Sizing Methods

Infiltration systems should be sized to store the design infiltration volume. Infiltration systems can be sized by one of two methods – the "Static Method" or the "Dynamic Method" – which are described below.

Static Method

In the Static Method, infiltration systems are sized to hold the design infiltration volume and fully infiltrate this volume into the underlying soil within 48 hours after the end of the storm. This method is more conservative and generally results in larger infiltration systems since it does not account for exfiltration from the system (infiltration into underlying soils) during the storm.

- Size the infiltration system to hold the design infiltration volume. Assume the entire design infiltration volume is discharged to the infiltration system before infiltration begins. Exfiltration during the storm event is not considered in sizing or modeling infiltration systems using the Static Method.

- The static storage volume – the volume of stormwater a structural stormwater BMP can physically hold – should be equal to or greater than the design infiltration volume.

    - The static storage volume includes the volume of ponded water below the elevation associated with the maximum ponding depth (for surface infiltration systems), the volume associated with void spaces in the subsurface engineered porous media (e.g., bioretention soil, pea gravel layer, gravel/stone reservoir), and the volume within subsurface structures (chambers, pipes, tanks, etc.). It doesn't include the additional treatment volume as a result of the water that infiltrates into the underlying soil while the system is filling or stormwater that bypasses the system through inlet or outlet controls. Table 10- 5 provides equations for calculating the static storage volume for stormwater infiltration systems. Table 10- 5 also includes the corresponding equations for calculating the minimum required surface area of a stormwater infiltration system for a given design infiltration volume or static storage volume.

- A default porosity value of 0.4 should be used for stone reservoirs in the static storage volume calculation. A default porosity value of 0.3 should be used for engineered soil media and sand for bioretention systems, tree filters, and sand filters designed for infiltration. Other porosity values may be used as determined from testing of the proposed materials.

➢ Confirm that the bottom of the infiltration system is large enough to ensure that the infiltration system will completely drain in 48 hours or less after the end of the storm. Calculate the drain time using the following equation:

$$T_d = \left(\frac{V}{K * A}\right) * 12\ inches/foot$$

where:

T_d = drain time (hours)
V = design infiltration volume or static storage volume calculated using the equations in Table 10- 5 (cubic feet)
K = design infiltration rate (inches per hour)
A = average surface area of infiltration system (square feet)

- The design infiltration rate (K) in the drain time equation should be the infiltration rate that is representative of the most restrictive layer in the infiltration system (i.e., surface loam layer, filter media layer for bioretention and other filtering systems used for infiltration, and the underlying soils) as described in General Design Guidance.

- The infiltration rate should be assumed to be constant for the purpose of the drain time analysis.

- Only bottom surface area should be considered. No credit is allowed for sidewall (i.e., horizontal) exfiltration. The average surface area of the infiltration system between the maximum ponding depth and the bottom of the system should be used in the drain time calculation for surface infiltration systems.

- If the drain time analysis indicates the system cannot completely drain within 48 hours after the end of the storm, the bottom area of the infiltration system should be increased, or the design infiltration volume should be reduced by reducing or disconnecting impervious area.

- An underdrain can also be added to meet the drain time requirement. The volume of stormwater infiltrated versus discharged via the underdrain will depend on the infiltration rate of the underlying soils (and filter media for

Filtering BMPs and dry water quality swales). Retention credit is only allowed for the volume of stormwater infiltrated into the underlying soils, not for stormwater that bypasses the system through inlet or outlet controls. The volume of stormwater infiltrated versus discharged via the underdrain will depend on the infiltration rate of the underlying soils. Retention credit is only allowed for the volume of stormwater infiltrated into the underlying soils, not for stormwater that bypasses the system through inlet or outlet controls

Table 10- 5 Equations for Calculating the Static Storage Volume and Required Surface Area of Stormwater Infiltration Systems (Static Method)

Stormwater BMP Type and Description	Static Storage Volume Description	Equation
Infiltration Trench Provides temporary storage of runoff through surface ponding and within the void spaces of the stone-filled trench for subsequent infiltration into the underlying soils.	Ponding water storage volume and void space volume of stone	$V = (A * D_{ponding}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) A = average area between maximum ponding depth and the trench surface (square feet) $D_{ponding}$ = maximum ponding depth (feet) L = length (feet) W = width (feet) D_{stone} = depth of stone (feet) n_{stone} = porosity of stone (use default value of 0.4). Other porosity values may be used as determined from testing of the proposed materials. $A_{required} = \frac{V}{(D_{ponding}) + (D_{stone} * n_{stone})}$ $A_{required}$ = minimum required surface area of infiltration trench (square feet) V = design infiltration volume (cubic feet)

Stormwater BMP Type and Description	Static Storage Volume Description	Equation
Subsurface Infiltration (Chambers, Dry Wells, and Infiltrating Catch Basins Provides temporary storage of runoff using the combination of storage structures (e.g., galleys, chambers, manholes, catch basins, etc.) and void spaces within the underlying and surrounding stone that is used to backfill the system for subsequent infiltration into the underlying soils.	Water storage volume of storage structures and void space volumes of stone underlying and surrounding the storage structures	Static storage volume equations vary based on type of system. Refer to manufacturer's design guidance for calculating static storage volume for manufactured infiltration chambers and similar subsurface storage units. When calculating the stone storage capacity, subtract the storage volume of the chambers from the calculated storage volume of the stone layer before multiplying by stone porosity.
Infiltration Basin Provides temporary storage of runoff through surface ponding storage for subsequent infiltration into the underlying soils.	Ponding water storage volume	$V = A * D_{ponding}$ V = static storage volume (cubic feet) A = average area between maximum ponding depth and the basin bottom (square feet) $D_{ponding}$ = maximum ponding depth (feet) $A_{required} = \frac{V}{D_{ponding}}$ $A_{required}$ = minimum required surface area of infiltration basin (square feet) V = design infiltration volume (cubic feet)

Stormwater BMP Type and Description	Static Storage Volume Description	Equation
Permeable Pavement Provides filtering of runoff through a surface course, choker and filter course, and temporary storage of runoff within the void spaces of a subsurface stone reservoir course prior to infiltration into subsoils.	Void space volume of choker course (stone), filter course (sand), and stone reservoir.	$V = L * W * (D_{stone} * n_{stone} + D_{sand} * n_{sand})$ V = static storage volume (cubic feet) L = length (feet) W = width (feet) D_{stone} = depth of stone courses (feet) D_{sand} = depth of sand filter course (feet) n_{stone} = porosity of stone courses (use default value of 0.4) n_{sand} = porosity of sand filter course (use default value of 0.3) Other porosity values may be used as determined from testing of the proposed materials. $A_{required} = \frac{V}{D_{stone} * n_{stone} + D_{sand} * n_{sand}}$ $A_{required}$ = minimum required surface area of permeable pavement (square feet) V = design infiltration volume (cubic feet)

Stormwater BMP Type and Description	Static Storage Volume Description	Equation
Bioretention and Tree Filter (when designed for infiltration) Provides temporary storage of runoff for filtering through an engineered soil media. The storage capacity includes void spaces in the filter media and temporary ponding at the surface. After runoff has passed through the filter media, some of it is infiltrated into the underlying soils and some is collected by an underdrain overflow pipe for discharge if an underdrain is used.	Ponding water storage volume and void space volume of soil filter media and gravel/stone layers (pea gravel and stone reservoir) if underdrain system is used or if design includes a stone reservoir without an underdrain.	Static storage volume equations vary based on type and configuration of bioretention system. Refer to manufacturer's design guidance for manufactured tree filters. $V = (L * W * D_{ponding}) + (L * W * D_{soil} * n_{soil}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) L = length of bioretention system (feet) W = average width of bioretention system between maximum ponding depth and the bottom of the system (feet) $D_{ponding}$ = maximum ponding depth (feet) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain gravel and/or stone reservoir layer(s) between bottom of the bioretention soil layer and native soil (feet) n_{soil} = porosity of bioretention soil (use default value of 0.3) n_{stone} = porosity of gravel/stone (use default value of 0.4) Other porosity values may be used as determined from testing of the proposed materials. $A_{required} = \frac{V}{(D_{ponding}) + (D_{soil} * n_{soil}) + (D_{stone} * n_{stone})}$ $A_{required}$ = minimum required surface area of bioretention system (square feet) V = design infiltration volume (cubic feet)

Stormwater BMP Type and Description	Static Storage Volume Description	Equation
Surface Sand Filter (when designed for infiltration) Provides filtering of runoff through a sand filter course and temporary storage of runoff through surface ponding and within void spaces of the sand and washed stone layers. After runoff has passed through the filter media, some of it is infiltrated into the underlying soils and some is collected by an underdrain overflow pipe for discharge.	Ponding volume and void space volume of sand and gravel/stone layers.	$V = (A * D_{ponding}) + (A_{bed} * D_{sand} * n_{sand}) + (A_{bed} * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) A = average area between maximum ponding depth and the filter bed surface (square feet) A_{bed} = surface area of filter bed (square feet) $D_{ponding}$ = maximum ponding depth above filter bed (feet) D_{sand} = depth of sand layer (feet) D_{stone} = depth of underdrain stone layer (feet) n_{sand} = porosity of sand (use default value of 0.3) n_{stone} = porosity of stone (use default value of 0.4) Other porosity values may be used as determined from testing of the proposed materials. $A_{required} = \frac{V}{(D_{ponding}) + (D_{sand} * n_{sand}) + (D_{stone} * n_{stone})}$ $A_{required}$ = minimum required surface area of filter bed (square feet) V = design infiltration volume (cubic feet)

Stormwater BMP Type and Description	Static Storage Volume Description	Equation
Dry Water Quality Swale (when designed for infiltration) Provides temporary surface ponding storage of runoff in an open vegetated channel through permeable check dams and filtering through an engineered soil media (bioretention soil) below the bottom of the swale. After runoff has passed through the engineered soil media, some of it is infiltrated into the underlying soils and some is collected by an underdrain overflow pipe for discharge if an underdrain is used.	Water storage volume of swale and void space volume of soil filter media and gravel/stone layers (pea gravel and stone reservoir) if underdrain system is used or if design includes a stone reservoir without an underdrain.	$V = (L * W * D_{ponding}) + (L * W * D_{soil} * n_{soil}) + (L * W * D_{stone} * n_{stone})$ V = static storage volume (cubic feet) L = length of swale (feet) W = average width of swale between maximum ponding depth and the bottom of the swale (feet) $D_{ponding}$ = maximum ponding depth (feet) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain stone/gravel layer (feet) n_{soil} = porosity of bioretention soil (use default value of 0.3) n_{stone} = porosity of gravel/stone (use default value of 0.4) Other porosity values may be used as determined from testing of the proposed materials. $A_{required} = \frac{V}{(D_{ponding}) + (D_{soil} * n_{soil}) + (D_{stone} * n_{stone})}$ $A_{required}$ = minimum required surface area of swale (square feet) V = design infiltration volume (cubic feet)

Dynamic Method

The Dynamic Method accounts for exfiltration of stormwater into the underlying soil during the time required for the infiltration system to completely fill. This method is less conservative and can result in smaller infiltration systems, especially in more permeable soils (HSG A and B soils), which can be helpful for space-constrained sites and for more cost-effective infiltration system designs overall.

- When the Dynamic Method is used, the design infiltration rate should be determined from field infiltration testing and be equal to 50% of the field measured infiltration rate, regardless of USDA soil textural class or Hydrologic Soil Group. Default infiltration rates should not be used when using the Dynamic Method for sizing infiltration BMPs.

- Calculate the required surface area of the infiltration system using the appropriate sizing equation from Table 10- 6 or a stormwater hydrologic/hydraulic routing model (e.g., HydroCAD or similar software).

- Confirm that the bottom of the infiltration system is large enough such that the infiltration system will completely drain in 48 hours or less after the end of the storm. Use the drain time equation presented above for the Static Method or a stormwater hydrologic/hydraulic routing model (e.g., HydroCAD or similar software).

    - The drain time should be based on the design infiltration rate (see General Design Guidance).

    - The infiltration rate should be assumed to be constant for the purpose of the drain time analysis.

    - Only the bottom surface area should be considered. No credit is allowed for sidewall (i.e., horizontal) exfiltration. The average surface area of the infiltration system between the maximum ponding depth and the bottom of the system should be used in the drain time calculation for surface infiltration systems.

    - If the drain time analysis indicates the system cannot completely drain within 48 hours after the end of the storm, the bottom area of the infiltration system should be increased, or the design infiltration volume should be reduced by reducing or disconnecting impervious area.

    - An underdrain can also be added to meet the drain time requirement.

Table 10- 6 Equations for Calculating the Required Surface Area of Stormwater Infiltration Systems (Dynamic Method)

Stormwater BMP Type and Description	Equation
Infiltration Trench Provides temporary storage of runoff through surface ponding and within the void spaces of the stone-filled trench for subsequent infiltration into the underlying soils.	$$A_{required} = \frac{V}{(D_{ponding}) + (D_{stone} * n_{stone}) + (K * T/12)}$$ $A_{required}$ = minimum required surface area of infiltration trench (square feet) V = design infiltration volume (cubic feet) $D_{ponding}$ = maximum ponding depth (feet) D_{stone} = depth of stone (feet) n_{stone} = porosity of stone (use default value of 0.4) K = design infiltration rate (inches per hour) (50% of the slowest observed field infiltration rate or 0.5 inches per hour if grass/loam surface is used, whichever value is lower) T = time to fill trench (hours) (assumed to be 2 hours for design purposes)
Subsurface Infiltration (Chambers, Dry Wells, and Infiltrating Catch Basins) Provides temporary storage of runoff using the combination of storage structures (e.g., galleys, chambers, manholes, catch basins, etc.) and void spaces within the underlying and surrounding stone that is used to backfill the system for subsequent infiltration into the underlying soils.	Required surface area equations vary based on type of system. Refer to manufacturer's design guidance for calculating required surface area for manufactured infiltration chambers and similar subsurface storage units.

Stormwater BMP Type and Description	Equation
Infiltration Basin Provides temporary storage of runoff through surface ponding for subsequent infiltration into the underlying soils.	$A_{required} = \frac{V}{(D_{ponding}) + (K * T/12)}$ $A_{required}$ = minimum required surface area of infiltration basin (square feet) V = design infiltration volume (cubic feet) $D_{ponding}$ = maximum depth of ponding (feet) K = design infiltration rate (inches per hour) (50% of the slowest observed field infiltration rate or 0.5 inches per hour if grass/loam surface is used, whichever value is lower) T = time to fill basin (hours) (assumed to be 2 hours for design purposes)
Permeable Pavement Provides filtering of runoff through a surface course, choker and filter course, and temporary storage of runoff within the void spaces of a subsurface stone reservoir course prior to infiltration into subsoils.	$A_{required} = \frac{V}{(D_{stone} * n_{stone} + D_{sand} * n_{sand}) + (K * T/12)}$ $Arequired$ = minimum required surface area of permeable pavement (square feet) V = design infiltration volume (cubic feet) D_{stone} = depth of stone courses (feet) D_{sand} = depth of sand filter course (feet) n_{stone} = porosity of stone courses (use default value of 0.4) n_{sand} = porosity of sand filter course (use default value of 0.3) K = design infiltration rate (inches per hour) (50% of the slowest observed field infiltration rate) T = time to fill system (hours) (assumed to be 2 hours for design purposes)
Bioretention and Tree Filter (when designed for infiltration)	Required surface area equations vary based on type and configuration of bioretention system. Refer to manufacturer's design guidance for manufactured tree filters.

Stormwater BMP Type and Description	Equation
Provides temporary storage of runoff for filtering through an engineered soil media. The storage capacity includes void spaces in the filter media and temporary ponding at the surface. After runoff has passed through the filter media, some of it is infiltrated into the underlying soils and some is collected by an underdrain system for discharge.	$A_{required} = \frac{V}{(D_{ponding}) + (D_{soil} * n_{soil}) + (D_{stone} * n_{stone}) + (K * T/12)}$ $A_{required}$ = minimum required surface area of bioretention system (square feet) V = design infiltration volume (cubic feet) $D_{ponding}$ = maximum ponding depth (feet) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain gravel and/or stone reservoir layer(s) between bottom of the bioretention soil layer and native soil (feet) n_{soil} = porosity of bioretention soil (use default value of 0.3) n_{stone} = porosity of gravel/stone (use default value of 0.4) Other porosity values may be used as determined from testing of the proposed materials. K = design infiltration rate (inches per hour) (50% of the slowest observed field infiltration rate or 0.5 inches per hour for the bioretention soil media, whichever value is lower) T = time to fill bioretention system (hours) (assumed to be 2 hours for design purposes)

Stormwater BMP Type and Description	Equation
Surface Sand Filter (when designed for infiltration) Provides filtering of runoff through a sand filter course and temporary storage of runoff through surface ponding and within void spaces of the sand layer and underdrain stone layer. After runoff has passed through the filter media, some of it is infiltrated into the underlying soils and some is collected by an underdrain system for discharge.	$A_{required} = \frac{V * D_{sand}}{[(K)(D_{ponding} + D_{sand} + D_{stone})(T)]}$ $A_{required}$ = minimum required surface area of filter bed (square feet) V = design infiltration volume (cubic feet) K = design infiltration rate (ft/day) (50% of the slowest observed field infiltration rate, 3.5 ft/day for the sand filter media, or 1.0 ft/day if a loam/grass surface is used, whichever value is lowest) D_{sand} = depth of sand layer (feet) D_{stone} = depth of underdrain stone layer (feet) $D_{ponding}$ = depth of ponding above filter bed (feet) T = maximum filter bed drain time (days), use 2 days (48 hours)
Dry Water Quality Swale (when designed for infiltration) Provides temporary surface ponding storage of runoff in an open vegetated channel through permeable check dams and filtering through an engineered soil media (bioretention soil) below the bottom of the swale. After runoff has passed through the engineered soil media, some of it is infiltrated into the underlying soils and some is collected by an underdrain system for discharge.	$A_{required} = \frac{V * D_{soil}}{[(K)(D_{ponding} + D_{soil} + D_{stone})(T)]}$ $A_{required}$ = minimum required surface area of swale (square feet) V = design infiltration volume (cubic feet) K = design infiltration rate (ft/day) (50% of the slowest observed field infiltration rate or 1.0 ft/day for the engineered soil media, whichever value is lower) D_{soil} = depth of bioretention soil layer (feet) D_{stone} = depth of underdrain stone/gravel layer (feet) $D_{ponding}$ = depth of ponding above swale surface (feet) T = maximum filter bed drain time (days), use 2 days (48 hours)

Underdrained Systems

An underdrain should be included for infiltration systems in HSG C and D soils. Underdrains may also be used with some Infiltration BMPs and Filtering BMPs, regardless of soil type, to account for potential infiltration failure due to clogging, groundwater mounding, and periods of hydraulic over-loading due to excessive rainfall.

When underdrains are used, the infiltration system may not fully infiltrate the design infiltration volume since some water may discharge via the underdrain rather than through exfiltration into the underlying soil.

- Perforated underdrain pipes should be placed at the top of the underlying gravel/stone storage reservoir or sump. This type of "raised" underdrain design, which acts as an overflow for the internal gravel/stone storage reservoir, encourages infiltration of stormwater into the underlying soil before discharging via the underdrain. Chapter 13 - Structural Stormwater BMP Design Guidance provides additional guidance on the design of underdrain systems for various types of BMPs.

- A raised underdrain may be used to create a submerged internal water storage zone within some infiltration systems, such as a bioretention system designed for partial infiltration, which can enhance the removal of nitrogen.

- A stormwater hydrologic/hydraulic routing model (e.g., HydroCAD or similar software) should be used to calculate the volume of runoff infiltrated versus discharged through the underdrain. Only stormwater runoff that is infiltrated into the underlying soil can be credited toward the Required Retention Volume. Retention credit is not allowed for stormwater that is discharged through the underdrain or bypasses the system through inlet or outlet controls

Impermeable Liner

An underdrain system and impermeable liner are required for use with Filtering BMPs, dry water quality swales, and permeable pavement in the following situations:

- When receiving runoff from Land Uses with Higher Potential Pollutant Loads (LUHPPLs)
- In locations with subsurface contamination
- Where the required vertical separation to the SHGT cannot be met
- In locations with unacceptable horizontal setbacks for infiltration.

Such systems are suitable for providing treatment but do not provide retention credit. The impermeable liner should be installed under the bottom and along the side slopes of the BMP to prevent infiltration into the underlying and adjacent soil. The liner should consist of a 30 mil (minimum) HDPE or PVC liner.

Alternative liner systems that may be used with the approval of the review authority include:

- 6 to 12 inches of Low Permeability Fill consisting of clay soil (minimum 15% passing the #200 sieve and a minimum hydraulic conductivity of 1 x 10-5 centimeter per second (cm/sec)
- Bentonite
- A watertight concrete structure.

The impermeable liner should extend from the top of the freeboard to beneath the bottom of the practice and should cover the entire bottom of the excavation. The liner should be sufficiently anchored along the upper edge to prevent slipping and should not extend to the surface where it would be visible.

If designing a lined system in a location where the SHGT is located at or above the bottom of the liner or closed bottom of the system, complete a buoyancy analysis to ensure buoyancy of the system will not be an issue.