# BMP 6.4.3: Subsurface Infiltration Bed

Subsurface Infiltration Beds provide temporary storage and infiltration of stormwater runoff by placing storage media of varying types beneath the proposed surface grade. Vegetation will help to increase the amount of evapotranspiration taking place.

**Key Design Elements**

- Maintain a minimum 2-foot separation to bedrock and seasonally high water table, provide distributed infiltration area (5:1 impervious area to infiltration area - maximum), site on natural, uncompacted soils with acceptable infiltration capacity, and follow other guidelines described in Protocol 2: Infiltration Systems Guidelines
- Beds filled with stone (or alternative) as needed to increase void space
- Wrapped in nonwoven geotextile
- Level or nearly level bed bottoms
- Provide positive stormwater overflow from beds
- Protect from sedimentation during construction
- Provide perforated pipe network along bed bottom for distribution as necessary
- Open-graded, clean stone with minimum 40% void space
- Do not place bed bottom on compacted fill
- Allow 2 ft. buffer between bed bottom and seasonal high groundwater table and 2 ft. for bedrock.

**Potential Applications**

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

**Stormwater Functions**

Volume Reduction: High
Recharge: High
Peak Rate Control: Med./High
Water Quality: High

**Water Quality Functions**

TSS: 85%
TP: 85%
NO3: 30%

## Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

## Description

A Subsurface Infiltration Bed generally consists of a vegetated, highly pervious soil media underlain by a uniformly graded aggregate (or alternative) bed for temporary storage and infiltration of stormwater runoff. Subsurface Infiltration beds are ideally suited for expansive, generally flat open spaces, such as lawns, meadows, and playfields, which are located downhill from nearby impervious areas. Subsurface Infiltration Beds can be stepped or terraced down sloping terrain provided that the base of the bed remains level. Stormwater runoff from nearby impervious areas (including rooftops, parking lots, roads, walkways, etc.) can be conveyed to the subsurface storage media, where it is then distributed via a network of perforated piping.

The storage media for subsurface infiltration beds typically consists of clean-washed, uniformly graded aggregate. However, other storage media alternatives are available. These alternatives are generally variations on plastic cells that can more than double the storage capacity of aggregate beds, at a substantially increased cost. Storage media alternatives are ideally suited for sites where potential infiltration area is limited.

If designed, constructed, and maintained as per the following guidelines, Subsurface Infiltration features can stand-alone as significant stormwater runoff volume, rate, and quality control practices. These systems can also maintain aquifer recharge, while preserving or creating valuable open space and recreation areas. They have the added benefit of functioning year-round, given that the infiltration surface is typically below the frost line.

## Variations

As its name suggests, Subsurface Infiltration is generally employed for temporary storage and infiltration of runoff in subsurface storage media. However, in some cases, runoff may be temporarily stored on the surface (to depths less than 6 inches) to enhance volume capacity of the system. The overall system design should ensure that within the criteria in Chapter 3, the bed is completely empty.

## Applications

### Connection of Roof Leaders

Runoff from nearby roofs may be directly conveyed to subsurface beds via roof leader connections to perforated piping. Roof runoff generally has relatively low sediment levels, making it ideally suited for connection to an infiltration bed. However, cleanout(s) with a sediment sump are still recommended between the building and infiltration bed.

### Connection of Inlets

Catch Basins, inlets, and area drains may be connected to Subsurface Infiltration beds. However, sediment and debris removal should be provided. Storm structures should therefore include sediment trap areas below the inverts of discharge pipes to trap solids and debris. In areas of high traffic or excessive generation of sediment, litter, and other similar materials, a water quality insert or other pretreatment device may be needed.

**Under Recreational Fields**
Subsurface Infiltration is very well suited below playfields and other recreational areas. Special consideration should be given to the engineered soil mix in those cases.

**Under Open Space**
Subsurface Infiltration is also appropriate in either existing or proposed open space areas. Ideally, these areas are vegetated with native grasses and/or vegetation to enhance site aesthetics and landscaping. Aside from occasional clean-outs or outlet structures, Subsurface Infiltration systems are essentially hidden stormwater management features, making them ideal for open space locations (deed-restricted open space locations are especially desirable because such locations minimize the chance that Subsurface Infiltration systems will be disturbed or disrupted accidentally in the future).

## Other Applications
Other applications of Subsurface Infiltration beds may be determined by the Design Professional as appropriate.

## Design Considerations

1. Soil Investigation and Infiltration Testing is needed (Appendix C).

2. Guidelines for Infiltration Systems should be met (Appendix C).

3. The overall site should be evaluated for potential Subsurface Infiltration areas early in the design process, as effective design requires consideration of existing site characteristics (topography, natural features/drainage ways, soils, geology, etc.).

4. Control of Sediment is critical. Rigorous installation and maintenance of erosion and sediment control measures is needed to prevent sediment deposition within the stone bed. Nonwoven geotextile may be folded over the edge of the bed until the site is stabilized.

5. The Infiltration bed should be wrapped in non-woven geotextile filter fabric.

6. Subsurface Infiltration areas should not be placed on areas of recent fill or compacted fill. Any grade adjustments requiring fill should be done using the stone subbase material, or alternative. Areas of historical fill (>5 years) may be considered if other criteria are met.

7. The subsurface infiltration bed is typically comprised of a 12 to 36 inch section of aggregate, such as AASHTO No.3, which ranges 1-2 inches in gradation. Depending on local aggregate availability, both larger and smaller size aggregate has been used. The critical requirements are that the aggregate be uniformly graded, clean-washed, and contain at least 40% void space. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, and site grading. Infiltration beds are typically sized to mitigate the increased runoff volume from the design storm.

8. Water Quality Inlet or Catch Basin with Sump is needed for all surface inlets, should be designed to avoid standing water for periods greater than the criteria in Chapter 3.

9. Infiltration beds may be placed on a slope by benching or terracing infiltration levels. The slope of the infiltration bed bottom should be level or with a slope no greater than 1%. A level bottom assures even water distribution and infiltration.

10. Perforated pipes along the bottom of the bed can be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes may connect structures (such as cleanouts and inlet boxes). Pipes should lay flat along the bed bottom and provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

11. Cleanouts or inlets should be installed at a few locations within the bed and at appropriate intervals to allow access to the perforated piping network and or storage media.

12. All infiltration beds should be designed with an overflow for extreme storm events. Control in the beds is usually provided in the form of an outlet control structure. A modified inlet box with an internal concrete weir (or weir plate) and low-flow orifice is a common type of control structure. The specific design of these structures may vary, depending on factors such as rate and storage requirements, but it must always include positive overflow from the system. The overflow structure is used to maximize the water level in the stone bed, while providing sufficient cover for overflow pipes. Generally, the top of the outlet pipe should be 4 inches below the top of the aggregate to prevent saturated soil conditions in remote areas of the bed. As with all

infiltration practices, multiple discharge points are recommended. These may discharge to the surface or a storm sewer system.

13. Adequate soil cover (generally 12 - 18 inches) should be maintained above the infiltration bed to allow for a healthy vegetative cover.

14. Open space overlying infiltration beds can be vegetated with native grasses, meadow mix, or other low-growing, dense vegetation. These plants have longer roots than traditional grass and will likely benefit from the moisture in the infiltration bed, improving the growth of these plantings and, potentially increasing evapotranspiration.

15. Fertilizer use should be minimized.

16. The surface (above the stone bed) should be compacted as minimally as possible to allow for surface percolation through the engineered soil layer and into the stone bed.

17. When directing runoff from roadway areas into the beds, measures to reduce sediment should be used.

18. Surface grading should be relatively flat, although a relatively mild slope between 1% and 3% is recommended to facilitate drainage.

19. In those areas where the threat of spills and groundwater contamination exists, pretreatment systems, such as filters and wetlands, may be needed before any infiltration occurs. In Hot Spot areas, such as truck stops and fueling stations, the suitability of Subsurface Infiltration must be considered.

20. In areas with poorly-draining soils, Subsurface Infiltration areas may be designed to slowly discharge to adjacent wetlands or bioretention areas.

21. While most Subsurface Infiltration areas consist of an aggregate storage bed, alternative subsurface storage products may also be employed. These include a variety of proprietary, interlocking plastic units that contain much greater storage capacity than aggregate, at an increased cost.

22. The subsurface bed and overflow may be designed and evaluated in the same manner as a detention basin to demonstrate the mitigation of peak flow rates. In this manner, detention basins may be eliminated or significantly reduced in size.

23. During Construction, the excavated bed may serve as a Temporary Sediment Basin or Trap. This can reduce overall site disturbance. The bed should be excavated to at least 1 foot above the final bed bottom elevation for use as a sediment trap or basin. Following construction and site stabilization, sediment should be removed and final grades established. In BMPs that will be used for infiltration in the future, use of construction equipment should be limited as much as possible.

## Detailed Stormwater Functions

### Infiltration Area

Loading rate quidelines in Appendix C should be consulted**.**

The Infiltration Area is the bottom area of the bed, defined as:

Length of bed x Width of bed = Infiltration Area (if rectangular)

### Volume Reduction Calculations

Volume = Depth* (ft) x Area (sf) x Void Space
*Depth is the depth of water stored during a storm event, depending on the drainage area and conveyance to the bed.

Infiltration Volume = Bed Bottom Area (sf) x Infiltration design rate (in/hr) x Infiltration period* (hr) x (1/12)
*Infiltration Period is equal to 2 hours or the time of concentration, whichever is larger.

Additional storage/volume reduction can be calculated for the overlying soil as appropriate.

### Peak Rate Mitigation Calculations

See in Chapter 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

**Water Quality Improvement:** See in Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

## Construction Sequence

1. Due to the nature of construction sites, Subsurface Infiltration should be installed toward the end of the construction period, if possible. (Infiltration beds may be used as temporary sediment basins or traps as discussed above).

2. Install and maintain adequate Erosion and Sediment Control Measures (as per the Pennsylvania Erosion and Sedimentation Control Program Manual) during construction.

3. The existing subgrade under the bed areas should NOT be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement.

4. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material should be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake (or equivalent) and light tractor. All fine grading should be done by hand. All bed bottoms should be at level grade.

5. Earthen berms (if used) between infiltration beds should be left in place during excavation. These berms do not require compaction if proven stable during construction.

6. Install upstream and downstream control structures, cleanouts, perforated piping, and all other necessary stormwater structures.

7. Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation and installation of structures. Geotextile should be placed in accordance with manufacturer's standards and recommendations. Adjacent strips of geotextile should overlap a minimum of 16 inches. It should also be secured at least 4 feet outside of bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile along bed edges can be cut back to the edge of the bed.

8. Clean-washed, uniformly graded aggregate should be placed in the bed in maximum 8-inch lifts. Each layer should be lightly compacted, with construction equipment kept off the bed bottom as much as possible.

9. Approved soil media should be placed over infiltration bed in maximum 6-inch lifts.

10. Seed and stabilize topsoil.

11. Do not remove inlet protection or other Erosion and Sediment Control measures until site is fully stabilized.

## Maintenance Issues

Subsurface Infiltration is generally less maintenance intensive than other practices of its type. Generally speaking, vegetation associated with Subsurface Infiltration practices is less substantial than practices such as Recharge Gardens and Vegetated Swales and therefore requires less maintenance. Maintenance activities required for the subsurface bed are similar to those of any infiltration system and focus on regular sediment and debris removal. The following represents the recommended maintenance efforts:

- All Catch Basins and Inlets should be inspected and cleaned at least 2 times per year.

- The overlying vegetation of Subsurface Infiltration features should be maintained in good condition, and any bare spots revegetated as soon as possible.

- Vehicular access on Subsurface Infiltration areas should be prohibited, and care should be taken to avoid excessive compaction by mowers. If access is needed, use of permeable, turf reinforcement should be considered.

## Cost Issues

The construction cost of Subsurface Infiltration can vary greatly depending on design variations, configuration, location, desired storage volume, and site-specific conditions, among other factors. Typical construction costs are about $5.70 per square foot, which includes excavation, aggregate (2.0 feet assumed), non-woven geotextile, pipes and plantings.

## Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Stone** for infiltration beds shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

2. **Non-Woven Geotextile** shall consist of needled non-woven polypropylene fibers and meet the following properties:
   a. Grab Tensile Strength (ASTM-D4632) 120 lbs
   b. Mullen Burst Strength (ASTM-D3786) 225 psi
   c. Flow Rate (ASTM-D4491) 95 gal/min/ft$^2$
   d. UV Resistance after 500 hrs (ASTM-D4355) 70%
   e. Heat-set or heat-calendared fabrics are not permitted
      Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

3. **Topsoil** may be amended with compost (See soil restoration BMP 6.7.2)

4. **Pipe** shall be continuously perforated, smooth interior, with a minimum inside diameter of 6-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

5. **Storm Drain Inlets and Structures**
   a. Concrete Construction: Concrete construction shall be in accordance with Section 1001, PennDOT Specifications, 1990 or latest edition.
   b. Precast Concrete Inlets and Manholes: Precast concrete inlets may be substituted for cast-in-place structures and shall be constructed as specified for cast-in-place.

      Precast structures may be used in only those areas where there is no conflict with existing underground structures that may necessitate revision of inverts. Type M standard PennDOT inlet boxes will be modified to provide minimum 12 inch sump storage and bottom leaching basins, open to gravel sumps in sub-grade, when situated in the recharge bed.
   c. All PVC Catch Basins/Cleanouts/Inline Drains shall have H-10 or H-20 rated grates, depending on their placement (H-20 if vehicular loading).
   d. Steel reinforcing bars over the top of the outlet structure shall conform to ASTM A615, grades 60 and 40.
   e. Permanent turf reinforcement matting shall be installed according to manufacturers' specifications.

6. **Alternative storage media:** Follow appropriate Manufacturers' specifications.

7. **Vegetation** see Local Native Plant List and Appendix B.