Stormwater Basin Retrofits:

Achieving Improved Water Quality and Quantity Management in Existing Facilities

bucks county planning commission

One of the major sources of water pollution today is nonpoint source pollutants, often resulting from stormwater runoff from existing developed areas. Stormwater runoff from developed areas contains a variety of pollutants including sediments, nutrients such as nitrogen and phosphorous, fertilizers, road salt and trash. Historically, one of the principal approaches used to control stormwater runoff were conventional detention basins. However, these basins were often designed primarily to reduce the rate of stormwater runoff with little focus on improving water quality in the receiving stream.

Recognizing the importance of addressing both stormwater quantities and quality, several alternative approaches to conventional basin design have emerged. This brochure is designed to illustrate how one of these approaches, the retrofit of existing basins into naturalized basins, can contribute to improved water quality and reduced downstream erosion, via reduced water quantity, in the receiving stream.

Financed in part by a Growing Greener II Grant provided by the Pennsylvania Department of Environmental Protection (PA DEP). The views expressed herein are those of the authors and do no necessarily reflect the views of PA DEP.

Funding also provided by Bedminster, East Rockhill, and West Rockhill townships and the Pennridge School District.

Credits:

Cover Photograph	www.stormwaterbmp.org
Drawing 1	Mid-America Regional Council
Drawing 2	University of New Hampshire Stormwater Center
Table 1	Edge of the Woods Native Plant Nursery
Drawings 3–6	Borton Lawson Engineering

Conventional Stormwater Detention Basin Shortcomings

A conventional detention basin consists of a large, mowed depression, often containing a concrete low-flow channel.

A conventional detention basin with a low flow concrete channel

The design of conventional detention basins has primarily focused on controlling the velocity of stormwater runoff, with little consideration given to environmental impacts such as:

Degraded Water Quality—Stormwater runoff picks up pollutants including sediments, lawn chemicals, and fertilizers as it travels over roadways, parking lots, and maintained landscapes. These nonpoint pollutants are then transported into creeks, lakes, and rivers without any filtering.

Reduced Groundwater Recharge—Conventional detention basin design which focuses solely on moving water rapidly out of the basin reduces the opportunity for groundwater recharge resulting in decreased stream base flow, streambank erosion, and degraded stream habitat.

Degraded Air Quality—The inclusion of traditional turf grasses in convention detention basins requires mowing which results in high levels of carbon monoxide, volatile organic compounds and nitrogen oxides, being emitted into the air. According to the U.S. Environmental Protection Agency, One gas mower spews 87 lbs. of the greenhouse gas CO2, and 54 lbs. of other pollutants into the air every year.

Reduced Habitats—Lawn grasses in conventional basins do not provide any beneficial habitat for birds, insects, and other wildlife.

These environmental impacts are also accompanied by shortcomings associated with the low-flow channel itself including adverse effects such as heating of the stormwater runoff, low infiltration rates, and reduced settling of suspended solids. Cumulatively the negative environmental consequences of traditional stormwater basins have resulted in the need for a more environmentally sensitive approach to basin design.

Naturalized Basin Retrofits

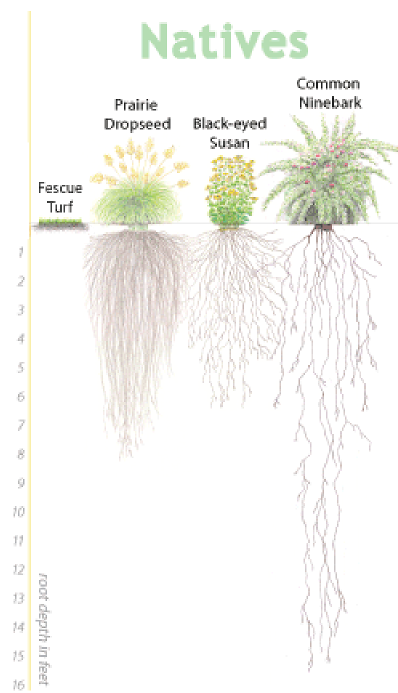
The shortcomings of conventional detention basin design can be addressed by retrofitting them through a naturalization process. The naturalization of a basin is designed to improve water quality, and better manage water quantities, by incorporating a variety of modifications designed to manage runoff from smaller more frequent storms. The primary management strategy of these retrofit modifications is to detain the water within the basin longer than the traditional basin design would allow. These modifications need to be incorporated into an engineering plan for the site to ensure that the basin continues to function effectively. Some of the modifications that can be incorporated into a naturalized basin retrofit include:

Remove the impervious concrete low-flow channel—Remove the low-flow channel to help reduce the velocity and temperature of stormwater runoff.

Replace grass with native vegetation—Plant native trees, shrubs, grasses, and other vegetation that are well-adapted to the environmental conditions of this region. Native vegetation enhances both absorption of rainfall and evaporation of soil moisture due to deeper root systems than traditional mown turf grass.

Drawing 1

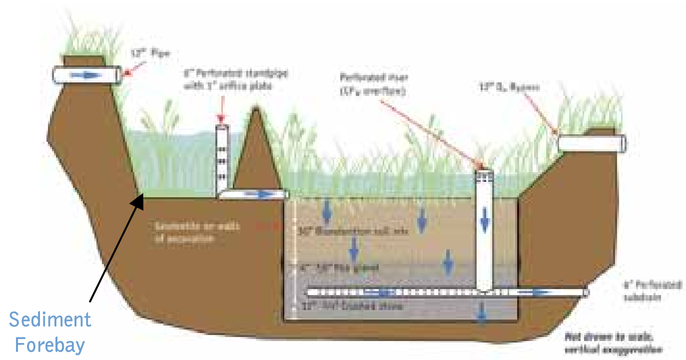
Wildflower and tall meadow plants in naturalized basins have deeper root systems versus mown turf grass allowing these plants to help filter and reduce the velocity of stormwater.



Modify the outlet control structure—Install a water quality orifice such as a weir plate over the lowest orifice of the outlet control structure to create a shallow impoundment or pooling area.

Create a sediment forebay—Create a small basin within the basin after the basin inlet to isolate sediment and other nonpoint source pollutants before the main storage chamber of the basin.

Drawing 2



Sediment Forebay Example

Relocate the inlet point—Relocate the point of inflow to a basin farther away from the outlet to increase the flow path within the basin.

Construct earthen berms—Construct earthen berms inside the basin to direct the flow of water away from the outlet structure and extend the flow path through the basin to allow for increased contact with vegetation.

Create bioretention facilities—Construct bioretention facilities, which are depressed areas in which soils are enhanced with organic material, and planted with trees and shrubs. These facilities can be incorporated either inside the basin or in separate areas that can receive stormwater before entering the basin.

Excavate the bottom of the basin—Flatten the bottom of the basin to spread the stormwater out thus increasing its exposure to vegetation and increasing the infiltration area.

Naturalized Basin Maintenance

Unlike conventional detention basins, which require frequent mowing, naturalized basins require little maintenance, particularly once they are established. The most significant maintenance occurs during the first and second growing seasons when monitoring and controlling weeds is required while the native vegetation is becoming established.

Table 1

Maintenance schedule for Naturalized Basins

	Year 1	Year 2	Ongoing
Mowing	Once a month to a height of 4–6 inches to help control weeds and aid in the root growth of native grasses.	Mow once in early spring (March – April) to a height of 4–6 inches. Mow again in late June / early July to remove cold season grasses to help provide space for warm season grasses.	Mow annually, usually in the early to mid-spring. A second fall mowing can be done if there are significant weeds species that need to be controlled.
Mowing cautions	Mark trees and shrubs to prevent damage during mowing. If regular mowing has not been carried out during the summer and grass and weeds have not developed seed heads, do not mow basins in the fall.	Do not mow between April 1 and mid-June to help protect nesting areas and provide food and cover for young birds. Protect trees and shrubs by marking and leaving an unmown buffer around them.	
Invasive Plants	Remove as necessary including shoots and roots by hand pulling, stem cutting at the ground, and girdling. Avoid the use of pesticides and fertilizers in the basin where possible.	Remove as necessary including shoots and roots by hand pulling, stem cutting at the ground, and girdling. Avoid the use of pesticides and fertilizers in the basin where possible.	Remove as necessary including shoots and roots by hand pulling, stem cutting at the ground, and girdling. Avoid the use of pesticides and fertilizers in the basin where possible.
Other	Remove trash, sediment, and pollutants for inflow and outflow and basin as necessary. Inspect trees and shrubs for damage from mowing, animals or insects.	Remove trash, sediment, and pollutants for inflow and outflow and basin as necessary. Inspect trees and shrubs for damage from mowing, animals or insects.	Remove trash, sediment, and pollutants for inflow and outflow and basin as necessary. Prune trees and shrubs as necessary according to Penn State Cooperative Extension recommendations.

Naturalized Basin Ecosystems

The naturalization of a basin featuring a combination of native plants and some wet areas provides the critical elements for a balanced ecosystem by providing habitats for a variety of animal populations. Beneficial birds and insects will be attracted to a naturalized basin due to the presence of seeds and berries. However, other less beneficial animal populations may also seek habitat within the ecosystem provided by the basin and raise concerns among adjacent neighbors. Frequently expressed concerns include:

Mosquitoes and West Nile Virus—Mosquitoes thrive where standing water lies undisturbed for several days. Standing water can occur in residential areas as well as naturally wet areas. However, the many birds, dragonflies, and toads present in the newly created ecosystem will prey on mosquitoes, gnats, and ticks and help reduce the populations of these. The Pennsylvania Department of Environmental Protection (PaDEP) can provide further information through the West Nile Program.

Lyme Disease—Wherever mice and deer live, the potential for Lyme disease exists. Few residential areas are far from either mice or deer. Mown paths within and around naturalized basins should therefore provide ample setbacks from adjacent properties to help minimize the migration to neighboring homes.

Rodents/Vermin—Some pest animals actually prefer residential areas to a natural meadow. A successful naturalization project will not provide a reliable food source for vermin. Field mice and any other meadow rodents will attract hawks and birds of prey to control these naturally occurring animals.

Appearance—A misunderstanding of the purpose and natural appearance of the basin may also need to be addressed, particularly during the early years while the naturalized plants need time to get established. Mown grass trails through and around the exterior of the basin meadow areas help to convey that the naturalized area is intentional. Trails encourage closer exploration to see the true beauty of the natural site and provide a visual transition between the natural area and the adjacent properties.

West Rockhill Elementary School – Stormwater Basin Retrofit

The stormwater basin at West Rockhill Elementary School in Sellersville was selected from a list of eligible facilities for a naturalized basin retrofit design. The list of eligible sites was prepared as part of an inventory and assessment of all stormwater facilities within the East Branch Perkiomen Creek, portions of the West Branch Neshaminy Creek, North Branch Neshaminy Creek, and Unami-Ridge Valley Creeks conducted in 2005. The inventory and assessment was funded by the Pennsylvania Department of Environmental Protection (PaDEP) Coastal Zone Management and Growing Greener grant programs.

The inventoried facilities were evaluated and ranked for their potential in undergoing a stormwater facility retrofitting process. Ranking of these facilities was based on a variety of factors including ownership; the estimated quantity of pollutants; the magnitude of the water quality improvements a retrofit would provide; ease of access and implementation; and educational impact.

The concept of conducting the stormwater facility inventory and assessment was part of a recommendation for the Pennridge Water Resources Plan to establish a watershed monitoring program. The plan was prepared by the Pennridge Area Coordinating Committee (PACC), an intermunicipal partnership among eight municipalities, the Pennridge School District, the Pennridge Chamber of Commerce, and the Bucks County Community College.

Site Background

Situated on 21 acres in upper Bucks County, West Rockhill Elementary School was completed in September 1990. Stormwater management consists of a large detention basin discharging into the East Branch Perkiomen Creek watershed. The existing detention basin consists of a low-flow concrete channel that increases the rate of runoff. The low-flow channel is subject to short-circuiting due to the proximity of the inlet and outlet structures.

The 0.60-acre basin receives significant amounts of stormwater via a centralized stormwater collection system that collects runoff from roofs, driveways, and the adjacent parking areas. There is evidence of pollutants and sediment transported by stormwater runoff within the basin as evidenced by sediment deposits visible in the low-flow concrete channel.

West Rockhill Elementary School conventional stormwater detention basin showing concrete low flow channel leading to outlet structure near Washington Avenue.

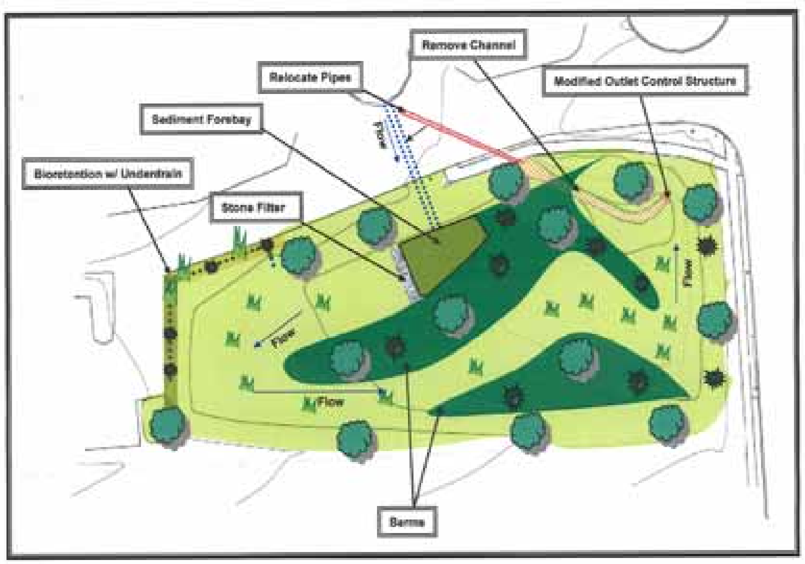
West Rockhill Elementary School conventional stormwater detention basin showing inlet into basin and adjacent impervious surface areas.

Retrofit Design

Initially three separate design concepts were developed by Borton-Lawson Engineering with the objectives of improving the quality of stormwater runoff discharged from the basin. These design concepts featured a variety of modifications, each with different levels of pollutant removal effectiveness.

Alternative 1

Extended Flowpath with Sediment Forebay



Drawing 3

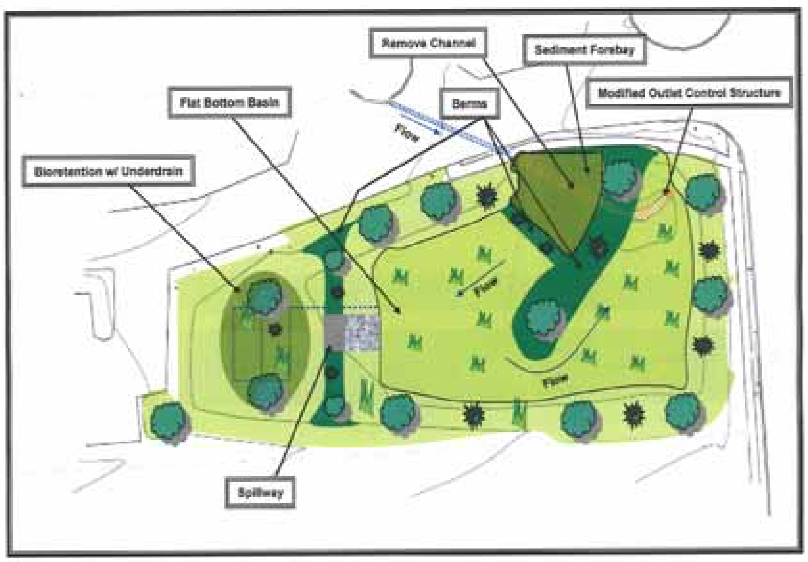
Basin Modifications

- Relocate storm sewer pipes discharging into basin to extend the flow path through the basin;
- Remove low-flow channel to increase filtering by basin vegetation
- Install a sediment forebay;
- Create earthen diversion berms to extend the flow path through the basin;
- Naturalize the basin with native vegetation;
- Install a modified outlet control structure to detain smaller storms in the basin for a longer period of time;
- Create an external bioretention island to provide several layers of treatment.

Pollutant Removal: Low to Moderate

[Alternative 2](#)

Flat Bottom Basin with Internal Bioretention



Drawing 4

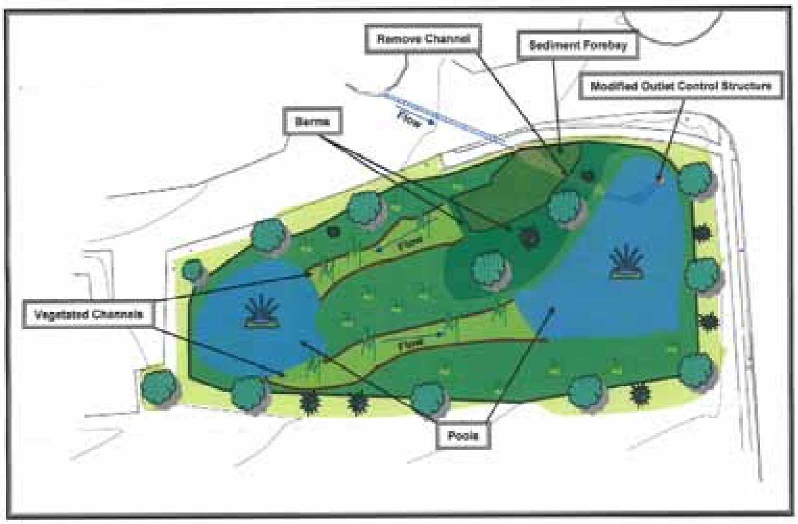
Basin Modifications

- Remove low-flow channel to increase filtering by basin vegetation;
- Create a flat bottom basin to allow the stormwater to spread out across the basin bottom, maximizing infiltration and exposure to vegetation;
- Install a sediment forebay;
- Create earthen diversion berms to extend the flow path through the basin;
- Naturalize the basin with native plants;
- Install a modified outlet control structure to detain smaller storms in the basin for a longer period of time;
- Create an internal bioretention island to provide several layers of treatment

Pollutant Removal: Moderate

Alternative 3

Pocket Wetland with Micropools



Drawing 5

Basin Modifications

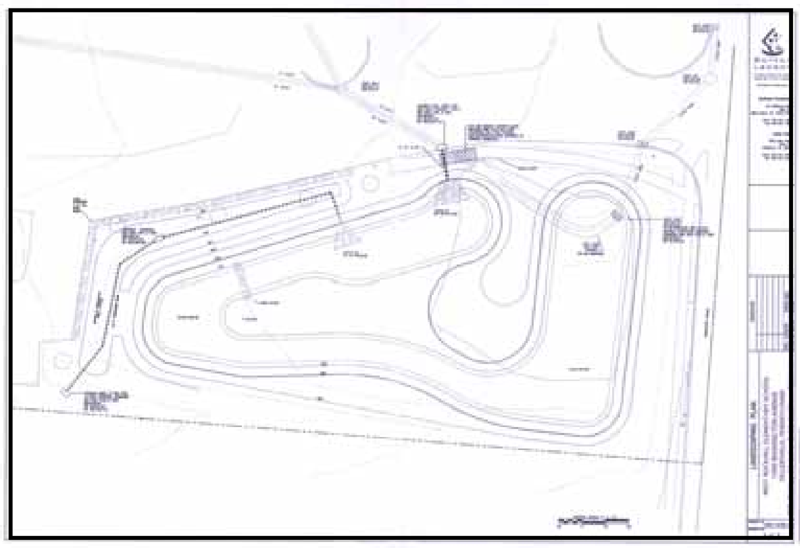
- Remove low-flow channel to increase filtering by basin vegetation;
- Create micropools to support different types of vegetation;
- Install sediment forebay;
- Create stormwater wetland to provide varying water levels and increase biodiversity;
- Create earthen diversion berms to extend flow path through basin;
- Naturalize basin with native plants;
- Modify outlet control structure to detain smaller storms in the basin for a longer period of time;
- Create an irregular basin bottom to support different planting zones;
- Install an aerator (fountain) to increase oxygen within the ponded section of the basin and prevent stagnation.

Pollutant Removal: High

Through a series of meetings with Pennridge School District representatives, a final concept plan, representing a hybrid of the three initial concept plans, was developed to address their concerns over safety, maintenance, and costs.

West Rockhill Elementary School

Final Basin Retrofit Plan



Drawing 6

Basin Modifications

- Remove low-flow channel;
- Create earthen diversion berms, and relocate point of inflow to the basin to extend the flow path through the basin;
- Naturalize the basin with native plants to increase infiltration of stormwater;
- Install a modified outlet control structure to detain smaller storms in the basin for a longer period of time;
- Excavate the bottom of the basin to allow the stormwater to spread out across the basin bottom, maximizing infiltration and exposure to vegetation;
- Create an internal bioretention island to provide several layers of treatment;
- Install a rock filter to trap incoming sediment.

Basin Vegetation Plan

The vegetation plan for the final naturalized basin retrofit plan includes over 85 trees and shrubs, encompassing over 7 species. Vegetation was selected on the basis of sustaining growth in a high moisture presence setting. (See table below)

Qty	Common Name	Scientific Name	Type	Height (ft)	Spread (ft)	Ecological Value	Comments
10	Spice Bush	Lindera benzoin	Shrub	6-12	6-12	Very High – song birds	Red Berries
9	Cranberrybush Viburnum	Viburnum trilobum	Shrub	4-6	4-6	Moderate	White Spring Flowers
14	Low Bush Blueberry	Vaccinium angustifolium	Shrub	0.5-2	2-4	Very High	White flowers, edible berries
15	Arrowwood Virbunum	Viburnum dentatum	Shrub	3-5	3-5	High- attracts birds and butter-flies	White flowers in spring, blue berries in fall
13	Bayberry	Myrica Pennsylvanica	Shrub	5-7	4-6	High-nesting, food, cover	Berries last into winter
8	River Birch	Betula nigra	Tree	35-50	15-35	High –songbirds	Interesting peeling bark
9	Red Maple	Acer rubrum	Tree	40-60	35-45	High- nesting habitat	Tall, fast growing tree
8	Common Serviceberry	Amelanchier arborea	Tree	15-25	12-15	High	White flowers, edible berries

The vegetation plan also includes a variety of smaller herbaceous plants that are typically incorporated as part of a conservation seed mix. The following table lists the species included in a typical mix and the percentages of the seed per species. The mix makes planting easier and the variety of species planted make it nearly certain that a variety of species will survive and thrive in the naturalized basin bottom.

Ernst Conservation Seed Mix-ERNMX-122					
Percent	**Scientific Name**	**Common Name**	**Percent**	**Scientific Name**	**Common Name**
20.00%	*Elymus virginicus*	Virginia Wild Rye	2.00%	*Iris versicolor*	Blue Flag
19.00%	*Carex vulpinoidea*	Fox Sedge	2.00%	*Juncus tenuis, PA Ecotype*	Path Rush, PA Ecotype
6.00%	*Scirpus atrovirens*	Green Bulrush	2.00%	*Mimulus ringens*	Square Stemmed Monkey Flower
5.00%	*Heliopsis helianthoides*	Ox-Eye Sunflower	2.00%	*Scirpus polyphyllus*	Many Leaved Bulrush
5.00%	*Verbena hastate*	Blue Vervain	2.00%	*Vernonia gigantean*	Giant Ironweed
3.00%	*Carex lurida*	Lurid/Shallow Sedge	1.00%	*Carex stipata*	Awl Sedge
3.00%	*Eupatorium perfoliatum*	Boneset	1.00%	*Carex tribuloides*	Bristlebract Sedge
3.00%	*Gylceria grandis*	American Mannagrass	1.00%	*Eupatorium fistulosum*	Joe Pye Weed
3.00%	*Glyceria striata*	Fowl Mannagrass	1.00%	*Geum laciniatum*	Rough Avens
3.00%	*Juncus effuses*	Soft Rush	1.00%	*Glyceria Canadensis*	Rattlesnake Grass
3.00%	*Onoclea sensibilis*	Sensitive Fern	1.00%	*Lilium superbum*	Turk's Cap Lilly
2.00%	*Carex comosa*	Cosmos/Bristly Sedge	1.00%	*Penthorum sedoides*	Ditch Stonecrop
2.00%	*Carex lupulina*	Hop Sedge	1.00%	*Senna hebecarpa*	Wild Senna
2.00%	*Carex scoparia*	Blunt Broom Grass	1.00%	*Solidago patula*	Rough Leaved Goldenrod
2.00%	*Helenium autumnale*	Common Sneezeweed	Seed Rate =1/2 lbs. Per 1,000 S.F.		

Glossary of Terms

baseflow — sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural base flow is sustained largely by ground-water discharges.

evaporation — the process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces. See transpiration.

evapotranspiration — the sum of evaporation and transpiration.

first flush — the initial 0.5 to 1.0 inch of rainfall in which nonpoint source pollutants are washed off of the land surfaces and are transported to receiving water bodies and watercourses.

ground water — (1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturated zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

ground-water recharge — inflow of water to a ground-water reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge.

impervious surface — a surface that cannot be penetrated by runoff and prevents infiltration from occurring.

infiltration — flow of water from the land surface into the subsurface.

non-point source (NPS) pollution — form of pollution caused by sediment, nutrients, organic, and toxic substances originating from land-use activities carried to lakes and streams by surface runoff. Non-point source pollution is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land, it picks up soil particles and pollutants, such as nutrients and pesticides.

runoff — precipitation from rain or melting snow that flows over the ground to natural surface depressions, ponds, lakes, creeks, streams, rivers, or man-made stormwater management facilities.

transpiration — process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores. See evapotranspiration.

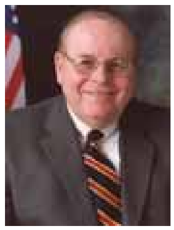
Where can I get more information on retrofitting existing stormwater basins?

Bucks County Planning Commission	215-345-3400
Borton-Lawson Engineering	484-821-0470
Perkiomen Watershed Conservancy	610-287-9383

Websites: www.greenworks.tv/stormwater
www.lowimpactdevelopment.org
www.pecpa.org
www.buckscounty.org

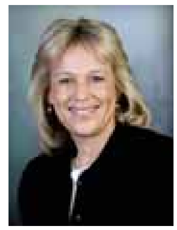
Project Partners

Bucks County Board of Commissioners



Charles H. Martin
Chairman

James F. Cawley, Esq.
Vice Chairman



Diane M. Ellis-Marseglia, LCSW

David M. Sanko
Chief Operating Officer

Bucks County Planning Commission

Darrin Hoffman, *Chairman*
David R. Nyman, *Vice Chairman*
Walter S. Wydro, *Secretary*
Kathleen M. Babb
H. Paul Kester
Edward Kisselback
Carol A. Pierce
David H. Platt

Lynn T. Bush, *Executive Director*

Bucks County Planning Commission

Neshaminy Manor Center
1260 Almshouse Road
Doylestown, PA 18901
Phone: 215-345-3400
Fax: 215-345-3886
E-mail: bcpc@co.bucks.pa.us

engineering Borton Lawson architecture
www.borton-lawson.com

Pennridge School District

1200 North 5th Street . Perkasie, PA 18944 . Phone: 215-453-2710 . Fax: 215-257-4594
www.pennridge.org