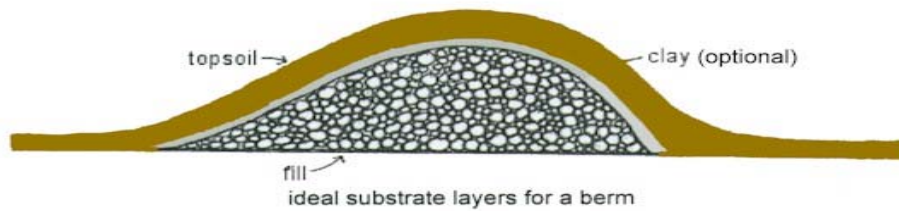


BMP 6.4.10: Infiltration Berm & Retentive Grading



An Infiltration Berm is a mound of compacted earth with sloping sides that is usually located along a contour on relatively gently sloping sites. Berms can also be created through excavation/removal of upslope material, effectively creating a Berm with the original grade. Berms may serve various stormwater drainage functions including: creating a barrier to flow, retaining flow and allowing infiltration for volume control, and directing flows. Grading may be designed in some cases to prevent rather than promote stormwater flows, through creation of "saucers" or "lips" in site yard areas where temporary retention of stormwater does not interfere with use.

<p style="text-align: center;"><u>Key Design Elements</u></p> <ul style="list-style-type: none"> ▪ 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 ▪ Berms should be relatively low, preferably no more than 24 inches in height. ▪ If berms are to be mowed, the berm side slopes should not exceed a ratio of 4:1 to avoid "scalping" by mower blades. ▪ The crest of the berm should be located near one edge of the berm, rather than in the middle, to allow for a more natural, asymmetrical shape. ▪ Berms should be vegetated with turf grass at a minimum, however more substantial plantings such as meadow vegetation, shrubs and trees are recommended. 	<p style="text-align: center;"><u>Potential Applications</u></p> <p>Residential: Yes Commercial: Yes Ultra Urban: Limited Industrial: Yes Retrofit: Yes Highway/Road: Yes</p>
	<p style="text-align: center;"><u>Stormwater Functions</u></p> <p>Volume Reduction: Low/Med. Recharge: Low Peak Rate Control: Medium Water Quality: Med./High</p>
	<p style="text-align: center;"><u>Water Quality Functions</u></p> <p>TSS: 60% TP: 50% NO3: 40%</p>

Other Considerations

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

Description

Infiltration Berms are linear landscape features located along (i.e. parallel to) existing site contours in a moderately sloping area. They can be described as built-up earthen embankments with sloping sides, which function to divert, retain and promote infiltration, slow down, or divert stormwater flows. Berms are also utilized for reasons independent of stormwater management, such as to add interest to a flat landscape, create a noise or wind barrier, separate land uses, screen undesirable views or to enhance or emphasize landscape designs. Berms are often used in conjunction with recreational features, such as pathways through woodlands. Therefore, when used for stormwater management, berms and other retentive grading techniques can serve multifunctional purposes and are easily incorporated into the landscape.

Infiltration Berms create shallow depressions that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater. Infiltration berms may be constructed in series along a gradually sloping area.

1. Infiltration berms can be constructed on disturbed slopes and revegetated as part of the construction process. Infiltration berms should not be installed on slopes where soils having low shear strength (or identified as “slip prone” or “landslide prone”, etc.) have been mapped.
2. They can be installed along the contours within an existing woodland area to slow and infiltrate runoff from a development site.
3. May be constructed in combination with a subsurface infiltration trench at the base of the berm.

Infiltration Berms can provide runoff rate and volume control, though the level to which they do is limited by a variety of factors, including design variations (height, length, etc.), soil permeability rates, vegetative cover, and slope. Berms are ideal for mitigating runoff from relatively small impervious areas with limited adjacent open space (e.g. roads, small parking lots). Systems of parallel berms have been used to intercept stormwater from roadways or sloping terrain. Berms can sometimes be threaded carefully along contour on wooded hillsides, minimally disturbing existing vegetation and yet still gaining stormwater management credit from the existing woodland used. Conversely, berms are often incapable of controlling runoff from very large, highly impervious sites. Due to their relatively limited volume capacity, the length and/or number of berms required to retain large quantities of runoff make them impractical as the lone BMP in these cases. In these situations, berms are more appropriately used as pre- or additional-treatment for other more distributed infiltration systems closer to the source of runoff (i.e. porous pavement with subsurface infiltration).

Retentive grading may be employed in portions of sites where infiltration has been deemed to be possible and where site uses are compatible. Ideally, such retentive grading will serve to create subtle “saucers,” which contain and infiltrate stormwater flows. The “lip” of such saucers effectively function as a very subtle berm, which can be vertically impervious when vegetated and integrated into the overall landscape.

Variations

Diversion Berms

Diversion Berms can be used to protect slopes from erosion and to slow runoff rate. They can also be used to direct stormwater flow in order to promote longer flow pathways, thus increasing the time of concentration. Diversion berms often:

1. Consist of compacted earth ridges usually constructed across a slope in series to intercept runoff.
2. Can be incorporated within other stormwater BMPs to increase travel time of stormwater flow by creating natural meanders while providing greater opportunity for pollutant removal and infiltration.



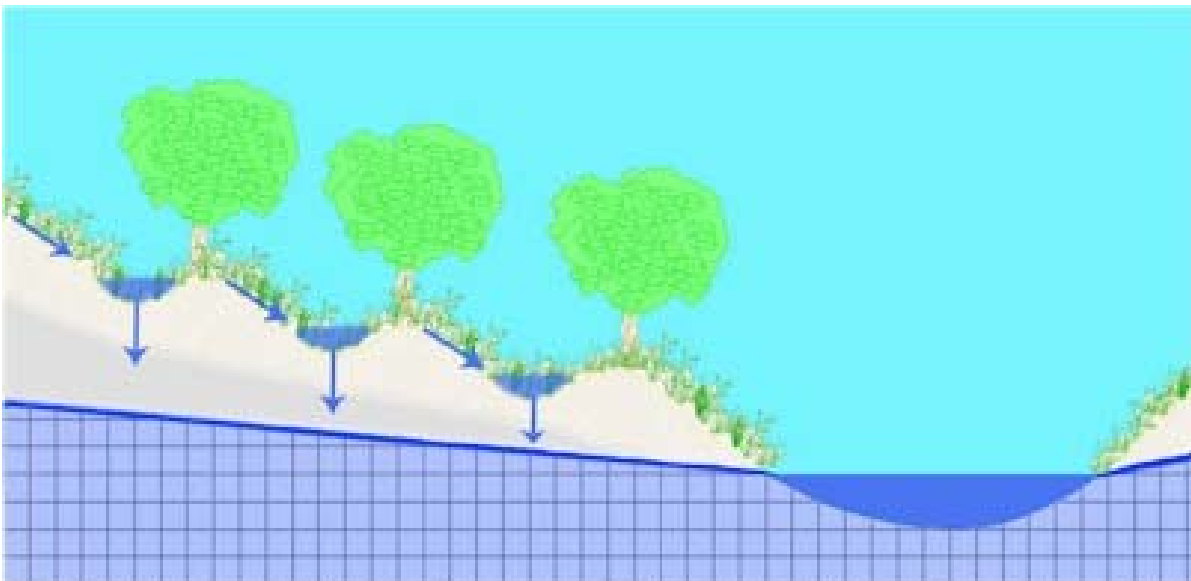
Applications

- **Meadow/Woodland Infiltration Berms**
 Infiltration Berms effectively control both the rate and volume of stormwater runoff. The berms are constructed along the contours and serve to collect and retain stormwater runoff, allowing it to infiltrate through the soil mantle and recharge the groundwater. Depressed areas adjacent to the berms should be level so that concentrated flow paths are not encouraged. Infiltration berms may have a variety of vegetative covers but meadow and woodland are recommended in order to reduce maintenance. If turf grass is used, berms in series should be constructed with enough space between them to allow access for maintenance vehicles. Also, berm side slopes should not exceed a 4:1 ratio. Woodland infiltration berms can sometimes be installed within existing wooded areas for additional stormwater management. Berms in wooded areas can even improve the health of existing vegetation, through enhanced groundwater recharge. Care should be taken during construction to ensure minimum disturbance to existing vegetation, especially tree roots.

- **Slope Protection**
 Diversion Berms can be used to help protect steeply sloping areas from erosion. Berms may divert concentrated discharge from a developed area away from the sloped area. Additionally, berms may be installed in series down the slope to retain flow and spread it out along multiple level berms to discourage concentrated flow.

- **Flow Pathway Creation**
 Berms may be utilized to create or enhance stormwater flow pathways within existing or proposed BMPs, or as part of an LID (Low Impact Development) strategy. Berms can be installed such that vegetated stormwater flow pathways are allowed to “meander” so that stormwater travel time is increased. For example, berms can be utilized within existing BMPs as part of a retrofit strategy to eliminate short-circuited inlet/outlet situations within detention basins provided care is taken to ensure the required storage capacity of the basin is maintained. Flow pathway creation can be utilized as part of an LID strategy to disconnect roof leaders and attenuate runoff, while increasing pervious flow pathways within developed areas. Berms should be designed to compliment the landscape while diverting runoff across vegetated areas and allowing for longer travel times to encourage pollutant removal and infiltration.

- **Constructed Wetland Berms**
 Berms are often utilized within constructed wetland systems in order to create elongated flow pathways with a variety of water depths. See BMP 6.6.1 – Constructed Wetlands.



Design Considerations

1. Sizing criteria are dependent on berm function, location and storage volume requirements.
 - a. Low **berm height** (less than or equal to 24 inches) is recommended to encourage maximum infiltration and to prevent excessive ponding behind the berm. Greater heights may be used where berms are being used to divert flow or to create “meandering” or lengthened flow pathways. In these cases, stormwater is designed to flow adjacent to (parallel to), rather than over the crest of the berm. Generally, more berms of smaller size are preferable to fewer berms of large size.

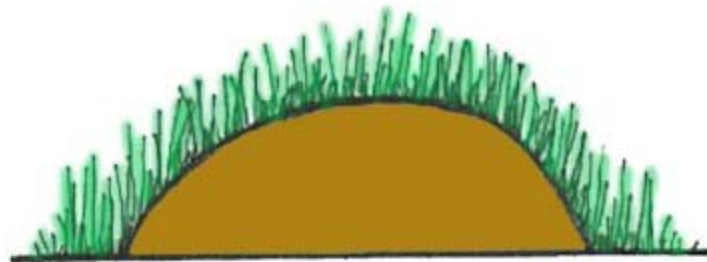
b. **Berm length** is dependent on functional need and site size. Berms installed along the contours should be level and located across the slope. Maximum length will depend on width of the slope. Generally speaking, diversion berm length will vary with the size and constraints of the site in question.

2. **Infiltration Berms** should be constructed along (parallel to) contours at a constant elevation.
3. **Soil.** A berm may consist entirely of high quality topsoil. To reduce cost, only the top foot needs to consist of high quality Topsoil, with well-drained soil making up the remainder of the berm. The use of gravel is not recommended in the layers directly underneath the topsoil because of the tendency of the soil to wash through the gravel. In some cases, the use of clay may be required due to its cohesive qualities (especially where the berm height is high or relatively steeply sloped). However, well-compacted soil usually is sufficient provided that the angle of repose (see below) is not exceeded for the soil medium used.

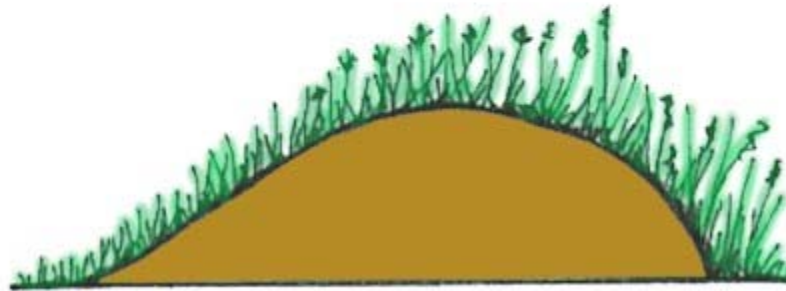
A more sustainable alternative to importing berm soil from off-site is to balance berm cut and fill material as much as possible, provided on-site soil is deemed suitable as per the Specifications below. Ideally, the concave segment (infiltration area) of the berm is excavated to a maximum depth of 12 inches and then used to construct the convex segment (crest of berm).

4. The **Angle of Repose of Soil** is the angle at which the soil will rest and not be subject to slope failure. The angle of repose of any soil will vary with the texture, water content, compaction, and vegetative cover. Typical angles of repose are given below:
 - a. Non-compacted clay: 5-20%
 - b. Dry Sand: 33%
 - c. Loam: 35-40%
 - d. Compacted clay: 50-80%
5. **Side Slopes.** The angle of repose for the soil used in the berm should determine the maximum slope of the berm with additional consideration to aesthetic, drainage, and maintenance needs. If a berm is to be mowed, the slope should not exceed a 4:1 ratio (horizontal to vertical) in order to avoid "scalping" by mower blades. If trees are to be planted on berms, the slope should not exceed a 5:1 ratio. Other herbaceous plants, which do not require mowing, can tolerate slopes of 3:1. Berm side slopes should not exceed a 2:1 ratio.
6. **Plant Materials.** It is important to consider the function and form of the berm when selecting plant materials. If using trees, plant them in a pattern that appears natural and accentuates the berm's form. Consider tree species appropriate to the proposed habitat. If turf will be combined with woody and herbaceous plants, the turf should be placed to allow for easy maneuverability while mowing. Low maintenance plantings, such as trees and meadow plants, rather than turf and formal landscaping, are encouraged.
7. **Infiltration Design.** Infiltration berms located along slopes should be composed of low berms (less than 12 inches high) and should be vegetated. Subsurface soils should be uncompacted to encourage infiltration behind the berms. Soil testing is not required where berms are located within an existing woodland, but soil maps/data should be consulted when siting the berms. Where feasible, surface soil testing should be conducted in order to estimate potential infiltration rates.

8. **Infiltration Trench Option.** Soil testing is recommended for infiltration berms that will utilize a subsurface infiltration trench. Infiltration trenches are not recommended in existing woodland areas as excavation and installation of subsurface trenches could damage tree root systems. See BMP 6.4.4 – Infiltration Trench, for information on infiltration trench design.
9. **Aesthetics.** To the extent possible, berms should reflect the surrounding landscape. Berms should be graded so that the top of the berm is smoothly convex and the toes of the berms are smoothly concave. Natural, asymmetrical berms are usually more effective and attractive than symmetrical berms. The crest of the berm should be located near one end of the berm rather than in the middle.



undesirable shape for a berm



desirable shape for a berm

Detailed Stormwater Functions

Infiltration Area

The Infiltration Area is the ponding area behind the berm, defined as:
 Length of ponding x Width ponding area = Infiltration Area (Ponding Area)

Volume Reduction Calculations

Storage volume can be calculated for Infiltration Berms. The storage volume is defined as the ponding area created behind the berm, beneath the discharge invert (i.e. the crest of the berm). Storage volume can be calculated differently depending on the variations utilized in the design.

Surface Storage Volume is defined as the volume of water stored on the surface at the ponding depth. This is equal to:

Cross-sectional area of ponded water x Berm length = Surface Storage Volume

Peak Rate Mitigation:

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

Water Quality Improvement:

See Section 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

The following is a typical construction sequence for a infiltration berm without a subsurface infiltration trench, though alterations will be necessary depending on design variations.

1. Install temporary sediment and erosion control BMPs as per the Pennsylvania Erosion and Sediment Pollution Control Program Manual.
2. Complete site grading and stabilize within the limit of disturbance except where Infiltration Berms will be constructed; make every effort to minimize berm footprint and necessary zone of disturbance (including both removal of existing vegetation and disturbance of empty soil) in order to maximize infiltration.
3. Lightly scarify the soil in the area of the proposed berm before delivering soil to site.
4. Bring in fill material to make up the major portion of the berm. Soil should be added in 8-inch lifts and compacted after each addition according to design specifications. The slope and shape of the berm should be graded out as soil is added.
5. Protect the surface ponding area at the base of the berm from compaction. If compaction of this area does occur, scarify soil to a depth of at least 8 inches.
6. Complete final grading of the berm after the top layer of soil is added. Tamp soil down lightly and smooth sides of the berm. The crest and base of the berm should be at level grade.
7. Plant berm with turf, meadow plants, shrubs or trees, as desired.
8. Mulch planted and disturbed areas with compost mulch to prevent erosion while plants become established.

Maintenance Issues

Infiltration Berms have low to moderate maintenance requirements, depending on the design.

Infiltration Berms

- Regularly inspect to ensure they are infiltrating; monitor drawdown time after major storm events
- Inspect any structural components, such as inlet structures to ensure proper functionality
- If planted in turf grass, maintain by mowing. Other vegetation will require less maintenance. Trees and shrubs may require annual mulching, while meadow planting requires annual mowing and clippings removal.
- Avoid running heavy equipment over the infiltration area at the base of the berms. The crest of the berm may be used as access for heavy equipment when necessary to limit disturbance.
- .
- Routinely remove accumulated trash and debris.
- Remove invasive plants as needed
- Inspect for signs of flow channelization; restore level gradient immediately after deficiencies are observed

Diversion Berms

- Regularly inspect for erosion or other failures.
- Regularly inspect structural components to ensure functionality.
- Maintain turf grass and other vegetation by mowing and re-mulching.
- .
- Remove invasive plants as needed.
- Routinely remove accumulated trash and debris.

Cost Issues

Infiltration berms can be less expensive than other BMPs options because extensive clearing and grubbing is not necessary. Cost will depend on height, length and width of berms as well as desired vegetation.

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. Soil Materials

- a. Satisfactory soil materials are defined as those complying with ASTM D2487 soil classification groups GW, GP, GM, SM, SW, and SP.
- b. Unsatisfactory soil materials are defined as those complying with ASTM D2487 soil classification groups GC, SC, ML, MH, CL, CH, OL, OH, and PT.
- c. Topsoil: Topsoil stripped and stockpiled on the site should be used for fine grading. Topsoil is defined as the top layer of earth on the site, which produces heavy growths of crops, grass or other vegetation.

- d. Soils excavated from on-site may be used for berm construction provided they are deemed satisfactory as per the above recommendations or by a soil scientist.

2. Placing and Compacting of Berm Area Soil

- a. Ground Surface Preparation: Remove vegetation, debris, unsatisfactory soil materials, obstructions, and deleterious materials from ground surface prior to placement of fill. Plow strip, or break up sloped surfaces steeper than 1 vertical to 4 horizontal so that fill material will bond with existing surface.
- b. When existing ground surface has a density less than that specified under g. (below) for particular area classification, break up ground surface, pulverize, bring the moisture-condition to optimum moisture content, and compact to required depth and percentage of maximum density.
- c. Place backfill and fill materials in layers not more than 8 inches in loose depth for material to be compacted by heavy compaction equipment, and not more than 4 inches in loose depth for material to be compacted by hand-operated tampers.
- d. Before compaction, moisten or aerate each layer as necessary to provide optimum moisture content. Compact each layer to required percentage of maximum dry density or relative dry density for each area classification. Do not place backfill or fill material on surfaces that are muddy, frozen, or contain frost or ice.
- e. Place backfill and fill materials evenly adjacent to structures, piping, or conduit to required elevations. Prevent wedging action of backfill against structures or displacement of piping or same elevation in each lift.
- f. Control soil and fill compaction, providing minimum percentage of density specified for each area classification indicated below. Correct improperly compacted areas or lifts if soil density tests indicate inadequate compaction.
- g. Percentage of Maximum Density Requirements: Compact soil to not less than the following percentages of maximum density, in accordance with ASTM D 1557:
 - Under lawn or unpaved areas, compact top 6 inches of subgrade and each layer of backfill or fill material at 85 percent maximum density.
 - Under infiltration areas no compaction shall be permitted.

3. Grading

- a. General: Uniformly grade areas within limits of grading under this section, including adjacent transition areas. Smooth finished surface within specified tolerances; compact with uniform levels or slopes between points where elevations are indicated or between such points and existing grades.
- b. Lawn or Unpaved Areas: Finish areas to receive topsoil to within not more than 0.10 foot above or below required subgrade elevations.
- c. Compaction: After grading, compact subgrade surfaces to the depth and indicated percentage of maximum or relative density for each area classification.

4. Temporary Seeding

- a. Temporary seeding and mulching shall be required on all freshly graded areas immediately following earth moving procedures. Seed-free straw or salt hay mulch shall be applied at a rate of 75 lbs. per 1,000 square feet over temporary seeded areas. Straw bale barriers shall be placed in swale areas until vegetation is established.
- b. Should temporary seeding not be possible or not establish itself properly, mulch as described above, pending fine grading or permanent seeding.

5. Finish Grading

- a. Spreading of topsoil and finish grading shall be coordinated with the work of the Landscape Contractor.
- b. Verify that the rough grades meet requirements for tolerances, materials, and compaction.
- c. Surface of subgrades shall be loosened and made friable by cross-discing or harrowing to a depth of 2 inches. Stones and debris more than 1-1.5 inches in any dimension shall be raked up and grade stakes and rubbish removed.
- d. Topsoil shall be uniformly spread to minimum depths after settlement of 6 inches on areas to be seeded and 4 inches on areas to be sodded. Correct any surface irregularities to prevent formation of low spots and pockets that would retain water.
- e. Topsoil shall not be placed when the subgrade is frozen, excessively wet, or extremely dry and no topsoil shall be handled when in a frozen or muddy condition. During all operations following topsoil spreading, the surface shall be kept free from stones over 1-1.5 inches in size or any rubbish, debris, or other foreign material.
- f. After placing topsoil rake soil to a smooth, even-draining surface and compact lightly with an empty water roller. Leave finish graded areas clean and well raked, ready for lawn work.

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