Snohomish County Drainage Manual

Volume III
Hydrologic Analysis and Flow Control BMPs

July 2020 Ecology Review DRAFT~~raft~~J~~anuary~~uly ~~20~~2~~1~~6

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Chapter 1 - Introduction

1.1 Purpose of this Volume

This volume of the Snohomish County Drainage Manual ~~provides~~sets forth specific requirements and information for providing stormwater flow control for new development and redevelopment, as required by SCC 30.63A.550. This volume provides requirements and techniques for hydrologic modeling of runoff treatment and flow control BMPs, basin planning, and closed depressions. It also sets forth~~Additionally,~~ design and construction criteria ~~information for~~ for flow control BMPs including detention, infiltration, bioretention, and permeable pavement ~~is included~~.

~~This volume of the Snohomish County Drainage Manual provides best management practices (BMPs) for providing stormwater flow control for new development and redevelopment, as required by SCC 30.63A.550. This volume presents techniques of hydrologic analysis, and BMPs related to management of the amount and timing of stormwater flows from developed sites.~~

BMPs for preventing pollution of stormwater runoff and for treating contaminated runoff are presented in Volumes IV and V, respectively.

1.2 Content and Organization of this Volume

Volume III of the ~~stormwater~~ drainage manual contains three chapters. Chapter 1 serves as an introduction. Chapter 2 ~~reviews methods of hydrologic analysis, covers the use of hydrograph methods for designing BMPs, and provides an overview of various computerized modeling methods and analysis of closed depressions~~ covers required hydrologic methods for runoff treatment and flow control BMPs, basin planning, and closed depression analysis. Chapter 3 describes flow control BMPs and provides design specifications for roof downspout runoff controls, detention facilities, and infiltration facilities, and selected design information for bioretention and permeable pavement.

~~This volume includes three appendices. Appendix A has an appendix containing isopluvial maps for western Washington. Appendix B has information and assumptions on the Western Washington Hydrology Model (WWHM). Appendix C includes detailed information concerning how to represent various Low Impact Development (LID) techniques in continuous runoff models so that the models predict lower surface runoff rates and volumes.~~

1.3 How to Use this Volume

SCC 30.63A.300 through SCC 30.63A.310 and Volume I of this manual should be consulted to determine the applicable requirements for runoff treatment and flow control. After these requirements have been determined, this volume should be consulted for determining hydrologic analysis requirements for runoff treatment and flow control BMPs. This volume should be referenced for the design and construction of flow control ~~facilities~~BMPs, including analysis of infiltration BMPs. Volume V, in conjunction with this volume, may need to be referenced for the purpose of designing runoff treatment

BMPs. ~~These~~ Runoff treatment and flow control ~~facilities~~ BMPs can then be included in Stormwater Site Plans as required by SCC 30.63A.400.

Chapter 2 - Hydrologic Analysis

The broad definition of hydrology is "the science which studies the source, properties, distribution, and laws of water as it moves through its closed cycle on the earth (the hydrologic cycle)." As applied in this manual, however, the term "hydrologic analysis" addresses and quantifies only a small portion of this cycle. That portion is the relatively short-term movement of water over the land resulting directly from precipitation and called surface water or stormwater runoff. Localized and long-term ground water movement must also be of concern, but generally only as this relates to the movement of water on or near the surface, such as stream base flow or infiltration systems.

The purpose of this chapter is to define the minimum computational standards required, to outline how these may be applied, and to reference where more complete details may be found, should they be needed. This chapter also provides details on the hydrologic design process; that is, what are the steps required in conducting a hydrologic analysis, including flow routing.

2.1 Minimum Computational Standards

~~The following~~

A continuous runoff hydrologic model must be used for design of all flow control and treatment facilities with the exception of wetpool treatment facilities, which may be designed using either a continuous runoff hydrologic model or a single event hydrologic model.

Two continuous simulation runoff models are acceptable for design of flow control and treatment facilities, and for modeling for wetlands needed to meet Minimum Requirement 8:

- WWHM2012 Version 4.2.16, released October 10, 2018, and subsequent versions approved by Ecology
- MGSFlood Version 4.49, released May 9, 2019, and subsequent versions approved by Ecology, with the caveat that MGSFlood cannot be used to design BMP T7.30 Bioretention.~~:~~

In this Drainage Manual, the term "approved continuous runoff hydrologic model" means the models described above. Additional information about Ecology approval for hydrologic models is found within the online version of the 2019 Stormwater Management Manual for Western Washington under the "Additional Resources" tab.

Current and past versions of WWHM are available from Ecology at: https://data.wa.gov/Natural-Resources-Environment/Western-Washington-Hydrology-Model-WWHM-/5sqj-8rp7

~~https://fortress.wa.gov/ecy/ezshare/wq/Permits/Flare/2019SWMMWW/2019SWMMWW.htm#Topics/AppStatusOfContSimMod.htm)~~

Wetpool treatment facilities may be designed using the continuous runoff hydrologic models described above, the Soil Conservation Service Unit Hydrograph (SCSUH) single event model, or the Santa Barbara Unit Hydrograph (SBUH) single event model.~~The minimum computational standards depend on the type of information required and the size of the drainage area to be analyzed, as follows:~~

~~1. 1. For the purpose of designing most types of runoff treatment BMPs, a calibratedan approved continuous runoffsimulation hydrologic model based on the EPA's HSPF (Hydrologic Simulation Program-Fortran) program , or an approved equivalent model, must be used to calculate runoff and determine the water quality design flow rates and volumes.~~

~~For the purpose of designing wetpool treatment facilities, there are two acceptable methods: an approved continuous runoff hydrologic model to estimate the simulated daily volume that represents the upper limit of the range of daily volumes that accounts for 91% of the entire runoff volume over a multi-decade period of record91st percentile, 24-hour runoff volume, or the NRCS (Natural Resources Conservation Service) curve number method to determine a water quality design storm volume as defined in section 2.3.1. The water quality design storm volume is the amount of runoff predicted from the 6-month, 24-hour storm.~~

~~For the purpose of designing flow control BMPs, a calibratedan approved continuous runoff simulation hydrologic model, based on the EPA's HSPF, must be used.~~

~~The circumstances under which different methodologies apply are summarized below.~~

~~Summary of the application design methodologies~~		
	~~BMP designs in western Washington~~	
~~Method~~	~~Treatment~~	~~Flow Control~~
~~SCSUH/SBUH (Soil Conservation Service Unit Hydrograph/Santa Barbara Unit Hydrograph)~~	~~Method applies for BMPs that are sized based on the volume of runoff from a 6-month, 24-hour storm. Currently, that includes only wetpool facilities.~~ ~~**Note**: These BMPs don't require generating a hydrograph.~~	~~Not Applicable~~
~~Continuous Runoff Hydrologic Models: (WWHM or approved alternatives. See below)~~	~~Method applies to all BMPs.~~	~~Method applies throughout Western Washingtonto all BMPs.~~

2. ~~2. If a basin plan is being prepared, then a hydrologic analysis should be performed using a calibrated continuous simulation model such as the EPA's HSPF model, the EPA's Stormwater Management Model (SWMM), or an equivalent model as approved by Snohomish County.~~

3. ~~Significant progress has been made in the development and availability of HSPF-based continuous runoff models for Western Washington. The Department of Ecology has coordinated the development of the Western Washington Hydrology Model (WWHM). It uses rainfall/runoff relationships developed for specific basins in the Puget Sound region to all parts of western Washington. Where field monitoring establishes basin-specific rainfall/runoff parameter calibrations, those can be entered into the model, superseding the default input parameters.~~

4. ~~Two other HSPF-based continuous runoff models are allowed by Snohomish County for drainage design: MGS Flood and KCRTS (King County Runoff Time Series).~~

~~2.1.1Discussion of Hydrologic Analysis Methods Used for Designing BMPs~~

~~This section provides a discussion of the methodologies to be used for calculating stormwater runoff from a project site. It includes a discussion of estimating stormwater runoff with single event models, such as the SBUH, versus continuous simulation models.~~

~~A continuous simulation model has considerable advantages over the single event-based methods such as the SCSUH, SBUH, or the Rational Method. HSPF is a continuous simulation model that is capable of simulating a wider range of hydrologic responses than the single event models such as the SBUH method. Single event models cannot take into account storm events that may occur just before or just after the single event (the design storm) that is under consideration. In addition, the runoff files generated by the HSPF models are the result of a considerable effort to introduce local parameters and actual rainfall data into the model and therefore produce better estimations of runoff than the SCSUH, SBUH, or Rational methods.~~

~~Ecology has developed a continuous simulation hydrologic model (WWHM) based on the HSPF for use in western Washington (see Section 2.2). Continuous rainfall records/data files have been obtained and appropriate adjustment factors were developed as input to HSPF. Input algorithms (referred to as IMPLND and PERLND) have been developed for a number of watershed basins in King, Pierce, Snohomish, and Thurston counties. These rainfall files and model algorithms are used in the HSPF in western Washington. Until basin-specific calibrations of HSPF are developed, the input data mentioned above must be used.~~

~~While SBUH may give acceptable estimates of total runoff volumes, it tends to overestimate peak flow rates from pervious areas because it cannot adequately model subsurface flow (which is a dominant flow regime for pre-development conditions in western Washington basins). One reason SBUH overestimates the peak flow rate for pervious areas is that the actual time of concentration is typically greater than what is assumed. Better flow estimates could be made if a longer time of concentration was used. This would change both the peak flow rate (i.e., it would be lower) and the shape of the hydrograph (i.e., peak occurs somewhat later) such that the hydrograph would better reflect actual predeveloped conditions.~~

~~Another reason for overestimation of the runoff is the curve numbers (CN) in the 1992 Manual. These curve numbers were developed by US Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS) and published as the Western Washington Supplemental Curve Numbers. These CN values are typically higher than the standard CN values published in Technical Release 55, June 1986. In 1995, the NRCS recalled the use of the western Washington CNs for floodplain management and found that the standard CNs better describe the hydrologic conditions for rainfall events in western Washington. However, based on runoff comparisons with the KCRTS better estimates of runoff are obtained when using the western Washington CNs for the developed areas such as parks, lawns, and other landscaped areas. Accordingly, the CNs in this manual (see Table 2.3) are changed to those in the Technical Release 55 except for the open spaces category for the developed areas which include, lawn, parks, golf courses, cemeteries, and landscaped areas. For these areas, the western Washington CNs are used. These changes are intended to provide better runoff estimates using the SBUH method.~~

~~Another major weakness of SBUH is that it is used to model a 24-hour storm event, which is too short to model longer-term storms in western Washington. The use of a longer-term (e.g. 3- or 7-day storm) is perhaps better suited for western Washington.~~

~~Related to the last concern is the fact that single event approaches, such as SBUH, assume that flow control ponds are empty at the start of the design event. Continuous runoff models are able to simulate a continuous long-term record of runoff and soil moisture conditions. They simulate situations where ponds are not empty when another rain event begins.~~

~~Finally, single event models do not allow for estimation and analyses of flow durations nor water level fluctuations. Flow durations are necessary for discharges to streams. Estimates of water level fluctuations are necessary for discharges to wetlands and for~~

~~tracking influent water elevations and bypass quantities to properly size treatment facilities.~~

2.2 ~~Western Washington Hydrology Model~~Continuous Runoff Hydrologic Model Method

This section discusses requirements applicable to the use of approved continuous runoff hydrologic models for runoff treatment and flow control design.

~~This section summarizes the assumptions made in creating the western Washington Hydrology Model (WWHM) and discusses limitations of the model. Appendix III-B contains more information on the assumptions and on WWHM. The web address for WWHM is: www.ecy.wa.gov/programs/wq/stormwater/wwhmtraining/index.html.~~

2.2.1 Runoff Treatment Design Standard

Water Quality Design Volume

For ~~the~~ designing a wetpool treatment ~~facilities~~facility estimate the simulated daily volume that represents the upper limit of the range of daily volumes that accounts for 91% of the entire runoff volume over a multi-decade period of record. Approved continuous runoff hydrologic models provide the ability to calculate this volume.

Water Quality Design Flow Rate

The water quality design flow rate is dependent on the location of the runoff treatment BMPs relative to detention BMPs. The water quality design flow rate for treatment systems downstream of detention facilities is the full 2-year release rate from the detention facility.

The water quality design flow rate for treatment systems upstream of detention facilities, or for projects in which detention is not required, is the flow rate at or below which 91% of the runoff volume, as estimated by an approved continuous runoff model, will be treated.

Design criteria for treatment facilities are assigned to achieve the applicable performance goal at the water quality design flow rate (e.g., 80% ~~percent~~ TSS removal).

For treatment facilities not preceded by an equalization or storage basin, and when runoff flow rates exceed the water quality design flow rate, the treatment facility should continue to receive and treat the water quality design flow rate to the applicable treatment performance goal. Only the higher incremental portions of flow rates are bypassed around a treatment facility. Snohomish County encourages design of systems that engage a bypass at higher flow rates provided the reduction in pollutant loading exceeds that achieved with bypass at the water quality design flow rate.

Treatment facilities preceded by an equalization or storage basin may identify a lower water quality design flow rate provided that at least 91 ~~percent~~% of the estimated runoff volume in the time series of an approved continuous runoff hydrologic model is treated to the applicable performance goals (e.g., 80~~ percent~~% TSS removal at the water quality design flow rate and 80~~ percent~~% TSS removal on an annual average basis).

Runoff flow rates in excess of the water quality design flow rate can be routed through the facility provided a net pollutant reduction is maintained.

~~2.2.1Limitations to the WWHM~~

~~The WWHM has been created for the specific purpose of sizing stormwater control facilities for new developments in western Washington. The WWHM can be used for a range of conditions and developments; however, certain limitations are inherent in this software. These limitations are described below.~~

~~The WWHM uses the EPA HSPF software program to do all of the rainfall-runoff and routing computations. Therefore, HSPF limitations are included in the WWHM. For example, backwater or tailwater control situations are not explicitly modeled by HSPF. This is also true in the WWHM.~~

~~WWHM3 and WWHM2012 can model flow routed through multiple stormwater control facilities. In addition, WWHM2012 can route flow through a natural lake or wetland in addition to multiple stormwater control facilities.~~

2.2.2 Flow Control Design Standards

Flow control requirements are set forth in SCC 30.63A.550 and Volume I of this manual. Additional requirements for discharges to wetlands are set forth in SCC 30.63A.570. Note that compliance with Minimum Requirement 5 (SCC 30.63A.550) can be achieved by matching developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 8% of the 2-year peak flow to 50% of the 2-year peak flow, and that this is the only path for compliance for new development or redevelopment projects of 5 acres or larger outside an Urban Growth Area.

Minimum Requirement 7 specifies that stormwater discharges to streams shall match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow. There are three criteria by which flow duration values are compared:

1. If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 50% and 100% of the 2-year predevelopment peak flow values (100 ~~Percent~~% Threshold) then the flow duration requirement has not been met.
2. ~~I~~ If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 100% of the 2-year and 100% of the 50-year predevelopment peak flow values more than 10~~ percent~~% of the time (110~~ Percent~~% Threshold) then the flow duration requirement has not been met.
3. If more than 50~~ percent~~% of the flow duration levels exceed the 100~~ percent~~% threshold then the flow duration requirement has not been met.

Wetlands

Minimum Requirement 8 includes measures to protect the hydroperiod of wetlands. Flow components feeding the wetland under both pre- and post-development scenarios are assumed to be the sum of the surface, interflow, and ground water flows from the project site. Further guidance for wetland protection is provided in Appendix I-D of Volume I.

Bypass Flow

Bypass occurs when a portion of the development does not drain to a stormwater detention facility. On-site runoff from a proposed development project may bypass the flow control facility if all the following conditions are met.

1. Runoff from both the bypass area and the flow control facility converges within a quarter mile downstream of the project site discharge point.
2. The flow control facility is designed to compensate for the uncontrolled bypass area such that the net effect at the point of convergence downstream is the same with or without bypass.
3. The 100-year peak discharge from the bypass area will not exceed 0.4 cfs.
4. Runoff from the bypass area will not create a significant adverse impact to downstream drainage systems or properties.
5. Water quality requirements applicable to the bypass area are met.

Inflow from Areas that Don't Require Flow Control

This guidance applies to flow control BMPs that are receiving flow from areas in addition to the areas that must be mitigated.

Depending on site layout and topography, flow control BMPs may need to be positioned on a site such that runoff from areas that do not need to be mitigated are directed to the flow control BMP. These additional areas may come from on-site or off-site.

As an example, a redevelopment project may need to provide flow control for the new hard surfaces and not for the replaced hard surfaces, but the proposed flow control BMP is placed such that flow from the new and replaced hard surfaces is directed to it. The flow from the replaced hard surfaces would be considered additional flow to the flow control BMP.

Runoff from these additional areas must be modeled using the acreages associated with the existing land use areas. For the purposes of modeling in an approved continuous runoff hydrologic model, these additional areas are entered under the predeveloped and mitigated scenarios using the existing land cover.

The performance of flow control BMPs can be compromised if the additional area, beyond the area that needs to be mitigated, is too large. If the existing 100-year peak flow rate from the additional area is greater than 50% of the 100-year developed peak flow rate (undetained) from the area requiring mitigation, then the runoff from the additional area must not flow to the on-site flow control BMP. The bypass of the additional area runoff must be designed ~~so as to~~to achieve both of the following:

1. Any existing contribution of flows to an on-site wetland must be maintained.

2. Flows from the additional areas that are naturally attenuated by the project site under predeveloped conditions must remain attenuated, either by natural means or by providing additional on-site detention so that peak flows do not increase.

2.2.3 General Design Standards

~~2.2.2Assumptions Made in Creating the WWHM~~

~~Precipitation data~~

- ~~The WWHM uses over 50 years of precipitation data to simulate the potential impacts of land use development in western Washington. A minimum period of 20 years is required to simulate enough peak flow events to produce accurate flow frequency results.~~
- ~~WWHM uses over 17 precipitation stations to representing the different rainfall regimes found in western Washington.~~
- ~~These stations represent rainfall at elevations below 1500 feet -snowfall and snowmelt are not included in the WWHM.~~
- ~~The primary source for precipitation data is National Weather Service stations.~~
- ~~The base computational time step used in versions of WWHM that predate WWHM2012 is one hour. WWHM2012 uses precipitation data with a 15-minute time step to generate the runoff hydrograph.~~

Precipitation ~~multiplication factors~~Multiplication Factors~~.~~

The project applicant must obtain a modification in accordance with SCC 30.63A.830 in order to change any precipitation multiplication factors assigned in an approved continuous runoff hydrologic model.

- ~~WWHM uses precipitation multiplication factors to increase or decrease recorded precipitation data to better represent local rainfall conditions.~~
- ~~The factors are based on the ratio of the 24-hour, 25-year rainfall intensities for the representative precipitation gage and the surrounding area represented by that gage's record.~~
- ~~The factors have been placed in the WWHM database and linked to each county's map. The project applicant must obtain a modification in accordance with SCC 30.63A.830 in order to change the coefficient for a specific site. Changes made by the user will be recorded in the WWHM output. WWHM does not allow the precipitation multiplication factor to go below 0.8 or above 2.~~

Pan ~~evaporation data~~Evaporation Data~~.~~

The project applicant must obtain a modification in accordance with SCC 30.63A.830 in order to change any pan evaporation coefficients assigned in an approved continuous runoff hydrologic model.

- ~~The WWHM uses pan evaporation coefficients to compute the actual evapotranspiration potential (AET) for a site, based on the potential evapotranspiration (PET) and available moisture supply. AET accounts for the precipitation that returns to the atmosphere without becoming runoff.~~
- ~~The pan evaporation coefficients have been placed in the WWHM database and linked to each county's map. The project applicant must obtain a modification in accordance with SCC 30.63A.830 in order to change the coefficient for a specific site. Changes made by the user will be recorded in the WWHM output.~~

Soil ~~data~~Data~~.~~

Approved continuous runoff hydrologic models use three predominante soil types to represent the soils of western Washington: outwash, till, and saturated. Refer to Table 3.1 for identification of hydrologic soil groups for use in assigning soils to the model. Soils will be assigned based on the following: outwash (A or B), till (C), and saturated (D or wetland).

- ~~The WWHM uses three predominate soil type to represent the soils of western Washington: till, outwash, and saturated.~~
- ~~The user determines actual local soil conditions for the specific development planned and inputs that data into the WWHM. The user inputs the number of acres of outwash (A/B), till (C), and saturated (wetland) soils for the site conditions.~~
- ~~Additional soils will be included in the WWHM if appropriate HSPF parameter values are found to represent other major soil groups.~~

Vegetation ~~data~~Data~~.~~

Approved continuous runoff hydrologic models use three predominante vegetation categories: forest, pasture, and lawn (also known as grass).

See Minimum Requirement 7 in Volume I, Chapter 2.5.7 for requirements pertaining to the assignment of predeveloped land conditions.

Forest and pasture vegetation areas are only appropriate for separate undeveloped parcels dedicated as open space, wetland buffer, or park within the total area of the development. Development areas (except as specified in LID modeling, such as BMP T5.13: Post-Construction Soil Quality and Depth) must only be designated as forest or pasture in the hydrologic model if legal restrictions can be documented that protect these areas from future disturbances.

- ~~The WWHM will represent the vegetation of western Washington with three predominate vegetation categories: forest, pasture, and lawn (also known as grass).~~
- ~~The predevelopment land conditions is a fully-forested condition (soils and vegetation) of second-growth forest to which the Western Washington Hydrologic Model (WWHM) is calibrated. However, the user has the option of specifying pasture if there is documented evidence that pasture vegetation was native to the~~

~~predevelopment site. In highly urbanized basins (see Minimum Requirement #7 in Volume I, Chapter 2, it is possible to use the existing land cover as the pre-developed land condition.~~

Development ~~land use data~~Land Use Data~~.~~

Development land use data are used to represent the type of development planned for the site and are used to determine the appropriate size of the required stormwater mitigation facility. All impervious area on a site containing new development or redevelopment shall be modeled as effective impervious unless explicitly stated under the definition of effective pervious area in Volume I.

- ~~Development land use data are used to represent the type of development planned for the site and are used to determine the appropriate size of the required stormwater mitigation facility.~~
- ~~Earlier versions of WWHM included a Standard residential development option which made specific assumptions about the amount of impervious area per lot and its division between driveways and rooftops. Streets and sidewalk areas were input separately. Ecology had selected a standard impervious area of 4200 square feet per residential lot, with 1000 square feet of that as driveway, walkways, and patio area, and the remainder as rooftop area. The more recent versions of WWHM (e.g., WWHM3 or WWHM2012) no longer have the Standard residential development category. Use the above land use assumptions for a modeling runoff from standard residential development or, where better land use information is available, use that information to model and estimate runoff from the residential development.~~
- ~~The WWHM distinguishes between effective impervious area and non-effective impervious area in calculating total impervious area.~~
- ~~Credits are given for infiltration and dispersion of roof runoff and for use of porous pavement for driveway areas.~~
- ~~Forest and pasture vegetation areas are only appropriate for separate undeveloped parcels dedicated as open space, wetland buffer, or park within the total area of the development. Development areas must only be designated as forest or pasture in the hydrologic model if legal restrictions can be documented that protect these areas from future disturbances.~~
- ~~The WWHM can model bypassing a portion of the runoff from the development area around a stormwater detention facility and/or having offsite inflow enter the development area.~~

Application ~~of WWHM~~ in Redevelopments Projects

Redevelopment requirements may allow, for some portions of the ~~redevelopment project area~~site, the predeveloped condition to be modeled as the existing condition rather than forested or pasture condition. For instance, where the replaced impervious areas do not have to be served by updated flow control facilities because area or cost thresholds in SCC 30.63A.310 are not exceeded.

~~Pervious and Impervious Land Categories (PERLND and IMPLND parameter values)~~

- ~~In WWHM (and HSPF) pervious land categories are represented by PERLNDs; impervious land categories by IMPLNDs~~
- ~~The WWHM provides over 20 unique PERLND parameters that describe various hydrologic factors that influence runoff and 4 parameters to represent IMPLND.~~
- ~~These values are based on regional parameter values developed by the U.S. Geological Survey for watersheds in western Washington (Dinicola, 1990) plus additional HSPF modeling work conducted by AQUA TERRA Consultants.~~
- ~~Surface runoff and interflow will be computed based on the PERLND and IMPLND parameter values. Groundwater flow can also be computed and added to the total runoff from a development if there is a reason to believe that groundwater would be surfacing (such where there is a cut in a slope). However, the default condition in WWHM assumes that no groundwater flow from small catchments reaches the surface to become runoff.~~

~~Flow control standards.~~

~~Flow control requirements are set forth in SCC 30.63A.550 and Volume I of this manual. Additional requirements for discharges to wetlands are set forth in SCC 30.63A.570. Note that compliance with Minimum Requirement 5 (SCC 30.63A.550) can be achieved by matching developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 8% of the 2-year peak flow to 50% of the 2-year peak flow, and that this is the only path for compliance for new development or redevelopment projects of 5 acres or larger outside an Urban Growth Area.~~

~~Minimum Requirement #7 specifies that stormwater discharges to streams shall match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow.~~

~~WWHM computes the predevelopment 2- through 100-year flow frequency values and computes the post-development runoff 2- through 100-year flow frequency values from the outlet of the proposed stormwater facility. The model uses pond discharge data to compare the predevelopment and postdevelopment durations and determines if the flow control standards have been met. There are three criteria by which flow duration values are compared:~~

1. ~~If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 50% and 100% of the 2-year predevelopment peak flow values (100 Percent Threshold) then the flow duration requirement has not been met.~~
2. ~~If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 100% of the 2-year and 100% of the 50-year predevelopment peak flow values more than 10 percent of the time (110 Percent Threshold) then the flow duration requirement has not been met.~~
3. ~~If more than 50 percent of the flow duration levels exceed the 100 percent threshold then the flow duration requirement has not been met.~~

~~Minimum Requirement 8 specifies that total discharge to a wetland must not deviate by more than 20% on a single event basis, and must not deviate by more than 15% on a monthly basis. Flow components feeding the wetland under both pre- and post-development scenarios are assumed to be the sum of the surface, interflow, and ground water flows from the project site.~~

2.3 Single Event Hydrograph Method

Hydrograph analysis utilizes the standard plot of runoff flow versus time for a given design storm, thereby allowing the key characteristics of runoff such as peak, volume, and phasing to be considered in the design of drainage facilities. Because the only utility for single event methods in this manual is to size wet pool treatment facilities, only the subjects of design storms, curve numbers and calculating runoff volumes are presented. If single event methods are used to size temporary and permanent conveyances, the reader should reference other texts and software for assistance.

2.3.1 Water Quality Design Storm

~~The design storm for sizing wetpool treatment facilities is the 6-month, 24-hour storm. Unless amended to reflect local precipitation statistics, the 6-month, 24-hour precipitation amount may be assumed to be 72 percent of the 2-year, 24-hour amount. Precipitation estimates of the 6-month and 2-year, 24-hour storms for certain towns and cities are listed in Appendix 1I-B of Volume I. For other areas, interpolating between isopluvials for the 2-year, 24-hour precipitation and multiplying by 72% yields the appropriate storm size.~~

~~The total depth of rainfall (in tenths of an inch) for storms of 24-hour duration and 2, 5, 10, 25, 50, and 100-year recurrence intervals are published by the National Oceanic and Atmospheric Administration (NOAA). The information is presented in the form of "isopluvial" maps for each state. Isopluvial maps are maps where the contours represent total inches of rainfall for a specific duration. Isopluvial maps for the 2, 5, 10, 25, 50, and 100-year recurrence interval and 24-hour duration storm events can be found in the NOAA Atlas 2, "Precipitation - Frequency Atlas of the Western United States, Volume IX-Washington." Appendix IIIII-A provides the isopluvials for the 2, 10, and 100-year, 24-hour design storms. Other precipitation frequency data may be obtained through Western Regional Climate Center (WRCC) at Tel: (775) 674-7010.~~ Appendix III-A provides an isopluvial map for the 2-year, 24-hour rainfall depth at locations in Western Washington. The design storm for sizing wetpool treatment facilities is the 6-month, 24-hour rainfall depth, which shall be calculated as 72% of the 2-year, 24-hour rainfall depth at the project location. For projects locations that do not lie on an isopluvial contour, interpolate between isopluvial contours for the 2-year, 24-hour rainfall depth and multiply by 72% to determine the design storm depth.

2.3.2 Runoff Parameters

All storm event hydrograph methods require input of parameters that describe physical drainage basin characteristics. These parameters provide the basis from which the runoff hydrograph is developed. This section describes only the key parameter of curve number that is used to estimate the runoff from the water quality design storm.

Curve Number

The NRCS (formerly SCS) has, for many years, conducted studies of the runoff characteristics for various land types. After gathering and analyzing extensive data, NRCS has developed relationships between land use, soil type, vegetation cover, interception, infiltration, surface storage, and runoff. The relationships have been characterized by a single runoff coefficient called a "curve number." The National Engineering Handbook - Section 4: Hydrology (NEH-4, SCS, August 1972) contains a detailed description of the development and use of the curve number method.

NRCS has developed "curve number" (CN) values based on soil type and land use (see "Urban Hydrology for Small Watersheds", Technical Release 55 (TR-55), June 1986, NRCS). The combination of these two factors is called the "soil-cover complex." The soil-cover complexes have been assigned to one of four hydrologic soil groups, according to their runoff characteristics. NRCS has classified over 4,000 soil types into these four soil groups. Table 3.1 shows the hydrologic soil group of most soils in the state of Washington and provides a brief description of the four groups. For details on other soil types refer to the NRCS publication mentioned above (TR-55, 1986).

Table 3.1
Hydrologic Soil Series for Selected Soils in Washington State

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Agnew	C	Hoko	C
Ahl	B	Hoodsport	C
Aits	C	Hoogdal	C
Alderwood	C	Hoypus	A
Arents, Alderwood	B	Huel	A
Arents, Everett	B	Indianola	A
Ashoe	B	Jonas	B
Baldhill	B	Jumpe	B
Barneston	C	Kalaloch	C
Baumgard	B	Kapowsin	C/D
Beausite	B	Katula	C
Belfast	C	Kilchis	C
Bellingham	D	Kitsap	C
Bellingham variant	C	Klaus	C
Boistfort	B	Klone	B
Bow	D	Lates	C
Briscot	D	Lebam	B
Buckley	C	Lummi	D
Bunker	B	Lynnwood	A
Cagey	C	Lystair	B
Carlsborg	A	Mal	C
Casey	D	Manley	B
Cassolary	C	Mashel	B
Cathcart	B	Maytown	C
Centralia	B	McKenna	D
Chehalis	B	McMurray	D
Chesaw	A	Melbourne	B
Cinebar	B	Menzel	B
Clallam	C	Mixed Alluvial	variable
Clayton	B	Molson	B
Coastal beaches	variable	Mukilteo	C/D
Colter	C	Naff	B
Custer	D	Nargar	A
Custer, Drained	C	National	B
Dabob	C	Neilton	A
Delphi	D	Newberg	B
Dick	A	Nisqually	B
Dimal	D	Nooksack	C
Dupont	D	Norma	C/D
Earlmont	C	Ogarty	C
Edgewick	C	Olete	C
Eld	B	Olomount	C
Elwell	B	Olympic	B
Esquatzel	B	Orcas	D
Everett	A	Oridia	D
Everson	D	Orting	D
Galvin	D	Oso	C
Getchell	A	Ovall	C
Giles	B	Pastik	C
Godfrey	D	Pheeney	C
Greenwater	A	Phelan	D
Grove	C	Pilchuck	C
Harstine	C	Potchub	C
Hartnit	C	Poulsbo	C
Hoh	B	Prather	C
Puget	D	Solleks	C
Puyallup	B	Spana	D

Table 3.1
Hydrologic Soil Series for Selected Soils in Washington State

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Queets	B	Spanaway	A/B
Quilcene	C	Springdale	B
Ragnar	B	Sulsavar	B
Rainier	C	Sultan	C
Raught	B	Sultan variant	B
Reed	D	Sumas	C
Reed, Drained or Protected	C	Swantown	D
Renton	D	Tacoma	D
Republic	B	Tanwax	D
Riverwash	variable	Tanwax, Drained	C
Rober	C	Tealwhit	D
Salal	C	Tenino	C
Salkum	B	Tisch	D
Sammamish	D	Tokul	C
San Juan	A	Townsend	C
Scamman	D	Triton	D
Schneider	B	Tukwila	D
Seattle	D	Tukey	C
Sekiu	D	Urbana	C
Semiahmoo	D	Vailton	B
Shalcar	D	Verlot	C
Shano	B	Wapato	D
Shelton	C	Warden	B
Si	C	Whidbey	C
Sinclair	C	Wilkeson	B
Skipopa	D	Winston	A
Skykomish	B	Woodinville	B
Snahopish	B	Yelm	C
Snohomish	D	Zynbar	B
Solduc	B		

Notes:

Hydrologic Soil Group Classifications, as Defined by the Soil Conservation Service:

A = *(Low runoff potential) Soils having low runoff potential and high infiltration rates, even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr.).*

B = *(Moderately low runoff potential). Soils having moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.3 in/hr.).*

C = *(Moderately high runoff potential). Soils having low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine textures. These soils have a low rate of water transmission (0.05-0.15 in/hr.).*

D = *(High runoff potential). Soils having high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr.).*

* = *From SCS, TR-55, Second Edition, June 1986, Exhibit A-1. Revisions made from SCS, Soil Interpretation Record, Form #5, September 1988 and various county soil surveys.*

Additional Note: Where field infiltration tests indicate a measured (initial) infiltration rate less than 0.30 in/hr, ~~the WWHM user may model~~ the site may be modeled as a C soil in an approved continuous runoff hydrologic model.

Table 3.2 shows the CNs, by land use description, for the four hydrologic soil groups. These numbers are for a 24-hour duration storm and typical antecedent soil moisture condition preceding 24-hour storms.

Many factors may affect the CN value for a given land use. For example, the movement of heavy equipment over bare ground may compact the soil so that it has a lesser infiltration rate and greater runoff potential than would be indicated by strict application of the CN value to developed site conditions.

CN values can be area weighted when they apply to pervious areas of similar CNs (within 20 CN points). However, high CN areas should not be combined with low CN areas. In this case, separate estimates of S (potential maximum natural detention) and Q_d (runoff depth) should be generated and summed to obtain the cumulative runoff volume unless the low CN areas are less than 15~~ percent~~% of the subbasin.

Separate CN values must be selected for the pervious and impervious areas of an urban basin or subbasin. For residential areas the percent impervious area given in Table 3.2 must be used to compute the respective pervious and impervious areas. For proposed commercial areas, planned unit developments, etc., the percent impervious area must be computed from the site plan. For all other land uses the percent impervious area must be estimated from best available aerial topography and/or field reconnaissance. The pervious area CN value must be a weighted average of all the pervious area CNs within the subbasin. The impervious area CN value shall be 98.

Example: Selection of CN values for development project

Existing l~~L~~and u~~U~~se	~~———~~F~~f~~orest (undisturbed)
Future l~~L~~and u~~U~~se	~~———~~R~~r~~esidential plat (3.6 DU/GA)
Basin s~~S~~ize	~~———~~60 acres
Soil t~~T~~ype	~~———~~80~~ percent~~% Alderwood, 20~~ percent~~% Ragnor

Table 3.1 shows that Alderwood soil belongs to the "C" hydrologic soil group and Ragnor soil belongs to the "B" group. Therefore, for the existing condition, CNs of 70 and 55 are read from Table 3.2 and areal weighted to obtain a CN value of 67. For the developed condition with 3.6 DU/GA the percent impervious of 39~~ percent~~% is interpolated from Table 3.2 and used to compute pervious and impervious areas of 36.6 acres and 23.4 acres, respectively. The 36.6 acres of pervious area is assumed to be in Fair condition ~~-~~(for a conservative design) with residential yards and lawns covering the same proportions of Alderwood and Ragnor soil (80~~ percent~~% and 20~~ percent~~% respectively). Therefore, CNs of 90 and 85 are read from Table 2.3 and areal weighted to obtain a pervious area CN value of 89. The impervious area CN value is 98. The result of this example is summarized below:

On-Site Condition	Existing	Developed
Land use	Forest	Residential
Pervious area	60 ac.	36.6 ac.
CN of pervious area	67	89
Impervious area	0 ac.	23.4 ac.
CN of impervious area	--	98

Table 3.2 - Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas

(Sources: TR 55, 1986, and Stormwater Management Manual, 1992. See Section 2.1.1 for explanation)				
	CNs for hydrologic soil group			
Cover type and hydrologic condition.	A	B	C	D
Curve Numbers for Pre-Development Conditions				
Pasture, grassland, or range-continuous forage for grazing:				
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77
Curve Numbers for Post-Development Conditions				
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[1]				
Fair condition (grass cover on 50% - 75% of the area).	77	85	90	92
Good condition (grass cover on >75% of the area)	68	80	86	90
Impervious areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs[2], driveways, etc. (excluding right-of-way)	98	98	98	98
Permeable Pavement ~~**(See Appendix C to decide which condition below to use)**~~				
~~Landscaped area~~Porous Asphalt, Pervious Concrete, or Grid/Lattice Systems (without underdrains)	77	85	90	92
~~50% landscaped area/50% impervious~~Paving Blocks (without underdrains)	87	91	94	96
~~100% impervious area~~All Permeable Pavement Types (with underdrains)	98	98	98	98
Paved	98	98	98	98
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range-continuous forage for grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Poor (Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning).	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77

Table 3.2 continued - Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas

Single family residential[3]: Dwelling Unit/Gross Acre	Should only be used for subdivisions > 50 acres	Average Percent impervious area[3,4]	
1.0 DU/GA		15	Separate curve number
1.5 DU/GA		20	shall be selected for
2.0 DU/GA		25	pervious & impervious
2.5 DU/GA		30	portions of the site or
3.0 DU/GA		34	basin
3.5 DU/GA		38	
4.0 DU/GA		42	
4.5 DU/GA		46	
5.0 DU/GA		48	
5.5 DU/GA		50	
6.0 DU/GA		52	
6.5 DU/GA		54	
7.0 DU/GA		56	
7.5 DU/GA		58	
PUD's, condos, apartments, commercial businesses, industrial areas & & subdivisions < 50 acres	%impervious must be computed	Separate curve numbers shall be selected for pervious and impervious portions of the site	
For a more detailed and complete description of land use curve numbers refer to chapter two (2) of the Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986).			

[1] Composite CN's may be computed for other combinations of open space cover type.

[2]Where impervious surface runoff is infiltrated or dispersed according to the requirements in Chapter 3, the average percent impervious area may be adjusted in accordance with the procedure described under "Flow Credit for NPGIS Runoff Infiltration" (Section 3.1.1), and "Flow Credit for NPGIS Runoff Dispersion" (Section 3.1.2).

[3]Assumes impervious surface runoff is directed into street/storm system.

[4]All the remaining pervious area (lawn) are considered to be in good condition for these curve numbers.

SCS Curve Number Equations for determination of runoff depths and volumes

The rainfall-runoff equations of the SCS curve number method relates a land area's runoff depth (precipitation excess) to the precipitation it receives and to its natural storage capacity, as follows:

$Q_d = (P - 0.2S)^2 / (P + 0.8S)$ for $P \geq 0.2S$ and

~~and~~ $Q_d = 0$ for $P < 0.2S$

w~~W~~here~~:~~

Q_d = runoff depth in inches over the area,
P = precipitation depth in inches over the area, and
S = potential maximum natural detention, in inches over the area, due to infiltration, storage, etc.

The area's potential maximum detention, S, is related to its curve number, CN:

$S = (1000 / CN) - 10$

The combination of the above equations allows for estimation of the total runoff volume by computing total runoff depth, Q_d, given the total precipitation depth, P.

2.4 Closed Depression Analysis

The analysis of closed depressions requires careful assessment of the existing hydrologic performance in order to evaluate the impacts a proposed project will have. Closed depressions generally facilitate infiltration of runoff. If a closed depression is classified as a wetland, then SCC 30.63A.570 applies. If there is an outflow from this wetland to a surface water, the flow from this wetland must also meet the requirements of SCC 30.63A.550.

Chapter 3 - Flow Control Design

This chapter presents methods, criteria, and details for hydraulic analysis, design, and construction of best management practices (BMPs) used to meet the on-site stormwater management requirements of SCC 30.63A.525 and the flow control requirements of SCC 30.63A.550. In addition, this chapter contains information for the design and construction of stormwater infiltration facilities and permeable pavement that can meet the stormwater treatment requirements of 30.63A.530.

The Underground Injection Control (UIC) regulations of Chapter 173-218 WAC apply to stormwater infiltration systems, although those regulations contain exemptions for various kinds of stormwater infiltration systems. These regulations are implemented by the Washington State Department of Ecology, and Snohomish County recommends that the applicant contact that department for project-specific determinations about UIC regulation applicability. Snohomish County does not implement or enforce the state UIC regulations.

3.1 Roof Downspout Controls

This section presents the criteria for design and implementation of roof downspout controls in accordance with the on-site stormwater management requirements of Minimum Requirement 5 as set forth in SCC 30.63A.525 and Volume I, Chapter 2.5.5 of this manual.

~~Ecology's Western Washington Hydrology Model (WWHM) incorporates flow credits for BMP T5.10A – Downspout Full Infiltration Systems, and BMP T5.10B – Downspout Dispersion Systems.~~

3.1.1 Downspout Full Infiltration Systems (BMP T5.10A)

Downspout full infiltration systems are trench or drywell designs intended only for use in infiltrating runoff from residential roofs that are classified as non-pollution generating. downspout drains. They are not designed to directly infiltrate runoff from commercial roofs, residential metal roofs unless those roofs are determined to be non-pollution generating, or other pollutant-generating impervious surfaces.

Infeasibility Criteria for downspout full infiltration systems

A downspout full infiltration system is considered feasible on a site if all of the following are true.

- The particle size distribution of the soil is classified according to the USDA Textural Triangle (see Figure 3.1) as loam, sandy loan, loamy sand, or sand, based on ASTM Standard Test Method for Particle Size Analysis of Soils ASTM D422-63 (2002);
- The depth from final grade to seasonal high water table, hardpan, or other low permeability layer is 3 feet or more;
- The depth from the bottom elevation of the infiltration system to seasonal high water table, hardpan, or other low permeability layer is 1 foot or more; and

- The downspout infiltration system can be installed in conformance with the design criteria below.

There are two types of downspout full infiltration systems: downspout infiltration drywells (see Figure 3.2) and downspout infiltration trenches (see Figures 3.3 and 3.4). Downspout infiltration drywells can only be used on project sites with a soil texture of medium sand or coarser as described in Table 3.3.

Design Criteria for Downspout Infiltration Trenches

1. The minimum trench lengths per 1,000 square feet (plan view) of roof area based on soil type shown in Table 3.3 shall be used for sizing roof downspout infiltration trenches.
2. The maximum length of trench shall not exceed 100 feet from the inlet sump.
3. Filter fabric shall be placed over the drain rock as shown on Figure 3.3 prior to backfilling.
4. Concentrated flow shall not be directed to adjoining lots.
5. Infiltration trenches shall not be placed in fill material unless the fill is placed and compacted under the direct supervision of a geotechnical engineer or civil engineer with geotechnical expertise, and if the measured infiltration rate is at least 8 inches per hour (see Chapter 3.3 for infiltration rate measurement methodology).
6. Infiltration trenches shall not be built on slopes steeper than 25~~ percent~~% (4:1). A geotechnical analysis and report may be required on slopes over 15~~ percent~~% or if located within 200 feet of the top of a geologic hazard area.
7. Trenches may be located under pavement if a small yard drain or catch basin with grate cover is placed at the end of the trench pipe such that overflow would occur out of the catch basin at an elevation at least one foot below that of the pavement, and in a location which can accommodate the overflow without creating a significant adverse impact to downhill properties or drainage systems.

Table 3.3 - Minimum Downspout Infiltration Trench Lengths based on Soil Type

Soil type	Trench length (ft)
Loam	190
Sandy loam	125
Loamy sand	75
"Fine sand" - less than 50% of sand fraction remaining on #40 sieve	75
"Medium sand" - more than 50% of sand fraction remaining on #40 sieve	30
"Coarse sand" - more than 50% of sand fraction remaining on #4 sieve	20
Fill (see criterion 6 below)	60

Design criteria for roof downspout infiltration drywells

1. Drywell bottoms must be a minimum of 1 foot above seasonal high groundwater level or impermeable soil layers.
2. Drywells installed in "fine sand" or "medium sand" as designated above or finer-grained material shall contain a minimum of 90 cubic feet of washed drain rock for each 1000 square feet (plan view) of contributing roof area.
3. Drywells installed in "coarse sand" as designated above or coarser material must contain a minimum of 60 cubic feet of washed drain rock for each 1000 square feet (plan view) of contributing roof area.
4. Drywells shall be a minimum of 48 inches in diameter and deep enough to contain the gravel amounts specified above.
5. Filter fabric (geotextile) must be placed on top of the drain rock and on trench or drywell sides prior to backfilling.
6. Downspout infiltration drywells must not be built on slopes greater than 25% (4:1). Drywells may not be placed on or above a landslide hazard area or slopes greater than 15% without evaluation by a professional engineer with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist, and with Snohomish County approval.
7. Concentrated flow may not be directed to adjoining lots.

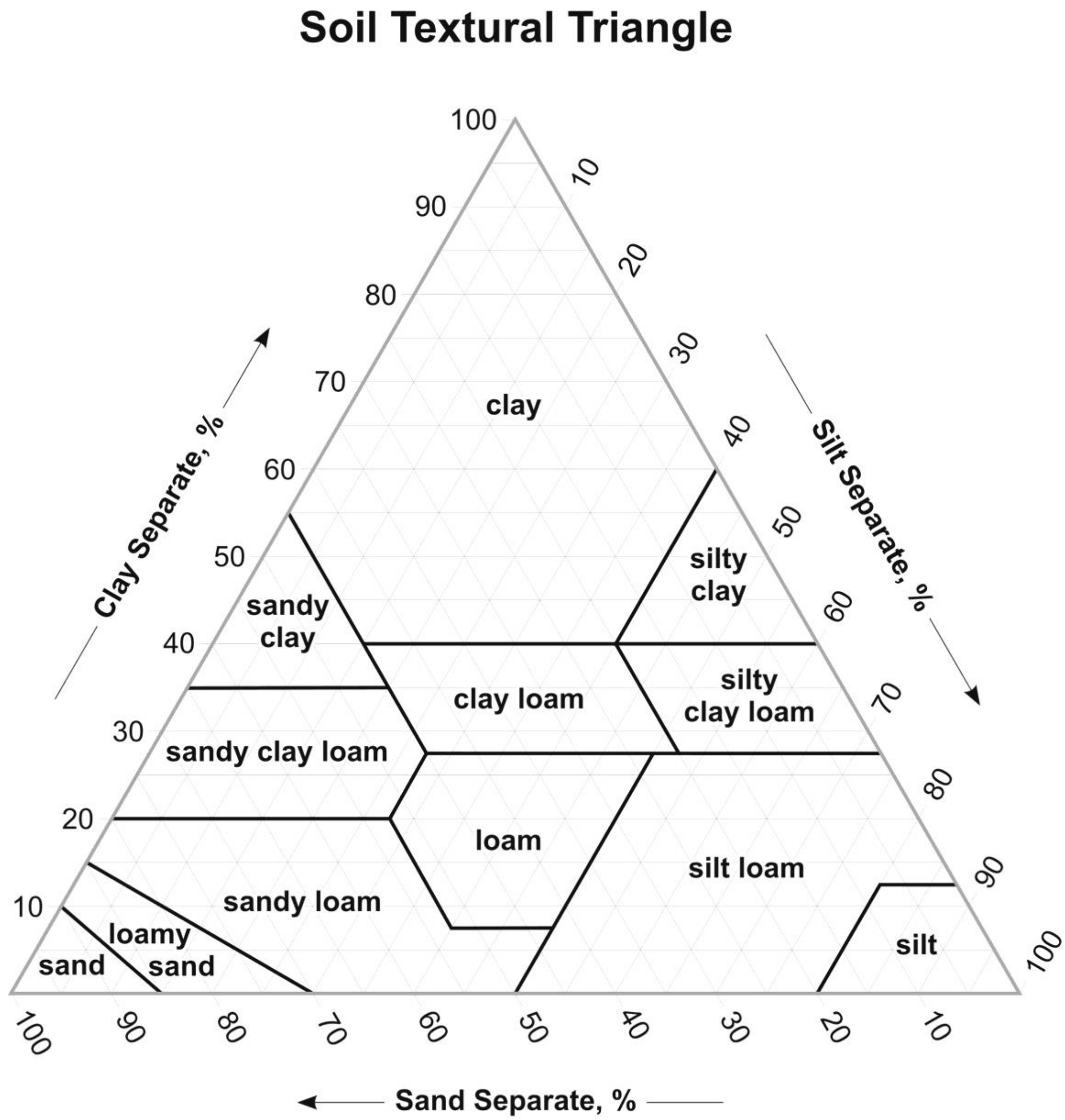


Figure 3.1 - –USDA Textural Triangle

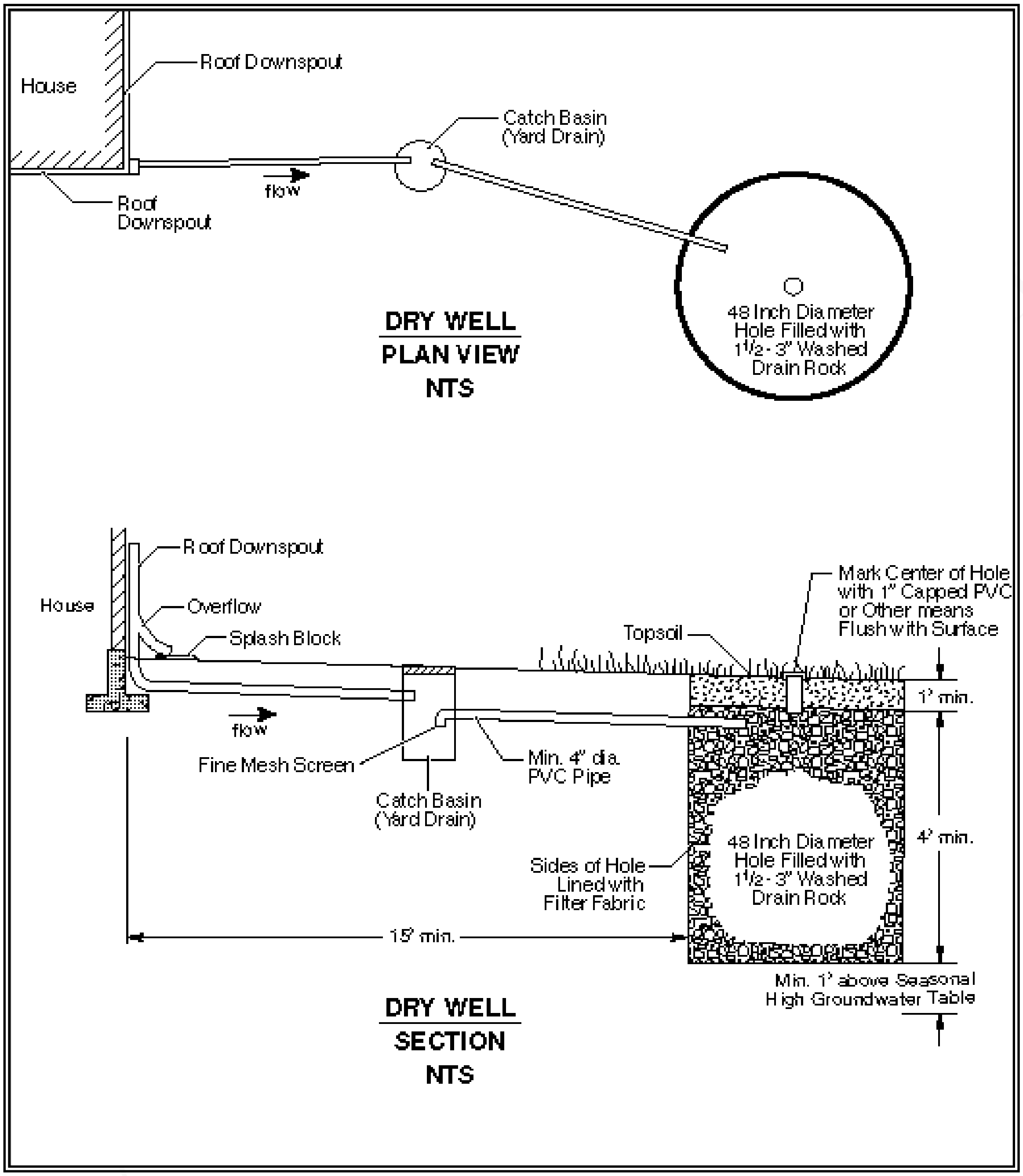


Figure 3.2 ~~–~~ – Downspout Infiltration Drywell

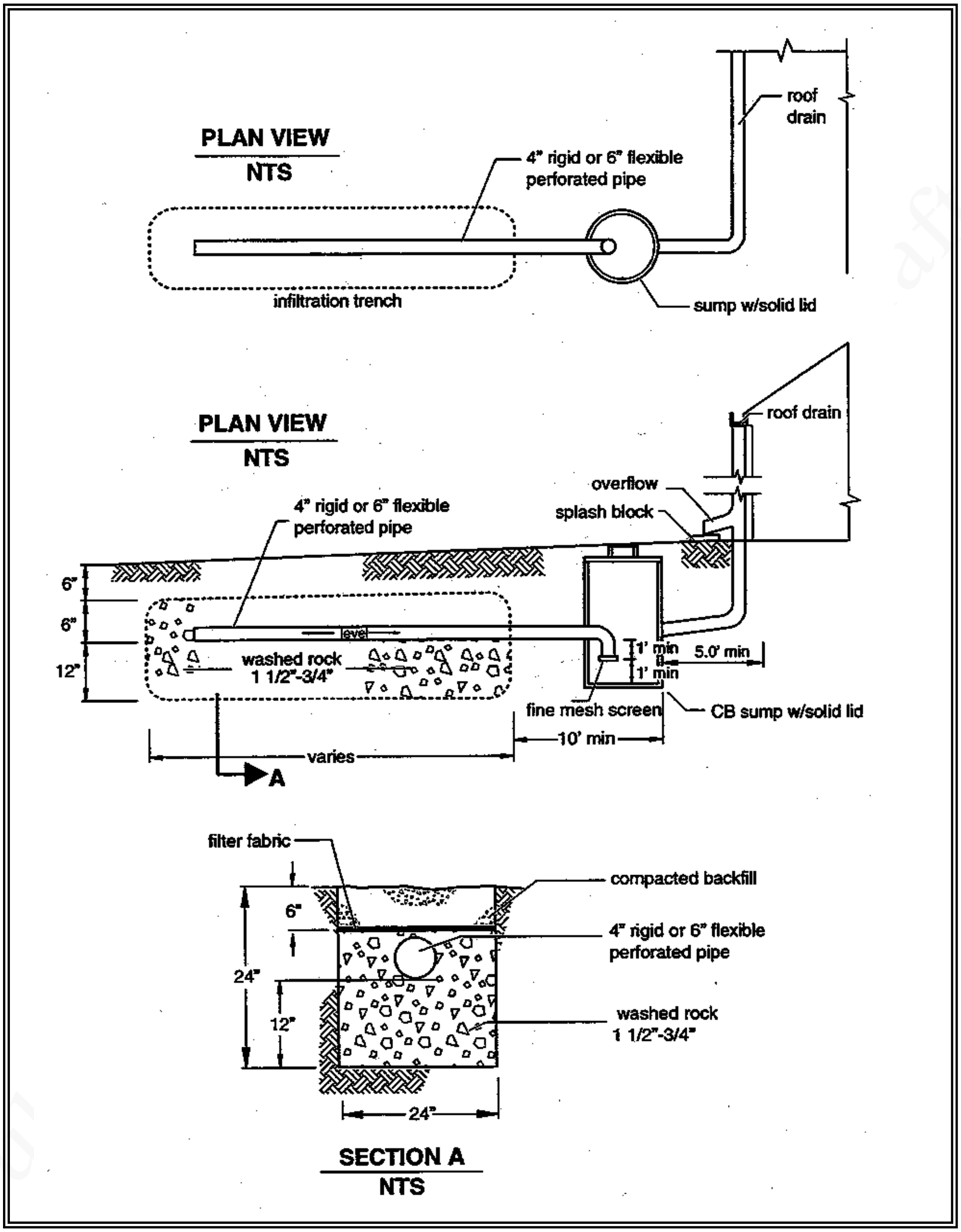


Figure 3.3 - –Downspout Infiltration Trench

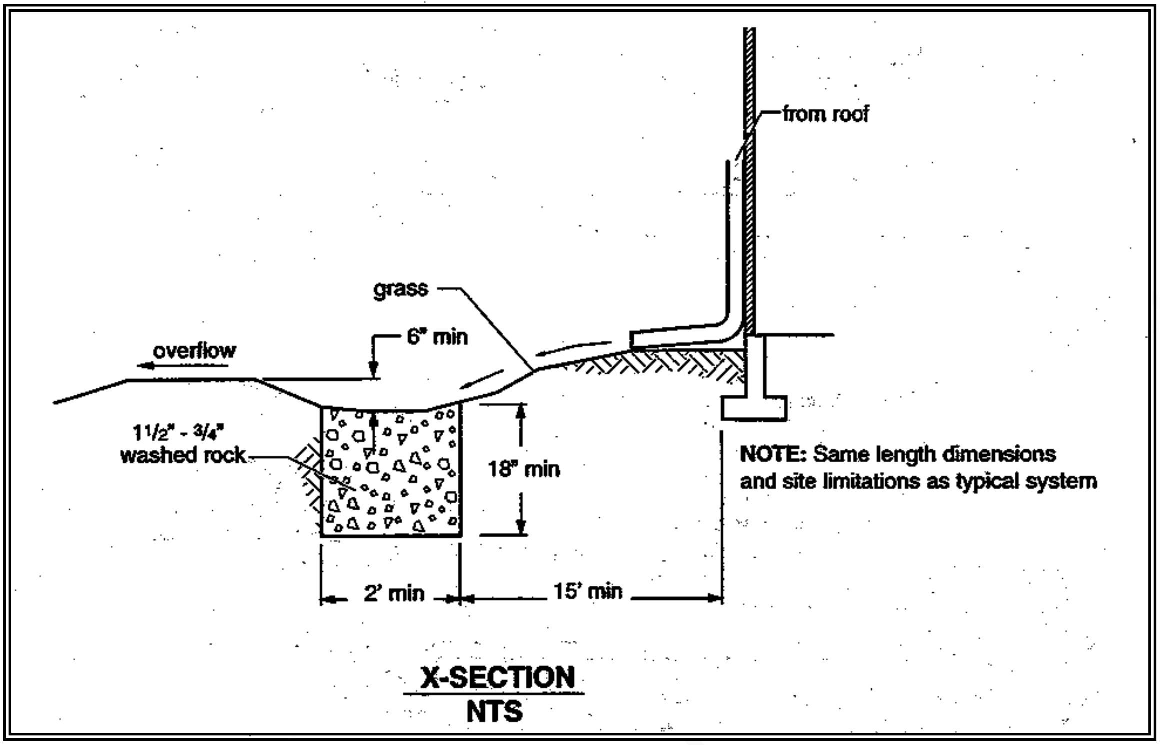


Figure 3.4 - –Alternative Downspout Infiltration Trench System for Coarse Sand and Gravel

~~Hydrologic Modeling Credits for Downspout Infiltration BMPs~~Runoff model representation

If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the total project area used for sizing stormwater facilities.

3.1.2 Downspout Dispersion Systems (BMP T5.10B)

There are two types of downspout dispersion systems: splash blocks (see Figure 3.5) and dispersion trenches (see Figures 3.6 and 3.7). Downspout dispersion systems are intended to infiltrate some runoff and spread the rest over vegetated pervious areas.

Infeasibility criteria for downspout dispersion systems

Splash blocks, dispersion trenches or both shall be used if the discharge point has a vegetated flowpath of at least 50 feet, measured from the discharge point to the downstream property line, other stormwater infiltration or dispersion system (such as a driveway dispersion trench), stream, wetland, geologic hazard area, or impervious surface. Critical area buffers can be included in the calculation of the flowpath length.

Only dispersion trenches shall be used if the vegetated flowpath as described above is between 50 feet and 25 feet long.

Downspout dispersion systems are not allowed if a vegetated flowpath of 25 feet or more cannot be provided or if the use of a dispersion system might cause erosion or flooding problems onsite or on adjacent properties. In these cases, perforated stubout connections must be used unless they are not feasible due to soil or groundwater conditions.

For sites with septic systems, the discharge point of a downspout dispersion system must be downslope of the primary and reserve drainfield areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.

Design Criteria for Splashbocks

A typical splash block is shown in Figure 3.5. Splash blocks with downspout extensions should be considered if the ground is fairly level, if the structure includes a basement, or if foundation drains are proposed.

1. A maximum of 700 square feet of roof area may drain to each splash block.
2. A splash block or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each discharge point.
3. No erosion or flooding of downstream properties may result.
4. Runoff discharged towards landslide hazard areas must be evaluated by a professional engineer with geotechnical expertise or a qualified geologist. Splash blocks may not be placed on or above slopes greater than 15% or above erosion hazard areas without evaluation by a professional engineer with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist, and Snohomish County approval.
5. For purposes of maintaining adequate separation of flows discharged from adjacent dispersion devices, the outer edge of the vegetated flowpath segment for the dispersion trench must not overlap with other flowpath segments, except those associated with sheetflow from a non-native impervious surface.

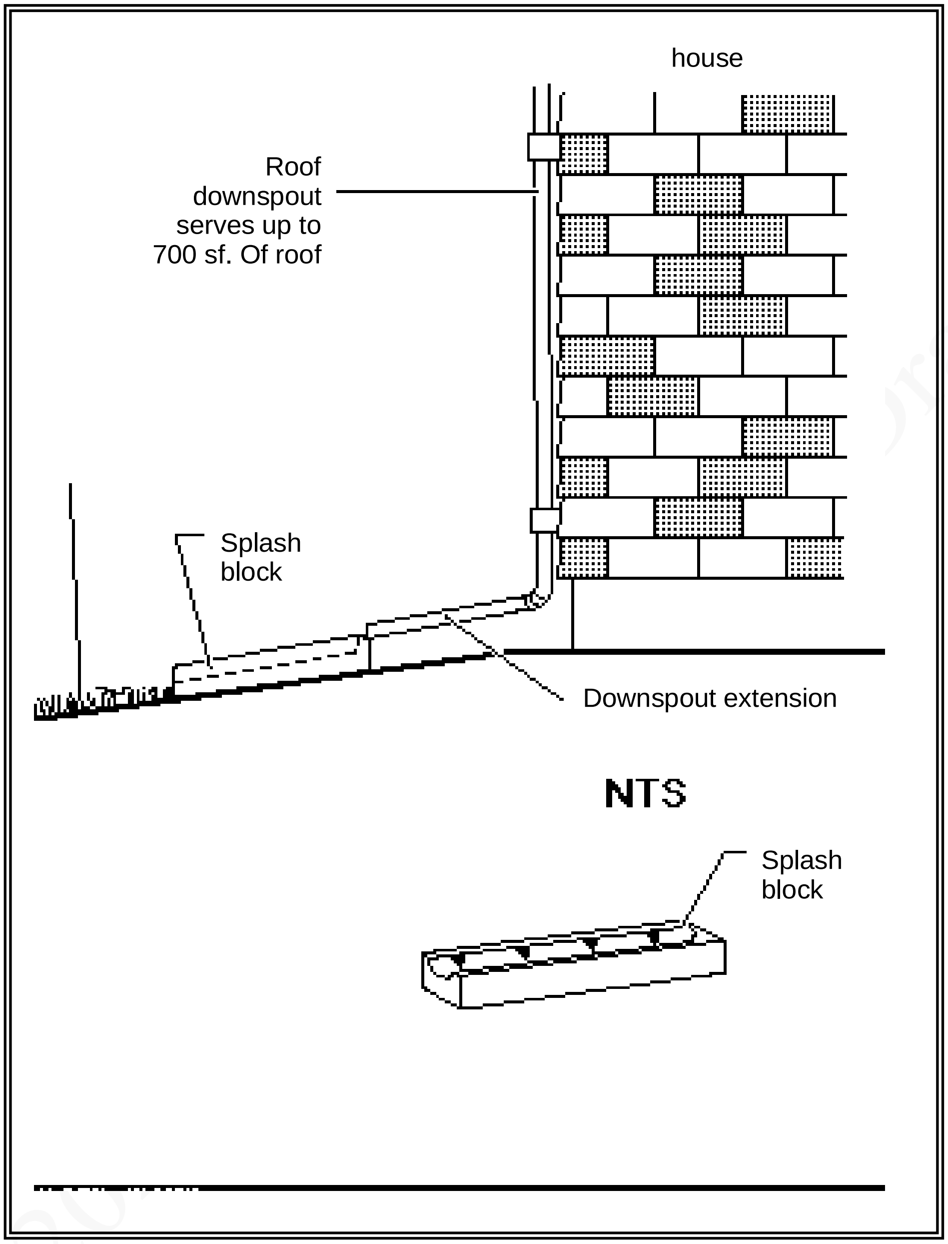


Figure 3.5 - –Splash Block Dispersion

Design Criteria for Dispersion Trenches

1. Trenches serving up to 700 square feet of roof area shall be 10 feet long by 2 feet wide as shown in Figure 3.6. For roof areas larger than 700 square feet, the trench length shall be calculated at a rate of 1 foot of trench per 70 square feet of roof area. The maximum length for a single dispersion trench shall be 50 feet.
2. For trenches larger than 10 feet in length, a notched grade board as shown in Figure 3.7 shall be used.
3. No erosion or flooding of downstream properties may result.
3. Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or a licensed geologist, hydrogeologist, or engineering geologist. The discharge point may not be placed on or above slopes greater than 15% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and Snohomish County approval.
4. For purposes of maintaining adequate separation of flows discharged from adjacent dispersion devices, the outer edge of the vegetated flowpath segment for the dispersion trench must not overlap with other flowpath segments, except those associated with sheetflow from a non-native impervious surface.

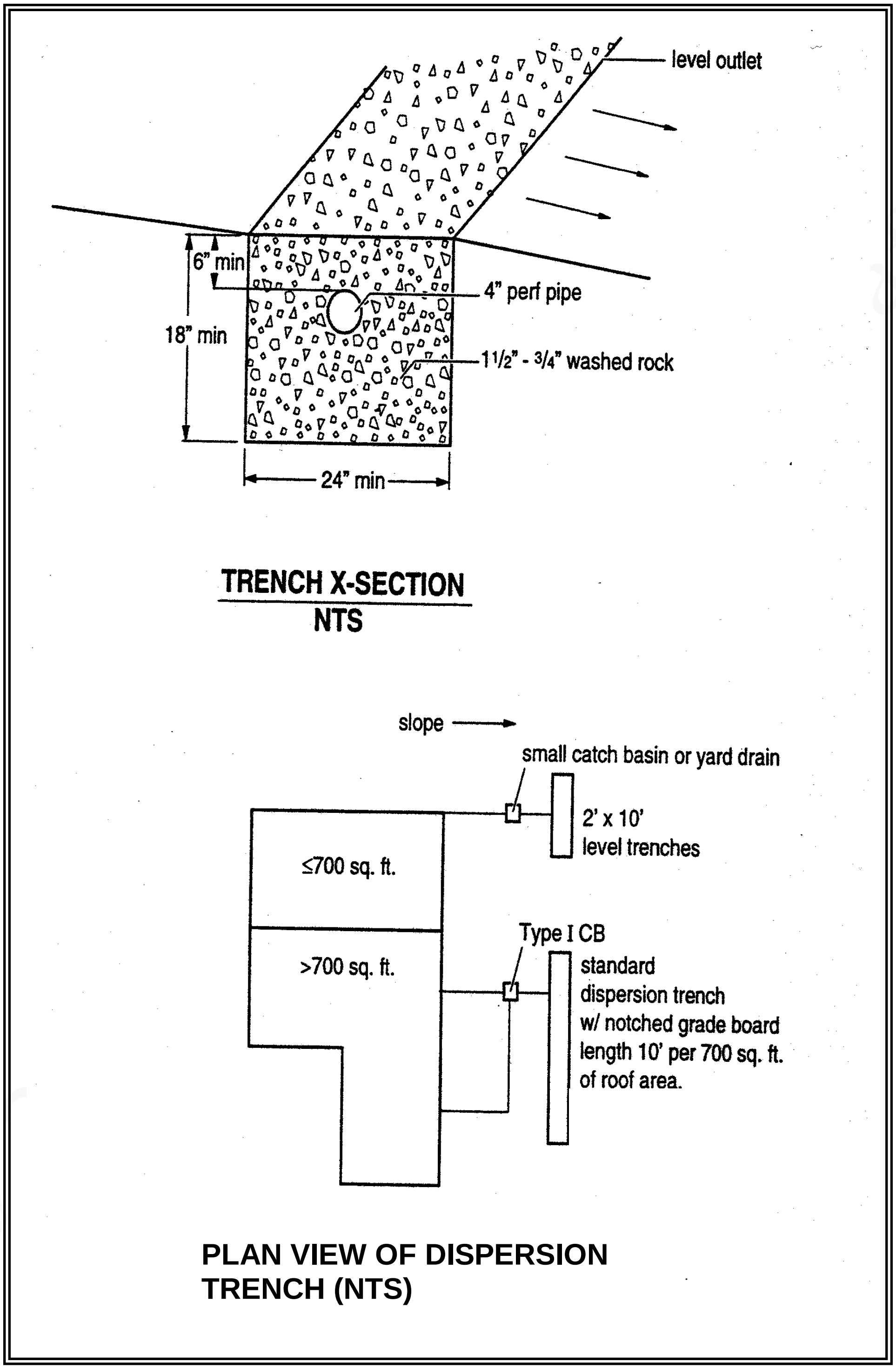


Figure 3.6 - Dispersion Trench

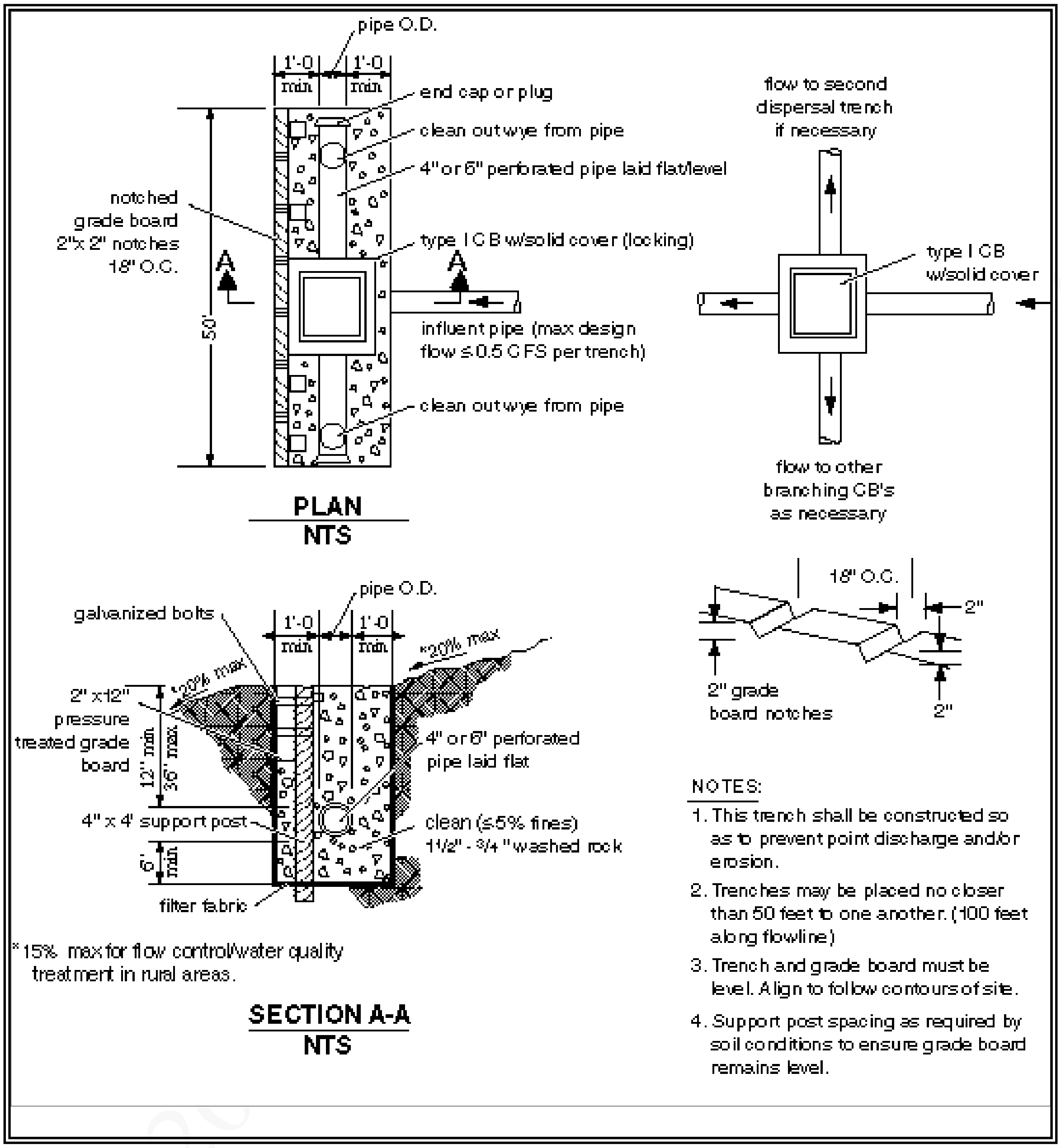


Figure 3.7 - Dispersion Trench with Notched Grade Board

Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710. In addition, multiple dispersion trenches shall be separated by a minimum of 50 feet.

~~Hydrologic Modeling Credits for Roof Runoff Dispersion Systems~~Runoff model representation

~~For single-family residential lots greater than 22,000 square feet, i~~If roof runoff is dispersed according to the requirements of this section the roof area should be modeled as a lateral flow impervious basin connected to a lawn/landscape lateral flow basin which represents the area used for dispersion. Alternatively, where multiple downspout dispersions will occur the following methods may be used.

- ~~and~~ If the vegetative flow path is 50 feet or larger through undisturbed native landscape or lawn/landscape area that meets BMP T5.13, the NPGIS area may be modeled as grassed surface.
- –If the available vegetated flowpath is 25 to 50 feet, use of a dispersion trench allows modeling the roof as 50% impervious/50% ~~landscape~~grass. ~~This is done in the WWHM on the Mitigated Scenarios screen by entering the NPGIS area into one of the entry options for dispersal of impervious area runoff.~~For the purpose of tracking impervious area modeled as pervious area, WWHM2012 provides LID pervious land segment entries to represent the impervious area being modeled as grass.

3.1.3 Perforated Stub-out Connections (BMP T5.10C)

A perforated stub-out connection is a length of perforated pipe within a gravel-filled trench that is placed between a roof downspout and a stub-out to the local drainage system. Figure 3.8 illustrates a perforated stub-out connection. These systems are intended to provide some infiltration during drier months. During the wet winter months, they may provide little or no flow control.

Perforated stub-outs are not appropriate when seasonal water table is < 1 foot below trench bottom.

In projects subject to Minimum Requirement 5, perforated stub-out connections may be used only when all other higher priority on-site stormwater management BMPs are not feasible, per the criteria for each of those BMPs.

Design Criteria for Perforated Stub-Out Connections

1. Sections of the stub-out located under impervious or heavily compacted surface (e.g., driveways and parking areas) shall be non-perforated pipe.
2. Trenches shall be 2 feet wide and backfilled with washed drain rock. The drain rock shall extend to a depth of at least 8 inches below the bottom of the pipe and should cover the pipe. The pipe shall be laid level and the rock trench covered with filter fabric and 6 inches of fill (see Figure 3.8).

3. Potential runoff discharge towards a landslide hazard area must be evaluated by a professional engineer with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist. The perforated portion of the pipe may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a professional engineer with geotechnical expertise or qualified geologist and Snohomish County approval.

4. For sites with septic systems, the perforated portion of the pipe must be downgradient of the drainfield primary and reserve areas. This requirement can be waived if site topography will clearly prohibit flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.

Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710.

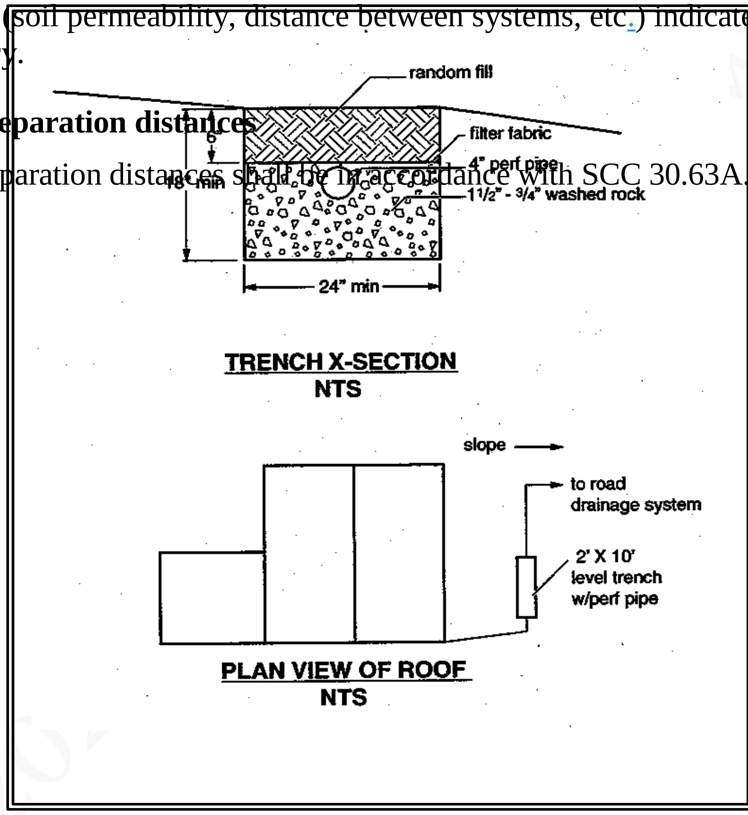


Figure 3.8 – Perforated Stub-Out Connection

3.2 Detention Facilities

This section presents the methods, criteria, and details for design and analysis of detention facilities. These facilities provide for the temporary storage of increased surface water runoff resulting from development pursuant to the performance standards set forth in SCC 30.63A.550.

There are three primary types of detention facilities described in this section: detention ponds, tanks, and vaults.

Stormwater detention facilities that can impound 10 acre-feet (435,600 cubic feet; 3.26 million gallons) or more with the water level measured at the embankment crest ~~are~~ may be subject to the state's dam safety requirements, set forth in Chapter 173-175 Washington Administrative Code. Technical design requirements and procedural requirements for plan review and approval described in detail in guidance documents developed by and available from the Washington State Department of Ecology Dam Safety Office at https://ecology.wa.gov/Water-Shorelines/Water-supply/Dams~~http://www.ecy.wa.gov/programs/wr/dams/dss.html~~.

3.2.1 Detention Ponds

Standards and Specifications

Engineering standards and specifications for detention ponds are set forth in Chapter 5-10 of EDDS and in this section. A schematic drawing of typical detention pond is shown in Figure 3.9. See also EDDS Standard Drawings 5-240A, 5-240B, and other drawings in Chapter 5 EDDS.

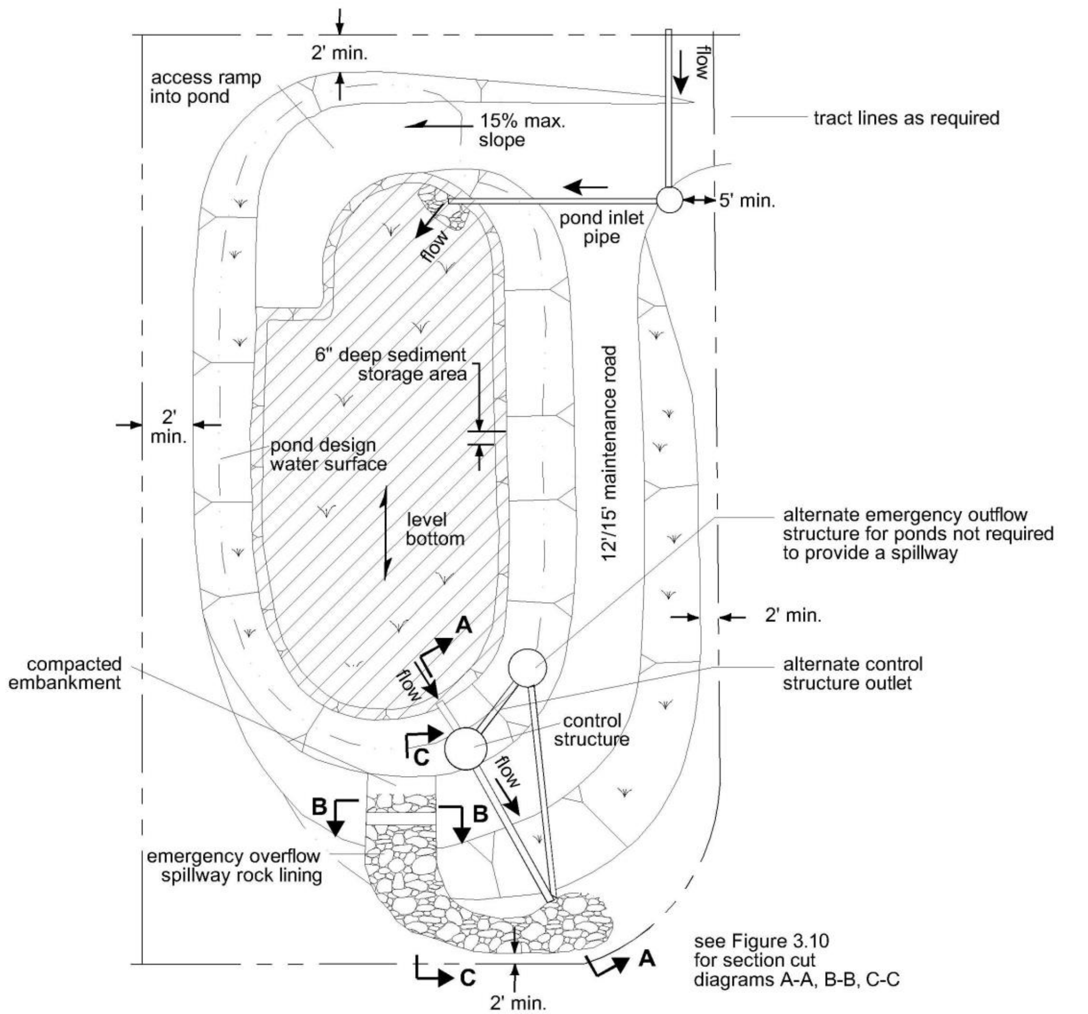
Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-10.

Landscaping

Vegetation and landscaping requirements for the functional components and areas of stormwater flow control and treatment facilities are set forth in Chapter 5 of Snohomish County EDDS. These functional components and areas include, but are not limited to, earthen berms, infiltration and detention pond bottoms, filter beds, bioretention facilities, vegetated slopes and swales used for stormwater treatment or flow control, access roads for these facilities, and any other components or areas used for or required for proper function, inspection, maintenance, or repair of these facilities, as described in Chapter 30.63A SCC, Snohomish County EDDS, or the Drainage Manual.

Vegetation and landscaping requirements for other areas of tracts or lots that contain stormwater flow control and treatment facilities are set forth in SCC 30.25.023. Appendix B of Snohomish County EDDS contains a list of plants that can be used to meet the visual screening requirements of SCC 30.25.023.



NOTE:

This detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 3.9 – Typical Detention Pond

Outfall systems

Properly designed outfalls are critical to reducing the chance of adverse impacts as the result of concentrated discharges from pipe systems and culverts, both onsite and downstream. Outfall systems include rock splash pads, flow dispersal trenches, gabion or other energy dissipaters, and tightline systems. A tightline system is typically a continuous length of pipe used to convey flows down a steep or sensitive slope with appropriate energy dissipation at the discharge end. Detailed requirements for outfall systems are found in Volume V, Chapter 4.5.3.

Maintenance

Maintenance requirements for drainage facilities are set forth in Chapter 7.54 SCC and Volume V, Chapter 4.6 and Volume VI of this manual.

Methods of Analysis

Detention Volume and Outflow

The volume and outflow design for detention ponds must be in accordance with ~~SCC 30.63A.550 and~~ the hydrologic analysis and design methods in Chapter ~~1~~ 2 of this Volume. Design of outflow control structures is discussed in Section 3.2.4.~~Design guidelines for restrictor orifice structures are given in Chapter 3.2.4.~~

Note: The design water surface elevation is the highest elevation which occurs in order to meet the required outflow performance for the pond.

Detention Ponds in Infiltrative Soils.

Detention ponds may occasionally be sited on till soils that are sufficiently permeable for a properly functioning infiltration system (see Chapter 3.3). These detention ponds have a surface discharge and may also utilize infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements of Chapter 3.3 for infiltration ponds, including a soils report, testing, groundwater protection, pre-settling, and construction techniques.

Emergency Overflow Spillway Capacity.

For impoundments under 10 acre-feet, the emergency overflow spillway weir section must be designed to pass the 100-year runoff event for developed conditions assuming a broad-crested weir. The broad-crested weir equation for the spillway section in EDDS Standard Drawing 5-240B is:

$$Q_{100} = C\,(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}(\operatorname{Tan}\theta)\,H^{5/2}\right] \qquad \text{(equation 1)}$$

w~~W~~here Q_{100} = peak flow for the 100-year runoff event (cfs)

C = discharge coefficient (0.6)

g = gravity (32.2 ft/sec^2)

L = length of weir (ft)

H =	height of water over weir (ft)
θ =	angle of side slopes

Q_{100} is either the peak volumetric flow rate calculated using a 10-minute time step from the 100-year, 24-hour storm and a Type 1A distribution, or the 100-year~~, 1-hour~~ flow rate, indicated by an approved continuous runoff hydrologic model~~, multiplied by a factor of 1.6~~.

Assuming C = 0.6 and Tan θ = 3 (for 3:1 slopes), the equation becomes:

$$Q_{100} = 3.21[LH^{3/2} + 2.4\,H^{5/2}] \qquad \text{(equation 2)}$$

To find *L* for the weir section, the equation is rearranged to use the computed Q_{100} and trial values of H (0.2 feet minimum):

$$L = [Q_{100}/(3.21H^{3/2})] - 2.4\ H \quad \text{or} \quad 6 \text{ feet minimum} \quad \text{(equation 3)}$$

3.2.2 Detention Pipes

Detention pipes, sometimes referred to as detention tanks, are underground storage facilities typically constructed with large diameter corrugated metal pipe. Detention pipe detail drawings are shown in EDDS Standard Drawings 5-290 and 5-295. Standard control structure details and notes are shown in EDDS Chapter 5 Standard Drawings.

Design Criteria

Engineering standards and specifications for detention pipes are set forth in Chapter 5-16 of Snohomish County EDDS.

The applicant shall submit calculations showing that the detention pipe is designed to be nonbuoyant based on groundwater conditions at the project site.

Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-16.

Maintenance.

Maintenance requirements for drainage facilities are set forth in Chapter 7.54 SCC and Volume V, Chapter 4.6 of this manual.

Methods of analysis for detention volume and outflow

The volume and outflow design for detention tanks must be in accordance with hydrologic analysis and design methods in Chapter 2 of this volume. Design of outflow control structures is discussed in Section 3.2.4.

3.2.3 Detention Vaults

Detention vaults are detention structures that detain the water in an enclosed concrete vault. A standard detention vault detail is shown in EDDS Standard Drawing 5-280. Standard control structure details and notes are shown in EDDS Chapter 5 Standard Drawings.

Design Criteria

Engineering standards and specifications for detention vaults are set forth in Chapter 5 Section 5-15 of Snohomish County EDDS. Design of outflow control structures is discussed in Section 3.2.4.

The applicant shall submit calculations showing that the detention vault is designed to be nonbuoyant based on groundwater conditions at the project site.

Access

Access to drainage facilities shall be provided in accordance with the requirements of SCC 30.63A.720 and Snohomish County EDDS.

Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-15.

Maintenance

Maintenance requirements for drainage facilities are set forth in Chapter 7.54 SCC and Volume V, Chapter 4.6 of this manual.

Methods of analysis for detention volume and outflow

The volume and outflow design for detention vaults must be in accordance with hydrologic analysis and design methods in Chapter 2 of this volume. Design of outflow control structures is discussed in Section 3.2.4.

3.2.4 Control Structures

Control structures are catch basins or manholes with a restrictor device for controlling outflow from a facility to meet the desired performance. Riser type restrictor devices ("tees" or "FROP-Ts") also provide some incidental oil/water separation to temporarily detain oil or other floatable pollutants in runoff due to accidental spill or illegal dumping.

The restrictor device usually consists of two or more orifices and/or a weir section sized to meet performance requirements.

Standard control structure details and notes are shown in EDDS Chapter 5 Standard Drawings.

Design Criteria

Multiple Orifice Restrictor

In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.

1. Minimum orifice diameter is 0.5 inches. Note: In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth need not be reduced to less than 3 feet in an attempt to meet the performance standards. Also, under such circumstances, flow-throttling devices may be a feasible option. These devices will throttle flows while maintaining a plug-resistant opening.
2. Orifices shall be constructed on a tee section as shown in EDDS Standard Drawing 5-270B.

3. In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g., a 13-inch diameter orifice positioned 0.5 feet from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements (see Figure 3.12).
4. Consideration must be given to the backwater effect of water surface elevations in the downstream conveyance system. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes.

Riser and Weir Restrictor

1. Properly designed weirs may be used as flow restrictors **(**see EDDS Standard Drawing 5-265 and Figure 3.11 through Figure 3.13). However, they must be designed to provide for primary overflow of the developed 100-year peak flow discharging to the detention facility.
2. The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design must still provide for primary overflow of the developed 100-year peak flow assuming all orifices are plugged. Figure 3.14 can be used to calculate the head in feet above a riser of given diameter and flow.

Access~~.~~

Access to drainage facilities shall be provided in accordance with the requirements of Chapter 30.63A.720 and Snohomish County EDDS.

Information Plate~~.~~

It is recommended that a brass or stainless steel plate be permanently attached inside each control structure with the following information engraved on the plate:

- Name and file number of project
- Name and company of (1) developer, (2) engineer, and (3) contractor
- Date constructed
- Date of manual used for design
- Outflow performance criteria
- Release mechanism size, type, and invert elevation
- List of stage, discharge, and volume at one-foot increments
- Elevation of overflow

Maintenance~~.~~

Maintenance requirements for drainage facilities are set forth in Chapter 7.54 SCC and Volume V, Chapter 4.6 of this manual.

Methods of Analysis

Orifices

Flow-through orifice plates in the standard tee section or turn-down elbow may be approximated by the general equation:

$$Q = C\,A\,\sqrt{2gh} \qquad \text{(equation 4)}$$

where
- Q = flow (cfs)
- C = coefficient of discharge (0.62 for plate orifice)
- A = area of orifice (ft^2)
- h = hydraulic head (ft)
- g = gravity (32.2 ft/sec^2)

Figure 3.10 illustrates this simplified application of the orifice equation.

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(equation 5)}$$

where
- d = orifice diameter (inches)
- Q = flow (cfs)
- h = hydraulic head (ft)

Rectangular Sharp-Crested Weir

The rectangular sharp-crested weir design shown in Figure 3.11 may be analyzed using standard weir equations for the fully contracted condition.

$$Q = C\,(L - 0.2H)H^{3/2} \qquad \text{(equation 6)}$$

where
- Q = flow (cfs)
- C = 3.27 + 0.40 H/P (ft)
- H, P are as shown in Figure 3.11
- L = length (ft) of the portion of the riser circumference as necessary not to exceed 50 ~~percent~~% of the circumference
- D = inside riser diameter (ft)

Note that this equation accounts for side contractions by subtracting 0.1H from L for each side of the notch weir.

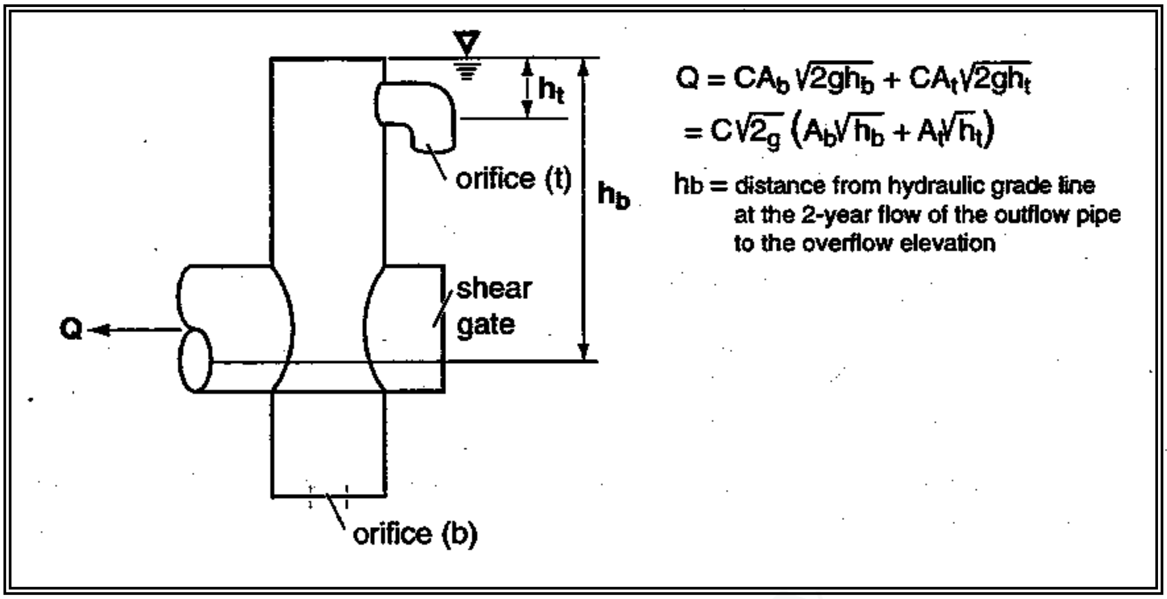


Figure 3.10 - Simple Orifice

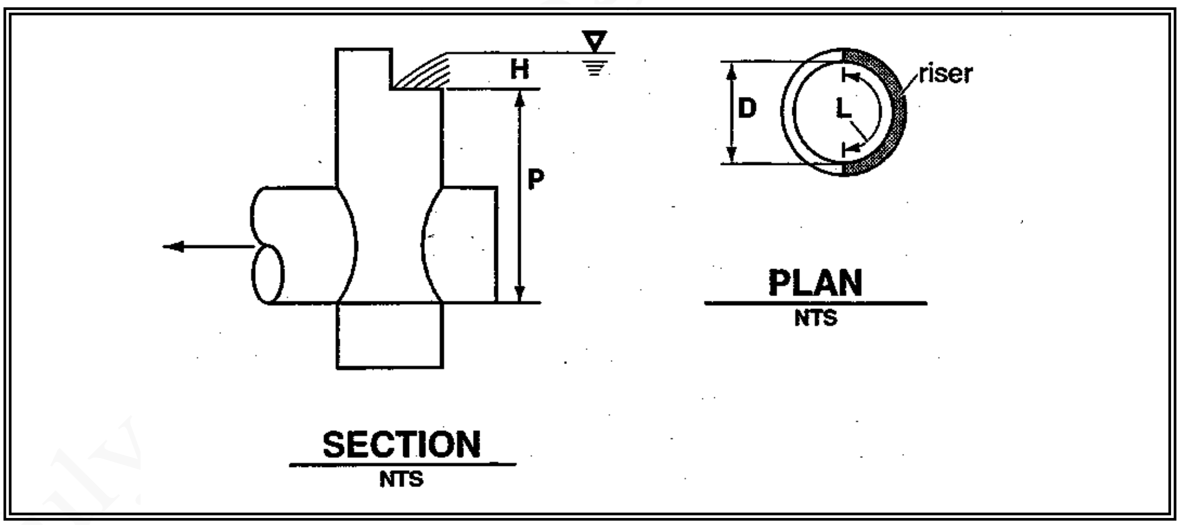
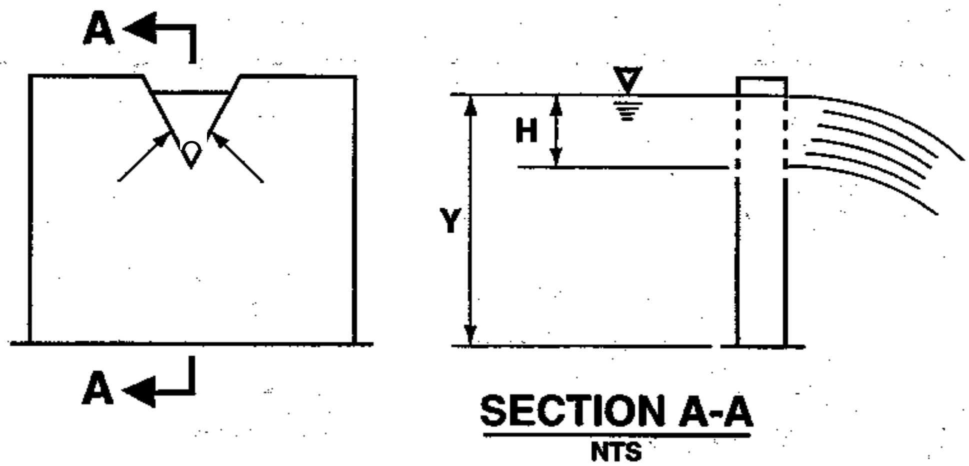


Figure 3.11 - Rectangular, Sharp-Crested Weir

V-Notch Sharp - Crested Weir

V-notch weirs as shown in Figure 3.12 may be analyzed using standard equations for the fully contracted condition.



$$O = C_d(\mathrm{Tan}\ \Theta/2)H^{5/2}. \text{ in cfs}$$

Where values of C_d may be taken from the following chart:

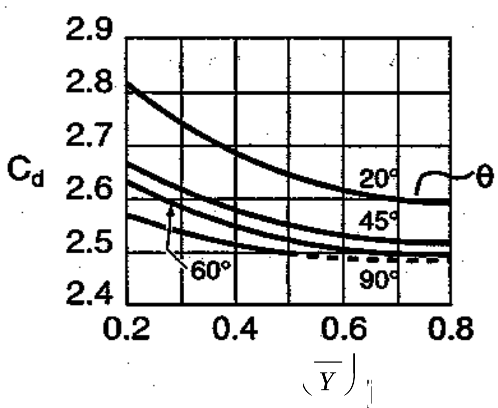


Figure 3.12 - V-Notch, Sharp-Crested Weir

Proportional or Sutro Weir

Sutro weirs are designed so that the discharge is proportional to the total head. This design may be useful in some cases to meet performance requirements.

The sutro weir consists of a rectangular section joined to a curved portion that provides proportionality for all heads above the line A-B (see Figure 3.13). The weir may be symmetrical or non-symmetrical.

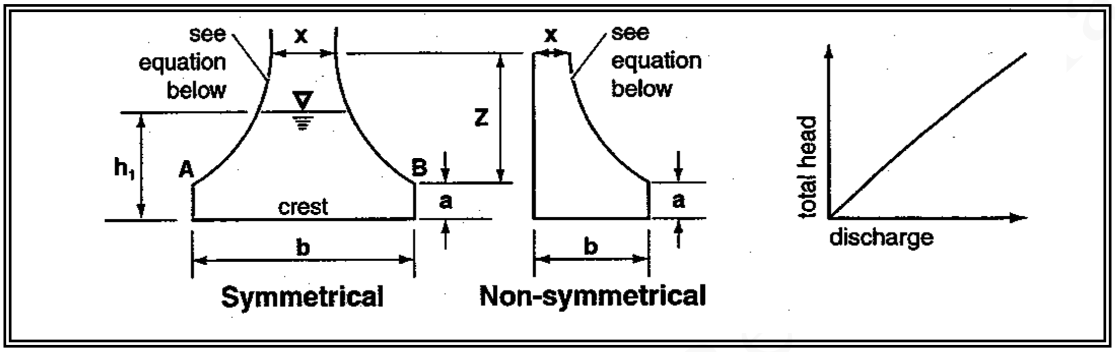


Figure 3.13 - Sutro Weir

For this type of weir, the curved portion is defined by the following equation (calculated in radians):

$$\frac{x}{b} = 1 - \frac{2}{\pi} Tan^{-1} \sqrt{\frac{Z}{a}} \qquad \text{(equation 7)}$$

where a, b, x and Z are as shown in Figure 3.13. The head-discharge relationship is:

$$Q = C_d\, b\, (\sqrt{2ga})(h_1 - \frac{a}{3}) \qquad \text{(equation 8)}$$

Values of *Cd* for both symmetrical and non-symmetrical sutro weirs are summarized in Table 3.4.

Note: When b > 1.50 or a > 0.30, use Cd = 0.6.

Table 3.4
Values of C_d for Sutro Weirs

Cd *Values, Symmetrical*

b (ft)					
a (ft)	**0.50**	**0.75**	**1.0**	**1.25**	**1.50**
0.02	0.608	0.613	0.617	0.6185	0.619
0.05	0.606	0.611	0.615	0.617	0.6175
0.10	0.603	0.608	0.612	0.6135	0.614
0.15	0.601	0.6055	0.610	0.6115	0.612
0.20	0.599	0.604	0.608	0.6095	0.610
0.25	0.598	0.6025	0.6065	0.608	0.6085
0.30	0.597	0.602	0.606	0.6075	0.608

***Cd* Values, Nonsymmetrical**

***b* (ft)**					
a (ft)	**0.50**	**0.75**	**1.0**	**1.25**	**1.50**
0.02	0.614	0.619	0.623	0.6245	0.625
0.05	0.612	0.617	0.621	0.623	0.6235
0.10	0.609	0.614	0.618	0.6195	0.620
0.15	0.607	0.6115	0.616	0.6175	0.618
0.20	0.605	0.610	0.614	0.6155	0.616
0.25	0.604	0.6085	0.6125	0.614	0.6145
0.30	0.603	0.608	0.612	0.6135	0.614

Riser Overflow

The nomograph in Figure 3.14 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year peak flow for developed conditions).

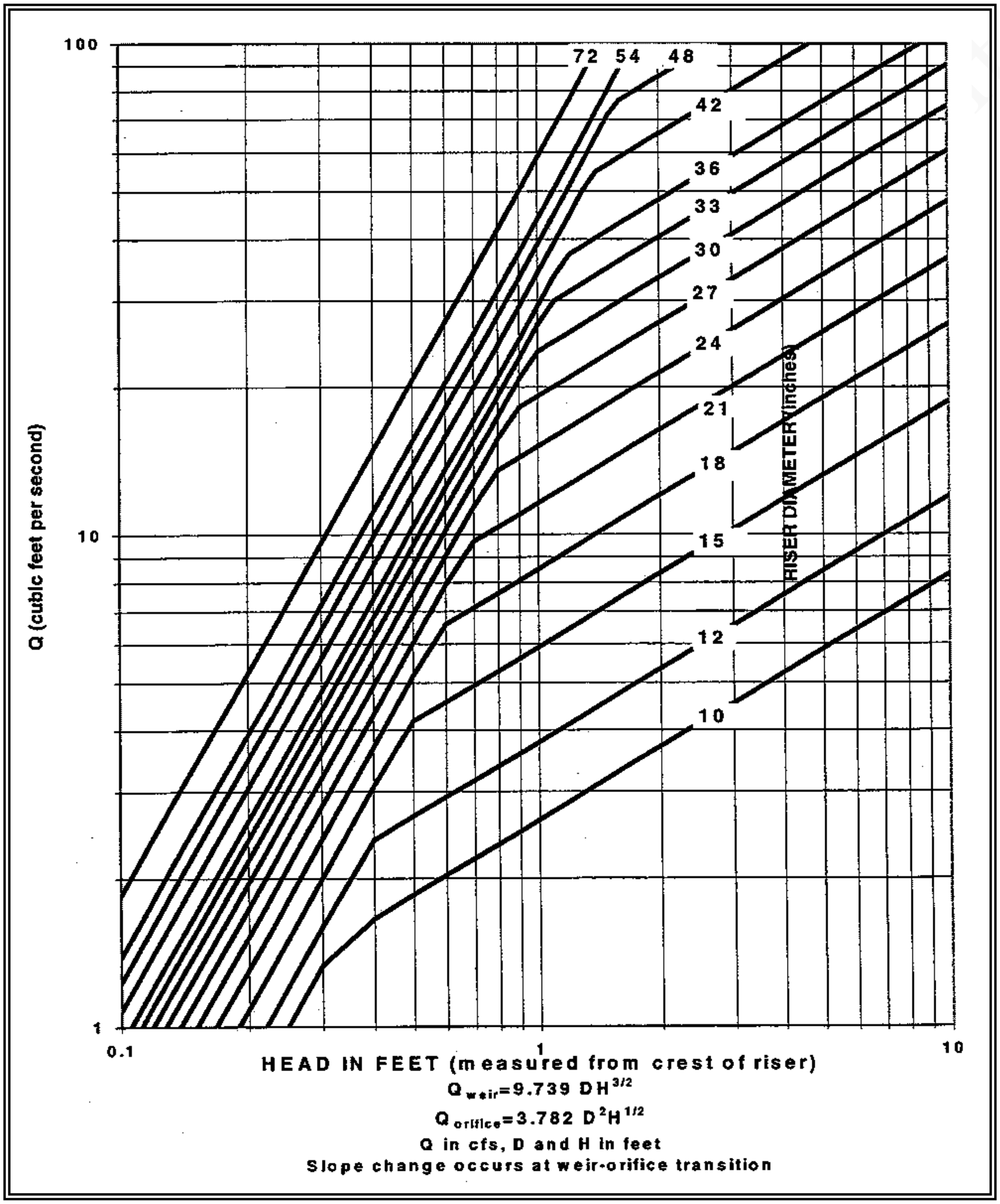


Figure 3.14 - Riser Inflow Curves

3.2.5 Other Detention Options

Use of Parking Lots for Additional Detention~~.~~

~~In accordance with Volume I, Chapter 2 of this manual, private~~ Private parking lots may be used to provide detention volume if all of the following requirements are met:

1. P~~p~~onding is limited to a 0.5-~~-~~foot elevation at the curb line;
2. N~~n~~o ponding is allowed in the emergency or drive lanes during a 100-year storm event;
3. D~~d~~ischarges from the project site must meet the flow control standard applicable to the project in accordance with Volume III, Chapter 3 of this manual; and
4. T~~t~~he proposal complies with all other applicable code requirements and regulations.

Use of Roofs for Detention

Detention ponding on roofs of structures may be used to meet flow control requirements provided all of the following are met:

1. The roof support structure is analyzed by a structural engineer to address the weight of ponded water.
2. The roof area subject to ponding is sufficiently waterproofed to achieve a minimum service life of 30 years.
3. The minimum pitch of the roof area subject to ponding is 1/4-inch per foot.
4. An overflow system is included in the design to safely convey the 100-year peak flow from the roof.
5. A mechanism is included in the design to allow the ponding area to be drained for maintenance purposes or in the event the restrictor device is plugged.

3.3 Infiltration Facilities for Flow Control and for Treatment

3.3.1 Purpose

The purpose of stormwater infiltration facilities is to infiltrate stormwater runoff into the native soil on a project site. The infiltration facilities described in this chapter can be used in partial or total fulfillment of Minimum Requirement 6 – Runoff Treatment, and/or Minimum Requirement 7 – Flow Control. NOTE: while some of the BMPs described in this section, notably permeable pavement and bioretention systems, may be used to meet Minimum Requirement 5 – On-site Stormwater Management, this chapter does not directly address satisfaction of that Minimum Requirement. See the sections in Volumes III and V pertaining to those BMPs for that information.

See Section 3.3.10 for site characterization methods and tests required to determine feasibility of bioretention and permeable pavement used to meet Minimum Requirement 5, and for design of those BMPs if they are feasible.

3.3.2 Description

An infiltration facility is essentially an excavated area used for distributing the stormwater runoff into the underlying soil. The excavated area may be left unfilled, as with a typical infiltration pond or basin, partially filled, as with a bioretention system, fully filled as with an infiltration trench, or covered with a vault. In addition, while areas paved with permeable pavement that do not accept runoff from other areas are not, strictly speaking, considered infiltration systems, the hydraulic capacity and other characteristics of the underlying soil must be tested by the methods used for infiltration facilities. A schematic drawing of a typical stormwater infiltration pond is shown in Figure 3.15.

NOTE: T~~t~~he Underground Injection Control (UIC) regulations of Chapter 173-218 WAC apply to stormwater infiltration systems, although those regulations contain exemptions for various kinds of stormwater infiltration systems. These regulations are implemented by the Washington State Department of Ecology, and Snohomish County recommends that the applicant contact that department for project-specific determinations about UIC regulation applicability. Snohomish County does not implement or enforce the state UIC regulations.

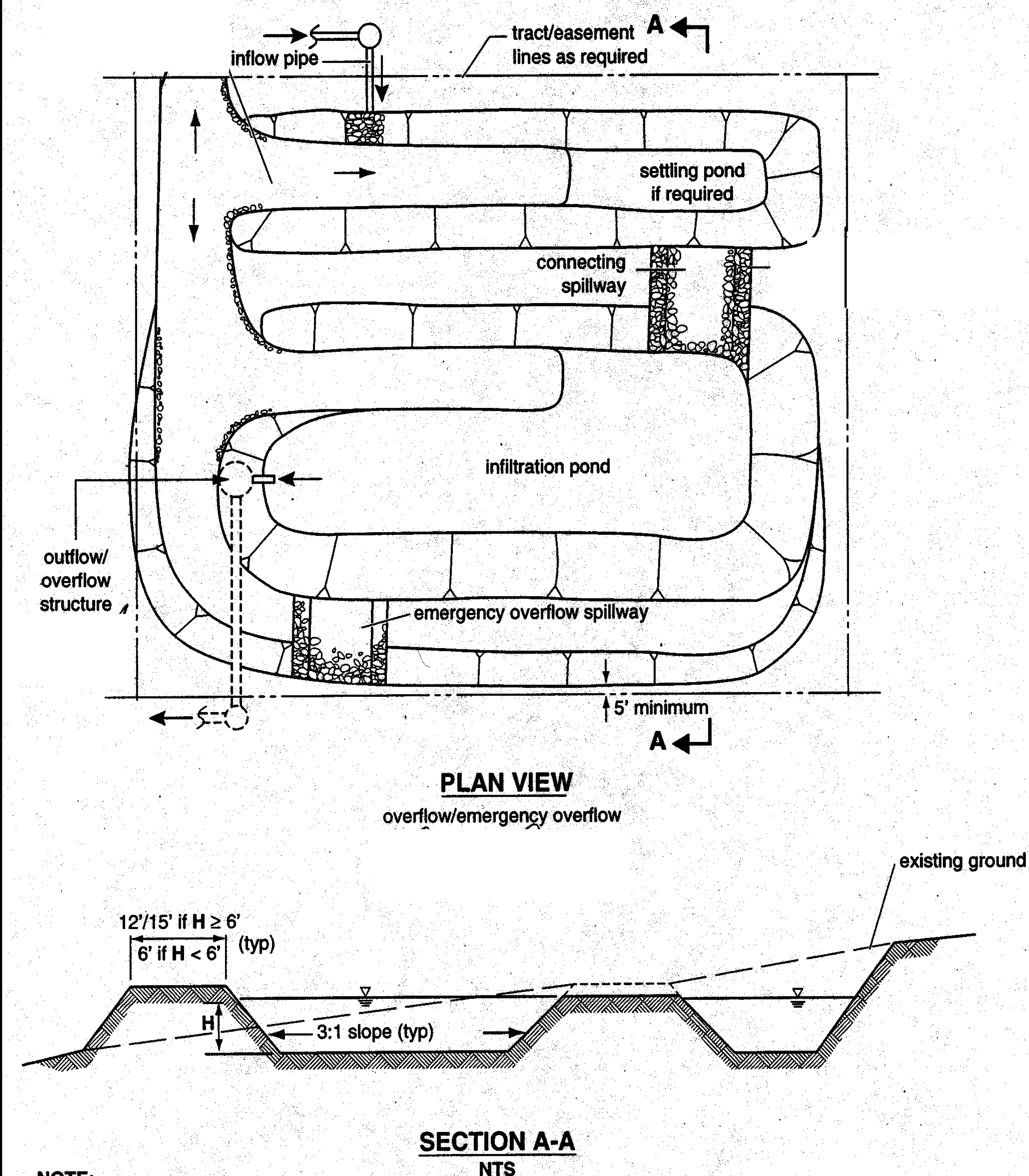
3.3.3 Applications

Infiltration facilities can be used to provide compliance with the LID performance standard of Minimum Requirement 5 set forth in SCC 30.63A.525, the stormwater treatment requirements of Minimum Requirement 6 set forth in SCC 30.63A.530, or the flow control requirement of Minimum Requirement 7 set forth in SCC 30.63A.550. Stormwater that does not infiltrate in these facilities must be managed to comply with the flow control requirements of SCC 30.63A.550.

There are two design approaches for infiltration facilities. The Simplified Approach, described in Section 3.3.4, can be used in the following cases:

- determining the trial geometry of an infiltration facility
- designing an infiltration facility for residential short plat projects
- designing an infiltration facility for commercial development projects with less than one acre of contributing area.

The Detailed Approach, described in Section 3.3.8, can be used for all projects and must be used for projects that do not qualify for the Simplified Approach.



NOTE:
Detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 3.15 - Typical Infiltration Pond/Basin

3.3.4 Simplified Approach

1. Select a location~~:~~

Select the location for the proposed facility based on the ability to convey flow to the facility and the expected soil conditions at that location. Conduct a preliminary surface and subsurface characterization study (Section 3.3.5). Do a preliminary review of site suitability based on the Site Suitability Criteria in Section 3.3.7.

2. Estimate volume of stormwater, Vdesign~~:~~

Estimate the volume of stormwater (Vdesign) by using ~~a~~ an approved continuous runoff hydrologic model ~~approved by Snohomish County for the calculations~~. The runoff file developed for the project site serves as input to the infiltration basin.

For infiltration basins sized to meet the stormwater treatment requirement of Minimum Requirement 6 (SCC 30.63A.530), the basin must successfully infiltrate 91% of the influent runoff file. The remaining 9% of the influent file can bypass the infiltration facility. However, if the bypassed flow discharges to a surface water that is not exempt from flow control, the bypassed flow must meet the flow control standard of SCC 30.63A.550.

For infiltration basins sized to meet the flow control standard, the basin must infiltrate either all of the influent file, or a sufficient amount of the influent file such that any overflow/bypass meets the flow duration standard. In addition, the overflow/bypass must meet the LID performance standard if that standard is used to meet Minimum Requirement 5 (SCC 30.63A.525).

3. Develop trial infiltration facility geometry~~:~~

Assume an infiltration rate based on previously available data, or, if those data are not available, use a default infiltration rate of 0.5 inches/hour. This trial facility geometry should be used to help locate the facility and for planning purposes in developing the geotechnical subsurface investigation plan.

4. Complete a~~A~~ More Detailed Site Characterization Study and Evaluate Site Suitability Criteria~~:~~

Perform a site characterization study in accordance with Section 3.3.5~~,~~ and evaluate site suitability in accordance with Section 3.3.7. The geotechnical investigation evaluates the suitability of the site for infiltration, establishes the infiltration rate for design, and evaluates slope stability, foundation capacity, and other geotechnical design information needed to design and assess constructability of the facility.

5. Determine the infiltration rate

Estimate the long-term infiltration rate by first using the Large Scale or Small Scale Pilot Infiltration Test (PIT) method described in Section 3.3.6 to estimate an initial saturated hydraulic conductivity. Testing should occur between December 1 and April 1. For soils not consolidated by glacial advance (e.g., recessional outwash soils), or for public road construction projects, the initial saturated conductivity rate may be estimated using the grain size analysis method described in Section 3.3.6. Assume the saturated hydraulic conductivity is the initial (short-term) infiltration rate for the facility. ~~–~~Calculate the design infiltration rate by adjusting the short-term rate using the appropriate correction factors as described in Section 3.3.6 for the PIT results or the Gradation Analysis results.

6. Determine the size of the infiltration facility, or go to Step 6 of Detailed Approach~~:~~

If the proposed facility meets the criteria for using the Simplified Approach, determine the size of the facility as described below; otherwise, go to Step 6 of the Detailed Approach (see Section 3.3.8).

Ensure that the maximum pond depth stays below the minimum required freeboard. For infiltration facilities intended to meet the stormwater treatment requirements of Minimum Requirement 6, use the output files from the hydrologic model used for design to document that the facility can infiltrate 91~~ percent~~% of the influent runoff file and that the ~~91st percentile, 24-hour runoff volume ~~water quality design volume can infiltrate through the infiltration basin surface within 48 hours. The latter can be calculated by multiplying a horizontal projection of the infiltration basin mid-depth dimensions by the estimated long-term infiltration rate; and multiplying the result by 48 hours.

For infiltration facilities intended to meet the flow control requirement of Minimum Requirement 7, use the output files from the hydrologic model used for design to document that the facility's discharge meets the applicable flow control standard.

For infiltration facilities intended to meet the LID performance standard in Minimum Requirement 5, use the output files from the hydrologic model used for design to document that the facility's discharge meets that standard.

3.3.5 Site Characterization Criteria

Conduct a characterization study containing the information listed below. Information gathered during initial geotechnical investigations shall be used for the site characterization study.

NOTE: See Section 3.3.10 for site characterization methods and tests required to determine feasibility of bioretention and permeable pavement used to meet Minimum Requirement 5, and for design of those BMPs if they are feasible.

Surface Features Characterization:

1. Topography within 500 feet of the proposed facility.
2. Anticipated site use (street/highway, residential, commercial, high-use site).
3. Location of water supply wells within 500 feet of proposed facility.
4. Location of ground water protection areas and/or 1, 5 and 10 year time of travel zones for municipal well protection areas.
5. A description of local site geology, including soil or rock units likely to be encountered, the groundwater regime, and geologic history of the site.

Subsurface Characterization:

Step 1~~.~~

Dig test pits to a depth below the base of the infiltration facility of at least 5 times the maximum design depth of ponded water proposed for the infiltration facility, but not less than 10 feet below the base of the facility. If groundwater is less than 15 feet from the estimated base of facility and a ground water mounding analysis is necessary, determine the thickness of the saturated zone.

Collect representative samples from each soil type and/or unit within the infiltration receptor to a depth below the base of the infiltration facility of 2.5 times the maximum design ponded water depth, but not less than 10 feet. For large infiltration facilities serving drainage areas of 10 acres or more, perform soil grain size analyses on layers up to 50 feet deep (or no more than 10 feet below the water table).

Step 2~~.~~

If the soil grain size method is used to estimate the infiltration rate, obtain samples adequate for the purposes of that method. For infiltration basins, use at least one test pit per 5,000 ft^2 of basin infiltrating surface (in no case less than two per basin). For infiltration trenches, use at least one test pit per 50 feet of trench length (in no case less than two per trench).

The depth and number of test pits and samples shall be increased if, in the judgment of a licensed engineer with geotechnical expertise, a licensed geologist, engineering geologist, hydrogeologist, or other licensed professional acceptable to the Snohomish County, the conditions are highly variable and such increases are necessary to accurately estimate the performance of the infiltration system. The number of test pits may be decreased if, in the opinion of the licensed engineer or other professional, the conditions are relatively uniform and the borings/test pits omitted will not influence the design or successful operation of the facility. At sites with a winter water table less than three feet from the surface, soil sampling need not be conducted lower than two feet below the ground water table.

Step 3~~.~~

Prepare detailed logs for each test pit and a map showing their locations. Logs must include at a minimum, depth of pit, soil descriptions, depth to water, presence or absence of stratification. The licensed professional may consider additional methods of analysis to substantiate the presence of stratification that will significantly impact the design of the infiltration facility.

Step 4~~.~~

Install ground water monitoring wells (or driven well points if expected shallow depth to ground water) to locate the ground water table and establish its gradient, direction of flow, and seasonal variations, considering both confined and unconfined aquifers. For facilities serving a drainage area less than an acre, establish that the depth to ground water or other hydraulic restriction layer will be at least 10 feet below the base of the facility. Use subsurface explorations or information from nearby wells. A minimum of three wells per infiltration facility, or three hydraulically connected surface or ground water features, are needed to determine the direction of flow and gradient. Snohomish County may allow the use of only one monitoring well to make these determinations if the applicant demonstrates in the Stormwater Site Plan, to the County's satisfaction, that there is a low risk of down-gradient impacts. If the ground water in the area is known to be greater than 50 feet below the proposed facility, detailed investigation of the ground water regime is not necessary. Monitoring through at least one wet season is required, unless substantially equivalent site historical data regarding ground water levels is available.

Step 5~~.~~

If using the soil Grain Size Analysis Method for estimating infiltration rates, determine the soil gradation characteristics and other properties necessary to complete the infiltration facility design, in accordance with the requirements set forth in Section 3.3.6.

Soil Testing

Soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered shall include:

- Grain-size distribution (ASTM D422 or equivalent AASHTO specification) if using the grain size analysis method to estimate infiltration rates
- Visual grain size classification
- Percent clay content (include type of clay, if known)
- Color/mottling
- Variations and nature of stratification

If the infiltration facility will provide treatment as well as flow control, the soil characterization shall also include cation exchange capacity (CEC) and organic matter content for each soil type and strata where distinct changes in soil properties occur, to a depth below the base of the facility of at least 2.5 times the maximum design water depth, but not less than 6 feet. For soils with low CEC and organic content, deeper characterization of soils may be warranted (refer to Section 3.3.7 Site Suitability Criteria).

Infiltration Receptor:

The infiltration receptor (unsaturated and saturated soil receiving the stormwater) characterization shall include:

1. The information obtained from ground water monitoring in #4 of the Subsurface Characterization above.
2. An assessment of the ambient ground water quality.
3. An estimate of the volumetric water holding capacity of the infiltration receptor soil. This is the soil layer below the infiltration facility and above the seasonal high-water mark, bedrock, hardpan, or other low permeability layer. Conduct this analysis at a conservatively high infiltration rate based on vadose zone porosity, and the water quality runoff volume to be infiltrated. This, along with an analysis of ground water

movement, will be useful in determining if there are volumetric limitations that would adversely affect drawdown, and if a ground water mounding analysis should be conducted.

4. Determination of:
   - Depth to ground water table and to bedrock/impermeable layers;
   - Seasonal variation of ground water table based on well water levels and observed mottling;
   - Existing ground water flow direction and gradient;
   - Lateral extent of infiltration receptor;
   - Horizontal hydraulic conductivity of the saturated zone to assess the aquifer's ability to laterally transport the infiltrated water;
   - Impact of the infiltration rate and volume at the project site on ground water mounding, flow direction, and water table; and
   - T~~t~~he discharge point or area of the infiltrating water.

Conduct a ground water mounding analysis at all sites where the depth to seasonal ground water table or low permeability stratum is less than 15 feet from the estimated bottom elevation of the infiltration facility, and the area contributing runoff to the infiltration facility is one acre or larger.

3.3.6 Determining the Design Saturated Hydraulic Conductivity

The design saturated hydraulic conductivity ($K_{sat,design}$) shall be determined by measuring the initial saturated hydraulic conductivity ($K_{sat, initial}$) by one of three field methods, then correcting that initial value by applying correction factors. The correction factors are derived by different methods depending on whether the Simplified Approach (Section 3.3.4) or the Detailed Approach (Section 3.3.8) is used for design of the infiltration facility.

The Large-Scale Pilot Infiltration Test (PIT) method may be used to determine the initial saturated hydraulic conductivity for all projects.

The Small-Scale PIT method may be used if the drainage area to the infiltration facility is less than 1 acre, or if the soil analysis shows that 50% or more of the sand fraction remains on the #40 sieve and the site geotechnical investigation suggests uniform subsurface characteristics for the project site. The Small-Scale PIT method may also be used for design of bioretention systems that will be used to infiltrate stormwater, and for permeable pavement.

The Soil Grain Size Analysis method may be used if the soil is recessional outwash or similar soil that has not been compacted by glacial advance.

Determining $K_{sat, initial}$ b~~B~~y Large-Scale Pilot Infiltration Test (PIT) Method

- Excavate the test pit to the estimated surface elevation of the proposed infiltration facility. Lay back the slopes or shore the sides of the test pit as needed to avoid caving or erosion of the sideslopes during the test.
- The plan view surface area of the bottom of the test pit shall be approximately 100 square feet. Accurately document the size and geometry of the test pit.
- Install a vertical measuring rod of a minimum 5-foot length marked in half-inch increments in the center of the pit bottom to measure water depth.
- Use a rigid 6-inch-diameter pipe with a splash plate on the bottom to convey water to the pit.
- Taking care to minimize excessive disturbance of the pit bottom or sideslopes, add water to the pit at a rate that will maintain a 6-12 inch water level above the bottom of the pit. (Note: for infiltration facilities that will serve areas greater than 5 acres and for which the maximum water depth is multiple feet, the maintained test water depth may be greater than one foot.) At intervals of 15 to 30 minutes, record the cumulative volume of water added, instantaneous flow rate, and water depth. Continue adding water at a rate that maintains the water depth for at least one hour after the measured flow rate does not by more than 5%, and for no less than 6 hours.
- After the flow rate has stabilized for at least one hour, turn off the water and measure water depth at 15-minute intervals until the pit is empty. Use these data to calculate $K_{sat, initial}$ in inches / hour.
- When the pit is empty, excavate the bottom of the pit to determine whether, in the judgment of the project engineer or certified soils professional, a mounding analysis is necessary.

Determining $K_{sat, initial}$ By Small-Scale Pilot Infiltration Test (PIT) Method

As noted above, this method may be used if the drainage area to the infiltration facility is less than 1 acre, or if the soil analysis shows that 50% or more of the sand fraction remains on the #40 sieve and the site geotechnical investigation suggests uniform subsurface characteristics for the project site. NOTE: Section 3.3.10 of this volume contains instructions for using the Small-Scale PIT method to determine $K_{sat, initial}$ for bioretention systems and permeable pavement.

- Excavate the test pit to the estimated surface elevation of the proposed infiltration facility. Lay back the slopes or shore the sides of the test pit as needed to avoid caving or erosion of the sideslopes during the test.
- The plan view surface area of the bottom of the test pit shall be 12 to 32 square feet. Document the size and geometry of the test pit.
- Install a vertical measuring rod marked in half-inch increments in the center of the pit bottom to measure water depth.

- Use a rigid pipe of diameter between 3 inches and 4 inches with a splash plate on the bottom to convey water to the pit.
- Pre-soak period: taking care to minimize excessive disturbance of the pit bottom or sideslopes, add water to the pit so that there is at least 12 inches of standing water in the pit for at least six hours.
- Following the six-hour pre-soak period, add water to the pit at a rate that will maintain a 6-12 inch water level above the bottom of the pit. At intervals of 15 to 30 minutes, record the cumulative volume of water added, instantaneous flow rate, and water depth. Continue adding water at a rate that maintains the water depth for at least one hour after the measured flow rate does not by more than 5%, and for no less than 6 hours.
- After the flow rate has stabilized for at least one hour, turn off the water and measure water depth at 15-minute intervals until the pit is empty. Use these data to calculate $K_{sat,\ initial}$ in inches / hour.
- When the pit is empty, excavate the bottom of the pit to determine whether, in the judgment of the project engineer or certified soils professional, a mounding analysis is necessary.

Soil Grain Size Analysis Method

As noted above, this method may be used if the soil is recessional outwash or similar soil that has not been compacted by glacial advance, or for public road construction projects.

- Using ASTM soil size distribution test procedure (ASTM D422), analyze the soil particle size distribution in each defined layer below the infiltration pond to a depth below the pond bottom of 2.5 times the maximum depth of water in the pond, but not less than 10 feet.
- Estimate the initial saturated hydraulic conductivity $K_{sat,\ initial}$ (cm/sec) using the following equation:

$$\log 10 (K_{sat,\ initial}) = -1.57 + 1.9\ D_{10} + 0.015\ D_{60} - 0.013\ D_{90} - 2.08\ f_{fines}$$

in which

D_{10} = grain size diameter (mm) for which 10% of the sample by weight is more fine

D_{60} = grain size diameter (mm) for which 60% of the sample by weight is more fine

D_{90} = grain size diameter (mm) for which 90% of the sample by weight is more fine

f_{fines} = fraction of the sample by weight that passes a #200 soil sieve.

For large infiltration facilities serving drainage areas of 10 acres or more, soil grain size analyses should be performed on layers up to 50 feet deep (or no more than 10 feet below the water table).

If the licensed professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the facility, soil layers at greater depths must be considered when assessing the site's hydraulic conductivity characteristics. Only the layers near and above the water table or low permeability zone (e.g., a clay, dense glacial till, or rock layer) need to be considered, as the layers below the ground water table or low permeability zone do not significantly influence the rate of infiltration. This equation for estimating K_{sat} assumes minimal compaction consistent with the use of low to moderate ground pressure excavation equipment, e.g., tracked equipment.

Once the $K_{sat,\ initial}$ for each layer has been identified, determine the harmonic mean of the $K_{sat,\ initial}$ values using the following equation:

$$\text{harmonic mean } K_{sat,\ initial} = d / \sum (d_i / K_i)$$

in which

d = total thickness of analyzed soil column

d_i = thickness of soil layer i

$K_i = K_{sat,\ initial}$ for soil layer i

The thickness of the soil column (*d*) typically would include all layers between the pond bottom and the water table. For sites with water tables greater than 100 feet below the ground surface where ground water mounding to the base of the pond is not likely to occur, analyze the soil to a depth of 20 times the depth of pond or 50 feet, whichever is less.

For sites where the lowest conductivity layer is within five feet of the base of the pond, or for designing bioretention facilities and permeable pavement, use the lowest $K_{sat,\ initial}$ value for the equivalent hydraulic conductivity.

Calculating $K_{sat,\ design}$ for infiltration basins (BMP T7.10) and infiltration trenches (BMP T7.20)

For infiltration basins (BMP T7.10) and infiltration trenches (BMP T7.20), the design saturated hydraulic conductivity $K_{sat,\ design}$ shall be calculated from the $K_{sat,\ initial}$ value by using the correction factor values in Table 3.5 and the equation

$$K_{sat,\ design} = K_{sat,\ initial} * CF_V * CF_t * 0.9$$

in which

CF_V = site variability correction factor

CF_t = test method uncertainty correction factor

0.9 = long-term conductivity loss correction factor

Table 3.5 - $K_{sat,\ design}$ Correction Factors for Infiltration Basins and Trenches

CF_V – highly uniform soils on project site	1.0
CF_V – highly uniform soils on project site, only one test performed for multiple facilities	0.7
CF_V – variable soils on project site, only one test performed for multiple facilities	0.4
CF_t – Large-scale PIT	0.75
CF_t – Small-scale PIT	0.5
CF_t – Grain Size Analysis	0.4

3.3.7 Site Suitability Criteria (SSC)

This section provides criteria that must be considered for siting infiltration systems. When a site investigation reveals that any of the applicable criteria cannot be met appropriate mitigation measures must be implemented so that the infiltration facility will not pose a threat to safety, health, and the environment.

For site selection and design decisions a geotechnical and hydrogeologic report shall be prepared by a qualified engineer with geotechnical and hydrogeologic experience, or a licensed geologist, hydrogeologist, or engineering geologist. The design engineer may utilize a team of certified or registered professionals in soil science, hydrogeology, geology, and other related fields.

SSC-1 Setbacks and S~~s~~eparations for I~~i~~nfiltration F~~f~~acilities

Setback and separation distances for infiltration facilities are set forth in SCC 30.63A.710 and Snohomish County EDDS Chapter 5-11 for open infiltration ponds and EDDS Chapter 5-18 for closed infiltration vaults. In addition, the following separation distances are required for stormwater infiltration facilities (both open and closed).

- 100 feet from drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies. Infiltration facilities upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Washington State Department of Health requirements. Snohomish County may require a larger setback if roadway deicers or herbicides are likely to be present in the influent to the infiltration system.
- 20 feet from critical area protection areas

- Evaluate on-site and off-site structural stability due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties, especially on hills with known side-hill seeps.
- NOTE: T~~t~~he Washington State Department of Ecology, Washington State Department of Health, or the Snohomish Health District may have additional setback and separation requirements.

SSC-2 Ground Water Protection Areas

A site is not suitable if the infiltration facility will cause a violation of Washington State ground water quality standards (Chapter 173-200 WAC). The project applicant shall determine the need for pollutant removal requirements upstream of the infiltration facility and shall document these determinations in the Stormwater Site Plan. The applicant shall also determine whether the site is located in an aquifer sensitive area, sole source aquifer, or a wellhead protection zone, and incorporate appropriate protection measures into the project on the basis of these determinations.

SSC-3 High Vehicle Traffic Areas

An infiltration BMP may be considered for runoff from areas of industrial activity and the high vehicle traffic areas described below. For such applications sufficient pollutant removal (including oil removal) must be provided upstream of the infiltration facility to ensure that ground water quality standards will not be violated and that the infiltration facility is not adversely affected.

High Vehicle Traffic Areas are:

- Commercial or industrial sites subject to an expected average daily traffic count (ADT) ≥100 vehicles/1,000 ft^2 gross building area (trip generation), and
- Road intersections with an ADT of ≥ 25,000 on the main roadway, and ≥ 15,000 on any intersecting roadway.

SSC-4 Soil Infiltration Rate/Drawdown Time

For infiltration facilities used for treatment purposes, the measured (initial) soil infiltration rate shall be a maximum of 9.0 inches/hour, to a depth of 2.5 times the maximum design pond water depth, or a minimum of 6 ft. below the base of the infiltration facility. Design (long-term) infiltration rates up to 3.0 inches/hour can also be considered if the infiltration receptor is not a sole-source aquifer, and, in the judgment of the site professional, the treatment soil has characteristics comparable to those specified in SSC-6 to adequately control the target pollutants. The design infiltration rate shall also be used for maximum drawdown time and routing calculations.

There is no maximum drawdown time for infiltration facilities designed only to meet flow control requirements. If sizing a treatment facility, document that the water quality design ~~storm runoff~~ volume ~~(indicated by WWHM or MGS Flood, or runoff from a 6-month, 24-hour storm)~~ can infiltrate through the infiltration basin surface within 48 hours. This can be calculated by multiplying the ~~a~~ horizontal projection of the infiltration basin mid-depth dimensions and the estimated long-term infiltration rate, and multiplying the result by 48 hours.

This drawdown restriction is intended to meet the following objectives:

- aerate vegetation and soil to keep the vegetation healthy
- enhance the biodegradation of pollutants and organics in the soil.

Note that this is a check procedure, not a method for determining basin size. If the design fails the check procedure, redesign the basin.

SSC-5 Depth to Bedrock, Water Table, or Impermeable Layer

The base of all infiltration basins or trench systems shall be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan) or other low permeability layer. A separation down to 3 feet may be allowed if the ground water mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures meet the site suitability criteria specified in this section and will prevent overtopping.

SSC-6 Soil Physical and Chemical Suitability for Treatment

(Applies to infiltration facilities used as treatment facilities, not to facilities used for flow control)

The soil texture and design infiltration rates shall be considered along with the physical and chemical characteristics specified below to determine if the soil is adequate for removing the target pollutants. The following soil properties shall be used in making such a determination:

- Cation exchange capacity (CEC) of the treatment soil must be ≥5 milliequivalents CEC/100 grams dry soil as measured by USEPA Method 9081, Cation Exchange Capacity of Soils (Sodium Acetate).
- Depth of soil used for infiltration treatment must be a minimum of 18 inches.
- Organic Content of the treatment soil must be 1 per cent or greater, as measured by ASTM D2974–07 - Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils.
- Waste fill materials shall not be used as infiltration soil media nor shall such media be placed over uncontrolled or non-engineered fill soils.
- Engineered soils may be used to meet the design criteria in this chapter and the performance goals in Chapters 3 and 4 of Volume V.

SSC-7 Seepage Analysis and Control

Determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites.

SSC-8 Cold Climate and Impact of Roadway Deicers

Consider the potential impact of roadway deicers on potable water wells in the siting determination. Implement mitigation measures if the infiltration of roadway deicers could cause a violation of ground water quality standards.

3.3.8 Detailed Approach

Steps 1 – 5

Implement as set forth for the Simplified Approach set forth in Section 3.3.4.

Step 6: -Calculate the hydraulic gradient

Note: The units in this equation vary from the units normally used in this manual.

Calculate the steady state hydraulic gradient "i" as:

$$i = \{ (D_{wt} + D_{pond}) * CF_{size} \} / 138.62 * K^{0.1}$$

in which

D_{wt} = depth from base of infiltration facility to water table (feet)

D_{pond} = 0.25 * maximum depth of water in the facility (feet)

CF_{size} = correction factor for pond size

K = saturated hydraulic conductivity (feet / day)

For ponds with a bottom area of less than or equal to 0.6 acres, CF_{size} = 1, and for ponds with a bottom area of 6 acres or more, CF_{size} = 0.2. For ponds with a bottom area greater than 0.6 acres and less than 6 acres, CF_{size} is calculated as:

$$CF_{size} = 0.73 * (\text{pond bottom area in acres})^{-0.76}$$

This equation generally will result in a calculated gradient of less than 1.0 for moderate to shallow ground water depths (or to a low permeability layer) below the facility, and conservatively accounts for the development of a ground water mound. A more detailed ground water mounding analysis using a program such as MODFLOW will usually result in a gradient that is equal to or greater than the gradient calculated as above. If the calculated gradient is greater than 1.0, the water table is considered to be deep, and a maximum gradient of 1.0 must be used. Typically, a depth to ground water of 100 feet or more is required to obtain a gradient of 1.0 or more using this equation.

Step 7: ——Calculate the preliminary design infiltration rate f_{prelim} using the following equation

$$f_{prelim} = Ki$$

Step 8: ——Determine the final design infiltration rate f_{design} by adjusting the preliminary design infiltration rate f_{prelim} for the effect of pond aspect ratio A_r

Determine the pond aspect ratio A_r as follows:

A_r = pond aspect ratio = (pond bottom length / pond bottom width)

Determine the pond aspect correction factor CF_{aspect} as follows:

$$CF_{aspect} = 0.02\ A_r + 0.98$$

If CF_{aspect} is less than 1.4,

$$f_{design} = f_{prelim} * CF_{aspect}$$

If CF_{aspect} is 1.4 or greater,

$$f_{design} = f_{prelim} * 1.4$$

Step 9: Determine the size of the infiltration facility

See Section 3.3.9.

Step 10: Ground Water Mounding Analysis

On projects where an infiltration facility has a drainage area exceeding 1 acre and has less than fifteen feet depth to seasonal high ground water (as measured from the bottom of the infiltration basin or trench) or other low permeability stratum, determine the final design infiltration rate using an analytical ground water model to investigate the effects of the local hydrologic conditions on facility performance. These larger projects can use the design infiltration rate determined above as input to an approved continuous runoff hydrologic model to do an initial sizing. Then complete the ground water modeling (mounding analysis) of the proposed infiltration facility. Use MODRET or an equivalent model unless the local government approves an alternative analytic technique. Export the full output hydrograph of the developed condition and use it as input to MODRET. Note that an iterative process may be required beginning with an estimated design rate, ~~WWHM~~ sizing, then ground water model testing.

Step 11: Performance Testing

Test and monitor the constructed facility to demonstrate that the facility performs as designed. Use the same test methods for saturated hydraulic conductivity as used in the planning stages so that results are comparable. Perform the testing after stabilizing the construction site. Submit the results and comparisons to the pre-project measured (initial) and design rates to the local stormwater authority that approved the project design. If the rates are lower than the design saturated hydraulic conductivity, the applicant shall implement measures to improve infiltration capability within the footprint of the constructed facility and re-test. If less intensive measures prove unsuccessful, replacement of the top foot of soil – or more if visual observation indicates deeper fouling of the bed with fine sediment – with a soil meeting the design needs (i.e., treatment, flow control, or both) shall be provided. Longer-term monitoring of drawdown times and periodic testing of the facility should provide an indication of when the facility needs maintenance to restore infiltration rates.

3.3.9 Calculating the Size of Infiltration Facilities

The size of the infiltration facility shall be determined by routing the influent runoff file generated by the continuous runoff hydrologic model through it. To prevent the onset of anaerobic conditions, an infiltration facility designed for treatment purposes must be designed to drain the water quality design volume within 48 hours (see Section 3.3.7, SSC-4.) In general, an infiltration facility has two discharge modes. The primary mode of discharge from an infiltration facility is infiltration into the ground. However, when the infiltration capacity of the facility is reached, additional runoff to the facility will cause the facility to overflow. Overflows from an infiltration facility must comply with the flow control requirements of Minimum Requirement 7 (see SCC 30.63A.550). Infiltration facilities used for runoff treatment must not overflow more than 9% of the influent runoff file. Infiltration facilities may used to comply with the performance standard requirement of Minimum Requirement 5, in which case the overflow discharges must match developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 8% of the 2-year peak flow to 50% of the 2-year peak flow.

In order to determine compliance with the flow control requirements~~, the Western Washington Hydrology Model (WWHM), or an appropriately calibrated continuous simulation model based on HSPF,~~ an approved continuous runoff hydrologic model must be used. When using WWHM2012 for simulating flow through an infiltrating facility, represent the facility by using a Pond Element and entering the pre-determined infiltration rates. Below are the procedures for sizing an infiltration facility (A) to completely infiltrate 100% of runoff; (B) to treat 91% of runoff to meet the water quality treatment requirements, and (C) to partially infiltrate runoff in conjunction with a detention facility that provides flow control for the overflow from the infiltration facility.

(A) For 100% infiltration

1. ~~(1)~~ Enter dimensions of the infiltration pond,
2. ~~(2)~~ Enter the infiltration rate and safety (rate reduction) factor. When using the Simplified Approach, enter the measured (initial) saturated hydraulic conductivity (Ksat) and the Total Correction Factor as determined using Section 3.3.6; OR, enter the estimated final design infiltration rate after application of the correction factor and a safety factor of 1. For the Detailed Approach, enter your preliminary design infiltration rate after completing Steps 1 through 7 (in Section 3.3.8), then enter the correction factor for the pond aspect, as noted in Step 8 (in Section 3.3.8), as the safety factor in the model input.
3. ~~(3)~~ Enter a riser height and diameter.
4. ~~(4)~~ Run only HSPF for Developed Mitigated Scenario. –Do not run “Duration.”
5. ~~(5)~~ Check the Percentage Infiltrated. If less than 100% of the influent infiltrated, increase pond the dimensions and repeat this procedure until 100% infiltration occurs.

(B) For 91% infiltration (water quality treatment volume)

The procedure is the same as above, except that the target infiltration volume is 91%.

Infiltration facilities for treatment can be located upstream or downstream of detention and can be off-line or on-line.

An ***on-line*** infiltration treatment facility placed ***upstream or downstream*** of a detention facility must be sized to infiltrate 91% of the runoff file volume directed to the infiltration facility.

An ***off-line*** infiltration treatment facility placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at or below the ~~15-minute~~ water quality flow rate, as predicted by ~~WWHM (or other~~an approved continuous runoff hydrologic model~~)~~, to the infiltration facility. Within ~~the~~ WWHM2012, the flow splitter icon is placed ahead of the pond element which represents the infiltration facility. The infiltration facility must be sized to infiltrate all the runoff sent to it (no overflows from the infiltration facility are allowed).

An ***off-line*** infiltration treatment facility placed ***downstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention pond, as predicted by ~~WWHM (or other~~an approved continuous runoff hydrologic model~~)~~, to the infiltration facility. Within ~~the~~ WWHM2012, the flow splitter icon is placed ahead of the pond element which represents the infiltration facility. The infiltration facility must be sized to infiltrate all the runoff sent to it (no overflows from the infiltration facility are allowed).

See Volume V, Section 4.5.1 information on flow splitter design.

(C) Partial infiltration with detention system providing flow control for the stormwater not infiltrated

A detention facility can be placed downstream of an infiltration facility that does not provide 100% infiltration. Design the detention facility to meet the flow duration standard of Minimum Requirement 7, and, if required, of Minimum Requirement 5.

BMP T7.10 Infiltration Basin

Description

Infiltration basins are earthen impoundments used for the collection, temporary storage and infiltration of incoming stormwater runoff.

Design Criteria for Infiltration Basins

Engineering standards and specifications for infiltration basins are set forth in Section 5-11 of Snohomish County EDDS.

For infiltration treatment facilities constructed in soils with very low permeability or in engineered soils, line the sidewalls of the facility with a minimum of 18 inches of treatment soil to prevent seepage of untreated flows through the sidewalls.

Maintenance

Maintenance requirements for drainage facilities are set forth in Chapter 7.54 SCC and Volume V, Chapter 4.6 of this manual.

BMP T7.20 Infiltration Trench

This section covers design, construction, and maintenance criteria specific for infiltration trenches.

Description

Infiltration trenches are generally at least 24 inches wide, and are backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed covered area with a surface inlet.

See Figures 3.16 for schematic of an infiltration trench and Figures 3.17 through 3.21 examples of trench designs. Figure 3.22 shows a schematic drawing of an observation well (see also Figure 3.16).

Engineering standards and specifications for infiltration trenches are set forth in Section 5-14 of Snohomish County EDDS.

Design Criteria and Maintenance Standards

- Standards and specifications for infiltration trenches are set forth in Chapter 5, Section 5-14 of Snohomish County EDDS. Maintenance requirements for drainage facilities are set forth in Chapter 7.54 SCC and Volume V, Chapter 4.6 of this manual.

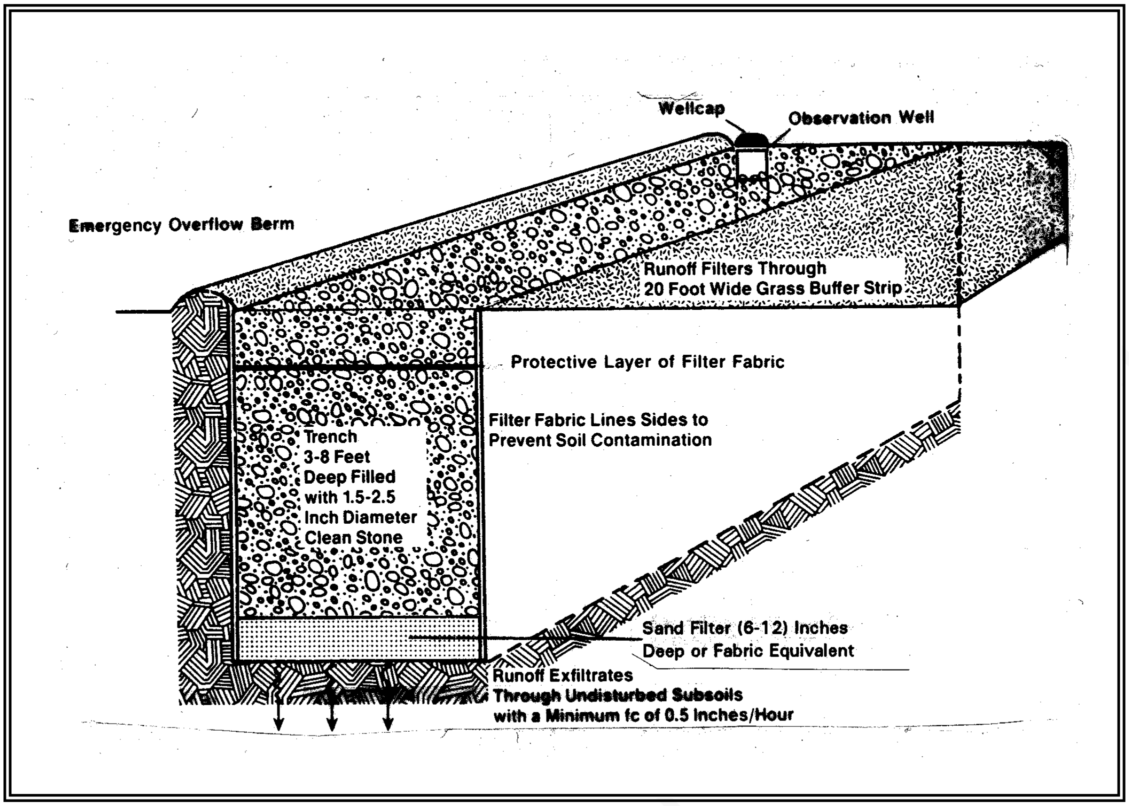


Figure 3.16 -– Schematic of an Infiltration Trench

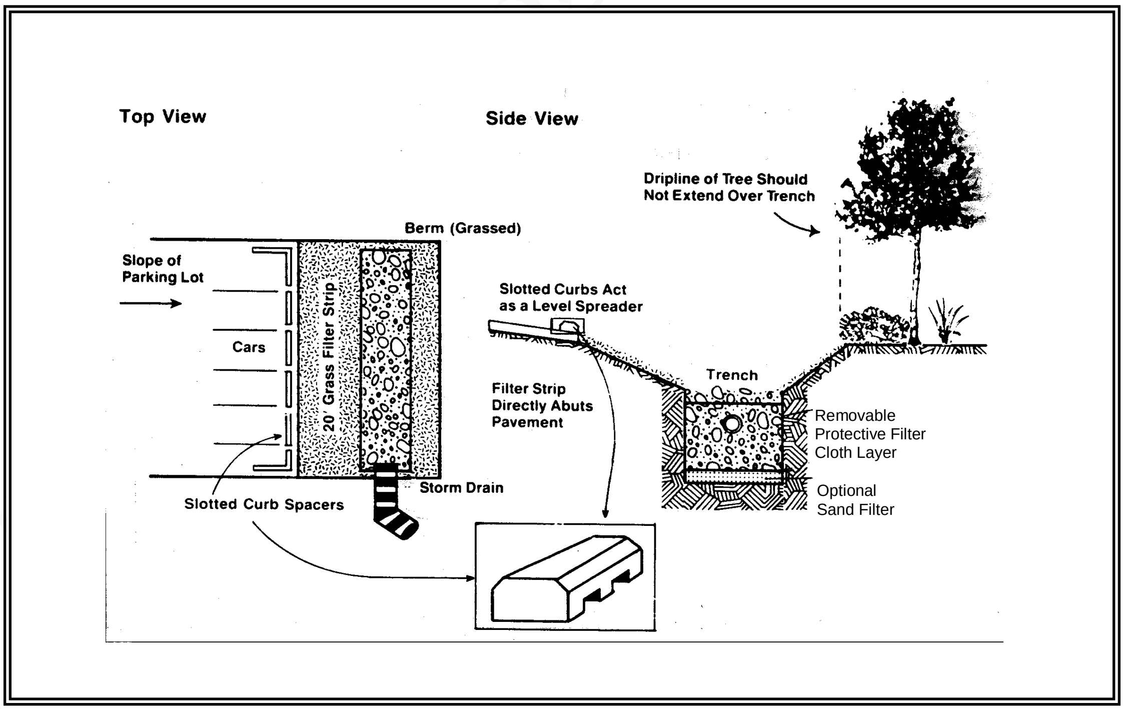


Figure 3.17 -– Parking Lot Perimeter Trench Design

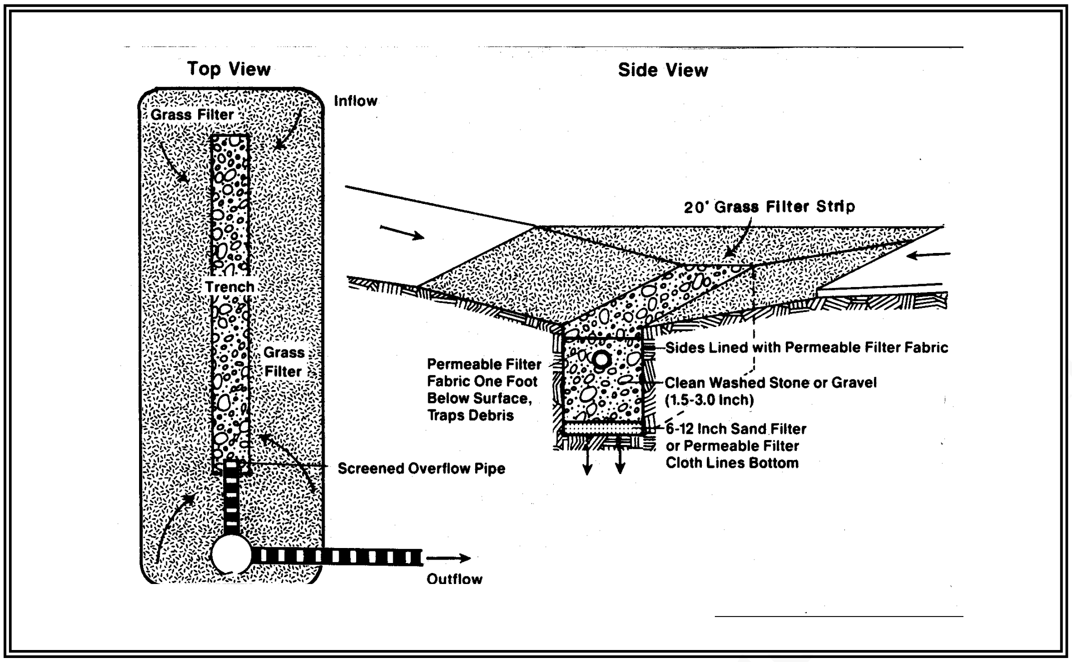


Figure 3.18 - Median Strip Trench Design

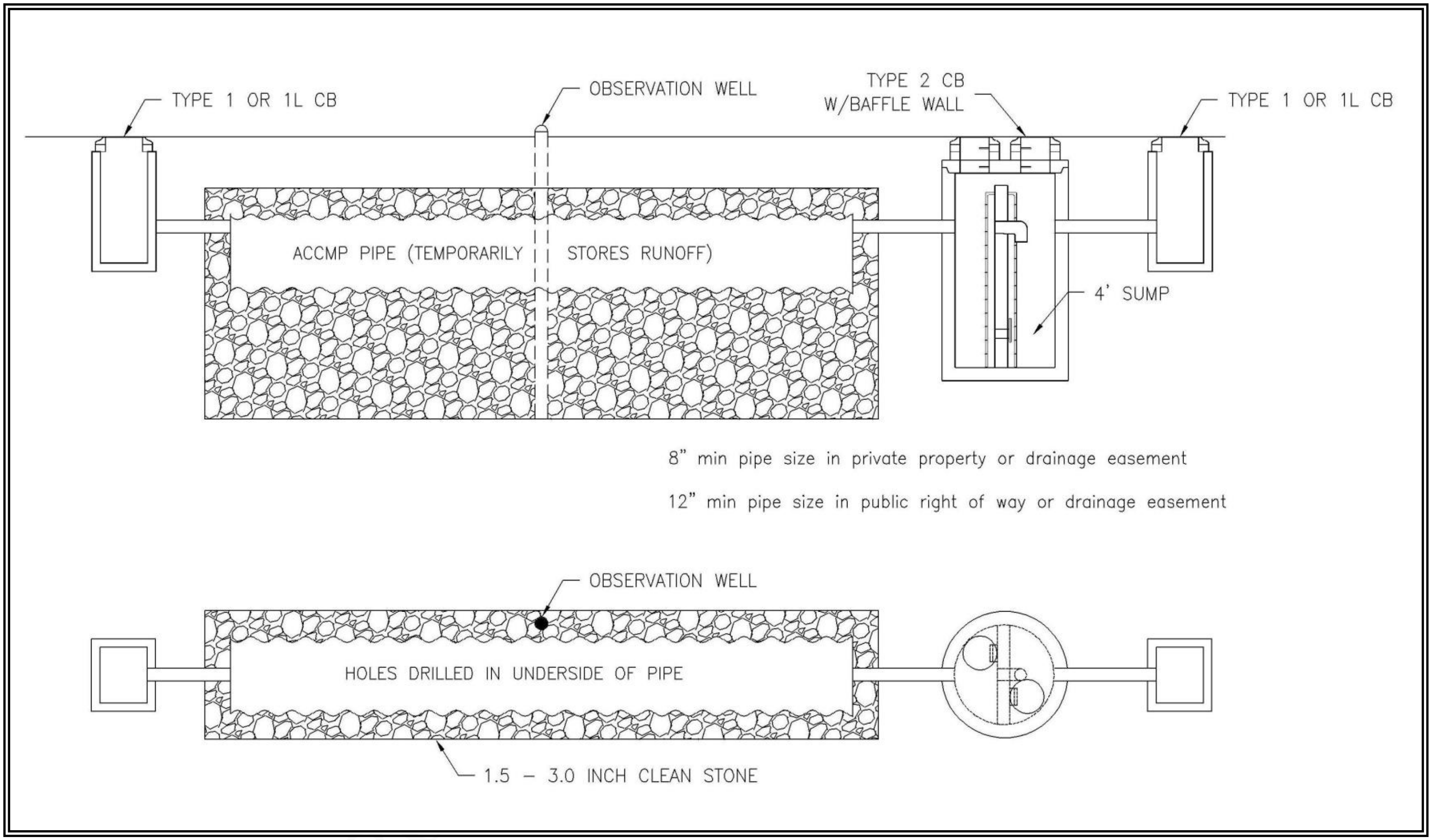


Figure 3.19 - Oversized Pipe Trench Design

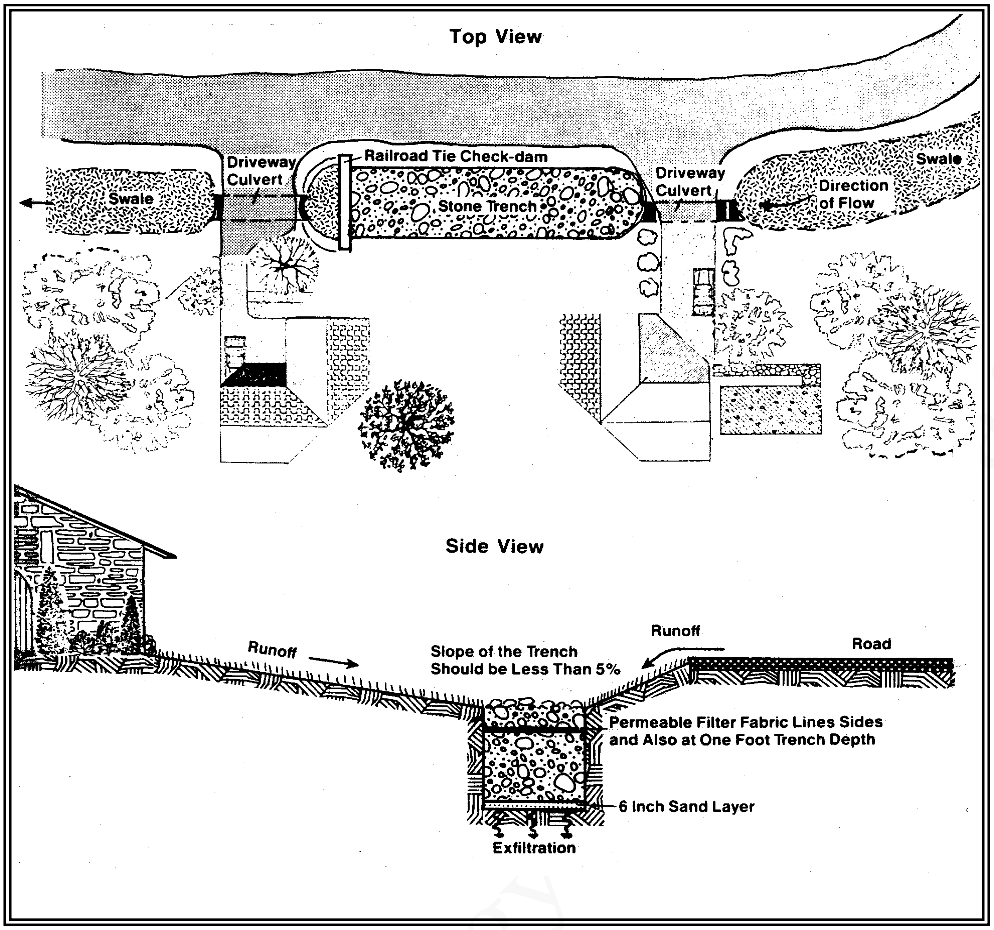


Figure 3.20 – Swale/Trench Design

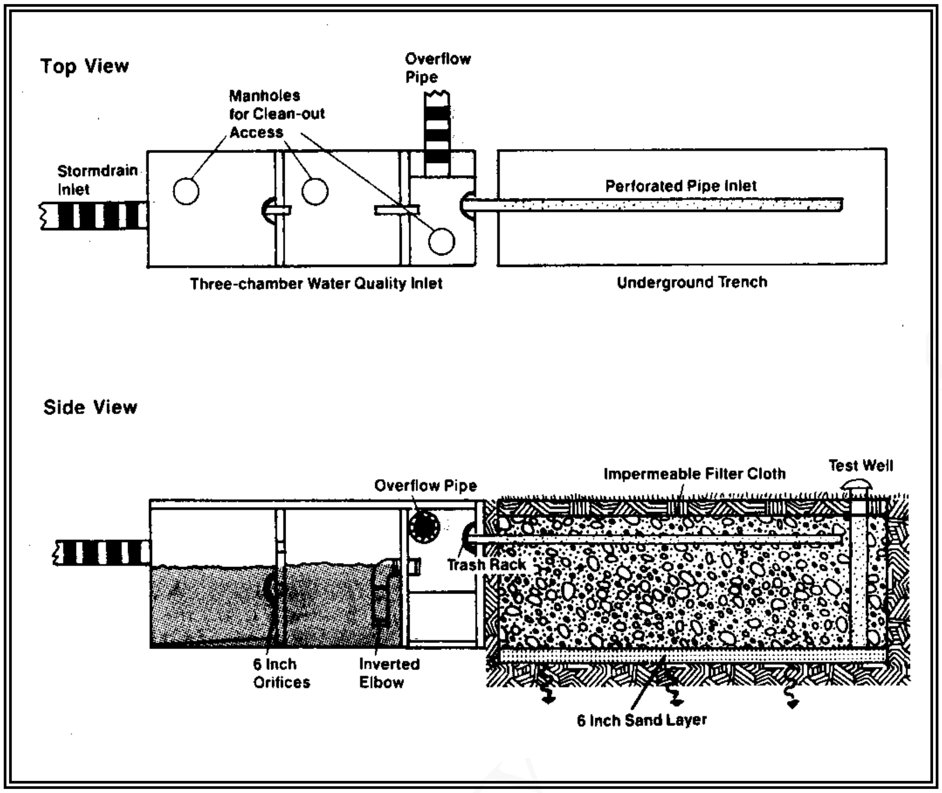


Figure 3.21 - Underground Trench with Oil/Grit Chamber

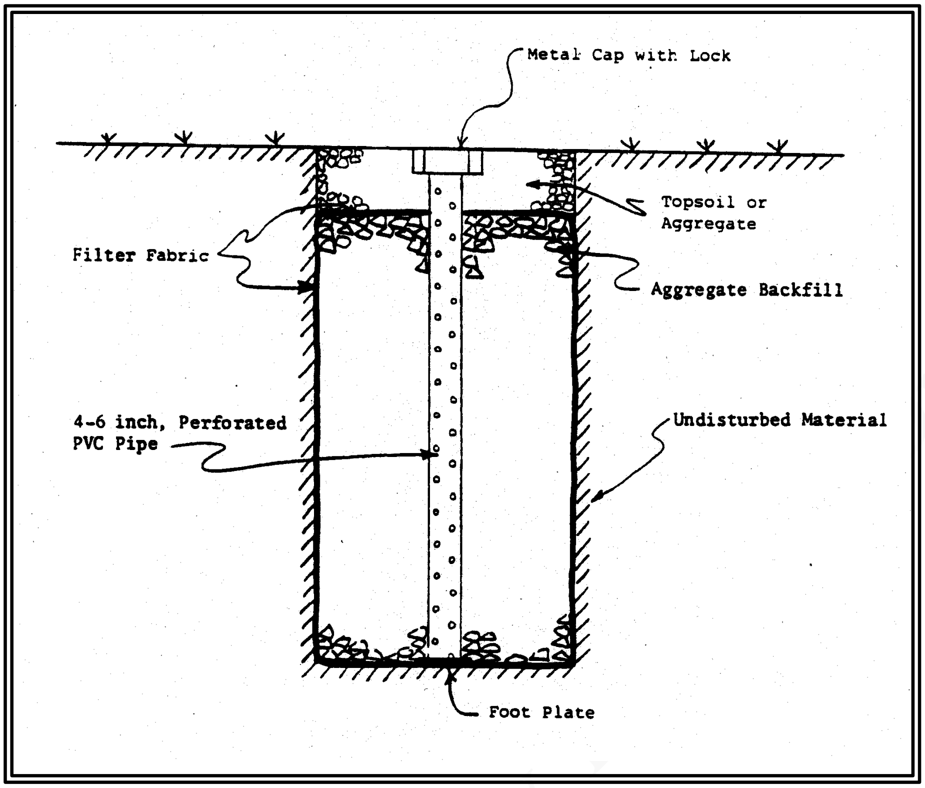


Figure 3.22 - Observation Well -(as shown in Figure 3.16)

3.3.10 Test Requirements for Infeasibility Determination and Selected Design Aspects of Bioretention and Permeable Pavement

This section sets forth test requirements for infeasibility determination and selected design aspects of bioretention and permeable pavement. Much of the information mirrors that applicable to larger-scale infiltration facilities, but some of the specific requirements (such as the required depth of excavation needed for testing) are less stringent for these BMPs.

BMP T7.30 in Volume V, Chapter 7 of this manual and Chapter 5 in EDDS sets forth other information for bioretention. BMP T5.15 in Volume V, Chapter 5 of this manual and Chapter 11 in EDDS set forth other information for permeable pavement.

Bioretention

<u>Soil characterization</u>

Analyze each defined layer in the soil from the top of the final bioretention area subgrade to 3 feet below the subgrade.

NOTE: bioretention is categorically determined to be infeasible if bedrock or seasonal high water table are encountered above the following depths:

- *1 foot below the subgrade if the contributing area does not exceed any of the following criteria:*
    - *5,000 square feet of pollution generating impervious surface;*
    - *10,000 square feet of impervious surface; or*
    - *0.75 acres of pervious surface;*
- *3 feet below the subgrade if the contributing area exceeds any of the criteria stated above.*

  In such cases, further soil characterization and determination of saturated hydraulic conductivity are not required to determine infeasibility.

Soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered shall include:

- Grain-size distribution (ASTM D422 or equivalent AASHTO specification)
- Visual grain size classification
- Percent clay content (include type of clay, if known)
- Color/mottling
- Variations and nature of stratification

NOTE: S~~s~~ince treatment is provided by the bioretention soil mix, testing for cation exchange capacity (CEC) and organic matter content is not required.

Initial saturated hydraulic conductivity $K_{sat, initial}$

If the soil is recessional outwash or similar soil that has not been compacted by glacial advance, the initial saturated hydraulic conductivity $K_{sat, initial}$ may be determined by either the small-scale pilot infiltration test (PIT) method or the soil grain size analysis method. Otherwise, the small-scale PIT method must be used.

Small-scale pilot infiltration test (PIT) method for bioretention

- Excavate the test pit to the estimated elevation at which the imported soil mix will lie on top of the underlying native soil. The plan view surface area of the bottom of the test pit shall be 12 to 32 square feet. The excavation used for soil characterization may be used if it is of adequate plan view surface area. Lay back the slopes or shore the sides of the test pit as needed to avoid caving or erosion of the sideslopes during the test.
- Document the size and geometry of the test pit.
- Install a vertical measuring rod marked in half-inch increments in the center of the pit bottom to measure water depth.
- Use a rigid pipe of diameter between 3 inches and 4 inches with a splash plate on the bottom to convey water to the pit.
- Pre-soak period: taking care to minimize excessive disturbance of the pit bottom or sideslopes, add water to the pit so that there is at least 12 inches of standing water in the pit for at least six hours.
- Following the six-hour pre-soak period, add water to the pit at a rate that will maintain a 6-12 inch water level above the bottom of the pit. At intervals of 15 to 30 minutes, record the cumulative volume of water added, instantaneous flow rate, and water depth. Continue adding water at a rate that maintains the water depth for at least one hour after the measured flow rate does not by more than 5%, and for no less than 6 hours.
- After the flow rate has stabilized for at least one hour, turn off the water and measure water depth at 15-minute intervals until the pit is empty. Use these data to calculate $K_{sat, initial}$ in inches / hour.
- When the pit is empty, excavate the bottom of the pit to determine whether, in the judgment of the project engineer or certified soils professional, a mounding analysis is necessary.

Soil grain size analysis

This method may be used if the soil is recessional outwash or similar soil that has not been compacted by glacial advance.

- Using the grain size distribution results from the soil characterization described above, estimate the initial saturated hydraulic conductivity $K_{sat,\ initial}$ (cm/sec) using the following equation:

$$\log 10 (K_{sat,\ initial}) = -1.57 + 1.9\ D_{10} + 0.015\ D_{60} - 0.013\ D_{90} - 2.08\ f_{fines}$$

in which

D_{10} = grain size diameter (mm) for which 10% of the sample by weight is more fine

D_{60} = grain size diameter (mm) for which 60% of the sample by weight is more fine

D_{90} = grain size diameter (mm) for which 90% of the sample by weight is more fine

f_{fines} = fraction of the sample by weight that passes a #200 soil sieve.

<u>Calculating $K_{sat,\ design}$ for bioretention used to comply with Minimum Requirement 5</u>

The design saturated hydraulic conductivity $K_{sat,\ design}$ shall be calculated from the $K_{sat,\ initial}$ value according to the following equation:

$$K_{sat,\ design} = K_{sat,\ initial} * CF_V$$

in which

CF_V = site variability correction factor, ranging from 0.33 to 1.0

The licensed professional preparing the Stormwater Site Plan shall determine the value for CF_V based on the degree to which the tests done for $K_{sat,\ initial}$ are representative of the project site. If an infiltration test is conducted for each bioretention area or the range of uncertainty is low (for example, conditions are known to be uniform through previous exploration and site geological factors), a correction factor of 1.0 is appropriate.

Alternatively, fewer $K_{sat,\ initial}$ tests and or high site variability would merit a lower correction factor.

Since the overlying bioretention soil mix protects the underlying native soil from sedimentation, a correction factor for the extent of influent control and clogging the sub-grade soil over time is not needed.

Permeable pavement

<u>Soil characterization</u>

Analyze each defined layer below the top of the final subgrade to a depth of 1 foot below the subgrade. Soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered shall include:

- Grain-size distribution (ASTM D422 or equivalent AASHTO specification) if using the grain size analysis method to estimate infiltration rates
- Visual grain size classification
- Percent clay content (include type of clay, if known)
- Color/mottling
- Variations and nature of stratification
- Cation exchange capacity (CEC) (USEPA Method 9081, Cation Exchange Capacity of Soils (Sodium Acetate))
- Organic matter content (ASTM D2974–07 - Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils)

<u>Initial saturated hydraulic conductivity $K_{sat,\ initial}$</u>

If the soil is recessional outwash or similar soil that has not been compacted by glacial advance, the initial saturated hydraulic conductivity $K_{sat,\ initial}$ may be determined by either the small-scale pilot infiltration test (PIT) method or the soil grain size analysis method. Otherwise, the small-scale PIT method must be used.

Small-Scale Pilot Infiltration Test (PIT) Method

Perform test as described above for bioretention, with the following exceptions:

- For design of a permeable pavement installation, excavate to one foot below the final subgrade.
- If the native soils will have to meet a minimum subgrade compaction requirement, compact the native soil to that requirement prior to testing. Permeable pavement design in accordance with BMP T7.30 requires compaction to 90% - 92%.

Soil grain size analysis

This method may be used if the soil is recessional outwash or similar soil that has not been compacted by glacial advance.

Perform test as described above for bioretention.

Calculating $K_{sat, design}$ for permeable pavement used to comply with Minimum Requirement 5

The design saturated hydraulic conductivity $K_{sat, design}$ shall be calculated from the $K_{sat, initial}$ value according to the following equation:

$$K_{sat, design} = K_{sat, initial} * CF_v * CF_m$$

in which

CF_v = site variability correction factor, ranging from 0.33 to 1.0

CF_m = pavement base material correction factor, ranging from 0.9 to 1.0

The licensed professional preparing the Stormwater Site Plan shall determine the value for CF_v based on the degree to which the tests done for $K_{sat, initial}$ are representative of the project site. If an infiltration test is conducted for each permeable pavement area or the range of uncertainty is low (for example, conditions are known to be uniform through previous exploration and site geological factors), a correction factor of 1.0 is appropriate. Alternatively, fewer $K_{sat, initial}$ tests and or high site variability would merit a lower correction factor.

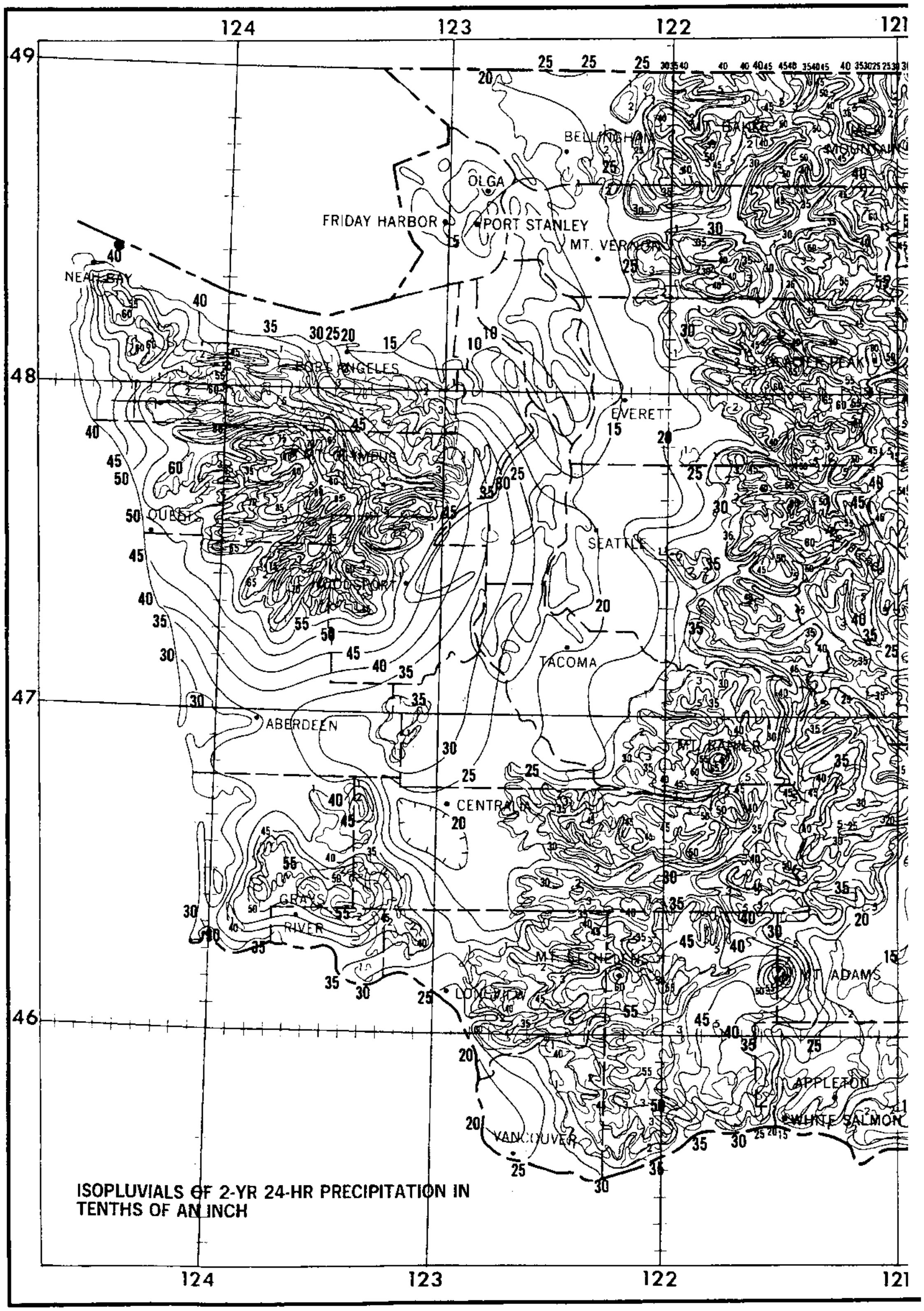
The licensed professional preparing the Stormwater Site Plan shall determine the value for CF_m based on the quality of the aggregate base material. A correction factor of 1.0 may be used if the aggregate base material is clean washed material with 1% or less fines passing the 200 sieve; otherwise, a correction factor of 0.9 shall be used.

Appendix III-A
Isopluvial Maps for Design Storms

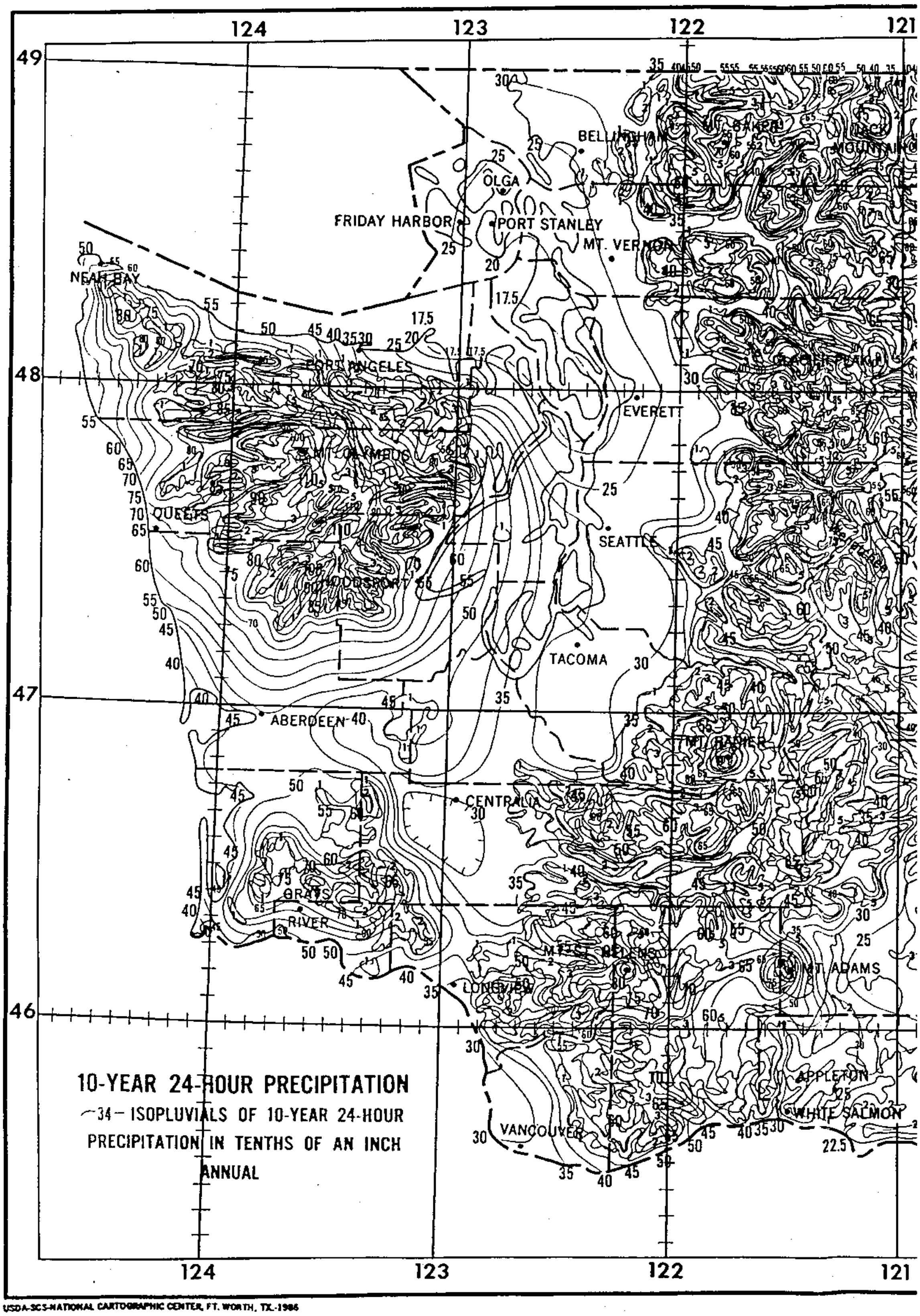
Included in this appendix are the 2, 10 and 100-year, 24-hour design storm and mean annual precipitation isopluvial maps for Western Washington. These have been taken from NOAA Atlas 2 "Precipitation - Frequency Atlas of the Western United States, Volume IX, Washington, and are available on link at the following web address:

http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas2_Volume9.pdf

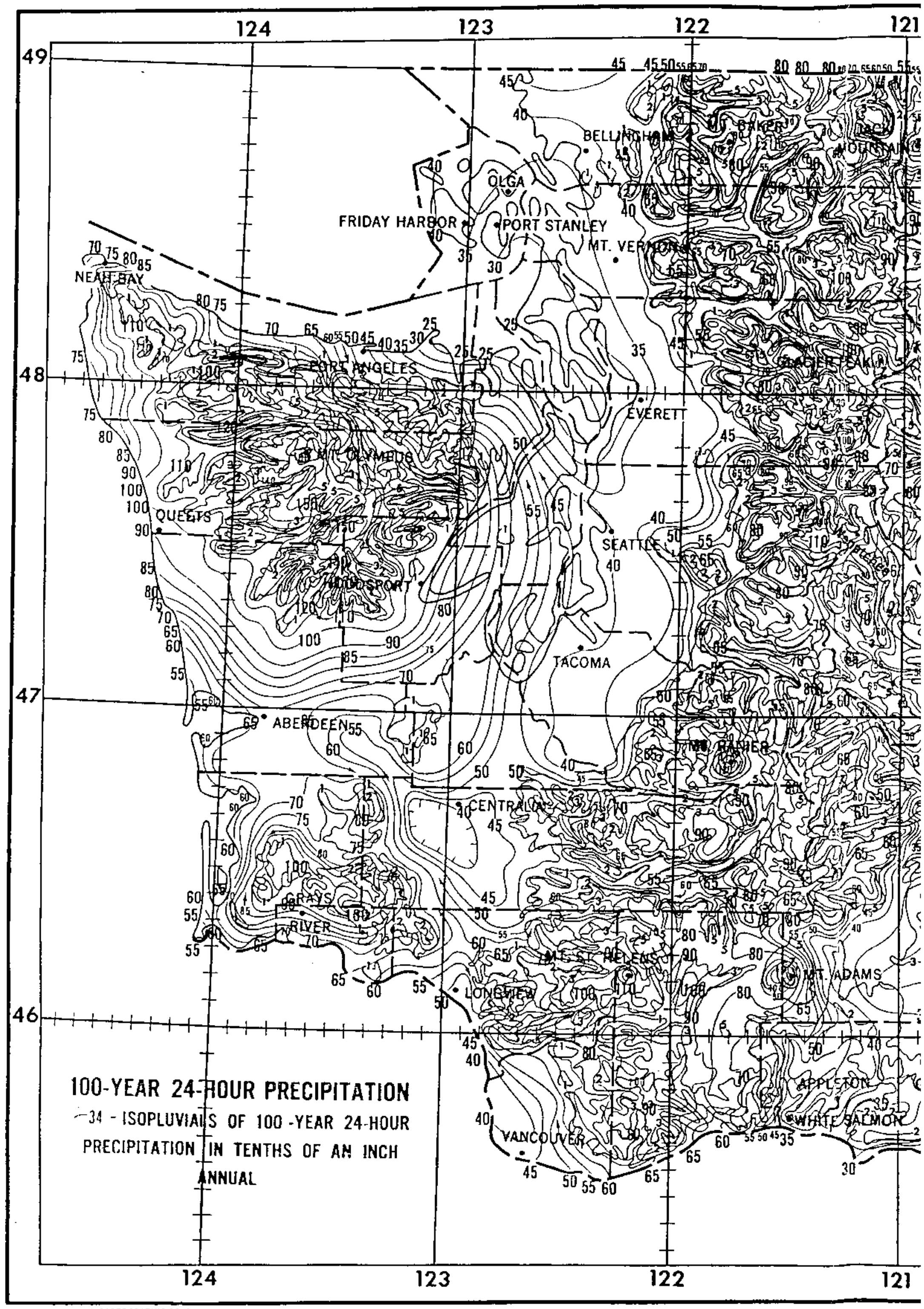
Western Washington Isopluvial 2-year, 24 hour



Western Washington Isopluvial 10-year, 24 hour



Western Washington Isopluvial 100-year, 24 hour



~~Appendix III-B~~
~~Western Washington Hydrology Model – Information, Assumptions, and Computation Steps~~

~~The following text in this Appendix is presented as written in the 2012 Ecology Stormwater Management Manual for Western Washington, modified in December 2014.~~

~~* * * * * * * * *~~

~~This appendix describes some of the information and assumptions used in the Western Washington Hydrology Model (WWHM). However, since the first version of WWHM was developed and released to public in 2001, WWHM program has gone through several upgrades incorporating new features and capabilities. It is anticipated that the next upgrade to WWHM will add low impact development (LID) modeling capability. WWHM users should periodically check Ecology's WWHM web site for the latest releases of WWHM, user manual, and any supplemental instructions.~~

~~WWHM has been created for the specific purpose of sizing stormwater control facilities for new development and redevelopment projects in Western Washington. WWHM can be used for a range of conditions and developments; however, certain limitations are inherent in this software. These limitations are described below.~~

~~The WWHM uses the EPA HSPF software program to do all of the rainfall-runoff and routing computations. Therefore, HSPF limitations are included in the WWHM. For example, HSPF does not explicitly model backwater or tailwater control situations. This is also true in the WWHM.~~

~~WWHM Information and Assumptions~~

~~1. Precipitation data.~~

~~Length of record.~~

~~The WWHM uses long-term (50-70 years) precipitation data to simulate the potential impacts of land use development in western Washington. A minimum period of 20 years is required to simulate enough peak flow events to produce accurate flow frequency results. A 40 to 50-year record is preferred. The actual length of record of each precipitation station varies, but all exceed 43 years.~~

~~Rainfall distribution.~~

~~The precipitation data are representative of the different rainfall regimes found in western Washington. More than 17 precipitation stations are used. These stations represent rainfall at elevations below 1500 feet. Snowfall and melt are not included in the WWHM.~~

~~The primary source for precipitation data is National Weather Service stations. During development of WWHM, county engineers at 19 western Washington counties were contacted to obtain local precipitation data.~~

~~Earlier versions of WWHM used hourly data from the precipitation stations in the table below to generate precipitation timeseries for use in WWHM. For WWHM2012, more recent precipitation data have been used to generate precipitation timeseries in15-min time steps:~~

~~Precipitation Station~~	~~Years of Data~~	~~County Coverage~~
~~Astoria, OR~~	~~1955-1998 = 43~~	~~Wahkiakum~~
~~Blaine~~	~~1948-1998 = 50~~	~~Whatcom, San Juan~~
~~Burlington~~	~~1948-1998 = 50~~	~~Skagit, Island~~
~~Clearwater~~	~~1948-1998 = 50~~	~~Jefferson (west)~~
~~Darrington~~	~~1948-1996 = 48~~	~~Snohomish (northeast)~~
~~Everett~~	~~1948-1996 = 48~~	~~Snohomish (excluding northeast)~~
~~Frances~~	~~1948-1998 = 50~~	~~Pacific~~
~~Landsburg~~	~~1948-1997 = 49~~	~~King (east)~~
~~Longview~~	~~1955-1998 = 43~~	~~Cowlitz, Lewis (south)~~
~~McMillian~~	~~1948-1998 = 50~~	~~Pierce~~
~~Montesano~~	~~1955-1998 = 43~~	~~Grays Harbor~~
~~Olympia~~	~~1955-1998 = 43~~	~~Thurston, Mason (south), Lewis (north)~~
~~Port Angeles~~	~~1948-1998 = 50~~	~~Clallam (east)~~
~~Portland, OR~~	~~1948-1998 = 50~~	~~Clark, Skamania~~
~~Quilcene~~	~~1948-1998 = 50~~	~~Jefferson (east), Mason (north), Kitsap~~
~~Sappho~~	~~1948-1998 = 50~~	~~Clallam (west)~~
~~SeaTac~~	~~1948-1997 = 49~~	~~King (west)~~

~~The records were reviewed for length, quality, and completeness of record. Annual totals were checked along with hourly maximum totals. Using these checks, data gaps and errors were corrected, where possible. A "Quality of Record" summary was produced for each precipitation record reviewed.~~

~~The reviewed and corrected data were placed in multiple WDM (Watershed Data Management) files. One WDM file was created per county and contains all of the precipitation data to be used by the WWHM for that particular county.~~

~~Computational time step.~~

~~The computational time step used in earlier versions of WWHM is one hour. The one-hour time step was selected to better represent the temporal variability of actual precipitation than daily data. WWHM2012 incorporates 15-minute precipitation time series.~~

~~2. Precipitation multiplication factors.~~

~~Precipitation multiplication factors increase or decrease recorded precipitation data to better represent local rainfall conditions. This is particularly important when the precipitation gage is located some distance from the study area.~~

~~Precipitation multiplication factors were developed for western Washington. The factors are based on the ratio of the 24-hour, 25-year rainfall intensities for the representative precipitation gage and the surrounding area represented by that gage's record. The 24-hour, 25-year rainfall intensities were determined from the NOAA Atlas 2 (*Precipitation-Frequency Atlas of the Western United States, Volume IX – Washington, 1973*).~~

~~These multiplication factors were created for the Puget Sound lowlands plus all western Washington valleys and hillside slopes below 1500 feet elevation. The factors were placed in the WWHM database and linked to each county's map. They are transparent to the general user. The advanced user will have the ability to change the precipitation multiplication factor for a specific site. However, such changes will be recorded in the WWHM output.~~

~~3. Pan evaporation data.~~

~~Pan evaporation data are used to determine the potential evapotranspiration (PET) of a study area. Actual evapotranspiration (AET) is computed by the WWHM based on PET and available moisture supply. AET accounts for the precipitation that returns to the atmosphere without becoming runoff. Soil moisture conditions and runoff are directly influenced by PET and AET.~~

~~Evaporation is not highly variable like rainfall. Puyallup pan evaporation data are used for all of the 19 western Washington counties.~~

~~Pan evaporation data were assembled and checked for the same time period as the precipitation data and placed in the appropriate county WDM files.~~

~~Pan evaporation data are collected in the field, but PET is used by the WWHM. PET is equal to pan evaporation times a pan evaporation coefficient. Depending on climate, pan evaporation coefficients for western Washington range from 0.72 to 0.82.~~

~~NOAA Technical Report NWS 33, *Evaporation Atlas for the Contiguous 48 United States*, was used as the source for the pan evaporation coefficients. Pan evaporation coefficient values are shown on Map 4 of that publication.~~

~~As with the precipitation multiplication factors, the pan evaporation coefficients have been placed in the WWHM database and linked to each county's map. They will be transparent to the general user. The advanced user will have the ability to change the coefficient for a specific site. However, such changes will be recorded in the WWHM output.~~

~~4. Soil data.~~

~~Soil type, along with vegetation type, greatly influences the rate and timing of the transformation of rainfall to runoff. Sandy soils with high infiltration rates produce little or no surface runoff; almost all runoff is from groundwater. Soils with a compressed till layer slowly infiltrate water and produce larger amounts of surface runoff during storm events.~~

~~The WWHM uses three predominate soil type to represent the soils of western Washington: till, outwash, and saturated~~

~~Till soils have been compacted by glacial action. Under a layer of newly formed soil lies a compressed soil layer commonly called "hardpan". This hardpan has very poor infiltration capacity. As a result, till soils produce a relatively large amount of surface runoff and interflow. A typical example of a till soil is an Alderwood soil (SCS class C). Where field infiltration tests indicate a measured (initial) infiltration rate less than 0.30 in/hr, the user may model the site as a class C soil.~~

~~Outwash soils have a high infiltration capacity due to their sand and gravel composition. Outwash soils have little or no surface runoff or interflow. Instead, almost of their runoff is in the form of groundwater. An Everett soil (SCS class A) is a typical outwash soil.~~

~~Outwash soils over high groundwater or an impervious soil layer have low infiltration rates and act like till soils. Where groundwater or an impervious soil layer is within 5 feet from the surface, outwash soils may be modeled as till soils in the WWHM.~~

~~Saturated soils are usually found in wetlands. They have a low infiltration rate and a high groundwater table. When dry, saturated soils have a high storage capacity and produce very little runoff. However, once they become saturated they produce surface runoff, interflow, and groundwater in large quantities. Mukilteo muck (SCS class D) is a typical saturated/wetland soil.~~

~~The user will be required to investigate actual local soil conditions for the specific development planned. The user will then input the number of acres of outwash (A/B), till (C), and saturated/wetland soils for the site conditions.~~

~~Alluvial soils are found in valley bottoms. These are generally fine-grained and often have a high seasonal water table. There has been relatively little experience in calibrating the HSPF model to runoff from these soils, so in the absence of better information, these soils may be modeled as till soils.~~

~~Additional soils will be included in the WWHM if appropriate HSPF parameter values are found to represent other major soil groups.~~

~~The three predominate soil types are represented in the WWHM by specific HSPF parameter values that represent the hydrologic characteristics of these soils. More information on these parameter values is presented below.~~

~~5. Vegetation data.~~

~~As with soil type, vegetation types greatly influence the rate and timing of the transformation of rainfall to runoff. Vegetation intercepts precipitation, increases its ability to percolate through the soil, and evaporates and transpires large volumes of water that would otherwise become runoff.~~

~~The WWHM will represent the vegetation of western Washington with three predominate vegetation categories: forest, pasture, and lawn (also known as grass).~~

~~Forest vegetation represents the typical second growth Douglas fir found in the Puget Sound lowlands. Forest has a large interception storage capacity. This means that a large amount of precipitation is caught in the forest canopy before reaching the ground and becoming available for runoff. Precipitation intercepted in this way is later evaporated back into the atmosphere. Forest also has the ability to transpire moisture from the soil via its root system. This leaves less water available for runoff.~~

~~Pasture vegetation is typically found in rural areas where the forest has been cleared and replaced with shrub or grass lots. Some pasture areas may be used to graze livestock. The interception storage and soil evapotranspiration capacity of pasture are less than forest. Soils may have also been compressed by mechanized equipment during clearing activities. Livestock can also compact soil. Pasture areas typically produce more runoff (particularly surface runoff and interflow) than forest areas.~~

~~Lawn vegetation is representative of the suburban vegetation found in typical residential developments. Soils have been compacted by earth moving equipment, often with a layer of topsoil removed. Sod and ornamental bushes replace native vegetation. The interception storage and evapotranspiration of lawn vegetation is less than pasture. More runoff results.~~

~~Predevelopment default land conditions are forest, although the user has the option of specifying pasture if there is documented evidence that pasture vegetation was native to the predevelopment site. If this option is used, the change will be recorded in the WWHM output.~~

~~Forest vegetation is represented by specific HSPF parameter values that represent the forest hydrologic characteristics. As described above, the existing regional HSPF parameter values for forest are based on undisturbed second-growth Douglas fir forest found today in western Washington lowland watersheds.~~

~~Postdevelopment vegetation will reflect the new vegetation planned for the site. The user has the choice of forest, pasture, and landscaped vegetation. Forest and pasture are only appropriate for postdevelopment vegetation in parcels separate from standard residential or non-standard residential/commercial. Development areas must only be designated as forest or pasture where legal restrictions can be documented that protect these areas from future disturbances. The WWHM assumes the pervious land portion of developed areas is covered with lawn vegetation, as described above.~~

~~6. Development land use data.~~

~~The WWHM user must enter land use information for the pre-developed condition and the proposed development condition into the model. WWHM users must select the appropriate land use category and slope, where slope of 0-5% is flat, 5-15% is moderate, and greater than 15% is steep. The land use categories include: Impervious areas such as Roads, Roof, Driveways, Sidewalks, Parking, Ponds; and Pervious areas such as Lawn (this includes lawn, garden, areas with ornamental plants, and any natural areas not legally protected from future disturbance), Forest, and Pasture. The soils types available are A/B (outwash), C (Till), and Saturated (wetland).~~

~~Forest and pasture vegetation areas are only appropriate for separate undeveloped parcels dedicated as open space, wetland buffer, or park within the total area of the standard residential~~

~~development.~~ ~~***Development areas must only be designated as forest or pasture where legal restrictions can be documented that protect these areas from future disturbances.***~~

~~Impervious, as the name implies, allows no infiltration of water into the pervious soil. All runoff is surface runoff. Impervious land typically consists of paved roads, sidewalks, driveways, and parking lots. Roofs are also impervious.~~

~~For the purposes of hydrologic modeling, only effective impervious area is categorized as impervious. Effective impervious area (EIA) is the area where there is no opportunity for surface runoff from an impervious site to infiltrate into the soil before it reaches a conveyance system (pipe, ditch, stream, etc.). An example of an EIA is a shopping center parking lot where the water runs off the pavement and directly goes into a catch basin where it then flows into a pipe and eventually to a stream. In contrast, some homes with impervious roofs collect the roof runoff into roof gutters and send the water down downspouts. When the water reaches the base of the downspout it can be directed into an infiltration system. If roof runoff is infiltrated according to the requirements of BMP T5.10A, the roof area can be considered ineffective impervious area. The roof area may be discounted from the project area entered into WWHM.~~

~~The non-effective impervious area uses the adjacent or underlying soil and vegetation properties. Vegetation often varies by the type of land use. The assumption is made in the WWHM that the EIA equals the TIA (total impervious area). This is consistent with King County's determination of EIA acres for new developments. Where appropriate, the TIA can be reduced through the use of runoff credits (more on that below).~~

~~Earlier versions of WWHM (WWHM1 and WWHM2) provided the 2 optional features below for modeling of Standard Residential development and obtaining flow credits for incorporating low impact development (LID) techniques. Later upgrades to WWHM have provided for direct input of the standard residential development details by the WWHM users. WWHM2012 allows direct modeling of some LID techniques through use of new LID Elements. Other LID techniques will continue to be modeled in accordance with Appendix C of the Stormwater Management Manual for Western Washington.~~

~~**Standard Residential:**~~ ~~For housing developments where lot-specific details (e.g., size of roof and driveway) are not yet determined, the earlier versions of WWHM provided a set of default assumptions about the amount of impervious area per lot and its division between driveways and rooftops under the "Standard Residential" development land use type. Later versions of WWHM (e.g., WWHM3 or WWHM2012) do not have this option programmed in the model but the land use assumptions for the "Standard Residential" development are given below.~~

~~Ecology has selected a standard impervious area of 4200 square feet per residential lot, with 1000 square feet of that as driveway, walkways, and patio area, and the remainder as rooftop area. The rest of the lot acres will be assumed to be landscaped area (including lawn). The user inputs the number of residential lots and the total acreage of the residential lots (public right-of-way acreages and non-residential lot acreages excluded). The number of residential lots and the associated number of acres will be used to compute the average number of residential lots per acre. This value together with the number of residential lots and the impervious area in the public right-of-way will be used by the model to calculate the TIA for the proposed development. The areas covered by streets, parking areas, and sidewalk areas are input separately by the user.~~

~~**Runoff Credits:** Please note that the modeling of runoff credits using some of the low impact development techniques described in Appendix C have been updated. WWHM 2012 can now provide LID modeling capabilities in accordance with this manual. **The following LID credit modeling is based on modeling in earlier versions of WWHM (WWHM2 and WWHM3)**.~~

~~Runoff credits can be obtained using any or all of the low impact development methods listed below. The WWHM has an automated procedure for taking credits for infiltrating or dispersing roof runoff - methods #1 and #2 below. Credits for using methods 3,4,8, and 9 must be taken by following the guidance in Appendix C. Methods 5, 6, and 10 also have guidance in Appendix C for taking credits. However, the new LID elements in WWHM2012 would allow direct modeling of methods 4, 5, 6, and 10 which would be a better representation of how they function to reduce surface runoff. Roof areas using method #7 -rainwater harvesting systems designed in accordance with the guidance in Appendix C need not be entered into the model. Also, if using method 11 – Full dispersion – the runoff model need not be used for the area that meets the criteria in Appendix C.~~

~~Infiltrate roof runoff~~

~~Disperse roof runoff~~

~~Disperse driveway and other hard surface runoff~~

~~Porous pavement for driveways and walks~~

~~Porous pavement for roads and parking lots~~

~~Vegetated Roofs~~

~~Rainwater Harvesting~~

~~Reverse slope sidewalks~~

~~Low impact foundations~~

~~Bioretention Areas~~

~~Full dispersion~~

~~Infiltrate Roof Runoff~~

~~Credit is given for disconnecting the roof runoff from the development's stormwater conveyance system and infiltrating on the individual residential lots. The WWHM assumes that this infiltrated roof runoff does not contribute to the runoff flowing to the stormwater detention pond site. It disappears from the system and does not have to be mitigated. See Chapter 3.1.1 of this volume for design requirements for downspout infiltration systems.~~

~~Disperse Roof Runoff~~

~~Credit is also given for disconnecting the roof runoff from the development's stormwater conveyance system and dispersing it on the lawn/landscaped surface of individual lots. If the runoff is dispersed using a dispersion trench designed according to the requirements of Chapter 3.1.1 of this volume, on single-family lots greater than 22,000 square feet, and the vegetative flow path of the runoff is 50 feet or longer through undisturbed native or compost-amended soils, the roof area can be entered into the model as landscaped area rather than impervious surface.~~

~~Disperse driveway and other hard surface runoff:~~

~~If runoff is dispersed in accordance with the guidance in BMP T5.11 or BMP T5.12, the driveway or other hard surface may be modeled as landscaped area.~~

~~Porous pavement~~

~~The third option for runoff credit is the use of porous pavement for private driveways, sidewalks, streets, and parking areas. The LID credit guidance in Appendix C was developed before WWHM2012, with the capability to directly model permeable pavements, became available. The LID credit guidance in Appendix C will direct you to enter a certain percentage of the pervious pavement area into the landscaped area category rather than the street/sidewalk/parking lot category. Even thoughWWHM2012 has other methods for calculating the impacts of permeable pavement, the methods described in Part 1 of Appendix C are still appropriate to use where the pervious pavement does not have a significant depth of base course for storage.~~

~~Follow similar procedures for vegetated roofs, reverse slope sidewalks, and low impact foundations. The LID credit guidance of Appendix C directs how these surfaces should be entered into the model. If you do not know the specific quantities of the different land cover types for your development (e.g., the individual lots will be sold to builders who will determine layout and size of home), you should start with the assumption of 4200 sq. ft. of impervious area per lot – including 1,000 sq. ft. for driveways, and begin making adjustments in those totals as allowed in the LID guidance of Appendix C.~~

~~Other Development Options and Model Features~~

~~WWHM allows the flexibility of bypassing a portion of the development area around a flow control facility and/or having off-site inflow that is entering the development area pass through the flow control facility.~~

~~Bypass occurs when a portion of the development does not drain to a stormwater detention facility. On-site runoff from a proposed development project may bypass the flow control facility provided that all of the following conditions are met.~~

~~Runoff from both the bypass area and the flow control facility converges within a quarter-mile downstream of the project site discharge point.~~

~~The flow control facility is designed to compensate for the uncontrolled bypass area such that the net effect at the point of convergence downstream is the same with or without bypass.~~

~~The 100-year peak discharge from the bypass area will not exceed 0.4 cfs.~~

~~Runoff from the bypass area will not create a significant adverse impact to downstream drainage systems or properties..~~

~~Water quality requirements applicable to the bypass area are met.~~

~~Off-site Inflow occurs when an upslope area outside the development drains to the flow control facility in the development. If the existing 100-year peak flow rate from any upstream off-site area is greater than 50% of the 100-year developed peak flow rate (undetained) for the project site, then the runoff from the off-site area must not flow to the on-site flow control facility. The bypass of off-site runoff must be designed so as to achieve both of the following:~~

~~Any existing contribution of flows to an on-site wetland must be maintained.~~

~~Off-site flows that are naturally attenuated by the project site under predeveloped conditions must remain attenuated, either by natural means or by providing additional on-site detention so that peak flows do not increase.~~

~~Application of WWHM in Re-developments Projects~~

~~WWHM allows only forest or pasture as the predevelopment land condition in the Design Basin screen. This screen does not allow other types of land uses such as impervious and landscaped areas to be entered for existing condition. However, WWHM can be used for redevelopment projects by modeling the existing developed areas that are not subject to the flow control requirements of Volume I as off-site areas. For the purposes of predicting runoff from such an existing developed area, enter the existing area in the Off-site Inflow screen. This screen is designed to predict runoff from impervious and landscaped areas in addition to the forest and pasture areas. If the existing 100-year peak flow rate from the existing developed areas that are not subject to flow control is greater than 50% of the 100-year developed peak flow rate (undetained but subject to the flow control requirements of Volume I), then the runoff from the off-site area must not be allowed to flow to the on-site flow control facility.~~

~~7. PERLND and IMPLND parameter values.~~

~~In WWHM (and HSPF) pervious land categories are represented by PERLNDs; impervious land categories (EIA) by IMPLNDs. An example of a PERLND is a till soil covered with forest vegetation. This PERLND has a unique set of HSPF parameter values. For each PERLND there are 16 parameters that describe various hydrologic factors that influence runoff. These range from interception storage to infiltration to active ground water evapotranspiration. Only four parameters are required to represent IMPLND.~~

~~The PERLND and IMPLND parameter values to be used in the WWHM are listed below. These values are based on regional parameter values developed by the U.S. Geological Survey for watersheds in western Washington (Dinicola, 1990) plus additional HSPF modeling work conducted by AQUA TERRA Consultants.~~

~~PERLND Parameters~~

~~LZSN = lower zone storage nominal (inches)~~

~~INFILT = infiltration capacity (inches/hour)~~

~~LSUR = length of surface overland flow plane (feet)~~

~~SLSUR = slope of surface overland flow plane (feet/feet)~~

~~KVARY = ground water exponent variable (inch~~~~$^{-1}$)~~

~~AGWRC = active ground water recession constant (day~~~~$^{-1}$)~~

~~INFEXP = infiltration exponent~~

~~INFILD = ratio of maximum to mean infiltration~~

~~BASETP = base flow evapotranspiration (fraction)~~

~~AGWETP = active ground water evapotranspiration (fraction)~~

~~CEPSC = interception storage (inches)~~

~~UZSN = upper zone storage nominal (inches)~~

~~NSUR = roughness of surface overland flow plane (Manning's n)~~

~~INTFW = interflow index~~

~~IRC = interflow recession constant (day-1)~~

~~LZETP = lower zone evapotranspiration (fraction)~~

~~A more complete description of these PERLND parameters is found in the HSPF User Manual (Bicknell et al, 1997).~~

~~PERLND parameter values for other additional soil/vegetation categories will be investigated and added to the WWHM, as appropriate.~~

~~IMPLND Parameters~~

	~~EIA~~
~~Name~~	
~~LSUR~~	~~400~~
~~SLSUR~~	~~0.01~~
~~NSUR~~	~~0.10~~
~~RETSC~~	~~0.10~~

~~IMPLND parameters:~~

~~LSUR = length of surface overland flow plane (feet)~~

~~SLSUR = slope of surface overland flow plane (feet/feet)~~

~~NSUR = roughness of surface overland flow plane (Manning's n)~~

~~RETSC = retention storage (inches)~~

~~A more complete description of these IMPLND parameters is found in the HSPF User Manual (Bicknell et al, 1997).~~

~~The PERLND and IMPLND parameter values will be transparent to the general user. The advanced user will have the ability to change the value of a particular parameter for that specific site. However, the only PERLND and IMPLND parameters that are authorized to be adjusted by the user are LSUR, SLSUR, and NSUR. These are parameters whose values are observable at an undeveloped site, and whose values can be reasonably estimated for the proposed development site. Any such changes will be recorded in the WWHM output. The user should submit justifications for changes with their project submittal to the reviewing jurisdiction. Ecology will issue guidance within the WWHM Users Manual on the range of and methods for estimating acceptable parameter changes.~~

~~Earlier versions of WWHM (WWHM1 and WWHM2) provided only one category of moderate land slope (typically 5-15% slopes). In more recent versions of WWHM (WWHM3 and WWHM2012), two additional land categories have been added to account for the flat (0-5%) and steep (15-25%) land slopes.~~

~~Surface runoff and interflow will be computed based on the PERLND and IMPLND parameter values. Ground water flow can also be computed and added to the total runoff from a development if there is a reason to believe that ground water would be surfacing (such as where~~

~~there is a cut in a slope). However, the default condition in WWHM assumes that no ground water flow from small catchments reaches the surface to become runoff. This is consistent with King County procedures (King County, 1998).~~

~~8. Guidance for flow-related standards.~~

~~Use flow-related standards to determine whether or not a proposed stormwater facility will provide a sufficient level of mitigation for the additional runoff from land development. Guidance is provided on the standards that must be met to comply with the Ecology Stormwater Management Manual.~~

~~There are three flow-related standards stated in Volume I: Minimum Requirement #5 – On-site Stormwater Management; Minimum Requirement #7 - Flow Control and Minimum Requirement #8 - Wetlands Protection.~~

~~Minimum Requirement #5 allows the user to demonstrate compliance with the LID Performance Standard of matching developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 8% of the 2-year peak flow to 50% of the 2-year peak flow. If the post-development flow duration values exceed any of the predevelopment flow levels between 8% and 50% of the 2-year predevelopment peak flow values, then the LID performance standard not been met.~~

~~Minimum Requirement #7 specifies that stormwater discharges to streams shall match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow. In general, matching discharge durations between 50% of the 2-year and 50-year will result in matching the peak discharge rates in this range.~~

~~WWHM uses the predevelopment peak flow value for each water year to compute the predevelopment 2- through 100-year flow frequency values. The postdevelopment runoff 2- through 100-year flow frequency values are computed from the outlet of the proposed stormwater facility. The user must enter the stage-surface area-storage-discharge table (HSPF FTABLE) for the stormwater facility. The model then routes the postdevelopment runoff through the stormwater facility. As with the predevelopment peak flow values, the model will select the maximum developed flow value for each water year to compute the developed 2- through 100-year flow frequency.~~

~~The actual flow frequency calculations are made using the federal standard Log Pearson Type III distribution described in Bulletin 17B (United States Water Resources Council, 1981). This standard flow frequency distribution is provided in U.S. Geological Survey program J407, version 3.9A-P, revised 8/9/89. The Bulletin 17B algorithms in program J407 are included in the WWHM calculations.~~

~~Minimum Requirement #7 is based on flow duration. WWHM will use the entire predevelopment and post-development runoff record to compute flow duration. The standard requires that post-development runoff flows must not exceed the flow duration values of the predevelopment runoff between the predevelopment flow values of 50 percent of the 2-year flow and 100 percent of the 50-year flow.~~

~~Flow duration is computed by counting the number of flow values that exceed a specified flow level. The specified flow levels used by WWHM in the flow duration analysis are listed below.~~

~~50% of the 2-year predevelopment peak flow.~~

~~100% of the 2-year predevelopment peak flow.~~

~~100% of the 50-year predevelopment peak flow.~~

~~In addition, flow durations are computed for 97 other incremental flow values between 50 percent of the 2-year predevelopment peak flow and 100 percent of the 50-year predevelopment peak flow.~~

~~There are three criteria by which flow duration values are compared:~~

~~If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 50% and 100% of the 2-year predevelopment peak flow values (100 Percent Threshold) then the flow duration requirement has not been met.~~

~~If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 100% of the 2-year and 100% of the 50-year predevelopment peak flow values more than 10 percent of the time (110 Percent Threshold) then the flow duration requirement has not been met.~~

~~If more than 50 percent of the flow duration levels exceed the 100 percent threshold then the flow duration requirement has not been met.~~

~~The results are provided in the WWHM report.~~

~~Minimum Requirement #8 specifies that total discharges to wetlands must not deviate by more than 20% on a daily basis, and must not deviate by more than 15% on a monthly basis. Flow components feeding the wetland under both Pre-and Post-development scenarios are assumed to be the sum of the surface, interflow, and ground water flows from the project site. The WWHM is being revised to more easily allow this comparison.~~

~~References for Western Washington Hydrology Model~~

~~Beyerlein, D.C. 1996. Effective Impervious Area: The Real Enemy. Presented at the Impervious Surface Reduction Research Symposium, The Evergreen State College. Olympia, WA.~~

~~Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr, A.S. Donigian Jr, and R.C. Johanson. 1997. Hydrological Simulation Program – Fortran User's Manual for Version 11. EPA/600/R-97/080. National Exposure Research Laboratory. Office of Research and Development. U.S. Environmental Protection Agency. Research Triangle Park, NC.~~

~~Dinicola, R.S. 1990. Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington. Water-Resources Investigations Report 89-4052. U.S. Geological Survey. Tacoma, WA.~~

~~King County. 1998. Surface Water Design Manual. Department of Natural Resources. Seattle, WA.~~

~~United States Water Resources Council. 1981. Guidelines for Determining Flood Flow Frequency. Bulletin #17B of the Hydrology Committee. Washington, DC.~~

~~Appendix III-C~~
~~Washington State Department of Ecology Low Impact Development Flow Modeling Guidance~~

~~The following text in this Appendix is presented as written in the 2012 Ecology Stormwater Management Manual for Western Washington, modified in December 2014~~

~~Note – The modeling guidance in this section was developed for use with an earlier version of WWHM, WWHM3. Since then, WWHM has been updated to incorporate direct modeling of some LID techniques in WWHM2012 to better represent how they would function to reduce surface runoff. The new LID elements include Permeable Pavement, Green Roof, and Bio-retention discussed in Part 2 of this Appendix.~~

~~The Washington State Department of Ecology (Ecology) requires the use of the Western Washington Hydrology Model (WWHM) and other approved runoff models (currently approved alternative models are the King County Runoff Time Series and MGS Flood) for estimating surface runoff and sizing stormwater control and treatment facilities. Part 1 of this appendix explains how to represent various LID techniques within WWHM 3 so that their benefit in reducing surface runoff can be estimated. The lower runoff estimates should translate into smaller stormwater treatment and flow control facilities. In certain cases, use of various techniques can result in the elimination of those facilities.~~

~~As Puget Sound gains more experience with and knowledge of LID techniques, the design criteria will evolve. Also, our ability to model their performance will change as our modeling techniques improve. Therefore, we anticipate this guidance will be updated periodically to reflect the new knowledge and modeling approaches.~~

~~One such update should be available later this year (2012). The updated guidance will explain modeling techniques to be used with the latest publicly available version of the WWHM (tentative name: WWHM 2012). A summary of the modeling techniques planned for WWHM 2012 is included as Part 2 in this appendix. Because WWHM 2012 and the updated LID modeling guidance won't be released until later this year, municipal stormwater permittees are not obligated to require its use the 2013-2018 permit term. However, because WWHM 2012 will make modeling LID developments easier and more technically accurate; and because it will include a number of other updates and improvements (e.g., updated rainfall files), Ecology will encourage its use. We anticipate that most local governments will choose to require its use or an equivalent program (e.g., an updated MGS Flood) once they are readily available. Ecology intends to make sure that sufficient training opportunities are available on WWHM 2012, so that municipal staff and designers have adequate opportunity to become familiar with it prior to the deadlines in the municipal permits for adopting and applying updated stormwater requirements.~~

~~Part 1: Guidance for Use with WWHM 3~~

~~C.1 Permeable Pavements~~

~~C.1.1 Porous Asphalt or Concrete~~

~~Pavement Description~~	~~Model surface as:~~
~~Base material laid above surrounding grade without underlying perforated drain pipes to collect stormwater~~	~~Grass over underlying soil type (till or outwash)~~
~~Base material laid above surrounding grade with underlying perforated drain pipes to collect stormwater (either within or below base course)~~	~~Impervious surface~~
~~Base material laid partially or completely below surrounding grade without underlying perforated drain pipes~~	~~Grass over underlying soil type, OR Impervious surface routed to a gravel trench/bed (1)~~
~~Base material laid partially or completely below surrounding grade with underlying perforated drain pipes at or below bottom of base course~~	~~Impervious surface~~
~~Base material laid partially or completely below surrounding grade with underlying perforated drain pipes above bottom of base course~~	~~Impervious surface routed to a gravel trench/bed (1)~~
~~Base material laid partially or completely below surrounding grade with underlying perforated drain pipes above bottom of base course IF pipe function is to distribute runoff directly below the wearing surface AND pipes are above surrounding grade~~	~~Grass over underlying soil type, OR Impervious surface routed to a gravel trench/bed (1)~~

~~Notes:~~

~~1. See section C.11 for detailed instructions concerning how to represent the base material below grade as a gravel trench/bed in the Western Washington Hydrology Model~~

~~*C.1.2 Grid/lattice systems (non-concrete) and Paving Blocks*~~

~~**Pavement Description**~~	~~**Model surface as:**~~
~~Base material laid above surrounding grade without underlying perforated drain pipes to collect stormwater~~	~~Grid/lattice systems: Grass over underlying soil type (till or outwash)~~ ~~Paving Blocks: 50% grass on underlying soil, 50% impervious~~
~~Base material laid above surrounding grade with underlying perforated drain pipes~~	~~Impervious surface~~
~~Base material laid partially or completely below surrounding grade without underlying perforated drain pipes~~	~~Grid/lattice systems: grass on underlying soil OR impervious surface routed to gravel trench/bed (1)~~ ~~Paving blocks: 50% grass, 50% impervious surface OR impervious surface routed to gravel trench/bed (1)~~
~~Base material laid partially or completely below surrounding grade with underlying perforated drain pipes at or below bottom of base course~~	~~Impervious surface~~
~~Base material laid partially or completely below surrounding grade with underlying perforated drain pipes above bottom of base course~~	~~Impervious surface routed to a gravel trench/bed (1)~~
~~Base material laid partially or completely below surrounding grade with underlying perforated drain pipes above bottom of base course IF pipe function is to distribute runoff directly below the wearing surface AND pipes are above surrounding grade~~	~~Impervious surface routed to a gravel trench/bed (1)~~

~~Notes:~~

~~1. See section C.11 for detailed instructions concerning how to represent the base material below grade as a gravel trench/bed in the Western Washington Hydrology Model~~

~~C.2 Dispersion~~

~~*C.2.1 Full Dispersion for the Entire Development Site*~~

~~Residential Developments that implement BMP T5.30 do not have to use approved runoff models to demonstrate compliance. They are assumed to fully meet the treatment and flow control requirements.~~

~~*C.2.2 Full Dispersion for Part of the Development Site*~~

~~Those portions of residential developments that implement BMP T5.30 do not have to use approved runoff models to demonstrate compliance. They are assumed to fully meet the treatment and flow control requirements.~~

~~*C.2.3 Partial Dispersion on residential lots and commercial buildings*~~

~~If roof runoff is dispersed on single-family lots or commercial lots according to the design criteria and guidelines in BMP T5.10B of Volume III, through undisturbed native landscape or lawn/landscape area that meets the guidelines in BMP T5.13, the user has two options.~~

~~Option 1: The roof area may be modeled as landscaped area if the vegetated flow path is 50 feet or more. In WWHM this can be done on the Mitigated Scenario screen by entering the roof area into one of the entry options for dispersal of impervious area runoff. Alternatively, in WWHM, this can be done by entering the roof area as landscaped area with the appropriate landscaped slope. Where the flow path is between 25 and 50 feet and a dispersion trench is used, the roof area may be modeled as 50% landscape/50% impervious. Do this in WWHM on the Mitigated Scenario screen by entering 50% of the roof area as impervious and the other 50% as landscaped area.~~

~~Option #2: Use the lateral flow basin elements in WWHM for dispersing runoff from the roof area on the landscaped area. In this option, the "Impervious Lateral Basin" element/icon is used to represent the roof area(s). That element/icon is then connected to a "Pervious Lateral Basin" icon that represents the pervious area into which the roof is being dispersed. The user must direct Surface Flow from the Impervious Lateral Basin (roof area) to the "Surface" Flow of the Pervious Lateral Basin (landscaped area). Then, the user should direct surface runoff and interflow from the Pervious Lateral Basin to a treatment system, retention/detention basin, or directly to a point of compliance.~~

~~Whether option #1 or #2 is used, the vegetated flow path is measured from the downspout or dispersion system discharge point to the downgradient edge of the vegetated area. That flow path must be at least 50 feet unless a dispersion trench per BMP T5.10B is used with a vegetated flow path of 25 to 50 feet.~~

~~Where BMP T5.11 (concentrated flow dispersion) or BMP T5.12 (sheet flow dispersion) of Volume V – Chapter 5 is used to disperse runoff from impervious areas other than roofs into a native vegetation area or an area that meets the guidelines in BMP T5.13 of Volume V – Chapter 5, the same two options as described above are available. The user may model the impervious area as landscaped area (50 feet or more of vegetated flow path), 50% landscape/50% impervious (25 to 50 feet of vegetated flow path), or the lateral flow element/icons may be used. As above, the vegetated flow path from the dispersal point to the downgradient edge of the vegetated area must be at least 50 feet, unless a dispersion trench (see BMP 5.10B) is used with a vegetated flow path of 25 to 50 feet.~~

~~**C.3 Downspout Full Infiltration**~~

~~Roof areas served by downspouts that drain to infiltration dry wells or infiltration trenches that are sized in accordance with the guidance in BMP T5.10A do not have to be entered into the runoff model. They are assumed to fully infiltrate the roof runoff.~~

~~**C.4 Vegetated Roofs**~~

~~*C.4.1 Option 1 Design Criteria*~~

~~3 inches to 8 inches of soil/growing media~~

~~Runoff Model Representation~~

~~50% till landscaped area; 50% impervious area~~

~~*C.4.2 Option 2 Design Criteria*~~

~~≥ 8 inches of soil/media~~

~~Runoff Model Representation~~

~~50% till pasture; 50% impervious area~~

~~C.5 Rainwater Harvesting~~

~~Do not enter drainage area into the runoff model.~~

~~*Note:* This applies only to drainage areas for which a monthly water balance indicates no overflow of the storage capacity.~~

~~C.6 Reverse Slope Sidewalks~~

~~Enter sidewalk area as landscaped area over the underlying soil type.~~

~~Alternatively, use the "lateral flow" icons. Use the "Lateral Flow Impervious Area" icon for the sidewalk, and use the "Lateral Flow Basin" icon for the downgradient vegetated area.~~

~~C.7 Minimal Excavation Foundations~~

~~Where residential roof runoff is dispersed on the upgradient side of a structure in accordance with the design criteria and guidelines in BMP T5.10B of Volume III – Chapter 3, the tributary roof area may be modeled as pasture on the native soil.~~

~~In "step forming," the building area is terraced in cuts of limited depth. This results in a series of level plateaus on which to erect the form boards. Where "step forming" is used on a slope, the square footage of roof that can be modeled as pasture must be reduced to account for lost soils. The following equation (suggested by Rick Gagliano of Pin Foundations, Inc.) can be used to reduce the roof area that can be modeled as pasture.~~

$$\cancel{A_1 - \frac{dC(.5)}{dP} X A_1 = A_2}$$

~~A_1 = roof area draining to up gradient side of structure~~

~~dC = depth of cuts into the soil profile~~

~~dP = permeable depth of soil (The A horizon plus an additional few inches of the B horizon where roots permeate into ample pore space of soil).~~

~~A_2 = roof area that can be modeled as pasture on the native soil. The rest of the roof is modeled as impervious surface unless it is dispersed in accordance with the next bullet.~~

~~If roof runoff is dispersed downgradient of the structure in accordance with the design criteria and guidelines in BMP T5.10B of Volume III – Chapter 3, AND there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in BMP T5.13 of Volume V – Chapter 5, the tributary roof areas may be modeled as landscaped area. Alternatively, use the lateral flow elements to send roof runoff onto the lawn/landscape area that will be used for dispersion.~~

~~C.8 Tree Retention and Planting~~

~~*C.8.1 Tree Retention Flow Control Credit*~~

~~Flow control credits for retained trees are provided in Table C.1 by tree type. These credits can be applied to reduce impervious or other hard surface area requiring flow control. Credits are given as a percentage of the existing tree canopy area. The minimum credit for existing trees ranges from 50 to 100 square feet.~~

~~Table C.1~~
~~Flow Control Credits for Retained Trees.~~

~~**Tree Type**~~	~~**Credit**~~
~~Evergreen~~	~~20% of canopy area (minimum of 100 sq. ft./tree~~
~~Deciduous~~	~~10% of canopy area (minimum of 50 sq. ft./tree~~

~~Impervious Area Mitigated = Σ Canopy Area x Credit (sq. ft.)~~

~~Tree credits are not applicable to trees in native vegetation areas used for flow dispersion or other flow control credit. Credits are also not applicable to trees in planter boxes. The total tree credit for retained and newly planted trees shall not exceed 25 percent of impervious or other hard surface requiring mitigation.~~

~~*C.8.2 Newly Planted Tree Flow Control Credits*~~

~~Flow control credits for newly planted trees are provided in Table C.2 by tree type. These credits can be applied to reduce the impervious or other hard surface area requiring flow control. Credits range from 20 to 50 square feet per tree.~~

~~Table C.2.~~
~~Flow Control Credits for Newly Planted Trees.~~

~~**Tree Type**~~	~~**Credit**~~
~~Evergreen~~	~~50 sq. ft. per tree~~
~~Deciduous~~	~~20 sq. ft. per tree~~

~~Impervious Area Mitigated = Σ Number of Trees x Credit (%)/100.~~

~~Tree credits are not applicable to trees in native vegetation areas used for flow dispersion or other flow control credit. Credits are also not applicable to trees in planter boxes. The total tree credit for retained and newly planted trees shall not exceed 25 percent of impervious or other hard surface requiring mitigation.~~

~~**C.9 Soil Quality and Depth**~~

~~All areas that meet the soil quality and depth requirement may be entered into the model as pasture rather than lawn/landscaping.~~

~~C.10. Bioretention~~

~~C.10.1 Runoff Model Representation~~

~~Pothole design (bioretention cells)~~

~~Bioretention is represented by using the “Gravel trench/bed” icon with a steady-state infiltration rate. Proper infiltration rate selection is described below. The user inputs the dimensions of the gravel trench. Layer 1 on the input screen is the bioretention soil layer. Enter the soil depth and a porosity of 40%. Layer 2 is the free standing water above the bioretention soil. Enter the maximum depth of free standing water (i.e., up to the invert of an overflow pipe or a spillway, whatever engages first for surface release of water), and 100% for porosity. Bioretention with underlying perforated drain pipes that discharge to the surface can also be modeled as gravel trenches/beds with steady-state infiltration rates. However, the only volume available for storage (and modeled as storage as explained herein) is the void space within the imported material (usually sand or gravel) below the bioretention soil and below the invert of the drain pipe.~~

~~Using one of the procedures explained in Volume III - Chapter 3 of this manual, estimate the initial measured (a.k.a., short-term) infiltration rate of the native soils beneath the bioretention soil and any base materials. Because these soils are protected from fouling, no correction factor will be applied.~~

~~Facilities without an underdrain:~~

~~If using the default bioretention soil mix from Chapter 7 of Volume V, 12 inches per hour is the initial infiltration rate. The long-term rate is either 3inches per hour or 6 inches per hour depending upon the size of the drainage area, and the use of a pretreatment device for solids removal prior to the bioretention facility. See Chapter 7 of Volume V. If using a custom imported soil mix other than the default, its saturated hydraulic conductivity (used as the infiltration rate) must be determined using the procedures described in Chapter 7 of Volume V. The long-term infiltration rate is one-fourth or one-half of that rate depending upon the size of the drainage area and the use of a pretreatment device for solids removal. See Chapter 7 of Volume V.~~

~~Facilities with an elevated underdrain :~~

~~Note that only the estimated void space of the aggregate bedding layer that is below the invert of the underdrain pipe provides storage volume that provides a flow control benefit. Assume a 40% void volume for the Type 26 mineral aggregate specificed in Chapter 7 of Volume V.~~

~~Linear Design: (bioretention swale or slopes)~~

~~Swales~~

~~Where a swale design has a roadside slope and a back slope between which water can pond due to an elevated, and an overflow/drainage pipe at the lower end of the swale, the swale may be modeled as a gravel trench/bed with a steady state infiltration rate. This method does not apply to swales that are underlain by a drainage pipe.~~

~~If the long-term infiltration rate through the imported bioretention soil is lower than the infiltration rate of the underlying soil, the surface dimensions and slopes of the swale should be entered into the WWHM as the trench dimensions and slopes. The effective depth is the distance from the soil surface at the bottom of the swale to the invert of the overflow/drainage pipe. If the~~

~~infiltration rate through the underlying soil is lower than the estimated long-term infiltration rate through the imported bioretention soil, the trench/bed dimensions entered into the WWHM should be adjusted to account for the storage volume in the void space of the bioretention soil. Use 40 percent porosity for bioretention planting mix soils recommended above for Layer 1 in WWHM.~~

~~This procedure to estimate storage space should only be used on bioretention swales with a 1% slope or less. Swales with higher slopes should more accurately compute the storage volume in the swale below the drainage pipe invert.~~

~~For a swale design with an underdrain, the directions above under Pothole design apply.~~

~~C.10.2 WWHM Routing and Runoff File Evaluation~~

~~In WWHM3, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage be exceeded. So in the Riser/Weir screen, for the Riser head enter a value slightly smaller than the effective depth of the trench (say 0.1 ft below the Effective Depth); and for the Riser diameter enter a large number (say 10,000 inches) to ensure that there is ample capacity for overflows. The overflow should be routed to the point of compliance or a downstream facility. If the facility is underdrained, the underdrain must be similarly routed.~~

~~Within the model, route the runoff into the gravel trench by grabbing the gravel trench icon and placing it below the tributary "basin" area. Be sure to include the surface area of the bioretention area in the tributary "basin" area. Run the model to produce the effluent runoff file from the theoretical gravel trench. For projects subject to the flow control standard, compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. A conveyance system should be designed to route all overflows from the bioretention areas to centralized treatment facilities, and to flow control facilities if flow control applies to the project.~~

~~C.10.3 Modeling of Multiple Bioretention facilities~~

~~Where multiple bioretention facilities are scattered throughout a development, it may be possible to cumulatively represent a group of them that have similar characteristics as one large bioretention facility serving the cumulative area tributary to those facilities. For this to be a reasonable representation, the design of each bioretention facility in the group should be similar (e.g., same depth of soil, same depth of surface ponded water, roughly the same ratio of impervious area to bioretention volume). In addition, the group should have similar (0.5x to 1.5x the average) controlling infiltration rates (i.e., either the long-term rate of the bioretention soil, or the initial rate of the underlying soil) that can be averaged as a single rate.~~

~~C.11 WWHM Instructions for Estimating Runoff Losses in Road Base Material Volumes that are Below Surrounding Grade~~

~~Introduction~~

~~This section applies to roads or parking lots that have been constructed with a permeable pavement and whose underlying base materials extend below the surrounding grade of land. The over-excavated volume can temporarily store water before it infiltrates or overflows to the surrounding ground surface. This section describes design criteria and modeling approaches for such designs.~~

~~*Pre-requisite*~~

~~Before using this guidance to estimate infiltration losses, the designer should have sufficient information to know whether adequate depth to a seasonal high ground water table, or other infiltration barrier (such as bedrock) is available. The minimum depth necessary is 3 feet as measured from the bottom of the base materials.~~

~~*C.11.1 Instructions for Roads on Zero to 2% Grade*~~

~~For road projects whose base materials extend below the surrounding grade, the below grade volume of base materials may be modeled in WWHM as a Gravel trench/bed with a set infiltration rate. The pervious pavement area is entered as a basin with an equivalent amount of impervious area that is routed to the gravel trench/bed. If an underdrain is installed at the bottom of the base materials, the pavement is modeled as impervious surface without a gravel trench.~~

~~First, place a "basin" icon in the "Schematic" grid. Enter the appropriate pre-developed and post-developed descriptions of your project site (or threshold discharge area of the project site). Assume that your pervious pavement surfaces are impervious surfaces. By placing a Gravel trench/bed icon below the basin icon in the Schematic grid, we are routing the runoff from the road and any other tributary area into the below grade volume that is represented by the Gravel trench/bed.~~

~~Enter the dimensions of the Gravel trench/bed: the length of the base materials that are below grade (parallel to the road); the width of the below grade material volume; and the depth. The available storage is the void volume in the gravel base layer below the pervious pavement. Enter the void ratio for the gravel base in the Layer 1 field. For example, for a project with a gravel base of 32% porosity, enter 0.32 for the Layer 1 porosity. If the below grade base course has perforated drainage pipes elevated above the bottom of the base course, but below the elevation of the surrounding ground surface, the "Layer 1 Thickness" is the distance from the invert of the lowest pipe to the bottom of the base course.~~

~~Also in WWHM3, the Gravel trench/bed facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. So for the "Riser Height", enter a value slightly smaller than the effective depth of the base materials (say 0.1 ft below the Effective Total Depth); and for the "Riser Diameter" enter a large value (say 10,000 inches) to ensure that there is ample capacity should overflows from the trench occur.~~

~~For all infiltration facilities, WWHM3 has a button that asks, "Use Wetted Surface Area?" The answer should remain "NO."~~

~~Using one of the procedures explained in Chapter 3, estimate the initial measured (a.k.a., short-term) infiltration rate of the native soils beneath the base materials. Enter that into the "measured infiltration rate" field. For the Infiltration Reduction Factor, enter 0.5.~~

~~Run the model to produce the overflow runoff file from the gravel trench. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. Design the road base materials to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.~~

~~*C.11.2 Instructions for Roads on Grades above 2%*~~

~~Road base material volumes that are below the surrounding grade and that are on a slope can be modeled as a gravel trench with an infiltration rate and a nominal depth. Represent the below grade volume as the gravel trench. Grab the gravel trench icon and place it below the "basin" icon so that the computer model routes all of the runoff into the gravel trench.~~

~~The dimensions of the gravel trench are: the length (parallel to and beneath the road) of the base materials that are below grade; the width of the below grade base materials; and an Effective Total Depth of 1 inch. In WWHM3, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. So, enter 0.04 ft (½ inch) for the "Riser Height" and a large Riser Diameter (say 1000 inches) to ensure that there is no head build up.~~

~~*Note:* If a drainage pipe is embedded and elevated in the below grade base materials, the pipe should only have perforations on the lower half (below the spring line) or near the invert. Pipe volume and trench volume above the pipe invert cannot be assumed as available storage space. If a drainage pipe is placed at the bottom of the base material, the pavement is modeled as an impervious surface without any gravel trench.~~

~~Estimate the infiltration rate of the native soils beneath the base materials. See the previous section (Instructions for Roads on Zero to 2% Grade) for estimating options and for how to enter infiltration rates and infiltration reduction factors for the gravel trench. In the "Material Layers" field, enter ½ inch for Layer 1 Thickness and its appropriate porosity. For all infiltration facilities, WWHM3 has a button that asks, "Use Wetted Surface Area?" The answer should remain "NO."~~

~~Run the model to produce the effluent runoff file from the gravel trench (base materials). Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.~~

~~*C.11.3 Instructions for Roads on a Slope with Internal Dams within the Base Materials that are Below Grade*~~

~~In this option, a series of infiltration basins is created by placing relatively impermeable barriers across the below grade base materials at intervals downslope. The barriers inhibit the free flow of water down the grade of the base materials. The barriers must not extend to the elevation of the surrounding ground. Provide a space sufficient to pass water from upgradient to lower gradient basins without causing flows to surface out the sides of the base materials that are above grade.~~

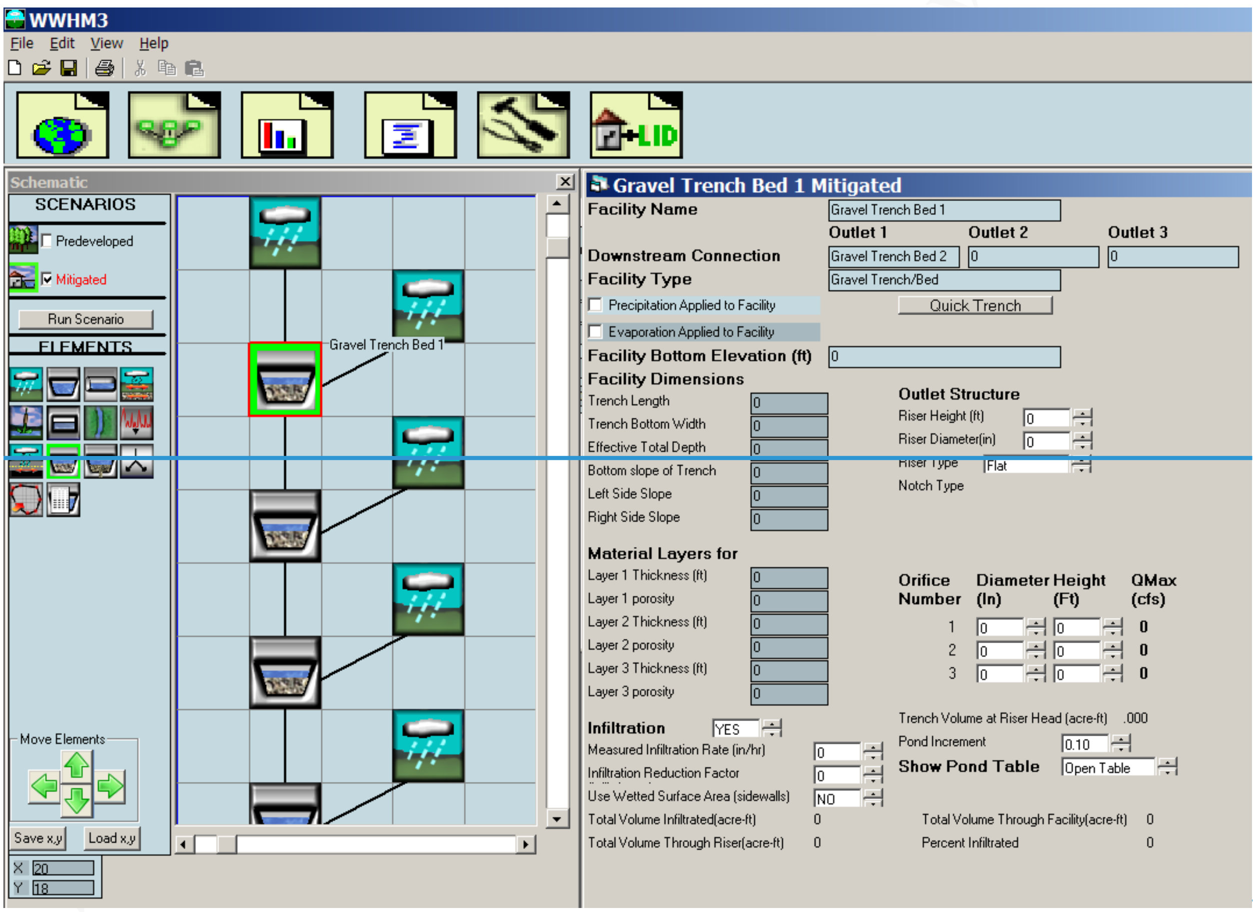
~~Each stretch of trench (cell) that is separated by barriers can be modeled as a gravel trench. This is done by placing the "Gravel trench/bed" icons in series in WWHM. For each cell, determine the average depth of water within the cell (Average Cell Depth) at which the barrier at the lower end will be overtopped.~~

~~Specify the dimensions of each cell of the below-grade base materials using the "Gravel trench/bed" dimension fields for: the "Trench Length" (length of the cell parallel to the road); the "Trench Bottom Width"(width of the bottom of the base material); and the Effective Total Depth (the Average Cell Depth as determined above).~~

~~Also in WWHM3, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. For each trench cell, the available storage is the void space within the Average Cell Depth. WWHM calculates the storage/void volume of the trench cell using the porosity values entered in the "Layer porosity" fields. The value for the "***Riser Height***" should be slightly below the "Effective Total Depth" (say by about 1/8" to ¼"). For the ***Riser diameter***, enter a large number (say 10,000 inches) to ensure that there is ample capacity should overflows from the below-grade trench occur.~~

~~Each cell should have its own tributary drainage area that includes the road above it, any project site pervious areas whose runoff drains onto and through the road, and any off-site areas. Each drainage area is represented with a "basin" icon.~~

~~Below is the computer graphic representation of a series of Gravel trench/beds and the Basins that flow into them.~~



~~It is possible to represent a series of cells as one infiltration basin (using a single gravel trench icon) if the cells all have similar length and width dimensions, slope, and Average Cell Depth. A single "basin" icon is also used to represent all of the drainage area into the series of cells.~~

~~On the Gravel Trench screen under "Infiltration", there is a field that asks the following "Use Wetted Surface Area?" By default, it is set to "NO". It should stay "NO" if the below-grade base material trench has sidewalls steeper than 2 horizontal to 1 vertical.~~

~~Using the procedures explained above for roads on zero grade, estimate the infiltration rate of the native soils beneath the trench. Also as explained above, enter the appropriate values into the "Measured Infiltration Rate" and "Infiltration Reduction Factor" boxes.~~

~~Run the model to produce the effluent runoff file from the below grade trench of base materials. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved size a downstream retention or detention facility (using the WWHM standard procedures) and locate it in the field. Design the road base materials to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.~~

~~Part 2: Summary of WWHM 2012 Representation of LID BMPs~~

~~Downspout Dispersion – BMP T5.10B~~

~~Where BMP T5.10B – Downspout Dispersion - is used to disperse runoff into an undisturbed native landscape area or an area that meets BMP T5.13 – Soil Quality and Depth, and the vegetated flow path is at least 25 feet, the connected roof area should be modeled as a lateral flow impervious area. Do this in WWHM on the Mitigated Scenario screen by connecting the dispersed impervious area to the lawn/landscape lateral flow soil basin element representing the area that will be used for dispersion. If the flow path is only 25 – 50 feet long, flows must be distributed using a dispersion trench (see Figures 3.XX and 3.XX in this volume) as a prerequisite to use of the lateral flow element.~~

~~Ecology may develop guidance for representing multiple downspout dispersions in a project site. If such guidance is not forthcoming, in situations where multiple downspout dispersions will occur, Ecology may allow the roof area to be modeled as a landscaped area (where the 50 foot flowpath requirement is met), or as 50% landscape/50% lawn (where a gravel trench is used to disperse into a vegetated area with a 25 to 50 foot flowpath) so that the project schematic in WWHM becomes manageable.~~

~~Concentrated Flow Dispersion – BMP T5.11~~

~~Where BMP T5.11- Concentrated Flow Dispersion - is used to disperse impervious area runoff into an undisturbed native landscape area or an area that meets BMP T5.13 – Soil Quality and Depth, and the vegetated flow path is at least 50 feet, the impervious area should be modeled as a lateral flow impervious area. Do this in WWHM on the Mitigated Scenario screen by connecting the dispersed impervious area to the lawn/landscape lateral flow soil basin element representing the area that will be used for dispersion.~~

~~Ecology may develop guidance for representing multiple concentrated flow dispersions in a project site. If such guidance is not forthcoming, in situations where multiple concentrated flow dispersions will occur, Ecology may allow the impervious area to be modeled as a landscaped area so that the project schematic in WWHM becomes manageable.~~

~~Sheet Flow Dispersion – BMP T5.12~~

~~Where BMPT5.12 – Sheet Flow Dispersion - is used to disperse impervious area runoff into an undisturbed native landscape area or an area that meets BMP T5.13 – Soil Quality and Depth, the impervious area should be modeled as a lateral flow impervious area. Do this in WWHM on the Mitigated Scenario screen by connecting the dispersed impervious area to the lawn/landscape lateral flow soil basin element representing the area that will be used for dispersion.~~

~~Ecology may develop guidance for representing multiple sheet flow dispersions in a project site. If such guidance is not forthcoming, in situations where multiple sheet flow dispersions will occur, Ecology may allow the impervious area to be modeled as a landscaped area so that the project schematic in WWHM becomes manageable.~~

~~Post-Construction Soil Quality and Depth – BMP T5.13~~

~~Enter area as pasture~~

~~Bioretention – BMP T7.30~~

~~Use new bioretention element for each type: cell, swale, or planter box.~~

~~The equations used by the elements are intended to simulate the wetting and drying of soil as well as how the soils function once they are saturated. This group of LID elements uses the modified Green Ampt equation to compute the surface infiltration into the amended soil. The water then moves through the top amended soil layer at the computed rate, determined by Darcy's and Van Genuchten's equations. As the soil approaches field capacity (i.e., gravity head is greater than matric head), the model determines when water will begin to infiltrate into the second soil layer (lower layer). This occurs when the matric head is less than the gravity head in the first layer (top layer). The second layer is intended to prevent loss of the amended soil layer. As the second layer approaches field capacity, the water begins to move into the third layer – the gravel underlayer. For each layer, the user inputs the depth of the layer and the type of soil.~~

~~For the Ecology-recommended soil specifications for each layer in the design criteria for bioretention, the model will automatically assign pre-determined appropriate values for parameters that determine water movement through that soil. These include: wilting point, minimum hydraulic conductivity, maximum saturated hydraulic conductivity, and Van Genuchten number.~~

~~If a user opts to use soils that deviate from the recommended specifications, the default parameter values do not apply. The user will have to use the Gravel Trench element to represent the bioretention facility and follow the procedures identified for WWHM3.~~

~~For Bioretention with underlying perforated drain pipes that discharge to the surface, the only volume available for storage (and modeled as storage as explained herein) is the void space within the aggregate bedding layer below the invert of the drain pipe. Use 40% void space for the Type 26 mineral aggregate specified in Chapter 7 of Volume V.~~

~~Using one of the procedures explained in Volume III - Chapter 3 of this manual, estimate the initial measured (a.k.a., short-term) infiltration rate of the native soils beneath the bioretention soil and any base materials. Because these soils are protected from fouling, no correction factor will be applied.~~

~~Permeable Pavements – BMP T5.15~~

~~Use new porous pavement element.~~

~~User specifies pavement thickness & porosity, aggregate base material thickness & porosity, maximum allowed ponding depth & infiltration rate into native soil. For grades greater than 2%, see additional guidance under the WWHM3 section.~~

~~Vegetated Roofs – BMP T5.17~~

~~Use new green roof element~~

~~User specifies media thickness, vegetation type, roof slope, and length of drainage.~~

~~Impervious Reverse Slope Sidewalks – BMP T5.18~~

~~Use the lateral flow elements to send the impervious area runoff onto the lawn/landscape area that will be used for dispersion.~~

~~Ecology may develop guidance for representing multiple impervious reverse slope sidewalks in a project site. If such guidance is not forthcoming, in situations where multiple impervious reverse slop sidewalks will occur, Ecology may allow the impervious area to be modeled as a landscaped area so that the project schematic in WWHM becomes manageable.~~

~~Minimal Excavation Foundations – BMP T5.19~~

~~Where residential roof runoff is dispersed on the up gradient side of a structure in accordance with the design criteria and guidelines in BMP T5.10B, the tributary roof area may be modeled as pasture on the native soil.~~

~~In "step forming," the building area is terraced in cuts of limited depth. This results in a series of level plateaus on which to erect the form boards. Where "step forming" is used on a slope, the square footage of roof that can be modeled as pasture must be reduced to account for lost soils. The following equation (suggested by Rick Gagliano of Pin Foundations, Inc.) can be used to reduce the roof area that can be modeled as pasture.~~

~~$A_1 - \frac{dC(.5)}{dP} X A_1 = A_2$~~

~~A_1 = roof area draining to up gradient side of structure~~

~~dC = depth of cuts into the soil profile~~

~~dP = permeable depth of soil (The A horizon plus an additional few inches of the B horizon where roots permeate into ample pore space of soil).~~

~~A_2 = roof area that can be modeled as pasture on the native soil. The rest of the roof is modeled as impervious surface unless it is dispersed in accordance with the next bullet.~~

~~If roof runoff is dispersed down gradient of the structure in accordance with the design criteria and guidelines in BMP T5.10B, AND there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in BMP T5.13, the tributary roof areas should be modeled as a lateral flow impervious area. This is done in WWHM on the Mitigated Scenario screen by connecting the dispersed impervious area to the lawn/landscape lateral flow soil basin element representing the area that will be used for dispersion.~~

~~Ecology may develop guidance for representing multiple downspout dispersions in a project site. If such guidance is not forthcoming, in situations where multiple downspout (down gradient) dispersions will occur, Ecology may allow the roof area to be modeled as a landscaped area so that the project schematic in WWHM becomes manageable.~~

~~Full dispersion – BMP T5.30~~

~~Full downspout infiltration – BMP T5.10A~~

~~Rainwater Harvesting – BMP T5.20~~

~~If BMP design criteria are followed, the area draining to the three BMPs listed immediately above is not entered into the runoff model.~~

~~Newly planted trees – BMP T5.16~~

~~Retained trees – BMP T5.16~~

~~If BMP design criteria are followed, the total impervious/hard surface areas entered into the runoff model may be reduced by an amount indicated in the criteria for the tree BMPs listed immediately above.~~

~~Perforated Stub-out Connection – BMP T5.10C~~

~~Any flow reduction is variable and unpredictable. No computer modeling techniques are allowed that would predict any reduction in flow rates and volumes from the connected area.~~