Category 1
Ecology-Approved BMPs Not in the HRM

For instructions on seeking approval to use these BMPs, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the *Highway Runoff Manual* (HRM). All BMPs referenced in Category 1 that are not included herein can be found in Chapter 5, Section 5-4, of the HRM.

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Category 1
Ecology-Approved BMPs Not in the HRM

1 Vault-Type BMPs

BMP RT.19 – Wet Vault

> *WSDOT does not recognize this BMP as a viable highway application for basic treatment due to safety, cost, and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).*

Introduction

General Description

Wet vaults are underground structures similar in appearance to detention vaults (see BMP FC.04), except wet vaults have permanent pools of water in the bottom that dissipate flow energy and improve the settling of particulate pollutants (see Figures RT.19.1 – RT.19.4). Wet vaults provide basic runoff treatment. Being under-ground, wet vaults lack the biological pollutant-removal mechanisms, such as soil microbial activity and algae uptake, present in surface wet ponds (see BMP RT.12 in the HRM).

Applications and Limitations

Applications

Wet vaults are used for projects that have limited or no ROW to construct an above ground basic runoff treatment facility.

Limitations

Because of a wet vault's high capital cost, associated maintenance and safety issues for personnel maintaining the vault, and the vault's eventual replacement cost, above ground basic runoff treatment facilities are preferred over enclosed underground wet vaults. Underground vaults are difficult to maintain due to poor accessibility and reduced ability to determine when maintenance is necessary. Typically, the increased construction and long-term maintenance expenses offset any initial cost savings derived from smaller right of way purchases. Wet vaults should only be used as a last resort when all other options are not feasible. **Wet vaults are Category I BMPs that require approval by the Region Hydraulics Engineer and approval by the local area Maintenance Superintendent.**

If underground structures are the only BMP types feasible on the project, wet vaults can be constructed to include a live storage for flow control. The PEO shall coordinate with the local area Maintenance Superintendent when a combined wet/detention vault is proposed on the project to discuss maintenance access, dewatering for maintenance, and internal vault cell cleanout procedures.

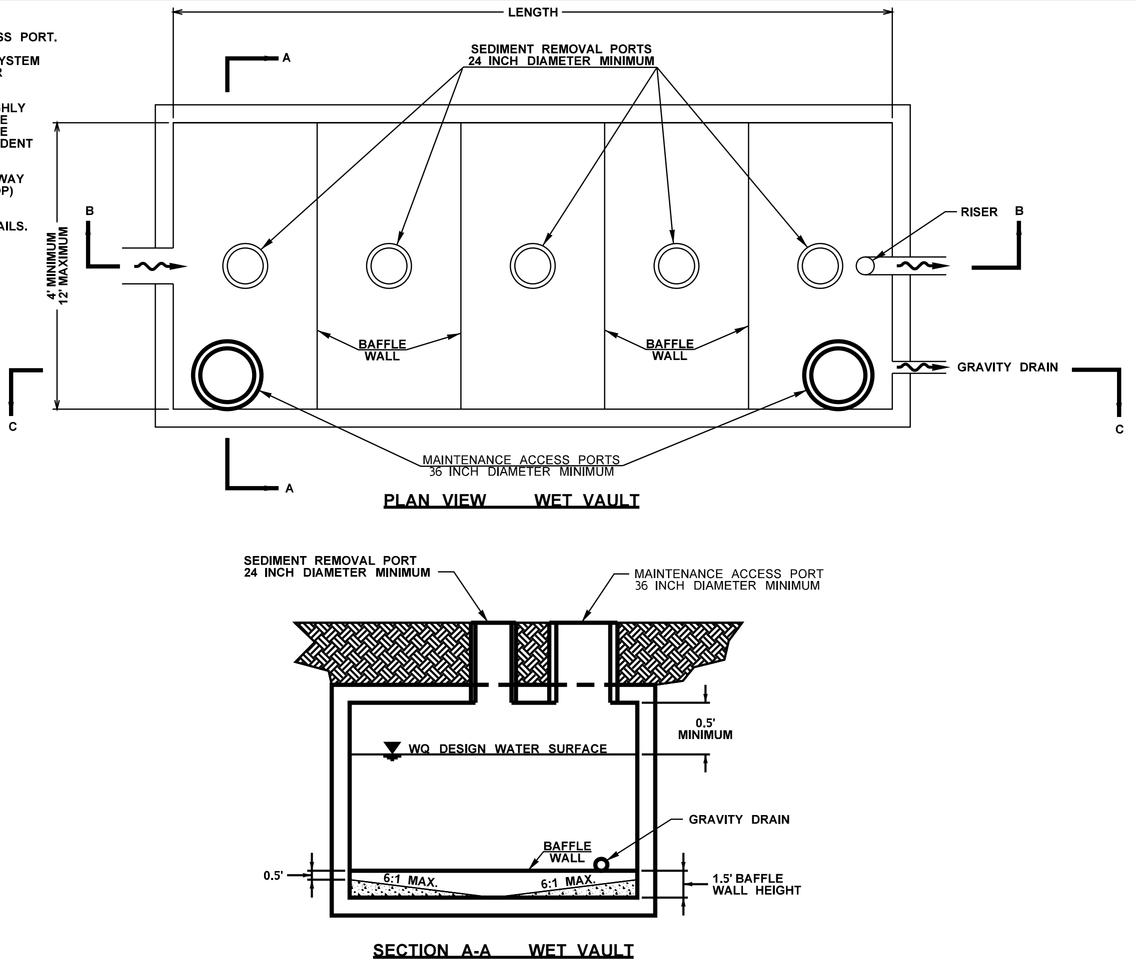
Per the WSDOT Bridge Inspection Manual, vaults under roadways are considered subject to the National Bridge Inspection Standards (NBIS) when the minimum clear span along the centerline of the roadway exceeds 20 feet AND is wider than 12 feet, including any structure that has any portion directly under a lane or shoulder. Wet Vaults may exceed one of the vault dimensions listed above but shall not exceed both vault dimension maximums.

If maintenance access includes vehicles driving over the vault structural design shall be performed by an engineer licensed in compliance with the Materials section of FC04 Detention Vault. Coordination with Area Maintenance to determine applicable vehicle loads is required.

Design Flow Elements

Flows to Be Treated

The PEO shall use the same “Flows to Be Treated Primary Overflow” design criteria and requirements as shown in Wet Ponds HRM BMP RT.12 in the HRM).



NOTES:

ALL VAULT AREAS MUST BE WITHIN 50 FEET OF A MAINTENANCE ACCESS PORT.

VENTILATION MUST BE PROVIDED. VENTILATION COULD BE A PASSIVE SYSTEM OR ACTIVE SYSTEM. CONSULT WITH REGION HYDRAULICS ENGINEER FOR MORE DETAILS.

ALL VAULTS MUST BE BUILT OUTSIDE THE ROADWAY PRISM. WITHIN HIGHLY URBANIZED AREAS, CITY LIMITS AND CONSTRAINED BY RIGHT-OF-WAY, THE ENTIRE VAULT OR PART OF THE VAULT COULD BE LOCATED WITHIN THE SHOULDER UPON APPROVAL OF THE REGION MAINTENANCE SUPERINTENDENT AND REGION HYDRAULICS ENGINEER.

THE VAULT SHALL BE PARTITIONED INTO INTERNAL CELLS IN SUCH A WAY THAT THE TOTAL VOLUME IN EACH CELL (UP TO THE BAFFLE WALL TOP) SHALL BE EQUAL TO OR LESS THAN SIX CUBIC YARDS.

SEE SECTION B-B OF HRM FIGURE 5-32 FOR CONTROL STRUCTURE DETAILS.

Figure RT.19.1. Wet vault Option A.

NOTES:

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SEE SECTION B-B OF HRM FIGURE 5-32 FOR CONTROL STRUCTURE DETAILS.

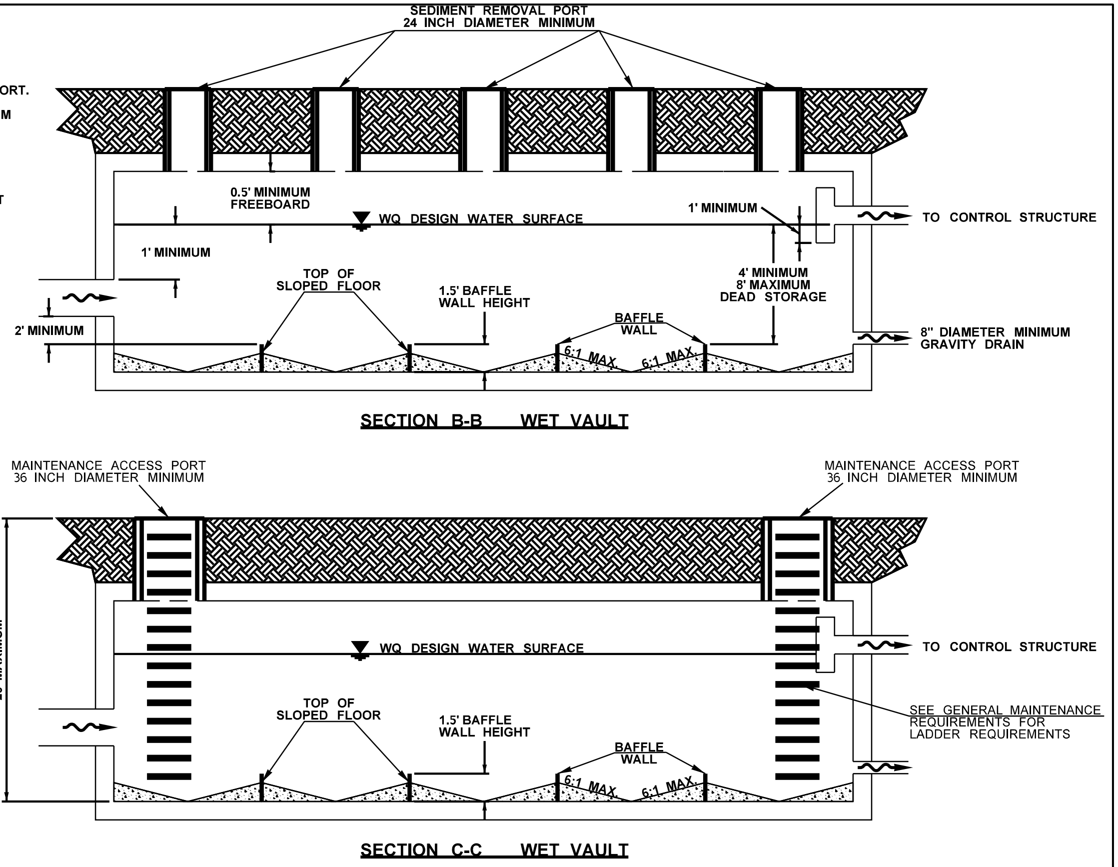

Figure RT.19.2 Wet vault Option A

NOTES:

ALL VAULT AREAS MUST BE WITHIN 50 FEET OF A MAINTENANCE ACCESS PORT.

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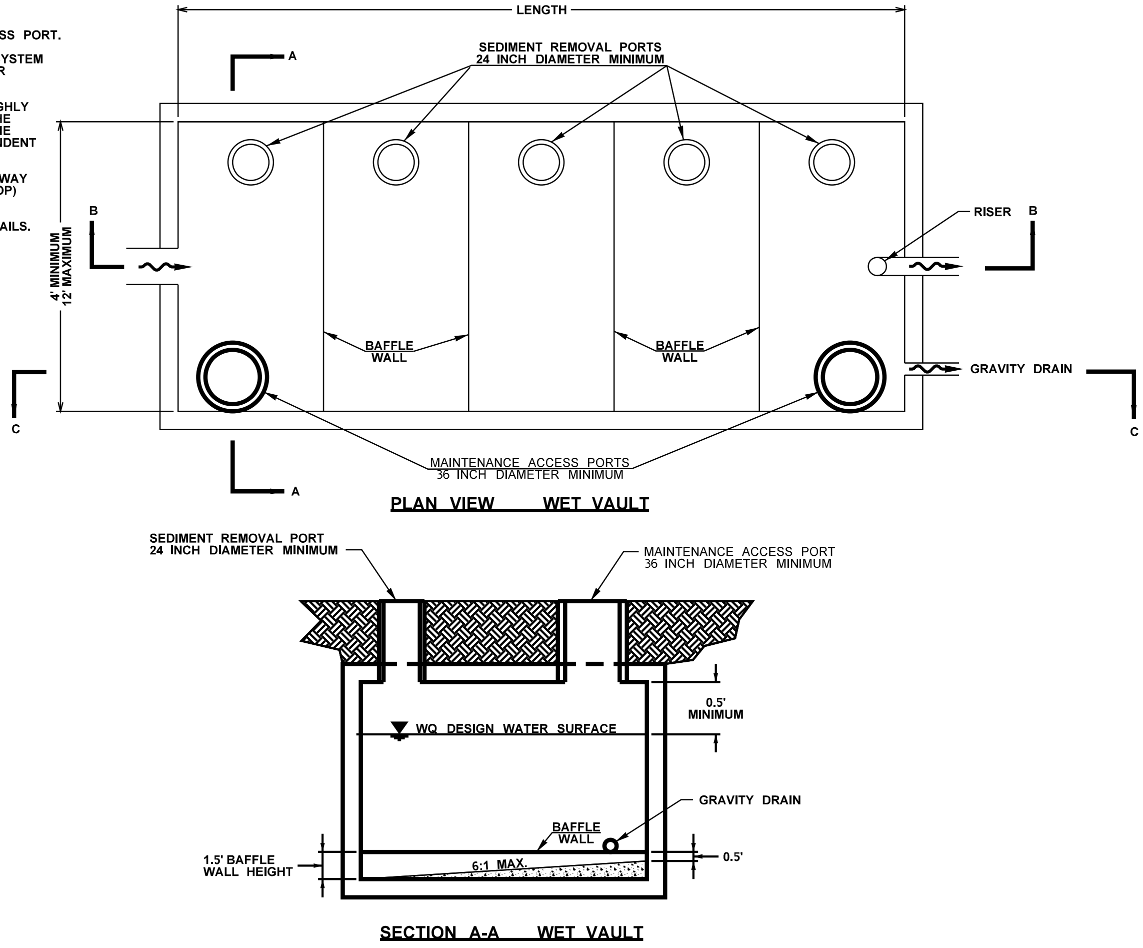

Figure RT.19.3 Wet vault Option B

NOTES:

ALL VAULT AREAS MUST BE WITHIN 50 FEET OF A MAINTENANCE ACCESS PORT.

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SEE SECTION B-B OF HRM FIGURE 5-32 FOR CONTROL STRUCTURE DETAILS.

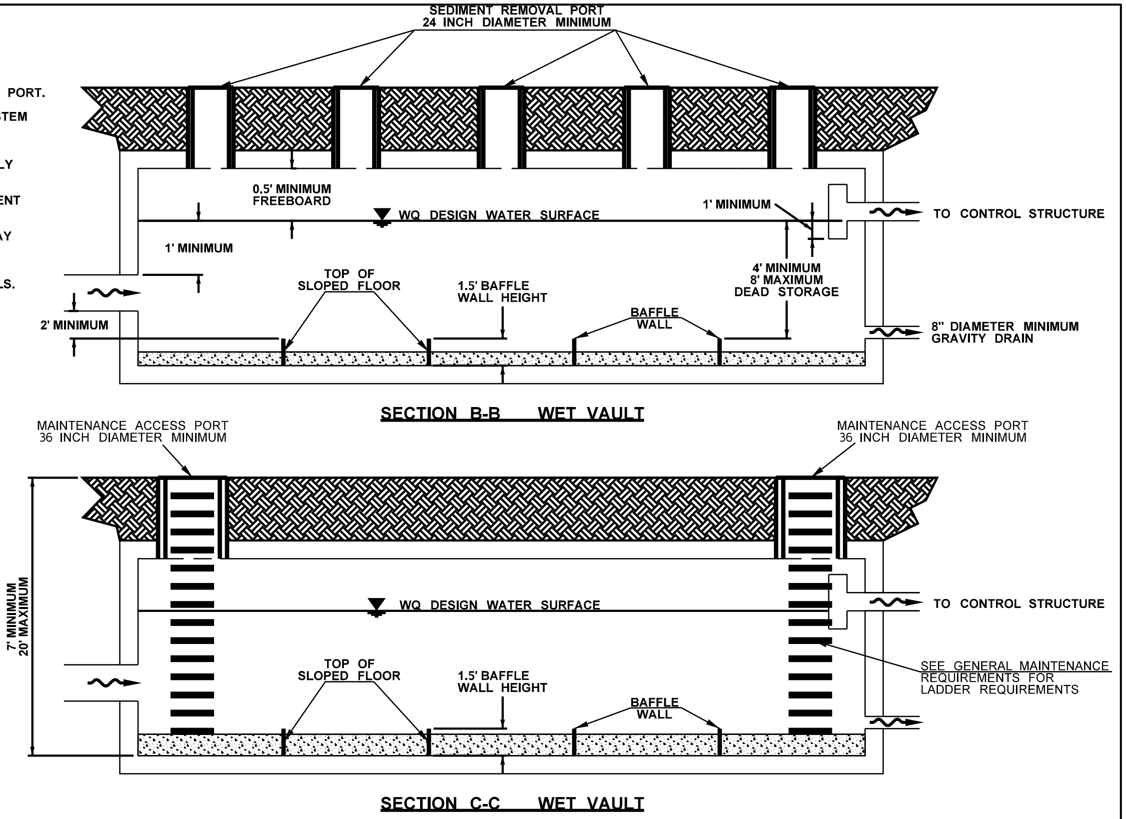

Figure RT.19.4 Wet vault Option B

Structural Design Considerations

Geometry

The geometry of the wet vault is extremely important for it to successfully function as a stormwater BMP and to facilitate successful maintenance of the vault. The distance between the inlet and outlet shall be maximized. See the vault Figures RT.19.1 – RT.19.4 for length, width, and height minimums, maximums, and other requirements. Wet vaults shall be designed with bottoms that are sloped toward the sediment removal ports to facilitate sediment removal.

A wet vault is considered a “Buried Structure” in the WSDOT Bridge Design Manual (BDM) and shall meet all requirements for Buried Structures in the BDM Section 8.3. The design guidance and requirements for wet vaults in this section shall supersede any discrepancies between the BDM and this section.

Wet Vault Bottom

The interior floor layout of the wet vault shall be designed for sediment storage in a series of internal sedimentation cells that can be vacuumed from the sediment removal portals in the top of the vault. Along the length of the vault, each sedimentation cell shall be divided by a baffle wall that is 18 inches tall. Figures RT.19.1 – RT.19.4 shows the two available options along with vault bottom floor, internal cell, maintenance access port, and sediment removal port details and spacing requirements. The PEO shall coordinate with the local area Maintenance Superintendent to determine which internal vault bottom sedimentation cell layout to use to facilitate maintenance operations.

The actual vault bottom and the bottom of dead storage are two different things. The bottom of dead storage is a flat line above the actual bottom of the vault that is used to calculate the wet vault dead storage to determine if the wet vault meets the basic runoff treatment volume requirement. Any volume below the dead storage is used for sediment storage and for shaping the bottom of the vault floor into the internal cells for sediment storage. The PEO shall design the dimensions of each internal sediment cell below the dead storage to not exceed 6 cubic yards of sediment storage volume.

Outlet Control Structure

The outlet pipe shall have a tee riser section. The lower arm should extend 1 foot below the runoff treatment design water surface to trap oils and floatables in the wet vault. See Figures RT.19.2 and RT.19.4.

Primary Overflow

The PEO shall use the same “Primary Overflow” and “Design Method Design Steps D1 – D3” design criteria and requirements as shown in HRM BMP RT.12 Wet Pond. The PEO shall provide a minimum of 6 inches of freeboard at the 100-year peak design flow for developed site conditions. (See Chapter 4 of the HRM for hydrologic methods.)

Materials

The PEO shall use the same "Materials" design criteria, structural requirements, and professional engineering licensing requirements as shown in Detention Vaults BMP FC.04.

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

Galvanized materials shall not be used in stormwater BMPs.

Sizing Procedure

The PEO shall use the same "Design Method" design criteria and requirements as shown in Wet Ponds BMP RT.12 in the HRM, except for the following modifications:

- The inlet to the wet vault shall be submerged, with the inlet pipe invert a minimum of 3 feet from the vault bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1 foot, if possible.
- The number of inlets to the wet vault should be limited, and the flow path length should be maximized from inlet to outlet (for example, locate the inlet and outlet in opposing corners of the vault).
- Wet vaults shall have a length-to-width ratio of 5:1 or greater. Wet vaults that have a dead storage volume of less than 2,000 cubic feet (inside dimensions) can have a lower length-to-width ratio of 3:1.
- A gravity drain for maintenance shall be installed to dewater the wet vault.
- The gravity drain shall drain the wet vault to the bottom of the dead storage.
- The gravity drain shall be 8 inches (minimum) in diameter and controlled by a valve that can be opened and closed from the finished grade. The valve location shall be accessible and well-marked, with at least 1 foot of paving placed radially around the box. The valve shall also be protected from damage and unauthorized operation.

Site Design Elements

Groundwater

The PEO shall use the same "Groundwater" design criteria and requirements as shown in Detention Vaults BMP FC.04.

Setback Requirements

The PEO shall use the same "Setback Requirements" design criteria and requirements as shown in Detention Vaults BMP FC.04.

General Maintenance Requirements

The PEO shall use the same "General Maintenance Requirements" design criteria and requirements as shown in Detention Vaults BMP FC.04. This includes a requirement for flow bypass system to take each individual vault cell offline for maintenance. The one exception to the "General Maintenance Criteria" in BMP FC.04 is the following:

- Lockable grates instead of solid manhole covers are recommended to increase air contact with the wet pool and for ventilation. Note: Underground vaults with stagnant water make prime habitat for mosquito larvae. Grated covers allow easy access by adult mosquitoes. If lockable grates are selected include mosquito control measures. For example, wet vaults designed as oil/water separators could potentially trap enough oil to create lethal conditions for mosquito larvae. If mosquito control measures are not feasible select solid covers to control disease vectors associated with mosquitos.

BMP CO.03 – Combined Wet/Detention Vault

WSDOT does not recognize this BMP as a viable highway application for combined basic treatment and flow control due to safety, cost and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

Introduction

General Description

Combined wet/detention vaults have the appearance of detention vaults (see BMP FC.04), but contain a permanent pool of water in the bottom for runoff treatment. The following design procedures, requirements, and recommendations cover differences in the design of the stand-alone wet vault (see BMP RT.19) combined with detention storage.

Applications and Limitations

Applications

Combined wet/detention vaults are very efficient for sites where space limitations preclude the use of surface runoff treatment and flow control facilities. The runoff treatment facility may often be placed beneath the detention facility without increasing the facility surface area.

The basis for pollutant removal in a combined wet/detention vault is the same as that for the stand-alone wet vault (see BMP RT.19). However, in the combined facility, the detention function creates fluctuating water levels and added turbulence. For simplicity, the positive effect of the extra live storage volume and the negative effect of increased turbulence are assumed to balance, and are thus ignored, when sizing the wet pool volume.

Limitations

Because of a combined wet/detention vault's high capital cost, associated maintenance and safety issues for personnel maintaining the vault, and the vault's eventual replacement cost, above ground stormwater facilities are preferred over enclosed underground vaults. Underground vaults are difficult to maintain due to poor accessibility and reduced ability to determine when maintenance is necessary. Typically, the increased construction and long-term maintenance expenses offset any initial cost savings derived from smaller right of way purchases. Combined wet/detention vaults should only be used as a last resort when all other options are not feasible. **Combined wet/detention vaults are Category I BMPs that require approval by the Region Hydraulics Engineer and approval by the local area Maintenance Superintendent.**

Per the WSDOT Bridge Inspection Manual, vaults under roadways are considered subject to the National Bridge Inspection Standards (NBIS) when the minimum clear span along the centerline of the roadway exceeds 20 feet AND is wider than 12 feet, including any structure that has any portion directly under a lane or shoulder. Combined Wet/Detention Vaults may exceed one of the vault dimensions listed above but shall not exceed both vault dimension maximums.

If maintenance access includes vehicles driving over the vault structural design shall be performed by an engineer licensed in compliance with the Materials section of FC04 Detention Vault. Coordination with Area Maintenance to determine applicable vehicle loads is required.

Design Flow Elements

Flows to Be Treated

The PEO shall use the same "Flows to Be Treated" design criteria and requirements as shown in Wet Vaults (see BMP RT.19) and Detention Vaults (see BMP FC.04).

Structural Design Considerations

Geometry

The geometry of the combined wet/detention vault is extremely important for it to successfully function as a stormwater BMP and to facilitate successful maintenance of the vault. The distance between the inlet and outlet shall be maximized. See Figures CO.03.1 – CO.03.4 for length, width, and height minimums, maximums, and other requirements. Combined wet/detention vaults shall be designed with bottoms that are sloped toward the sediment removal ports to facilitate sediment removal.

A combined wet/detention vault is considered a "Buried Structure" in the WSDOT Bridge Design Manual (BDM) and shall meet all requirements for Buried Structures in the BDM Section 8.3. The design guidance and requirements for combined wet/detention vaults in this section shall supersede any discrepancies between the BDM and this section.

Combined Wet/Detention Vault Bottom

The interior floor layout of the combined wet/detention vault shall be designed for sediment storage in a series of internal sedimentation cells that can be vacuumed from the sediment removal portals in the top of the vault. Along the length of the vault, each sedimentation cell shall be divided by a baffle wall that is 18 inches tall. Figures CO.03.1 – CO.03.4 show the two available options along with vault bottom floor, internal cell, maintenance access port, and sediment removal port details and spacing requirements. The PEO shall coordinate with the local area Maintenance Superintendent to determine which internal vault bottom sedimentation cell layout to use to facilitate maintenance operations.

The actual vault bottom and the bottom of dead storage are two different things. The bottom of dead storage is a flat line above the actual bottom of the vault that is used to calculate the wet vault dead storage to determine if the combined wet/detention vault meets the basic runoff treatment volume requirement. Any volume below the dead storage is used for sediment storage and for shaping the bottom of the vault floor into the internal cells for sediment storage. The PEO shall design the dimensions of each internal sediment cell below the dead storage to not exceed 6 cubic yards of sediment storage volume.

Primary Overflow

The PEO shall use the same "Primary Overflow" design criteria and requirements as shown in Detention Vaults (see BMP FC.04).

Outlet Control Structure

The PEO shall use the same "Outlet Control Structure" design criteria and requirements as shown in Detention Vaults BMP FC.04.

Materials

The PEO shall use the same "Materials" design criteria, structural requirements, and professional engineering licensing requirements as shown in Detention Vaults BMP FC.04.

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

Galvanized materials shall not be used in stormwater BMPs.

Sizing Procedure

The PEO shall use the same "Sizing Procedure" design criteria and requirements as shown in Wet Vaults BMP RT.19 (dead storage volume requirement) and "Flows to be Detained" in Detention Vaults BMP FC.04 (live storage volume requirement).

Site Design Elements

Groundwater Issues

The PEO shall use the same "Groundwater" design criteria and requirements as shown in Detention Vaults BMP FC.04.

Setback Requirements

The PEO shall use the same "Setback Requirements" design criteria and requirements as shown in Detention Vaults BMP FC.04.

General Maintenance Requirements

The PEO shall use the same "General Maintenance Requirements" design criteria and requirements as shown in Detention Vaults BMP FC.04.

NOTES:

ALL VAULT AREAS MUST BE WITHIN 50 FEET OF A MAINTENANCE ACCESS PORT.

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SEE SECTION B-B OF HRM FIGURE 5-32 FOR CONTROL STRUCTURE DETAILS.

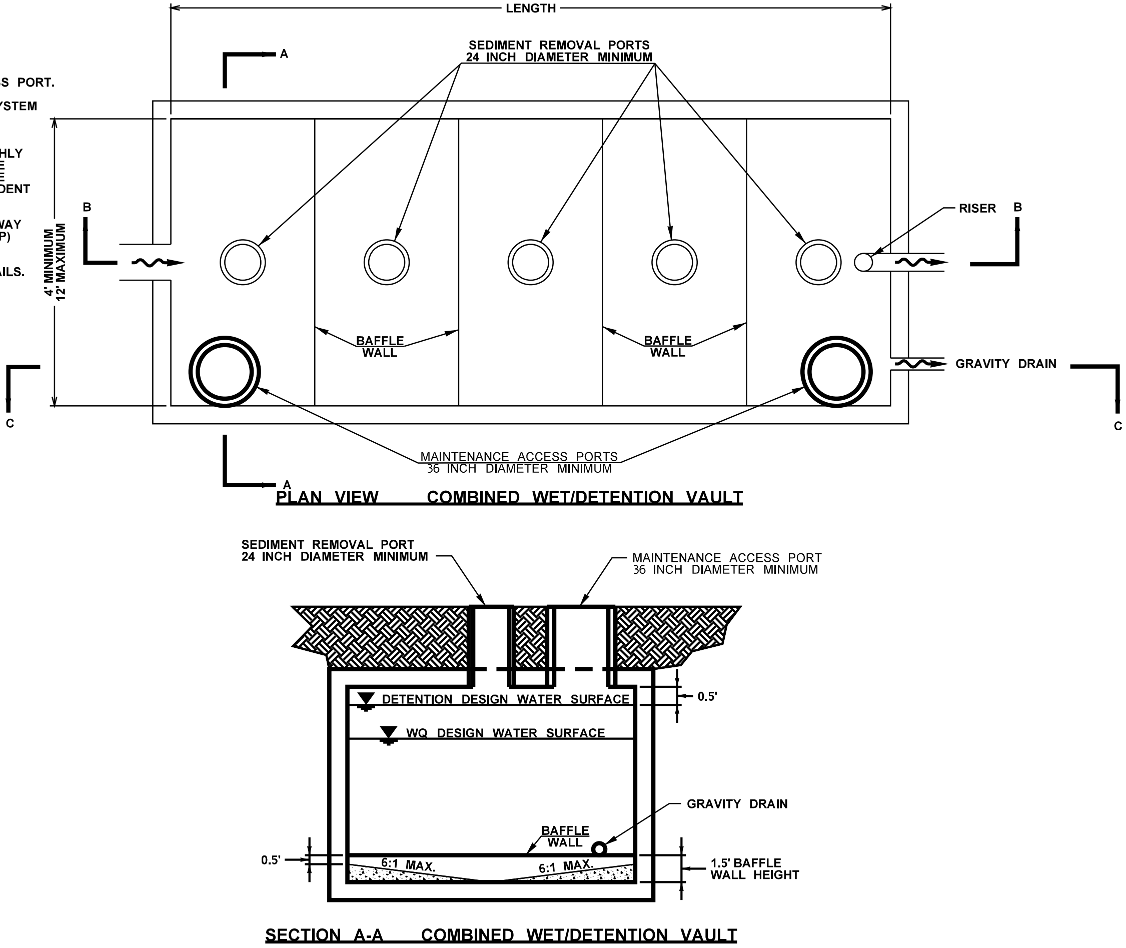

Figure CO.03.1 Combined wet/detention vault Option A.

NOTES:

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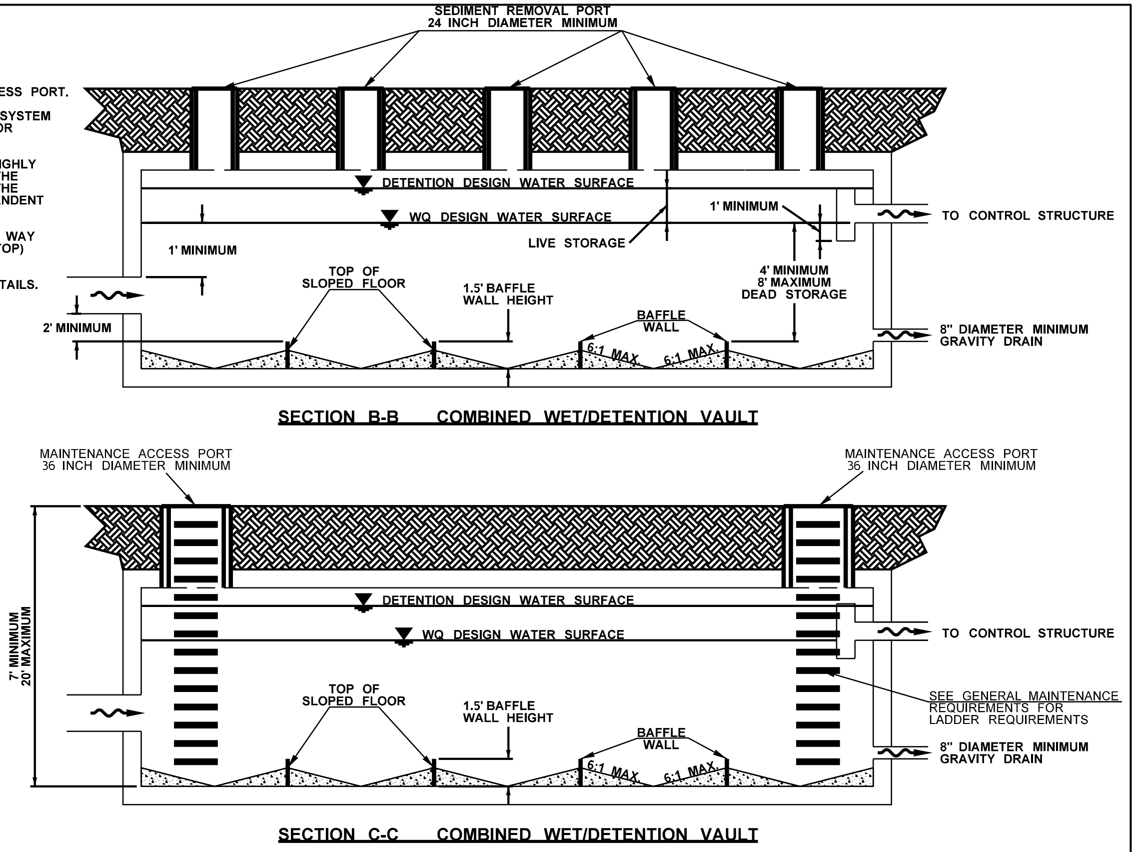

Figure CO.03.2 Combined wet/detention vault Option A.

NOTES:

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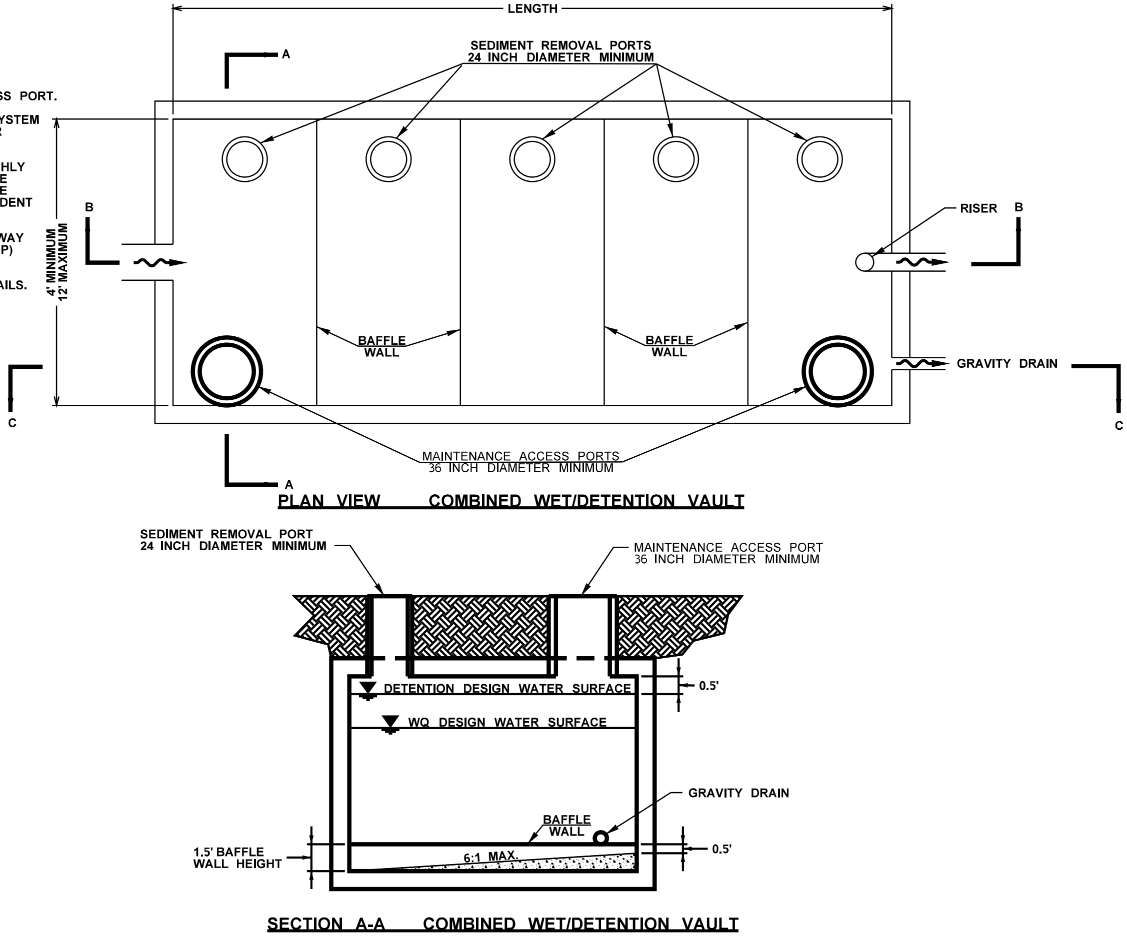
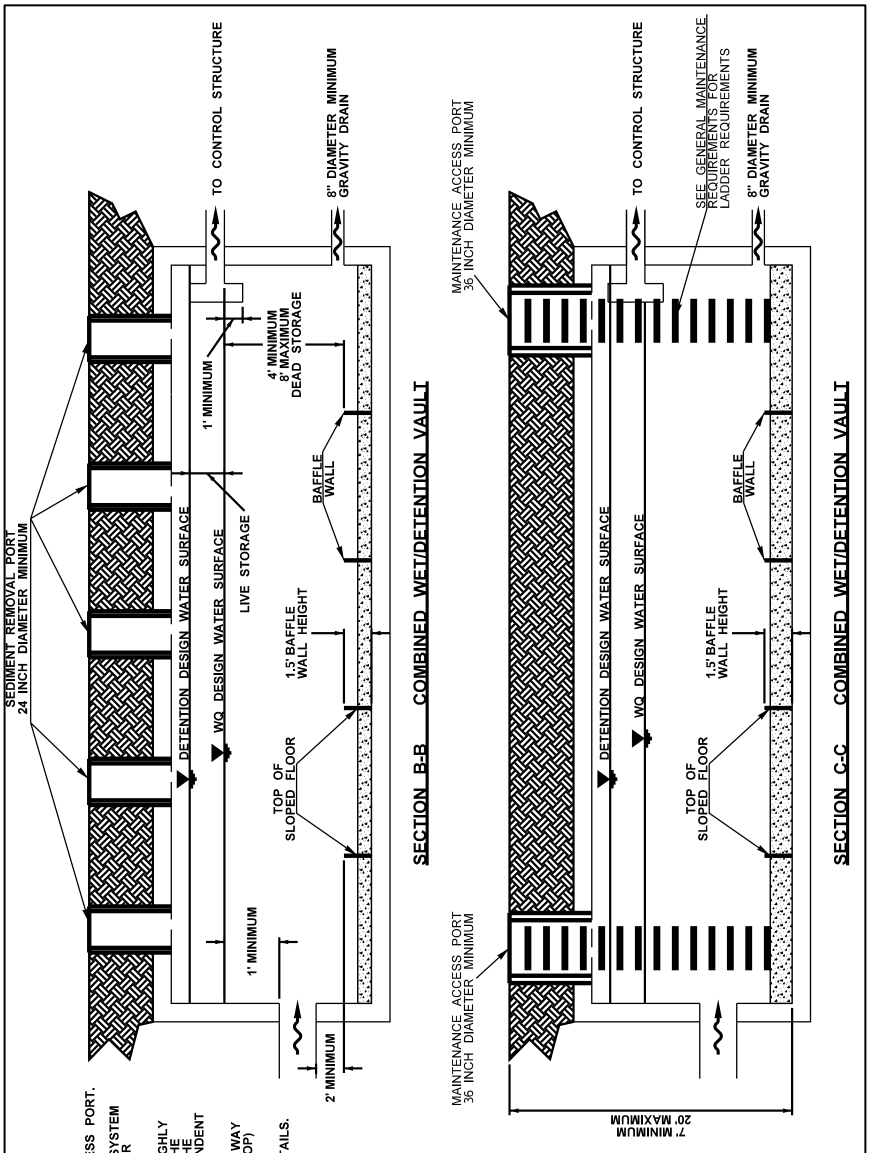


Figure CO.03.3 Combined wet/detention vault Option B.



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SEE SECTION B-B OF HRM FIGURE 5-32 FOR CONTROL STRUCTURE DETAILS.

Figure CO.03.4 Combined wet/detention vault Option B.

BMP FC.04 – Detention Vault

WSDOT does not recognize this BMP as a viable highway application for flow control due to safety, cost, and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

Introduction

General Description

Detention vaults are box-shaped underground storage facilities, typically constructed with reinforced concrete, that provide live storage detention volume to enable the reduction of stormwater runoff flow rates that would otherwise discharge from a project site (see Figures FC.04.1 - FC.04.4). Detention vaults are commonly used for flow control when infiltration is infeasible and space is not available for surface detention facilities. Detention vaults are designed to drain the live storage volume completely after a storm event so that the live storage volume is available for the next event.

In addition to functional design criteria, features to address maintenance and safety for personnel who maintain underground detention vaults are just as important. The detention vault design criteria have been updated to reflect these important items.

Applications and Limitations

Applications

Detention vaults are used for projects that have limited or no ROW to construct an above ground detention facility.

Limitations

Because of a detention vault's high capital cost, associated maintenance and safety issues for personnel maintaining the vault, and the vault's eventual replacement cost, above ground open air detention facilities are preferred over enclosed underground detention vaults. Underground vaults are difficult to maintain due to poor accessibility and reduced ability to determine when maintenance is necessary. Typically, the increased construction and long-term maintenance expenses offset any initial cost savings derived from smaller right of way purchases. Detention vaults should only be used as a last resort when all other options are not feasible. **Detention vaults are Category I BMPs that require approval by the Region Hydraulics Engineer and approval by the local area Maintenance Superintendent.**

If underground structures are the only BMP types feasible on the project, detention vaults can be constructed to include a dead storage for basic runoff treatment. The PEO shall coordinate with the local area Maintenance Superintendent when a combined wet/detention vault is proposed on the project to discuss maintenance access, dewatering for maintenance, and internal vault cell cleanout procedures.

Per the WSDOT Bridge Inspection Manual, vaults under roadways are considered subject to the National Bridge Inspection Standards (NBIS) when the minimum clear span along the centerline of the roadway exceeds 20 feet AND is wider than 12 feet, including any structure that has any portion directly under a lane or shoulder. Detention Vaults may exceed one of the vault dimensions listed above but shall not exceed both vault dimension maximums.

If maintenance access includes vehicles driving over the wet vault vehicle load design shall be performed by a structural engineer licensed in the State of Washington. Coordination with Area Maintenance to determine applicable vehicle loads is required.

Design Flow Elements

Flows to Be Detained

The flows to be detained by detention vaults are the same as those for detention ponds (see BMP FC.03 in the HRM).

Note: The detention design water surface elevation is the highest water surface elevation projected in order to satisfy the outflow criteria.

NOTES:

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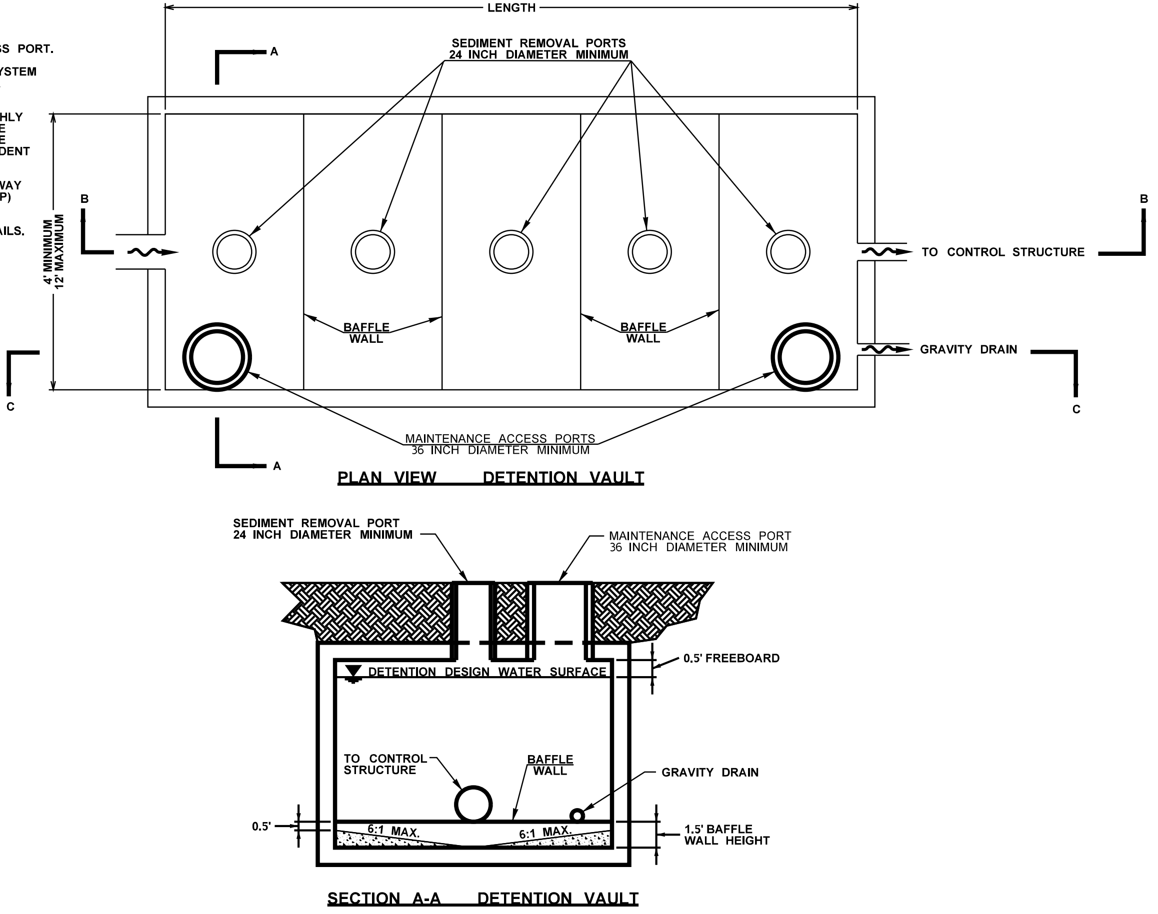

Figure FC.04.1. Detention vault Option A.

NOTES:

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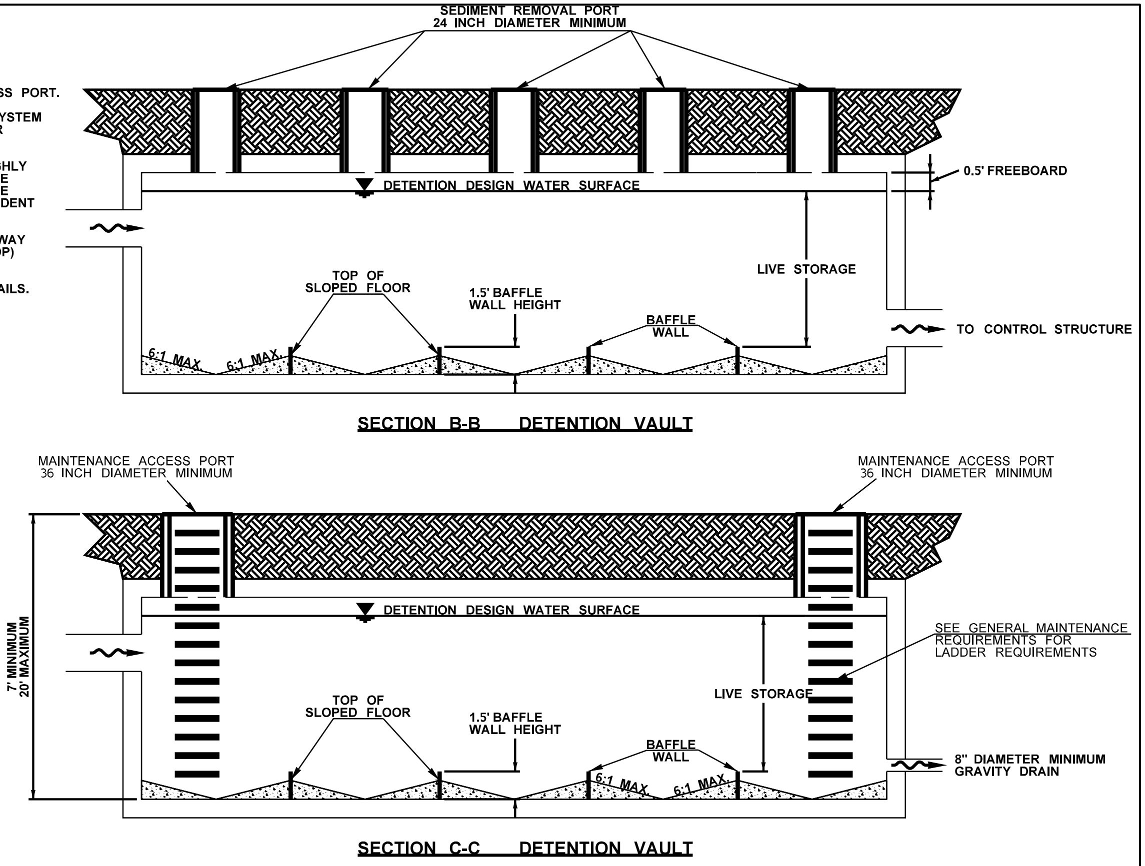


Figure FC.04.2. Detention vault Option A.

NOTES:

ALL VAULT AREAS MUST BE WITHIN 50 FEET OF A MAINTENANCE ACCESS PORT.

VENTILATION MUST BE PROVIDED. VENTILATION COULD BE A PASSIVE SYSTEM OR ACTIVE SYSTEM. CONSULT WITH REGION HYDRAULICS ENGINEER FOR MORE DETAILS.

ALL VAULTS MUST BE BUILT OUTSIDE THE ROADWAY PRISM. WITHIN HIGHLY URBANIZED AREAS, CITY LIMITS AND CONSTRAINED BY RIGHT-OF-WAY, THE ENTIRE VAULT OR PART OF THE VAULT COULD BE LOCATED WITHIN THE SHOULDER UPON APPROVAL OF THE REGION MAINTENANCE SUPERINTENDENT AND REGION HYDRAULICS ENGINEER.

THE VAULT SHALL BE PARTITIONED INTO INTERNAL CELLS IN SUCH A WAY THAT THE TOTAL VOLUME IN EACH CELL (UP TO THE BAFFLE WALL TOP) SHALL BE EQUAL TO OR LESS THAN SIX CUBIC YARDS.

SEE SECTION B-B OF HRM FIGURE 5-32 FOR CONTROL STRUCTURE DETAILS.

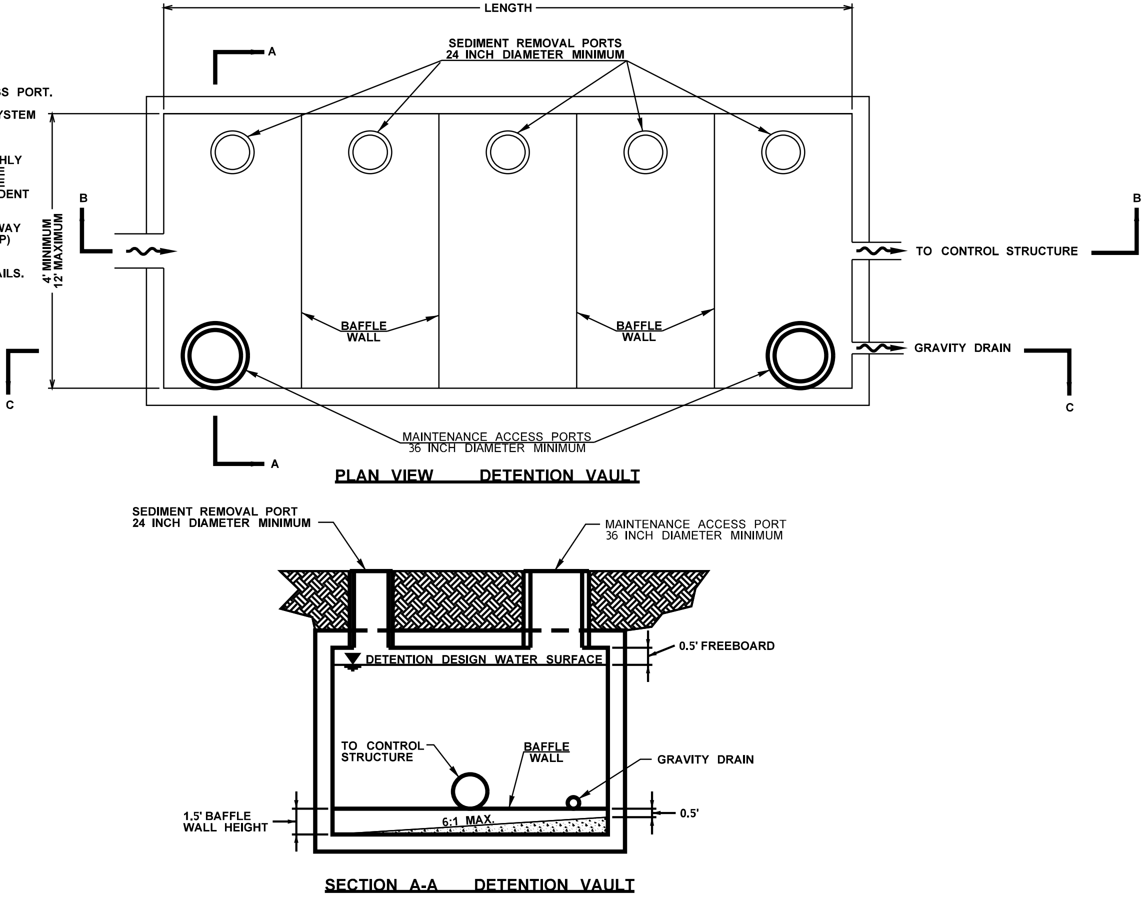
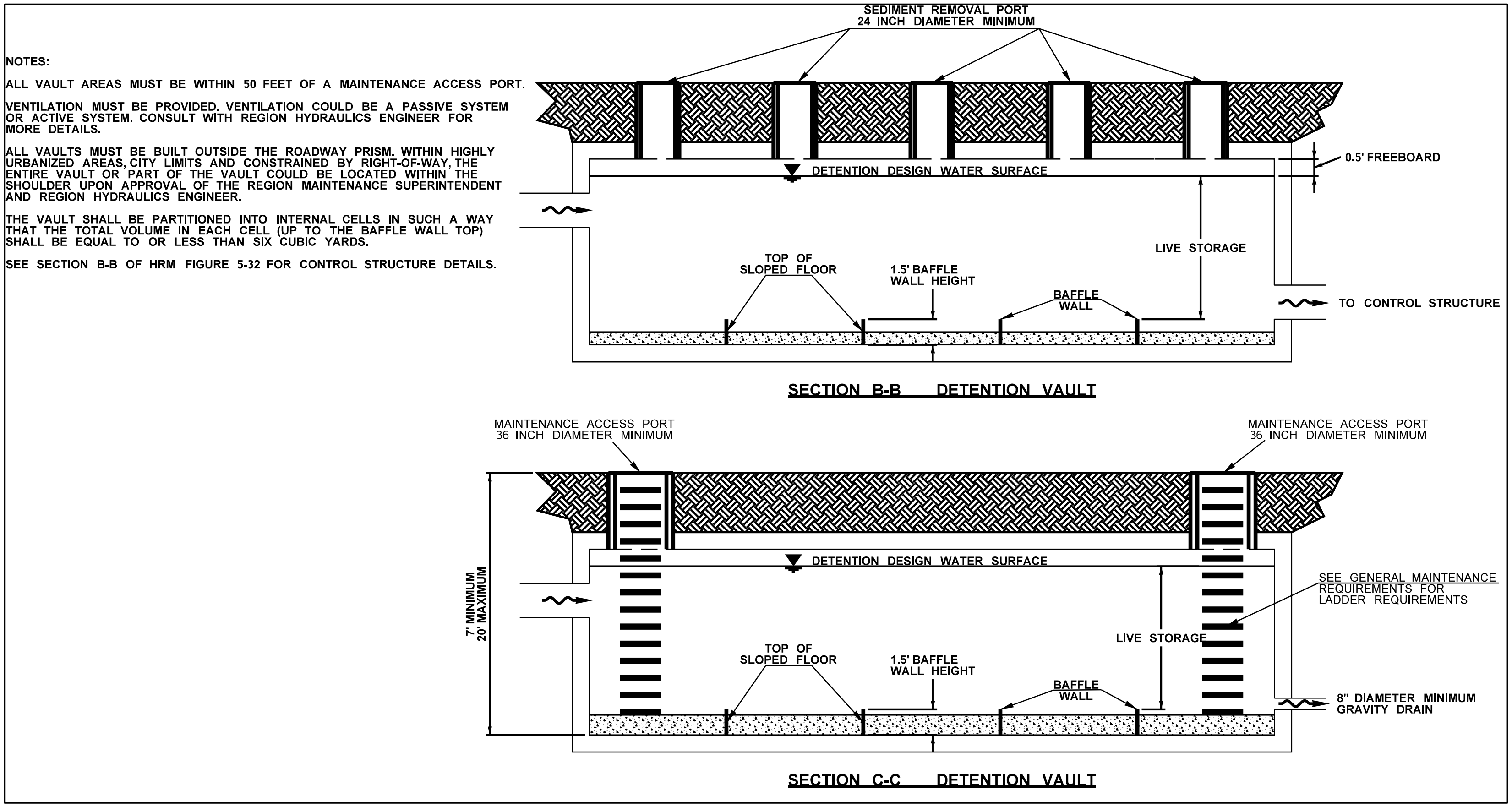


Figure FC.04.3. Detention vault Option B.



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SEE SECTION B-B OF HRM FIGURE 5-32 FOR CONTROL STRUCTURE DETAILS.

Figure FC.04.4. **Detention vault Option B.**

Structural Design Requirements and Considerations

Geometry

The geometry of the detention vault is extremely important for it to successfully function as a stormwater BMP and to facilitate successful maintenance of the vault. The distance between the inlet and outlet shall be maximized. See the vault drawings FC.04.1 – FC.04.4 for length, width, and height minimums, maximums, and other requirements. Detention vaults shall be designed with bottoms that are sloped toward the sediment removal ports to facilitate sediment removal.

A detention vault is considered a "Buried Structure" in the WSDOT Bridge Design Manual (BDM) and shall meet all requirements for Buried Structures in the BDM Section 8.3. The design guidance and requirements for detention vaults in this section shall supersede any discrepancies between the BDM and this section.

Detention Vault Bottom

The interior floor layout of the detention vault shall be designed for sediment storage in a series of internal cells that can be vacuumed from the sediment removal portals in the top of the vault. Along the length of the vault, each cell shall be divided by a baffle wall that is 18 inches tall. Figures FC.04.1 – FC.04.4 show the two available options along with vault bottom floor, internal cell, and sediment removal port details and spacing requirements. The PEO shall coordinate with the local area Maintenance Superintendent to determine which internal vault bottom cell layout to use to facilitate maintenance operations.

The actual vault bottom and the bottom of live storage are two different things. The bottom of live storage is a flat line above the actual bottom of the vault that is used to calculate the detention vault live storage to determine if the detention vault meets the flow control standard. Any volume below the live storage is used for sediment storage and for shaping the bottom of the vault floor into the internal cells for sediment storage. The PEO shall design the dimensions of each internal cell below the live storage to not exceed 6 cubic yards of sediment storage volume.

Inlet and Outlet

The distance between all inlet pipe(s) and the outlet pipe shall be maximized. The inlet pipe(s) to the detention vault shall be high enough to alleviate any backwatering effects to the upstream conveyance system. If any inlet pipe discharges to the detention vault below the top of live storage (i.e., is submerged), the effects of the backwatering shall be included in the conveyance design of the upstream system that has the submerged discharge condition. The invert elevation of the outlet pipe to the control structure should be elevated above top of the sediment storage elevation.

Outlet Control Structure

The PEO shall use the same "Outlet Control Structure" design criteria and requirements as shown in Detention Ponds HRM BMP FC.03. One additional option is to place the riser standpipe control structure physically inside of the vault and eliminate the external catch basin. If this option is used, a sump just for the riser standpipe shall be constructed. The PEO shall coordinate with the local area Maintenance Superintendent to determine which riser standpipe control structure configuration will be acceptable to facilitate successful maintenance of the vault.

Primary Overflow

The PEO shall use the same "Primary Overflow" design criteria and requirements as shown in Detention Ponds HRM BMP FC.03.

Materials

See the WSDOT Bridge Design Manual (BDM) 8.3 for the material design specification requirements. See the BDM Chapter 1 for the professional engineering type licensing requirements for vault designs.

Galvanized materials shall not be used in stormwater BMPs.

Site Design Elements

Groundwater

See the WSDOT BDM 8.3 for detention vault buoyancy considerations and buoyancy design requirements.

Setback Requirements

Detention vaults shall be a minimum of 5 feet from any property line or vegetative buffer. This distance may need to be increased based on the permit requirements of the local jurisdiction.

Detention vaults shall be 100 feet from any septic tank or drain field, except wet vaults, which shall be a minimum of 20 feet.

The designer should request from the WSDOT Materials Laboratory a geotechnical report for the project that evaluates any potential structural site instability due to extended subgrade saturation or head loading of the permeable layer, including the potential impacts to down-gradient properties (especially on hills with known side-hill seeps). The report should address the adequacy of the proposed detention vault locations and recommend the necessary setbacks from any steep slopes and building foundations. See the WSDOT BDM 8.3 for other geotechnical field investigation considerations dealing with vaults.

General Maintenance Requirements

The below section replaces the "Vaults/Tanks/Catch Basins/Manholes" requirements section of HRM Section 5-3.7.1.

Access Roads

- Locate maintenance access ports, sediment removal ports, and the control structure out of the roadway prism. In most areas, closure of traffic lanes to clean vaults is not allowed during daylight hours. Maintenance at night involves additional risk and requires worksite lighting and possibly noise restrictions.
- Access to each opening into the vault, including the inlet and outlet pipes, shall be discussed and agreed upon with the local maintenance superintendent to ensure the vault is easily accessible for maintenance.
- Locate manhole and catch basin lids within or at the edge of the access road and at least 3 feet from a property line. Manhole and catch basin lids shall be locking and rim elevations shall match proposed finish grade.
- The PEO shall provide adequate right of way for vault maintenance including providing space for necessary support equipment, including holding tanks, towed pumps, and equipment for confined-space entry. Consult with the local area maintenance office on access needs for support equipment. It is recommended that any tract not abutting WSDOT right of way have a 15 to 20 foot-wide extension of the tract to an acceptable access location.

Openings

- Provide access over the inlet pipe, over the outlet structure, and to the sump in each cell of the vault.
- Sediment removal portals shall have a minimum 24-inch circular diameter ring cover plate that is traffic rated.
- Each internal sediment cell shall have at least one sediment removal portal that is centered over the low point of the cell. The PEO shall size the dimensions of each sediment cell to not exceed 6 CY of sediment storage volume.
- A minimum of two maintenance access portals (one each in corner on opposite ends of the vault) will be provided for each detention vault. The portals shall have a minimum 36-inch circular diameter ring and cover plate that is traffic rated.
- Maintenance access portals need to be added and spaced so that they are within a maximum of 50 feet from any location within the vault. The PEO may need additional maintenance portals on large vaults.
- All access openings shall have round solid locking lids.

Entry

- All maintenance access portals shall have a permanent ladder system constructed in the interior of the detention vault that will:
    - Have an extendable ladder safety post system that extends at least 42 inches above the ground surface opening of the maintenance access portals
    - Be designed to functionally line up with the maintenance access portals such that maintenance personnel entering and exiting the detention vault may do so with the aid of the extendable ladder safety post system and not be hindered

  when entering or exiting the detention vault in any way. Provide ladders and handholds only at the outlet pipe and inlet pipe, and as needed to meet Washington Industrial Safety and Health Act (WISHA) confined-space requirements.

  - Be free of any obstructions for the entire length of the ladder to enable movement of maintenance personnel and equipment and for potential emergency extraction of maintenance personnel that may be performed by lift methods. Platforms will need to be kept out of the immediate ladder space.
  - Extend to the vault floor.
  - If ladders are greater than 20 feet long, the PEO shall design and install a telescoping extension ladder safety system to provide fall protection that meets Washington Industrial Safety and Health Act (WISHA) requirements.
- Ensure detention vaults comply with WISHA confined-space requirements, which include clearly marking entrances to confined-space areas. The PEO may do this by hanging a removable sign in the maintenance access portal riser, just under the access lid.

Other Access Issues

- The detention vaults shall have a bypass system to take each individual detention vault cell offline one at a time. The bypass system shall have valves that can be opened and closed from the ground surface. Operation of the bypass system will be clearly explained in the BMP maintenance manual. An equivalent or alternative bypass system can be proposed but shall be reviewed and approved by the local maintenance Superintendent.
- The maximum depth from finished grade to the bottom of the sediment storage inside the vault is 20 feet. Most Vactor trucks become inefficient beyond this depth. The PEO shall contact the local area maintenance office to verify the maximum allowable vault depth based on the operating depths of the maintenance equipment for the area where the vault will be built.
- No electrical equipment will be allowed to be housed inside the detention vault.

2 Media Filtration BMPs

BMP RT.14 – Sand Filter Basin

WSDOT does not recognize this BMP as a viable highway application for basic or enhanced treatment due to cost and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

Introduction

General Description

Sand filter basins operate much like runoff treatment infiltration ponds (see Figures RT.14.1 through RT.14.4). However, instead of infiltrating to native soils, stormwater filters through a constructed sand bed with an underdrain system. Runoff enters the sand filter bed area and spreads over the surface of the filter. As flows increase, water ponds to a greater depth above the filter bed until it can percolate through the sand. Common configurations for this BMP are open basins with side slopes similar to stormwater ponds and open basins with structural walls or stabilized side slopes. The treatment pathway is vertical (downward through the sand) rather than horizontal as it is in biofiltration swales and filter strips. High flows in excess of the runoff treatment goal simply spill out over the top of the facility. Water that percolates through the sand is collected in an underdrain system of drain rock and perforated pipes, which directs the treated runoff to the downstream drainage system.

A sand filter removes pollutants by filtration. As stormwater passes through the sand, pollutants are trapped in the small spaces between sand grains or adhere to the sand surface. Over time, soil bacteria will also grow in the sand bed and some biological treatment may occur.

Sand filter basins can be designed in two sizes: basic and large. Based upon experience in King County, Washington, and Austin, Texas, basic sand filters should be capable of achieving the following average pollutant-removal goals:

- 80% TSS removal at influent event mean concentrations (EMCs) of 30 to 300 milligrams per liter (mg/L) (King County 1998; Chang 2000)
- Oil and grease removal to below 10-mg/L daily average and 15 mg/L at any time, with no ongoing or recurring visible sheen in the discharge

Large sand filters are expected to remove at least 50% of the total phosphorus compounds by collecting and treating a minimum of 91% of the mean annual runoff volume.

Applications and Limitations

Basic sand filters can be used to meet basic runoff treatment objectives (see Table 3-1 in Chapter 3 of the HRM), and large sand filters can be used to treat stormwater for additional removal of phosphorus or dissolved metals. Basic sand filters can also be used as part of a two-facility treatment train to treat stormwater for removal of phosphorus or dissolved metals.

Sand filters can be used where site topography and drainage provide adequate hydraulic head to operate the filter. An elevation difference of at least 4 feet between the inlet and outlet of the filter is usually needed to install a sand filter.

Sand filters can be located off-line before or after detention facilities. On-line sand filters should be located only downstream of a detention facility.

Sand filters are designed to prevent water from backing up into the sand layer from underneath, and thus the underdrain system shall drain freely. A sand filter is more difficult to install in areas with high water tables where groundwater could potentially flood the underdrain system. Clearance should be sufficient between the seasonal high groundwater level (highest level of groundwater observed) and the bottom of the sand filter to permit adequate drainage (at least 2 feet is recommended). In high water table areas, adequate drainage of the sand filter may require additional engineering analysis and design considerations.

Water standing in the underdrain system also keeps the sand saturated. Under these conditions, oxygen can be depleted, releasing pollutants such as metals and phosphorus that are more mobile under anoxic conditions.

Because the surface of the sand filter clogs with sediment and other debris, this BMP should not be used in areas where heavy sediment loads are expected. A sand filter should not be used during construction to control sediments unless the sand bed is replaced periodically during construction and after the site is stabilized.

Although the sand filter basin BMP may have fairly good applications in urbanized settings where space is limited, its initial high construction cost and high maintenance frequency (and associated costs) make it an undesirable choice of treatment. It should be considered only when no other options are feasible. To ensure sand filters are used only when absolutely necessary, the HQ Hydraulics Office shall approve their use.

Presettling and/or Pretreatment

Pretreatment is necessary to reduce velocities to the sand filter and to remove debris, floatables, large particulate matter, and oils.

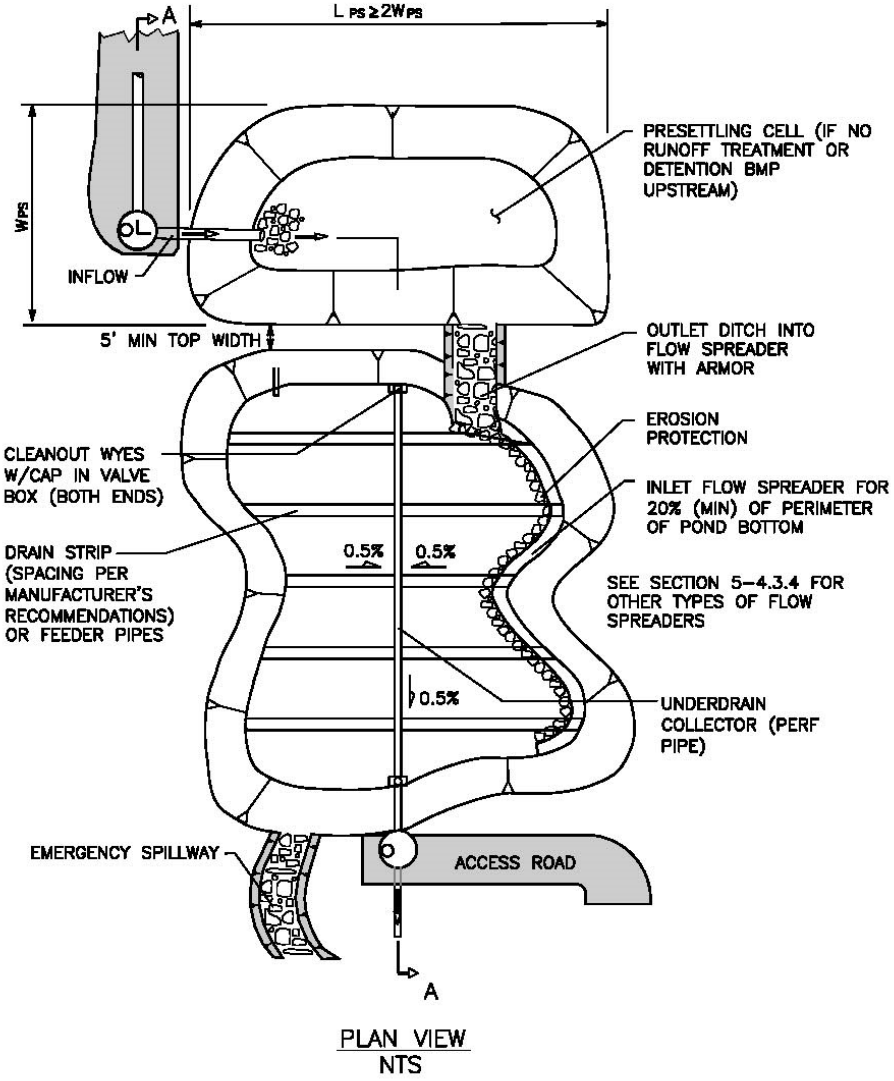

Figure RT.14.1. Sand filter basin with pretreatment cell.

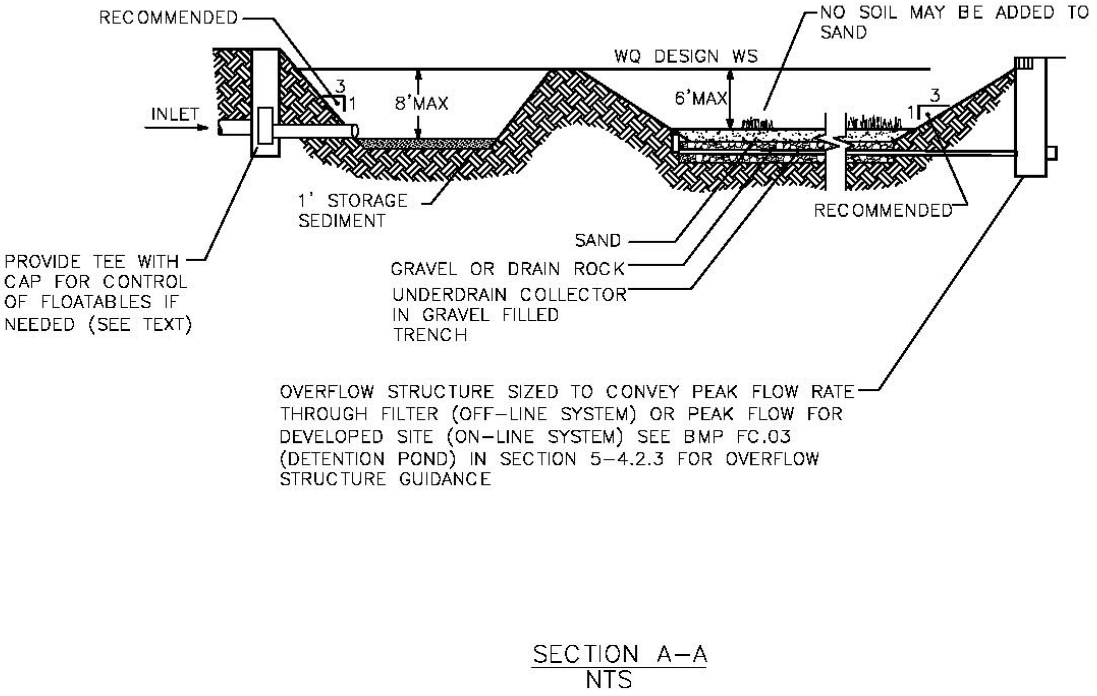

Figure RT.14.2. Sand filter basin with pretreatment cell: Cross section.

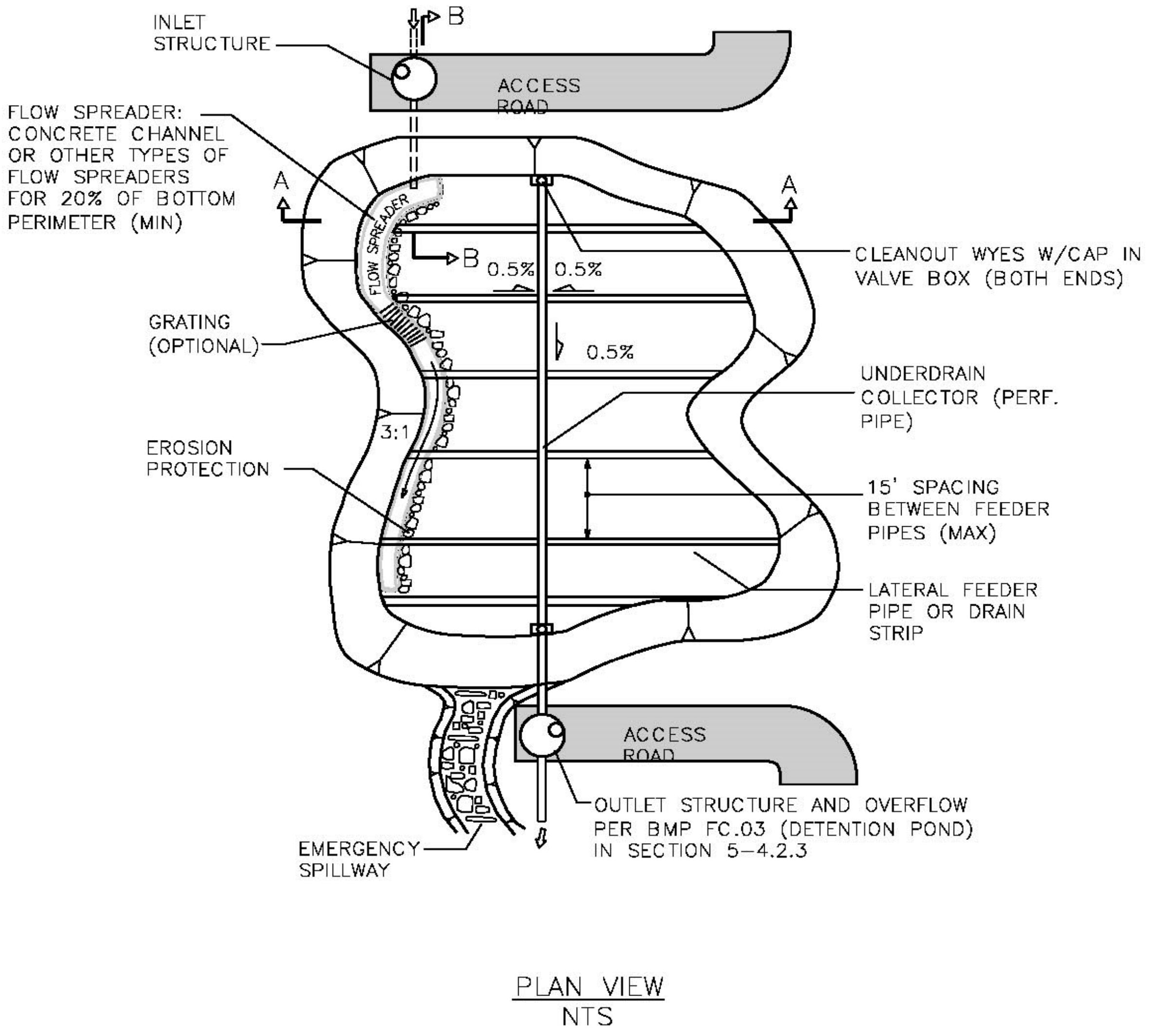

Figure RT.14.3. **Sand filter basin with flow spreader.**

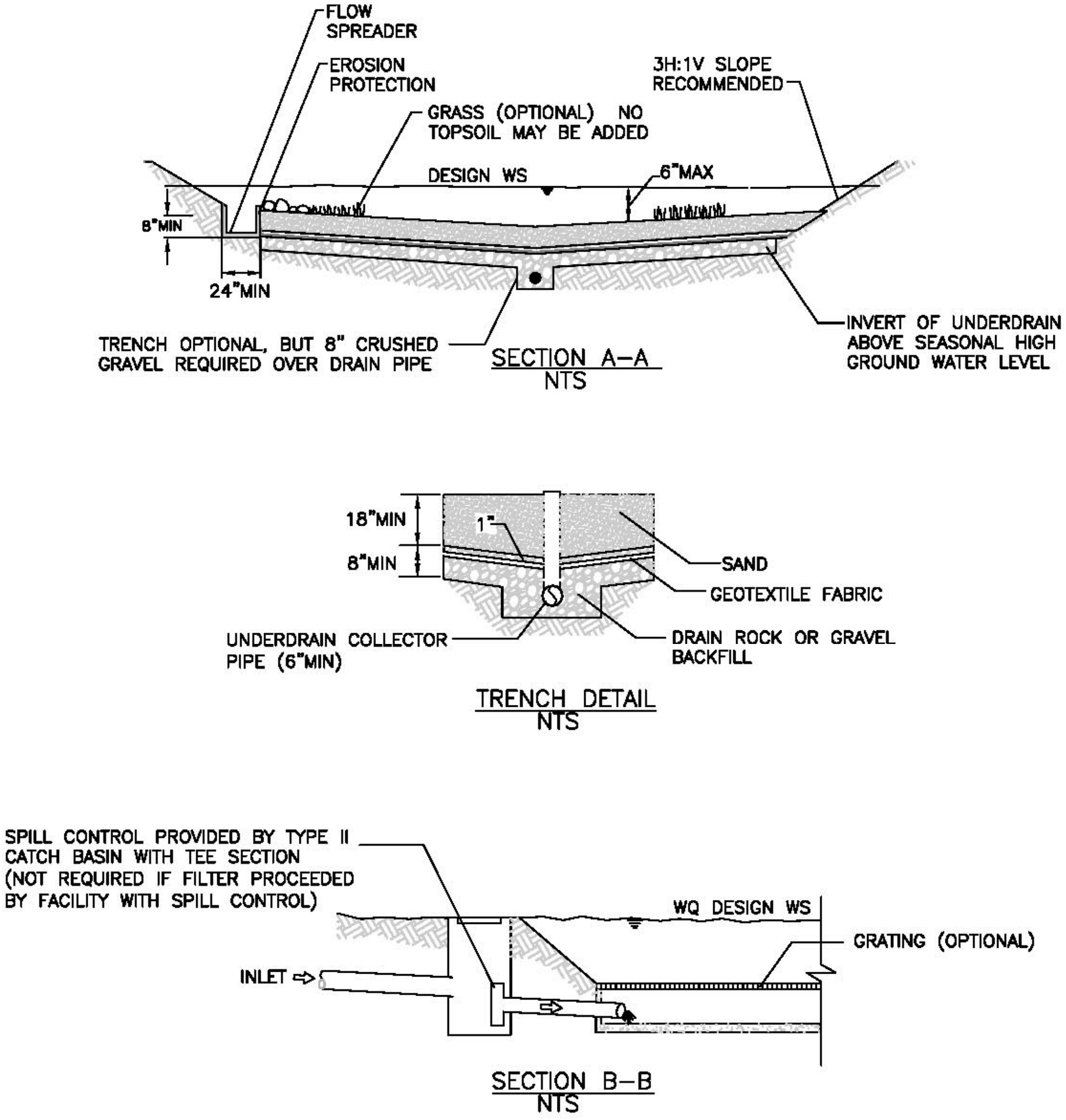

Figure RT.14.4. Sand filter basin with flow spreader: Detail and cross sections.

Design Flow Elements

Flows to Be Treated

Sand filters are designed to capture and treat the runoff treatment design storm volume when the simple sizing method described below (for eastern Washington) is used. When the continuous runoff model sizing method (for western Washington, also described below) is used, sand filters are designed to capture and treat 91% of the total runoff volume (95% for large sand filters), and bypass or overflow 9% of the total runoff volume (5% for large sand filters).

Primary Overflow

Sand filter facilities shall include an overflow structure. The overflow elevation should coincide with the maximum design hydraulic head above the sand bed. For overflow structure design guidelines, see BMP FC.03 in the HRM.

Location of Sand Filter With Respect to Detention Facilities and Conveyance Systems

The size of the sand filter varies depending on whether it is upstream or downstream of the on-site detention facility. Additionally, the location of the sand filter with respect to the on-site drainage conveyance system dictates the need (or lack thereof) for a flow splitter. Figure RT.14.5 shows various configurations for sand filters in relation to detention facilities and conveyance systems that are referred to throughout this section.

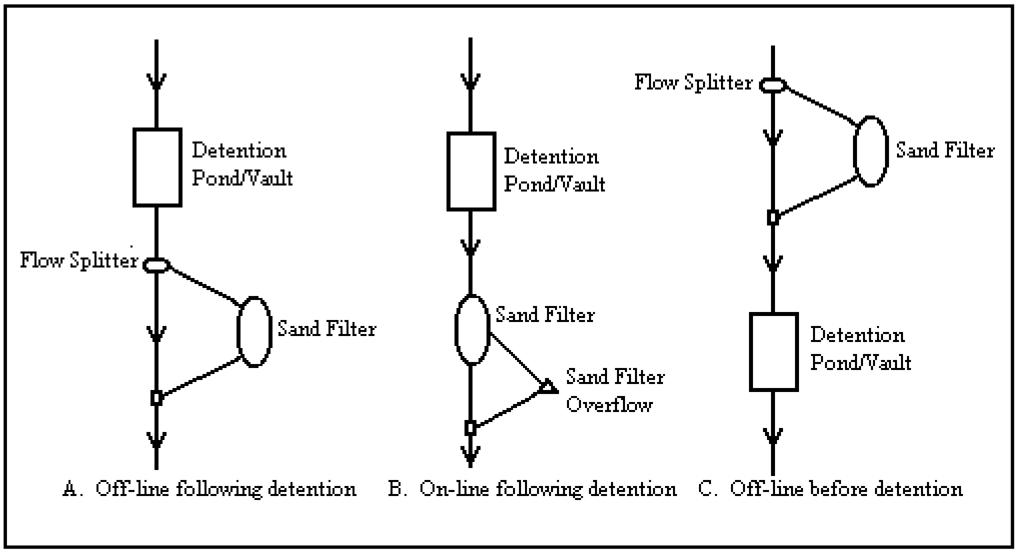

Figure RT.14.5. **System layout options for sand filters with detention BMPs.**

Flow Splitters

An off-line sand filter shall be designed to filtrate all of the water it receives. Therefore, a continuous runoff model that directs all flows at or below a design flow rate to the filter shall be used to determine an acceptable combination of filter size and minimum storage reservoir above

the filter. The system needs to ensure complete filtration of all runoff directed to the filter. (See Section 5-4.3.4 in Chapter 5 of the HRM for flow splitter design guidelines.)

Flow Spreaders

Flow spreading structures (such as flow spreaders, weirs, or multiple orifice openings) should be designed to minimize turbulence and to spread the flow uniformly across the surface of the sand filter (see Figures RT.14.3 and RT.14.4). Stone riprap or other energy-dissipation devices should be installed to prevent erosion of the sand medium and to promote uniform flow (see Section 5-4.3.5 in Chapter 5 of the HRM).

Emergency Overflow Spillway

Sand filters designed as on-line facilities shall include an emergency overflow spillway. For design guidelines, see BMP FC.03 in the HRM.

Structural Design Considerations

A sand filter is designed with two parts: a temporary storage reservoir to store runoff and a sand filter bed through which the stored runoff percolates. Usually the storage reservoir is placed directly above the filter, and the base of the reservoir is the top of the sand bed. For this case, the storage volume determines the hydraulic head over the filter surface. Greater hydraulic head increases the rate of flow through the sand.

Geometry

Two methods are given here to size sand filters: a simple sizing method (for eastern Washington) and a continuous runoff model sizing method (for western Washington). The simple sizing method uses standard values to define filter hydraulic characteristics for determining the sand surface area. This method is useful for planning purposes, for a first approximation to begin iterations in the detailed method, or when use of the continuous runoff model is not desired or not available.

The continuous runoff model sizing method uses a continuous simulation computer model to determine sand filter area and pond size based on specific site conditions. Use of the continuous runoff model design method very often results in filter sizes that are smaller than those derived by the simple method, especially if the facility is downstream of a detention pond. Both methods include parameters for sizing either a basic or a large sand filter.

For either method, the following design criteria apply:

- Sand filter bed depth: 1.5 to 2.5 feet
- Maximum ponding depth: 1.0 to 6.0 feet
- Percentage of sand filter perimeter with flow spreader: 30% minimum (if the length-to-width ratio of the filter is 2:1 or greater, then a flow spreader shall be located on the longer side)

Simple Sizing Method (for Eastern Washington)

This method applies to the off-line placement of a sand filter upstream or downstream of detention facilities. A conservative design approach is described below using a routing adjustment factor. If this approach is used, computations of flow routing through the filter do not need to be performed. An alternative simple approach for off-line placement downstream of detention facilities is to route the full 2-year release peak rate from the detention facility (sized to match the predeveloped peak flow rates) to a sand filter with sufficient surface area and reservoir storage volume to effectively filter the peak flow rate.

Basic Sand Filter

For sizing a basic sand filter, apply a routing adjustment factor of 0.7 to the runoff volume associated with a 6-month, 24-hour storm event to compensate for routing through the sand bed at the maximum ponding depth. Design a flow splitter to route the runoff treatment design flow rate to the sand filter.

Large Sand Filter

For sizing a large sand filter, use the same procedures as 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 drainage areas. For a large sand filter upstream or downstream of a detention facility, design a flow splitter to route the runoff treatment flow rate to the sand filter, with the following exceptions:

- For off-line large sand filters, multiply the runoff treatment design flow rate of the basic sand filter by 1.2 to design the flow splitter.
- Apply a scale-up factor of 1.6 to the surface area of the sand filter after sizing the basic sand filter for the 6-month, 24-hour storm according to the design procedure outlined below.

Example Calculation

Design Specifications

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 variations in flow percolation through the sand bed caused by the hydraulic head variations in the water ponded above the sand bed during and following a storm. 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, $A_{sf} = A_tQ_dR/\{K(h+L)/L\}t$

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

where: Q_{sf} = flow rate (ft^3/day) at which runoff is filtered by the sand filter bed

A_{sf} = sand filter surface area (ft^2)

Q_d = design storm runoff depth (ft) for the 6-month, 24-hour storm. Use the SCS curve number equations detailed in Chapter 4 of the HRM to estimate Q_d.

R = routing adjustment factor. Use $R = 0.7$ ($R = 1.0$ for large sand filter).

A_t = tributary drainage area (ft^2)

K = hydraulic conductivity of the sand bed (ft/day). Use 2 feet per day for filters with a presettling basin.

i = hydraulic gradient of the pond above the filter $(h+L)/L$ (ft/ft)

F = filtration rate (ft/day) ($F = Ki$)

d = maximum depth of water over sand filter surface (ft)

h = average depth of water over sand filter surface (ft) ($h = d/2$)

t = recommended maximum drawdown time (days). In general, 1 day (24 hours) is used from the completion of inflow into the sand filter facility (assume the presettling basin in front of the sand filter is full of water) of a discrete storm event to the completion of outflow from the sand filter underdrain of that same storm event.

L = sand bed depth (ft). Generally use 1.5 feet.

Given conditions:

- Sedimentation basin is fully ponded and no ponded water is above the sand filter
- A_t = 10 acres
- Q_d = 0.922 inches (0.0768 ft) for SeaTac rainfall
- Curve number = 96.2 for 85% impervious and 15% till grass tributary surfaces

- R = 0.7
- Maximum drawdown time through sand filter = 24 hours
- Maximum pond depth above sand filter = either 3 feet or 6 feet (two examples are calculated below)
- h = 1.5 feet or 3 feet
- Design hydraulic conductivity of basic sand filter, K = 2.0 feet/day (1 inch/hour).

Using design equation:

$$A_{sf} = A_t Q_d RL/Kt(h+L)$$

At pond depth of 6 feet:

$$A_{sf} = (10)43{,}560(0.0768)(0.7)(1.5)/(2)(1)(4.5) = 3{,}911 \text{ square feet}$$

Therefore, A_{sf} for the basic sand filter becomes:

3,911 square feet at pond depth of 6 feet
5,867 square feet at pond depth of 3 feet

Using the 1.6 scale-up factor, the large sand filter design sizes for the conditions of this example become:

6,258 square feet at pond depth of 6 feet
9,387 square feet at pond depth of 3 feet

Continuous Runoff Model Sizing Method (for Western Washington)

Basic Sand Filter

This method is intended to capture and treat 91% of the runoff volume (based on a long-term time series) through the use of a continuous runoff model coupled with a flow-routing routine that determines stage-storage-discharge relationships. Until a 15-minute time series is available, a 1-hour time series in a continuous simulation model can be used for facility sizing.

Off-line: An off-line basic sand filter located upstream of detention facilities should have an upstream flow splitter that is designed to bypass the incremental portion of flows above the runoff treatment design flow rate. The long-term runoff time series used as input to the sand filter should be modified to use all flows up to the runoff treatment design flow rate and to disregard all flows above that rate. The design overflow volume for off-line sand filters is zero because all flows routed to the filter are at or below the runoff treatment design flow. Therefore, the goal is to size the storage reservoir so that its capacity is not exceeded. Note: An emergency overflow should nonetheless be included in the design.

If a modeling routine is not available to modify a runoff time series as described above, then the storage reservoir for the off-line facility can be sized as if in an on-line mode. All of the postdevelopment runoff time series is routed to the storage reservoir, which is then sized to overflow 9% of the total runoff volume of the time series. In actual practice, an off-line flow splitter does not route all of the postdevelopment time series to the storage reservoir, so the reservoir should not overflow if operating within design criteria. This design approach should result in slightly oversizing the storage reservoir.

Downstream of detention facilities, the flow splitter should be designed to bypass the incremental portion of flows above the flow rate that corresponds with treating 91% of the runoff volume of the long-term time series. Because flow rates are reduced by the detention facility, this flow rate is lower than the runoff treatment design flow rate for facilities located upstream of detention. Accordingly, the design flow rate should be adjusted to use the flow rate corresponding to treating 91% of the runoff volume from the postdeveloped runoff time series. Note: Downstream of detention facilities, a 1-hour time series may be used to compute the sand filter size until such time as a 15-minute time series is available. Due to the flow-dampening effect of the detention facilities, there should be little difference between a sand filter sized to treat 91% of the runoff volume using 15-minute versus 1-hour time series data.

On-line: Small sand filters that are on-line (all flows enter the storage reservoir) should be located only downstream of detention facilities to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants. The storage pond above the sand bed should be sized to restrict the total amount of overflow from the reservoir to 9% of the total runoff volume of the long-term time series.

Large Sand Filter

This method is intended to capture and treat a minimum of 95% of the mean annual runoff volume using a method similar to that described for the basic sand filter basins.

Off-line: An off-line large sand filter should have an upstream flow splitter that is designed to bypass the incremental portion of flows above the flow rate that corresponds with treating 95% of the runoff volume of the long-term time series (using 15-minute time steps if available). The design overflow volume for off-line sand filters is zero because all flows routed to the filter shall be treated. Therefore, the goal is to size the storage reservoir so that its capacity is not exceeded. Note: An emergency overflow shall be included in the design.

Because flow rates are reduced by a detention facility, a large sand filter downstream of detention facilities will be smaller than a filter upstream of detention. A conservative design would use a flow splitter to route the full 2-year release rate from the detention facility, sized to match predeveloped flow durations, to a filter with sufficient surface area to infiltrate at that flow rate. Such a design should treat over 95% of the runoff volume.

On-line: Large sand filters that are on-line (all flows enter the storage reservoir) should be located only downstream of detention facilities to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants. The storage reservoir above the filter bed should be sized to restrict the total amount of overflow from the reservoir to 5% of the total runoff volume of the long-term time series. On-line large sand filters are not a preferred design because of the extended timeframe during which the filter is saturated, which reduces the potential for phosphorus removal.

Underdrains

Acceptable types of underdrains include (1) a central collector pipe with lateral feeder pipes, (2) a geotextile drain strip in an 8-inch gravel backfill or drain rock bed, and (3) longitudinal pipes in an 8-inch gravel backfill or drain rock bed with a collector pipe at the outlet end. The following are design criteria for the underdrain piping:

- Where placed upstream of detention facilities, underdrain piping should be sized to convey double the 2-year return frequency flow calculated by a continuous simulation model. The doubling factor is a conversion from the 1-hour time step to a 15-minute time step; omit this factor if a 15-minute time step is available. Downstream of detention, the underdrain piping should be sized for the 2-year return frequency flow calculated by a continuous simulation model.
- Internal diameters of underdrain pipes should be a minimum of 6 inches, with perforations of ½-inch holes spaced 6 inches apart longitudinally (maximum). Rows of perforations should be 120º radially apart (with holes oriented downward). The maximum perpendicular distance between two feeder pipes shall be 15 feet. All piping is to be Schedule 40 PVC or greater wall thickness. Drain piping can be installed in basin and trench configurations.
- The main collector underdrain pipe should be at a slope of 0.5% minimum.
- A geotextile fabric for underground drainage (see Section 9-33 of the WSDOT *Standard Specifications*) shall be used between the sand layer and drain rock and placed so that 1 inch of drain rock is above the fabric. Drain rock should be washed free of clay and organic material.

Cleanout wyes with caps or junction boxes shall be provided at both ends of the collector pipes. Cleanouts shall extend to the surface of the filter. A valve box shall provide access to the cleanouts. Access for cleaning all underdrain piping is needed, which may consist of installing cleanout ports that tee into the underdrain system and surface above the top of the sand bed. An inlet shutoff or bypass valve is recommended to facilitate maintenance of the sand filter. Note: Other equivalent energy dissipaters can be used if needed.

Materials

The filter medium in a basic or large sand filter shall consist of a sand meeting the size gradation (by weight) given in Table RT.14.1. This gradation is equivalent to fine aggregate Class 1 for Portland Cement Concrete, as referenced in Section 9-03.1(2)B of the *Standard Specifications,* which can also be used in a sand filter application.

Berms, Baffles, and Slopes

To facilitate mowing, side slopes for earthen/grass embankments should not exceed 3H:1V.

Table RT.14.1 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

Liners

- Low-permeability liners should generally be installed below the sand bed for retention of soluble pollutants such as metals and toxic organics and where the underflow could cause problems with nearby structures (see Section 5-4.3.3 in Chapter 5 of the HRM). Low-permeability liners may be made of clay, concrete, or geomembrane materials.

- If a low-permeability liner is not required, then a geotextile fabric liner should be installed that retains the sand and meets the underground drainage geotextile specifications listed in Section 9-33 of the WSDOT *Standard Specifications*—unless the basin has been excavated to bedrock.

- If a low-permeability liner is not provided, then an analysis should be made of the possible adverse effects of seepage zones on groundwater and on nearby building foundations, basements, roads, parking lots, and sloping sites. Sand filters should be located at least 20 feet downslope and 100 feet upslope from building foundations. Sand filters without low-permeability liners should not be built on fill sites.

Site Design Elements

Setback Requirements

Setback requirements for sand filter basins are the same as those for detention ponds (see BMP FC.03 in the HRM).

Landscaping (Planting Considerations)

Landscape uses may be somewhat constrained because the vegetation capable of surviving in sand is limited. Grass has been grown successfully on top of several sand filters in western Washington where the grass seed was tailored for growth in sand with highly variable degrees of saturation. Note: Trees and shrubs that generate a large leaf fall should be avoided in the immediate vicinity of the filter because leaves and other debris can clog the surface of the filter.

Maintenance Access Roads (Access Requirements)

An access ramp, or equivalent access, is necessary for maintenance purposes at the inlet and the outlet of an aboveground sand filter. The ramp slope shall not exceed 15%.

BMP RT.15 – Linear Sand Filter

WSDOT does not recognize this BMP as a viable highway application for basic or enhanced treatment due to cost and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

Introduction

General Description

Linear sand filters are long, shallow, rectangular vaults (see Figure RT.15.1) housing the same type and depth of sand media specified in BMP RT.14, Sand Filter Basin. They typically consist of two cells or chambers, one for settling the coarse sediment in the runoff entering the filter facility and the other for housing the sand filter media. Stormwater flows from the settling cell into the sand filter cell via a weir section that also functions as a flow spreader to distribute the flow over the sand. The outlet consists of an underdrain pipe system that connects to the storm drain system.

Applications and Limitations

Linear sand filters can be designed in two sizes: basic and large. Basic linear sand filters can be used to meet oil control and basic runoff treatment requirements (see Table 3-1 in Chapter 3 of the HRM) or as part of a two-facility treatment train for phosphorus or enhanced treatment. Large linear sand filters are used to meet the enhanced treatment objectives.

Linear sand filters are designed to treat runoff from high-use sites (see Section 5-3.5, Step 3, in Chapter 5 of the HRM) for removal of TSS and oil and grease. They are best suited for treating runoff from small drainage areas (less than 5 acres), particularly long, narrow spaces such as the perimeter of a paved surface. The goal is to keep linear sand filters fairly shallow and narrow. A linear sand filter can be located along the perimeter of a paved impervious surface and can be installed upstream or downstream of a vegetated filter strip. If used for oil control, the filter should be located upstream from the main runoff treatment facility (wet pond, biofiltration swale, bioinfiltration swale, or combined detention and wet pond).

Presettling/Pretreatment

A sediment chamber is included in linear sand filter design. If the sand filter is preceded by another runoff treatment facility and the flow enters the sand filter as sheet flow, the requirement for the sediment cell may be waived.

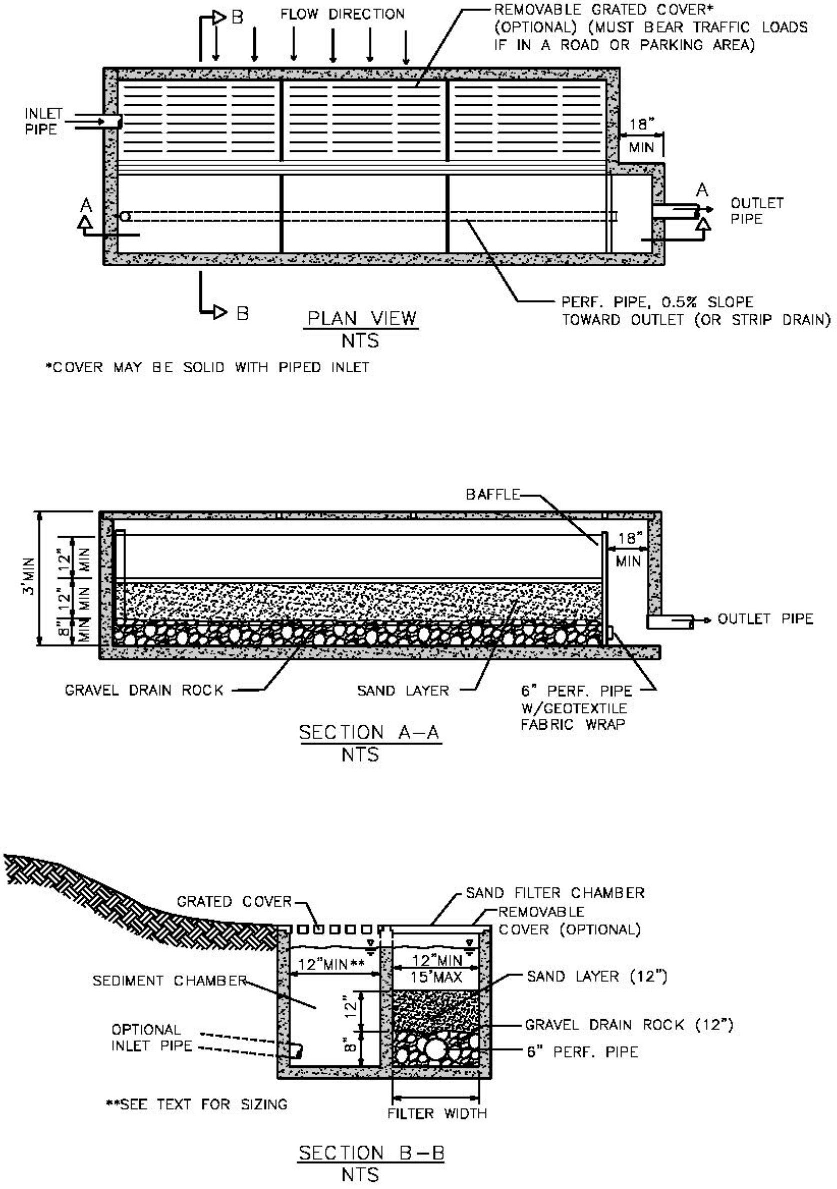

Figure RT.15.1. **Linear sand filter with sediment chamber.**

Design Flow Elements

Flows to Be Treated

The flows to be treated by linear sand filters are the same as those for sand filter basins (see BMP RT.14).

Flow Spreaders

The weir section dividing the presettling and sand filter cells functions as a flow spreader.

Emergency Overflow Spillway

A linear sand filter shall have a surface overflow spillway, a piped overflow, or other emergency overflow route for safely controlling the overflow. The overflow shall meet the conveyance requirements specified in the WSDOT *Hydraulics Manual*.

Structural Design Considerations

Geometry

Calculate sand filter area using one of the methods described in BMP RT.14. The width of the sand cell shall be 1 foot minimum—up to 15 feet maximum. The sand filter bed shall be a minimum of 12 inches deep and have an 8-inch layer of drain rock with perforated drainpipe beneath the sand layer.

Set sedimentation cell width as follows:

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

Stormwater may enter the sedimentation cell as sheet flow or via a piped inlet. The two cells should be separated by a divider wall that is level and extends a minimum of 12 inches above the sand bed.

The drainpipe shall be a minimum 6-inch diameter, wrapped in geotextile fabric, and sloped a minimum of 0.5%.

If separated from traffic areas, a linear sand filter may be covered or open. If covered, the cover shall be removable for the entire length of the filter. Covers shall be grated if flow to the filter is from sheet flow. Covered linear sand filters shall be vented. 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.

Intent: Grates are important to allow air exchange above the sand. Poor air exchange hastens anoxic conditions, which may result in release of pollutants such as phosphorus and metals and may cause objectionable odors.

Materials

Linear sand filters shall conform to the materials and structural suitability criteria specified for detention vaults (see BMP FC.04).

Specifications for sand media and drain rock are the same as those for sand filter basins (see BMP RT.14).

Site Design Elements

Setback Requirements

Setback requirements for linear sand filters are the same as those for detention vaults (see BMP FC.04).

Maintenance Access Roads (Access Requirements)

Maintenance access provisions are the same as those required for detention vaults (see BMP FC.04), except that if the linear sand filter is covered, the cover shall be removable for the entire length of the filter.

BMP RT.18 – Canister Filters

> *WSDOT does not recognize this BMP as a viable highway application for basic treatment or for enhanced treatment when used as part of a treatment train due to cost and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).*

Introduction

General Description

The Washington State Department of Ecology (Ecology) is responsible for reviewing and approving proprietary stormwater BMPs for runoff treatment, flow control, and pretreatment uses through the Technology Assessment Protocol – Ecology (TAPE). The designer needs to review and understand the specific applications and limitations of the specific canister filter type BMP before specifying it for a project. A detailed list of canister filter BMPs can be found at:

🖱 https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies.

To include any proprietary BMP the designer must confirm current TAPE approval for general use (not conditional use or pilot use) for the required compliance function (pretreatment, basic treatment, enhanced treatment, oil control, phosphorus control). Local area maintenance supervisor and Region Hydraulics approval is required for use on a WSDOT project.

3 Oil Control BMPs

BMP RT.20 – Baffle-Type (API) Oil/Water Separator

WSDOT does not recognize this BMP as a viable highway application for oil control due to cost and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

Introduction

General Description

The purpose of oil and water separator BMPs is to remove oil and other water-insoluble hydrocarbons, and settleable solids from stormwater runoff. It uses gravity to remove floating and dispersed oil. Oil and water separator BMPs typically consist of three bays: a forebay, a separator bay, and an afterbay.

API separators are composed of three bays separated by baffles. The efficiency of API separators is dependent on detention time in the center bay and on droplet size. API type separators rarely treat stormwater to reduce oil levels below 10 mg/l. Typically, the use of API separators should be limited to protection from large oil spills and not for small amounts of oil on the pavement surfaces. The Washington State Department of Ecology has made modifications to the API sizing equations to account for drainage areas less than 2 acres.

Applications and Limitations

Baffle-type oil/water separators can be used to meet oil control requirements when a site meets the criteria described in Section 5-3.5 of the HRM. Separators should be used where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator. For low concentrations of oil, other treatment methods (such as sand filters or emerging technologies) may be more applicable.

For inflows from small drainage areas (such as fueling stations and maintenance shops), a coalescing plate separator (see BMP RT.21) is typically considered due to space limitations. However, if the coalescing plates are likely to become plugged due to high sediment load, then a baffle-type separator may be considered. (See the *Structural Design Considerations* below.)

Do not use oil and water separator BMPs for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.

Oil and water separator BMPs shall be placed upstream of other Runoff Treatment BMPs and as close to the source of oil generation as possible.

It is preferred to have oil and water separator BMPs be located off-line, bypassing flows greater than the Water Quality Design Flow Rate multiplied by the ratio indicated in the

SWMMWW Figure V-7.8: Ratio of SBUH Peak/WQ Flow (Off-line). If it is necessary to locate the separator on-line, try to minimize the size of the area needing oil control, and use the on-line Water Quality Design Flow Rate multiplied by the ratio indicated in the SWMMWW Figure V-7.7: Ratio of SBUH Peak/WQ Flow (On-line).

Use only impervious conveyances for oil contaminated stormwater.

In moderately pervious soils where seasonal groundwater may induce flotation, buoyancy of the separator vault structure shall be balanced by ballasting or other methods, as appropriate.

Construction of oil/water separators should follow and conform to the manufacturer's recommended construction procedures and installation instructions as well as the WSDOT *Standard Specifications*. After the oil/water separator is installed, it shall be thoroughly cleaned and flushed before it begins operating.

Oil and water separator BMPs require intense maintenance to be sufficiently effective in achieving oil and TPH removal down to the required levels.

Presettling/Pretreatment

Pretreatment should be considered if the level of total suspended solids (TSS) in the inlet flow would impair the long-term efficiency of the separator.

Design Flow Elements

Flows to Be Treated

The PEO shall use the “Design Criteria” and requirements shown in Ecology’s Stormwater Management Manual for Western Washington (SWMMWW) BMP T11.10 API (Baffle Type) Separator to size the oil/water separator.

Flow Splitters

Oil/water separators shall be installed off-line from the primary drainage system. For flow splitter design guidelines, see Section 5-4.3.4 in Chapter 5 of the HRM.

Structural Design Considerations

Geometry and Design Method

The PEO shall use the “General Design Criteria” from the Ecology’s SWMMWW V-13.1 Introduction to Oil and Water Separator BMPs for geometric design requirements.

The PEO shall use Figure V-13.2: API (Baffle Type) Separator, Figure V-13.3: Recommended Values of F for Various Vales of Vh/Vt, and the “Design Criteria” and requirements shown in Ecology’s SWMMWW BMP T11.10 API (Baffle Type) Separator to size the oil/water separator.

Materials

- Vault material and structural specifications are the same as those for BMP FC.04, Detention Vault.
- All metal parts shall be corrosion resistant. Galvanized materials shall not be used in stormwater BMPs.
- Vault baffles shall be made of concrete, stainless steel, fiberglass-reinforced plastic, or other acceptable material, and shall be securely fastened to the vault.
- Gate valves, if used, shall be designed for seating and unseating heads appropriate for the design conditions.

Site Design Elements

Setback Requirements

Setback requirements for baffle-type oil/water separators are the same as those for detention vaults (see BMP FC.04).

Maintenance Access Roads (Access Requirements)

Access requirements for baffle-type oil/water separators are the same as those for detention vaults (see BMP FC.04), except for the following modifications:

- Access to each compartment is required. If the length or width of any compartment exceeds 50 feet, an additional access point for each 50 feet is required.
- Access points for the forebay and afterbay shall be positioned partially over the inlet or outlet tee to allow visual inspection as well as physical access to the bottom of the vault.

Operation and Maintenance

Oil/water separators shall be cleaned regularly (see BMP Maintenance Standards for further details) to keep accumulated oil from escaping during storm events. The baffle type separator has the advantage that they can be maintained with normal maintenance equipment and supplies.

BMP RT.21 – Coalescing Plate Separator

WSDOT does not recognize this BMP as a viable highway application for oil control due to cost and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

Introduction

General Description

The purpose of oil and water separator BMPs is to remove oil and other water-insoluble hydrocarbons, and settleable solids from stormwater runoff. It uses gravity to remove floating and dispersed oil. Oil and water separator BMPs typically consist of three bays: a forebay, a separator bay, and an afterbay.

Coalescing Plate (CP) separators use a series of parallel plates in the separator bay, which improve separation efficiency by providing more surface area. CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates. See BMP T11.11: Coalescing Plate (CP) Separator.

Coalescing plate oil/water separators typically are manufactured units consisting of a baffled vault containing several inclined corrugated plates stacked and bundled together (see Figure V-13.4:Coalescene Plate Separator in Ecology's SWMMWW). The plates are equally spaced (typical plate spacing ranges from ¼ to 1 inch) and are made of a variety of materials, the most common being fiberglass and polypropylene. Efficient separation results because the plates reduce the vertical distance oil droplets shall rise in order to separate from the stormwater. Once they reach a plate, oil droplets form a film on the plate surface. The film builds up over time until it becomes thick enough to migrate upward under the influence of gravity along the inclined plate. When the film reaches the edge of the plate, oil is released as large droplets, which rise rapidly to the surface where the oil accumulates until it is removed during maintenance activities. Because the plate pack significantly increases treatment effectiveness, coalescing plate separators can achieve a specified treatment level with a smaller vault size than that required for a simple baffle-type oil/water separator. The plate stacks have the disadvantage of being difficult to clean and require more maintenance time and equipment. Coordinate with Area Maintenance before including a coalescing plate separator.

Applications and Limitations

Same as for BMP RT.20 – Baffle-Type (API) Oil/Water Separator.

Presettling/Pretreatment

Pretreatment should be considered if the level of total suspended solids (TSS) in the inlet flow would cause the coalescing plates to clog or otherwise impair the long-term efficiency of the separator.

Design Flow Elements

Flows to Be Treated

The PEO shall use the "Design Criteria" and requirements shown in Ecology's Stormwater Management Manual for Western Washington BMP T11.11 Coalescing Plate (CP) Separator to size the oil/water separator.

Flow Splitters

Coalescing plate separators shall be installed off-line from the primary drainage system. For flow splitter design guidelines, see Section 5-4.3.4 in Chapter 5 of the HRM.

Structural Design Considerations

Geometry and Design Method

The PEO shall use the "General Design Criteria" from the Ecology's SWMMWW V-13.1 Introduction to Oil and Water Separator BMPs for geometric design requirements.

The PEO shall use Figure V-13.4: Coalescing Plate Separator and the "Design Criteria" and requirements shown in Ecology's Stormwater Management Manual for Western Washington BMP T11.11 Coalescing Plate (CP) Separator to size the oil/water separator.

The vault outlet pipe shall be sized to pass the design flow before overflow using the pipe sizing methods in the WSDOT *Hydraulics Manual.* The vault outlet pipe shall be backsloped or have a tee extending 1 foot above and below the runoff treatment design water surface to provide for secondary trapping of oils and floatables in the vault. Note that the invert of the outlet pipe sets the runoff treatment (water quality or WQ) design water surface elevation.

Separator vaults shall have a shutoff mechanism on the outlet pipe to prevent oil discharges during maintenance and to serve as an emergency shutoff in case of a spill. The shutoff valve shall have the ability to be opened or closed from the ground surface.

Separator vaults shall be watertight. Where pipes enter and leave a vault below the runoff treatment design water surface, they shall be sealed using a nonporous, nonshrinking grout.

Absorbents and/or skimmers should be used in the afterbay, as needed.

Materials

- Vault material and structural specifications are the same as those for BMP FC.04, Detention Vault.
- All metal parts shall be corrosion resistant. Galvanized materials shall not be used in stormwater BMPs.
- Vault baffles shall be made of concrete, stainless steel, fiberglass-reinforced plastic, or other acceptable material and shall be securely fastened to the vault.

- Gate valves, if used, shall be designed for seating and unseating heads appropriate for the design conditions.
- Plate packs shall be made of fiberglass, stainless steel, or polypropylene.
- It is recommended that the entire space between the sides of the plate pack and the vault wall be filled with a solid but lightweight removable material, such as a plastic or polyethylene foam, to prevent the flow from short-circuiting around the sides of the plate pack. Rubber flaps are not effective for this purpose.

Site Design Elements

Setback Requirements

Setback requirements for coalescing plate oil/water separators are the same as those for detention vaults (see BMP FC.04).

Maintenance Access Roads (Access Requirements)

Access requirements for coalescing plate oil/water separators are the same as those for detention vaults (see BMP FC.04), except for the following modifications:

- Access to each compartment is required. If the length or width of any compartment exceeds 50 feet, an additional access point for each 50 feet is required.
- Access points for the forebay and afterbay shall be positioned partially over the inlet or outlet tee to allow visual inspection as well as physical access to the bottom of the vault.
- Access to the compartment containing the plate pack shall be via a removable panel that can be opened wide enough to remove the entire coalescing plate pack from the cell for cleaning or replacement. Doors or panels shall have stainless steel lifting eyes, and panels shall weigh no more than 1.5 tons per door or panel. The door or panel shall be at grade. With approval from the local maintenance superintendent, an access opening can exceed the 1.5-ton maximum weight if the opening is spring loaded and can fully open by itself.
- A parking area or access pad (25- by 15-foot minimum) shall be provided near the coalescing plate oil/water separator structure to allow the plate pack to be removed from the vault by a truck-mounted crane or backhoe and to allow accumulated solids and oils to be extracted from the vault using a Vactor truck.

Operation and Maintenance

The plate stacks have the disadvantage of being difficult to clean and require more maintenance time and equipment. Coordinate with Area Maintenance before including a coalescing plate separator.

Oil/water separators shall be cleaned regularly (see BMP Maintenance Standards below for further details) to keep accumulated oil from escaping during storm events.

4 Closed Depression

WSDOT does not recognize this BMP as a viable highway application for flow control or runoff treatment without considerable upfront site investigation, soil investigation, design, and analysis. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

Analysis of closed depressions requires that the PEO carefully assess the existing hydrologic performance in order to evaluate a proposed project's potential impacts. Thoroughly review the applicable flow control requirements (see Minimum Requirement 6, Section 3-3.6) and the local government's Sensitive Areas Ordinance and Rules (if applicable) prior to proceeding with the analysis. Use a calibrated continuous simulation hydrologic model for closed depression analysis and design of mitigation facilities. Where an adequately calibrated continuous simulation model is not available, follow the procedures listed below.

Analysis and Design Criteria

Determine the infiltration rates used in the analysis of closed depressions according to the procedures in Section 4-5. For closed depressions containing standing water, perform soil texture tests on dry land adjacent to, and on opposite sides of, the standing water (as practicable). Ensure the elevation of the testing surface at the bottom of the test pit is 1 foot above the standing water elevation. Perform a minimum of four tests to estimate an average surface infiltration rate.

Projects proposing to modify or compensate for replacement storage in a closed depression shall meet the design criteria for detention ponds as described in Chapter 5.

Western Washington Method of Analysis

Analyze closed depressions using hydrographs routed as described in Section 4-5. Address infiltration where appropriate. In assessing the impacts of a proposed project on the performance of a closed depression, there are three cases that dictate different approaches to meeting Minimum Requirement 6 (see Section 3-3.6) and applicable local requirements. ***Note:*** Where there is a flooding potential, concern about rising groundwater levels, or local sensitive area ordinances and rules, this analysis may not be sufficient and local governments may require more stringent analysis.

Case 1

The 100-year recurrence interval storm runoff from an approved continuous simulation program, flowing from the TDA to the closed depression, is routed into the closed depression using only infiltration as outflow. If predevelopment runoff does not overflow the closed depression, then no runoff may leave the closed depression at the 100-year recurrence interval following development of a proposed project. This may be accomplished by excavating additional storage volume in the closed depression, subject to all applicable requirements (for example, providing a defined overflow system).

Case 2

The 100-year recurrence interval storm runoff from an approved continuous simulation program, from the TDA to the closed depression, is routed into the closed depression using only infiltration as outflow. If runoff overflows the closed depression under existing conditions during the 100-year recurrence interval storm, the performance objective can be met by excavating additional storage volume in the closed depression, subject to all applicable requirements (for example, providing a defined overflow system).

Case 3

The 100-year recurrence interval storm runoff from an approved continuous simulation program, from the TDA to the closed depression, is routed into the closed depression using only infiltration as outflow, and both cause overflow to occur. The closed depression must then be analyzed as a detention/infiltration pond. The required performance, therefore, is to meet the runoff duration standard specified in Minimum Requirement 6 (see Section 3-3.6), using an adequately calibrated continuous simulation model. This will require a control structure, emergency overflow spillway, access road, and other design criteria. Also, depending on who will maintain the system, it will require placing the closed depression in a tract dedicated to the responsible party.

Eastern Washington Methods of Analysis

The Stormwater Management Manual for Eastern Washington (SWMMEW) states that local jurisdiction guidelines should be followed. The Spokane County Guidelines are included below. Other eastern Washington regions are encouraged to provide comment on their local guidelines and compare them to those stated below.

Depending upon soil characteristics, a closed depression may or may not accumulate surface water during periods of the year. Some closed depressions may be classified as wetlands. The design team must coordinate its stormwater design with consideration of any wetland area, as defined by applicable regulations that may govern wetland areas. If the proper authorities agree that none of these closed areas is a wetland, and the design team desires to fill these natural depressions, the designer evaluating the site and formulating a stormwater disposal concept will consider these natural depressions and replace any disturbed depressions. Normally, the natural storage volume lost due to the proposed earthwork shall be replaced using a 1:1 ratio as a minimum. A higher ratio may be required if the new area infiltrates water at a lower rate than occurred in the natural depression. The road and drainage plans shall include: (1) a grading plan of the closed depression area to be filled in, (2) both existing and finished grade contours, and (3) compaction and fill material requirements.

1. For natural depressions that are capable of complete water disposal within 72 hours by infiltrating the runoff generated from a 100-year, 24-hour storm event, a properly designed grassed percolation area, or combination grassed percolation area/drywell that is equal or greater in volume and that will also completely infiltrate the runoff from a 100-

year, 24-hour storm event within a 72-hour time period, could be an acceptable substitution.

2. For natural depressions that do not drain within 72 hours, it is acceptable to consolidate all the volumes of the depressions from the subject site that are proposed for filling into one or more infiltration/evaporative ponds that will emulate the natural condition. If the site has a disposal area that will allow increased percolation from the natural condition, a Design Deviation may be granted for increased infiltration if it can be demonstrated that the groundwater levels in the area will not be adversely affected and runoff treatment problems will not increase.
3. For sites with natural depressions, clearly identify the location of all depressions that could contain more than 50 cubic feet of stormwater. For these types of depressions, survey each depression and show the maximum volume that each could hold, as well as show the maximum storage capacity water elevation contour line on the predeveloped condition basin map. Ensure the basin map shows adequate survey data points to demonstrate that accurate volume calculations can be made from them. If the site contains many small depressions that will hold water, but are smaller than 50 cubic feet in size, adjust the runoff factors to allow for this retention of stormwater or make other adjustments to the runoff model that are approved in writing by region or HQ hydraulics staff. If the site had depression storage in its historic natural state, and grading and filling have been done to these natural features, the PEO shall reasonably estimate the depression storage that was on the site and comply with the provisions of this section.

If the total storage capacity of a closed depression exceeds the maximum volume used (as computed using the water budget method), clearly identify both volumes in the Hydraulic Report, and show both of these water surface elevation contour lines in the basin map.

If a closed depression is to remain or be replaced, ensure the lowest floor elevation or road grade of any building or road adjacent to it is at or above the maximum water elevation and outside the limits of the closed depression. Compute the maximum water elevation using the water budget method as per the standards for an evaporative systems design unless the pond can naturally drain within 72 hours following a 100-year, 24-hour storm event. If the depression can drain within the 72-hour time period, compute the maximum water elevation as the elevation containing the runoff from a 100-year, 24-hour storm event. If the limits of the high water in the infiltration facility are considered in the design, provide a geotechnical report that shows site-specific infiltration testing results and verifies that each depression being used will drain within the 72-hour period unless waived by region or HQ hydraulics staff based on knowledge of approved soils under the site. Ensure the closed depression is placed in a drainage easement or separate tract if the development is noncommercial. The easement shall be granted to WSDOT and any other entity responsible for maintaining the closed depression.

5 Permeable Pavement

IN.06 – Permeable Pavement Surfaces

Test Section of Pervious Pavement at Anacortes Ferry Terminal

Description: The pervious concrete or asphalt pavement surface is an open-graded mix placed in a manner that results in a high degree of interstitial spaces or voids within the cemented aggregate. This technique allows runoff to infiltrate through to the subsoils.

Geometry Limitations

Limited to pedestrians and light to medium-load parking areas.

BMP Function*

☑ LID
☑ Flow Control
☐ Runoff Treatment
  ☐ Oil Control
  ☐ Phosphorus
  ☐ TSS - Basic
  ☐ Dissolved Metals - Enhanced

*Currently, this BMP cannot be considered a stand-alone runoff treatment BMP. A sand filter or soils meeting the Site Suitability Criteria 5 and 7 must be beneath the Pervious Pavement. See the SWMMWW BMP T5.15 for more details on how to design Pervious Pavement as part of a BMP treatment train for runoff treatment.

Effective Life (Years)

➲ --

Capital Cost	**O & M Cost**
➲ Medium	➲ High

Additional Constraints/Requirements

☑ 4-5 Infiltration Design Criteria
☐ Setback
☐ Landscaping/Planting
☐ Wetland Planting and Plant Establishment
☐ Inlet and Outlet Spacing
☐ Overflow
☐ Multidisciplinary Team
☑ WSDOT Pavement Engineer Approval
☐ Soil Amendments/Compost
☐ Energy Dissipater/Level Spreader
☐ 5-4.3.3 Facility Liners
☑ 5-4.3.7 Signing
☐ Fencing
☐ Presettling/Pretreatment
☐ Underdrain
☑ Soil Preparation

TMDL/303(d) – Considerations[1]

Avoid	**Preferred**	
☐	☑	Fecal Coliform
☐	☑	Phosphorus
☐	☑	Nitrogen
☐	☑	Temperature
☐	☑	Dissolved Metals
☐	☑	Total Suspended Solids/Turbidity
☐	☑	Dissolved Oxygen
☐	☑	pH
☐	☑	Oil/Grease
☐	☑	PAHs
☐	☑	Pesticides

1. See Table 3-1 and Section 2-4.2 for additional guidance.

Maintenance Requirements

☐ Access Roads or Pullouts
☐ Vactor Truck Access
☐ Mowing
☐ Valve Access
☑ Specialized Equipment
☑ Specialized Training

Further Requirements: See Sections 5-3.6.1 and 5-5. Consult WSDOT Maintenance for guidance.

Introduction

WSDOT does not recognize this BMP as a viable highway application for flow control or runoff treatment due to cost and performance considerations associated with maintaining this treatment option. For instructions on seeking approval for using this BMP, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

General Description

Pervious (porous) surfaces can be applied to non-pollution-generating surfaces such as pedestrian/bike paths, raised traffic islands, and sidewalks. Pervious surfaces with a media filtration sublayer (such as sand or an amended soil) could be applied to pollution-generating surfaces (such as parking lots) for calculating runoff treatment. Sublayers constructed of amended soils could affect the performance of permeable pavement and should not be used in areas intended to carry vehicle traffic. Pervious surfaces allow stormwater to pass through and infiltrate the soil below, thereby reducing the rate and volume of runoff associated with conventional surfacing and fostering groundwater recharge.

Applications and Limitations

Applications

Permeable pavement has not been proven to stand up to high traffic levels. The use of permeable pavement by WSDOT is limited to applications that can accommodate pedestrians and light- to medium-load parking areas, excluding heavy truck traffic. Consider permeable pavement in the following areas:

- Sidewalks, bicycle trails, and community trail/pedestrian path systems
- Light vehicle access areas such as maintenance/enforcement areas on divided highways
- Public and municipal parking lots, including perimeter and overflow parking areas
- Driveways

Pervious surface systems function as stormwater infiltration areas and temporary stormwater retention areas. This combination of functions offers the following benefits:

- Captures and retains precipitation on site
- Mimics natural soils filtration throughout the pavement depth, underlying sub-base reservoir, and native soils for improved groundwater quality
- Eliminates surface runoff, depending on existing soil conditions
- Greatly reduces or eliminates the need for an on-site stormwater management system
- Reduces drainage water runoff temperatures
- Increases recharge of groundwater
- Provides runoff treatment with a media filtration layer

- Thaws faster when covered by ice or snow

Limitations

Pervious surfaces are vulnerable to clogging from sediment in runoff or from dirt and debris that accumulates and falls off vehicles. The following techniques will reduce this potential:

- **Surface runoff**. Do not locate pervious surfaces where turbid runoff from adjacent areas can introduce sediments onto the pervious surface. Designs should slope impervious runoff away from permeable pavement installations to the maximum extent possible.
- **Diversion**. Design French drains, or other diversion structures, into the system to avoid unintended off-site runoff. Separate pervious systems using edge drain systems, turnpikes, and curbing.
- **Cold climates**. Sanding or repeated snow removal can lead to clogging and a reduction in surface permeability. Do not use pervious surfaces in traffic areas where sanding or extensive snow removal is carried out in the winter.
- **Slopes**. Ensure off-site drainage slopes immediately adjacent to the pervious surface are less than 5% to reduce the chance of soil loss that would cause clogging.

Examples of situations where the use of pervious surfaces is not recommended include the following:

- Main line roadway.
- Roadway shoulders.
- Roadways with high volume and heavy trucks.
- Areas such as maintenance yards that are subject or potentially subject to higher pollutant loadings, spills, and piles of bulk materials (such as sand or salt).
- Areas prone to the accumulation of organic debris from overhanging vegetation or areas prone to moss growth.
- Where the requirements defined in the *Site Suitability Criteria* cannot be met (see Section 4-5.1), specifically:
    - Areas where the risk of groundwater contamination from organic compounds is high (for example, fueling stations, commercial truck parking areas, and maintenance and storage yards).
    - Within 100 feet of a drinking water well and within areas designated as sole-source aquifers.
    - Areas with a high-water table or impervious soil layer as defined in Section 4-5, Infiltration Design Criteria.
    - Within 100 feet upgradient or 10 feet downgradient from building foundations. Closer upgradient distances may be considered where the minimum seasonal depth to groundwater lies below the foundation or where it can be demonstrated that infiltrating water from the pervious surface will not affect the foundation.

Construction Practices

Handling and placement practices for pervious surfaces are different from conventional pavement placement. Unlike conventional pavement construction, it is important that the underlying native or subgrade soils be nominally consolidated to prevent settling and to minimize the effect of intentional or inadvertent heavy compaction due to heavy equipment operation during construction. Consolidation can be accomplished using static dual-wheel small mechanical rollers or plate vibration machines. If heavy compaction does occur, then tilling may be necessary to a depth of 2 feet or more below the materials placement. This would occur prior to subsequent application of the separation and aggregate storage layer.

Design Criteria

All projects considering the use of pervious surfaces require the coordination of the HQ Design, Materials Lab, and Maintenance offices, and the HQ Highway Runoff Unit. The final design shall be approved by the HQ Materials Office and Highway Runoff Unit.

General Criteria

- As long as runoff is not directed to the pervious asphalt from adjacent surfaces, the estimated long-term infiltration rate may be as low as 0.1 inch/hour. Provide underdrains for soils with lower infiltration rates to prevent prolonged saturated soil conditions at or near the ground surface within the pavement section (PSAT, 2005).
- For initial planning purposes, note that pervious surface systems will work well on Hydrologic Soil Groups A and B and can be considered for Group C soils. Standard three-layer placement sections for Group D soils may not be applicable.
- For projects constructed upon Group C and D soils, conduct a minimum of three soil gradation analyses or three infiltration tests to establish on-site soil permeability. Otherwise, conduct a minimum of one such test for Group A and B soils to verify adequate permeability.
- Ideally, design the base layer with sufficient depth to meet flow control requirements (taking into account infiltration). If the infiltration rate and base layer’s recharge bed storage does not meet flow control requirements, the PEO may need to provide an underdrain system. The underdrain may be discharged to a bioretention area, dispersion system, or stormwater detention facility.
- Do not allow turbid runoff to the pervious surface from off-site areas. The PEO may incorporate infiltration trenches or other options into the design to ensure long-term infiltration through the pervious surface.
- Install any necessary boreholes to a depth of 10 feet below the base of the reservoir layer and monitor the water table at least monthly for a year.
- Note that pervious surfaces require more maintenance than conventional pavement installations. The primary concern in maintaining the continued effectiveness of a pervious surface system is to prevent the surface from clogging with fine sediments and debris. (See Section 5-5 for operation and maintenance guidelines.)

Pavement Structure Elements

Pervious surfaces consist of a number of components: the surface pavement, an underlying aggregate storage layer, a separation layer, and the native soil or subgrade soil (see Figure IN.06.1). The PEO may need to consider an overflow or underdrain system as part of the pavement's overall design.

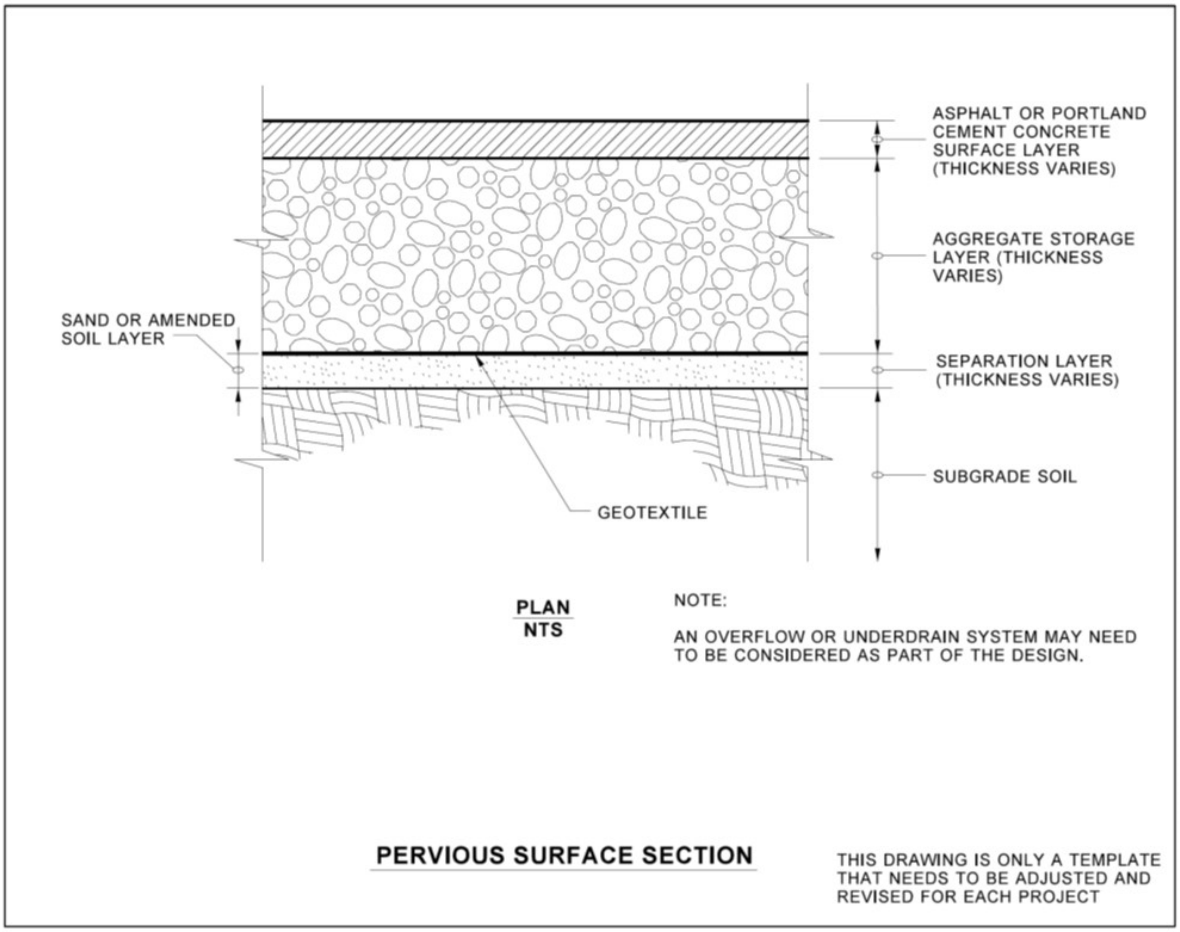

Figure IN.06.1 Permeable pavement structure elements.

Surface Layer

The surface layer is the first component of a pervious system's design that creates the appropriate conditions for water to infiltrate through the surface. Pervious paving systems allow infiltration of storm flows; however, do not allow the wearing course to become saturated from excessive water volume stored in the aggregate storage layer (PSAT, 2005). The two types of surface layers that will be described (or are considered appropriate for the locations described in this section) are: Portland Cement-Based Permeable Pavement Materials and Asphalt-Based Permeable Pavement Materials. Each of these materials is further described in the following sections.

Portland Cement-Based Permeable Pavement Materials

The surface layer consists of specially formulated mixtures of Portland cement, uniform open-graded coarse aggregate, and potable water. The depth of the surface layer may increase from a minimum of 4 inches, depending on the required bearing strength and pavement design requirements. The gradation required to obtain a pervious concrete pavement is of the open-graded or coarse type (AASHTO Grading No. 67 is typical). For additional information, refer to the permeable pavement specifications.

Due to the relatively low water content of the concrete mix, an agent may be added to retard concrete setup time. When properly handled and installed, permeable pavement has a higher percentage of void space than conventional pavement (approximately 12% to 20%), which allows rapid percolation of stormwater through the pavement. The initial permeability can commonly exceed 200 inches per hour (Chollack et al., 2001; Mallick et al., 2000).

Asphalt-Based Permeable Pavement Materials

The surface asphalt layer consists of an open-graded asphalt mixture. The depth of the surface layer may increase from a minimum of 4 inches, depending on the required infiltration, subgrade bearing strength, and pavement design requirements.

Pervious asphalt pavement consists of an open-graded coarse aggregate. The pervious asphalt creates a surface layer with interconnected voids that provide a high rate of permeability.

Aggregate Storage Layer

The underlying aggregate storage layer is the second component of a pervious surface's design. The aggregate storage layer is composed of a crushed aggregate and provides the following:

- A stable base for the pavement.
- A high degree of permeability to disperse water downward through the underlying layer to the separation layer.
- A temporary reservoir that slows the migration of water prior to infiltration into the underlying soil.
- Base material is often composed of larger aggregate (1.5 to 2.5 inches) with smaller stone (leveling or choker course) between the larger stone and the wearing course. Typical void space in base layers ranges from 20% to 40% (WSDOT, 2003; Cahill, Adams, and Marm, 2003).
- Depending on the target flow control standard and physical setting, retention or detention requirements can be partially or entirely met in the aggregate base (PSAT, 2005).
- Aggregate base depths of 18 to 36 inches are common depending on storage needs, and they provide the additional benefit of increasing the strength of the wearing

course by isolating underlying soil movement and imperfections that may be transmitted to the wearing course (Cahill et al., 2003).

Separation Layer

The third component of permeable pavement is the separation layer. This layer consists of a nonwoven geotextile fabric and possibly a treatment media base material. A geotextile fabric layer is placed between the base material and the native soil to prevent migration of fine soil particles into the base material, followed by a runoff treatment media layer if required.

- For geotextile, see WSDOT Standard Specification 9-33.
- For separation base material, see the FHWA manual *Construction of Pavement Subsurface Drainage Systems* (2002) for aggregate gradation separation base guidance.
- A treatment media layer is not required where subgrade soil is determined to have a long-term infiltration rate less than 3.0 inches per hour and a CEC of the subgrade soil that is at least 5 milliequivalents/100 grams of dry soil or greater (Ecology, 2001).
- If a treatment media layer is used, it shall be distributed below the geotextile layer and above the subgrade soil. The media can consist of a sand filter layer or amended soil. Engineered amended soil layers should be a minimum of 18 inches and incorporate compost, sphagnum peat moss, or other organic material to provide a cation exchange capacity of greater than or equal to 5 milliequivalents/ 100 grams of dry soil (Ecology, 2001). Gradations of the treatment media should follow base sizing.

Subgrade Soil

The underlying subgrade soil is the fourth component of permeable pavement. Runoff infiltrates into the soil and moves to the local interflow or groundwater layer. The PEO shall keep compaction of the subgrade to an absolute minimum to ensure the soil maintains a high rate of permeability while maintaining the structural integrity of the pavement.

Permeable Pavement Structural Design

Permeable Pavement Thickness

Thickness designs for pervious asphalt or concrete shall match those shown in the 2011 Pavement Policy available through the State Materials Laboratory:
🖱 http://www.wsdot.wa.gov/nr/rdonlyres/d7971b81-5443-45b9-8b9b-bfc0d721f5a1/0/wsdotpavementpolicyfinal71211.pdf

Aggregate Storage Layer Thickness

Once a pervious surface site is identified, contact the WSDOT Materials Lab to arrange for a required geotechnical investigation to be performed. On-site soils will be tested for porosity, permeability, organic content, and potential for cation exchange. The WSDOT Materials Lab, Geotechnical Services Division, will determine the quantity and depth of borings/test pits required and any groundwater monitoring needed to characterize the soil infiltration characteristics of the site. Where subgrade materials are marginal, the use of a geogrid placed directly on subgrade may be necessary. A sand layer is placed above the heavy geogrid, followed by geotextile for drainage. Coordinate with the HQ Geotechnical Services Division for these applications.

For determining a final design-level infiltration rate, refer to the design criteria provided in Section 4-5. ***Note:*** These criteria apply primarily to infiltration basins and may therefore exclude slower-percolating soils such as loams, which are potentially suitable for pervious surfaces.

Flow control modeling guidance for western Washington is found in Table 4-1 of Chapter 4. For sizing the permeable pavement aggregate recharged bed, contact the HQ Highway Runoff Unit.

Special Provisions

For special provisions in the development of Plans, Specifications, and Estimates (PS&E), contact the State Materials Office.

Design Flow Elements

Flows to Be Infiltrated

The design criteria below assume that it is feasible to meet the flow control requirements by sizing a storage volume within the subsurface layers. This needs to be explored further for viability. It is possible that the design criteria for an infiltration trench may be more comprehensive and applicable than the general guidelines provided below. There has been discussion in the past that using permeable pavement surfaces is a part of low-impact development (LID) practices and would only result in some form of credit being applied to flow control mitigation.

For western Washington, use an acceptable continuous runoff simulation model to size an infiltration basin, as described in Section 4-5, Infiltration Design Guidelines. Modeling guidelines can be derived from Section 4-3.6.1, Continuous Simulation Method. For eastern Washington, use an appropriate single-event-based model consistent with Section 4-5 guidelines. For sizing purposes, use the following guidelines:

- The bottom area of an “infiltration basin” will typically be equivalent to the area below the surrounding grade underlying the pervious surface. Adjust the depth of this “infiltration basin” so that it is sufficient to store the required design volume.
- Multiply this depth by a factor of 5. This will determine the depth of the gravel base underlying the pervious surface. This assumes a void ratio of 0.20—a conservative assumption. When the PEO uses a base material that has a different porosity, the PEO may substitute that value to determine the depth of the base. The minimum

base depth is 6 inches, which allows for adequate structural support of the pervious surface.

- For a large, contiguous area of pervious surface, such as a parking lot, the PEO may design the area with a level surface grade and a sloped subgrade to prevent water buildup on the surface, except under extreme conditions. Rare instances of shallow ponding in a parking lot are normally acceptable.
- For projects where ponding is unacceptable under any condition, the PEO may grade the surface of the parking lot at a 1% slope leading to a shallow swale, which would function to ensure emergency drainage (similar to an emergency overflow from a conventional infiltration pond). However, the PEO shall maintain the design depth of the base material at all locations.

6 Treatment Train Approach

WSDOT does not recognize the treatment train approach for phosphorus or dissolved metals removal as a viable highway application due to cost and performance considerations associated with maintaining these treatment options. For instructions on seeking approval for using these BMPs, refer to Section 5-3.6, Seeking Authorization for Alternative BMP Options, in Chapter 5 of the Highway Runoff Manual (HRM).

Table 6.1. Treatment train combinations for phosphorus removal in projects.

First Basic Runoff Treatment Facility	Second Runoff Treatment Facility
RT.04, RT.06 – Biofiltration Swale	RT.14, RT.16 – Sand Filter Basin
RT.02 – Vegetated Filter Strip	RT.15 – Linear Sand Filter (basic) with no presettling cell needed
RT.15 – Linear Sand Filter (basic)	RT.02 – Vegetated Filter Strip
RT.12 – Wet Pond (basic)	RT.14, RT.16 – Sand Filter Basin
RT.19 – Wet Vault (basic)	RT.14, RT.16 – Sand Filter Basin
RT.13 – Constructed Stormwater Treatment Wetland	RT.14, RT.16 – Sand Filter Basin
CO.01, CO.03 – Combined Wet/Detention Pond or Vault (basic)	RT.14, RT.16 – Sand Filter Basin

Table 6.2. Treatment train combinations for dissolved metals removal in projects.

First Basic Runoff Treatment Facility	Second Runoff Treatment Facility
RT.04, RT.06 – Biofiltration Swale	RT.14, RT.16 – Sand Filter Basin
RT.02 – Vegetated Filter Strip	RT.15 – Linear Sand Filter (basic) with no presettling cell needed
RT.15 – Linear Sand Filter (basic)	RT.02 – Vegetated Filter Strip
RT.12 – Wet Pond	RT.14, RT.16 – Sand Filter Basin
RT.19 – Wet Vault (basic)	RT.14, RT.16 – Sand Filter Basin
CO.01, CO.03 – Combined Wet/Detention Pond or Vault (basic)	RT.14, RT.16 – Sand Filter Basin

7 BMP Maintenance Standards

Table 7.1 Maintenance standards for wet vaults.

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and debris	Trash and debris have accumulated in vault, pipe, or inlet/outlet (includes floatables and nonfloatables).	No trash or debris remain in vault.
	Sediment accumulation in vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	No sediment remains in vault.
	Damaged pipes	Inlet/outlet piping is damaged or broken and in need of repair.	Pipe is repaired and/or replaced.
	Access cover damaged/ not working	Cover cannot be opened or removed by one person.	Cover is repaired or replaced to proper working specifications.
	Ventilation	Ventilation area is blocked or plugged.	Blocking material is removed or cleared from ventilation area. A specified percent of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault structure damage: includes cracks in walls or bottom, damage to frame or top slab	Maintenance/inspection personnel determine that the vault is not structurally sound.	Vault is replaced or repairs made so that the vault meets design specifications and is structurally sound.
		Cracks are wider than ½ inch at the joint of any inlet/outlet pipe, or there is evidence of soil particles entering through the cracks.	Vault is repaired so that no cracks are wider than ¼ inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles are corroding, cracking, warping, or showing signs of failure as determined by maintenance/inspection staff.	Baffles are 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, or is misaligned. Confined-space warning sign is missing.	Ladder is replaced or repaired to specifications and is safe to use, as determined by inspection personnel. Sign warning of confined space entry requirements is in place. Ladder and entry notification comply with WISHA standards.

Table 7.2 Maintenance standards for closed treatment systems (tanks/vaults).

Maintenance Component	Defect or Problem	Condition 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 are open and functioning.
	Debris and sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for ½ length of storage vault, or any point depth exceeds 15% of diameter. (Example: 72-inch storage tank requires cleaning when sediment reaches depth of 7 inches for more than ½ length of tank.)	All sediment and debris are removed from storage area.
	Joints between tank/pipe section	Openings or voids allow material to be transported into facility. (Will require engineering analysis to determine structural stability.)	All joints 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 is repaired or replaced to design specifications.
	Vault structure: includes cracks in walls or bottom, damage to frame or top slab	Cracks are wider than ½ inch and there is evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault is replaced or repaired to design specifications and is structurally sound.
		Cracks are wider than ½ inch at the joint of any inlet/outlet pipe, or there is evidence of soil particles entering the vault through the walls.	No cracks are more than ¼ inch wide at the joint of the inlet/outlet pipe.

Table 7.3 Maintenance standards for sand filters (aboveground/open).

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Aboveground (open sand filter)	Sediment accumulation on top layer	Sediment depth exceeds ½ inch.	No sediment deposit is observed on grass layer of sand filter that would impede permeability of the filter section.
	Trash and debris	Trash and debris have accumulated on sand filter bed.	Trash and debris are removed from sand filter bed.
	Sediment/debris in cleanouts	Cleanouts are full or partially plugged with sediment or debris.	Sediment is removed from cleanouts.
	Sand filter media	Drawdown of water through the sand filter media takes longer than 24 hours, 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 whether the lower sand has too high a proportion of fine material.)
	Prolonged flows	Sand is saturated for prolonged periods (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	Flows become concentrated over one section of the sand filter rather than dispersed.	Flow and percolation of water through sand filter are uniform and dispersed across the entire filter area.
	Erosion damage to slopes	Erosion is more than 2 inches deep, and potential for continued erosion is evident.	Slopes are stabilized using proper erosion control measures.
	Rock pad missing or out of place	Soil beneath the rock is visible.	Rock pad is replaced or rebuilt to design specifications.
	Flow spreader	Flow spreader is uneven or clogged so that flows are not uniformly distributed across sand filter.	Spreader is leveled and cleaned so that flows are spread evenly over sand filter.
	Damaged pipes	Any part of the piping is crushed or deformed more than 20%, or any other failure to the piping is observed.	Pipe is repaired or replaced.

Table 7.4 Maintenance standards for sand filters (belowground/enclosed).

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Belowground vault	Sediment accumulation on sand media section	Sediment depth exceeds ½ inch.	No sediment deposits are on sand filter section that would impede permeability of the filter section.
	Sediment accumulation in presettling portion of vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	No sediment deposits are in first chamber of vault.
	Trash and debris	Trash and debris have accumulated in vault or pipe inlet/outlet (includes floatables and nonfloatables).	Trash and debris are removed from vault and inlet/outlet piping.
	Sediment in drain pipes/cleanouts	Drain pipes or cleanouts are filled with sediment or debris.	Sediment and debris are removed.
	Short-circuiting	Seepage/flow occurs along the vault walls and corners. Sand is eroding near inflow area.	Sand filter media section is relaid and compacted along perimeter of vault to form a semiseal. Erosion protection is added to dissipate force of incoming flow and curtail erosion.
	Damaged pipes	Inlet or outlet piping is damaged or broken and in need of repair.	Pipe is repaired or replaced.
	Access cover damaged/not working	Cover cannot be opened, or cover has corroded/deformed. Maintenance person cannot remove cover using normal lifting pressure.	Cover is repaired to proper working specifications or replaced.
	Ventilation	Ventilation area is blocked or plugged.	Blocking material is removed or cleared from ventilation area. A specified percent of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault structure damage: includes cracks in walls or bottom, damage to frame or top slab	Cracks are wider than ½ inch and there is evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault is replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks are wider than ½ inch at the joint of any inlet/outlet pipe, or there is evidence of soil particles entering through the cracks.	Vault is repaired so that no cracks are wider than ¼ inch at the joint of the inlet/outlet pipe.
	Baffles/internal walls	Baffles or walls are corroding, cracking, warping, or showing signs of failure as determined by maintenance/inspection personnel.	Baffles are repaired or replaced to specifications.
	Access ladder damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, has missing rungs, or is cracked or misaligned.	Ladder is replaced or repaired to specifications and is safe to use as determined by inspection personnel.

Table 7.5 Maintenance standards for baffle oil/water separators (API type).

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Discharge water shows obvious signs of poor water quality.	Effluent discharge from vault should be clear without thick visible sheen.
	Sediment accumulation	Sediment depth in bottom of vault exceeds 6 inches.	No sediment deposits are on vault bottom that would impede flow through the vault and reduce separation efficiency.
	Trash and debris	Trash and debris have accumulated in vault or pipe inlet/outlet (includes floatables and nonfloatables).	Trash and debris are removed from vault and inlet/outlet piping.
	Oil accumulation	Oil accumulations exceed 1 inch at the surface of the water.	Oil is extracted from vault by vactoring and disposed of in accordance with state and local rules and regulations.
	Damaged pipes	Inlet or outlet piping is damaged or broken and in need of repair.	Pipe is repaired or replaced.
	Access cover damaged/not working	Cover cannot be opened, or cover is corroded/deformed.	Cover is repaired to proper working specifications or replaced.
	Vault structure damage: includes cracks in walls or bottom, damage to frame or top slab (see Table 5.5.5 in the HRM for further information on structure damage and fractures or cracks)	Cracks are wider than ½ inch and there is evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault is replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks are wider than ½ inch at the joint of any inlet/outlet pipe, or there is evidence of soil particles entering through the cracks.	Vault is repaired so that no cracks are wider than ¼ inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles are corroding, cracking, warping, or showing signs of failure as determined by maintenance/inspection personnel.	Baffles are repaired or replaced to specifications.
	Access ladder damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, has missing rungs, or is cracked or misaligned.	Ladder is replaced or repaired to specifications and is safe to use as determined by inspection personnel.

Table 7.6 Maintenance standards for coalescing plate oil/water separators.

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Discharge water shows obvious signs of poor water quality.	Effluent discharge from vault is clear with no thick visible sheen.
	Sediment accumulation	Sediment depth in bottom of vault exceeds 6 inches, or signs of sediment are visible on plates.	No sediment deposits are on vault bottom and plate media that would impede flow through the vault and reduce separation efficiency.
	Trash and debris	Trash and debris have accumulated in vault or pipe inlet/outlet (includes floatables and nonfloatables).	Trash and debris are removed from vault and inlet/outlet piping.
	Oil accumulation	Oil accumulation exceeds 1 inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. No visible oil is on water.
	Damaged coalescing plates	Plate media broken, deformed, cracked, 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 is repaired and or replaced.
	Baffles	Baffles are corroding, cracking, warping, or showing signs of failure as determined by maintenance/inspection personnel.	Baffles are repaired or replaced to specifications.
	Vault structure damage: includes cracks in walls or bottom, damage to frame or top slab	Cracks are wider than ½ inch and there is evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault is replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks are wider than ½ inch at the joint of any inlet/outlet pipe or there is evidence of soil particles entering through the cracks.	Vault is repaired so that no cracks are wider than ¼ 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, has missing rungs, or is cracked or misaligned.	Ladder is replaced or repaired to specifications and is safe to use as determined by inspection personnel.

Table 7.7 Maintenance standards for permeable pavement.

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment accumulation	Collection of sediment is too coarse to pass through pavement.	Remove sediment deposits with high-pressure vacuum sweeper.
	Accumulation of leaves, needles, and other foliage	Accumulation on top of pavement is observed.	Remove with a leaf blower or high-pressure vacuum sweeper.
	Trash and debris	Trash and debris have accumulated on the pavement.	Remove by hand or with a high-pressure vacuum sweeper.
	Oil accumulation	Oil collection is observed on top of pavement.	Immediately remove with a vacuum and follow up by a pressure wash or other appropriate rinse procedure.
Visual facility identification	Not aware of permeable pavement location	Facility markers are missing or not readable.	Replace facility identification where needed.
Annual minimum maintenance			Remove potential void-clogging debris with a biannual or annual high-pressure vacuum sweeping.