Stormwater Management

FOR EASTERN WASHINGTON

FINAL DRAFT

Stormwater Management Manual for Eastern Washington

Chapter 5 – Runoff Treatment Facility Design
Chapter 6 – Flow Control Facility Design

WASHINGTON STATE DEPARTMENT OF ECOLOGY

June 2003
Publication Number 03-10-038B

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Chapter 5 - Runoff Treatment Facility Design

5.1 Introduction

Best Management Practices (BMPs) are schedules of activities, prohibitions of practices, maintenance procedures, managerial practices, or structural features that prevent or reduce adverse impacts to waters of Washington State. BMPs for long-term management of stormwater at developed sites can be divided into three main categories:

- BMPs addressing the volume and timing of stormwater flows;
- BMPs addressing prevention of pollution from potential sources; and
- BMPs addressing treatment of runoff to remove sediment and other pollutants.

This section of the stormwater manual focuses on the third category, treatment of runoff to remove sediment and other pollutants at developed sites. The purpose of this section is to provide guidance for selection, design and maintenance of permanent runoff treatment facilities.

Runoff treatment facilities are designed to remove pollutants contained in stormwater runoff. The pollutants of concern include sand, silt, and other suspended solids; metals such as copper, lead, and zinc; nutrients (e.g., nitrogen and phosphorous); certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides. Methods of pollutant removal include sedimentation/settling, filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Floatable pollutants such as oil, debris, and scum can be removed with separator structures.

5.1.1 How to Use this Chapter

This chapter should be consulted to select specific BMPs for runoff treatment for inclusion in Stormwater Site Plans. This chapter can be used to select specific treatment facilities for permanent use at developed sites, and as an aid in designing and constructing these facilities.

5.1.2 Runoff Treatment Facilities

Treatment methods and facilities described in this chapter include:

- Infiltration and Bio-infiltration (Surface Infiltration)
- Biofiltration
- Subsurface Infiltration
- Wetpool (wet pond, wet vault)
- Filtration (sand filters, media filters)
- Evaporation Pond

- Oil Control
- Phosphorous Treatment and Metals Treatment

Performance Goals

The water quality design storm volume and flow rates are intended to capture and effectively treat at least 90 percent of the annual runoff volume. Pollutant removal performance goals have been selected for each of the major categories of BMPs. These goals are:

Basic Treatment Facilities

The Basic Treatment facility choices shown in Figure 5.2.1 are intended to achieve 80% removal of total suspended solids for influent concentrations that are greater than 100 mg/l, but less than 200 mg/l. For influent concentrations greater than 200 mg/l, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/l, the facilities are intended to achieve an effluent goal of 20 mg/l total suspended solids. The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable. The goal also applies on an average annual basis to the entire annual discharge volume (treated plus bypassed).

Oil Control Facilities

The Oil Control facility choices shown in Figure 5.2.1 are intended to achieve the goals of no ongoing or recurring visible sheen, and to have a 24-hour average Total Petroleum Hydrocarbon (TPH) concentration no greater than 10 mg/l, and a maximum of 15 mg/l for a discrete sample (grab sample).

Phosphorous Treatment

The Phosphorus Treatment facility choices shown in Figure 5.2.1 are intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations of 0.1 – 0.5 mg/l total phosphorus. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained.

Metals Treatment

The Metals Treatment facility choices shown in Figure 5.2.1 are intended to provide a higher rate of removal of dissolved metals than Basic Treatment facilities. Due to the sparse data available concerning dissolved metals removal in stormwater treatment facilities, a specific numeric removal efficiency goal could not be established at the time of publication. Instead, Ecology relied on available nationwide and local data, and knowledge of the pollutant removal mechanisms of treatment facilities to develop the list of options. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal assumes that the facility is treating stormwater with dissolved copper typically ranging from 0.003 to 0.02 mg/l, and dissolved zinc ranging from 0.02 to 0.3 mg/l.

The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of treatment facilities that treat flows higher than the water quality design flow rate as long as the reduction in dissolved metals loading meets the performance goal.

5.2 Treatment Facility Selection Process

This section describes a process for selecting the type of treatment facilities that will apply to individual projects. Refer to Sections 5.10 and 5.11 for additional details on three of the four treatment facility options - oil control treatment, phosphorus control, and Metals Treatment.

5.2.1 Step-by-Step Selection Process for Treatment Facilities

A seven-step selection process is used to aid the designer in choosing the appropriate treatment facility for a particular project. The seven steps are:

Step 1: Determine Where Site Discharges to:

A. Evaporation
B. Combined Sanitary Sewer
C. Surface Water
D. Surface Infiltration
E. Subsurface Infiltration

Step 2: If to Surface Water, Determine the Receiving Waters and Pollutants of Concern Based on Off-Site Analysis

Step 3: Determine if an Oil Control Facility/Device is Required

Step 4: Determine if Pollutant Removal via Infiltration and Collection is Practicable

Step 5: Determine if Control of Phosphorous is Required

Step 6: Determine if Metals Treatment is Required

Step 7: Select a Basic Treatment Facility

The process should be used in conjunction with Figures 5.2.1 and 5.2.2. Table 5.2.1 provides information on determining pollutant sources and pollutants of concern for some land uses. Table 5.2.2 provides information on the relative ability of different treatment facilities to remove key pollutants. Table 5.2.3 provides an initial screening of treatment facilities based upon several soil types. Table 5.2.4 provides suggested stormwater treatment options for arid and semi-arid climates. Table 5.2.5 discussed cold weather challenges to BMP design. And Table 5.2.6 provides a summary of BMP applicability in cold regions.

Refer to Figure 5.2.1 for a flow chart of the steps.

Step 1: Determine Where Site Discharges To:

__A. Evaporation__ (no additional treatment required)

__B. Combined Sanitary Sewer__ (no additional treatment required)

C. Surface Waters (proceed to Step 2)

__D. Surface Infiltration__ (proceed further with Step 1)

__E. Subsurface Infiltration__ (proceed further with Step 1)

Determine if Treatment is Required and Apply Infiltration BMP

Check the infiltration treatment design criteria in Section 5.4 of this chapter. Infiltration can be effective at treating stormwater runoff, but soil properties must be appropriate to achieve effective treatment while not adversely impacting ground water resources. The location and depth to bedrock, the water table, or impermeable layers, and the proximity to wells, foundations, septic tank drainfields, and unstable slopes can preclude the use of infiltration.

Infiltration treatment facilities should be preceded by a pretreatment facility, such as a presettling basin or vault, to reduce the occurrence of plugging. Any of the basic treatment facilities, and detention ponds designed to meet flow control requirements, can also be used for pre-treatment.

If an infiltration treatment facility is planned, please refer to the Core Elements in Chapter 2 – Core Elements for New Development and Redevelopment. They can affect the design and placement of facilities on your site.

Figure 5.2.2 describes a BMP selection process for discharges to subsurface infiltration facilities, sometimes referred to as drywells. One of the initial steps is to determine pollutant source and loading. The geologic matrix and depth to ground water should be determined using the criteria and guidance in Chapter 6. Using Table 5.6.3, a determination is then made whether treatment is required prior to discharge. If treatment is required, appropriate controls are then selected, such as oil control, and/or other treatment BMPs as applicable. The reader should use Chapter 6 for subsurface infiltration system siting and design guidance.

The local government should verify whether any type of groundwater quality management plans and/or local ordinances or regulations have been established such as:

- **Groundwater Management Plans (Wellhead Protection Plans):** To protect groundwater quality and/or quantity, these plans may identify actions required of stormwater discharges.

If Some or All Site Stormwater Discharges to Surface Waters, Proceed to Step 2; If There are No Discharges to Surface Waters, then Perform Step 1.

Step 2: Determine the Receiving Waters and Pollutants of Concern

To obtain a more complete determination of the potential impacts of a stormwater discharge, Ecology encourages local governments to require an Off-site Analysis similar to that in Chapter 3 – Preparation of Stormwater Site Plans. Also, see Core Element #5 in Chapter 2, Section 2.2.5. Even without an off-site analysis requirement, the project proponent must determine the natural receiving water for the stormwater drainage from the project site (wetland, lake, or stream). This is necessary to determine the applicable treatment menu from which to select treatment facilities. The identification of the receiving water should be verified by the local government agency with review responsibility. If the discharge is to the local municipal storm drainage system, the receiving water for the drainage system must be determined.

The local government should verify whether any type of water quality management plans and/or local ordinances or regulations have established specific requirements for the receiving waters. The developer/owner/engineer needs to check all other agencies for requirements. Examples of plans to be aware of include:

- **Watershed or Basin Plans:** These can be developed to cover a wide variety of geographic scales (e.g., Water Resource Inventory Areas, or sub-basins of a few square miles), and can be focused solely on establishing stormwater requirements (e.g., “Stormwater Basin Plans”), or can address a number of pollution and water quantity issues, including urban stormwater.

- **Water Clean-up Plans:** These plans are written to establish a Total Maximum Daily Load (TMDL) of a pollutant or pollutants in a specific receiving water or basin, and to identify actions necessary to remain below that maximum loading. The plans may identify discharge limitations or management limitations (e.g., use of specific treatment facilities) for stormwater discharges from new and redevelopment projects.

- **Lake Management Plans:** These plans are developed to protect lakes from eutrophication due to inputs of phosphorus from the drainage basin. Control of phosphorus from new development is a likely requirement in such plans.

An analysis of the proposed land use(s) of the project should also be used to determine the stormwater pollutants of concern. Table 5.2.1 lists the pollutants of concern from various land uses. Table 5.2.2 lists the ability of treatment facilities to remove key pollutants. Refer to these tables for examples of treatment options after determining whether oil control, phosphorus, enhanced, or basic treatments apply to the project. Those decisions are made in the steps below.

Step 3: Determine if an Oil Control Facility/Device is Required

The use of oil control devices and facilities is required for high use sites. High use sites are those that typically generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil. See Core Element #5 in Chapter 2, Section 2.2.5, Guidelines section, for a description of these sites.

Application on the Project Site Oil control facilities are to be placed upstream of other facilities, as close to the source of oil generation as practical. For high-use sites located within a larger commercial center, only the impervious surface associated with the high-use portion of the site is subject to treatment requirements. If common parking for multiple businesses is provided, treatment shall be applied to the number of parking stalls required for the high-use business only. However, if the treatment collection area also receives runoff from other areas, the treatment facility must be sized to treat all water passing through it.

High-use roadway intersections shall treat lanes where vehicles accumulate during the signal cycle, including left and right turn lanes and through lanes, from the beginning of the left turn pocket. If no left turn pocket exists, the treatable area shall begin at a distance equal to three car lengths from the stop line. If runoff from the intersection drains to more than two collection areas that do not combine within the intersection, treatment may be limited to any two of the collection areas.

Oil Control Treatment Options Oil control options include facilities that are small, treat runoff from a limited area, and require frequent maintenance. The options also include facilities that treat runoff from larger areas and generally have less frequent maintenance needs.

- **API-Type Oil/Water Separator –** See Section 5.10
- **Coalescing Plate Oil/Water Separator –** See Section 5.10

- **Catch Basin Inserts** – See Section 5.12
- **Bio-infiltration Swales –** See Section 5.4
- **Sand Filter –** See Section 5.8

Note*: Some land use types require the use of a spill control (SC-type) oil/water separator. Those situations are described in Chapter 8 and are separate from this treatment requirement. While a number of activities may be required to use spill control (SC-type) separators, only a few will necessitate an American Petroleum Institute (API) or a coalescing plate (CP)-type separators for treatment. The following urban land uses are likely to have areas that fall within the definition of "high-use sites" or have sufficient quantities of free oil present that can be treated by an API or CP-type oil/water separator:*

- Industrial Machinery and Equipment, and Railroad Equipment Maintenance
- Log Storage and Sorting Yards
- Aircraft Maintenance Areas
- Railroad Yards
- Fueling Stations
- Vehicle Maintenance and Repair
- Construction Businesses (paving, heavy equipment storage and maintenance, storage of petroleum products).

If oil control is required for the site, please refer to the General Requirements in Sections 5.3 and 5.10.6. These requirements may affect the design and placement of facilities on the site (e.g., flow splitting). If an Oil Control Facility is required, select and apply an Oil Control Facility. Refer to the Oil Control options listed above and in Figure 5.2.1.

Step 4: Determine if Infiltration for Pollutant Removal is Practicable

In some situations it may be feasible to treat stormwater through infiltration, after which it is collected in a conveyance system and discharged to a surface water. See Section 5.4 for planning guidance and design criteria to determine the feasibility of infiltration. Although a site may be unable to meet the criteria of Site Suitability Criteria 4 given in Section 5.4 (depth to impermeable layer >5), infiltration may be used near the ground surface as a treatment measure. The treated water can then be collected in perforated pipe or other conduit and discharged offsite. The outer boundaries of the infiltration facility must be lined to prevent unwanted exfiltration into the surrounding soils. Note that the other six Site Suitability Criteria listed in Section 5.4 must still be met in order to utilize this approach.

Step 5: Determine if Control of Phosphorous is Required

The requirement to provide phosphorous control is determined by the local jurisdiction, the Department of Ecology, or the USEPA. The local jurisdiction may have developed a management plan and implementing ordinances or regulations for control of phosphorus from new development and redevelopment for the receiving water(s) of the stormwater drainage. The local jurisdiction can use the following sources of information for pursuing plans and implementing ordinances and/or regulations:

Those waterbodies reported under section 305(b) of the Clean Water Act, and designated as not supporting beneficial uses due to phosphorous;

Those listed in Washington State's Nonpoint Source Assessment required under section 319(a) of the Clean Water Act due to nutrients.

If phosphorus control is required, select and apply a phosphorous treatment facility. Please refer to the Phosphorus Treatment options shown in Section 5.11 and Figure 5.2.1. Select a facility after reviewing the applicability and limitations, site suitability, and design criteria of each for compatibility with the site. You may also use Tables 5.2.1 through 5.2.6 as an initial screening of options.

If you have selected a phosphorus treatment facility, please refer to the General Requirements in Section 5.3. They may affect the design and placement of the facility on the site.

Note: *Project sites subject to the Phosphorus Treatment requirement could also be subject to the Metals Treatment requirement (see Step 6). In that event, apply a facility or a treatment train that is listed in both the Metals Treatment Menu and the Phosphorus Treatment Menu.*

Step 6: Determine if Metals Treatment is Required

Metals Treatment is required for:

- Industrial project sites,
- Commercial project sites,
- Multi-family project sites, and
- Arterials and highways

which discharge to fish-bearing streams, lakes, or to waters or conveyance systems tributary to fish-bearing streams or lakes. Areas of arterials and highways, multifamily, industrial and commercial project sites that do not discharge to fish-bearing streams or lakes or are identified in a storm drainage comprehensive plan or basin plan as subject to Basic Treatment requirements are not subject to Metals Treatment requirements. For developments with a mix of land use types, the Metals Treatment requirement shall apply when the runoff from the areas subject to the

Metals Treatment requirement comprise 50% or more of the total runoff within a threshold discharge area.

If the project must apply Metals Treatment, select and apply an appropriate Metals Treatment facility. Please refer to the Metals Treatment options shown in Figure 5.2.1 and detailed in Section 5.11. Select a facility after reviewing the applicability and limitations, site suitability, and design criteria of each for compatibility with the site. You may also use Tables 5.2.1 through 5.2.6 for an initial screening of the options or parts of the two facility treatment trains.

Note*: Project sites subject to the Metals Treatment requirement could also be subject to a phosphorus removal requirement if located in an area designated for phosphorus control. In that event, apply a facility or a treatment train that is listed in both the Metals Treatment Menu and the Phosphorus Treatment Menu. If you have selected an Metals Treatment facility, please refer to the General Requirements in Section 5.3. They may affect the design and placement of the facility on the site.*

If Phosphorus Control or Metals Treatment is Required, Step 7 is Not Required.

Step 7: Select a Basic Treatment Facility

Basic Treatment Options Any one of the following options may be chosen to satisfy the Basic Treatment requirement:

- Bio-infiltration swale (grassed percolation area)
- Biofiltration swale
- Vegetated Filter Strip
- Wetpond
- Wetvault
- Combined Detention/Wetpond
- Sand filter
- Media filter
- Evaporation pond

Refer to Tables 5.2.1 through 5.2.6 as an initial screening of options.

After selecting a Basic Treatment Facility, refer to the General Requirements in Section 5.3. They may affect the design and placement of the facility on the site.

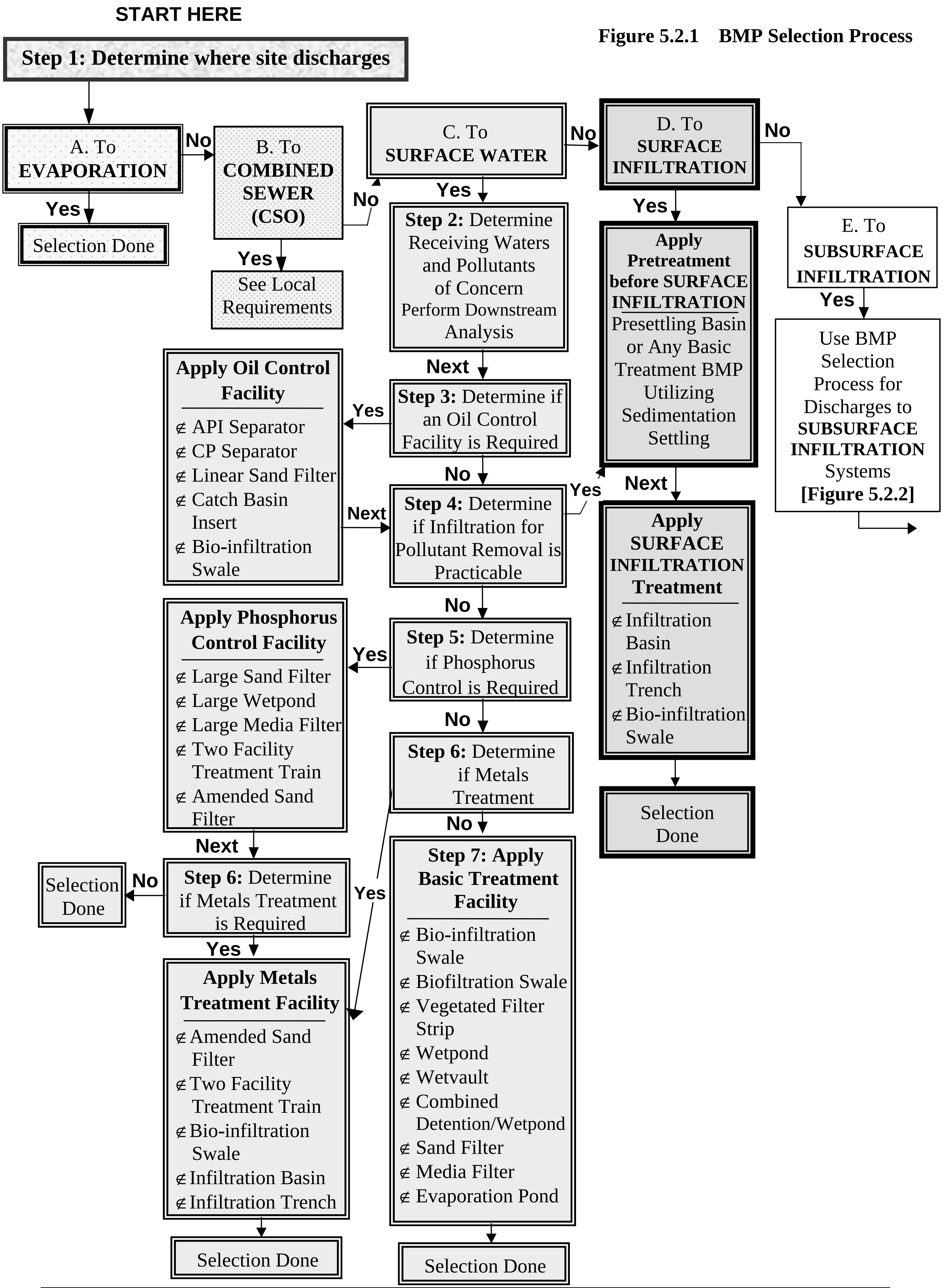
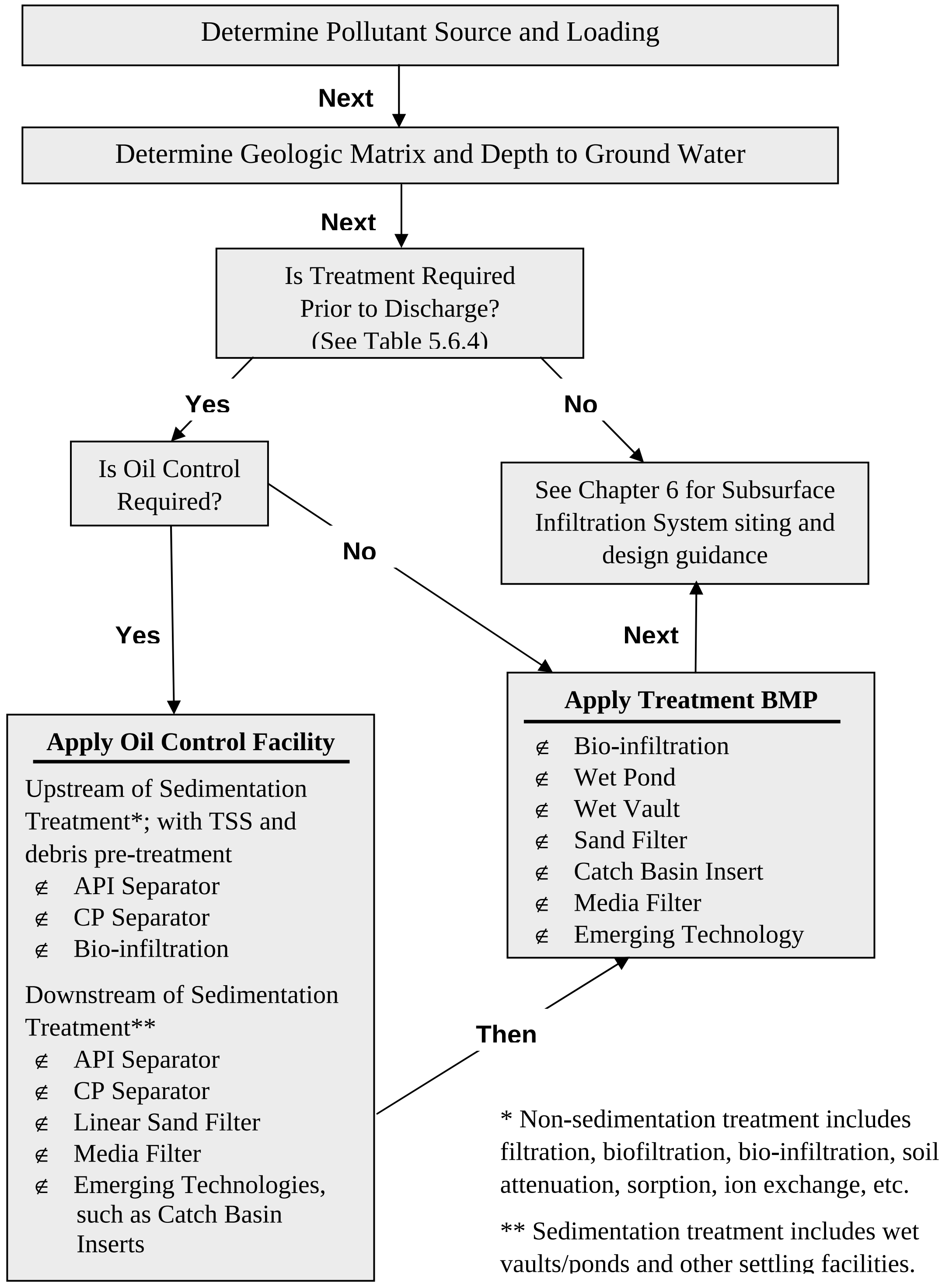


Figure 5.2.1 BMP Selection Process

Figure 5.2.2
BMP Selection Process for Discharges to Subsurface Infiltration Systems



5.2.2 Other Treatment Facility Selection Factors

The selection of a treatment facility should be based on site physical factors and pollutants of concern. The types of site physical factors that influence facility selection are summarized below.

Pollutants of Concern (Table 5.2.1 and 5.2.2)

Table 5.2.1 summarizes the pollutants of concern and those land uses that are likely to generate pollutants. It also provides suggested basic treatment options for each land use. For example, oil and grease are the expected pollutants from an uncovered fueling station. Using Table 5.2.1, a combination of an oil/water separator and a biofilter could be considered as the basic treatment for runoff from uncovered fueling stations. Table 5.2.2 is a general listing of the relative effectiveness of classes of treatment facilities in removing key stormwater pollutants.

Soil Type (Table 5.2.3)

The permeability of the soil underlying a treatment facility has a profound influence on its effectiveness. This is particularly true for infiltration treatment facilities that are best sited in sandy to loamy sand soils. They are not generally appropriate for sites that have final infiltration rates of less than 0.5 inches per hour. Wet pond facilities situated on coarser soils will need a synthetic liner or the soils amended to reduce the infiltration rate and provide treatment. Maintaining a permanent pool in the first cell is necessary to avoid resuspension of settled solids. Biofiltration swales in coarse soils can also be amended to reduce the infiltration rate.

High Sediment Input

High TSS loads can clog infiltration soil, sand filters and coalescing plate oil & water separators. Pretreatment with a presettling basin, wet vault, or another basic treatment facility would typically be necessary.

Annual Rainfall (Table 5.2.4)

Arid regions have annual rainfall less than 16 inches and semi-arid regions have annual rainfall from 16 to 35 inches. The amount of annual rainfall affects the effectiveness of BMPs that rely on vegetation for filter material or a pool of water for treatment. Table 5.2.4 identifies the preferred BMPs and the limitations to use in the arid and semi-arid climates found in most of Eastern Washington.

Other Physical Factors

- **Slope:** Steep site slopes restrict the use of several BMPs. A geotechnical/hydrologic evaluation should be done for sites on steeper slopes. See specific guidance for each BMP.

- **High Water Table:** Unless there is sufficient horizontal hydraulic receptor capacity the water table acts as an effective barrier to exfiltration and can sharply reduce the efficiency of an infiltration system. If the high water table extends to within five (5) feet of the bottom of an infiltration BMP, the site is seldom suitable.

∉ **Depth to Limiting Layer:** The downward exfiltration of stormwater is also impeded if a bedrock or till layer lies too close to the surface. If the impervious layer lies within five feet below the bottom of the infiltration BMP the site is not suitable. Similarly, pond BMPs are often not feasible if bedrock lies within the area that must be excavated.

∉ **Proximity to Foundations and Wells:** The downward exfiltration of stormwater can be impeded by many different types of impervious limiting layers, including but not limited to: bedrock, hardpan, till, or clay. This can be a real problem if the BMP is located too close to a building foundation. Another risk is ground water pollution, hence the requirement to site infiltration systems more than 100 feet away from drinking water wells.

Table 5.2.1
Typical Sources for Pollutants of Concern in Stormwater

Pollutant Sources	Pollutants of Concern
ROOFS:	
Metal	Zn
Vents & Emissions(1)	O & G, TSS, Organics
PARKING LOT/DRIVEWAY:	
>High-use Site	High O & G, TSS, Cu, Zn, PAH
<High-use	O & G, TSS
STREETS/HIGHWAYS:	
Arterials/Highways	O & G, TSS, Cu, Zn, PAH
Residential Collectors	Low O & G, TSS, Cu, Zn
High Use Site Intersections	High O & G, TSS, Cu, Zn, PAH
OTHER SOURCES:	
Industrial/Commercial Development	O & G, TSS, Cu, Zn
Residential Development	TSS, Pest/ Herbicides Nutrients
Uncovered Fueling Stations:	High O & G
Industrial Yards	High O & G, TSS, Metals, PAH
	Metals, TSS, PAH

Notes:
Application of effective source control measures is the preferred approach for pollutant reduction. Where source control measures are not used, or where they are ineffective, stormwater treatment is necessary.

Legend:

Cu = Copper
O & G = Oil and Grease
PAH = Polycyclic Aromatic Hydrocarbons
PGPS = Pollution-generating pervious surface
TSS = Total Suspended Solids
Zn = Zinc

(1) Manufacturing and Food Production

Table 5.2.2[4]
Ability of Treatment Facilities to Remove Key Pollutants[1] [3]

Treatment Facility	TSS	Dissolved Metals incl. Cu, Zn	Total Phosphorus	Pesticides/ Fungicides	Hydro-carbons incl. O&G, PAH
Wet Pond	Â	+	+		+
Wet Vault	Â				
Biofiltration	Â	+	+	+	+
Sand Filter	Â	+	+		+
Constructed Wetland	Â	Â	+	Â	Â
Leaf Compost Filters	Â	+		Â	Â
Infiltration[2]	Â	+		+	+
Oil/Water Separator					Â
Bio-infiltration	Â	Â	+	Â	Â

Footnotes:
Â Significant Process
+ Lesser Process
(1) Adapted from Kulzer, King Co. Additional BMPs not included in the table, but that have metals treatment benefit, are amended sand filter, and two facility treatment trains; for phosphorus treatment are large sand filter, two facility treatment trains, and amended sand filter.
(2) Assumes Loamy sand, Sandy loam, or Loam soils
(3) If a cell is blank, then the Treatment Facility is not particularly effective at treating the identified pollutant

Table 5.2.3
Screening Treatment Facilities Based on Soil Type

Soil Type	Infiltration	Wet Pond*	Bio-Infiltration	Biofiltration* (Swale or Filter Strip)
Coarse Sand or Cobbles	-	-	-	-
Sand	Â	-	-	-
Loamy Sand	Â	-	Â	Â
Sandy Loam	Â	-	Â	Â
Loam	-	-	Â	Â
Silt Loam	-	-	Â	Â
Sandy Clay Loam	-	Â	-	Â
Silty Clay Loam	-	Â	-	Not Generally Approp.
Sandy Clay	-	Â	-	Not Generally Approp.
Silty Clay	-	Â	-	-
Clay	-	Â	-	-

Notes:
Â Indicates that use of the technology is generally appropriate for this soil type.
- Indicates that use of the technology is generally not appropriate for this soil type
** Coarser soils may be used for these facilities if a liner is installed to prevent infiltration, or if the soils are amended to reduce the infiltration rate.*
***Note:** Sand filtration is not listed because its feasibility is not dependent on soil type.*

Table 5.2.4
Suggested Stormwater Treatment Options
Based on Rainfall

Stormwater Practice	Arid Watersheds < 16 in. rainfall	Semi-Arid Watersheds 16 in. to 35 in. rainfall
Sand filters	Preferred: Á requires greater pretreatment Á sensitive to sediment loadings	Preferred
Bio-infiltration Swales	Acceptable with Limitations: Á Use dryland grass	Preferred: Á Use dryland or irrigated grass
Extended detention dry ponds	Preferred: Á Multiple storm extended detention Á Stable pilot channels Á "Dry" forebay	Acceptable: Á dry or wet forebay needed
Infiltration	Acceptable with Limitations: Á See Table 5.6.4 Á minimize erodable soils that reduce infiltration Á pretreatment Á soil limitations	Acceptable with Limitations: Á See Table 5.6.4 Á minimize erodable soils that reduce infiltration Á pretreatment
Wet ponds	Not Recommended: Á evaporation rates are too high to maintain a normal pond without extensive use of scarce water	Limited Use: Á liners to prevent water loss require water balance analysis design for a variable rather than permanent normal pool Á use water sources such as AC condensate for pool Á aeration unit to prevent stagnation
Stormwater wetlands	Not Recommended: Á evaporation rates too great to maintain wetlands plants	Limited Use: Á require supplemental water Á submerged gravel wetlands can help reduce water loss
Biofiltration Swales	Not Recommended: Á not recommended for pollutant removal, but rock berms and grade control needed for open channels to prevent channel erosion	Limited Use: Á limited use unless irrigated Á rock berms and grade control essential to prevent erosion in open channels

Adapted from: Stormwater Strategies for Arid and Semi-Arid Watersheds, Watershed Protection Techniques, Vol. 3, No. 3, March 2000

5.2.3 Cold Weather Considerations

Objective

This section presents cold weather considerations for BMP selection and design. Discussion and guidance are given in the following areas:

- Cold weather challenges to BMP Design
- BMP applicability
- Snow and snowmelt considerations (see Section 4.2.8)

Cold Weather Challenges to BMP Design

Cold climates can present additional challenges to the selection, design, and maintenance of stormwater treatment BMPs due to one or more of the factors listed in Table 5.2.5. Engineers designing treatment BMPs in cold weather regions should be aware of these challenges and make provisions for them in their final designs.

Regions which have an average daily maximum temperature of 35 degrees or less during January, and which have a growing season less than 120 days, are especially vulnerable to the effects of cold weather. As illustrated in Figure 5.2.3, these criteria indicate that these cold weather conditions exist in many parts of eastern Washington and are therefore an important design concern.

This section of the manual describes the general concerns common to most BMPs. Cold weather considerations specific to a single BMP are presented in the discussion of that methodology.

Table 5.2.5
Cold Weather Challenges to BMP Design

Climatic Conditions	BMP Design Challenge
Cold Temperatures	∉ Pipe freezing ∉ Permanent pool ice-covered ∉ Reduced biological activity ∉ Reduced oxygen levels during ice cover ∉ Reduced settling velocities ∉ Impacts of road salt/deicers/chlorides ∉ Winter sanding impacts on facilities
Deep Frost Line	∉ Frost heaving ∉ Reduced soil infiltration ∉ Pipe freezing
Short Growing Season	∉ Short time period to establish vegetation ∉ Tolerance of plant species
Significant Snowfall	∉ High runoff volumes during snowmelt ∉ High runoff during rain-on-snow ∉ High pollutant loads during spring melt ∉ Other impacts of road salt/deicers/chlorides ∉ Snow management may affect BMP storage ∉ Winter sanding impacts on facilities

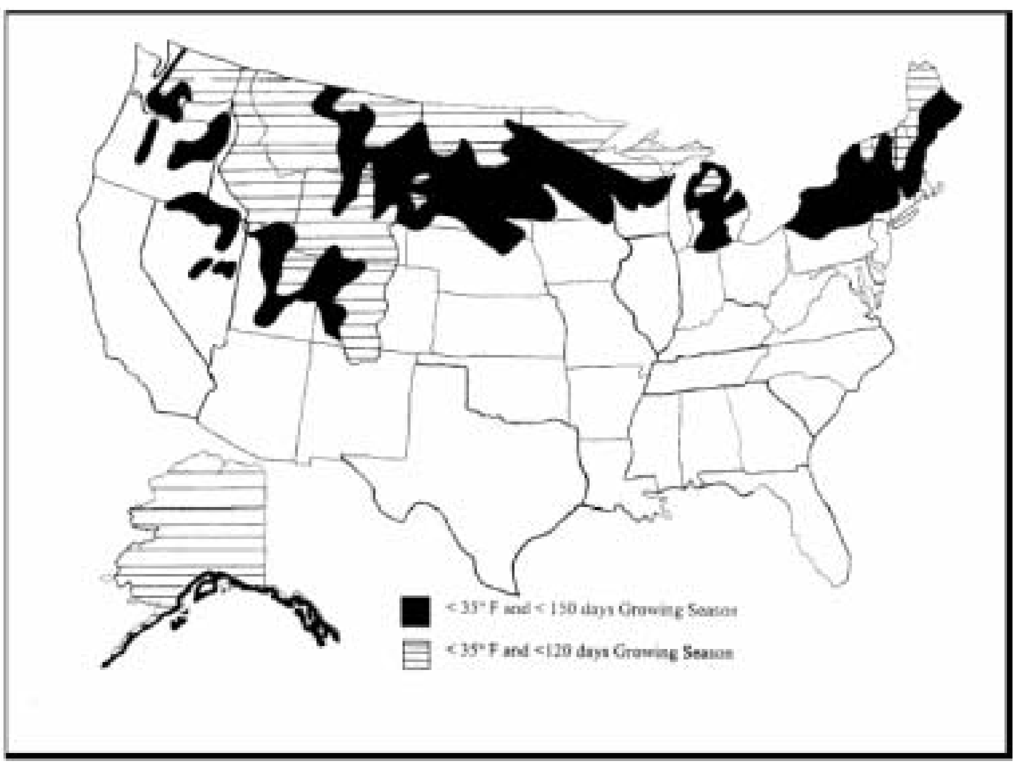
Much of the following information has been adapted from a report on Stormwater Practices for Cold Climates by the Center for Watershed Protection. The original recommendations presented in that report were based on two surveys of BMP designers from state and local governments or consulting firms. The first survey was a telephone polling of 140 individuals. The survey obtained qualitative information as well as BMP manuals. The second survey was a 6-page written questionnaire returned by 55 respondents. Additional information, including the entire manual, is available for downloading at:

http://www.stormwatercenter.net/Cold%20Climates/cold-climates.htm

The recommendations presented in the report were customized in response to regional experiences for eastern Washington. However, since local experiences are often the best measure of BMP performance, designers may want to consult with the local jurisdiction before making a final decision on the inclusion of cold weather measures.

As previously noted, Table 5.2.4 contains information regarding the effects of climatic conditions on BMP design for arid and semi-arid watersheds. For cold weather considerations, several of the most common effects are briefly described in the following sections. These discussions are not meant to address every possible design detail that an engineer may face when specifying an appropriate BMP for cold weather. The goal is to identify common BMP concerns such that the designer is aware of factors that might influence their designs.

Figure 5.2.3 Overlay of Maximum January Temperature and Growing Season (Source: U.S. Doc, 1975)



Pipe Freezing

Many BMPs rely on some piping system for the inlet, outlet, or underdrain system. Frozen pipes can crack due to ice expansion, creating a maintenance or replacement burden. In addition, pipe freezing reduces the capability of BMPs to treat runoff for water quality and can create the potential for flooding.

Ice Formation on Wet Ponds

The permanent pool of a wet pond serves several purposes. First, the water in the permanent pool slows down incoming runoff, allowing increased settling. In addition, the biological activity in this pool can act to remove nutrients, as growing algae, plants, and bacteria require these nutrients for growth. In some systems, such as sand filters, a permanent pool acts as a pretreatment measure, settling out larger sediment particles before full treatment by the BMP.

Ice cover on the permanent pool causes two problems. First, the treatment pool's volume is reduced. Second, because the permanent pool is frozen, it acts as an impermeable surface. Runoff entering the pond will either be forced under the ice, causing scouring of the bottom sediments, or it will flow over the top of the ice, where it receives very little treatment.

Reduced Biological Activity

Many BMPs rely on biological mechanisms to help reduce pollutants, especially nutrients and organic matter. In cold temperatures, microbial activity is sharply reduced when plants are dormant during longer winters, limiting these pollutant removal pathways.

Reduced Oxygen Levels in Bottom Sediments

In cold regions, oxygen exchange between the air-water interface in ponds and lakes is restricted by ice cover. In addition, warmer water sinks to the bottom during ice cover because it is denser than the cooler water near the surface. Although biological activity is limited in cooler temperatures the decomposition that takes place does so at the bottom of wet ponds, sharply reducing oxygen concentrations in bottom sediments. In these anoxic conditions, positive ions retained in sediments can be released from bottom sediments, reducing the BMPs ability to treat these nutrients or metals in runoff.

Reduced Settling Velocities

Settling is the most important removal mechanism in many BMPs. As water becomes cooler, its viscosity increases, reducing particle settling velocity. This reduced settling velocity influences pollutant removal in any BMP that relies on settling.

Frost Heave

The primary risk of frost heave is the damage of structures such as pipes or concrete materials to construct BMPs. Another concern is that infiltration BMPs can cause frost heave damage to other structures, particularly roads. The water infiltrated into the soil matrix can flow under a permanent structure and then refreeze. The sudden expansion associated with this freezing can cause damage to above ground structures.

Reduced Soil Infiltration

The rate of infiltration in frozen soils is limited, especially when ice lenses form. There are two results of this reduced infiltration. First, BMPs that rely on infiltration to function are ineffective when the soil is frozen. Second, runoff rates from snowmelt are elevated when the ground underneath the snow is frozen.

Short Growing Season

For some BMPs, such as bio-infiltration swales and biofiltration swales, vegetation is integral to the proper function of the BMP. When the growing season is shortened, establishing and maintaining this vegetation becomes more difficult. Some plant species go dormant at the onset of colder temperatures, reducing the pollutant removal efficiency in BMPs that rely on actively growing plant life.

High Pollutant Loading During Winter or Spring Thaw Periods

Winter or spring melt events are important because of increased runoff volumes and pollutant loads. The snowpack contains high pollutant concentrations due to the buildup of pollutants over a several-month period. Chloride loadings are highest in snowmelt events because of the use of deicing salts, such as sodium chloride and magnesium chloride. Excessive loadings can kill vegetation in swales and other vegetative BMPs. Research indicates roughly 65% of the annual sediment, organic, nutrient, and lead loads can be attributed to winter and spring melts.

Snow Management – Plowing and Sanding

Snow management can influence water quality and impact the selection of BMPs. Dumping snow into receiving waters is discouraged. Plowing snow onto pervious surfaces can help to decrease peak runoff rates and encourage infiltration. Snow with large amounts of sand, or bare surfaces with accumulated sand, however, can result in smothering or filling the capacity of stormwater BMPs.

BMP Applicability

Based on climate conditions and design obstacles, a list of BMP applicability in cold regions is presented in Table 5.2.6. Once again, these recommendations should be used as a rule-of-thumb rather than a hard and fast rule that can be applied in all instances. Also note that in order to meet the goal of treating 90% of the annual runoff, it may be necessary to oversize facilities in cold regions.

Table 5.2.6
Summary of BMP Applicability in Cold Regions

Section / BMP #	BMP Type	Applicability	Notes
6.4	Infiltration and Bio-infiltration		
T6.10	Infiltration Pond	fair	Can be effective but may be restricted by groundwater quality concerns related to infiltration of chlorides. Frozen ground may inhibit the infiltration capacity of ground.
T6.20	Infiltration Trench	fair	Same concerns as for Infiltration Pond
T6.21	Infiltration Swale	fair	Same concerns as for Infiltration Pond
T6.30	Bio-infiltration Swale	fair	Same concerns as for Infiltration Pond
6.5	Biofiltration		
T6.40	Biofiltration Swale	fair	Reduced effectiveness in the winter because of dormant vegetation. Very valuable for snow storage and meltwater infiltration.
T6.50	Vegetated Filter Strip	fair	Reduced effectiveness in the winter because of dormant vegetation. Very valuable for snow storage and meltwater infiltration.
6.6	Subsurface Infiltration	fair to good	Infiltration surface below frost line.
	Drywell	fair to good	Infiltration surface below frost line.
6.7	Wetpools		
T6.70	Basic Wetpond	fair	Can be effective but needs modifications to prevent freezing of outlet pipes. Limited by reduced treatment volume and biological activity during ice cover.

Table 5.2.6
Summary of BMP Applicability in Cold Regions

Section / BMP #	BMP Type	Applicability	Notes
T6.71	Large ED Wetpond (ED = Extended Detention)	good	Some modifications needed to conveyance structures. Extended detention storage provides treatment during winter season.
T6.72	Wet Vault	good	Design pool elevation below frost line or per manufacturer specs. Some modifications needed to conveyance structures.
T6.73	ED Wetland (ED = Extended Detention)	good	Extended detention storage provides treatment during winter season. Modifications needed to wetland plant species. Some modifications needed to conveyance structures.
6.8	Sand Filtration		
T6.80	Basic Sand Filter	poor	Frozen ground considerations, combined with frost heave, make this ineffective in cold climates.
T6.81	Large Sand Filter	poor	Same concerns as for Basic Sand Filter.
T6.82	Sand Filter Vault	good	Design filter elevation below frost line or per manufacturer specs
T6.83	Linear Sand Filter	poor to fair	Design filter elevation below frost line or per manufacturer specs. Cold conditions may plug surface inlet and impact performance.
6.9	Evaporation Ponds	fair to good	Evaporation not expected to result in significant water losses during cold weather; hence must size to provide adequate storage.
6.10	Oil and Water Separator		
T6.100	API Separator Bay	poor to fair	Check with the manufacturer for cold weather applicability.
T6.110	Coalescing Plate Bay	poor to fair	Check with the manufacturer for cold weather applicability.

Table 5.2.6
Summary of BMP Applicability in Cold Regions

Section / BMP #	BMP Type	Applicability	Notes
[not inserted in Manual yet]	Dry Ponds Large (ED) Dry Ponds (ED = Extended Detention)	fair	Few modifications needed to adapt to cold climates. Not highly recommended because of relatively poor warm season performance.

5.3 General Requirements for Stormwater Facilities

This section addresses general requirements for treatment facilities. Requirements discussed in this section include design volumes and flows, sequencing of facilities and basic siting requirements for treatment facilities.

5.3.1 Design Volume and Flow

Water Quality Design Storm Volume

Refer to Chapter 4 – Hydrologic Design and Analysis, for information on design storms, and the determination of peak flow rates and storm volumes.

"On-line" Systems

Most treatment facilities can be designed as "on-line" systems with flows above the water quality design flow or volume simply passing through the facility with lesser or no pollutant removal. However, it is sometimes desirable to restrict flows to treatment facilities and bypass the remaining higher flows around them. These are called "off-line" systems. An example of an on-line system is a biofiltration swale with overflow to a drywell.

Bypass Requirements

A bypass or overflow structure must be provided for all treatment BMPs unless the facility is able to convey the 25-year short duration storm without damaging the BMP or dislodging pollutants from within it. Bypass or overflow provisions must be provided for all flow-rate-based treatment BMPs and for volume-based treatment BMPs that require them. See local requirements for typical designs.

To design a bypass for a flow-rate-based runoff treatment facility:

1. Determine the maximum allowable velocity that will not result in damage of the facility or dislodging of pollutants from within it.
2. Size an orifice or weir in a flow splitter manhole, vault, etc. such that the maximum velocity is not exceeded for the 25-year event.
3. Size overflow (bypass) conveyance system to handle bypass flows.

To design a bypass for a volume-based runoff treatment facility such as a bioinfiltration swale, maintain an elevated inlet or other overflow structure that bypasses flows above the design volume for the treatment facility instead of using a flow-rate-based device. The bypassed water may flow to another treatment facility or directly into a conveyance system or infiltration facility. Bypass is not recommended for wet ponds, constructed wetlands, and similar volume-based treatment facilities. Inlet structures for these facilities should be designed to dampen velocities; the pond dimensions will further dissipate the energy. In these facilities, larger storms will be retained for a shorter detention time than the shorter storms for which the ponds are designed.

Summary of Areas Needing Treatment

All runoff from pollution-generating impervious surfaces meeting permitted thresholds is to be treated through the water quality facilities as required by Core Element #5.

- Lawns and landscaped areas specified are pervious but also generate run-off into street drainage systems. In those cases the runoff from the pervious areas must be estimated and added to the runoff from impervious areas to size treatment facilities.
- Drainage from impervious surfaces that are not pollution- generating need not be treated and may bypass runoff treatment, if it is not mingled with runoff from pollution-generating surfaces.
- Runoff from metal roofs must be treated unless the roofs are coated with an inert non-leachable material.
- Drainage from areas in native vegetation should not be mixed with untreated runoff from streets and driveways, if possible. It is best to infiltrate or disperse this relatively clean runoff to maximize recharge to shallow ground water, wetlands, and streams.
- If runoff from non-pollution generating surfaces reaches a runoff treatment BMP, flows from those areas must be included in the sizing calculations for the facility. Once runoff from non-pollution generating areas is mixed with runoff from pollution-generating areas, it cannot be separated before treatment.

5.3.2 Sequence of Facilities

In general, all treatment facilities may be installed upstream of detention facilities. However, not all treatment facilities can function effectively if located downstream of detention facilities. Those facilities that treat unconcentrated flows, such as filter strips, are usually not practical downstream of detention facilities. Other types of treatment facilities present special problems that must be considered before placement downstream of detention. These would include biofiltration swales or sand filters which are sensitive to saturation and continuous flow.

Oil control facilities may be located upstream or downstream of treatment facilities and as close to the source of oil-generating activity as possible. They should also be located upstream of detention facilities, if possible.

5.3.3 Setbacks, Slopes, and Embankments

The following guidelines for setbacks, slopes, and embankments are intended to provide for adequate maintenance accessibility to runoff treatment facilities. Setback requirements are generally required by local regulations, Uniform Building Code requirements, or other state regulations. Local governments should require specific setback, slopes and embankment limitations to address public health and safety concerns.

Setbacks

Local governments may require specific setbacks in sites with steep slopes, land-slide areas, open water features, springs, wells, and septic tank drain fields. Setbacks from tract lines are necessary for maintenance access and equipment maneuverability. Adequate room for maintenance equipment should be considered during site design.

Examples of setbacks commonly used include the following:

- Stormwater infiltration systems shall be set back at least 100 feet from open water features and 200 feet from springs used for drinking water supply. Infiltration facilities upgradient of drinking water supplies must comply with Health Department requirements (Washington Wellhead Protection Program, Department of Health, 12/93).
- Stormwater infiltration systems, and unlined wetponds and detention ponds shall be located at least 100 feet from drinking water wells and septic tanks and drainfields.
- All facilities shall be located away from any steep slope (greater than 15%), at a minimum distance equivalent to the height of the slope. A geotechnical report must address the potential impact of a wetpond on a steep slope.

Side Slopes and Embankments

- Side slopes should preferably not exceed a slope of 3H:1V. Moderately undulating slopes are acceptable and can provide a more natural setting for the facility. In general, gentle side slopes improve the aesthetic attributes of the facility and enhance safety.
- Interior side slopes may be retaining walls. The design shall be prepared and stamped by a licensed civil engineer, when required by code. A fence should be provided along the top of the wall.
- Maintenance access should be provided through an access ramp or other adequate means.
- Embankments that impound water must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC). If the impoundment has a storage capacity, including both water and sediment storage volumes, greater than 10 acre-feet above natural ground level, then dam safety design and review are required by the Department of Ecology. See Chapter 5 for more detail concerning Detention Ponds.

5.3.4 Maintenance Standards for Drainage Facilities

Each of the BMP sections which follows includes specific maintenance criteria the designer needs to be aware of when selecting that BMP. More information on maintenance criteria for all BMPs is included in Appendix 5A of this chapter.

5.4 Surface Infiltration and Bio-infiltration Treatment Facilities

5.4.1 Purpose

A stormwater infiltration treatment facility is an impoundment, typically a pond, trench, or bio-infiltration swale whose underlying soil removes pollutants from stormwater. These facilities serve the dual purpose of removing pollutants (TSS, heavy metals, phosphates, and organics) from stormwater and recharging aquifers. Infiltration treatment soils must contain sufficient organic matter and/or clays to sorb, decompose, and/or filter stormwater pollutants. Pollutant/soil contact time, soil sorptive capacity, and soil aerobic conditions are important design considerations.

The infiltration BMPs described in this section include:

- BMP T5.10 Infiltration ponds
- BMP T5.20 Infiltration trenches
- BMP T5.21 Infiltration swales
- BMP T5.30 Bio-infiltration swales (grassed percolation area)

5.4.2 Application

These infiltration and bio-infiltration treatment measures are capable of achieving the performance objectives cited in Section 5.1 for specific treatment menus. In general, these treatment techniques can capture and remove or reduce the target pollutants to levels that:

- will not adversely affect public health or beneficial uses of surface and ground water resources, and
- will not cause a violation of ground water quality standards

An infiltration trench or bio-infiltration swale is preferred, but an infiltration basin may be more applicable where an infiltration trench or bio-infiltration swale cannot be sufficiently maintained.

5.4.3 General Considerations for Infiltration and Bio-infiltration Facilities

Discussed below are several considerations common to infiltration and bio-infiltration treatment.

Design Infiltration Rate Determination

See Chapter 6 – Flow Control Facility Design, for information on determining infiltration rates. The following table can be used for determining presumptive rates for surface treatment facilities based on the USDA soil classification or the Unified Soil Classification System.

Table 5.4.1 Infiltration Rates for Surface Infiltration and Bio-infiltration Facilities

Textural Classification USDA	Unified Soil Classification System Group Symbol[1]	Presumptive Infiltration Rate (inches/hour)
Sand	SP-SM	See Note 2
Sand	SP-SC	See Note 2
Loamy Sand	SM, SC	2[3]
Sandy Loam	SM, SC	1[3]
Loam	ML, MH	0.5[3]

Notes:
1. Groups contain from two to eight soil types distinguished by Group Name.
2. Not suitable for infiltration treatment unless justified by geotechnical study and approved by permitting municipality.
3. Short-term infiltration rates from Washington State Department of Ecology, "Stormwater Management Manual for Western Washington" August 2001, Publication Numbers 99-11 through 99-15.

Site Suitability Criteria (SSC)

This section specifies the site suitability criteria that must be considered for siting infiltration treatment systems. Check with the local jurisdiction for reporting requirements and other possible requirements specific to local conditions. When a site investigation reveals that any of the seven applicable criteria cannot be met, appropriate mitigation measures must be implemented so that the infiltration facility will not pose a threat to human safety and health, and the environment.

For infiltration treatment, site selection, and design decisions, a geotechnical and hydrogeologic report should be prepared by a registered professional engineer with geotechnical expertise, or a registered geologist with hydrogeology specialty, if required by the site suitability criteria, or local jurisdiction requirements.

The seven site suitability criteria are as follows:

SSC-1 Setback Criteria

Setback requirements are generally required by local regulations, Uniform Building Code requirements, or state regulations. These Setback Criteria are provided as guidance.

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 Health Department requirements (Washington Wellhead Protection Program, DOH, 12/93): ∅100 feet

Note: *Additional setbacks should be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration system.*

∉ From building foundations: ∅20 feet downslope and 100 feet upslope

- From a Native Growth Protection Easement (NGPE): ∅20 feet
- From the top of slopes >15%: Setback distance to be determined by professional engineer, 50 feet minimum.

Also 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.

SSC-2 Ground Water Protection Areas

A site is not suitable if the infiltrated stormwater will cause a violation of Ecology's Ground Water Quality Standards. Local jurisdictions should be consulted for applicable pretreatment requirements and whether the site is located in an aquifer sensitive area, sole source aquifer, or a wellhead protection zone. See SSC-7 for verification testing guidance.

SSC-3 Soil Infiltration Rate/Drawdown Time

The long-term soil infiltration rate should be 2.4 in./hour, or less, to a depth of 2.5 times the maximum design flooded depth. This infiltration rate is also typical for soil textures that possess sufficient physical and chemical properties for adequate treatment, particularly for soluble pollutant removal (see SSC-5). It is comparable to the textures represented by Hydrologic Groups B and C.

It is necessary to empty the maximum ponded depth (water quality volume) from the infiltration basin within 24 hours from the completion of inflow to the storage pond in order to meet the following objectives:

- restore hydraulic capacity to receive runoff from a new storm
- maintain infiltration rates
- aerate vegetation and soil to keep the vegetation healthy, prevent anoxic conditions in the treatment soils, and enhance the biodegradation of pollutants and organics

SSC-4 Depth to Bedrock, Water Table, or Impermeable Layer

The base of all infiltration basins or trench systems should be ∅5 feet above the seasonal high-water mark, bedrock (or hardpan) or other low permeability layer. A minimum separation of 3 feet may be considered if the ground water mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures are judged by the professional engineer to be adequate to prevent overtopping and to meet the site suitability criteria specified in this section.

SSC-5 Soil Physical and Chemical Suitability for Treatment

The soil texture and design infiltration rates should 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 should be carefully considered in making such a determination:

∉ Cation exchange capacity (CEC) of the treatment soil must be ∅5 milliequivalents CEC/100 g dry soil (USEPA Method 9081). Consider empirical testing of soil sorption capacity, if practicable. Ensure that soil CEC is sufficient for expected pollutant loadings, particularly heavy metals. CEC values of >5 meq/100g are expected in loamy sands, according to Rawls, et al. Lower CEC content may be considered if it is based on a soil loading capacity determination for the target pollutants that is accepted by the local jurisdiction.

∉ Depth of soil used for infiltration treatment must be a minimum of 18 inches except for designed, vegetated infiltration facilities with an active root zone such as bio-infiltration swales.

∉ Organic content of the treatment soil (ASTM D 2974): Organic matter can increase the sorptive capacity of the soil for some pollutants. The site professional should evaluate whether the organic matter content is sufficient for control of the target pollutant(s).

∉ Waste fill materials should not be used as infiltration soil media nor should such media be placed over uncontrolled or non-engineered fill soils.

∉ Engineered soils may be used to meet the design criteria in this section. Field performance evaluation(s), using acceptable protocols, would be needed to determine feasibility and acceptability by the local jurisdiction.

∉ Local jurisdictions may establish pre-approved soil types for treatment suitability. Check locally for specific allowances and requirements.

SSC-6 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. Infiltration of stormwater is not recommended on or up-gradient of contaminated sites where infiltration of even clean water can cause contaminants to mobilize. Refer to SSC for Chapter 6 on filtration.

SSC-7 Construction Monitoring

The professional engineer should monitor the construction of the infiltration facility to ensure that the work is completed in compliance with the designer's intent, and the plans and specifications. Following construction, the facility should be visually monitored quarterly over a 2-year period to assess its performance as designed.

General Information for Infiltration Basins, Trenches, and Bio-infiltration Swales

This section covers the general design, construction, and maintenance criteria that apply to infiltration basins, trenches, and bio-infiltration swales.

Sizing Criteria: Size should be determined by using the method(s) outlined with each BMP, based on the requirement of infiltrating the Water Quality Design Storm Volume within 72 hours after cessation of flow.

Construction Criteria

- Excavation - Initial excavation should be conducted to within 1-foot of the final elevation of the floor of the infiltration facility. Final excavation to the finished grade should be deferred until all disturbed areas in the upgradient watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.
- Infiltration facilities should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized. Any accumulation of silt in the basin must be removed before putting it in service.
- Traffic Control - Relatively light-tracked equipment is recommended for excavation to avoid compaction of the floor of the infiltration facility. The use of draglines and trackhoes should be considered. The infiltration area should be flagged or marked to keep equipment away.

Maintenance Criteria

- Provision should be made for regular and perpetual maintenance of the infiltration basin/trench, including replacement and/or reconstruction of the treatment infiltration medium. Maintenance should be conducted when water remains in the basin or trench for more than 72 hours or overflows the basin/pond. Adequate access for O&M must be included in the design of infiltration basins and trenches. An Operation and Maintenance Plan, approved by the local jurisdiction, should ensure maintaining the desired efficiency of the infiltration facility.
- Debris/sediment accumulation - Removal of accumulated debris/sediment in the basin/trench should be conducted every 6

months or as needed to prevent clogging, or when water remains in the pond for greater than 72 hours.

∉ The treatment soil should be replaced or amended as needed to ensure it is maintaining adequate treatment capacity.

Verification of Performance

∉ During the first 1-2 years of operation verification testing as specified in SSC-7 is strongly recommended. Operating and maintaining ground water monitoring wells is also strongly encouraged.

5.4.4 Best Management Practices (BMPs) for Infiltration and Bio-infiltration Treatment

The three BMPs discussed below are recognized currently as effective treatment techniques using infiltration and bio-infiltration. Selection of a specific BMP will depend upon having followed the Treatment Facility Selection Process in Section 5.2.

BMP T5.10 Infiltration Ponds

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

Design Criteria Design of infiltration ponds for water quality treatment is identical to the criteria given in Section 6.3.6 (BMP F6.21), except that the allowable infiltration rate is limited to 2.4 in/hr or less.

BMP T5.20 Infiltration Trenches

Description Infiltration trenches are trenches, generally at least 24 inches wide, with a perforated pipe and backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then is gradually infiltrated into the surrounding soil.

Design Criteria The design of infiltration trenches for water quality treatment is identical to the criteria given in Section 6.3.7 (BMP F6.22), except that the allowable infiltration rate is limited to 2.4 in/hr or less.

BMP T5.21 Infiltration Swales

Description Infiltration swales are conveyances designed for removal of stormwater pollutants by percolation into the ground.

Design Criteria The design of infiltration swales for water quality treatment is identical to bio-infiltration swales (BMP T5.30, below) except that amended soil may be required to meet SSC-5 (Soil Physical and Chemical Suitability for Treatment). Greater soil depth is required for treatment because there is no uptake by vegetation. Appropriate vegetation or a landscaped rock surface such as river rock or crushed basalt is recommended for aesthetic purposes and for dust and erosion control.

BMP T5.30 Bio-infiltration Swale

Description Bio-infiltration swales, also known as Grassed Percolation Areas, combine grasses (or other vegetation) and soils to remove stormwater pollutants by percolation into the ground. Their pollutant removal mechanisms include filtration, soil sorption, and uptake by vegetated root zones. Bio-infiltration swales have been used in Spokane County for many years to treat urban stormwater and recharge the ground water.

In general, bio-infiltration swales are used for treating stormwater runoff from roofs, roads and parking lots. For flow control, flows greater than the Water Quality Design flows are typically overflowed to the subsurface through an appropriate conveyance facility such as a dry well, or to surface water through an overflow channel.

Design Criteria Bio-infiltration swales may be sized using several different design methods. Each of the approaches is valid in the context of this manual, although the local jurisdiction may, at its option, direct the designer to use a particular method.

Basic Design Method

This method prescribes a set runoff volume to be used in calculating the treatment volume of the bio-infiltration swale, based on the 2-year 24-hour precipitation at the site and the design infiltration rate. Table 5.4.2 and 5.4.3 illustrate the amount of runoff from 1,000 square feet of impervious area for various regions of Eastern Washington. The appropriate value for the site may be used to calculate the required volume of the bio-infiltration facility.

$V = A_i R/1,000$

Where: V = volume of the bio-infiltration swale (cu. ft.)

A_i = impervious area draining to bio-infiltration swale (sq. ft.)

R = runoff volume ratio shown in the third column of Tables 5.4.2 and 5.4.3

Table 5.4.2 Bio-infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.15 to 0.40 Inches/Hour

2-YEAR 24-HOUR PRECIPITATION (in)		SWALE VOLUME PER 1000 SQUARE-FEET OF IMPERVIOUS AREA	EXAMPLES OF APPLICABLE SITES
FROM	TO		
0.60	0.80	29.2 cubic-feet	Moses Lake
0.81	1.00	37.5 cubic-feet	Yakima, Kennewick
1.01	1.20	45.8 cubic-feet	Wenatchee, Walla Walla
1.21	1.40	55.8 cubic-feet	Colfax, Colville
1.41	1.55	61.3 cubic-feet	Lowlands Blue Mountains
1.56	and greater	Hydrograph Method Required	Eastern and Cascade Mountains

Table 5.4.3 Bio-infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.41 to 1.00 Inches/Hour

2-YEAR 24-HOUR PRECIPITATION (in)		SWALE VOLUME PER 1000 SQUARE-FEET OF IMPERVIOUS AREA	EXAMPLES OF APPLICABLE SITES
FROM	TO		
0.60	0.80	19.6 cubic-feet	Moses Lake
0.81	1.00	25.4 cubic-feet	Yakima, Kennewick
1.01	1.20	27.9 cubic-feet	Wenatchee, Walla Walla
1.21	1.40	33.8 cubic-feet	Colfax, Colville
1.41	1.55	36.7 cubic-feet	Lowlands Blue Mountains
1.56	and greater	Hydrograph Method Required	Eastern and Cascade Mountains

Alternative Design Method

This method uses the first one-half inch of runoff from impervious surfaces to size the bio-infiltration swale. This method is only applicable in Climate Regions 2 and 3.

$V = (A_I)(0.5 \text{ in.})/(12 \text{ in./ft.})$

Where: V = volume of the bio-infiltration swale (cu. ft.)

A_i = impervious area draining to bio-infiltration swale (sq. ft.)

Hydrograph Design Methods

These methods uses hydrologic models, such as SCS or the Santa Barbara Urban Hydrograph, to determine the quantity of runoff from the Water Quality Design Storm and then route the flow through the infiltration facility, assuming the long-term infiltration rate is used for the outflow calculations. This method is required in areas with greater than 1.56 inches of rainfall in the 2-year 24-hour storm and allowed in all other areas with the approval of the local jurisdiction. See Chapter 4 for more information on hydrologic methods.

Additional Design Criteria for Bio-infiltration Swales

- Use the same sizing guidance, off-line and on-line guidance, and design procedures as in Section 6.3.4.
- The maximum drawdown time for the flooded depth should be within 72 hours after cessation of flow.
- The swale bottom should be flat with a longitudinal slope less than 1%.
- The maximum flood depth of swale should be 6 inches, prior to overflow to a drywell or other infiltrative facility.

- The treatment soil should be at least 6 inches thick with a CEC of at least 5 meq/100 gm dry soil, organic content of at least 1%, and sufficient target pollutant loading capacity. (See Criteria for Assessing the Trace Element Removal Capacity of Bio-filtration Systems, Stan Miller, Spokane County, June 2000).
- Other combinations of treatment soil thickness, CEC, and organic content design factors can be considered if it is demonstrated that the soil and vegetation will provide a target pollutant loading capacity and performance level acceptable to the local jurisdiction.
- The treatment zone depth of 6 inches or more should contain sufficient organics and texture to ensure good growth of the vegetation.
- The average infiltration rate of the 6-inch thick layer of treatment soil should not exceed 1-inch per hour for a system relying on the root zone to enhance pollutant removal. Furthermore, a maximum infiltration rate of 2.4 inches per hour is applicable and Site Suitability Criteria in Section 5.4.3 must also be applied.
- Native grasses, adapted grasses, or other vegetation with significant root mass should be used. Grasses should be drought tolerant or irrigation should be provided.
- Pretreatment may be used to prevent the clogging of the treatment soil and/or vegetation by debris, TSS, and oil and grease.

Identify pollutants, particularly in industrial and commercial area runoff, that could cause a violation of Ecology's ground water quality Standards (Chapter 173-200 WAC). Include appropriate mitigation measures (pretreatment, source control, etc.) for those pollutants.

5.5 Biofiltration Treatment Facilities

5.5.1 Purpose

Biofiltration treatment facilities are vegetated treatment systems (typically grass) that remove pollutants by means of sedimentation, filtration, soil sorption, and/or plant uptake. They are typically configured as swales or filter strips. These facilities are designed to remove low concentrations and quantities of total suspended solids (TSS), heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater. The biofiltration BMPs described in this section include:

- BMP T5.40 Biofiltration swales
- BMP T5.50 Vegetated filter strip

5.5.2 Application

Biofiltration treatment facilities can be used as a basic treatment BMP for contaminated runoff from roadways, driveway, parking lots, and highly impervious ultra-urban areas or as the first stage of a treatment train. In cases where hydrocarbons, high TSS, or debris would be present in the runoff, such as high-use sites, a pretreatment system for those components would be necessary. Off-line location is preferred to avoid flattening vegetation and the erosive effects of high flows.

5.5.3 Best Management Practices (BMPs) for Biofiltration Treatment

The two BMPs discussed below are recognized currently as effective treatment techniques using biofiltration. Selection of a specific BMP should be coordinated with the Treatment Facility options provided in Section 5.2.

BMP T5.40 - Biofiltration Swale

Biofiltration is the simultaneous process of filtration, particle settling, adsorption, and biological uptake of pollutants in stormwater that occurs when runoff flows over and through vegetated areas. A biofiltration swale is a sloped, vegetated channel or ditch that provides both conveyance and water quality treatment to stormwater runoff. It does not provide stormwater quantity control but can convey runoff to BMPs designed for that purpose.

General Criteria

- Though the actual dimensions for a specific site may vary, the swale should generally have a length of 200 feet. The maximum bottom width is typically 10 feet. The depth of flow should not exceed 4 inches during the design storm. The flow velocity should not exceed 1 ft/sec.
- The channel slope should be at least 1 percent and no greater than 5 percent.
- The swale can be sized as both a treatment facility for the 6-month storm and as a conveyance system to pass the peak hydraulic flows of the 25-year storm if it is located "on-line."
- The ideal cross-section of the swale should be a trapezoid. The side slopes should be no steeper than 3:1.
- Roadside ditches should be regarded as significant potential biofiltration sites and should be utilized for this purpose whenever possible.
- If flow is to be introduced through curb cuts, place pavement slightly above the biofilter elevation. Curb cuts should be at least 12 inches wide to prevent clogging.
- Biofilters must be vegetated in order to provide adequate treatment of runoff.

- It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing grasses (or other vegetation) that can withstand prolonged periods of wetting, as well as prolonged dry periods (to minimize the need for irrigation). Consult the local NRCS office or the County Extension Service for specific vegetation selection recommendations.
- Biofilters should generally not receive construction-stage runoff. If they do, pre-settling of sediments should be provided. See BMPs C240 (Sediment Trap) and C241 (Temporary Sediment Pond) in Chapter 7 – Construction Stormwater Pollution Prevention. Such biofilters should be evaluated for the need to remove sediments and restore vegetation following construction. The maintenance of pre-settling basins or sumps is critical to their effectiveness as pretreatment devices.
- If possible, divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, protect graded and seeded areas with suitable erosion control measures.

Design Procedure

- **Step 1** - Determine the peak flow rate to the biofilter from the Water Quality Design Storm. See Chapter 4.
- **Step 2** - Determine the slope of the biofilter. This will be somewhat dependent on where the biofilter is placed. The slope should be at least 1 percent and shall be no steeper than 5 percent. When slopes less than 2 percent are used, the need for underdrainage must be evaluated.
- **Step 3** - Select a swale shape. Trapezoidal is the most desirable shape; however, rectangular and triangular shapes can be used. The remainder of the design process assumes that a trapezoidal shape has been selected.
- **Step 4** - Use Manning's Equation to estimate the bottom width of the biofilter. Manning's Equation for English units is as follows:

$$Q = (1.486\ A\ R^{0.667}\ S^{0.5}) / n$$

Where: Q = flow (cfs)

A = cross sectional area of flow (ft^2)

R = hydraulic radius of flow cross section (ft)

S = longitudinal slope of biofilter (ft/ft)

n = Manning's roughness coefficient (use n = 0.20 for typical biofilter with turf/lawn vegetation, and n = 0.30

for biofilter with less dense vegetation such as meadow or pasture.)

For a trapezoid, this equation cannot be directly solved for bottom width. However, for trapezoidal channels that are flowing very shallow the hydraulic radius can be set equal to the depth of flow. Using this assumption, the equation can be altered to:

$$B = ((0.135\ Q) / (y^{1.667}\ S^{0.5}))-zy$$

Where: B = bottom width of the swale

y = depth of flow

Z = the side slope of the biofilter in the form of z:1

Typically, the depth of flow for turf grass is selected to be 4 inches. For dryland grasses the depth of flow should be set to 3 inches. It can be set lower but doing so will increase the bottom width. Sometimes when the flowrate is very low the equation listed above will generate a negative value for B. Since it is not possible to have a negative bottom width, the bottom width should be set to 1 foot when this occurs.

Biofilters are limited to a maximum bottom width of 10 feet. If the required bottom width is greater than 10 feet, parallel biofilters should be used in conjunction with a device that splits the flow and directs the proper amount to each biofilter.

∉ **Step 5** - Calculate the cross sectional area of flow for the given channel using the calculated bottom width and the selected side slopes and depth.

∉ **Step 6** - Calculate the velocity of flow in the channel using:

$$V=Q/A$$

If V is less than or equal to 1 ft/sec, the biofilter will function correctly with the selected bottom width. Proceed to design step 7.

If V is greater than 1 ft/sec, the biofilter will not function correctly. Increase the bottom width, recalculate the depth using Manning's Equation and return to Step 5.

∉ **Step 7** - Select a location where a biofilter with the calculated width and a length of 200 feet will fit. If a length of 200 feet is not possible, the width of the biofilter must be increased so that the area of the biofilter is the same as if a 200 foot length had been used.

∉ **Step 8** - Select a vegetation cover suitable for the site. Consult the local NRCS office or the County Extension Service for guidance.

∉ **Step 9** - Determine the peak flow rate to the biofilter during the 25-year 24-hour storm. Using Manning's Equation, find the depth of flow (typically n=0.04 during the 25-year flow). The depth of the channel shall be 1 foot deeper than the depth of flow. Check to determine that shear stresses do not cause erosion. This step can be skipped if all storms larger than the short duration water quality storm bypass the biofiltration swale.

Construction and Maintenance Criteria

- Groomed biofilters planted in grasses shall be mowed during the summer to promote growth and pollutant uptake.
- Remove sediments during summer months when they build up to 4 inches at any spot, cover biofilter vegetation, or otherwise interfere with biofilter operation. Reseed bare spots created by removal equipment.
- Inspect biofilters periodically, especially after periods of heavy runoff. Remove sediments, fertilize, and reseed as necessary. Be careful to avoid introducing fertilizer to receiving waters or ground water.
- Clean curb cuts when soil and vegetation buildup interferes with flow introduction.
- Remove litter to keep biofilters free of external pollution.

See Appendix 5A for more detailed information.

BMP T5.50 Vegetated Filter Strip

A vegetated filter strip is a facility that is designed to provide stormwater quality treatment of conventional pollutants but not nutrients. See Figure 5.5.2. This BMP will not provide stormwater quantity control. Vegetated filter strips are primarily used adjacent and parallel to paved areas such as parking lots or driveways, and along rural roadways where sheet flow from the paved area will pass through the filter strip before entering a conveyance system or a quantity control facility, or is dispersed into areas where it can be infiltrated or evaporated. The vegetated filter strip is still in an interim phase of development. This BMP is acceptable for use on any project that meets the General Criteria listed below; however, the General Criteria may change in the future as research projects and field tests involving this BMP are completed.

General Criteria

- Along roadways, filter strips should be placed at least 1 foot, and preferably 3 to 4 feet from the edge of pavement, to accommodate a vegetation free zone.
- Once stormwater has been treated by a filter strip, it may need to be collected and conveyed to a stormwater quantity BMP.
- The flow from the roadway must enter the filter strip as sheet flow.
- Vegetated filter strips must not receive concentrated flow discharges.

- A maximum flowpath of each 30 feet can contribute to a filter strip designed via this method.
- Filter strips should be used where the roadway ADT is less than 30,000.
- Vegetated filter strips should not be used on roadways with longitudinal slopes greater than 5 percent because of the difficulty in maintaining the necessary sheet flow conditions.
- Vegetated filter strips should be constructed after other portions of the project are completed.

Design Procedure This procedure is based on the Narrow Area Filter Strips presented in the 1998 King County Surface Water Design Manual. The sizing of the filter strip is based on the length of the flowpath draining to the filter strip and the longitudinal slope of the filter strip itself (parallel to the flowpath).

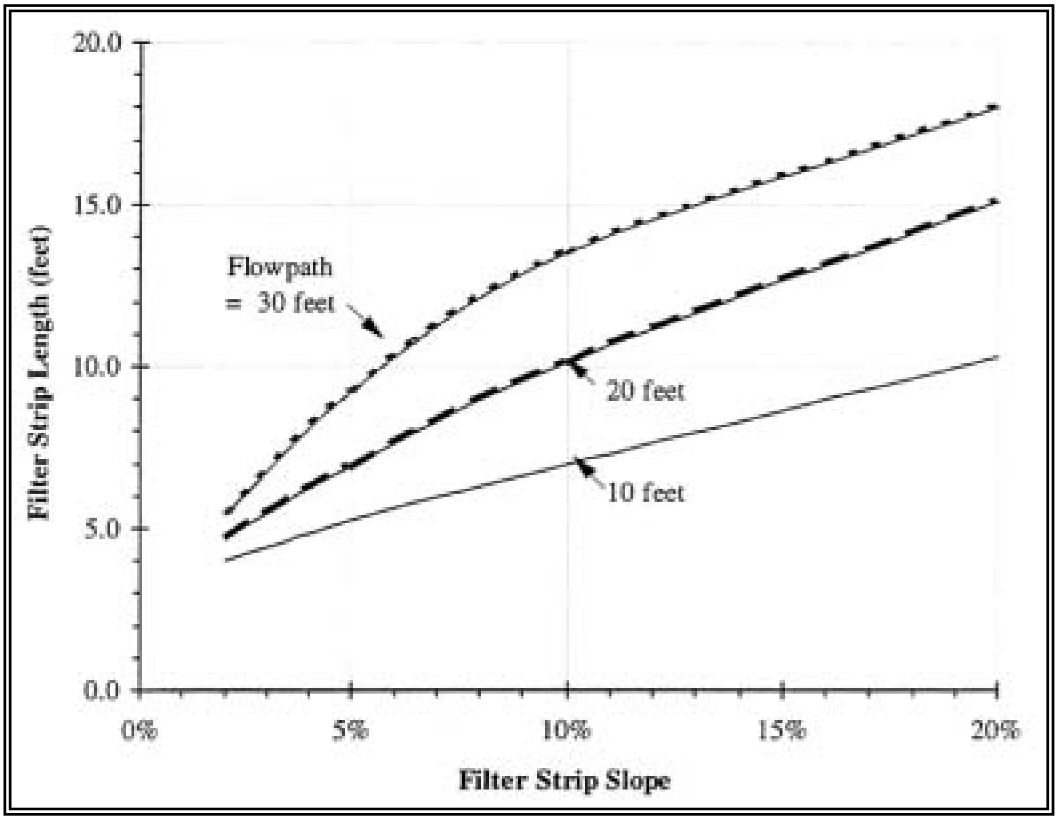
- **Step 1: Determine length of flowpath draining to the filter strip.** Determine the length of the flowpath from the upstream to the downstream edge of the impervious area draining to the filter strip. Normally this is the same as the width of the paved area, but if the site is sloped, the flow path may be longer. In the case of crowned roadways, the flowpath may be half the width of the roadway.
- **Step 2: Determine average longitudinal slope of the filter strip:** Calculate the longitudinal slope of the filter strip (parallel to the flowpath), averaged over the total width of the filter strip. If the slope is less than 2 percent, use 2 percent for sizing purposes. The maximum longitudinal slope allowed is 15 percent.
- **Step 3: Determine required length of the filter strip:** Use Figure 5.5.1 to size the filter strip based on flowpath length and filter strip (longitudinal) slope. To use the figure, find the length of the flowpath on one of the curves (interpolate between curves as necessary). Move along the curve to the point where the design longitudinal slope of the filter strip is directly below. Read the filter trip length to the left on the y-axis. The filter strip must be designed to provide this minimum length “L” along the entire stretch of pavement draining to it.

Construction and Maintenance Criteria

- Construct filter strips after completion of paving operations.
- Groomed filter strips planted in grasses should be mowed during the summer to promote growth.
- Inspect filter strips periodically, especially after periods of heavy runoff. Remove sediments and reseed as necessary. Catch basins or sediment sumps that precede filter strips should be cleaned to maintain proper function.

See Appendix 5A for more detailed information.

Figure 5.5.1 Vegetated Filter Strip Design Graph



From 1998 Surface Water Design Manual, King County

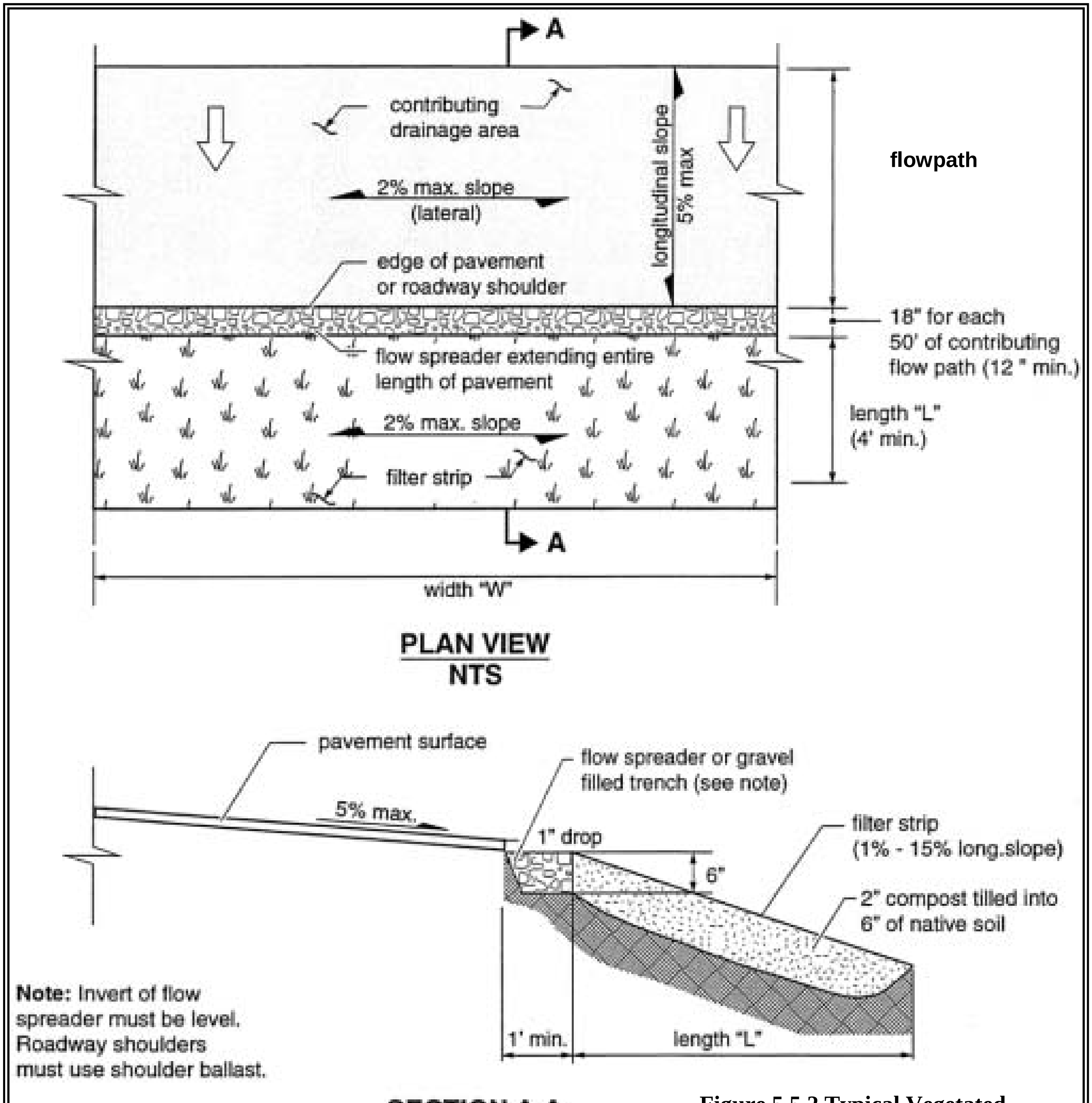


Figure 5.5.2 Typical Vegetated Filter Strip Details

From 1998 Surface Water Design Manual, King County

5.6 Subsurface Infiltration (Underground Injection Facilities)

> **Note to reviewers:** *Ecology is proposing to revise the existing UIC rule (Chapter 173-218 WAC). This section presents some of the proposed changes to the rule which are under consideration by Ecology and the UIC rule revision advisory committee. Input received during this public comment period will also be considered in that process. For more information about the rule revision contact Mary Shaleen-Hansen at maha461@ecy.wa.gov or (360) 407-6143. Information on the UIC Rule can also be accessed through Ecology's website at*
> http://www.ecy.wa.gov/programs/wq/grndwtr/uic

5.6.1 Purpose and Definitions

Subsurface infiltration is one of the preferred methods for disposing of excess stormwater in order to preserve natural drainage systems in eastern Washington. Subsurface infiltration is regulated by the Underground Injection Control (UIC) rule, which is intended to protect underground sources of drinking water. By definition, a UIC facility includes a manmade subsurface fluid distribution system, which means an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to infiltrate fluids into the ground or a dug hole that is deeper than the largest surface dimension. Buried pipe and/or tile networks that serve to collect water and discharge that water to a conveyance system or to surface water are not UIC facilities. For the purposes of this section, subsurface infiltration systems include drywells, pipe or french drains, drain fields and other similar devices that are designed to discharge stormwater directly into the ground. Many of these UIC facilities are designed to infiltrate the 10- or 25-year runoff event within a 48 to 72 hour period; check for local requirements.

The following types of stormwater infiltration facilities are <u>not</u> subject to the UIC rule: surface infiltration basins as described in BMP F6.21 and flow dispersion as described in BMPs F6.40, F6.41, F6.42 and T5.30 [SWMMWW]. This section of the Manual does not apply to those facilities or methods of stormwater disposal.

The UIC rule does apply to some designs of infiltration trenches as described in BMP F6.22 that include perforated pipe. Those facilities must be registered with the Department of Ecology (see Section 5.6.7). However, if those facilities are designed, constructed, operated and maintained according to the specifications of this Manual or another equivalent manual approved by Ecology, the facilities are rule authorized (no permits needed) and this section does not apply.

The majority of UIC facilities receiving stormwater discharges can be authorized by the UIC rule without requiring individual permits where the discharge, the site, and the structure of the facility meet the requirements detailed in this section. (Surface infiltration trenches that are designed, constructed, operated and maintained according to the specifications in BMP F6.22 of this Manual or in another equivalent manual approved by Ecology are also authorized by the UIC rule.) Facilities that cannot meet the requirements of this section must apply for individual permits from the Department of Ecology. In some cases, the discharge may be prohibited. See Section 1.3.4 for more information on the UIC rule-authorization basis and requirements.

The unsaturated geologic material between the bottom of the infiltration facility and the top of an unconfined aquifer, called the vadose zone, usually provides some level of treatment by removing contaminants by filtration, adsorption, and/or degradation. In some cases, the treatment provided by the vadose zone is suitable for protecting groundwater quality from contamination by stormwater runoff; in other cases, additional pre-treatment may be required to protect groundwater quality. This section defines site suitability, pre-treatment requirements, and design criteria for UIC rule-authorized discharges of stormwater to subsurface infiltration systems, including drywells.

This section does not apply to any UIC facilities that receive fluids other than stormwater (precluding accidental spills and illicit discharges, which are addressed in Section 5.6.4).

This section does not address the infiltration capacity of the vadose zone below the UIC facility, nor does it address the ability of the facility to meet local operational requirements to infiltrate a certain volume of water in a given amount of time.

5.6.2 Application and Limitations

Subsurface infiltration (UIC facilities) may be used to provide flow control of excess stormwater runoff where pollutant concentrations that reach groundwater are not expected to exceed Washington State groundwater quality standards; for flows greater than the water quality design storm (see Section 2.2.5); or where stormwater is adequately treated prior to discharge. Under certain conditions, subsurface infiltration may be considered to provide an acceptable level of treatment for removing pollutants from stormwater that exceed groundwater quality standards.

Rationale and evaluation criteria for authorization by rule: These criteria apply only to discharges of stormwater runoff to (and from) UIC facilities. The technical guidance for managing stormwater discharges to groundwater was developed using a risk-based approach. In order to be rule authorized, the discharge from a UIC structure must meet the "non-endangerment standard," which requires that the discharge comply with State groundwater quality standards when it reaches the water table, or first comes into contact with an aquifer (see Section 1.3.4 and WAC 173-200).

Potential Contaminants in Stormwater Runoff

A review of available urban and road runoff data (see Section 1.2.2 for additional detail and references) indicates that typical concentrations of copper, zinc, total suspended solids, chloride and phosphorus in urban and road runoff do not generally appear to be an issue of concern for meeting Washington State groundwater quality standards. Phosphorus in groundwater may still be a concern in small lake watersheds. Chromium, lead, iron and arsenic are potential pollutants of concern: if the suspended portion is removed by filtration, the typical dissolved fractions of the total concentrations of these metals in urban and road runoff are expected to meet State groundwater quality standards except for arsenic, which is naturally present at levels of concern in groundwater in many areas of Washington State. Oil, grease and PAHs are of potential concern, particularly in the event of a large spill reaching an unprotected UIC facility. Pollutants such as pesticides and nitrates may be a concern in areas where landscapes are intensively managed. Concentrations of fecal coliform in urban and road runoff commonly exceed groundwater quality standards and may exceed the capacity of the vadose zone remove bacteria to a level that meets standards; however, no stormwater treatment technology currently exists to practically address this issue.

Potential Removal of Contaminants by the Vadose Zone

Studies of sub-surface infiltration systems indicate that filtered and adsorbed pollutants accumulate in the vadose zone at depths of less than a few feet below the facilities at concentrations that may require soil cleanup activities upon decommissioning of a UIC facility (Mikkelsen et al 1996 #1 and #2; Appleyard 1993). Because contaminated soil removal and disposal costs can be considerable, project proponents may wish to consider including pre-treatment facilities to remove solids from stormwater runoff and avoid potential cleanup requirements following long-term use of the UIC facility. This caution is particularly addressed to UIC facilities receiving runoff from traffic areas with moderate to high use.

Studies of pollutant concentrations in water through and below infiltration systems show mixed results in the effectiveness of vadose zone filtration in protecting groundwater quality (USEPA 1999; Pitt 1999; Mason et al 1999; and Appleyard 1993). Many of the problems documented in these studies can be corrected by proper siting, design and use of the facilities; enhanced source control; additional pre-treatment prior to discharge to the facilities; or prohibition of the discharge. The remainder of this section details guidance intended to ensure that UIC facilities are properly sited, designed and operated to protect water quality.

Presumptive versus Demonstrative Compliance with the Rule

Project proponents may choose to follow either a presumptive or demonstrative approach to compliance with the UIC rule:

- The *presumptive* approach to protecting groundwater quality is defined as using the methods described in this section. This approach considers potential pollutant loading (based on the pollutant loading expected in storm runoff from a given land use or activity) and the treatment capacity of the vadose zone (based on subsurface geology and the thickness of the best naturally present matrices for removing pollutants).
- A *demonstrative* approach to protecting groundwater quality may consider site specific information that modifies either the pollutant loading category or the treatment capacity of the vadose zone or both for a stormwater discharge to a subsurface infiltration system. A demonstrative approach to protecting groundwater quality may also utilize a site specific analysis that otherwise demonstrates that the proposed discharge will comply with groundwater quality standards. Local governments might also modify the presumptive approach to protecting groundwater quality based on local information and planning that results in adoption of a UIC management plan that meets the non-endangerment standard.

The presumptive approach described in this section is based primarily on benefits provided by removal of the solid phase of pollutants in stormwater as it passes through the vadose zone. In almost all cases, removal of the solid phase of metals and most pesticides from stormwater results in meeting the groundwater standards. Filtration and separation are considered the most effective means of removing fecal coliform.

Necessary Source Control Activities

Additional, programmatic or source control activities may be necessary to protect groundwater from soluble pesticides, nitrates, and road salts and other anti-icers and deicers. To the maximum extent practicable, exposure of stormwater to these chemicals must be reduced by one or more of the following: a reduction in application rate or more selective use; increased source control activities; or separation of the areas of use from the contributing area draining to the UIC facility. Contact the local jurisdiction to determine whether specific source control requirements apply to your project in addition to those methods described in Chapter 8 for the proposed land use.

5.6.3 Siting Criteria and Treatment Requirements

Prior to evaluation of the water quality considerations, project proponents should be certain that the site meets the criteria in Section 6.3.5 of this Manual or appropriate alternative local criteria.

Where geologic and groundwater depth information are available, Tables 5.6.1 through 5.6.3 can be used to evaluate whether a stormwater discharge from a commercial or residential site to a UIC facility meets the non-endangerment standard. Industrial sites with no outdoor processing, storage or handling of raw or finished products may also use these tables; additional guidance for industrial sites is provided later in this sub-section (see "Land uses or activities with special treatment requirements"). Used together, the tables identify the extent to which the vadose zone may be presumed to provide sufficient treatment for a given pollutant loading surface in order to meet groundwater quality standards (see also the exceptions to Table 6.6.3 below). At sites where the vadose zone is considered to provide sufficient treatment to protect groundwater quality ("Suitable for all UIC facilities" or "Suitable for 2-stage drywell" in Table 5.6.3), pre-treatment is not required. If the proposed UIC facility cannot meet the depth/thickness requirements in Table 5.6.1 or in the exceptions below, the design must include pre-treatment for removal of solids. All high category pollutant loadings must provide pre-treatment for removal of oil. All project proponents should read Sections 5.6.4 Accidental Spills and 5.6.5 Prohibitions for additional considerations that may apply to their sites.

Evaluation of the Treatment Capacity of the Vadose Zone

Several alternative approaches are provided in Table 5.6.1 for identifying the proper treatment capacity classification of the vadose zone matrix. The designer can utilize grain size distribution and/or ratios, typical categories assigned by well drillers, and(or) geologic names. Geologic materials have been classified as having high, medium, low, or no treatment capacity. Keep in mind that the focus of this table is on a treatment layer, and not the depth to groundwater.

Native materials in the "high treatment capacity" category provide filtration combined with some chemically reactive characteristics, specifically cation exchange capacity. Native organic matter improves adsorption and filtration (Igloria et. al, 1997) but is rarely found at depths below UIC facilities, so this category generally relies on clay or fine silt materials to provide chemical reactivity. These may be mixtures of materials where silt and clay fill the pore spaces in matrix the coarser materials; the more compacted, the better the filtration.

Native materials in the "medium treatment capacity" category provide moderate to high filtration and have minor or no chemically reactive characteristics. Native materials in the "low treatment capacity" category provide some minimal filtration; the sand and gravel mixtures in this category may provide moderate filtration when a UIC facility is initially installed, but will typically yield preferential flow paths where treatment capacity is reduced. Materials in the "no treatment capacity" category do not provide any filtration to remove pollutants.

Table 5.1.1 is intended for use in meeting the presumptive approach; project proponents and local jurisdictions using the demonstrative approach may define other treatment capacity categories.

Subsurface Geologic Data

Geologic information may be available from regional subsurface geology maps in publications from the Department of Natural Resources or U.S. Geological Survey; from a well borehole log(s) in the same quarter section on the Department of Ecology website; or from local governments. Surface soils maps generally do not provide adequate information, although the parent material information provided may be helpful in some locations. Well borehole log locations should be verified, as electronic data bases contain many errors of this type. When using borehole logs, a "nearby" site is generally within a quarter of a mile. Subsurface geology can vary considerably in a very short horizontal distance in many areas of the state, so professional judgment should be used to determine whether the available data are adequate or site exploration is necessary. Where reliable regional information or nearby borehole logs are not readily available, it will be necessary to obtain data through site exploration. Alternatively, for small projects where site exploration is not cost-effective, a design professional might apply a conservative design approach subject to the approval of the local jurisdiction.

Depth to Groundwater

Groundwater depths may be available from Department of Ecology, Department of Natural Resources, or U.S. Geological Survey publications; or from local governments. Knowledge of the seasonal high water table is especially important for siting UIC facilities in areas with very shallow water tables (less than fifteen feet below the land surface), since significant mounding of infiltrating stormwater can occur above the water table (Appleyard,

1993) and UIC facilities must not discharge stormwater directly into groundwater at any time, even if the groundwater level is rising in response to the UIC discharge.

Water level information is also needed to confirm the thickness of the treatment layer in the vadose zone between the bottom of the UIC facility and the highest known groundwater level. Water level data associated with a single borehole log may be insufficient to determine the seasonal high water table, especially if the drilling occurred outside of the normal period of highest water tables (generally late winter through mid-spring in most of Washington State; but keep in mind that at sites in heavily irrigated areas, the seasonal high water table elevation may occur in late summer) and(or) following a wet season with lower than normal precipitation. At sites where the fluctuation of the seasonal water table is large (several feet) or unknown, designers should err on the side of caution: UIC facilities must not discharge stormwater directly into groundwater. The minimum required separation between the bottom of the facility and the highest seasonal water table depends upon the characteristics of the vadose zone, the potential for mounding of infiltrating stormwater above the water table, and the degree of certainty of available data as to the seasonal high water table elevation.

Well-head Protection

All UIC facilities must be sited in accordance with State or local Department of Health guidance and requirements. In particular, UIC facilities must be located the minimum required horizontal and(or) vertical distance from drinking water supply wells as required by the Department of Health. The current State regulation requires 100 feet of horizontal separation; local departments may establish stricter requirements and vertical separations. Project proponents should consider available information about the direction of local groundwater movement, time of travel, and vulnerability of drinking water supply wells to contamination when siting UIC facilities. Other setbacks may be required by local code. Some guidance regarding siting of stormwater facilities near geologic hazards is provided in Chapter 3.

Performance Consideration

As noted in Section 5.6.2 above, project proponents may wish to consider including pre-treatment facilities to remove solids from stormwater runoff and avoid potential cleanup requirements following long-term use of any UIC facility receiving runoff from traffic areas, regardless of the pollutant loading classification.

Exceptions Based on Site-Specific or Local Studies

Exceptions to Tables 5.6.1 through 5.6.3:

Where more or better site-specific data are gathered by the project proponent and local permission is granted, or where a local planning study is done with the intent of modifying the presumptive approach described in this section, the following modifications to the tables may be made:

∉ Where reliable, on-site information is available or where borehole logs exist for sites within one-quarter mile of the proposed UIC facility and local geology does not vary greatly, discharge of stormwater with *insignificant* or *low* pollutant loadings to a UIC facility above a vadose zone containing as little as three feet of a *high-capacity* treatment matrix thickness or ten feet of a *medium-capacity* treatment matrix thickness is allowed if implemented under a locally developed UIC management plan. Site specific water level data must be collected to justify the minimal separation from the water table if the three feet of high-capacity treatment matrix provides the entire separation between the bottom of the structure and the seasonal high water table; evaluation of the potential for mounding of infiltrating stormwater above the water table should also be considered.

∉ Where reliable, on-site information is available or where borehole logs exist for sites within one-quarter mile of the proposed UIC facility and local geology does not vary greatly, discharge of stormwater with *medium* or *high* pollutant loadings to a UIC facility above a vadose zone containing as little as six feet of a *high-capacity* treatment matrix thickness is allowed if implemented under a locally developed UIC management plan. Site specific water level data must be collected to justify the minimal separation from the water table if the six feet of high-capacity treatment matrix or ten feet of medium-capacity treatment matrix provides the entire separation between the bottom of the structure and the seasonal high water table; evaluation of the potential for mounding of infiltrating stormwater above the water table should also be considered. Use of a two-stage drywell (including spill control or a catch basin) is still required for *medium* pollutant loadings and pre-treatment for oil control is still required for *high* pollutant loadings.

∉ Where source control will eliminate or significantly reduce target pollutants from *high* or *medium* pollutant loadings and a local ordinance or other regulatory mechanism exists to enforce the source control activity as a requirement, the local jurisdiction may accept reclassification of these sites as medium or low, respectively.

∉ Where local jurisdiction planning efforts result in an alternative framework for evaluating the suitability of various discharges to UIC facilities, that approach may be used in lieu of Tables

5.6.1-5.6.3. Such an approach must be judged by the local jurisdiction to meet the non-endangerment standard for protecting groundwater under the local conditions. Other special conditions and exceptions listed in this subsection and in the subsections below on land uses or activities with special treatment requirements still apply.

Exceptions Based on Environmental Conditions

<u>UIC facilities located near surface water bodies that do not meet state water quality standards</u>: Where a UIC facility discharges to groundwater that contributes to baseflow in a nearby surface water body which does not meet State water quality standards for metals, fecal coliform and(or) phosphorus, the potential of the subsurface discharge to the UIC facility to contribute to the continued violation surface water quality standards must be considered. Shoreline regulations may also apply. Specific requirements are listed below.

- Where a UIC facility receives stormwater from a *medium* or *high* pollutant loading source area and discharges to a shallow water table (less than ten feet below the UIC facility) and it is less than 100 feet from a surface water body which is impaired due to **metals**, pre-treatment for solids removal is required. If the UIC facility is already required to apply pre-treatment for solids removal to protect the groundwater due to the expected pollutant load and(or) the limited treatment capacity of the vadose zone materials, then additional pre-treatment for metals removal is also required (see Section 2.2.6 and/or Section 5.2).
- Where a UIC facility discharges to a shallow water table (less than ten to fifteen feet below the land surface) and it is less than 100 feet from a surface water body is impaired due to **coliform bacteria**, then pre-treatment for solids removal is required. This pre-treatment requirement extends to UIC facilities up to one quarter mile from the surface water where the treatment capacity of the vadose zone is categorized as "low" or "none."
- Where a UIC facility is located near a surface water body which is impaired due to **phosphorus**, pre-treatment for removal of phosphorus may be required according to the remediation strategy adopted in a TMDL or other water clean-up plan. Check with the local jurisdiction for applicable requirements. If required, see Chapter 6.2 for more information.

Special Treatment Requirements

<u>Land uses or activities with special treatment requirements</u>:

- Where **fueling activities take place or petroleum products are stored and(or) transferred** in amounts greater than 1,500 gallons per year, the UIC facility must include a spill containment structure. A spill prevention, control and containment plan is also required for these sites (see Chapter 3).

- At all other **high-use sites** (see the definition in Section 2.2.5), the UIC facility must include a spill control device.
- At sites with stormwater associated with **industrial** activities as defined by EPA (40 CFR 122.26(b)(14)), pre-treatment for solids removal is required prior to discharge to a UIC facility where **outdoor processing, handling or storage of raw solid materials or finished products**, including outdoor loading areas for these materials or products, takes place. Stormwater associated with construction activities at sites classified as Category (x) under the federal rules are exempt from this requirement. If any activities at the facility fall under categories that are subject to benchmark monitoring requirements for nitrate, nitrite, ammonia or phosphorus under in the U.S. Environmental Protection Agency's multi-sector industrial permit (October 30, 2000), runoff from the site must be directed to biofiltration or bioinfiltration systems or to constructed wetlands with pre-treatment for removal of solids, or to sanitary sewer if allowed by the local jurisdiction. Facilities may complete a "no exposure" certification as part of Ecology's UIC facility registration process to be exempted from these requirements; in order to qualify, no outdoor processing, handling or storage of raw solid materials or finished products may take place at the facility.
- At **commercial** sites with **outdoor handling or storage of raw solid materials or treated wood products**, pre-treatment for solids removal is required prior to discharge to a UIC facility.
- Due to intensive fertilizer and pesticide use and the ineffectiveness of treatment facilities to remove those pollutants from runoff, UIC facilities should not be located at golf courses and other similarly **intensely managed landscape areas** such as many public ball fields and cemeteries. Runoff from the landscape areas should be directed to biofiltration or bioinfiltration systems or to constructed wetlands prior to discharge to UIC facilities. Limiting use of applied chemicals at these sites is encouraged, as is site design that minimizes runoff from the landscaped surface.
- Due to the ineffectiveness of stormwater treatment facilities in removing nutrients from runoff, UIC facilities may not be located at **sites that generate high nutrient loadings in**

runoff. Runoff from sites with high nutrient loadings should be directed to biofiltration or bioinfiltration systems or to constructed wetlands prior to discharge to UIC facilities, or used to irrigate crops in accordance with other applicable requirements.

Note that UIC facilities may still be employed for parking lots and other impervious areas at these sites in accordance with Tables 5.6.1-5.6.3.

Pre-Treatment Methods

Selection of pre-treatment BMPs: Where structural pre-treatment BMPs are required, the appropriate treatment BMPs must be selected from other sections in this chapter or from an equivalent manual approved by Ecology. (Source Control BMPs are described in Chapter 8.) Project proponents may also request conditional approval from Ecology for a new or experimental treatment method (see Chapter 5.12 Emerging Technologies). The BMPs and source control activities must be designed to remove or attenuate the target pollutants to levels that, following additional treatment through the vadose zone, will comply with groundwater quality standards when the discharge first comes into contact with an aquifer.

These BMPs include filtration and bio-infiltration BMPs; water quality vaults and wetpools; oil/water separators; manufactured devices (such as catch basin inserts, media filters and other emerging technology); and other approved facilities that provide treatment of expected pollutants (using filtration, adsorption, or sedimentation processes) for flows up to the water quality design storm (see Section 2.2.5).

Overflows or bypass flows from these treatment BMPs may be discharged directly to UIC facilities, provided that the entire water quality design storm flow is treated and that only the excess flows are routed directly to the drywell and discharged without treatment. Such discharge is allowed only provided that the frequency of overflow and the combination of site characteristics and expected pollutant loadings (based on projected land use) are not likely to result in contamination of groundwater.

5.6.4 Accidental Spills and Illicit Discharges

All impervious surfaces contributing stormwater to UIC structures should be qualitatively evaluated for risk of exposure to potential spills. For traffic surfaces, the designer should consider whether any of the following conditions are present: the bottom of a steep hill, a dangerous intersection, sharp turn in a road or other locations where traffic accidents are likely to occur; roads in industrial areas or with frequent daily travel by tanker trucks; or some other increased risk situation that might increase the potential for accidental spills. For commercial and industrial sites, the designer should consider the types of materials that will be handled and stored at the site; site layout and spill response plans; and probable employee training and preparation for responding to a spill and protecting the UIC facility from receiving the spilled material. In general, response to spills on roadways will be delayed, but response to an on-site spill at a well-prepared facility can be almost immediate.

If in the designer's judgment spills are likely during the life of the project, the UIC facility should include a spill containment structure or spill control device (see Chapter 8). The owner/operator should regularly inspect the facility in order to detect and attend to any unreported spills that may have occurred. All spills must be reported to Ecology.

It is preferable to prevent any spill from passing through the UIC facility and entering the vadose zone. If the potential for accidental spills is judged to be low and no spill containment structure or control device is present, or if the project proponent chooses to accept responsibility for cleanup and retrofit of the facility following a spill, the vadose zone may be used temporarily to contain a spill. A minimum of ten feet and preferably fifteen feet of separation between the bottom of the drywell and the top of an unconfined aquifer is deemed necessary to protect groundwater from most accidental or illicit spills that might occur on surfaces that drain to UIC structures. Regardless of the identified risk, in the event that a spill occurs and spreads through the vadose zone, the owner/operator must remove and properly dispose of the contaminated soils and replace them with clean materials as soon as practicable. In general, depths greater than 25 feet are difficult to clean up with soil removal equipment. If removal of deeper contaminated sediments is not practicable, long-term monitoring of the groundwater or application of other cleanup technologies may be required.

Areas or land uses that local jurisdictions determine to be subject to frequent spills or illegal dumping may be prohibited from using UIC facilities. Historic incidents in these areas may have been documented by the local jurisdiction, or there may be sufficient evidence to identify the location as an attractive nuisance. For example, UIC facilities at many auto parts shops, restaurants, and food processing facilities have been subject to frequent illicit discharges by customers or employees. Designers planning stormwater infrastructure for such facilities should discuss the potential problems with their clients and take care to locate UIC facilities in such a manner as to minimize easy, unobtrusive access for illegal dumping. Employee training will help to reduce these incidents.

5.6.5 Prohibitions

Due to potential contamination of groundwater, discharge of stormwater to UIC facilities is not allowed where any activities listed below take place out-of-doors. Conventional stormwater treatment is not considered protective of groundwater in these situations. If structural separation at the site prevents discharge of stormwater from the area to the UIC facility, the prohibition is limited to the portion of the site where that activity takes place; stormwater from other portions of the site such as roofs and parking areas may be discharged to UIC facilities in accordance with Tables 5.6.1-5.6.3. If structural separation is not practicable, stormwater from the entire site must be handled on site with a closed-loop system or discharged to sanitary sewer if allowed by the local jurisdiction.

- Areas where stormwater comes into contact with surfaces subject to:
  - Vehicle maintenance, repair and servicing;
  - Vehicle washing;
  - Airport deicing activities;
  - Storage of treated lumber;
  - Storage or handling of hazardous materials;
  - Storage, transfer, treatment or disposal of hazardous wastes;
  - Handling of radioactive materials;
- Recycling facilities (unless limited to glass products);
- Industrial or commercial areas without management plans for proper storage and spill prevention, control, and containment appropriate to the types of materials handled at the facility (see Chapter 3 for information on stormwater pollution prevention plans and Chapter 8 for source control);
- Sites where any activities subject to the Resource Conservation and Recovery Act (RCRA) take place.

See also "Land uses or activities with special treatment requirements" in sub-section 6.6.3 above.

5.6.6 Design Criteria

The UIC facility must be designed in accordance with local jurisdiction requirements or following the guidance in Sections 6.3.3 through 6.3.5. Pre-treatment facilities must be designed in accordance with the criteria established in Section 2.2.5 and in this Chapter; in another Manual or document approved by Ecology; or by local jurisdictions.

5.6.7 Construction Criteria

The UIC facility must be constructed in accordance with local jurisdiction requirements or following the guidance in Sections 6.3.3 through 6.3.5. Pre-treatment facilities must be constructed in accordance with the criteria established in Section 2.2.5 and in this Chapter; in another Manual or document approved by Ecology; or by local jurisdictions. All UIC facilities must be registered with the Department of Ecology in accordance with the submittal requirements established in the UIC rule. The project proponent should begin the registration process during the design phase and submit the completed paperwork prior to first use of the UIC facility.

5.6.8 Operation and Maintenance Criteria

The UIC facility must be operated and maintained in accordance with State or local jurisdiction requirements. Pre-treatment for solids removal is recommended to ensure protection of long-term infiltration capacity and reduced frequency of maintenance for any UIC facility; pre-treatment will also reduce the long-term accumulation of contaminants in the vadose zone. Pre-treatment facilities must be operated and maintained in accordance with the criteria established in this Manual, in another Manual or document approved by Ecology, or by local jurisdictions. Frequent inspections and regular maintenance will improve the long-term performance of the facilities.

Table 5.6.1 – Treatment capacity of vadose zone materials (subsurface geologic matrix above an unconfined aquifer) for removing contaminants from stormwater discharged to UIC facilities.

Presumed treatment capacity and conditions	Description of vadose zone layer
HIGH A minimum thickness of <u>ten feet</u> of these materials must be naturally present between the bottom of the UIC structure and the top of the highest known seasonal water table.*	Materials with average grain size <0.125mm *or* having a sand to silt/clay ratio of less than 1:1 and sand plus gravel less than 50% Lean, fat, or elastic clay Sandy or silty clay Silt Clayey or sandy silt Sandy loam or loamy sand Silt/clay with inter-bedded sand Well-compacted, poorly-sorted materials *This category generally includes till, hardpan, caliche, and loess*
MEDIUM A minimum thickness of <u>fifteen feet</u> of these materials must be naturally present between the bottom of the UIC structure and the top of the highest known seasonal water table.*	Materials with average grain size 0.125mm to 4mm *or* having a sand to silt/clay ratio between 1:1 and 9:1 and percent sand greater than or equal to percent gravel Fine, medium or coarse sand Gravelly sand Sand with inter-bedded clay and/or silt Poorly-graded/sorted, silty or muddy gravel Poorly-compacted, poorly-sorted materials *This category includes most outwash deposits, non-cavernous limestone, and some alluvium*
LOW A minimum thickness of <u>fifty feet</u> of these materials must be naturally present between the bottom of the UIC structure and the top of the highest known seasonal water table.	Materials with average grain size >4mm to 64mm *or* having a sand to silt/clay ratio greater than 9:1 and percent sand less than percent gravel Well-graded/sorted or clean gravel Sandy gravel *or* sand and gravel *This category includes some alluvium and outwash deposits*
NONE	Materials with average grain size >64mm *or* having total fines (sand and mud) less than 5% Boulders and/or cobbles Fractured rock *This category generally includes fractured basalt, other fractured bedrock, and cavernous limestone*

* See Section 5.6.2 narrative for possible exceptions to the thickness requirement.

Table 5.6.2 – Stormwater pollutant loading classifications for UIC facilities receiving stormwater runoff.

Pollutant loading classification	**Proposed land use or site characteristics***
Insignificant	Impervious surfaces not subject to motorized vehicle traffic or application of sand or deicing compounds Un-maintained open space
Low	Urban roads with ADT < 7,500 vehicles per day Freeways with ADT < 15,000 vehicles per day Parking areas with < 40 trip ends per 1,000 SF of gross building area or < 100 total trip ends (*e.g.* most residential parking and employee-only parking areas for small office parks or other commercial buildings) Most public parks (see prohibitions for exceptions) Roofs that are only subject to atmospheric deposition and normal heating, ventilation, and air conditioning system outputs Other land uses with similar traffic/use characteristics
Medium	Urban roads with ADT between 7,500 and 30,000 vehicles per day Freeways with ADT between 15,000 and 30,000 vehicles per day Parking areas with between 40 and 100 trip ends per 1,000 SF of gross building area or between 100 and 300 total trip ends (*e.g.* visitor parking for small to medium commercial buildings with a limited number of daily customers) Primary access points for high-density residential apartments Most intersections controlled by traffic signals Transit center bus stops Some high density residential roads and parking areas Roofs that are subject to ventilation systems that are specifically designed to remove commercial indoor pollutants Other land uses with similar traffic/use characteristics
High	All roads with ADT > 30,000 vehicles per day High-density intersections (see definition in Chapter 2.2.5) Parking areas with > 100 trip ends per 1,000 SF of gross building area or > 300 total trip ends (*e.g.* commercial buildings with a frequent turnover of visitors, such as grocery stores, shopping malls, restaurants, drive-through services, etc.) On-street parking areas of municipal streets in commercial and industrial areas Highway rest areas Other land uses with similar traffic/use characteristics

* See Section 5.6.3 prohibitions. Average daily traffic count (ADT) and trip ends must be calculated for the design life of the project and may be determined using "Trip Generation" published by the Institute of Transportation Engineers.

Table 5.6.3 – Matrix for determining suitability of subsurface discharge of stormwater from commercial and residential land uses to new UIC facilities

(See tables 5.6.1 and 5.6.2 for treatment capacity and pollutant loading definitions. All project proponents should read the entirety of Section 5.6 for exceptions or other requirements that apply in certain situations. Appropriate pre-treatment requirements must be determined using the information provided in Section 5.2 and in this section.)

Treatment capacity / **Pollutant loading**	*High*	*Medium*	*Low*	*None*
Insignificant	Suitable for all UIC facilities	Suitable for all UIC facilities	Suitable for all UIC facilities	Suitable for all UIC facilities
Low	Suitable for all UIC facilities	Suitable for all UIC facilities	Suitable for all UIC facilities	Pretreatment required to remove solids[1]
Medium	Suitable for 2-stage drywell*	Suitable for 2-stage drywell*	Pretreatment required to remove solids[1]	Pretreatment required to remove solids[1]
*High***	Pretreatment required to remove oil[2]	Pretreatment required to remove oil[2]	Pretreatment required to remove oil and solids[1,2]	Pretreatment required to remove oil and solids[1,2]

* A two-stage drywell includes a catch basin or spill control structure that traps small quantities of oils and solids; the spill control device may be a turned-down pipe elbow or other passive device.
** Note that the prohibitions listed in Section 5.6.5 still apply.
[1] Treatment to remove solids means basic treatment as defined in Section 2.2.5 and Section 5.2. Removal of solids should also remove a large portion of the metals in most stormwater runoff.
[2] Treatment to remove oil means oil control as defined in Section 2.2.5 and Section 5.2.

5.7 Wetpool Facilities

5.7.1 Purpose and Definition

A wetpond is a constructed stormwater pond that retains a permanent pool of water ("wetpool") at least during the wet season. The volume of the wetpool is related to the effectiveness of the pond in settling particulate pollutants. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak flow control can be provided in the "live storage" area above the permanent pool. Figures 5.7.1 and 5.7.2 illustrates a typical wet pond BMP.

The following design, construction, and operation and maintenance criteria cover two wetpond applications - the basic wetpond and the large wetpond. Large wetponds are designed for higher levels of pollutant removal.

BMP T5.70 Basic Wetpond

BMP T5.71 Large Wetpond

A wetpond is a constructed stormwater pond or portion of facility, that retains a pool of water (the “wetpool”). In some areas the wetpool may be permanent, at least during the wet season. The volume of the wet pond is related to the effectiveness of the pond in settling particulate pollutants. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak flow control can be provided in the "live storage" area above the permanent pool. Figures 5.7.1 and 5.7.2 illustrate a typical wet pond BMP.

A combined detention/wetpool places a detention pond or vault on top of the wetpond or vault. The wetpond or vault is designed per this section and the detention pond or vault is designed per Section 5.2. The sediment storage area of the detention facility can be deleted.

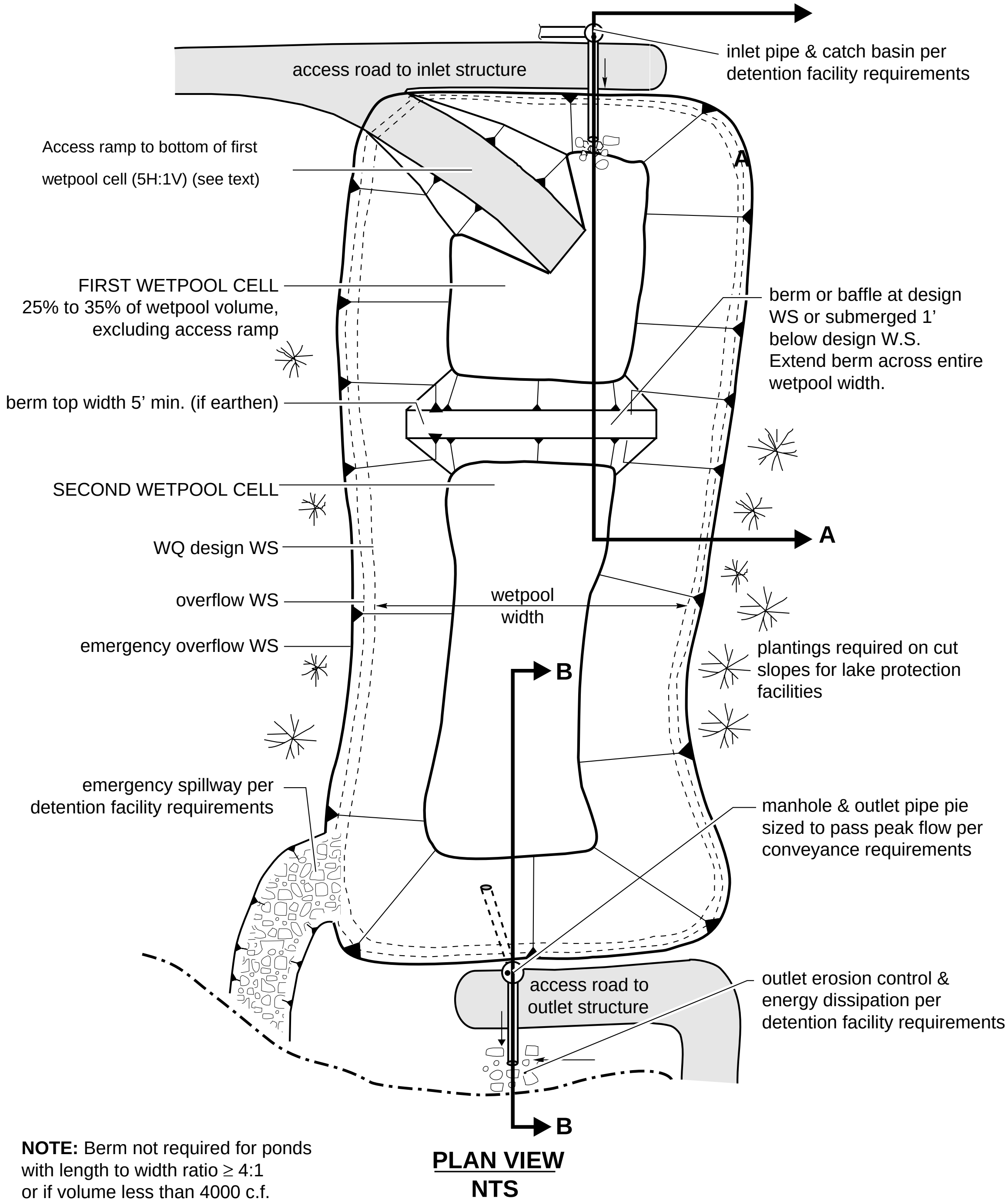


Figure 5.7.1 Wetpond/Wetpool (plan view)

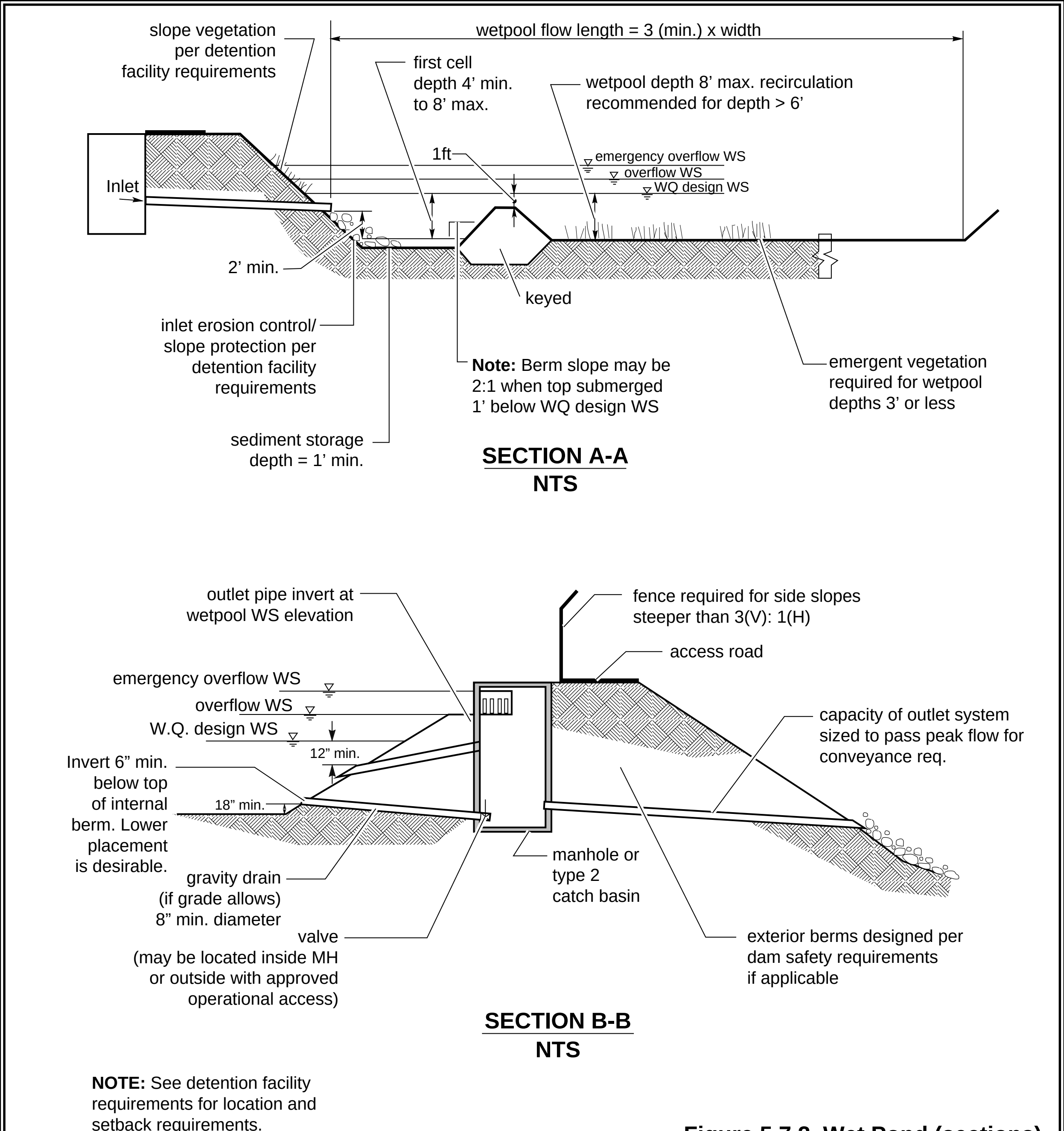


Figure 5.7.2 Wet Pond (sections)

5.7.2 Applications and Limitations

A wetpond requires a larger area than a biofiltration swale or a sand filter, but it can be integrated to the contours of a site fairly easily. In clayey or silty soils, the wetpond may hold a permanent pool of water that provides an attractive aesthetic feature. In more porous soils, wet ponds may still be used, but water seepage from unlined cells could result in a dry pond, particularly in the summer months. Lining the first cell with a low permeability liner is one way to deal with this situation. As long as the first cell retains a permanent pool of water, this situation will not reduce the pond's effectiveness but may be an aesthetic drawback.

Wet ponds may be single-purpose facilities, providing only runoff treatment, or they may be combined with a detention pond to also provide flow control. If combined, the wetpool can often be stacked under the detention pond with little further loss of development area. See Chapter 6 for the design of detention ponds.

5.7.3 Design Criteria

The primary design factor that determines a wet pond's treatment efficiency is the volume of the wetpool. The larger the wetpool volume, the greater the potential for pollutant removal. The wetpool volume provided shall be equal to or greater than the total volume of runoff from the water quality design storm.

Also important are the avoidance of short-circuiting and the promotion of plug flow. **Plug flow** describes the hypothetical condition of stormwater moving through the pond as a unit, displacing the "old" water in the pond with incoming flows. To prevent short-circuiting, water is forced to flow, to the extent practical, to all potentially available flow routes, avoiding "dead zones" and maximizing the time water stays in the pond during the active part of a storm.

Design features that encourage plug flow and avoid dead zones are:

- Dissipating energy at the inlet.
- Providing a large length-to-width ratio.
- Providing a broad surface for water exchange using a berm designed as a broad-crested weir to divide the extended detention dry pond into two cells rather than a constricted area such as a pipe.
- Maximizing the flowpath between inlet and outlet, including the vertical path, also enhances treatment by increasing residence time.

Sizing Procedure

Procedures for determining a wetpool's dimensions and volume are outlined below.

Step 1: Identify required wetpool volume using the following table or the SCS (now known as NRCS) curve number equations presented in Chapter 4 - Hydrologic Analysis and Design. For a Large Wetpond increase size of basic pond by 50%.

Table 5.7.1 Design Table for Basic Wetpond Sizing

2-YEAR 24-HOUR PRECIPITATION (in)		POND VOLUME PER 1000 SQUARE-FEET OF IMPERVIOUS AREA	EXAMPLES OF APPLICABLE SITES
FROM	TO		
0.60	0.80	43.3 cubic-feet	Moses Lake
0.81	1.00	57.1 cubic-feet	Yakima, Kennewick
1.01	1.20	79.7 cubic-feet	Wenatchee, Walla Walla
1.21	1.40	97.1 cubic-feet	Colfax, Colville
1.41	and greater	Hydrologic Method Required	Eastern and Cascade Mountains

Step 2: Determine wetpool dimensions. Determine the wetpool dimensions satisfying the design criteria outlined below and illustrated in Figures 5.7.1 and 5.7.2. A simple way to check the volume of each wetpool cell is to use the following equation:

$$V = \frac{h(A_1 + A_2)}{2}$$

Where: V = wetpool volume (cf)

h = wetpool average depth (ft)

A_1 = water quality design surface area of wetpool (sf)

A_2 = bottom area of wetpool (sf)

Step 3: Design primary overflow water surface. See Chapter 6 to determine the overflow water surface for detention ponds.

Step 4: Determine extended detention dry pond dimensions. General extended detention dry pond design criteria and concepts are shown in Figures 5.7.1 and 5.7.2.

Wetpool Geometry

The wetpool should be divided into two cells separated by a baffle or berm. The first cell should contain between 25 to 35 percent of the total wetpool volume. The baffle or berm volume shall not count as part of the total wetpool volume. The term baffle means a vertical divider placed across the entire width of the pond, stopping short of the bottom. A berm is a vertical divider typically built up from the bottom, or if in a vault, connects all the way to the bottom.

Intent The full-length berm or baffle promotes plug flow and enhances quiescence and laminar flow through as much of the entire water volume as possible. Alternative methods to the full-length berm or baffle that provide equivalent flow characteristics may be approved on a case-by-case basis by the local jurisdiction.

Sediment storage should be provided in the first cell. The sediment storage should have a minimum depth of 1-foot. A fixed sediment depth monitor should be installed in the first cell to gauge sediment accumulation unless an alternative gauging method is proposed.

The minimum depth of the first cell should be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.

The maximum depth of each cell should not exceed 8 feet (exclusive of sediment storage in the first cell). Pool depths of 3 feet or shallower (second cell) should be planted with emergent wetland vegetation.

Inlets and outlets should be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet should be at least 3:1. The **flowpath length** is defined as the distance from the inlet to the outlet, as measured at mid-depth. The **width** at mid-depth can be found as follows: width = (average top width + average bottom width)/2.

Ponds with wetpool volumes less than or equal to 4,000 cubic feet may be single celled (i.e., no baffle or berm is required). However, it is especially important in this case that the flow path length be maximized. The ratio of flow path length to width should be at least 4:1 in single celled extended detention dry ponds, but should preferably be 5:1.

All inlets should enter the first cell. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets. The first cell may be lined as needed.

Berms, Baffles, and Slopes

A berm or baffle should extend across the full width of the wetpool, and tie into the wetpool side slopes. If the berm embankments are greater than 4 feet in height, the berm must be constructed by excavating a key equal to 50 percent of the embankment cross-sectional height and width. This requirement may be waived if authorized by a geotechnical engineer based on specific site conditions. The geotechnical analysis should address situations in which one of the two cells is empty while the other remains full of water.

The top of the berm may extend to the WQ design water surface or be 1-foot below the WQ design water surface. If at the WQ design water surface, berm side slopes should be 3H:1V. Berm side slopes may be steeper (up to 2:1) if the berm is submerged 1-foot.

Intent Submerging the berm is intended to enhance safety by discouraging pedestrian access when side slopes are steeper than 3H:1V. An alternative to the submerged berm design is the use of barrier planting to prevent easy access to the divider berm in an unfenced extended detention dry pond.

If good vegetation cover is not established on the berm, erosion control measures should be used to prevent erosion of the berm back-slope when the pond is initially filled.

The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a licensed civil engineer. If a baffle or retaining wall is used, it should be submerged one foot below the design water surface to discourage access by pedestrians.

Embankments

Embankments that impound water must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC). If the impoundment has a storage capacity (including both water and sediment storage volumes) greater than 10 acre-feet (435,600 cubic feet or 3.26 million gallons) above natural ground level, then dam safety design and review are required by the Department of Ecology.

Inlet and Outlet

See Figures 5.7.1 and 5.7.2 details on the following requirements:

The inlet to the wetpool should be submerged with the inlet pipe invert a minimum of two feet from the pond bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1-foot, if possible.

Intent The inlet is submerged to dissipate energy of the incoming flow. The distance from the bottom is set to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

An outlet structure shall be provided. Either a Type 2 catch basin with a grated opening (jail house window) or a manhole with a cone grate (birdcage) may be used. No sump is required in the outlet structure for extended detention dry ponds not providing detention storage. The outlet structure receives flow from the pond outlet pipe. The grate or birdcage openings provide an overflow route should the pond outlet pipe become clogged. The overflow criteria provided below specifies the sizing and position of the grate opening.

The pond outlet pipe (as opposed to the manhole or type 2 catch basin outlet pipe) should be back-sloped or have a turn-down elbow, and extend 1 foot below the WQ design water surface. Note: A floating outlet, set to draw water from 1-foot below the water surface, is also acceptable if vandalism concerns are adequately addressed.

Intent The inverted outlet pipe provides for trapping of oils and floatables in the extended detention dry pond.

The pond outlet pipe shall be sized, at a minimum, to pass the WQ design flow. Note: The highest invert of the outlet pipe sets the WQ design water surface elevation.

The overflow criteria for single-purpose (treatment only, not combined with flow control) wetpools are as follows:

- The requirement for primary overflow is satisfied by either the grated inlet to the outlet structure or by a birdcage above the pond outlet structure.
- The bottom of the grate opening in the outlet structure should be set at or above the height needed to pass the WQ design flow through the pond outlet pipe. Note: The grate invert elevation sets the overflow water surface elevation.
- In on-line ponds, the grated opening should be sized to pass the 100-year design flow. The capacity of the outlet system should be sized to pass the peak flow for the conveyance requirements.
- An emergency spillway shall be provided and designed according to the requirements for detention ponds (see Chapter 6 – Flow Control Facility Design).
- A gravity drain for maintenance is recommended if grade allows.

Intent It is anticipated that sediment removal will only be needed for the first cell in the majority of cases. The gravity drain is intended to allow water from the first cell to be drained to the second cell when the first cell is pumped dry for cleaning.

All metal parts should be corrosion-resistant. Galvanized materials should not be used unless unavoidable.

Intent Galvanized metal contributes zinc to stormwater, sometimes in very high concentrations.

Access and Setbacks

All facilities shall be a minimum of 20 feet from any structure, property line, and any vegetated buffer required by the local government, and 100 feet from any septic tank/drainfield.

All facilities shall be located away from any steep (greater than 15 percent) slope, at a minimum distance equivalent to the height of the slope. A geotechnical report must address the potential impact of a wet pond on a steep slope.

Access and maintenance roads shall be provided and designed according to the requirements for detention ponds. Access and maintenance roads shall extend to both the extended detention dry pond inlet and outlet structures. An access ramp (5H minimum:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the pond.

If the dividing berm is also used for access, it should be built to sustain loads of up to 80,000 pounds.

Planting Requirements

If desired the pond may be planted with dryland grasses. Sod or wetland plants should be avoided unless irrigation will be provided during the dry months.

Recommended Design Features

The following design features should be incorporated into the extended detention dry pond design where site conditions allow:

The method of construction of soil/landscape systems can cause natural selection of specific plant species. Consult a soil restoration or wetland soil scientist for site-specific recommendations. The soil formulation will impact the plant species that will flourish or suffer on the site, and the formulation should be such that it encourages desired species and discourages undesired species.

For permanent wetpool depths in excess of 6 feet, it is recommended that some form of recirculation be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions.

A flow length-to-width ratio greater than the 3:1 minimum is desirable. If the ratio is 4:1 or greater, then the dividing berm is not required, and the pond may consist of one cell rather than two.

A tear-drop shape, with the inlet at the narrow end, rather than a rectangular pond is preferred since it minimizes dead zones caused by corners.

A small amount of base flow is desirable to maintain circulation and reduce the potential for low oxygen conditions during late summer.

Columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating, except that no trees or shrubs may be planted on berms meeting the criteria of dams regulated for safety. In addition to shade, trees and shrubs also discourage waterfowl use and the attendant phosphorus enrichment problems they cause. Trees should be set back so that the branches will not extend over the pond.

Intent Evergreen trees or shrubs are preferred to avoid problems associated with leaf drop, except on the south and west sides which may inhibit the melting of ice during the winter. Columnar deciduous trees (e.g., hornbeam, Lombardy poplar, etc.) typically have fewer leaves than other deciduous trees.

The number of inlets to the facility should be limited; ideally there should be only one inlet. The flowpath length should be maximized from inlet to outlet for all inlets to the facility.

The access and maintenance road could be extended along the full length of the extended detention dry pond and could double as playcourts or picnic areas. Placing finely ground bark or other natural material over the road surface would render it more pedestrian friendly.

The following design features should be incorporated to enhance aesthetics where possible:

Provide side slopes that are sufficiently gentle to avoid the need for fencing (3:1 or flatter).

Include fountains or integrated waterfall features for privately maintained facilities.

Provide visual enhancement with clusters of trees and shrubs. On most pond sites, it is important to amend the soil before planting since ponds are typically placed well below the native soil horizon in very poor soils. Make sure dam safety restrictions against planting do not apply.

Orient the pond length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

5.7.4 Construction Criteria

Sediment that has accumulated in the pond must be removed after construction in the drainage area of the pond is complete (unless used for a liner - see below).

Sediment that has accumulated in the pond at the end of construction may be used as a liner in excessively drained soils if the sediment meets the criteria for a low permeability liner, and is approved for use as such by a geotechnical engineer. Sediment used for a soil liner must be graded to provide uniform coverage and thickness.

5.7.5 Operation and Maintenance

Maintenance is of primary importance if wetpools are to continue to function as originally designed. A local government, a designated group such as a homeowners' association, or a property owner should accept the responsibility for maintaining the structures and the impoundment area. A specific maintenance plan should be formulated outlining the schedule and scope of maintenance operations.

The pond should be inspected by the local government annually. The maintenance standards contained in Appendix 5A are measures for determining if maintenance actions are required as identified through the annual inspection.

Site vegetation should be trimmed as necessary to keep the pond free of leaves and to maintain the aesthetic appearance of the site. Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.

Sediment should be removed when the 1-foot sediment zone is full plus 6 inches. Sediments should be tested for toxicants in compliance with current disposal requirements. Sediments must be disposed in accordance with current local health department requirements and the Minimum Functional Standards for Solid Waste Handling.

Any standing water removed during the maintenance operation must be properly disposed of. The preferred disposal option is discharge to a sanitary sewer at an approved location. Other disposal options include discharge back into the wetpool facility or the storm sewer system, if approved by the operator of the storm sewer system.

5.7.6 BMP T5.72 Wetvaults

Purpose and Definition

A wetvault is an underground structure similar in appearance to a detention vault, except that a wetvault has a permanent pool of water (wetpool) which dissipates energy and improves the settling of particulate pollutants (see the wetvault details in Figure 5.7.3). Being underground, the wetvault lacks the biological pollutant removal mechanisms, such as algae uptake, present in surface extended detention dry ponds.

Applications and Limitations

A wetvault may be used for commercial, industrial, or roadway projects if there are space limitations precluding the use of other treatment BMPs. The use of wetvaults for residential development is highly discouraged. Combined detention and wetvaults are allowed.

A wetvault is believed to be ineffective in removing dissolved pollutants such as soluble phosphorus or metals such as copper. There is also concern that oxygen levels will decline, especially in warm summer months, because of limited contact with air and wind. However, the extent to which this potential problem occurs has not been documented.

Below-ground structures like wetvaults are relatively difficult and expensive to maintain. The need for maintenance is often not seen and as a result routine maintenance does not occur.

If oil control is required for a project, a wetvault may be combined with an API oil/water separator.

Design Criteria

Sizing Procedure As with wet ponds, the primary design factor that determines the removal efficiency of a wetvault is the volume of the wetpool. The larger the volume, the higher the potential for pollutant removal. Performance is also improved by avoiding dead zones (like corners) where little exchange occurs, using large length-to-width ratios, dissipating energy at the inlet, and ensuring that flow rates are uniform to the extent possible and not increased between cells.

The sizing procedure for a wetvault is identical to the sizing procedure for an extended detention dry pond. The wetpool volume for the wetvault shall be equal to or greater than the total volume of runoff from the 6-month, 24-hour storm event.

Typical design details and concepts for the wetvault are shown in Figure 5.7.3.

Wetpool Geometry Same as specified for wet ponds (see BMP T5.70 and BMP T5.71) except for the following two modifications:

The sediment storage in the first cell shall be an average of 1-foot. Because of the v-shaped bottom, the depth of sediment storage needed above the bottom of the side wall is roughly proportional to vault width according to the schedule below:

Vault Width	Sediment Depth (from bottom of side wall)
15'	10"
20'	9"
40'	6"
60'	4"

The second cell shall be a minimum of 3 feet deep since planting cannot be used to prevent re-suspension of sediment in shallow water as it can in open ponds.

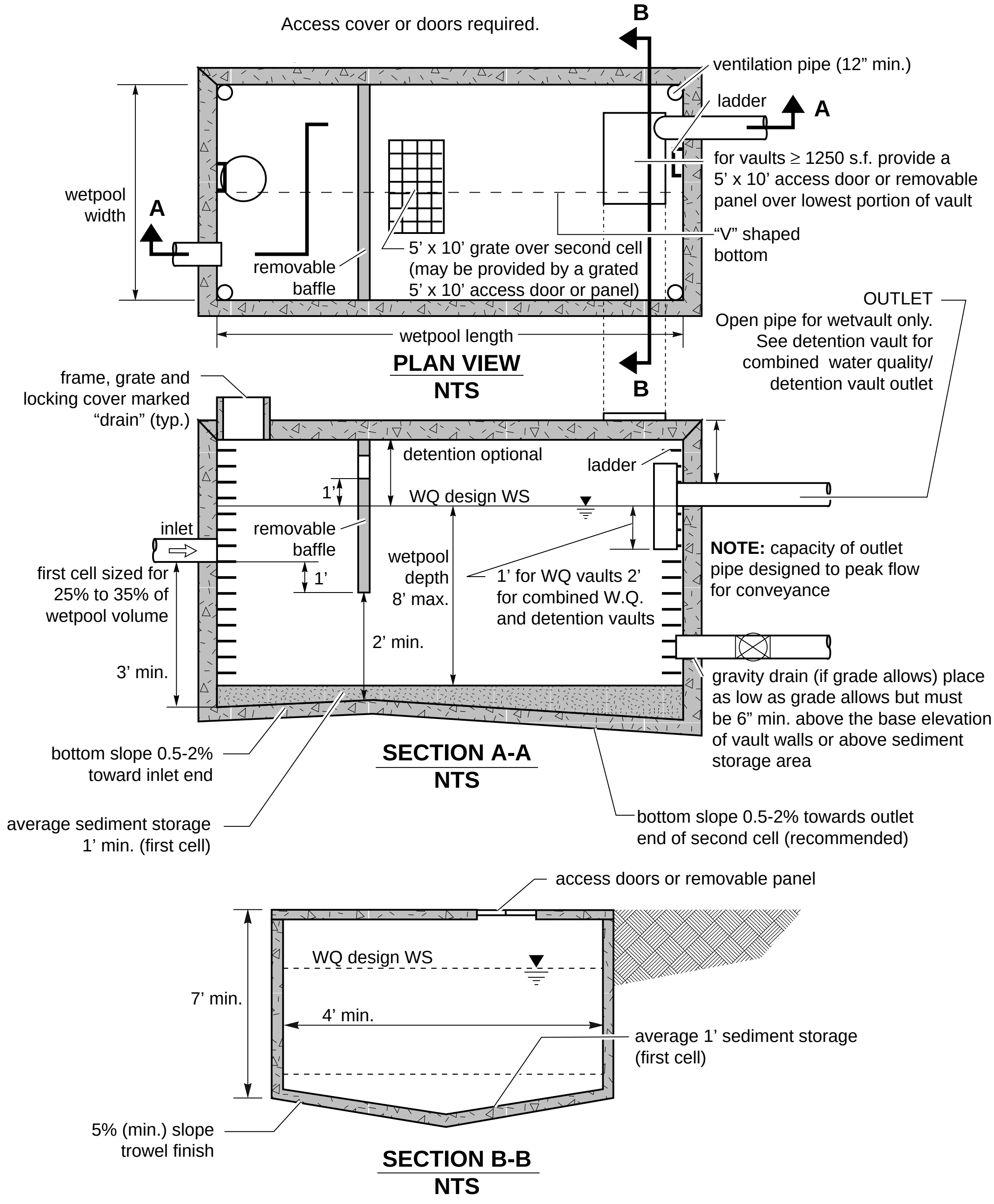


Figure 5.7.3 Wetvault

Vault Structure The vault shall be separated into two cells by a wall or a removable baffle. If a wall is used, a 5-foot by 10-foot removable maintenance access must be provided for both cells. If a removable baffle is used, the following criteria apply:

The baffle shall extend from a minimum of 1-foot above the WQ design water surface to a minimum of 1-foot below the invert elevation of the inlet pipe.

The lowest point of the baffle shall be a minimum of 2 feet from the bottom of the vault, and greater if feasible.

If the vault is less than 2,000 cubic feet (inside dimensions), or if the length-to-width ratio of the vault pool is 5:1 or greater, the baffle or wall may be omitted and the vault may be one-celled.

The two cells of a wetvault should not be divided into additional subcells by internal walls. If internal structural support is needed, it is preferred that post and pier construction be used to support the vault lid rather than walls. Any walls used within cells must be positioned so as to lengthen, rather than divide, the flowpath.

Intent Treatment effectiveness in wetpool facilities is related to the extent to which plug flow is achieved and short-circuiting and dead zones are avoided. Structural walls placed within the cells can interfere with plug flow and create significant dead zones, reducing treatment effectiveness.

The bottom of the first cell shall be sloped toward the access opening. Slope should be between 0.5 percent (minimum) and 2 percent (maximum). The second cell may be level (longitudinally) sloped toward the outlet, with a high point between the first and second cells. The intent of sloping the bottom is direct the sediment accumulation to the closest access point for maintenance purposes. Sloping the second cell towards the access opening for the first cell is also acceptable.

The vault bottom shall slope laterally a minimum of 5 percent from each side towards the center, forming a broad "v" to facilitate sediment removal. Note: More than one "v" may be used to minimize vault depth.

Exception: The Local Jurisdiction may allow the vault bottom to be flat if removable panels are provided over the entire vault. Removable panels should be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.

The highest point of a vault bottom must be at least 6 inches below the outlet elevation to provide for sediment storage over the entire bottom.

Provision for passage of flows should the outlet plug shall be provided.

Wetvaults may be constructed using arch culvert sections provided the top area at the WQ design water surface is, at a minimum, equal to that of a vault with vertical walls designed with an average depth of 6 feet.

Intent To prevent decreasing the surface area available for oxygen exchange.

Wetvaults shall conform to the "Materials" and "Structural Stability" criteria specified for detention vaults in Chapter 6.

Where pipes enter and leave the vault below the WQ design water surface, they shall be sealed using a non-porous, non-shrinking grout.

Inlet and Outlet The inlet to the wetvault shall be submerged with the inlet pipe invert a minimum of 3 feet from the vault bottom. The top of the inlet pipe should be submerged at least 1-foot, if possible.

Intent The submerged inlet is to dissipate energy of the incoming flow. The distance from the bottom is to minimize re-suspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

Unless designed as an off-line facility, the capacity of the outlet pipe and available head above the outlet pipe should be designed to convey the 100-year design flow for developed site conditions without overtopping the vault. The available head above the outlet pipe must be a minimum of 6 inches.

The outlet pipe shall be back-sloped or have tee section, the lower arm of which should extend 1 foot below the WQ design water surface to provide for trapping of oils and floatables in the vault.

The Local Jurisdiction may require a bypass/shutoff valve to enable the vault to be taken offline for maintenance.

Access Requirements Same as for detention vaults (see Chapter 6) except for the following additional requirement for wetvaults:

A minimum of 50 square feet of grate should be provided over the second cell. For vaults in which the surface area of the second cell is greater than 1,250 square feet, 4 percent of the top should be grated. This requirement may be met by one grate or by many smaller grates distributed over the second cell area. Note: a grated access door can be used to meet this requirement.

Intent The grate allows air contact with the wetpool in order to minimize stagnant conditions which can result in oxygen depletion, especially in warm weather.

Access Roads, Right of Way, and Setbacks Same as for detention vaults (Chapter 6).

Recommended Design Features

The following design features should be incorporated into wetvaults where feasible, but they are not specifically required:

- The floor of the second cell should slope toward the outlet for ease of cleaning.
- The inlet and outlet should be at opposing corners of the vault to increase the flowpath.
- A flow length-to-width ratio greater than 3:1 minimum is desirable.
- Lockable grates instead of solid manhole covers are recommended to increase air contact with the wetpool.
- Galvanized materials shall not be used unless unavoidable.
- The number of inlets to the wetvault should be limited, and the flowpath length should be maximized from inlet to outlet for all inlets to the vault.

Construction Criteria

Sediment that has accumulated in the vault must be removed after construction in the drainage area is complete. If no more than 12 inches of sediment have accumulated after the infrastructure is built, cleaning may be left until after building construction is complete. In general, sediment accumulation from stabilized drainage areas is not expected to exceed an average of 4 inches per year in the first cell. If sediment accumulation is greater than this amount, it will be assumed to be from construction unless it can be shown otherwise.

Operation and Maintenance

Accumulated sediment and stagnant conditions may cause noxious gases to form and accumulate in the vault. Vault maintenance procedures must meet OSHA confined space entry requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Facilities should be inspected by the local government annually. The maintenance standards contained in Appendix 5A of this chapter are measures for determining if maintenance actions are required as identified through the annual inspection.

Sediment should be removed when the 1-foot sediment zone is full plus 6 inches. Sediments should be tested for toxicants in compliance with current disposal requirements. Sediments must be disposed in accordance with current local health department requirements.

Any standing water removed during the maintenance operation must be properly disposed of. The preferred disposal option is discharge to a sanitary sewer at an approved location.

See Appendix 5A for more detailed information.

Modifications for Combining with a Baffle Oil/Water Separator

If the project site is a high-use site and a wetvault is proposed, the vault may be combined with a baffle oil/water separator to meet the runoff treatment requirements with one facility rather than two. Structural modifications and added design criteria are given below. However, the maintenance requirements for baffle oil/water separators must be adhered to, in addition to those for a wetvault. This will result in more frequent inspection and cleaning than for a wetvault used only for TSS removal. See Appendix 5A for information on maintenance of baffle oil/water separators.

1. The sizing procedures for the baffle oil/water separator (Section 5.10) should be run as a check to ensure the vault is large enough. If the oil/water separator sizing procedures result in a larger vault size, increase the wetvault size to match.
2. An oil retaining baffle shall be provided in the second cell near the vault outlet. The baffle should not contain a high-flow overflow, or else the retained oil will be washed out of the vault during large storms.
3. The vault shall have a minimum length-to-width ratio of 5:1.
4. The vault shall have a design water depth-to-width ratio of between 1:3 to 1:2.
5. The vault shall be watertight and shall be coated to protect from corrosion.
6. Separator vaults shall have a shutoff mechanism on the outlet pipe to prevent oil discharges during maintenance and to provide emergency shut-off capability in case of a spill. A valve box and riser shall also be provided.
7. Wetvaults used as oil/water separators must be off-line and must bypass flows greater than the WQ design flow.

Intent This design minimizes the entrainment and/or emulsification of previously captured oil during very high flow events.

5.7.7 BMP T5.73 Stormwater Treatment Wetlands

Purpose and Definition

In land development situations, wetlands are usually constructed for two main reasons: to replace or mitigate impacts when natural wetlands are filled or impacted by development (mitigation wetlands), and to treat stormwater runoff (stormwater treatment wetlands). Stormwater treatment wetlands are shallow man-made ponds that are designed to treat stormwater through the biological processes associated with emergent aquatic plants (see the stormwater wetland details in Figure 5.7.4 and Figure 5.7.5).

Wetlands created to mitigate disturbance impacts, such as filling, may not also be used as stormwater treatment facilities. This is because of the different, incompatible functions of the two kinds of wetlands. Mitigation wetlands are intended to function as full replacement habitat for fish and wildlife, providing the same functions and harboring the same species diversity and biotic richness as the wetlands they replace. Stormwater treatment wetlands are used to capture and transform pollutants, just as wetponds are, and over time pollutants will concentrate in the sediment. This is not a healthy environment for aquatic life. Stormwater treatment wetlands are used to capture pollutants in a managed environment so that they will not reach natural wetlands and other ecologically important habitats. In addition, vegetation must occasionally be harvested and sediment dredged in stormwater treatment wetlands, further interfering with use for wildlife habitat.

In general, stormwater wetlands perform well to remove sediment, metals, and pollutants that bind to humic or organic acids. Phosphorus removal in stormwater wetlands is highly variable.

Applications and Limitations

This stormwater wetland design occupies about the same surface area as wetponds, but has the potential to be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Careful planning is needed to be sure sufficient water will be retained to sustain good wetland plant growth. A source of irrigation water may be needed. Since water depths are shallower than in wetponds, water loss by evaporation is an important concern. Stormwater wetlands are a good WQ facility choice in areas with high winter groundwater levels.

Design Criteria

When used for stormwater treatment, stormwater wetlands employ some of the same design features as wetponds. However, instead of gravity settling being the dominant treatment process, pollutant removal mediated by aquatic vegetation and the microbiological community associated with that vegetation becomes the dominant treatment process. Thus when designing wetlands, water volume is not the dominant design criteria. Rather, factors which affect plant vigor and biomass are the primary concerns.

Wetland Geometry Criteria

1. Stormwater wetlands shall consist of two cells, a presettling cell and a wetland cell.

2. The presettling cell shall contain approximately 33 percent of the wetpool volume calculated in Step 1 above.

3. The depth of the presettling cell shall be between 4 feet (minimum) and 8 feet (maximum), excluding sediment storage.

4. One-foot of sediment storage shall be provided in the presettling cell.

5. The wetland cell shall have an average water depth of about 1.5 feet (plus or minus 3 inches).

6. The "berm" separating the two cells shall be shaped such that its downstream side gradually slopes to form the second shallow wetland cell (see the section view in Figure 5.7.4). Alternatively, the second cell may be graded naturalistically from the top of the dividing berm (see Criterion 8 below).

7. The top of berm shall be either at the WQ design water surface or submerged 1-foot below the WQ design water surface, as with wetponds. Correspondingly, the side slopes of the berm must meet the following criteria:

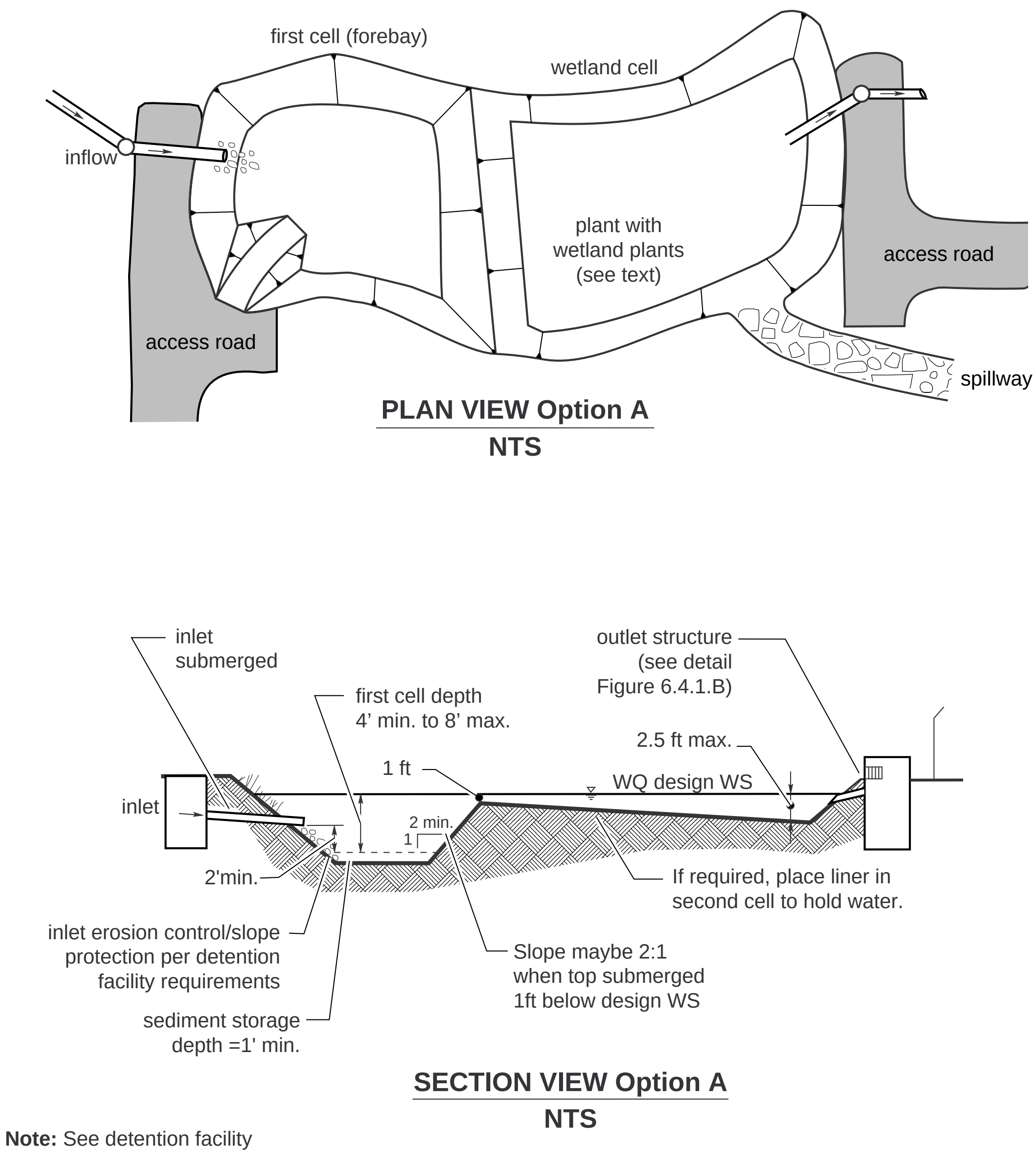
    a. If the top of berm is at the WQ design water surface, the berm side slopes shall be no steeper than 3H:1V.

    b. If the top of berm is submerged 1-foot, the upstream side slope may be up to 2H:1V. If the berm is at the water surface, then for safety reasons, its slope should be not greater than 3:1, just as the pond banks should not be greater than 3:1 if the pond is not fenced. A steeper slope (2:1 rather than 3:1) is allowable if the berm is submerged in 1 foot of water. If submerged, the berm is not considered accessible, and the steeper slope is allowable.

8. Two examples are provided for grading the bottom of the wetland cell. One example is a shallow, evenly graded slope from the upstream to the downstream edge of the wetland cell (see Figure 5.7.4). The second example is a "naturalistic" alternative, with the specified range of depths intermixed throughout the second cell (see Figure 5.7.5). A distribution of depths shall be provided in the wetland cell depending on whether the dividing berm is at the water surface or submerged (see Table 5.7.3 below). The maximum depth is 2.5 feet in either configuration. Other configurations within the wetland geometry constraints listed above may be approved by the local jurisdiction.

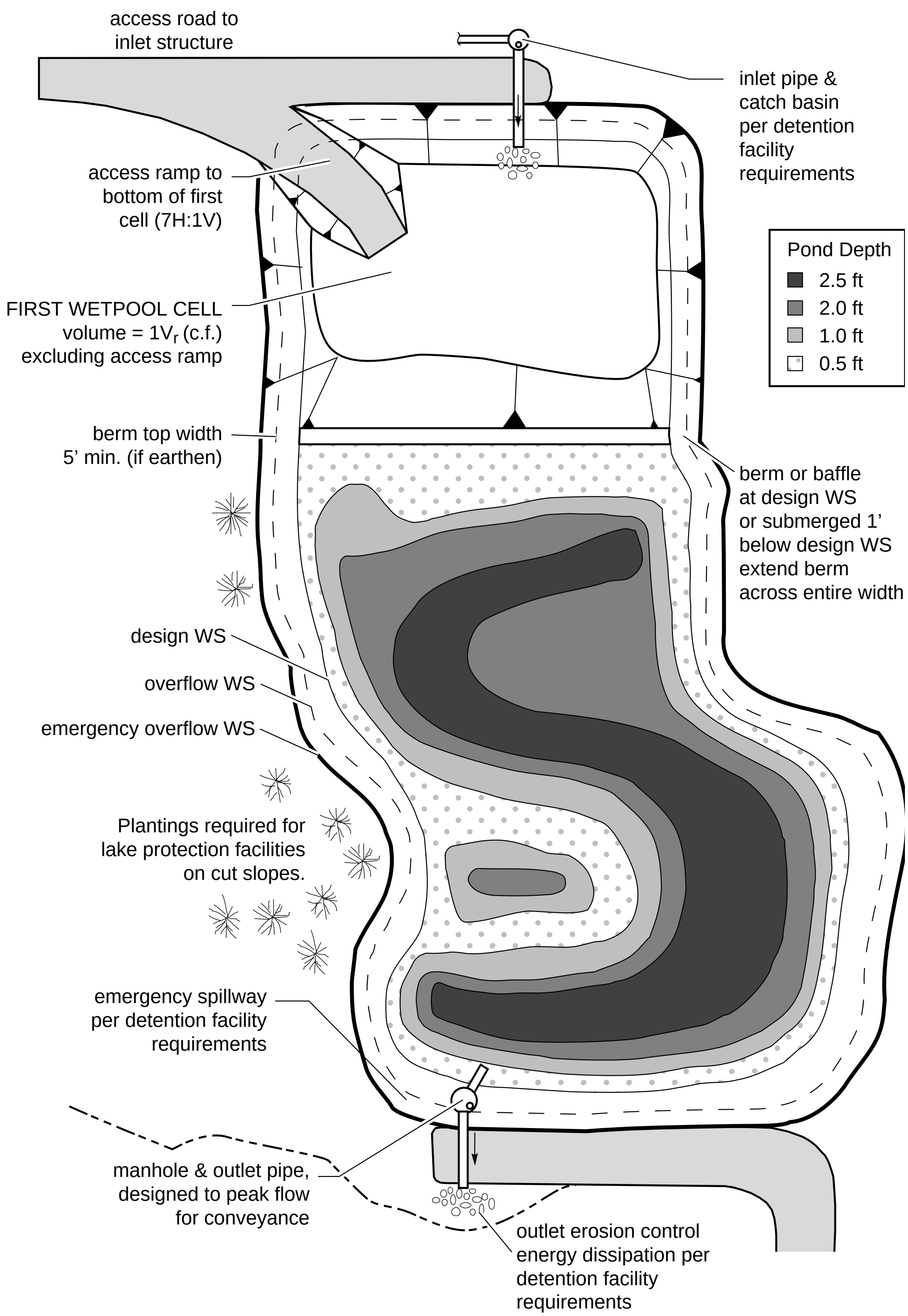
9. It is intended that the intent of the Wetland Geometry Criteria listed above generally be met. Appropriate deviations may be necessary, based upon site specific considerations.

Table 5.7.3 – Distribution of depths in wetland cell			
Dividing Berm at WQ Design Water Surface		**Dividing Berm Submerged 1-Foot**	
Depth Range (feet)	**Percent**	**Depth Range (feet)**	**Percent**
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20



Note: See detention facility requirements for location and setback requirements.

Figure 5.7.4 Stormwater Wetland — Option A
Note: Figure adapted from King County Surface Water Design Manual



PLAN VIEW Option B

NTS

Figure 5.7.5 Stormwater Wetland — Option B

Note: Figure adapted from King County Surface Water Design Manual

Sizing Procedure

Step 1: The volume of a basic wetpond is used as a template for sizing the stormwater wetland. See Section 5.7.3 for sizing procedure.

Step 2: Calculate the surface area of the stormwater wetland. The surface area of the wetland shall be the same as the top area of a wetpond sized for the same site conditions. Calculate the surface area of the stormwater wetland by using the volume from Step 1 and dividing by the average water depth (typically 3 feet).

Step 3: Determine the surface area of the first cell of the stormwater wetland. Use the volume determined from Criterion 2 under "Wetland Geometry", and the actual depth of the first cell.

Step 4: Determine the surface area of the wetland cell. Subtract the surface area of the first cell (Step 3) from the total surface area (Step 2).

Step 5: Determine water depth distribution in the second cell. Decide if the top of the dividing berm will be at the surface or submerged (designer's choice). Adjust the distribution of water depths in the second cell according to Criterion 8 under "Wetland Geometry" (below). Note: This will result in a facility that holds less volume than that determined in Step 1 above. This is acceptable.

Intent: The surface area of the stormwater wetland is set to be roughly equivalent to that of a wetpond designed for the same site so as not to discourage use of this option.

Step 6: Choose plants. See Table 5.7.2 for a list of plants recommended for wetpond water depth zones, or consult a wetland scientist.

Table 5.7.2 -- Emergent wetland plant species recommended for wetponds, Eastern Washington Arid and Cold Climates			
Species	**Common Name**	**Notes**	**Maximum Depth**
INUNDATION TO 1-FOOT			
Deschampsia caespitosa	Tufted hairgrass	Prairie to coast	to 2 feet
Carex nebrascensis	Nebraska sedge	Wet meadows to pond margins	
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	to 2 feet
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	to 2 feet
Juncus articulatus	Jointed rush	Wet soils, wetland margins	
Smilacina stellata	False Solomon's seal	Moist areas; needs saturated soils all summer	
Scirpus validus(2)	Soft-stem bulrush	Wet ground to shallow water	
Scirpus microcarpus(2)	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sagittaria latifolia(2)	Arrowhead	Margins of ponds, shallow water	
INUNDATION 1 TO 2 FEET			
Agrostis idahoensis	Idaho bent grass	Prairie, wet meadows	Does not withstand flooding-moist soil
Alisma plantago-aquatica	American water plantain	Shallow to deep marshes	
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	Best in 1' zone
Calamagrostis canadensis	Bluejoint reedgrass	Marshes, pond margins	
Juncus ensifolius	Dagger-leaf rush	Wet meadows, pastures, wetland margins	
Scirpus validus(2)	Soft-stem bulrush	Wet ground to 18 inches depth	18 inches
Sparganium eurycarpum	Broad-fruited burreed	Shallow standing water, saturated soils	
INUNDATION 1 TO 3 FEET			
Carex nebrascensis	Nebraska sedge	Wet meadows to pond margins	1.5 to 3 feet
Beckmania syzigachne(1)	American sloughgrass	Wet meadows to pond margins	
Scirpus acutus(2)	Hardstem bulrush	Single tall stems, not clumping	to 3 feet
Scirpus americanus(2)	Three-square bulrush		
INUNDATION GREATER THAN 3 FEET			
Nuphar polysepalum	Yellow water-lily	Deep water	3 to 7.5 feet
Potamogeton natans	Floating-leaf pondweed	Shallow to deep ponds	to 6 feet

Notes:

(1) Non-native species. However *Beckmania syzigachne* is native to Oregon.

(2) *Scirpus* tubers must be protected from foraging waterfowl until established. Emerging aerial stems should project above water surface to allow oxygen transport to the roots.

Primary sources: Washington State Department of Ecology, *Restoring Wetlands in Washington*, Pub. #93-17. Hortus Northwest, *Wetland Plants for Western Oregon*, Issue 4, 1993. Hitchcock and Cronquist, *Flora of the Pacific Northwest*, 1973.

Lining Requirements

In infiltrative soils, both cells of the stormwater wetland shall be lined. To determine whether a low-permeability liner or a treatment liner is required, determine whether the following conditions will be met. If soil permeability will allow sufficient water retention, lining may be waived.

1 The second cell must retain water for at least 10 months of the year.
2. The first cell must retain at least three feet of water year-round.
3. A complete precipitation record shall be used when establishing these conditions. Evapotranspiration losses shall be taken into account as well as infiltration losses.

<u>Intent:</u> Many wetland plants can adapt to periods of summer drought, so a limited drought period is allowed in the second cell. This may allow a treatment liner rather than a low permeability liner to be used for the second cell. The first cell must retain water year-round in order for the presettling function to be effective.

∉ If a low permeability liner is used, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) must be placed over the liner. For geomembrane liners, a soil depth of 3 feet is recommended to prevent damage to the liner during planting. Hydric soils are not required.

The criteria for liners given in Section 5.8.5 must be observed.

Inlet and Outlet

Same as for wetponds (see BMP T5.70 and BMP T5.71).

Access and Setbacks

∉ Location of the stormwater wetland relative to site constraints (e.g., buildings, property lines, etc.) shall be the same as for detention ponds (see Chapter 6). See Section 5.3.3 for typical setback requirements for WQ facilities.

∉ Access and maintenance roads shall be provided and designed according to the requirements for detention ponds (see Chapter 6). Access and maintenance roads shall extend to both the wetland inlet and outlet structures. An access ramp (7H minimum:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the wetland side slopes.

∉ If the dividing berm is also used for access, it should be built to sustain loads of up to 80,000 pounds.

Planting Requirements

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Table 5.7.2 or the recommendations of a wetland specialist. Note: Cattails (Typha latifolia) are not recommended. They tend to escape to natural wetlands and crowd out other species. In addition, the shoots die back each fall and will result in oxygen depletion in the wetpool unless they are removed.

Construction Criteria

- Construction and maintenance considerations are the same as for wetponds.
- Construction of the naturalistic alternative (Option B) can be easily done by first excavating the entire area to the 1.5-foot average depth. Then soil subsequently excavated to form deeper areas can be deposited to raise other areas until the distribution of depths indicated in the design is achieved.

Operation and Maintenance

- Wetlands should be inspected at least twice per year during the first three years during both growing and non-growing seasons to observe plant species presence, abundance, and condition; bottom contours and water depths relative to plans; and sediment, outlet, and buffer conditions.
- Maintenance should be scheduled around sensitive wildlife and vegetation seasons.
- Plants may require watering, physical support, mulching, weed removal, or replanting during the first three years.
- Nuisance plant species should be removed and desirable species should be replanted.
- The effectiveness of harvesting for nutrient control is not well documented. There are many drawbacks to harvesting, including possible damage to the wetlands and the inability to remove nutrients in the below-ground biomass. If harvesting is practiced, it should be done in the late summer.

5.8 Sand Filtration Treatment Facilities

5.8.1 Description

A typical sand filtration system consists of a pretreatment system, flow spreader(s), a sand bed, and the underdrain piping. The sand filter bed includes a geotextile fabric between the sand bed and the bottom underdrain system.

An impermeable liner under the facility may also be needed if the filtered runoff requires additional treatment to remove soluble ground water pollutants, or in cases where additional ground water protection is mandated. The variations of a sand filter include a basic or large sand filter, sand filter with level spreader, sand filter vault, and linear sand filter. (See Figure 5.8.1 for a basic sand filter.)

5.8.2 Performance Objectives

BMP T5.80 Basic sand filter:

Basic sand filters are expected to achieve the performance goals for Basic Treatment. Based upon experience in King County and Austin, Texas basic sand filters should be capable of achieving the following average pollutant removals:

80 percent TSS at influent Event Mean Concentrations (EMCs) of 30-300 mg/L (King County, 1998) (Chang, 2000) oil and grease to below 10 mg/L daily average and 15 mg/L at any time, with no ongoing or recurring visible sheen in the discharge.

BMP T5.81 Large sand filter:

Large sand filters are expected to remove at least 50 percent of the total phosphorous compounds (as TP) by collecting and treating 95% of the runoff volume. (ASCE and WEF, 1998)

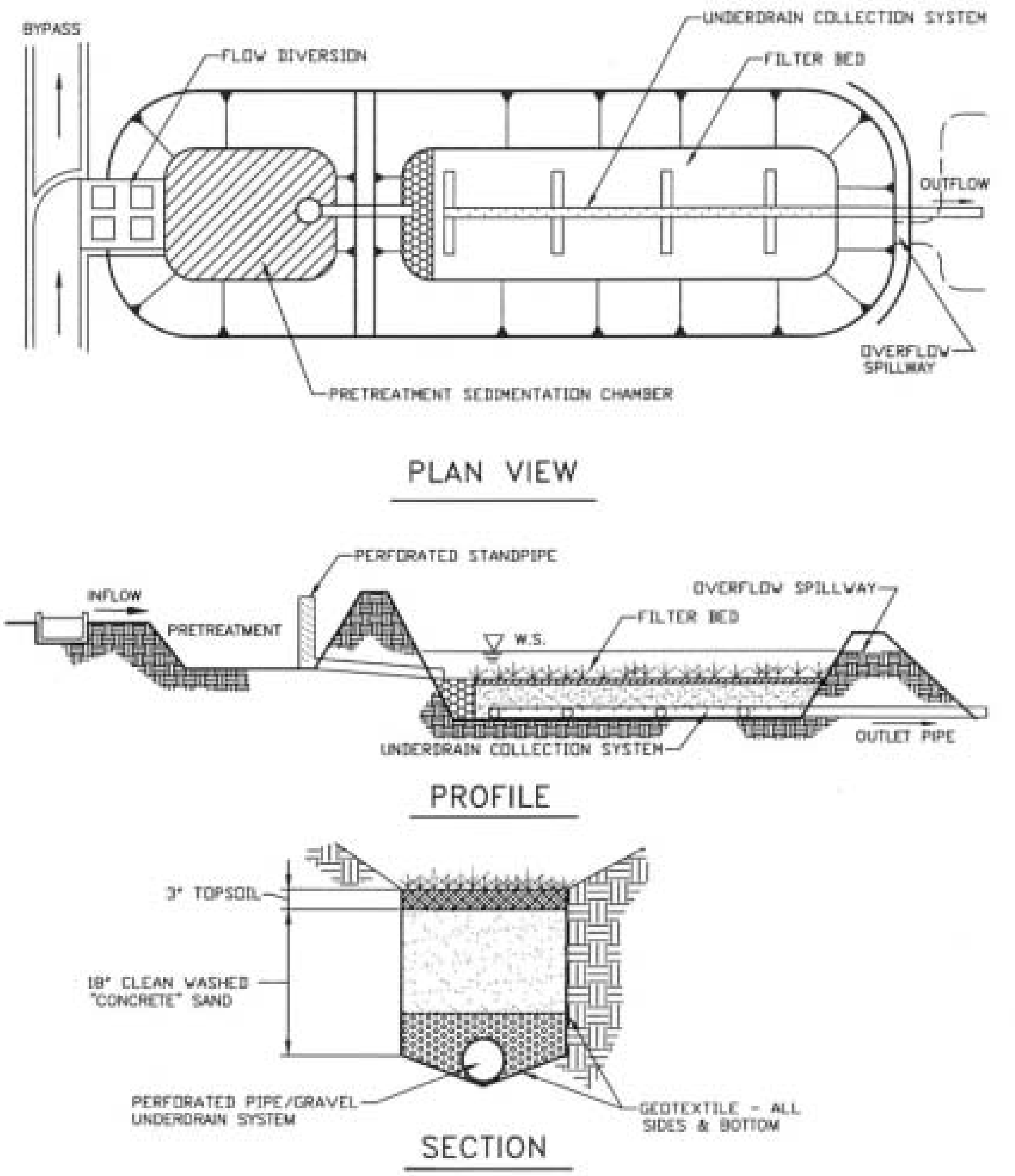


Figure 5.8.1 Sand Filter

5.8.3 Applications and Limitations

Sand filtration can be used in most residential, commercial, and industrial developments where debris, heavy sediment loads, and oils and greases will not clog or prematurely overload the sand, or where adequate pretreatment is provided for these pollutants. Specific applications include residential subdivisions, parking lots for commercial and industrial establishments, gas stations, high-use sites, high-density multi family housing, roadways, and bridge decks.

Sand filters should be located off-line before or after detention. Sand filters are also suited for locations with space constraints in retrofit, and new/re-development situations. Overflow or bypass structures must be carefully designed to handle the larger storms. An off-line system is sized to treat 90% of the annual runoff volume. If a project must comply with Core Element #6, Flow Control, the flows bypassing the filter and the filter discharge must be routed to a retention/detention facility or other appropriate flow control BMP (for example, infiltration BMPs such as infiltration trenches or drywells)

Pretreatment is necessary to reduce velocities to the sand filter and remove debris, floatables, large particulate matter, and oils. In high water table areas adequate drainage of the sand filter may require additional engineering analysis and design considerations. Surface filters will not provide treatment in the winter if the ground is frozen, but may still provide adequate treatment during warmer months. An underground filter should be considered in areas subject to freezing conditions. (Urbonas, 1997)

5.8.4 Site Suitability

The following site characteristics should be considered in siting a sand filtration system:

- Space availability, including a presettling basin
- Sufficient hydraulic head, at least 4 feet from inlet to outlet
- Average winter conditions at the project site do not create snow or ice conditions that prevent the filter from operating as designed
- Adequate Operation and Maintenance capability including accessibility for O & M
- Sufficient pretreatment of oil, debris and solids in the tributary runoff

5.8.5 Design Criteria

Objective: To capture and treat the Water Quality Design Storm volume (when using the Simple Sizing Method described below). Off-line sand filters can be located either upstream or downstream of detention facilities. On-line sand filters should only be located downstream of detention.

Simple Sizing Method This method applies to the off-line placement of a sand filter upstream or downstream of detention facilities. A conservative design approach is provided below using a routing adjustment factor that does not require flow routing computations through the filter. An alternative simple approach for off-line placement downstream of detention facilities is to route the full 2-year release rate from the detention facility (sized for duration control) to a sand filter with sufficient surface area to infiltrate at that flow rate.

Basic Sand Filter For sizing a Basic Sand Filter, a 0.7 routing adjustment factor is applied to compensate for routing through the sand bed at the maximum pond depth. A flow splitter should be designed to route the water quality design flow rate to the sand filter.

Large Sand Filter: For sizing a Large Sand Filter, use the same procedure as outlined above for the Basic Sand Filter. Then apply a scale-up factor of 1.6 to the surface area. This is considered a reasonable average for various impervious tributary sources. For a Large Sand Filter the flow splitter upstream or downstream of the detention facility should be designed to route the flow rate associated with conveying 95% of the annual runoff volume to the sand filter. Use the standard water quality design flow rate multiplied by 1.2.

Note*: An overflow should be included in the design of the sand filter pond. The overflow height should be at the maximum hydraulic head of the pond above the sand bed.*

Example calculation using the simple sizing method and a routing adjustment factor.

Design Specifications:

Background The sizing of the sand filter is based on routing the design runoff volume through the sand filter and using Darcy's Law to account for the increased flow through the sand bed caused by the hydraulic head variations in the pond above the sand bed. Darcy's Law is represented by the following equation:

$Q_{sf} = KiA_{sf} = FA_{sf}$ where: $i = (h+L)/L$

Therefore, $A_{sf}=Q_{sf}/Ki$

Also, $Q_{sf}=A_tQ_dR/t$

Substituting for Q_{sf}, $A_{sf}=A_tQ_dR/Kit$

Or, $A_{sf}=A_tQ_dR/ \{K(h+L)/Lt\}$

Or, $A_{sf}=A_tQ_dR/Ft$

Where:

Q_{sf} is the flow rate in cu. feet per day (or ft^3/sec.) at which runoff is filtered by the sand filter bed,

A_{sf} is the sand filter surface area (sq. ft.)

Q_d is the design storm runoff depth (ft.) for the water quality storm. It is estimated using the SCS Curve Number equations detailed in Chapter 4.

R is a routing adjustment factor. Use R = 0.7.

A_t is the tributary drainage area (sq. ft.)

K is the hydraulic conductivity of the sand bed. Use 2 ft./day or 1.0 inch/hour at full pre-sedimentation

i is the hydraulic gradient of the pond above the filter; (h+L)/L, (ft/ft)

F=Ki is the filtration rate, feet/day (or inches per hour)

d is the maximum sand filter pond depth, and h = d/2 in ft.

t is the recommended maximum drawdown time of 24 hours from the completion of inflow into the sand filter pond (assume ponded pre-settling basin) of a discrete storm event to the completion of outflow from the sand filter underdrain of that same storm event.

L is the sand bed depth; typically 1.5 ft.

Given condition:

Sedimentation basin fully ponded and no pond water above sand filter

(Full sedimentation prior to sand filter-24 hours residence of WQ storm runoff)

A_t = 10 acres is tributary drainage area

Q_d = 0.92 inches (0.0767 ft.), for Yakima Rainfall

with Curve Number = 96.2 for 85% impervious and 15% grass tributary surfaces

R = 0.7, the routing adjustment factor

Maximum drawdown time through sand filter, 24 hours

Maximum pond depth above sand filter, example at 3 and 6 feet,

h = 1.5 and 3 feet

Design Hydraulic Conductivity of basic sand filter, K, 2.0 feet/day (1 inch/hour)

Using Design Equation

$A_{sf} = A_{sf} = A_t Q_d R / \{K(h+L)/Lt\}$

At pond depth of 3 feet:

A_{sf} = (10 acres)(43,560 ft^2/acre)(0.0767 ft)(0.7)/ ″(2.0 ft/day)(1.5 ft + 1.5 ft)/(1.5 ft) (1 day)∈ 5,846 square feet

Therefore A_{sf} for Basic Sand Filter becomes:

5,846 square feet at pond depth of 3 feet

Additional Design Information

1. Runoff to be treated by the sand filter must be pretreated (e.g., pre-settling basin, etc. depending on pollutants) to remove debris and other solids, and oil from high use sites.

2. Inlet bypass and flow spreading structures (e.g., flow spreaders, weirs or multiple orifice openings) should be designed to capture the applicable design flow rate, minimize turbulence and to spread the flow uniformly across the surface of the sand filter. Stone riprap or other energy dissipation devices should be installed to prevent gouging of the sand medium and to promote uniform flow. Include emergency spillway or overflow structures.

3. The following are design criteria for the underdrain piping: *(types of underdrains include: a central collector pipe with lateral feeder pipes, or, a geotextile drain strip in an 8-inch gravel backfill or drain rock bed, or, longitudinal pipes in an 8-inch gravel backfill or drain rock with a collector pipe at the outlet end.)*

   - Upstream of detention underdrain piping should be sized to handle double the two-year design storm. Downstream of detention the underdrain piping should be sized for the two-year design storm. In both instances there should be at least one (1) foot of hydraulic head above the invert of the upstream end of the collector pipe.

   - Internal diameters of underdrain pipes should be a minimum of six (6) inches and two rows of ½-inch holes spaced 6 inches apart longitudinally (maximum), with rows 120 degrees apart (laid with holes downward). Maximum perpendicular distance between two feeder pipes must be 15 feet. All piping is to be schedule 40 PVC or greater wall thickness. Drain piping could be installed in basin and trench configurations. Minimum underdrain size should be 8 inches in diameter if filter is subject to freezing for a month or more.

   - Main collector underdrain pipe should be at a slope of 0.5 percent minimum (1% if subject to freezing for a month or more.)

   - A geotextile fabric must be used between the sand layer and drain rock or gravel and placed so that 1-inch of drain rock/gravel is above the fabric. Drain rock should be 0.75-1.5 inch rock or gravel backfill, washed free of clay and organic material. Increase gravel depth at base of filter to 18 inches if subject to freezing for a month or more.

   - Cleanout wyes with caps or junction boxes must be provided at both ends of the collector pipes. Cleanouts must extend to the surface of the filter. A valve box must be provided for access to the cleanouts. Access for cleaning all underdrain piping should be provided. This may consist of installing cleanout ports, which tee into the underdrain system and surface above the top of the sand bed. To facilitate maintenance of the sand filter an inlet shutoff/bypass valve is recommended.

Note: *Other equivalent energy dissipaters can be used if needed.*

4. Sand Specification The sand in a filter must consist of a medium sand meeting the size gradation (by weight) given in Table 5.8.1 below. The contractor must obtain a grain size analysis from the supplier to certify that the No. 100 and No. 200 sieve requirements are met. *(Note: Standard backfill for sand drains, Wa. Std. Spec. 9-03.13, does not meet this specification and should not be used for sand filters.)*

Table 5.8.1 - Sand Medium Specification

U.S. Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Source: King County Surface Water Design Manual, September 1998

5. Impermeable Liners for Sand Bed Bottom: Impermeable liners are generally required for soluble pollutants such as metals and toxic organics and where the underflow could cause problems with structures. Impermeable liners may be clay, concrete or geomembrane. Clay liners should have a minimum thickness of 12 inches and meet the specifications give in Table 5.8.2.

Table 5.8.2 - Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	$1 \times 10^{-6 \text{ max.}}$
Plasticity Index of Clay	ASTM D-423 & D-424	Percent	Not less than 15
Liquid Limit of Clay	ASTM D-2216	Percent	Not less than 30
Clay Particles Passing	ASTM D-422	Percent	Not less than 30
Clay Compaction	ASTM D-2216	Percent	95% of Standard Proctor Density

Source: City of Austin, 1988

If a geomembrane liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant. The geomembrane liner should be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane.

Concrete liners may also be used for sedimentation chambers and for sedimentation and sand filtration facilities less than 1,000 square feet in area. Concrete should be 5 inches thick Class A or better and should be reinforced by steel wire mesh. The steel wire mesh should be 6 gauge wire or larger and 6-inch by 6-inch mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete should have a minimum 6-inch compacted aggregate base. This base must consist of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75- to 1-inch.

If an impermeable liner is not required then a geotextile fabric liner should be installed that retains the sand unless the sand filter has been excavated to bedrock.

If an impermeable liner is not provided, then an analysis should be made of possible adverse effects of seepage zones on ground water, and near building foundations, basements, roads, parking lots and sloping sites. Sand filters without impermeable liners should not be built on fill sites and should be located at least 20-foot downslope and 100-foot upslope from building foundations.

6. Include an access ramp with a slope not to exceed 7:1, or equivalent, for maintenance purposes at the inlet and the outlet of a surface filter. Consider an access port for inspection and maintenance.
7. Side slopes for earthen/grass embankments should not exceed 3:1 to facilitate mowing.
8. High groundwater may damage underground structures or affect the performance of filter underdrain systems. There should be sufficient clearance (at least 2 feet is recommended) between the seasonal high groundwater level (highest level of ground water observed) and the bottom of the sand filter to obtain adequate drainage.
9. A sport-field sod, grown in sand, may be used on the sand surface. No other soil may be used due to the high clay content in most sod soils. No topsoil may be added to sand filter beds because fine-grained materials (e.g. silt and clay) reduce the hydraulic capacity of the filter.

5.8.6 Construction Criteria

No runoff should enter the sand filter prior to completion of construction and approval of site stabilization by the responsible inspector. Construction runoff may be routed to a pretreatment sedimentation facility, but discharge from sedimentation facilities should by-pass downstream sand filters. Careful level placement of the sand is necessary to avoid formation of voids within the sand that could lead to short-circuiting, (particularly around penetrations for underdrain cleanouts) and to prevent damage to the underlying geomembranes and underdrain system. Over-compaction should be avoided to ensure adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer (4 psig or less). After the sand layer is placed water settling is recommended. Flood the sand with 10-15 gallons of water per cubic foot of sand.

5.8.7 Maintenance Criteria

Inspections of sand filters and pretreatment systems should be conducted every 6 months and after storm events as needed during the first year of operation, and annually thereafter if filter performs as designed. Repairs should be performed as necessary. Suggestions for maintenance include:

Accumulated silt, and debris on top of the sand filter should be removed when their depth exceeds 1/2-inch. The silt should be scraped off during dry periods with steel rakes or other devices. Once sediment is removed, the design permeability of the filtration media can typically be restored by then striating the surface layer of the media. Finer sediments that have penetrated deeper into the filtration media can reduce the permeability to unacceptable levels, necessitating replacement of some or all of the sand.

Sand replacement frequency is not well established and will depend on suspended solids levels entering the filter (the effectiveness of the pretreatment BMP can be a significant factor).

Frequent overflow into the spillway or overflow structure or slow drawdown are indicators of plugging problems. A sand filter should empty in 24 hours following a storm event (24 hours for the pre-settling chamber), depending on pond depth. If the hydraulic conductivity drops to one (1) inch per hour corrective action is needed, e.g.:

- Scraping the top layer of fine-grain sediment accumulation (mid-winter scraping is suggested)
- Removal of vegetation
- Aerating the filter surface
- Tilling the filter surface (late-summer rototilling is suggested)
- Replacing the top 4 inches of sand
- Inspecting geotextiles for clogging
- For sand filters with sport sod/grass cover, remove and replace sod as appropriate. Sod removal may not be necessary for aeration of top of filter sand.

Rapid drawdown in the sand bed (greater than 12 inches per hour) indicates short-circuiting of the filter. Inspect the cleanouts on the underdrain pipes and along the base of the embankment for leakage.

Drawdown tests for the sand bed could be conducted, as needed, during the wet season. These tests can be conducted by allowing the filter to fill (or partially fill) during a storm event, then measuring the decline in water level over a 4-8 hour period. An inlet and an underdrain outlet valve would be necessary to conduct such a test.

Formation of rills and gullies on the surface of the filter indicates improper function of the inlet flow spreader, or poor sand compaction. Check for accumulation of debris on or in the flow spreader and refill rills and gullies with sand.

Avoid driving heavy equipment on the filter to prevent compaction and rut formation.

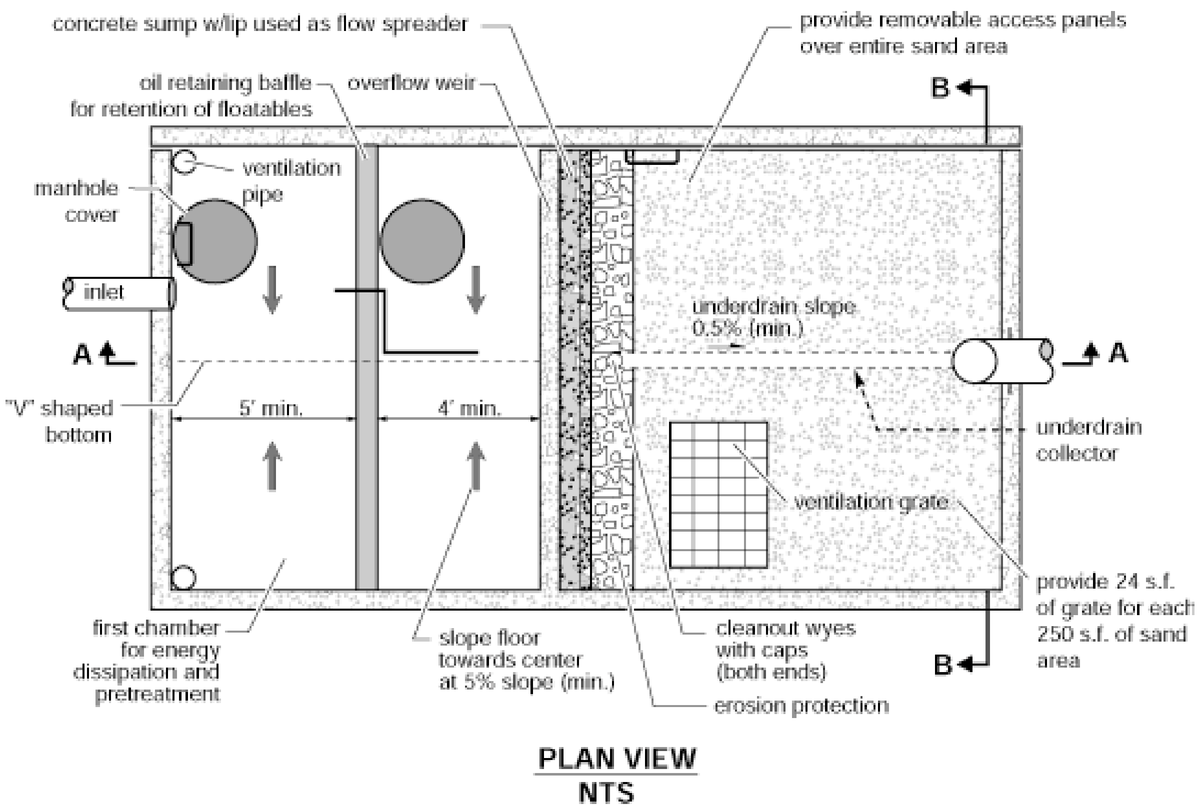


Figure 5.8.2a Sand Filter Vault

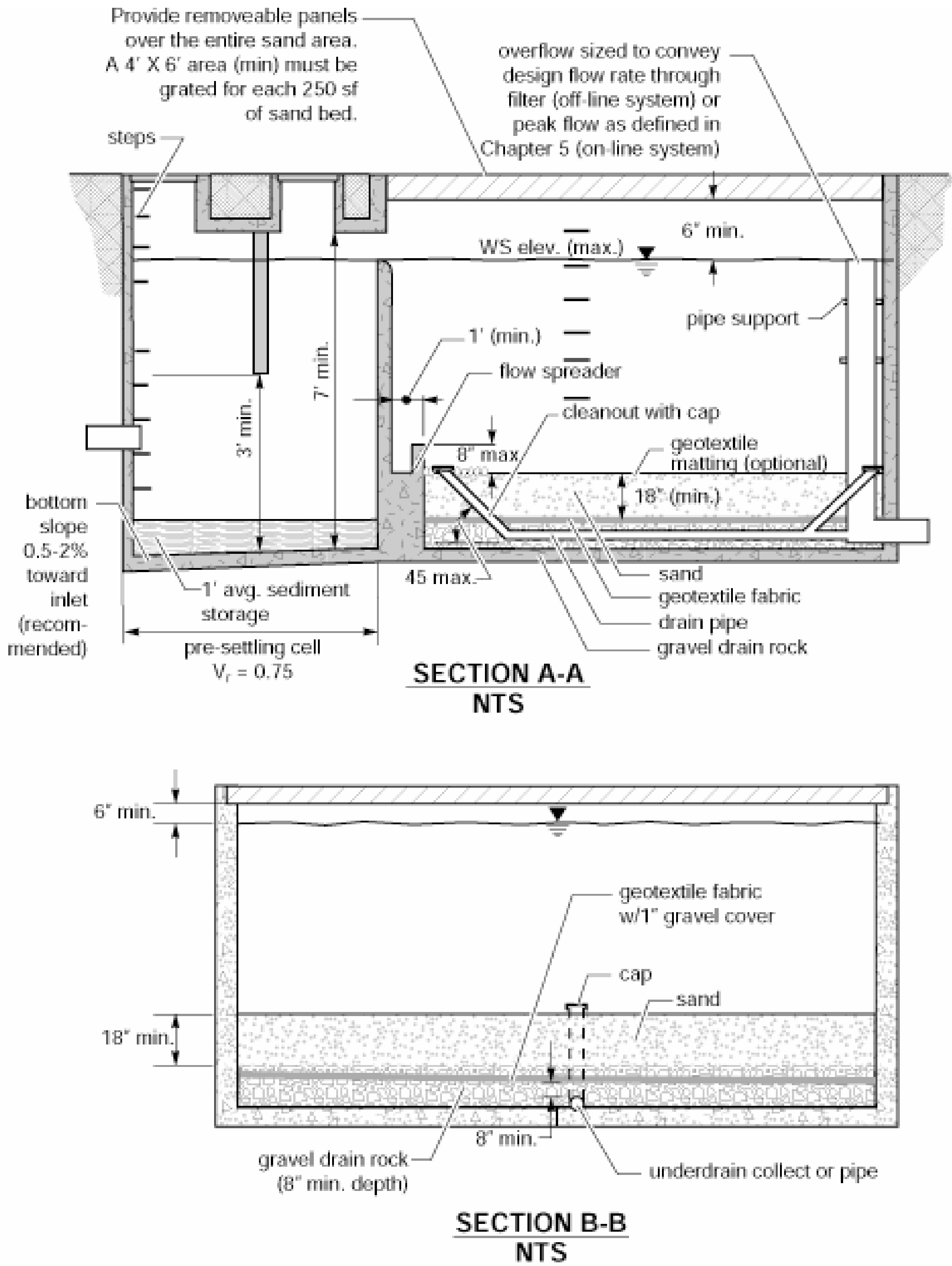


Figure 5.8.2b Sand Filter Vault (cont)

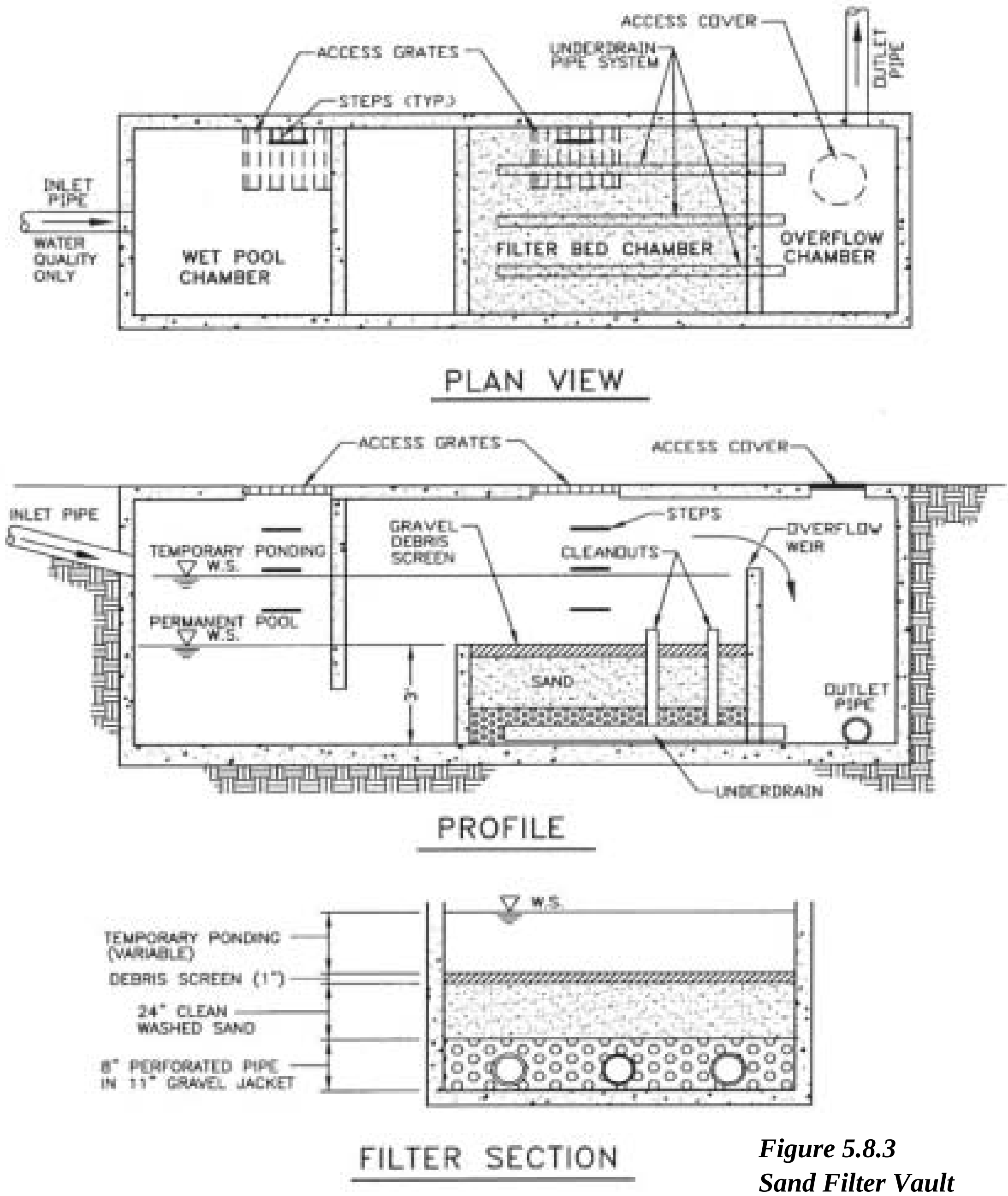


Figure 5.8.3
Sand Filter Vault

5.8.8 Sand Filtration BMPs

BMP T5.82 Sand Filter Vault

Description: (Figure 5.8.2a & b) A sand filter vault is similar to an open sand filter except that the sand layer and underdrains are installed below grade in a vault. It consists of presettling and sand filtration cells.

Applications and Limitations

- Use where space limitations preclude above ground facilities

- Not suitable where high water table and heavy sediment loads are expected
- An elevation difference of 4 feet between inlet and outlet is needed

Additional Design Criteria for Vaults

- Vaults may be designed as off-line systems or on-line for small drainages
- In an off-line system a diversion structure should be installed to divert the design flow rate into the sediment chamber and bypass the remaining flow to detention/retention (if necessary to meet Core Element #6), or to surface water.
- Optimize sand inlet flow distribution with minimal sand bed disturbance. A maximum of 8-inch distance between the top of the spreader and the top of the sand bed is suggested. Flows may enter the sand bed by spilling over the top of the wall into a flow spreader pad or alternatively a pipe and manifold system may be used. Any pipe and manifold system must retain the required permanent pool volume in the first cell, minimize turbulence, and be readily maintainable.
- If an inlet pipe and manifold system is used, the minimum pipe size should be 8 inches. Multiple inlets are recommended to minimize turbulence and reduce local flow velocities.
- Erosion protection must be provided along the first foot of the sand bed adjacent to the spreader. Geotextile fabric secured on the surface of the sand bed, or equivalent method, may be used.
- The filter bed should consist of a sand top layer, and a geotextile fabric second layer with an underdrain system.
- Design the presettling cell for sediment collection and removal. A V-shaped bottom, removable bottom panels, or equivalent sludge handling system should be used. One-foot of sediment storage in the presettling cell must be provided.
- The pre-settling chamber should be constructed to trap oil and trash. This chamber is usually connected to the sand filtration chamber with an invert elbow or underflow baffle to protect the filter surface from oil and trash.
- If a retaining baffle is necessary for oil/floatables in the presettling cell, it must extend at least one foot above to one foot below the design flow water level. Provision for the passage of flows in the event of plugging must be provided. Access opening and ladder must be provided on both sides of the baffle.
- To prevent anoxic conditions, a minimum of 24 square feet of ventilation grate should be provided for each 250 square feet of sand

bed surface area. For sufficient distribution of airflow across the sand bed, grates may be located in one area if the sand filter is small, but placement at each end is preferred. Small grates may also be dispersed over the entire sand bed area.

- Provision for access is the same as for wet vaults. Removable panels must be provided over the sand bed.
- Sand filter vaults must conform to the materials and structural suitability criteria specified for wet vaults.
- Provide a sand filter inlet shutoff/bypass valve for maintenance.
- A geotextile fabric over the entire sand bed may be installed that is flexible, highly permeable, three-dimensional matrix, and adequately secured. This is useful in trapping trash and litter.

BMP T5.83 Linear Sand Filter

Description:

Linear sand filters (Figure 5.8.4) are typically long, shallow, two-celled, rectangular vaults. The first cell is designed for settling coarse particles, and the second cell contains the sand bed. Stormwater flows into the second cell via a weir section that also functions as a flow spreader.

Application and Limitations

- Applicable in long narrow spaces such as the perimeter of a paved surface.
- As a part of a treatment train as downstream of a filter strip, upstream of an infiltration system, or upstream of a wet pond or a biofilter for oil control.
- To treat small drainages (less than 2 acres of impervious area).
- To treat runoff from high-use sites for TSS and oil/grease removal, if applicable.

Additional Design Criteria for Linear Sand Filters

- The two cells should be divided by a divider wall that is level and extends a minimum of 12 inches above the sand bed.
- Stormwater may enter the sediment cell by sheet flow or a piped inlet.
- The width of the sand cell must be 1-foot minimum to 15 feet maximum.
- The sand filter bed must be a minimum of 12 inches deep and have an 8-inch layer of drain rock with perforated drainpipe beneath the sand layer.
- The drainpipe must be 6-inch diameter minimum and be wrapped in geotextile and sloped a minimum of 0.5 percent.

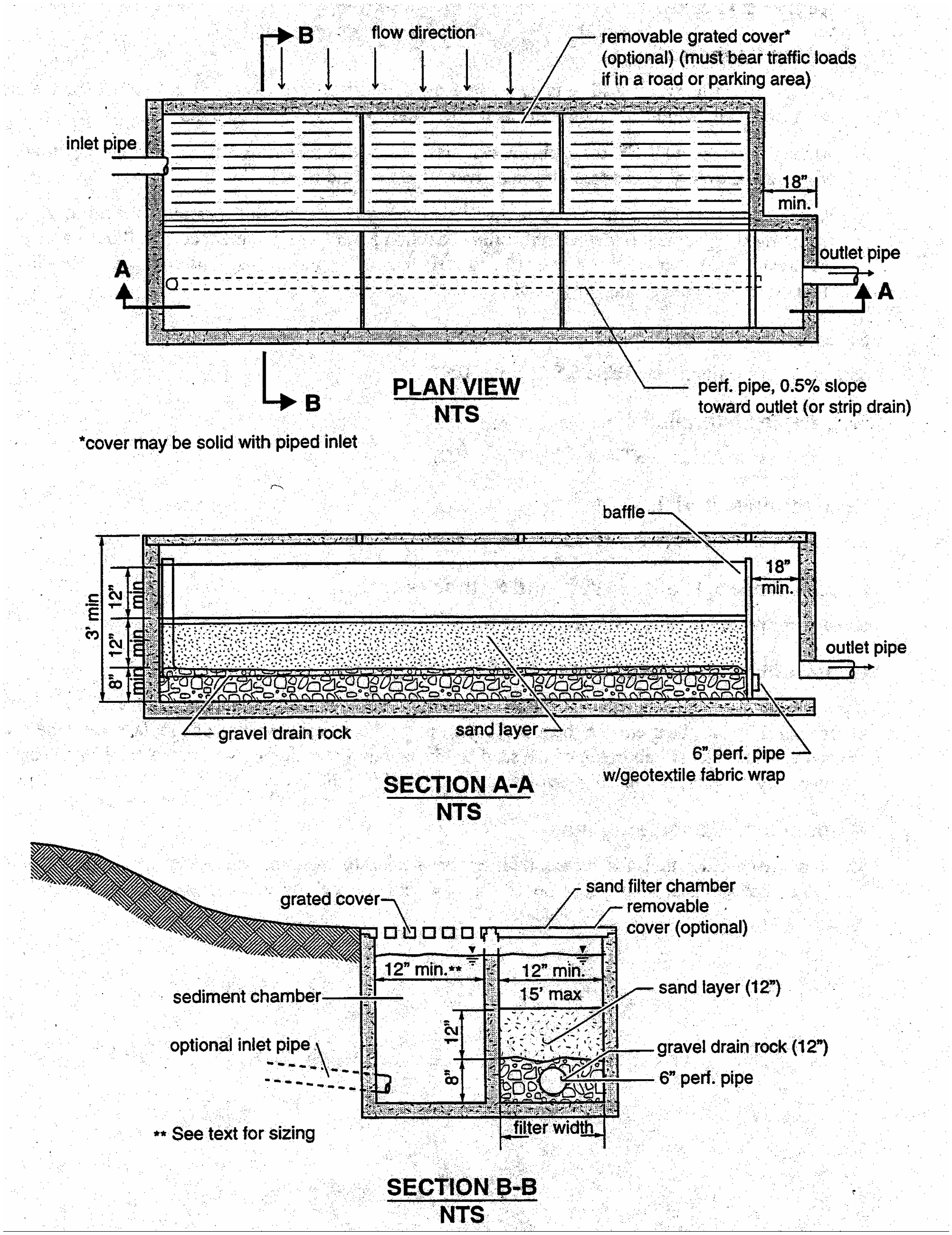


Figure 5.8.4 Linear Sand Filter

- Maximum sand bed ponding depth: 1-foot.
- Must be vented as for sand filter vaults
- Linear sand filters must conform to the materials and structural suitability criteria specified for wet vaults.
- Set sediment cell width as follows:

Sand filter width, (w) inches	12-24	24-48	48-72	72+
Sediment cell width, inches	12	18	24	w/3

5.9 Evaporation Ponds

Evaporation ponds are ponds with no outlet which settle out the suspended solids, heavy metals, and hydrocarbons and may be used for water quality treatment. See Section 5.4 for details on designing evaporation ponds.

5.10 Oil and Water Separators

This section provides a discussion of oil and water separators, including their application and design criteria. BMPs are described for baffle type and coalescing plate separators.

5.10.1 Purpose of Oil and Water Separators

To remove oil and other water-insoluble hydrocarbons, and settleable solids from stormwater runoff.

5.10.2 Description

Oil and water separators are typically the American Petroleum Institute (API) (also called baffle type) (American Petroleum Institute, 1990) or the coalescing plate (CP) type using a gravity mechanism for separation. See Figures 5.10.1 and 5.10.2. Oil removal separators typically consist of three bays; forebay, separator section, and the afterbay. The CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates. A spill control (SC) separator (Figure 5.10.3) is a simple catchbasin with a T-inlet for temporarily trapping small volumes of oil. The spill control separator is included here for comparison only and is not designed for, or to be used for treatment purposes.

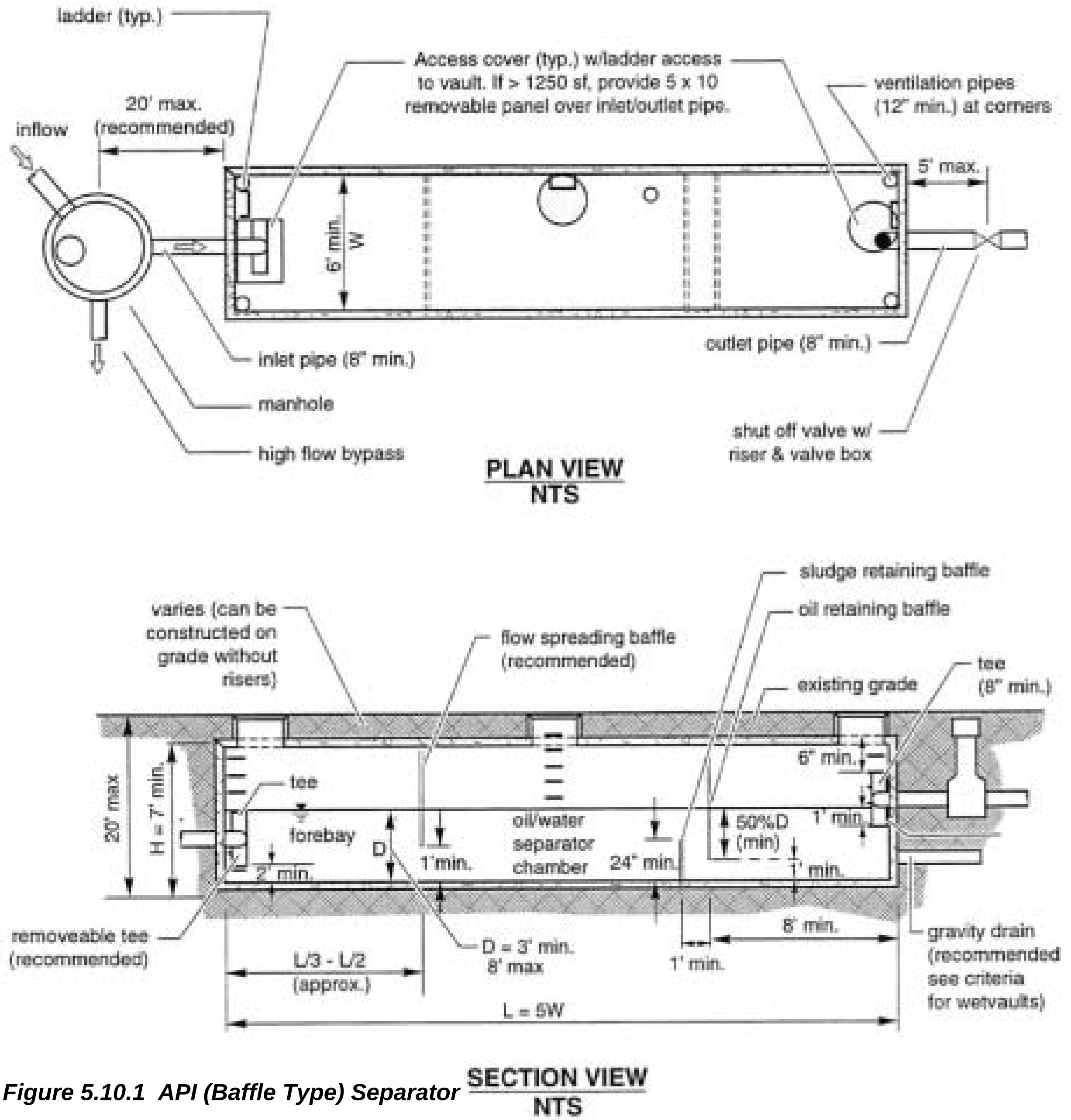


Figure 5.10.1 API (Baffle Type) Separator

Source: King County (reproduced with permission)

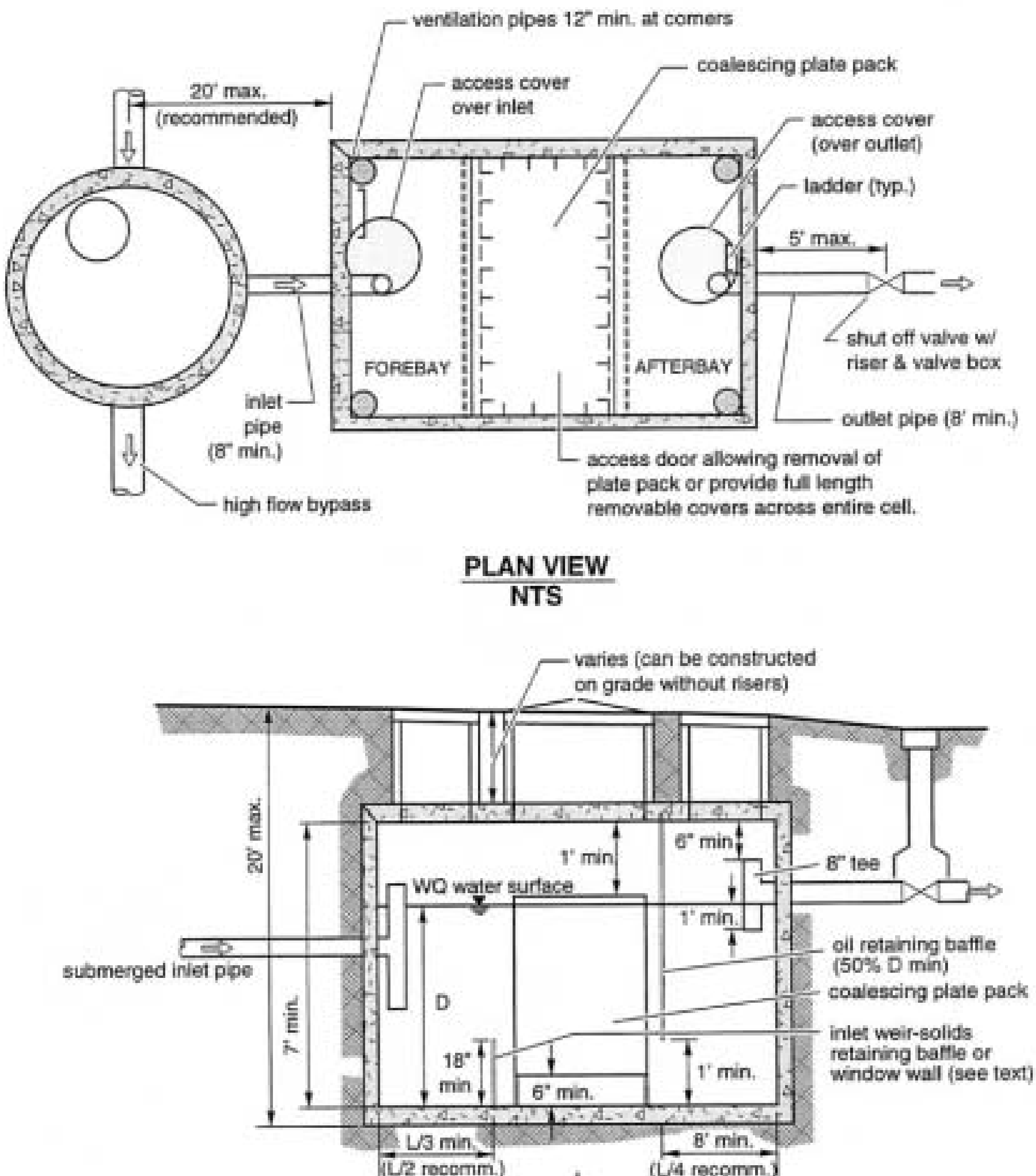


Figure 5.10.2 Coalescing Plate Separator

Source: King County (reproduced with permission)

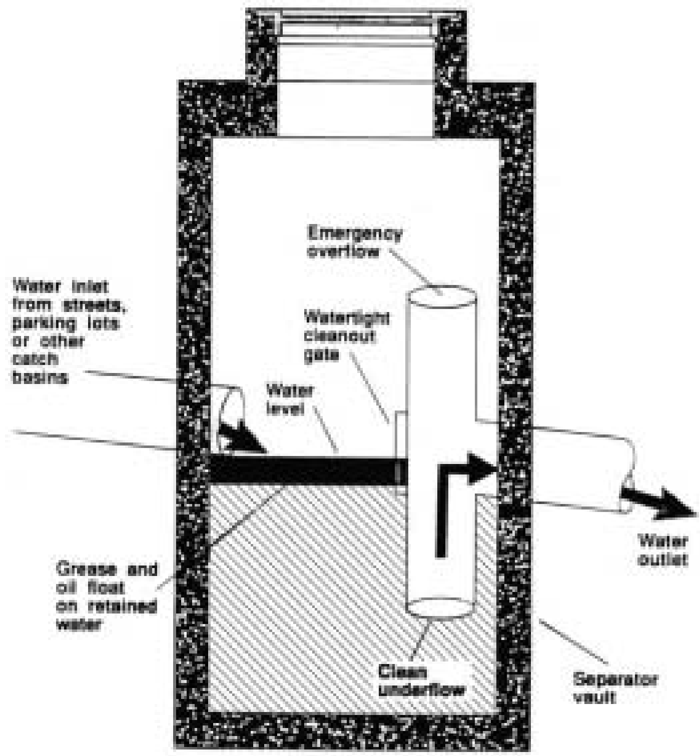


Figure 5.10.3 Spill Control Separator (not for oil treatment)

Source: 1992 Ecology Manual

5.10.3 Performance Objectives

Oil and water separators should be designed to remove oil and TPH down to 15 mg/L at any time and 10 mg/L on a 24-hr average, and produce a discharge that does not cause an ongoing or recurring visible sheen in the stormwater discharge, or in the receiving water (see also Section 5.2).

5.10.4 Applications/Limitations

The following are potential applications of oil and water separators where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator. (Seattle METRO, 1990; Watershed Protection Techniques, 1994; King County Surface Water Management, 1998) For low concentrations of oil, other treatments may be more applicable. These include sand filters and emerging technologies.

Facilities that would require oil control BMPs under the high-use site threshold described in Chapter 2 – Core Elements include parking lots at convenience stores, fast food restaurants, grocery stores, shopping malls, discount warehouse stores, banks, truck fleets, auto and truck dealerships, and delivery and commercial and industrial areas including petroleum storage yards, vehicle maintenance facilities, manufacturing areas, airports, utility areas (water, electric, gas), and fueling stations.

Without intense maintenance oil/water separators may not be sufficiently effective in achieving oil and TPH removal down to required levels.

Pretreatment should be considered if the level of TSS in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the separator.

For inflows from small drainage areas (fueling stations, maintenance shops, etc.) a coalescing plate (CP) type separator is typically considered, due to space limitations. However, if plugging of the plates is likely, then a new design basis for the baffle type API separator may be considered on an experimental basis.

5.10.5 Site Suitability

Consider the following site characteristics:

- Sufficient land area
- Adequate TSS control or pretreatment capability
- Compliance with environmental objectives
- Adequate influent flow attenuation and/or bypass capability
- Sufficient access for operation and maintenance (O & M)

5.10.6 Design Criteria-General Considerations

There is concern that oil/water separators used for stormwater treatment have not performed to expectations.(Watershed Protection Techniques, 1994; Schueler, Thomas R., 1990) Therefore, emphasis should be given to proper application (see Section 5.4), design, O & M, (particularly sludge and oil removal) and prevention of CP fouling and plugging.(US Army of Engineers, 1994) Other treatment systems, such as sand filters and emerging technologies, should be considered for the removal of insoluble oil and TPH.

The following are design criteria applicable to API and CP oil/water separators:

- If practicable, determine oil/grease (or TPH) and TSS concentrations, lowest temperature, pH; and empirical oil rise rates in the runoff, and the viscosity, and specific gravity of the oil. Also determine whether the oil is emulsified or dissolved. (Washington State Department of Ecology, 1995) Do not use oil/water separators for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.
- Locate the separator off-line and bypass flows in excess of 2.15 times the Water Quality design flow rate.

- Use only impervious conveyances for oil contaminated stormwater.
- Specify appropriate performance tests after installation and shakedown, and/or certification by a professional engineer that the separator is functioning in accordance with design objectives. Expeditious corrective actions must be taken if it is determined the separator is not achieving acceptable performance levels.
- Add pretreatment for TSS that could cause clogging of the CP separator, or otherwise impair the long-term effectiveness of the separator.

Criteria for Separator Bays:

- Size the separator bay for the Water Quality design flow rate x a correction factor of 2.15.
- To collect floatables and settleable solids, design the surface area of the forebay at 20 ft^2 per 10,000 ft^2 of area draining to the separator. The length of the forebay should be 1/3-1/2 of the length of the entire separator. Include roughing screens for the forebay or upstream of the separator to remove debris, if needed. Screen openings should be about 3/4 inch.
- Include a submerged inlet pipe with a turn-down elbow in the first bay at least two feet from the bottom. The outlet pipe should be a Tee, sized to pass the design peak flow and placed at least 12 inches below the water surface.
- Include a shutoff mechanism at the separator outlet pipe. (King County Surface Water Management, 1998)
- Use absorbents and/or skimmers in the afterbay as needed.

Criteria for Baffles:

- Oil retaining baffles (top baffles) should be located at least at 1/4 of the total separator length from the outlet and should extend down at least 50% of the water depth and at least 1 ft. from the separator bottom.
- Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

5.10.7 Oil and Water Separator BMPs

Two BMPs are described in this section. BMP T5.10 for baffle type separators, and BMP T6.11 for coalescing plate separators.

BMP T5.100 -API (Baffle type) Separator Bay

Design Criteria: The criteria for small drainages is based on Vh, Vt, residence time, width, depth, and length considerations. As a correction factor API's turbulence criteria is applied to increase the length.

Ecology is modifying the API criteria for treating stormwater runoff from small drainage area (fueling stations, commercial parking lots, etc.) by using the design hydraulic horizontal velocity, Vh, for the design Vh/Vt ratio rather than the API minimum of Vh/Vt = 15. The API criteria appear applicable for greater than two acres of impervious drainage area. Performance verification of this design basis must be obtained during at least one wet season using the test protocol referenced in Section 5.12 for new technologies.

The following is the sizing procedure using modified API criteria:

- Determine the oil rise rate, Vt, in cm/sec, using Stokes Law (Water Pollution Control Federation, 1985), or empirical determination, or 0.033 ft./min for 60   oil. The application of Stokes' Law to site-based oil droplet sizes and densities, or empirical rise rate determinations recognizes the need to consider actual site conditions. In those cases the design basis would not be the 60 micron droplet size and the 0.033 ft/min. rise rate.

- Stokes Law equation for rise rate, Vt (cm/sec):

$$V_t = g(\omega_w-\omega_o)D^2 /18\xi_w)$$

Where: g = gravitational constant (981 cm/sec²)

D = diameter of the oil particle in cm.

Use oil particle size diameter, D=60 microns (0.006 cm)

ω_w =0.999 gm/cc. at 32° F

ω_o: Select conservatively high oil density,

For example, if diesel oil @ ω_o=0.85 gm/cc and motor oil @ ω_o = 0.90 can be present then use ω_o=0.90 gm/cc

ξ_w = 0.017921 poise, gm/cm-sec. at T_w=32 °F, (See API Publication 421, February , 1990)

Use the following separator dimension criteria:

Separator water depth, d ∅3Ω8 feet (to minimize turbulence) (American Petroleum Institute, 1990; US Army Corps of Engineers, 1994).

Separator width, 6-20 feet (WEF & ASCE, 1998; King County Surface Water Management, 1998)

Depth/width (d/w) of 0.3-0.5 (American Petroleum Institute, 1990)

For Stormwater Inflow from Drainages under 2 Acres:

- Determine V_t and select depth and width of the separator section based on above criteria.

- Calculate the minimum residence time (t_m) of the separator at depth d:

- $t_m = d/V_t$
- Calculate the horizontal velocity of the bulk fluid, V_h, vertical cross-sectional area, A_v, and actual design V_h/V_t (American Petroleum Institute, 1990; US Army Corps of Engineers, 1994).

  $V_h = Q/dw = Q/A_v$ (V_h maximum at < 2.0 ft/min.)(American Petroleum Institute, 1990)

  Q = 2.15 x the Water Quality design flow rate in ft^3/min, at minimum residence time, t_m

  At V_h/V_t determine F, turbulence and short-circuiting factor (Appendix V-D of the SWMMWW) API F factors range from 1.28-1.74. (American Petroleum Institute, 1990)

- Calculate the minimum length of the separator section, l(s), using:

  $l(s) = FQt_m/wd = F(V_h/V_t)d$
  l(t) = l(f) + l(s) +l(a)
  l(t) = l(t)/3 + l(s) + l(t)/4

  Where:

  l(t) = total length of 3 bays
  l(f) = length of forebay
  l(a) = length of afterbay

- Calculate V = l(s)wd = FQtm, and Ah = wl(s)

  V = minimum hydraulic design volume
  A_h = minimum horizontal area of the separator

BMP T5.110 - Coalescing Plate (CP) Separator Bay

Design Criteria

Calculate the projected (horizontal) surface area of plates needed using the following equation:

Calculate the projected (horizontal) surface area of plates needed using the following equation:

$A_p = Q/V_t = Q/0.00386(\omega_w - \omega_o/\xi_w)$

$A_p = A_a$(cosine b)

Where:

Q = 2.15 x the water quality design flow rate, ft^3/min

V_t = Rise rate of 0.033 ft/min, or empirical determination, or Stokes Law based

A_p = projected surface area of the plate in ft^2; .00386 is unit conversion constant

ω_w=density of water at 32º F
ω_o= density of oil at 32º F
A_a = actual plate area in ft² (one side only)

b = angle of the plates with the horizontal in degrees (usually varies from 45-60 degrees).

ξ_w=viscosity of water at 32º F

- Plate spacing should be a minimum of 3/4 in (perpendicular distance between plates). (WEF & ASCE, 1998; US Army Corps of Engineers, 1994; US Air Force, 1991; Jaisinghani, R., 1979)
- Select a plate angle between 45° to 60° from the horizontal.
- Locate plate pack at least 6 inches from the bottom of the separator for sediment storage
- Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.
- Design inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow especially through and around the plate packs of the CP separator. The Reynolds Number through the separator bay should be <500 (laminar flow).
- Include forebay for floatables and afterbay for collection of effluent. (WEF & ASCE, 1998)
- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 in. (King County Surface Water Management, 1998).
- Design plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

5.10.8 Operation and Maintenance

- Prepare, regularly update, and implement an O & M Manual for the oil/water separators.
- Inspect oil/water separators monthly during the wet season of October 1-April 30 (WEF & ASCE, 1998; Woodward-Clyde Consultants) to ensure proper operation, and, during and immediately after a large storm event of greater than or equal to 1 inch per 24 hours.
- Clean oil/water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season (Woodward-Clyde Consultants), after all spills, and after a significant storm. Coalescing plates may be cleaned in-situ or after removal from the separator. An eductor truck may be used for oil, sludge, and

washwater removal. (King County Surface Water Management, 1998) Replace wash water in the separator with clean water before returning it to service.

∉ Remove the accumulated oil when the thickness reaches 1-inch. Also remove sludge deposits when the thickness reaches 6 inches (King County Surface Water Management, 1998).

∉ Replace oil absorbent pads before their sorbed oil content reaches capacity.

∉ Train designated employees on appropriate separator operation, inspection, record keeping, and maintenance procedures.

See Appendix 5A for more detailed information.

5.11 Phosphorus Treatment and Metals Treatment

5.11.1 Phosphorus Treatment

Where Applied – Phosphorus Treatment applies to projects within watersheds that have been determined by local governments, the Department of Ecology, or the USEPA to be sensitive to phosphorus and that are being managed to control phosphorus inputs from stormwater.

Performance Goal: The Phosphorus Treatment facility choices are intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations of 0.1 – 0.5 mg/l total phosphorus. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of treatment facilities that engage a bypass at flow rates higher than the water quality design flow rate. However, this is acceptable provided that the overall reduction in phosphorus loading (treated plus bypassed) is at least equal to that achieved with initiating bypass at the water quality design flow rate.

Phosphorus Treatment Options

Any one of the following options may be chosen to satisfy the phosphorus treatment requirement.

Infiltration With Appropriate Pretreatment – See Section 5.4.

Infiltration treatment – If infiltration is through soils meeting the minimum site suitability criteria for infiltration treatment (see Section 5.4), a presettling basin or a basic treatment facility can serve for pretreatment.

Infiltration preceded by Basic Treatment – If infiltration is through soils that do not meet the site suitability criteria for infiltration treatment, treatment must be provided by a basic treatment facility unless the soil and site fit the description in the next option below.

Infiltration preceded by Phosphorus Treatment – Requirements to be determined by TMDL.

Amended Sand Filter – See Section 5.12.

Note*: Processed steel fiber and crushed calcitic limestone are the only sand filter amendments for which Ecology has data that documents increased dissolved metals removal. Though Ecology is interested in obtaining additional data on the effectiveness of these amendments, local governments may exercise their judgment on the extent to which to allow their use.*

Large Wetpond – See Section 5.7.

Media Filter Targeted for Phosphorus Removal **–** See Section 5.12.

Note*: The use of a Stormfilter™ with iron-infused media is approved for use in limited circumstances, provided a monitoring program consistent with adopted protocols is implemented.*

Two-Facility Treatment Trains – See Table 5.11.1.

Table 5.11.1 - Treatment Trains for Phosphorus Removal

First Basic Treatment Facility	Second Treatment Facility
Biofiltration Swale	Basic Sand Filter or Sand Filter Vault
Vegetated Filter Strip	Linear Sand Filter (no presettling needed)
Linear Sand Filter	Filter Strip
Basic Wetpond	Basic Sand Filter or Sand Filter Vault
Wetvault	Basic Sand Filter or Sand Filter Vault
Basic Combined Detention and Wetpool	Basic Sand Filter or Sand Filter Vault
NOTE: See Section 5.2.3 (or Table 5.2.6) for Cold Weather Considerations and Table 5.2.4 for Arid and Semi-Arid Climate Considerations.	

5.11.2 Metals Treatment

Where Applied: Metals Treatment is required for:

- Industrial project sites,
- Commercial project sites,
- Multi-family project sites, and
- Arterials and highways

that discharge to fish-bearing streams, lakes, or to waters or conveyance systems tributary to fish-bearing streams or lakes. Areas of arterials and highways, multifamily, industrial and commercial project sites that do not discharge to fish-bearing streams or lakes or are identified in a storm drainage comprehensive plan or basin plan as subject to Basic Treatment requirements are not subject to Metals Treatment requirements. For developments with a mix of land use types, the Metals Treatment requirement shall apply when the runoff from the areas subject to the Metals Treatment requirement comprise 50% or more of the total runoff within a threshold discharge area.

Performance Goal: The Metals Treatment facility choices are intended to provide a higher rate of removal of dissolved metals than Basic Treatment facilities. Due to the sparse data available concerning dissolved metals removal in stormwater treatment facilities, a specific numeric removal efficiency goal could not be established at the time of publication. Instead, Ecology relied on available nationwide and local data, and knowledge of the pollutant removal mechanisms of treatment facilities to develop the list of options below. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal assumes that the facility is treating stormwater with dissolved copper typically ranging from 0.003 to 0.02 mg/l, and dissolved zinc ranging from 0.02 to 0.3 mg/l.

The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of treatment facilities that engage a bypass at flow rates higher than the water quality design flow rate as long as the reduction in dissolved metals loading exceeds that achieved with initiating bypass at the water quality design flow rate.

Metals Treatment Options

Any one of the following options may be chosen to satisfy the Metals Treatment requirement:

Infiltration with Appropriate Pretreatment – See Section 5.4.

Infiltration Treatment

If infiltration is through soils meeting the minimum site suitability criteria for infiltration treatment (see Section 5.4), a presettling basin or a basic treatment facility can serve for pretreatment.

Infiltration preceded by Basic Treatment

If infiltration is through soils that do not meet the soil suitability criteria for infiltration treatment, treatment must be provided by a basic treatment facility unless the soil and site fit the description in the next option below.

Infiltration preceded by Metals Treatment

If the soils do not meet the soil suitability criteria and the infiltration site is within ¼ mile of a fish-bearing stream, a tributary to a fish-bearing stream, or a lake, treatment must be provided by one of the other treatment facility options listed below.

Large Sand Filter – See Section 5.8.

Amended Sand Filter – See Section 5.12.

Note*: Processed steel fiber and crushed calcitic limestone are the only sand filter amendments for which Ecology has data that documents increased dissolved metals removal. Though Ecology is interested in obtaining additional data on the effectiveness of these amendments, local governments may exercise their judgment on the extent to which to allow their use.*

Two Facility Treatment Trains – See Table 5.11.2.

Table 5.11.2 -Treatment Trains for Dissolved Metals Removal

First Basic Treatment Facility	Second Treatment Facility
Biofiltration Swale	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Filter Strip	Linear Sand Filter with no pre-settling cell needed
Linear Sand Filter	Filter Strip
Basic Wetpond	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Wetvault	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Basic Combined Detention/Wetpool	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Basic Sand Filter or Sand Filter Vault with a presettling cell if the filter isn't preceded by a detention facility	Media Filter(1)
(1) The media must be of a nature that has the capability to remove dissolved metals effectively based on at least limited data. Ecology includes Stormfilter's ™ leaf compost and zeolite media in this category.	

5.12 Emerging Technologies

Emerging technologies are new technologies that have not been evaluated using approved protocols, but for which preliminary data indicate that they may provide a desirable level of stormwater pollutant removal.

5.12.1 Background

During the last 10 years, new technologies have been under development to meet the needs of urban stormwater pollutant control. However, because no standardized statewide procedure for evaluating these technologies was available, local jurisdictions and commercial establishments have had to individually decide on their use. This resulted in differences in the criteria for accepting new technologies.

Some emerging technologies have already been installed in Washington as parts of treatment trains or as stand-alone systems for specific applications. In some cases, emerging technologies are appropriate to remove metals, hydrocarbons, and nutrients. Emerging technologies can also be used for retrofits and where land is unavailable for larger treatment systems.

5.12.2 Ecology Role in Evaluating Emerging Technologies

Ecology has developed a new technology evaluation program which is briefly described in this chapter. The program is based on reviewing engineering reports on the performance of new technologies and reporting the results at Ecology's web site.

This program includes:

- A web site with brief descriptions of each new technology, TRC recommendations, and Ecology's determinations of the levels of development of each technology at: http://www.ecy.wa.gov/programs/wq/stormwater/new_tech/
- A Technical Review Committee (TRC) including representatives from local governments in eastern and western Washington that acts in an advisory capacity to provide recommendations to Ecology on the level of development of each technology.

5.12.3 Local Government Evaluation of Emerging Technologies

Local governments should consider the following as they make decisions concerning the use of new stormwater technologies in their jurisdictions:

Remember the goal: The goal of any stormwater management program or BMP is to treat and release stormwater in a manner that does not harm beneficial uses. Compliance with water quality standards is one measure of determining whether beneficial uses will be harmed.

Exercise reasonable caution: It is important to be cautious with the use of emerging, unproven, technologies for new development and for retrofits. Before selecting a new technology for a limited application, the local government should review evaluation information based on an acceptable protocol.

An emerging technology must not be used for new development sites unless there are data indicating that its performance is expected to be reasonably equivalent to a Basic Treatment, or as part of a treatment train. Local governments can refer to Ecology’s web site to obtain the latest performance verification of an emerging technology.

Local governments are encouraged to:

- Conduct a monitoring program, using an acceptable protocol, of those emerging technologies that have not been verified for limited or full-scale statewide use at Ecology’s web site.
- Look for achieving acceptable performance objectives as specified in Section 5.1.

To achieve the goals of the Clean Water Act and the Endangered Species Act, local government may find it necessary to retrofit many, existing stormwater discharges. In retrofit situations the use of any BMPs that make substantial progress toward these goals is a step forward and is encouraged by Ecology. To the extent practical, the performance of these BMPs should be evaluated, using approved protocols.

5.12.4 Testing Protocol

To properly evaluate new technologies, performance data must be obtained using an accepted protocol. A test protocol has been developed which serves to standardize the testing conditions. Sampling criteria, site and technology information, QA/QC, target pollutants, and evaluation report content, are specified in the protocol.

Other acceptable protocols may also be added to Ecology's web site. Such protocols may be developed by local, state, or federal agencies.

5.12.5 Assessing Levels of Development of Emerging Technologies

Ecology has received several submittals from vendors to approve their new technologies for statewide applications. However, none of the submittals included performance information using the Ecology testing protocol, or equivalent protocol. Moreover, it is evident that some technologies have been under development for many years and have been improved considerably during that time.

To assess and classify levels of developments, Ecology is proposing to use the criteria given below. These criteria will be included on the planned web site. Emerging technologies shall be used only within the application criteria and performance limits listed at Ecology’s web site. Best Professional judgment may be used in the interim until the Ecology-TRC process is operational.

- **Pilot Use Level –** This level will be designated for promising technologies that need more verification testing. Pilot studies could typically be conducted at roadway, commercial and residential sites, or specific land uses for which the system is marketed. Runoff at each site should be tested at full flow (design flow) conditions using reasonable evaluation criteria before deciding on a limited or general statewide use of the technology. The pilot studies should be conducted during dry and wet seasons.

- **General Use Level –** This level will be designated if the evaluation report demonstrates, with a sufficient degree of confidence, that the technology is expected to achieve Ecology's performance goals. To obtain general acceptance in eastern Washington, the performance criteria as specified in Section 5.1 must be met using the Ecology testing protocol, or other acceptable protocol. Final application, design and O&M criteria, and costs must be determined. Approvals may include application as part of a treatment train and/or as a stand-alone BMP.

- **Conditional Short-Term Use Designation –** This designation can be issued for those technologies that are in widespread use in Washington, and that are considered likely to attain a General Use

Level provided that testing following the Protocol is completed within a specified time-period.

5.12.6 Examples of Emerging Technologies for Stormwater Treatment and Control

The descriptions and other supplier information provided in this section should not be construed as approvals by Ecology of any of the technologies. Suppliers of these emerging technologies are encouraged to submit performance verification data to Ecology in accordance with the Ecology-TRC process described earlier in this Section.

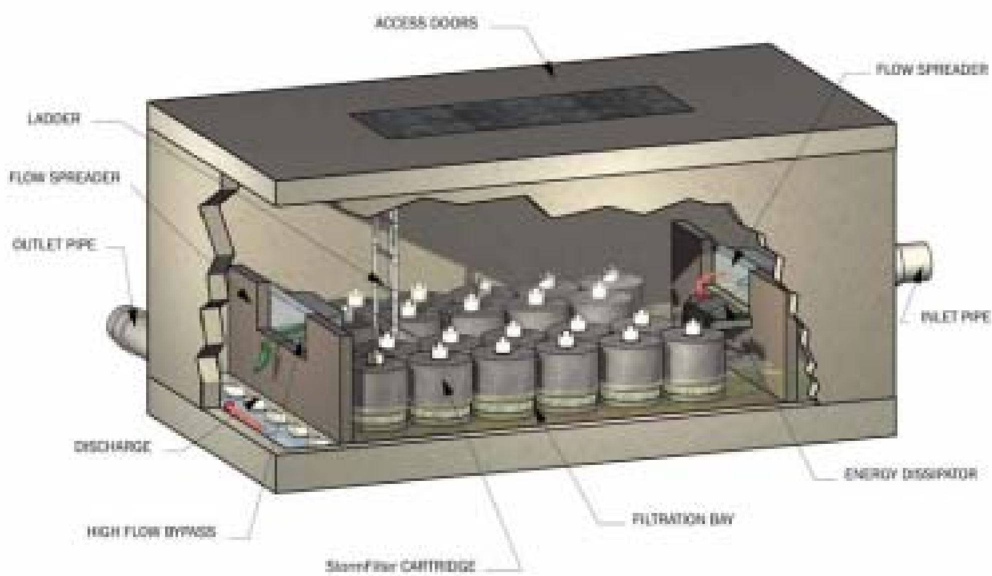


Figure 5.12.1 Vertical Media Filter

Media Filters

Introduction

The media filter technology has been under development in the Pacific Northwest since the early 1990s. During the early stages of development, a leaf compost medium was used in fixed beds, replacing sand. Continued development of this technology is based on placing the media in filter cartridges (vertical media filters) instead of fixed beds, and amending the media (Varner, Phyllis, City of Bellevue, 1999) with constituents that will improve effectiveness (See Figure 5.12.1). Many systems have been installed in the U.S. The primary target pollutants for removal are: TSS, total and soluble phosphorous, total nitrogen, soluble metals, and oil & grease and other organics.

Description

The media can be housed in cartridge filters enclosed in concrete vaults, or in fixed beds such as the sand filters described in Section 5.8. An assortment of filter media are available including leaf compost, pleated fabric, activated charcoal, perlite, amended sand and perlite, and zeolite. The system functions by routing the stormwater through the filtering or sorbing medium, which traps particulates and/or soluble pollutants. (Leif, Bill, 1999; Stormwater Management Company, 1999)

Performance Objectives

Media can be selected for removal of TSS, oil/grease or total petroleum hydrocarbons, soluble metals, nutrients and organics. (See Section 4 for performance objectives.)

Applications and limitations

Typical applications and limitations include:

- Pretreatment is required for high TSS and/or hydrocarbon loadings and debris that could cause premature failures due to clogging
- Media filtration, such as amended sand, (Varner, Phyllis, City of Bellevue, 1999) should be considered for some Metals Treatment applications to remove soluble metals and soluble phosphates
- These systems may be designed as on-line systems for small drainage areas, or as off-line systems.
- For off-line applications, flows greater than the design flow shall be bypassed.

Site Suitability

Consider:

- Space requirements
- Design flow characteristics
- Target pollutants
- O & M requirements
- Capital and annual costs

Design Criteria for TSS Removal

Determine TSS loading and peak design flow.

- ∉ TSS loading capacity per cartridge based on manufacturer's loading and flow design criteria to determine number and size of cartridges.
- ∉ Evaluate for pre-treatment needs. Typically, roadways, single family dwellings, and developments with steep slopes and erodible soils need pretreatment for TSS. Developments producing sustained oil and grease loads should be evaluated for oil and grease pretreatment needs.
- ∉ Select media based on pollutants of concern which are typically based on land use and local agency guidelines.

Pretreatment and Bypassing

- ∉ Use source control where feasible, including gross pollutant removal, sweeping, and spill containment Maintain catchbasins as needed to minimize inlet debris that could impair the operation of the filter media.
- ∉ Sedimentation vaults/ponds/ tanks, innovative more efficient catchbasins, oil/water separators for oil > 25 ppm, or other appropriate pre-treatment system to improve and maintain the operational efficiency of the filter media
- ∉ Bypassing of flows above design flows should be included.

Construction

- ∉ A precast or cast-in-place vault is typically installed over an underdrain manifold pipe system. This is followed by installation of the cartridges.
- ∉ Prior to cartridge installation construction sites must be stabilized to prevent erosion and solids loading.

Maintenance

- ∉ Follow manufacturers O & M guidelines to maintain design flows and pollutant removals
- ∉ Based on TSS loading and cartridge capacity calculate maintenance frequency Additional Applications, Limitations, Design, Construction, and Maintenance Criteria (See Ecology web site when available).

Amended Sand Filter

Description

The addition of media to improve the pollutant removal capabilities of basic sand filters.

Recent Performance Results

In a thorough study (Varner, Phyllis, City of Bellevue, 1999) of the performance of sand filters amended with processed steel fiber (95% sand and 5% processed steel fiber by volume), and crushed calcitic limestone (90% sand and 10% crushed calcitic limestone by volume), the City of Bellevue reported significant reductions in total phosphorus and dissolved zinc in runoff from the Lakemont residential area. Because the

Lakemont filter study was a detailed, well-documented, and reviewed analysis of a full scale operation, Ecology considers this technology as sufficiently advanced in development to allow its use as an option under the Metals Treatment Menu and the Phosphorus Treatment Menu. Sand filters amended with one of these media should be sized using the design criteria for a basic sand filter. Ecology prefers that these amendments be tested at another location to confirm the performances achieved by the Lakemont study and to further refine the design criteria.

Catch Basin Inserts (CBI)

Introduction

CBIs have been under development for many years in the Puget Sound Basin. They function similarly to media filtration except that they are typically limited by the size of the catchbasin. They also are likely to be maintenance intensive.

Description

Catch basin inserts typically consist of the following components:

- A structure (screened box, brackets, etc.) which contains a pollutant removal medium
- A means of suspending the structure in a catch basin
- A filter medium such as sand, carbon, fabric, etc.
- A primary inlet and outlet for the stormwater
- A secondary outlet for bypassing flows that exceed design flow

Applications and Limitations

By treating runoff close to its source, the volume of flow is minimized and more effective pollutant removal is therefore possible. Depending on the insert medium, removals of TSS, organics (including oils), and metals can be achieved. The main drawbacks are the limited retention capacities and maintenance requirements on the order of once per month in the wet season to clean or replace the medium. Based on two studies of catch basin inserts,(Koon, John, Interagency Catchbasin Insert Committee, 1995; Leif, William, Snohomish County 1998) the following are potential limitations and applications for specifically designated CBIs.

- CBIs are not recommended as a substitute for basic BMPs such as wet ponds, vaults, constructed wetlands, grass swales, sand filters or related BMPs.
- CBIs can be used as temporary sediment control devices and pretreatment at construction sites.
- CBIs can be considered for oil control at small sites where the insert medium has sufficient hydrocarbon loading capacity and rate of removal, and the TSS and debris will not prematurely clog the insert.

- CBIs can be used in unpaved areas and should be considered equivalent to currently accepted inlet protection BMPs.
- CBIs can be used when an existing catch basin lacks a sump or has an undersized sump.
- CBIs can cause flooding when plugged.
- CBIs may be considered in specialized small drainage applications for specific target pollutants where clogging of the medium will not be a problem

Manufactured Storm Drain Structures

Most of these types of systems marketed thus far are cylindrical in shape and are designed to fit into or adjacent to existing storm drainage systems or catch basins. The removal mechanisms include vortex-enhanced sedimentation, circular screening, and engineered designs of internal components, for large particle TSS and large oil droplets.

Vortex-enhanced Sedimentation

Description Vortex-enhanced Sedimentation consists of a cylindrical vessel with tangential inlet flow which spirals down the perimeter, thus causing the heavier particles to settle. It uses a vortex-enhanced settling mechanism (swirl-concentration) to capture settleable solids, floatables, and oil and grease. This system includes a wall to separate TSS from oil. See Figure 5.12.2.

Figure 5.12.2 - Vortex-enhanced settling mechanism

Applications, Limitations, Design, Construction, and Maintenance Criteria (See Ecology web site when available).

Vortex-enhanced Sedimentation and Media Filtration

Description   This system uses a two-stage approach which includes a Swirl Concentrator followed by a filtration chamber. See Figure 5.12.3.

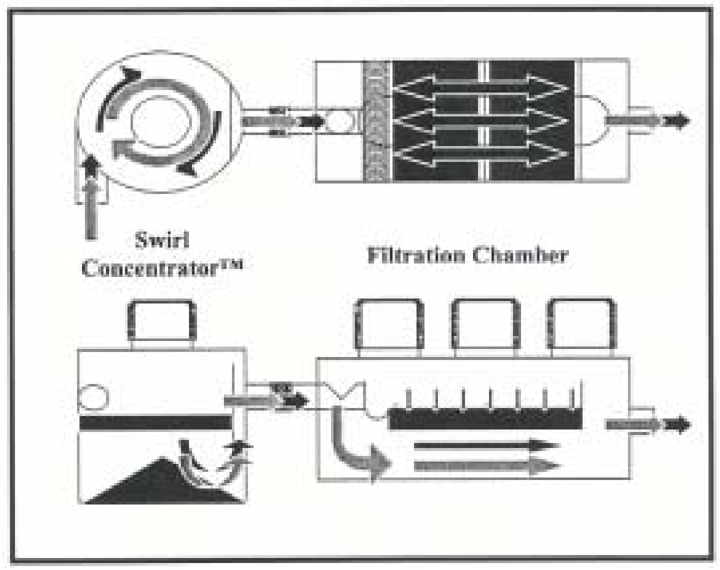


Figure 5.12.3 - Vortex-enhanced Sedimentation and Media Filtration

Cylindrical Screening System

Description   This system is comprised of a cylindrical screen and appropriate baffles and inlet/outlet structures to remove debris, large particle TSS, and large oil droplets. It includes an overflow for flows exceeding the design flow. Sorbents can be added to the separation chamber to increase pollutant removal efficiency. See Figure 5.12.4.

Figure 5.12.4 - Screen Separator

Engineered Cylindrical Sedimentation

Description This system is comprised of an engineered internal baffle arrangement and oil/TSS storage compartment designed to provide considerably better removals of large particle TSS and oil droplets than the standard catchbasins. It includes a bypass of flows higher than design flows, thus preventing scouring of collected solids and oils during the bigger storms.

5.12.7 High Efficiency Street Sweepers

Description A new generation of street sweepers has been developed that utilize strong vacuums to pick-up small particulates. They include mechanical sweeping and air filtration to control air emissions to acceptable levels. At least two manufacturers market what is referred to as a "high-efficiency" street sweeper.

Application High efficiency street sweepers are being marketed for roadways that are sufficiently accessible, need fine particulate removal (<250 microns), and for which a sufficient frequency of sweeping can be maintained to achieve proper removals of street dirt.

Limitations

- Limited field data and dependence on modeling projections
- May not be sufficiently effective during wet conditions

- More expensive than traditional sweepers - the cost of alternative BMPs should be compared.
- Increased storm frequency, with short intervals between storms, results in a need for increased frequency of sweeping.
- May depend on its availability, particularly during the wet season, and the need for a minimum in-place backup treatment facility.

Appendix 5A – Recommended Maintenance Criteria

The facility-specific maintenance standards contained in this section are intended to be conditions for determining if maintenance actions are required as identified through inspection. They are not intended to be measures of the facility's required condition at all times between inspections. In other words, exceedance of these conditions at any time between inspections and/or maintenance does not automatically constitute a violation of these standards. However, based upon inspection observations, the inspection and maintenance schedules shall be adjusted to minimize the length of time that a facility is in a condition that requires a maintenance action.

No. 1 – Wetponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size garbage can). In general, there should be no visual evidence of dumping. If less than threshold all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
	Poisonous Vegetation and noxious weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined by State or local regulations. (Apply requirements of adopted IPM policies for the use of herbicides).	No danger of poisonous vegetation where maintenance personnel or the public might normally be. (Coordinate with local health department) Complete eradication of noxious weeds may not be possible. Compliance with State or local eradication policies required
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants (Coordinate removal/cleanup with local water quality response agency).	No contaminants or pollutants present.
	Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. (Coordinate with local health department; coordinate with Ecology Dam Safety Office if pond exceeds 10 acre-feet.)

No. 1 – Wetponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
	Beaver Dams	Dam results in change or function of the facility.	Facility is returned to design function. (Coordinate trapping of beavers and removal of dams with appropriate permitting agencies)
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. Apply insecticides in compliance with adopted IPM policies
	Tree Growth and Hazard Trees	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove If dead, diseased, or dying trees are identified (Use a certified Arborist to determine health of tree or removal requirements)	Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (e.g., alders for firewood). Remove hazard Trees
Side Slopes of Pond	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. If erosion is occurring on compacted berms a licensed civil engineer should be consulted to resolve source of erosion.
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (If Applicable)	Liner is visible and has more than three 1/4-inch holes in it.	Liner repaired or replaced. Liner is fully covered.

No. 1 – Wetponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
Emergency Overflow/ Spillway and Berms over 4 feet in height.	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping. Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A licensed civil engineer should be consulted for proper berm/spillway restoration.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.

No. 1 – Wetponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Emergency Overflow/ Spillway	Emergency Overflow/ Spillway	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of out flow path of spillway. (Rip-rap on inside slopes need not be replaced.)	Rocks and pad depth are restored to design standards.
General	Water level	First cell is empty, doesn't hold water.	Line the first cell to maintain at least 4 feet of water. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.
	Trash and Debris	Accumulation that exceeds 1 CF per 1000-SF of pond area.	Trash and debris removed from pond.
	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Sediment Accumulation in Pond Bottom	Sediment accumulations in pond bottom that exceeds the depth of sediment zone plus 6-inches, usually in the first cell.	Sediment removed from pond bottom.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom, that exceeds 6-inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Settlement of Pond Dike/Berm	Any part of these components that has settled 4-inches or lower than the design elevation, or inspector determines dike/berm is unsound.	Dike/berm is repaired to specifications.
	Internal Berm	Berm dividing cells should be level.	Berm surface is leveled so that water flows evenly over entire length of berm.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.

No. 2 – Bio-infiltration/Infiltration Trenches/Basins

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Poisonous/Noxious Vegetation	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Contaminants and Pollution	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Rodent Holes	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
Storage Area	Sediment	Water ponding in infiltration pond after rainfall ceases and appropriate time allowed for infiltration. (A percolation test pit or test of facility indicates facility is only working at 90% of its designed capabilities. If two inches or more sediment is present, remove).	Sediment is removed and/or facility is cleaned so that infiltration system works according to design.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rain storms.	Gravel in rock filter is replaced.
Side Slopes of Pond	Erosion	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
Emergency Overflow Spillway and Berms over 4 feet in height.	Tree Growth	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Piping	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
Emergency Overflow Spillway	Rock Missing	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
	Erosion	See "Wet Ponds" (No. 1).	See "Wet Ponds" (No. 1).
Pre-settling Ponds and Vaults	Facility or sump filled with Sediment and/or debris	6" or designed sediment trap depth of sediment.	Sediment is removed.

No. 3 – Closed Treatment Systems (Tanks/Vaults)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Storage Area	Plugged Air Vents	One-half of the cross section of a vent is blocked at any point or the vent is damaged.	Vents open and functioning.
	Debris and Sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for 1/2 length of storage vault or any point depth exceeds 15% of diameter. (Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 length of tank.)	All sediment and debris removed from storage area.
	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into facility. (Will require engineering analysis to determine structural stability).	All joint between tank/pipe sections are sealed.
	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability).	Tank/pipe repaired or replaced to design.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound. Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls.	Vault replaced or repaired to design specifications and is structurally sound. No cracks more than 1/4-inch wide at the joint of the inlet/outlet pipe.
Manhole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
Catch Basins	See “Catch Basins” (No. 5)	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 4 – Control Structure/Flow Restrictor for Wetponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris (Includes Sediment)	Material exceeds 25% of sump depth or 1 foot below orifice plate.	Control structure orifice is not blocked. All trash and debris removed.
	Structural Damage	Structure is not securely attached to manhole wall.	Structure securely attached to wall and outlet pipe.
		Structure is not in upright position (allow up to 10% from plumb).	Structure in correct position.
		Connections to outlet pipe are not watertight and show signs of rust.	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.
		Any holes--other than designed holes--in the structure.	Structure has no holes other than designed holes.
Cleanout Gate	Damaged or Missing	Cleanout gate is not watertight or is missing.	Gate is watertight and works as designed.
		Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
		Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
		Gate is rusted over 50% of its surface area.	Gate is repaired or replaced to meet design standards.
Orifice Plate	Damaged or Missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.
Manhole	See “Closed Treatment Systems” (No. 3).	See “Closed Treatment Systems” (No. 3).	See “Closed Treatment Systems” (No. 3).
Catch Basin	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 5 – Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
General	Trash & Debris	Trash or debris which is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%.	No Trash or debris located immediately in front of catch basin or on grate opening.
		Trash or debris (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of six inches clearance from the debris surface to the invert of the lowest pipe.	No trash or debris in the catch basin.
		Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height.	Inlet and outlet pipes free of trash or debris.
		Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within the catch basin.
	Sediment	Sediment (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe.	No sediment in the catch basin
	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch (Intent is to make sure no material is running into basin).	Top slab is free of holes and cracks.
		Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached	Frame is sitting flush on the riser rings or top slab and firmly attached.
	Fractures or Cracks in Basin Walls/ Bottom	Maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards.
		Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	Pipe is regrouted and secure at basin wall.
	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
	Vegetation	Vegetation growing across and blocking more than 10% of the basin opening.	No vegetation blocking opening to basin.
		Vegetation growing in inlet/outlet pipe joints that is more than six inches tall and less than six inches apart.	No vegetation or root growth present.

No. 5 – Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
	Contamination and Pollution	See "Wetponds" (No. 1).	No pollution present.
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is closed
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Metal Grates (If Applicable)	Grate opening Unsafe	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.	Grate free of trash and debris.
	Damaged or Missing.	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.

No. 6 – Debris Barriers (e.g., Trash Racks)

Maintenance Components	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.	Barrier cleared to design flow capacity.
Metal	Damaged/ Missing Bars.	Bars are bent out of shape more than 3 inches.	Bars in place with no bends more than 3/4 inch.
		Bars are missing or entire barrier missing.	Bars in place according to design.
		Bars are loose and rust is causing 50% deterioration to any part of barrier.	Barrier replaced or repaired to design standards.
	Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe	Barrier firmly attached to pipe

No. 7 – Energy Dissipators

Maintenance Components	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
External:			
Rock Pad	Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil.	Rock pad replaced to design standards.
	Erosion	Soil erosion in or adjacent to rock pad.	Rock pad replaced to design standards.
Dispersion Trench	Pipe Plugged with Sediment	Accumulated sediment that exceeds 20% of the design depth.	Pipe cleaned/flushed so that it matches design.
	Not Discharging Water Properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a “sheet flow” of water along trench). Intent is to prevent erosion damage.	Trench redesigned or rebuilt to standards.
	Perforations Plugged.	Over 1/2 of perforations in pipe are plugged with debris and sediment.	Perforated pipe cleaned or replaced.
	Water Flows Out Top of “Distributor” Catch Basin.	Maintenance person observes or receives credible report of water flowing out during any storm less than the design storm or is causing or appears likely to cause damage.	Facility rebuilt or redesigned to standards.
	Receiving Area Over-Saturated	Water in receiving area is causing or has potential of causing landslide problems.	No danger of landslides.
Internal:			
Manhole/Chamber	Worn or Damaged Post, Baffles, Side of Chamber	Structure dissipating flow deteriorates to 1/2 of original size or any concentrated worn spot exceeding one square foot which would make structure unsound.	Structure replaced to design standards.
	Other Defects	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 8 – Biofiltration Swale

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits on grass treatment area of the bio-swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased.
	Standing Water	When water stands in the swale between storms and does not drain freely.	Any of the following may apply: remove sediment or trash blockages, improve grade from head to foot of swale, remove clogged check dams, add underdrains or convert to a wet biofiltration swale.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Level the spreader and clean so that flows are spread evenly over entire swale width.
	Constant Baseflow	When small quantities of water continually flow through the swale, even when it has been dry for weeks, and an eroded, muddy channel has formed in the swale bottom.	Add a low-flow pea-gravel drain the length of the swale or by-pass the baseflow around the swale.
	Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Determine why grass growth is poor and correct that condition. Re-plant with plugs of grass from the upper slope: plant in the swale bottom at 8-inch intervals. Or re-seed into loosened, fertile soil.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow vegetation or remove nuisance vegetation so that flow not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.
	Excessive Shading	Grass growth is poor because sunlight does not reach swale.	If possible, trim back over-hanging limbs and remove brushy vegetation on adjacent slopes.
	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.
	Trash and Debris Accumulation	Trash and debris accumulated in the bio-swale.	Remove trash and debris from bioswale.
	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8-inch intervals.

No. 9 – Vegetated Filter Strip

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits, re-level so slope is even and flows pass evenly through strip.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow grass, control nuisance vegetation, such that flow not impeded. Grass should be mowed to a height between 3-4 inches.
	Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.	Remove trash and debris from filter.
	Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.	Level the spreader and clean so that flows are spread evenly over entire filter width.

No. 10 – Wetvaults

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe or inlet/outlet (includes floatables and non-floatables).	Remove trash and debris from vault.
	Sediment Accumulation in Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6-inches.	Remove sediment from vault.
	Damaged Pipes	Inlet/outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened or removed, especially by one person.	Pipe repaired or replaced to proper working specifications.
	Ventilation	Ventilation area blocked or plugged.	Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection staff.	Baffles repaired or replaced to specifications.
	Access Ladder Damage	Ladder is corroded or deteriorated, not functioning properly, not attached to structure wall, missing rungs, has cracks and/or misaligned. Confined space warning sign missing.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel. Replace sign warning of confined space entry requirements. Ladder and entry notification complies with OSHA standards.

No. 11 – Sand Filters (above ground/open)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Above Ground (open sand filter)	Sediment Accumulation on top layer	Sediment depth exceeds 1/2-inch.	No sediment deposit on grass layer of sand filter that would impede permeability of the filter section.
	Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.	Trash and debris removed from sand filter bed.
	Sediment/ Debris in Clean-Outs	When the clean-outs become full or partially plugged with sediment and/or debris.	Sediment removed from clean-outs.
	Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24-hours, and/or flow through the overflow pipes occurs frequently.	Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material).
	Prolonged Flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities.	Low, continuous flows are limited to a small portion of the facility by using a low wooden divider or slightly depressed sand surface.
	Short Circuiting	When flows become concentrated over one section of the sand filter rather than dispersed.	Flow and percolation of water through sand filter is uniform and dispersed across the entire filter area.
	Erosion Damage to Slopes	Erosion over 2-inches deep where cause of damage is prevalent or potential for continued erosion is evident.	Slopes stabilized using proper erosion control measures.
	Rock Pad Missing or Out of Place	Soil beneath the rock is visible.	Rock pad replaced or rebuilt to design specifications.
	Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed across sand filter.	Spreader leveled and cleaned so that flows are spread evenly over sand filter.
	Damaged Pipes	Any part of the piping that is crushed or deformed more than 20% or any other failure to the piping.	Pipe repaired or replaced.

No. 12 –Sand Filters (below ground/enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below Ground Vault.	Sediment Accumulation on Sand Media Section	Sediment depth exceeds 1/2-inch.	No sediment deposits on sand filter section that which would impede permeability of the filter section.
	Sediment Accumulation in Pre-Settling Portion of Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6-inches.	No sediment deposits in first chamber of vault.
	Trash/Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Sediment in Drain Pipes/Cleanouts	When drain pipes, cleanouts become full with sediment and/or debris.	Sediment and debris removed.
	Short Circuiting	When seepage/flow occurs along the vault walls and corners. Sand eroding near inflow area.	Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal. Erosion protection added to dissipate force of incoming flow and curtail erosion.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover. Maintenance person cannot remove cover using normal lifting pressure.	Cover repaired to proper working specifications or replaced.
	Ventilation	Ventilation area blocked or plugged	Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab.	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles/Internal walls	Baffles or walls corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.

No. 12 –Sand Filters (below ground/enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel.

No. 13 – Media Filter

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below Ground Vault	Sediment Accumulation on Media.	Sediment depth exceeds 0.25-inches.	No sediment deposits which would impede permeability of the media.
	Sediment Accumulation in Vault	Sediment depth exceeds 6-inches in first chamber.	No sediment deposits in vault bottom of first chamber.
	Trash/Debris Accumulation	Trash and debris accumulated on filter bed.	Trash and debris removed from the filter bed.
	Sediment in Drain Pipes/Clean-Outs	When drain pipes, clean-outs, become full with sediment and/or debris.	Sediment and debris removed.
	Damaged Pipes	Any part of the pipes that are crushed or damaged due to corrosion and/or settlement.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened; one person cannot open the cover using normal lifting pressure, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking warping, and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.
Below Ground Cartridge Type	Filter Media	Drawdown of water through the media takes longer than 1 hour, and/or overflow occurs frequently.	Media cartridges replaced.
	Short Circuiting	Flows do not properly enter filter cartridges.	Filter cartridges replaced.

No. 14 – Baffle Oil/Water Separators (API Type)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with out thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6-inches in depth.	No sediment deposits on vault bottom that would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulation in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulations that exceed 1-inch, at the surface of the water.	Extract oil from vault by vactoring. Disposal in accordance with state and local rules and regulations.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	See “Catch Basins” (No. 5)	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

No. 15 – Coalescing Plate Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with no thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6-inches in depth and/or visible signs of sediment on plates.	No sediment deposits on vault bottom and plate media, which would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulation that exceeds 1-inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. Should be no visible oil depth on water.
	Damaged Coalescing Plates	Plate media broken, deformed, cracked and/or showing signs of failure.	A portion of the media pack or the entire plate pack is replaced depending on severity of failure.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and or replaced.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Vault Structure Damage - Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

No. 16 – Catch Basin Inserts

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Sediment Accumulation	When sediment forms a cap over the insert media of the insert and/or unit.	No sediment cap on the insert media and its unit.
	Trash and Debris Accumulation	Trash and debris accumulates on insert unit creating a blockage/restriction.	Trash and debris removed from insert unit. Runoff freely flows into catch basin.
	Media Insert Not Removing Oil	Effluent water from media insert has a visible sheen.	Effluent water from media insert is free of oils and has no visible sheen.
	Media Insert Water Saturated	Catch basin insert is saturated with water and no longer has the capacity to absorb.	Remove and replace media insert
	Media Insert-Oil Saturated	Media oil saturated due to petroleum spill that drains into catch basin.	Remove and replace media insert.
	Media Insert Use Beyond Normal Product Life	Media has been used beyond the typical average life of media insert product.	Remove and replace media at regular intervals, depending on insert product.

Table of Contents

Chapter 6 - Flow Control Facility Design

6.1 Introduction

This chapter of the stormwater manual focuses on techniques and BMPs related to implementation of Core Element #6 – Flow Control. This chapter presents methods, criteria, and details for hydraulic analysis and design of flow control facilities. Flow control facilities are detention, infiltration, or evaporation facilities engineered to meet the flow control standards specified by the regulatory agency.

The design criteria outlined in this chapter are applicable only to those infiltration facilities used for runoff quantity control. Design criteria for infiltration facilities used for runoff quality treatment are listed in Chapter 5.

Design considerations for conveyance systems are not included in the stormwater manual, as this topic is adequately covered in standard engineering references.

6.2 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 by the regulatory agency.

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

6.2.1 BMP F 6.10 Detention Ponds

The design criteria in this section are for detention ponds. However, many of the criteria also apply to infiltration ponds (Section 6.3 and Chapter 5 – Runoff Treatment Facility Design).

Dam Safety for Detention BMPs

Very large stormwater detention facilities that can impound 10 acre-feet (435,600 cubic feet; 3.26 million gallons) or more with the water level at the embankment crest are subject to the state's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020(1)). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled release of the pond contents. Peak flows from dam failures are typically much larger than the 100-year flows which these ponds are typically designed to accommodate.

The Dam Safety Office in the Department of Ecology is available to provide written guidance documents and technical assistance to project owners and design engineers in understanding and addressing the dam safety requirements for their specific project. If the pond will meet the size or depth criteria for dam safety it is requested that Dam Safety be contacted early in the facilities planning process.

Electronic versions of the guidance documents in PDF format are available on the Department of Ecology Web site at http://www.ecy.wa.gov/programs/wr/dams/dss.html.

Design Criteria

Standard details for detention ponds are shown in Figure 6.2.1 through Figure 6.2.3. Control structure details are provided in Section 6.2.4.

General

Ponds may be designed as flow-through systems (however, parking lot storage may be utilized through a back-up system; see Section 6.2.5). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sedimentation.

Pond bottoms should be level and be located a minimum of 0.5 foot (preferably 1 foot) below the inlet and outlet to provide sediment storage.

The design professional should carefully consider and evaluate any situation where a pond will be situated upslope from a structure or behind the top of a slope inclined in excess of 15 percent. The minimum setback from such a slope is equal to ‘h’, the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation.

Side Slopes

Interior side slopes up to the emergency overflow water surface should not be steeper than 3H:1V unless a fence is provided (see “Fencing”).

Exterior side slopes should not be steeper than 2H:1V unless analyzed for stability by a geotechnical engineer.

Pond walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete; (b) a fence is provided along the top of the wall; (c) the entire pond perimeter may be retaining walls, however, it is recommended that at least 25 percent of the pond perimeter be a vegetated soil slope not steeper than 3H:1V; and (d) the design is stamped by a licensed civil engineer with structural expertise. Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone type wall may be used if designed by a geotechnical engineer or a civil engineer with structural expertise. If the entire pond perimeter is to be retaining walls, ladders should be provided on the walls for safety reasons.

Embankments

Pond berm embankments higher than 6 feet must be designed by a professional engineer with geotechnical expertise.

For berm embankments 4 feet or less, the minimum top width should be 4 feet or as recommended by a geotechnical engineer.

Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.

Pond berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and width unless specified otherwise by a geotechnical engineer.

Embankment compaction should be accomplished in such a manner as to produce a dense, low permeability engineered fill that can tolerate post-construction settlements with a minimum of cracking. The embankment fill should be placed on a stable subgrade and compacted to a minimum of 95% of the Modified Proctor Maximum Density, ASTM Procedure D1557. Placement moisture content should lie within 1% dry to 3% wet of the optimum moisture content. The referenced degree of compaction may have to be increased to comply with local regulations.

The berm embankment should be constructed of soils with the following characteristics: a minimum of 20% silt and clay, a maximum of 60% sand, a maximum of 60% silt, with nominal gravel and cobble content. Soils outside this specified range can be used, provided the design satisfactorily addresses the engineering concerns posed by these soils. The paramount concerns with these soils are their susceptibility to internal erosion or piping and to surface erosion from wave action and runoff on the upstream and downstream slopes, respectively. Anti-seepage filter-drain diaphragms must be placed on outflow pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See Dam Safety Guidelines at www.ecy.wa.gov/programs/wr/dams/dss.html.

Overflow

1. In all ponds, tanks, and vaults, a primary overflow (usually a riser pipe within the control structure; see Section 6.2.4) must be provided to bypass the 25-year developed peak flow over or around the restrictor system. This assumes the facility will be full due to plugged orifices or high inflows; the primary overflow is intended to protect against breaching of a pond embankment (or overflows of the upstream conveyance system in the case of a detention tank or vault). The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

2. A secondary inlet to the control structure should be provided in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. A grated opening ("jailhouse

window") in the control structure manhole functions as a weir (see Figure 6.2.2) when used as a secondary inlet.

Note*: The maximum circumferential length of this opening must not exceed one-half the control structure circumference.* The "birdcage" overflow structure as shown in Figure 6.2.3 may also be used as a secondary inlet.

Emergency Overflow Spillway

Emergency overflow spillways are intended to control the location of pond overtopping in the event of total control structure failure (e.g., blockage of the control structure outlet pipe) or extreme inflows, and direct overflows back into the downstream conveyance system or other acceptable discharge point.

Emergency overflow spillways must be provided for ponds with constructed berms over 2 feet in height, or for ponds located on grades in excess of 5 percent. As an option for ponds with berms less than 2 feet in height and located at grades less than 5 percent, emergency overflow may be provided by an emergency overflow structure, such as a manhole fitted with a birdcage as shown in Figure 6.2.3. The emergency overflow structure must be designed to pass the 25-year developed peak flow, with a minimum 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, consideration should be given to providing an emergency overflow structure in addition to the spillway.

The emergency overflow spillway must be armored with riprap. The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows re-enter the conveyance system (see Figure 6.2.2). Guidance for the design of the riprap can be found in HEC-11, "Design of Riprap Revetment," and HEC-14, "Hydraulic Design of Energy Dissipators for Culverts and Channels."

Emergency overflow spillway designs should be analyzed as broad-crested trapezoidal weirs.

Access

The following guidelines for access may be used.

Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the pond (e.g., inlet or bypass structures). It is recommended that manhole and catch basin lids be in or at the edge of the access road and at least three feet from a property line.

An access ramp is needed for removal of sediment with a trackhoe and truck. The ramp should extend to the pond bottom if the pond bottom is greater than 1,500 square feet (measured without the ramp) and it may end at an elevation 4 feet above the pond bottom, if the pond bottom is less than 1,500 square feet (measured without the ramp).

On large, deep ponds, truck access to the pond bottom via an access ramp is necessary so loading can be done in the pond bottom. On small deep ponds, the truck can remain on the ramp for loading. On small shallow ponds, a ramp to the bottom may not be required if the trackhoe can load a truck parked at the pond edge or on the internal berm of a wetpond or combined pond (trackhoes can negotiate interior pond side slopes).

Access ramps must meet the requirements for design and construction of access roads specified below.

If a fence is required, access should be limited by a double-posted gate or by bollards – that is, two fixed bollards on each side of the access road and two removable bollards equally located between the fixed bollards.

Design of Access Roads

The design guidelines for access road are given below.

Maximum grade should be 20 percent.

Outside turning radius should be a minimum of 40 feet.

Fence gates should be located only on straight sections of road.

Access roads should be 15 feet in width on curves and 12 feet on straight sections.

A paved apron must be provided where access roads connect to paved public roadways.

Construction of Access Roads

Access roads may be constructed with an asphalt or gravel surface, or modular grid pavement. All surfaces must conform to the jurisdictional standards and manufacturer's specifications.

Fencing

A fence may also be needed around impoundments of open water. Refer to the Uniform Building Code or local building codes for fencing requirements in these areas.

Right-of-Way

Right-of-way may be needed for detention pond maintenance. It is recommended that any tract not abutting public right-of-way have 15-20 foot wide extension of the tract to an acceptable access location.

Setbacks

It is recommended that the ponded area be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government. Side slopes for the pond or berm should be a minimum of

5 feet from any structure or property line. The detention pond water surface at the pond outlet invert elevation must be set back 100 feet from proposed or existing septic system drainfields. However, the setback requirements are generally specified by the local government, Uniform Building Code, or other statewide regulation, and may be different from those mentioned above.

The design professional should carefully consider and evaluate any situation where an infiltration facility will be situated upslope from a structure or behind the top of a slope inclined in excess of 15 percent. The minimum setback from such a slope is equal to 'h', the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation.

Seeps and Springs

Intermittent seeps along cut slopes are typically fed by a shallow groundwater source (interflow) flowing along a relatively impermeable soil stratum. These flows are storm driven and should discontinue after a few weeks of dry weather. However, more continuous seeps and springs, which extend through longer dry periods, are likely from a deeper groundwater source. When continuous flows are intercepted and directed through flow control facilities, adjustments to the facility design may have to be made to account for the additional base flow (unless already considered in design).

Planting Requirements

Exposed earth on the pond bottom and interior side slopes may be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract may be planted with grass or be landscaped. See Chapter 7 - Construction Stormwater Pollution Prevention for typical seed mixes.

Landscaping

If provided, landscaping should adhere to the criteria that follow so as not to hinder maintenance operations. Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, "naturalistic" stormwater facilities may be placed in open space tracts.

The following guidelines should be followed if landscaping is proposed for facilities.

1. No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or flow spreaders. Species with roots that seek water, such as willow or poplar, should be avoided within 50 feet of pipes or manmade structures.
2. Planting should be restricted on berms that impound water either permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.

a) Trees or shrubs may not be planted on portions of water impounding berms taller than four feet high. Only grasses may be planted on berms taller than four feet.

   Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.

b) Trees planted on portions of water-impounding berms less than 4 feet high must be small, not higher than 20 feet mature height, and have a fibrous root system.

   These trees reduce the likelihood of blow-down trees, or the possibility of channeling or piping of water through the root system, which may contribute to dam failure on berms that retain water.

3. All landscape material, including grass, should be planted in good topsoil. Native underlying soils may be made suitable for planting if amended with 4 inches of well-aged compost tilled into the subgrade. Compost used should meet specifications for Grade A compost quality as described in Ecology publication 94-38.

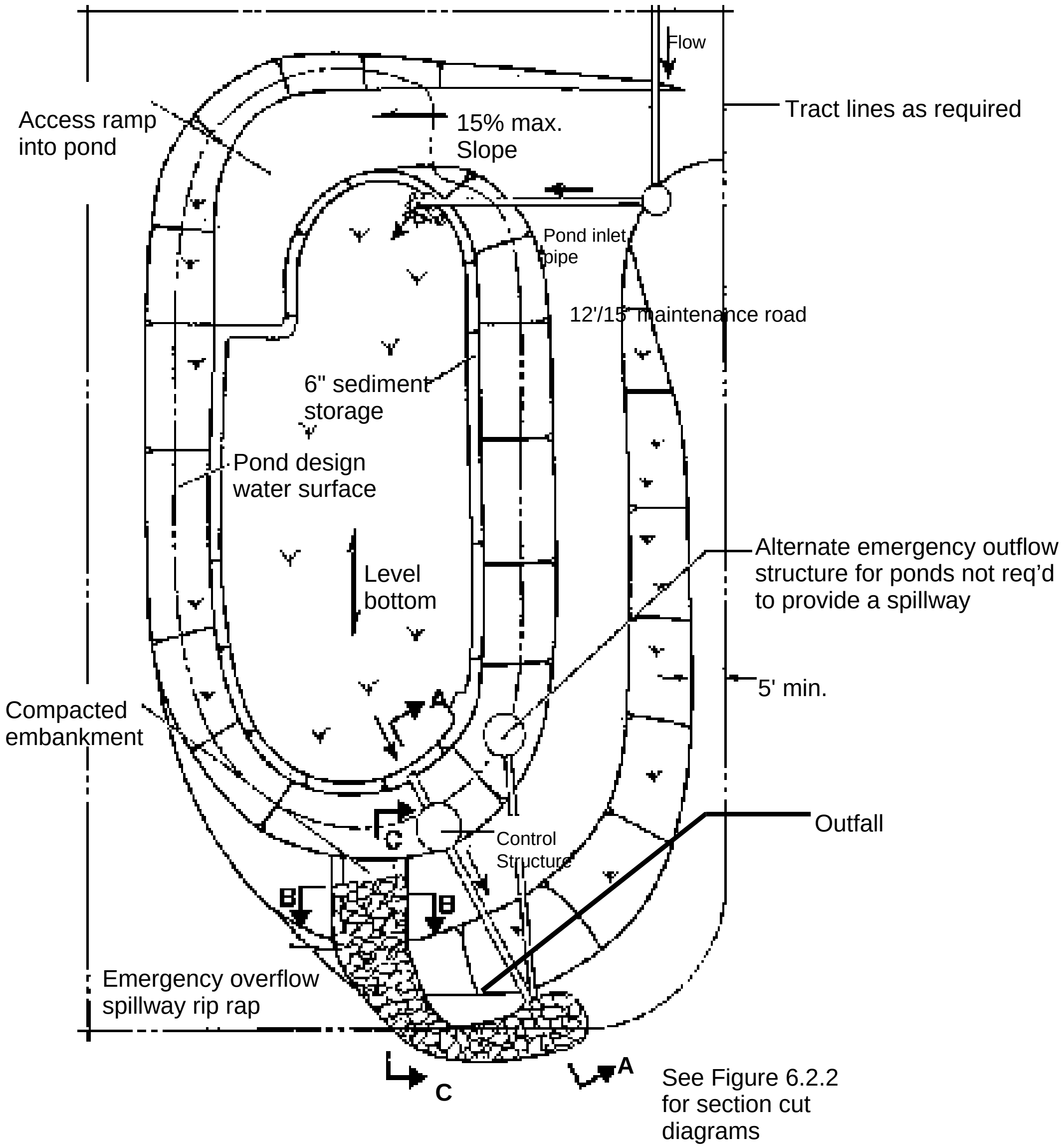
4. Soil in which trees or shrubs are planted may need additional enrichment or additional compost top-dressing. Consult a nurseryman, landscape professional, or arborist for site-specific recommendations.

5. For a naturalistic effect as well as ease of maintenance, trees or shrubs should be planted in clumps to form "landscape islands" rather than evenly spaced.

   The landscaped islands should be a minimum of six feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of 6 feet. Where tree foliage extends low to the ground, the six foot setback should be counted from the outer drip line of the trees (estimated at maturity). This setback allows a 6-foot wide mower to pass around and between clumps.

6. Evergreen trees and trees which produce relatively little leaf-fall (such as ash, locust, hawthorn) are preferred in areas draining to the pond.

7. Trees should be set back so that branches do not extend over the pond (to prevent leaf-drop into the water). Drought tolerant species are recommended.



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

Figure 6.2.1 - Typical Detention Pond

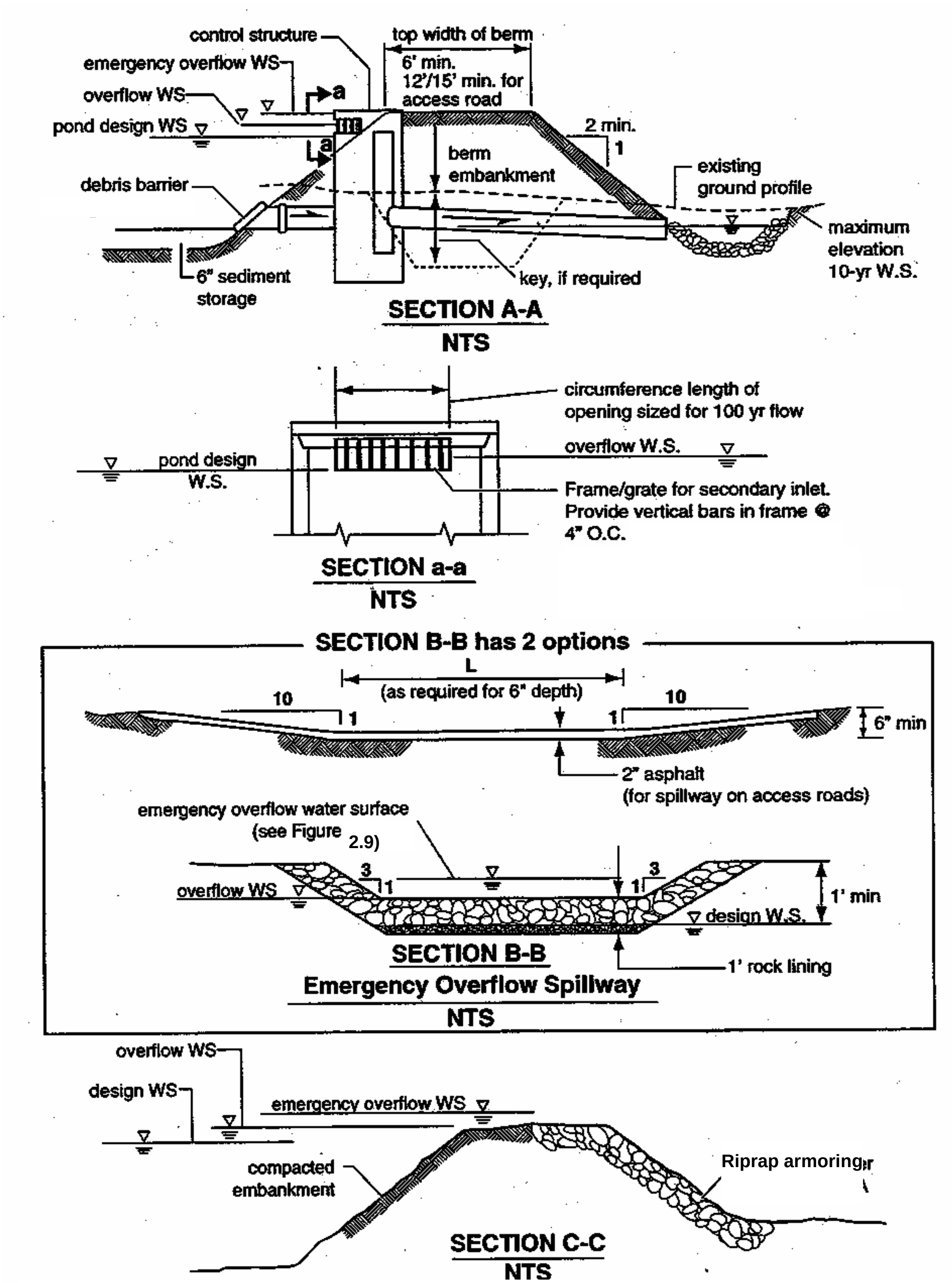
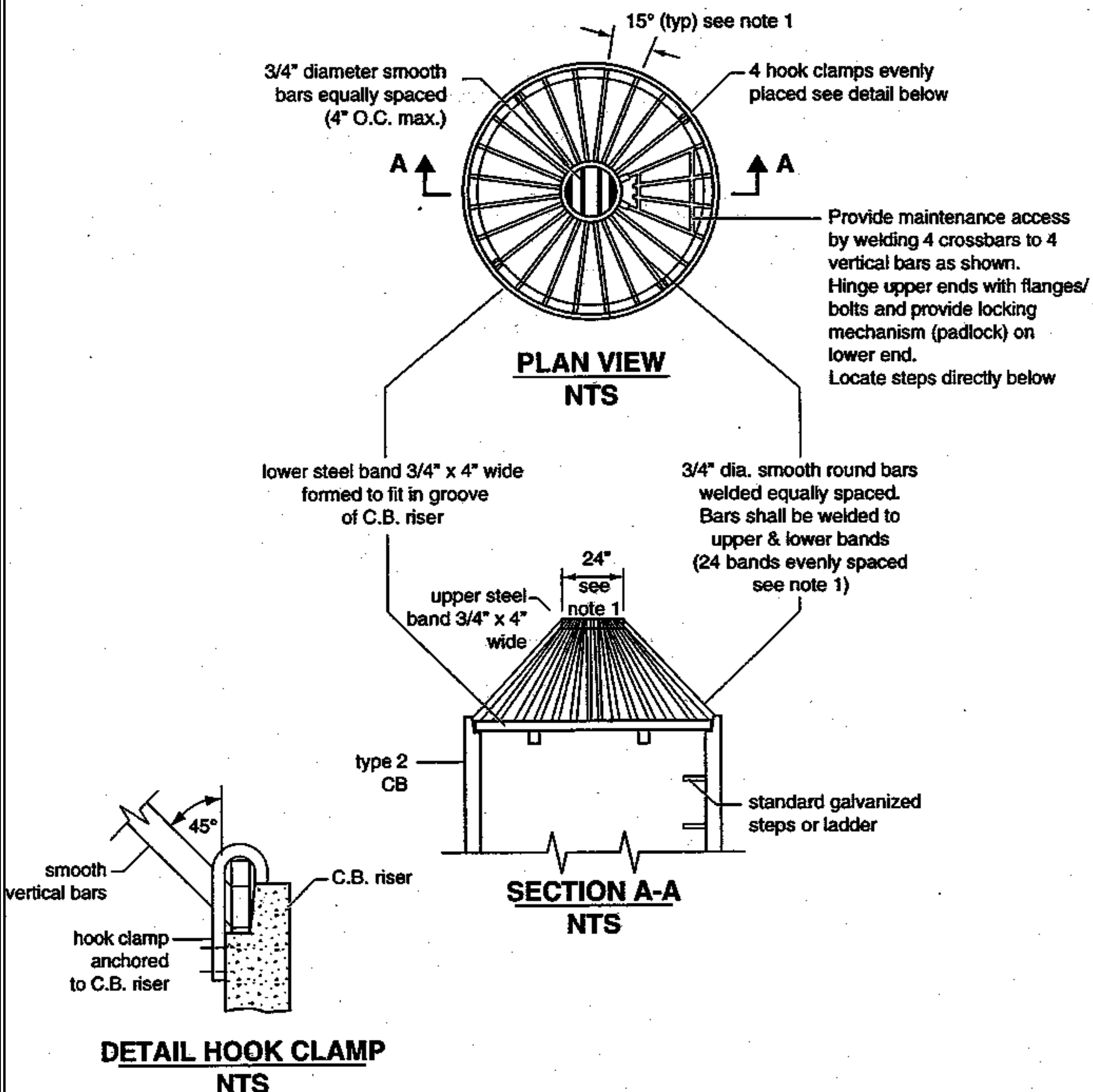


Figure 6.2.2 Typical Detention Pond Sections



NOTES:

1. Dimensions are for illustration on 54" diameter CB For different diameter CB's adjust to maintain 45° angle on "vertical" bars and 7" o.c. maximum spacing of bars around lower steel band.
2. Metal parts must be corrosion resistant; steel bars must be galvanized.
3. This debris barrier is also recommended for use on the inlet to roadway cross-culverts with high potential for debris collection (except on type 2 streams)

Figure 6.2.3 Overflow Structure

Maintenance

General. Maintenance is of primary importance if detention ponds are to continue to function as originally designed. A local government, a designated group such as a homeowners' association, or some individual should accept the responsibility for maintaining the structures and the impoundment area. A specific maintenance plan should be formulated outlining the schedule and scope of maintenance operations. Debris removal in detention basins can be achieved through the use of trash racks or other screening devices.

Design with maintenance in mind. Good maintenance will be crucial to successful use of the impoundment. Hence, provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance should be a basic consideration in design and in determination of first cost. See Appendix 6A for specific maintenance requirements.

Any standing water removed during the maintenance operation must be disposed of to a sanitary sewer at an approved discharge location. Pretreatment may be necessary. Residuals must be disposed of in accordance with state and local solid waste regulations (See Minimum Functional Standards For Solid Waste Handling, Chapter 173-304 WAC).

Vegetation. If a shallow marsh is established, then periodic removal of dead vegetation may be necessary. Since decomposing vegetation can release pollutants captured in the detention pond, especially nutrients, it may be necessary to harvest dead vegetation annually prior to the winter season. Otherwise the decaying vegetation can export pollutants out of the pond and also can cause nuisance conditions to occur.

Sediment. Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Sediment deposition should be periodically monitored in the basin. Owners, operators, and maintenance authorities should be aware that significant concentrations of metals (e.g., lead, zinc, and cadmium) as well as some organics such as pesticides, may be expected to accumulate at the bottom of these treatment facilities. Testing of sediment, especially near points of inflow, should be conducted periodically to determine the leaching potential and level of accumulation of potentially hazardous material before disposal.

Methods of Analysis

Detention Volume and Outflow. The volume and outflow design for detention ponds must be in accordance with the requirements of Core Element #6, and the hydrologic analysis and design methods in Chapter 4. Design guidelines for restrictor orifice structures are given in Section 6.2.4.

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 soils that are sufficiently permeable for a properly functioning infiltration system. 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 Section 6.3 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 25-year runoff event for developed conditions assuming a broad-crested weir. The broad-crested weir equation for the spillway section in Figure 6.2.4, for example, would be:

$$Q_{25} = C\,(2g)^{1/2}\left[\frac{2}{3} LH^{3/2} + \frac{8}{15}(\mathrm{Tan}\chi)\, H^{5/2}\right] \qquad \text{(Eq. 5.2.1)}$$

Where Q_{25} = peak flow for the 25-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)

χ = angle of side slopes

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

$$Q_{25} = 3.21[LH^{3/2} + 2.4\, H^{5/2}] \qquad \text{(Eq. 5.2.2)}$$

To find length *L* for the weir section, the equation is rearranged to use the computed Q_{25} and trial values of H (0.2 feet minimum):

$$L = [Q_{25}/(3.21H^{3/2})] - 2.4\,H \quad \text{or 6 feet minimum} \qquad \text{(Eq. 5.2.3)}$$

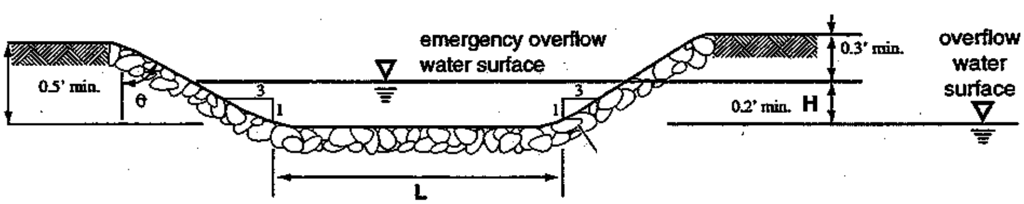


Figure 6.2.4 Weir Section for Emergency Overflow Spillway

6.2.2 BMP F 6.11 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Standard detention tank details are shown in Figures 6.2.5 and 6.2.6. Control structure details are shown in Section 6.2.4.

Design Criteria

General. Typical design guidelines are as follows:

1. Tanks may be designed as flow-through systems with manholes in line (see Figure 6.2.5) to promote sediment removal and facilitate maintenance. Tanks may be designed as back-up systems if preceded by water quality facilities, since little sediment should reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank
2. The detention tank bottom should be located 0.5 feet below the inlet and outlet to provide dead storage for sediment.
3. The minimum pipe diameter for a detention tank is 36 inches.
4. Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe.

   Note: *Control and access manholes should have ladder rungs to allow ready access to all tank access pipes when the catch basin sump is filled with water.*

Materials. Pipe material, joints, and protective treatment for tanks should be in accordance with Section 9.05 of the WSDOT/APWA Standard Specification.

Structural Stability. Tanks must meet structural requirements for overburden support and traffic loading if appropriate. H-20 live loads, or other loading criteria applicable to the site, must be accommodated for tanks lying under parking areas and access roads. Metal tank end plates must be designed for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker gage material than the pipe and/or require reinforcing ribs. Tanks must be placed on stable, well consolidated native material with a suitable bedding. Tanks must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Buoyancy. In moderately pervious soils where seasonal groundwater may induce flotation, buoyancy tendencies must be balanced either by ballasting with backfill or concrete backfill, providing concrete anchors, increasing the total weight, or providing subsurface drains to permanently lower the groundwater table. Calculations that demonstrate stability must be documented.

Access. The following guidelines for access may be used.

1. The maximum depth from finished grade to tank invert should be 20 feet.
2. Access openings should be positioned a maximum of 50 feet from any location within the tank.
3. All tank access openings should have round, solid locking lids (usually 1/2 to 5/8-inch diameter Allen-head cap screws).
4. 36-inch minimum diameter CMP riser-type manholes (Figure 6.2.6) of the same gage as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1-inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.
5. All tank access openings must be readily accessible by maintenance vehicles.
6. Tanks must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Access Roads Access roads are needed to all detention tank control structures and risers. The access roads must be designed and constructed as specified for detention ponds in Section 6.2.1.

Right-of-Way. Right-of-way may be needed for detention tank maintenance. It is recommended that any tract not abutting public right-of-way have a 15 to 20-foot wide extension of the tract to accommodate an access road to the facility.

Setbacks. It is recommended that facilities be a minimum of 5 feet from any structure, property line, and any vegetative buffer required by the local government and from any septic drainfield. However, the setback requirements are generally specified by the local government, Uniform Building Code, or other statewide regulation and may be different from those mentioned above.

Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix 6A for specific maintenance requirements.

Methods of Analysis

Detention Volume and Outflow. The volume and outflow design for detention tanks must be in accordance with the requirements of the regulatory agency and the hydrologic analysis and design methods in Chapter 4 - Hydrologic Analysis and Design. Restrictor and orifice design are given in Section 6.2.4.

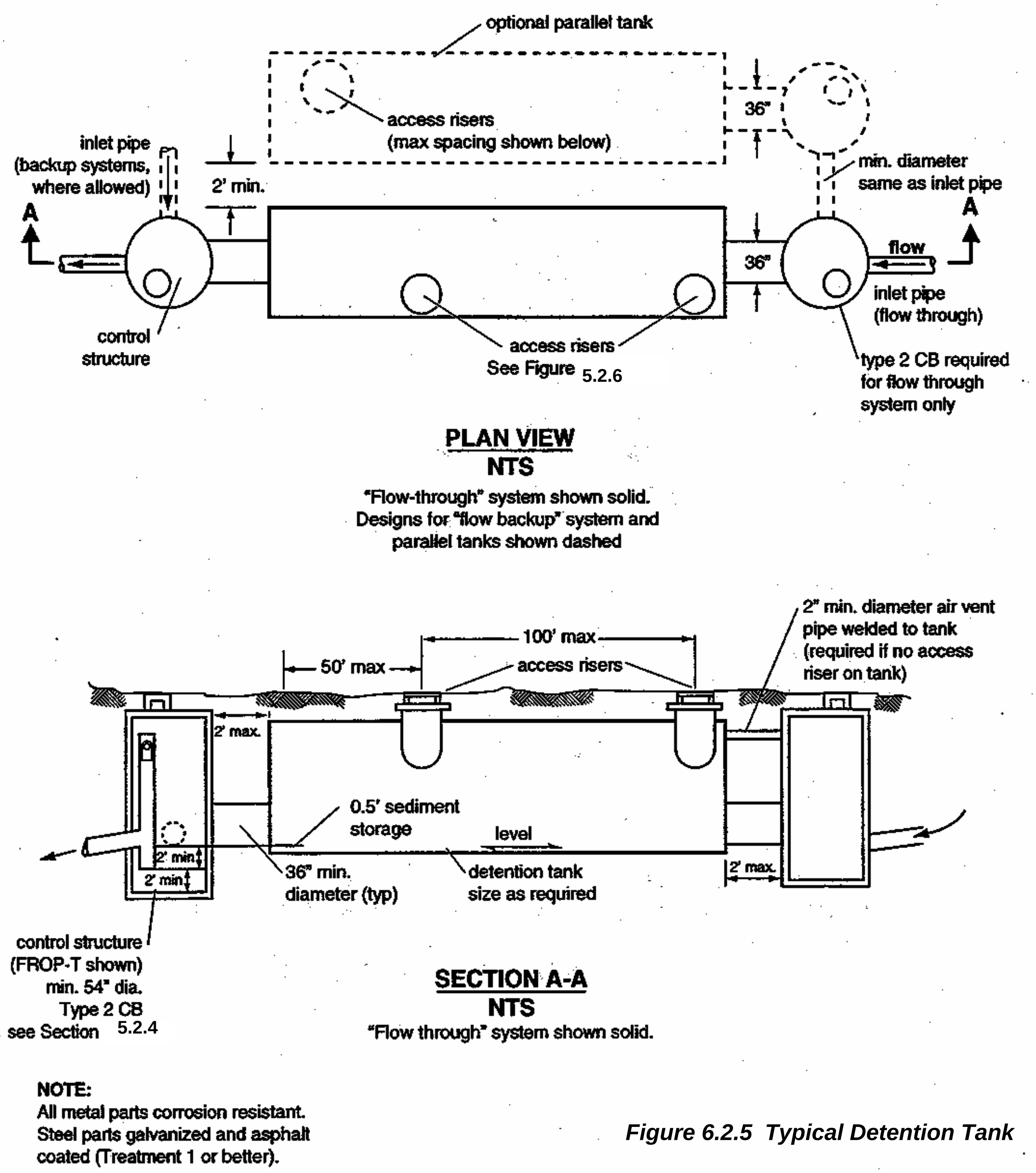


Figure 6.2.5 Typical Detention Tank

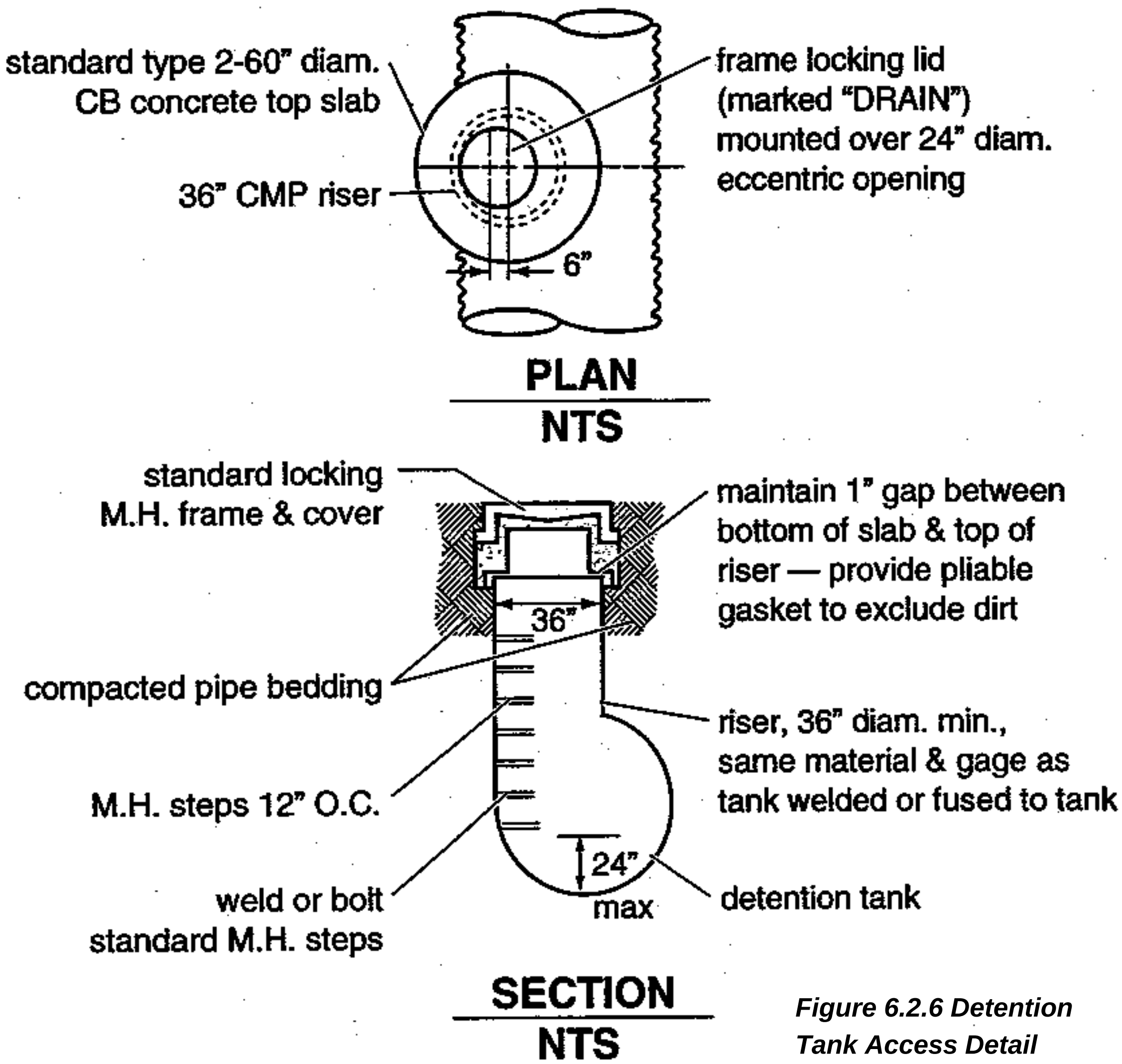


Figure 6.2.6 Detention Tank Access Detail

Notes for Figure 6.2.6:

Use adjusting blocks as required to bring frame to grade.
All materials to be aluminum or galvanized and asphalt coated (Treatment 1 or better).
Must be located for access by maintenance vehicles.
May substitute WSDOT special Type IV manhole (RCP only).

6.2.3 BMP F 6.12 Detention Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. A standard detention vault detail is shown in Figure 6.2.7. Control structure details are shown in Section 6.2.4.

Design Criteria

General. Typical design guidelines are as follows:

1. Detention vaults may be designed as flow-through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet should be maximized (as feasible).
2. The detention vault bottom may slope at least 5 percent from each side towards the center, forming a broad “v” to facilitate sediment removal. More than one “v” may be used to minimize vault depth. However, the vault bottom may be flat with 0.5-1 foot of sediment storage if removable panels are provided over the entire vault. It is recommended that the removable panels be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
3. The invert elevation of the outlet should be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet should also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.

Materials. Minimum 3,000 psi structural reinforced concrete may be used for detention vaults. All construction joints must be provided with water stops.

Structural Stability. All vaults must meet structural requirements for overburden support and H-20 traffic loading (See Standard Specifications for Highway Bridges, 1998 Interim Revisions, American Association of State Highway and Transportation Officials). Vaults located under roadways must meet any live load requirements of the local government. Cast-in-place wall sections must be designed as retaining walls. Structural designs for cast-in-place vaults must be stamped by a licensed civil engineer with structural expertise. Vaults must be placed on stable, well-consolidated native material with suitable bedding. Vaults must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Access. Access must be provided over the inlet pipe and outlet structure. The following guidelines for access may be used.

1. Access openings should be positioned a maximum of 50 feet from any location within the tank. Additional access points may be needed on large vaults. If more than one “v” is provided in the vault floor, access to each “v” must be provided.

2. For vaults with greater than 1,250 square feet of floor area, a 5' by 10' removable panel should be provided over the inlet pipe (instead of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided.
3. For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking manhole covers may be provided. Ladders and hand-holds need only be provided at the outlet pipe and inlet pipe, and as needed to meet OSHA confined space requirements. Vaults providing manhole access at 12-foot spacing need not provide corner ventilation pipes as specified in Item 10 below.
4. All access openings, except those covered by removable panels, may have round, solid locking lids, or 3-foot square, locking diamond plate covers.
5. Vaults with widths 10 feet or less must have removable lids.
6. The maximum depth from finished grade to the vault invert should be 20 feet.
7. Internal structural walls of large vaults should be provided with openings sufficient for maintenance access between cells. The openings should be sized and situated to allow access to the maintenance "v" in the vault floor.
8. The minimum internal height should be 7 feet from the highest point of the vault floor (not sump), and the minimum width should be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. Also the minimum internal height requirement may not be needed for any areas covered by removable panels.
9. Vaults must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.
10. Ventilation pipes (minimum 12-inch diameter or equivalent) should be provided in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Alternatively removable panels over the entire vault may be provided.

Access Roads. Access roads are needed to the access panel (if applicable), the control structure, and at least one access point per cell, and they may be designed and constructed as specified for detention ponds in Section 6.2.1.

Right-of-Way. Right-of-way is needed for detention vaults maintenance. It is recommended that any tract not abutting public right-of-way should have a 15 to 20-foot wide extension of the tract to accommodate an access road to the facility.

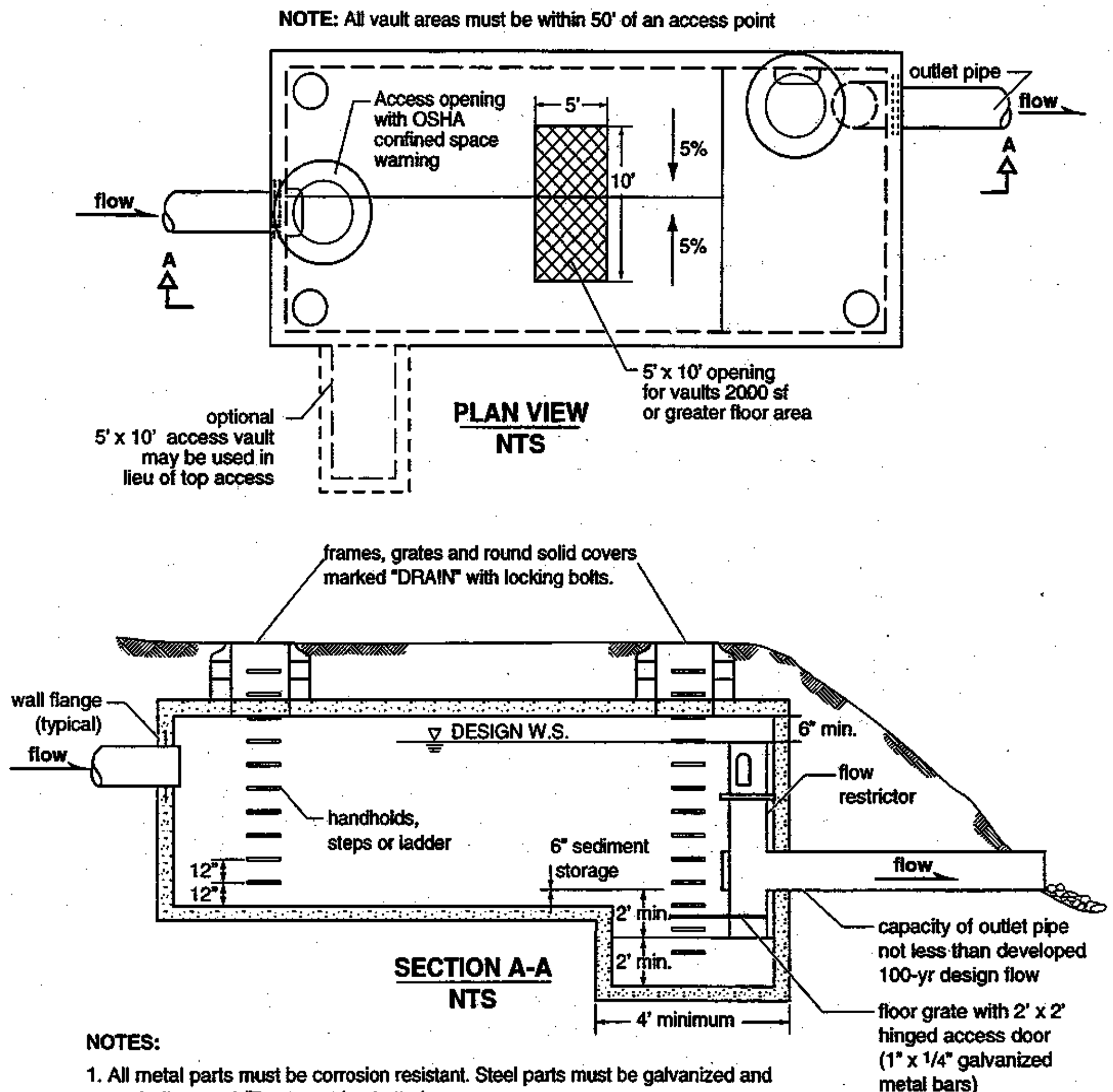
Setbacks. It is recommended that facilities be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government and from any septic drainfield. However, the setback requirements are generally specified by the local government, uniform building code, or other statewide regulation and may be different from those mentioned above.

The design professional should carefully consider and evaluate any situation where a pond will be situated upslope from a structure or behind the top of a slope inclined in excess of 15 percent. The minimum setback from such a slope is equal to 'h', the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation.

Maintenance. Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix 6A for specific maintenance requirements.

Methods of Analysis

Detention Volume and Outflow. The volume and outflow design for detention vaults must be in accordance with the requirements of the regulatory agency and the hydrologic analysis and design methods in Chapter 4. Restrictor and orifice design are given in Section 6.2.4.



NOTES:

1. All metal parts must be corrosion resistant. Steel parts must be galvanized and asphalt coated (Treatment I or better).
2. Provide water stop at all cast-in-place construction joints. Precast vaults shall have approved rubber gasket system.
3. Vaults ≤ 10' wide must use removable lids.
4. Prefabricated vault sections may require structural modifications to support 5' x 10' opening over main vault. Alternatively, access can be provided via a side vestibule as shown.

Figure 6.2.7 Typical Detention Vault

6.2.4 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 flow restrictor oil pollution control tees ("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 are shown in Figures 6.2.8 and 6.2.9.

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.

Control Structure	Pond Head
outlet pipe	very low
v-notch weir	low
slotted weir	moderate
multi-stage orifice	high

A 1-inch diameter minimum orifice is recommended, but must be confirmed with the requirements of the local jurisdiction.

1. Minimum orifice diameter is 1.0 inches, subject to confirmation by the local jurisdiction. 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 may be constructed on a tee section as shown in Figure 6.2.8 or on a baffle as shown in Figure 6.2.9.
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 6.2.12).
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.

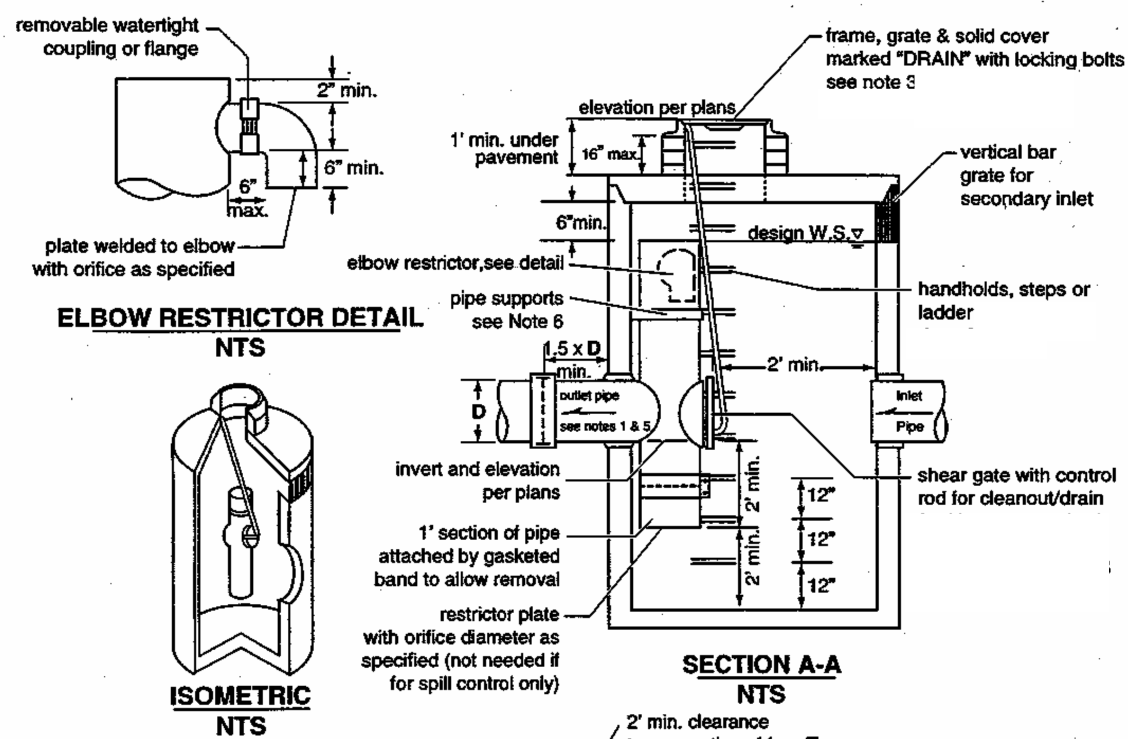
1. Properly designed weirs may be used as flow restrictors (see Figures 6.2.11 and 6.2.12). However, they must be designed to provide for primary overflow of the developed 25-year peak flow discharging to the detention facility.
2. The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design must still provide for primary overflow of the developed 25-year peak flow assuming all orifices are plugged. Figure 6.2.13 can be used to calculate the head in feet above a riser of given diameter and flow.

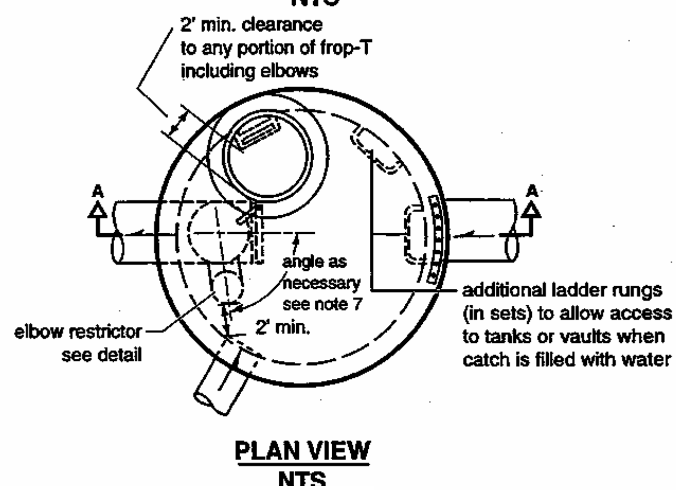
Access. The following guidelines for access may be used.

1. An access road to the control structure is needed for inspection and maintenance, and must be designed and constructed as specified for detention ponds in Section 6.2.1.
2. Manhole and catch basin lids for control structures must be locking, and rim elevations must match proposed finish grade.
3. Manholes and catch-basins must meet the OSHA and WISHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser, just under the access lid.

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
- Recommended frequency of maintenance.

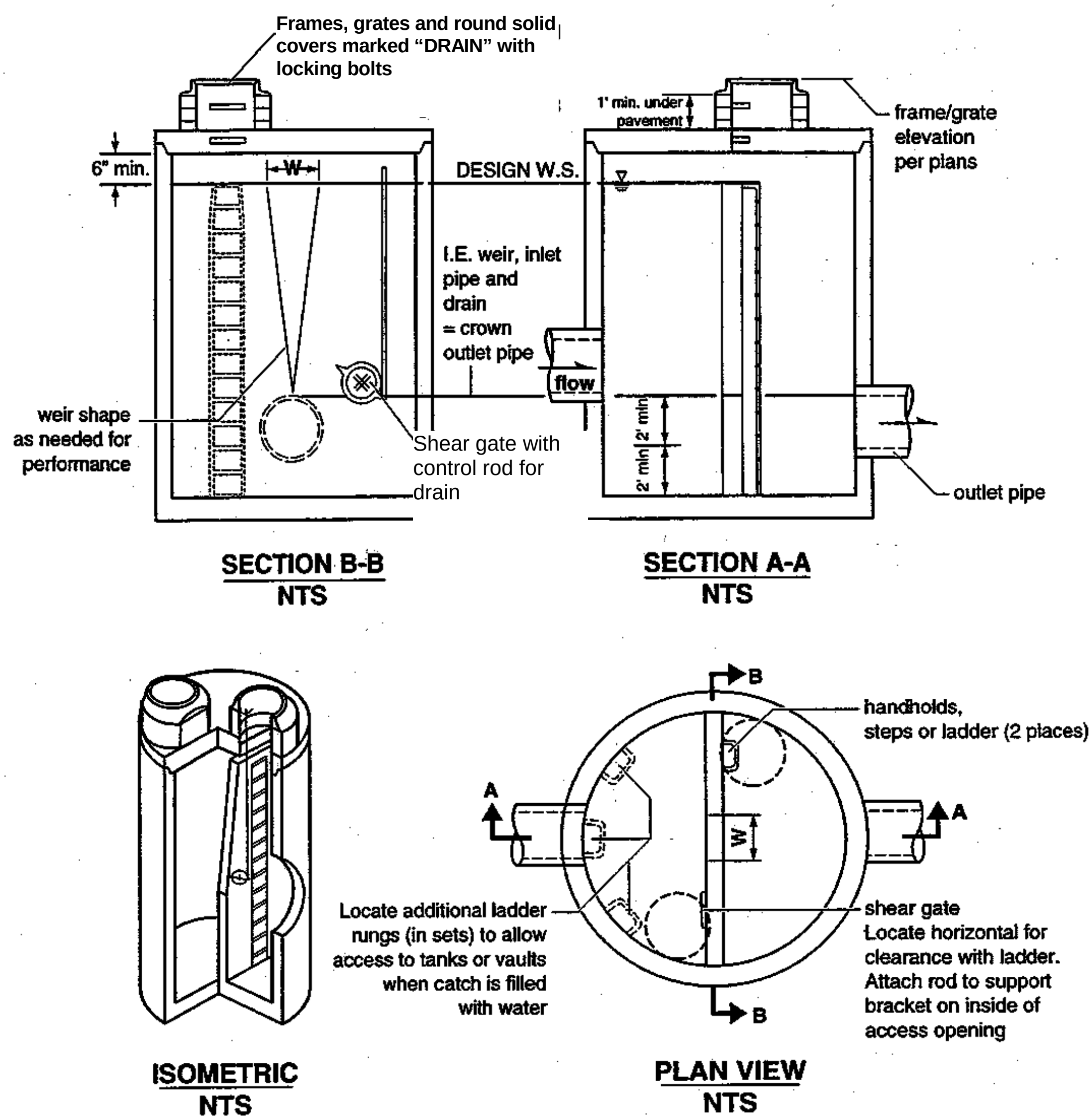




NOTES:

1. Use a minimum of a 54" diameter type 2 catch basin.
2. Outlet Capacity: 100-Year developed peak flow.
3. Metal Parts: Corrosion resistant. Non-Galvanized parts perferred. Galvanized pipe parts to have asphalt treatment 1.
4. Frame and ladder or steps offset so:
   A. Cleanout gate is visible from top.
   B. Climb-down space is clear of riser and cleanout gate.
   C. Frame is clear of curb.
5. If metal outlet pipe connects to cement concrete pipe: outlet pipe to have smooth O.D. equal to concrete pipe I.D. less 1/4"
6. Provide at least one 3" X .09 inches support bracket anchored to concrete wall. (maximum 3'-0" vertical spac
7. Locate elbow restrictor(s) as necessary to provide minimum clearance as shown.
8. Locate additional ladder rungs in structures used as access to tanks or vaults to allow access when catch basin is filled with water.

Figure 6.2.8 Flow Restrictor (TEE)



NOTES:

Outlet Capacity: 100-year developed peak flow.
Metal Parts: corrosion resistant steel parts galvanized and asphalt coated.
Catch Basin: type 2 Min. 72" diameter

Baffle Wall: to be designed with concrete reinforcing as required.
Spill containment must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill or illegal dumping.

Figure 6.2.9 Flow Restrictor (Weir)

Maintenance. Control structures and catch basins have a history of maintenance-related problems and it is imperative that a good maintenance program be established for their proper functioning. A typical problem is that sediment builds up inside the structure which blocks or restricts flow to the inlet. To prevent this problem these structures should be routinely cleaned out. Regular inspections of control structures should be conducted to detect the need for non-routine cleanout, especially if construction or land-disturbing activities are occurring in the contributing drainage area.

A 15-foot wide access road to the control structure should be installed for inspection and maintenance. Appendix 6A provides maintenance recommendations for control structures and catch basins.

Methods of Analysis

This section presents the methods and equations for design of control structure restrictor devices. Included are details for the design of orifices, rectangular sharp-crested weirs, v-notch weirs, sutro weirs, and overflow risers.

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

$$Q = C\,A\sqrt{2gh} \qquad \text{(Eq. 5.2.4)}$$

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 6.2.10 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:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(Eq. 5.2.5)}$$

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

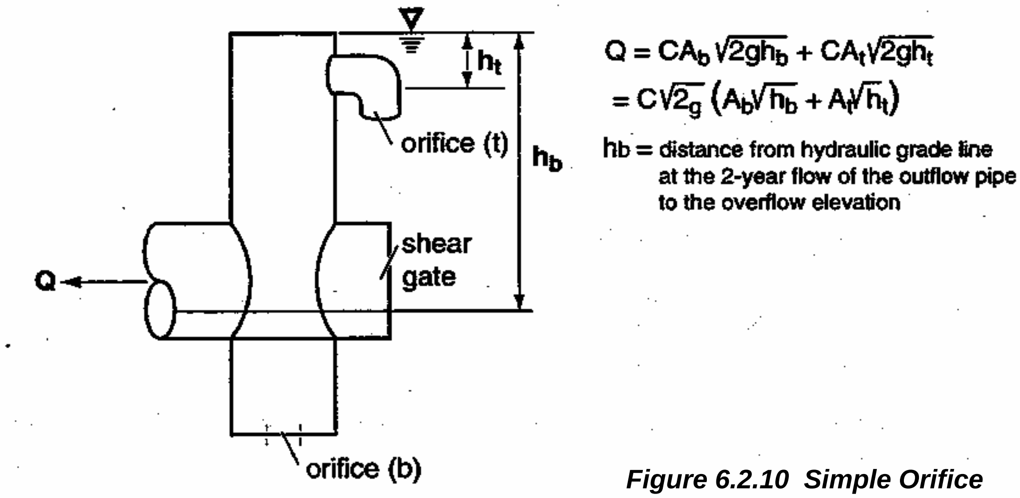


Figure 6.2.10 Simple Orifice

Rectangular Sharp-Crested Weir. The rectangular sharp-crested weir design shown in Figure 6.2.11 may be analyzed using standard weir equations for the fully contracted condition.

$$Q=C\,(L - 0.2H)H^{3/2} \qquad \text{(Eq. 5.2.6)}$$

where Q = flow (cfs)
C = 3.27 + 0.40 H/P (ft)
H, P are as shown below
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.*

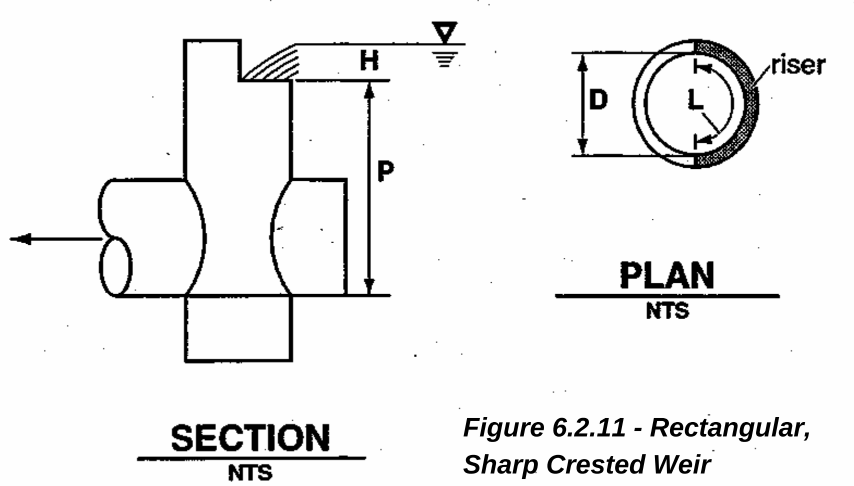
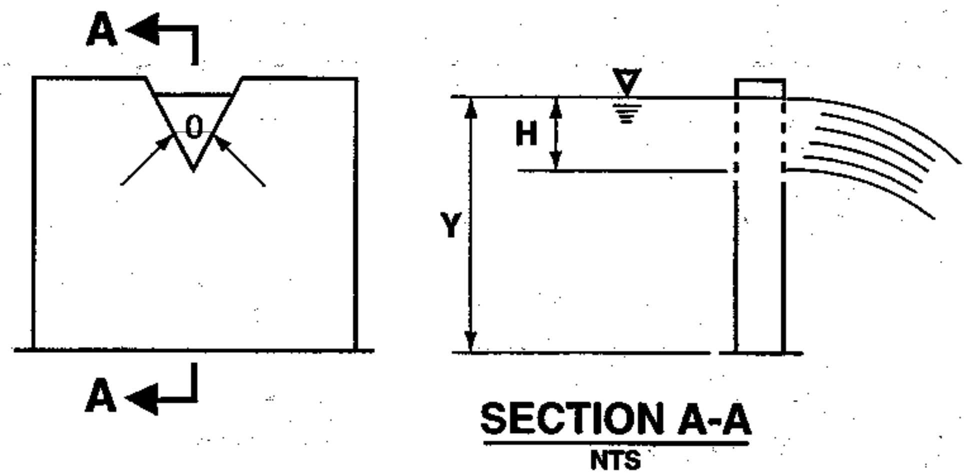


Figure 6.2.11 - Rectangular, Sharp Crested Weir

V-Notch Sharp-Crested Weir. V-notch weirs as shown in Figure 6.2.12 may be analyzed using standard equations for the fully contracted condition.



$$Q = C_d(\tan \theta/2)Y^{5/2}, \text{ in cfs}$$

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

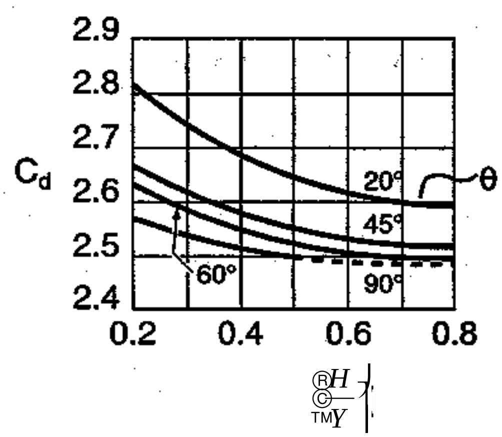
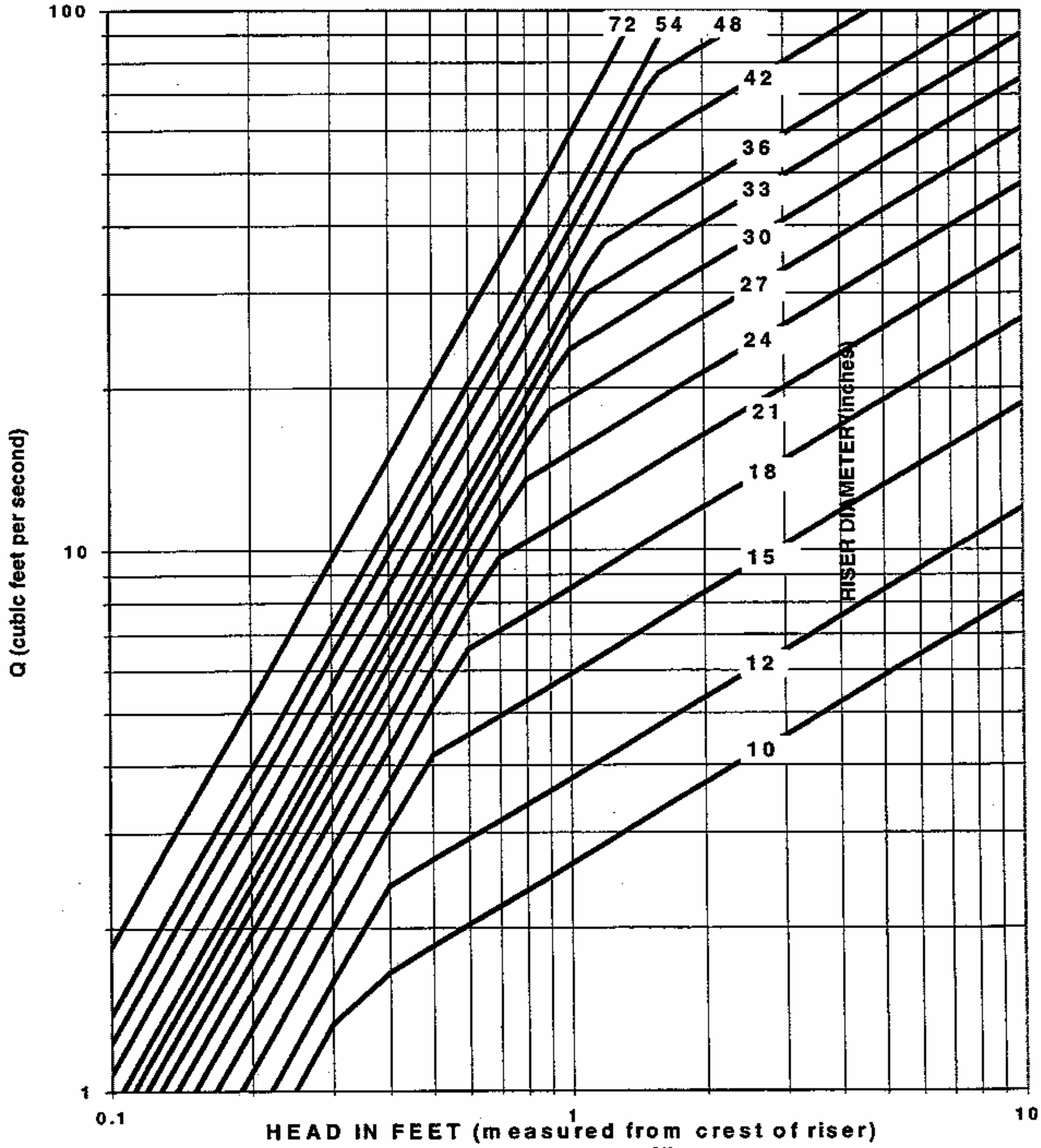


Figure 6.2.12 V-Notch, Sharp-Crested Weir

Riser Overflow. The nomograph in Figure 6.2.13 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 25-year peak flow for developed conditions).



$Q_{weir} = 9.739\ DH^{3/2}$

$Q_{orifice} = 3.782\ D^2 H^{1/2}$

Q in cfs, D and H in feet

Slope change occurs at weir-orifice transition

Figure 6.2.13 Riser Inflow Curves

6.2.5 Supplemental Guidelines for Detention

Use of Parking Lots for Additional Detention. Private parking lots may be used to provide additional detention volume for runoff events greater than the design storm, provided all of the following are met:

1. The depth of water detained does not exceed 1 foot at any location in the parking lot for runoff events up to and including the 100-year event.
2. The gradient of the parking lot area subject to ponding is 1 percent or greater.
3. The emergency overflow path is identified and noted on the engineering plan. The overflow must not create a significant adverse impact to downhill properties or drainage system.
4. Fire lanes used for emergency equipment are free of ponding water for all runoff events up to and including the 100-year event.

6.3 Infiltration of Stormwater for Quantity Control

6.3.1 Description

An infiltration BMP is typically an open basin (pond), trench, or buried perforated pipe used for distributing the stormwater runoff into the underlying soil (See Figure 6.3.2). Stormwater drywells receiving uncontaminated or properly treated stormwater can also be considered as infiltration facilities. (See Underground Injection Control Program, Chapter 173-218 WAC).

Coarser more permeable soils can be used for quantity control provided that the stormwater discharge does not cause a violation of ground water quality criteria. Treatment for removal of TSS, oil, and/or soluble pollutants may be necessary prior to conveyance to an infiltration BMP. Companion practices, such as street sweeping, catch basin inserts, and similar BMPs can provide additional benefit, and reduce the cleaning and maintenance needs for the infiltration facility. The hydraulic design goal should be to mimic the natural hydrologic balance between surface and groundwater.

6.3.2 Applications

Infiltration facilities are used to convey stormwater runoff from new development or redevelopment to the ground and ground water after appropriate treatment. Runoff in excess of the infiltration capacity must be detained and released in compliance with the flow control requirements of the local jurisdiction.

Infiltration facilities may be used for quantity control where treatment is not required or for flows greater than the water quality design storm, or where runoff is treated prior to discharge. See Susceptibility Rating

Tables 5.6.1 to 5.6.3 and the matrix of treatment requirements in Table 5.6.4 for determining when treatment is required prior to infiltration.

Discharge of uncontaminated or properly treated stormwater to drywells must be done in compliance with Ecology’s UIC regulations (Chapter 173-218 WAC).

Benefits of infiltration include:

- Ground water recharge
- Retrofits in limited land areas: Infiltration trenches can be considered for residential lots, commercial areas, parking lots, and open space areas.
- Flood control
- Streambank erosion control

Not all sites are suitable for infiltration facilities. The following Site Suitability Criteria should be considered when evaluating a site for its ability to utilize infiltration.

SSC-1 Setback Criteria

Setback requirements are generally required by local regulations, uniform building code requirements, or other state regulations.

These Setback Criteria are provided as guidance.

- Stormwater infiltration facilities should be set back at least 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, and special zones, must comply with Health Dept. requirements (Washington Wellhead Protection Program, DOH, 12/93).
- Additional setbacks must be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration system
- From building foundations; ∅20 feet downslope and ∅100 feet upslope
- From a Native Growth Protection Easement (NGPE); ∅20 feet
- The design professional should carefully consider and evaluate any situation where a pond will be situated upslope from a structure or behind the top of a slope inclined in excess of 15 percent. The minimum setback from such a slope is equal to 'h', the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation.
- 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.

SSC-2 Ground Water Protection Areas

A site is not suitable if the infiltration facility will cause a violation of Ecology's Ground Water Quality Standards. Local jurisdictions should be consulted for applicable pollutant removal requirements upstream of the infiltration facility, and to determine whether the site is located in an aquifer sensitive area, sole source aquifer, or a wellhead protection zone.

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, or ∅15,000 on any intersecting roadway.

SSC-4 Soil Infiltration Rate/Drawdown Time

Design to completely drain ponded runoff within 72 hours after flow to it has stopped.

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

The base of all infiltration basins or trench systems should 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 considered if the ground water mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures are judged by the design professional to be adequate to prevent overtopping and meet the site suitability criteria specified in this section.

SSC-6 Previously contaminated soils or unstable soils

The design professional should investigate whether the soil under the proposed infiltration facility has contaminants that could be transported by infiltrate from the facility. If so, measures should be taken for remediation of the site prior to construction of the facility, or an alternative location should be chosen. The designer should also determine if the soil beneath the proposed infiltration facility is unstable, due to improper placement of fill, subsurface geologic features, etc. If so, further investigation and planning should be undertaken prior to siting of the facility.

6.3.3 Determination of Infiltration Rates

Many qualitative and quantitative procedures have been developed to estimate the infiltration rates of soils, including those created by the American Society for Testing and Materials (ASTM), the Soil Conservation Service (SCS), American Association of State Highway and Transportation Officials (AASHTO), and the Bureau of Reclamation. Common field and laboratory test procedures include the constant-head permeability test, test pits, and the borehole percolation test.

A reliable, cost-effective approach to estimating infiltrative capacities of soils is based on standard laboratory grain size analysis (ASTM D2487-90) and/or Atterberg limits determinations (ASTM D4318-84), in conjunction with the ASTM D2488-90 visual/manual procedure. Guidance for conducting geotechnical studies that support presumptive infiltration rates are contained in Appendix 6B. Infiltration rates for surface BMPs are shown in Table 5.4.1.

6.3.4 General Design, Maintenance, and Construction Criteria for Infiltration Facilities

This section covers design, construction and maintenance criteria that apply to subsurface infiltration facilities such as drywells, infiltration basins, and trenches.

Design Criteria – Sizing Facilities

The size of the infiltration facility can be determined by routing the appropriate stormwater runoff through it. To prevent the onset of anaerobic conditions, the infiltration facility must be designed to drain completely 72 hours after the flow to it has stopped.

Inflow to infiltration facilities is calculated according to the methods described in Chapter 4. The storage volume in the pond, drywell, perforated pipe, or voids in the gravel, is used to detain runoff prior to infiltration. The infiltration rate and size of the infiltration area are used in conjunction with the size of the storage area to design the facility.

In general, an infiltration facility should have 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 requirements of the local jurisdiction.

Additional Design Criteria

- Slope of the base of the infiltration facility should be less than 3 percent.
- Spillways/Overflow structures- A nonerodible outlet or spillway with a firmly established elevation must be constructed to discharge overflow. Ponding depth, drawdown time, and storage volume are calculated from that reference point.

Construction Criteria

- Excavate infiltration trenches and basins to final grade only after construction has been completed and all upgradient soil has been stabilized. Initial basin excavation should be conducted to within 1-foot of the final elevation of the basin floor. Any accumulation of silt in the infiltration facility must be removed before putting it in service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.
- Infiltration facilities should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized.
- Traffic Control - Relatively light-tracked equipment is recommended for this operation to avoid compaction of the basin floor. The use of draglines and trackhoes should be considered for constructing infiltration basins. The infiltration area should be flagged or marked to keep heavy equipment away.

Maintenance Criteria

- Provision should be made for regular and perpetual maintenance of the infiltration basin/trench, with adequate access. Maintenance should be conducted when water remains in the basin or trench for more than 72 hours. An Operation and Maintenance Plan, approved by the local jurisdiction, should ensure maintaining the desired infiltration rate.
- Debris/sediment accumulation- Removal of accumulated debris/sediment in the basin/trench should be conducted every 6 months or as needed to prevent clogging, or when water remains in the pond for greater than 72 hours.
- 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.

Verification of Performance

- During the initial operation, verification of facility performance is recommended, along with a maintenance program that results in achieving expected performance levels. Operating and maintaining ground water monitoring wells is also encouraged.

6.3.5 BMP F 6.20 Drywells

This section covers design and maintenance criteria specific for drywells.

Description

Drywells are subsurface concrete structures, typically precast, that convey stormwater runoff into the soil matrix. They can be used as standalone structures, or as part of a larger drainage system (i.e., the overflow for a bio-infiltration swale).

Design Criteria for Infiltration Drywells

Figures 6.3.1 through 6.3.3 show typical infiltration drywell systems (at the time of publication of this document). These systems are designed as specified below.

Drywell bottoms should be a minimum of 5 feet above seasonal high groundwater level or impermeable soil layers. Refer to the Site Suitability Criteria in this chapter.

Typically drywells are 48 inches in diameter (minimum) and have a depth of approximately 5 to 10 feet, or more.

Filter fabric (geotextile) may need to be placed on top of the drain rock and on trench or drywell sides prior to backfilling to prevent migration of fines into the drain rock, depending on local soil conditions and local jurisdiction requirements.

Drywells should be no closer than 30 feet center to center or twice the depth in free flowing soils, whichever is greater.

Drywells should 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 qualified geologist and jurisdiction approval.

Maintenance Criteria for Drywells

- Remove debris and sediment from the drywell grate on a semi-annual basis, or as required to prevent the buildup of materials that could inhibit infiltration.

City of East Wenatchee Standard Detail

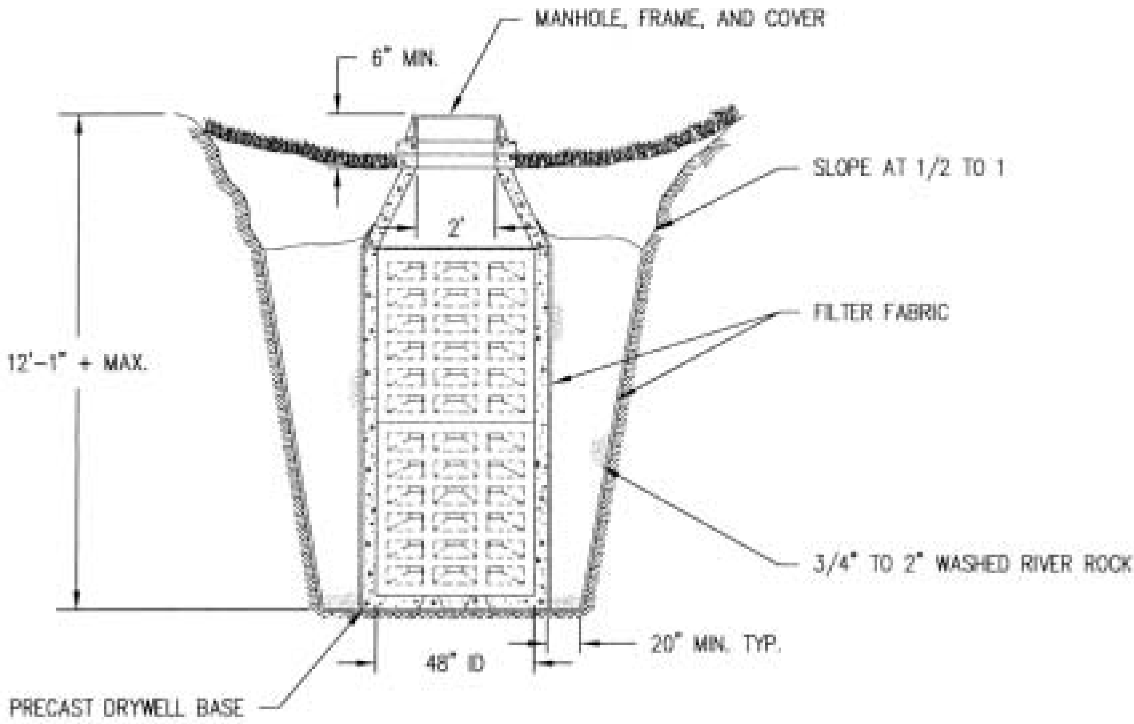


Figure 6.3.1 - Sample Infiltration Drywell (not to scale)

Spokane County Standard Detail

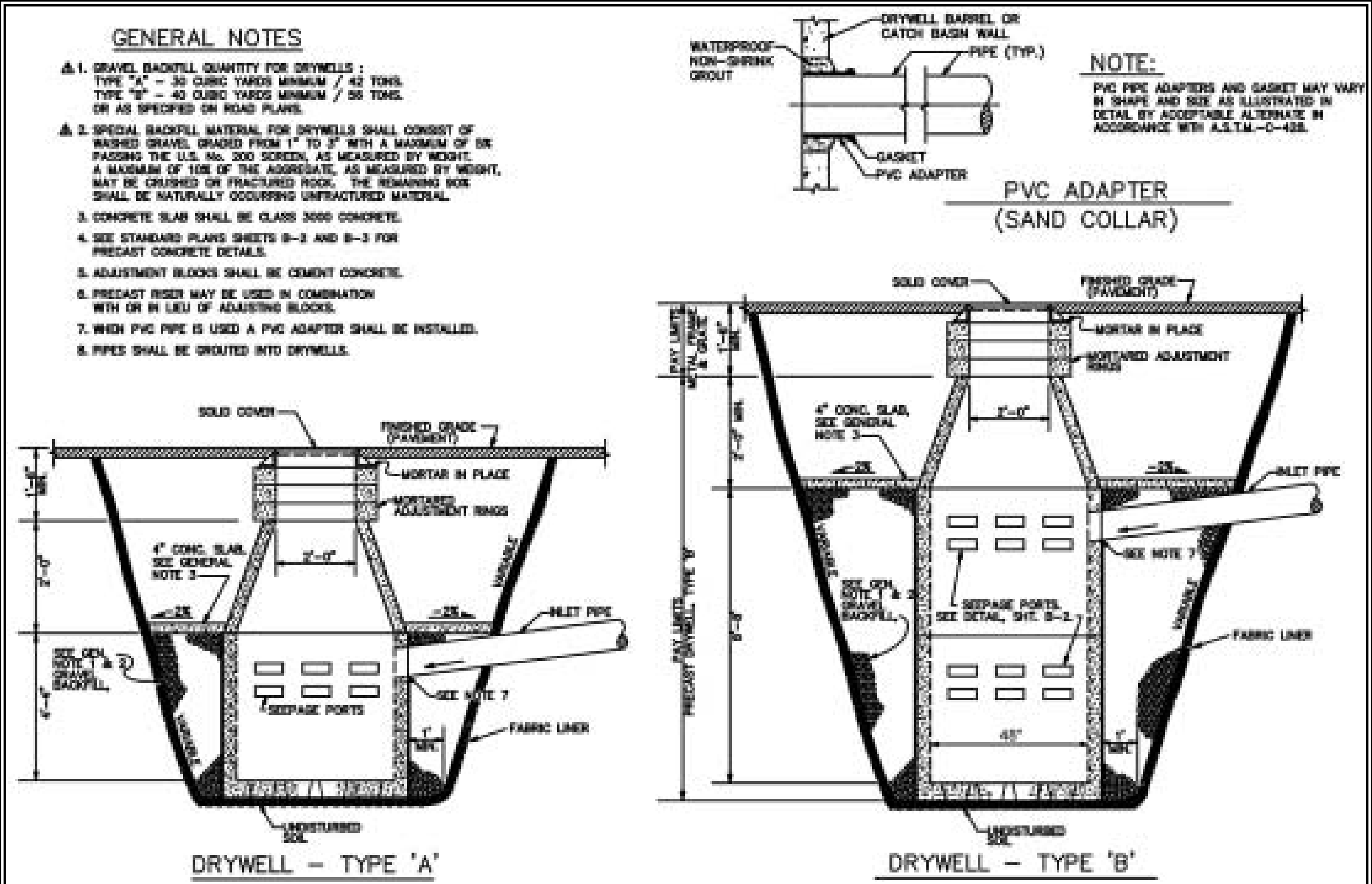


Figure 6.3.2 - Sample Infiltration Drywell

FINAL DRAFT

City of Kennewick Standard Detail

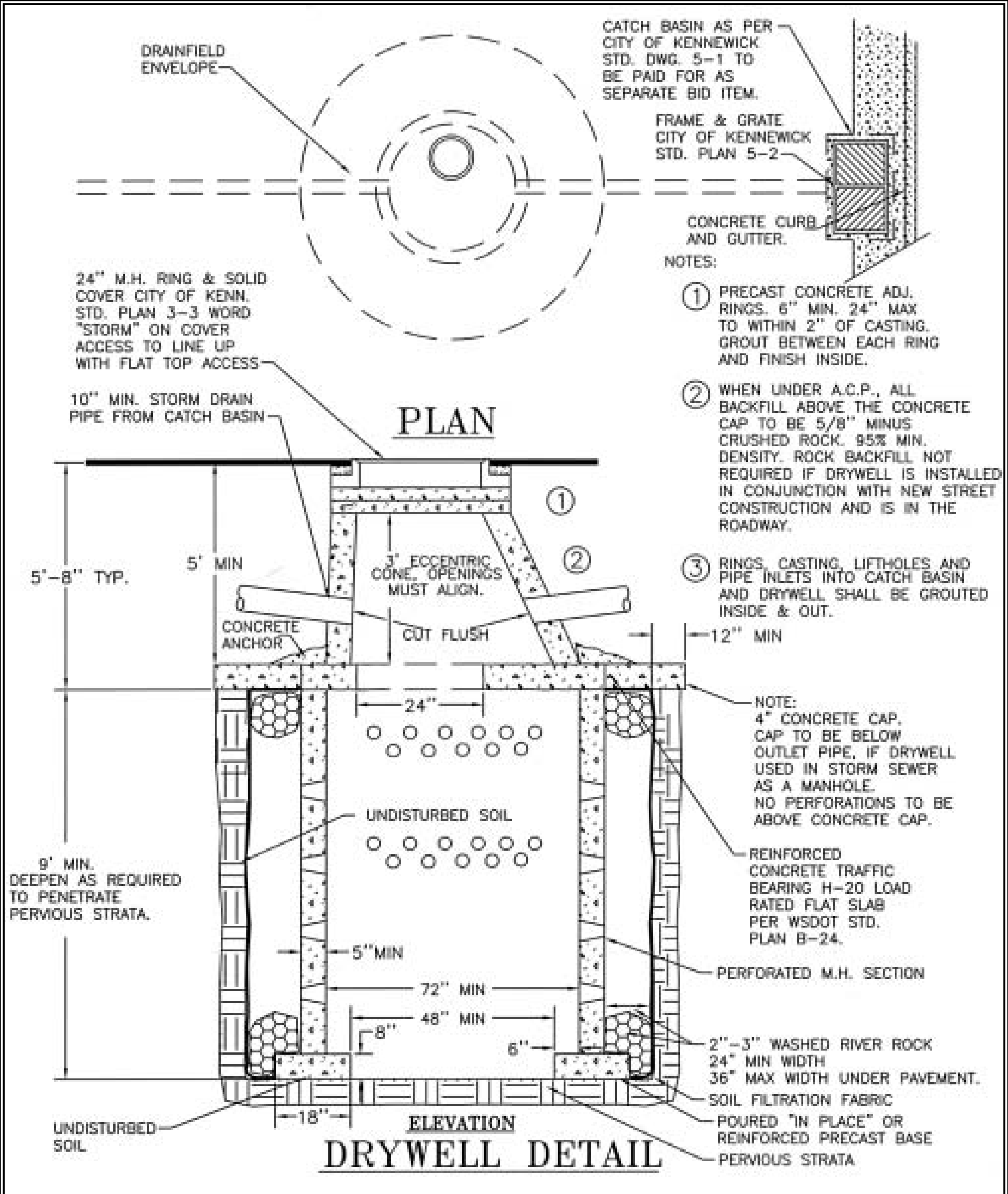


Figure 6.3.3 - Sample Infiltration Drywell

6.3.6 BMP F 6.21 Infiltration Ponds

This section covers design and maintenance criteria specific for infiltration ponds (see schematic in Figure 6.3.4).

Description

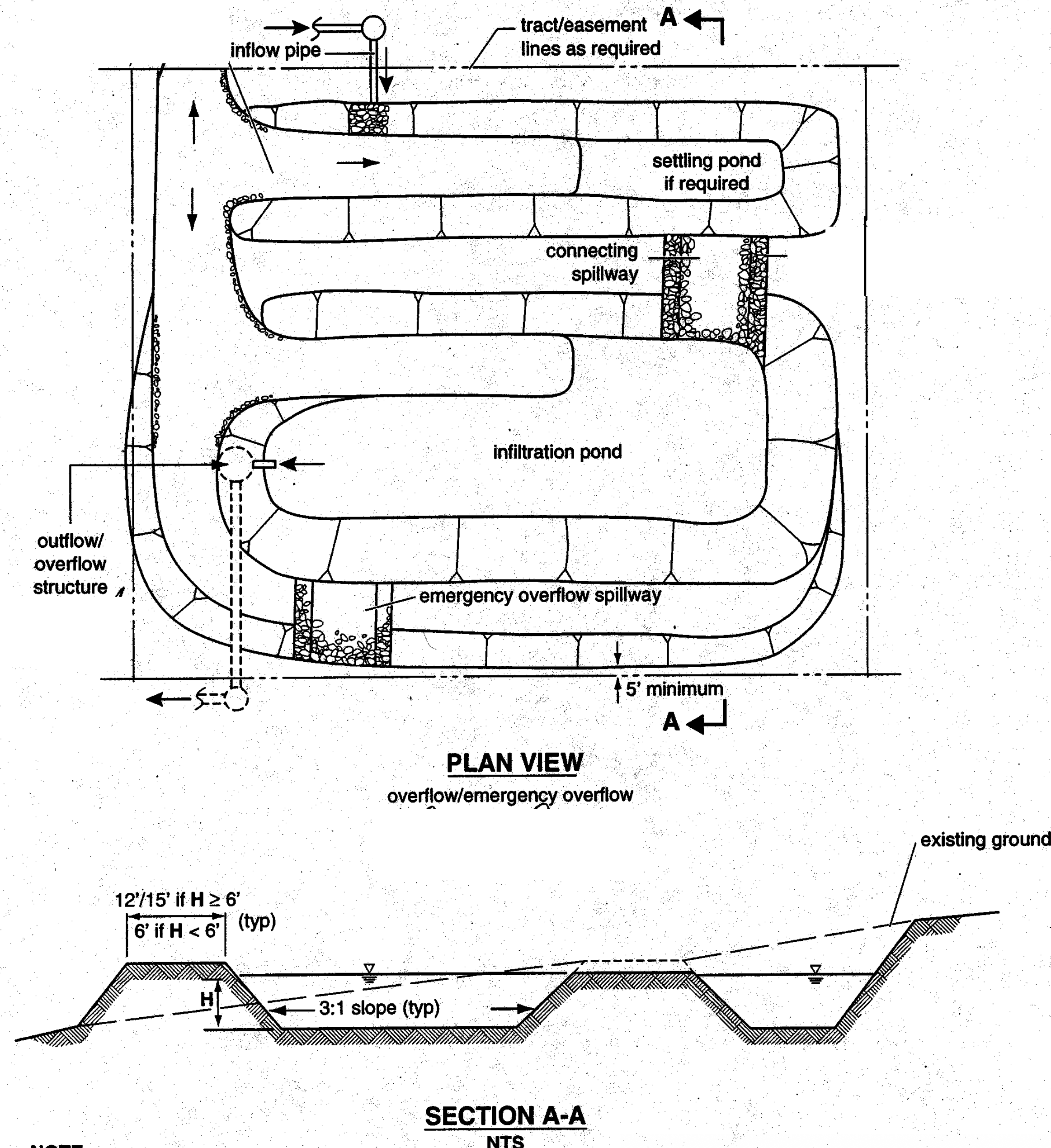
Infiltration ponds are earthen impoundments used for the collection, temporary storage and infiltration of incoming stormwater runoff. See Table 5.4.1 for design infiltration rates.

Design Criteria for Infiltration Ponds

- Access should be provided for vehicles to easily maintain the forebay (presettling pond) area and not disturb vegetation, or resuspend sediment any more than is necessary. See Section 6.2.1 for design criteria regarding access roads.
- A minimum of one foot of freeboard is recommended when establishing the design ponded water depth. Freeboard is measured from the rim of the infiltration facility to the maximum ponding level or from the rim down to the overflow point if overflow or a spillway is included.
- Lining Material - Ponds can be open or covered with a 6 to 12-inch layer of filter material such as coarse sand, or a suitable filter fabric to help prevent the buildup of impervious deposits on the soil surface. A nonwoven geotextile should be selected that will function sufficiently without plugging. The filter layer can be replaced or cleaned when/if it becomes clogged.
- Vegetation – The embankment, emergency spillways, spoil and borrow areas, and other disturbed areas should be stabilized and planted, preferably with grass, in accordance with the Stormwater Site Plan (See Chapter 3). Without healthy vegetation the surface soil pores would quickly plug.

Maintenance Criteria for Infiltration Ponds

- Maintain pond floor and side slopes to minimize erosion. This enhances infiltration, prevents erosion and consequent sedimentation of the pond floor, and prevents invasive weed growth. Where appropriate, bare spots are to be immediately stabilized and revegetated.
- Vegetation growth should not be allowed to exceed 18 inches in height. Mow the slopes periodically and check for clogging, and erosion.
- Seed mixtures should be appropriate for the climate. The use of slow-growing, stoloniferous grasses will permit long intervals between mowing. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to ground water pollution. Consult the local extension agency for appropriate fertilizer types, including slow release fertilizers, and application rates.



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

Figure 6.3.4 Typical Infiltration Pond

6.3.7 BMP F 6.22 Infiltration Trenches

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. Perforated rigid pipe of at least 8-inch diameter can also be used to distribute the stormwater in a stone trench.
- See Figures 6.3.5 - 6.3.9 for examples of trench designs.

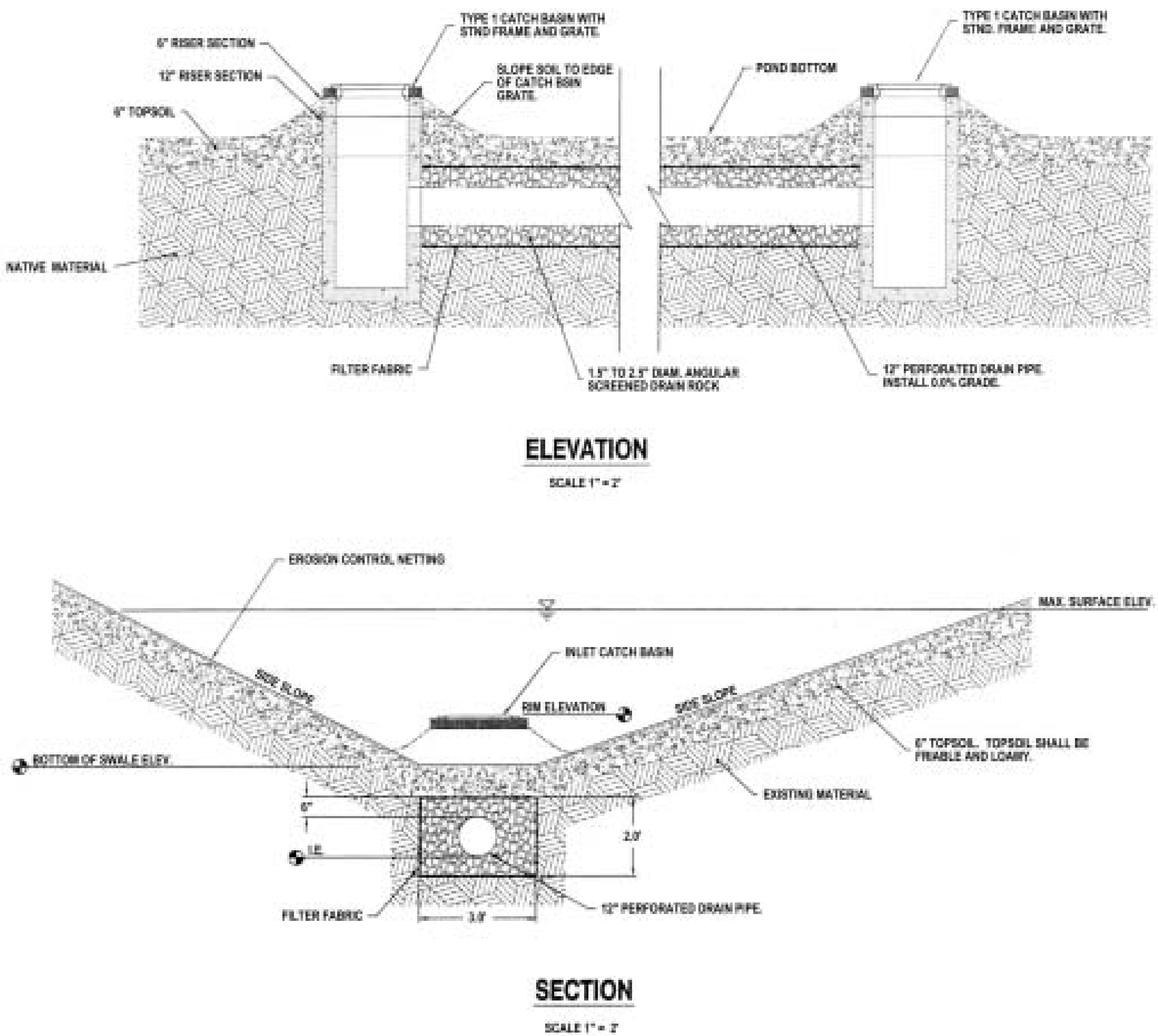


Figure 6.3.6 Sample Infiltration Trench/Pond with Catch Basin Inlet

(courtesy RH2 Engineering, Inc., Wenatchee)

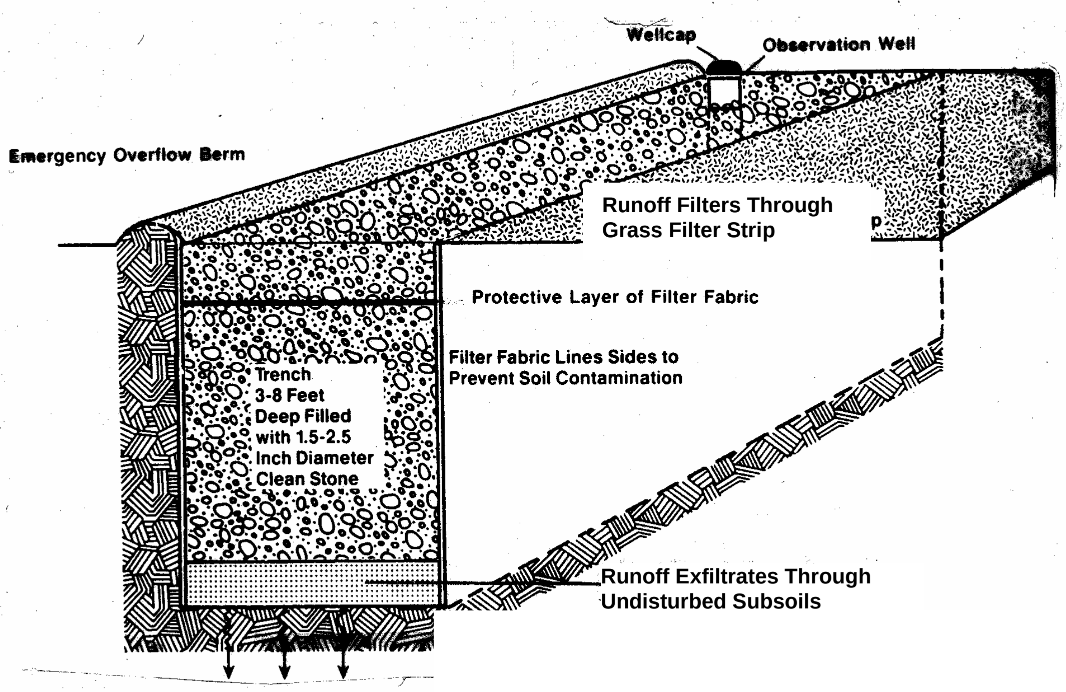


Figure 6.3.7 Schematic of Infiltration Trench

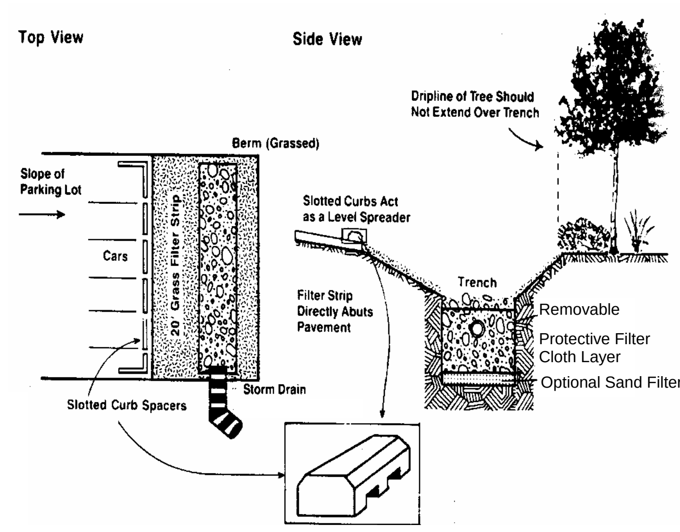


Figure 6.3.8 Parking Lot Perimeter Trench Design

Source: Schueler (reproduced with permission)

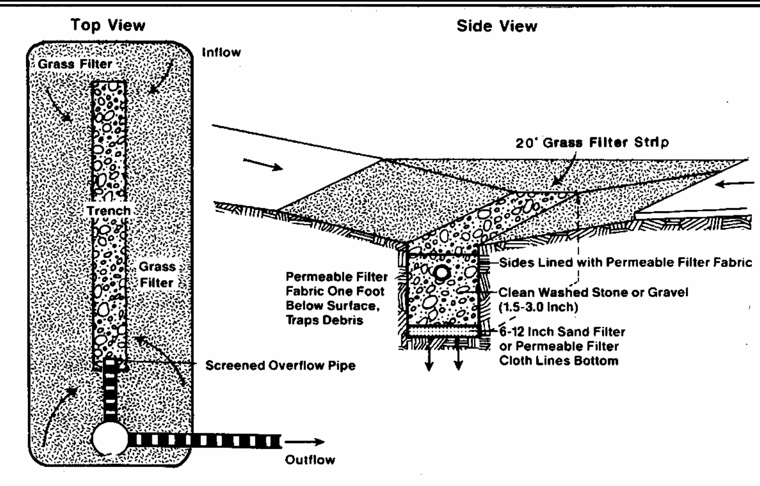


Figure 6.3.9 Median Strip Trench Design

Source: Schueler (reproduced with permission)

Design Criteria

- Due to accessibility and maintenance limitations infiltration trenches must be carefully designed and constructed. The local jurisdiction should be contacted for additional specifications.
- Consider including an access port or open or grated top for accessibility to conduct inspections and maintenance.
- Backfill Material - The aggregate material for the infiltration trench should consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. Void space for these aggregates should be in the range of 30 to 40 percent. For calculations assume a void space of 30 percent maximum.
- Perforated Pipe - a minimum of 8-inch perforated pipe should be provided to increase the storage capacity of the infiltration trench and to enhance conveyance of flows throughout the trench area.
- Geotextile fabric liner - The aggregate fill material shall be completely encased in an engineering geotextile material. In the case of an aggregate surface, geotextile should surround all of the aggregate fill material except for the top one-foot, which is placed over the geotextile. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging.
- The bottom sand or geotextile fabric as shown in the attached figures is optional.

Refer to the WSDOT Design Manual, Section 530, pages 1 through 24, which discusses geosynthetics. This section contains information on functions and applications, types and characteristics, and design *approaches. The WSDOT 2002 Standard Specifications, English units version, section 9-33, includes specifications for geotextiles, classed pursuant to the design manual discussions and definitions.*

Refer to the Federal Highway Administration Manual "Geosynthetic Design and Construction Guidelines," Publication No. FHWA HI-95-038, May 1995 for design guidance on geotextiles in drainage applications. Refer to the NCHRP Report 367, "Long-Term Performance of Geosynthetics in Drainage Applications," 1994, for long-term performance data and background on the potential for geotextiles to clog, blind, or to allow piping to occur and how to design for these issues.

- Surface Cover - A stone filled trench can be placed under a porous or impervious surface cover to conserve space.
- Observation Well - An observation well should be installed at the lower end of the infiltration trench to check water levels, drawdown time, sediment accumulation, and conduct water quality monitoring. Figure 6.3.10 illustrates observation well details. It should consist of a perforated PVC pipe which is 4 to 6 inches in diameter and it should be constructed flush with the ground elevation. For larger trenches a 12-36 inch diameter well can be installed to facilitate maintenance operations such as pumping out the sediment. The top of the well should be capped to discourage vandalism and tampering.
- Catch Basin and Tee - A tee section should be provided in the nearest catch basin upstream of the infiltration trench if a catch basin is used (see Figure 6.3.5). The tee will trap floatable debris and oils.

Construction Criteria

- Trench Preparation - Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care should also be taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic.
- Stone Aggregate Placement and Compaction - The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.
- Potential Contamination - Prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate must be removed and replaced with uncontaminated stone aggregate.
- Overlapping and Covering - Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. When overlaps are required

between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

∉ Voids behind Geotextile - Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. Soil piping, geotextile clogging, and possible surface subsidence should be avoided by this remedial process.

∉ Unstable Excavation Sites - Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. Trapezoidal, rather than rectangular, cross-sections may be needed.

Maintenance Criteria

∉ Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well.

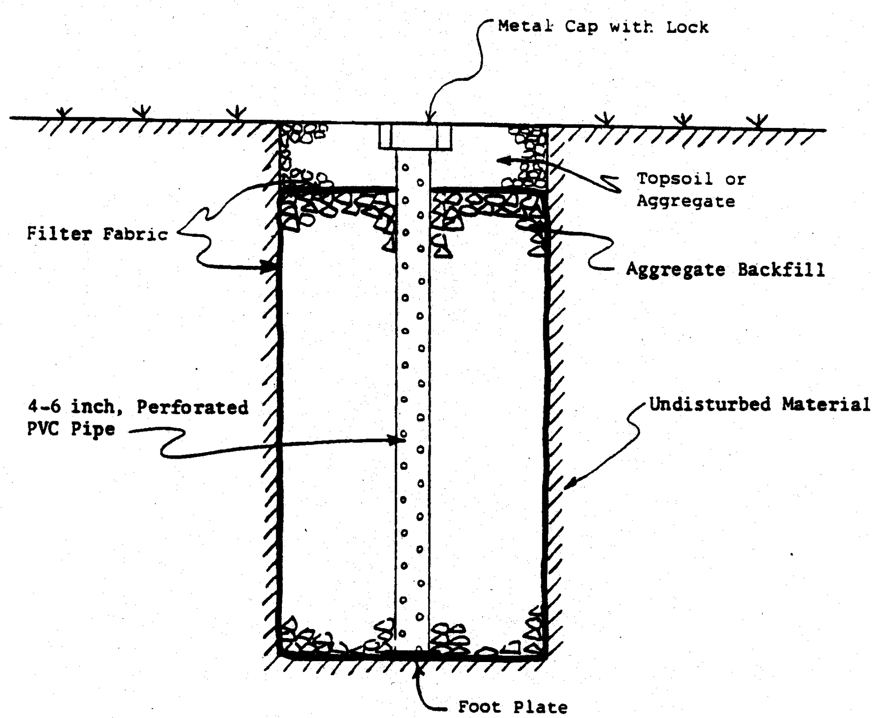


Figure 6.3.10 Observation Well Details

6.4 Evaporation Ponds

This section provides the methods for the design of evaporation ponds, which can be used to collect and dispose of stormwater when surface discharge is not available or the soils are not conducive to infiltration facilities.

For the design of evaporative facilities, a water budget is required. A cumulative, month-by-month water budget is performed as follows:

Vin - Vout = φVmonth

Ɇ Vmonth = φVyear

Where:

V_{in} Volume of water into evaporative facility, (usually cubic ft./month). V_{in} is a combination of stormwater runoff, direct rainfall onto the pond surface, groundwater seepage into evaporative facility, and any other source of water into the facility.

V_{out} Volume of water out of the evaporative facility (usually a cubic ft/month). V_{out} is all outflows, it can be a combination surface evaporation, plant evapotranspiration, ground infiltration, or any other qualified outflow.

φV_{month} Net volume of storage increase (or decrease) into the evaporative facility (usually cubic ft./month).

φV_{year} Cumulative net volume of storage in evaporative facility until storage equilibrium is obtained. Equilibrium is obtained when the volume of water in the cycle is less than the volume stored at the beginning of the cycle, evaluated over at least two calendar years.

It is recommended that a freeboard of at least 1 foot be maintained in the pond at all times. The use of a spreadsheet to perform the calculations can be helpful.

The water budget cycle should be performed on a month-by-month basis, until a steady-state condition occurs (i.e., the volume at the end of the cycle is less than or equal to the volume at the start of the cycle). The minimum duration of the water budget cycle is to be two years. The cycle is to start in the month which yields the greatest net storage volume for the year. Normally, beginning the water budget in September, October, or November produces the largest required storage volume. Contributing off-site areas are to be included in the analysis, considering existing locations.

The climatological data source for evaporation and mean annual precipitation rates used in the water budget are available from the National Oceanic and Atmospheric Administration (NOAA), or other reliable sources. The Western Region Climate Center maintains data for several western states (http://www.wrcc.dri.edu/summary/climsmwa.html). Average monthly precipitation rates and average monthly evaporation rates should be used in the water budget analysis, as a minimum.

6.4.1 Runoff Volume Determinations

Runoff volume from the basin directing stormwater into the evaporative systems shall be included in the water budget analysis. Runoff volume can be determined using the SCS hydrographic method, or other methods approved by the local jurisdiction.

When preparing the water budget, antecedent moisture conditions need to be considered during the months of the year when the ground may be saturated or frozen. For the SCS method the curve numbers (CN) should be adjusted as shown in Table 6.4.1 and Section 4.5. This requirement is applicable in climatic regions 1, 3, and 4 only. Climatic region 2 should use AMC II curve numbers throughout the year.

Table 6.4.1
Curve Number Adjustment for Antecedent Moisture Condition

Month	Antecedent Moisture Condition (AMC)	Minimum Runoff Curve Number (CN)
April-October	Normal (AMC = II)	See Table 4.5.2
November, March	Wet (AMC = III)	See Table 4.5.3
December-February	-	95

Water loss through evaporation from overland surface areas is normally not to be considered in the water budget, for the areas contributing runoff to the evaporative pond(s), due to the wide variation in evaporative rates which occur over these types of surfaces. The only reduction which can be considered in the analysis is runoff interception and surface infiltration, which is normally accounted for in the SCS curve members or rational coefficients.

Disposal is primarily through evaporation from the pond surface. Credit for infiltration through soils will not be considered in the water budget analysis in the absence of any site specific infiltration testing work being performed.

Geosynthetic or natural liners may be used to limit infiltration outflow volumes in areas where this is desired, or in locations where the seasonal water table will adversely impact the pond.

6.4.2 Other Design Considerations

When credit for infiltration is proposed, site characterization, testing, and reporting is to be done in accordance with Section 6.3.

The design of the evaporative pond facility will need to evaluate the potential of groundwater seeping into the pond from the surrounding area for an unlined pond and evaluate the potential for groundwater mounding or uplift for a lined pond. A geotechnical evaluation should be performed, evaluating this potential negative impact, and, if needed, mitigation measures should be provided.

Sources of imported water need to be considered in the water budget design and calculations. Other sources may include irrigation, sewer septic tank/drainfield systems, natural springs, foundation drains, de-watering wells, etc. The geotechnical engineer shall address this issue in his/her report, and the designer should include any imported water in the water budget analysis.

The maximum water surface elevation permissible in the water budget is to be below the finish floor elevations of the surrounding buildings (existing or proposed). Privately owned parking lot areas, can be used for temporary storage of stormwater and considered in the water budget analysis. If ponding is proposed in parking lot areas, the maximum water depth should normally not exceed 1 foot.

If snow removal operations deposit snow into an evaporative system, this added factor must be considered in the water budget, especially if snow from another basin is put into the system. Temporary sediment ponds should to be included in the design, to prevent sediment-laden runoff from entering the pond and storm disposal system during construction.

6.5 Natural Dispersion

Natural dispersion attempts to minimize the hydrologic changes created by new impervious surfaces by restoring the natural drainage patterns of sheet flow and infiltration. There are three types of natural dispersion. They are:

- BMP F6.40 Concentrated Flow Dispersion
- BMP F6.41 Sheet Flow Dispersion
- BMP F6.42 Full Dispersion

6.5.1 BMP F6.40 Concentrated Flow Dispersion

Purpose and Definition

Dispersion of concentrated flows from driveways or other pavement through a vegetated pervious area attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits.

Applications and Limitations

- Any situation where concentrated flow can be dispersed through vegetation.
- Dispersion for driveways will generally only be effective for single-family residences on large lots and in rural short plats. Lots proposed by short plats in urban areas will generally be too small to provide effective dispersion of driveway runoff.
- Figure 6.5.1 shows two possible ways of spreading flows from steep driveways.

Design Guidelines

- A vegetated flowpath of at least 50 feet should be maintained between the discharge point and any property line, structure, steep slope, stream, lake, wetland, lake, or other impervious surface.
- A maximum of 700 square feet of impervious area may drain to each dispersion BMP.
- A pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each discharge point.
- No erosion or flooding of downstream properties may result.
- Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. The discharge point shall not be placed on or above slopes greater than 6:1 or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by the local jurisdiction.
- For sites with septic systems, the discharge point should be downgradient of the drainfield primary and reserve areas. This requirement may be waived by the local jurisdiction if site topography clearly prohibits flows from intersecting the drainfield.

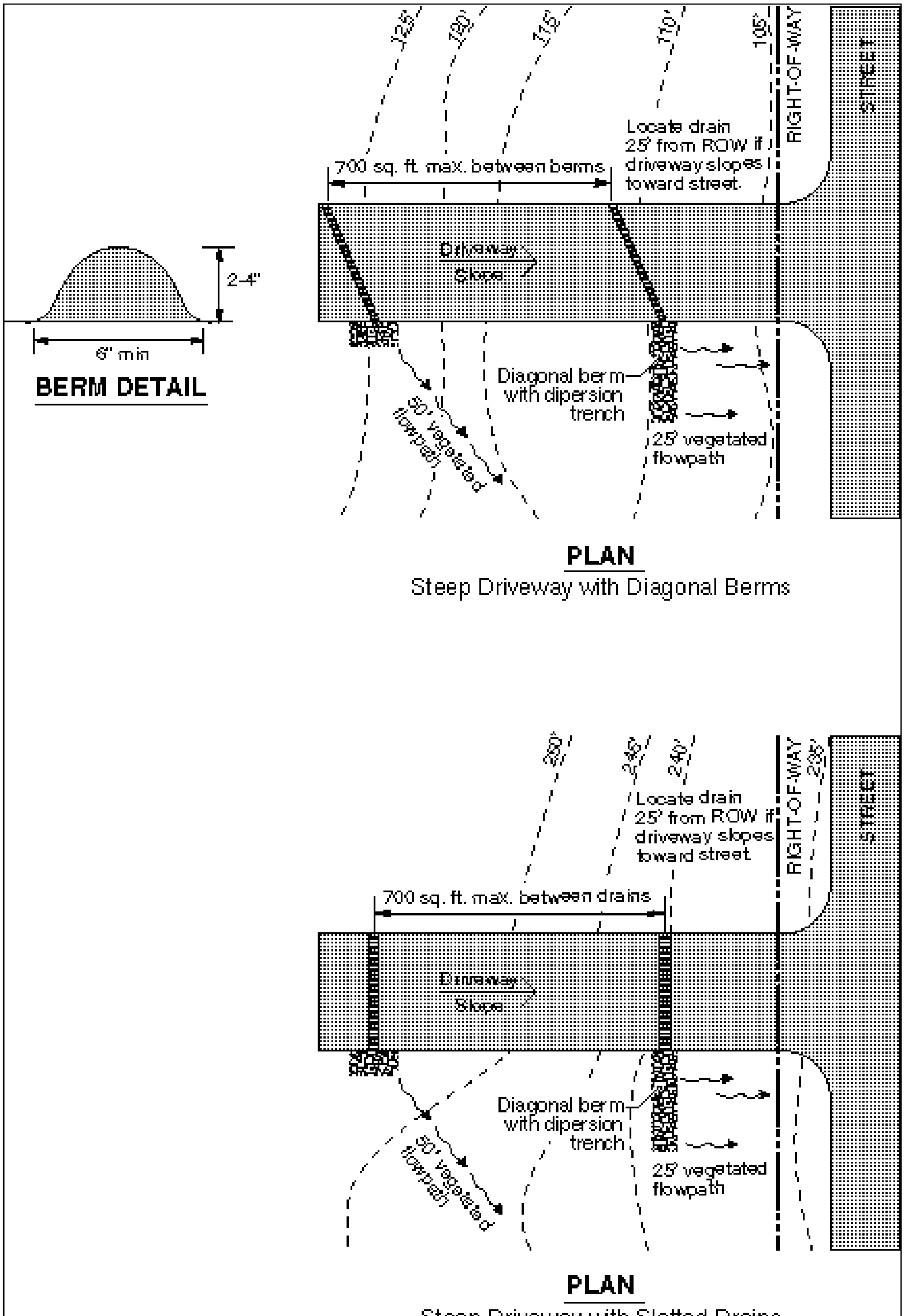


Figure 6.5.1 Typical Concentrated Flow Dispersion for Steep Driveways

6.5.2 BMP F6.41 Sheet Flow Dispersion

Purpose and Definition

Sheet flow dispersion is the simplest method of runoff control. This BMP can be used for any impervious or pervious surface that is graded so as to avoid concentrating flows. Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective attenuation and treatment.

Applications and Limitations

Flat or moderately sloping (<15% slope) impervious surfaces such as driveways, sport courts, patios, and roofs without gutters; sloping cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture; or any situation where concentration of flows can be avoided.

Design Guidelines

- See Figure 6.5.2 for details for driveways.
- A 2-foot-wide transition zone to discourage channeling should be provided between the edge of the driveway pavement and the downslope vegetation, or under building eaves. This may be an extension of subgrade material (crushed rock), modular pavement, drain rock, or other material acceptable to the local jurisdiction.
- A vegetated buffer width of 10 feet of vegetation must be provided for up to 20 feet of width of paved or impervious surface. An additional 5 feet of width must be added for each addition 20 feet of width or fraction thereof.
- A vegetated buffer width of 25 feet of vegetation must be provided for up to 150 feet of contributing cleared area (i.e., bare soil, non-native landscaping, lawn, and/or pasture). Slopes within the 25-foot minimum flowpath through vegetation should be no steeper than 8 percent. If this criterion cannot be met due to site constraints, the 25-foot flowpath length must be increased 1.5 feet for each percent increase in slope above 8%.
- No erosion or flooding of downstream properties may result.
- Runoff discharge toward landslide hazard areas must be evaluated by a geotechnical engineer or a qualified geologist. The discharge point may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by the local jurisdiction.
- For sites with septic systems, the discharge point must be downgradient of the drainfield primary and reserve areas. This requirement may be waived by the local jurisdiction if site topography clearly prohibits flows from intersecting the drainfield.

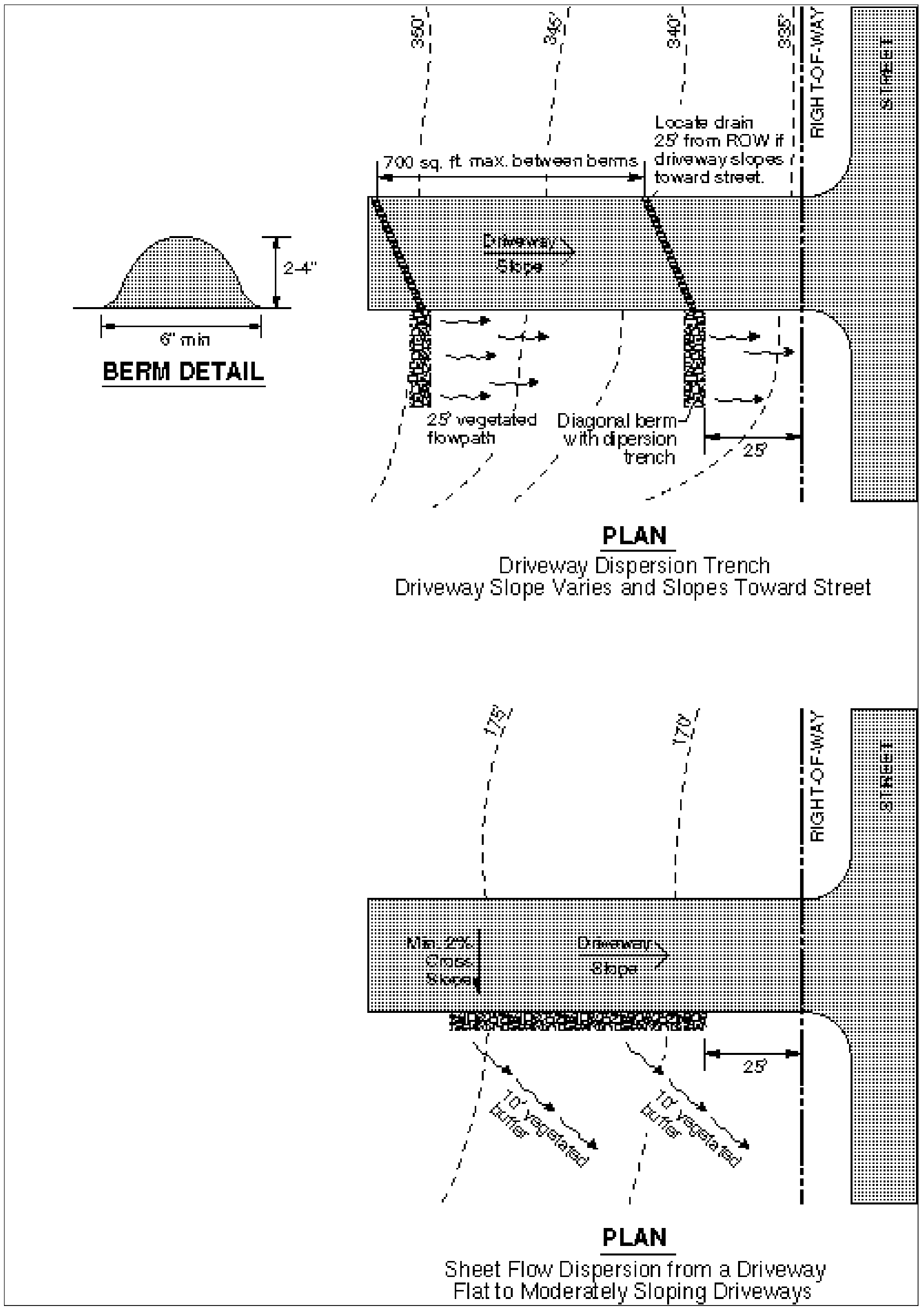


Figure 6.5.2 Sheet Flow Dispersion for Driveways

6.5.3 BMP F6.42 Full Dispersion

Note to reviewers: *This BMP was proposed at the last meeting of the Manual Subcommittee during consideration of comments received during the first public comment period. The text below has not been reviewed by the Subcommittee. We include it here to solicit your input and to notify you that we intend to develop a BMP for full dispersion for the final Manual. Please provide your comments, suggestions and concerns.*

Purpose and Definition

This BMP allows for "fully dispersing" runoff from impervious surfaces and cleared areas of commercial and residential development sites that protect a portion of the site (or for large sites, a portion of an area within a sub-basin drainage on the site) in a natural, native vegetation cover condition. Natural vegetation is preserved and maintained in accordance with the guidelines of BMP T5.20 [SWMMWW]. Runoff from roofs, driveways, and roads within the development is dispersed within the site by utilizing the areas of preserved vegetation.

Applications and Limitations

- Up to 10% of the site that is impervious surface can be rendered non-effective impervious area by dispersing runoff from it into the native vegetation area. Any additional impervious areas (this BMP recommends limiting additional impervious areas to not more than another 10% for rural areas) are considered effective impervious surfaces with the exception of roofs served by drywells.
- Types of development that retain a percentage of the site (or for large sites, a portion of an area within a sub-basin drainage on the site) in a forested natural, native vegetation cover condition may also use these BMPs to avoid triggering the flow control facility requirement or to minimize its use at the site.

Design Guidelines

Impervious areas of residential developments can meet treatment and flow control requirements by distributing runoff into native vegetation areas that meet the limitations and design guidelines below if the ratio of impervious area to native vegetation area does not exceed 15%. Vegetation must be preserved and maintained according to the requirements of BMP T5.20 [SWMMWW].

The requirement operates on a “sliding scale” comparing the percentage of the site with undisturbed native vegetation to the percentage of the site with impervious surface that drains into those areas of preserved native vegetation:

% of site with impervious surface that drains into native vegetation area	% of site with undisturbed native vegetation
10.0	65
9.0	60
8.25	55
7.5	50
6.75	45
6.0	40
5.25	35
4.5	30
3.75	25
3.0	20

- **Roof Downspouts**

  Roof surfaces that are connected to drywells are considered “fully dispersed” provided that they are designed according to local requirements. Otherwise, the roof runoff is assumed to run into the street, and that volume must be added to the volume dispersed in the roadway dispersion component of this BMP.

- **Driveway Dispersion**

  Driveway surfaces are considered to be "fully dispersed" if the site meets the required ratio of impervious surfaces to preserved native vegetation above, <u>and</u> if they comply with the driveway dispersion BMPs – BMP T6.40 and BMP T6.41 - and have flow paths through native vegetation exceeding 100 feet. This also holds true for any driveway surfaces that comply with the roadway dispersion BMPs described below.

- **Roadway Dispersion BMPs**

  Roadway surfaces are considered to be "fully dispersed" if the site meets the required ratio of impervious surfaces to preserved native vegetation above, <u>and</u> if they comply with the following dispersion requirements:

  1. Roadway runoff dispersion is allowed only on rural neighborhood collectors and local access streets. To the extent feasible, driveways should be dispersed to the same standards as roadways to ensure adequate water quality protection of downstream resources.

  2. The road section shall be designed to minimize collection and concentration of roadway runoff. Sheet flow over roadway fill slopes (i.e., where roadway subgrade is above adjacent right-of-way) should be used wherever possible to avoid concentration.

3. When it is necessary to collect and concentrate runoff from the roadway and adjacent upstream areas (e.g., in a ditch on a cut slope), concentrated flows shall be incrementally discharged from the ditch via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows shall not exceed 0.5 cfs at any one discharge point from a ditch for the 100-year runoff event. Where flows at a particular ditch discharge point were already concentrated under existing site conditions (e.g., in a natural channel that crosses the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.
4. Ditch discharge points with up to 0.2 cfs discharge for the peak 100-year flow shall use rock pads or dispersion trenches to disperse flows. Ditch discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow shall use only dispersion trenches to disperse flows.
5. Dispersion trenches shall be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end, shall be aligned perpendicular to the flowpath, and shall be minimum 2 feet by 2 feet in section, 50 feet in length, filled with ¾-inch to 1½-inch washed rock, and provided with a level notched grade board (see Figure 6.5.3). Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between up to 4 trenches. Dispersion trenches shall have a minimum spacing of 50 feet.
6. After being dispersed with rock pads or trenches, flows from ditch discharge points must traverse a minimum of 100 feet of undisturbed native vegetation before leaving the project site, or entering an existing onsite channel carrying existing concentrated flows across the road alignment.

   Note: In order to provide the 100-foot flowpath length to an existing channel, some roadway runoff may unavoidably enter the channel undispersed. Also note that water quality treatment may be waived for roadway runoff dispersed through 100 feet of undisturbed native vegetation.
7. Flowpaths from adjacent discharge points must not intersect within the 100-foot flowpath lengths, and dispersed flow from a discharge point must not be intercepted by another discharge point. To enhance the flow control and water quality effects of dispersion, the flowpath shall not exceed 15% slope, and shall be located within designated open space.

   Note: Runoff may be conveyed to an area meeting these flowpath criteria.

8. Ditch discharge points shall be located a minimum of 100 feet upgradient of steep slopes (i.e., slopes steeper than 40%), wetlands, and streams.
9. Where the local jurisdiction determines there is a potential for significant adverse impacts downstream (e.g., erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

∉ **Cleared Area Dispersion BMPs**

The runoff from cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture is considered to be "fully dispersed" if it is dispersed through at least 25 feet of native vegetation in accordance with the following criteria:

1. The contributing flowpath of cleared area being dispersed must be no more than 150 feet, AND
2. Slopes within the 25-foot minimum flowpath through native vegetation should be no steeper than 8%. If this criterion can not be met due to site constraints, the 25-foot flowpath length must be increased 1.5 feet for each percent increase in slope above 8%.

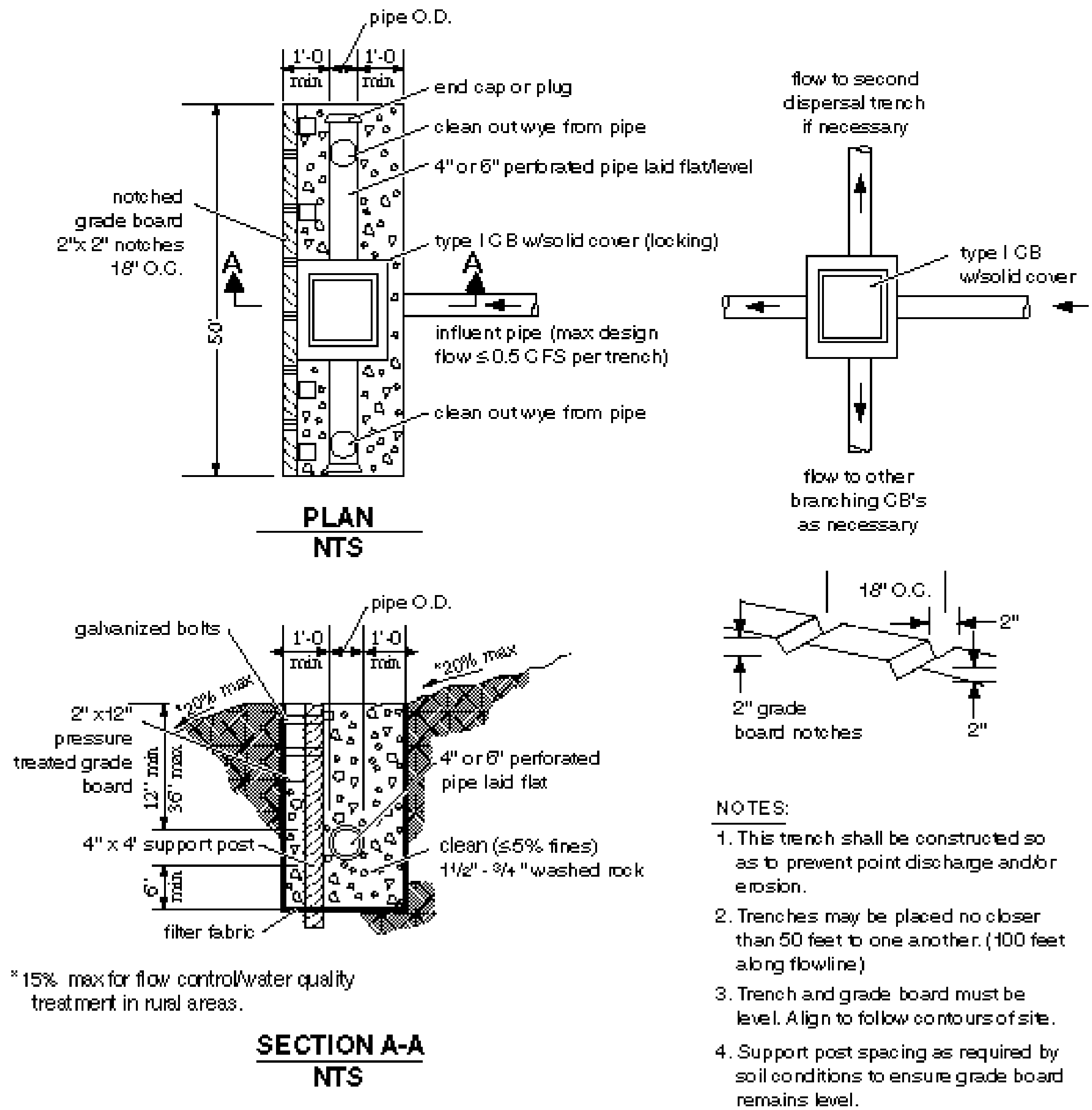


Figure 6.5.3 Standard Dispersion Trench with Notched Grade Board

Appendix 6A – Maintenance Requirements

Maintenance Requirements for Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	**Any trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size garbage can). In general, there should be no visual evidence of dumping.** If less than threshold all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
	Poisonous Vegetation and noxious weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined by State or local regulations. (Apply requirements of adopted Integrated Pest Management (IPM) policies for the use of herbicides).	No danger of poisonous vegetation where maintenance personnel or the public might normally be. (Coordinate with local health department) Complete eradication of noxious weeds may not be possible. Compliance with State or local eradication policies required
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants (Coordinate removal/cleanup with local water quality response agency).	No contaminants or pollutants present.
	Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. (Coordinate with local health department and Ecology Dam Safety Office if pone exceeds 10 acre feet)
	Beaver Dams	Dam results in change or function of the facility.	Facility is returned to design function. (Coordinate trapping of beavers and removal of dams with appropriate permitting agencies)
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. Apply insecticides in compliance with adopted IPM policies.

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
	Tree Growth and Hazard Trees	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove If dead, diseased, or dying trees are identified (Use a certified Arborist to determine health of tree or removal requirements)	Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (e.g., alders for firewood). Remove hazard trees
Side Slopes of Pond	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. If erosion is occurring on compacted berms a licensed civil engineer should be consulted to resolve source of erosion.
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (If Applicable)	Liner is visible and has more than three 1/4-inch holes in it.	Liner repaired or replaced. Liner is fully covered.
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Emergency Overflow/Spill way and Berms over 4 feet in height	Tree Growth	Tree growth on emergency spillways create blockage problems and may cause failure of the berm due to uncontrolled overtopping. Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A licensed civil engineer should be consulted for proper berm/spillway restoration.
	Piping	Discernible water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
Emergency Overflow/Spill way	Emergency Overflow/ Spillway	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of out flow path of spillway. (Rip-rap on inside slopes need not be replaced.)	Rocks and pad depth are restored to design standards.
	Erosion	See “Side slopes of Pond”	

Maintenance Requirements for Detention Vaults/Tanks

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Storage Area	Plugged Air Vents	One-half of the cross section of a vent is blocked at any point or the vent is damaged.	Vents open and functioning.
	Debris and Sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for 1/2 length of storage vault or any point depth exceeds 15% of diameter. (Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 length of tank.)	All sediment and debris removed from storage area.
	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into facility. (Will require engineering analysis to determine structural stability).	All joint between tank/pipe sections are sealed.
	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability).	Tank/pipe repaired or replaced to design.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls.	No cracks more than 1/4-inch wide at the joint of the inlet/outlet pipe.
Manhole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.

Maintenance of Control Structures

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris (Includes Sediment)	Material exceeds 25% of sump depth or 1 foot below orifice plate.	Control structure orifice is not blocked. All trash and debris removed.
	Structural Damage	Structure is not securely attached to manhole wall.	Structure securely attached to wall and outlet pipe.
		Structure is not in upright position (allow up to 10% from plumb).	Structure in correct position.
		Connections to outlet pipe are not watertight and show signs of rust.	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.
		Any holes--other than designed holes--in the structure.	Structure has no holes other than designed holes.
Cleanout Gate	Damaged or Missing	Cleanout gate is not watertight or is missing.	Gate is watertight and works as designed.
		Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
		Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
		Gate is rusted over 50% of its surface area.	Gate is repaired or replaced to meet design standards.
Orifice Plate	Damaged or Missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Manhole	See requirements for vaults/tanks		
General	Trash & Debris	Trash or debris which is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%.	No Trash or debris located immediately in front of catch basin or on grate opening.
		Trash or debris (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of six inches clearance from the debris surface to the invert of the lowest pipe.	No trash or debris in the catch basin.
		Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height.	Inlet and outlet pipes free of trash or debris.
		Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within the catch basin.
	Sediment	Sediment (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe. Measured from the bottom of basin to invert of the lowest pipe into or out of the basin.	No sediment in the catch basin
	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch (Intent is to make sure no material is running into basin).	Top slab is free of holes and cracks.
		Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached	Frame is sitting flush on the riser rings or top slab and firmly attached.
	Fractures or Cracks in	Maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards.

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
	Basin Walls/ Bottom	Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	Pipe is regrouted and secure at basin wall.
	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
	Vegetation	Vegetation growing across and blocking more than 10% of the basin opening.	No vegetation blocking opening to basin.
		Vegetation growing in inlet/outlet pipe joints that is more than six inches tall and less than six inches apart.	No vegetation or root growth present.
	Contamination and Pollution	See "Detention Ponds"	No pollution present.
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is closed
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Metal Grates (if applicable)	Grate opening Unsafe	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.	Grate free of trash and debris.
	Damaged or Missing.	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.

Maintenance Requirements for Drywells

The structural life of a drywell is approximately 20 years, although hydraulic failure could potentially occur at anytime. Drywell performance is dependent upon proper installation, regularly scheduled maintenance and contaminants reaching swale and drywell facility. The following schedule is recommended as a guide; actual schedule may need to be varied based upon observed performance.

Maintenance interval	***Description of maintenance to be performed***
every 3 months	Visually inspect.
every 6 months	Remove debris and sediment.
annually	Check for structural damage.
Whichever is more frequent: above schedule or below observed events:	
following substantial (>24 hr) rainfall event	If possible, observe facilities in operation during the rainfall event. Aim to identify and correct problem prior to failure.
following intense but short duration event	
following snowmelt event	It is especially important to observe the facilities if the melt occurred concurrently with frozen ground conditions.

<u>DEFINITIONS OF MAINTENANCE TASKS</u>:

1) **Visual Inspection**: Ensure metal grate and drywell are free of debris and obstructions. Remove any debris from on top of or around drywell and grate. Remove grate and inspect drywell for debris and sediment build-up in the barrel. Debris needs to be removed immediately, if possible. Sediment needs to be cleaned out before depth reaches the lowest row of slots providing outflow from drywell barrel.

   Anytime that standing water is noticed in a drywell or swale more than 24 hours after an event has ceased, a visual inspection is warranted. When standing water is observed, the inspector should be aware of any signs of illicit discharge. If any of the following are observed, in addition to the sod and topsoil being affected and requiring replacement, if it is evident that discharge was made directly into the drywell, the drywell and affected surrounding drain rock must be replaced as soon as possible: oil sheen, spilled paint, burned area due to battery acid, multi-colored appearance of antifreeze, brown to black fuel oil, or any other materials that may be deemed deleterious to water quality. Sod, topsoil and drain rock removed must be handled and disposed of in a manner consistent with a hazardous material.

2) **Remove Debris and Sediment:** Remove any large debris that would interfere with the vactoring (suction removal) of the drywell. Sediment must be completely suctioned out of the drywell barrel. Care should be taken to note the depth of the sediment. If it appears that the sediment is increasing with depth at each inspection, this may be a sign that the swale is not functioning properly; stormwater may be ponding and spilling, carrying sediment laden stormwater into the drywell, rather than infiltrating at the design rate.

3) **Check for Structural Damage:** Inspect metal frame and grate, adjustment rings, mortar or any other visible parts of the drywell structure. The metal frame and grate should sit flush on the top ring. Any separation of ¾ inch of greater must be adjusted and repaired. The drywell should be replaced or repaired to design standards if it has settled more than 2 inches or if standing water fails to drain out of the barrel slots. Adjustment rings should be free of cracks. Crack repair should adhere be performed when:

location of crack	***maximum width of crack***
top ring of drywell	¼ inch
drywell barrel	½ inch and longer than 3 feet
drywell floor	½ inch and longer than 1 foot

It should be noted that any crack, regardless of location or width, in which sediment is observed, needs to be repaired as soon as possible. Cracks should be repaired with mortar similar to that used between the adjustment rings. Mortar or grout should be waterproof and of the non-shrink variety.

Maintenance Requirements for Infiltration Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash & Debris	See "Detention Ponds".	See "Detention Ponds".
	Poisonous/Noxious Vegetation	See "Detention Ponds".	See "Detention Ponds".
	Contaminants and Pollution	See "Detention Ponds".	See "Detention Ponds".
	Rodent Holes	See "Detention Ponds".	See "Detention Ponds".
Storage Area	Sediment	Water ponding in infiltration pond after rainfall ceases and appropriate time allowed for infiltration. (A percolation test pit or test of facility indicates facility is only working at 90% of its designed capabilities. If two inches or more sediment is present, remove).	Sediment is removed and/or facility is cleaned so that infiltration system works according to design.
Filter Bags (if applicable)	Filled with Sediment and Debris	Sediment and debris fill bag more than 1/2 full.	Filter bag is replaced or system is redesigned.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rain storms.	Gravel in rock filter is replaced.
Side Slopes of Pond	Erosion	See "Detention Ponds".	See "Detention Ponds".
Emergency Overflow Spillway and Berms over 4 feet in height.	Tree Growth	See "Detention Ponds".	See "Detention Ponds".
	Piping	See "Detention Ponds".	See "Detention Ponds".
Emergency Overflow Spillway	Rock Missing	See "Detention Ponds".	See "Detention Ponds".
	Erosion	See "Detention Ponds".	See "Detention Ponds".
Pre-settling Ponds and Vaults	Facility or sump filled with Sediment and/or debris	6" or designed sediment trap depth of sediment.	Sediment is removed.

Maintenance Requirements for Evaporation Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash & Debris	See "Detention Ponds".	See "Detention Ponds".
	Poisonous/Noxious Vegetation	See "Detention Ponds".	See "Detention Ponds".
	Contaminants and Pollution	See "Detention Ponds".	See "Detention Ponds".
	Rodent Holes	See "Detention Ponds".	See "Detention Ponds".
Side Slopes of Pond	Erosion	See "Detention Ponds".	See "Detention Ponds".
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (If Applicable)	Liner is visible and has more than three 1/4-inch holes in it.	Liner repaired or replaced. Liner is fully covered.
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
General	Inlet Pipe	Inlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom, that exceeds 6-inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.

Maintenance Requirements for Evaporation Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General (cont'd)	Snow	Snow removal operations deposit snow into evaporative system	This added factor must be considered in the water budget, especially if snow from another basin is put into the system. Temporary sediment ponds should be included in the design, to prevent sediment-laden runoff from entering the pond and storm disposal system during construction.

Appendix 6B – Storm Drainage Design Guideline for Site Characterization

Storm Drainage Design Guideline for Site Characterization

Geotechnical site characterization should be conducted to demonstrate the site's general suitability for on-site storm water disposal. The scope of the investigation should consist of, but not be limited to, the following elements:

1. Review applicable geologic maps of the site area, to identify any site conditions that can impact the use of storm drainage disposal systems. This may include outcrops, borrow pits, or existing ground water conditions.
2. Site explorations should consist of a minimum of three exploratory test pits or borings on the site and specifically in the planned disposal area. The explorations should extend at least 5 ft. below the bottom of the proposed disposal facility.
3. Samples recovered from the site exploration work may be tested to assess gradational characteristics to help verify the soil classification for comparison with the mapped soil unit.
4. Include a surface reconnaissance of surrounding properties, particularly in the anticipated down-gradient ground water flow direction, to assess potential impact of additional ground water.
5. Perform laboratory testing to determine Unified Soil Classification Group Symbol and Group Name of the site soils.
6. Provide a summary report, describing the results of the work. Include a vicinity map, an exploration site plan, and laboratory test results. Include information regarding the depth to ground water and the presence of any limiting layers which may control ground water flow. Consider feasibility and limitations for on-site disposal. Include information on how the field permeability testing was performed and the assumptions made for determining the recommended infiltration rate. The report shall be prepared under the direction of a licensed professional civil engineer or geotechnical engineer and appropriately signed and sealed.

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