LOW IMPACT DEVELOPMENT (LID) STORMWATER MANAGEMENT

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Outline

- Introduction
  - The Water Cycle and Land Development Process
  - Conventional Stormwater Management Techniques
- LID: A Better Way to Manage Our Water Resources
  - "Non-Structural" BMPs: First Reduce the Problem
    - Protect Sensitive and Special Value Resources
    - Cluster and Concentrate
    - Minimize Disturbance / Minimize Maintenance
    - Reduce Impervious Cover
    - Disconnect / Distribute / Decentralize
  - "Structural" BMPs: Mitigate the Rest
    - Porous Pavement Systems
    - Infiltration Basins/ Beds / Trenches
    - Bioretention / Rain Gardens
    - Green Roofs
    - Rainfall Capture & Reuse
    - Landscape Restoration
  - Case Studies

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Critical Link between Land and Water


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The Hydrologic (Water) Cycle

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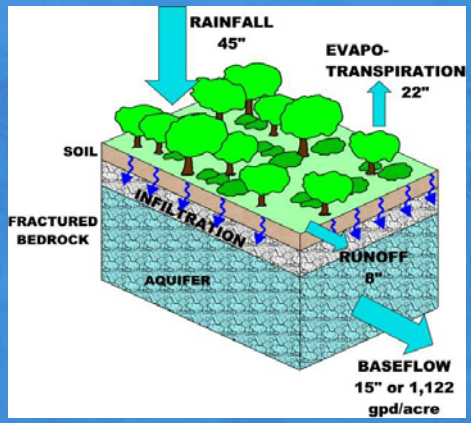
Annual Natural Hydrologic Cycle For an Average Year



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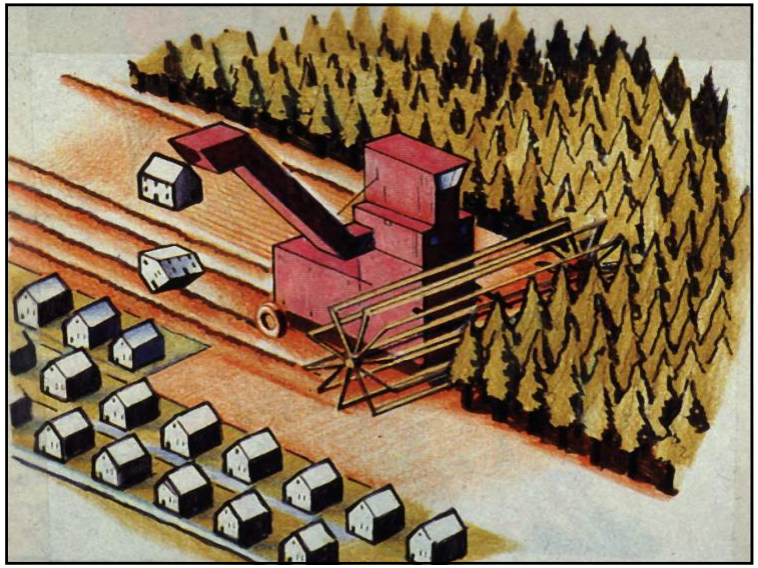
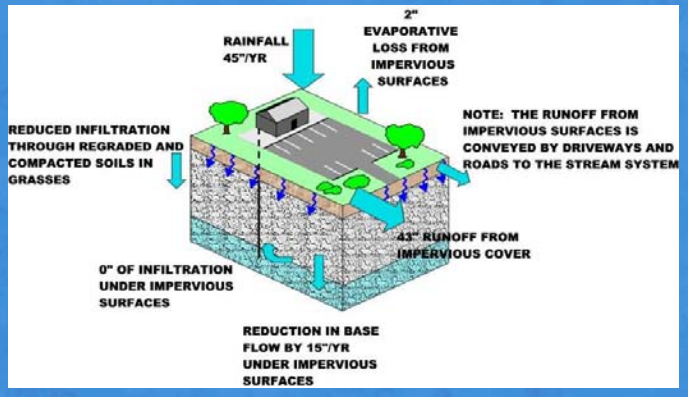


Annual Hydrologic Cycle for Impervious Surfaces for an Average Year



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Stormwater Impacts of Conventional Development

- Not just Increased Flooding…
- Increased Runoff Volume
- Decreased Evapotranspiration and Groundwater Recharge
- Increased Frequency of Runoff Events
- Faster Conveyance of Water
- Erosion and Stream Channel Changes
- Decreased Baseflow
- Impacted Aquatic Life
- Pollutants and Temperature Impacts

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…not to mention other impacts of conventional development practices…

- Habitat Loss/Biodiversity
- Wetlands/Floodplains/Other Areas
- Soils/Special Geologic Features
- Air Quality/Microclimate
- Noise
- Historical/Archaeological
- Aesthetics/Scenic
- Quality of Life
- Public Health

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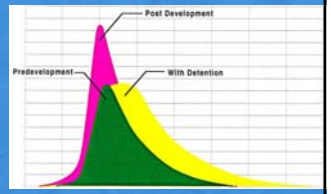
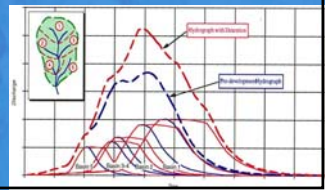
Conventional Stormwater Management

- Controls Peak **Rate** of Runoff to Predevelopment Conditions for Large Storms (theoretically)
- Fails to Control **Volume** of Runoff
- Fails to Control NPS **Pollutant** Loadings





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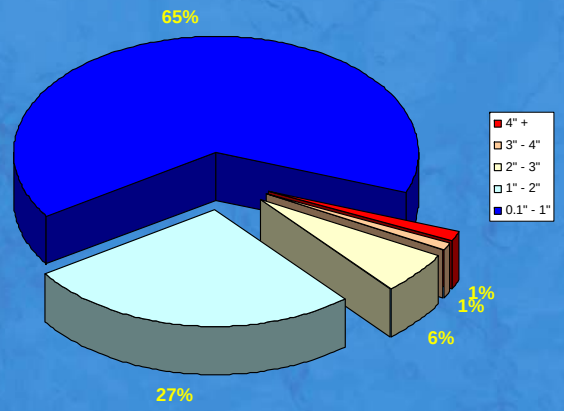
Average Rainfall Distribution by Storm Magnitude



1926 to 2003 Rainfall Data for Harrisburg, Pennsylvania

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Detention Basins typically only slow the Largest Storms

We Still have...

- Flooding
- Polluted Runoff
- Eroded Streams

Flood & Drought:

Opposite Sides of the Same Coin

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And when Rainfall cannot reach the Groundwater…

…our streams, wells, and wetlands run dry.

When the well is dry, we know the worth of water.

- Benjamin Franklin

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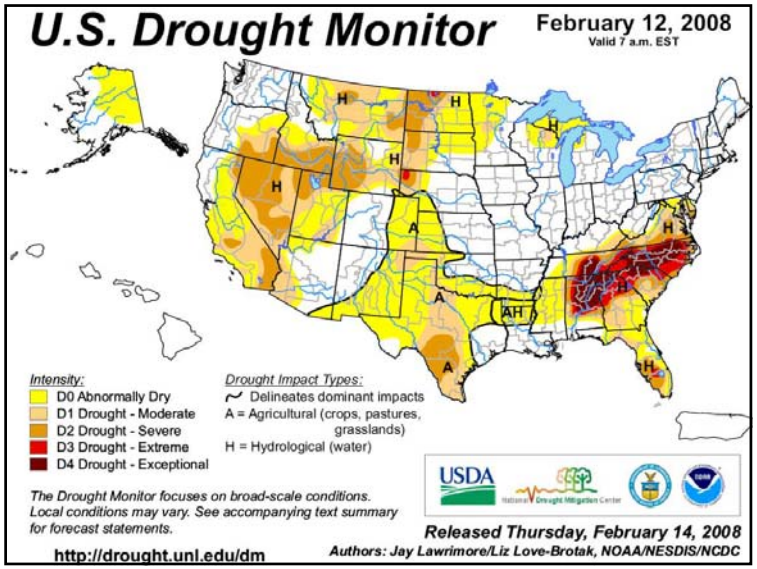

Paradigm Shift:

Better Ways to Manage Our Water Resources

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NRC Report, Oct. 2008

- ***"EPA's current approach to regulating stormwater is unlikely… to adequately control stormwater's contribution to waterbody impairment…***
- ***Flow and related parameters like impervious cover should be considered for use as proxies for stormwater pollutant loading…***
- ***Nonstructural SCMs [BMPs] … can dramatically reduce the volume of runoff and pollutant load from a new development…***
- ***SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant loading of small storms."***

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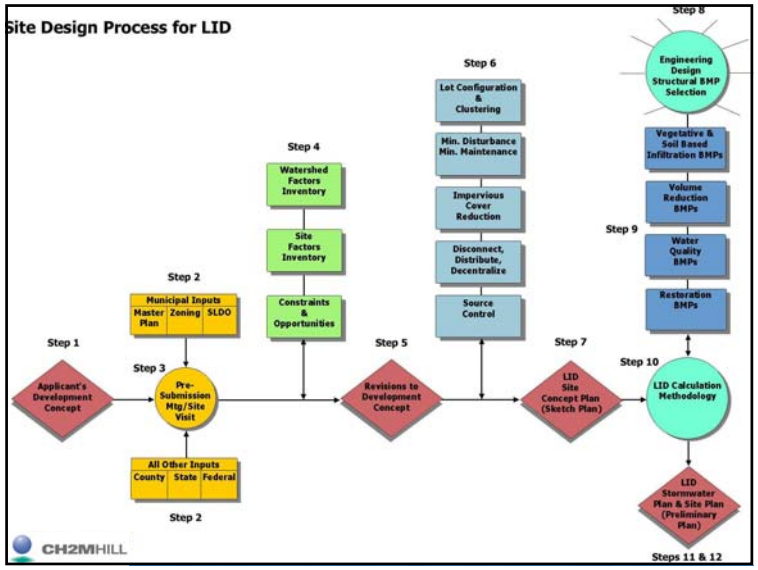

Non-Structural BMPs - Prevention

Protect Sensitive and Special Value Resources
- BMP 1.1 Protect sensitive/special value features
- BMP 1.2 Protect/conserve/enhance utilize riparian areas
- BMP 1.3 Protect/utilize natural flow pathways

Cluster and Concentrate
- BMP 2.1 Cluster uses at each site; Build on the smallest area possible
- BMP 2.2 Concentrate uses areawide through Smart Growth practices

Minimize Disturbance and Minimize Maintenance
- BMP 3.1 Minimize total disturbed area – grading
- BMP 3.2 Minimize soil compaction in disturbed areas
- BMP 3.3 Re-vegetate and re-forest disturbed areas using native species

Reduce Impervious Cover
- BMP 4.1 Reduce street imperviousness
- BMP 4.2 Reduce parking imperviousness

Disconnect/Distribute/Decentralize
- BMP 5.1 Rooftop disconnection
- BMP 5.2 Disconnection from storm sewers

Source Control
- BMP 6.1 Street Sweeping

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Non-Structural BMPs

1.0 Protect Sensitive and Special Value Resources

- **BMP 1.1** Protect sensitive/special value features
- **BMP 1.2** Protect/conserve/enhance utilize riparian areas
- **BMP 1.3** Protect/utilize natural flow pathways in overall stormwater planning and design

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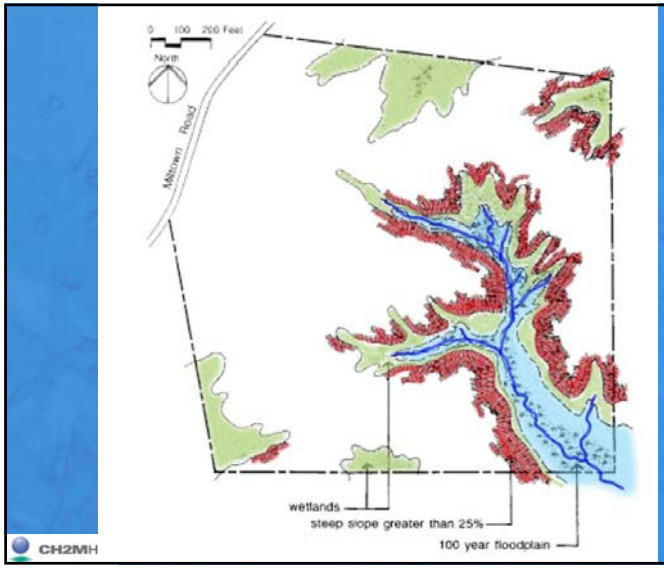

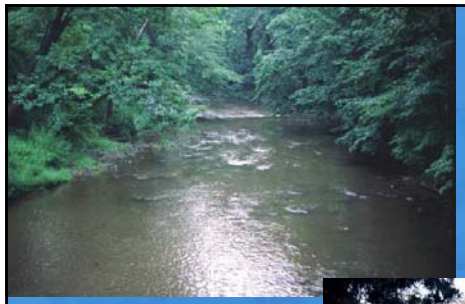

Critical: Riparian Buffers

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Riparian Buffer Benefits

- Streambank Stabilization
- Aquatic Habitat and Food Web
- Water Temperature Moderation (shading)
- Nutrient Removal
- Sediment Control
- Flood reduction
- Wildlife Habitat
- In-stream Pollutant Removal (2 to 10 times greater for forested buffers) – Stroud Water Research Center

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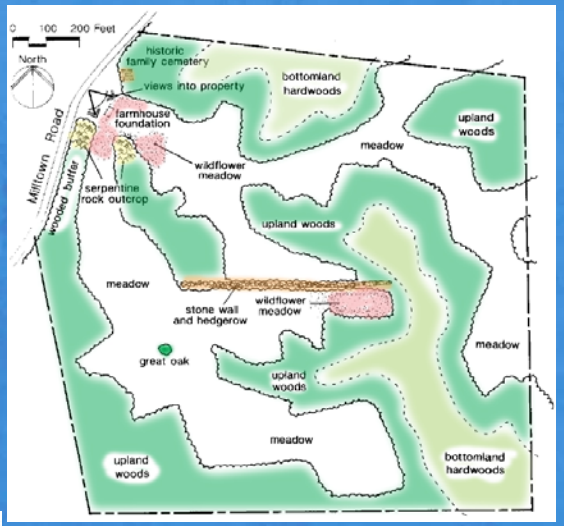

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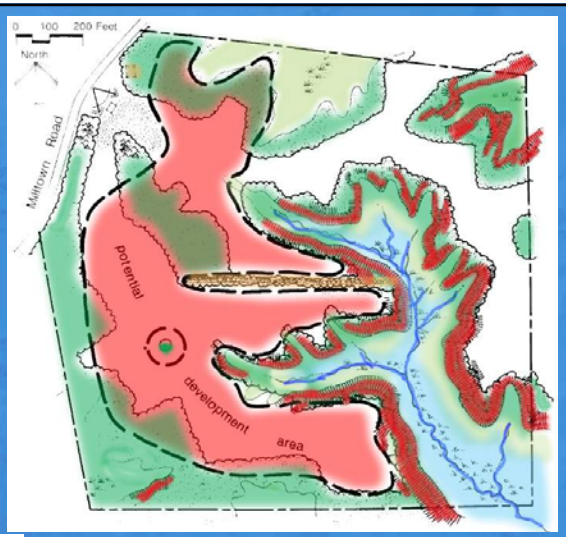

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Non-Structural BMPs

2.0 Cluster and Concentrate

BMP 2.1 Cluster uses at each site; build on the smallest area possible

BMP 2.2 Concentrate uses areawide through Smart Growth practices

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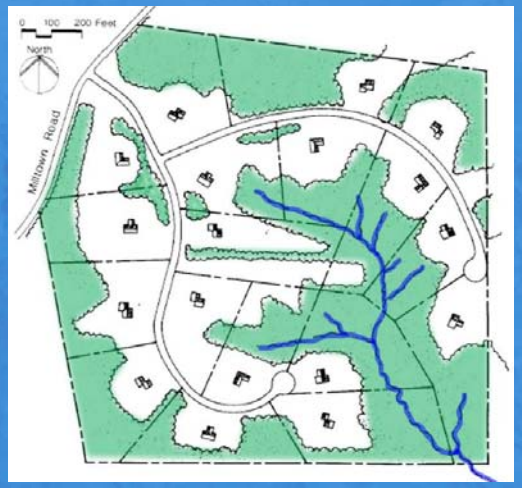

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Case Study
Chapel Run
Conventional Development

Total size of site: 96 acres
Total number of lots: 142
Average size of lots: 1/2 acre
Percent undisturbed: 0%
Percent impervious: 29%

Delaware Dept. of Natural Resources and Environmental Control
Environmental Management Center
Brandywine Conservancy

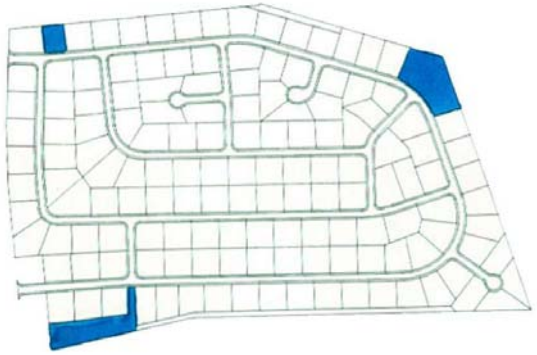
Case Study
Chapel Run
Conservation Design
Parkway Alternative

Total size of site: 96 acres
Total number of lots: 142
Average size of lots: 1/4 acre
Percent undisturbed: 59.6%
Percent impervious: 14.9%

Delaware Dept. of Natural Resources and Environmental Control
Environmental Management Center
Brandywine Conservancy

Conservation Design for Stormwater Management

Case Study: Chapel Run
Sussex County
April, 1997

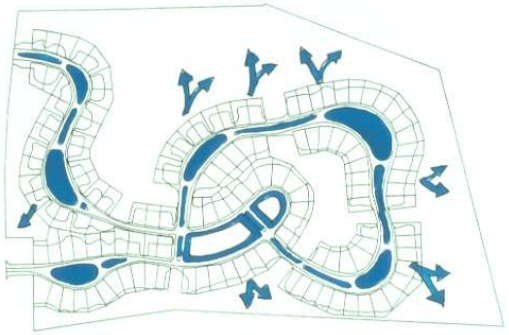


DNREC
Environmental Management Center
Brandywine Conservancy

Conventional Development

Conservation Design for Stormwater Management

Case Study: Chapel Run
Sussex County
April, 1997



DNREC
Environmental Management Center
Brandywine Conservancy

Conservation Design Stormwater Management

Cost Comparison: Chapel Run

Conventional Development	$2,460,200
Conservation Design-Parkway	$ 888,735

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Non-Structural BMPs

3.0 Minimize Disturbance and Minimize Maintenance

- **BMP 3.1** Minimize total disturbed area – grading
- **BMP 3.2** Minimize soil compaction in disturbed areas
- **BMP 3.3** Re-vegetate and re-forest disturbed areas, using native species

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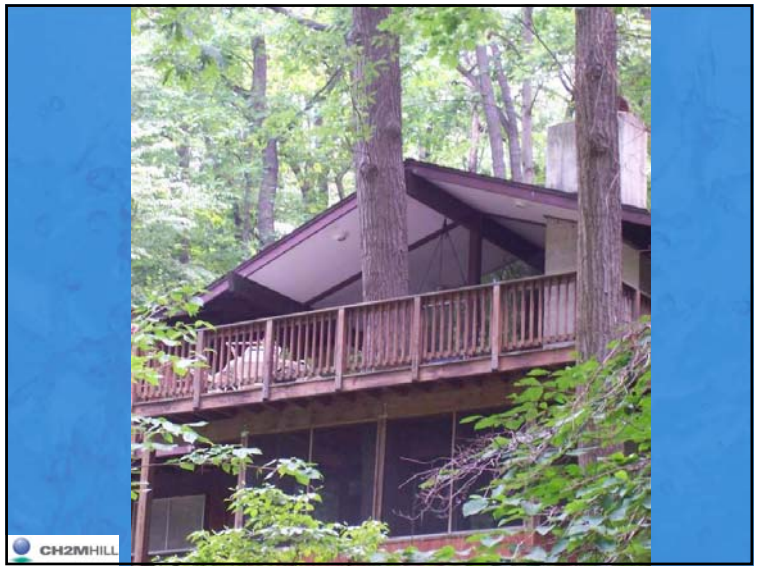

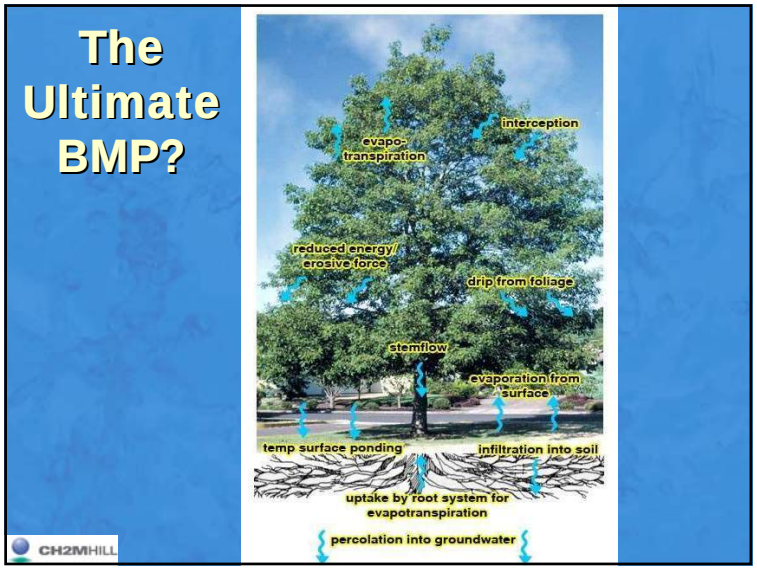
The Ultimate BMP?
interception
evapo-transpiration
reduced energy/ erosive force
drip from foliage
stemflow
evaporation from surface
temp surface ponding
infiltration into soil
uptake by root system for evapotranspiration
percolation into groundwater
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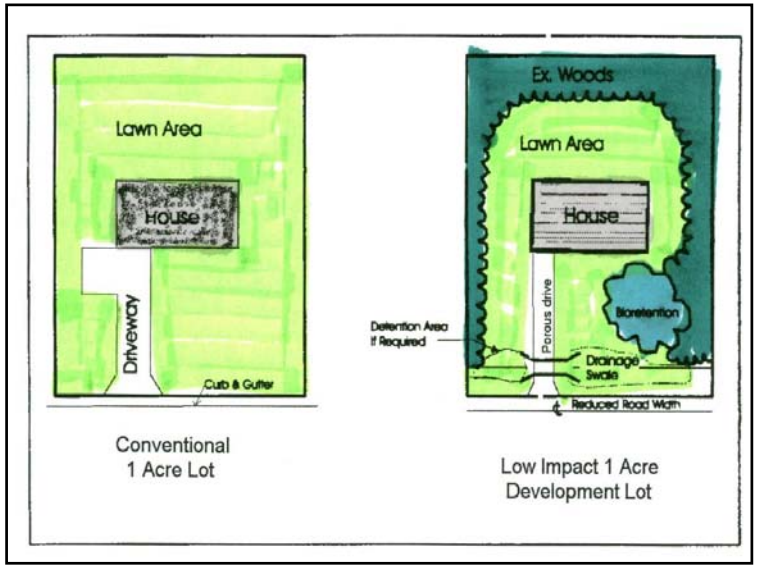
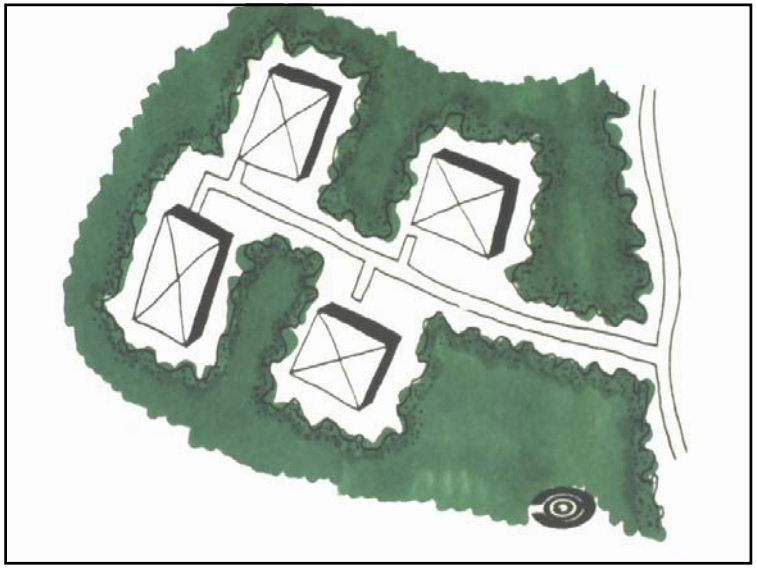

Lawn Area
House
Driveway
Curb & Gutter
Conventional
1 Acre Lot
Ex. Woods
Lawn Area
House
Bioretention
Detention Area If Required
Porous drive
Drainage Swale
Reduced Road Width
Low Impact 1 Acre
Development Lot



Common Bulk Density Measurements or How compacted is this soil?

David B. Friedman, District Director -- Ocean County Soil Conservation District

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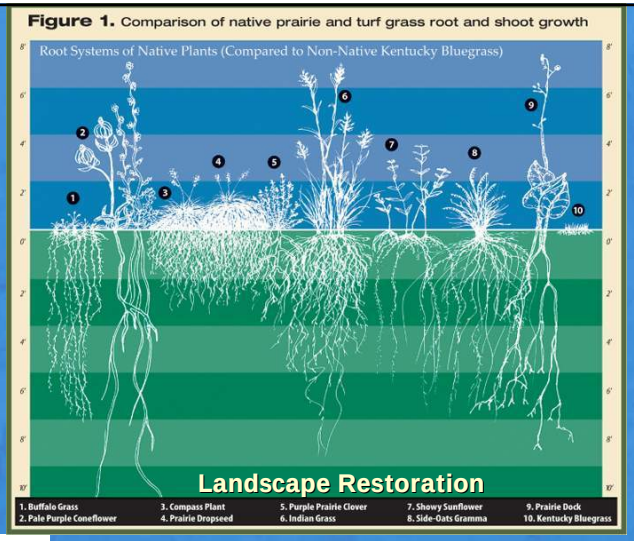

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Source: *Stormwater* Magazine, March/April 2007

Non-Structural BMPs

4.0 Reduce Impervious Cover

BMP 4.1 Reduce street imperviousness
BMP 4.2 Reduce parking imperviousness

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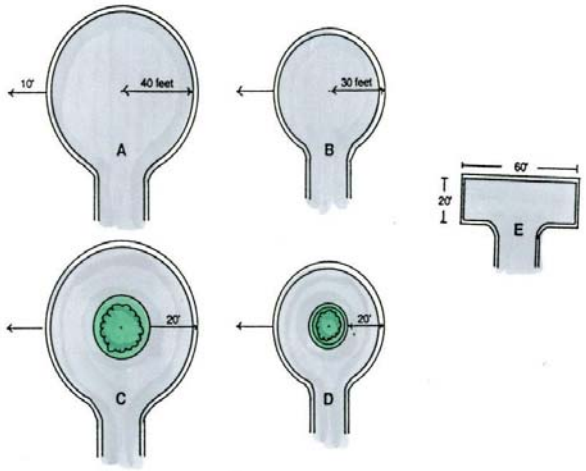
Table 1: Narrow Residential Street Widths

Jurisdiction	Residential Street Pavement Width	Maximum Daily Traffic (trips/day)
State of New Jersey	20 ft. (no parking)	0-3,500
	28 ft. (parking on one side)	0-3,500
State of Delaware	12 ft. (alley)	---
	21 ft. (parking on one side)	---
Howard County, Maryland	24 ft. (parking not regulated)	1,000
Charles County, Maryland	24 ft. (parking not regulated)	---
Morgantown, West Virginia	22 ft. (parking on one side)	---
Boulder, Colorado	20 ft.	150
	20 ft. (no parking)	350-1,000
	22 ft. (parking on one side)	350
	26 ft. (parking on both sides)	350
	26 ft. (parking on one side)	500-1,000
Bucks County, Pennsylvania	12 ft (alley)	---
	16-18 ft. (no parking)	200
	20-22 ft. (no parking)	200-1,000
	26 ft. (parking on one side)	200
	28 ft. (parking on one side)	200-1,000

CH (Cohen, 1997; Bucks County Planning Commission, 1980; Center for Watershed Protection, 1998)

FIGURE 41: FIVE TURNAROUND OPTIONS AT THE END OF A RESIDENTIAL STREET



Structural Stormwater Measures: Best Management Practices (BMPs)

- Volume
- Water Quality
- Peak Rate
- Stream Impacts

Prevent First. Mitigate Second.

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Structural Best Management Practices (BMPs)

Runoff Volume / Infiltration-Oriented
Vegetative and soil-based

1. Rain / recharge gardens / Bioretention
2. Vegetated filter strips
3. Vegetated Swales (Bio-infiltration, Dry, Wet)
4. Porous pavement with infiltration beds
5. Infiltration basins
6. Subsurface infiltration beds
7. Infiltration trenches
8. French drains / dry wells
9. Outlet control (level spreaders, etc.)
10. Retentive grading techniques, berms

Runoff Volume / Non-Infiltration-Oriented

11. Vegetated roofs
12. Cisterns / Rain Barrels / Capture Reuse

Runoff Quality / Non-Infiltration

13. Constructed wetlands
14. Wet ponds / retention basins
15. Filters
16. Water quality inserts
17. Detention / Extended Detention
18. Special Storage: Parking Lot, Rooftop, etc.

Restoration BMPs

19. Riparian Corridor Restoration
20. Revegetation / Reforestation
21. Soils Amendment

One size no longer fits all...

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Structural BMPs

Vegetative/Soil-Based Infiltration Systems

- Porous Pavement
- Infiltration Basin
- Infiltration Bed
- Infiltration Trench
- Rain Garden/Bioretention
- Dry Well / Seepage Pit
- Constructed Filter
- Vegetated Swale
- Vegetated Filter Strip
- Berm

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Pollutant Removal Effectiveness

POLLUTANT	INFILTRATION PRACTICES	*Stormwater Wetlands*	*Stormwater Ponds Wet*	*Filtering Practices*	*Water Quality Swales*	*Stormwater Dry Ponds*
Total Phosphorus	70	49	51	59	34	19
Soluble Phosphorus	85	35	66	3	38	-6
Total Nitrogen	51	30	33	38	84	25
Nitrate	82	67	43	-14	31	4
Copper	N/A	40	57	49	51	26
Zinc	99	44	66	88	71	26
TSS	95	76	80	86	81	47

Water quality benefits of porous pavement with infiltration from "National Pollutant Removal Performance Database for Stormwater Treatment Practices" Center for Watershed Protection, June 2000

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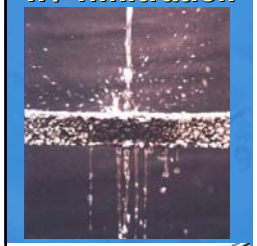
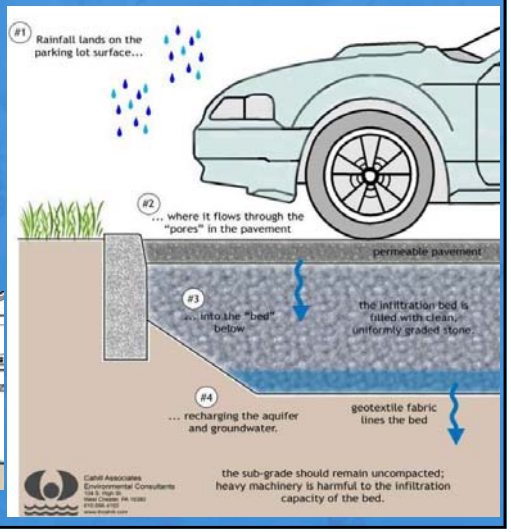
Porous Paving w/ Infiltration





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Porous Asphalt/Concrete 101

- **What is it?**
  - Asphalt/concrete in which fine particles are kept to a minimum
- **Why?**
  - This allows rainfall to drain through the pavement rather than running off
- **Where does the rainfall go?**
  - A bed beneath the pavement receives rainfall from the pavement as well as – potentially – inflow from other areas

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Porous Pavement in Action

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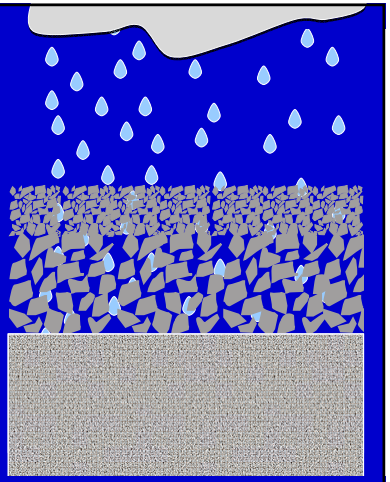
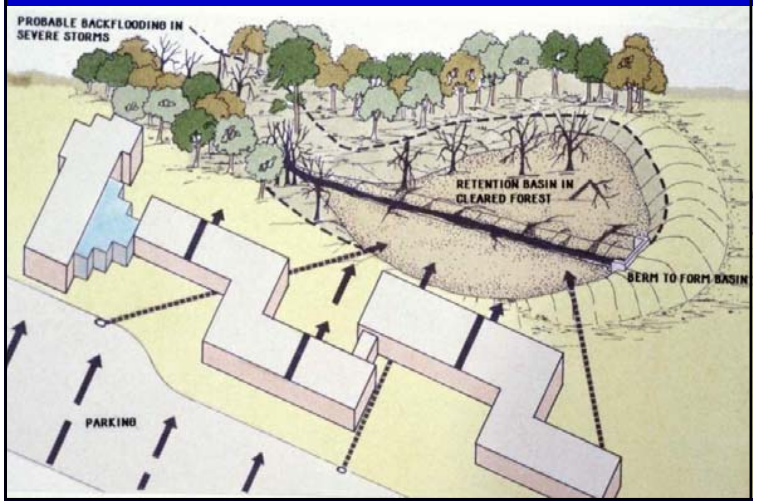
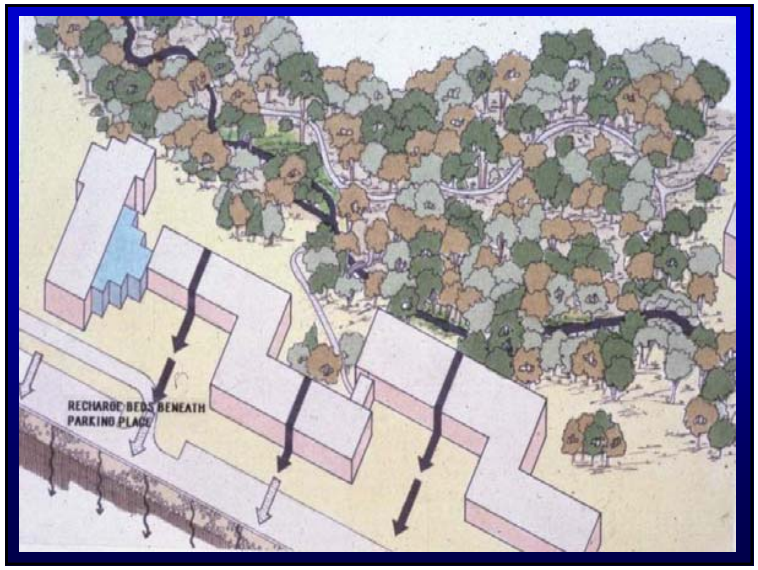
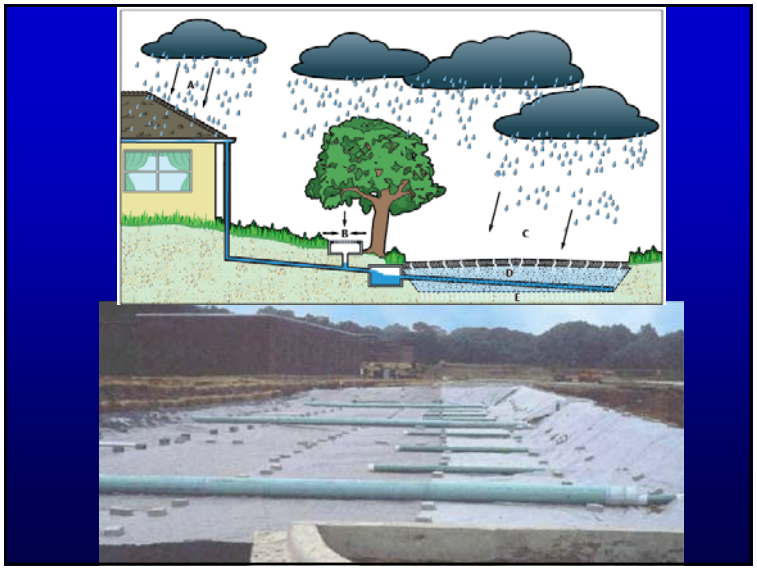


Animation courtesy of Kent Hansen, NAPA

DuPont Barley Mills Office Complex







Costs of Porous Pavement (Asphalt)

- Generally costs the same or less for the site
- Actual asphalt is somewhat more expensive (special gradation and higher grade binder)
- Reduces Piping Infrastructure and Basins

- Kaiser Modesto site (2006) – cost savings of approximately $300,000
- Port of Portland – cost savings of $250,000

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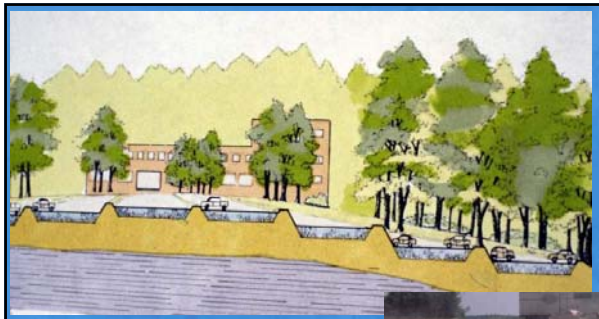

Siemens and SmithKline

- Steep Slopes
- Limestone Geology
- *Exceptional Value*
  Valley Creek

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Pathways

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Porous Asphalt Playground
(no puddles!)

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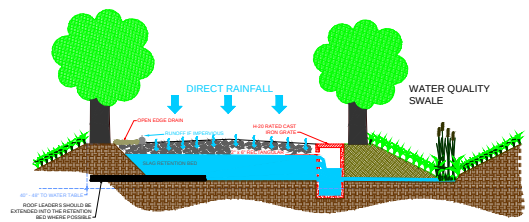
- Porous Pavement
- Vegetated Swales
- Fewer Pipes



Ford

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Structural Best Management Practices (BMPs)

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One size no longer fits all...

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Case Studies

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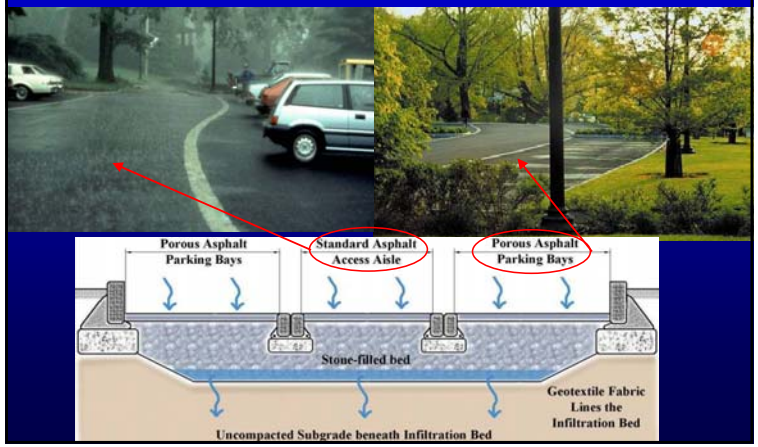
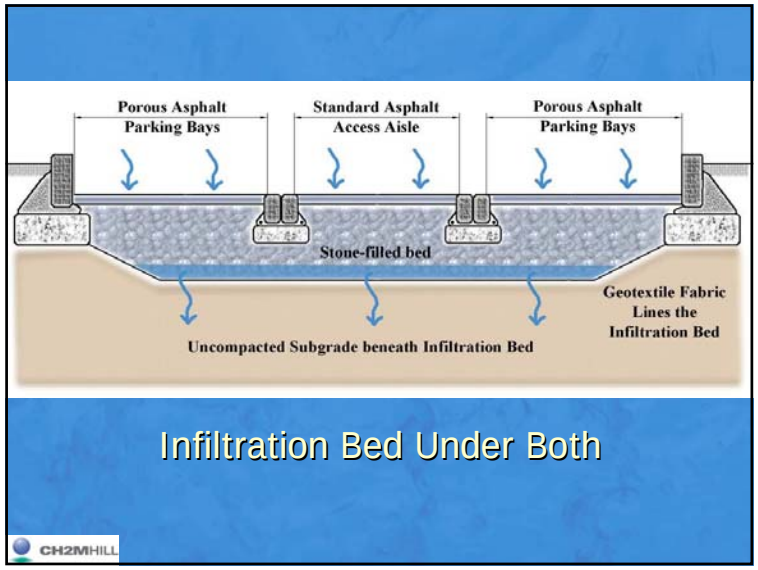
Morris Arboretum, Philadelphia, PA (1984)



Morris Arboretum (early 1980's): Porous vs. Standard



Infiltration Bed Under Both

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Penn State Berks Campus

- Reduce Site Disturbance
- Porous Pavement
- Infiltration beneath walkways
- Reduced Impervious Walkways - Grasspave
- Infiltration with Shallow Contour Trench
- Eliminated Existing Small Detention Basin
- Limestone

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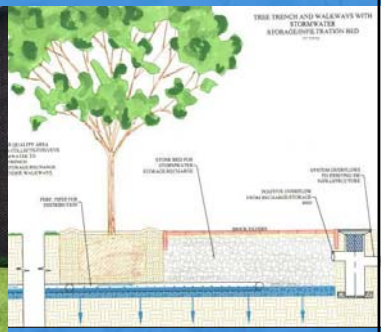
Infiltration Beneath Standard Walkways



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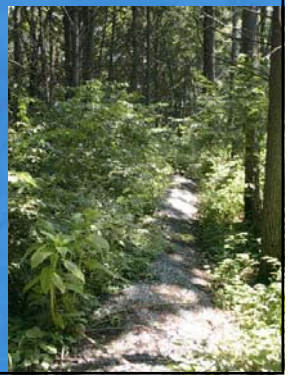
- *Reduced Disturbance*



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Stormwater Management for The Village at Springbrook
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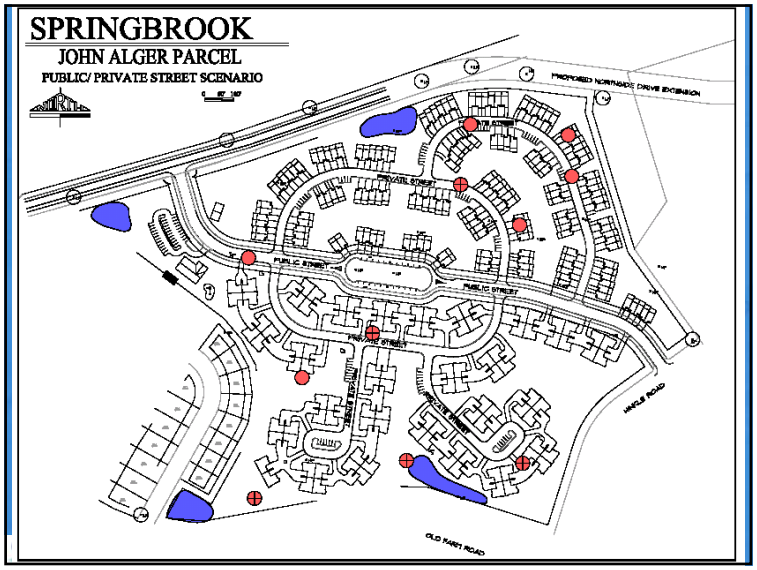
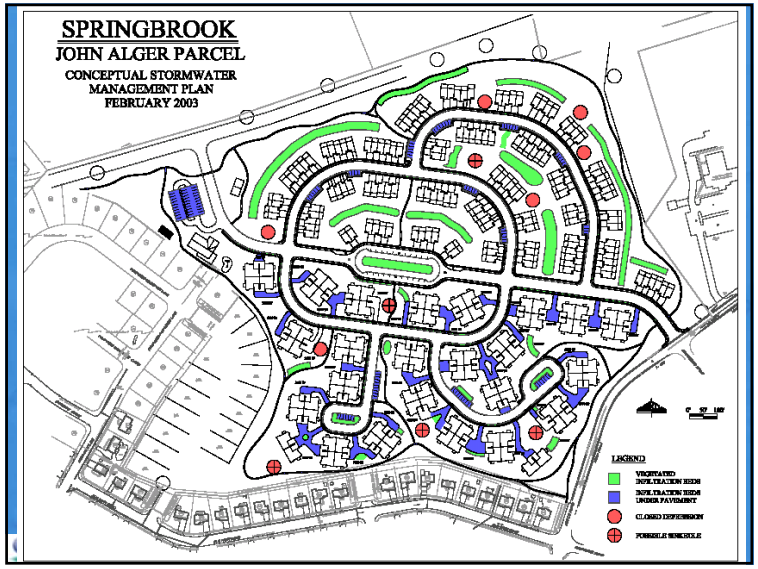

SPRINGBROOK
JOHN ALGER PARCEL
PUBLIC/ PRIVATE STREET SCENARIO


SPRINGBROOK
JOHN ALGER PARCEL
CONCEPTUAL STORMWATER MANAGEMENT PLAN
FEBRUARY 2003
LEGEND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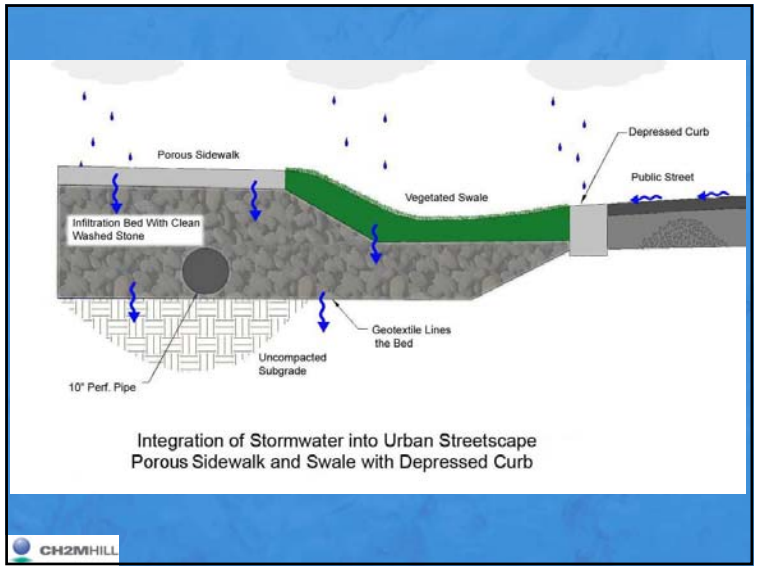
Porous Sidewalk
Depressed Curb
Public Street
Vegetated Swale
Infiltration Bed With Clean Washed Stone
Geotextile Lines the Bed
Uncompacted Subgrade
10" Perf. Pipe
Integration of Stormwater into Urban Streetscape
Porous Sidewalk and Swale with Depressed Curb
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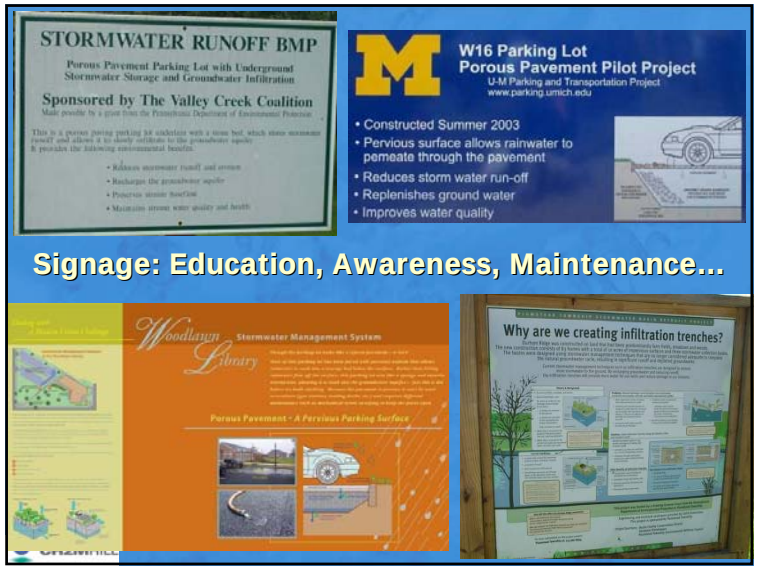

Penn New School
43rd and Locust Streets

- PaDEP Growing Greener & Philadelphia Water Department
- Porous Pavement Play Yard
- Infiltration Bed Beneath Athletic Field
- Rain Gardens and Native Vegetation
- Environmental Education

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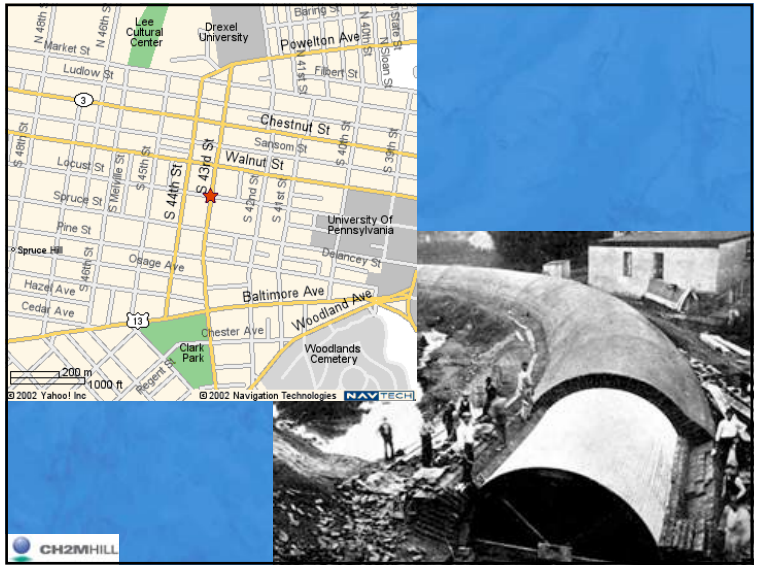

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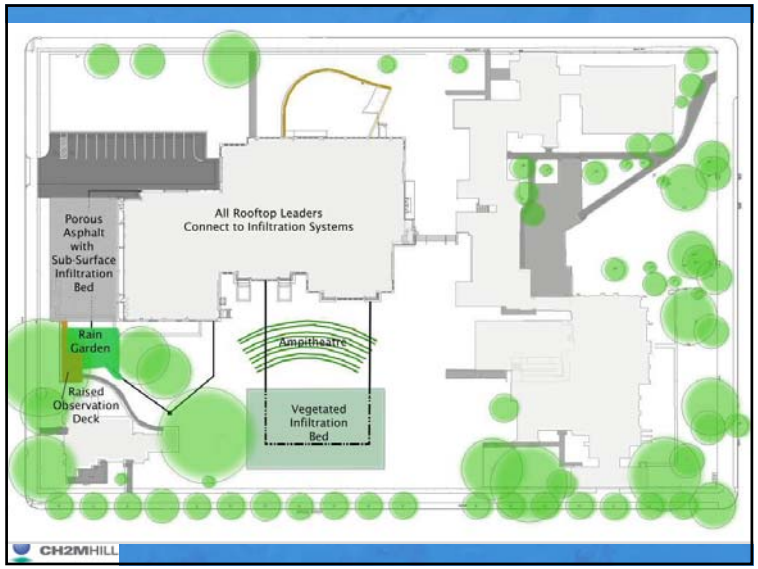
Porous Asphalt with Sub-Surface Infiltration Bed
All Rooftop Leaders Connect to Infiltration Systems
Rain Garden
Amphitheatre
Raised Observation Deck
Vegetated Infiltration Bed
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Porous Pavement Playfield Philadelphia
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Health&Science
Excess rainfall wreaks havoc on antiquated urban sewer systems, and thus on the cleanliness of waterways. Philadelphia is using "green" methods to channel the overflow.
Capturing the rain
How Combined Sewers Work
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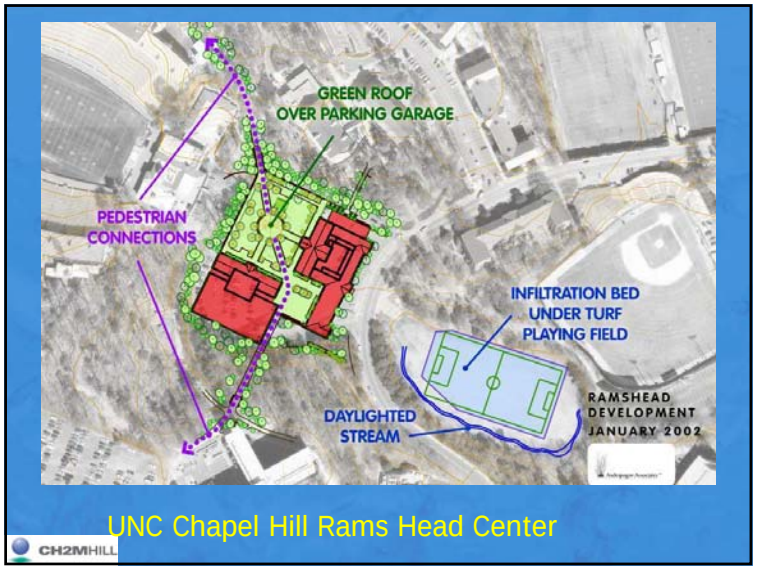
GREEN ROOF OVER PARKING GARAGE
PEDESTRIAN CONNECTIONS
INFILTRATION BED UNDER TURF PLAYING FIELD
DAYLIGHTED STREAM
RAMSHEAD DEVELOPMENT JANUARY 2002
UNC Chapel Hill Rams Head Center
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Rams Head Plaza at University of North Carolina


Flood test of cistern area
Bricks being placed above cistern
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University of North Carolina

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Woodlawn Library, Wilmington DE

Site Plan and BMPs

- Formerly a DMV Facility
- CSO Area
- Demonstration
- Capture 2 inch rain

Part of a City-wide program for CSO Reduction

Before

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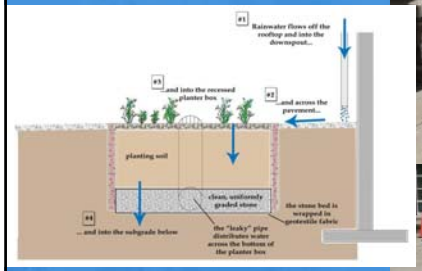
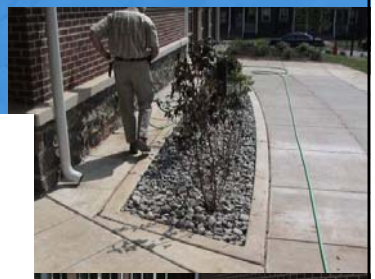
Planter Box





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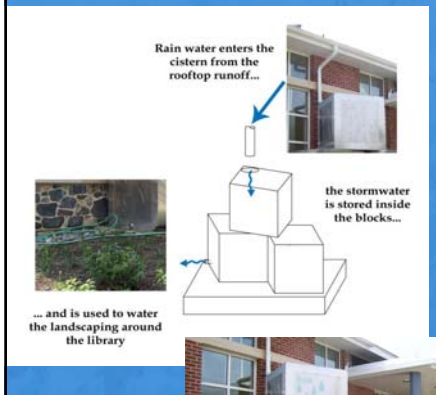

Cisterns (Water Re-use)

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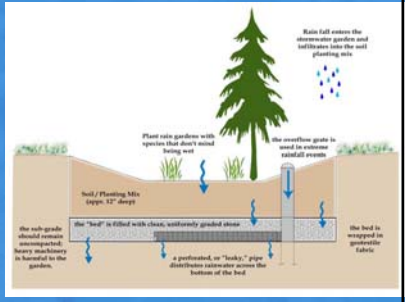
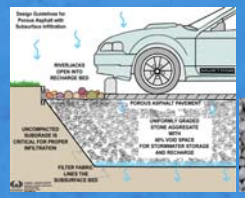
Bioretention (Rain Gardens)



Porous Asphalt Parking



For a successful LID Project:

- Select it right
- Design it right
- Build it right
- Maintain it right

Selection Considerations

Site-Related Considerations

- Climate
- Geology
- Soils
- Water Table
- Topography
- Sensitive & Special Value Resources
- Watershed
- Previous Disturbance
- Surrounding Properties

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Site Criteria for Infiltration-Oriented BMPs

- Measured soil permeability rate greater than 0.25 inches per hour
- Minimum Bedrock Separation of 2 feet
- Infiltration device at least 3 feet above seasonally high water table
- Setback from water supplies – 50 ft.
- Setback from buildings w/basements – 10 ft. down-gradient/50 ft. up-gradient
- Setback from septic beds – 50 ft.
- Special Areas considerations

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Project-Related Considerations

- Ownership (Private, Public, HOA)
- Maintenance
- Education
- Proposed Uses
- Density / Layout
- Potential Pollutant Loading (Hot Spots, Sediment)
- Traffic
- Cost
- Aesthetics
- Construction, Staging, Schedule

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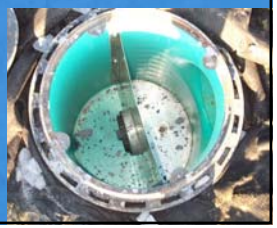
Design Criteria

- Spread It Out!
- Minimize excavation / maximize soil buffer
- Do not infiltrate in compacted fill
- Level Bed Bottoms
- Positive overflow
- Drawdown Time
- Pre-treatment for “hot-spots”
- Construction oversight!
- Keep it Clean – E&S Control
- The Details are critical...



Construction Criteria

- Understand the system & get the details right
- Inspection Important
- Protect soils - Do not compact!
- Protect infiltration BMPs from sediment until drainage area is completely stabilized
- Sequencing, staging, stockpiling
- Use good materials (aggregate, asphalt, etc.)
- Establish/protect vegetation

Stone must be clean!

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What Happens on the Land....

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Jersey City Reservoir, Morris County

...has everything to do with what happens in the water.

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Top Ten Low Impact Development (LID) Stormwater Management Principles:

-Plan first!
-Prevent! Then Mitigate.
-Manage as a Resource – not a Waste!
-Balance the natural water cycle.
-Disconnect. Decentralize. Distribute.
-Use natural systems.
-Minimize disturbance.
-Maximize the multiple benefits of LID.
-Use LID everywhere!
-Integrate maintenance.

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QUESTIONS?

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