Pennsylvania Stormwater Best Management Practices Manual

Chapter 9

Case Studies: Innovative Stormwater Management Approaches and Practices

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9.1 Introduction

Although examples of BMPs have been included throughout all chapters of this manual with a considerable number of illustrations, in most cases these examples have been necessarily condensed and highly summarized. Most examples have not been able to do justice to all aspects of the site development program and the site design and stormwater management plans that have been developed. Consequently, early in the process of developing this new manual, the decision was made to include a chapter that highlights functioning projects in Pennsylvania communities that have successfully incorporated many of the Non-Structural and Structural BMPs that are described in this manual. Clearly, seeing is believing – there is great value in being able to visit and view firsthand successful applications of the many different BMPs which have been presented.

This chapter is a work in progress, where PADEP hopes to increase its file of successful case studies over time. In particular, the hope is to add many more successful applications from all regions of the state. Many of the innovative projects that have been undertaken have occurred in projects in southeastern and southcentral Pennsylvania, to some extent reflecting the greater amount of land development activity occurring in that region of Pennsylvania.
A Self-Guided Stormwater Best Management Practices Tour has been developed recently by the Chester County Conservation District and funded by the PADEP Growing Greener Grant Program. The Tour ingeniously features 21 different sites that include a variety of both non-structural and structural BMPs applied in residential, commercial, and recreational land use settings. The entire Tour and all of the written and photographic material which describes the sites and stormwater practices is available on line through the Chester County Conservation District website. Several of the BMPs included in the tour are featured in this chapter. Many other County Conservation Districts have also installed demonstration BMPs at their office locations, including Westmoreland, Adams, Dauphin and Erie Counties.

The case studies that have been included in this chapter are designed to focus on successful BMP application - what works. Over time, this case study discussion will be expanded to include lists of what to avoid – what doesn't work – as well. PADEP invites all interested stormwater stakeholders to submit case study information in the future for additional projects. Section 9.2 is a list of information and data items that case study descriptions should address, although it is recognized that some data gaps may exist.

9.2 Outline of Information Needed for Case Studies

PADEP Stormwater Manual Case Study
Outline of Needed Information/Data

Name of Project:
Address of Project:
- Street
- Municipal/county
- Year constructed
- Developer/builder/owner (name and contact information, if available)

Natural Site Features:
Water Resources
Major Watershed/minor watershed
- Stream classification
- Special: water supply source? TMDL? Impaired streams?
- Streams, ponds, lakes?

Drainage features on the site
- Wetlands? Floodplains? Riparian areas?
- Wells (existing and future)? Zone of contribution? Zone of influence? Groundwater protected area?

Geology
- Rock/aquifer type?
- Special? Limestone? Subsidence potential? Fracture/fault traces? Lineaments?

Soils Hydrologic Soil Group A thru D?
- Soil testing performed?
- Thickness?
- Other?

Slopes?
Vegetation
- Existing at site?
- Extent of vegetation disturbed/removed?
- Re-vegetation?

Proposed Use/Building Program
- How much?
- Of what?
- Total site area?
- Total disturbed area?
- Total impervious area?
- Costs of development?

Proposed Stormwater BMPs
- Structurals?
  - Design specs, calculations, etc.
- Non-Structurals?
  - Design specs, calculations, etc.
- Maintenance issues?
- Other special issues?
- Costs of site work and stormwater elements?

9.3 Case Studies

The following case studies present examples of a range of structural and nonstructural BMPs that have been successfully implemented across the state. The information provided has been assembled from contributing Conservation Districts within Pennsylvania. Each case study has been developed to include a high level of detail from the information provided, however data gaps do exist. For further information, the reader is encouraged to contact the conservation district in the county where the project is located.

Case Study 1: Penn State University - Centre County Visitor Center, Centre County

- **Porous Asphalt Parking Lots underlain with Subsurface Infiltration Beds**
- **Porous Concrete Sidewalks**
- **Subsurface Infiltration Trenches**
- **Vegetated Infiltration Bed**
- **Several Rain Gardens / Bioretention areas**

Project Background
The Penn State University/Centre County Visitor Center in State College was constructed in 1999 on a site underlain by the Nittany Formation. The Visitor's Center incorporates a number of stormwater infiltration techniques, shown in Figure 9-1, and was designed to imitate the natural hydrologic system that existed at the site before development.

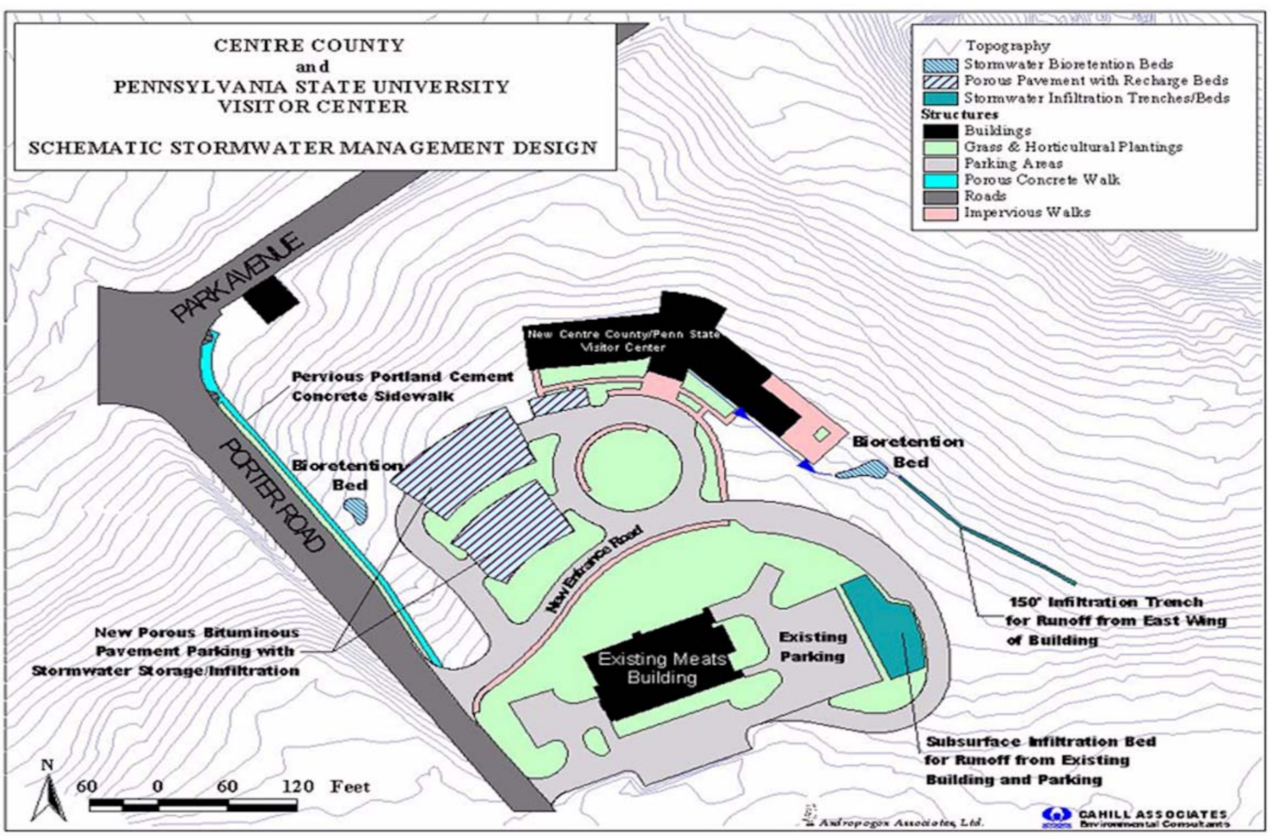

Figure 9-1. Stormwater Management System at PSU Visitor's Center in Centre County, PA.

According to the soil survey, the soil at this site was classified as the Hagerstown Series, well-drained soils that formed in limestone residuum. Typically, the surface layer was dark-brown silt loam about eight (8) inches thick. The subsoil consisted of yellowish-red and reddish-brown silty clay, clay, and silty-clay loam approximately 37 inches thick. The substratum was generally yellowish-brown clay loam to a depth of about 75 inches. The entire 5-acre site was underlain by the same soil series.

This information indicated several important characteristics of this site, even before detailed testing was completed. The soil was well-drained with probably at least 5 to 6 feet of soil above the weathered bedrock. Some clay was contained in the soils, which was a positive element since some mix of clay would prevent water from draining excessively rapidly and would serve to remove pollutants.

The underlying geology was classified as the Nittany Formation according to the Department of Environmental Resources, Bureau of Topographic and Geologic Survey (1982). This formation consists of light to dark gray, finely to coarsely crystalline dolomite with alternating beds of sandy, cherty dolomite. The rock is moderately resistant to weathering and is slightly weathered to a shallow depth. The development of joint and solution channel openings in the rock is common. Bedrock pinnacles are also common in the interface between the rock and soil mantle, which can make excavation of the rock difficult. No specific geologic features (i.e. fracture traces) are indicated for this site.

Again, this information was crucial to developing a more detailed site investigation program. The presence of pinnacles required a field investigation that can provide a site-specific understanding of the pinnacle locations. In addition, the tendency for joint and solution channel openings to form indicates a strong need to disperse stormwater and avoid concentrated points of storage or infiltration.

One additional piece of important information is that several University water supply wells are located approximately 1/2-mile downstream of this site, indicating the importance of maintaining groundwater recharge and water quality.

Site Testing: Geotechnical Investigation for Building Structure

The initial field investigation involved the excavation of five test borings, two groundwater-monitoring wells, and four test pits. The initial tests were all installed as part of the geotechnical investigation for the proposed building (independent of SWM), but provided useful and valid information for the stormwater system as well. In other words, the stormwater design engineer should make use of all available data developed at the site.

This information included the following findings:
Groundwater was not encountered in any of the borings or test pits.
Auger refusals were encountered at depths ranging from 2 feet to 8.7 feet – very shallow.
Refusal materials were encountered in three of the four test pits ranging from 3.1 to 4.8 feet.
The dolomitic limestone rock cores were weathered and fractured near the surface.
The rock contained interbedded clay seams.
No evidence of subsurface activity associated with sinkholes was encountered.

Site Testing: Geotechnical Investigation for Stormwater Management

The information from the building geotechnical investigation confirmed that bedrock depth was variable and could be quite shallow. Based on this information, a more detailed geotechnical investigation was developed that included a grid of shallow core borings, to a depth of ten feet or refusal, approximately 25 feet on-center. The shallow augers confirmed that there was considerable variation in the top of rock reflecting the pinnacle nature of the underlying bedrock.

Seven additional test pits were also excavated at the same time that the borings were undertaken. These test pits were a critical part of the investigation and provided direct physical observation of the soil layers and geology, confirming the soil survey series designations (which may or may not be correct for the site). In this situation the test pits indicated the considerable variability in the top of rock; even within a distance of eight feet (the length of the test pit), the surface of the bedrock could vary by two to three feet. At the same time, simple percolation tests were also conducted at the test pits to provide an estimate of the infiltration capabilities of the soil.

Compilation of Data: Cross Section Development

Before any design of the site and stormwater system takes place, the engineer should understand the data in relation to the proposed use of the site. The most effective way to understand this information is to incorporate it into the site plans. The location of the test borings and test pits is indicated on Figure 9-2, which also indicates the proposed site layout. Next to each test boring, the depth to bedrock is indicated. This is the first step in laying out the stormwater components. The engineer should strive to integrate the information on a single sheet that helps the engineer visualize and determine feasible areas for infiltration systems. At the Penn State Visitor Center, the area of the parking lots had been generally proposed. The next step in design was to develop a profile of this information. Several cross sections of the site were developed in the area of the proposed parking lots. On each profile, the existing surface topography, the depth to bedrock and any other relevant information was plotted.

Stormwater Management Design: Fit to Site and Close to Source

Using these profiles, the parking bays and infiltration beds were “fit” into the hillside, stepping down the hillside with two parking bays, and adjusting the bottoms of the infiltration beds to “step down” as well. This is shown in Figure 9-3.

Several items in design should be noted. Because the rock was shallow in places, the existing soil was not excavated. Instead, the beds were “built up” using berms to avoid soil excavation, and only the organic layer was removed. Where rock was very shallow, infiltration was limited to what would naturally fall or drain to the area before development, and no attempt was made to convey additional stormwater to the area. Instead, the pre-development balance (or Loading Rate) was carefully maintained.

Development of cross sections can be an extremely useful element in design of infiltration systems on carbonate rock. Because the beds must be carefully set with adequate soil mantle, the cross sections provide the design engineer with the information necessary for the layout. Additionally, cross sections provide the Contractor with the necessary information to build the system. In the same manner that profiles are required for utility pipe design (i.e., water, wastewater, and stormwater pipes), profiles are an important component of design of infiltration BMPs in carbonate rock.

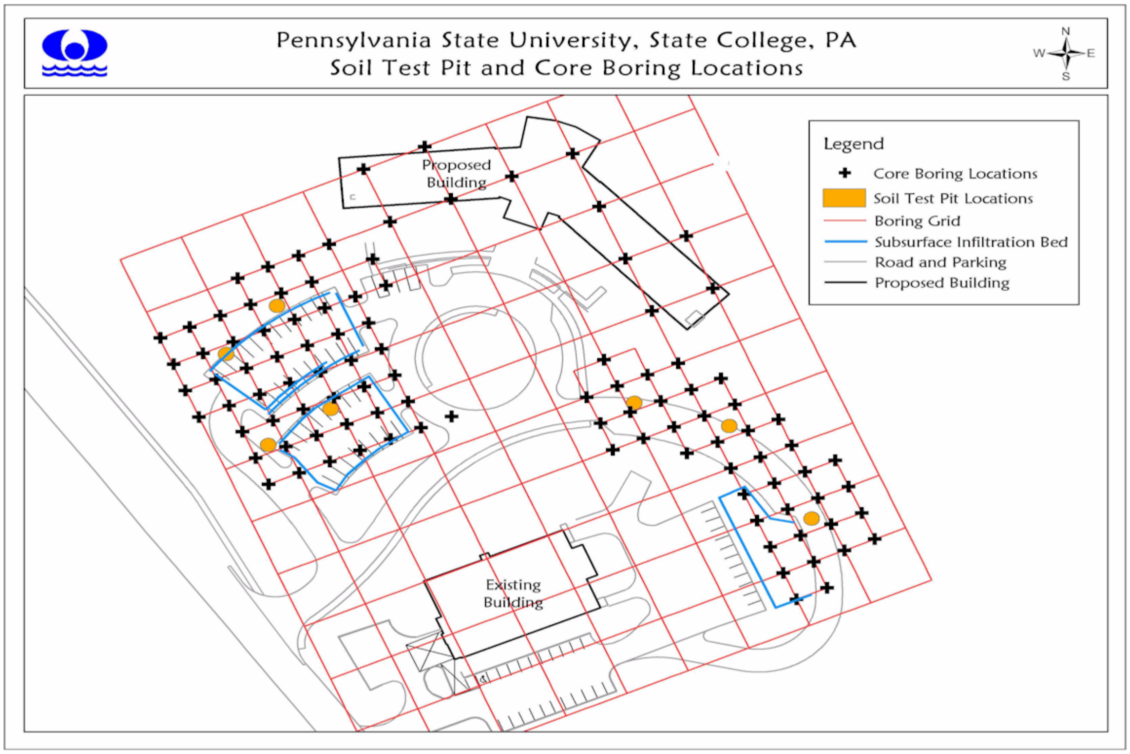

Figure 9-2. Core Boring and Soil Test Pit Locations at the PSU Visitor's Center, Centre County.

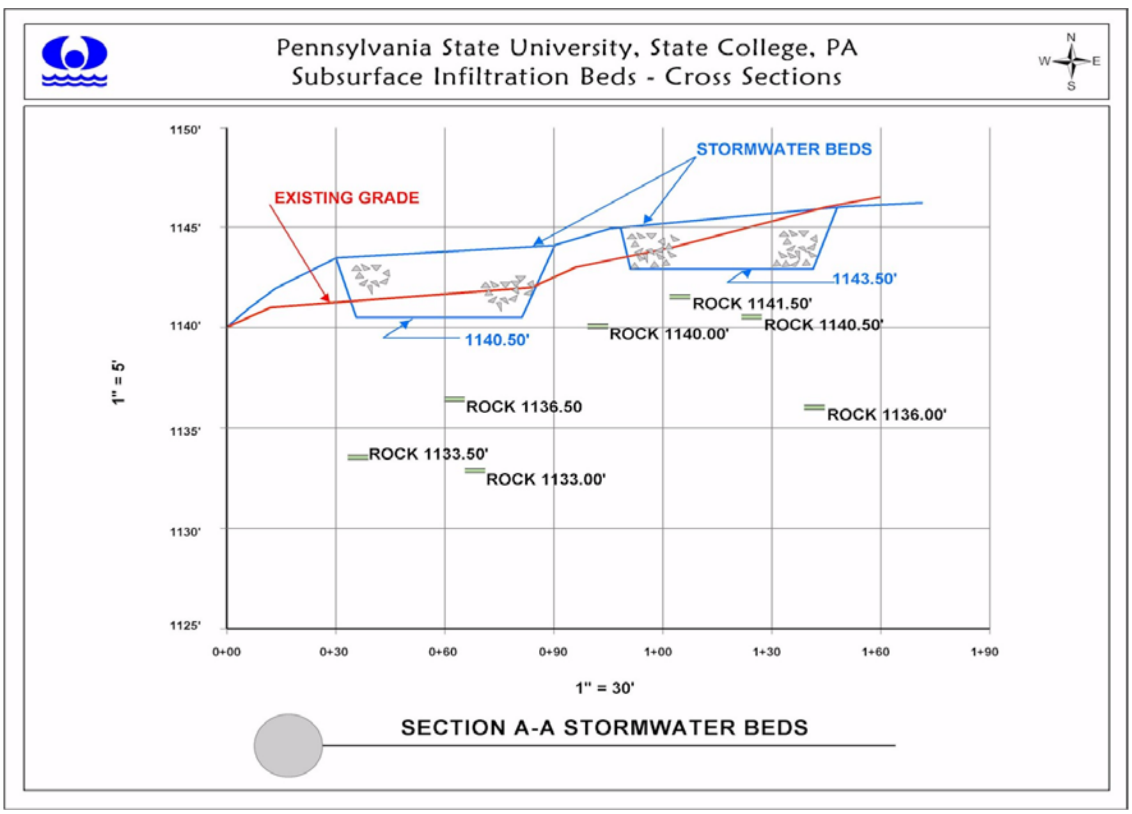

Figure 9-3. Cross-section view showing bedrock pinnacles, existing grade, and proposed stormwater infiltration beds with elevations.

Finally, and most importantly, it was recognized at the Visitor Center that any attempt to convey stormwater from one portion of the site to another would result in stormwater pipes that would be placed in the bedrock. Given the pinnacled nature of the site, it would be inevitable that any length of pipe would be forced to traverse bedrock. To avoid this situation, stormwater is managed as close to the source as possible and a variety of measures are incorporated:

Runoff from the roof of the eastern side of the building is conveyed to a Rain Garden and then to a subsurface Infiltration Trench located on contour.

The Infiltration Trench (Figure 9-4) intercepts a portion of the entrance road runoff. To compensate for the remainder, a vegetated subsurface Infiltration Bed (Figure 9-5) was located immediately adjacent to an existing, uncontrolled parking lot.

The runoff from the western portion of the building is conveyed to the parking lot immediately adjacent to the building where the soil mantle is suitable and the top of bedrock was much deeper (Figure 9-6). In several key locations where stormwater management was needed, small Rain Gardens (Figure 9-7), designed to infiltrate, were incorporated to avoid installing stormwater pipes.

Porous concrete sidewalks were constructed to manage the rainfall incident to them (Figure 9-8).

Figure 9-4. Infiltration trench located on contour, State College, Centre County.

Figure 9-5. Vegetated infiltration bed, State College, Centre County.

Figure 9-6. Porous asphalt parking lot, State College, Centre County.

Figure 9-7. Rain Garden, State College, Centre County.

Figure 9-8. Porous concrete sidewalks, State College, Centre County.

Engineering Plans

The final and critical element to stormwater infiltration system design was to provide the Contractor the required information to build the systems. The subsurface grading of the stormwater infiltration beds was critical to their success. In addition to the cross sections provided, each system should indicate the subsurface contours. An example from the Visitor Center is provided in Figure 9-9. This grading information allowed the earthwork contractor to construct the bed as designed. Because this information is "sub-surface," it would not normally be part of a site-grading plan. However, adding this grading information to the stormwater plan was critical.

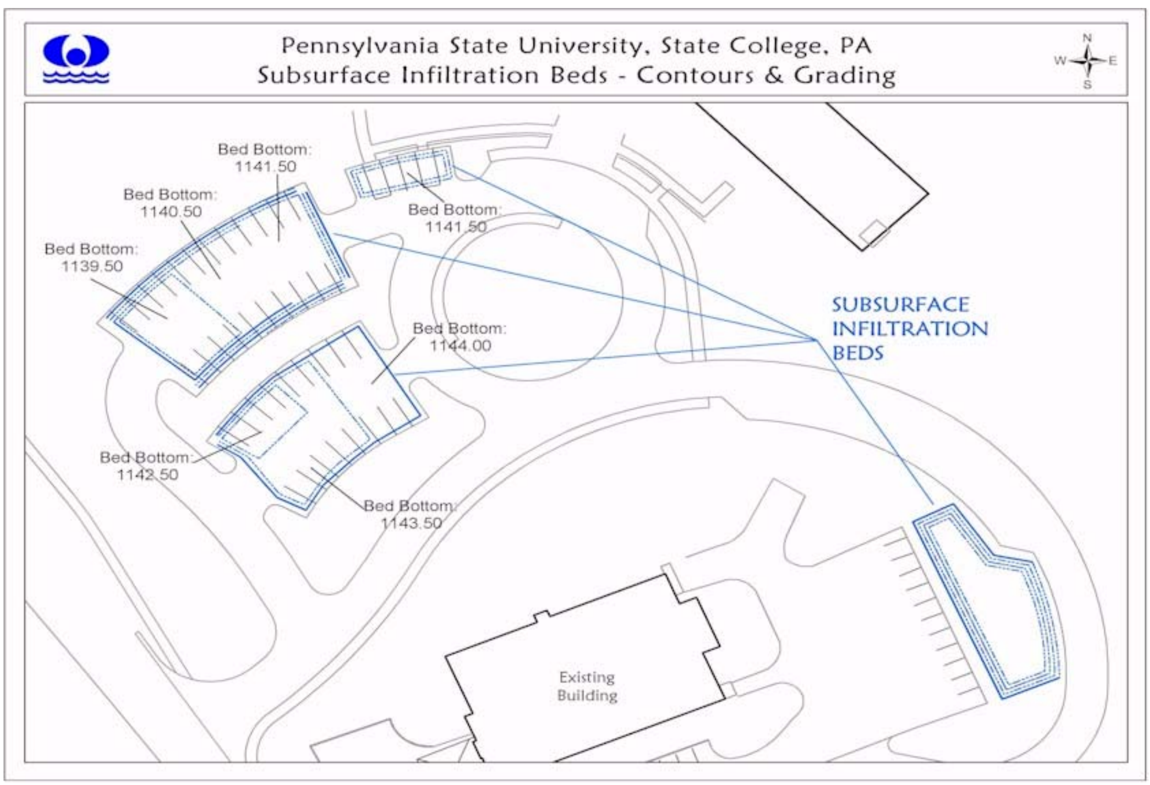

Figure 9-9. Subsurface contours and grading for the infiltration beds at PSU Visitor's Center, Centre County.

Case Study 2: Dennis Creek Streambank Restoration, Franklin County

- **Riparian Buffer Reestablishment**
- **Wetland Restoration**
- **Monitoring**

Partnership began with the Franklin County Watershed Association, an informal cooperative group of landowners, farmers, municipal authorities, and other local officials

Part of the Potomac River Basin, the watershed originates in Hamilton Township, Franklin County, near Chambersburg, PA in the pristine headwaters in of the Kittatinny Mountain Ridge. However, nutrient runoff and the presence of cattle in the stream have degraded both the macro-invertebrate life living within the stream as well as the streambanks themselves.

Historically, the watershed and forestland was cleared as fuel for the iron industries, causing severe erosion problems. As the iron industry gave way to the agricultural industry, erosion problems continued and were exacerbated by overgrazing, cattle waste pollution, and unprotected streambanks.

A first step to restore Dennis Creek was to install several miles of streambank fencing to keep cattle out of the stream itself and allow for revegetation of the riparian buffer. This practice alone provided immediate water quality and macro-invertebrate community improvements. Fences are maintained through the local partnership

Because many riparian areas had no trees or vegetation, another task in this project included the streambank planting of trees and native warm season grasses, as well as the restoration of wetlands for stormwater runoff quality control. A newly restored marsh provides animal habitat and water quality improvement in the intensely farmed watershed

A water quality-monitoring program involving government agencies, school students and others has been implemented to measure the project success.

Important project points:

- Total watershed area is 14 square miles
- Resulted in improved hunting and fishing opportunities for community and an educational opportunity for students
- Video located on the web: http://www.greentreks.org/watershedstv/more_information/featuredtopic_denniscreek.asp

Figure 9-10. Dennis Creek Watershed in Franklin County, PA.

Case Study 3: Commerce Plaza III, Lehigh County

- **Vegetated infiltration basin**
- **Concrete level spreader**
- **Vegetated swale**

Project Background

Commerce Plaza III, in Upper Macungie Township and South Whitehall Township in Lehigh County, PA is a mid-rise office complex that was proposed for a 49-acre site. A major concern during the design phase was to locate elements of the site stormwater management system away from limestone formations to avoid potential sinkhole problems. The site, historically in agricultural use before subdivision, had a pre-existing sinkhole located near the area slated for stormwater management.

Figure 9-11. Vegetated infiltration basin in Lehigh County.

BMP Description

The vegetated infiltration basin (Figure 9-11) collects stormwater runoff from one parking lot and one building, and mitigates runoff from two additional buildings nearby. The basin was designed with a high loading rate of impervious surface runoff to BMP area. Stormwater runoff sheet flows from the inlet to a concrete level spreader (Figure 9-12) into the infiltration basin. The surface of the infiltration basin was graded with extreme care, creating an even basin surface elevation to receive stormwater. Figure 9-13 shows the vegetated swale inflow to the infiltration basin.

Figure 9-12. Level spreader distributes stormwater into the infiltration basin.

Figure 9-13. Vegetated swale

Soils: Figure 9-14 shows the Commerce Plaza office location along with the corresponding soil series. The infiltration basin at Commerce Plaza III is located within the Washington soil series. Washington soils found in Lehigh County are deep, well-drained soils, whose underlying material is glacial till, or frost-churned material weathered from limestone.

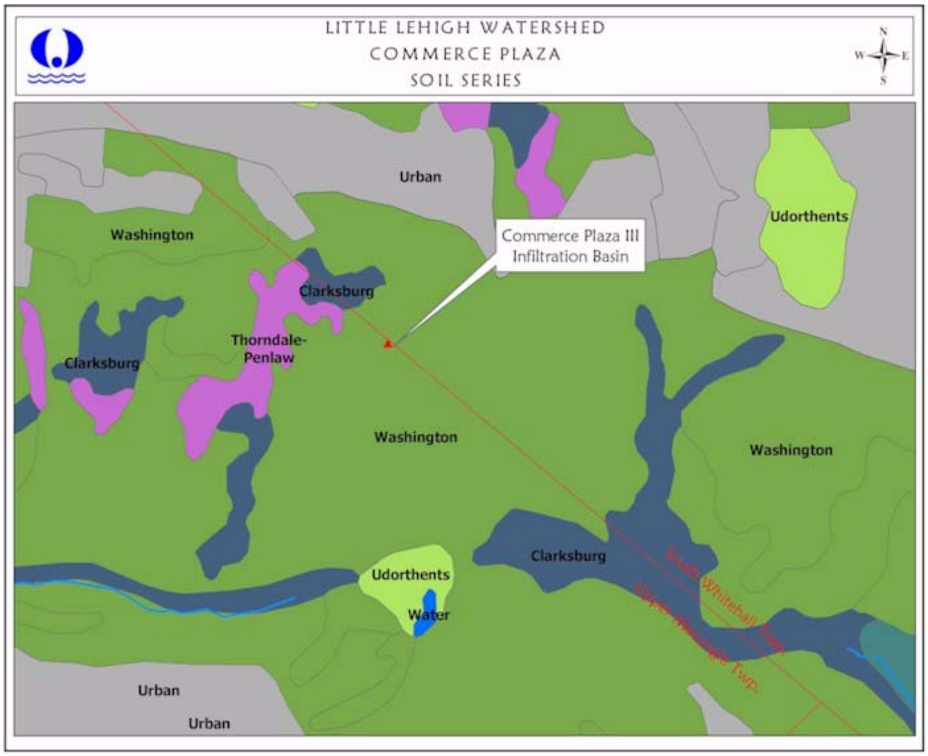

Figure 9-14. Commerce Plaza soils, NRCS.

Geology: Figure 9-15 shows the BMP location along with the corresponding surficial geologic formations. The site is located on the Epler Formation of the Beekmantown Group. The Epler Formation dates from the Lower Ordovician and is a medium to dark-medium gray, finely crystalline, silty limestone interbedded with some thin- to thick-bedded cryptocrystalline dolomite.

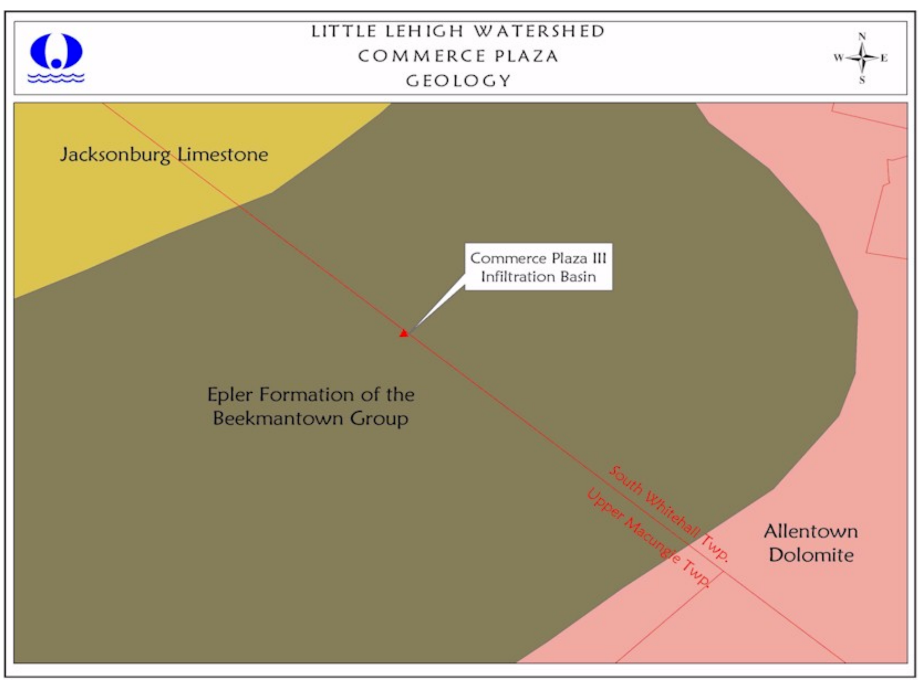

Figure 9-15. Commerce Plaza in Lehigh County is located on limestone geology.

Case Study 4: Flying J. Truck Plaza for Welsh Oil of Indiana Truck Refueling Terminal, Cumberland County

- **Subsurface Infiltration Bed**
- **Perimeter Trench Drain**
- **Treatment Wetlands**
- **Vegetated Infiltration Filters**
- **Curb Cuts with Filter Strips**

Project Background

In 1993, Flying J Truck Plaza, a truck refueling facility in Middlesex Township, Cumberland County, Pennsylvania, was faced with complying with municipal open space requirements and the site area needed for their development program. Conventional stormwater detention basins exceeded site area limits required, and as a result, the use of groundwater recharge beds for stormwater management was proposed. Subsurface infiltration beds, located beneath the truck parking facility itself, provided additional space for parking.

Situated over a carbonate formation, the possibility of sinkholes was thoroughly investigated utilizing ground-penetrating radar to map the underlying bedrock. By designing recharge beds to distribute the infiltrating stormwater over a large area where the soil mantle was sufficiently thick, the development of solution channels in the carbonate was minimized. Use of a recharge design for stormwater management for a facility serving as many as 1,500 heavy trucks per day in a sensitive carbonate context had to be coupled with special water quality measures. A two-stage pretreatment system was designed, including a settling unit and vegetated filtration system to remove first flush pollutants from stormwater runoff before entering the groundwater.

Figure 9-16. Perimeter trench drain.

Figure 9-17. Vegetated infiltration filters.

Site Description

Soils: The primary soils found on the site include Duffield silt loam (DuA and DuB), Hagerstown silt loam (HaB), and Huntington silt loam (HuA); with Berks shaley silt loam and Blairton silt loam found primarily around the site perimeter.

Design Images and Details

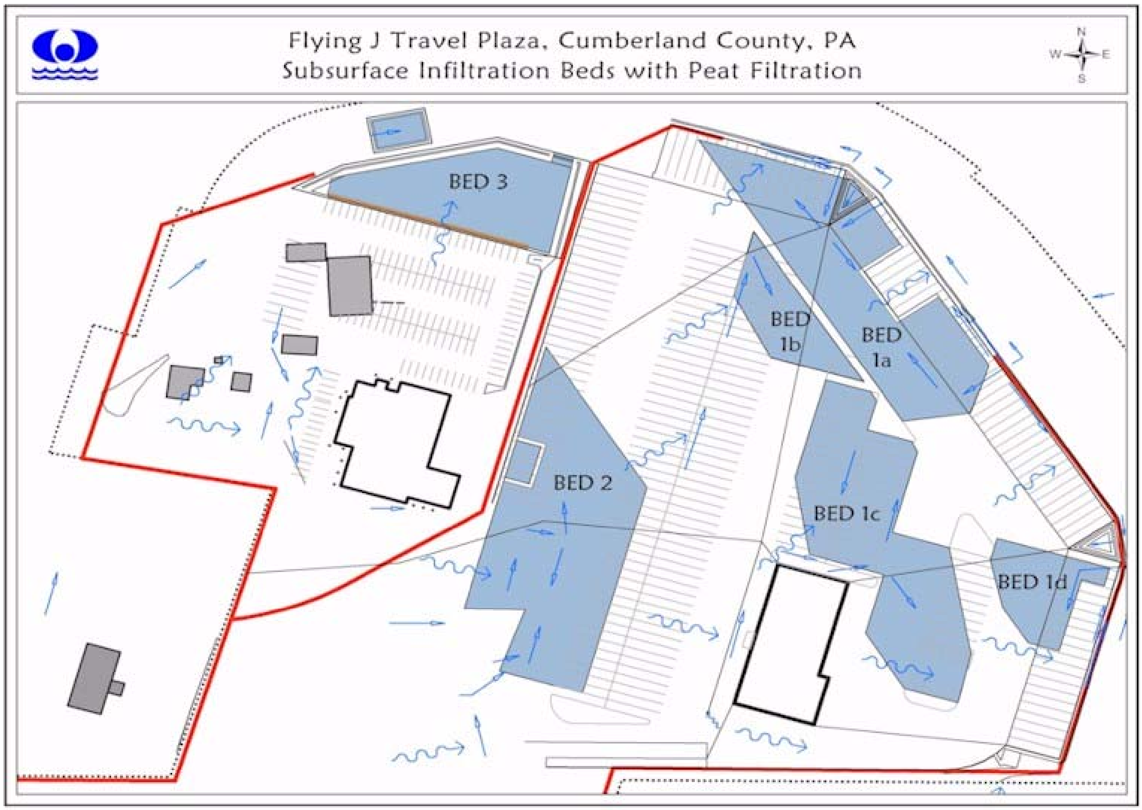

Figure 9-18. Stormwater flow path for the Travel Plaza stormwater management system.

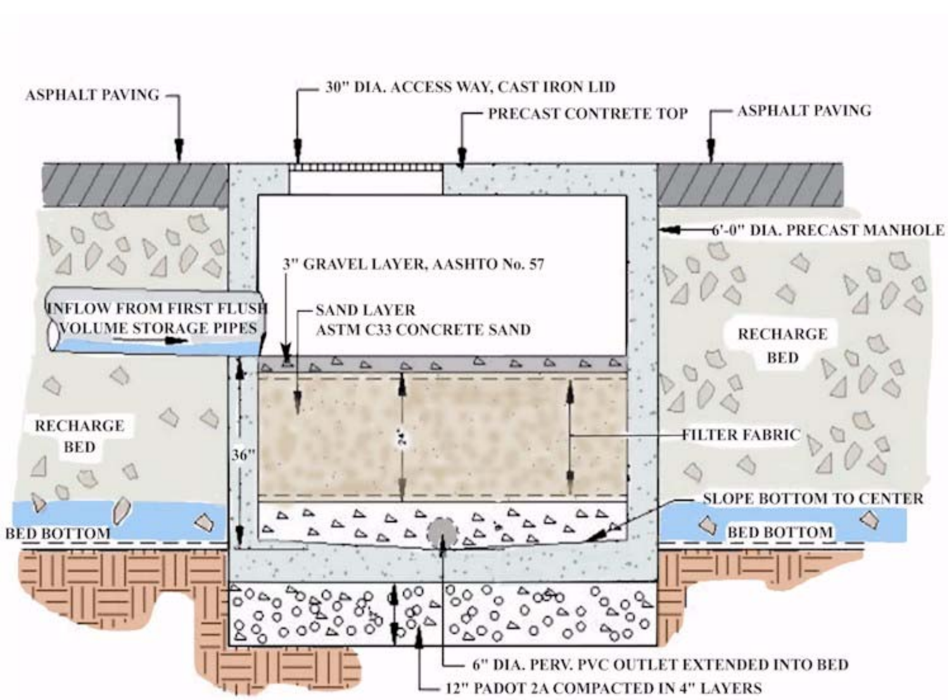

Figure 9-19. Shows the construction design detail for the filter station at the Truck Plaza.

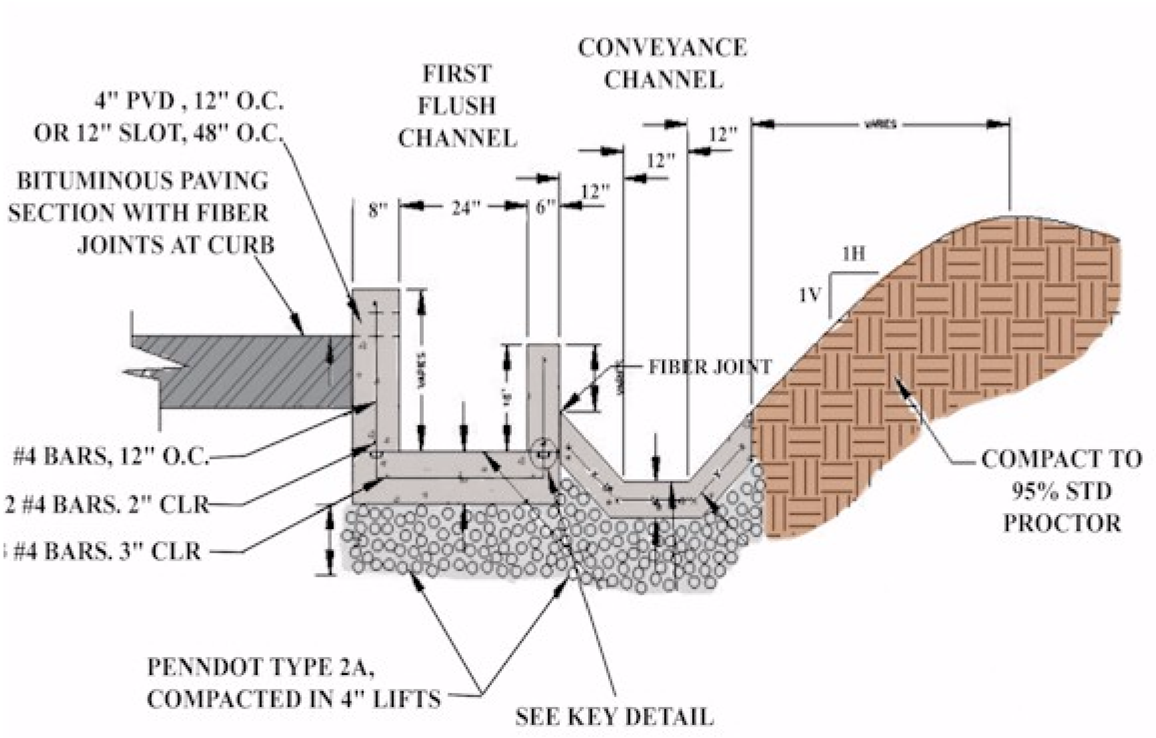

Figure 9-20. Shows the construction design detail for the perimeter channel section.

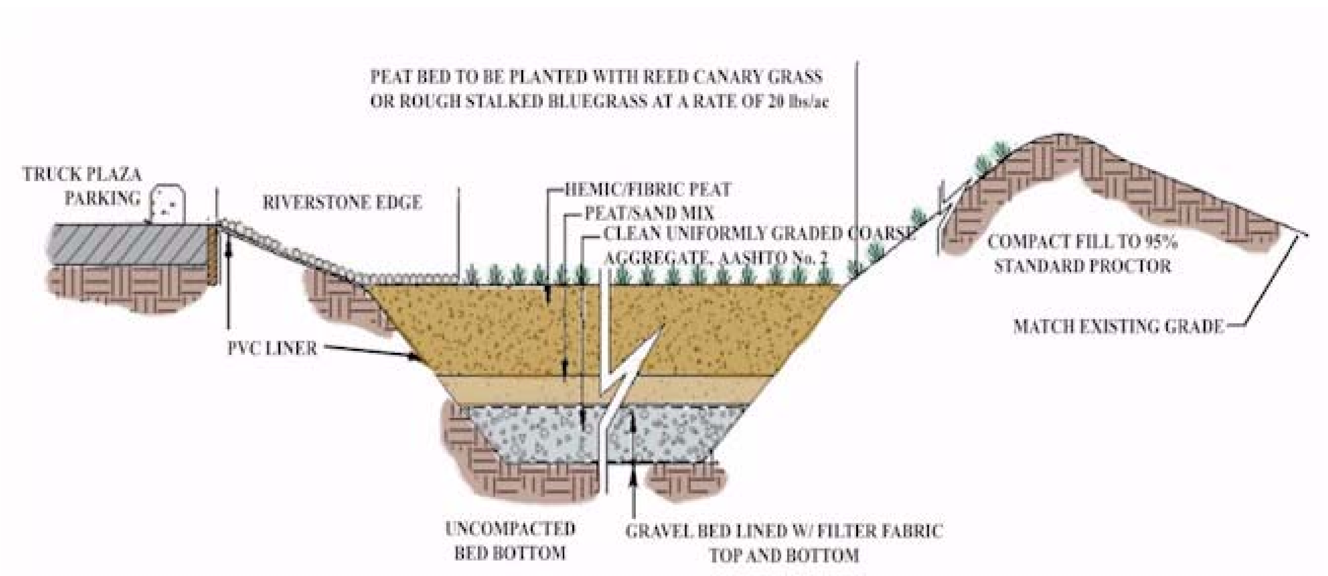

Figure 9-21. Illustrates the peat infiltration bed that is adjacent to the truck parking lot.

Case Study 5: Ephrata Performing Arts Center, Lancaster County

- **Porous Asphalt parking lot**
- **Vegetated Swale**

Site Address
Ephrata Performing Arts Center
Cocalico Road
Ephrata, PA 17522

Project Background
The Ephrata Performing Arts Center is located in the existing Grater Park, and includes the Ephrata Playhouse, American Legion, other miscellaneous buildings and associated parking facilities. The project was proposed in coordination with a planned expansion and remodeling of the existing playhouse that required new parking facilities to support the additional use.

The new porous parking lot consists of two rows on each end of the existing lot. A total of 9,200 square feet of porous parking area was installed, providing 40 new parking spaces on the site. The new parking was installed in an existing lawn area and vegetated bioretention swales were included in the design. The project was completed in September 2004.

Site Description
The site is located within the Cocalico Creek Watershed. The stream is classified WWF (Warm Water Fishery) and is on the 303(d) list of impaired streams for siltation/sediment. The site is bordered to the north by Cocalico Creek.

The site is underlain by the Snitz Creek (CsC) Formation, which is a Cambrian Age Dolomite and Sandstone. All BMPs were installed within the Hagerstown Urban Soil Complex, which is classified as Hydrologic Soil Group “C”. Percolation tests were conducted on the underlying soils and infiltration rates observed were ½ inch per hour or greater. There was no disturbance of steep slopes involved in the project; all construction occurred on slopes of 6 percent or less.

BMP Description
The porous parking is underlain by a stone infiltration bed with various benches ranging in depth from 18 to 48 inches and receives runoff from surrounding impervious driveways and parking areas. The bed connected to the northernmost parking row is designed to overflow to a flat grassed area, and the bed under the southern row discharges to a vegetated bioretention swale. As part of the design, a portion of the existing impervious parking area was removed and a bioretention bed was installed to promote the additional infiltration of runoff conveyed by the existing parking areas.

Figure 9-22. Construction of porous asphalt parking area to compliment building expansion.


Figure 9-23. Completed porous asphalt parking lot at Ephrata Performing Arts Center.

Case Study 6: Lebanon Valley Agricultural Center, Lebanon County

- **Porous Asphalt parking lot**

Site Address:
Lebanon Valley Agricultural Center
2120 Cornwall Road
Lebanon, PA 17042

Project Background
The porous parking lot at the Lebanon Valley Agricultural Center was installed to provide additional parking at the existing site. The completed lot provides 58 new spaces, 40 of which are porous. The center drive lane is conventional asphalt with porous pavement limited to the parking bays. The porous parking installation was completed in July 2003.

Site Description
The Lebanon Valley Agricultural Center is located within the Snitz Creek Watershed, which is classified TSF (Trout Stocking Fishery). The site contains no wetlands, floodplains or riparian zones. Bedrock on the site belongs to the Richland Formation, a carbonate formation composed primarily of finely crystalline dolomite and oolitic limestone. Sandstone beds and pinnacles are present throughout the formation and sinkholes and closed depressions are prevalent. Hydrologic Soil Group (HSG) B and C soils are found on the site.

BMP Description
The porous pavement parking lot was installed on an existing lawn area and is underlain by a 24 -inch infiltration bed. The bed was excavated and unwoven geotextile fabric was placed on the undisturbed subsoil. Clean AASHTO #1 aggregate was placed in the bed in 12-inch lifts and lightly rolled to prevent settling. Finally, a 3-inch choker course comprised of AASHTO #57 was placed over the larger aggregate and was finish graded to prepare for the asphalt pavement.

The porous parking receives runoff from the center drive lane, which was constructed with conventional asphalt. The overflow design is comprised of four 4-inch pipes placed at the top of the infiltration bed and discharging to a well-vegetated area. Two 6-inch pipes, which discharge to an existing vegetated swale on the site, provide additional overflow. The project site has been observed during several high intensity storms and appears to be working successfully as there was little or no discharge apparent from the overflow pipes.

Figure 9-24. Completed porous asphalt parking lot at Lebanon County Conservation District.

Case Study 7: Penn State University Berks County Campus, Berks County

- **Porous Asphalt Parking Lots underlain with Subsurface Infiltration Beds**
- **Subsurface Infiltration Trench underlying Standard Asphalt Walkway**
- **Minimum Disturbance**
- **Level Spreader Pipe in the Woods**

In addition to its Main Campus in State College, Pennsylvania State University maintains several satellite campus sites throughout the state. Each of these regional campus sites represents a major investment in educational resources and recently underwent a substantial expansion and development of additional facilities. In 1999, the PSU campus in Reading developed a dormitory complex to accommodate some 400 resident students. The dormitory complex, which consisted of seven attached buildings, was situated in a wooded knoll on the attractive campus. This facility required additional parking spaces for some 320 cars.

Prior to the new development, the area of the campus in question consisted of existing dormitories, a parking lot, a soccer field, a wooded hillside, and lower-lying meadow. The site drains to Tulpehocken Creek, a pristine tailwater fishery that provides habitat to numerous trout species. The soils on the site were mostly well-draining Hydrologic Soil Group ‘B’ classification. The campus had historically been hindered by the formation of sinkholes in the carbonate bedrock formation underlying it at shallow elevations. In fact, one of the two existing on-site detention basins (Figure 9-25) had suffered from severe sinkhole problems. This particular basin experienced at least two major sinkholes during its lifespan, which required massive (and expensive) remediation efforts involving concrete plugging and lining. The goal of the stormwater management for the new development was thus twofold: mitigation of newly generated site runoff and reduction of existing runoff to the existing basins.

Figure 9-25. Existing sinkhole-plagued detention basin.

The original development plan called for the construction of a new, standard asphalt parking lot in an area of existing woodlands, which would be drained by a new detention basin. The new dormitory complex was going to be located in a highly disruptive fashion in the wooded knoll. The original plan was eventually discarded in favor of a more sustainable approach involving minimum disturbance, volume reduction, water quality improvement, and groundwater recharge. The first major improvement to the plan was the repositioning of the new dormitories in a more organic fashion along the contours in the woods. This sensitive positioning preserved healthy trees and minimized earth disturbance, which was limited to within 15ft of the new structures. Another major improvement was relocating the new parking lot away from existing woods and into the meadow. Also, this parking lot was constructed with porous asphalt and underlain by an aggregate infiltration bed.

The stormwater management plan for the developed site was a great improvement over the existing condition. Stormwater management for new dormitories consisted of an aggregate infiltration trench beneath a standard asphalt walkway "interior" of the complex and "exterior" level spreader perforated pipes along contours in the woods. Roof leaders on the interior halves of the dormitories were connected to the aggregate trench/walkway. (These walkways were stabilized beyond the standard asphalt by a "grass pavement" for fire truck access.) Likewise, roof leaders on the exterior halves were directly connected to the level spreader perforated pipes in the woods. These laterally extending pipes were designed to maintain soil moisture for the woodlands.

Figure 9-26. Example of minimum disturbance and prevent erosion or disturbance on the hillside.

Figure 9-27. Level spreader pipe/infiltration trench in woods.

Figure 9-28. Standard asphalt walkway w/ subsurface infiltration trench.

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The new porous asphalt parking lot was designed to mitigate incident rainfall and direct runoff from the nearby access road and existing dormitories. The porous parking lot has so far effectively discouraged the concentration of stormwater runoff downhill and allowed the incident rainfall to pass directly through the parking bays, slowly percolating into the soil and recharging the aquifer system. This system has also dramatically reduced discharges to the existing sinkhole-plagued basins. To date, neither the porous parking lot nor the existing basins have experienced additional sinkhole problems. Furthermore, polluted runoff from the site, usually described as nonpoint source pollution (NPS), was significantly removed by the overall plan. The new improvements at the PSU Berks County campus have had virtually zero impact on regional water resources.

The cost of the new porous asphalt parking lot with subsurface aggregate infiltration bed came to around $1100 per space, in 1999 dollars. When all related site work (lighting, landscaping, erosion and sedimentation control, etc.) was considered, the final cost per space was around $2200, also in 1999 dollars

Figure 9-29. Porous asphalt parking lot with subsurface infiltration bed.

Case Study 8: Warm Season Meadows at Williams Transco, East Whiteland Township, Chester County

- **Re-Vegetation as Natural Open Space Meadow, Using Native Plants and Replacing Maintained Lawn**

Project Background
This site is largely unpaved land consisting of fields interspersed with an office building, an employee parking area, and utility structures and right-of-way areas, all previously maintained as conventional lawn area. Utility line areas consist primarily of poles, towers, and guidelines that disturb minimum earth once in place.

At this utility company corporate office and utility right-of-way site in the Valley Creek Watershed (classified as Exceptional Value, EV), a re-landscaping plan was developed for the site, which included use of native warm season meadow grasses well suited to the local climate. Re-landscaping included switch grass and native blue stem, planted on about 25 acres of land that had previously been fields of relatively conventional turf grass that was subject to fertilizer and herbicide/pesticide applications as well as regular mowing. Prior to this planting of meadow grasses, herbicide was carefully applied to kill existing vegetation including undesirable invasive plants; this herbicide application was timed so that it wouldn't harm an existing stand of native blue stem. The native meadow grasses were planted using no-till planting practices to prevent excessive earth disturbance. The new grasses grow during the middle of the growing season and are dormant in the spring and fall. They are best harvested after the spring nesting season, but require no mowing.

Stormwater Management Functional Benefits
Establishing warm season meadow of native grasses is included in this manual as a BMP because the overall environmental performance of unmowed, unmaintained native grass meadows is superior to that of mowed and maintained turf grass fields, both in terms of stormwater quantity and stormwater quality. Meadows promote stormwater infiltration into the ground; through interception of any stormwater flow (sheet or channelized), rate of flow is slowed. Periodic application of fertilizers and herbicides is eliminated; therefore chemical pollution to surface runoff as well as to the groundwater is reduced. Native grasses also have a greater potential to uptake any pollutants present in stormwater runoff, in contrast to conventional turf grass, although no pollutant reduction analysis specifically has been performed for this BMP project. To a large extent, sediment and grit, oil and grease, as well as nutrients present in site stormwater runoff will be filtered by the natural biological and physical filtration processes provided by native meadow grasses prior to being discharged into receiving waters or being percolated deeper into the groundwater. Additionally, established warm season grassy meadows provide natural open space habitat and are especially attractive to wildlife, including birds.

Operation and Maintenance: The Chester County Conservation District considers planted meadows to be a "low maintenance" BMP. Warm season native meadow grasses should be burned every 3 to 4 years to invigorate stem growth, remove thatch, and eliminate growth of invasive plants. At this site, burning is not an acceptable management option due to the nature of current site activities and proximity to residential areas; however, as an alternative to burning, the site owner can harvest cut on a 3-4 year cycle. The new meadow grasses with their low nutrient requirements, do not require fertilization above and beyond available soil nutrients. Meadow grass does need to be periodically cut around guide wires, structures and buildings to permit inspection and maintenance of structures. To ensure that this BMP is maintained properly, procedures and specifications for meadow maintenance should be documented and maintained on the site.

Cost Issues

The cost of establishing native meadows is low, relative to many other types of stormwater management practices, and is typically not significantly more expensive than installation of a conventional landscape. Operating and maintenance costs usually are less than conventional landscaping. For example, at this site, the warm season meadow offers the site owner cost savings conservatively estimated at $350 per acre per year through avoidance of mowing, without including the added costs of fertilization and herbicide applications. Additionally, the meadow grasses can be harvested annually and sold at current market value. Other factors that may affect cost of establishing a warm season grass meadow include site conditions, such as the cost of land, local topography, rocky or highly permeable soil, and bedrock.

For More Information

For more information about this BMP site, contact the site owner, Williams Transco, at 610-644-7373 (Robert Hill, Assistant District Manager). Although this site is part of the Chester County BMP Tour, site visits should be individually arranged. Also, Tim Smail at the Chester County office of the USDA-Natural Resource Conservation Service assisted in the BMP design.

Figures 9-30 & 9-31. Warm season native grassy meadows established at this site provide greater stormwater infiltration opportunities than maintained turf grass fields. Low maintenance meadows enhance wildlife habitat.

Case Study 9: Hills of Sullivan Residential Subdivision, London Grove Township, Chester County

- **Infiltration Trenches**
- **Berms**

Project Background

This sizable single-family development was constructed over 15 years ago and is located in the White Clay Creek watershed (classified CWF, TSF). London Grove Township at that time was one of the few municipalities in Chester County, as well as the state, to require in its stormwater regulations that runoff volumes for up to the 2-year storm not be increased, pre- to post-development. The site can be reached from Rose Hill Road south, left onto Avondale Road, right onto Clay Creek Road, left onto Angelica Drive and then best accessed via the trail located in HOA-owned open space (follow a narrow trail from Angelica Drive just above a bridge and above the creek).

Project Description

At the encouragement of the Township and its Municipal Engineer, an integrated system of berms and infiltration trenches was constructed. The typical berm/trench consisted of narrow, elongated, surface depressions created by built up earthen embankments, or berms, that promote stormwater infiltration. At this site, the infiltration trenches are elongated, shallow trenches on the surface that collect and temporarily store stormwater runoff from the upslope residential lots and streets and promote its infiltration (in contrast to sub-surface, excavated, fabric-wrapped, stone-filled trenches as described in Chapter 6). Stormwater that collects in these narrow depressions on the hillside gradually seeps through the soil into the ground and eventually into the creek and water table below. These berms/trenches follow the contours of the land in a parallel sequence. There are three 400 foot-long trenches terraced, or stepped, down the slope with one below another.

When the uphill trench is filled to capacity, stormwater overflows into the trench below. There is also a single 1,000 foot-long trench that functions independently of the three terraced trenches. This large trench receives stormwater through a subsurface pipe. Because stormwater entering this trench is conveyed through a pipe with a steep slope and has high velocity, a concrete chamber is used to dissipate its energy before discharging into the trench. When this trench overflows, stormwater spills over its downslope berm and flows down the bank into the stream below. For an infiltration trench to properly function, the bottom soil must be permeable and remain uncompacted for the life of the structure. Soil percolation tests performed prior to trench construction and at the conclusion of earth disturbance are used to ensure soil infiltration capacity. Vegetation has naturally established itself in the trenches. The berms, which double as a walking path, consist of a gravel and grassy base and are wide enough to permit access for future maintenance of these structures.

Stormwater Function

Infiltration trenches replenish the water table, recharge groundwater supplies, and stabilize base flow in streams. They provide efficient recharge because the infiltration occurs relatively close to where the runoff is generated, thus limiting evaporative loss and infiltrating more rainfall. Infiltration trenches provide an opportunity for physical filtration of pollutants in stormwater runoff removing suspended solids including dirt and sand particles (solids accumulate in vegetation and bottom soils). Oil and grease bound to suspended particles, and their heavy metal constituents, may also be filtered from runoff. These structures also provide naturally vegetated open space for wildlife. The trenches/berms function as a walking trail for the community and provide maintenance access.

This BMP is not advisable for use in drainage areas that have extensive stormwater pollution sources (i.e., "hotspots"), because by itself such a system has limited pollutant removal capabilities. Functioning as designed, infiltration structures can approximate the following pollutant removal efficiencies for non-excessive nonpoint source pollutant loadings as would be expected from single-family residential land uses:

- Total Suspended Solids (TSS): 95 %
- Total Phosphorus: 70 %
- Total Nitrogen: 51 %
- Metals (copper and zinc): 99 %
- Bacteria: Not Applicable

Operation and Maintenance: The Chester County Conservation District considers infiltration trenches to have moderate maintenance requirements. Operation and maintenance requirements include the following (provided in this case by the Homeowners' Association):

- Regularly inspect to ensure adequate infiltration
- Regularly inspect structural components (i.e. energy dissipater, inlet structure) to ensure they are functioning properly
- Periodically trim plants to ensure their growth does not impede the flow of water through the structure
- Remove invasive plants as necessary (remove shoots and roots)
- Routinely remove accumulated trash and debris
- Avoid running heavy equipment in the trenches to prevent soil compaction
- At the completion of construction, scrape soils to remove accumulated sediment and conduct soil percolation test
- Do not apply chemical pesticides or fertilizers to turf in and around infiltration structures

Cost Factors

In general, the cost to construct and maintain infiltration trenches is usually comparable to the cost of constructing and maintaining large stormwater basins, which would have otherwise been necessary. Given the age of this project, specific cost data have not been available. Soil percolation tests performed before and after construction, as well as measures taken to protect the infiltration basin from sediment inundation during construction add moderately to project costs, but are essential in order to ensure proper function of the infiltration trenches/berms.

For More Information

Contact London Grove Township at 610-345-0100 or the Township Engineer, Larry Walker (URS) at 302-791-0700. London Grove Township has worked to apply this and other infiltration-oriented BMPs in other developments, such as Ashland Woods, located near the intersection of Sullivan Road and New Garden Station Road on Jack Reynolds Way, where infiltration basins are located on individual lots owned by individual homeowners.

Figure 9-32. View from Clay Creek Rd: trenches/berms at the base of the grassy hill in background; trenches/berms barely visible through trees as horizontal undulations.

Figure 9-33. This grassy path is an embankment, or berm, creating depressions for recharge trenches located to the left of the path.

Figure 9-34. Narrow, vegetated infiltration trenches/berms follow land contours and take on a naturalized appearance.

Figure 9-35. This trench/berm has a subsurface energy dissipater to reduce the velocity of entering stormwater.

Case Study 10: Applebrook Golf Course Community, Chester County

- **Constructed Treatment Wetland**
- **Two Wet Ponds**
- **Grass Swales**
- **Fertigation**
- **Cold Water Discharge**
- **Open Storage**

In the spring of 2002, stormwater management improvements were constructed at Applebrook Golf Course Community in East Goshen, Chester County. These improvements were intended to substantially improve the quality of site runoff, reduce the peak runoff rates, stabilize flow to adjacent natural wetlands and streams, and provide stable habitat for plants and wildlife, including sensitive and native endangered species. As the site is within the Ridley Creek watershed, which is deemed Exceptional Value by the state, these goals were especially important.

Figure 9-36. Constructed wetland in background.

The most significant BMPs constructed as part of the strategy were a constructed treatment wetland and two wet ponds. Other stormwater measures at the golf course included grass swales, fertigation (fertilization and irrigation), cold-water discharges, and open space donation. The constructed treatment wetland at the site was designed primarily with water quality objectives in mind. It was constructed in a low-lying area near natural wetlands in the Ridley Creek floodplain. This allowed it to take advantage of inflows of water between storm events and to maintain sufficient soil moisture. Through physical, biological, and chemical processes, constructed wetlands can efficiently remove a great many contaminants commonly found in runoff (suspended solids, nutrients (nitrogen and phosphorus), heavy metals, toxic organics, and petroleum compounds). Wetland vegetation, algae, and bacteria allow for the biological uptake of contaminants. Wetland vegetation also provides physical and chemical pollutant filtering mechanisms, which greatly enhance the quality of the runoff from the golf course, as well nearby residential development. Constructed wetlands also play a role in reducing peak rates from a site, stabilize flow, and provide valuable habitat opportunities.

A wet pond is a stormwater management feature that maintains a permanent pool of water (retention) and has additional capacity for stormwater detention. Two wet ponds were constructed at the golf course as part of the improvements. The smaller of these two wet ponds has the preferable elongated shape, while the larger is comprised of two cells. When the first cell has reached capacity, water spills over into the second cell. The larger pond receives treated wastewater from a nearby, township-owned wastewater treatment facility. Water is pumped from this pond and used in the site's fertigation system.

Constructed wetlands are considered to be a low to moderate stormwater BMP. Typical operation and maintenance requirements include: manual adjustment of the water level (especially during plant establishment), manual removal of invasive plant species, and cleaning out of outlet structures when excessive amounts of sediment have accumulated.

Figure 9-37. Large pond, constructed wetland, managed and naturalized areas of golf course.

Other BMPs constructed at the golf course include grass swales, fertigation, cold-water discharges, and open space donation. The various grass swales at the golf course provide a sustainable alternative to concrete-lined channels or conventional storm sewers. Their many benefits include the filtering out of runoff pollutants, large storm conveyance, enhanced infiltration opportunities, and peak rate reduction.

The site's fertigation system provides a sustainable alternative to conventional fertilization. The system uses water from the larger of the two wet ponds, which receives wastewater effluent from the Township's nearby sewage treatment plant. Water from this wet pond is pumped for use in golf course irrigation and fertilization. This system allows fertilizers to be introduced to the irrigation water in solution form, a technique that allows 100% fertilizer use, as opposed to only 20% when dry fertilizer application is employed.

Figure 9-38. Pond water is pumped up to a waterfall and returns to pond through grass swales enhancing aeration.

Water from the wet pond is pumped at or near the bottom so that the coldest water is returned to Ridley Creek. This is an important consideration for the trout in the exceptional value creek. The development includes an area of wetlands of approximately 70 acres that was donated by the developer to the Township as open space. There is a conservation easement on this land, which restricts the cutting/mowing of vegetation to permit wetland plants to mature. The eased land includes the constructed wetland, the natural wetland, the stream, and its adjacent floodplains.

References

Chester County Stormwater BMP Tour Guide. Published by Chester County Conservation District.

Center for Watershed Protection. *A Review of Stormwater Treatment Practices* (published presentation).

Pennsylvania Handbook of Best Management Practices for Developing Areas. Spring 1988. CH2MHILL

Case Study 11: Swan Lake Drive Development, Delaware County

- **Vegetated Infiltration Beds**

Site Address
Swan Lake Drive
Concord, PA 19061
Delaware County

Project Background
This project consists of the development of eight single-family dwellings on approximately 12 acres near the intersection of Mattson and Concord Roads in Delaware County. Stormwater on the site is managed with on-lot vegetated infiltration beds which reduce runoff volume and help protect water quality within an existing spring fed pond and associated wetlands.

Site Description
The Swan Lake Drive Development is located within the Greens Creek Watershed, which drains to the West Branch of Chester Creek. Predevelopment conditions on the site consisted of rolling farmland with woodlands located on the northern third of the property. Three small streams traverse through the parcel from west to east. Adjacent to the streams are floodplains with some associated wetland areas.

Existing soils on the property consist of the Glenville, Glenelg, Brandywine and Worsham Series. All soils are classified as silt loams and range in permeability from moderate to low permeability. Infiltration testing was conducted on the site and the soils were found to be suitable for infiltration.

BMP Description
Vegetated infiltration beds were constructed to manage the rooftop runoff from each individual lot as well as runoff generated by driveway and road areas from a large portion of the development. The remaining runoff on site was conveyed to the existing pond. Shallow subsurface infiltration beds (no greater than 2.5 feet deep) were installed on all eight lots and rooftop runoff from each home is conveyed to the onsite infiltration bed. A larger infiltration bed was constructed to manage the runoff from driveways and Swan Lake Drive. Stormwater overflow and some overland flow are directed into the existing pond at the bottom of the site. The infiltration systems on the site provide capacity to store/infiltrate approximately 11,000 cubic feet of runoff over a 24-hour period.