Stormwater Management

FOR EASTERN WASHINGTON

DRAFT

Stormwater Management Manual for Eastern Washington

Chapter 5 – Detention, Retention and Infiltration Design
Chapter 6 – Water Quality Facility Design

WASHINGTON STATE DEPARTMENT OF ECOLOGY

September 2002
Publication Number 02-10-040B
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Chapter 5 - Detention, Retention and Infiltration Design

5.1 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 6.

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

5.2 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.

5.2.1 BMP F 5.10 Detention Ponds

The design criteria in this section are for detention ponds. However, many of the criteria also apply to infiltration ponds (Section 5.3 and Chapter 6 - Water Quality 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 5.2.1 through Figure 5.2.3. Control structure details are provided in Section 5.2.4.

General

Ponds may be designed as flow-through systems (however, parking lot storage may be utilized through a back-up system; see Section 5.2.5). 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 5.2.4) 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 5.2.2) 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 5.2.3 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 5.2.3. 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 5.2.2). 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.

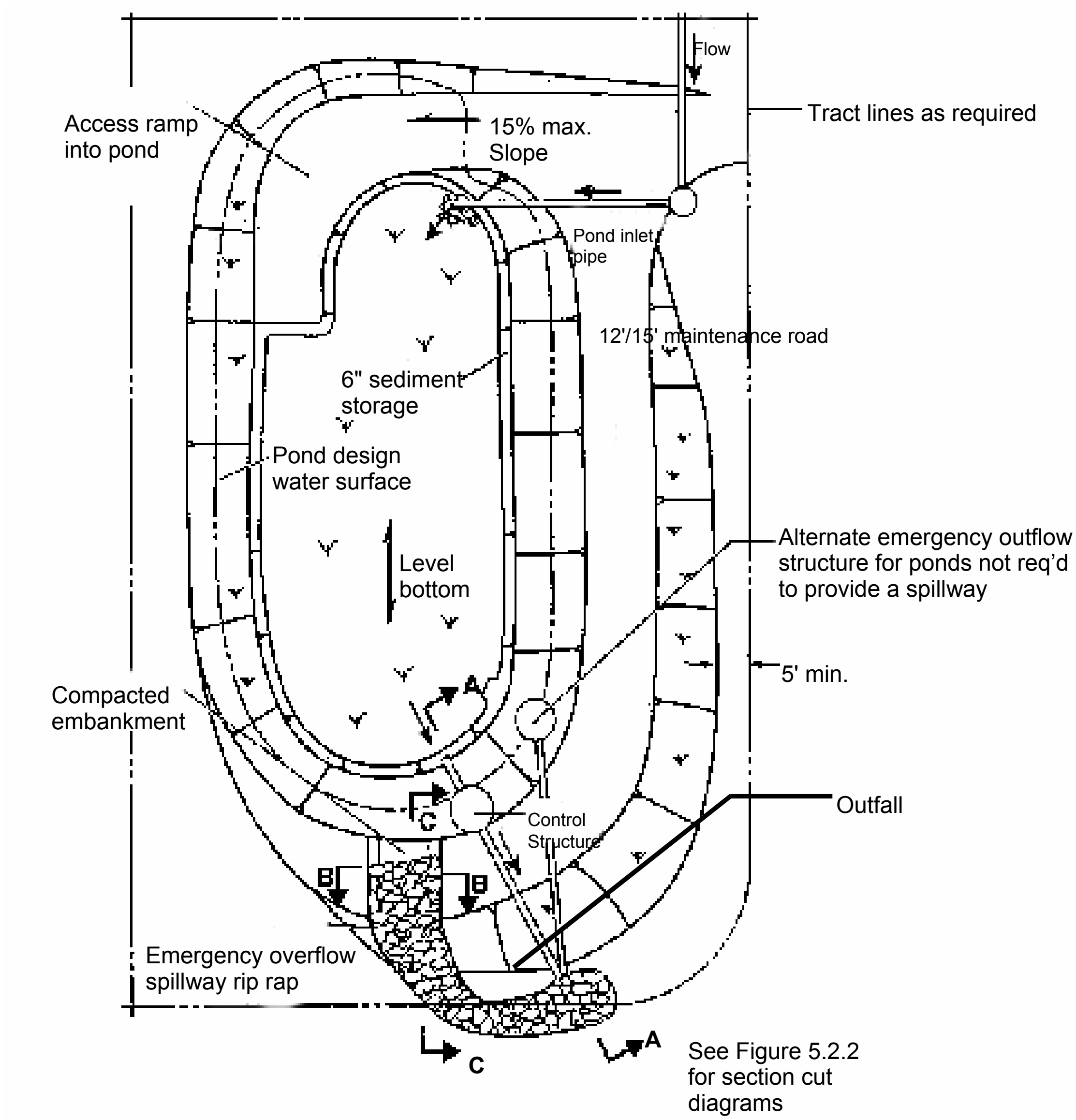
4. Soil in which trees or shrubs are planted may need additional enrichment or additional compost top-dressing. Consult a nurseryman, landscape professional, or arborist for site-specific recommendations.

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 5.2.1 - Typical Detention Pond

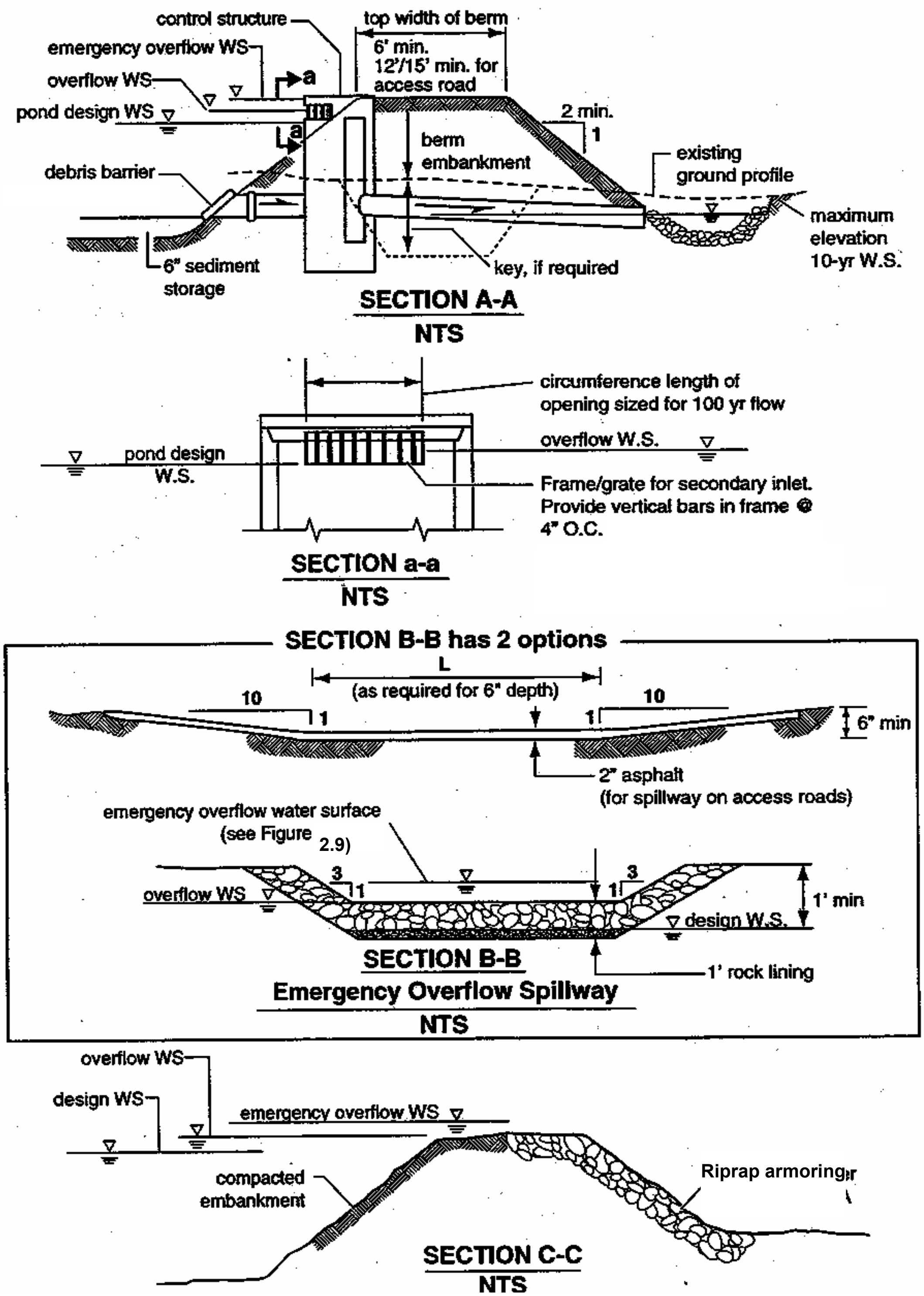
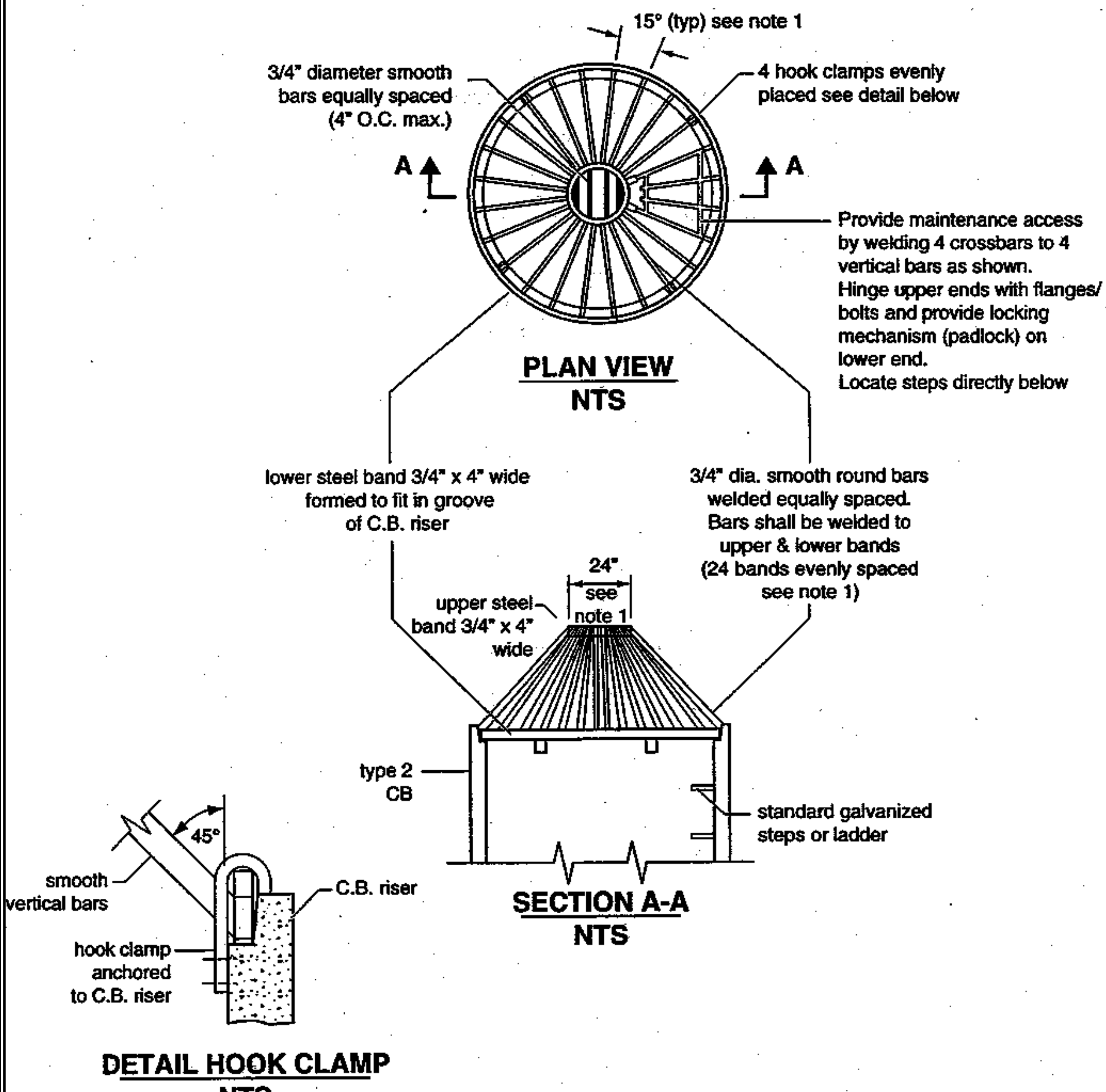


Figure 5.2.2 Typical Detention Pond Sections



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 5.2.3 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 5A 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 continually 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 regularly 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 the regulatory agency, and the hydrologic analysis and design methods in Chapter 4. Design guidelines for restrictor orifice structures are given in Section 5.2.4.

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 5.3 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 5.2.4, for example, would be:

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

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)
- θ = angle of side slopes

Assuming C = 0.6 and Tan θ = 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 width L for the weir section, the equation is rearranged to use the computed Q_{25} and trial values of H (0.2 feet minimum):

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

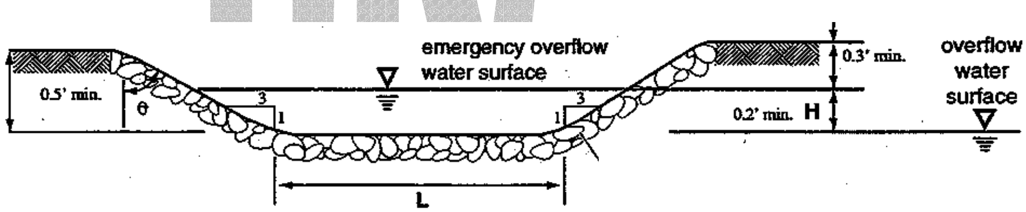


Figure 5.2.4 Weir Section for Emergency Overflow Spillway

5.2.2 BMP F 5.11 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Standard detention tank details are shown in Figures 5.2.5 and 5.2.6. Control structure details are shown in Section 5.2.4.

Design Criteria

General. Typical design guidelines are as follows:

1. Tanks may be designed as flow-through systems with manholes in line (see Figure 5.2.5) 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 additional 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 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 5.2.6) 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 5.2.1.

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 5A 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 5.2.4.

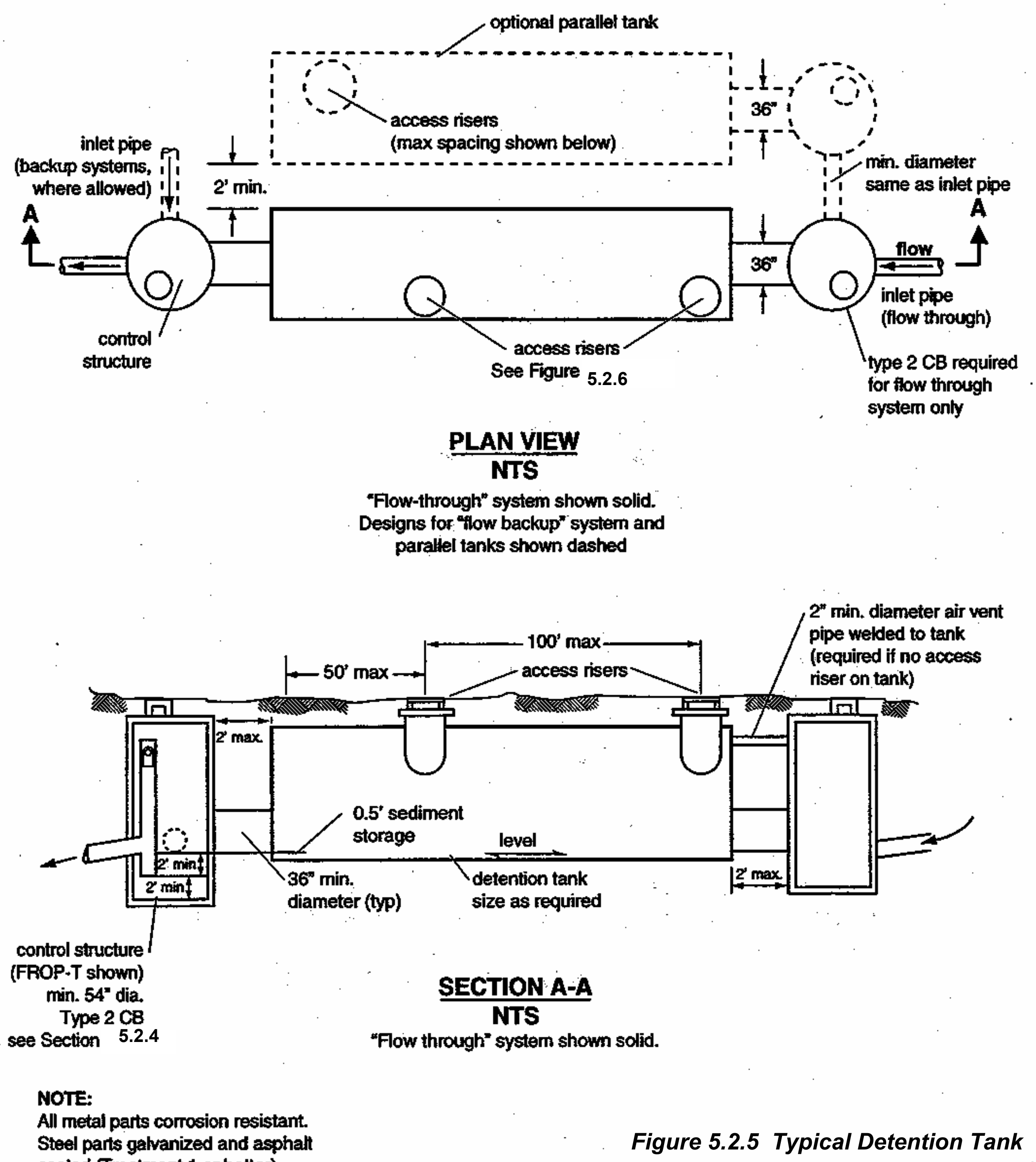


Figure 5.2.5 Typical Detention Tank

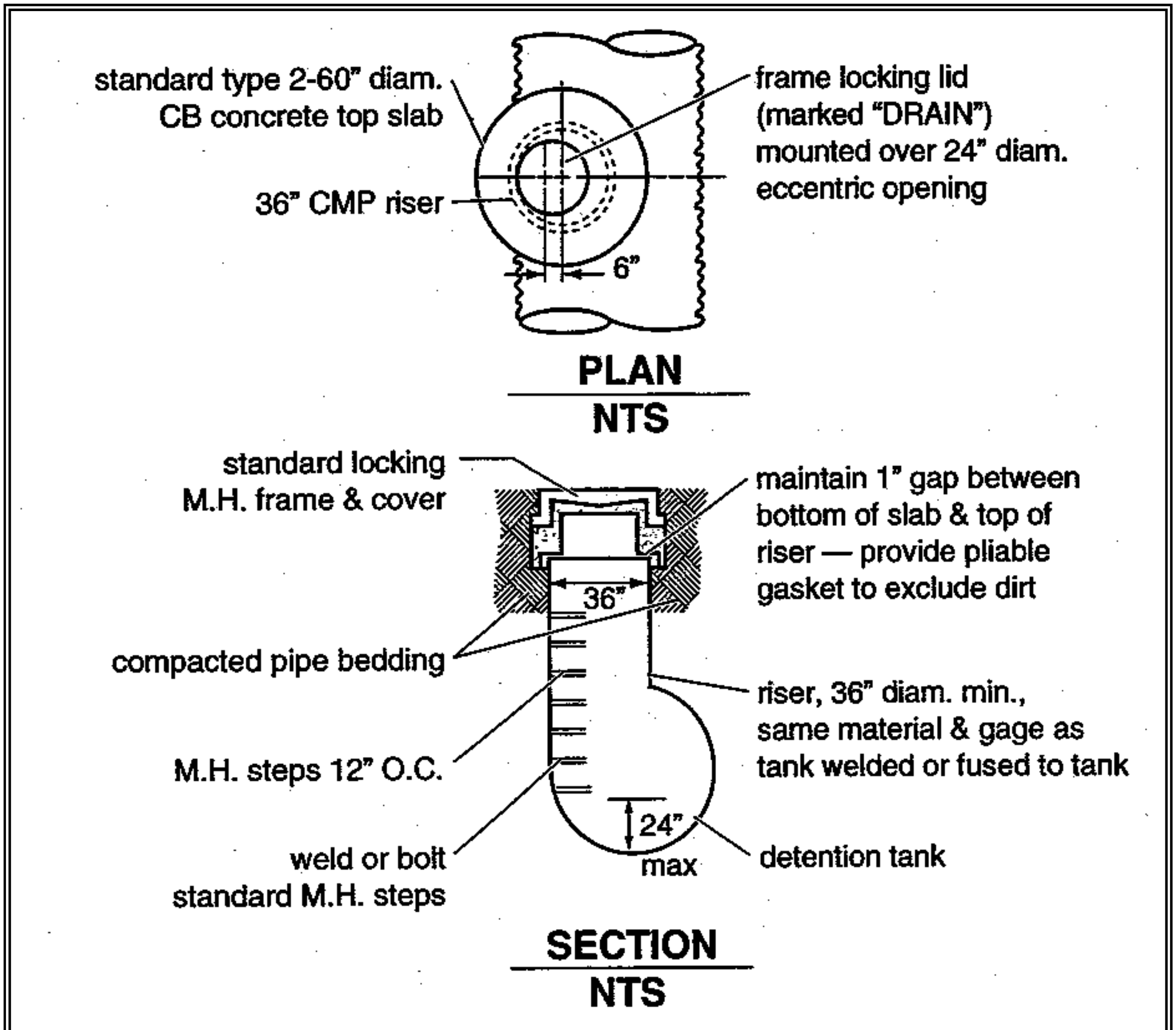


Figure 5.2.6 Detention Tank Access Detail

Notes for Figure 5.2.6:

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).

5.2.3 BMP F 5.12 Detention Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. A standard detention vault detail is shown in Figure 5.2.7. Control structure details are shown in Section 5.2.4.

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 5.2.1.

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.

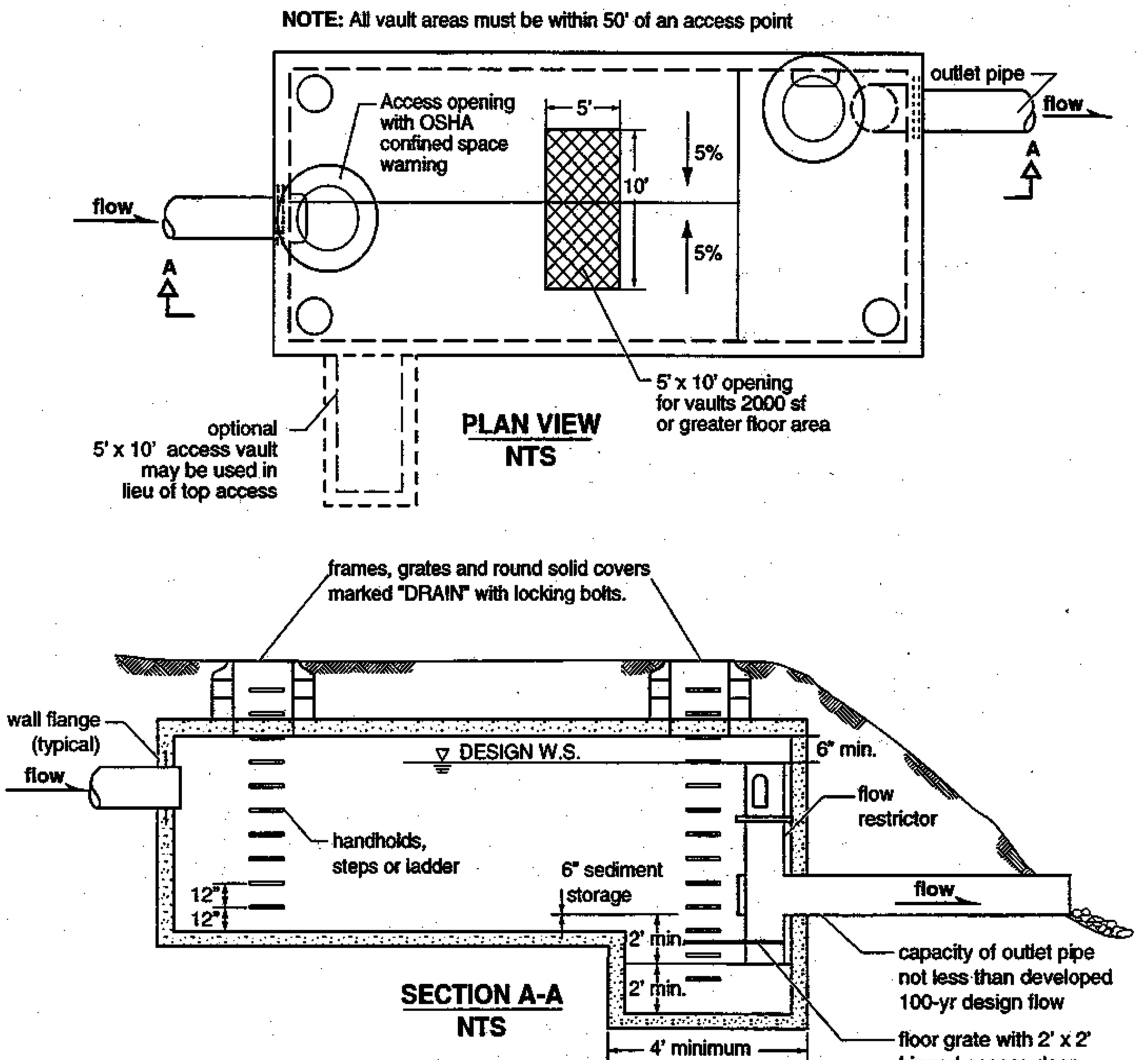
Setbacks. It is recommended that facilities be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government and from any septic drainfield. However, the setback requirements are generally specified by the local government, uniform building code, or 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 5A 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 5.2.4.



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 5.2.7 Typical Detention Vault

5.2.4 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 5.2.8 and 5.2.9.

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.

> ***5-1 Feedback requested:*** *Orifices may require special design considerations for the freezing weather conditions in eastern Washington. What is an appropriate minimum size for a standard orifice type? What other orifice designs, such as slots, should be considered for discharges of flows that require a smaller orifice than the minimum?*

1. Minimum orifice diameter is 0.5 inches. Note: In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth need not be reduced to less than 3 feet in an attempt to meet the performance standards. Also, under such circumstances, flow-throttling devices may be a feasible option. These devices will throttle flows while maintaining a plug-resistant opening.
2. Orifices may be constructed on a tee section as shown in Figure 5.2.8 or on a baffle as shown in Figure 5.2.9.
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 5.2.12).
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 5.2.11 and 5.2.12). However, they must be designed to provide for primary

overflow of the developed 25-year peak flow discharging to the detention facility.

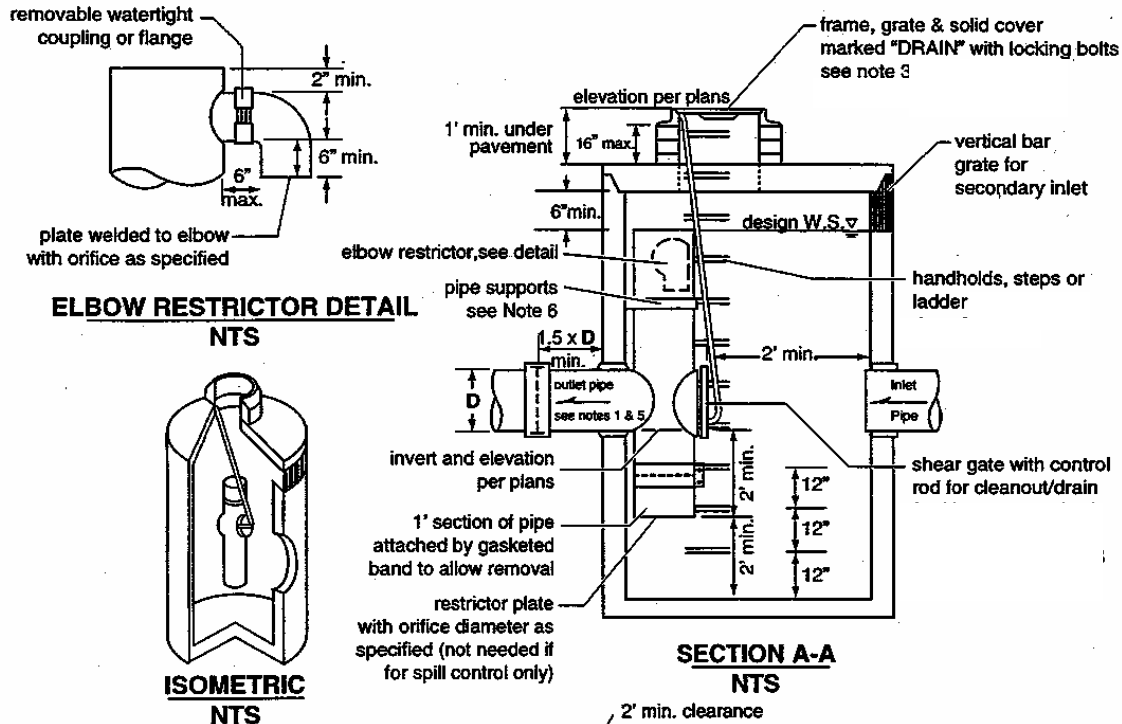
2. The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design must still provide for primary overflow of the developed 25-year peak flow assuming all orifices are plugged. Figure 5.2.13 can be used to calculate the head in feet above a riser of given diameter and flow.

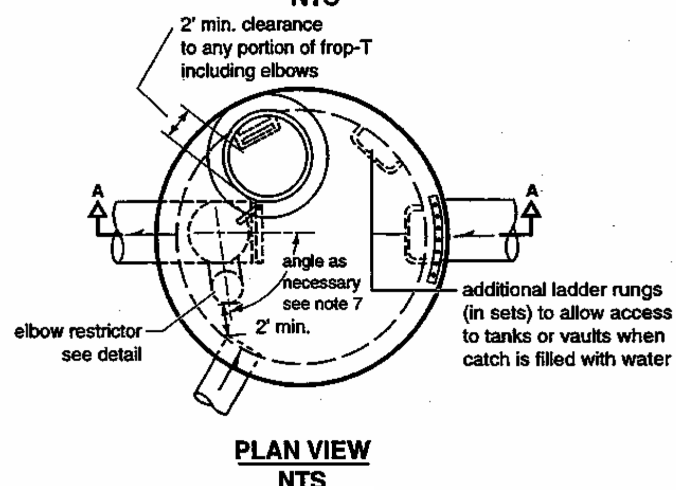
Access. The following guidelines for access may be used.

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 5.2.1.
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 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.

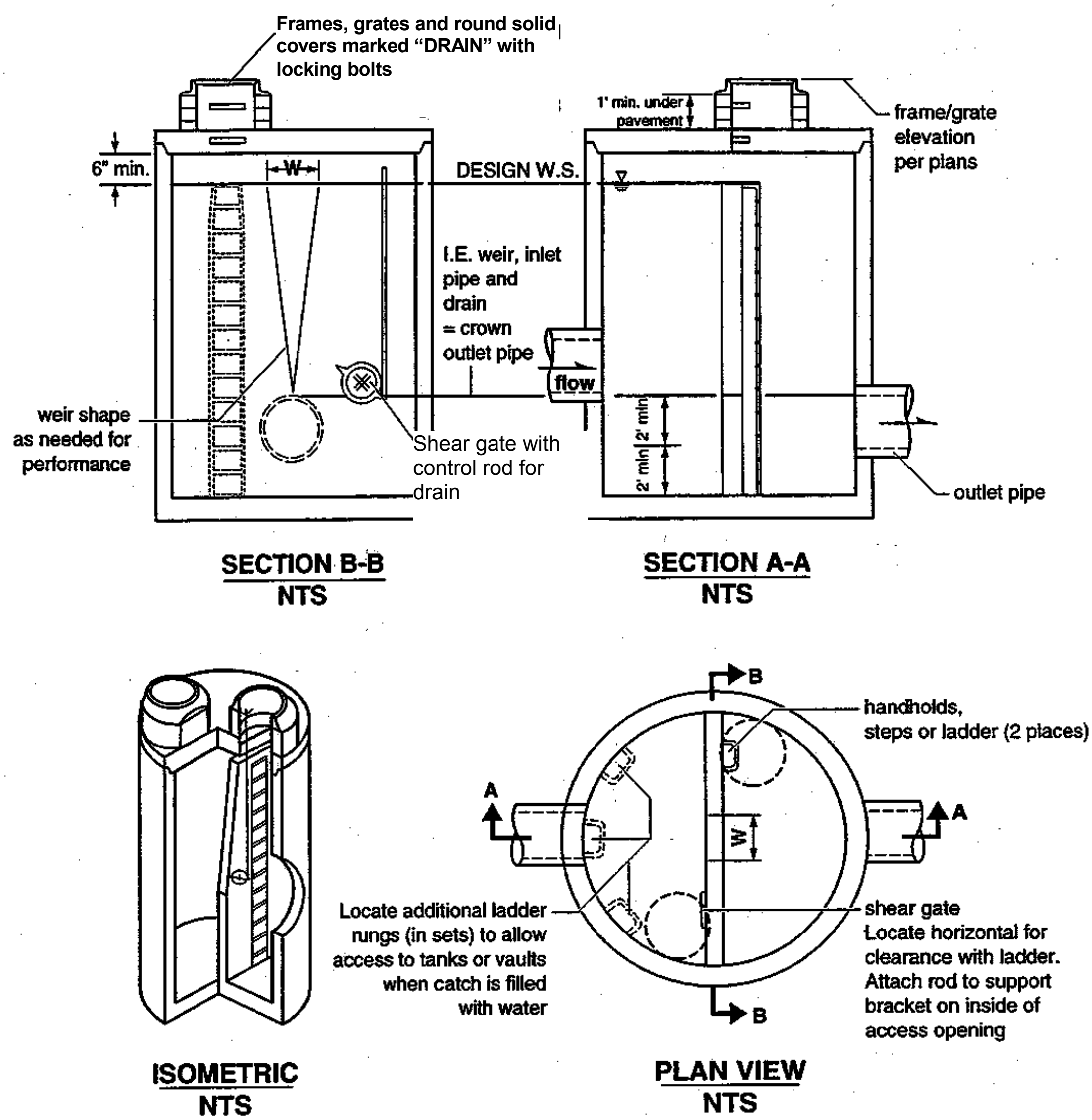




NOTES:

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 5.2.8 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 5.2.9 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 at least twice per year. 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 5A 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 5.2.10 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)

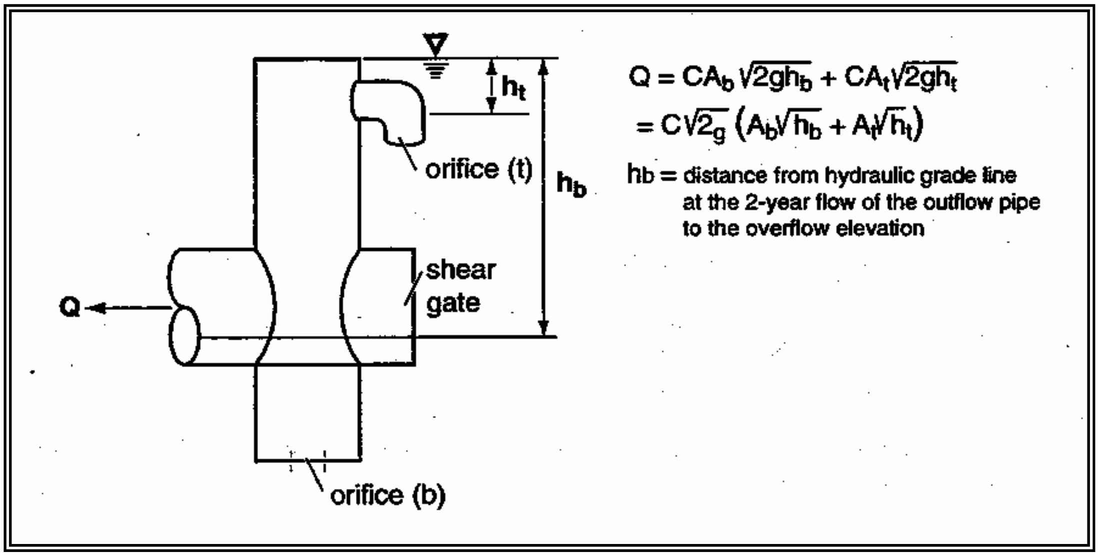


Figure 5.2.10 Simple Orifice

Rectangular Sharp-Crested Weir. The rectangular sharp-crested weir design shown in Figure 5.2.11 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.*

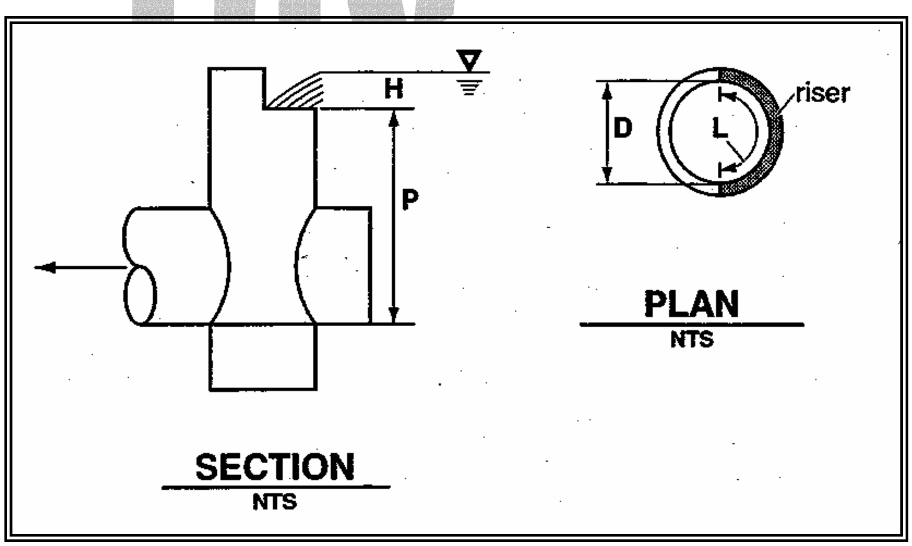
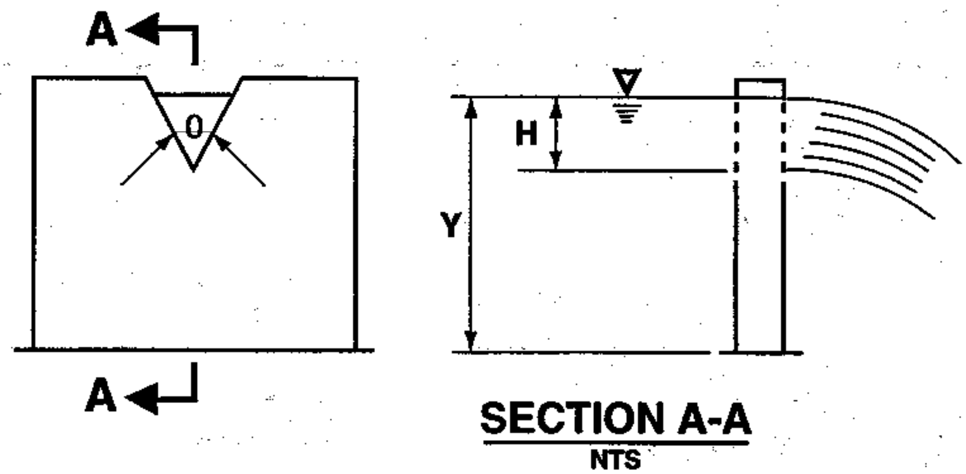


Figure 5.2.11 - Rectangular, Sharp Crested Weir

V-Notch Sharp-Crested Weir. V-notch weirs as shown in Figure 5.2.12 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:

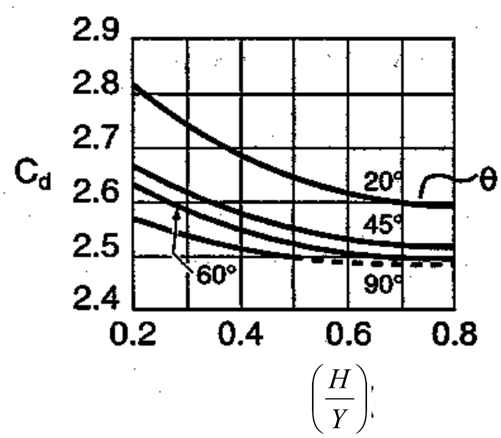


Figure 5.2.12 V-Notch, Sharp-Crested Weir

Riser Overflow. The nomograph in Figure 5.2.13 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).

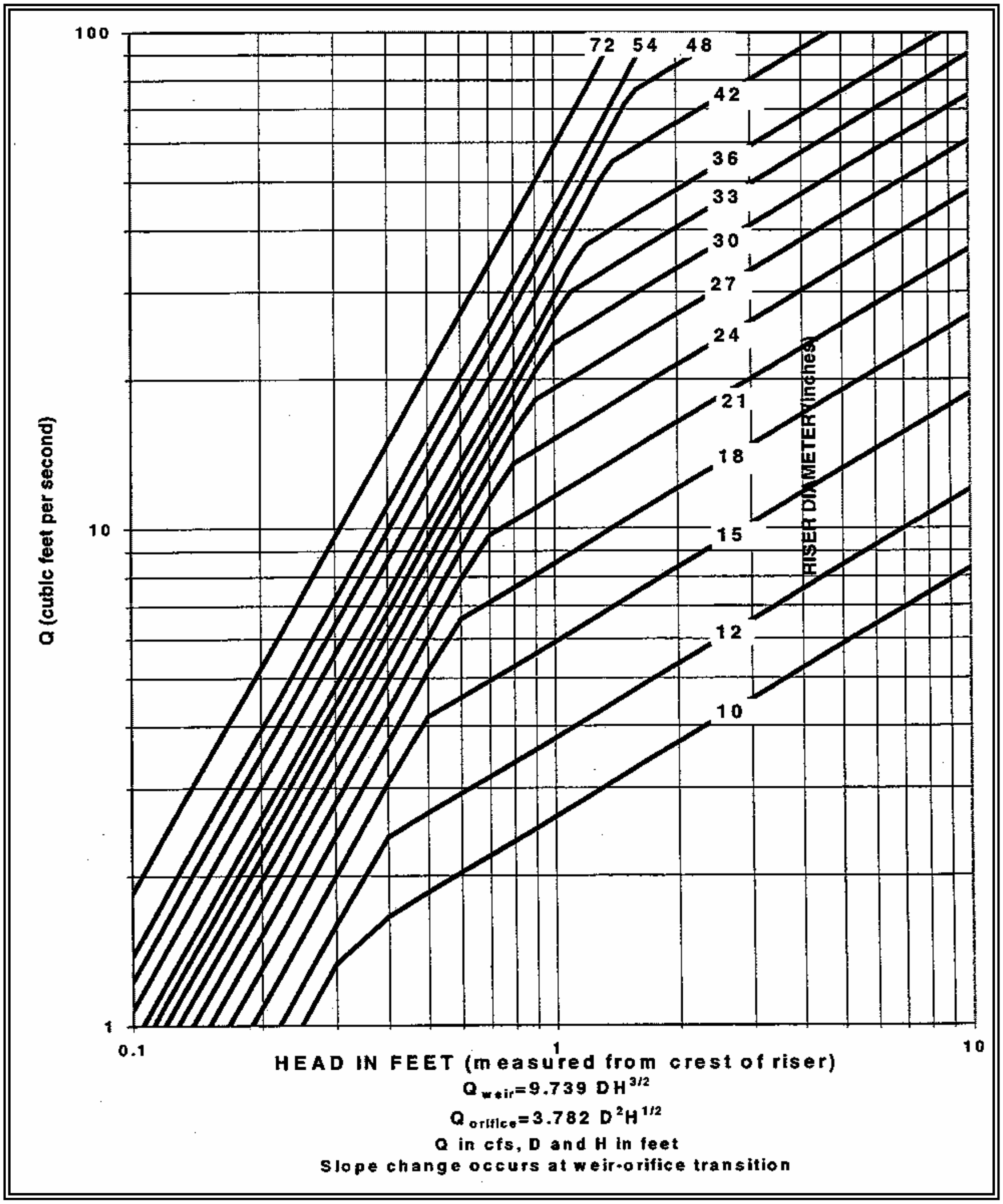


Figure 5.2.13 Riser Inflow Curves

5.2.5 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.

5.3 Infiltration of Stormwater for Quantity Control

5.3.1 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 5.3.2). 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. Typically, treatment for removal of TSS, oil, and/or soluble pollutants is necessary prior to conveyance to an infiltration BMP. The hydraulic design goal should be to mimic the natural hydrologic balance between surface and groundwater.

5.3.2 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 regulatory agency.

Infiltration facilities may be used for quantity control where treatment is not required or for flows greater than the water quality design storm, and where runoff is treated prior to discharge. See Susceptibility Rating Tables 6.5.1 to 6.5.3 and the matrix of treatment requirements in Table 6.6.4 for determining when treatment is required prior to infiltration.

Discharge of uncontaminated or properly treated stormwater to drywells should 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 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; $\geq$ 20 feet downslope and $\geq$100 feet upslope
- From a Native Growth Protection Easement (NGPE); $\geq$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) $\geq$100 vehicles/1,000 ft^2 gross building area (trip generation), and
- Road intersections with an ADT of $\geq$ 25,000 on the main roadway, or $\geq$ 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 $\geq$ 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.

5.3.3 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. Table 5.3.5 correlates SCS textural soil classifications with Unified Soil Classification System and Atterberg limits-determined classifications. The table includes a presumptive infiltration rate of 72 inches per hour, which corresponds to design flow rates of 0.3 cubic feet per second (cfs) and 1.0 cfs, respectively, into single- and double depth drywells based on current practice in the City of Spokane and Spokane County. Other infiltration rates shown in Table 5.3.5 are preliminary, pending confirmation through proposed controlled field and laboratory tests in Spokane. These rates may be used in the design of single- and double-depth drywells if approved by municipalities, which are responsible for issuing permits for construction of such facilities. The presumptive rates also may be used for design of other subsurface BMPs provided the rate is based on a geotechnical study of the site and approved by the permitting agency. Guidance for conducting geotechnical studies that support presumptive infiltration rates shown in Table 5.3.5 are contained in Appendix 5B. Infiltration rates for surface BMPs are shown for informational purposes only.

Information for Reviewers: *Some infiltration rates shown in the following table, including the highest rates, are based on current drywell design practice, and some limited field research and laboratory testing in Spokane County and the City of Spokane. The maximum allowable rate of 72 inches per hour corresponds to maximum allowable drywell capacities of 0.3 and 1.0 cubic feet per second for single- and double-depth drywells, respectively. The maximum infiltration rate is further based on a wetted area of gravel envelope, which is an element of all drywell installations in the Spokane area, of 600 square feet for a double-depth drywell, not including the bottom area. Maximum allowable capacities of drywells with smaller gravel envelopes and/or such facilities installed in soil with an infiltration rate of less than 72 inches per hour, should be adjusted downward accordingly.*

The presumptive infiltration rates for the given soil classifications shown below should be expected to vary depending on site location in eastern Washington. Factors which influence infiltration rates include but are not *necessarily limited to: site geologic setting; natural soil moisture content; in-place soil density; depth of groundwater or impervious stratum beneath the infiltration facility; and particle size distribution. The rates shown for the corresponding soil classifications should not be used for design of infiltration facilities other than drywells.*

5-2 Feedback Requested: *Reviewers are requested to provide information regarding infiltration rates for soil types common to their area and for the types of infiltration facilities used for on-site stormwater disposal in their locale. Methods for establishing design infiltration rates are also requested from reviewers. The presumptive rates shown below will be modified in the final version of the manual based on information received from reviewers.*

Table 5.3.5
Textural Soil Classification Compared To
Unified Soil Classification System and Presumptive Infiltration Rates

Textural Classification USDA	Unified Soil Classification System Group Symbol[1]	Presumptive Infiltration Rate (inches/hour)
Not Applicable	GW	72[2,3]
Not Applicable	GP	72[2,3]
Not Applicable	GW-GM	30-42[4]
Not Applicable	GW-GC	24-36[4]
Not Applicable	GP-GM	18-36[4]
Not Applicable	GP-GC	12-30[4]
Not Applicable	GM	See Note 5
Not Applicable	GC	See Note 5
Sand	SW	72[2,3]
Sand	SP	72[2,3]
Sand	SW-SM	18-36[4]
Sand	SW-SC	12-30[4]
Sand	SP-SM	See Note 5
Sand	SP-SC	See Note 5

Notes for Table 5.3.5:

1. Groups contain from two to eight soil types distinguished by Group Name.
2. For use in design of single-depth and double-depth drywells only, with respective flow rates of 0.3 and 1.0 cubic feet per second. Geologic conditions might warrant reduced rates.
3. Allowable design infiltration rate for Standard drywell installation, City of Spokane and Spokane County.
4. Suggested preliminary allowable design infiltration rate for low-flow subsurface BMPs. Flow rates of 0.3 and 1.0 cfs for single- and double-depth drywells must be reduced in proportion to reduced infiltration rate.
5. Not suitable for infiltration unless justified by geotechnical study and approved by permitting municipality.

5.3.4 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.

Infiltration facilities are sized according to the design storms using hydrograph methods and level pool routing 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 regulatory agency.

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.
- A common requirement is to store the 10-year design storm below the surface in drywells or infiltration trenches.

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 first 1-2 years of operation verification testing is recommended, along with a maintenance program that results in achieving expected performance levels. Operating and maintaining ground water monitoring wells is also encouraged.

5.3.5 BMP F 5.20 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 5.3.1 through 5.3.3 show typical infiltration drywell systems. 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 feet. If precast concrete drywell barrels are used, the depth may reach 10 feet or more.

Filter fabric (geotextile) should be placed on top of the drain rock and on trench or drywell sides prior to backfilling.

Spacing between drywells should be a minimum of 20 feet.

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 over the drywell on a semi-annual basis, or as required to prevent the buildup of materials that could inhibit infiltration.

City of East Wenatchee Standard Detail

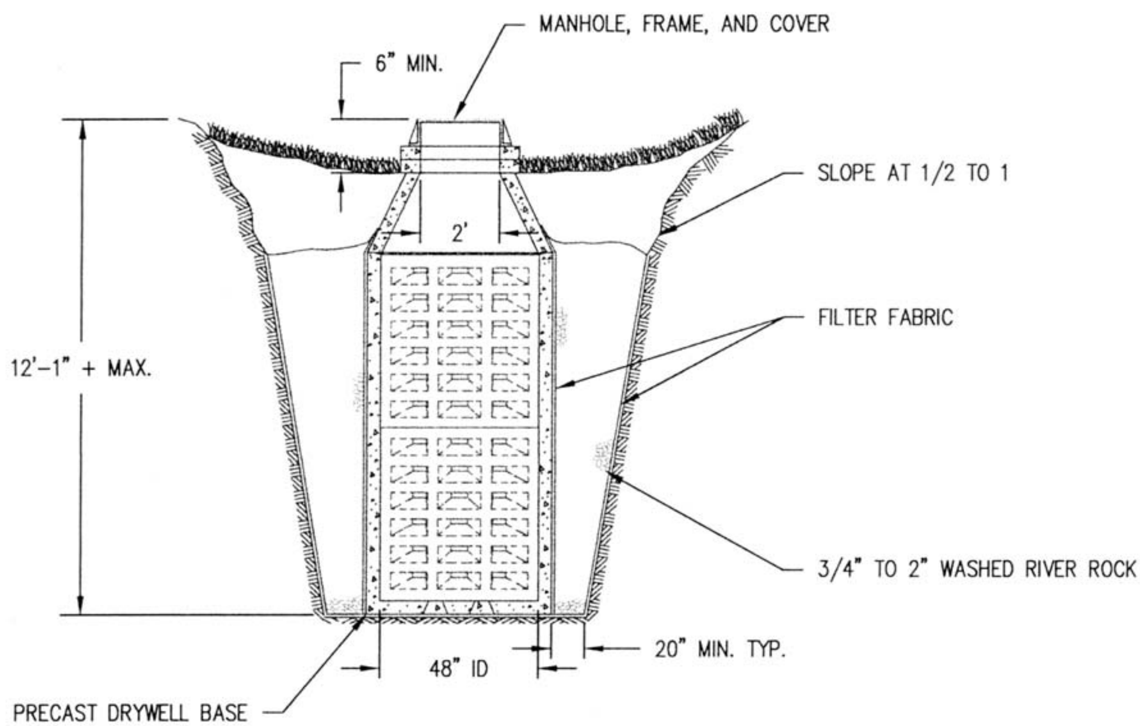


Figure 5.3.1 - Sample Infiltration Drywell (not to scale)

Spokane County Standard Detail

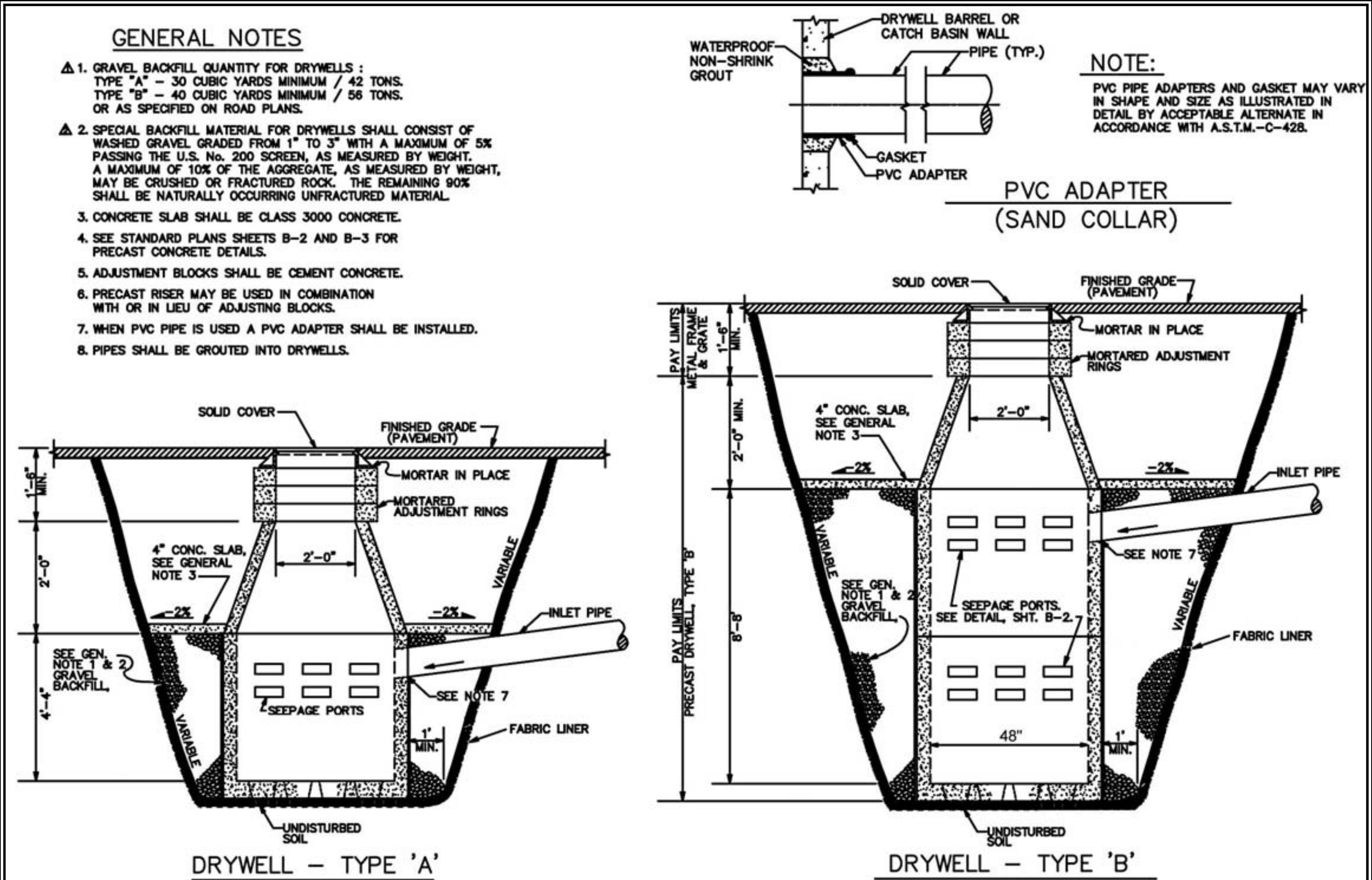


Figure 5.3.2 - Sample Infiltration Drywell

City of Kennewick Standard Detail

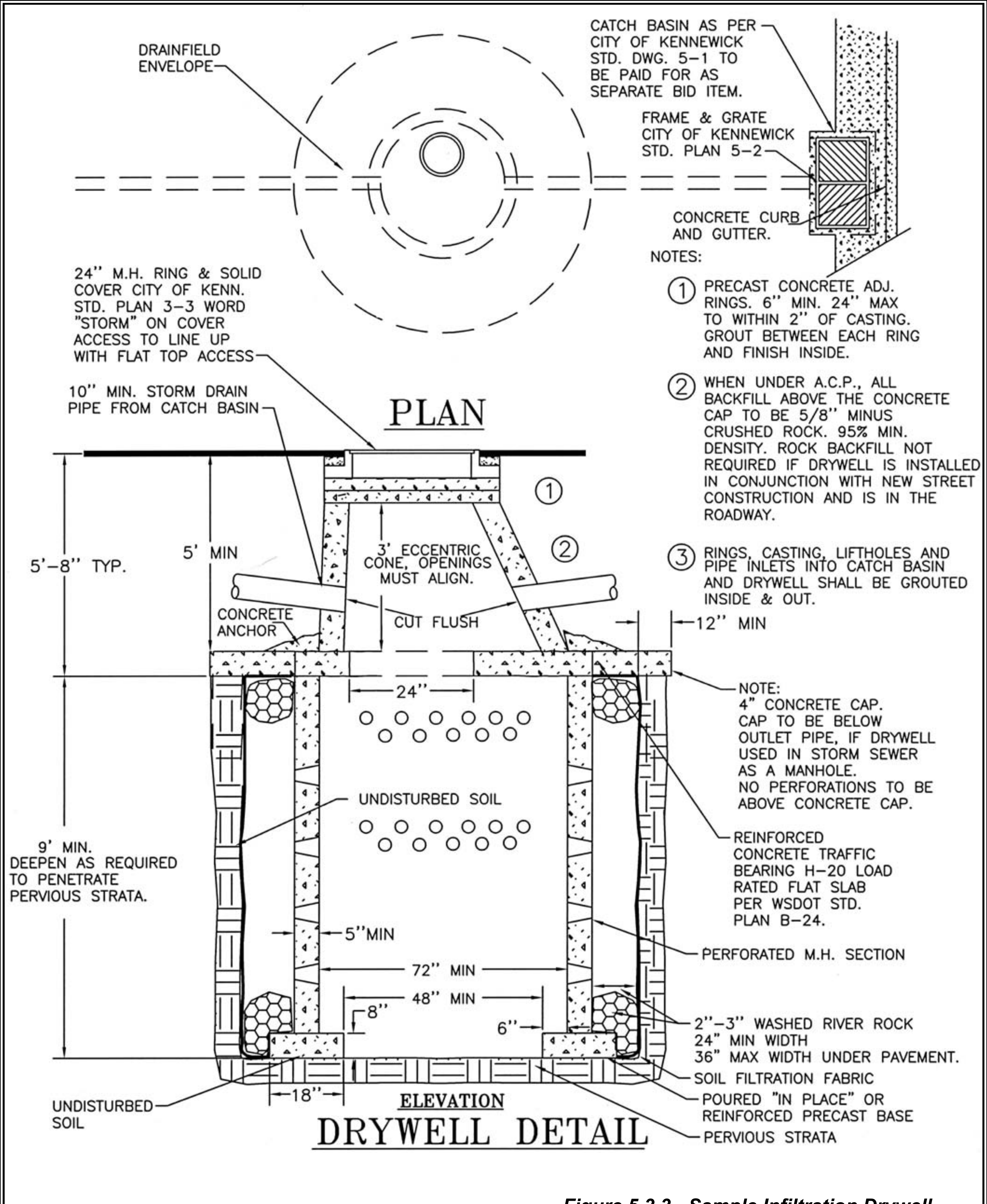


Figure 5.3.3 - Sample Infiltration Drywell

5.3.6 BMP F 5.21 Infiltration Basins

This section covers design and maintenance criteria specific for infiltration basins (see schematic in Figure 5.3.4).

Description

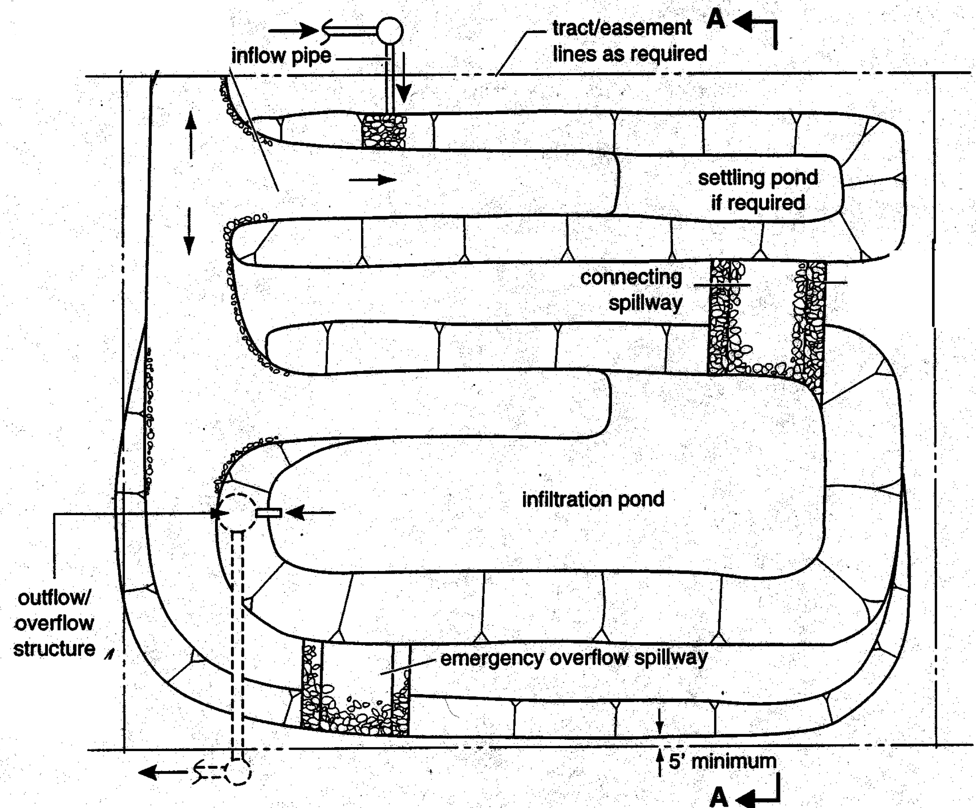
Infiltration basins are earthen impoundments used for the collection, temporary storage and infiltration of incoming stormwater runoff.

Design Criteria for Basins

- Access should be provided for vehicles to easily maintain the forebay (presettling basin) area and not disturb vegetation, or resuspend sediment any more than is necessary. See Section 5.2.1 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 - Basins 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.

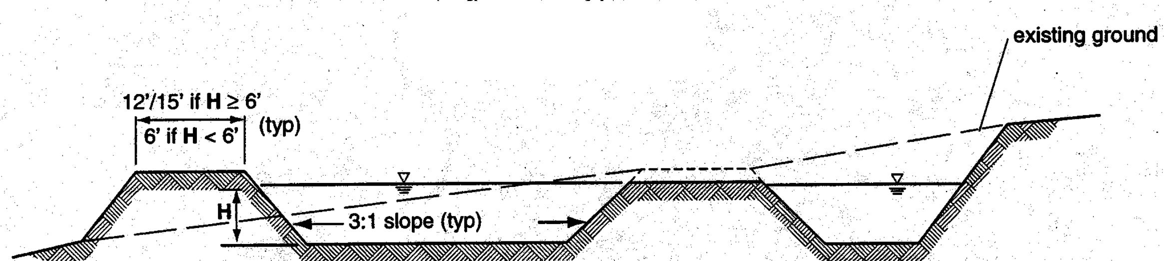
Maintenance Criteria for Basins

- Maintain basin floor and side slopes to promote dense turf with extensive root growth. This enhances infiltration, prevents erosion and consequent sedimentation of the basin floor, and prevents invasive weed growth. 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.



PLAN VIEW

overflow/emergency overflow



SECTION A-A

NTS

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

Figure 5.3.4 Typical Infiltration Pond/Basin

5.3.7 BMP F 5.22 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 5.3.5 - 5.3.9 for examples of trench designs.

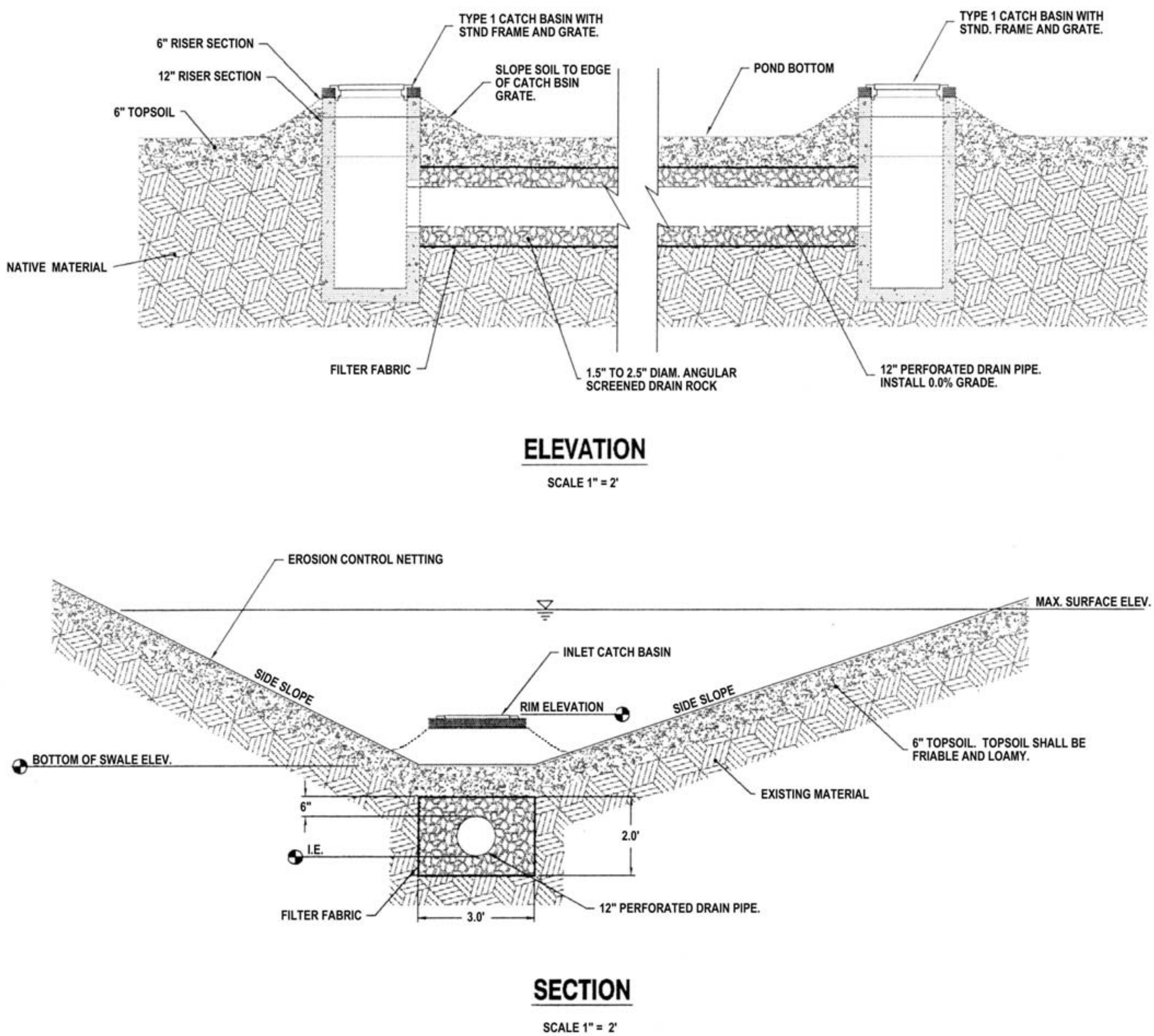


Figure 5.3.6 Sample Infiltration Trench/Pond with Catch Basin Inlet

(courtesy RH2 Engineering, Inc., Wenatchee)

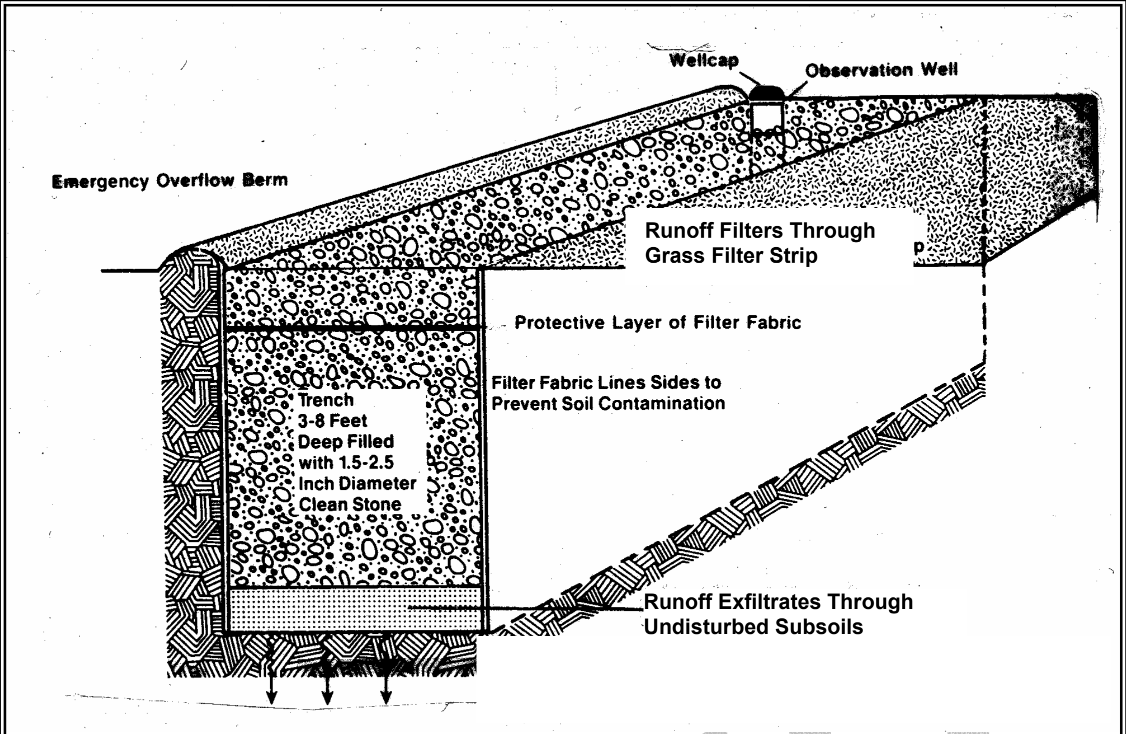


Figure 5.3.7 Schematic of Infiltration Trench

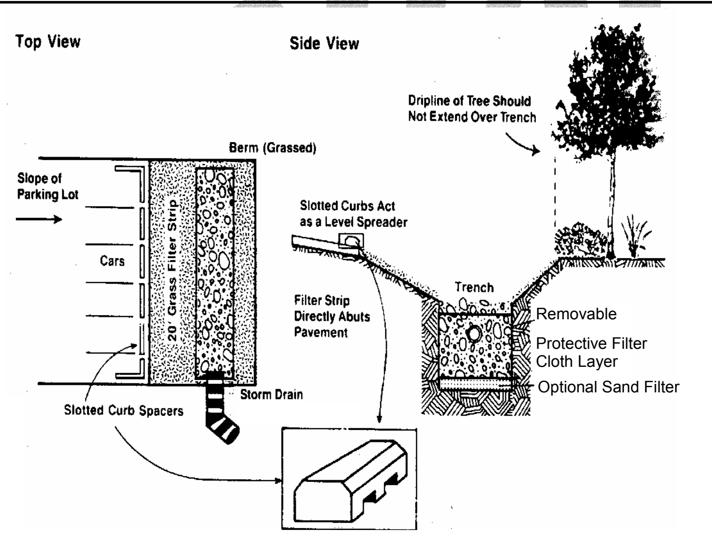


Figure 5.3.8 Parking Lot Perimeter Trench Design

Source: Schueler (reproduced with permission)

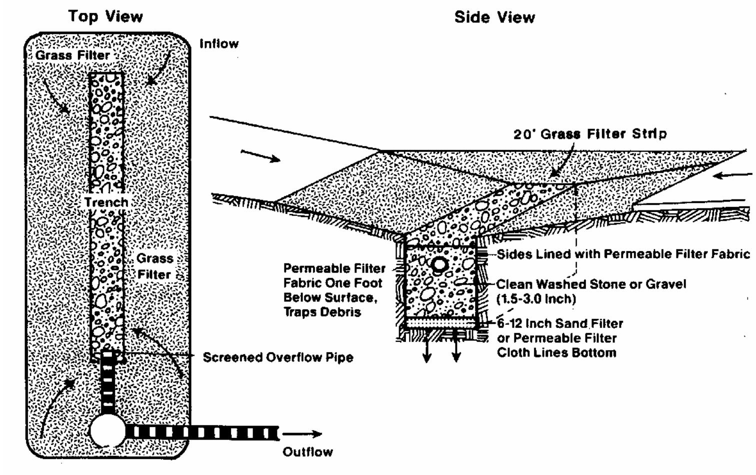


Figure 5.3.9 Median Strip Trench Design

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 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 5.3.10 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 5.3.5). 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.

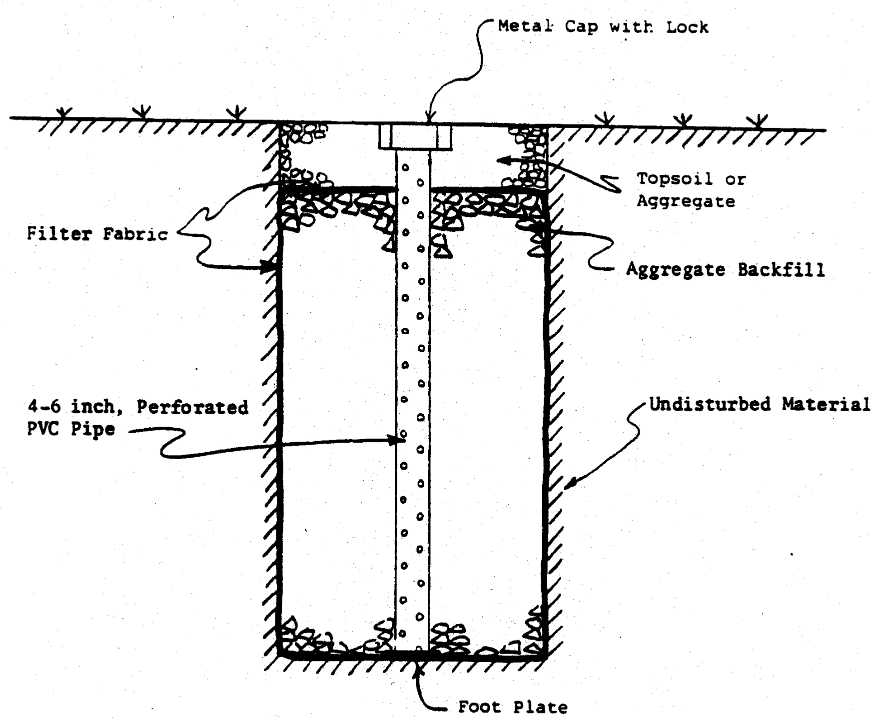


Figure 5.3.10 Observation Well Details

5.4 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:

$$V_{in} - V_{out} = \Delta V_{month}$$

$$\Sigma V_{month} = \Delta V_{year}$$

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.

ΔV_{month} Net volume of storage increase (or decrease) into the evaporative facility (usually cubic ft./month).

ΔV_{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 to account for seasonal variations in precipitation rates and evaporation rates. 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.

5.4.1 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 approval authority.

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 5.4.1 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 5.4.1
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.

5.4.2 Other Design Considerations

When credit for infiltration is proposed, site characterization, testing, and reporting is to be done in accordance with Section 5.3.

The design of the evaporative pond facility will need to evaluate the potential of groundwater seeping into the pond from the surrounding area, under existing conditions. 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.

5.5 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 two types of natural dispersion. They are:

- BMP F5.40 Concentrated Flow Dispersion
- BMP F5.41 Sheet Flow Dispersion

5.5.1 BMP F5.40 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 5.5.1 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 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 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.

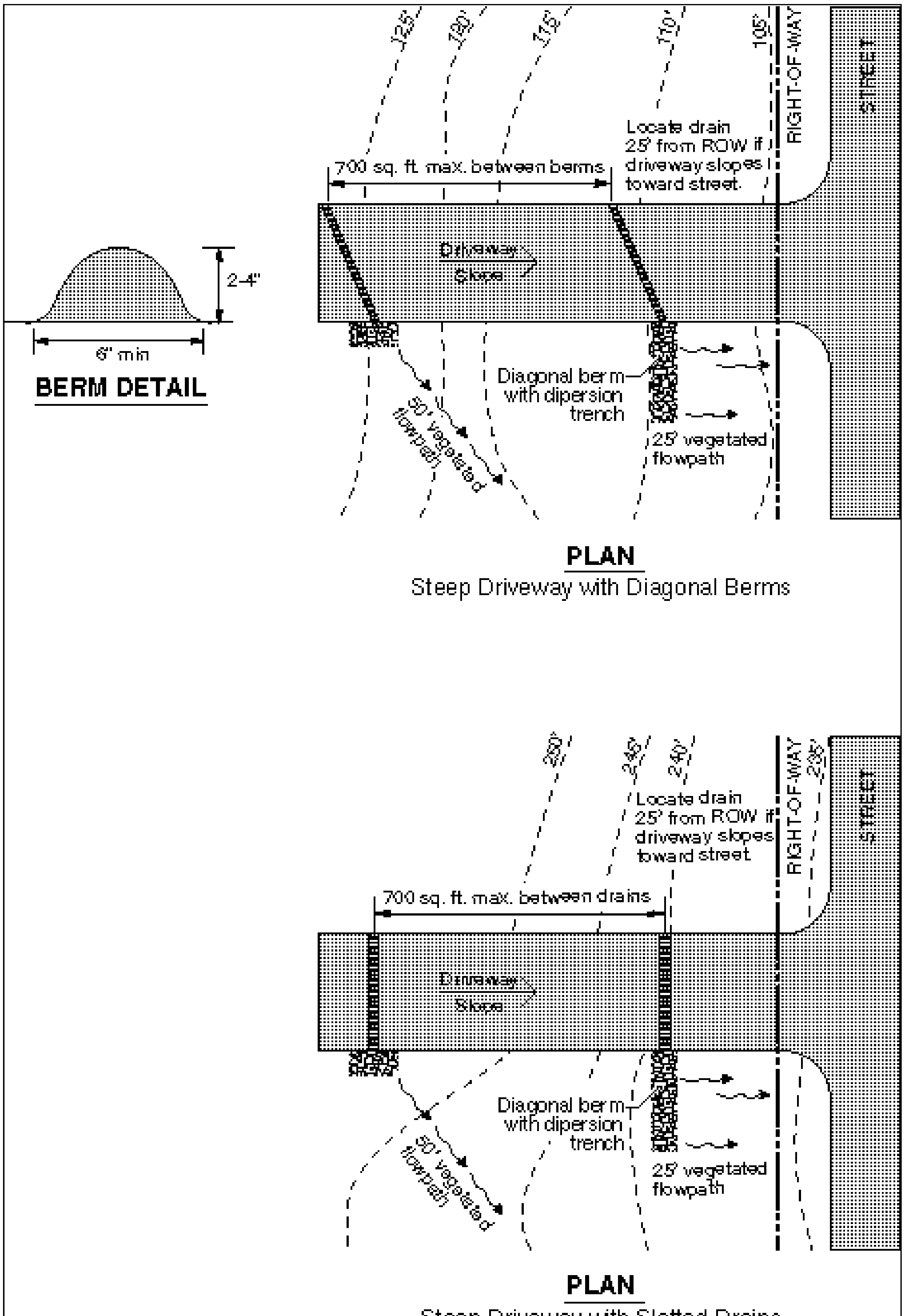


Figure 5.5.1 Typical Concentrated Flow Dispersion for Steep Driveways

5.5.2 BMP F5.4.1 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.

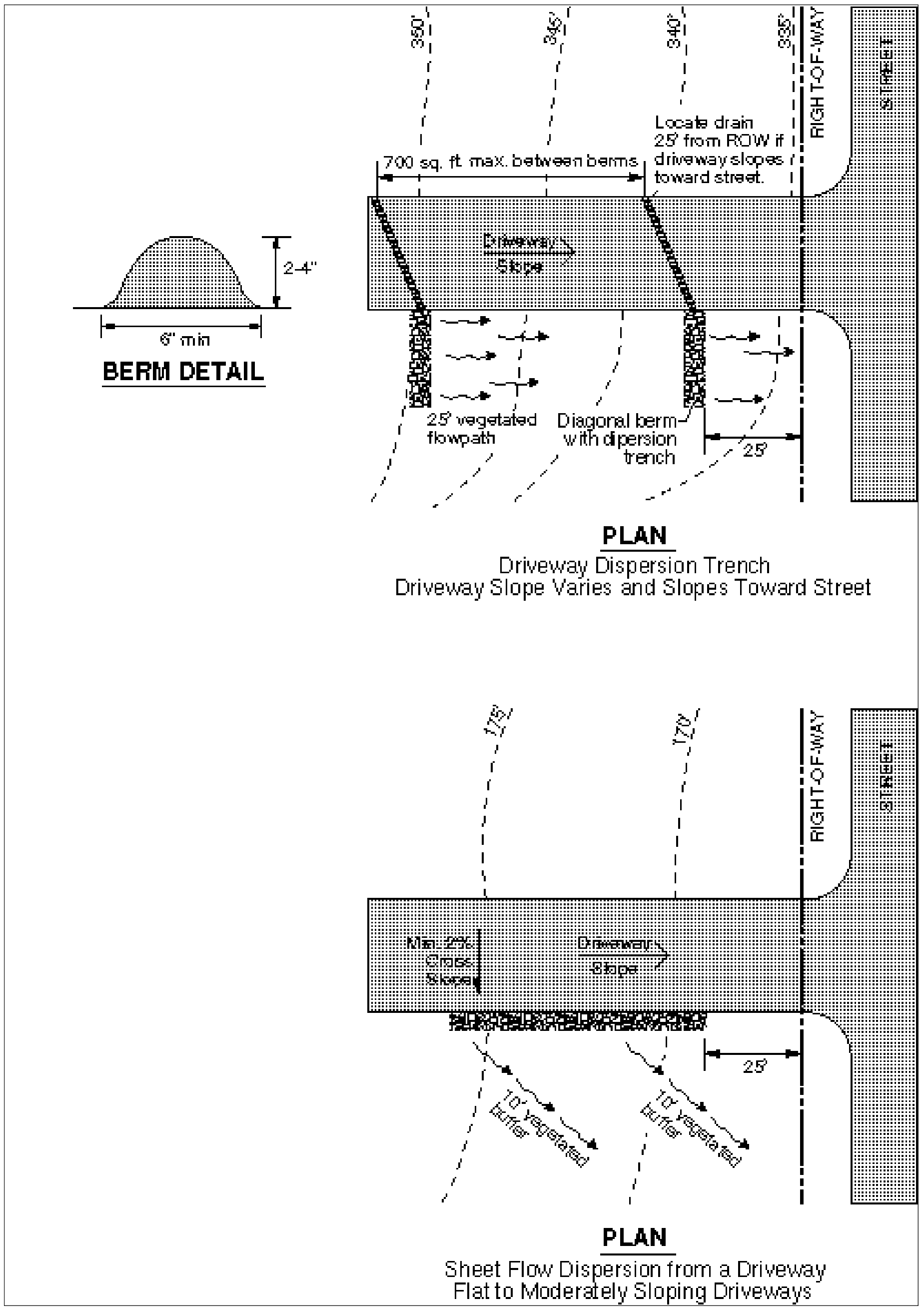
Applications and Limitations

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 5.5.2 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 5.5.2 Sheet Flow Dispersion for Driveways



Appendix 5A – 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 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.

Appendix 5B – 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.

Table of Contents

Chapter 6 - Water Quality Facility Design

6.1 Introduction

6-1 Feedback requested: *This chapter is based largely on Volume V of the Stormwater Management Manual for Western Washington (August 2001), the proposed requirements for Underground Injection Control, and current practices in Spokane County.*

If reviewers are aware of any proven or emerging Best Management Practices that are not included in this Manual and are appropriate for treating and removing pollutants in urban stormwater in arid/semi-arid and cold-weather climates, the Eastern Washington Stormwater Manual Subcommittee would appreciate receiving technical information including design, studies, and references regarding those technologies.

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.

6.1.1 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.

6.1.2 Runoff Treatment Facilities

Treatment methods and facilities described in this chapter include:

- Infiltration and Bio-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 about 90 to 95 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 6.2.1 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 6.2.1 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 6.2.1 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 6.2.1 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.

6.2 Treatment Facility Selection Process

This section describes a step-by-step process for selecting the type of treatment facilities that will apply to individual projects. Physical features of sites that are applicable to treatment facility selection are also discussed. Refer to Sections 6.10 and 6.11 for additional details on three of the four treatment facility options - oil control treatment, phosphorus control, and Metals Treatment.

6.2.1 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 if Site Discharges to Ground or Groundwater, or to Surface Waters; or both

Step 2: 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 6.2.1 and 6.2.2. Table 6.2.1 provides information on determining pollutant sources and pollutants of concern for some land uses. Table 6.2.2 provides information on the relative ability of different treatment facilities to remove key pollutants. Table 6.2.4 provides suggested stormwater treatment options for arid and semi-arid climates.

Step 1: Determine if Site Discharges to an Infiltration Facility (Ground or Groundwater) or to Surface Waters; or both

If Site Discharges to Ground or Groundwater via Infiltration

Determine if Treatment is Required and Apply Infiltration BMP

Check the infiltration treatment design criteria in Section 6.4 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.

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 Site Discharges to Surface Waters, Proceed to Step 2

Step 2: Determine the Receiving Waters and Pollutants of Concern Based on Off-Site Analysis

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. 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. 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 6.2.1 lists the pollutants of concern from various land uses. Table 6.2.2 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 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 6.10
- **Coalescing Plate Oil/Water Separator** – See Section 6.10
- **Catch Basin Inserts** – See Section 6.12
- **Bio-infiltration Swales** – See Section 6.4
- **Sand Filter** – See Section 6.8

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 Section 4. 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. **Please refer to the Oil Control options listed above and in Figure 6.2.1. After selecting an Oil Control Facility, proceed to Step 4. If an Oil Control Facility is not required, proceed directly to Step 4.**

Step 4: Determine if Pollutant Removal via Infiltration and Collection 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. Although a site may be unable to meet the criteria of Site Suitability Criteria 4 given in Section 6.4 (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 6.4 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 6.11 and Figure 6.2.1. 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 6.2.1 through 6.2.4 as an initial screening of options.

If you have selected a phosphorus treatment facility, please refer to the General Requirements in Section 6.3. 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.*

If phosphorus treatment is not required for the site, proceed to Step 6.

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 6.2.1 and detailed in Section 6.11. 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 6.2.1 through 6.2.4 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 6.3. They may affect the design and placement of the facility on the site.*

If Metals Treatment does not apply to the site, proceed to Step 7.

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 6.2.1 through 6.2.4 as an initial screening of options.

After selecting a Basic Treatment Facility, refer to the General Requirements in Section 6.3. They may affect the design and placement of the facility on the site.

You have completed the treatment facility selection process.

Figure 6.2.1
BMP Selection Process

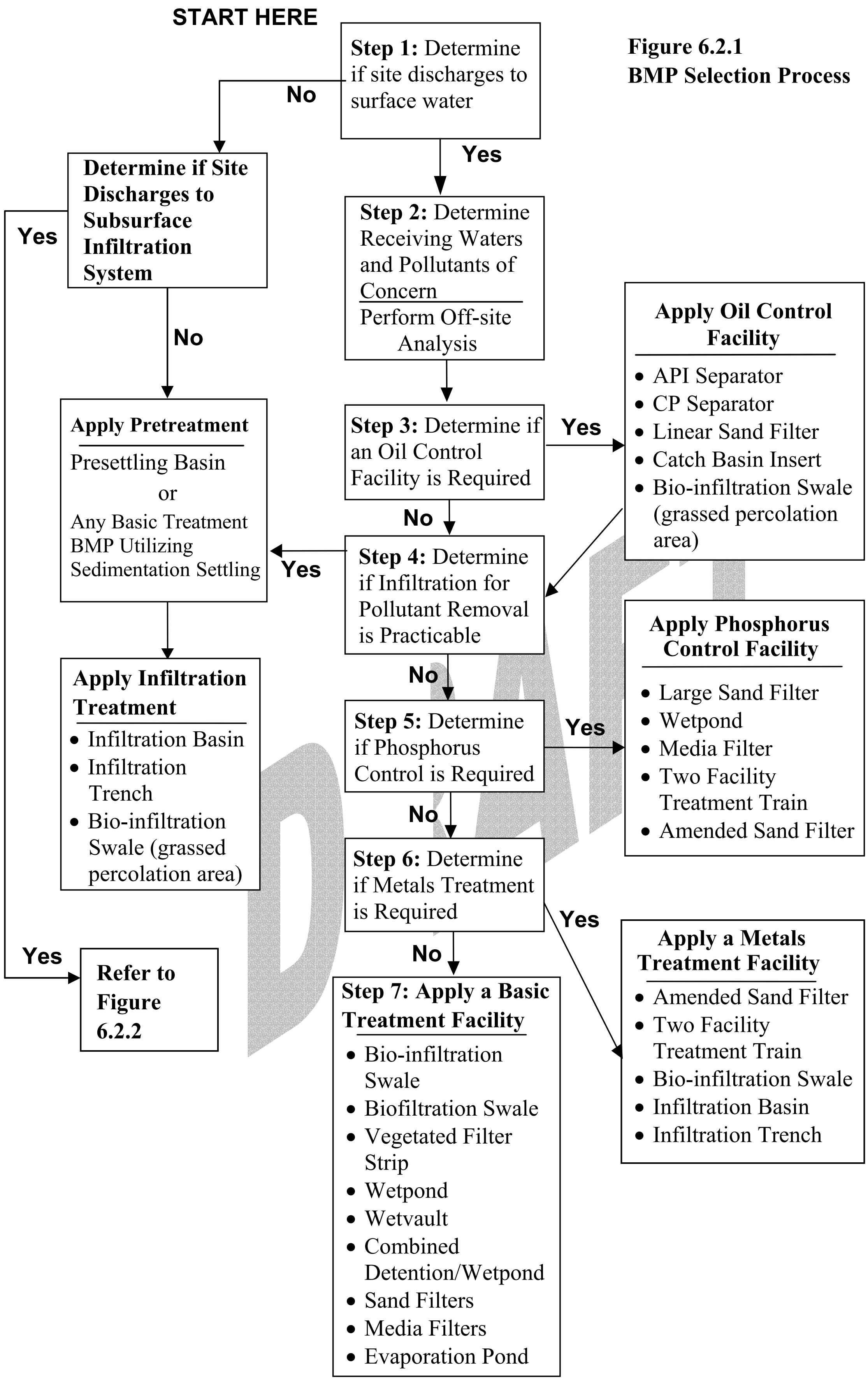
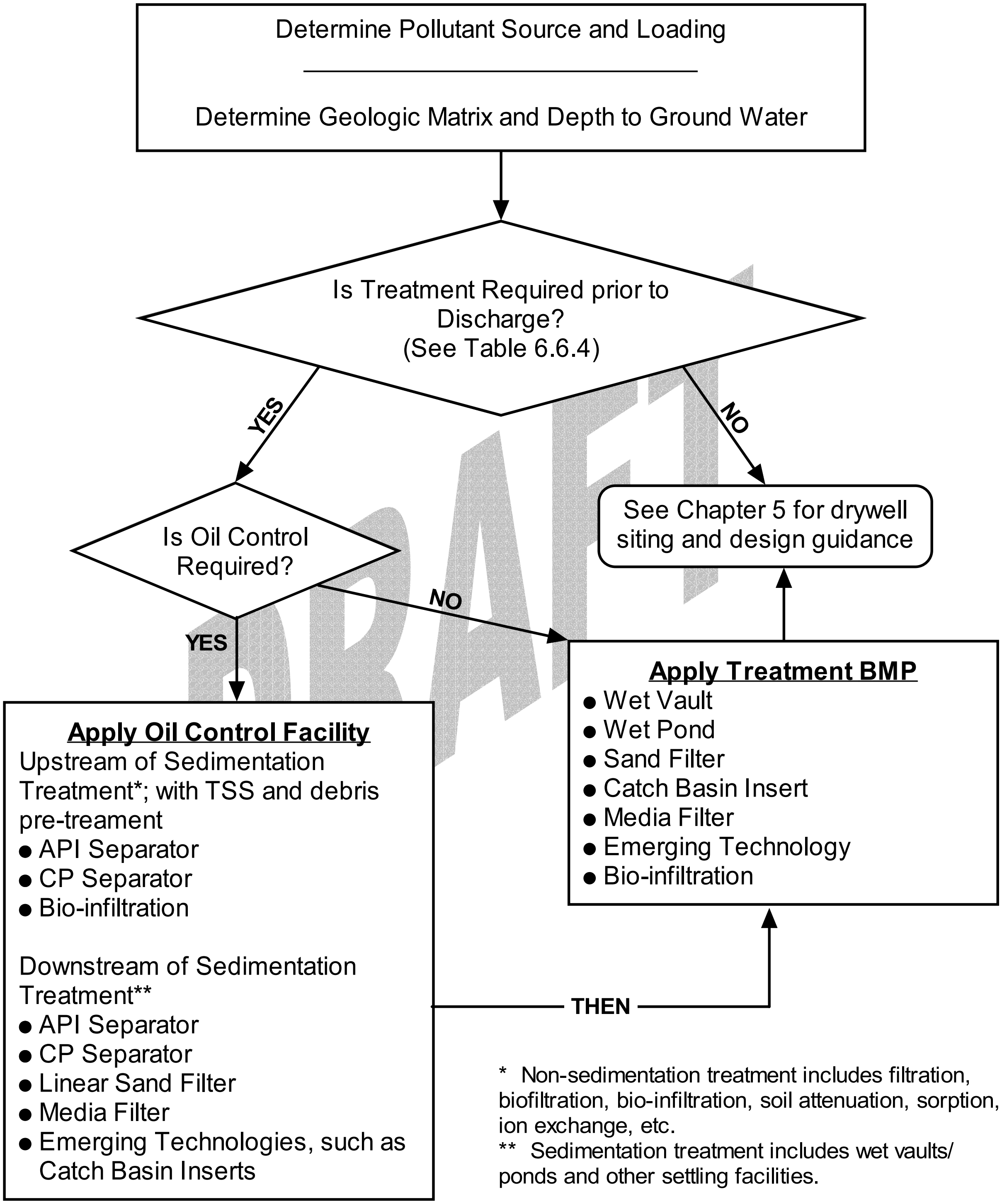


Figure 6.2.2
BMP Selection Process for Discharges to Subsurface Infiltration Systems



* Non-sedimentation treatment includes filtration, biofiltration, bio-infiltration, soil attenuation, sorption, ion exchange, etc.
** Sedimentation treatment includes wet vaults/ ponds and other settling facilities.

6.2.2 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 6.2.1 and 6.2.2)

Table 6.2.1 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 6.2.1, a combination of an oil/water separator and a biofilter could be considered as the basic treatment for runoff from uncovered fueling stations. Table 6.2.2 is a general listing of the relative effectiveness of classes of treatment facilities in removing key stormwater pollutants.

Soil Type (Table 6.2.3)

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 6.2.4)

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 6.2.4 identifies the preferred BMPs and the limitations to use in the arid and semi-arid climates found in most of Eastern Washington.

Cold Weather Considerations

The following information is adapted from Stormwater Practices for Cold Climates by the Center for Watershed Protection. More information and the entire manual is available for downloading at: http://www.stormwatercenter.net/Cold%20Climates/cold-climates.htm

Cold climates can present additional challenges to the selection, design, and maintenance of stormwater treatment BMPs. The designer who is designing treatment BMPs in cold weather areas should be aware of these challenges and make provisions for them in the final design. Several of the most common effects of cold weather are described below.

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 because 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.

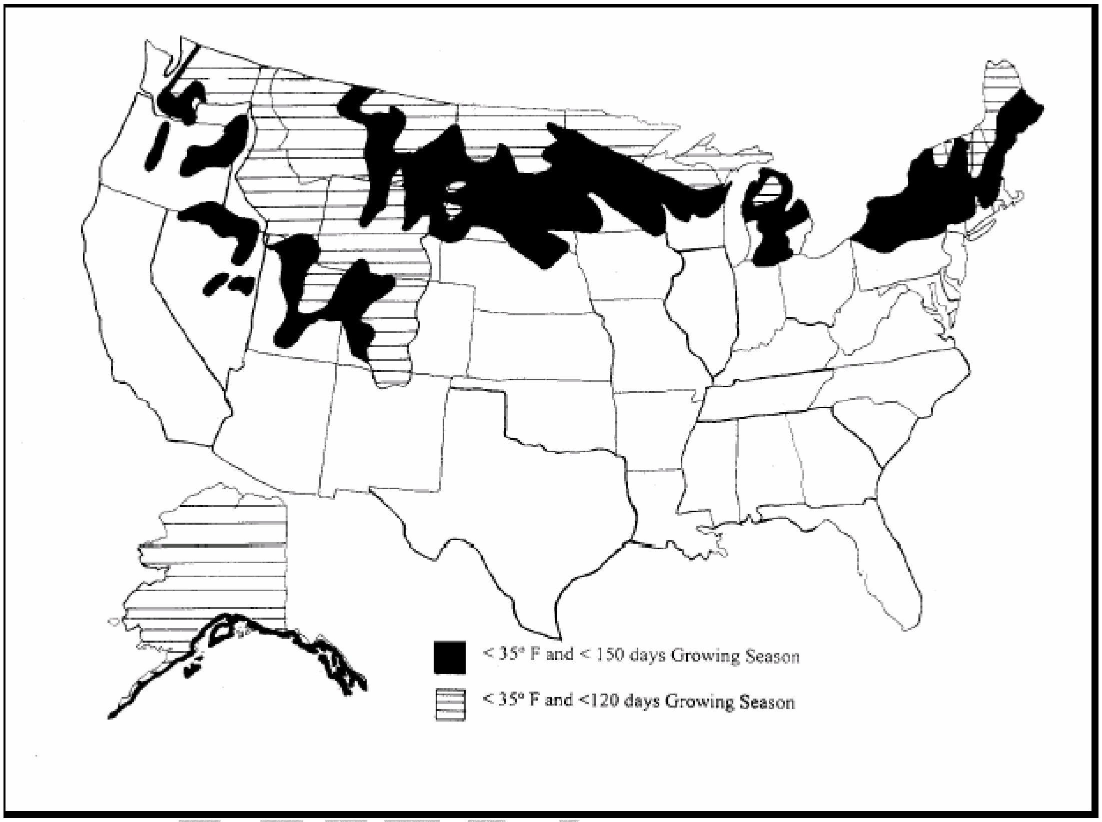
High Pollutant Loading During Winter or Spring Thaw Periods

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. Research has indicated that roughly 65% of the sediment, organic, nutrient, and lead loads can be attributed to winter and spring melts.

Cold Weather Areas in Eastern Washington

Regions which have a normal 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. Figure 6.2.3 illustrates these areas in the United States. The depth of snow and the frost depth should also be considered when evaluating the incorporation of cold weather measures in the design of BMPs. The designer should consult with the local plan authority before making a final decision on the inclusion of cold weather measures.

Figure 6.2.3 Overlay of Maximum January Temperature and Growing Season (Source: U.S. Doc, 1975)



6.2.3 Other Physical Factors

- **Slope:** Steep slopes restrict the use of several BMPs. For example, biofiltration swales are usually situated on sites with slopes of less than 6%, although greater slopes can be considered. Infiltration BMPs are not suitable when the slope exceeds 15%.
- **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 Bedrock/ Hardpan/Till:** 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:** Since infiltration BMPs convey runoff back into the soil, some sites may experience problems with local seepage. 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 6.2.1
Suggested Stormwater Treatment Options for
New Development and Redevelopment Projects

Pollutant Sources	Pollutants of Concern
ROOFS:	
Metal	Zn
Vents & Emissions(2)	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

Table 6.2.2
Ability of Treatment Facilities to Remove Key Pollutants[1] [3]

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

Footnotes:
■ *Significant Process*
+ *Lesser Process*
(1) *Adapted from Kulzer, King Co.*
(2) *Assumes Loamy sand, Sandy loam, or Loam soils*
(3) *If neither a Significant or Lesser Process is shown, the Treatment Facility is not particularly effective at treating the identified pollutant*

Table 6.2.3
Screening Treatment Facilities Based on Soil Type

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

Notes:
■ *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 6.2.4
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: ▪ requires greater pretreatment ▪ sensitive to sediment loadings	Preferred:
Bio-infiltration Swales	Acceptable with Limitations: ▪ Use dryland grass	Preferred: ▪ Use dryland or irrigated grass
Extended detention dry ponds	Preferred: ▪ Multiple storm extended detention ▪ Stable pilot channels ▪ "Dry" forebay	Acceptable: ▪ dry or wet forebay needed
Infiltration	Acceptable with Limitations: ▪ See Table 6.6.4 ▪ limit pervious area treatment ▪ multiple pretreatment ▪ soil limitations	Acceptable with Limitations: ▪ See Table 6.6.4 ▪ limit pervious area treatment ▪ multiple pretreatment
Wet ponds	Not Recommended: ▪ evaporation rates are too high to maintain a normal pond without extensive use of scarce water	Limited Use: ▪ liners to prevent water loss require water balance analysis design for a variable rather than permanent normal pool ▪ use water sources such as AC condensate for pool ▪ aeration unit to prevent stagnation
Stormwater wetlands	Not Recommended: ▪ evaporation rates too great to maintain wetlands plants	Limited Use: ▪ require supplemental water ▪ submerged gravel wetlands can help reduce water loss
Biofiltration Swales	Not Recommended: ▪ not recommended for pollutant removal, but rock berms and grade control needed for open channels to prevent channel erosion	Limited Use: ▪ limited use unless irrigated ▪ 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

6.3 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.

6.3.1 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.

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.

6.3.2 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.

6.3.3 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, if the design is prepared and stamped by a licensed civil engineer. 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.

6.3.4 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 6A of this chapter.

6.4 Surface Infiltration and Bio-infiltration Treatment Facilities

6.4.1 Purpose

A stormwater infiltration treatment facility is an impoundment, typically a basin, 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 T6.10 Infiltration basins
- BMP T6.20 Infiltration trenches
- BMP T6.21 Infiltration swales
- BMP T6.30 Bio-infiltration swales (grassed percolation area)

6.4.2 Application

These infiltration and bio-infiltration treatment measures are capable of achieving the performance objectives cited in Section 6.1 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.

6.4.3 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 5 – Detention, Retention, and Infiltration 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.

Information for Reviewers*: The presumptive infiltration rates for the given soil classifications shown below should be expected to vary depending on site location in Eastern Washington. Factors which influence infiltration rates include but are not necessarily limited to: site geologic setting; natural soil moisture content; in-place soil density; depth of groundwater or impervious stratum beneath the infiltration facility; and particle size distribution.*

6-2 Feedback Requested: *Reviewers are requested to provide information regarding surface infiltration rates for soil types common to their area and for the types of surface infiltration facilities used for on-site stormwater treatment in their locale. Methods for establishing design infiltration rates are also requested from reviewers. The presumptive rates shown below will be modified in the final version of the manual based on information received from reviewers.*

Table 6.4.1 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. 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.

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.

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.

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 pond should be monitored quarterly over a 2-year period to assess the performance of the facility in terms of water quantity and quality perspectives.

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.

6.4.4 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 should be coordinated with the Treatment Facility options provided in Section 6.2.

BMP T6.10 Infiltration Basins

The design of infiltration basins for water quality treatment is identical to the procedure given in Chapter 5, except that the allowable infiltration rate is limited to 2.4 in/hr or less.

BMP T6.20 Infiltration Trenches

The design of infiltration trenches for water quality treatment is identical to the procedure given in Chapter 5, except that the allowable infiltration rate is limited to 2.4 in/hr or less.

BMP T6.21 Infiltration Swales

The design of infiltration swales for water quality treatment is identical to bio-infiltration swales except that amended soil may be required to meet SSC-5. Greater soil depth is required for treatment because there is no uptake by vegetation. A landscape rock surface such as river rock or crushed basalt is recommended for aesthetic purposes and for dust control.

BMP T6.30 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 four 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.

Preferred Method 1

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 6.4.2 and

6.4.3 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 column 4 of Table 6.4.3

Table 6.4.2 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 6.4.3 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 1

This method matches Spokane County's method and 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 Methods - Preferred Design Method 2 and Alternative Design Method 2

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 5.3.4.
- 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 flooded depth of the swale should be 6 inches.

- The treatment soil should be at least 6 inches thick with a CE.C 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 treatment soil infiltration rate should not exceed 1-inch per hour for a treatment zone depth of 6 inches relying on the root zone to enhance pollutant removal. The Site Suitability Criteria in Section 6.4.3 must also be applied, if a design soil depth of 6 inches is used then a maximum infiltration rate of 2.4 inches per hour is applicable.
- 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.

6.5 Biofiltration Treatment Facilities

6.5.1 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 T6.40 Biofiltration swales
- BMP T6.50 Vegetated filter strip

6.5.2 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.

6.5.3 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 6.2.

BMP T6.40 - 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

- The swale should have a length of 200 feet. The maximum bottom width is 10 feet. The depth of flow must not exceed 4 inches during the 6-month storm.
- 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.
- Install low-flow biofiltration swales within ponds where sufficient land does not exist for both.
- 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.

BMP T6.50 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 6.5.2. 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 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 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.

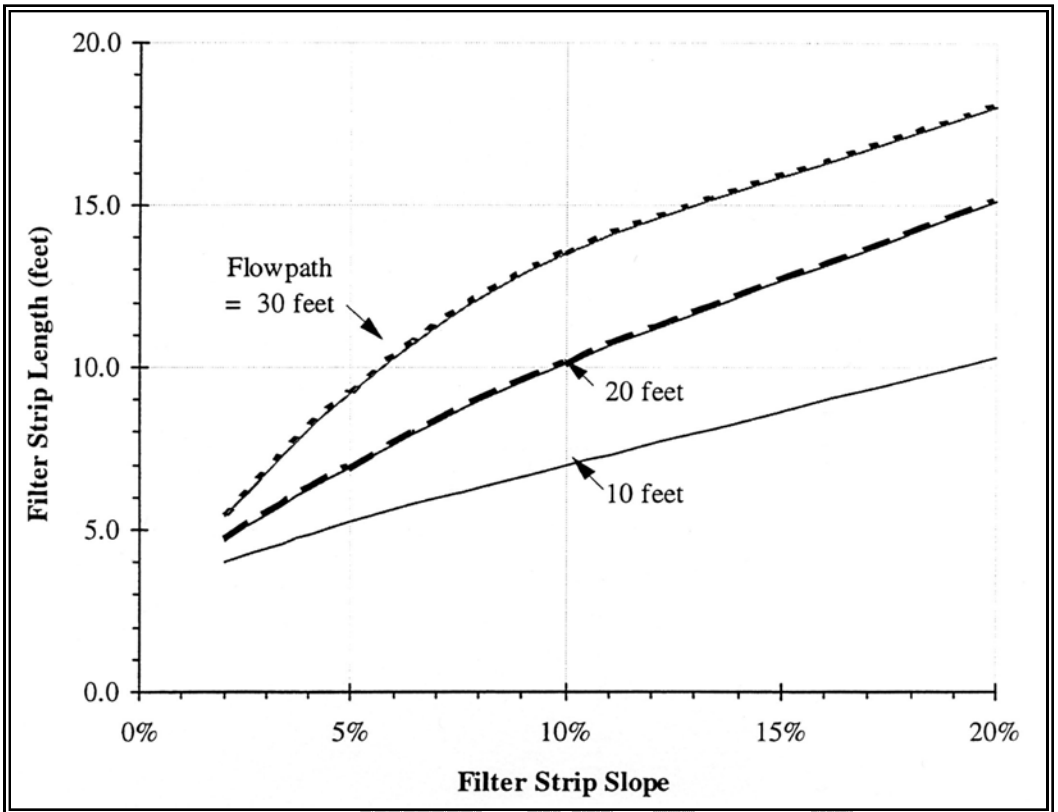
Design Procedure This procedure is based on the Narrow Area Filter Strips presented in the 1998 King County Surface Water Design Manual. The sizing of the filter strip is based on the length of the flowpath draining to the filter strip and the longitudinal slope of the filter strip itself (parallel to 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.
- **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 20 percent.
- **Step 3: Determine required length of the filter strip:** Use Figure 6.5.1 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.

Figure 6.5.1 Filter Strip Design Graph



From 1998 Surface Water Design Manual, King County

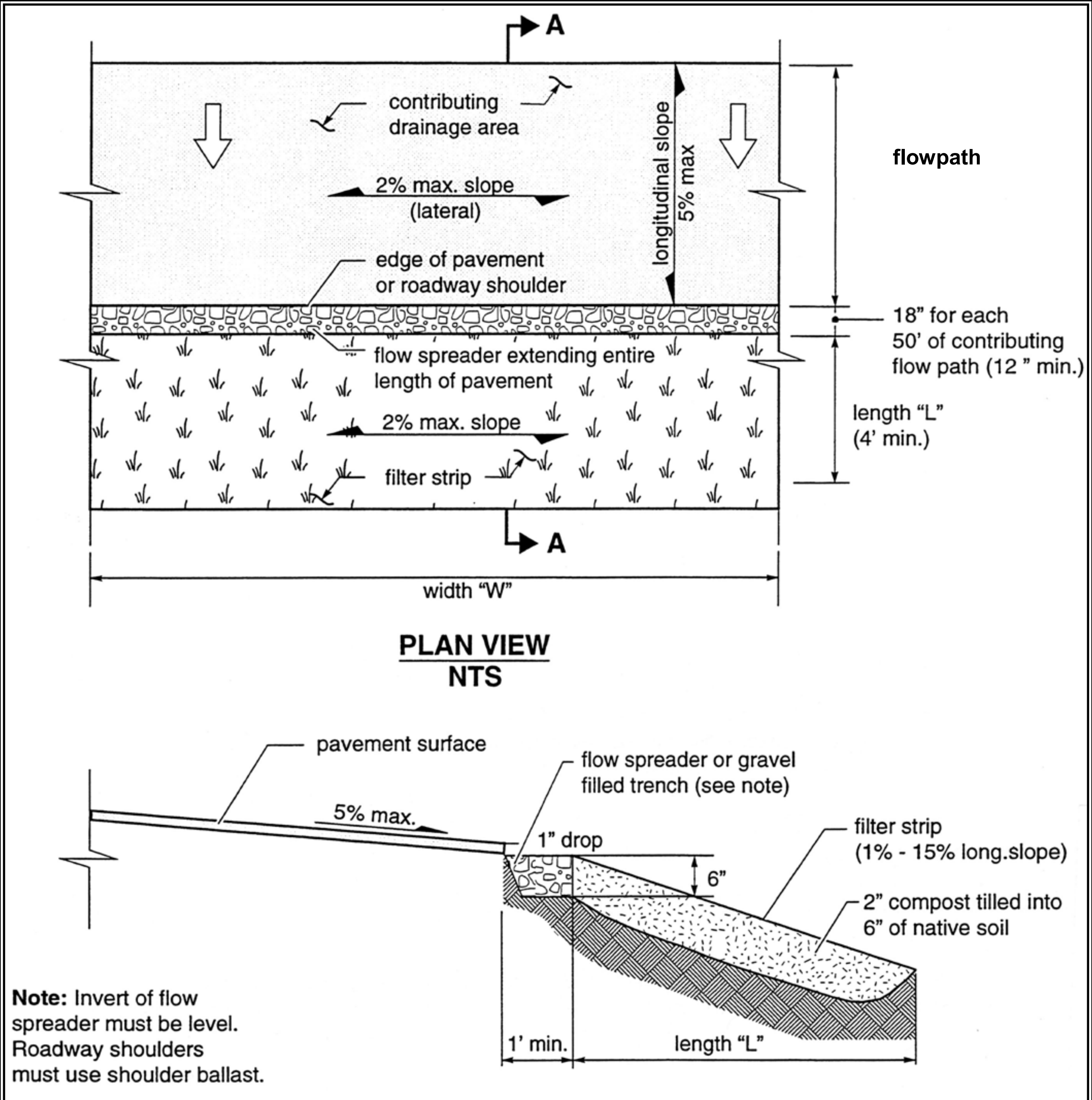


Figure 6.5.2 Typical Filter Strip Details

From 1998 Surface Water Design Manual, King County

6.6 Subsurface Infiltration

6.6.1 Purpose

This section provides site suitability, treatment requirements, and design criteria for subsurface infiltration including drywells.

6.6.2 Application

Subsurface infiltration may be considered as an infiltration treatment BMP for treating runoff from sources generating light to moderate pollutant loads under certain conditions. Subsurface infiltration may also be used as flow control BMPs where treatment is not required or for flows greater than the water quality design storm, and where runoff is treated prior to discharge.

6.6.3 General Considerations for Subsurface Infiltration

In developing technical guidance for managing stormwater discharges to groundwater, Ecology proposes to use a risk-based approach that relies on existing data and local programs. This risk-based approach considers Overall Susceptibility and Potential Pollutant Loading and Land Use. Susceptibility means the ease with which contaminants can move from the land surface to the aquifer based solely on the types of surface and subsurface materials in the area. Information on potential pollutant loading associated with various land use comes from the literature (especially Robert Pitt, and Richard Claytor and Thomas Schueler1). Land use information would be available from the project proposal and from local zoning regulations.

6.6.4 Siting Criteria and Treatment Requirements

Where regional geologic information and groundwater depth information are available, Tables 6.6.1 through 6.6.4 can be used to determine treatment requirements for subsurface discharge. Where regional geologic information and groundwater depth information is not readily available, it will be necessary to obtain the data through review of local well logs or through site exploration. Alternatively, for small projects where site exploration is not cost-effective, the design professional could use the most conservative (protective) approach, subject to approval of the local approval authority.

These tables and the matrix that follows may be modified by local government where alternative susceptibility rating methods have been developed and/or site specific analysis demonstrates that the proposed land use and geologic conditions at the site will result in attenuation or treatment of the expected pollutants.

[1] Robert Pitt, "Groundwater Contamination from Stormwater Infiltration", 1996; and Richard Claytor and Thomas Schuler, 'Design of Stormwater Filtering Systems", Center for Watershed Protection, 1996

Table 6.6.1
Geologic Matrix and Susceptibility Rating

Geologic Matrix	**Susceptibility** *(point rating – description)*
Unfractured Igneous or Metamorphic Bedrock, Shale, Marine Clay, Clay, Dense Sandstone, Hardpan *(matrix not suitable for infiltration of stormwater due to low infiltration rate)*	0 - Very low
Loess, Glacial Till, Fractured Igneous or Metamorphic Bedrock Silt, Clayey Sands, Weathered Basalt	1 - Low
Silty Sands, Fine Sands, Permeable Basalt Clean Sands, Karst Limestone	2 - Moderate
Sand and Gravel Gravel	3 - High

Table 6.6.2
Depth to Groundwater and Susceptibility Rating

Depth to Groundwater	**Susceptibility** *(point rating - description)*
Confined Aquifer	0 - Very Low
> 50 feet	0 - Very Low
25 - 50 feet	1 – Low
10 - 25 feet	2 – Moderate
0 - 10 feet	3 – High

Table 6.6.3
Overall Susceptibility

Overall Susceptibility – from Combined Ratings of Geologic Matrix and Depth to Groundwater	
Description (Combined Options from Geologic Matrix & Depth to Groundwater)	*Combined Point Ratings*
Very Low (very low + very low)	0
Low (low + low; or very low + low)	1-2
Moderate (low + moderate; or moderate + moderate; or low + high)	3 – 5
High (moderate + high; or high + high)	>5

Table 6.6.4
A Suggested Matrix for Determining Treatment Requirements
for Subsurface Discharge
(Based on Potential Land Use and Pollutant Loading and Depth to Groundwater)

Overall Susceptibility – from Geologic Matrix & Depth to Groundwater / **Potential Pollutant Loading and Land Use**	**High Susceptibility**	**Moderate Susceptibility**	**Low Susceptibility**	**Very Low Susceptibility** *(May not be practicable for infiltration)*
Non Pollutant Generating Surface Residential Roofs, Bicycle paths	Direct Discharge without treatment; volume may be a problem	Direct Discharge without treatment		
Light Pollutant Loadings Residential Streets Rural highways Low maintenance landscape (for example; no pesticides, fertilizer applied according to label.)	Discharge following treatment and /or source control; volume may be a problem	Discharge following treatment and /or source control; Pretreatment for sediment may be necessary to protect integrity of drywell	Direct Discharge without treatment; Pretreatment for sediment may be necessary to protect integrity of drywell	
Moderate Pollutant Loadings High density residential Commercial area – low to moderate traffic Light industry, warehouses Arterials, Urban highways Landscape – treated with pesticides, fertilizer	No discharge; or Discharge following treatment and source control where justified by site specific analysis	Discharge following treatment and/or source control	Discharge following treatment	Discharge following treatment and /or source control
Heavy Pollutant Loadings (see notes below) High ADT Intersections High traffic commercial Gas stations, vehicle repair and maintenance Heavy industry	No discharge*; or Discharge following treatment and source control	Discharge following treatment and source control.		

See Notes on next page.

Notes for Table 6.6.4:

- Treatment BMPs include: Filtration, bio-infiltration, biofiltration, wetponds, wet vaults, catch basin inserts, media filters, and other emerging technologies, that provide treatment of expected pollutants for runoff flows up to the water quality design storm.
- Source Control BMPs include: Structures or operations intended to prevent pollutants from coming into contact with stormwater through physical separation of areas or careful management of activities that are sources of pollutants.
- High ADT Intersections/High Traffic Commercial includes: A road intersection with a measured average daily traffic (ADT) count of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway; commercial or industrial sites with ADT greater than 100 vehicles per 1,000 square feet of gross building area; or commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including routinely delivered heating oil; commercial or industrial sites subject to parking, storage, or maintenance of 25 or more vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc).
- * Sites that use, store, and handle hazardous substances that have the potential to reach the subsurface and do not have a stormwater pollution prevention plan in accordance with the industrial stormwater permit program and or the future UIC rule requirements, Chapter 173-218 WAC can not discharge to a subsurface infiltration system.

The following text can be used in conjunction with Table 6.6.4.

Direct discharge to subsurface infiltration systems without Treatment

Stormwater runoff that is not contaminated or not likely to be contaminated can be discharged directly to subsurface infiltration systems without treatment. This includes discharges from non-pollutant generating surfaces such as landscaping and vegetated areas that have not been treated with pesticides or fertilizers, non-contaminant generating roofs, bicycle paths, etc.

Stormwater runoff from pollutant generating surfaces – generating light pollutant loadings - can be discharged directly to subsurface infiltration systems without treatment in the following situations. Note that pretreatment for sediment may be necessary to protect integrity of the subsurface infiltration system.

Susceptibility to contamination is very low or low

- Susceptibility to contamination is moderate and source control eliminates or significantly reduces target pollutants
- Susceptibility to contamination is moderate or low and the fraction of runoff from sources generating light pollutant loadings is less than

20% of the total contributing impervious area. An alternative percentage may be used, where established by local government as part of a drinking water source control or ground water protection program.

Stormwater runoff from pollutant generating surfaces – generating moderate pollutant loading; can be discharged directly to subsurface infiltration systems without treatment provided:

- Susceptibility to contamination is very low and source control eliminates or significantly reduces target pollutants
- Susceptibility to contamination is moderate or low and the fraction of runoff from sources generating moderate pollutant loadings is less than 20% of the total contributing impervious are. An alternative percentage may be used, where established by local government as part of a drinking water source control or ground water protection program.

Discharge to subsurface infiltration systems following the use of treatment BMPs:

In the following situations, urban stormwater runoff can be discharged to a subsurface infiltration system, following treatment using appropriate stormwater treatment BMPs. Appropriate treatment BMPs are BMPs selected from the Stormwater Management Manual for Eastern Washington, or equivalent manual approved by Ecology, that are designed to remove or attenuate the pollutants to acceptable levels.

Stormwater runoff from pollutant generating surfaces – generating light pollutant loading

Stormwater runoff from pollutant generating surfaces – generating *moderate pollutant loading*; provided:

- Susceptibility to contamination is low
- Susceptibility to contamination is moderate and source control eliminates or significantly reduces target pollutants

Stormwater runoff from pollutant generating surfaces – generating *heavy pollutant loadings*; provided;

- Susceptibility to contamination is very low, low, or moderate and source control eliminates or significantly reduces target pollutants

Treatment BMPs include:

- Filtration and bio-infiltration BMPs that provide treatment of expected pollutants for flows up to the WQ design storm;
- Water quality vaults, wetpool BMPs, oil/water separators that provide treatment of expected pollutants. Use of these BMPs may be limited

to certain land uses or to areas where the susceptibility to contamination is moderate.

- Manufactured devices (such as catch basin inserts, media filters and other emerging technology) that provide treatment of expected pollutants (using filtration, adsorption, or sedimentation processes) for flows up to the WQ design storm;

Overflows or bypass flows from these treatment BMPs may be discharged to subsurface infiltration systems; provided that the WQ design storm flows are treated and only the excess flows are routed directly to the subsurface infiltration system and discharged without treatment. Also, the frequency of overflow, the combination of site characteristics, and the expected pollutant loading (based on projected land use) are to not likely result in contamination of ground water.

The following uses of subsurface infiltration systems may not be allowed due to potential contamination of ground water unless an accepted stormwater pollution prevention plan is in place along with appropriate BMPs.

- Runoff from activities where there is a high risk of runoff being contaminated as a result of spills or illicit discharges; such as vehicle repair and servicing, hazardous materials handling.
- Sites with moderate to high susceptibility to contamination receiving runoff from commercial or industrial sites with moderate to heavy pollutant loadings, or roads with high ADT.

6.6.5 Design Criteria

Where subsurface infiltration systems receive treated runoff, runoff from non-pollutant generating surfaces, or by-passed flows greater than the water quality design storm, the design criteria in Chapter 5 may be used.

Where subsurface infiltration systems are used as infiltration treatment BMPs, the design criteria in Chapter 5 may be used, with the following conditions:

- The site meets the pollutant loading criteria for direct discharge.
- The site meets the susceptibility criteria for direct discharge.

6.7 Wetpool Facilities

6.7.1 Purpose and Definition

BMP T6.70 Basic Wetpond

BMP T6.71 Large Wetpond

A wet pond is a constructed stormwater pond that retains a pool of water (the "wetpool"), with the only discharge by evaporation and slow infiltration. 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 6.7.1 and 6.7.2 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.

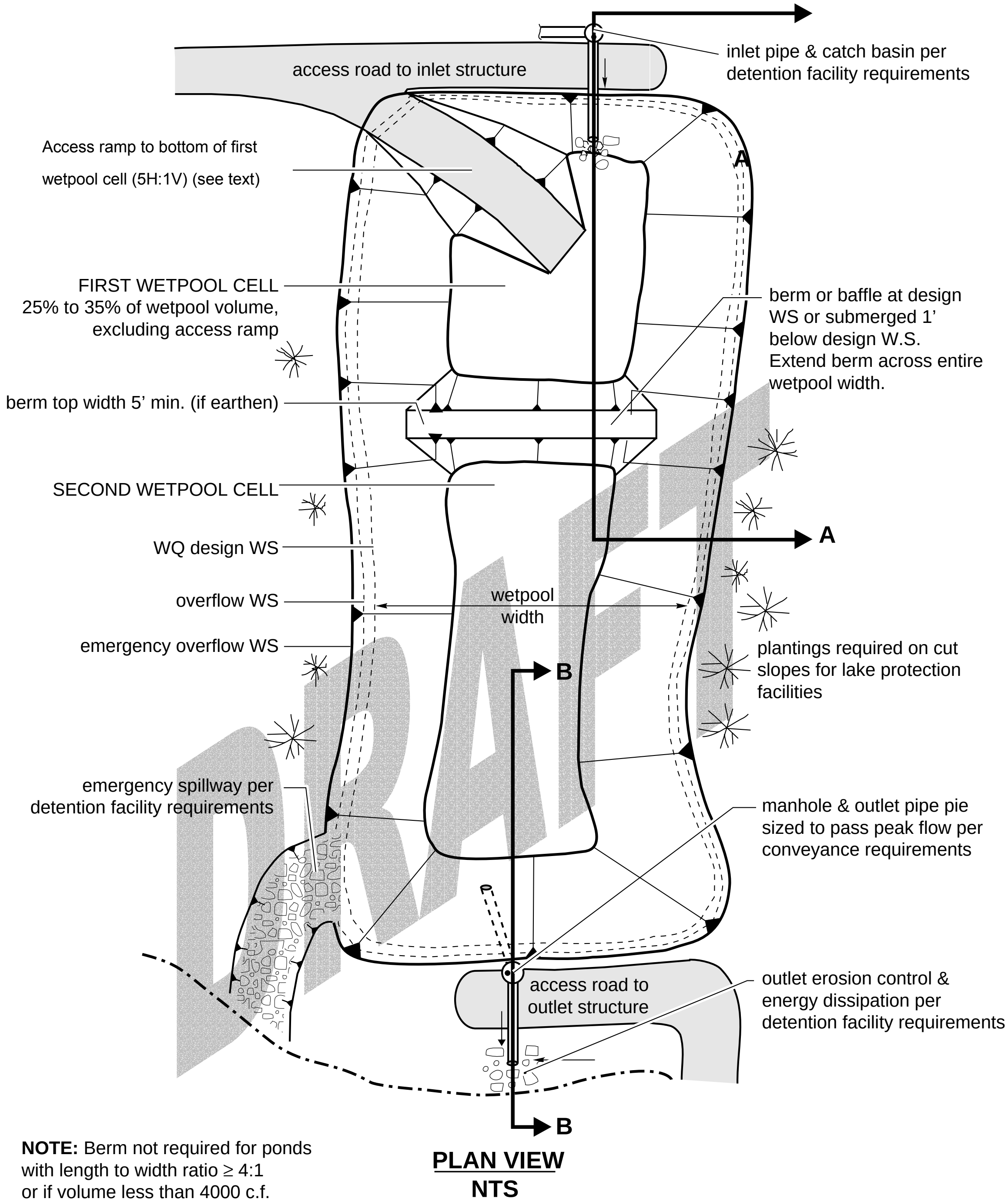


Figure 6.7.1 Wetpond (plan view)

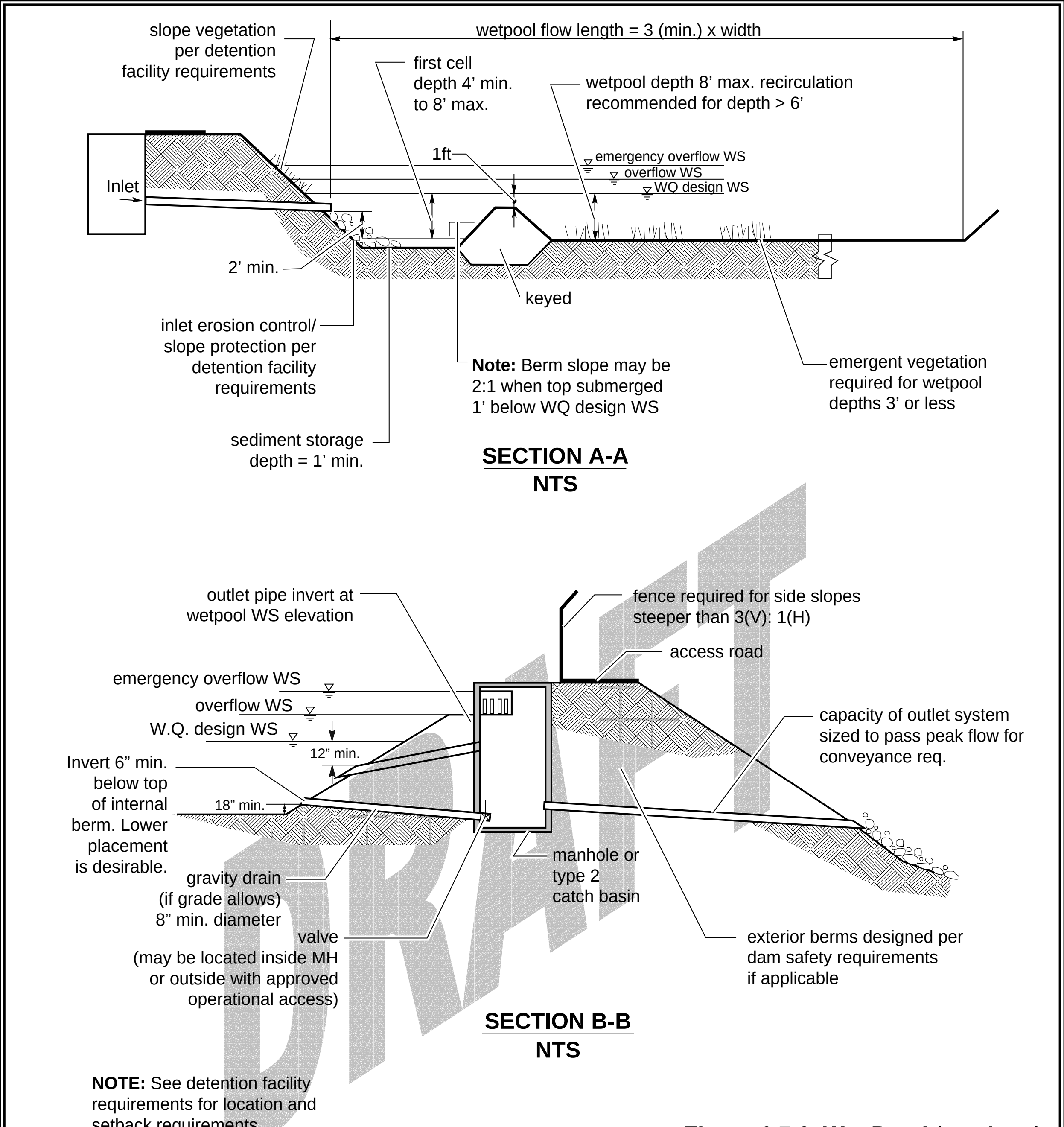


Figure 6.7.2 Wet Pond (sections)

6.7.2 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 5 for the design of detention ponds.

6.7.3 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 6.7.1 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 6.7.1 and 6.7.2. 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 5 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 6.7.1 and 6.7.2.

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. See Chapter 5 – Detention, Retention, and Infiltration Design.

Inlet and Outlet

See Figures 6.7.1 and 6.7.2 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 (see Chapter 5 – Detention, Retention, and Infiltration Design for an illustration). 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 5 – Detention, Retention, and Infiltration 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.

Evergreen or 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. 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.

6.7.4 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.

6.7.5 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 Section 4.6 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.

6.7.6 BMP T6.72 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 6.7.3). 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 6.7.3.

Wetpool Geometry Same as specified for wet ponds (see BMP T10.10) 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.

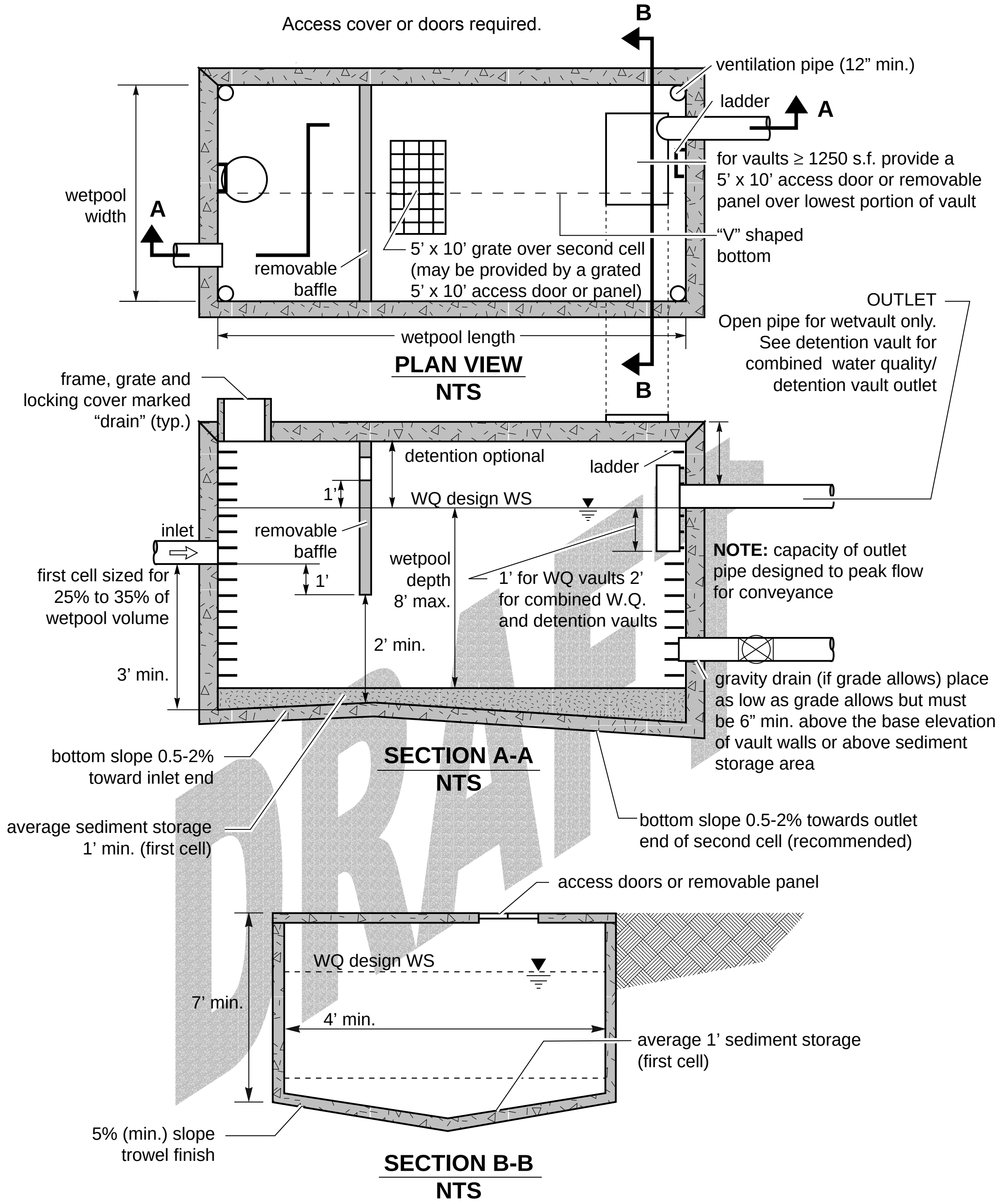


Figure 6.7.3 Wetvault

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 Plan Approval Authority 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 5.

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 Plan Approval Authority 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 5) 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 5).

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 6A 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.

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 6A for information on maintenance of baffle oil/water separators.

1. The sizing procedures for the baffle oil/water separator (Section 6.10) 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.

6.8 Sand Filtration Treatment Facilities

6.8.1 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 6.8.1 for a basic sand filter.)

6.8.2 Performance Objectives

BMP T6.80 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 T6.81 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)

6.8.3 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)

6.8.4 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

6.8.5 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

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

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 6.8.1 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 6.8.1 - 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 6.8.2.

Table 6.8.2 - Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	1 x 10^{-6} 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 basins 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 basin 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.

6.8.6 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.

6.8.7 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 (and topsoil if applicable)
- Aerating the filter surface
- Tilling the filter surface (late-summer rototilling is suggested)
- Replacing the top 4 inches of sand (and topsoil if applicable)
- Inspecting geotextiles for clogging

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.

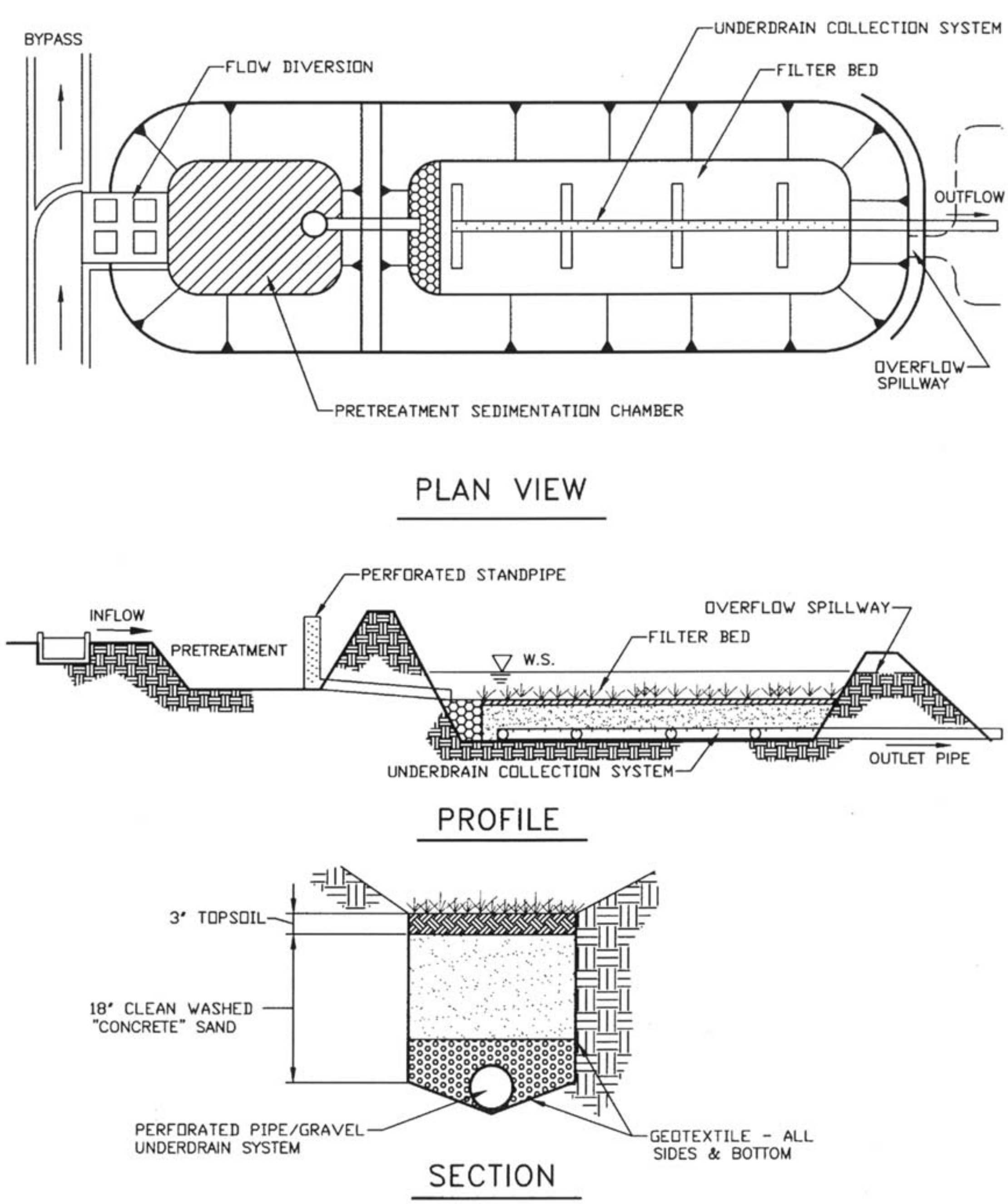


Figure 6.8.1 Sand Filter

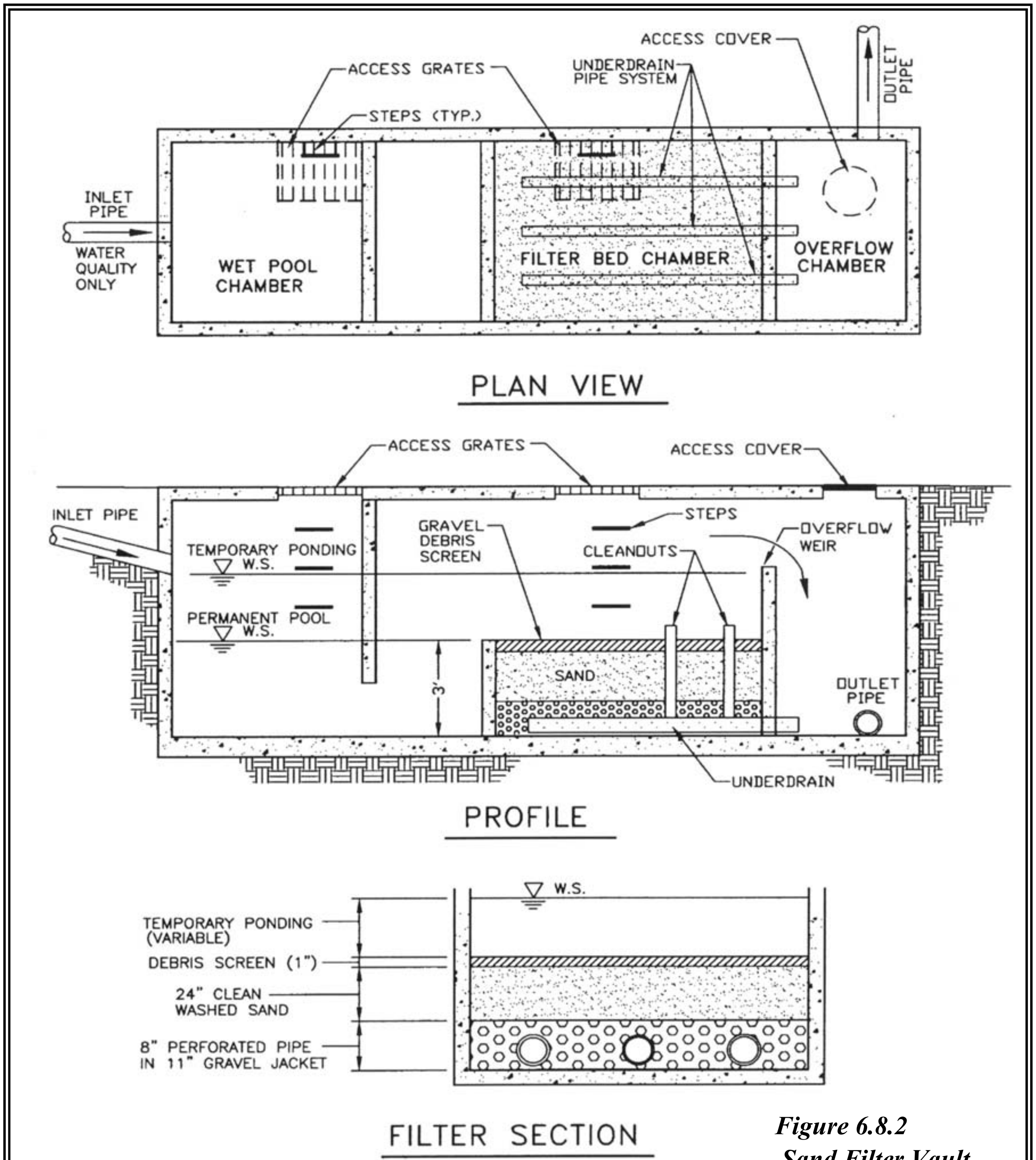


Figure 6.8.2
Sand Filter Vault

Sand Filter Vault

BMP T6.90 Sand Filter Vault

Description: (Figure 6.8.2) 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 T6.91 Linear Sand Filter

Description:

Linear sand filters 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.

- 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

6.9 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.

6.10 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.

6.10.1 Purpose of Oil and Water Separators

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

6.10.2 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 6.10.1 and 6.10.2. 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 6.10.3) 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.

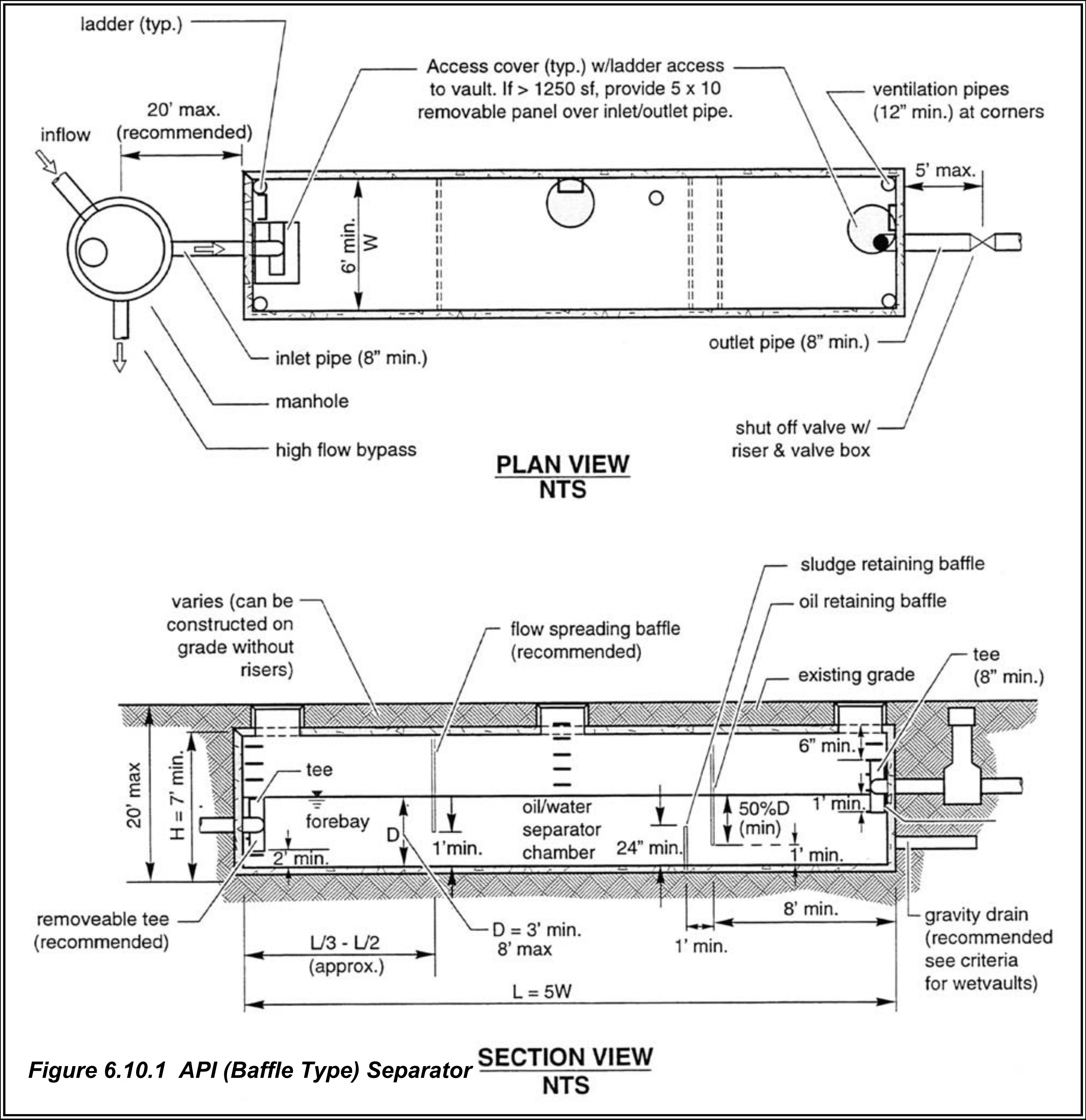


Figure 6.10.1 API (Baffle Type) Separator

Source: King County (reproduced with permission)

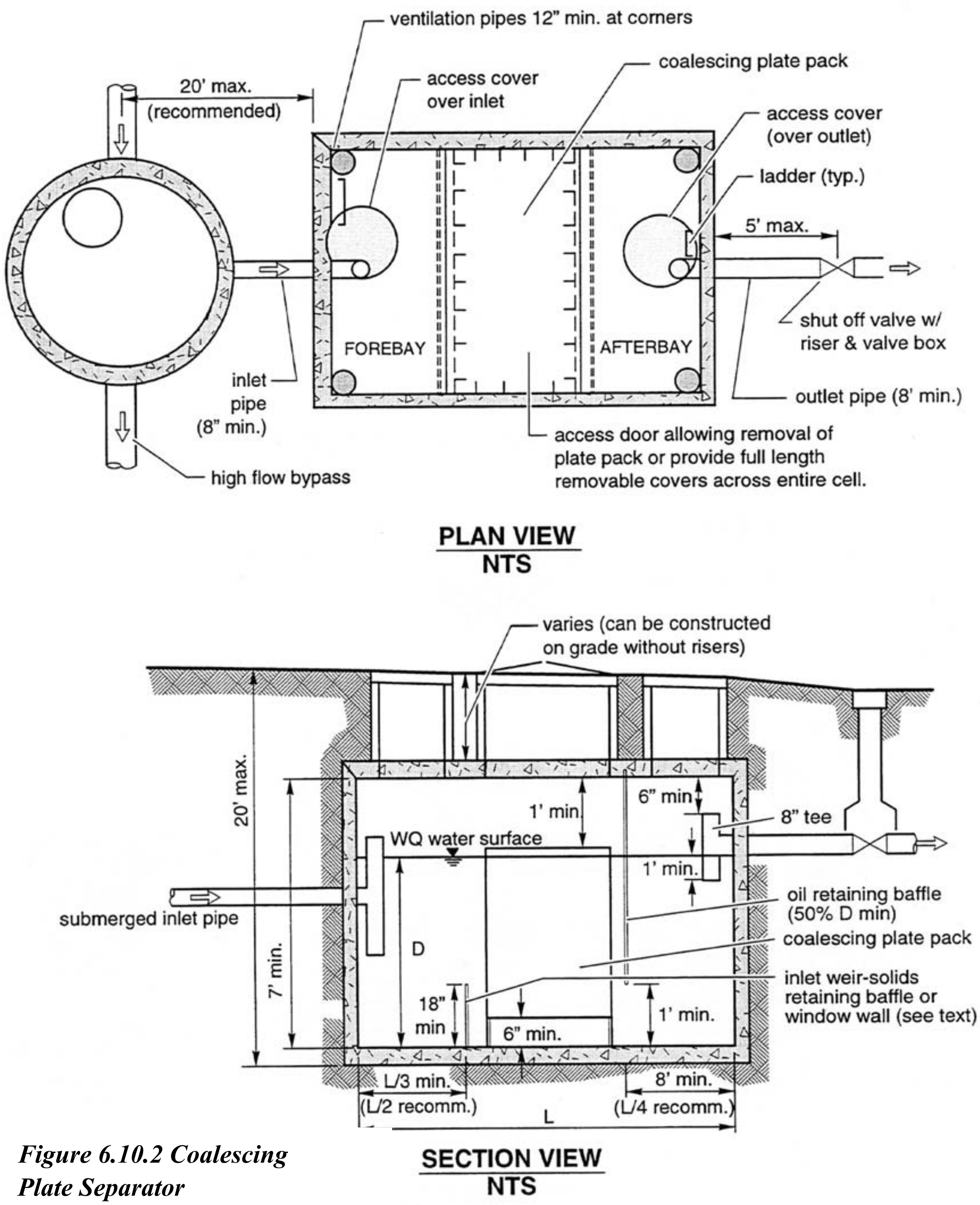


Figure 6.10.2 Coalescing Plate Separator

Source: King County (reproduced with permission)

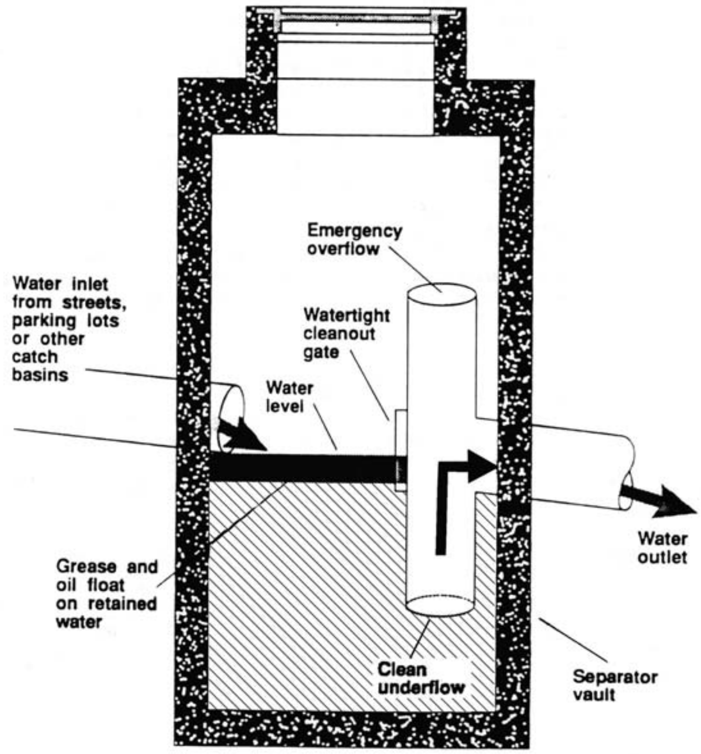


Figure 6.10.3 Spill Control Separator (not for oil treatment)

Source: 1992 Ecology Manual

6.10.3 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 6.2).

6.10.4 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. (See 6.5.7 Design Criteria).

6.10.5 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)

6.10.6 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 6.4), 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.

6.10.7 Oil and Water Separator BMPs

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

BMP T6.10 -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 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 60μ 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):

$$V_t = g(\sigma_w - \sigma_o)D^2 / 18\eta_w)$$

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)

σ_w =0.999 gm/cc. at 32° F

σ_o: Select conservatively high oil density,

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

η_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 ≥3≤8 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 ft³/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 T6.11 - 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:

$A_p = Q/V_t = Q/0.00386(\sigma_w - \sigma_o/\eta_w)$

$A_p = A_a(\text{cosine } b)$

Where:

Q = 2.15 x the water quality design flow rate, ft³/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 ft²; .00386 is unit conversion constant

σ_w=density of water at 32º F
σ_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).

η_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.

6.10.8 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.

6.11 Phosphorus Treatment and Metals Treatment

6.11.1 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. These treatment options apply to stormwater conveyed to the lake by surface flow as well as to stormwater infiltrated within one-quarter mile of the lake in soils that do not meet the site suitability criteria in Section 6.4.

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 6.4.

Infiltration treatment – If infiltration is through soils meeting the minimum site suitability criteria for infiltration treatment (see Section 6.4), 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 – If the soils do not meet the site suitability criteria and the infiltration site is within ¼ mile of a phosphorus-sensitive receiving water, or a tributary to that water, treatment must be provided by one of the other treatment facility options listed below.

Amended Sand Filter – See Section 6.8.

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 6.7.

Media Filter Targeted for Phosphorus Removal – See Section 6.12.

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 6.11.1.

Table 6.11.1 - 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

6.11.2 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 6.4.

Infiltration Treatment

If infiltration is through soils meeting the minimum site suitability criteria for infiltration treatment (see Section 6.4), 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 6.8.

Amended Sand Filter – See Section 6.12.

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 6.11.2.

Table 6.11.2 -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.	

6.12 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.

6.12.1 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.

6.12.2 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.

> ***6-3 Feedback Requested:*** *Ecology has been working to develop methods for evaluating new and emerging technologies and plans to place a Technology Assessment Protocol on the Stormwater Home Page by mid-October 2002. We particularly invite public comment on how to make the technology assessment process work for Eastern Washington.*

6.12.3 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 6.1.

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.

6.12.4 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.

6.12.5 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 statewide acceptance the performance criteria as specified in Section 6.1 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.

6.12.6 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.

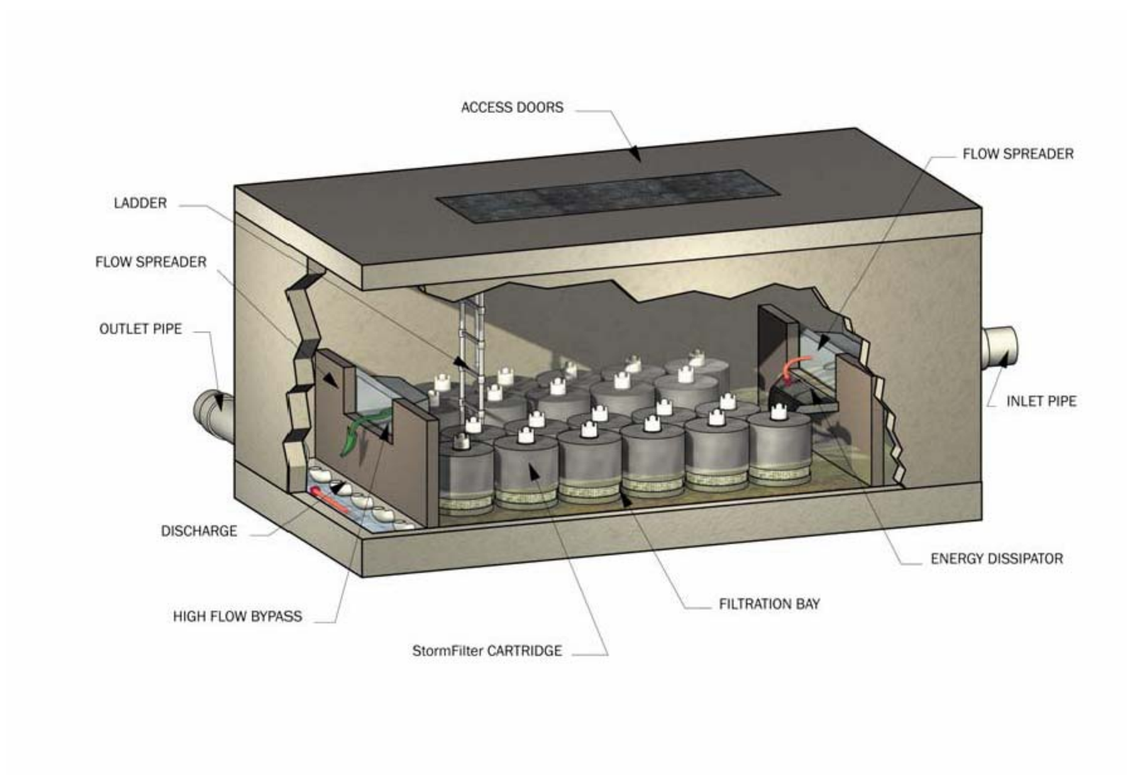


Figure 6.12.1 Vertical Media Filter

Courtesy of Stormwater Management Inc.

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 6.12.1). 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 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 thusfar 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 6.12.2.

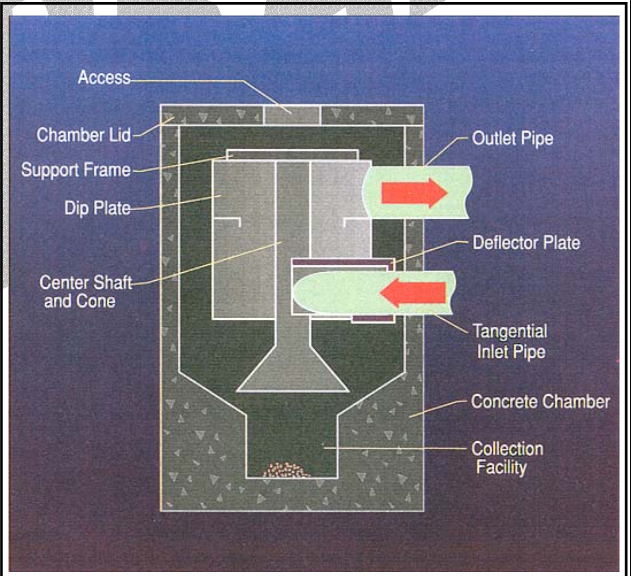


Figure 6.12.2 - Vortex-enhanced settling mechanism

Courtesy of HIL, Inc.

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 6.12.3.

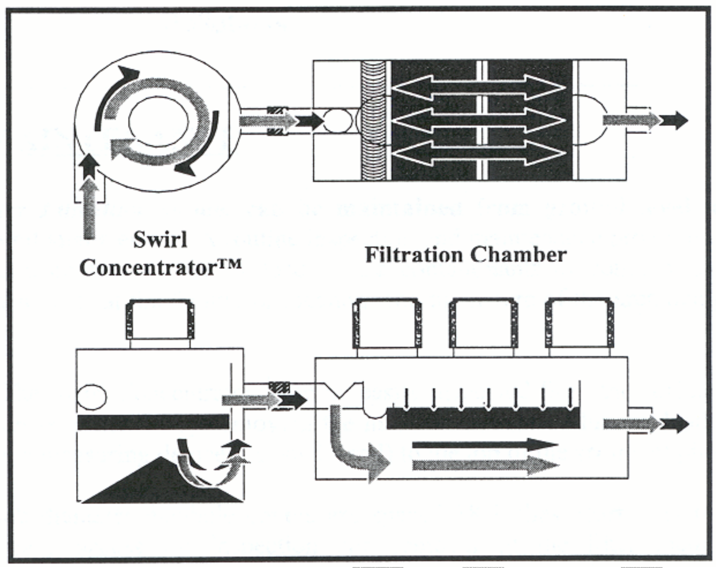


Figure 6.12.3 - Vortex-enhanced Sedimentation and Media Filtration

Courtesy of Aquafilter, Inc.

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 6.12.4.

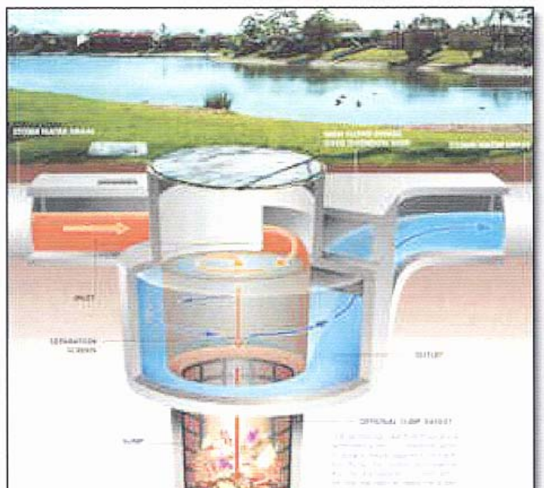


Figure 6.12.4 - Screen Separator

Courtesy of CDS, Inc.

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.

6.12.7 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 6A – 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.	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.
	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.