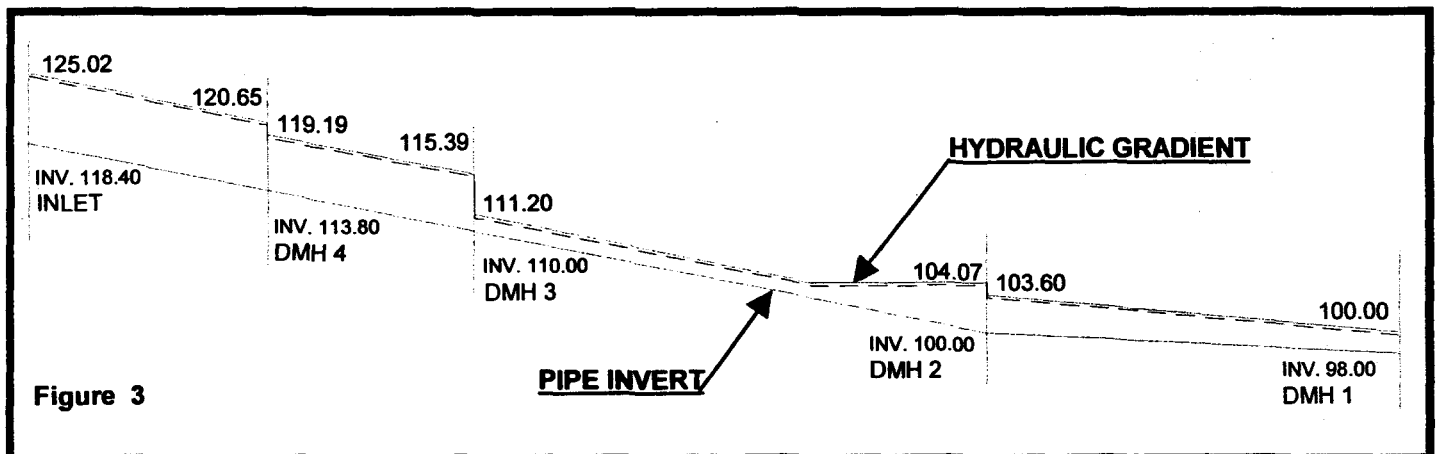
4. With the selected pipe size between DMH 2 and DMH 3, 24" diameter pipe at S = 0.040, compute the head loss elevation in the pipe:

h = SL
h = (0.040) (250) = 10.00 feet

Since the pipe is not flowing full as determined by the pipe flow chart, the elevation head loss and the normal depth must be added to the invert of DMH 2. Therefore, the downstream hydraulic gradient at DMH 3 is

100.00 + 10.00 + 1.20 = 111.20

5. Compute the upstream hydraulic gradient at DMH 3 by adding to the invert elevation the manhole losses and entrance control losses for open channel flow. Only manhole losses "C" and "D" need be considered.

From the charts:

C = 2(0.40) = 0.80   (90° Bend)
D   = 0.69
**   1.49 ft.   (Total DMH losses)**

Entrance control loss for Q = 30 cfs, D = 24" is:

H/D = 1.95, From Plate 19
H   = 3.90 feet

The upstream hydraulic gradient at DMH 3 is:

110.00 + 1.49 + 3.90 = 115.39

6. With selected pipe size between DMH 3 and DMH 4, 18" diameter pipe at S = 0.038, compute the head loss in the pipe:

h$_f$ = S$_f$L
h$_f$ = (0.038) (100) = 3.80 feet

The downstream hydraulic gradient at DMH 4 is:

115.39 + 3.80 = 119.19

since the tailwater condition of the pipe is submerged.

7. Since there is a bend greater than 10° at DMH 4, compare losses and use the higher HGL.

A = 0.66   C = 0.80
B = 0.00   D = 0.00
C = 0.80 (0.40 x 2)   0.80
D = 0.00
   1.46

Entrance control loss for Q = 20 cfs, D = 18" is:

H/D = 3.0 From Plate 19
H   = 4.50
119.19 + 1.46 = 120.65 > 113.80 + 4.50 + 0.80 = 119.10

The upstream hydraulic gradient at DMH 4 is 120.65.

8. Since the pipe is flowing full, the downstream hydraulic gradient at the inlet is determined by friction loss in the length of pipe.

$h_f = S_f L$
h_f = (0.038) (115) = 4.37 feet
120.65 + 4.37 = 125.02

Entrance control loss at the inlet for Q = 20 cfs, D = 18" is:

H/D = 3.0 From Plate 19
H   = 4.50
118.40 + 4.50 = 122.90

Since the hydraulic gradient is higher, the top of headwall must be at least 125.02 + 1 foot = 126.02.

Adjust pipe sizes if warranted by the hydraulic gradient as computed above.

														Manhole Losses					Hydraulic Grade Elev.			
Inlet	T_c	C	I / i	Drain Area	Q Runoff / Accum Q	d_n	V_F	Size of Pipe	Length of Seg.	S_f	s	Invert Elevation	H_f	A	B	C	D	Ent. Cont.	Down	Up	Finished Grade Elevation	Remark
DMH 1												98.00								100.00		
				10	30	2.0	9.5	24	200	.018	.010		3.60					3.80	103.60			
DMH 2												100.00		.47	0	0	0	3.80		104.07		
				10	30	1.2	9.5	24	250	.018	.040		4.50						111.20			
DMH 3												110.00		.66	0	.80	.69	3.90		115.39		
				7	20	1.5	11.3	18	100	.038	.038		3.80						119.19			
DMH 4												113.80		.66	0	.80	0	4.35		120.65		
				7	20	1.5	11.3	18	115	.038	.040		4.37						125.02			
INLET												118.40										

PROJECT: XYZ Subdivision
DRAIN LINE A

DRAINAGE DESIGN DATA

DATE: 10/28/85
COMPUTED BY: TM
CHECKED BY: LW

Suggested layout of tabulated computation form for DRAINAGE DESIGN DATA to be submitted for approval

18" Conc. Pipe

D_n = 1.2 ft.
Dr. Area = 3 ac.
Q = 10 cfs
n = 0.013
S = 0.010
V_F = 5.7 fps

DMH 4 **DMH 3** **DMH 2** **DMH 1**

18" Conc. Pipe

D_n = 1.5 ft.
Dr. Area = 7 ac.
Q = 20 cfs
n = 0.013
S = 0.040
V_F = 11.3 fps

18" Conc. Pipe

D_n = 1.5 ft.
Dr. Area = 7 ac.
Q = 20 cfs
n = 0.013
S = 0.038
V_F = 11.3 fps

24" Conc. Pipe

D_n = 1.2 ft.
Dr. Area = 10 ac.
Q = 30 cfs
n = 0.013
S = 0.040
V_F = 9.5 fps

24" Conc. Pipe

D_n = 2.0 ft.
Dr. Area = 10 ac.
Q = 30 cfs
n = 0.013
S = 0.010
V_F = 9.5 fps

INLET

EXISTING DITCH

PLAN

Scale: 1" = 100'

130   130

EXISTING GROUND ALONG C/L
NEW DRAIN PIPE

120   120

CURB GRADE

18" RCP Cl. III
115' @ 4%

110   110

18" RCP Cl. III
100' @ 3.8%

EXISTING GROUND LINE

0 + 00   1 + 15   2 + 15

24" RCP Cl. III   250' @ 4%

HYDRAULIC GRADIENT

100   100

INLET   DMH 4   DMH 3   PIPE INVERT   24" RCP Cl. III   200' @ 1%

118.40   113.80   110.00

4 + 65   6 + 65

DMH 2   DMH 1

100.00   98.00

PROFILE

Horizontal Scale: 1" = 100'
Vertical Scale: 1" = 10'

10

EXAMPLE 1, 6.22 ACRE RESIDENTIAL DEVELOPMENT

A 6.22-acre site will be developed for the future construction of 22 single family residential houses.   The site is divided into two drainage areas, as shown in Figure 1.

FIGURE1: EXAMPLE 1 DEVELOPMENT PLAN

Based on the size, the project meets the criteria of a Priority A1 new development project and requires preparation of a storm water quality report (SWQR). As specified in Section B.6 of §1-5.1 Part I, water quality criteria shall be achieved with LID Site Design, Source Control, LID Retention, LID Biofiltration (if LID Retention is infeasible), and Alternative Compliance (if LID Retention and LID Biofiltration are infeasible). Implementation of each of these five elements for this example is presented below.

A. LID SITE DESIGN

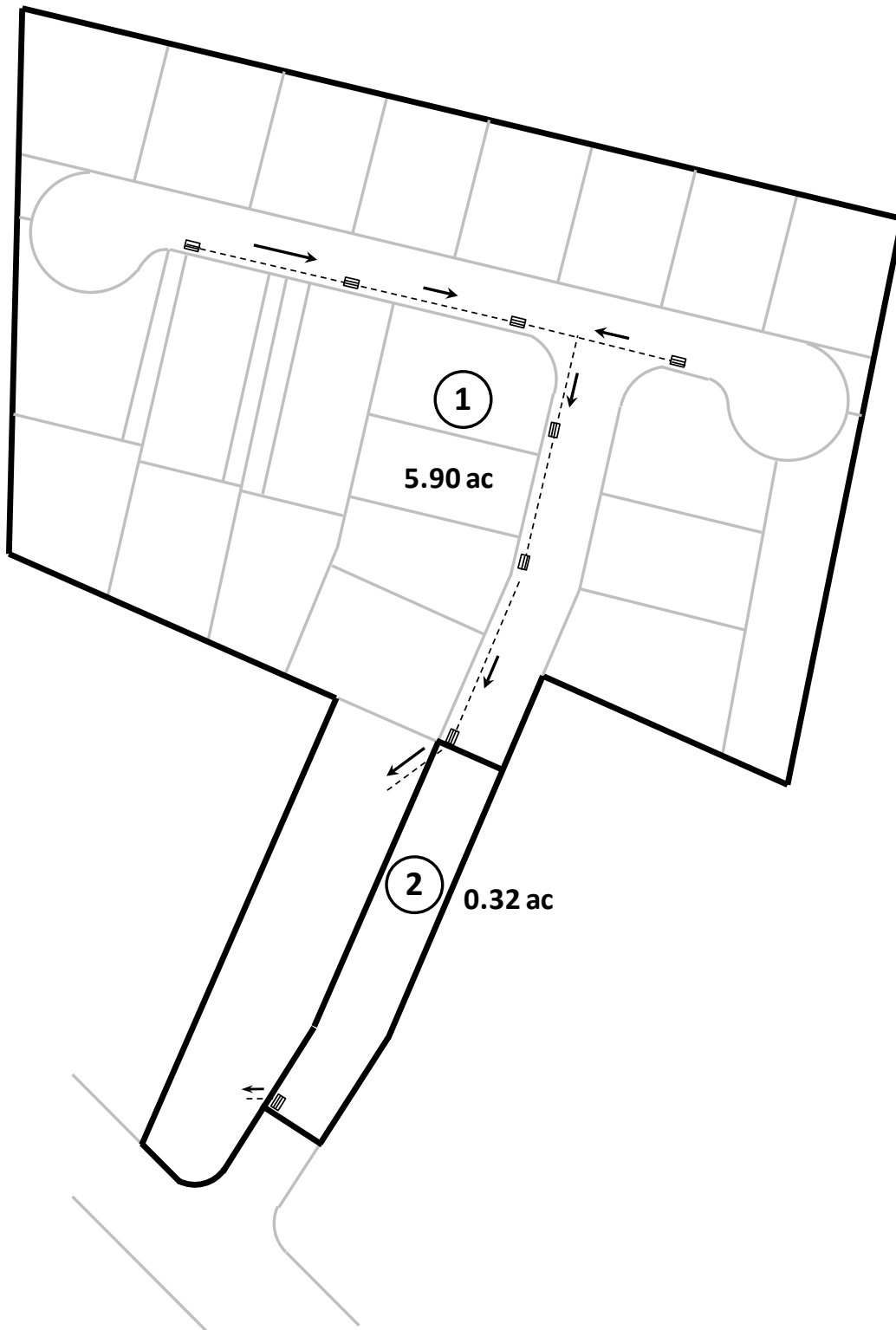The *City and County of Honolulu Storm Water BMP Guide* (*BMP Guide*) identifies 5 LID Site Design Strategies for new development and redevelopment projects. Those that are applicable to this project will be implemented.

B. SOURCE CONTROL

The *BMP Guide* identifies 12 Source Control BMPs for new development and redevelopment projects. Those that are applicable to this project will be implemented.

C. LID RETENTION

Assume for purposes of this example that retention is feasible. Although many, if not all, of the 7 LID Retention BMPs identified in the *BMP Guide* may be implemented, details for an Infiltration Basin are presented below.

Assume that a single Infiltration Basin will be used for both drainage areas (see Figure 2). The sizing of the Infiltration Basin is accomplished using the City's BMP sizing worksheet, which is consistent with the Step-by-Step Sizing Procedure provided in the *BMP Guide*. The sizing worksheet is presented in Figure 3, and the calculations are summarized as follows:

1. Water Quality Volume (WQV). For purposes of this example, assume 70% impervious cover. Using a 1-inch design storm depth, the WQV for 6.22 acres is calculated to be 15,353 cubic feet.

2. Maximum allowable storage depth. For purposes of this example, assume a soil infiltration rate of 1.5 in/hr and an infiltration rate safety factor of 2. Using a drawdown time of 48 hours, the maximum allowable storage depth is calculated to be 3.0 feet.

3. Design storage depth. The ponding depth is set to 3 feet, which is equal to or less than the maximum allowable storage depth.

4. Basin invert footprint. Using a basin fill time of 2 hours (industry accepted practice), the required invert surface area is calculated to be 4,913 square feet.

5. BMP area requirements. The invert width is set to 25 feet, and the invert length is calculated to be 196.5 feet. Using a side slope of 3:1 and a freeboard depth of 1 foot (actual free board requirements must be determined for flood design storm), the top width and top length are calculated to be 49 feet and 220.5 feet, respectively. The total area, excluding pretreatment, is calculated to be 10,806 square feet.

The BMP layout and BMP details are presented in Figures 2 and 4, respectively. The Infiltration Basin will have two inlet points; one at the eastern end capturing 5.90 acres of roadway and residential lot runoff, and one at the western end capturing 0.32 acres of roadway runoff.

BMP Sizing Assumptions

Tributary Area	6.22 ac
Impervious Cover	70%
Design Storm Depth	1 in
Infiltration Rate	1.5 in/hr
Infiltration Rate Safety Factor	2
Basin Drawdown Time	48 hrs
Basin Fill Time	2 hrs

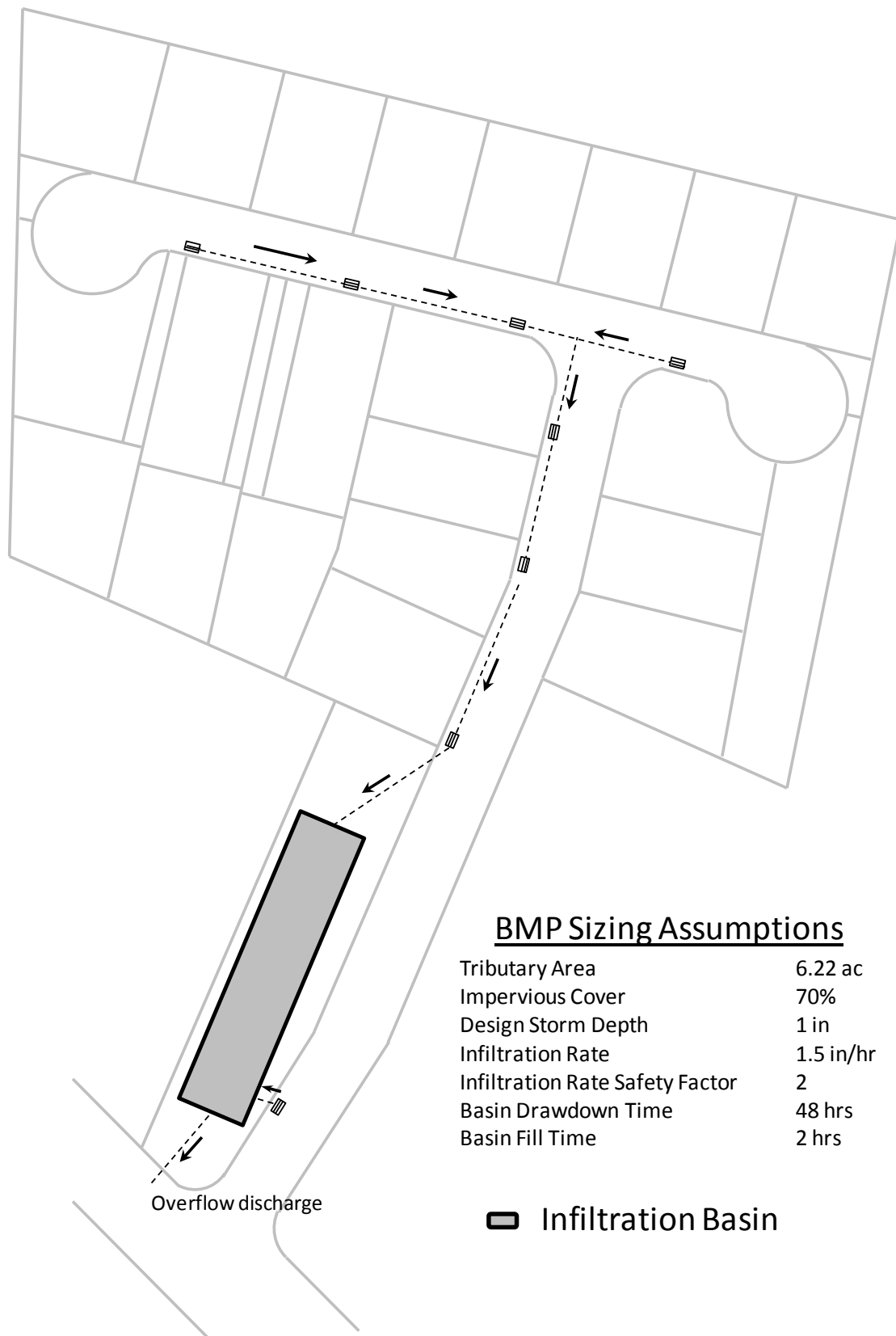Overflow discharge

▢ Infiltration Basin

FIGURE 2: BMP LAYOUT, RETENTION

BMP Sizing Worksheet: Infiltration Basin

Project: 6.22 ac Residential Development   **Date:** July 2012

1. Water Quality Volume

a.	BMP Tributary Drainage Area, **A**	6.22	ac
b.	% Impervious Area, **I**	70	%
c.	Water Quality Design Storm Depth, **P**	1.0	in
d.	Volumetric Runoff Coefficient, **C**	0.68	
e.	Water Quality Volume, **WQV**	15,353	cu-ft

2. Maximum Storage Depth

a.	Soil Infiltration Rate, **k** (0.5 min)	1.5	in/hr
b.	Infiltration Rate Safety Factor (2 - 5), **F$_s$**	2	
c.	Drawdown Time, **t**	48	hrs
d.	Max. Storage Depth, **d$_{max}$**	3.0	ft

3. Design Storage Depth

a.	Ponding Depth, **d$_p$**	3.00	ft

4. Basin Invert Footprint

b.	Reservoir Fill Time, **T**	2	hrs
c.	Min. Bottom Surface Area, **A$_b$**	4,913	sq-ft

5. BMP Area Requirements

a.	Side Slopes (length per unit height), **z** (3.0 min)	3	
b.	Freeboard, **f** (1.0 min)	1	ft
c.	Invert Width, **w$_b$**	25.0	ft
d.	Invert Length, **l$_b$**	196.5	ft
e.	Top Width, **w$_t$**	49.0	ft
f.	Top Length, **l$_t$**	220.5	ft
g.	Min. Top Surface Area excluding pretreatment, **A$_{BMP}$**	10,806	sq-ft

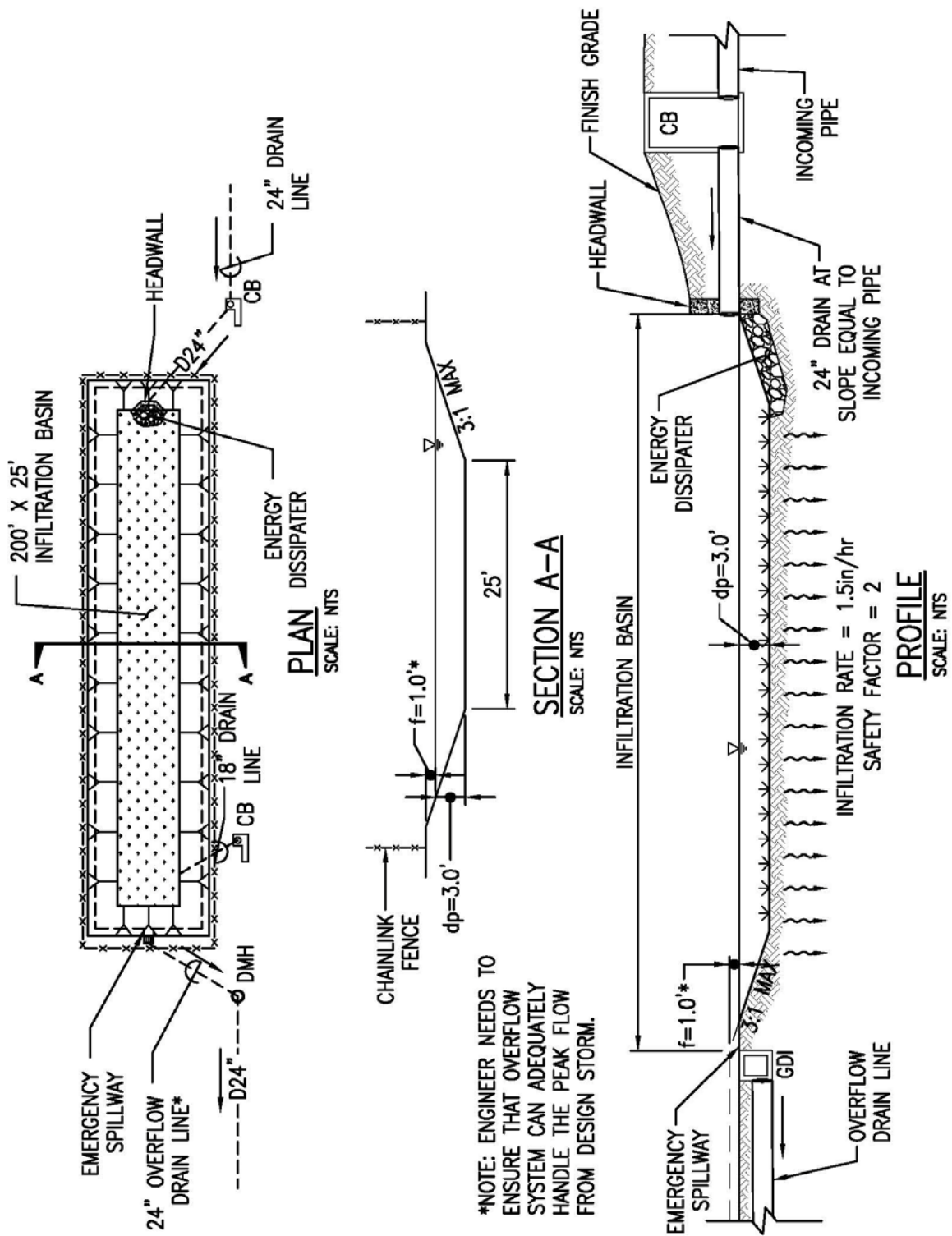**FIGURE 3: INFILTRATION BASIN SIZING WORKSHEET**

FIGURE 4: BMP DETAILS, RETENTION

D. LID BIOFILTRATION

For purposes of this example, assume that retention is determined to be infeasible, but biofiltration is feasible. Of the 7 LID Biofiltration BMPs identified in the *BMP Guide*, the water quality criteria may be met by biofiltering the runoff from both drainage areas with a Vegetated Swale. See Figure 5 for the proposed layout.

The sizing of the Vegetated Swale is accomplished using the City's BMP sizing worksheet, which is consistent with the Step-by-Step Sizing Procedure provided in the *BMP Guide*. The sizing worksheet is presented in Figure 6, and the calculations are summarized as follows:

1. Water Quality Flow Rate (WQF). For purposes of this example, assume a weighted runoff coefficient of 0.7. Using a rainfall intensity of 0.4 in/hr, the WQF for 6.22 acres is calculated to be 1.74 cfs.

2. Swale geometry. The bottom width, depth of flow, side slope, longitudinal slope, and Manning's roughness coefficient are set to 7 feet, 4 inches, 3, 4%, and 0.20, respectively.

3. Swale hydraulic capacity. Using the dimensions from step 2, the cross sectional area, wetted perimeter, and hydraulic radius are calculated to be 2.67 sq-ft, 9.11 ft, and 0.29 ft. The design flow rate is calculated to be 1.75 cfs, which is equal to or greater than the WQF.

4. Design flow velocity. The design flow velocity is calculated to be 0.66 feet per second, which is less than the minimum allowed velocity of 1 foot per second.

5. Swale length. Using a hydraulic residence time of 7 minutes, the swale length is calculated to be 276 feet.

6. BMP area requirements. Using 6 inches of freeboard, the required total surface area is calculated to be 3,310 sq-ft. At 276 feet long, this equates to a top width of 12 feet.

The vegetated swale does not require pretreatment, as specified in the *BMP Guide*. The BMP details for the vegetated swale are presented in Figure 7.

E. ALTERNATIVE COMPLIANCE

If LID Retention and LID Biofiltration are determined to be infeasible, alternative compliance would be required. Options include treating the runoff with Other Treatment Control BMPs identified in the BMP Guide (detention basin, manufactured treatment device, sand filter, etc.).

BMP Sizing Assumptions

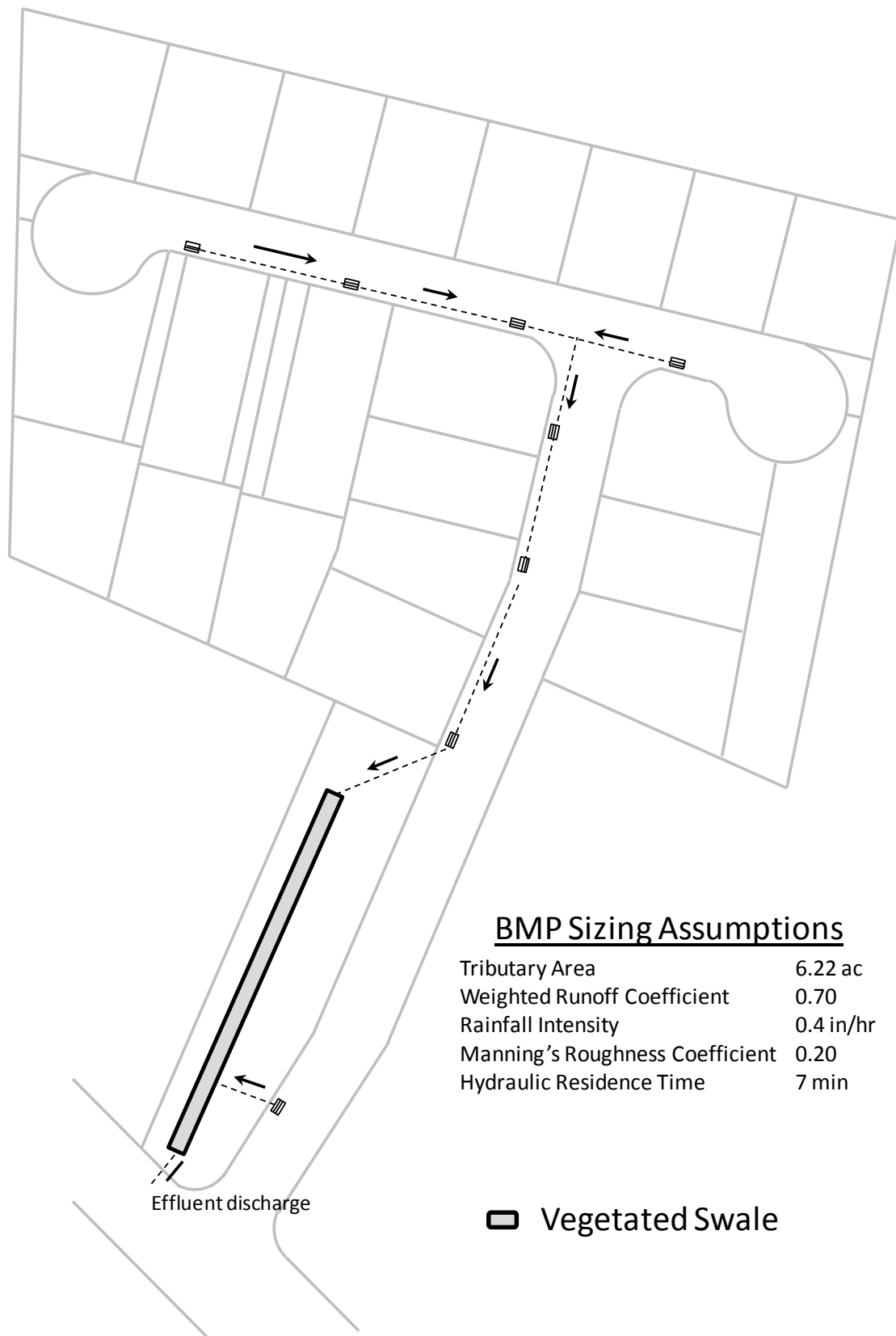|	
Tributary Area	6.22 ac
Weighted Runoff Coefficient	0.70
Rainfall Intensity	0.4 in/hr
Manning's Roughness Coefficient	0.20
Hydraulic Residence Time	7 min

Effluent discharge

☐ Vegetated Swale

FIGURE 5: BMP LAYOUT, BIOFILTRATION

BMP Sizing Worksheet: Vegetated Swale

Project: 6.22 ac Residential Development   **Date:** July 2012

1. Water Quality Flow Rate			
a. BMP Tributary Drainage Area, **A**		6.22	ac
b. Weighted Runoff Coefficient, **C**		0.7	
c. Rainfall Intensity, **i**		0.4	in/hr
d. Water Quality Flow Rate, **WQF**		1.74	cfs
2. Swale Geometry			
a. Bottom Width, **b** (10.0 ft max)		7.00	ft
b. Flow Depth, **y** (4.0 in max)		4.0	in
c. Side Slopes (length per unit height), **z** (3.0 max)		3	ft/ft
d. Longitudinal Slope, **s**		4.0	%
e. Manning's Roughness Coefficient, **n**		0.20	
3. Swale Hydraulic Capacity			
a. Cross-sectional Area @ Flow Depth, **A**		2.67	sq-ft
b. Wetted Perimeter, **WP**		9.11	ft
c. Hydraulic Radius, **R**		0.29	ft
d. Calculated Flow Rate, **Q**		1.75	cfs
4. Design Flow Velocity			
a. Design Flow Velocity, **V** (1.0 fps max)		0.66	fps
5. Swale Length			
a. Hydraulic Residence Time, **T** (7.0 min)		7	min
b. Minimum Length, **L**		276	ft
6. BMP Area Requirements			
a. Freeboard, **f** (6 min)		6	in
b. Embankment Top Surface Area, A_{BMP}		3,310	sq-ft

FIGURE 6: VEGETATED SWALE SIZING WORKSHEET

24" DRAIN LINE

CB

D24"

276' x 7'
VEGETATED SWALE
SLOPE = 4.0%

A
A

PLAN
SCALE: NTS

18" DRAIN
LINE

CB

24" OVERFLOW
DRAIN LINE*

D24"

DMH

*NOTE: ENGINEER NEEDS TO
ENSURE THAT OVERFLOW SYSTEM
CAN ADEQUATELY HANDLE THE PEAK
FLOW FROM DESIGN STORM.

3:1 MAX

f=6"*

7'

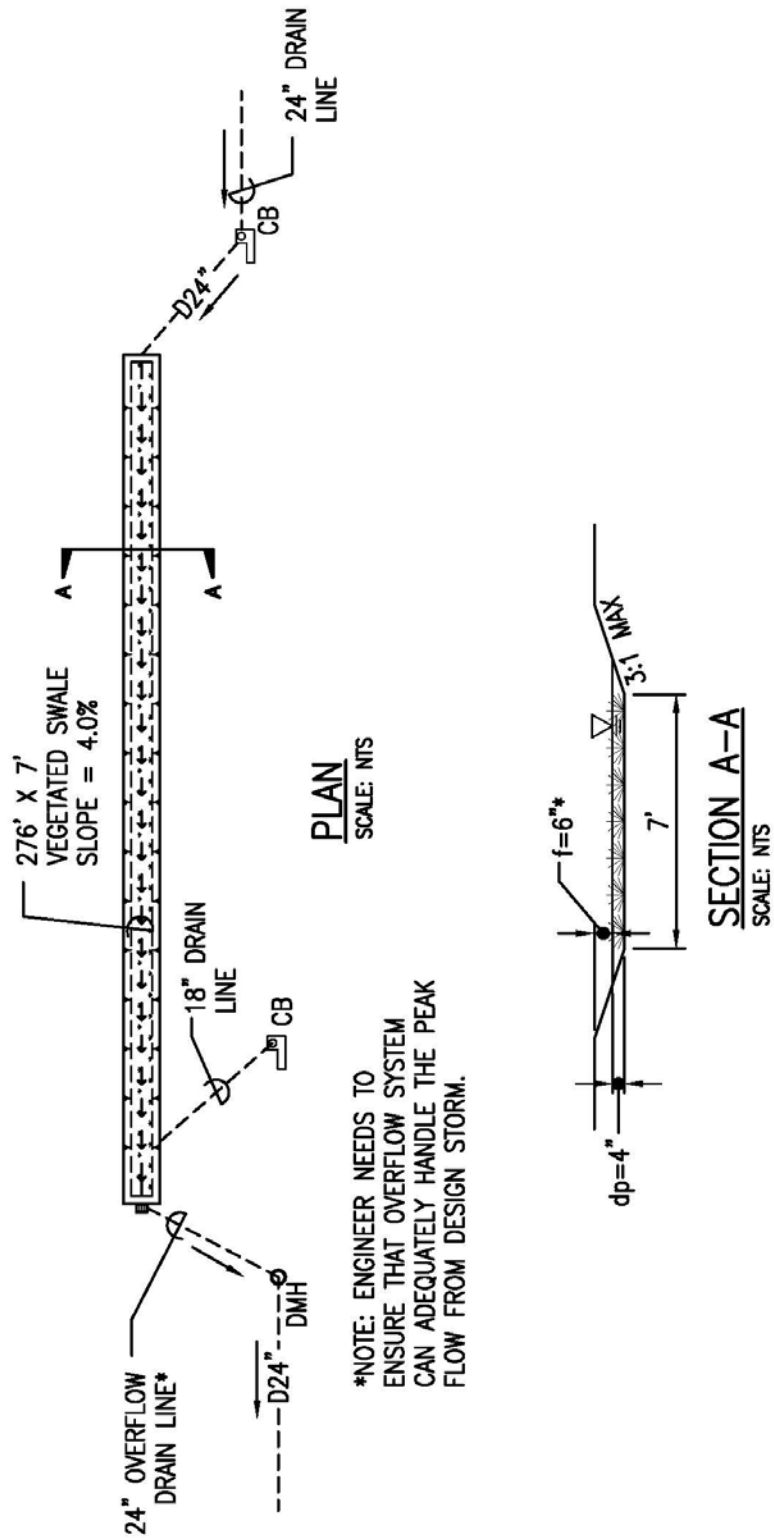dp=4"

SECTION A—A
SCALE: NTS

FIGURE 7: BMP DETAILS, BIOFILTRATION

EXAMPLE 2, 3.44 ACRE COMMERCIAL DEVELOPMENT

A 3.44-acre site will be developed for the construction of a commercial development of 4 retail establishments.   The site is divided into 7 drainage areas, as shown in Figure 1.
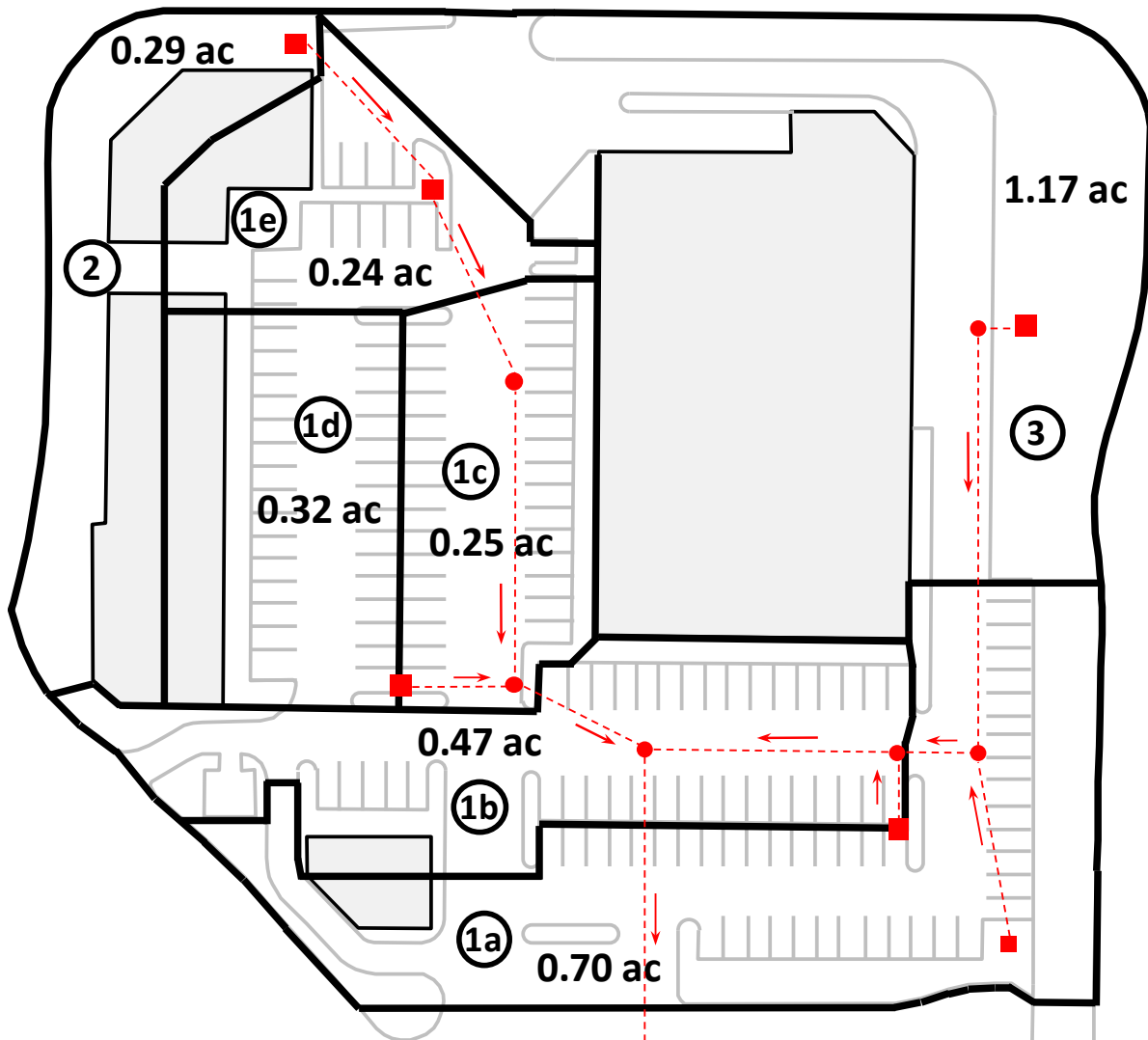

FIGURE 1: EXAMPLE 2 DEVELOPMENT PLAN

Based on the size, the project meets the criteria of a Priority A2 new development project and requires preparation of a storm water quality checklist (SWQC). As specified in Section B.6 of §1-5.1 Part I, water quality criteria shall be achieved with LID Site Design, Source Control, LID Retention or LID Biofiltration, and Alternative Compliance (if necessary). Implementation of each of these four elements for this example is presented below. References to specific proprietary products should not be interpreted as an endorsement of those products.

A. LID SITE DESIGN

The *City and County of Honolulu Storm Water BMP Guide* (*BMP Guide*) identifies 5 LID Site Design Strategies for new development and redevelopment projects.   Those that are applicable to this project will be implemented.

B. SOURCE CONTROL

The *BMP Guide* identifies 12 Source Control BMPs for new development and redevelopment projects. Those that are applicable to this project will be implemented.

C. LID RETENTION OR BIOFILTRATION

Retention or biofiltration requirements are presented for each drainage area individually, as each drainage area has its own characteristics and options.

C.1 Drainage Area 1

Drainage Area 1 is composed of 5 subareas as shown in Figure 1. The runoff from each subarea may be retained with permeable pavement if retention is feasible (see Figure 2), or biofiltered with a vegetated bio-filter (see Figure 3). The sizing of both BMPs is accomplished using the City's BMP sizing worksheets, which are consistent with the Step-by-Step Sizing Procedures provided in the *BMP Guide*.

Permeable Pavement. The BMP sizing worksheet for Drainage Area 1a is presented in Figure 4, and the calculations are summarized as follows:

1. Water Quality Volume (WQV). Assuming 70% impervious cover, and using a 1-inch design storm depth, the WQV is calculated to be 1,957 cubic feet.

2. Maximum allowable storage depth. For illustration purposes, assume a soil infiltration rate of 1.5 in/hr and an infiltration rate factor of safety of 2. Using a drawdown time of 48 hours, the maximum allowable storage depth is calculated to be 3.0 feet.

3. Design depths. The pavement course and reservoir course are set to 7 inches and 36 inches, respectively. Using a pavement course porosity of 0.15 and a reservoir course porosity of 0.35, the total effective water storage depth is calculated to be 1.14 feet, which is equal to or less than the maximum allowable storage depth.

4. Pavement surface area. Using a fill time of 2 hours, the required surface area is calculated to be 1,550 square feet.

The length of the permeable pavement is set to the length of the corresponding parking area, and the width is then calculated using the required surface area. This results in a width of 6.48 feet. The necessary length will achieved with two sections, one for each parking area.

The calculations for the other 4 subareas follow the same steps using the same design parameters for constructability and consistency. A summary is as follows:

Subarea ID	Drainage Area (ac)	% Impervious Cover	WQV (cu-ft)	Surface Area (sq-ft)	Length (ft)	Width (ft)
1a	0.70	70%	1,957	1,550	239	6.48
1b	0.47	95%	1,544	1,223	140	8.74
1c	0.25	95%	821	651	140	4.65
1d	0.32	95%	1,051	833	140	5.95
1e	0.24	90%	749	593	87	6.82

BMP Details are presented in Figure 5.
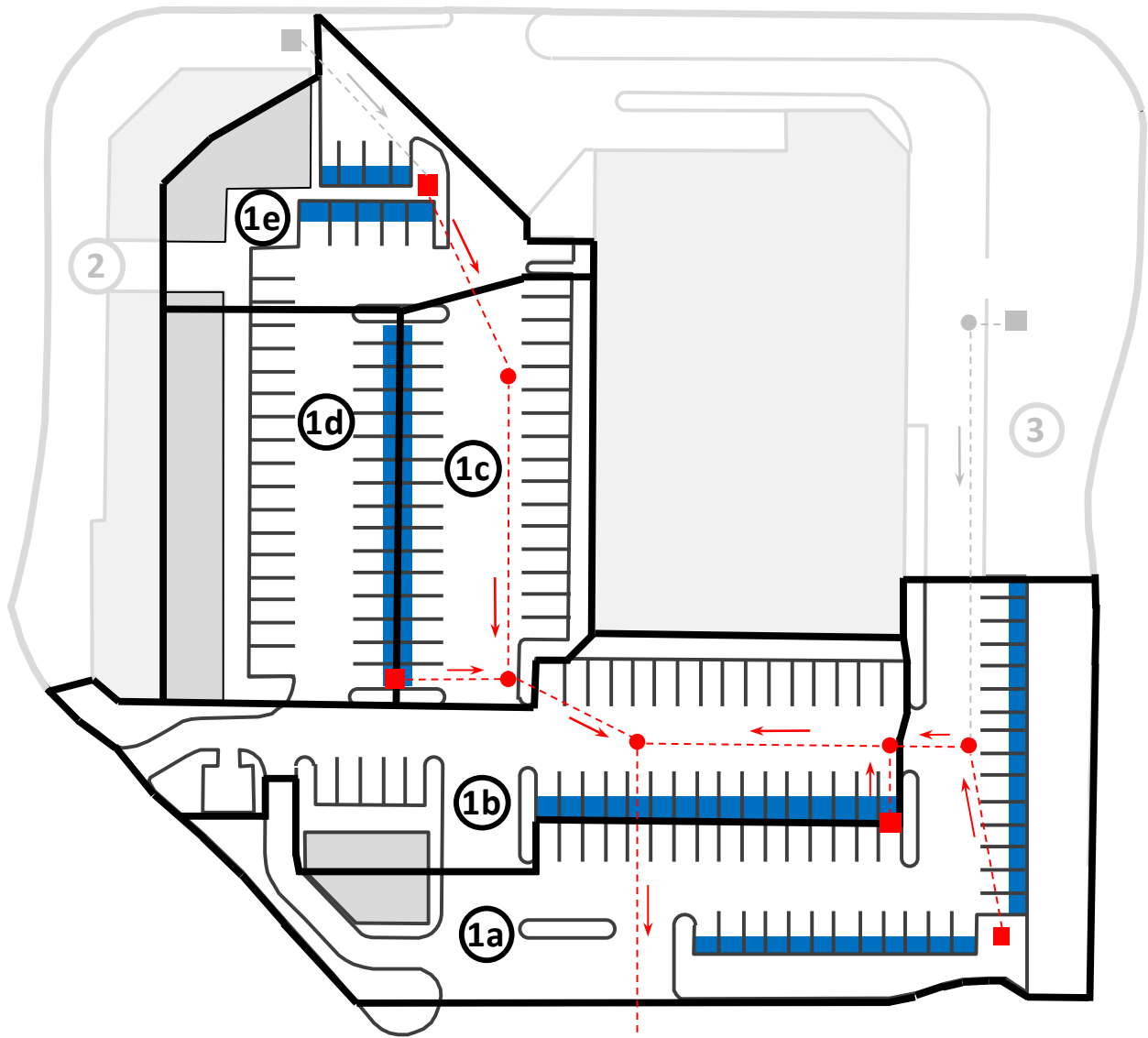
Permeable Pavement Design Parameters

Design Storm Depth	1 in
Infiltration Rate	1.5 in/hr
Infiltration Rate Safety Factor	2
Drawdown Time	48 hrs
Pavement Course Thickness	7 in
Reservoir Course Thickness	36 in

FIGURE 2: BMP LAYOUT 1, DRAINAGE AREA 1
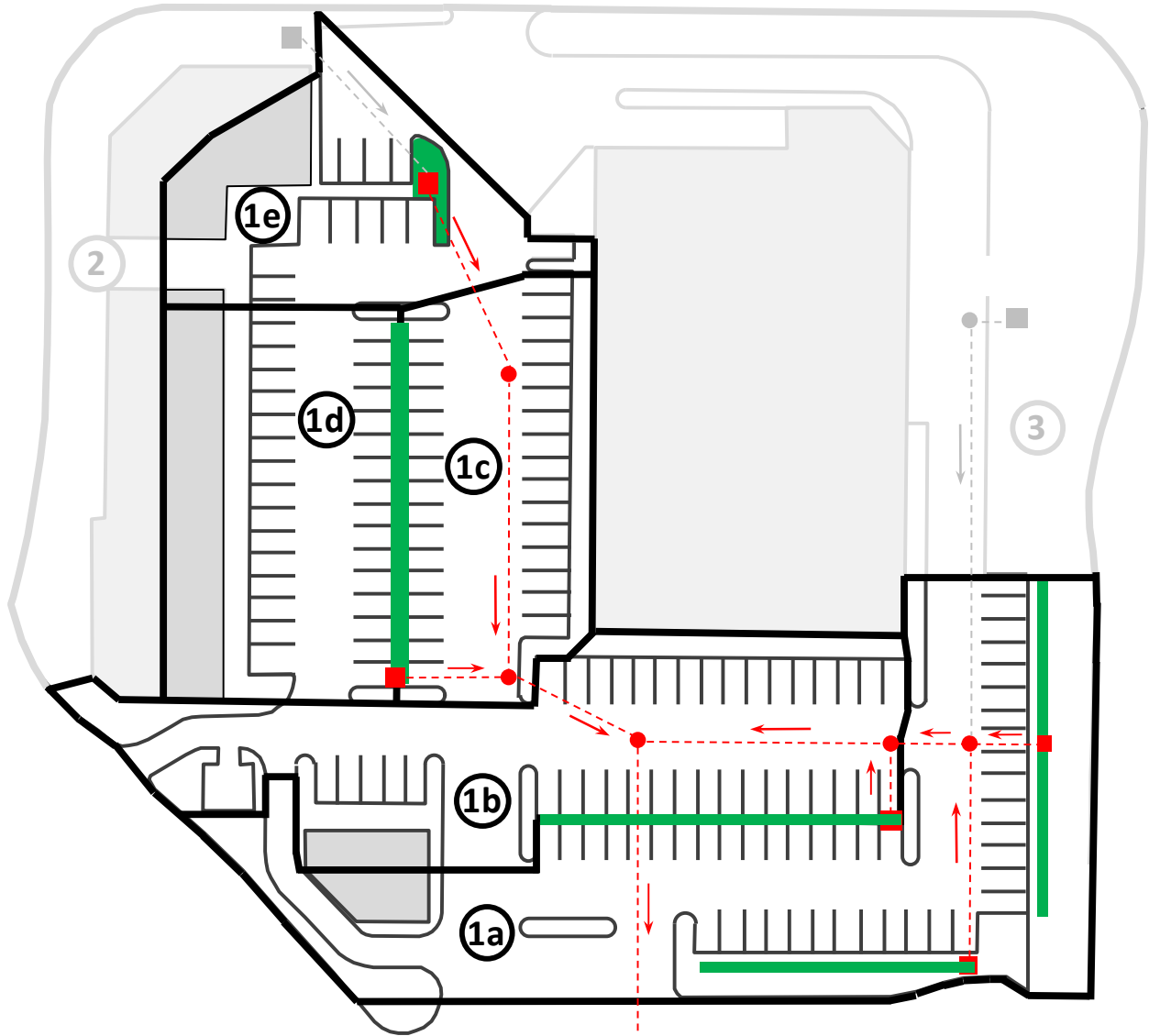
Vegetated Bio-Filter Design Parameters

Design Storm Depth	1 in
Planting Media Thickness	2 ft
Maximum Ponding Depth	4 in
Filter Bed Drain Time	48 hrs

FIGURE 3: BMP LAYOUT 2, DRAINAGE AREA 1

1. Water Quality Volume

a. BMP Tributary Drainage Area, **A**   0.70   ac

b. % Impervious Area, **I**   80   %

c. Water Quality Design Storm Depth, **P**   1.0   in

d. Volumetric Runoff Coefficient, **C**   0.77

e. Water Quality Volume, **WQV**   1,957   cu-ft

2. Maximum Storage Depth

a. Soil Infiltration Rate, **k** (0.5 min)   1.5   in/hr

b. Infiltration Rate Safety Factor (2 - 5), F_s 2

c. Drawdown Time, **t**   48   hrs

d. Max. Storage Depth, d_{max} 3.0   ft

3. Design Storage Depths

a. Pavement Course Thickness, l_p 7.0   in

b. Reservoir Course Thickness, l_r 36.0   in

c. Pavement Course Porosity, n_p 0.15

d. Reservoir Course Porosity, n_r 0.35

e. Total Effective Storage Depth, d_t 1.14   ft

4. BMP Area Requirements

a. Fill Time, **T**   2   hrs

b. Min. Surface Area, A_{BMP} 1,550   sq-ft

FIGURE 4: PERMEABLE PAVEMENT SIZING WORKSHEET (DA 1A)

ASPHALT PAVEMENT/PORTLAND CEMENT CONCRETE

PERMEABLE PAVEMENT THICKNESS, Ip = 7.0 in

RESERVOIR COURSE THICKNESS, Ir = 36 in

SOIL INFILTRATION RATE, k = 1.5 in/hr SAFETY FACTOR, SF = 2

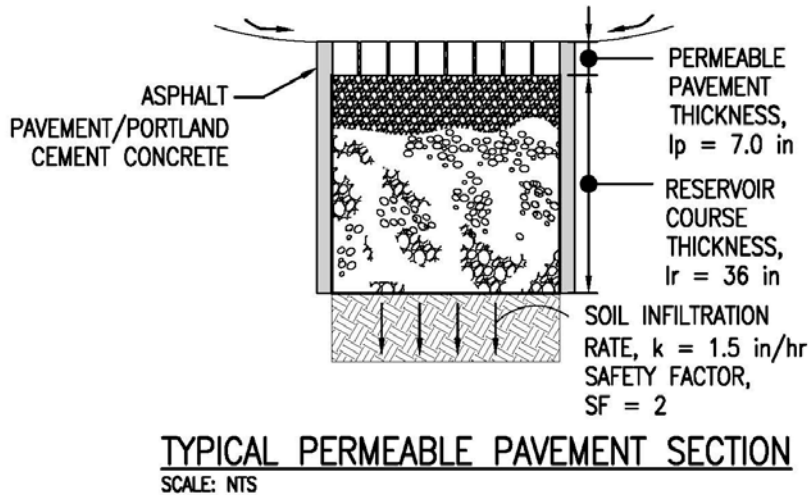TYPICAL PERMEABLE PAVEMENT SECTION
SCALE: NTS

FIGURE 5: PERMEABLE PAVEMENT DETAILS

Vegetated Bio-Filter. The BMP sizing worksheet for Drainage Area 1a is presented in Figure 6, and the calculations are summarized as follows:

1. Water Quality Volume (WQV). The WQV is the same as that given above for the permeable pavement option.

2. Design depths. The planting media depth and maximum ponding depth are set to 2 feet and 4 inches, respectively.

3. Filter bed surface area. Using a planting media permeability coefficient of 1 ft/day and a filter bed drain time of 48 hours, the required filter bed surface area, excluding pretreatment, is calculated to be 903 square feet.

4. Filter bed dimensions. The width of the filter bed is set such that the resulting length occupies the length of the respective parking areas. Using this approach, the filter bed width is set to 3.75 feet.

5. Total Area. Using an embankment side slope of 0 and 3 inches of freeboard, the total BMP areas are the same as the filter bed surface area. Similarly to the retention option, the Vegetated Bio-Filter will be divided into two sections.

The calculations for the other 4 subareas follow the same steps using the same design parameters for constructability and consistency. A summary of all 5 subareas is as follows:

Subarea ID	Drainage Area (ac)	% Impervious Cover	WQV (cu-ft)	Surface Area (sq-ft)	Length (ft)	Width (ft)
1a	0.70	70%	1,957	903	239	3.78
1b	0.47	95%	1,544	713	140	5.09
1c	0.25	95%	821	379	140	2.71
1d	0.32	95%	1,051	485	140	3.47
1e	0.24	90%	749	346	37	13

Not that for Drainage Area 1e, the length and width given above represent maximum values since the BMP area is an irregular shape (i.e., not rectangular). For this reason, the length times the width does not equal the required surface area. BMP details are presented in Figure 7.

1. Water Quality Volume

a.	BMP Tributary Drainage Area, **A**	0.70	ac
b.	% Impervious Area, **I**	80	%
c.	Water Quality Design Storm Depth, **P**	1.0	in
d.	Volumetric Runoff Coefficient, **C**	0.77	
e.	Water Quality Volume, **WQV**	1,957	cu-ft

2. Filter Bed Surface Area

a.	Planting Media Depth, l_m (2.0 - 5.0 ft)	2.0	ft
b.	Maximum Ponding Depth, d_p (12 in)	4.0	in
c.	Planting Media Coefficient of Permeability, **k**	1	ft/day
d.	Filter Bed Drain Time, **t**	48	hrs
e.	Filter Bed Surface Area, A_{BMP}	903	sq-ft

3. BMP Area

a.	Side Slopes (length per unit height), **z**	0	
b.	Freeboard, **f**	0.25	ft
c.	Filter Bed Width, w_b	3.78	ft
d.	Filter Bed Length, l_b	239	ft
e.	Top Width, w_t	3.78	ft
f.	Top Length, l_t	239	ft
g.	Min. Top Surface Area excluding pretreatment, A_{BMP}	903	sq-ft

FIGURE 6: VEGETATED BIO-FILTER SIZING WORKSHEET (DA 1A)

FREEBOARD, f=3"
PONDING DEPTH, dp=4"
PLANTING MEDIA DEPTH, lm = 2'
1' GRAVEL
6" UNDERDRAIN (TYP.)
VARIES, SEE PLAN
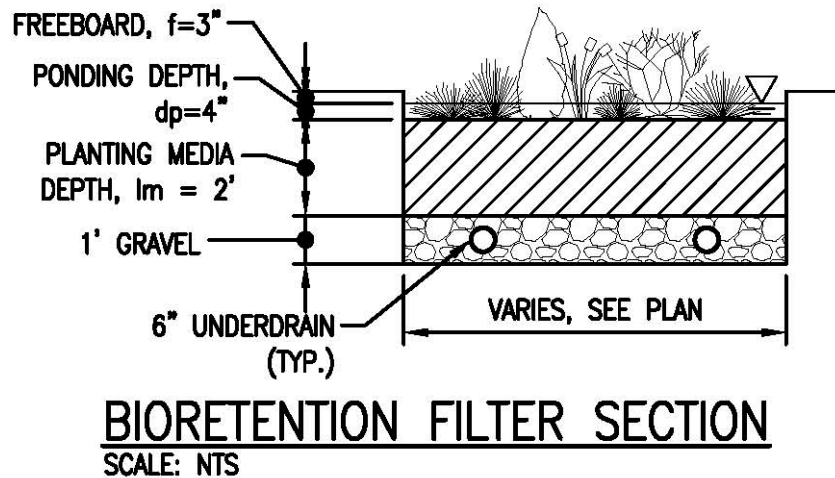
BIORETENTION FILTER SECTION
SCALE: NTS

**FIGURE 7: VEGETATED BIO-FILTER DETAILS**

C.2 Drainage Area 2

The 0.29 acres of runoff from Drainage Area 2 may not be retained because there is not enough space to meet the building setback criterion (20 feet). It may be biofiltered with either a vegetated swale (see Figure 8) or vegetated bio-filter (see Figure 9). The sizing of the BMPs is accomplished using the City's BMP sizing worksheets, which are consistent with the Step-by-Step Sizing Procedure provided in the *BMP Guide*.

Vegetated Swale. The BMP sizing worksheet is presented in Figure 10, and the calculations are summarized as follows:

1. Water Quality Flow Rate (WQF). Assuming a weighted runoff coefficient of 0.50, and using a rainfall intensity of 0.4 in/hr, the WQF is calculated to be 0.058 cfs.

2. Swale geometry. The bottom width, depth of flow, side slope, longitudinal slope, and Manning's roughness coefficient are set to 3 feet (to minimize the length), 1.25 inches, 3:1, 2%, and 0.20, respectively.

3. Swale hydraulic capacity. The cross sectional area, wetted perimeter, and hydraulic radius are calculated to be 0.35 sq-ft, 3.66 ft, and 0.09 ft, respectively. The design flow rate is calculated to be 0.075 cfs, which is equal to or greater than the WQF.

4. Design flow velocity. The design flow velocity is calculated to be 0.22 feet per second, which is less than the maximum allowed velocity of 1 foot per second.

5. Swale length. Using a hydraulic residence time of 7 minutes, the swale length is calculated to be 92 feet.

6. BMP area requirements. Using 6 inches of freeboard, the required total surface area is calculated to be 607 sq-ft. At 92 feet long, this equates to a top width of 6.6 feet.

BMP details are presented in Figure 11.
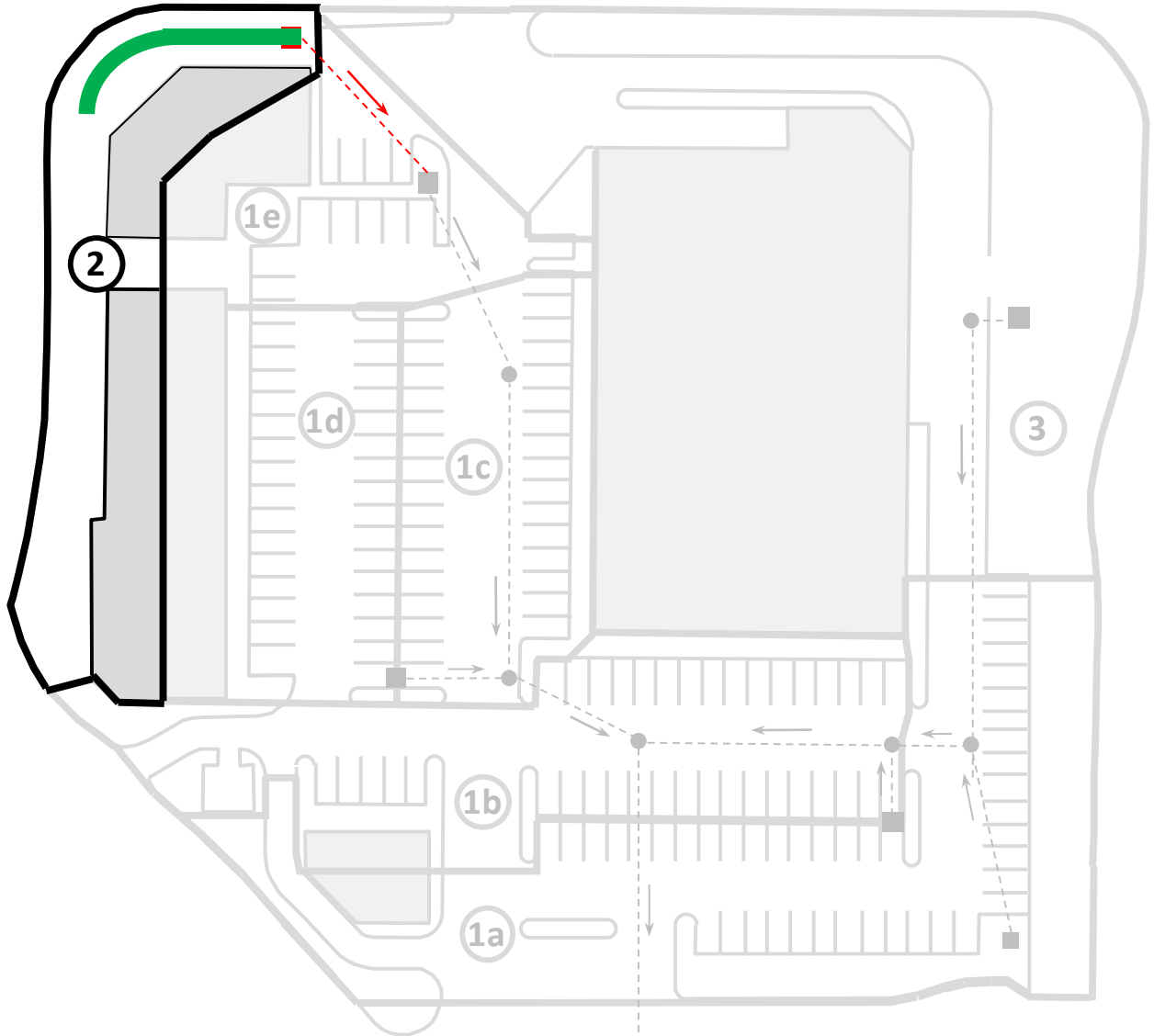
Vegetated Swale Design Parameters

Weighted Runoff Coefficient	50%
Rainfall Intensity	0.4 in/hr
Manning's Roughness Coeff.	0.20
Hydraulic Residence Time	7 min

FIGURE 8: BMP LAYOUT 1, DRAINAGE AREA 2

<u>Vegetated Bio-Filter Design Parameters</u>

Design Storm Depth	1 in
Planting Media Thickness	2 ft
Maximum Ponding Depth	4 in
Filter Bed Drain Time	48 hrs

FIGURE 9: BMP LAYOUT 2, DRAINAGE AREA 2

1. Water Quality Flow Rate

   a. BMP Tributary Drainage Area, **A**   0.29   ac

   b. Weighted Runoff Coefficient, **C**   0.5

   c. Rainfall Intensity, **i**   0.4   in/hr

   d. Water Quality Flow Rate, **WQF**   0.058   cfs

2. Swale Geometry

   a. Bottom Width, **b** (10.0 ft max)   3.00   ft

   b. Flow Depth, **y** (4.0 in max)   1.25   in

   c. Side Slopes (length per unit height), **z** (3.0 max)   3   ft/ft

   d. Longitudinal Slope, **s**   2.0   %

   e. Manning's Roughness Coefficient, **n**   0.20

3. Swale Hydraulic Capacity

   a. Cross-sectional Area @ Flow Depth, **A**   0.35   sq-ft

   b. Wetted Perimeter, **WP**   3.66   ft

   c. Hydraulic Radius, **R**   0.09   ft

   d. Calculated Flow Rate, **Q**   0.075   cfs

4. Design Flow Velocity

   a. Design Flow Velocity, **V** (1.0 fps max)   0.22   fps

5. Swale Length

   a. Hydraulic Residence Time, **T** (7.0 min)   7   min

   b. Minimum Length, **L**   92   ft

6. BMP Area Requirements

   a. Freeboard, **f** (6 min)   6   in

   b. Embankment Top Surface Area, **A**$_{BMP}$ 607   sq-ft

FIGURE 10: VEGETATED SWALE SIZING WORKSHEET (DA 2)

92' X 3' VEGETATED SWALE
SLOPE = 2.0%

GDI

24" OVERFLOW DRAIN LINE*

D24"

GDI

PLAN
SCALE: NTS

*NOTE: ENGINEER NEEDS TO
ENSURE THAT OVERFLOW SYSTEM
CAN ADEQUATELY HANDLE THE PEAK
FLOW FROM DESIGN STORM.

f=6"*

y=1.25"
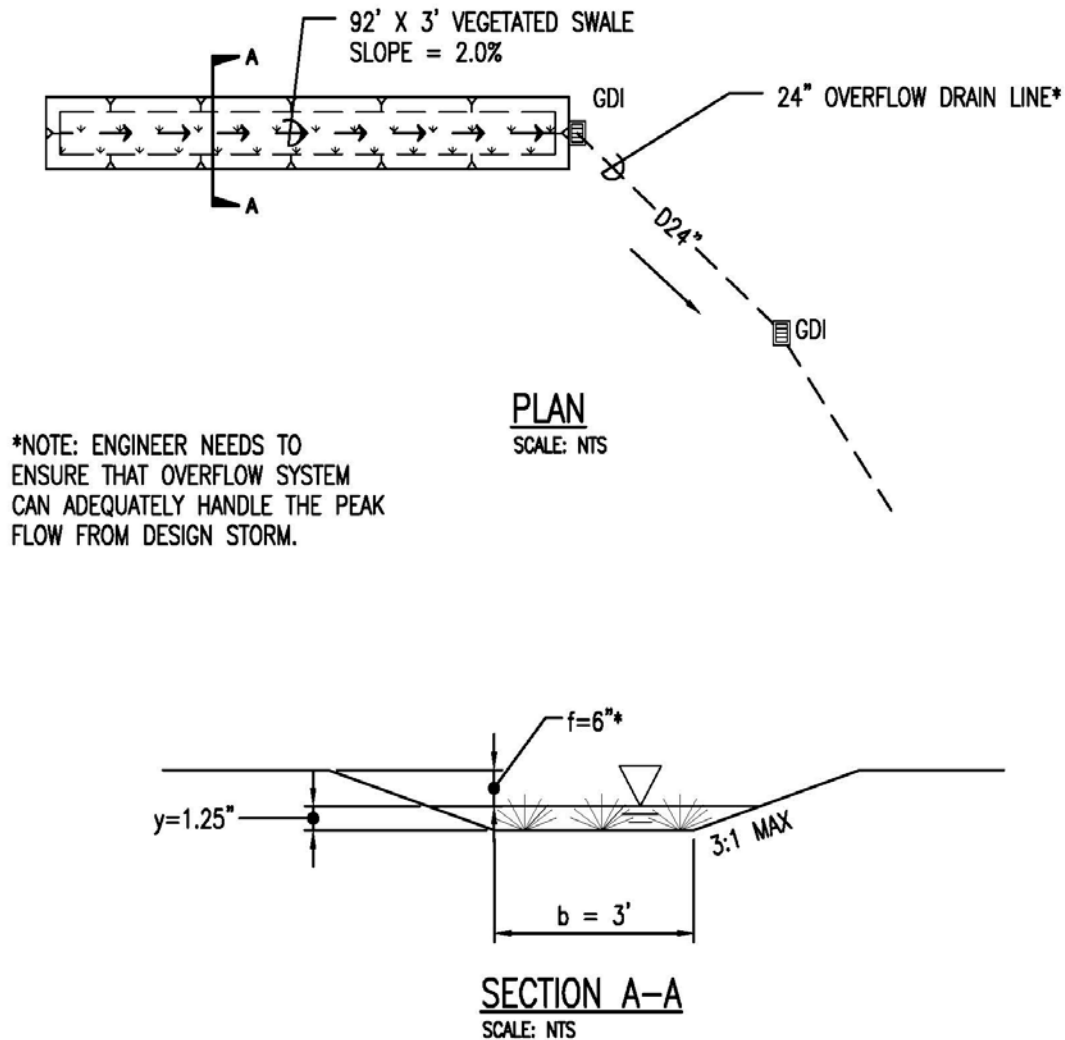
3:1 MAX

b = 3'

SECTION A-A
SCALE: NTS

FIGURE 11: VEGETATED SWALE DETAILS

Vegetated Bio-Filter. The BMP sizing worksheet is presented in Figure 12, and the calculations are summarized as follows:

1. Water Quality Volume (WQV). Assuming 50% impervious cover, and using a 1-inch design storm depth, the WQV is calculated to be 526 cubic feet.

2. Design depths. For constructability and consistency, the planting media depth and maximum ponding depth used for Drainage Area 1 are used here.

3. Filter bed surface area. Using the same parameters as those presented for Drainage Area 1, the required filter bed surface area is calculated to be 243 square feet.

4. Filter bed dimensions. The width and length of the filter bed are set to 5 feet and 49 feet, respectively, which are based on available space and drainage area characteristics.

5. <u>Total Area</u>. Using an embankment side slope of 3:1 and 3 inches of freeboard, the top width, top length, and total BMP area are calculated to be 8.5 feet, 52.1 feet, and 443 square feet, respectively.

BMP details are presented in Figure 7.

---

1. Water Quality Volume

    a. BMP Tributary Drainage Area, **A**   0.29   ac

    b. % Impervious Area, **I**   50   %

    c. Water Quality Design Storm Depth, **P**   1.0   in

    d. Volumetric Runoff Coefficient, **C**   0.5

    e. Water Quality Volume, **WQV**   526   cu-ft

2. Filter Bed Surface Area

    a. Planting Media Depth, l_m (2.0 - 5.0 ft)   2.0   ft

    b. Maximum Ponding Depth, d_p (12 in)   4.0   in

    c. Planting Media Coefficient of Permeability, **k**   1   ft/day

    d. Filter Bed Drain Time, **t**   48   hrs

    e. Filter Bed Surface Area, A_{BMP} 243   sq-ft

3. BMP Area

    a. Side Slopes (length per unit height), **z**   3

    b. Freeboard, **f**   0.25   ft

    c. Filter Bed Width, w_b 5.0   ft

    d. Filter Bed Length, l_b 49   ft

    e. Top Width, w_t 8.5   ft

    f. Top Length, l_t 52.1   ft

    g. Min. Top Surface Area excluding pretreatment, A_{BMP} 443   sq-ft

---

FIGURE 12: VEGETATED BIO-FILTER SIZING WORKSHEET (DA 2)

C.3 Drainage Area 3

The 1.17 acres of runoff from Drainage Area 3 may be retained with an infiltration basin if retention is feasible (See Figure 13), or biofiltered with a vegetated bio-filter (see Figure 14). The sizing of both BMPs is accomplished using the City's BMP sizing worksheets, which are consistent with the Step-by-Step Sizing Procedure provided in the *BMP Guide*.

Infiltration Basin. The BMP sizing worksheet is presented in Figure 15, and the calculations are summarized as follows:

1. Water Quality Volume (WQV). Assuming 75% impervious cover, and using a 1-inch design storm depth, the WQV is calculated to be 3,079 cubic feet.

2. Maximum allowable storage depth. Using the same parameters as those presented for Drainage Area 1, the maximum allowable storage depth is calculated to be 3.0 feet.

3. Design storage depth. The ponding depth is set to 3 feet, which is equal to or less than the maximum allowable storage depth.

4. Basin invert footprint. Using a basin fill time of 2 hours (industry accepted practice), the required invert surface area is calculated to be 985 square feet.

5. BMP area requirements. Based on available space, the invert width is set to 10 feet, and the invert length is calculated to be 98.5 feet. Using a side slope of 3:1 and a freeboard depth of 1 foot (actual free board requirements must be determined for flood design storm), the top width and top length are calculated to be 34 feet and 122.53 feet, respectively. The total footprint is calculated to be 4,166 square feet.

BMP details are presented in Figure 16.

Vegetated Bio-Filter. The BMP sizing worksheet is presented in Figure 17, and the calculations are summarized as follows:

1. Water Quality Volume (WQV). The WQV is the same as that given above for the infiltration basin (3,079 cubic feet).

2. Design depths. For constructability and consistency, the planting media depth and maximum ponding depth used for Drainage Area 1 are used here.

3. Filter bed surface area. Using the same parameters as those presented for Drainage Area 1, the required filter bed surface area is calculated to be 1,421 square feet.

4. Filter bed dimensions. Based on available space, the invert width is set to 20 feet, and the invert length is calculated to be 71 feet.

5. Total Area. Using an embankment side slope of 3:1 and 3 inches of freeboard, the top dimensions are calculated to be 24 feet by 75 feet, and the total BMP area is calculated to be 1,752 square feet.
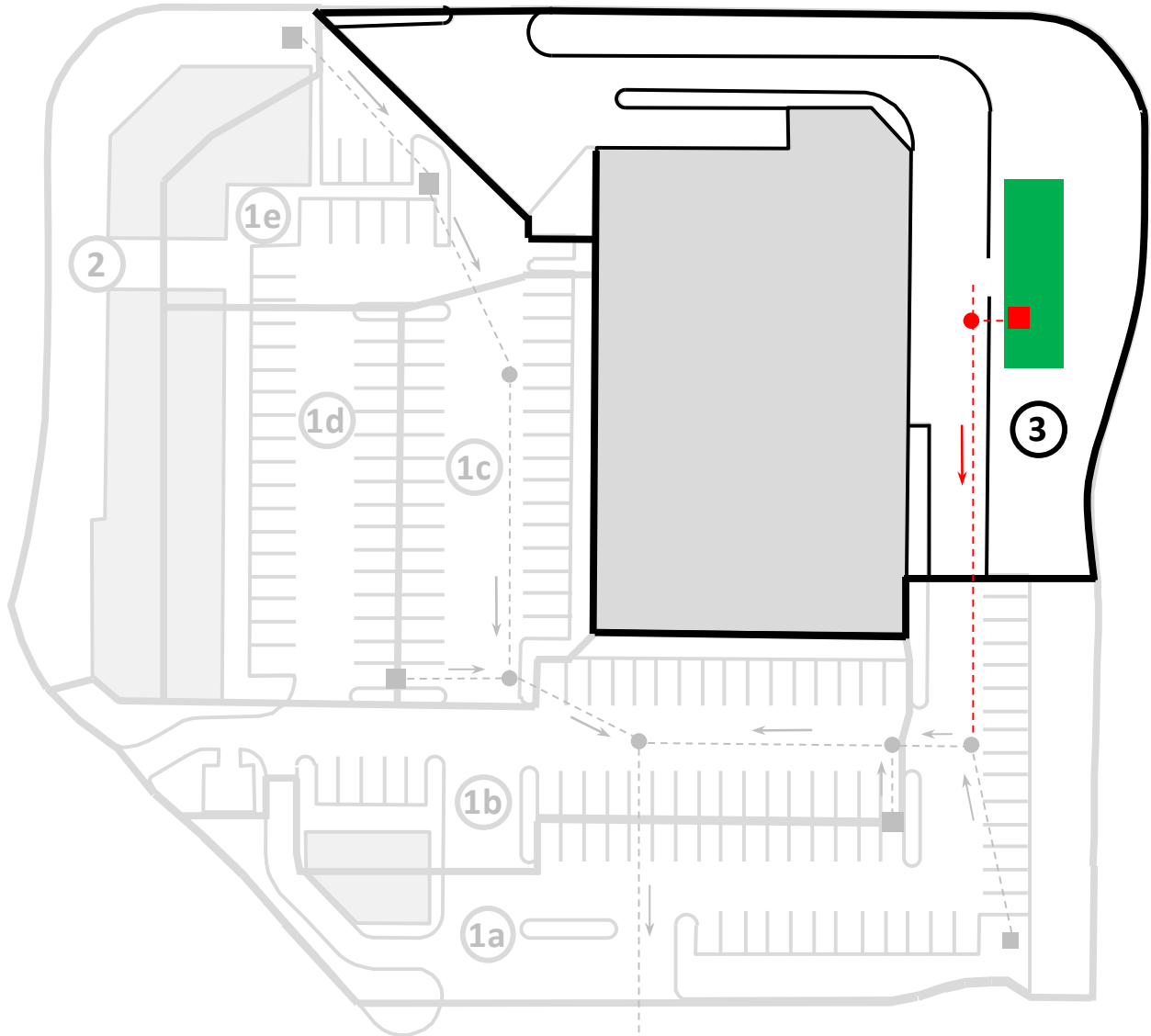
BMP details are presented in Figure 7.
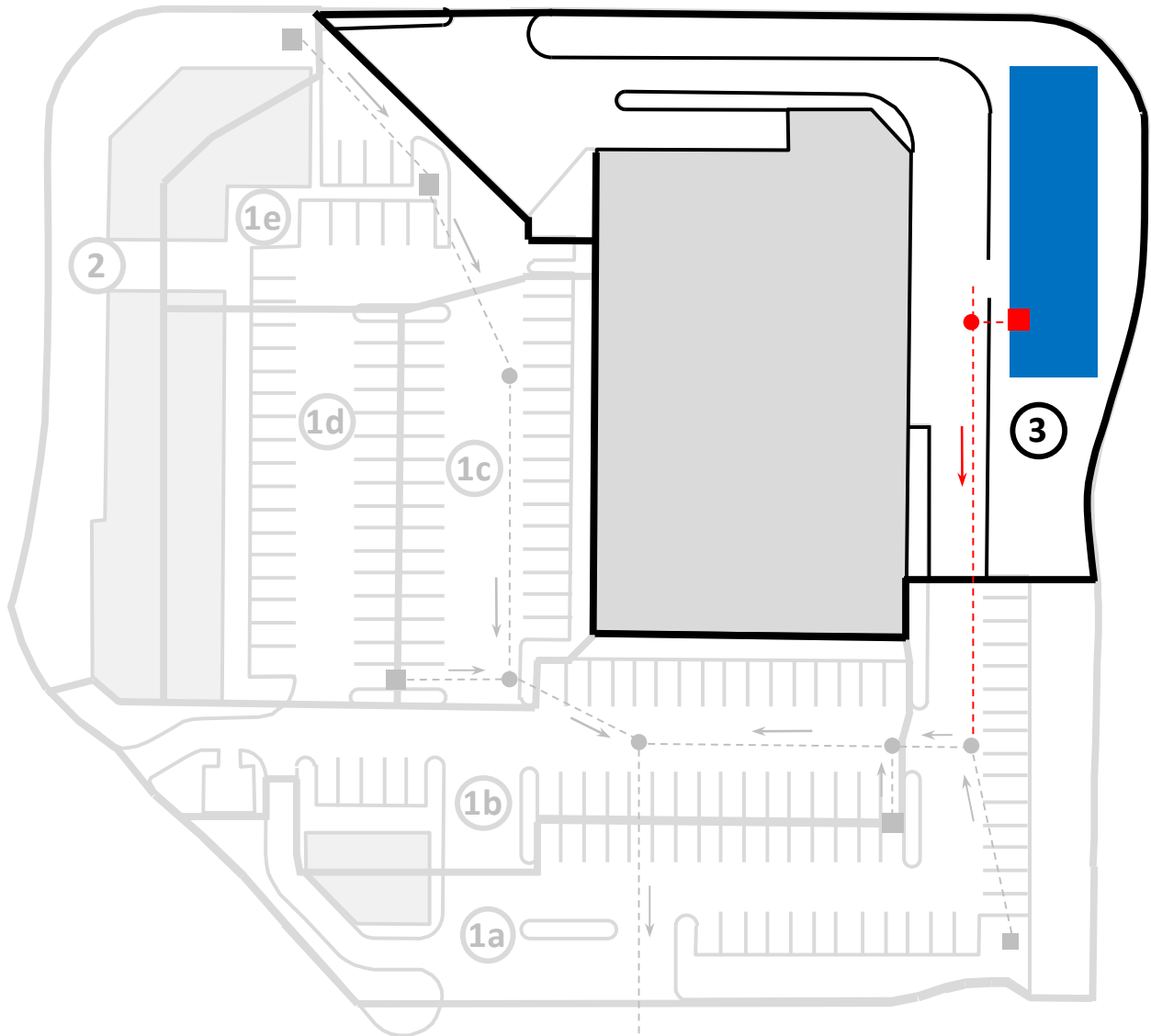
Infiltration Basin Design Parameters

Design Storm Depth	1 in
Infiltration Rate	1.5 in/hr
Infiltration Rate Safety Factor	2
Drawdown Time	48 hrs
Basin Fill Time	2 hrs

FIGURE 13: BMP LAYOUT 1, DRAINAGE AREA 3

Vegetated Bio-Filter Design Parameters

Design Storm Depth	1 in
Planting Media Thickness	2 ft
Maximum Ponding Depth	4 in
Filter Bed Drain Time	48 hrs

FIGURE 14: BMP LAYOUT 2, DRAINAGE AREA 3

1. Water Quality Volume

a. BMP Tributary Drainage Area, **A** | 1.17 | ac

b. % Impervious Area, **I** | 75 | %

c. Water Quality Design Storm Depth, **P** | 1.0 | in

d. Volumetric Runoff Coefficient, **C** | 0.725 |

e. Water Quality Volume, **WQV** | 3,079 | cu-ft

2. Maximum Storage Depth

a. Soil Infiltration Rate, **k** (0.5 min) | 1.5 | in/hr

b. Infiltration Rate Safety Factor (2 - 5), **F_s** | 2 |

c. Drawdown Time, **t** | 48 | hrs

d. Max. Storage Depth, **d_{max}** | 3.0 | ft

3. Design Storage Depth

a. Ponding Depth, **d_p** | 3.00 | ft

4. Basin Invert Footprint

b. Reservoir Fill Time, **T** | 2 | hrs

c. Min. Bottom Surface Area, **A_b** | 985 | sq-ft

5. BMP Area Requirements

a. Side Slopes (length per unit height), **z** (3.0 min) | 3 |

b. Freeboard, **f** (1.0 min) | 1 | ft

c. Invert Width, **w_b** | 10.0 | ft

d. Invert Length, **l_b** | 98.5 | ft

e. Top Width, **w_t** | 34.00 | ft

f. Top Length, **l_t** | 122.53 | ft

g. Min. Top Surface Area excluding pretreatment, **A_{BMP}** | 4,166 | sq-ft
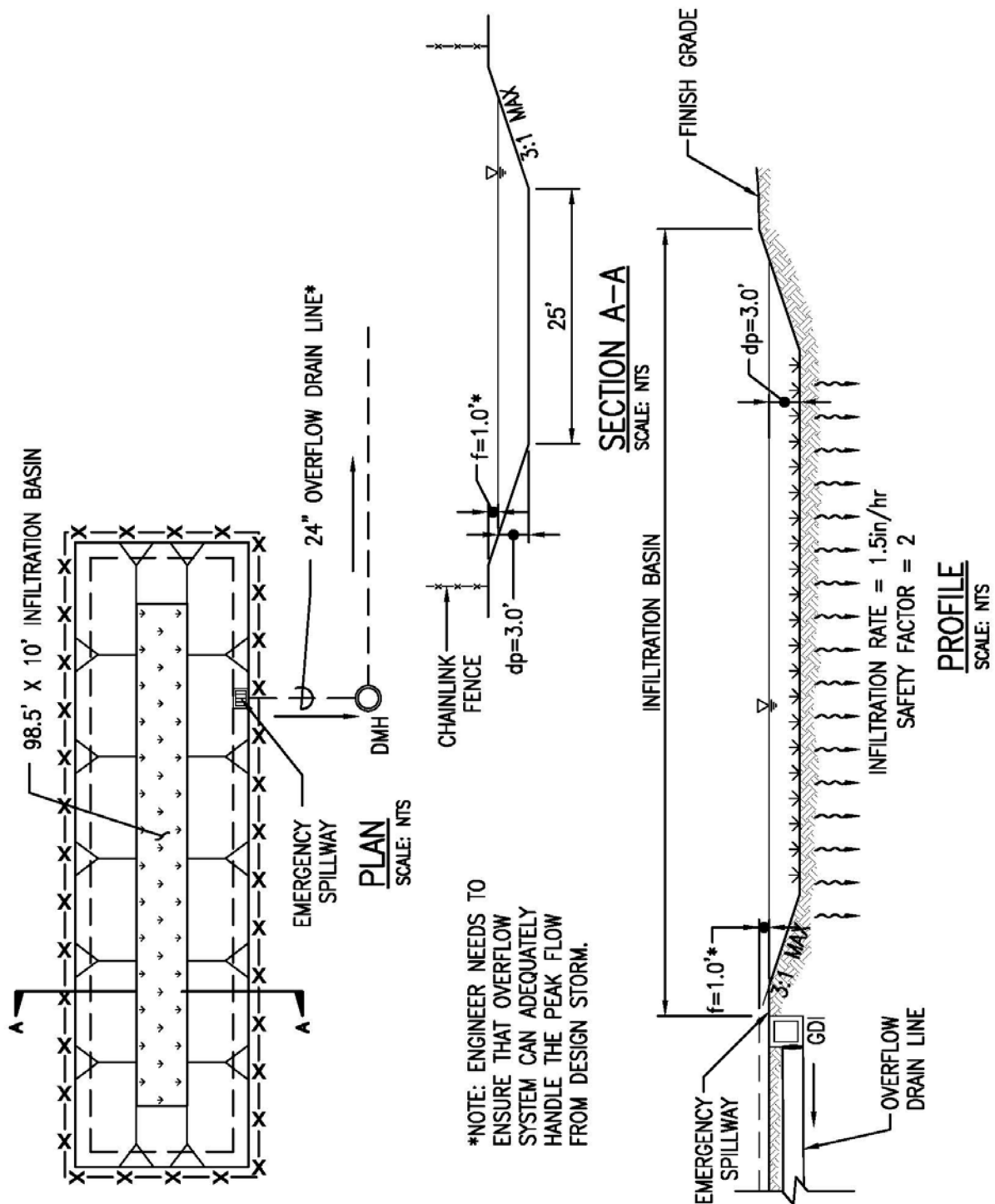
FIGURE 15: INFILTRATION BASIN SIZING WORKSHEET (DA 3)

FIGURE 16: INFILTRATION BASIN DETAILS

1. Water Quality Volume		
a. BMP Tributary Drainage Area, **A**	1.17	ac
b. % Impervious Area, **I**	75	%
c. Water Quality Design Storm Depth, **P**	1.0	in
d. Volumetric Runoff Coefficient, **C**	0.725	
e. Water Quality Volume, **WQV**	3,079	cu-ft

2. Filter Bed Surface Area		
a. Planting Media Depth, l_m (2.0 - 5.0 ft)	2.0	ft
b. Maximum Ponding Depth, d_p (12 in)	4.0	in
c. Planting Media Coefficient of Permeability, **k**	1	ft/day
d. Filter Bed Drain Time, **t**	48	hrs
e. Filter Bed Surface Area, A_{BMP}	1,421	sq-ft

3. BMP Area		
a. Side Slopes (length per unit height), **z**	3	
b. Freeboard, **f**	0.25	ft
c. Filter Bed Width, w_b	20	ft
d. Filter Bed Length, l_b	71.06	ft
e. Top Width, w_t	23.50	ft
f. Top Length, l_t	74.56	ft
g. Min. Top Surface Area excluding pretreatment, A_{BMP}	1,752	sq-ft

FIGURE 17: VEGETATED BIO-FILTER SIZING WORKSHEET (DA 3)

D. ALTERNATIVE COMPLIANCE

If LID Retention and LID Biofiltration are determined to be infeasible, alternative compliance would be required. Options include treating the runoff with Other Treatment Control BMPs identified in the BMP Guide (detention basin, manufactured treatment device, sand filter, etc.).

EXAMPLE 3, 0.74 ACRE COMMERCIAL DEVELOPMENT

A restaurant is being constructed on a 0.74-acre site. The layout is presented in Figure 1, and includes more than 10,000 square feet of impervious surface.
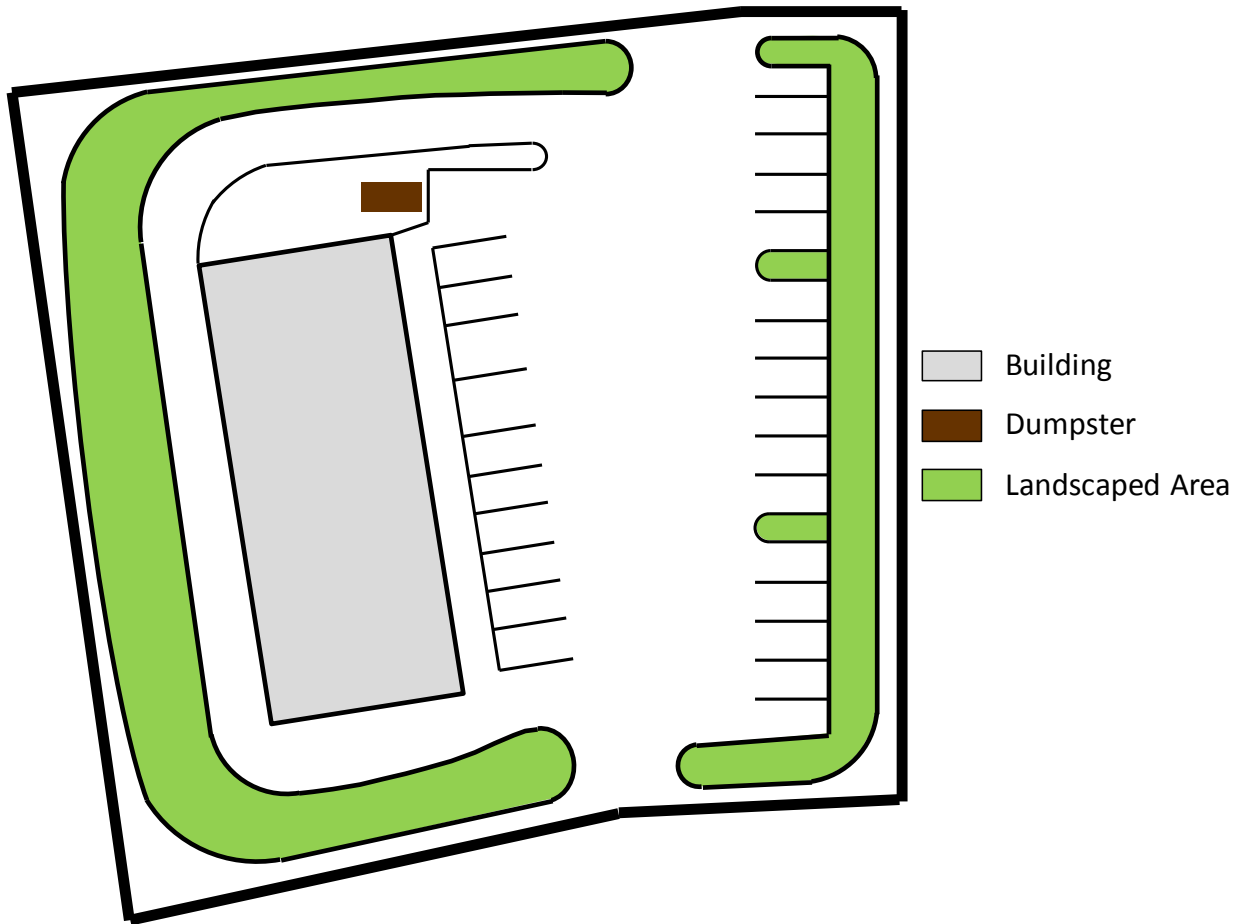

FIGURE1: EXAMPLE 3 DEVELOPMENT PLAN

The project meets the criteria of a Priority B new development project and requires the preparation of a Storm Water Quality Checklist (SWQC). As specified in Section B.6 of §1-5.1 Part I, water quality criteria shall be achieved by considering LID Site Design and implementing appropriate Source Control. Each of these elements is presented below.

A. LID SITE DESIGN

All 5 LID Site Design Strategies specified in the *City and County of Honolulu Storm Water BMP Guide* (*BMP Guide*) were considered. The strategy "Direct Runoff to Landscaped Areas" will be implemented by directing all pavement runoff to the surrounding landscaped areas, and directing roof runoff to the adjacent landscaped area using roof drains. Details are shown in Figure 2.

B. SOURCE CONTROL

The *BMP Guide* identifies 12 Source Control BMPs for new development and redevelopment projects. The following ones will be implemented:

- Automatic Irrigation Systems

  - Irrigation system will be designed to each landscape area's specific water requirements.

  - Irrigation system will be designed to minimize the runoff of excess irrigation water into the storm water drainage system.

  - Plants with similar water requirements will be grouped together in order to reduce excess irrigation runoff and promote surface filtration.

- Storm Drain Inlets

  - All storm drain inlets and catch basins within the project area will be stenciled with appropriate signage.

- Outdoor Trash Storage

  - Dumpster area will be graded towards vegetated/landscaped area.

  - Drip pans will be placed underneath dumpster to reduce/prevent leaking of liquid wastes.

  - Dumpster with attached lids will be used to prevent rainfall from entering container.

  - Dumpster area will be paved with an impervious surface to mitigate spills.

  - Signs will be posted indicating that hazardous material are not to be disposed of therein.

- Parking Areas

  - Pavement runoff will be directed towards vegetated/landscaped areas.
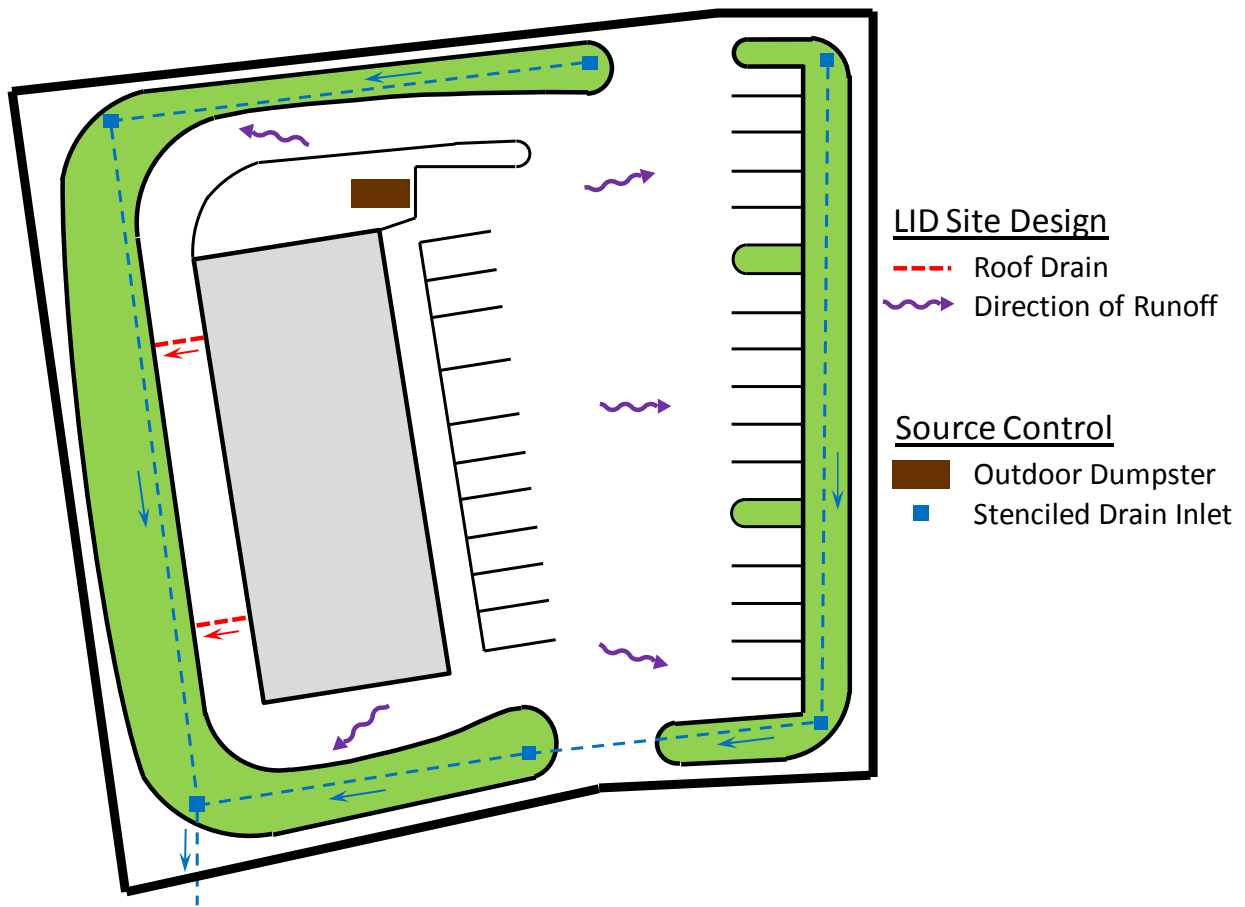
Details are shown in Figure 2.

FIGURE2: LID SITE DESIGN AND SOURCE CONTROL PLAN

Appendix E

A Sample of CDS Unit Operation and Maintenance Guideline

OPERATIONS AND MAINTENANCE GUIDELINES

CDS Stormwater Treatment Unit

INTRODUCTION

The CDS unit is an important and effective component of your storm water management program and proper operation and maintenance of the unit are essential to demonstrate your compliance with local, state and federal water pollution control requirements.

The CDS technology features a patented non-blocking, indirect screening technique developed in Australia to treat water runoff. The unit is highly effective in the capture of suspended solids, fine sands and larger particles. Because of its non-blocking screening capacity, the CDS unit is un-matched in its ability to capture and retain gross pollutants such as trash and debris. In short, CDS units capture a very wide range of organic and in-organic solids and pollutants that typically result in tons of captured solids each year such as: Total suspended solids (TSS) and other sedimentitious materials, oil and greases, trash, and other debris (including floatables, neutrally buoyant, and negatively buoyant debris). These pollutants will be captured even under very high flow rate conditions.

CDS units are equipped with conventional oil baffles to capture and retain oil and grease. Laboratory evaluations show that the CDS units are capable of capturing up to 70% of the free oil and grease from storm water. CDS units can also accommodate the addition of oil sorbents within their separation chambers. The addition of the oil sorbents can ensure the permanent removal of 80% to 90% of the free oil and grease from the storm water runoff.

OPERATIONS

The CDS unit is a non-mechanical self-operating system and will function any time there is flow in the storm drainage system. The unit will continue to effectively capture pollutants in flows up to the design capacity even during extreme rainfall events when the design capacity may be exceeded. Pollutants captured in the CDS unit's separation chamber and sump will be retained even when the units design capacity is exceeded.

CDS UNIT INSPECTION

Access to the CDS unit is typically achieved through two manhole access covers – one allows inspection (and clean out) of the separation chamber (screen/cylinder) & sump and another allows inspection (and cleanout) of sediment captured and retained behind the screen.

The unit should be periodically inspected to determine the amount of accumulated pollutants and to ensure that the cleanout frequency is adequate to handle the predicted pollutant load being processed by the CDS unit. The unit should be periodically inspected for indications of vector infestation, as well. The recommended cleanout of

solids within the CDS unit's sump should occur at 75% to 85% of the sump capacity. However, the sump may be completely full with no impact to the CDS unit's performance.

CONTECH Stormwater Solutions (previously CDS Technologies) recommends the following inspection guidelines: For new initial operation, check the condition of the unit after every runoff event for the first 30 days. For ongoing operations, the unit should be inspected after the first six inches of rainfall at the beginning of the rainfall season and at approximately 30-day intervals. The visual inspection should ascertain that the unit is functioning properly (no blockages or obstructions to inlet and/or separation screen), evidence of vector infestation, and to measure the amount of solid materials that have accumulated in the sump, fine sediment accumulated behind the screen, and floating trash and debris in the separation chamber. This can be done with a calibrated dipstick, tape measure or other measuring instrument so that the depth of deposition in the sump can be tracked.

CDS UNIT CLEANOUT

The frequency of cleaning the CDS unit will depend upon the generation of trash and debris and sediments in your application. Cleanout and preventive maintenance schedules will be determined based on operating experience unless precise pollutant loadings have been determined.

Access to the CDS unit is typically achieved through two manhole access covers – one allows cleanout of the separation chamber (screen/cylinder) & sump and another allows cleanout of sediment captured and retained behind the screen. For units possessing a sizable depth below grade (depth to pipe), a single manhole access point would allow both sump cleanout and access behind the screen.

CONTECH Stormwater Solutions Recommends The Following:

> NEW INSTALLATIONS: Check the condition of the unit after every runoff event for the first 30 days. The visual inspection should ascertain that the unit is functioning properly (no blockages or obstructions to inlet and/or separation screen), measuring the amount of solid materials that have accumulated in the sump, the amount of fine sediment accumulated behind the screen, and determining the amount of floating trash and debris in the separation chamber. This can be done with a calibrated "dip stick" so that the depth of deposition can be tracked. Refer to the "Cleanout Schematic" **(Appendix B) f**or allowable deposition depths and critical distances. Schedules for inspections and cleanout should be based on storm events and pollutant accumulation.

> ONGOING OPERATION: During the rainfall season, the unit should be inspected at least once every 30 days. The floatables should be removed and the sump cleaned when the sump is 75-85% full. If floatables accumulate more rapidly than the settleable solids, the floatables should be removed using a vactor truck or dip net before the layer thickness exceeds approximately one foot.

> Cleanout of the CDS unit at the end of a rainfall season is recommended because of the nature of pollutants collected and the potential for odor generation

from the decomposition of ma terial collected and retai ned. This end of season cleanout will assist in preventing the dischar ge of pore water from the CDS ® unit during summer months.

USE OF SORBENTS –The addition of sorbents is **not a requirement** for CDS units to effectively c ontrol oil and grease from storm water. The conventional oil baffle within a unit assures satisfactory oil and grease removal. However, the addition of sorbents is a unique enhancement capability unique to CDS units, enabling increased oil and grease capture efficiencies beyond that obtainable by conventional oil baffle systems.

Under normal operations, CDS units will provide effluent concentrations of oil and grease that are less than 15 parts per million (ppm) for all dry weather spills where the volume is less than or equal to the spill capture vo lume of the CDS unit. During wet weat her flows, the oil baffle system can be expected to remove between 40 and 70% of the free oil and grease from the storm water runoff.

CONTECH Stormwater Solutions only recommends the addition of sorbents to the separation chamber if there are specific land use activities in the catchment watershed that could produce exceptionally large concentrations of oil and grease in the runoff, concentration levels well above typical amounts. If site evaluations merit an increased control of free oil and grease then oil sorbents can be added to the CDS unit to thoroughly address these particular pollutants of concern.

Recommended Oil Sorbents

Rubberizer® Particulate 8-4 mesh or OARS ™ Particulate for Filtration, HPT4100 or equal. Rubberizer is supplied by Haz-Mat Response Technologies, Inc. 4626 Sant a Fe Street, San Diego, CA 92109 (800) 542-3036. OARS is supplied by AbTec h Industries, 4110 N. Scottsdale Road, Suite 235, Scottsdale, AZ 85251 (800) 545-8999.

The amount of sorbent to be added to the CDS separation chamber can be determined if sufficient information is k nown about the concentration of oil and grease in t he runoff. Frequent ly the actual concentrati ons of oil and grease are too variable and the amount to be added and frequency of cleaning will be determined by periodic observa tion of the sorbent. As an initial application, CDS recommends that approximately 4 to 8 pounds of sorbent material be added to the separation chamber of the CDS units per acre of parking lot or road surface per year. Typically this amount of sorbent results in a ½ inch to one (1”) inch depth of sorbent material on the liquid surface of the separation chamber. The oil and grease loading of the sorbent material should be observed after major storm events. Oil Sorbent material may also be furnished in pillow or boom configurations.

The sorbent material should be replaced when it is fully discolore d by skim ming the sorbent from the surface. The sorbent may require disposal as a spec ial or hazardous waste, but will depend on local and state regulatory requirements.

CLEANOUT AND DISPOSAL

A vactor truck is recommended for cleanout of the CDS unit and can be easily accomplished in less than 30-40 minutes fo r most installations. Standard vactor operations should be employed in the cleanout of the CDS unit. Disposal of material from the CDS unit should be in accordance with the local municipalit y's requirements. Disposal of the decant material to a POTW is recommended. Field decanting to th e storm drainage system is not recommended. Solids can be disposed of in a similar fashion as those materials collected from street sweeping operations and catch-basin cleanouts.

MAINTENANCE

The CDS unit should be pumped down at least once a year and a thorough inspection of the separation chamber (inlet/cylinder and separation screen) and oil baffle performed. The unit's inter nal components should not show any signs of damage or any loosening of the bolts used to fasten the various components to the manhole structure and to each other. Ideally, the screen should be power washed for the inspection. If any of the internal components is damaged or if any fasteners appear to be damaged or missing, please contact CONTECH at 800.338.2211 to make arrangements to have the damaged items repaired or replaced.

The screen assembly is fabricated from Type 316 stainless steel and fastened with Type 316 stainless steel fasteners that are easily removed and/or replaced with conventional hand tools. The damaged screen assembly should be replaced with the new screen assembly placed in the same orientation as the one that was removed.

CONFINED SPACE

The CDS unit is a confined space environ ment and only properly trained personn el possessing the neces sary safety equipment s hould enter the unit to perform particular maintenance and/or inspection activities beyond nor mal procedure. Inspections of the internal components can, in most cases, be accomplished by observations from the ground surface.

VECTOR CONTROL

Most CDS units do not readily facilitate vector infestation. However, for CDS units that may experience extended periods of non-operation (stagnant flow conditions for more than approximately one week) ther e may be the potential for vector infestation. In the event that these conditions exist, the CDS unit may be designed to minimize potential vector habitation through the use of physical barriers (such as seals, plugs and/or netting) to seal out potential vectors. The CDS unit may also be configured to allow drain-down under favorable soil conditions where infiltration of storm water runoff is permissible. For standard CDS units that show evidence of mosquito infestation, the

application of larvicide is one control strategy that is recommended. Typical larvicide applications are as follows:

SOLID B.t.i. LARVICIDE: ½ to 1 briquet (typically treats 50-100 sq. ft.) one time per month (30-days) or as directed by manufacturer.

SOLID METHOPRENE LARVICIDE (not recommended for some locations): ½ to 1 briquet (typically treats 50-100 sq. ft.) one time per month (30-days) to once every 4-½ to 5-months (150-days) or as directed by manufacturer.

RECORDS OF OPERATION AND MAINTENANCE

CONTECH Stormwater Solutions recomme nds that the owner m aintain annual records of the operation and maintenance of the CDS unit to document the effective maintenance of this import ant component of your storm water management program. The attached **Annual Record of Operations and Maintenance** form (see **Appendix A**) is suggested and should be retained for a minimum period of three years.

APPENDIX A

ANNUAL RECORDS OF
OPERATIONS & MAINTENANCE
AND INSPECTION CHECKLISTS

ANNUAL RECORD OF
OPERATION AND MAINTENANCE

OWNER _____

ADDRESS_____

OWNER REPRESENTATIVE_____**PHONE**_____

INSTALLATION:
        MODEL DESIGNATION_____ __ _____   **DATE** _____

        SITE LOCATION_____

INSPECTIONS:

DATE/ INSPECTOR	SCREEN/INLET INTEGRITY	FLOATABLES DEPTH	DEPTH TO SEDIMENT (inches)	SEDIMENT VOLUME* (CUYDS)	SORBENT DISCOLORATION

DEPTH FROM COVER TO BOTTOM OF SUMP (SUMP INVERT) _____

DEPTH FROM COVER TO SUMP @ 75% FULL _____

VOLUME OF SUMP @ 75% FULL =_____**CUYD**

VOLUME/INCH DEPTH _____**CUFT/IN OF SUMP**

VOLUME/FOOT DEPTH_____**CUYD/FT OF SUMP**

Calculate Sediment Volume = (Depth to Sump Invert – Depth to Sediment)(Volume/inch)

OBSERVATIONS OF FUNCTION: _____

_____

_____

CLEANOUT:

DATE	VOLUME FLOATABLES	VOLUME SEDIMENTS	METHOD OF DISPOSAL OF FLOATABLES, SEDIMENTS, DECANT AND SORBENTS

OBSERVATIONS:
_____
_____
_____
_____

SCREEN MAINTENANCE:

DATE OF POWER WASHING, INSPECTION AND OBSERVATIONS:
_____
_____

CERTIFICATION:_____   **TITLE:**_____   **DATE:**_____

INSPECTION CHECKLIST

1. During the rainfall season, inspect and check condition of unit at east once every 30 days ☐

2. Ascertain that the unit is funcioning properly (no blockages or obstructions to inlet and/or separation screen) ☐

3. Measure amount of solid material s that have accumulated in the sump (Unit should be cleaned when the sump is 75-85% full) ☐

4. Measure amount of fine sediment accumulated behind the screen ☐

5. Measure amount of floating trash and debris in the separation chamber ☐

MAINTENANCE CHECKLIST

1. Cleanout unit at the end and beginning of the rainfall season ☐

2. Pump down unit (at least once a year) and thoroughly inspect separation chamber, separation screen and oil baffle ☐

3. No visible signs of damage or loosening of bolts to internal components observed * ☐

* If there is any damage to the internal components or any fasteners are damaged or missing please contact CONTECH (800.338.1122).