



# Green Streets, Clear Skies, Blue Waters

**Gerald Kauffman**

**Director, IPA's Water Resources Agency**

**Sustainable Delaware 2009**

**4th Institute for American Architects Conference**

**October 15, 2009 • Newark, Delaware**

# Top Four Environmental Concerns

*I'm going to read you a list of environmental problems. As I read each one, please tell me if you personally worry about this problem a great deal, a fair amount, only a little, or not at all. First, how much do you personally worry about ... ?*

	Great deal	Fair amount	Only a little/Not at all
	%	%	%
Pollution of drinking water	59	25	16
Pollution of rivers, lakes, and reservoirs	52	31	17
Contamination of soil and water by toxic waste	52	28	19
Maintenance of the nation's supply of fresh water for household needs	49	31	19
Air pollution	45	31	24
The loss of tropical rain forests	42	26	32
Extinction of plant and animal species	37	28	34
The "greenhouse effect" or global warming/ Global warming	34	26	40

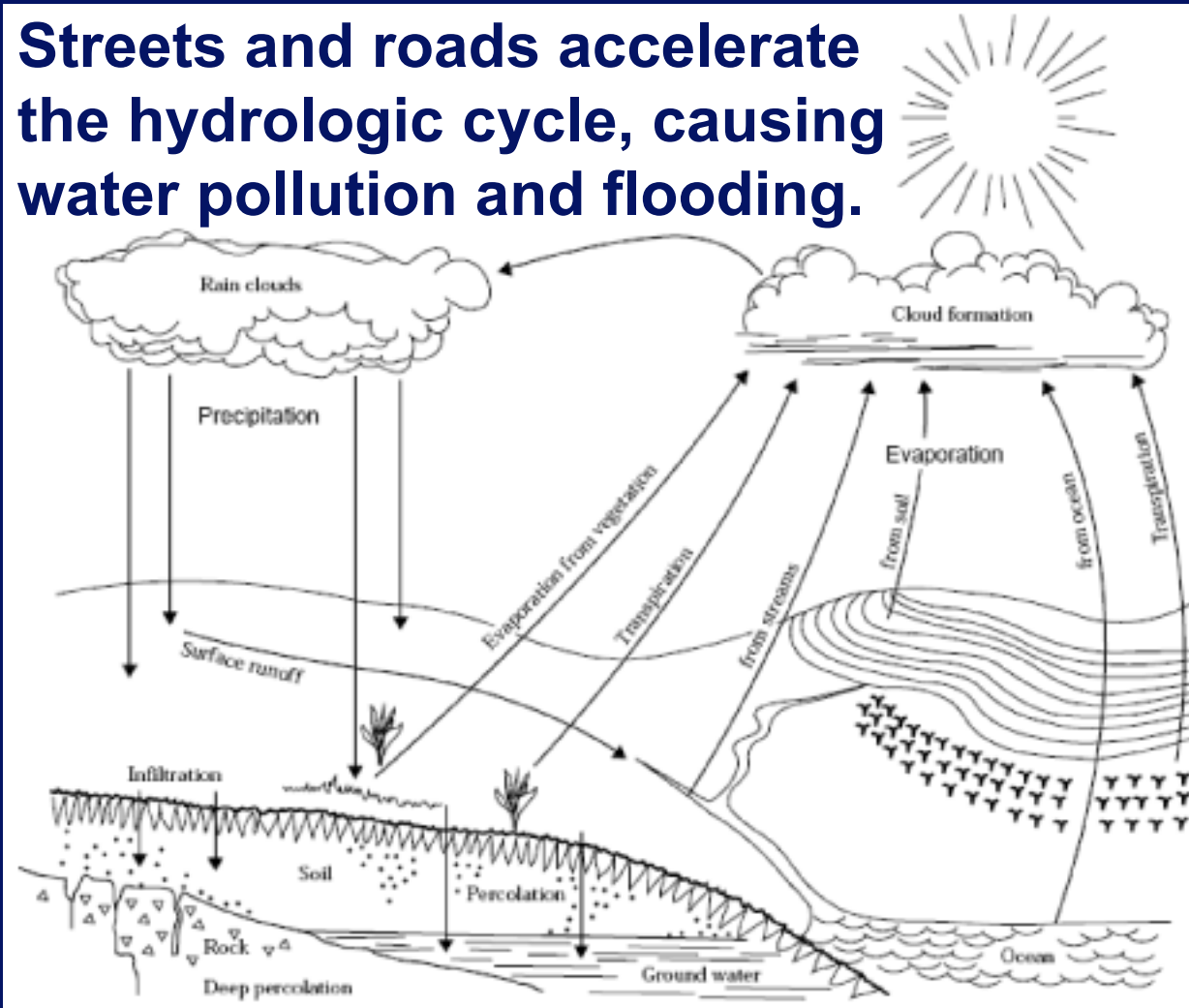
March 5-8, 2009

GALLUP POLL

**The top four concerns of Americans are water-related.**

# The Hydrologic Cycle

**Streets and roads accelerate the hydrologic cycle, causing water pollution and flooding.**



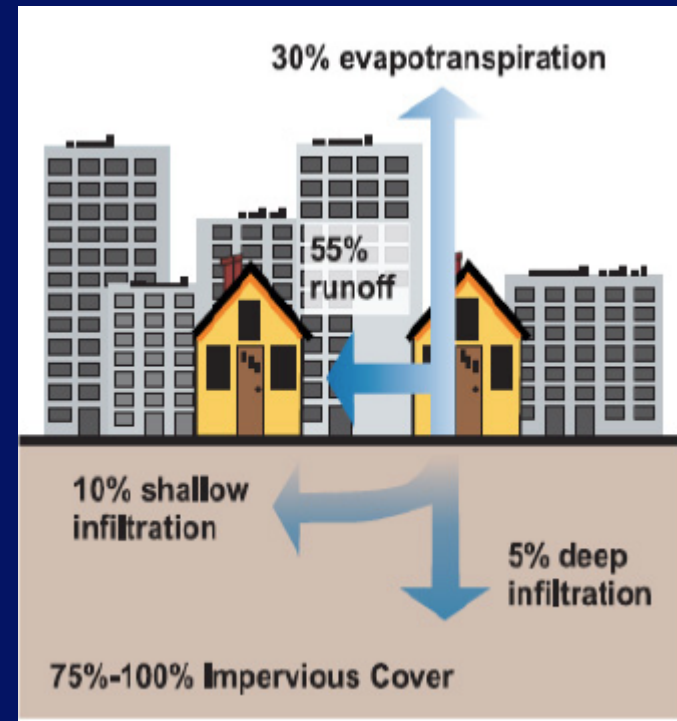
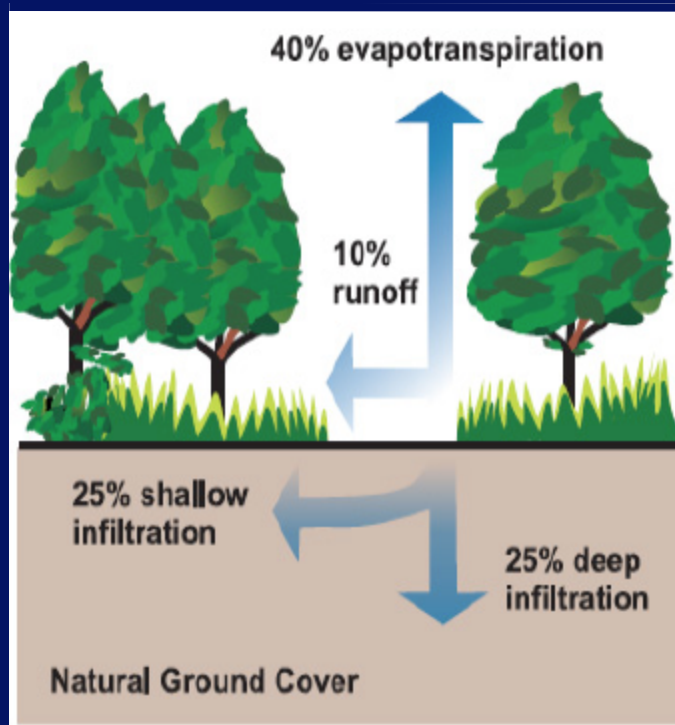
# Hydrologic Basis

$$P = R + I + ET - \Delta S$$

**Precipitation + Impervious Cover  
= Stormwater Runoff**



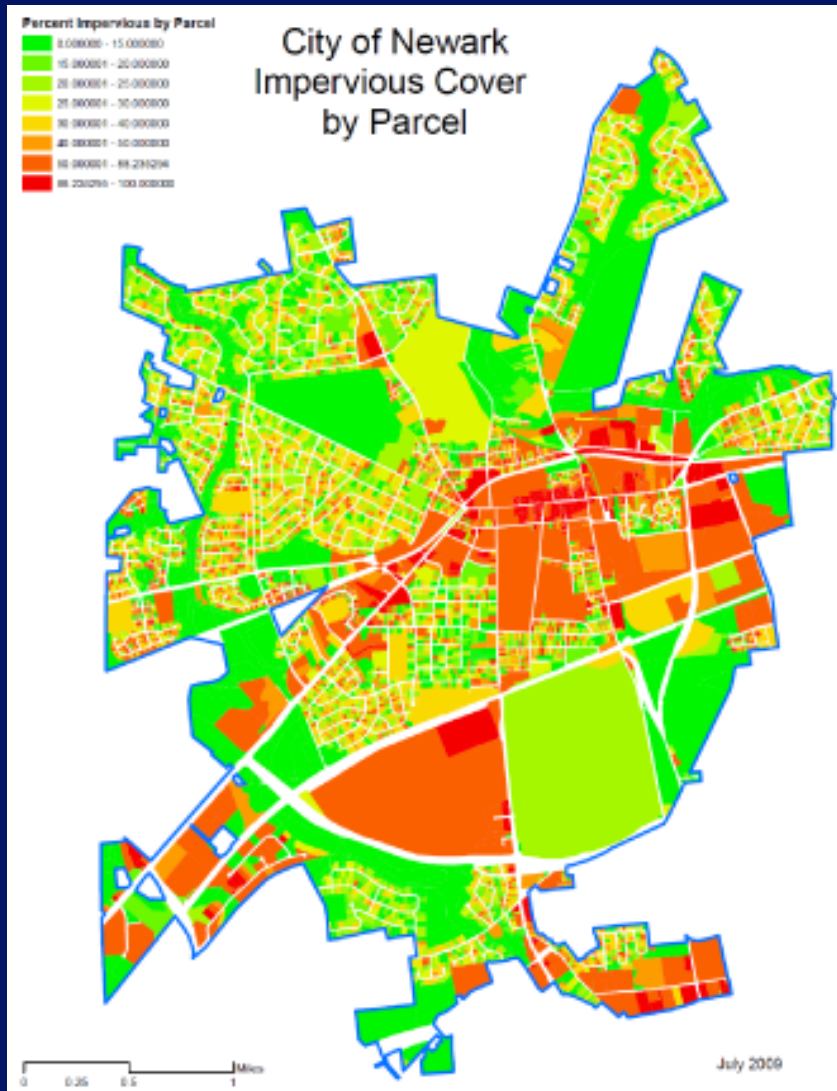
# From the Science of Hydrology



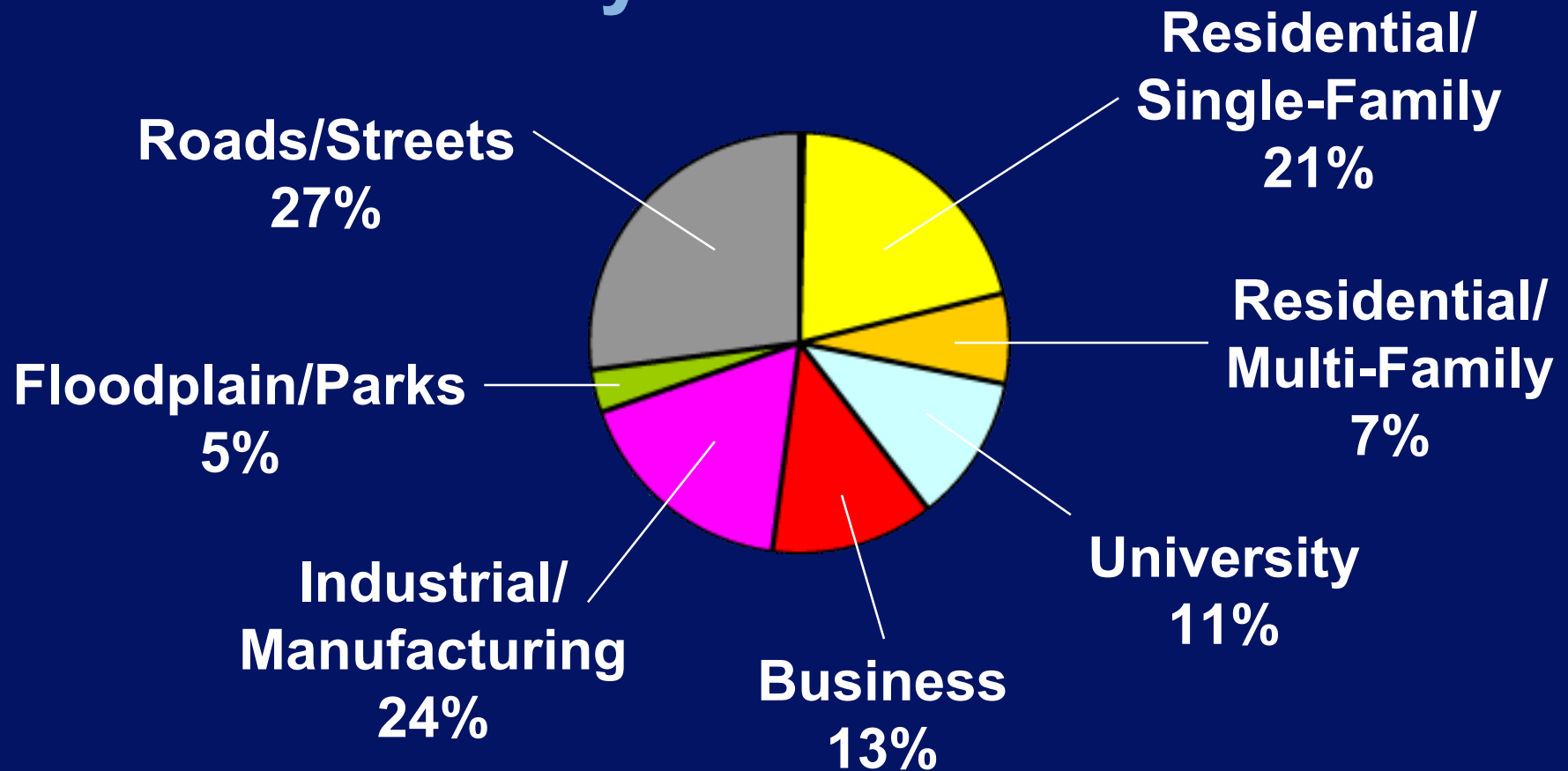
**The quantity and quality of stormwater runoff is directly proportional to the amount of impervious roof and pavement area from roads and streets.**

# City of Newark Impervious Coverage

**Over 30% of the City of Newark is covered by impervious roof/pavement.**



# City of Newark Impervious Cover by Land Use



# What's Old Is New

**“Architects have employed green street design for centuries.”**

- **Greene Countrie Towne** (William Penn 1682)
- **Garden City** (late 18th century)
- **City Beautiful** (early 20th century)
- **Country Place Era** (roaring '20s)
- **Greenbelt** (1930s, Roosevelt's New Deal)
- **New Urbanism** (21st century)
- **Low-Impact Development**
- **Smart Growth**

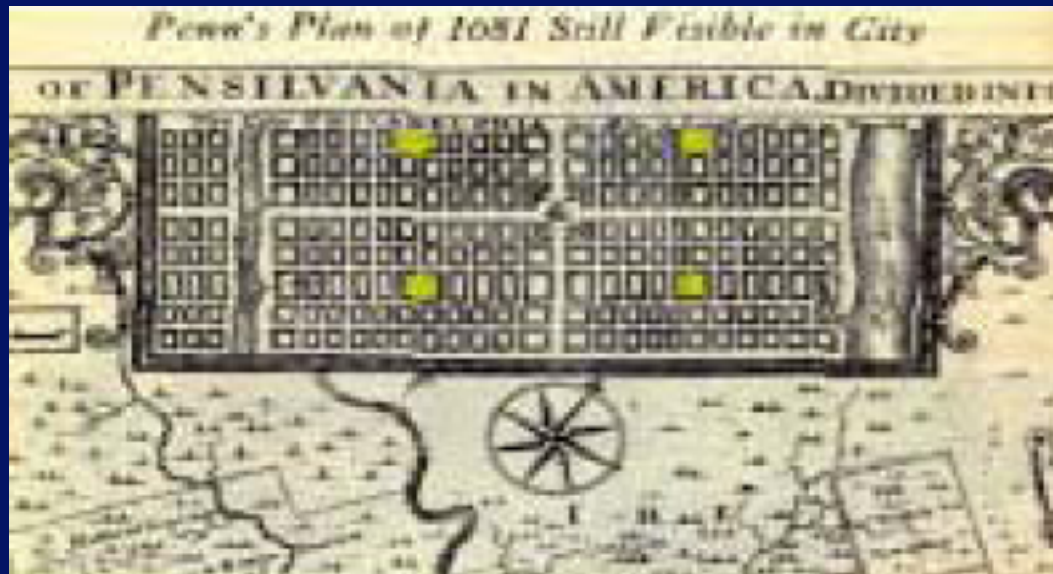
# 300 BCE - Appian Way, Rome



## Quote from William Penn

**“Let every house be placed...in the middle of its plat, as to the breadthway of it, so that there may be ground on each side for gardens or orchards, or fields, that it may be a greene country towne, which will never be burnt and always wholesome.”**

*William Penn, 30th of Sept., 1681, Philadelphia*





# 18th Century Philadelphia



# Philadelphia, Near Independence Hall

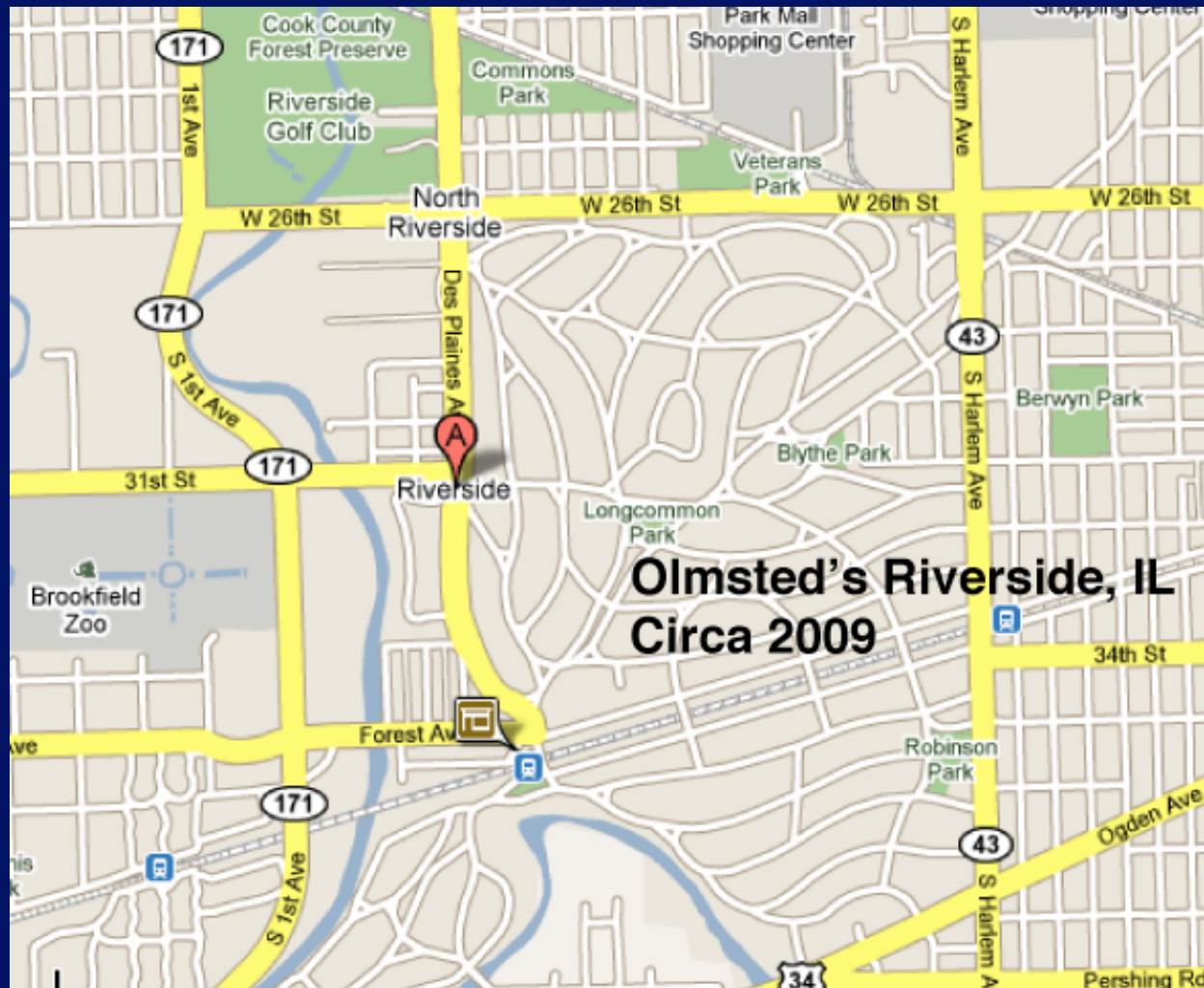




# Olmstead's Riverside, Illinois, c. 1870



# Olmstead's Riverside, Illinois, Today



## Riverside, Illinois

- **Olmsted and Vaux designed in 1868**
- **1600 acres total, 1000 acres as open space**
- **Shaded parkway and boulevards**
- **Preserved floodplain and parks**
- **Curved streets, following land contours**
- **Absence of perpendicular intersections**
- **Narrow streets, 18 ft.**
- **Minimize sidewalks**
- **F. L. Wright and J. Jensen built prairie-style homes here that incorporated green principles.**

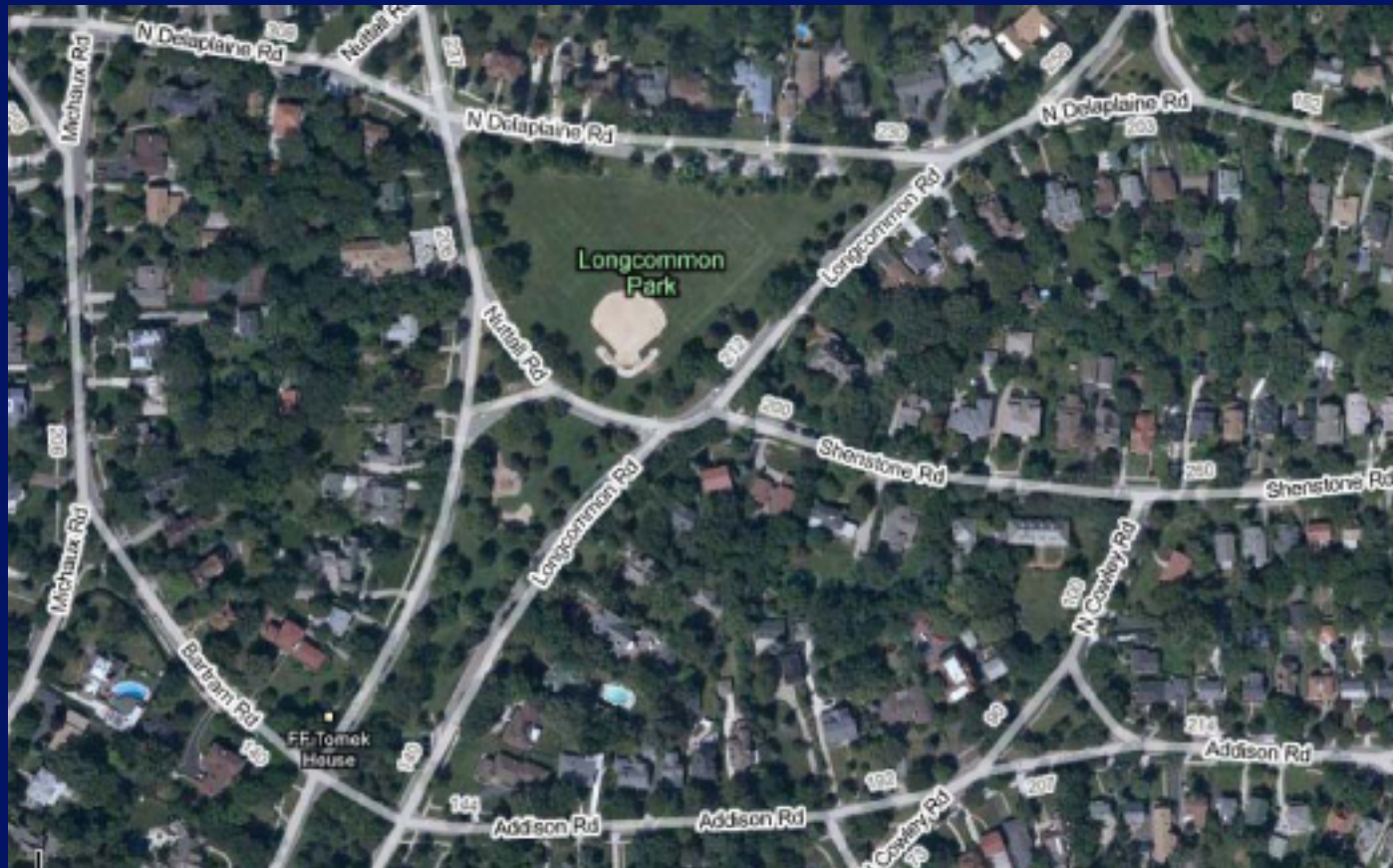
# Olmstead's Design Principles

- **Walks/roads designed for positive drainage**
- **600 ft. to open space from residence**
- **Transportation to city via railroad and parkway**
- **Separate walking paths from driving**
- **100-ft. lot frontage**
- **30-ft. minimum setback**
- **Visual access to open space**
- **Triangle parks**
- **Sunken roads**



# Olmstead's Riverside, Illinois, Today

**Notice triangular parks and narrow 18-ft.-wide roads.**



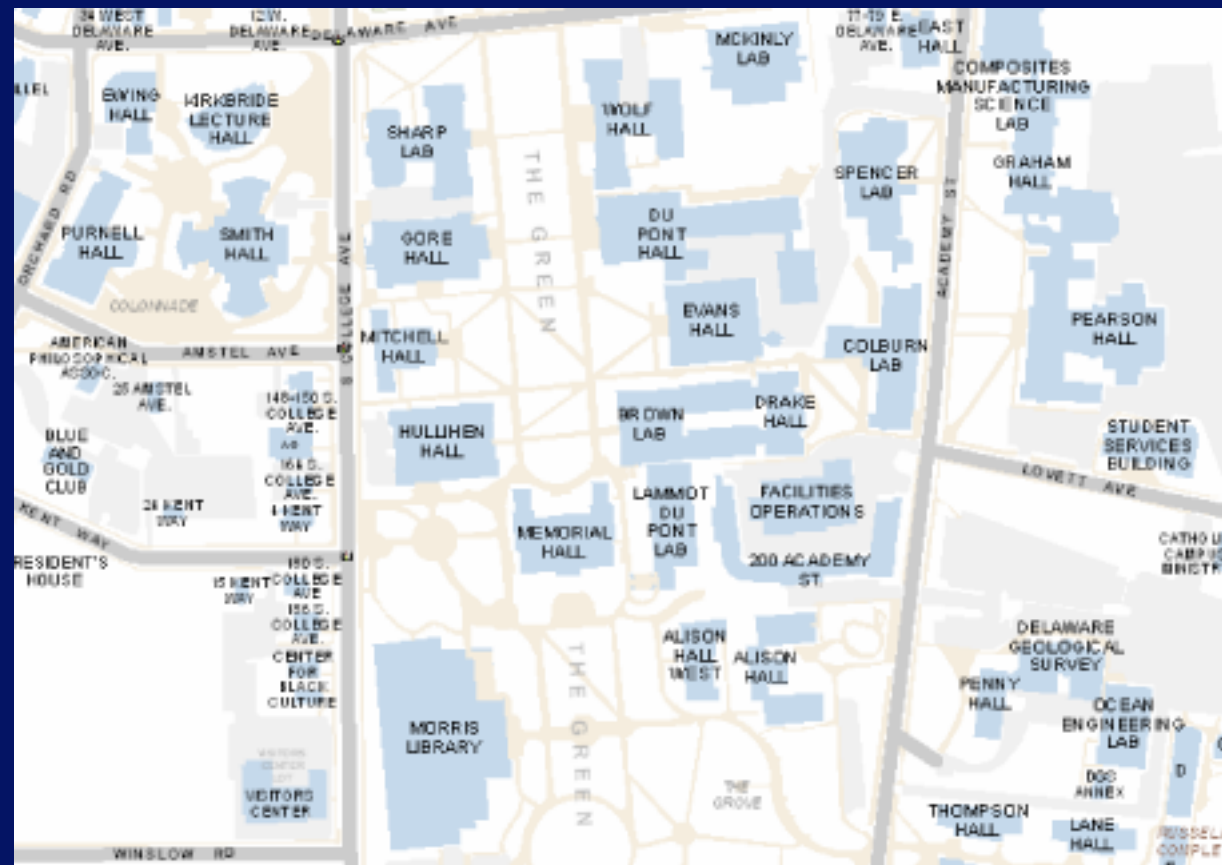
# Olmstead's Riverside, Illinois, Today

**Notice triangular parks and narrow 18-ft.-wide roads.**



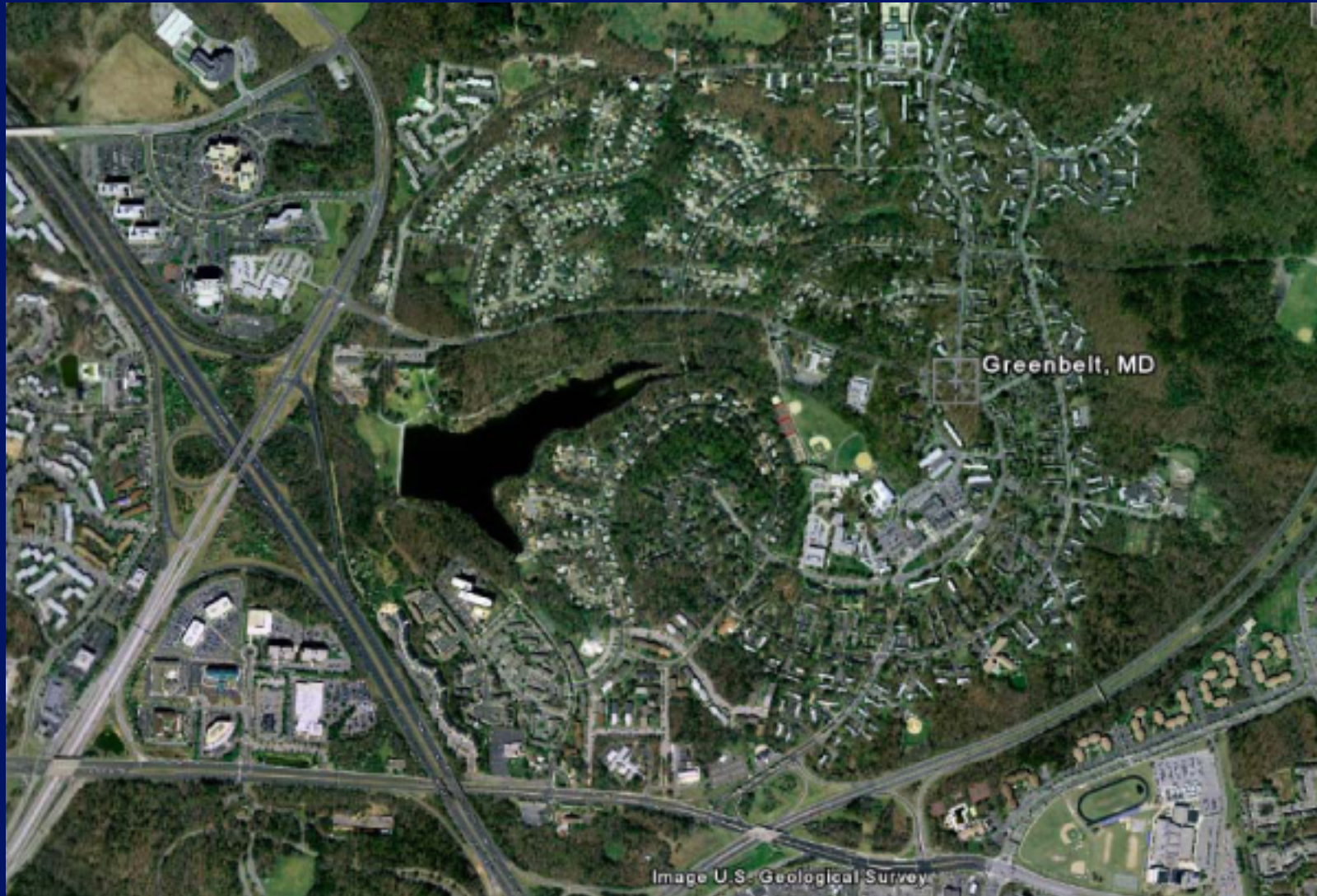
# University of Delaware Campus

**Marian Coffin (1920s) drew landscape plans during Country Place Era. UD campus a giant city block. Optimum Pedestrian floor/area ratio = 0.75**





# Greenbelt, Maryland, 1930s





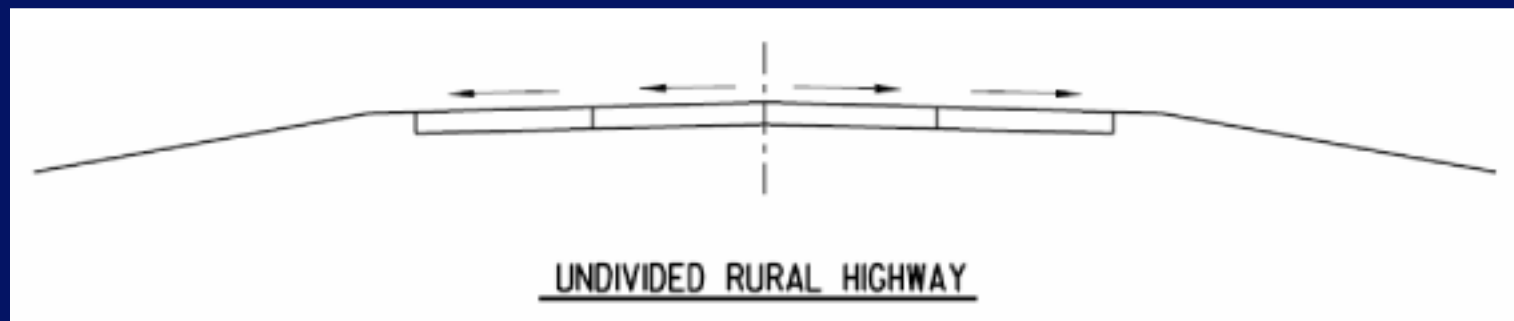
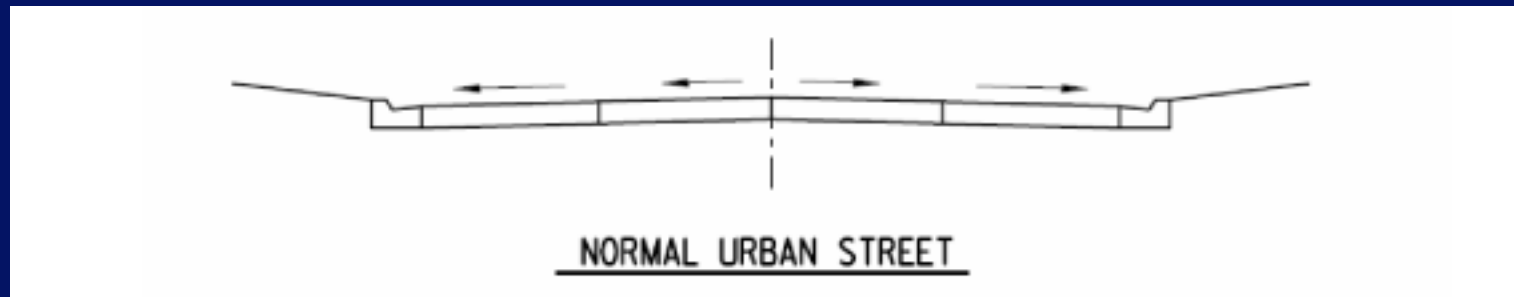
# Greenbelt, Maryland, 1930s

Separation of transportation modes



# Typical Street Design Cross-section

Highway and street design manuals (DeIDOT typ.) require wide street cross-sections. These show typical 48-ft. streets, 12-ft. lanes.





# Arden, Delaware, Built 1900





# Comparison of Road Widths





# Typical New Construction



# The Math of Street Impervious

**Street pavement cost per mile  
(2-in. asphalt @ \$10/yd<sup>2</sup>)**

- **32-ft. street = 168,960 ft<sup>2</sup> = 18,773 yd<sup>2</sup> = \$187,730**
- **24-ft. street = 126,720 ft<sup>2</sup> = 14,080 yd<sup>2</sup> = \$140,800**
- **18-ft. street = 95,040 ft<sup>2</sup> = 10,560 yd<sup>2</sup> = \$105,560**

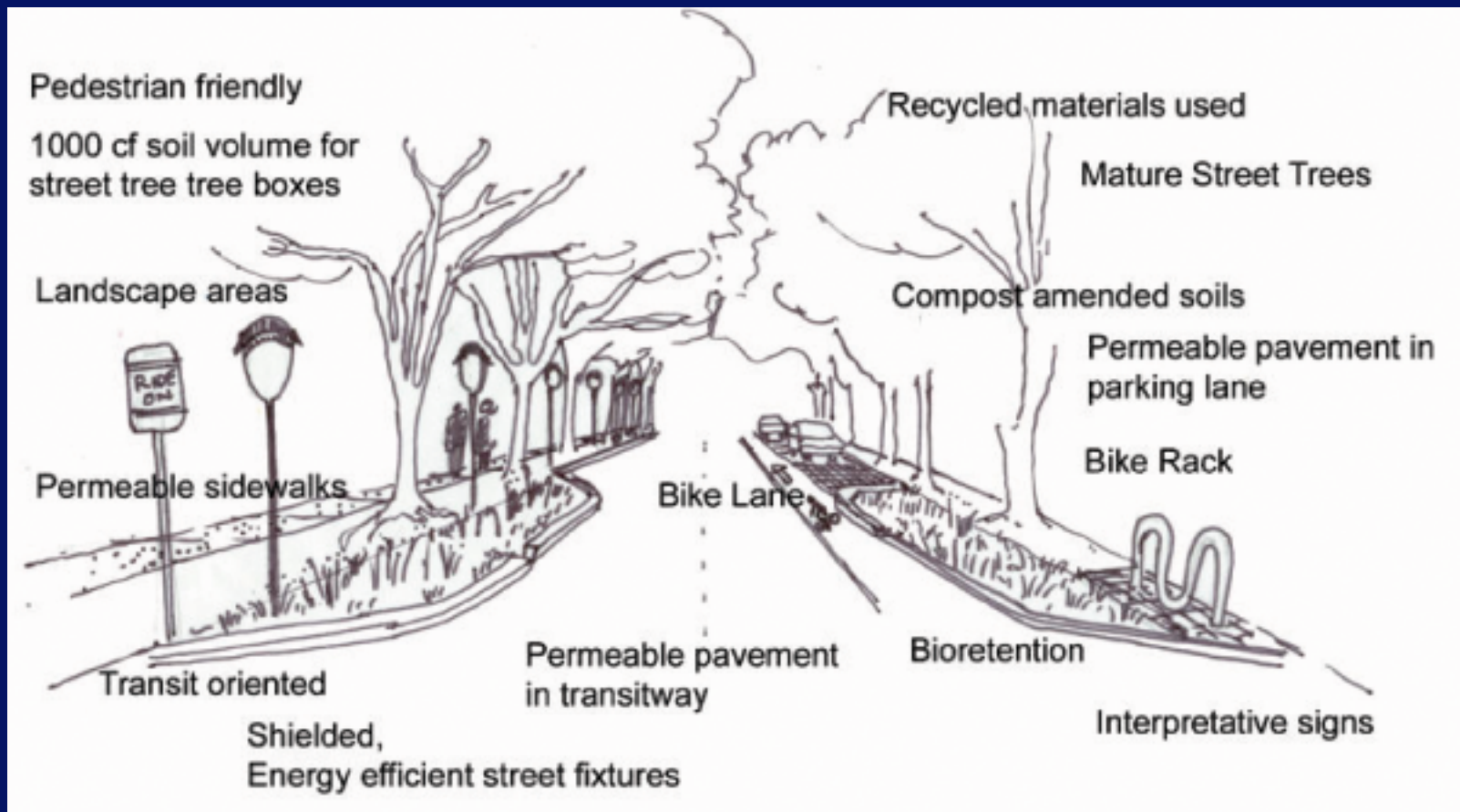
# “Green Street” Techniques

**“available to mitigate impervious impacts”**

- **1. Rain Harvesting**
- **2. Rain Gardens**
- **3. Stormwater Planters**
- **4. Permeable Paving**
- **5. Green Roofs**

**Sources: Cities of Portland and Seattle and EPA**

# Anatomy of a Green Street

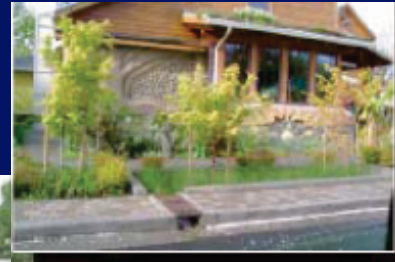
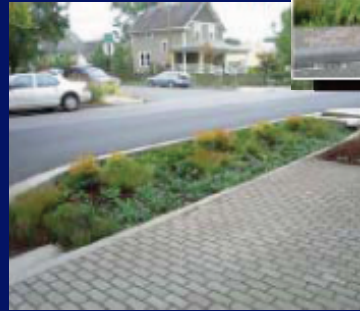




# Examples



# Examples

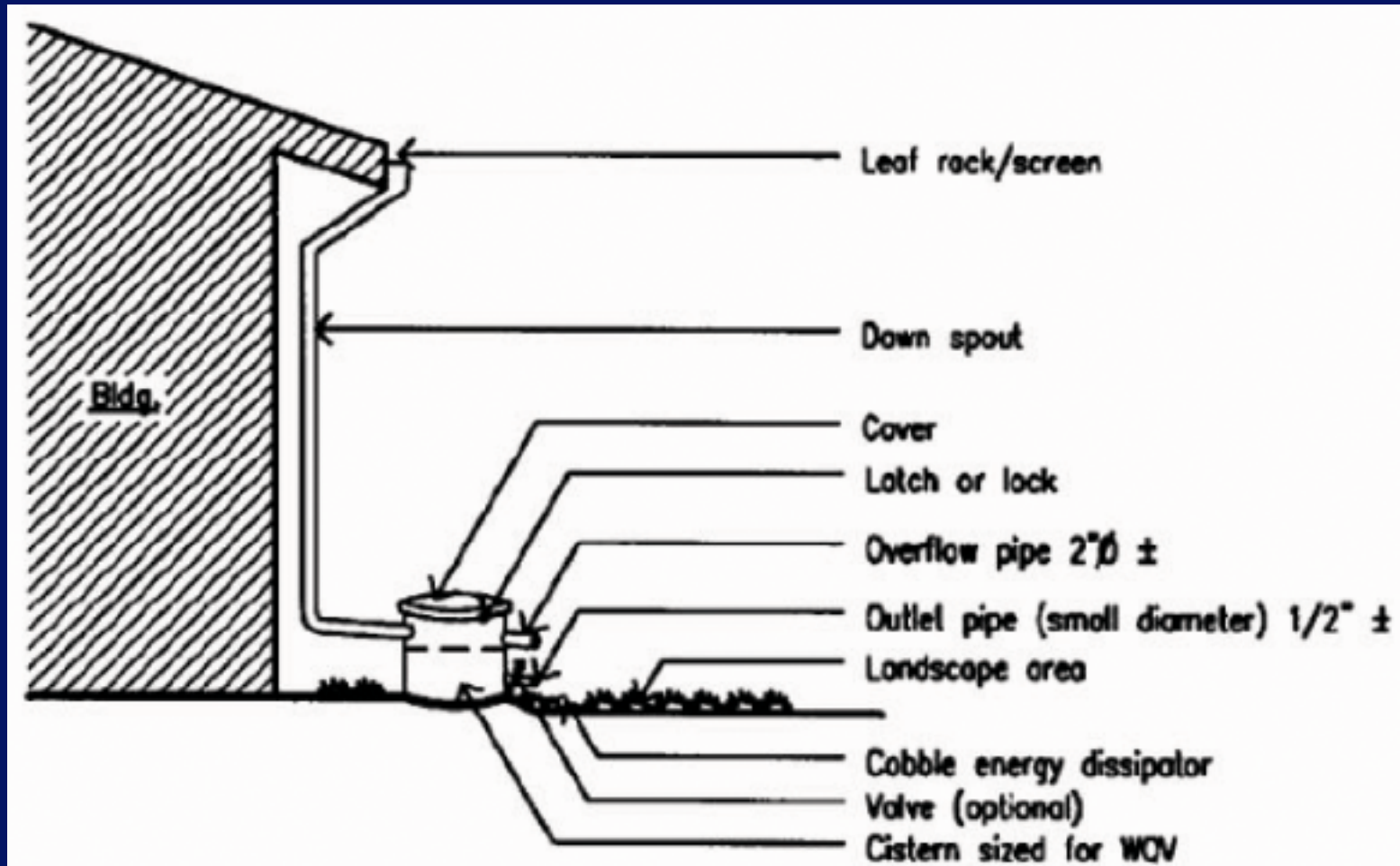




# Examples

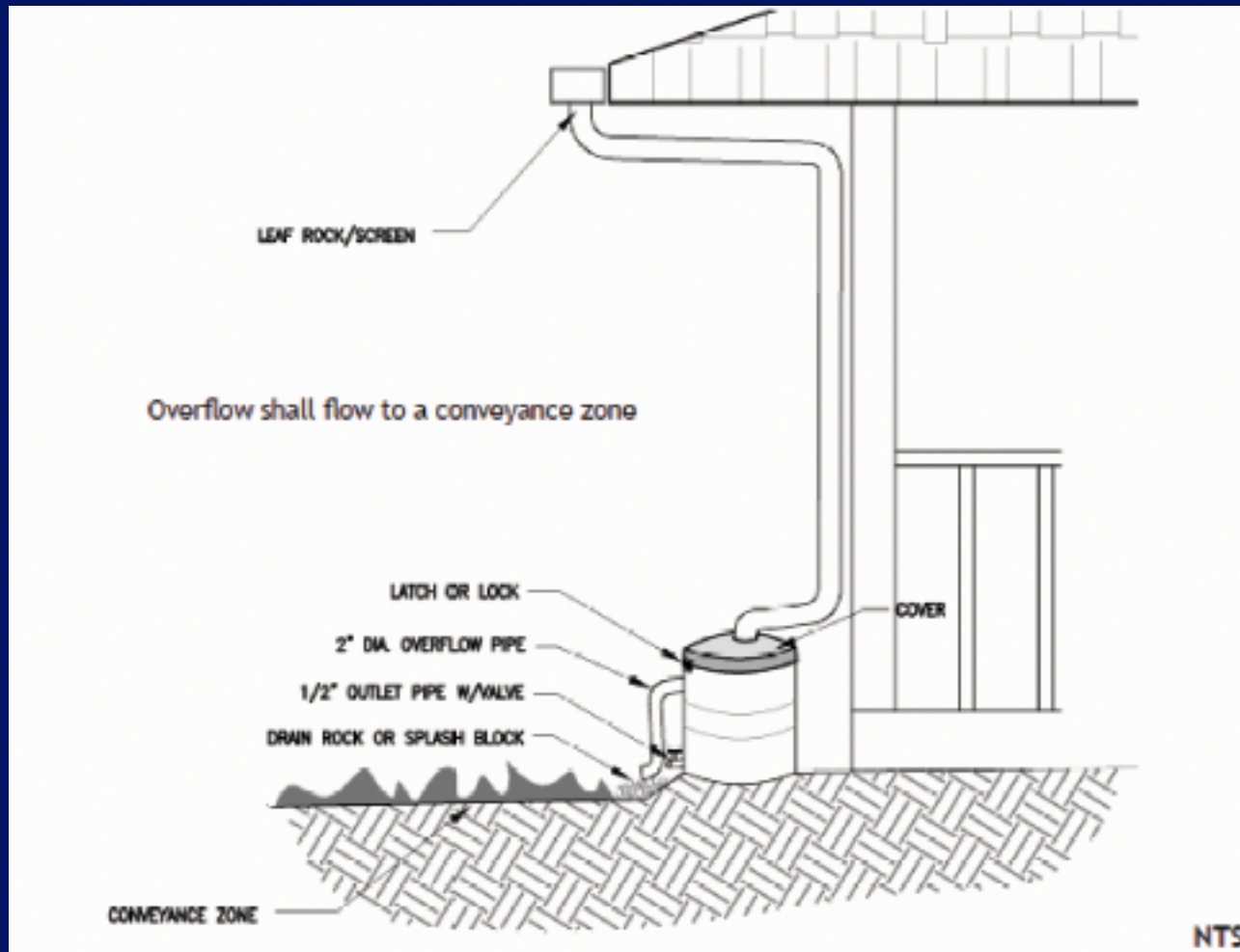


# 1. Rain Harvesting



Bay Area Stormwater Management Agencies Association, *Start at the Source* (1999)

# Rain Barrel Connected to Downspout





# Examples



# Chicago





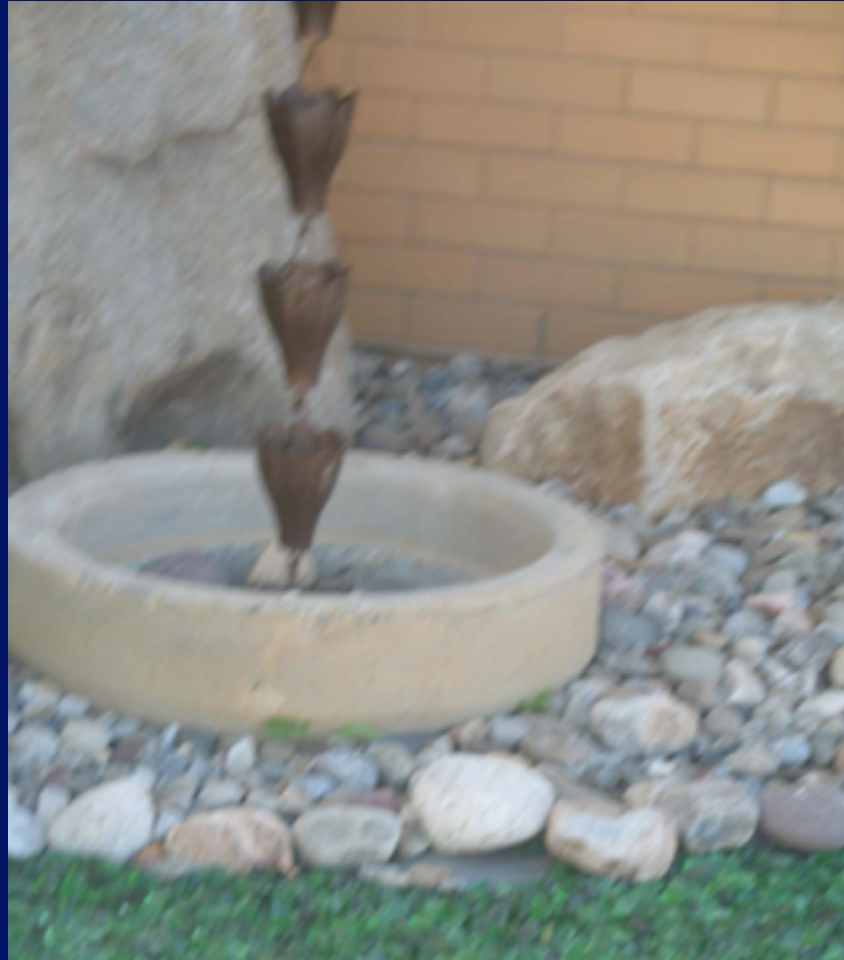
# Cisterns at CBF Headquarters



Photo: Chesapeake Bay Foundation



# Rain Spout



**Dansko, West Grove, Pa.**

# Cistern

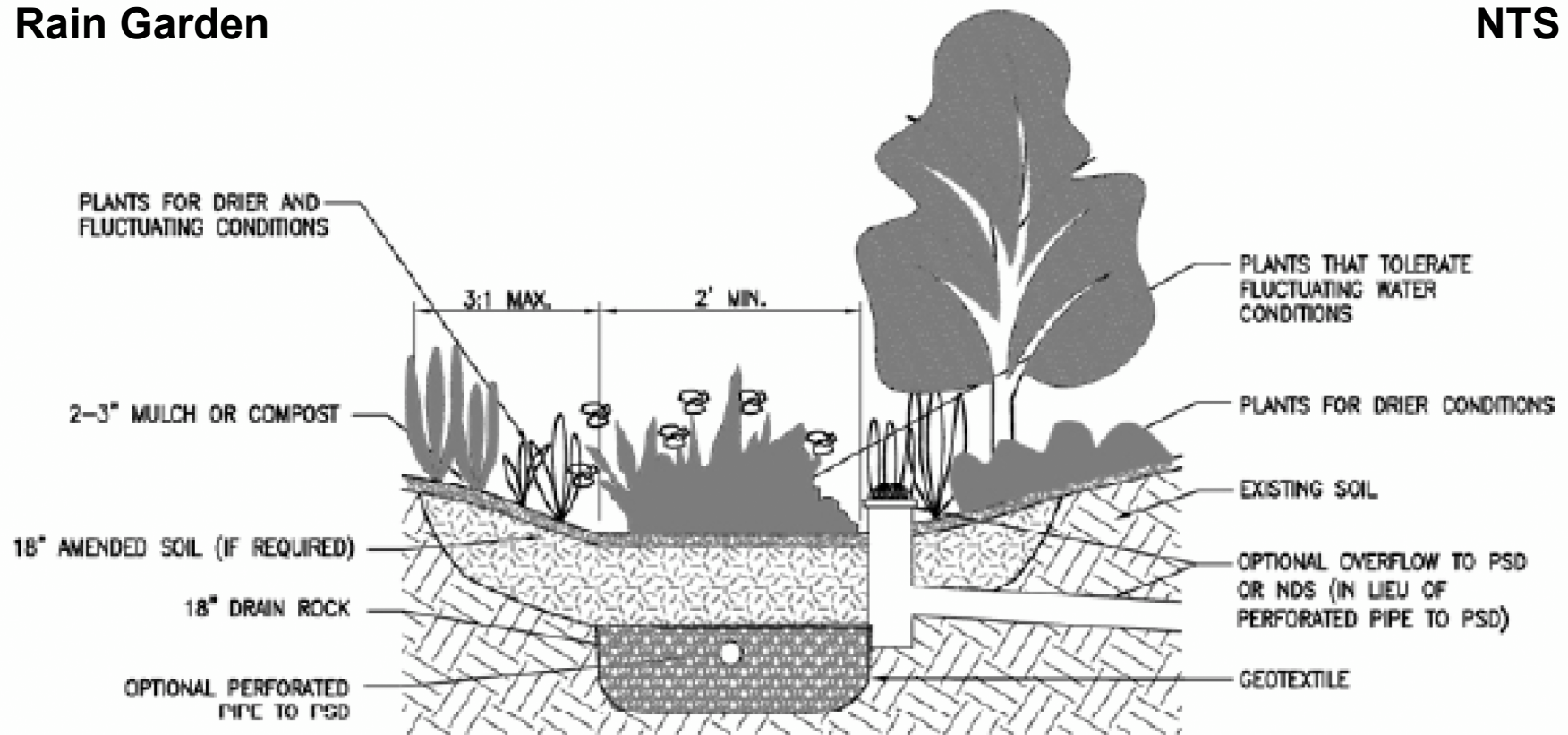


Cistern  
Rain, stream, ocean  
Woodlawn Library  
Wilmington, Del.

## 2. Rain Gardens

### Rain Garden

NTS



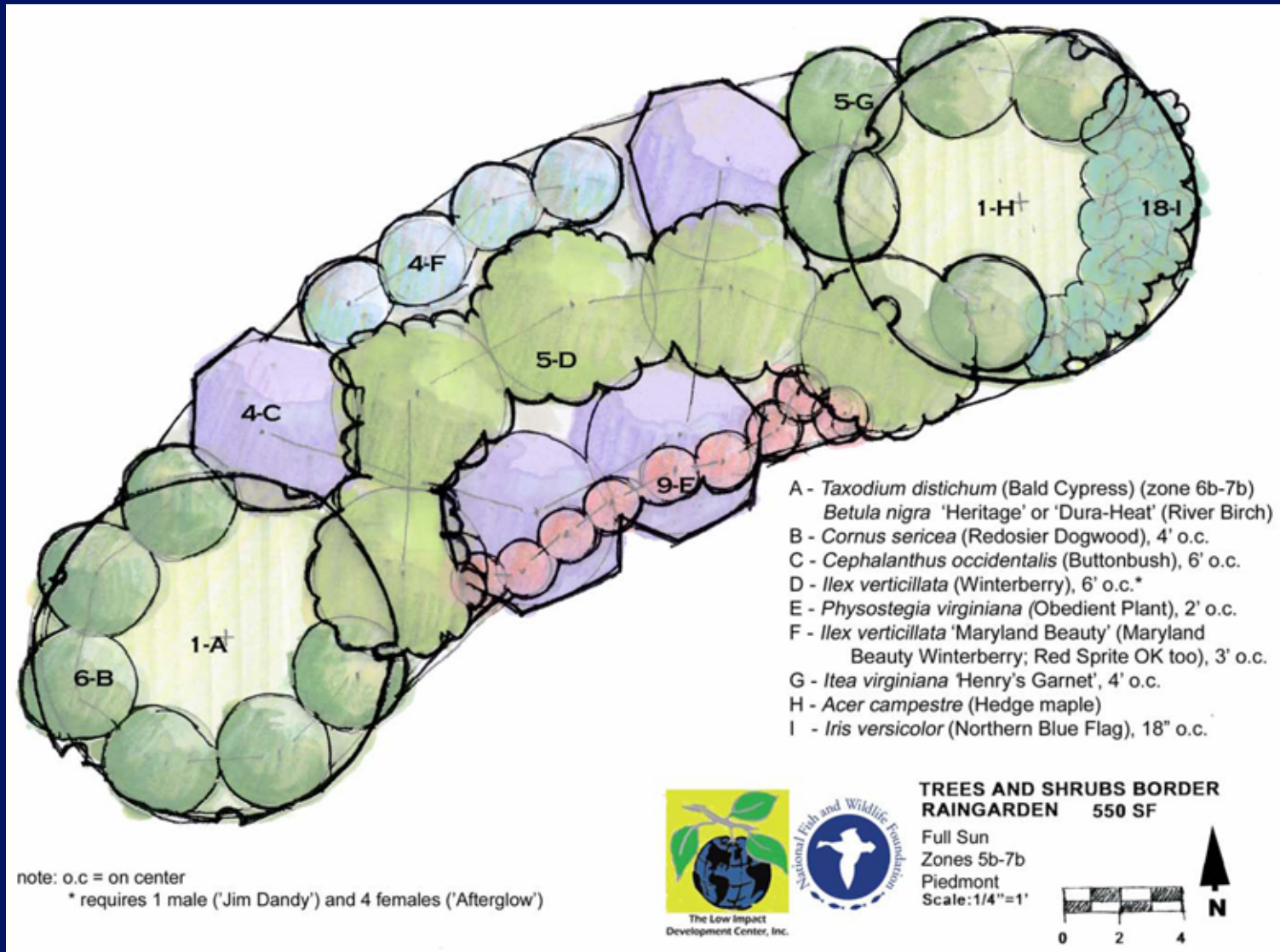


# Residential Rain Garden



**Rain gardens can be planted and shaped to fit the character of individual residences.**

# Design





# Rain Garden



Rain Garden  
Dansko  
West Grove, Pa.



# Rain Garden





# UD Rain Garden Educational Signage



**Rain Garden**

## A Rain Garden's Benefits and Beauty

**What is a "Rain Garden"?**

A rain garden is a shallow landscaped depression that captures the rain as it runs off impervious surfaces. This allows the collected water to evaporate into the air, soak into the ground, or be absorbed by plants and turned into oxygen.

**Why do we need "Rain Gardens"?**

As you look around and notice sidewalks, driveways, parking lots, and rooftops, these surfaces do not allow rain to soak into the earth. Rain falls on these surfaces and immediately runs off directly into our streams and rivers, often collecting ground pollution such as fertilizers, pesticides, oil from cars, dog waste, and garbage. This results in an accumulation of a large volume of stormwater runoff, eroding streambeds as it rushes to our waterways bringing all sorts of pollutants with it. This is not only harmful to the plants and animals living in these waterways but also to people, as many people depend on these surface waters for their clean drinking water. Those who get their clean drinking water pumped up from the ground are also affected, because the impervious surfaces do not allow water to soak back into the ground to replenish the supply.

**What do "Rain Gardens" do?**

- Reduce the opportunity for flooding
- Create habitat for wildlife like birds and butterflies
- Protect rivers and streams from erosion and pollution
- Conserve water by utilizing a natural resource like rain for free

- Promote infiltration of water to replenish groundwater
- Enhance aesthetic appeal, thereby increasing property value
- Reduce landscape maintenance by eliminating the need for fertilizers, pesticides, and mowing

**Designing a Rain Garden**

1. Determine your ideal rain garden site. Always locate the rain garden near a stormwater outlet like an existing grate or swale to treat any overflow above the garden's capacity.
2. Determine the amount of rain draining into the garden.
3. Determine the desired size of your rain garden.
4. Determine the infiltration rate at which rain soaks into the soil of the rain garden. Initially, this rain garden did not infiltrate all of the collected stormwater within the ideal timeframe. Further investigation found that under the top four feet of clay was a sand layer and then a gravel layer. Thirteen 7.5 foot borings were augered into the sand and gravel layer and then backfilled with half-inch stones. This allowed the water to infiltrate within the ideal four-day period.





5. Determine the depth by ensuring that the rain garden will only hold water for up to four days. Try to avoid heavy machinery from entering the rain garden depression.
6. Determine your planting selection and design.


















Photo credit: UD Rain Garden Project. Photo credit: UD Rain Garden Project. Photo credit: UD Rain Garden Project. Photo credit: UD Rain Garden Project. Photo credit: UD Rain Garden Project.

The observation patio area you are standing on was made using a permeable paving technique that promotes stormwater infiltration and decreases runoff. The patio and steps were installed by Creative Pavers ([www.creativepavers.com](http://www.creativepavers.com)).



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# UD Rain Garden



Rain Garden  
UD  
Newark, Del.



# UD Rain Garden





# Rain Garden

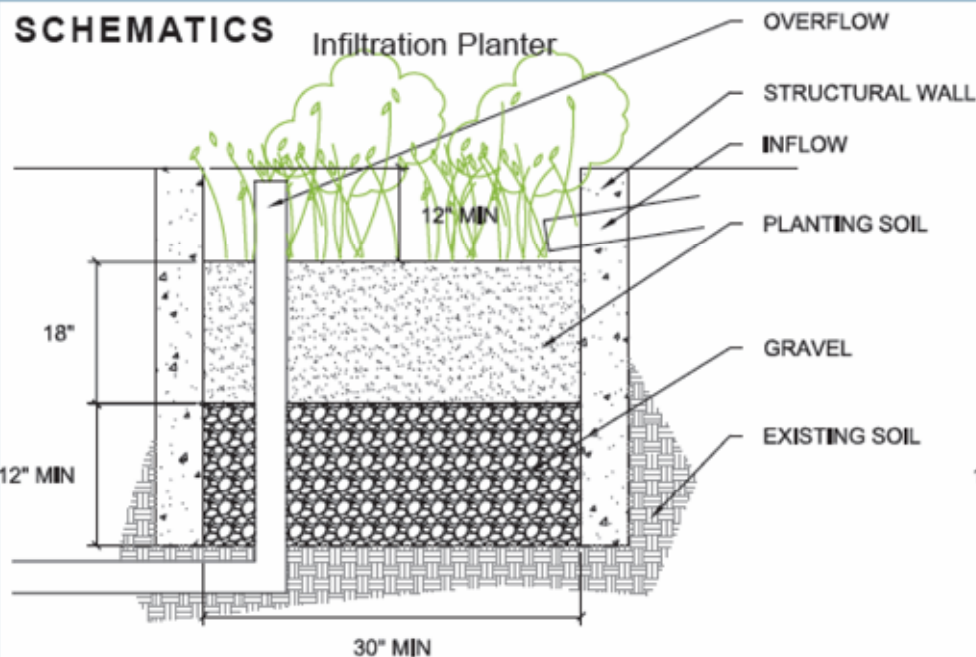


Rain Garden  
Woodlawn Library  
Wilmington, Del.

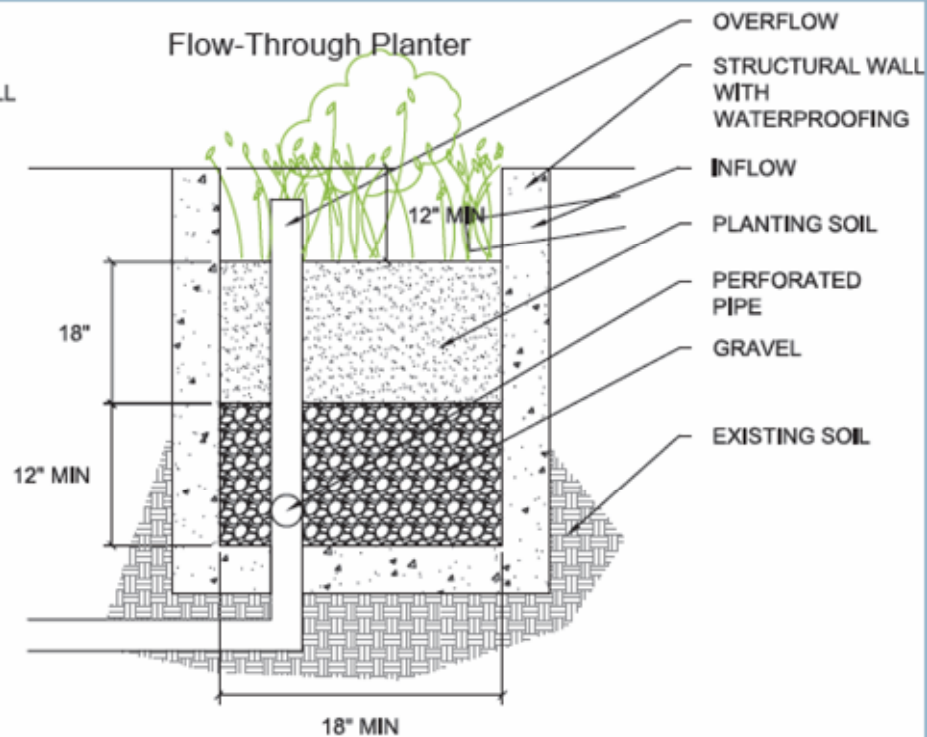
# 3. Stormwater Planters

## SCHEMATICS

### Infiltration Planter



### Flow-Through Planter



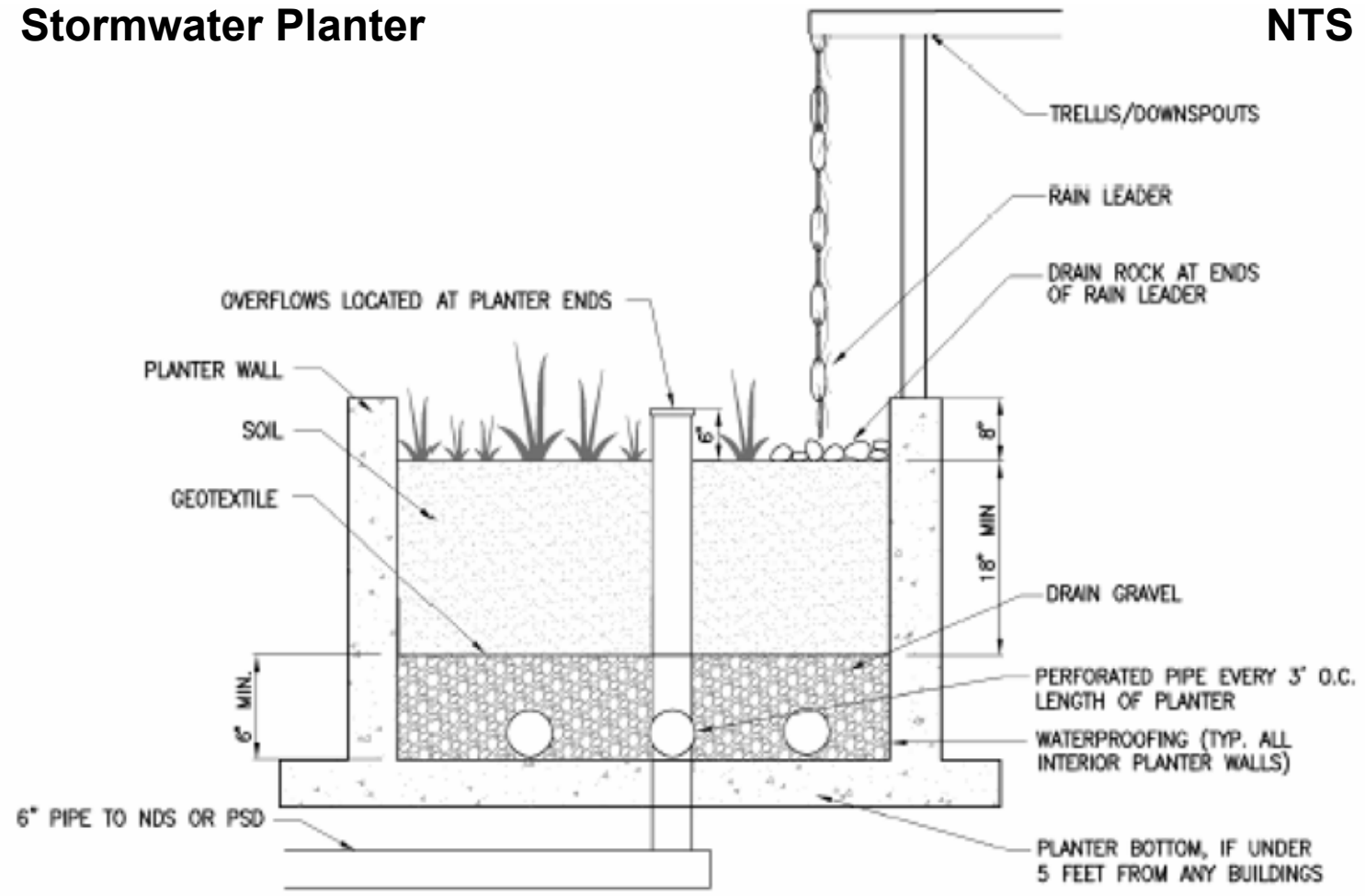
Adapted from:  
 Portland: Stormwater Management Manual (Adopted July 1, 1999, Revised September 1, 2004)  
<http://www.portlandonline.com/bes/index.cfm?c=dfbbh> Accessed 01/29/2008



# Stormwater Planters

## Stormwater Planter

NTS



# Stormwater Planters

## Stormwater Planter

Alternative Names: Infiltration Planter, Flow-Through Planter, Contained Planter



### DESCRIPTION

A stormwater planter is a small, contained vegetated area that collects and treats stormwater using bioretention. Bioretention systems collect and filter stormwater through layers of mulch, soil and plant root systems, where pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed. Treated stormwater is then infiltrated into the ground as groundwater (Infiltration Planter) or, if infiltration is not appropriate, discharged into a traditional stormwater drainage system (Flow-Through Planter). Stormwater planters do not require a large amount of space and can add aesthetic appeal and wildlife habitat to city streets, parking lots, and commercial and residential properties. Stormwater planters typically contain native, hydrophilic flowers, grasses, shrubs and trees.

# Street-side Application

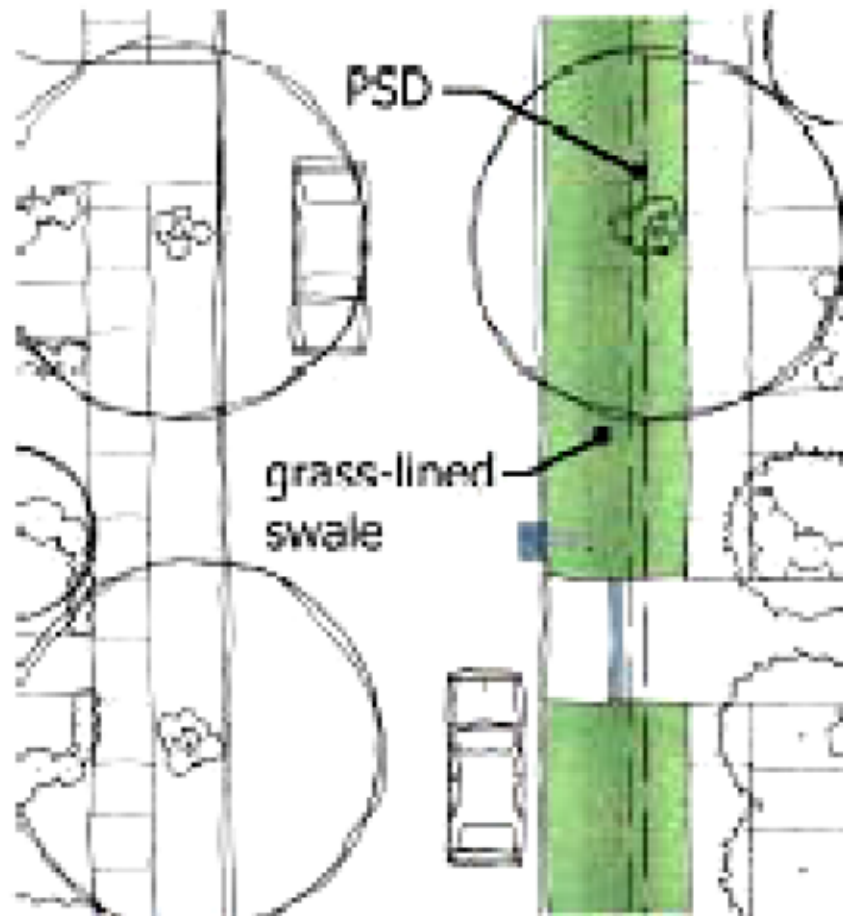




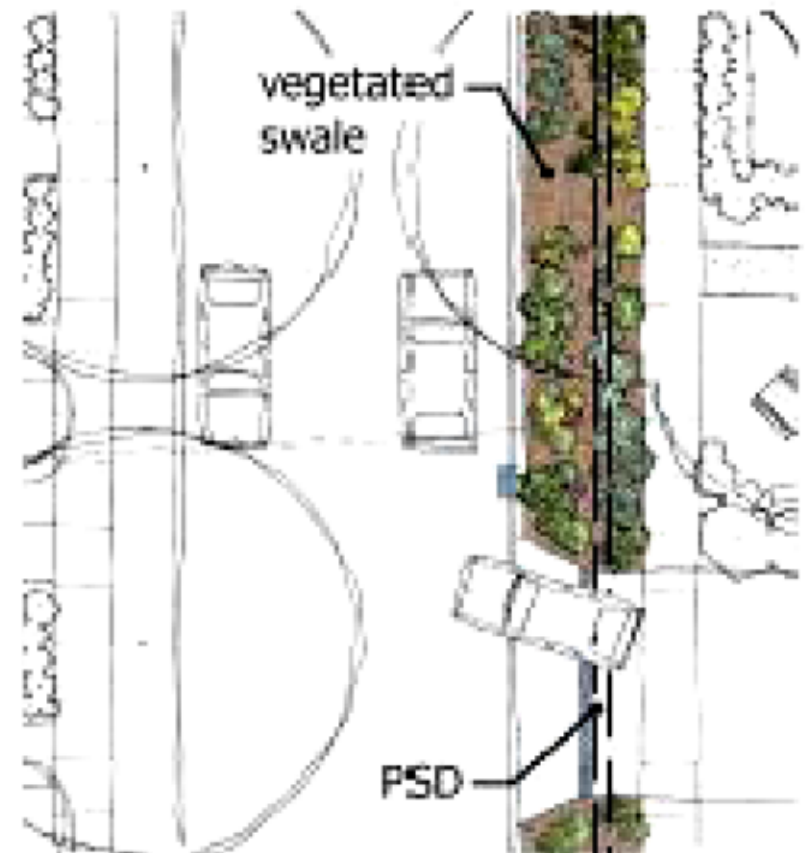
# Street-side Application



# Street-side Application



*Grass-lined swale in the NDS with the PSD buried below*



*Vegetated swale in the NDS with the PSD buried below*

# Example Swales



**NDS**  
**(grass-lined swale in ROW)**



**NDS**  
**(vegetated swale in ROW)**



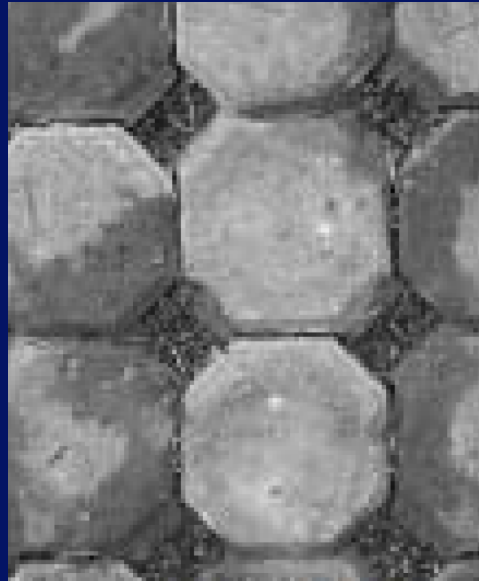
# Example



## 4. Permeable Paving



**water infiltrates  
through porous  
gravel mat**

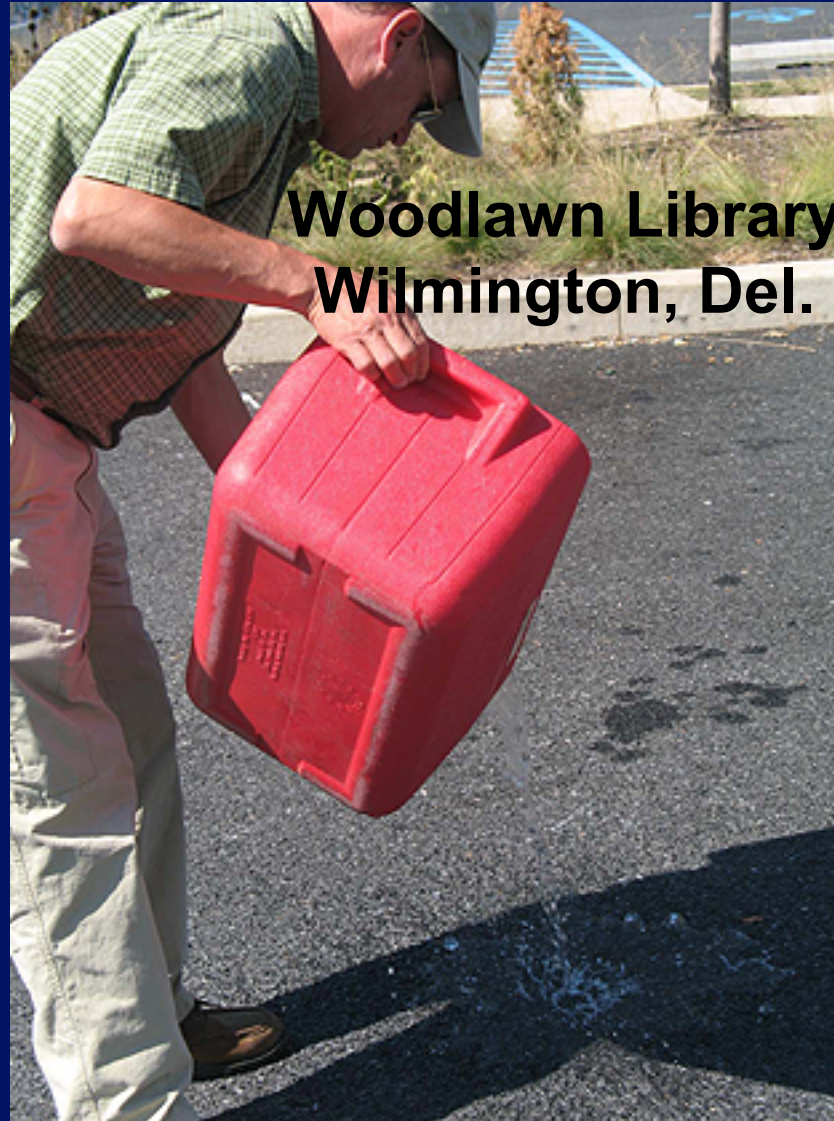


**pavers on a  
porous base with  
sand-filled joints**



**water passes  
through void  
spaces in  
porous concrete**

# Permeable Paving



**Woodlawn Library  
Wilmington, Del.**



# Woodlawn Library, Wilmington, Del.

*Woodlawn Library* **Stormwater Management System**

*Though the parking lot looks like a typical pavement— it isn't!*

*Most of this parking lot has been paved with pervious asphalt that allows rainwater to soak into a storage bed below the surface. Rather than letting rainwater flow off the surface, this parking lot acts like a sponge and absorbs stormwater, allowing it to soak into the groundwater aquifer— just like it did before we built anything. Because the pavement is porous, it can't be used everywhere (gas stations, loading docks, etc.) and requires different maintenance such as mechanical street sweeping to keep the pores open.*

**Porous Pavement • A Pervious Parking Surface**

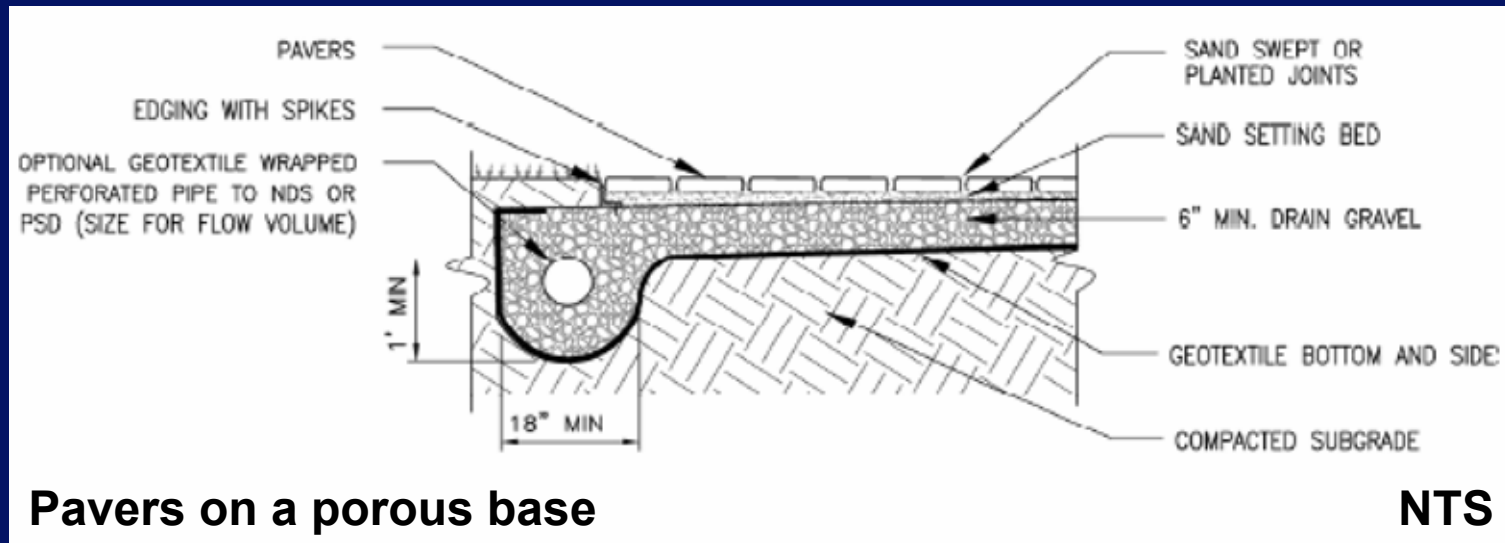
Standard asphalt

Porous Asphalt

- 1 Rainfall lands on the parking lot surface.
- 2 ...so it flows through the holes in the pavement.
- 3 ...into the 'bed' below. The 'bed' is filled with clean uniform graded stone.
- 4 ...recharging the aquifer and groundwater.

Permeable Asphalt

# Porous Asphalt



**Porous asphalt is a surface that is designed to allow infiltration. This material can be used for vehicular or pedestrian areas. Suppliers may require a minimum order due to asphalt-manufacturing limitations.**

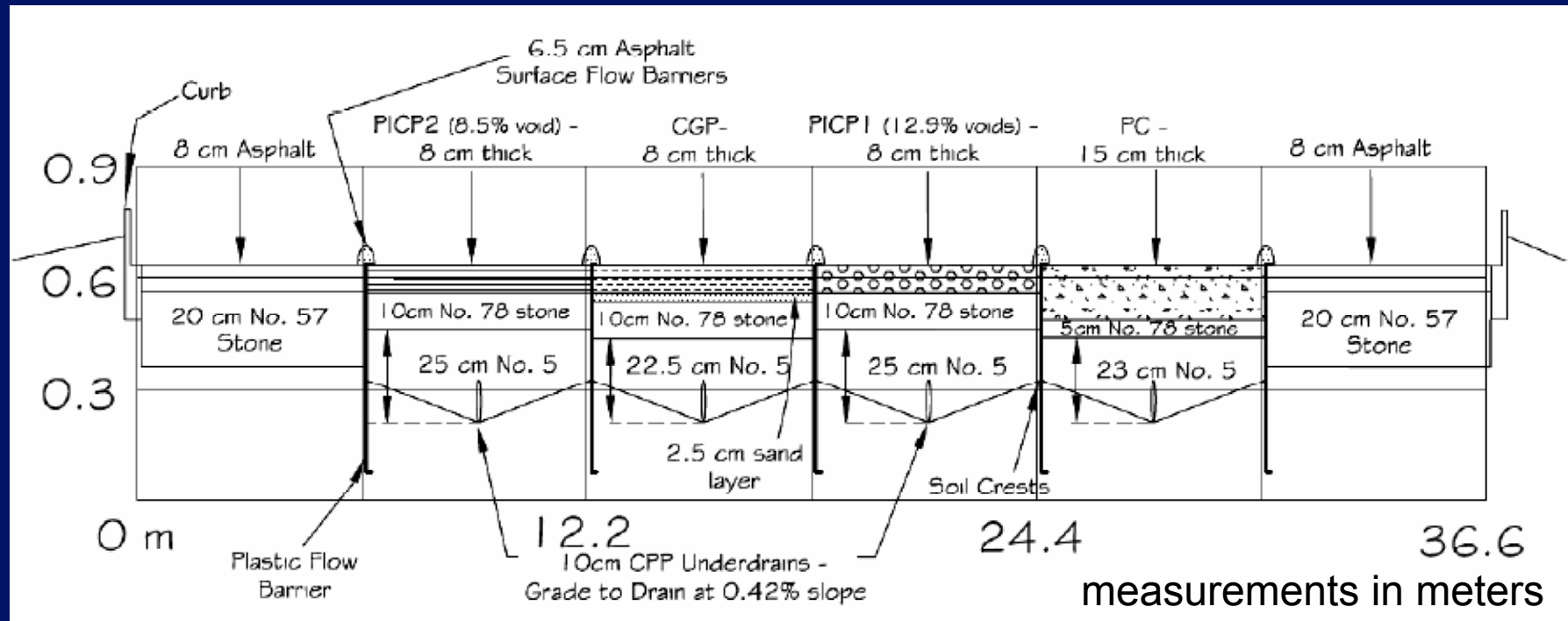
# Examples of Permeable Pavement



**Permeable pavement sections surfaced with (left to right) pervious concrete, permeable interlocking concrete pavers with 12.9% open surface area (PICP1), concrete grid pavers, and permeable interlocking concrete pavers with 8.5% open surface area (PICP2).**



# Parking Lot Cross-Section



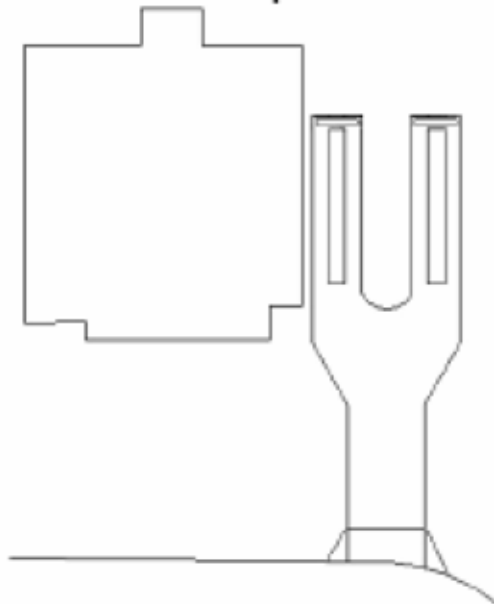
# Brattebo and Booth, U. of Washington

## Abstract

This study examined the long-term effectiveness of permeable pavement as an alternative to traditional impervious asphalt pavement in a parking area. Four commercially available permeable pavement systems were evaluated after six years of daily parking usage for structural durability, ability to infiltrate precipitation, and impacts on infiltrate water quality. All four permeable pavement systems showed no major signs of wear. Virtually all rainwater infiltrated through the permeable pavements, with almost no surface runoff. The infiltrated water had significantly lower levels of copper and zinc than the direct surface runoff from the asphalt area. Motor oil was detected in 89% of samples from the asphalt runoff but not in any water sample infiltrated through the permeable pavement. Neither lead nor diesel fuel were detected in any sample. Infiltrate measured five years earlier displayed significantly higher concentrations of zinc and significantly lower concentrations of copper and lead.

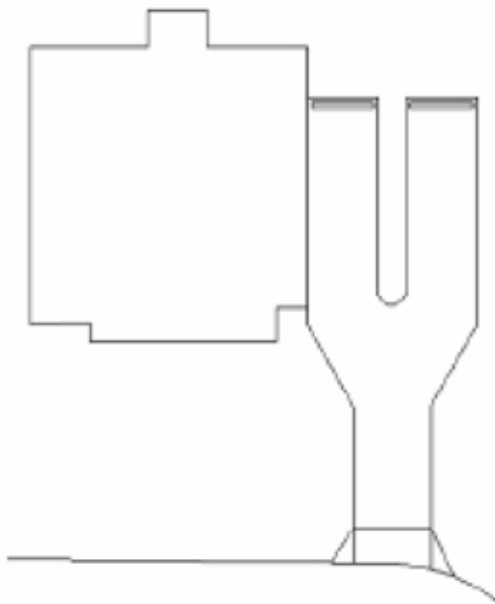
# Driveway Reduction

reduced length drive  
"Hollywood Drive" style  
with wheel stops



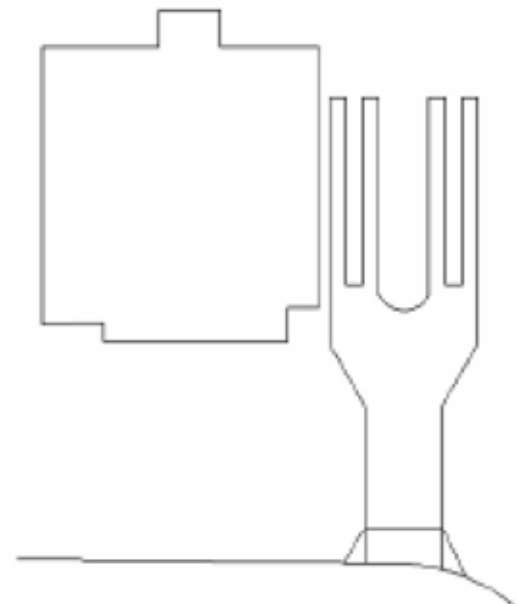
impervious: 503 sf

reduced length drive  
with wheel stops



impervious: 786 sf

reduced length drive  
"Hollywood Drive" style



impervious: 503 sf

**Driveway reduction**

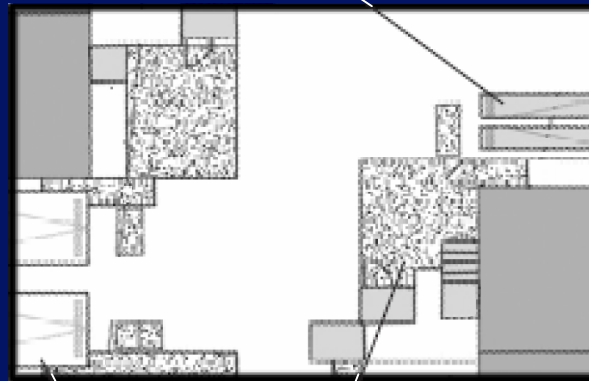
**NTS**



# Impervious Surface Reduction

This example shows the use of a porous gravel mat for patios and porous pavement for the driveways as strategies to reduce the impervious surface area.

**“Hollywood Drive” with reduced length**



**porous concrete driveway**

**porous gravel mat patio**

## 5. Green Roof



# Green Roof

**Dansko  
West Grove, Pa.**





# Typical Daily Water Use

Outdoor watering used 38% of water in office buildings that can be supplemented by green-streets techniques.

Daily Use	Office Buildings	Hotels
<b>Potable indoor uses</b>		
• Showers	—	27%
• Faucets	1%	1%
• Kitchen	3%	10%
• Other uses	10%	19%
<b>Subtotal</b>	<b>14%</b>	<b>57%</b>
<b>Non-potable indoor uses</b>		
• Toilets/urinals	25%	9%
• Laundry	—	14%
• Cooking	23%	10%
<b>Subtotal</b>	<b>48%</b>	<b>33%</b>
<b>Outdoor uses</b>	<b>38%</b>	<b>10%</b>

# Estimated Energy Consumption for Water Treatment and Distribution

**“The transport and treatment of water has high energy demands, 1,450 kWh per MG of water.”**

<b>Activity</b>	<b>Energy Consumption (kWh/MG)</b>
<b>Supply and conveyance</b>	<b>150</b>
<b>Water treatment</b>	<b>100</b>
<b>Distribution</b>	<b>1,200</b>
<b>Total</b>	<b>1,450</b>

# Carbon Dioxide Emissions from Electric Power Generation

Fuel Type	CO <sub>2</sub> Output Rate Lbs. CO <sub>2</sub> / kWh	CO <sub>2</sub> Output / MG Water Delivered (x 1,450kWh)
Coal	2.117	3,070 lbs.
Petroleum	1.915	2,775 lbs.
Natural Gas	1.314	1,905 lbs.

The carbon reductions associated with rainwater harvesting are admittedly not on the order of magnitude required to significantly impact climate change. However, **the connection between potable-water use and energy demand is important** to recognize in the broader context of sustainable water management.



# American Clean Energy Act of 2009

(approved by House, pending in Senate)

- **Changes the green economy**
- **Puts price on carbon**
- **Incentives for white roofs and pavement**
- **Investments in reforestation by power companies to cool streets and buildings**

# **Sustainability**

**= People, Planet, Prosperity**

**= Equity, Environment, Economy**

- **Maintenance concerns of green streets?**
- **Why not stormwater fees to pay for O&M?**
- **Don't we need a UD School of Architecture?**
- **Revamp DNREC as the Delaware Department of Environmental Sustainability.**