CLARK COUNTY

STORMWATER MANUAL

NOVEMBER 2009

Acknowledgements

Development of the Clark County Stormwater Manual was a team effort between Clark County, citizens of Clark County and consultant services. The individuals listed below contributed their time, expertise, and support to make the project a success.

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1 Introduction

1.1 PURPOSE

The purpose of this Clark County Stormwater Manual (SWM) is to identify stormwater management requirements for new development and redevelopment projects in Clark County, in accordance with Clark County Code (CCC) Chapter 40.385. These requirements safeguard public health, safety, and welfare by protecting the quality of surface water and groundwater for drinking water supply, recreation, fishing, and other beneficial uses through application of best management practices (BMPs) for stormwater management and erosion control.

1.2 RELATIONSHIP TO THE STORMWATER MANAGEMENT MANUAL FOR WESTERN WASHINGTON (SMMWW)

Clark County's National Pollutant Discharge Elimination System (NPDES) Phase I permit identifies stormwater management requirements for Clark County. One of the requirements is that the County must adopt the *Stormwater Management Manual for Western Washington* (SMMWW; Department of Ecology 2005) or an equivalent. The County has elected to adopt the SMMWW.

Local jurisdictions may modify or add to the SMMWW requirements, as long as the requirements are equivalent to or stricter than the SMMWW requirements. This Clark County SWM identifies these county-specific modifications and additions. It does not repeat the content of the SMMWW, so both manuals must be consulted. It does, however, direct the user to the relevant sections of the SMMWW.

Where portions of the Clark County SWM and SMMWW conflict, the requirements in the Clark County SWM apply.

Where provisions of the Clark County SWM conflict with other Clark County Code, state, or federal requirements, the more stringent provisions apply.

The SMMWW (Volume I, Section 1.6) provides a detailed description of the relationship of the SMMWW to other state and federal requirements.

1.3 GENERAL APPLICABILITY

All new development and redevelopment projects in Clark County, as defined below, are subject to the requirements of this manual.

- **New development:** Land-disturbing activities, including Class IV General Forest Practices that are conversions from timber land to other uses; construction or installation of a building or other structure; creation of impervious surfaces; and subdivision, short subdivisions, and binding site plans, as defined and applied in Chapter 58.17 of the Revised Code of Washington (RCW). Projects meeting the definition of redevelopment are not considered to be new development.

- **Redevelopment:** On a site that is already substantially developed (i.e., has 35 percent or more of existing impervious surface coverage), the creation or addition of impervious surfaces; the expansion of a building footprint or addition or replacement of a structure; construction, installation, or expansion of a building or other structure; replacement of impervious surface that is not part of a routine maintenance activity; and land-disturbing activities.

► *Infill projects (as defined in CCC section 40.260.110) are a type of new development or redevelopment.*

- **Road-related development:** Land-disturbing activity where the sole objective is the development or redevelopment of roads, sidewalks, and bike lanes.

- **Drainage projects:** Excavation or construction of pipes, culverts, channels, embankments, or other flow-altering structures in any stream, stormwater facility, or wetland in Clark County.

► *County road-related development and drainage projects are not subject to Chapter 10 of this manual (Financial Guarantees).*

Chapter 2 identifies the specific requirements that apply to various types of projects, as well as exemptions from the requirements.

1.4 HOW THIS MANUAL IS ORGANIZED

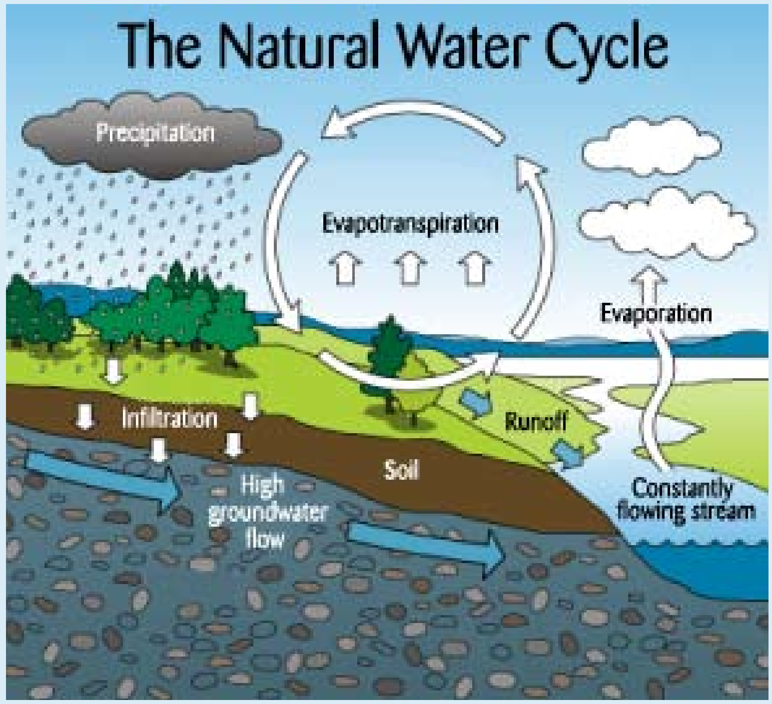
- **Chapter 2:** The SMMWW identifies 10 minimum requirements for stormwater management. Chapter 2 of this manual describes how to identify which of the minimum requirements apply to a specific project in Clark County. It then tells how to meet those applicable minimum requirements by using the appropriate sections of the SMMWW and/or other chapters of this Clark County SWM that supersede or supplement the SMMWW.

- **Chapters 3 through 7** contain the information that **supersedes or supplements** the SWWMM in regard to the 10 minimum requirements, as identified in Chapter 2.
- **Chapters 8-11** identify Clark County requirements that are **in addition to** the 10 minimum requirements.

THE IMPORTANCE OF STORMWATER MANAGEMENT

The Water Cycle

The earth's water continuously circulates from the atmosphere to the land, from there into groundwater and surface water, and then back to the atmosphere. This is called the water cycle, or hydrologic cycle, and is key to understanding stormwater impacts.



In natural (undeveloped) conditions, rainfall infiltrates slowly into the ground. Natural biologic processes cleanse the water as it moves through vegetation and soil and into groundwater. Because most rainstorms are not large enough to fully saturate the soil, only a small percentage of rainwater flows over the surface as runoff. What does become runoff usually travels in a slow, meandering pace. Particles and sediments settle out along the way, ridding the water of impurities before it flows into rivers and streams.

The Effects of Development

Development drastically alters the natural water cycle. Impervious surfaces such as buildings, roads, parking lots, and sidewalks prevent rain from soaking into the ground. There is less vegetation to soak up, store, and evaporate water. The natural soil structure is lost as a result of grading and compaction during construction. As a result, stormwater runoff greatly increases, flowing over land surfaces or through conveyance systems (such as pipes and ditches) into rivers and streams.

This alteration of the water cycle can have significant negative effects on surface water and groundwater, causing harm to fish and wildlife, drinking water supplies, property, recreation, and other beneficial uses.

- Increased runoff volume and speed cause flooding and erosion and destroy natural habitat in rivers and streams.
- Because less water infiltrates into the ground, less groundwater recharge occurs. This reduces drinking water and irrigation supplies and also reduces base flows in streams, which is harmful to fish and aquatic organisms.
- Impervious surfaces retain heat, which increases runoff temperature during warm weather. This in turn raises the temperature of the receiving waters, with negative impacts on aquatic life.
- Stormwater runoff picks up oil, fertilizers and pesticides, metals, chemicals, sediments, bacteria, trash and debris, and other pollutants and carries them into rivers and streams.

Mitigation through Stormwater Management

Stormwater management reduces stormwater runoff volume, speed, and pollutants so new development and redevelopment maintain a better balance with the natural water cycle. This is achieved through the following basic approaches.

- **Source control** best management practices (BMPs) prevent stormwater from coming into contact with pollutants in the first place. Examples include sweeping (instead of hosing) water to clean an area, and covering oily parts and equipment with a tarp. Source control BMPs are a cost-effective way to reduce pollutants in stormwater and should therefore be a first consideration in all projects.

- **Treatment** BMPs reduce pollutant loads and concentrations in stormwater runoff through physical, biological, and chemical removal mechanisms. Examples include biofiltration, dispersion, constructed wetlands, and proprietary filter systems. These BMPs can accomplish significant levels of pollutant load reductions if properly designed and maintained.

- **Flow control** BMPs detain, retain, or infiltrate stormwater runoff to control the flow rate, frequency, duration, and volume of runoff leaving the site. Examples include detention ponds, infiltration systems, and constructed wetlands.

Low impact stormwater approaches emphasize capturing, treating, and infiltrating stormwater at the source. Techniques are used that mimic natural processes by allowing stormwater to slowly soak into the ground or filter through vegetation—for example, porous pavement, rain gardens and infiltration planters, and green roofs. In addition, design and construction methods can be employed to preserve and take advantage of the site's natural features, such as open spaces, native vegetation, natural depressions, and wetlands. This approach—also known as low impact development—provides multiple environmental, aesthetic, and cost benefits in addition to stormwater management.

2 Minimum Requirements

2.1 INTRODUCTION

This chapter provides the following information:

- **Section 2.2:** How to identify which minimum requirements apply to a project.
- **Section 2.3:** How to meet the applicable minimum requirements by using the appropriate sections of the Stormwater Management Manual for Western Washington (SMMWW) and/or other sections of this Clark County SWM.
- **Section 2.4:** Exemptions to the minimum requirements.

► *All new development and redevelopment projects are subject to the applicable minimum requirements in this chapter.*

Clark County also has other requirements that are not included under the minimum requirements. They are identified in:

- Chapter 8 (Conveyance Systems)
- Chapter 9 (Offsite Analysis and Mitigation)
- Chapter 10 (Financial Guarantees)
- Chapter 11 (Additional Requirements)

2.2 HOW TO IDENTIFY APPLICABLE MINIMUM REQUIREMENTS

The **SMMWW (Volume I, Section 2.5)** identifies 10 minimum requirements for stormwater management, which apply to projects in Clark County. These minimum requirements are:

1. **Preparation of Stormwater Site Plans**
2. **Construction Stormwater Pollution Prevention**
3. **Source Control of Pollution**
4. **Preservation of Natural Drainage Systems and Outfalls**
5. **Onsite Stormwater Management**
6. **Runoff Treatment**
7. **Flow Control**
8. **Wetlands Protection**
9. **Basin/Watershed Planning**
10. **Operation and Maintenance**

Not all of the minimum requirements apply to every project; the applicability varies, depending on the project type, size, and location. To determine which requirements apply to a specific project, consult **Figure 2-1** (for urban new developments) or **Figure 2-2** (for urban redevelopments), or the **Rural Properties** section for rural projects. [1]

[1] *Figures 2-1 and 2-2 are adapted from Volume I, Section 2.4 of the SMMWW, which also gives a written description of how the minimum requirements apply to various types and sizes of projects.*

FIGURE 2-1. **Urban New Development Flow Chart**

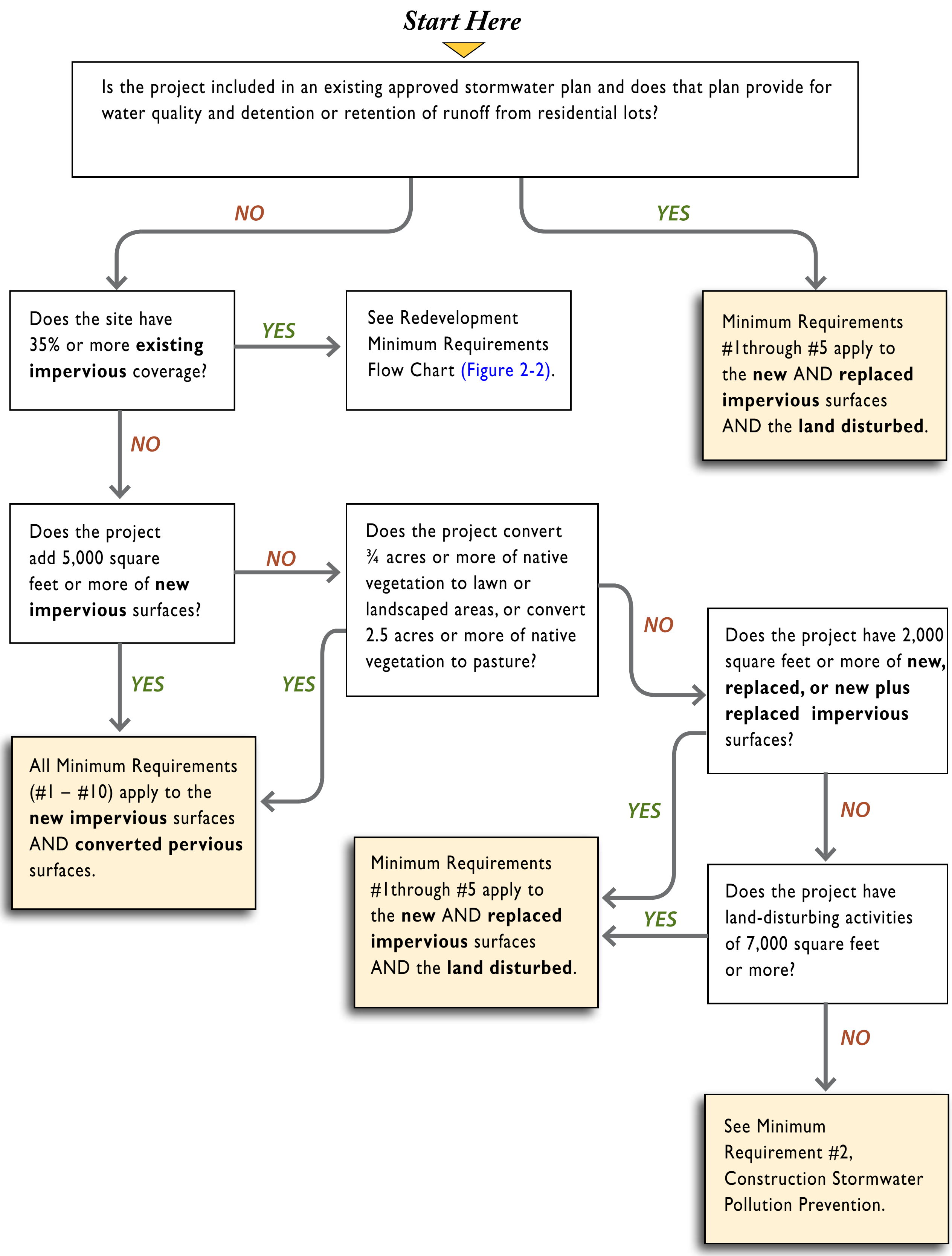
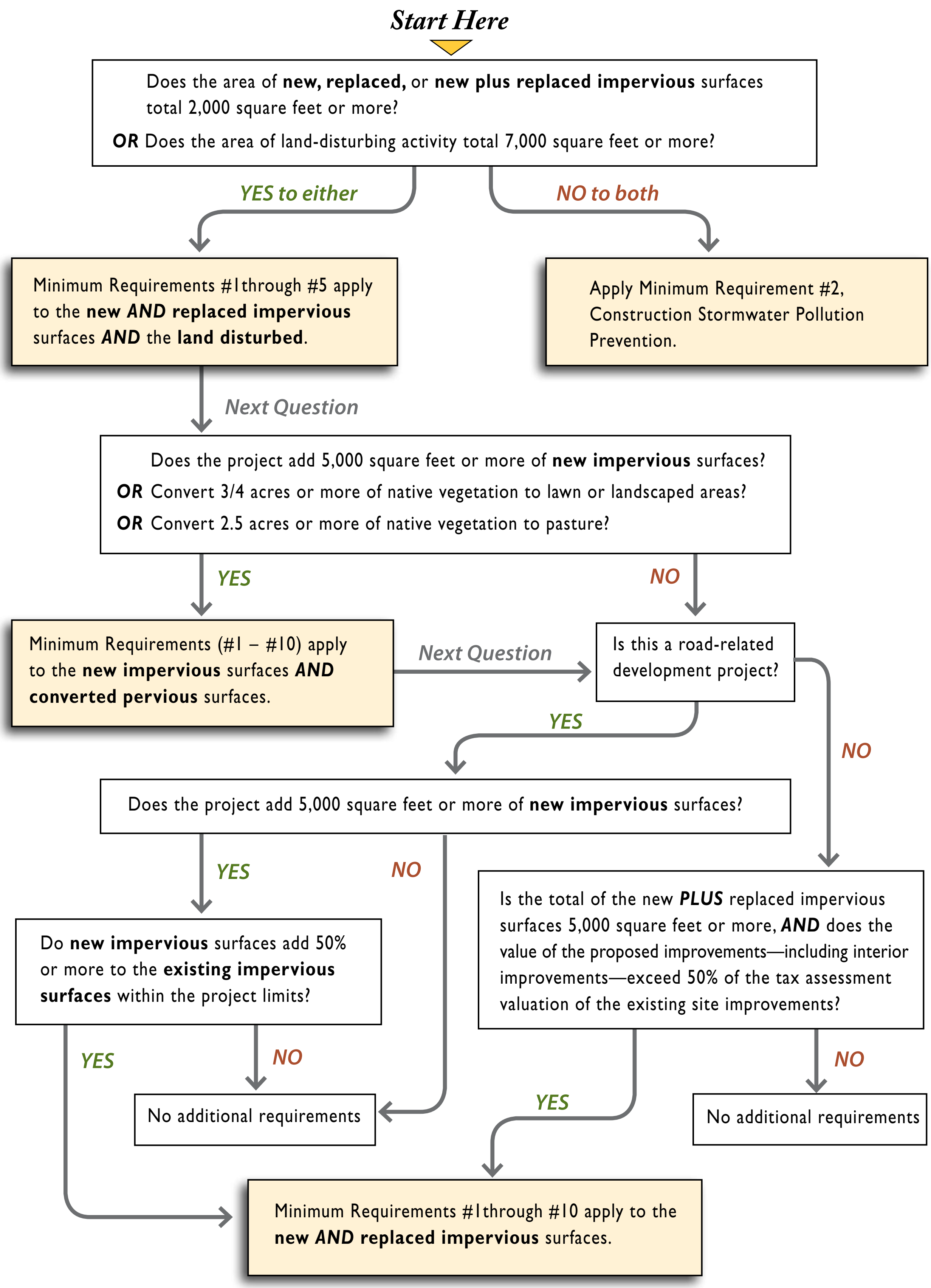


FIGURE 2-2. **Urban Redevelopment Flow Chart**



Rural Properties

All rural new development and re-development shall comply with the following:

a. Minimum Requirement #2 and Section 40.385.030.

b. New development and redevelopment that adds or replaces impervious area of greater than two thousand (2,000) square feet and less than five percent (5%) of a site, or is land disturbing activity greater than seven thousand (7,000) square feet are subject to the minimum requirements dependent on site-specific characteristics.

1) Minimum requirements No. 1 through No. 5 shall apply if the project meets all of the following criteria:
(a) Is outside of habitat or wetland areas or their buffers; and,
(b) Does not generate runoff in channelized flow or discharge directly or indirectly to the county's storm sewer system; and,
(c) Is not located in, or discharge onto steep slope hazard areas or landslide hazard areas as designated in Section 40.430.010.

2) Projects not meeting all the criteria in Section 40.385.020.A.5.b.(1) shall be subject to minimum requirements No. 1 through No. 10.

c. New development and redevelopment that adds impervious area of greater than two thousand (2,000) square feet and that is more than five percent (5%) of a site shall comply with minimum requirements No. 1 through No. 10 for the new impervious surface.

d. An off-site analysis as described in the Stormwater Manual, unless exempted by Section 40.385.010(C)(4).

e. The county may allow the Minimum Requirements to be met for an equivalent (flow and pollution characteristics) area within the same site. For public road projects, the equivalent area does not have to be within the same project limits but must drain to the same receiving water. For frontage improvements required within the public right-of-way, the equivalent area must be immediately adjacent to the site.

2.3 HOW TO MEET THE MINIMUM REQUIREMENTS

After determining which minimum requirements apply to a specific project, refer to the relevant requirements (1 through 10) below to determine how to meet each requirement.

In some cases (e.g., for Minimum Requirements 4 and 5), it is necessary to consult Volume I, Section 2.5 of the SMMWW as a starting point.

This is indicated by the symbol SMMWW

In other cases (e.g., for Minimum Requirements 1, 2, and 3), the Clark County SWM or other Clark County documents supersede/replace the SMMWW and should be consulted as the starting point.

This is indicated by the symbol Clark Co.

► *The Clark County SWM sometimes refers to other sections of the SMMWW (besides Section 2.5) that provide additional information and direction. Those cross-references are identified in the relevant chapters of the Clark County SWM.*

1. Preparation of Stormwater Site Plans

Clark Co. Consult Chapter 3 (Submittals) of this manual to fulfill Minimum Requirement 1.

2. Construction Stormwater Pollution Prevention

Clark Co. Consult Chapter 7 (Construction Stormwater Pollution Prevention Plans) of this manual to fulfill Minimum Requirement 2. (Chapter 7 replaces Section 2.5.2 of the SMMWW.)

Also consult Chapter 3, Section 3.5 of this manual for requirements regarding submittal of a construction stormwater pollution prevention plan.

3. Source Control of Pollution

Clark Co. Consult Clark County Code Chapter 13.26A and the County's Stormwater Pollution Control Manual to fulfill Minimum Requirement 3.

4. Preservation of Natural Drainage Systems and Outfalls

SMMWW Consult Section 2.5.4 of the SMMWW to fulfill Minimum Requirement 4.

5. Onsite Stormwater Management

SMMWW Consult Section 2.5.5 of the SMMWW to fulfill Minimum Requirement 5.

Clark Co. Also consult Chapter 4 (Low Impact Development) of this manual to identify low-impact BMPs that can be considered for onsite stormwater management, in addition to the BMPs identified in the SMMWW.

► *Clark County requires the following low-impact BMPs to be used where feasible:*
- *Dispersion and soil quality BMPs describe in Volume V, Chapter 5 Section 5.3.1 of the SMMWW.*
- *Roof downspout BMPs described in Volume III, Chapter 3 of the SMMWW.*

6. Runoff Treatment

SMMWW Consult Section 2.5.6 of the SMMWW to fulfill Minimum Requirement 6.

Clark Co. In addition to the SMMWW requirements, consult Chapter 5 (Hydrologic Analysis) of this manual concerning the use of single-event hydrologic models for designing water quality facilities in Clark County.

7. Flow Control

SMMWW Consult Section 2.5.7 of the SMMWW to fulfill Minimum Requirement 7.

Clark Co. In addition to the SMMWW requirements, consult Chapter 5 (Hydrologic Analysis) of this manual for information on the use of the Western Washington Hydrology Model (WWHM) in Clark County and a step-by-step process for using existing detention facilities that were previously designed using single-event models.

Also consult Chapter 6 (Design Methodology for Stormwater Infiltration Facilities) of this manual for infiltration requirements in Clark County. Although the County requires the use of either the simplified or detailed approaches when designing infiltration systems (as described in Volume III, Section 3.3 of the SMMWW), the methods in Chapter 6 must be used to determine the design infiltration rate.

8. Wetlands Protection

SMMWW Consult Section 2.5.8 of the SMMWW to fulfill Minimum Requirement 8.

Clark Co. In addition to the SMMWW requirements, consult Chapter 11 of this manual and Clark County Code 40.450 for additional information relating to this requirement.

9. Basin/Watershed Planning

SMMWW Consult Section 2.5.9 of the SMMWW to fulfill Minimum Requirement 9.

Also consult:

Clark Co. Clark County Code Section 40.385, which contains additional basin planning and regional stormwater facility requirements.

Clark County Clean Water Program (360-387-6118, extension 4345), which can provide a list of basin plans that have been adopted.

10. Operation and Maintenance

Clark Co. Consult Clark County's Stormwater Facility Maintenance Manual (Clark County 2008) to fulfill Minimum Requirement 10.

2.4 EXEMPTIONS FROM THE MINIMUM REQUIREMENTS

Total Exemptions

The following activities are exempt from Clark County Code Chapter 40.385 and the Clark County SWM. Other state and federal requirements may apply.

- Forest practices regulated under Title 222 of the Washington Administrative Code (WAC), except Class IV General Forest Practices that are conversions from timber land to other uses.
- Construction of agricultural buildings or other impervious surfaces for carrying out agricultural activities; provided that no stormwater is released from the site directly or indirectly to the county's stormwater conveyance system.
- Normal landscape maintenance activities and gardening.
- The following road maintenance practices:
  - Pothole and square cut patching
  - Overlaying existing asphalt or concrete pavement without expanding the area of coverage
  - Shoulder grading
  - Regrading/reshaping drainage systems
  - Crack sealing
  - Resurfacing with in-kind material without expanding the road prism
  - Vegetation management

Partial Exemptions

- The construction of single-family homes, duplexes, and their accessory structures are exempt from minimum requirements 6 through 10, provided the following conditions are met:
  - The project site is included in a stormwater plan previously approved by the county.
  - The stormwater plan provides for water quality and detention or retention of runoff from residential lots.
- Drainage projects that do not create new underground injection control wells are exempt from Minimum Requirement 6 (Runoff Treatment), and the responsible official may waive all or parts of Minimum Requirement 1 (Preparation of a Site Stormwater Plan) if the project meets other applicable requirements of this chapter.
- Underground utility projects that replace the ground surface with in-kind material or materials with similar runoff characteristics are subject only to Minimum Requirement 2 (Construction Stormwater Pollution Prevention).
- New development and redevelopment that meet the criteria in Appendix I-E (Flow Control-Exempt Surface Waters) of the SMMWW and all of the following criteria are exempt from Minimum Requirement 7 (Flow Control):
  - Project meets the exemption requirements (described in Volume I, Section 2.5.7 of the SMMWW) for discharges to one of the following water bodies:
    - Columbia River
    - Lake River
    - Lewis River, downstream of the confluence with Quartz Creek
    - Lewis River, East Fork, downstream of the confluence with Big Tree Creek
    - Vancouver Lake
  - Runoff is treated in accordance with Minimum Requirement 6 (Runoff Treatment) and CCC Section 40.385.020(B).
  - The discharge structure is designed to avoid erosion during all storms up to the 100-year storm.
  - If an existing discharge structure is used, the discharge structure and conveyance system leading to the discharge must have adequate capacity to meet the requirements of Chapter 8 (Conveyance Systems) of this manual.

- New development and redevelopment are exempt from Minimum Requirement 8 (Wetlands Protection), provided that:
  - The project does not change the rate, volume, duration, or location of discharges to and from the project site (e.g., where existing impervious surface is replaced with other impervious surface having similar runoff-generating characteristics, or where pipe/ditch modifications do not change existing discharge characteristics), or
  - The project discharges to a slope wetland or riverine wetland where no depressional characteristics exist, or
  - The project meets the land cover percentage requirements for full dispersion in accordance to SMMWW or this manual for flow control, or
  - The county determines, based on information in the preliminary stormwater plan or information submitted for wetland review per CCC 40.450, that the proposed project will not degrade wetland function.

3 Submittals

3.1 INTRODUCTION

This chapter provides the following information:

- **Section 3.2:** How to prepare and submit a preliminary stormwater plan.
- **Section 3.3:** How to prepare and submit a final stormwater plan.
- **Section 3.4:** How to make changes to a stormwater plan.
- **Section 3.5:** How to prepare and submit a construction stormwater pollution prevention plan.

► *This chapter fulfills Minimum Requirement 1 (Preparation of Stormwater Site Plans)*

3.2 PRELIMINARY STORMWATER PLAN

Purpose

In accordance with Minimum Requirement 1, a preliminary stormwater plan is required for all new development and redevelopment projects that are not exempted from all minimum requirements (as described in Chapter 2, Section 2.4). The purpose of the preliminary stormwater plan is to allow Clark County to determine whether a proposal will meet the requirements of Clark County Code Chapter 40.385.

The preliminary stormwater plan submittal shall consist of:

1) A preliminary development plan.

2) A preliminary technical information report (TIR) prepared in the standardized format described in the sections below.

The preliminary stormwater plan shall identify how stormwater runoff that originates on the site or flows through the site is currently controlled and how this will change with the proposed development or redevelopment project. If the site is within the region covered by a basin plan, the information needed in the preliminary stormwater plan may be reduced.

The project engineer shall include a statement that all the required information is included in the preliminary stormwater plan and that the proposed stormwater facilities are feasible. All plans, studies, and reports that are part of the preliminary and final stormwater plans shall be signed and dated by the registered soil scientist and the professional civil engineer(s) (registered in the state of Washington) responsible for preparation of the report.

The preliminary stormwater plan shall be submitted with the land use application.

Modification of Content Requirements

The responsible official may waive in writing some or all of the content requirements in the preliminary stormwater plan if:

- The development project is included in an approved final stormwater plan that meets the requirements of this chapter; or
- A basin plan exists that makes some of the information irrelevant.

The waiver of some or the entire preliminary stormwater plan does not relieve the applicant of the requirement to prepare a final stormwater plan.

Preliminary Development Plan

The preliminary development plan shall consist of 22-inch x 34-inch or 24-inch x 36-inch drawings for existing and proposed conditions. The preliminary development plan shall show the character of the existing site and proposed features, including but not limited to:

1. Existing and proposed property boundaries, easements, and rights-of-way.
2. Existing and proposed contours with a 2-foot maximum contour interval, unless the responsible official determines a lesser interval is sufficient to show drainage patterns and basin boundaries.
3. Offsite areas contributing runoff to the site.
4. Natural and manmade drainage features adjacent to the site, including existing and proposed (if known) stormwater facilities.
5. Existing onsite water wells, known agricultural drain tiles, areas of potential slope instability, structures, utilities, and septic tanks and drain fields.
6. Location of the 100-year floodplain and floodways and shoreline management area limits on the site.

7. Existing water resource features on and adjacent to the site, including streams, wetlands, springs, sinks, and stormwater facilities.

8. Existing and proposed drainage flow routes for each threshold discharge area (TDA) to and from the site, including bypass flows.

9. Proposed location of structural source control BMPs implemented in accordance with Minimum Requirement 3 (Source Control of Pollution), where applicable.

10. Point of discharge locations from the proposed project site that preserve the natural drainage patterns and existing outfall locations, in accordance with Minimum Requirement 4 (Preservation of Natural Drainage Systems and Outfalls).

11. Areas of the project site where onsite stormwater management BMPs will be effectively implemented, in accordance with Minimum Requirement 5 (Onsite Stormwater Management), including low impact development BMPs. The plan must show the areas of retained native vegetation, required flow lengths, and vegetated flow paths for proper implementation of these BMPs.

12. All existing drainage facilities, including structural water quality or flow control BMPs and conveyance systems.

13. Existing and proposed pollution-generating pervious surfaces (PGPS), including lawn, landscaped areas, and pasture areas.

14. Existing areas of the site predominantly covered by native vegetation (i.e., native trees, shrubs, and herbaceous plants as defined by the Washington State Department of Ecology [Ecology]) and areas of native vegetation to be preserved under proposed conditions.

15. Approximate location and size of proposed runoff treatment and flow control facilities implemented in accordance with Minimum Requirements 6 and 7.

16. The delineated wetland boundary (for sites that discharge stormwater to a wetland, either directly or indirectly through a conveyance system, and must meet Minimum Requirement 8 [Wetlands Protection]).

17. A conceptual grading plan that verifies the constructability of a stormwater facility (for sites with slopes greater than 5 percent).

18. The responsible official may require additional site or vicinity information if needed to determine the feasibility of the stormwater proposal.

Preliminary Technical Information Report (TIR)

The preliminary TIR shall contain all technical information and analyses necessary to determine that the proposed stormwater facilities are feasible. The required contents of the preliminary TIR are identified below.

Table of Contents

1. List of section headings and their respective page numbers.
2. List of tables with page numbers.
3. List of figures with page numbers.
4. List of attachments, numbered.
5. List of references.

Map Submittals

All maps shall contain a scale and north arrow.

1. **Vicinity Map:** All vicinity maps shall clearly show the project site.

2. **Soils Map:** The soils map shall show soils within the contributing area that drains to the site itself. Soils maps may be obtained from the following sources:

   – Updated version of the Soil Survey of Clark County, Washington, originally published in 1972, and updated by the Natural Resources Conservation Service (NRCS).

   – Geographic information system (GIS) maps of soils from Clark County GIS.

   – Washington soil survey data as available on the NRCS website (http://websoilsurvey.nrcs.usda.gov).

   – If the maps do not appear to accurately represent the soils for the site, the applicant is responsible for verifying the actual soils for the site.

3. **Other Maps:** The following additional maps shall be required in the situations noted:

   – Wellhead Protection. If the site lies within the 10-year time-of-travel zone of a public water supply well or within a Category I or II critical aquifer recharge area (CARA), maps showing all of the zones of contribution that overlap the site are required. See Clark County Code (CCC) Chapter 40.410 for CARA regulations.

   – Floodplains. If a floodplain mapped by the Federal Emergency Management Agency (FEMA) exists on or adjacent to the site, a map showing the floodplain is required.

   – Shoreline Management Area. If the site contains or is adjacent to a stream or lake regulated under the Washington Shorelines Management Act, a map showing the boundary of the shoreline management area in relation to the site is required.

Section A – Project Overview

1. Describe the site location.

2. Describe the topography, natural drainage patterns, vegetative ground cover, and presence of critical areas (CCC Chapter 40.440). Critical areas that receive runoff from the site shall be described to a minimum of ¼ mile away from the site boundary.

3. Identify and discuss existing onsite stormwater systems and their functions.

4. Identify and discuss site parameters that influence stormwater system design.

5. Describe drainage to and from adjacent properties.

6. For agricultural sites with drain tiles, discuss the impact of construction on the drain tiles, site drainage, and the impact of the drainage tiles on proposed stormwater facilities.

7. Describe adjacent areas, including streams, lakes, wetland areas, residential areas, and roads that might be affected by the construction project.

8. Generally describe proposed site construction, size of improvements, and proposed methods of mitigating stormwater runoff quantity and quality impacts.

Section B – Minimum Requirements

Describe the land-disturbing activity and document the applicable minimum requirements for the project site. (See Chapter 2 of this manual for guidance.) Include the following information in table format:

1. The amount of existing impervious surface.
2. The amount of new impervious surface.
3. The amount of replaced impervious surface.
4. The amount of native vegetation converted to lawn or landscaping.
5. The amount of native vegetation converted to pasture.
6. The total amount of land-disturbing activity.

Provide a statement that confirms the minimum requirements that will apply to the development activity. For land-disturbing activities where minimum requirements 1 through 10 must be met:

1. Provide the amount of effective impervious area in each TDA, and document through an approved continuous runoff simulation model (e.g., the Western Washington Hydrologic Model [WWHM]) the increase in the 100-year flood frequency from pre-developed to developed conditions for each TDA.

2. List the TDAs that must meet the runoff control requirements listed in Minimum Requirement 6.

3. List the TDAs that must meet the flow control requirements listed in Minimum Requirement 7.

4. List the TDAs that must meet the wetlands protection requirements listed in Minimum Requirement 8.

Section C – Soils Evaluation

1. Describe the site's suitability for stormwater infiltration for flow control, runoff treatment, and low impact development (LID) measures.

2. Identify water table elevations, flow directions (where available), and data on seasonal water table fluctuations with minimum and maximum water table elevations where these may affect stormwater facilities.

3. Identify and describe soil parameters and design methods for use in hydrologic and hydraulic design of proposed facilities.

4. Report findings of testing and analysis used to determine the infiltration rate.

5. Where unstable or complex soil conditions exist that may significantly affect the design of stormwater facilities, the responsible official may require a preliminary soils report that addresses stormwater design considerations arising from soil conditions. The preliminary soils report shall be prepared by a registered professional engineer proficient in geotechnical investigation and engineering or a registered soil scientist. The preliminary soils report shall include a soils map developed using the criteria set in the *NRCS National Soil Survey Handbook* (NRCS 2007) and the *SCS Soil Survey Manual* (SCS 1993), at a minimum scale of 1:5,000 (12.7 inch/mile).

Section D – Source Control

If the development activity includes any of the activities listed in Section 2.2 of Volume IV of the *Stormwater Management Manual for Western Washington* (SMMWW), identify the source control BMPs to be used with the land-disturbing activity.

Section E – Onsite Stormwater Management BMPs

1. On the preliminary development plan or other maps, show the site areas where onsite stormwater management BMPs will be effectively implemented. (See Volume III, Chapter 3 and Volume V, Chapter 5 of the SMMWW and Chapter 4 of this manual.) The plan must show the areas of retained native vegetation and required flow lengths and vegetated flow paths, as required for proper implementation of each onsite stormwater BMP. Arrows must show the stormwater flow path to each BMP.

2. Identify and describe geotechnical studies or other information used to complete the analysis and design of each onsite stormwater BMP.

3. Identify the criteria (and their sources) used to complete analyses for each onsite stormwater BMP.

4. Describe how design criteria will be met for each proposed onsite stormwater management BMP.

5. Describe any onsite application of LID measures planned for the project. Provide a plan that shows the proposed location and approximate size of each LID facility.

6. Identify and describe any assumptions used to complete the analysis.

7. Describe site suitability, including hydrologic soil groups, slopes, area of native vegetation, and adequate location of each BMP.

Section F – Runoff Treatment Analysis and Design

For land-disturbing activities where the thresholds within Minimum Requirement 6 indicate that runoff treatment facilities are required:

1. Document the level of treatment required (basic, enhanced, phosphorus, oil/water separation), based on procedures in Volume V, Chapter 2 of the SMMWW.

2. Provide background and description to support the selection of the treatment BMPs being proposed. Include an analysis of initial implementation costs and long-term maintenance costs.

3. Identify geotechnical or soils studies or other information used to complete the analysis and design.

4. Identify the BMPs used in the design, and their sources.

5. Summarize the results of the runoff treatment design, and describe how the proposed design meets the requirements of CCC Chapter 40.385 and the SMMWW.

6. Provide a table that lists the amount of pollution-generating pervious surfaces (PGPS) and pollution-generating impervious surfaces (PGIS).

Section G – Flow Control Analysis and Design

For land-disturbing activities where the thresholds within Minimum Requirement 7 indicate that flow control facilities are required:

1. Identify the site's suitability for stormwater infiltration for flow control, including tested infiltration rates, logs of soil borings, and other information.

2. Identify and describe geotechnical or other studies used to complete the analysis and design.

3. If infiltration cannot be provided for flow control, provide the following additional information:

   – Identify the areas where flow control credits can be obtained for dispersion, LID, or other measures, per the requirements in the SMMWW.

   – Provide the approximate sizing and location of flow control facilities for each TDA, per Volume III of the SMMWW.

   – Identify the criteria (and their sources) used to complete the analyses, including pre-developed and post-developed land use characteristics.

   – Complete a hydrologic analysis for existing and developed site conditions, in accordance with the requirements of CCC Section 40.385.020(C) and Chapter 2, Volume III of the SMMWW, using an approved continuous runoff simulation model (the Clark County version of WWHM). Compute existing and developed flow durations for all subbasins. Provide an output table from the continuous flow model.

   – Include and reference all hydrologic computations, equations, graphs, and any other aids necessary to clearly show the methodology and results.

   – Include all maps, exhibits, graphics, and references used to determine existing and developed site hydrology.

4. Submit electronic copies of the WWHM (.wdm, .prj, .usi) project files upon request.

Section H – Wetlands Protection

For projects with stormwater discharges to a wetland, either directly or indirectly through a conveyance system, the preliminary TIR shall describe wetland protection measures to be implemented in accordance with Minimum Requirement 8. The narrative shall describe the measures that will maintain the hydrologic conditions, hydrophytic vegetation, and substrate characteristics necessary to support existing and designated uses.

3.3 FINAL STORMWATER PLAN

Purpose

In accordance with Minimum Requirement 1, the final stormwater plan provides final engineering design and construction drawings for the stormwater aspects of a proposed new development or redevelopment project. The final stormwater plan shall be submitted and approved by the responsible official before construction of the development can begin.

Modification of Content Requirements

The responsible official may waive in writing some or all of the content requirements in the final stormwater plan if:

- The development project is included in an approved final stormwater plan that meets the requirements of this chapter; or
- A basin plan exists that makes some of the information irrelevant.

Final Stormwater Plan Submittal

The final stormwater plan submittal shall include the following:

1. Any easements, covenants, or agreements necessary to permit construction.
2. Final engineering plans that provide sufficient detail to allow construction of the stormwater facilities. These plans shall be stamped, signed, and dated by the engineer(s), registered in the state of Washington, responsible for hydrologic, hydraulic, geotechnical, structural, and general civil engineering design and by the project engineer responsible for the preparation of the final stormwater plan. The final engineering plan shall show all utilities to ensure that conflicts between proposed utility lines do not exist.
3. The approved preliminary stormwater plan, with an explanation of any differences between the design concepts included in the preliminary and final stormwater plans. If a final stormwater plan differs from the approved preliminary stormwater plan in a manner that, in the opinion of the responsible official, raises material water quality or quantity control issues, it shall require another SEPA determination (if subject to the State Environmental Policy Act [SEPA]) and a post-decision review, in accordance with CCC Section 40.520.060.
4. A final development plan (which may be a part of the final engineering plans or a separate plan). See the requirements identified below.
5. A final technical information report (TIR). See the requirements identified below.
6. A construction stormwater pollution prevention plan (SWPPP). See Section 3.5 below.

Final Development Plan

The final development plan shall be consistent with the preliminary development plan and may be combined with the final engineering plans. In addition to the information required in the preliminary development plan, the final plan requires the following information:

1. Threshold discharge area (TDA) delineations, and total impervious and pervious area delineations and acreages by TDA.

2. The acreage of pollution-generating pervious surfaces (PGPS) and pollution-generating impervious surfaces (PGIS) used in the hydraulic/hydrologic calculations both onsite and offsite that contribute surface runoff.

3. Directions and lengths of overland, pipe, and channel flow.

4. Outfall points from each TDA and overflow routes for the 100-year storm.

5. Onsite conveyance systems, including pipes, catch basins, channels, ditches, swales, and culverts.

6. Primary flow path arrows for drainage under developed conditions, with the calculated flow rates. Cross-reference the flow rates to the hydrological model output file used to calculate the flow rates.

7. The responsible official may require additional site or vicinity information if needed to determine the feasibility of the stormwater proposal.

Final Technical Information Report (TIR)

The final TIR shall be a comprehensive report, supplemental to the final engineering plans, that contains all technical information and analyses necessary to complete final engineering plans based on sound engineering practices and appropriate geotechnical, hydrologic, hydraulic, and water quality design.

The final TIR shall be stamped, signed, and dated by the professional engineer(s), registered in the state of Washington, responsible for hydrologic, hydraulic, geotechnical, structural, and general civil engineering design.

The required contents of the final TIR, which is part of the final stormwater plan, are identified below.

Table of Contents

See the preliminary TIR requirements in Section 3.2.

Map Submittals

See the preliminary TIR requirements in Section 3.2.

Section A – Project Overview

Provide the information from the preliminary TIR, with the following additional elements:

1. Reference the conceptual design proposed in the preliminary stormwater plan.
2. Identify revisions to the conceptual design contained within the final engineering plans.

Section B – Minimum Requirements

Provide the information from Section B of the preliminary TIR, revised as necessary for the final design. Confirm the applicable minimum requirements identified in the preliminary TIR. For land-disturbing activities where minimum requirements 1 through 10 must be met, provide the required information listed in Section B of the preliminary TIR, revised to reflect the final design.

Section C – Soils Evaluation

See the preliminary TIR requirements in Section 3.2.

Section D – Source Control

See the preliminary TIR requirements in Section 3.2.

Section E – Onsite Stormwater Management BMPs

Provide the information from the preliminary TIR, with the following additional elements:

1. Reference the conceptual design proposed in the preliminary stormwater plan.
2. Identify revisions to the conceptual design contained within the final engineering plans.
3. For bioretention systems, provide the following:
   a. The proposed soil matrix for the facility.
   b. The planting plan, listing proposed plant types and locations.
   c. Detail drawings, including the following:
      – If an underdrain is used, show drain rock, pipe, and filter fabric specifications.
      – All stormwater piping associated with the facility, including catch basin, pipe materials, sizes, slopes, and invert elevations.
      – Rain garden width, length, side slopes, and maximum design water depth.
      – Irrigation system, if installed.
      – Designs for any retaining walls proposed. Structural walls shall meet county building permit requirements.

4. For porous pavements, provide the following:
   a. Supporting design calculations showing adequate infiltration rates to accommodate flows from all impervious surfaces directed onto any porous pavement.
   b. Geotextile specification.
   c. Base material gradation.
   d. Asphalt mix design and void calculations.
   e. Acceptance test procedures.
   f. Detail drawings, including the following:
      – Geotextile
      – Base material
      – Asphalt layer
5. For reversed slope sidewalks, show the following:
   – Details on the planting plan for any areas receiving water from reversed slope sidewalks.
6. Describe how the project will fully implement required BMP T5.13, Soil Quality and Depth. Clark County and the Washington Department of Ecology recommend using guidelines at http://www.soilsforsalmon.org to develop the soil management plan.

Section F – Runoff Treatment Analysis and Design

For land-disturbing activities where the thresholds within Minimum Requirement 6 indicate that runoff treatment facilities are required, provide the information from the preliminary TIR, with the following additional elements:

1. Reference the conceptual runoff treatment design proposed in the preliminary stormwater plan.
2. Identify revisions to the conceptual runoff treatment design contained in the preliminary stormwater plan.
3. Complete a detailed analysis and design of all proposed runoff treatment system elements, in accordance with CCC Section 40.385.020(B) and Volume V of the SMMWW. Reference runoff treatment system elements to labeled points shown on the site location map or final development plan.
4. Include and reference all computations, equations, charts, nomographs, detail drawings, and other tabular or graphic aids used to design water quality system elements in the technical appendix.
5. Summarize the results of the runoff treatment design, and describe how the proposed design meets the requirements of CCC Chapter 40.385 and the SMMWW.

Section G - Flow Control Analysis and Design

For land-disturbing activities where the thresholds within Minimum Requirement 7 indicate that flow control facilities are required:

1. Identify revisions to the conceptual design proposed in the preliminary stormwater plan.
2. Identify initial conditions, including stream base flows, beginning water surface elevations, hydraulic or energy grade lines, initial groundwater elevations, beginning storage volumes, and other data or assumptions used to complete the analyses of initial conditions. Reference the sources of information.
3. Describe any assumptions used to complete the analysis, including flow credits through the use of onsite stormwater BMPs or LID measures.
4. Complete a detailed hydrologic analysis for existing and developed site conditions, in accordance with the requirements of CCC Section 40.385.020 (C) and Chapter 2, Volume III of the SMMWW, using an approved continuous runoff simulation model (the Clark County version of WWHM). Compute pre-developed and developed flow durations for all subbasins. Provide an output table from the continuous flow model, including the following:
   a. Flow rates for the 2-, 10-, and 100-year return periods for pre-developed and developed conditions.
   b. A table listing the pass/fail rates for each flow level where duration statistics were calculated.
   c. A graph showing the flow rate on the y axis and percent time exceeding on the x axis for pre-developed conditions and post-developed mitigated conditions, from 50 percent of the 2-year flow rate through the 50-year flow rate.
5. Provide a hydraulic analysis of pipes and/or channels that lead to and/or from the outlet structure. The analysis should confirm the capacity of pipes and channels to convey the peak flow rates for the 2-, 10-, 50-, and 100-year return period flow rate with the water surface elevation of the pond at the elevation for those return period flow rates.
6. Submit electronic copies of the WWHM (.wdm, .prj, .usi) project files to allow reviewers to run the model and confirm the model results.
7. Refer to labeled points shown on the site location map and development plan.
8. Include and reference all hydrologic and hydraulic computations, equations, rating curves, stage/storage/discharge tables, graphs, and any other aids necessary to clearly show the methodology and results.
9. Include all maps, exhibits, graphics, and references used to determine existing and developed site hydrology.

Section H - Flow Control System Plan

1. Provide an illustrative sketch of the flow control facility and its appurtenances.

2. Show basic measurements necessary to confirm storage volumes.

3. Show all orifice, weir, and flow restrictor dimensions and elevations.

4. The sketch shall correspond with final engineering plans. Alternatively, a final site grading plan that incorporates the above information may be included as an attachment to the final stormwater plan.

5. Provide electronic copies of the drawings used for analysis, measurement, and design inputs for the hydrologic analysis submitted with the final drawing in one of the following approved file formats: Portable Document Format (.pdf), AutoCAD (.dwg, .dxf), or MicroStation (.dgn).

Section I – Wetlands Protection

For projects with stormwater discharges to a wetland, either directly or indirectly through a conveyance system, the TIR shall describe wetland protection measures to be implemented, in accordance with Minimum Requirement 8. The narrative shall describe the measures that will maintain the hydrologic conditions, hydrophytic vegetation, and substrate characteristics necessary to support existing and designated uses.

Section J – Other Permits

Construction of roads and stormwater facilities may require additional permits from other agencies. These permits may contain requirements that affect the design of the stormwater system. This section lists the titles of other possible required permits, the agencies that require the permits, and the permit requirements, if known, that affect the final stormwater plan. Approved permits that are critical to the feasibility of the stormwater facility design shall be included in this section.

1. **Onsite sewage disposal**: Clark County Health Department or Washington Department of Health

2. **Developer/local agency agreement:** Washington State Department of Transportation (WSDOT)

3. **Short-term water quality modification approval:** Washington State Department of Ecology (Ecology)

4. **Hydraulic project approval:** Washington Department of Fish and Wildlife (WDFW)

5. **Dam safety permit:** DOE

6. **Section 10, 404, and 103 permits:** U.S. Army Corps of Engineers

7. **Surface mining reclamation permits:** Washington Department of Natural Resources

8. **Clark County critical aquifer recharge area (CARA) permit:** CCC Chapter 40.410

9. **Clark County floodplain permit:** CCC Chapter 40.420

10. **Clark County geohazard permit**: CCC Chapter 40.430

11. **Clark County habitat permit:** CCC Chapter 40.440

12. **Clark County wetland permit**: CCC Chapter 40.450

13. **Clark County shoreline management permit:** CCC Chapter 40.460

14. **Underground injection control (UIC) well registration:** Ecology

Section K – Conveyance Systems Analysis and Design

1. Reference the conceptual drainage design proposed in the preliminary stormwater plan.

2. In the technical appendix, include and reference all computations, equations, charts, nomographs, detail drawings, and other tabular or graphic aids used to design water quality system elements.

3. Identify revisions to the conceptual drainage design contained in the preliminary stormwater plan.

4. Identify the criteria used to complete the analyses and their sources.

5. Identify and discuss initial conditions, including stream base flows, beginning water surface elevations, hydraulic or energy grade lines, beginning storage elevations, and other data or assumptions used to complete the analyses of initial conditions. Reference the sources of information.

6. Describe any assumptions used to complete the analyses.

7. Complete a detailed hydraulic analysis of all proposed collection and conveyance system elements and existing collection and conveyance elements, including outfall structures and outlet protection, that influence the design or are affected by the proposal, in accordance with Chapter 8 (Conveyance Systems) of this manual. Compute and tabulate the following:

   a. Identify design flows and velocities and conveyance element capacities for all conveyance elements within the development.

   b. Identify the 10-year recurrence interval stage for detention facility outfalls (see Chapter 8). Provide stage-frequency documentation from WWHM.

   c. Compute existing 100-year floodplain elevations and lateral limits for all channels, and verify no net loss of conveyance or storage capacity from development.

d. Reference conveyance system elements to labeled points shown on the site location map or development plan.

e. Verify the capacity of each conveyance system element to convey design flow and discharge at non-erosive velocities. Verify the capacity of the onsite conveyance system to convey design flows that result from ultimate build-out of upstream areas.

f. Include and reference all hydraulic computations, equations, pipe flow tables, flow profile computations, charts, nomographs, detail drawings, and other tabular or graphic aids used to design and confirm the performance of conveyance systems.

g. Summarize the results of system analyses, and describe how the proposed design meets the requirements of this chapter.

Section L – Offsite Analysis

If applicable, provide the results of an offsite analysis prepared in accordance with Chapter 9 (Offsite Analysis and Mitigation) of this manual. (See exemptions in Chapter 9.)

Section M—Approval Conditions Summary

List each preliminary approval condition related to stormwater control, wetlands, floodplains, and other water-related issues, and explain how the final design addresses or conforms to each condition.

Section N – Special Reports and Studies

Where site-specific characteristics, such as steep slopes, wetlands, and sites located in wellhead protection areas, present difficult drainage and water quality design problems, the responsible official may require additional information or the preparation of special reports and studies that further address the specific site characteristics, the potential for impacts associated with the development, and the measures that would be implemented to mitigate impacts. Special reports shall be prepared by professionals with expertise in the particular area of analysis, who shall date, sign, stamp, and otherwise certify the report. Subjects of special reports may include, but are not be limited to:

1. Geotechnical
2. Wetlands
3. Floodplains and floodways
4. Groundwater
5. Structural design
6. Fluvial geomorphology (erosion and deposition)

All special reports and studies shall be included in the technical appendix.

Section O – Groundwater Monitoring Program

Where required by **CCC Chapter 40.385**, a groundwater monitoring program shall be included in the final stormwater plan. The groundwater monitoring program shall be prepared by a person with expertise in groundwater contamination investigation, prevention, and monitoring and shall clearly describe a comprehensive groundwater testing and evaluation program designed to ensure compliance with federal and state of Washington laws and the requirements of CCC Chapter 40.385. The responsible official will review proposed groundwater monitoring programs on a site-specific basis.

Section P – Maintenance and Operations Manual

The project engineer shall prepare a maintenance and operations manual for each stormwater control or treatment facility to be privately maintained and for those that constitute an experimental system to be maintained by the county. The manual, which may be brief, shall be written in an orderly and concise format that clearly describes the design and operation of the facility. The manual shall also provide an outline of required maintenance tasks, with recommended frequencies at which each task should be performed. The manual shall contain or reference procedures from the latest version of Clark County's ***Stormwater Facility Maintenance Manual*** (Clark County 2008).

Technical Appendix

All TIRs shall contain a technical appendix that includes all computations completed in the preparation of the TIR, together with copies of referenced data, charts, graphs, nomographs, hydrographs, stage-storage discharge tables, maps, exhibits, and all other information required to clearly describe the stormwater flow control and runoff treatment design for the proposed development activity. The format of the technical appendix shall follow as closely as possible the section format of the TIR and shall be adequately cross-referenced to ensure that the design may be easily followed, checked, and verified. The technical appendix shall also contain all special reports and studies, other than those included as attachments to the TIR.

3.4 STORMWATER PLAN CHANGES

If the designer must make changes or revisions to the final stormwater plan after final approval, the proposed revisions shall be submitted to Clark County prior to construction. The submittals shall include the following:

1. Substitute pages for the originally approved final stormwater plan, identifying the proposed changes.

2. Revised drawings, showing any structural changes.

3. Any other supporting information that explains and supports the reason for the change.

All revisions shall be stamped, signed, and dated by the professional engineer(s), registered in the state of Washington, responsible for hydrologic, hydraulic, geotechnical, structural, and general civil engineering design.

3.5 CONSTRUCTION STORMWATER POLLUTION PREVENTION PLAN (SWPPP)

In accordance with Minimum Requirement 2, a Construction Stormwater Pollution Prevention Plan (SWPPP) is required for all project sites where the new, replaced, or new plus replaced impervious surfaces total 2,000 square feet or more or where 7,000 square feet or more of land is disturbed. The Construction SWPPP shall be submitted and approved before undertaking any land-disturbing activity. The Construction SWPPP shall be stamped by an engineer licensed in the state of Washington, and submitted with the final stormwater plan. Chapter 7 of this manual provides guidance for developing the Construction SWPPP.

The Construction SWPPP shall consist of two parts: a narrative and drawings. The following two sections describe the contents of the narrative and drawings.

Section A – Narrative

The narrative shall address the following:

1. **Twelve (12) elements** – Describe how the Construction SWPPP addresses each of the 12 required elements. Include the type and location of BMPs used to satisfy the required element. If an element is not applicable to a project, provide a written justification for why it is not necessary (see Chapter 7 of this manual).

2. **Project description** – Describe the nature and purpose of the construction project. Include the total size of the area; any increase in existing impervious area; the total area expected to be disturbed by clearing, grading, excavation, or other construction activities, including offsite borrow and fill areas; and the volumes of grading cut and fill that are proposed.

3. **Existing site conditions** – Describe the existing topography, vegetation, and drainage. Include a description of any structures or development on the parcel, including the area of existing impervious surfaces.

4. **Adjacent areas** – Describe adjacent areas, including streams, lakes, wetlands, residential areas, and roads that might be affected by the construction project. Provide a description of the downstream drainage leading from the site to the receiving body of water.

5. **Critical areas** – Describe areas on or adjacent to the site that are classified as critical areas. Critical areas that receive runoff from the site shall be described up to ¼ mile away. The distance may be increased by the plan approval authority. Describe special requirements for working near or within these areas.

6. **Soil** – Describe the soil on the site, giving such information as soil names, mapping unit, erodibility, settleability, permeability, depth, texture, and soil structure.

7. **Potential erosion problem areas** – Describe areas on the site that have potential erosion problems.

8. **Construction phasing** – Describe the intended sequence and timing of construction activities and proposed construction phasing.

9. **Construction schedule** – Describe the construction schedule. If the schedule extends into the wet season, describe what activities will continue during the wet season and how the transport of sediment from the construction site to receiving waters will be prevented.

10. **Financial/ownership responsibilities** – Describe ownership and obligations for the project. Include bond forms and other evidence of financial responsibility for environmental liabilities associated with construction.

11. **Engineering calculations** – Attach any calculations made for the design of such items as sediment ponds, diversions, and waterways, as well as calculations for runoff and stormwater detention design (if applicable). Engineering calculations must bear the signature and stamp of an engineer licensed in the state of Washington.

12. Identify a responsible, certified **erosion control specialist**. Include telephone and/or pager numbers.

Section B – Drawings

1. **Vicinity map** – Provide a map with enough detail to identify the location of the construction site, adjacent roads, and receiving waters.

2. **Site map** – Provide a site map(s) showing the following features:

   a. A legal description of the property boundaries or an illustration of property lines (including distances) in the drawings.

   b. The direction of north in relation to the site.

   c. Existing structures and roads, if present.

   d. Boundaries and labeling of the different soil types.

   e. Areas of potential erosion problems.

   f. Any onsite and adjacent surface waters, critical areas, their buffers, FEMA base flood boundaries, and shoreline management boundaries.

   g. Existing contours and drainage basins and the direction of flow for the different drainage areas.

   h. Final and interim grade contours as appropriate, drainage basins, and the direction of stormwater flow during and upon completion of construction.

   i. Areas of soil disturbance, including all areas affected by clearing, grading, and excavation.

j. Locations where stormwater discharges to surface waters during and upon completion of construction.

k. Existing unique or valuable vegetation and the vegetation that is to be preserved.

l. Cut and fill slopes, indicating top and bottom of slope catch lines.

m. Stockpile, waste storage, and vehicle storage/maintenance areas.

n. Total cut and fill quantities and the method of disposal for excess material.

3. **Conveyance systems –** Show on the site map the following temporary and permanent conveyance features:

   a. Locations for swales, interceptor trenches, or ditches.

   b. Drainage pipes, ditches, or cut-off trenches associated with erosion and sediment control and stormwater management.

   c. Temporary and permanent pipe inverts and minimum slopes and cover.

   d. Grades, dimensions, and direction of flow in all ditches and swales, culverts, and pipes.

   e. Details for bypassing offsite runoff around disturbed areas.

   f. Locations and outlets of any dewatering systems.

4. **Location of detention BMPs –** Show on the site map the locations of stormwater detention BMPs.

5. **Erosion and sediment control (ESC) BMPs –** Show on the site map all major structural and non-structural ESC BMPs, including:

   a. The location of sediment pond(s), pipes, and structures.

   b. Dimension pond berm widths and inside and outside pond slopes.

   c. The trap/pond storage required and the depth, length, and width dimensions.

   d. Typical section views through pond and outlet structure.

   e. Typical details of gravel cone and standpipe and/or other filtering devices.

   f. Stabilization technique details for inlets and outlets.

   g. Control/restrictor device location and details.

   h. Stabilization practices for berms, slopes, and disturbed areas.

   i. Rock specifications and detail for rock check dam, if used.

   j. Spacing for rock check dams, as required.

   k. Front and side sections of typical rock check dams.

   l. The location, detail, and specification for silt fence.

   m. The construction entrance location and a detail.

6. **Detailed drawings**. Any structural practices used that are not referenced in this manual or other local manuals shall be explained and illustrated with detailed drawings.

7. **Other pollutant BMPs**. Indicate on the site map the location of BMPs to be used for the control of pollutants other than sediment.

8. **Monitoring locations.** Indicate on the site map the water quality sampling locations, if required by the local permitting authority or the Department of Ecology. Sampling stations shall be located in accordance with applicable permit requirements.

9. **Notes** addressing construction phasing and scheduling shall be included on the drawings.

4 Low Impact Development

4.1 INTRODUCTION

This chapter provides information about the use of low impact development (LID) best management practices (BMPs) in new development and redevelopment, with the goal of reducing runoff and improving the quality of surface water and groundwater. While LID BMPs are not required, their use contributes to achieving the water quality goal, sustainability vision, and environmental framework plan policy of the county's Comprehensive Growth Management Plan (Clark County 2005) and helps meet Minimum Requirement 5. This chapter includes:

- **Section 4.2:** LID Design Guidelines
- **Section 4.3:** LID Operations and Maintenance

► *This chapter relates to Minimum Requirement 5 (Onsite Stormwater Management). It identifies low impact BMPs that can be considered for onsite stormwater management, in addition to the BMPs identified in Volume V of the Stormwater Management Manual for Western Washington (SMMWW).*

Credits

Through the use of LID BMPs identified in this chapter, runoff treatment and flow control facilities required under Minimum Requirement 6 (Runoff Treatment) and Minimum Requirement 7 (Flow Control) may be reduced in size. Runoff treatment/flow control facility credits for LID BMPs are described in Volume III, Appendix B of the SMMWW and in the design standards of this chapter.

LID Practices

The BMPs listed in this chapter are intended to mitigate the impacts associated with surface water runoff generated from roads, driveways, rooftops, and other forms of impervious surfaces. Individual LID BMPs can be used to manage runoff from specific areas or distributed throughout a development to manage runoff where possible. However, LID BMPs are only a part of the low impact development practice. LID BMPs and the general construction layout should be used in concert with a site's natural features to result in a planned low impact development.

Planned low impact developments preserve and use a site's natural features such as open spaces, robust native vegetation, natural depressions, wetlands, and other areas that naturally use runoff. Natural features are preserved through the use of sustainable construction practices such as clustered lots, narrower streets, and loops instead of cul-de-sacs. Preserving natural features first, LID BMPs are then integrated into the development of the site to further use and return runoff to the environment naturally. The Puget Sound Action Team has recommended that developments defined as planned low impact developments be designed to reduce conventionally sized detention ponds by at least 40 to 80 percent (PSAT and WSU 2005). This reduction greatly reduces the reliance on traditional flow control and treatment facilities.

Planned low impact development is the preferred stormwater management practice, followed by the use of distributed individual LID BMPs. In addition, other stormwater management BMPs are available to help reach the goal of sustainable stormwater management.

The BMPs and practices in the SMMWW are approved for use in Clark County. Specific onsite BMPs are found in Volume V Chapter 5 of the SMMWW and include the following:

- Downspout dispersion
- Concentrated flow dispersion
- Sheet flow dispersion
- Post-construction soil quality and depth
- Preserving natural vegetation
- Better site design
- Full dispersion

In addition, the following LID BMPs are described in Section 4.2 of this *Clark County Stormwater Manual (SWM)*:

- Bioretention facilities such as rain gardens, stormwater infiltration planters, and curb extensions
- Porous pavements
- Reverse sloped sidewalks
- Rain barrels
- Green roofs
- Dispersion onto pasture and cropland

Site Analysis

Knowing how the site used stormwater historically is important for determining appropriate BMPs. The site analysis provides information about stormwater use, both currently and before any land use changes altered those processes. That information helps the designer determine the best site layout and decide which BMPs will either maintain or restore the natural pre-developed stormwater process. The following items from the site analysis should be used to determine appropriate site layouts and LID BMPs:

- Location and quantity of offsite drainage entering the site and onsite drainage leaving the site
- Slopes throughout the site
- Locations of existing mature vegetation (trees and shrubs) that retain intact upper soil profiles for stormwater processing
- Small depressions onsite that retain stormwater runoff
- Depths and conditions of the upper soil profile, along with the identification of the lower soils

Conformance

All uses of LID BMPs shall conform to all relevant requirements and standards of Title 40 of the Clark County Code.

Soil Infiltration Rates

Infiltration rates shall be determined for the design of all proposed bioretention facilities and porous pavements. The infiltration rate for the planting mix placed as topsoil in bioretention facilities shall be determined separately from the underlying native soil. The infiltration rate used for modeling these facilities shall be the lower of the rate of the planting mix or the rate of the underlying soil after correction factors have been applied.

Planting Mix Infiltration Rates (Bioretention Facilities)

Infiltration Test

Planting mix infiltration rates shall be determined in accordance with ASTM D 2434 as specified in **Appendix III-C** of the **SMMWW**.

Correction Factor

A correction factor of two shall be applied to the planting mix infiltration rate (reduce the infiltration rate by half).

Underlying Soil Infiltration Rates (Bioretention and Porous Pavement Facilities)

Infiltration Test

Underlying native soil infiltration rates shall be determined using one of the following methods:

- ASTM gradation method as described in **Volume III, Chapter 3** of the **SMMWW**.
- In-situ testing methods (the single-ring falling head test and the pilot infiltration test [PIT]), described in Section 6.6 of this manual.

Correction Factor

For bioretention facilities with a tributary area equal to or less than 5,000 square feet of pollution-generating impervious surfaces (PGIS), or 10,000 square feet of impervious surface, or ¾ acre of lawn or landscape, the underlying soil does not require a correction factor.

For bioretention facilities with a tributary area greater than 5,000 square feet of PGIS, or 10,000 square feet of impervious surface, or ¾ acre of lawn or landscape, infiltration rates shall be determined and correction factors shall be applied as described in Section 6.6 of this manual.

For porous pavement, infiltration rates shall be determined and correction factors shall be applied as described in Section 6.6 of this manual.

4.2 LID DESIGN GUIDELINES

Bioretention Areas – Rain Gardens, Planters, Curb Extensions

Description

Bioretention areas are stormwater retention systems that are designed to mimic forested systems, which control stormwater through detention, infiltration, and evapotranspiration. In contrast to current stormwater pond design, these facilities are small-scale (usually managing contributing areas of 1 acre or less) and are integrated into the landscape or hardscape. Many types of bioretention facilities are available to accommodate different project sites. This chapter provides general standards for all bioretention facilities, in addition to standards unique to three types of bioretention facilities: rain gardens, planters, and curb extensions.

- **Rain gardens** are landscaped depressions used to collect, filter, and infiltrate stormwater runoff, allowing pollutants to settle and filter out as the water percolates through the soil and infiltrates into the ground. In addition to providing pollution reduction, rain gardens can also manage flow rates and volumes.

- **Stormwater infiltration** planters are similar to rain gardens, but are usually built as structural landscaped reservoirs with retaining walls. Planters should be integrated into the overall site design. Numerous design variations of shape, wall treatment, and planting scheme can be used to fit the character of a site. An overflow to an approved conveyance and disposal method is required for facilities not capable of infiltrating the 100-year storm.

- **Curb extensions** are similar to rain gardens and stormwater planters and are constructed to receive stormwater runoff directly from streets. Runoff enters the curb extension through curb cuts and is then managed through detention, infiltration, and evapotranspiration. Overflow is directed to a downstream outlet or routed to a dispersion location. The downstream outlet can be another curb cut with a crest slightly higher than the finished surface mulch layer of the curb extension.

Applicability and Limitations

Bioretention facilities may be used to manage stormwater runoff from all types of impervious surfaces, on private property and within the public right-of-way where sheet flow or small amounts of concentrated flow can be directed to the facilities. The following criteria shall be addressed when selecting bioretention BMPs for use on a site:

- The underlying soils have a design infiltration rate of 1 inch per hour or greater.

- Seasonal high groundwater levels or other impermeable layers are at least 1 foot below the lowest elevation of the bioretention facility soil.

- There is a maximum bioretention design water surface drawdown time of 24 hours during periods of no rain.

- A minimum of 3 feet of clearance is available between the lowest elevation of the bioretention facility soil, or any underlying gravel layer, and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the bioretention facility meets or exceeds any of the following limitations:
  - 5,000 square feet of pollution-generating surfaces
  - 10,000 square feet of impervious area
  - ¾ acre of lawn and landscape

Bioretention facilities can be used to receive rooftop runoff in areas where infiltration facilities are not feasible and in preference to using dispersion BMPs, or where dispersion BMP criteria cannot be met. Bioretention facilities are applicable in parking lots as concave landscaped areas (i.e., situated lower than the height of the parking lot surface so stormwater runoff is directed as sheet flow into the bioretention facility). This application, in concert with porous surfaces in the parking lot, can greatly reduce runoff rates and volumes.

Fertilizers and pesticides degrade pollutant removal capability of the bioretention facility and may contribute additional pollutants to received runoff. Selected plants should not require the use of these products, and the design soil mix should be selected for optimum fertility.

Design Criteria for Rain Gardens

- The minimum dimensions for bottom width and length for any rain garden shall be 5 feet.
- Side slopes within rain gardens shall be no steeper than 3 horizontal to 1 vertical.
- The maximum bioretention water depth for rain gardens shall be no less than 6 inches and no more than 12 inches. Above 12 inches, an overflow route shall be designated to disperse the excess flow or convey it safely to another stormwater facility.
- In constrained areas without an accessible route to safely convey overflow (e.g., a rain garden within the loop of a roadway or in the landscape island within a parking lot), an adequately sized catch basin shall be used with a rim elevation set 6 inches above the bottom of the rain garden. The outlet from the catch basin can then be designed to access another stormwater facility or dispersion location.
- An additional 12 inches of detention storage can be added above the bioretention design water surface, provided that the release structure is designed with the outflow set at the bioretention water surface.

FIGURE 4-1: **Typical Rain Garden**

(Source: Puget Sound Action Team)

Design Criteria for Stormwater Infiltration Planters

- Individual infiltration planters shall be designed to receive the runoff from less than 15,000 square feet of impervious area.

- The minimum width of any planter shall be 30 inches.

- The depth provided for temporary runoff storage shall be at least 12 inches, unless a larger-than-required planter square footage is used.

- Planters shall be constructed flat.

- Planter walls shall be made of stone, concrete, brick, wood, or other durable material. Chemically treated wood that can leach out toxic chemicals and contaminate stormwater shall not be used.

- An appropriately sized catch basin shall be installed with a rim elevation set 4 inches below the top of the planter walls. The overflow route from the catch basin shall be designed to access another stormwater facility, or dispersed per the requirements in the SMMWW.

Design Criteria for Curb Extensions

- The minimum width for any curb extension shall be 5 feet.

- The depth of the curb extension shall be 6 inches minimum from the inlet at the gutter elevation to the bottom of the facility.

- The inlet curb cut top lengths shall be 2 feet.

- The longitudinal slope of the curb extension excavation shall match the road and shall be no steeper than a 3 percent grade.

- Longitudinal and cross slopes of soil placed within the curb extension shall be flat.

- Either an adequately sized downstream outlet curb cut or catch basin shall be installed with a rim elevation set 6 inches above the bottom of the curb extension. The outlet from the curb cut or catch basin shall access a conveyance system, another stormwater facility, or a dispersion location.

FIGURE 4-2: **Curb Extension**

Source: City of Portland

Design Criteria for Bioretention

Soils

A soils report stamped, signed, and dated by a geotechnical engineer registered in the state of Washington shall be prepared and shall include the following information:

- A detailed description of the condition of the pre-development upper soil structure.
- Infiltration rates determined in accordance with this chapter.
- Wet season water table at the location proposed for bioretention facility construction.

Bioretention facilities soil mixes shall be one of the following:

- A soil mix that with a minimum depth of 18 inches meeting the following criteria:
  - The texture of the soil mix shall be loamy sand (USDA Soil Textural Classification) with a clay content of less than 5 percent by dry weight.
  - The planting soil mix placed in the cell shall be a highly permeable soil mixed thoroughly with compost amendment and a surface mulch layer.
  - The final soil mix (including compost and soil) shall have a minimum short-term hydraulic conductivity of 1.0 inches/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 80 percent compaction per ASTM Designation D 1557.
  - The pH for the soil mix shall be between 5.5 and 7.0.
  - The final soil mixture shall have a minimum organic content of approximately 10 percent by dry weight.

  - See Section 6.1 of the *Low Impact Development Technical Guidance Manual for Puget Sound* for more information.
  - Compost amendment:
    - Material must be in compliance with Washington Administrative Code (WAC) chapter 173-350-220, available online at http://www.ecy.wa.gov/programs/swfa/facilities/350.html.
    - pH between 5.5 and 7.0.
    - Carbon nitrogen ratio between 20:1 and 35:1 (35:1 CN ratio recommended for native plants).
    - Organic matter content between 35 and 65 percent.

- A soil mix that with a minimum depth of 24 inches meeting the following criteria:
  - The soil mix shall meet a minimum of 5 millequivalents CEC/100grams dry soil.
  - The soil mix shall contain a minimum 10 percent of organic content.
  - The soil shall be composed of less than 25 percent gravel by weight with at least 75 percent of the soil passing the #4 sieve, and the portion passing the #4 sieve must meet one of the following gradations:
    - At least 50 percent must pass the #40 sieve and at least 2 percent must pass the #100 sieve,

      OR
    - At least 25 percent must pass the #40 sieve and at least 5 percent must pass the #200 sieve.

- A soil mix that with a minimum depth of 24 inches meeting the following criteria:
  - The soil mix shall meet a minimum of 5 millequivalents CEC/100grams dry soil.
  - The soil mix shall contain a minimum 10 percent of organic content.
  - The soil must have a measured infiltration rate of 9 inches per hour or less.

Planting Requirements

A dense mix of plantings in bioretention facilities is critical to successful hydrologic function, prevents erosion, prevents weeds from invading, and enhances aesthetic value. For all bioretention facilities, the following plant quantities and sizes shall be installed per 100 square feet of surface area:

- 20: Shrubs, large clump-grasses, sedges, or rushes; minimum 1-gallon container at initial planting; 12- to 24-inch diameter at maturity.

- 40: Shrubs, large clump-grasses, sedges, or rushes; minimum 4-inch container at initial planting; 12- to 24-inch diameter at maturity.

Perennial accent plants and bulbs may be planted sporadically throughout bioretention facilities to add seasonal color and variability.

Table 4-1 is an example planting plan for a 100-square-foot bioretention facility, using plant species with demonstrated good survival rates and low maintenance needs in the seasonal wet and dry conditions.

TABLE 4-1. Example Bioretention Planting Plan

Species	Pot Size	Diameter at Maturity	Coverage at Maturity (ft2)	No. of Plants per 100 (ft2)	Total Coverage (ft2)
Grooved Rush	1 gallon	18 inches	1.8	10	18
Grooved Rush	4 inches	18 inches	1.8	10	18
Variegated Tufted Hair Grass	1 gallon	12 inches	0.8	15	12
Variegated Tufted Hair Grass	4 inches	12 inches	0.8	5	4
Blue Oat Grass	1 gallon	24 inches	3.1	5	15.5
Blue Oat Grass	4 inches	24 inches	3.1	5	15.5
Orange New Zealand Sedge	1 gallon	18 inches	1.8	10	18
			Total:	**60**	**101**

Access and Setbacks

Bioretention facilities shall be located at least 5 feet from building foundations and property lines, and not upslope of building structures unless it can be demonstrated that buildings or other structures are adequately protected from increased groundwater resulting from the bioretention facility.

Construction Considerations

Bioretention areas shall be clearly marked and fenced before site work begins to avoid soil disturbance during construction. Compaction of the base and sidewalls of the facility shall be minimized. Excavation shall not be allowed during wet or saturated conditions. Excavation shall be performed by machinery operating adjacent to the bioretention facility, and no heavy equipment with narrow tracks, narrow tires, or large-lugged, high-pressure tires shall be allowed on the bottom of bioretention areas.

Onsite soil mixing or placement shall not be performed if soil is saturated. The bioretention facility soil mixture shall be placed and graded by excavators and/or backhoes operating adjacent to the facility.

Maintenance Considerations

Bioretention facilities do not require much in the way of maintenance. In the first year of operation, plants shall be inspected and replaced as necessary. Plants shall be watered during prolonged dry periods, especially during the first year, and trash and debris shall be removed when found. The following maintenance activities shall be performed at least annually:

- Herbicide, fertilizer, and pesticide use shall be minimized to the maximum extent possible prior to, during, and after construction.
- Watering shall be performed during prolonged dry periods after plants are established.
- Soil and plant material shall be periodically inspected, and replaced if damage has occurred.
- Periodic pruning shall be performed to maintain function and aesthetics. Dead plants shall be replaced upon discovery.
- Periodic weeding shall be performed until plants are established.
- Mulch shall be replaced annually in bioretention facilities where heavy metal deposition is likely (parking lots and roads). Otherwise, mulch shall be replaced or added as necessary to maintain 2 to 3 inches of depth every 2 years.
- Litter and debris shall be removed upon discovery.
- Sediment shall be removed and tested for toxicants in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones or if visual or olfactory indications of pollution are noticed.

Property owners are responsible for and can perform annual inspections and maintenance and shall keep records of inspections and maintenance that can be reviewed by the county as requested.

Additional Specific Flow Control/Treatment Facility Credit Requirements

To receive credit for flow control and/or treatment, bioretention facilities (rain gardens, stormwater infiltration planters, and curb extensions) must meet all criteria and be modeled in accordance with the Bioretention Areas (Rain Gardens) section of Appendix III-C of the SMMWW.

Porous Pavements

Description

Porous pavements allow rainwater to pass directly through the paving surface into base rock layers, where it can infiltrate into underlying soils.

FIGURE 4-3. **Porous Pavement**

Source: City of Gresham

Applicability and Limitations

Porous pavement can be used for both public and private parking lots, sidewalks, and the following roadways as described in the Clark County Transportation Standards (CCC Chapter 40.350):

- Urban neighborhood circulator
- Urban local residential access
- Urban loop and urban cul-de-sac
- Urban infill A and B
- Urban alley

Publicly owned porous pavement surfaces shall be limited to porous asphalt and porous concrete mixes placed over an open-graded base rock layer. Privately owned porous pavements may also include interlocking pavers and grid and lattice systems.

Porous pavement surfaces shall not be used to manage runoff from adjacent impervious surfaces without supporting design calculations showing adequate infiltration rates to accommodate flows. Otherwise, porous pavements shall be solely for the purpose of infiltrating rainfall that falls directly upon them.

Pervious surfaces shall not drain to porous pavement surfaces at any time. Debris, sediment, or any particulate material shall be prevented from migrating from pervious areas onto porous pavement surfaces. Porous pavement surfaces shall not be used in areas subject to sanding for traction during snow and ice accumulation.

Porous pavement surfaces shall not be used to mitigate runoff for the following land uses:

- An area of a commercial or industrial site subject to an expected average daily traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area.
- An area of a commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including routinely delivered heating oil.
- An area of a commercial or industrial site subject to parking, storage, or maintenance of 25 or more vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.).
- A road intersection with a measured ADT count of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements. The traffic count can be estimated using information from Trip Generation, published by the Institute of Traffic Engineers (ITE 2003) or from a traffic study performed by a professional engineer or transportation specialist with experience in traffic estimation.
- Areas of sites with industrial machinery and equipment.
- Railroad yards and areas where railroad equipment maintenance is performed.
- Log storage and sorting yards.
- Aircraft maintenance areas.
- Fueling stations.
- Vehicle maintenance and repair areas.

Design Criteria

Qualified Contractors

Installation shall be performed only by contractors with at least five successful applications of the selected product. If the installation contractor does not have adequate experience, the contractor shall retain a qualified consultant to monitor production, handling, and placement operations.

Slopes

Porous pavement shall be constructed at a maximum slope of 5 percent.

Subgrade

The subgrade shall be compacted to the minimum necessary for structural stability. Static, dual-wheel small mechanical rollers or plate vibration machines shall be used for compaction. Heavy compaction from heavy equipment operation shall not be allowed. The subgrade shall not be subjected to truck traffic.

Geotextile

A geotextile fabric between the subgrade and stone reservoir shall be installed to keep soil out of the base materials. The geotextile fabric shall pass water at a greater rate than the subgrade soils.

Base Material

At a minimum, layers shall include:

- **Top course:** 2-inch-thick layer of aggregate that meets the requirements for maintenance rock in Section 9-03.9(4) of the WSDOT Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT 2008).
- **Stone reservoir:** 6-inch-thick layer of aggregate that meets the requirements for shoulder ballast in Section 9-03.9(2) of the WSDOT Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT 2008).

Other rock may be used with prior approval from the county.

Pavement

For all surface types, a minimum initial infiltration rate of 1 inch per hour is necessary. To improve the probability of long-term performance, significantly higher infiltration rates are desirable.

Products shall have adequate void spaces through which water can infiltrate. Void space shall be within the range of 15 – 20 percent.

The mix design and void calculation shall be submitted for review and approval.

Drainage Conveyance

Roads shall still be designed with adequate drainage conveyance facilities, as if the road surface were impervious. Roads with base courses that extend below the surrounding grade shall have a designed drainage flow path to safely move water away from the road prism and into the roadside drainage facilities. The use of perforated storm drains to collect and transport infiltrated water from under the road surface will result in less effective designs and less flow reduction credit. Flow reduction credit shall be calculated in accordance with the SMMWW.

Acceptance Test

Driveways can be tested by simply throwing a bucket of water on the surface. If pooling or runoff is observed, additional testing may be required prior to acceptance. Note that this tests the paved surface only, not the infiltration capacity below.

Roads shall be initially tested with the bucket test. If pooling or runoff is observed, the initial infiltration shall be tested with a 6-inch ring, sealed at the base to the road surface, or with a sprinkler infiltrometer. The road surface shall be wetted continuously for 10 minutes, then tested to determine compliance with the 1-inch-per-hour minimum rate.

Construction Considerations

Soils shall not be tracked onto the wear layer or the base course during construction.

Maintenance Considerations

The project shall be inspected upon completion, and any accumulation of fine material shall be removed.

Surfaces shall be inspected and swept with a high-efficiency sweeper or vacuum sweeper twice per year: once in the autumn after leaf fall and again in early spring. High-pressure washing shall follow sweeping once per year. Driveway surfaces (such as small residential driveways) may be maintained with high-pressure washing once per year. For roadways and parking lots, if annual infiltration rate testing is conducted and demonstrates that a rate of 10 inches per hour or greater is being maintained, the sweeping/pressure washing frequency can be reduced to once per year.

Property owners are responsible for annual inspections and maintenance and shall keep records of inspections and maintenance that can be reviewed by the county as requested.

Additional Specific Flow Control/Treatment Facility Credit Requirements

To receive credit for flow control and/or treatment, porous pavement must meet all criteria and be modeled in accordance with Appendix III-C of the SMMWW.

Reverse Sloped Sidewalks

Description

Reverse sloped sidewalks are sidewalks that are sloped to drain away from the road and onto adjacent vegetated areas that provide infiltration and/or bioretention. It is recommended that runoff from reverse sloped sidewalks be directed into another LID BMP such as a rain garden, planter, or appropriately planted soil amendments if the onsite soils are poorly drained or disturbed in a manner that reduces infiltration rates.

Applicability and Limitations

Reverse sloped sidewalks can be used along both public and private streets and paths and in public rights-of-way where there is sufficient area to construct adequate receiving areas.

Design Criteria

Sidewalk

Reversed sloped sidewalks shall be constructed in accordance with Clark County sidewalk design standards, except they shall have a maximum 5 percent longitudinal slope and they may have up to a 2 percent reverse cross slope. The sidewalks shall then drain to a minimum of 10 feet of vegetated area downslope that is not directly connected to the drainage system.

Receiving Area

The vegetated area receiving flow from the reversed sloped sidewalk shall consist of undisturbed native soil and dense, healthy, native vegetation; a dispersion area; a bioretention facility; or appropriately planted soil amendments that meet BMP T5.13 in the SMMWW if planted with a permanent grass seed mix applied at a rate of 80 pounds per acre. The grass seed mix shall consist of (percentages by weight):

- 40 percent turf-type rye
- 40 percent fescue
- 10 percent white Dutch clover
- 10 percent colonial bent grass

Alternate seed mixes or planting plans may be approved if a horticulturist or landscape architect recommends a different mix or plan. If a grass seed mix is used, the vegetation shall not be located in shaded areas without enough sunlight to ensure healthy grass growth.

Construction Considerations

Runoff shall be diverted around the receiving area for a reversed sloped sidewalk until vegetation is established, or an erosion control blanket shall be placed over any exposed soil and freshly applied seed mix. This requirement does not apply to receiving areas consisting of undisturbed native soil and native vegetation.

If reversed sloped sidewalks are put into operation before all construction in the contributing drainage catchment is complete and there is potential for sediment to reach the receiving area, the following requirements apply:

- Erosion control shall be in place to protect receiving areas consisting of undisturbed native soils and vegetation, rain gardens, or planters.
- Receiving areas consisting of amended soils and grass seed mix shall be cleaned of sediment and replanted prior to acceptance by the county.

Maintenance Considerations for Receiving Areas

Herbicide, fertilizer, and pesticide use shall be minimized to the maximum extent possible prior to, during, and after construction.

For the use of other LID BMPs as receiving areas, the relevant BMP maintenance considerations shall apply.

For receiving areas consisting of amended soils with grass seed mix, the following maintenance considerations shall apply:

- Irrigation may be required in summer months; site planning shall address the need for sprinklers or other means of irrigation.
- Grass shall be mowed to maintain an average grass height of between 4 and 9 inches. Monthly mowing is needed from May through September to maintain grass vigor.
- If flow channelization or erosion has occurred, the receiving area shall be regraded to produce a flat bottom width and then reseeded as necessary. If regrading is required every year, a low-flow drain shall be installed rather than yearly regrading.

Additional Specific Flow Control/Treatment Facility Credit Requirements

If the receiving area is another LID BMP facility other than amended soils, the sidewalk area shall be modeled as impervious area routed to the LID BMP facility, and the LID BMP facility shall be modeled in accordance with the credits described in Appendix III-C of the SMMWW.

If the receiving area consists of a vegetated area as described in this standard, or the amended soils LID BMP, modeling shall be in accordance with guidance for reverse sloped sidewalks in Appendix III-C of the SMMWW.

Rain Barrels

FIGURE 4-4. **Rain Barrel**

Description

Rain barrels are low-cost, effective, and easily maintainable water reuse systems designed to collect stormwater runoff from non-polluting surfaces. They operate by storing a volume of runoff, typically from rooftops, for later reuse and work to both reduce site runoff and decrease the demands on treated potable water supplies. Reuse of the runoff can be for irrigation, such as lawn and garden watering, and for potable and non-potable uses with the appropriate storage and water quality treatment requirements.

Applicability and Limitations

Both residential and commercial/industrial LID sites can use rain barrels. Water collected and stored in rain barrels may be reused only on the site where the water was collected. Use of a water reuse system as a potable source requires the approval of various state and local agencies, as required for any water right.

Water reuse systems are highly suitable for highly urban areas and commercial centers where larger buildings, especially multistory buildings, encompass nearly all of the area and it may not be feasible to preserve natural protection areas. In these areas, any type of stormwater treatment is expensive because of the high cost of land; therefore, the cost of a water reuse system can be more competitive. Because multistory buildings require a more constant and larger demand for non-potable water, the storage area required for rooftop runoff would not be as large, further reducing the costs of these systems.

Water reuse systems, including rain barrels, do not provide water quality treatment and are not given water quality treatment credits. Water quality treatment in accordance with the SMMWW is required for rain barrel discharges if the tributary area is a pollution-generating surface. (See the **SMMWW** for definitions of pollution-generating surfaces.)

Design Criteria

Rain barrels may be any clean, watertight container intended for the use of storing liquids. Containers that have ever contained solvents, petroleum products, industrial detergents, or other health or environmentally hazardous chemicals shall not be used. The following components shall be required as a minimum on all rain barrels:

- Non-leaking storage container, such as a 55-gallon drum, sealed wine barrel, plastic barrel, etc.
- Inlet grate or screen to prevent debris from entering the rain barrel through the inlet.
- Overflow system directed in a manner to prevent downstream property damage. For rain barrels collecting water from rooftops only, the overflow may be plumbed into the downspout of the gutter system from which the rain barrel is collecting water.
- Outlet for using stored water (typically a hose bib), properly installed to prevent dripping or leaking.
- Sturdy base to safely support the rain barrel.
- Rain barrels used for the collection and storage of water for uses other than onsite irrigation must meet applicable storage and treatment requirements.

The following design is for a typical residential rain barrel, using parts available at local hardware stores (adapted from Montgomery County, Maryland).

Parts

Container

- 55- to 100-gallon barrel.
- Typical single-family residential rain barrels should store approximately 60 gallons.

Overflow

- 1¼-inch adapter insert male pipe thread (MPT).
- Size 24 25-50 mm metal hose clamp.
- 1¼-inch sump pump hose.
- Silicone sealer or Teflon tape (optional).

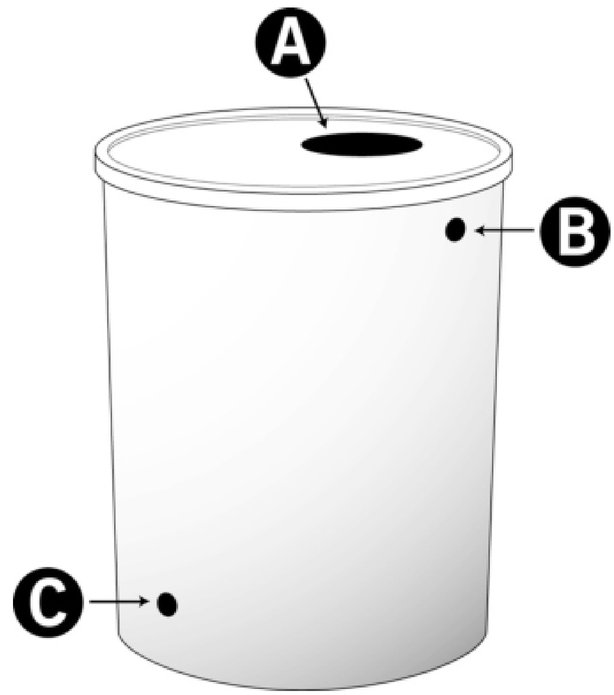
Inlet grate

- 6-inch NDS green grate.
- 6- to 7-inch metal clamp #10.
- 12-inch square window screen.

Hose bib/sillcock

- Brass sillcock/hose bib ¾-inch MPT.
- Silicone sealer or Teflon tape (optional).

Basic Instructions



Step A

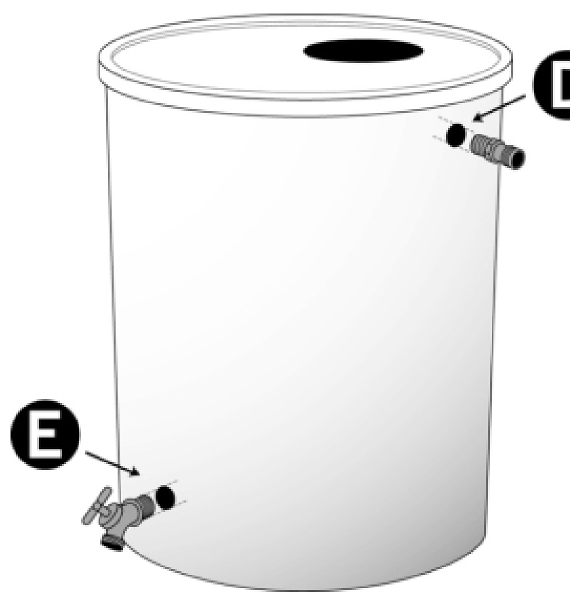
Cut a hole in the top of the barrel for the inlet drain. The hole should only be large enough to allow the grate to rest on its flange. Cut the hole using a RotoZip™ drill, or carefully measure and mark the area to be cut, start a pilot hole, and cut out the marked area with a jigsaw.

Step B

Use a 1½-inch keyhole bit to cut a hole to accommodate the 1¼-inch overflow adapter. The hole may need to be rasped or sanded somewhat larger to screw in the adapter. The fit should be snug.

Step C

Use a 15/16-inch drill bit to cut a hole for the ¾-inch brass hose bib.

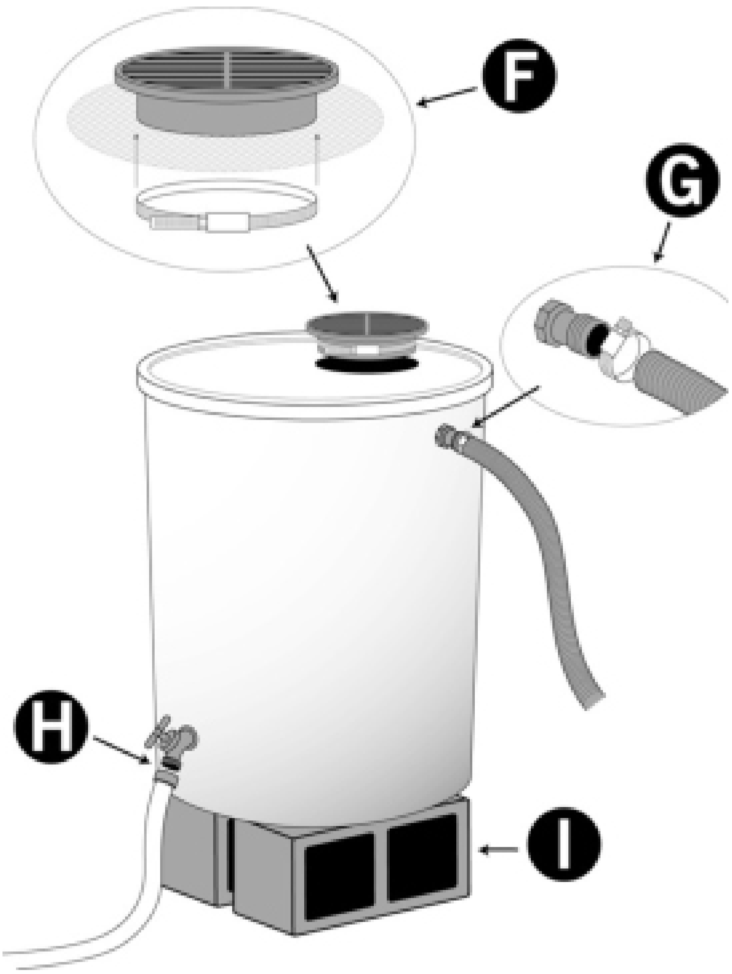


Step D

Insert the threaded end of the over-flow adapter insert into the overflow hole. Keep the adapter straight when screwing it into the barrel.

Step E

Insert the threaded hose bib into the drilled hole. Keep the hose bib straight when screwing it into the barrel. Apply a bead of silicone caulk or wrap Teflon tape around the bib before inserting it to ensure a tight, drip-free connection.



STEP F

Use the larger #10 metal clamp to firmly attach the window screen to the bottom of the green grate. Tighten the clamp with a screwdriver or nutdriver. Place the inlet assembly into the barrel.

STEP G

Slide the smaller size 25 metal hose clamp over the barbed section of the adapter insert. Slide one end of the sump pump hose over the adapter, and use the hose clamp to firmly attach the hose to the adapter.

STEP H

Attach a garden hose or soaker hose to the hose bib.

STEP I

Use cinderblocks or similar pavers to elevate the completed rain barrel off the ground to ensure easier access to the hose bib and to facilitate gravity-fed drainage.

Maintenance Considerations

- The following maintenance shall be performed on rain barrels:
- Rain gutters supplying water to rain barrels shall be kept clean of debris to prevent mosquito eggs and larvae from entering the barrel.
- All connections shall be routinely checked, and debris shall be cleaned from the barrel's inlet screen when needed.
- Rain barrels shall be used/drained at regular intervals, especially before the winter season. Rain barrels shall be kept half-filled during winter months to prevent them from breaking if the stored water is frozen.

Additional Specific Flow Control/Treatment Facility Credit Requirements

To receive credit for flow control, rain barrels must meet all criteria and be modeled in accordance with guidance for rainwater harvesting from Appendix III-C of the SMMWW. Flow control credits are not provided for the use of the residential rain barrels described in this section.

Green Roofs

■ FIGURE 4-5. **Green Roof**

Description

Green roofs are roof installations that partially or entirely cover a roof area with vegetation for hydrologic purposes. These installations generally fall into two categories: roof gardens and ecoroofs.

- **Roof gardens** are heavyweight installations with a variety of plants, often including larger shrubs and even small trees. They are generally constructed to form a park-like setting in urban areas and are intended for public use. Because of the complexity of roof garden designs, they must be approved on an individual basis.
- **Ecoroofs** are more common, lighter-weight installations with a more limited variety of plants. They are designed primarily for hydrologic and thermal benefits and may or may not be accessible to the public. Ecoroofs are also suitable for retrofits.

Applicability and Limitations

Green roofs are applicable for reducing peak stormwater runoff. They are especially useful when no other means of runoff storage or infiltration are available.

The primary limitations on green roofs are structural. Structural roof support must be sufficient to support the weight of the green roof. This is especially a concern for retrofit projects. A registered engineer should be consulted to ensure that sufficient structural support is provided for green roof installations.

Roof slope shall not be greater than 20 percent.

Design Criteria

Green roof installations shall include the following components.

Waterproofing

Because of the frequent presence of water and damp materials, waterproofing is a particular concern in green roof applications. In general, a green roof serves to protect rather than degrade the underlying waterproofing treatment, as it acts as protection from UV radiation, wind, pollution, and extreme heat cycling. Existing building codes for waterproof membrane installation shall be used for green roof applications.

Drainage Layer

A layer beneath the growing media is needed that allows water to drain from the roof structure and flow to the roof's drainage system. It shall consist of a thin layer of gravel or corrugated plastic drainage sheeting. The material used to form the drainage layer shall have sufficient compression strength to support the growing medium and vegetative matter, while providing sufficient flow rate to adequately drain under typical conditions. Required compression strength shall be determined from a calculation of saturated weight of the growing medium and expected mass of the fully mature vegetation. The drainage layer shall be capable of conveying flows generated by the 2-year peak intensity rainfall with a 5-minute time of concentration.

Filter Layer/Root Barrier

Filter layers and root barriers perform the function of retaining the growing medium and preventing unwanted root expansion. This layer shall consist of one or more layers of non-woven geotextile fabric placed between the growing medium and drainage layer. The geotextile shall not inhibit the infiltration rates of rainwater. Alternatively, soil retention and root inhibition can be incorporated into other component layers. Root barriers that use herbicides or copper shall not be used.

Growing Medium

Proprietary mixes that consist of topsoil and mineral content (such as expanded clay) with other organic material are acceptable. A mix of one-fourth topsoil, one-fourth compost, and one-half pumice perlite shall be used. Mulch shall be used only during vegetation establishment periods. A depth of 3 to 6 inches is required for the growing medium.

Vegetation

Key characteristics for rooftop vegetation shall include minimal maintenance; self-propagation; heat, cold, and wind resistance; and the ability to thrive in shallow soils without fertilization or permanent irrigation. Vegetation shall include small succulents, hearty wildflowers, and shallow-rooting grasses and grow to provide at least 90 percent coverage of the vegetated area at maturity. This may be accomplished through the use of vegetated mats, plugs, sprigs, or seeds.

Modular Units

Modular units demonstrated to have all of the required components are acceptable.

Insulation

It is generally accepted that green roofs provide a benefit to roof insulation, but the degree of this benefit is still under research. For the time being, therefore, buildings that use green roofs shall adhere to insulation requirements in the building code.

Drainage

Roof drains shall be sized per building code requirements. Installations on flat roofs (<2 percent) shall design the structure so the drainage layer in all areas has at least a 2 percent slope. Rooftop conveyances shall be capable of collecting runoff from all surface and drainage layers to prevent excessive ponding. Limited ponding in the drainage layer may be acceptable for horticultural purposes.

Irrigation

Irrigation shall be provided until vegetation has become established. Hand, drip, and subsurface irrigation techniques are permitted. Irrigation shall be required during periods of limited precipitation if needed to maintain vegetation.

Maintenance Considerations

- All facility components, including structural components, waterproofing, drainage and filter layers, growing media, and vegetation, shall be inspected for proper operation at least twice annually throughout the life of the roof garden.

- Roof drain inlets shall be cleared of any soil, vegetation, or other debris that might restrict flow or obstruct free drainage of the pipe and shall be checked for cracks, settling, and proper alignment.

- To maintain sufficient plant coverage, bare areas shall be replanted as needed. Invasive or nuisance species shall be removed regularly and shall not be allowed to accumulate and exclude planted species. At a minimum, weeding shall be scheduled before major weed varieties disperse seeds. Weeding shall be performed manually and without the use of herbicides. Mulch shall be used only during vegetation establishment periods.

Additional Specific Flow Control/Treatment Facility Credit Requirements

To receive credit for flow control and/or treatment, green roofs must meet all criteria and be modeled in accordance with guidance for vegetated roofs from Appendix III-C of the SMMWW.

Dispersion onto Pasture and Cropland

Description

This LID BMP consists of fully dispersing runoff by directing it onto a pasture or cropland surface where it can be dispersed, infiltrated, evaporated, and consumed by plant uptake.

Applicability and Limitations

On a single-family residential lot or an agriculture parcel or parcels under the same ownership and greater than 22,000 square feet, full dispersion techniques presented in the SMMWW (BMP T5.30) and full dispersion onto pasture and croplands are allowed when in compliance with the following criteria:

- Cropland shall consist of land used to grow grass, grain, or row crops, including berries, nursery stock, and orchards.
- The crop or pasture land shall be under the same ownership as the project site.
- For soils with an infiltration rate less than 4 inches per hour, pasture or cropland shall have been cleared prior to the adoption of this standard.
- The total site area shall consist of at least 75 percent cropland, and no more than 15 percent of the site draining to the dispersion area shall be impervious surfaces. Less stringent ratios of sending land and receiving land uses may be submitted, with supporting modeling results showing flow control requirements are satisfied for the site.
- No more than 10 percent of the pasture or cropland used for dispersion shall be used for purposes other than plant growth (for example, but not limited to, unpaved roads, staging areas, equipment storage, animal pens, haystacks, wheel lines, campsites, trails, etc).
- Runoff from a driveway through the dispersion area shall be dispersed per BMP T5.11 or BMP T5.12 from the SMMWW and shall have a flow path exceeding 300 feet.
- Land used for dispersion shall be downslope from building sites and shall not exceed 5 percent slope.
- There shall be a minimum 3-foot depth to the average annual maximum groundwater elevation.
- The length used for dispersion shall be 300 feet or greater.
- The preserved area is not required to be placed in a separate tract or recorded easement.
- The applications and limitations for BMP T5.30 shall also apply to this BMP. Where conflicts occur between the requirements in BMP T5.30 and the requirements in this Clark County SWM, the requirements in this section shall apply.

Design Criteria

Runoff shall evenly sheet flow onto dispersion areas naturally or via a dispersion trench or other structure designed to evenly spread and dissipate concentrated flows into sheet flow.

Additional Specific Flow Control/Treatment Facility Credit Requirements

The land use where this BMP is applied shall be considered "fully dispersed" (i.e., zero percent effective impervious).

4.3 LID OPERATIONS AND MAINTENANCE

Stewardship and management plans that address long-term protection and maintenance shall be developed for all properties that contain LID BMPs and submitted to the county for approval. At a minimum, the following shall be specifically addressed in the stewardship and management plans for all LID BMPs used onsite:

- Identification and location of all LID BMPs.
- Inspection, monitoring, and maintenance activities needed to ensure continued performance of the intended function of the LID BMPs.

The county may require the installation of fencing and signage around LID BMPs. Private home owner deed restrictions and homeowners/building covenants shall be required for all properties with onsite LID BMPs to ensure that the stormwater management applications continue to function as designed. The deed restrictions or covenants shall specifically address and/or append the requirements and responsibilities for long-term management and maintenance of any LID BMPs.

Education

Education measures describing the functions of conservation areas and LID BMPs shall be implemented during the initial and all successive sales of properties using LID BMPs. Brochures or plans shall provide the following:

- An overview describing the function and need for natural resource protection, vegetation retention areas, and LID BMPs.
- A description of the tree/plant species located within the vegetation retention areas and guidelines for protection of the vegetation.
- Stewardship and management plans.
- Contacts for questions on maintenance needs and enforcement.

The developer shall provide brochures and plans to the initial property owner and to the county upon the sale of the property. The county shall provide a copy of the brochure or guide to new property owners at successive sales of the property.

Monitoring

One-year bonds shall be required, and the developer shall replace vegetation if one-third or more of the vegetation, based on plant count, dies within the first year of operation of an LID BMP.

The county shall have access to all public and private LID BMPs for monitoring, as determined necessary by the county.

Inspection

The county shall inspect the LID BMPs during construction of the facility and upon completion of the facility.

Ownership

Private Property

LID facilities located on private property that receives runoff from only the private property shall be owned and maintained by the private property owner.

Public Property

LID facilities located on public property that receives any runoff from public property shall be owned and maintained by the county.

Public Right-of-Way

LID facilities located in a public right-of-way that receives all runoff from private property and/or residential street runoff shall be owned by the county. Maintenance shall be the responsibility of the owner(s) of the private property contributing runoff to the facility and/or the homeowners association regulating the property and residential streets contributing flows to the facility.

LID facilities located in the public right-of-way shall be constructed in coordination and sequenced with the construction of all other utilities in the right-of-way in a manner that prevents impacts to the intended function of the LID facility.

Access and Easements

Large open space areas adjacent to riparian areas, wetlands, or critical fish and wildlife habitat areas may be transferred to local land trusts for long-term management and stewardship or managed by homeowners/building associations with specific maintenance covenants.

Access and maintenance easements shall be provided for all LID BMPs located on private property for periodic inspection, monitoring, and maintenance, in accordance with CCC Chapter 40.385 and Chapter 11 of this manual.

Maintenance Plan

A maintenance plan shall be distributed to the initial property owner and county by the developer and kept on record with the county for distribution to future property owners. The maintenance plan shall include the following:

- A base map of all LID BMPs on the property.
- A narrative describing what to inspect and the maintenance requirements for each type of BMP used, along with intervals for conducting all maintenance activities. Information about required maintenance can be found in the sections that describe each BMP, above.

LID Details

Appendix B contains details that can be referenced for LID designs. Other manuals and details may be used, provided they meet the requirements in this manual and in the SMMWW.

Clark County makes no representations or warranties regarding the accuracy or fitness of a detail for a particular purpose. The designer is responsible for using sound engineering judgment regarding the use of these details.

5 Hydrologic Analysis

5.1 INTRODUCTION

This chapter provides supplemental guidance for performing hydrologic calculations for the design of stormwater facilities for new development and redevelopment projects in Clark County. It includes:

- **Section 5.2:** Single-event models for sizing conveyance, collection systems, and volume-based water quality facilities, and guidance on the use of continuous simulation hydrologic models within Clark County.
- **Section 5.3:** Guidance for using existing detention facilities that were previously designed using single-event models.

► *This chapter relates to Minimum Requirement 7 (Flow Control). It supplements and revises portions of the SMMWW, Volume III, Chapter 2: Hydrologic Analysis.*

Applicability

For the purposes of designing open or closed channel conveyance systems and collection systems (catch basins and inlets), one of the following methods shall be used to determine the peak flow rate for the design storm:

- **Santa Barbara Urban Hydrograph (SBUH) method:** This method shall be used only for basins of less than 1,000 acres.
- **Rational Method:** This method can be used for basins of less than 25 acres, with a time of concentration of less than 100 minutes.

Guidance for conveyance system design is provided in Chapter 8 of this Clark County Stormwater Manual (SWM). Guidance for collection system design is provided in Chapter 11.

For designing wet pools and other volume-based water quality facilities, the SBUH method shall be used. For designing all other stormwater facilities, a continuous simulation hydrologic model shall be used.

5.2 HYDROLOGIC METHODS

Santa Barbara Urban Hydrograph (SBUH)

A description of the calculations for this method can be found in the Highway Runoff Manual (WSDOT 2006b). Calculation of the peak flow rate or volume using SBUH is usually performed with a spreadsheet or a commercial software program. The following information is required for an SBUH analysis:

- Time of concentration.
- Precipitation: 24-hour average daily precipitation for the design storm and for a 2-year event (used in the time of concentration calculations).
- Runoff curve number.
- Impervious and pervious areas.

The sections below provide supplemental information about estimation of the time of concentration, 2-year precipitation depth, and runoff curve numbers.

Time of Concentration

Time of concentration (T_c) is the sum of the travel times for sheet flow, shallow concentrated flow, and channel flow. Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of the time of concentration. The minimum time of concentration is 5 minutes.

Sheet Flow

With sheet flow, the friction value ($\mathbf{n_s}$) is used (a modified Manning's effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment). These $\mathbf{n_s}$ values are for very shallow flow depths of about 0.1 foot and are used only for travel lengths up to 300 feet. Table B-1 in Appendix B gives Manning's $\mathbf{n_s}$ values for sheet flow for various surface conditions.

For sheet flow of up to 300 feet, use Manning's kinematic solution to directly compute T_t:

$$T_t = \frac{0.42\,(n_s L)^{0.80}}{P_2^{0.527}\,(S_0)^{0.4}} \qquad \textbf{Equation 5-1}$$

where:

$\mathbf{T_t}$ = travel time (minutes)

$\mathbf{n_s}$ = sheet flow Manning's effective roughness coefficient (Table D-1)

L = flow length (feet)

$\mathbf{P_2}$ = 2-year, 24-hour rainfall (inches)

$\mathbf{S_0}$ = slope of hydraulic grade line (land slope, feet/feet)

The maximum allowable distance for sheet flow shall be 300 feet; the remaining overland flow distance shall be shallow concentrated flow until the water reaches a channel.

Shallow Concentrated Flow

After a maximum of 300 feet, sheet flow is assumed to become shallow concentrated flow. The average velocity for this flow can be calculated using the k_s values from Table B-1, in which average velocity is a function of watercourse slope and type of channel. The average velocity of flow, once it has measurable depth, shall be computed using the following equation:

$$V = k\sqrt{S_0}$$ **Equation 5-2**

where:

V = velocity (feet/seconds)

k = time of concentration velocity factor (feet/seconds)

S_0 = slope of flow path (feet/feet)

"**k**" is computed for various land covers and channel characteristics, with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

$$k = \frac{1.49\,R^{0.667}}{n}$$ **Equation 5-3**

where:

R = an assumed hydraulic radius

n = Manning's roughness coefficient for open channel flow (Table B-2)

"**k**" values have been tabulated in Table C-1. After computing the velocity, T_t can be computed as follows:

$$T_t = \frac{L}{60V}$$ **Equation 5-4**

where:

L = flow length (feet)

V = average velocity (feet/second)

60 = conversion factor from seconds to minutes

Channel Flow

Open channels are assumed to begin where surveyed cross-section information has been obtained, where channels are visible on aerial photographs, or where lines indicating streams appear on maps and are field verified. The **kc** values from Table B-1 can be used to estimate average flow velocity. After average velocity is computed, the travel time for the channel segment can be calculated using Equation 5-4.

Time of Concentration Calculation

The time of concentration is the sum of the Tt values for the various consecutive flow segments.

$$T_t = T_t 1 + T_{t\,2} + \ldots T_{t\,m} \qquad \textbf{Equation 5-5}$$

Precipitation

The standard design hyetograph is the Soil Conservation Service (SCS) Type 1A 24-hour rainfall distribution resolved into 10-minute time intervals, which can be found in Appendix B. Various interpretations of the hyetograph are available and may differ slightly from distributions used in other unit hydrograph-based computer simulations. Other distributions will be accepted with adequate justification and as long as they do not decrease the peak flow rate.

The hyetographs provide a dimensionless distribution of rainfall over a 24-hour period. These values are multiplied by the 24-hour rainfall depth for use in the SBUH method. Appendix B provides the 24-hour design storm isopluvials for Clark County for determining rainfall depth for different storm frequencies. These have been taken from the National Oceanic and Atmospheric Administration (NOAA) Atlas 2 Precipitation – Frequency Atlas of the Western United States, Volume IX, Washington (Miller et al. 1973). This 24-hour rainfall depth is used in SBUH calculations.

Runoff Curve Numbers

The curve numbers in Section 2.3 of the SMMWW shall be used. The NRCS soil classifications for use in determining the appropriate runoff curve numbers can be obtained from one of the following three sources:

- Updated version of the Soil Survey of Clark County, Washington, originally published in 1972 and updated by the NRCS.
- GIS maps of soils from Clark County GIS.
- Washington Soil Survey Data as available on the NRCS website.

Hydrologic soils groups for NRCS soil classifications for typical Clark County soils are listed in Table B-4 in Appendix B.

Rational Method

The Rational Method is a simple method for calculating the peak flow rate that can easily be performed by hand. The formula for the rational method is:

$$Q = CIA \qquad \text{Equation 5-6}$$

where:

Q = flow (ft^3/second)

C = dimensionless runoff coefficient

I = rainfall intensity (inches/hour)

A = drainage area (acres)

The following information is required for the Rational Method:

1. Runoff coefficient, which can be found in Table B-5.
2. Time of concentration. This is described above and is used for determining rainfall intensity.
3. Rainfall intensity. These values can be obtained from Figures B-6 to B-8 in Appendix B.
4. Drainage area, which is calculated using topographic site maps.

Continuous Simulation Hydrologic Models

The Department of Ecology has moved from calculating stormwater runoff using a single, 24-hour storm event model to using a continuous hydrologic model that models rainfall/runoff relationships over long time periods. Ecology has developed the Western Washington Hydrology Model (WWHM) for use in western Washington. WWHM uses the software program HSPF (Hydrologic Simulation Program – Fortran) as its base to model hydrologic processes.

WWHM uses rainfall and evaporation data and 18 model parameters to simulate runoff from three components: groundwater, interflow, and surface runoff. The model user can specify where these three types of runoff should be directed. Normally, surface runoff and interflow is directed to the stormwater facility. Precipitation data are obtained from local sources (WWHM uses Portland Airport data for Clark County, scaled for different areas of the county), and currently all evaporation data used in WWHM are from a pan evaporation station located in Puyallup, Washington. The 18 model parameters were set based upon calibration modeling conducted by the U.S. Geological Survey (USGS) on three basins in the Puget Sound area, with some revisions made by the WWHM developers. Additional information on WWHM can be found in Volume III of the SMMWW or in the WWHM help files and users manual.

A Clark County version of WWHM is being developed and is the only continuous simulation hydrologic model approved for use in Clark County.

Data Requirements

WWHM requires the following information:

- Site location. The site location is picked from a map to determine the proper scaling of rainfall data.

- Soil type and associated NRCS hydrologic soil group for all soils on the site.

- Types of pre-developed land cover and the acreage of each. WWHM has three land cover categories:
  - Forest, which is designated as second growth Douglas Fir.
  - Pasture, which is non-forested natural areas, scrub, and rural vegetation.
  - Lawn.

Clark County is currently developing a calibrated WWHM model specific to local soils and rainfall data. Until a calibrated model specific to Clark County is available, HSG B soils with tested infiltration rates that render infiltrating stormwater impractical may be modeled as HSG C for the purpose of flow control design.

Pre-developed Land Cover

The pre-developed condition for modeling flow control facilities shall be the land cover condition existing at the time of the development application. Where an approved watershed study exists, the land cover condition to be matched shall be commensurate with achieving a target flow regime identified in the study. If no land cover condition or target flow regime is identified, land cover condition to be matched shall be as required above.

This requirement does not apply to project sites that will retain all stormwater runoff onsite.

5.3 RETROFIT OF EXISTING FLOW CONTROL FACILITIES FOR PROJECT COMPLIANCE

This procedure is to be used for a new project site where flow control requirements are to be met using a pond that was originally designed using a peak flow standard and single-event methodology. The original flow control release rates for the existing pond are to be added to the flow control targets for the new project. If the existing detention facility is not sized sufficiently for the new flow targets, the pond size will need to be revised.

Step 1:

Estimate the pre-development target peak flows for the existing drainage area tributary to the facility. Use the same pre-development land covers that were originally approved for designing the pond. Do not include the area from the new project. Use the SBUH method to determine the target peak flows of the following:

- ½ of the pre-development peak flow of a 2-year, 24-hour storm.
- The pre-development peak flow of a 10-year, 24-hour storm.
- The pre-development peak flow of a 100-year, 24-hour storm.

Step 2:

Estimate the pre-development runoff flows for the new project site. The pre-developed land cover requirements of this manual shall be used for determining the pre-development flows. The pre-development runoff flows of interest are:

- ½ of the peak flow of a 2-year, 24-hour storm.
- The peak flow of a 2-year, 24-hour storm.
- The peak flow of a 10-year, 24-hour storm.

The Interim Guidance provided in the 2001 SMMWW (Ecology 2001) identifies a procedure for using these SBUH-derived peak flows for controlling the post-developed peak flows. The method roughly approximates the detention required to meet a flow duration standard. The method includes over-controlling the post-developed peak flows, as indicated in Step 3 below, and restricting the use of variable assumptions for estimating flows as follows:

Restricted Variable Assumptions

1. The flow path length assumed for sheet flow runoff in the pre-developed condition calculations shall not be less than 300 feet.
2. The Manning's effective roughness coefficient for pre-developed forested conditions shall be 0.8. For pasture conditions, the coefficient shall be 0.15.

In the table of curve numbers in **Volume III, Chapter 2** of the **SMMWW**, the curve numbers for pre-developed forest and pasture conditions shall be selected from the "fair" category.

Step 3:

Determine the regulatory target flows by summing the flows of Steps 1 and 2, as follows:

Step 1		Step 2		Regulatory Target Flows
½ the 2-year	+	½ the 2-year	=	the target control level for the 2-year post-development peak flow
10-year	+	2-year	=	the target control level for the 10-year post-development peak flow
100-year	+	10-year	=	the target control level for the 100-year post-development peak flow

Step 4:

Determine the post-development flows of the entire drainage area for the 2-year, 24-hour storm; the 10-year, 24-hour storm; and the 100-year, 24-hour storm. For existing land areas not proposed for improvement, use the same land covers and flow routing assumptions that were used in the original design. For the land that is proposed for improvement in the project, use the proposed land covers.

Step 5:

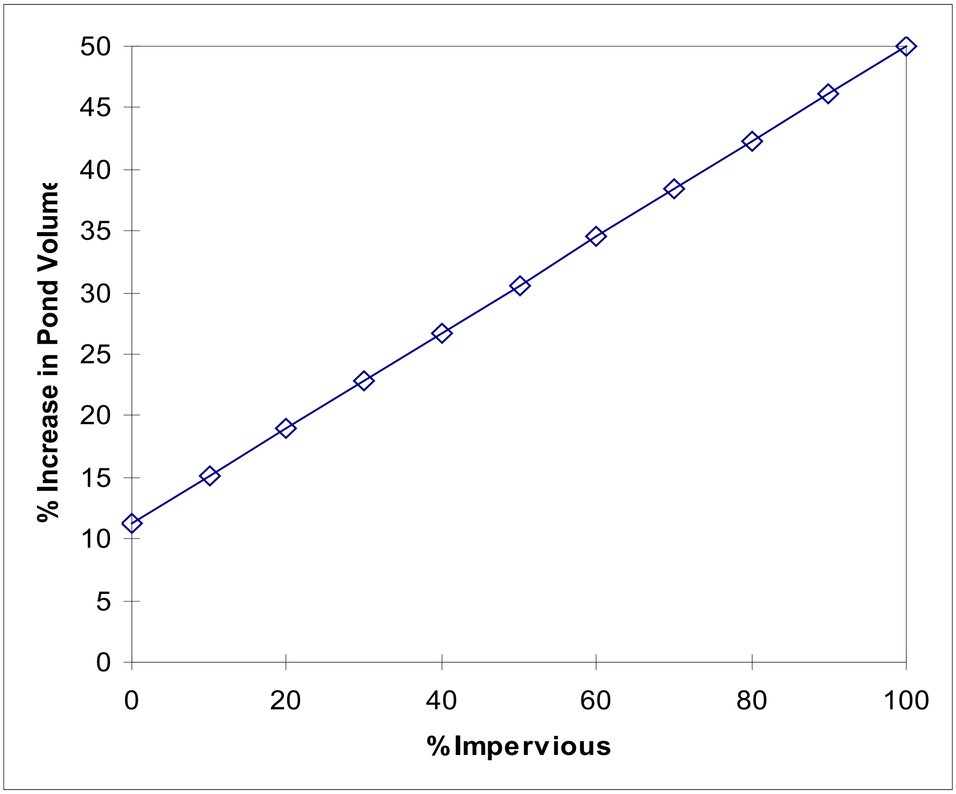
Using the existing detention basin and discharge structure, determine whether the post-development flows of Step 4 are controlled to the regulatory target flows in Step 3.

Step 6:

If the existing detention basin and discharge structure do not meet the regulatory target flows, modify the detention basin volume and/or the discharge structure until the targets are achieved.

Volume correction factor: If the pre-developed condition of the project site was modeled as pasture, the cubic foot increase in the detention volume of Step 4 must be increased by the percentage indicated in the y-axis in **Figure 5-1**. The % impervious land cover of the x-axis pertains only to the project site.

FIGURE 5-1. **Pond Volume Correction Factor**



6 Design Methodology for Stormwater Infiltration Facilities

6.1 INTRODUCTION

Stormwater infiltration facilities can be used for both flow control and runoff treatment. Infiltration facilities for flow control are used to reduce the volume and rate of stormwater runoff by conveying flows from new development or redevelopment to the ground and groundwater after appropriate treatment. Infiltration facilities for treatment purposes rely on the soil profile to provide treatment and reduce the pollutant loads in runoff. In either case, proper design of infiltration facilities requires careful determination of the infiltration rates on the project site.

This chapter supplements Volume III, Section 3.3 of the Stormwater Management Manual for Western Washington (SMMWW). The SMMWW must be consulted for design of stormwater infiltration systems, but the material in this chapter provides the following modifications:

- **Section 6.5:** Infiltration Receptor Characterization. This section modifies the infiltration receptor characterization in Section 3.3.5 of the SMMWW.
- **Section 6.6:** Allowable Infiltration Testing Methods. This section modifies testing method 3 (in-situ infiltration measurements) in Section 3.3.6 of the SMMWW.
- **Section 6.9:** Timing. This section modifies the construction criteria in Section 3.3.9 of the SMMWW.
- **Section 6.10:** Monitoring and Testing of Stormwater Infiltration Facilities. This section modifies the verification of performance in Section 3.3.9 of the SMMWW.

This chapter also provides information on the following topics:

- **Section 6.2:** Other Regulatory Requirements
- **Section 6.3:** Depth to Groundwater
- **Section 6.4:** Infiltration Testing Frequency

- **Section 6.7:** Closed Depressions
- **Section 6.8:** Groundwater Mounding Analysis
- **Section 6.11:** Stormwater Infiltration Facility Setbacks

► *This chapter relates to Minimum Requirement 7 (Flow Control). It supplements and modifies portions of the SMMWW in Volume III, Section 3.3 (Infiltration for Flow Control and for Treatment).*

6.2 OTHER REGULATORY REQUIREMENTS

Washington State Department of Ecology Underground Injection Control

Ecology classifies some stormwater infiltration facilities as Underground Injection Control (UIC) wells. These include below-surface infiltration facilities such as drywells and perforated pipes. The two major requirements of Ecology's UIC regulations are to register UICs and to provide measures for the protection of groundwater from pollution associated with stormwater. Ecology's UIC guidelines, as found in Guidance for UIC Wells that Manage Stormwater (Ecology 2006), provide design information that must be followed for UIC installation. These regulations have requirements for minimum depth to groundwater (5 feet), as well as siting and installation requirements. They also list development activities that are prohibited from using UICs.

Where UIC regulations conflict with county code, the more stringent of the two regulations shall apply.

Clark County Code 40.410 CARA

Clark County Code 40.410, which is the county's Critical Aquifer Recharge Area (CARA) ordinance, specifies that Class V injection wells are not allowed in Category I CARAs, and a permit is required for their installation in Category II CARAs. Stormwater infiltration facilities are classified as Class V injection wells.

6.3 DEPTH TO GROUNDWATER

Ecology criteria on UICs list a minimum depth to groundwater (5 feet). For facilities that are not considered UICs, the base of all infiltration basins or trench systems shall be greater than 5 feet above the seasonal high-water mark, bedrock (or hardpan), or other low permeability layer. A separation down to 3 feet may be considered if the county judges the groundwater mounding analysis, volumetric receptor capacity, and design of the overflow and/or bypass structures to be adequate to prevent overtopping and meet the site suitability criteria specified in the SMMWW.

6.4 INFILTRATION TESTING FREQUENCY

As part of the design of the infiltration facilities, the ground beneath the proposed infiltration facility must be tested for the infiltration rate of the soil, and the depth to groundwater must be determined. Locations for performing infiltration tests shall be as follows:

- A minimum of one infiltration test shall be conducted for each proposed infiltration facility location.
- At least one infiltration test shall be conducted for each location where the soil characteristics significantly vary within the vicinity of the proposed infiltration facility.
- One infiltration test shall be conducted for each proposed drywell location.

The geotechnical engineer/geologist shall determine the actual number of tests based on the variability of subsurface soil and groundwater conditions and the degree of certainty related to the future location of the infiltration system(s).

Ideally, tests should be conducted at the proposed depth and location of the final system; however, future system locations are often not known or accessible during the field testing. Therefore, at a minimum, the tests shall be conducted in the general vicinity of the future system and in soil conditions similar to those into which the infiltration system will discharge.

6.5 INFILTRATION RECEPTOR CHARACTERIZATION

One groundwater monitoring well shall be installed in each proposed infiltration facility location, unless the highest groundwater level is demonstrated to be at least 15 feet below the proposed facility. These wells shall be installed and monitored during at least one wet season (December through June) within 3 years prior to the date of final approval.

These modifications will help ensure a more accurate representation of the infiltration characteristics at the location of the proposed facility.

6.6 ALLOWABLE INFILTRATION TESTING METHODS

The single-ring falling head infiltration test and the pilot infiltration test (PIT) are the acceptable methods for determining infiltration rates on a site. Note that the USDA Soil Textural Classification and the ASTM Gradation Testing methods discussed in Volume III, Section 3.3.6 of the SMMWW are not allowed in Clark County for determining infiltration rates for stormwater infiltration facilities.

The pilot infiltration test (PIT) shall be performed in accordance with the guidance in Appendix III-D of the SMMWW. The single-ring falling head infiltration test shall be conducted using the following procedures, in accordance with ASCE (2007).

Single-Ring Falling Head Infiltration Test Procedures

Test Procedure

The test procedure is based in large part on mathematical equations derived from Darcy's Law for saturated flow in homogeneous isotropic media. The following equation shall be used for determining the soil coefficient of permeability:

$$k = \frac{L}{t} \ln \frac{h_1}{h_2} \qquad \textbf{Equation 6-1}$$

where:

k = coefficient of permeability (in/hr)

L = length of flow (in)

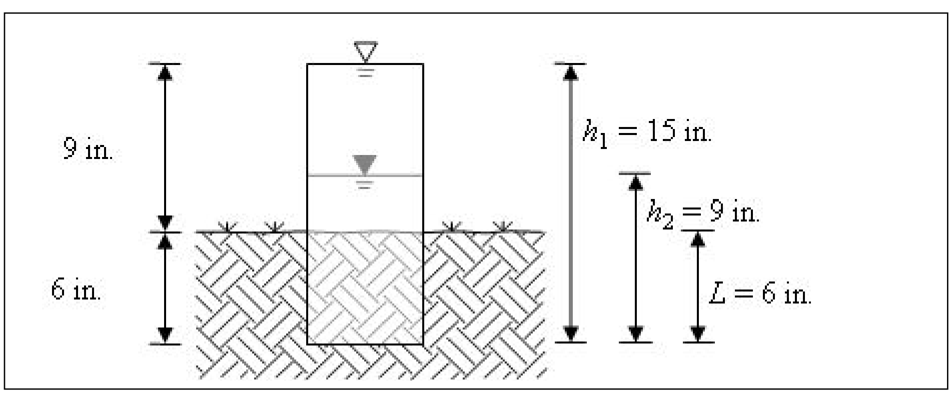
t = time (hr)

h_1 = initial head (in)

h_2 = final head (in)

The recommended test configuration and procedure described below has been developed using Equation 6-1 so that the observed drawdown rate can be divided in half to achieve the approximate coefficient of permeability. However, different test configurations can be used to fit varying site conditions or test depths. In all cases, the coefficient of permeability shall be calculated using Equation 6-1 and the principles outlined in the following procedure. **Figure 6-1** shows the test configuration and relevant parameters.

FIGURE 6-1. **Single-Ring Falling Head Infiltration Test Procedure**



Source: ASCE 2007.

Begin the infiltration test procedure by embedding a 6-inch-diameter, 15-inch-long, rigid standpipe 6 inches (**L**, as noted in Equation 6-1 and Figure 6-1) into the ground at the depth and location of the proposed test. The standpipe should be as thin-walled as practical, and the pipe should be carefully pressed or inserted vertically into the soil. Saturate or presoak the soil by maintaining measurable water in the standpipe for at least 4 hours. (A 4-hour presoak phase is assumed to allow adequate soil saturation to properly measure and calculate the coefficient of permeability. This should be verified by ensuring that the cumulative water drop in inches during the saturation period exceeds the standpipe embedment depth.)

After the saturation period, fill the pipe to the top (i.e., the pipe will contain a 9-inch vertical column of free water). Note that although the pipe contains 9 inches of water, the initial system head ($\mathbf{h_1}$) is 15 inches because head is measured from the top of the free water surface to the bottom of the soil specimen inside the pipe. Perform as many repeated 6-inch drawdown trials as can be completed in a 1-hour time period (i.e., allow the water in the pipe to drop from 15 to 9 inches [$\mathbf{h_1}$ to $\mathbf{h_2}$], and then repeat the process). Conclude the field test and record the following parameters: field observed drawdown rate, **L, t,** $\mathbf{h_1}$, and $\mathbf{h_2}$.

If the water level does not drop 6 inches in a 1-hour time period, the test can be concluded after 1 hour by recording the drawdown rate as the drop over the 1-hour time period. The applicable test parameters (**L, t,** $\mathbf{h_1}$, and $\mathbf{h_2}$) should also be recorded. In this case, $\mathbf{h_2}$ would equal $\mathbf{h_1}$ minus the amount of water drop observed over the 1-hour time period.

If desired, 6-inch drawdown trials may be performed during the saturation period. If three consecutive 6-inch drawdown trials indicate the rate has stabilized to within 5 percent variation between all three trials, the test may be concluded and the average rate of the three tests may be recorded as the drawdown rate. The applicable test parameters should also be recorded.

Coefficient of Permeability

After the field test procedure has been performed and the relevant test parameters recorded, the coefficient of permeability should be calculated using Equation 6-1. As described previously, the coefficient of permeability obtained from Equation 6-1 is the approximate rate at which water can be expected to infiltrate vertically into a given soil surface under long-term saturated flow conditions. This value should be reported by the geotechnical engineer/geologist as the soil coefficient of permeability for the tested location.

Test Limitations

It should be noted that the coefficient of permeability calculations identified above are based on ideal homogenous isotropic media. Because Clark County soils are often fluvially deposited, stratified, and interbedded, they are frequently neither homogenous nor isotropic. This may result in permeability coefficients that vary with depth and direction. Groundwater mounding or an elevated seasonal groundwater table may also affect the infiltration rate. In rare cases, the soil's ability to infiltrate water may be determined by its horizontal rather than vertical coefficient of permeability. The design professional should verify whether these are reasonable assumptions to allow for an approximate estimate of the soil coefficient of permeability. If not, specialized testing or analysis may be required.

Infiltration systems can be expected to undergo long-term degradation of infiltration capacity as a result of siltation, debris collection, and soil crusting; therefore, a correction factor must be calculated into the coefficient of permeability for the design of infiltration systems. Correction factors should be applied to the calculated coefficient of permeability to determine the allowable design infiltration rate.

Modification to the Recommended Single-Ring Falling Head Infiltration Test Procedures

The recommended test configuration described above has been designed to produce an observed drawdown rate that is approximately twice the coefficient of permeability. This is due to careful selection of the test configuration and geometry and may provide the benefit of simplicity and standardization. It is important to note that the coefficient of permeability will equal approximately one-half of the observed drawdown rate only when full 6-inch drawdown trials are conducted, and the relevant test parameters equal those indicated in the standpipe schematic shown in Figure 6-1. However, the test configuration, standpipe length, embedment depth, and other parameters may be modified by an experienced geotechnical professional, provided that Equation 6-1 is used to calculate the coefficient of permeability. This provides the professional consultant with flexibility to modify or tailor the test configuration, based on site-specific conditions. When the test configuration or procedure is modified, the geotechnical report must consider the implications of the modifications, such as:

- Standpipe diameters smaller than 6 inches may be adversely affected by the presence of large gravels or cobbles.

- Standpipe embedments of less than 6 inches in some granular soils may result in an inadequate seal around the pipe and subsequent seepage around the pipe tip, which may result in an overestimate of the coefficient of permeability.

Excessive head in the standpipe may result in an overestimate of the coefficient of permeability. The head shall be limited to one-half the height of the anticipated water depth in the proposed infiltration system (e.g., a field test for a pond with a maximum retained water depth of 3 feet shall have a maximum head of 1.5 feet).

Alternative Test Procedure – Auger Borehole

While the test pit and falling head method recommended above are the preferred methods for infiltration testing, they are neither feasible nor practical in some environments. Examples of such environments include cohesionless soils where open test pits pose a collapse hazard, systems at depths deeper than the reach of standard construction excavation equipment, or developed sites with existing asphalt or concrete pavements. In such situations, infiltration testing is often conducted in exploratory hollow-stem auger boreholes by geotechnical engineers and geologists. Auger borehole infiltration testing is an acceptable alternative to the suggested methods, provided the test method and calculation of the coefficient of permeability follow the test procedure below.

Test Procedure

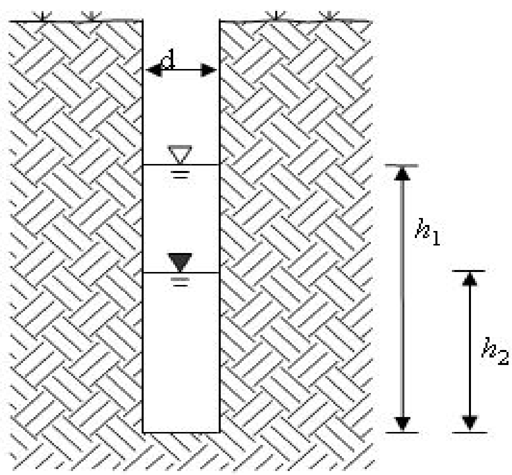
Advance an auger borehole to the desired elevation of the infiltration test. The auger must be hollow-stem, or the boring must be cased to prevent lateral leakage. Sample subsurface soils at depth to confirm that appropriately granular soils are present at or below the auger tip. Log the boring in accordance with Unified Soil Classification System (USCS) specifications, and collect a soil sample from the zone where the infiltration test is performed.

As the tip of the auger reaches the test zone, apply down pressure to the drill pipe and advance the auger slightly into the soil to form a seal. Withdraw the inner plug and rod from the hollow-stem auger to expose the test zone soil inside the auger. Measure and record the inner auger diameter (**d**). Pour water into the standpipe or auger and saturate the soils, as described previously.

After the presoak period, establish an initial head of water in the auger ($\mathbf{h_1}$). Depending on the soil gradation, range of expected infiltration rates, and proposed depth of retained water in the future infiltration system, the head level may vary, based on the geotechnical professional's recommendations. However, an initial head in excess of 4 feet or greater than the future depth of retained water in the system is not recommended. Also, water levels should not rise above joints between auger sections, so water does not leak out of the joints and skew drawdown readings.

Begin conducting the infiltration test by recording the time (**t**) required for the head in the auger to drop from the initial head ($\mathbf{h_1}$) to the final head ($\mathbf{h_2}$). Refill the standpipe or auger and conduct multiple test runs until relatively constant rates are achieved (less than 5 percent variation between three consecutive trials). An electric water level probe, indicator rod with pegs set at a 6-inch interval, or a float and tape may be used to accurately measure the drop in head over elapsed time. **Figure 6-2** shows the auger borehole test configuration and relevant parameters.

FIGURE 6-2. **Single-Falling Head Test Procedure (Auger Borehole Method)**



Source: ASCE 2007.

After relatively constant drawdown rates are observed as described above, record the final test parameters (**d**, $\mathbf{h_1}$, $\mathbf{h_2}$, and **t**).

Coefficient of Permeability

After the field test procedure has been performed and the relevant test parameters recorded, the coefficient of permeability should be calculated using Equation 6-2 (Lambe and Whitman 1969). Equation 6-2 applies only for coefficient of permeability calculations using the auger borehole method. The value obtained from Equation 6-2 should be reported by the geotechnical professional as the soil coefficient of permeability for the tested location.

$$\mathbf{k} = \frac{\pi \cdot d}{11\,t} \ln \frac{h_1}{h_2}$$

EQUATION 6-2

where:

k = coefficient of permeability (in/hr)

L = length of flow (in)

t = time (hr)

$\mathbf{h_1}$ = initial head (in)

$\mathbf{h_2}$ = final head (in)

Test Limitations

The test limitations described above for the suggested standard methods also apply to the auger borehole method. In addition, the borehole method assumes flush soil at the bottom of the auger and groundwater levels sufficiently below the depth of the test.

Soil swelling, segregation, and consolidation are assumed to be negligible. Hydraulic loss in the auger is also assumed to be negligible. This method also assumes homogenous soils with directional isotropy (i.e., the horizontal and vertical coefficients of permeability are constant and equal). The design professional should verify whether these are reasonable assumptions to allow for an approximate estimate of the soil coefficient of permeability. If not, specialized testing or analysis may be required.

Allowable Infiltration Rates

The correction factors in **Table 6-1** shall be used to establish the allowable infiltration rate for both the PIT test and the single-ring falling head test for closed infiltration systems. The safety factor for a sacrificial system can be reduced if the system is designed to infiltrate runoff for a design event with a 2-year return period.

An overflow route shall be identified for stormwater flows that overtop the facility when infiltration capacity is exceeded or the facility becomes plugged and fails. The overflow route shall be able to safely convey the 100-year peak flow to the downstream conveyance system or other acceptable discharge point, in accordance with conveyance requirements.

TABLE 6-1. Coefficient of Permeability Correction Factors

Design Condition	Correction Factor
Base Correction Factor	
The base correction factor is meant to account for soil variability and long-term system degradation due to siltation, crusting, or other factors.	2
Soils Correction Factor	
Additive correction factor recommended by geotechnical professional as a result of soil or groundwater conditions.	Minimum value of 2, or greater as recommended by the geotechnical engineer
System Design Correction Factors	
If the infiltration facility serves a basin with an impervious area greater tha.. 2 acres.	Add ½
If the infiltration facility serves a basin with an impervious area greater than 5 acres.	Add 1
Infiltration facilities in closed depressions.	Add 2
If a sacrificial system is provided and left operational following permanent site stabilization.	Subtract ½

6.7 CLOSED DEPRESSIONS

Where the entire project site is located within a closed depression, Clark County may waive the requirement for a route for the 100-year overflow, provided the facility is sized to fully infiltrate the 100-year event and the facility does not have berms on any side.

6.8 GROUNDWATER MOUNDING ANALYSIS

Groundwater mounding occurs under infiltration areas where the infiltration of stormwater causes the water under the infiltration facility to "mound up" before dispersing into the ground. This can occur where groundwater or a low permeability soil layer is near the surface. Groundwater mounding can cause reduced infiltration rates and the failure of infiltration facilities.

CCC Chapter 40.385 requires a groundwater mounding analysis to be conducted at all sites where the following occurs:

- The depth to either the seasonal groundwater table or a low permeability soil stratum is less than 5 feet from the infiltration facility bottom; or
- The depth to the seasonal groundwater table or low permeability stratum is less than 15 feet, and the effective impervious area contributing runoff to the infiltration facility is greater than 1 acre.

Groundwater modeling (mounding analysis) of the proposed infiltration facility shall be done using the design infiltration rate and the estimated maximum groundwater elevation determined for the proposed facility location.

6.9 TIMING

No permanent infiltration systems shall be allowed into service until the entire contributing drainage area has received final stabilization (to avoid clogging of the facility by eroded soil), and permanent county-approved water quality BMPs are in place. For open infiltration systems, rough excavating using heavy equipment shall only be allowed down to 3 feet above the proposed bottom elevation. Final grading of the infiltration facility shall occur only after the contributing drainage areas are fully stabilized. Final grading shall be performed using equipment positioned along the sides of the facility and not on the bottom of the facility. The infiltration facility shall be cordoned off to prevent equipment from compacting soil in the infiltration area.

6.10 MONITORING AND TESTING OF STORMWATER INFILTRATION FACILITIES

Before the county accepts any infiltration facility, the completed facility shall be tested to demonstrate that it performs as designed. If the facility performance is not satisfactory, the facility shall be modified or expanded as needed to make it function as designed.

During construction of the infiltration facility, the geotechnical specialist who performed the testing shall observe the excavation and confirm that the soils are consistent with those tests on which the design was based. This observation shall take place prior to the placement of any filter fabric or drain rock specified on the plans.

In addition to the observation, additional infiltration tests shall be performed to confirm the original tests through the base of the facility. This is especially important in layered soils with mixed silt and sand. If the tested coefficient of permeability determined at the time of construction is at least 95 percent of the uncorrected coefficient of permeability used to determine the design rate, construction shall be allowed to proceed. If the tested rate does not meet this requirement, an additional testing plan shall be submitted to Clark County that follows the requirements in Chapter 3 of this manual. This plan shall address steps to correct the problem, including additional testing and/or resizing of the facility to ensure that the system will dispose of the necessary stormwater.

6.11 STORMWATER INFILTRATION FACILITY SETBACKS

Stormwater infiltration facilities shall be set back according to **Table 6-2**.

TABLE 6-2. **Stormwater Infiltration Facility Setbacks**

Stormwater Infiltration Facility Setback From:	Distance
Drinking water wells[1]	100 feet minimum
Building foundations	20 feet minimum, upslope 100 feet minimum, downslope
Slopes equal to or greater than 15%	50 feet minimum
Roof downspout systems	10 feet minimum from any structure or property line

1 *Infiltration facilities upslope of drinking water supplies and within the 1-, 5-, and 10-year time of travel zones must comply with Washington State Department of Health requirements.*

These setbacks may be reduced if a report is prepared that accurately characterizes the movement of groundwater within 20 feet of the infiltration facility, and this characterization demonstrates that groundwater will not affect the building, drinking water well, or other applicable structure.

7 Construction Stormwater Pollution Prevention Plans

7.1 INTRODUCTION

This chapter provides the following information:

- **Section 7.2:** Construction Stormwater Pollution Prevention Plan (SWPPP) Requirements.
- **Section 7.3:** Construction SWPPP Elements. These are the 12 elements that must be included in the Construction SWPPP in order to meet Minimum Requirement 2.
- **Section 7.4:** Sediment Trap and Temporary Sediment Pond Sizing.

Projects in which the new, replaced, or new plus replaced impervious surfaces total 2,000 square feet or more, or that disturb 7,000 square feet or more of land, must prepare a Construction SWPPP (see Chapter 3 for submittal requirements). Each of 12 elements must be considered and included in the Construction SWPPP, unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the narrative of the Construction SWPPP.

Projects that add or replace less than 2,000 square feet of impervious surface or disturb less than 7,000 square feet of land are not required to prepare a Construction SWPPP, but must consider all of the 12 elements and develop controls for all elements that pertain to the project site.

All new development and redevelopment projects are responsible for preventing erosion and discharge of sediment and other pollutants into receiving waters. The Construction SWPPP shall be implemented beginning with initial soil disturbance and until final stabilization.

Sediment and erosion control BMPs shall be consistent with the BMPs contained in Volume II, Chapters 3 and 4, of the *Stormwater Management Manual for Western Washington* (SMMWW) and/or other equivalent BMPs contained in technical stormwater manuals approved by Clark County and the Department of Ecology.

► *This chapter fulfills Minimum Requirement 2 (Construction Stormwater Pollution Prevention). It supersedes Section 2.5.2 of the SMMWW.*

► *See Volume II of the SMMWW for the design of BMPs to meet the requirements of this chapter.*

7.2 CONSTRUCTION SWPPP REQUIREMENTS

The Construction SWPPP shall include a narrative and drawings. The narrative shall include documentation to explain and justify the pollution prevention decisions made for the project (see Section 3.5).

All BMPs shall be clearly referenced in the narrative and marked on the drawings.

Clearing and grading activities for developments shall be permitted only if conducted pursuant to an approved site development plan (e.g., subdivision approval) that establishes permitted areas of clearing, grading, cutting, and filling. When establishing these permitted clearing and grading areas, consideration should be given to minimizing removal of existing trees and minimizing disturbance/compaction of native soils, except as needed for building purposes. These permitted clearing and grading areas and any other areas required to preserve critical or sensitive areas, buffers, native growth protection easements, or tree retention areas as may be required by local jurisdictions shall be delineated on the site plans and the development site.

Seasonal Work Limitations

From October 1 through April 30, clearing, grading, and other soil-disturbing activities may be authorized by the county only if silt-laden runoff will be prevented from leaving the site through a combination of the following:

- Site conditions, including existing vegetative coverage, slope, soil type, and proximity to receiving waters.
- Limitations on activities and the extent of disturbed areas.
- Proposed erosion and sediment control measures.

Based on the information provided and/or local weather conditions, the county may expand or restrict the seasonal limitation on site disturbance. The following activities are exempt from the seasonal clearing and grading limitations:

- Routine maintenance and necessary repair of erosion and sediment control BMPs.
- Routine maintenance of public facilities or existing utility structures that do not expose the soil or result in the removal of the vegetative cover to soil.
- Activities where there is 100 percent infiltration of surface water runoff within the site in approved and installed erosion and sediment control facilities.

7.3 CONSTRUCTION SWPPP ELEMENTS

The construction site operator shall include each of the 12 elements below in the Construction SWPPP and ensure they are implemented, unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the Construction SWPPP.

1. **Preserve Vegetation/Mark Clearing Limits**

   a. Prior to beginning land-disturbing activities, including clearing and grading, clearly mark all clearing limits, sensitive areas and their buffers, and trees that are to be preserved within the construction area.

   b. The duff layer, native top soil, and natural vegetation shall be retained in an undisturbed state to the maximum degree practicable.

2. **Establish Construction Access**

   a. Construction vehicle access and exit shall be limited to one route, if possible.

   b. Access points shall be stabilized with quarry spalls, crushed rock, or other equivalent BMP to minimize the tracking of sediment onto public roads.

   c. Wheel wash or tire baths shall be located onsite if the stabilized construction entrance is not effective in preventing sediment from being tracked onto public roads.

   d. If sediment is tracked offsite, roads shall be cleaned thoroughly at the end of each day or more frequently during wet weather. Sediment shall be removed from roads by shoveling or pickup sweeping and shall be transported to a controlled sediment disposal area.

   e. Street washing is allowed only after sediment is removed in accordance with 2.d, above. Street wash wastewater shall be controlled by pumping it back onsite or otherwise be prevented from discharging into systems tributary to waters of the state.

3. **Control Flow Rates**

   a. Properties and waterways downstream from development sites shall be protected from erosion resulting from increases in the velocity and peak volumetric flow rate of stormwater runoff from the project site.

   b. Where necessary to comply with 3.a, above, stormwater retention or detention facilities shall be constructed as one of the first steps in grading. Detention facilities shall be functional prior to construction of site improvements (e.g., impervious surfaces).

   c. If permanent infiltration ponds are used for flow control during construction, these facilities shall be protected from siltation during the construction phase in accordance with the Construction SWPPP, including but not limited to temporary sedimentation ponds.

4. **Install Sediment Controls**

   a. Stormwater runoff from disturbed areas shall pass through a sediment pond or other appropriate sediment removal BMP prior to leaving a construction site or prior to discharge to an infiltration facility. Runoff from fully stabilized areas may be discharged without a sediment removal BMP, but shall meet the flow control performance standard of 3.a, above.

   b. Sediment control BMPs (sediment ponds, traps, filters, etc.) shall be constructed as one of the first steps in grading. These BMPs shall be functional before other land-disturbing activities take place.

   c. BMPs intended to trap sediment onsite shall be located in a manner to avoid interference with the movement of juvenile salmonids attempting to enter off-channel areas or drainages.

5. **Stabilize Soils**

   a. Exposed and unworked soils shall be stabilized by application of effective BMPs that prevent erosion.

   b. No soils shall remain exposed and unworked for more than the time periods set forth below to prevent erosion:

      - During the dry season (May 1 – September 30): 7 days
      - During the wet season (October 1 – April 30): 2 days

   c. Soils shall be stabilized at the end of the shift before a holiday or weekend if needed, based on the weather forecast.

   d. Soil stockpiles shall be stabilized from erosion, protected with sediment trapping measures, and, where possible, located away from storm drain inlets, waterways, and drainage channels.

6. **Protect Slopes**

   a. Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion.

   b. Offsite stormwater (run-on) or groundwater shall be diverted away from slopes and undisturbed areas with interceptor dikes, pipes, and/or swales. Offsite stormwater shall be managed separately from stormwater generated on the site.

   c. At the top of slopes, drainage shall be collected in pipe slope drains or protected channels to prevent erosion. Temporary pipe slope drains shall handle the expected peak 10-minute flow velocity from a Type 1A, 10-year, 24-hour frequency storm for the developed condition. Alternatively, the 10-year, 1-hour flow rate predicted by an approved continuous runoff model, increased by a factor of 1.6, may be used. The hydrologic analysis shall use the existing land cover condition for predicting flow rates from tributary areas outside the project limits.

For tributary areas on the project site, the analysis shall use the temporary or permanent project land cover condition, whichever will produce the highest flow rates. If the Western Washington Hydrology Model is used to predict flows, bare soil areas shall be modeled as "landscaped area."

d. Excavated material shall be placed on the uphill side of trenches, consistent with safety and space considerations.

e. Check dams shall be placed at regular intervals within constructed channels that are cut down a slope.

7. **Protect Drain Inlets**

a. Storm drain inlets made operable during construction shall be protected so stormwater runoff does not enter the conveyance system without first being filtered or treated to remove sediment.

b. Inlet protection devices shall be cleaned or removed and replaced when sediment has filled one-third of the available storage (unless a different standard is specified by the product manufacturer).

8. **Stabilize Channels and Outlets**

a. All temporary onsite conveyance channels shall be designed, constructed, and stabilized to prevent erosion from the following expected peak flows. Channels shall handle the expected peak 10-minute flow velocity from a Type 1A, 10-year, 24-hour frequency storm for the developed condition. Alternatively, the 10-year, 1-hour flow rate predicted by an approved continuous runoff model, increased by a factor of 1.6, may be used. The hydrologic analysis shall use the existing land cover condition for predicting flow rates from tributary areas outside the project limits. For tributary areas on the project site, the analysis shall use the temporary or permanent project land cover condition, whichever will produce the highest flow rates. If the Western Washington Hydrology Model is used to predict flows, bare soil areas shall be modeled as "landscaped area."

b. Stabilization, including armoring material, adequate to prevent erosion of outlets, adjacent streambanks, slopes, and downstream reaches shall be provided at the outlets of all conveyance systems.

9. **Control Pollutants**

a. All pollutants, including waste materials and demolition debris, that occur onsite shall be handled and disposed of in a manner that does not cause contamination of stormwater.

b. Cover, containment, and protection from vandalism shall be provided for all chemicals, liquid products, petroleum products, and other materials that have the potential to pose a threat to human health or the environment. Onsite fueling tanks shall include secondary containment.

c. Maintenance, fueling, and repair of heavy equipment and vehicles shall be conducted using spill prevention and control measures. Contaminated surfaces shall be cleaned immediately following any spill incident.

d. Wheel wash or tire bath wastewater shall be discharged to a separate onsite treatment system or to the sanitary sewer with local sewer district approval.

e. Application of fertilizers and pesticides shall be conducted in a manner and at application rates that will not result in loss of chemical to stormwater runoff. Manufacturers' label requirements for application rates and procedures shall be followed.

f. BMPs shall be used to prevent or treat contamination of stormwater runoff by pH-modifying sources. These sources include, but are not limited to: bulk cement, cement kiln dust, fly ash, new concrete washing and curing waters, waste streams generated from concrete grinding and sawing, exposed aggregate processes, dewatering concrete vaults, concrete pumping and mixer washout waters. Construction site operators are required to adjust the pH of stormwater if necessary to prevent violations of water quality standards.

g. Construction site operators shall obtain written approval from Clark County and the Department of Ecology prior to using chemical treatment other than CO_2 or dry ice to adjust pH.

10. **Control Dewatering**

a. Foundation, vault, and trench dewatering water, which have similar characteristics to stormwater runoff at the site, shall be discharged into a controlled conveyance system prior to discharge to a sediment trap or sediment pond.

b. Clean, non-turbid dewatering water, such as well-point ground water, can be discharged to systems tributary to or directly into surface waters of the state, as specified in 8, above, provided the dewatering flow does not cause erosion or flooding of receiving waters. Clean dewatering water shall not be routed through stormwater sediment ponds.

c. Other dewatering disposal options may include: (i) infiltration; (ii) transport offsite in a vehicle, such as a vacuum flush truck, for legal disposal in a manner that does not pollute state waters; (iii) onsite chemical treatment or other suitable treatment technologies approved by the county; (iv) sanitary sewer discharge with local sewer district approval, if there is no other option; or (v) use of a sedimentation bag with outfall to a ditch or swale for small volumes of localized dewatering.

d. Highly turbid or contaminated dewatering water shall be handled separately from stormwater.

11. **Maintain BMPs**

a. All temporary and permanent erosion and sediment control BMPs shall be inspected, maintained, and repaired as needed to ensure continued performance of their intended function in accordance with BMP specifications.

b. All temporary erosion and sediment control BMPs shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed.

12. **Manage the Project**

a. Development projects shall be phased to the maximum degree practicable and shall take into account seasonal work limitations.

b. Construction site operators shall maintain, and repair as needed, all sediment and erosion control BMPs to ensure continued performance of their intended function.

c. Construction site operators shall periodically inspect their sites. Site inspections shall be conducted by a Certified Erosion and Sediment Control Lead who shall be identified in the Construction SWPPP and shall be present onsite or on call at all times.

d. Construction site operators shall maintain, update, and implement their Construction SWPPP. Construction site operators shall modify their Construction SWPPP whenever there is a change in design, construction, operation, or maintenance at the construction site that has, or could have, a significant effect on the discharge of pollutants to waters of the state.

7.4 SEDIMENT TRAP AND TEMPORARY SEDIMENT POND SIZING

For sediment traps and temporary sediment ponds, it is acceptable to use an approved continuous runoff model to calculate the design flows, **Q2** and **Q10**, as follows:

Sediment Trap

Q2 = design inflow (cfs) based on the 2-year flow rate (1-hour time step in an approved continuous runoff model) for the developed (unmitigated) site, multiplied by a factor of 1.3. The 10-year peak flow shall be used if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection. **Q10** is the 10-year flow rate (1-hour time step in an approved continuous runoff model) for the developed (unmitigated) site, multiplied by a factor of 1.6.

Temporary Sediment Pond Sizing

Q2 and **Q10** are the same as those used for Sediment Trap, above.

If a continuous runoff model is used to design the principal spillway, Q10 is the 10-year flow rate (1-hour time step) for the developed (unmitigated) site, multiplied by a factor of 1.6.

If a continuous runoff model is used to design the emergency spillway, the 100-year flow is the 100-year flow rate (1-hour time step) for the developed (unmitigated) site, multiplied by a factor of 1.6.

8 Conveyance Systems

8.1 INTRODUCTION

This chapter presents design requirements for open channel and closed conduit stormwater conveyance systems. These requirements in this chapter are in addition to the minimum requirements identified in Chapter 2.

Open channel conveyance systems are preferred over closed conduits where feasible, especially where they might provide opportunities for water quality treatment, habitat improvement, or emergency overland flood relief routes.

This chapter includes:

- **Section 8.2:** Design and Construction Standards
- **Section 8.3:** Design Storm Frequency
- **Section 8.4:** Hydraulic Methods
- **Section 8.5:** Outfalls
- **Section 8.6:** Outfalls to Detention Ponds
- **Section 8.7:** Conveyance System Easements

► *All new development and redevelopment projects in Clark County are subject to these requirements.*

8.2 DESIGN AND CONSTRUCTION STANDARDS

The following design standards shall be followed:

- Culverts shall be designed in accordance with the Washington State Department of Transportation Hydraulics Manual (WSDOT 2007).
- Fish passage culverts shall meet the design criteria specified in the Washington Department of Fish and Wildlife Fish Passage Design at Road Culverts (WDFW 2003).
- All pipe materials, joints, manholes, and other products associated with conveyance systems shall be designed and constructed in accordance with the 2008 edition of the Washington State Department of Transportation Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT 2008).

8.3 DESIGN STORM FREQUENCY

The peak runoff rate from the design storms to be used for design of stormwater conveyance systems shall be as follows:

- The 10-year storm: Contributing drainage areas less than 40 acres.
- The 25-year storm: Contributing drainage areas of 40 acres or more.
- The 100-year storm:
  - Culverts with contributing drainage areas greater than 200 acres.
  - Culverts in areas of special flood hazard, as described in FEMA Flood Insurance Rate Maps (FIRM) and reports for Clark County.

The design storm shall be applied to the entire contributing drainage area projected under full build-out conditions.

8.4 HYDRAULIC METHODS

Closed Conduit Systems

Two hydraulic methods can be used for the design of pipelines. The first method is a gravity flow or open channel design, which is most commonly performed using Manning's equation. This method assumes that flow is steady (does not change with time) and uniform (the depth and velocity remain constant throughout the pipe for a given flow). Manning's equation can be found in standard hydraulic textbooks and in the WSDOT Hydraulics Manual (WSDOT 2007).

The second method is a pressure flow design, where the water surface elevation rises above the crown of the pipe. A backwater analysis is performed to determine the level of the water surface (the hydraulic grade line) for a pipeline system with a given diameter, slope, and flow rate. This method also assumes steady flow, but the flow is not necessarily uniform (the slope of the hydraulic grade line differs from the slope of the pipe).

New pipes shall be designed to operate in an open-channel regime during the design storm and shall be sized using open channel design methods. Under certain hydrologic and hydraulic conditions, however, flow can rise above the pipe, creating a pressurized pipeline. For those situations, it is important to determine the hydraulic grade line to ensure that water does not overtop manholes and catch basins. A backwater analysis shall be calculated under any of the following conditions:

- Pipes with slopes less than 0.50 percent.
- Pipes with velocities over 6.5 feet per second (fps) (for subcritical flow only).
- Inlet and outlet pipes forming a sharp angle (45 degrees or greater) at junctions.
- Pipe inverts less than 3 feet deep when entering and leaving junctions.

Gravity Flow Analysis

When using Manning's equation for the design, each pipe within the system shall be sized and sloped such that its barrel capacity at normal full flow is equal to or greater than the required conveyance capacity for the peak runoff of the design storm. **Table 8-1** provides the Manning's "**n**" values to be used.

Nomographs may also be used for sizing the pipes. For pipes flowing partially full, the actual velocity can be estimated from engineering nomographs by calculating Q_{full} and V_{full} and using the ratio of Q_{design}/Q_{full} to find **V** and **d** (the depth of flow). These nomographs can be found in most standard hydraulics manuals or in the WSDOT Hydraulics Manual (WSDOT 2007).

TABLE 8-1. Manning's "n" Values for Pipes

Type of Pipe Material	Backwater Analysis	Manning's Equation
A. Concrete pipe and CPEP-smooth interior pipe	0.012	0.013
B. Annular corrugated metal pipe or pipe arch:		
1. 2-2/3" x ½" corrugation (riveted)		
a. Plain or fully coated	0.024	0.028
b. Paved invert (40% of circumference paved):		
(1) flow full depth	0.018	0.021
(2) flow 0.8 depth	0.016	0.018
(3) flow 0.6 depth	0.013	0.015
c. Treatment 5	0.013	0.015
2. 2.3" x 1" corrugation	0.027	0.031
3. 3.6" x 2" corrugation (field bolted)	0.030	0.035
C. Helical 2-2/3" x ½" corrugation and CPEP-single wall	0.024	0.028
D. Spiral rib metal pipe and PVC pipe	0.011	0.013
E. Ductile iron pipe cement lined	0.012	0.014
F. High density polyethylene pipe (butt fused only)	0.009	0.009

CPEP = corrugated polyethylene pipe; PVC = polyvinyl chloride.

Backwater Analysis

This method uses a rearranged version of Manning's equation expressed in terms of the friction slope. This equation is used to calculate the barrel friction, which is then combined with other friction terms to generate water surface elevations along the length of the pipeline. This method is computationally intensive and is generally performed using computer programs. Detailed information on this method, including procedures for computation by hand, can be found in Section 6.6 of the WSDOT Hydraulics Manual (WSDOT 2007) or Section 7 of Hydraulic Engineering Circular No. 22, Urban Drainage Design Manual (FHWA and NHI 2001). Manning's "**n**" values shall be per **Table 8-1**.

When conditions require calculation of the hydraulic grade line, the design engineer shall analyze for the design storm event and the 25- and 100-year, 24-hour storm events. For the 25-year event, there shall be a minimum of 1.0 feet of freeboard between the water surface and the top of any manhole or catch basin.

For the 100-year event, overtopping of the pipe conveyance system may occur; however, the additional flow shall not extend beyond one-half of the lane width of the outside lane of the traveled way and shall not exceed 4 inches in depth at its deepest point. Off-channel storage on private property is allowed with recording of the proper easements. The overtopping flow shall be analyzed by open channel flow methods and added to the flow capacity where it re-enters the pipe system.

Minimum Pipe Diameter

The minimum pipe diameter shall be 12 inches, except that single laterals less than 50 feet in length may be 8 inches in diameter.

Allowable Velocities and Slopes

The minimum velocity is 3 feet per second at design flow. This minimum may be waived through the county's Type I or Type II administrative variance process where topography and existing drainage systems make it impractical to meet the standard [see CCC Section 40.385.040(E)(3)].

Table 8-2 lists maximum slopes, velocities, and anchor spacings. If velocities exceed 15 feet per second for the conveyance system design event, anchors shall be provided at bends and junctions.

TABLE 8-2. Maximum Pipe Slopes and Velocities

Type of Pipe Material	Pipe Slope Above Which Pipe Anchors Required	Maximum Slope Allowed	Maximum Velocity Allowed
CMP, Spiral Rib, PVC, CPE	20% (1 anchor per 100 L.F. of pipe)	30%	30 fps
Concrete or smooth-lined CPE	10% (1 anchor per 50 L.F. of pipe)	20%	30 fps
Ductile Iron*	20% (1 anchor per pipe section)	None	None
HDPE**	40% (1 anchor per 100 L.F. of pipe)	None	None

* *Flanged joints required.*

** *Butt-fused joints required.*

CPE = corrugated polyethylene; HDPE = high density polyethylene; L.F. = linear feet; fps = feet per second; PVC = polyvinyl chloride

High-density polyethylene (HDPE) pipe systems longer than 100 feet shall be anchored at the upstream end if the slope exceeds 25 percent, and the downstream end shall be placed in a minimum 4-foot-long section of the next larger pipe size. This sliding sleeve connection allows for the high thermal expansion/contraction coefficient of the pipe material.

Pipeline Alignments

Where a minimal fall is necessary between the inlet and outlet pipes in a structure, pipes shall be aligned vertically by one of the following, in order of preference:

- Match pipe crowns
- Match 80 percent diameters of pipes
- Match pipe inverts

Pipe direction changes or size increases or decreases are allowed only at manholes and catch basins.

Downsizing of pipes is allowed only under the following conditions:

- No hydraulic jump can occur.
- Downstream pipe slope is significantly greater than the upstream slope.
- Velocities remain in the 3 - 8 fps range.

Open Conveyances

Where space and topography permit, open conveyances are the preferred means of collecting and conveying stormwater. Public safety must be considered when open conveyances are adjacent to traveled ways and/or accessible to the public.

Open conveyances shall be designed by one of the following methods:

- Manning's equation (for uniform flow depth, flow velocity, and constant channel cross-section)
- Direct step backwater method (using the energy equation for varying stream channel cross-section)
- Standard step backwater method (using a computer program)

Manning's equation may be used where uniform flow conditions exist (i.e., the flow depth and velocity remain constant throughout the channel reach). However, if a flow restriction (such as a culvert or bridge) causes flows to rise above normal depth within a channel reach, a backwater analysis shall be performed, using either the direct step or standard step backwater methods.

Direct step methods may be calculated using a spreadsheet or computer program (see the 2005 King County Surface Water Design Manual for an example). The standard step method is a variation of the direct step method and is commonly performed using a computer program because of the iterative process involved. The most common program using the standard step method is the U.S. Army Corps of Engineers HEC-RAS program.

Allowable Velocities

Velocities must be low enough to prevent channel erosion, based on the native soil characteristics or the compacted fill material. For velocities above 5 fps, channels shall have an 8-inch-thick rock-lined bottom and side slope to the top of the roadway shoulder or shall be stabilized in a fashion acceptable to the county. Water quality shall not be degraded by passage through an open conveyance. **Table 8-3** provides specific guidance on channel protection measures.

TABLE 8-3. **Open Conveyance Protection**

Velocity at Design Flow (fps)	Protection	Thickness	Minimum Height Required Above Water Surface
0-5	Grass lining*	N/A	0.5 feet
5-10	Light loose riprap**	1 foot	1.5 feet
10-20	Heavy loose riprap**	2 feet	1.5 feet
20+	Engineered dissipater required	Varies	2.0 feet

* *Bioengineered lining allowed for design flow up to 8 fps.*

** *Riprap shall be in accordance with WSDOT/APWA Standard Specifications (WSDOT 2008).*
Note: *Riprap sizing governed by side slopes on channel, assumed ~3.1.*

Channels with a slope of less than 6 percent and peak velocities of less than 5 fps shall be lined with vegetation. Other conveyance protection systems may be allowed if submitted through the appropriate variance process [see CCC Section 40.385.040(E)(3)].

Side Slopes and Minimum Freeboard

Channel side slopes shall not exceed 2:1 for undisturbed ground (cuts) as well as for disturbed ground (embankments). All constructed channels shall be compacted to a minimum 95 percent compaction, as verified by a modified Proctor test (ASTM D1557/ AASHTO T180).

Channels shall be designed with a minimum freeboard of 0.5 feet when the design flow is 10 cfs or less and 1 foot when the design discharge is greater than 10 cfs.

8.5 OUTFALLS

All pipes and culverts that discharge to streams, rivers, ponds, lakes, or other open bodies of water are designated as outfalls. The design and installation of proper energy dissipaters is critical to prevent erosion at or downstream of the point of discharge. Energy dissipater systems include rock splash pads, flow dispersal trenches, and gabion mattresses.

All energy dissipation at outfalls shall be designed for peak flows from a 100-year, 24-hour storm event. **Table 8-4** summarizes the rock requirements for rock splash pad outfalls.

TABLE 8-4. Rock Requirements for Rock Splash Pad Outfalls

Discharge Velocity (fps)	Type1	Thickness	Width	Length	Height
0-5	Quarry spalls	1 foot	Diameter + 6 feet	8 feet or 4x diameter, whichever is greater	Crown + 1 foot
5-10	Light loose riprap	2 feet	Diameter + 6 feet or 2 x diameter, whichever is greater	12 feet or 4x diameter, whichever is greater	Crown +1 foot
10-20	Heavy loose riprap	As required	As required	As required	Crown + 1 foot
20+	Engineered dissipater required				

1. Riprap and quarry spalls shall meet WSDOT specifications (2008) for the classes noted.

Other energy dissipation systems may be allowed if submitted through the appropriate variance process [see CCC Section 40.385.040(E)(3)].

8.6 OUTFALLS TO DETENTION PONDS

Invert elevations for conveyance outfalls into detention ponds shall be set at an elevation where the water surface elevation in the detention pond has a 10 percent or smaller chance of being equaled or exceeded in any given year. This is determined in Western Washington Hydrology Model (WWHM) by performing a stage-frequency analysis.

After performing the duration analysis and determining the final detention pond size, go to the "Analysis" section of WWHM, select the "STAGE Mitigated" dataset, and click on "Run Analysis." The stage frequency summary is tabulated in the upper right corner. Select the 10-year stage and set the invert elevation of the outfall pipe at or above this elevation.

8.7 CONVEYANCE SYSTEM EASEMENTS

Publicly Owned Systems

Easements shall be provided to the county for access and maintenance of all conveyance systems within the site that will be maintained by the county (including streams, if used). The minimum widths of easements shall be as indicated in **Table 8-5**, although the responsible official may require increased widths when necessary to ensure adequate area for equipment access and maintenance.

TABLE 8-5. **Easement Widths for Publicly Owned Conveyance Systems**

Pipe Diameter	Easement Width
<= 36 inches	20 feet
> 36 inches	20 feet plus the pipe's inside diameter
Open conveyances	Top width of channel plus 15 feet on one side
Pipes shall be located with their center line no closer than one-quarter the easement width from an abutting property line.	

Privately Owned Systems

Stormwater easements shall be provided to the county for access and inspection of all conveyance systems within the development site that will be privately owned and maintained (including streams, if used). The minimum widths of easements shall be as listed in the Publicly Owned Systems section above, except under the following conditions:

- For pipes used for rear and side lot drainage collection systems, where the inside diameter of the pipes is less than or equal to 12 inches and the pipes are less than or equal to 5 feet deep at the invert, the easement shall be 10 feet or equal to the lot setback if the pipe is located within the setback.
- No buildings or other structures that prevent access are permitted within easements.

9 Offsite Analysis and Mitigation

9.1 INTRODUCTION

This chapter provides requirements for offsite analysis and mitigation. These requirements are in addition to the minimum requirements identified in Chapter 2.

The offsite analysis is a field investigation of downstream impacts on water quality and surface water conditions resulting from a development, redevelopment, or other land-disturbing activity. An offsite analysis must be performed for all development and redevelopment activities that meet the applicability thresholds identified under Minimum Requirement 7, except those that meet one of the exemptions identified in Section 9.2 of this chapter.

This chapter includes:

- **Section 9.2:** Exemptions
- **Section 9.3:** Offsite Analysis
- **Section 9.4:** Mitigation

The information in this chapter is supplementary to Volume I, Section 3.3 of the SMMWW, Optional Guidance 2: Off Site Analysis and Mitigation.

► *All new development and redevelopment projects are subject to these requirements, except projects that are identified as exempt in Section 9.2.*

9.2 EXEMPTIONS

A project is exempt from performing an offsite analysis if any of the following three conditions apply:

1. Based on the information in the final technical information report (TIR), the county determines that there is sufficient evidence to conclude that the project will not have a significant adverse impact on the downstream and\or upstream drainage system.

2. The project:

   (a) Adds less than 2,000 square feet of new impervious surface in the urban area or adds less than 5% of the site as new impervious surface in the rural area; and

   (b) Adds less than 35,000 square feet of new pervious surface; and

   (c) Does not construct or modify a drainage pipe/ditch that is 12 inches or more in size/depth or that receives runoff from a drainage pipe/ditch that is 12 inches or more in size/depth; and

   (d) Does not contain or lie adjacent to a landslide, steep slope, or erosion hazard area.

3. The project does not change the rate, volume, duration, or location of discharges to and from the project site (e.g., where existing impervious surface is replaced with other impervious surface having similar runoff-generating characteristics or where pipe/ditch modifications do not change existing discharge characteristics).

9.3 OFFSITE ANALYSIS

The offsite analysis shall extend downstream for the entire flow path, from the development site to the receiving water or up to 1 mile, whichever is less. If the receiving water is within ¼ mile, the analysis shall extend within the receiving water to ¼ mile from the development site. The analysis shall extend upstream to a point where any backwater effects created by the project cease. The applicant shall use best efforts to obtain these data, while respecting private property.

The existing conditions and potential impacts to be evaluated shall include, at a minimum, but not be limited to:

1. Excessive sedimentation.

2. Upland erosion impacts, including landslide hazards.

3. Stream channel erosion at the outfall location.

4. Streambank erosion.

5. Conveyance system capacity.

6. Localized flooding.

7. Violations of surface water quality standards as identified in a basin plan or a total maximum daily load (TMDL); or violations of groundwater standards in a wellhead protection area.

8. Spills and discharges of priority pollutants, as defined by the federal Clean Water Act.

Existing offsite impacts that are not affected by the project site do not require mitigation. However, in cases where the project site was the cause of the existing impact, it is the responsibility of the applicant to mitigate for those impacts.

Qualitative Analysis

The following subsections describe components (or tasks) of the qualitative analysis.

Task 1: Map of the Study Area

A site map shall be submitted showing property lines, topography (at a minimum, a USGS 1:24000 quadrangle topographic map), site boundaries, study area boundaries, downstream flow path, and potential/existing problems.

Task 2: Review of All Available Information on the Study Area

This task shall include all available basin plans, groundwater management area plans, drainage studies, floodplain/floodway FEMA maps, wetlands inventory maps, critical areas maps, stream habitat reports, salmon distribution reports, and other applicable studies.

Task 3: Field Inspection of the Study Area

The design engineer shall physically inspect the existing onsite and offsite drainage systems of the study area for each discharge location for existing or potential problems and drainage features. An initial inspection and investigation shall include the following:

1. Investigate problems reported or observed during the review of available information.

2. Locate existing/potential constrictions or capacity deficiencies in the drainage system.

3. Identify existing/potential flooding problems.

4. Identify existing/potential overtopping, scouring, bank sloughing, or sedimentation.

5. Identify significant destruction of aquatic habitat (e.g., siltation, stream incision).

6. Collect qualitative data on features such as land use, impervious surface, topography, soils, presence of streams, and wetlands.

7. Collect information on pipe sizes, channel characteristics, and drainage structures.

8. Verify tributary drainage areas identified in task 1.

9. Contact Clark County Public Works, neighboring property owners, and residents about drainage problems.

10. Note date and weather at time of inspection.

Task 4: Description of the Drainage System and Its Existing and Predicted Problems

For each drainage system component (e.g., pipes, culverts, bridges, outfalls, ponds, vaults), the analysis shall include the location, physical description, problems, and field observations.

All existing or potential problems (e.g., ponding water, erosion) identified in tasks 2 and 3 shall be described. The descriptions shall be used to determine whether adequate mitigation can be identified or whether more detailed quantitative analysis is necessary. The following information shall be provided for each existing or potential problem:

1. Magnitude of or damage caused by the problem.
2. General frequency and duration.
3. Return frequency of storm or flow when the problem occurs (may require quantitative analysis).
4. Water elevation when the problem occurs.
5. Names and concerns of the parties involved.
6. Current mitigation of the problem.
7. Possible cause of the problem.
8. Whether the project is likely to aggravate the problem or create a new one.

Quantitative Analysis

Upon review of the qualitative analysis, Clark County may require a quantitative analysis, depending on the presence of existing or predicted flooding, erosion, or water quality problems and on the proposed design of the onsite drainage facilities. The analysis shall repeat tasks 3 and 4 above, using quantitative field data, including profiles and cross-sections.

The quantitative analysis shall provide information on the severity and frequency of an existing problem or the likelihood of creating a new problem. It shall evaluate proposed mitigation intended to avoid aggravation of the existing problem and creation of a new problem.

9.4 MITIGATION

Clark County may require mitigation measures, depending on the results of the above analyses. Mitigation measures shall take the form of acceptable BMPs for downstream erosion control. The publication entitled *Integrated Streambank Protection Guidelines* (WDFW et al. 2003) shall be used to guide design and installation of streambank erosion BMPs within and adjacent to streams. Where the offsite analysis reveals impacts other than the types listed in task 4 above, the county may require mitigation of a type to be determined by the responsible official.

10 Financial Guarantees

10.1 INTRODUCTION

This chapter identifies the financial requirements for projects in Clark County.

► *All new development and redevelopment projects are subject to the requirements in this chapter, except:*

- *County road-related development*
- *County drainage projects*

10.2 FINANCIAL GUARANTEES

Performance Security

In lieu of completing required stormwater facilities within a preliminary plat prior to recording, the applicant may, with the approval of the county, post a performance bond or other security acceptable to the responsible official in the amount of one hundred fifty percent (150%) of the estimated cost (prepared by the project engineer) of completing construction per the approved stormwater plan. After determination by the responsible official that all facilities are constructed in compliance with the approved plan, are performing their intended functions in a satisfactory manner, and that the maintenance bonding requirements of Section 40.385.020(E)(3) are met, the performance bond or security shall be released. No building permits shall be issued until the stormwater facilities are completed and provisionally accepted.

Maintenance Security

In cases identified in Section 40.385.020(E)(3), a maintenance bond or other security acceptable to the responsible official, in the amount of ten percent (10%) of the project engineer's construction cost, shall be posted and maintained throughout the two- (2-) year initial maintenance period for a stormwater facility.

11 Additional Requirements

11.1 INTRODUCTION

This chapter identifies the following additional requirements (in addition to the minimum requirements identified in Chapter 2) for projects in Clark County:

- **Section 11.2:** Maintenance of Private Drainage Facilities
- **Section 11.3:** County Acceptance of New Stormwater Facilities
- **Section 11.4:** Deeds and Easements
- **Section 11.5:** Construction Materials
- **Section 11.6:** Drainage Structure Labeling and Signing
- **Section 11.7:** Wetland Protection
- **Section 11.8:** Drainage of Roadway Pavements
- **Section 11.9** Standard Drainage and Erosion Control Details

► *All new development and redevelopment projects are subject to the applicable requirements in this chapter.*

11.2 MAINTENANCE OF PRIVATE DRAINAGE FACILITIES

If a project's stormwater facilities are not dedicated to, and accepted by, the county, the applicant shall make arrangements for assumption of maintenance.

- If the project is a subdivision or short subdivision, the applicant shall form a homeowners association. The document that creates the homeowners association shall at a minimum include the following provisions:
  - Members of the homeowners association shall be responsible for maintenance of storm drainage facilities.
  - The operation and maintenance manual prepared by the project engineer in accordance with this manual shall be included by reference.
  - The homeowners association shall have the power to assess fees to maintain stormwater facilities.

– The homeowners association shall be responsible for payment of financial sanctions/ repayments if the county has to conduct repairs/activities because of hazardous conditions.

– A maintenance covenant shall be recorded with the Clark County Auditor for the plat and recorded against each lot within the subdivision or short division. See Appendix C for an example covenant.

- If the project is other than a subdivision, short subdivision, or large lot division, the applicant shall describe the organization or persons that will own and maintain the facility and show how maintenance activities will be financed.
- On a case-by-case basis, where the applicant satisfactorily demonstrates to the responsible official that the project has little or no liability concerns, a private agreement maintenance agreement may be accepted.

The responsible official must approve maintenance arrangements before county approval of the final stormwater plan. The final stormwater plan shall clearly indicate what portions of the stormwater facilities Clark County will maintain. Final plats shall include a note specifying the party(ies) responsible for long-term maintenance of stormwater facilities.

At a minimum, maintenance activities shall be to the standards in the county's *Stormwater Facility Maintenance Manual* (Clark County 2008) pursuant to CCC Chapter 13.26A. Additional activities may be required.

11.3 COUNTY ACCEPTANCE OF NEW STORMWATER FACILITIES

For stormwater facilities that will be owned by the county, the county will provisionally accept ownership upon approval of the record drawings, approval of a facilities inspection, and receipt of a workmanship and materials bond (or other secure method) in the amount of 10 percent of the construction cost (as prepared by the project engineer) and acceptable to the responsible official. Provisional acceptance of the facilities does not relieve the applicant from any obligation to undertake any remedial measures to correct deficiencies in the design, construction, maintenance, or operation of the facilities.

No sooner than 18 months after the provisional acceptance of the facilities, the applicant shall notify the responsible official that the facilities are eligible for final acceptance. The applicant shall continue to maintain the facilities until the county inspects and subsequently accepts the facilities.

The county may accept new stormwater facilities that are constructed under an accepted site development permit that meets all of the following conditions:

1. Improvements in residential plats have been completed on at least 80 percent of the lots, unless waived by the county.
2. All stormwater facilities have been tested, inspected, and accepted by Clark County, and said drainage facilities have been in satisfactory operation for at least 2 years.

3. All stormwater facilities reconstructed during the maintenance period have been accepted by Clark County.

4. The stormwater facility, as designed and constructed, conforms to the provisions of this manual.

5. All easements and tracts required under this manual, entitling the county to properly operate and maintain the subject stormwater facilities, have been conveyed to Clark County and have been recorded with the Clark County Auditor.

6. An operations and maintenance manual, including a maintenance schedule, has been submitted to and accepted by Clark County.

7. A complete and accurate set of reproducible Mylar as-built (record) drawings has been provided to Clark County.

8. A complete and accurate set of the as-built (record) drawings has been provided to Clark County on computer disk in one of the following approved file formats: Portable Document Format (.pdf), AutoCAD (.dwg, .dxf), or MicroStation (.dgn).

11.4 DEEDS AND EASEMENTS

The following deeds and easements shall be used, as appropriate, to convey property or rights to Clark County:

- **Statutory Warrantee Deed** (Individual, Partnership, or Corporate): Conveys real property to Clark County.
- **Storm Sewer Easement:** Conveys to Clark County the right to have and maintain a storm sewer system across a specific parcel of property.
- **Slope and Utility Easement:** Conveys the right to have fill material or a cut slope and utilities on private property.
- **Quit Claim Deed:** Conveys maintained but undocumented right-of-way to Clark County.

Easements or a covenant acceptable to the responsible official shall be provided to the county for purposes of inspection and maintenance of all privately maintained facilities. The minimum dimensions of easements must allow for access by standard maintenance equipment vehicles to all areas within the stormwater facilities.

11.5 CONSTRUCTION MATERIALS

All materials used in construction of private and county drainage facilities shall meet the standards in the 2008 edition of the Washington State Department of Transportation (WSDOT) Standard Specifications for Road, Bridge, and Municipal Construction, as amended or supplemented by the state or county. The applicant is responsible for contacting the county to obtain any modifications or supplements.

11.6 DRAINAGE STRUCTURE LABELING AND SIGNAGE

All catch basins and manholes capable of accepting stormwater shall be signed or stenciled as follows:

- For infiltration systems, stenciling must read:
  "Please Protect—Drains to Drinking Water."
- For facilities draining to surface waters, stenciling must read:
  "Please Protect—Drains to Stream" or "Lake" as appropriate.
- Signs must be installed along water quality biofiltration systems and must read:
  "Water Quality Filter—Please Leave Vegetated."
- Fenced detention and retention basins must be marked with a sign that reads
  "[Public/Private] Stormwater Facility."

11.7 WETLAND PROTECTION

If the county determines that the proposed project will degrade wetland function (based on information in the preliminary stormwater plan or information submitted for wetland review per Chapter 40.450), the applicant shall implement flow control or other measures to mitigate the adverse impacts of the alteration, in accordance with the wetland hydrology protection guidelines in Volume I, Appendix 1-D of the SMMWW.

Stormwater Facilities in Wetland Buffers

Clark County Code 40.450 contains detailed information about the allowance of stormwater facilities in wetland buffers. This section summarizes that information; however, the code should also be reviewed before proposing any facilities within wetland buffers.

- Stormwater dispersion facilities are allowed in all wetland buffers.
- The use of low impact development designs may result in a reduction in buffer intensity.
- Stormwater facilities (not including LID or dispersion BMPs) are allowed only in buffers of wetlands with low habitat function (less than 20 points on the habitat section of the rating system form – see CCC 40.450), provided that the facilities are built on the outer edge of the buffer and do not degrade the existing buffer function and are designed to blend with the natural landscape. See CCC 40.450 for a list of activities that are considered to degrade a wetland.

11.8 DRAINAGE OF ROADWAY PAVEMENTS

Drainage design for roadways shall be in accordance with Hydraulic Engineering Circular No. 12, Drainage of Highway Pavements (FHWA 1984) or Hydraulic Engineering Circular No. 22, Urban Drainage Design Manual (FHWA and NHI 2001). Single-event stormwater models, as described in Chapter 5, shall be used to determine peak flow rates for sizing collection systems (catch basins and inlets).

For the 10-year storm, street ponding shall be limited to one-half of the roadway area and shall not exceed the capacity of the inlet or produce a flow depth of greater than 0.12 foot at the edge of the travel lane.

For roadway flooding conditions during the 100-year storm, one travel lane in either direction shall remain open to emergency vehicles at all times. A travel lane will be considered to be open to emergency vehicles if the maximum depth of flow in the travel lane does not exceed 0.5 foot.

For parking lot flooding conditions during the 100-year storm, the maximum depth of ponding shall not exceed 1.5 feet.

11.9 STANDARD DRAINAGE AND EROSION CONTROL DETAILS

Appendix D contains Clark County's standard details for drainage and erosion control. Clark County makes no representations or warranties regarding the accuracy or fitness of a detail for a particular purpose. The designer is responsible for using sound engineering judgment regarding the use of these details.

11.10 TESTING OF STORM SEWER PIPE

Storm sewers constructed of thermoplastic pipe shall be tested for deflection not less than 30 days after the trench backfill and compaction has been completed. The test shall be conducted by pulling a properly sized "go-no go" mandrel through the completed pipeline. Testing shall be conducted on a manhole-to-manhole basis and shall be done after the line has been completely flushed out with water.

The mandrel shall be a rigid, nonadjustable mandrel having an effective length of not less than its normal diameter and an odd number of legs (nine legs minimum). Minimum diameter at any point along the full length of the mandrel shall be 95 percent of the base inside diameter of the pipe being tested.

The contractor shall be required, at no expense to the contracting agency, to locate and uncover any sections failing to pass the test and, if not damaged, reinstall the pipe. The use of a vibratory re-rounding device or any process other than removal or reinstallation shall not be acceptable. The contractor shall retest the section after replacement of the pipe. Pipe large enough to work inside of may be accepted on the basis of direct measurement.

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