Green Infrastructure – What is it and how can we determine how good it really is?

Metropolitan Washington Council of Governments
Serving the National Capital Region

Presentation to
Regional Monitoring Subcommittee
Metropolitan Washington Council of Governments
Regional Monitoring Subcommittee Meeting
Monday, June 8, 2009

David Sample
Assistant Professor
Biological Systems Engineering

VirginiaTech
Invent the Future

CENTER for WATERSHED STUDIES at VIRGINIA TECH

Biological Systems Engineering

Outline

- Introduction
  - BSE and the Center for Watershed Studies
  - CEE in Northern Virginia
- Green Infrastructure Practices
  - Sustainable Development and LID
  - Chesapeake Bay Issues and LID Practices
  - Overview of LID Practices-What they are, How they work
- What we need to know about Green Infrastructure
  - Measuring Effectiveness
  - Costs-Capital, O&M, Implementation Costs
  - Aggregation and Uncertainty
  - Barriers to Implementation
  - Adaptive Management

Outline-Con't

- Active Research Areas
  - Chesapeake Bay Stewardship Fund Projects
    - Stormwater Treatment Wetland, Fairfax, VA
    - LID Demonstration Park (Science Museum, Richmond, VNEMO)
  - LID Effectiveness-WSSI Site, Gainesville, VA
  - Phosphorus Testing and BMP Effectiveness
  - Adsorptive Media Evaluations
    - Fly Ash
    - Steel Slag
    - Potential Test Sites
  - Watershed Evaluations
    - Fairfax County LID Effectiveness (USGS)
    - Fairfax Boulevard Redevelopment Study
- Conclusion
  - Implementation
  - Research

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Biological Systems Engineering

- Department in the Colleges of Agriculture and Life Sciences and the College of Engineering
- Supporting the Sustainable Production, Processing and Utilization of Biological Materials
- Program Features:
  - 25 full time faculty
  - Ranked #7 in U.S. News and World Report
  - Undergraduate Research (NSF Fellows)
  - Small classes
  - Hands On Lab and Field Activities

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Center for Watershed Studies/Land and Water Faculty

- Brian Benham
- Luc Claessens
- Theo Dillaha
- Conrad Heatwole
- Cully Hession
- Leigh-Anne Krometis
- Saied Mostaghimi
- David Sample
- Durelle Scott
- Mary Leigh Wolfe
- Tess Wynn
- Gene Yagow
- Joanna York

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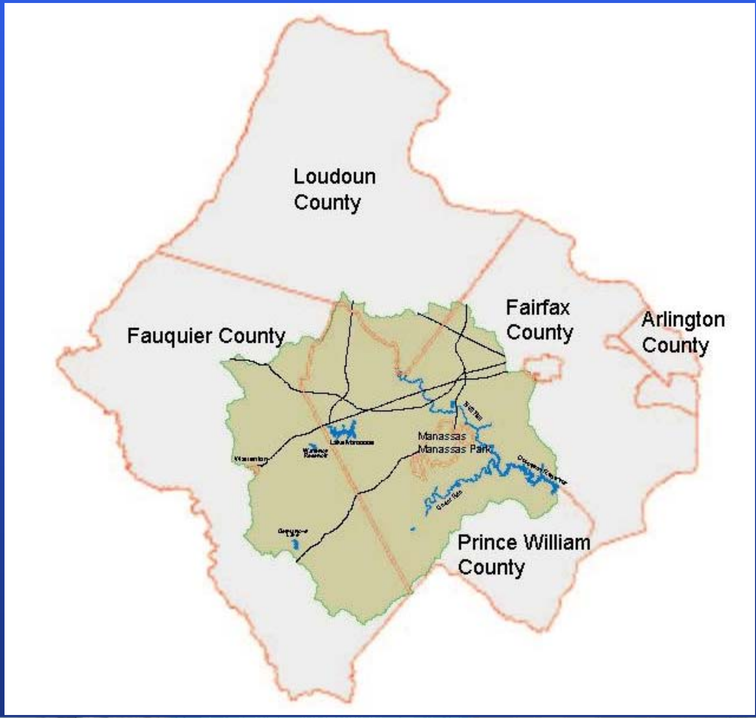
Department of Civil and Environmental Engineering and OWML

- Virginia Tech CEE Department is consistently ranked in the top 10 nationally at both the undergraduate and graduate levels
- 46 Faculty, 6 of whom are in the National Capital Region
- Presence in Alexandria, Falls Church, and Manassas (OWML Lab.)
- CEE-OWML has been monitoring the Occoquan watershed in NOVA for over 35 years



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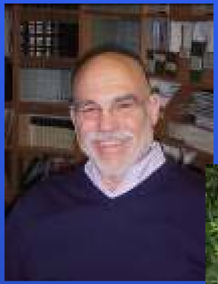
Metropolitan Water Faculty

- Faculty involved in teaching, research, and outreach in environmental engineering with a focus on watershed systems:
  - Tom Grizzard, CEE
  - Glenn Moglen, CEE
  - Adil Godrej, CEE
  - David Sample, BSE



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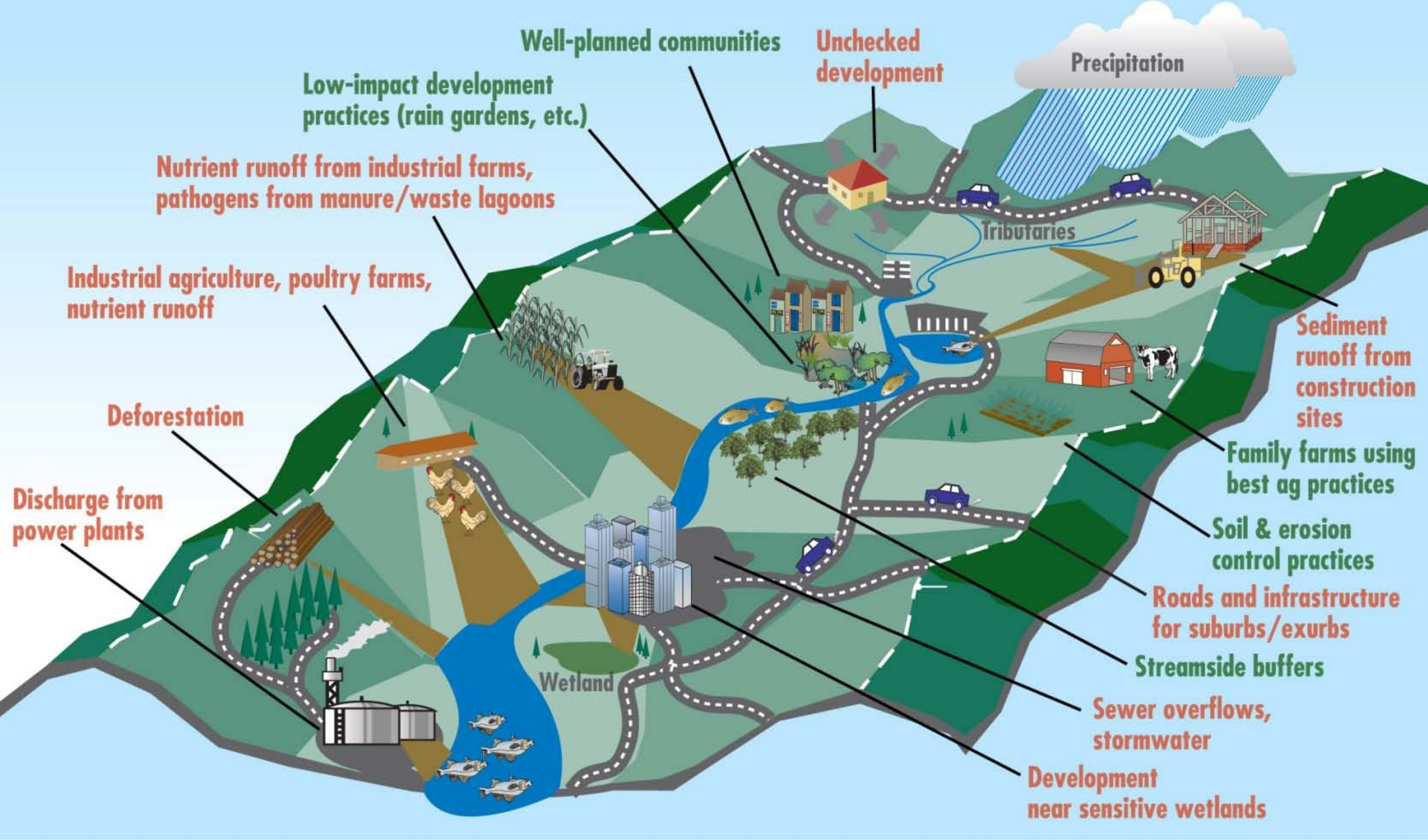
Green Infrastructure
What is it?

Urban Watershed



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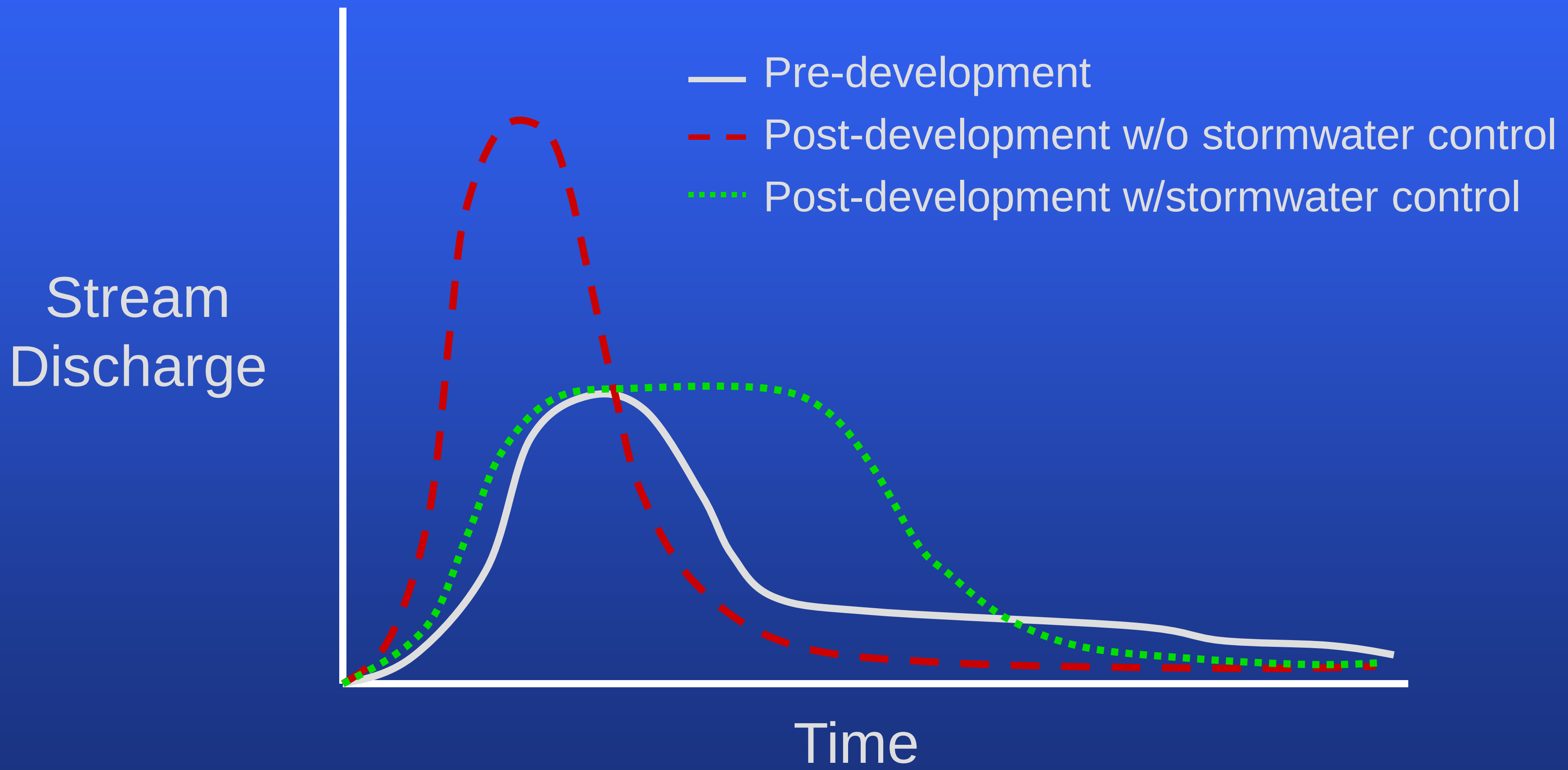
Source: Potomac Conservancy (2007) State of the Nation's River. Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols, University of Maryland Center for Environmental Science.

Urban Impacts-Peak Runoff



Sources: Tess Wynn, "Low Impact Development", 2009, Biological Systems Engineering, Virginia Tech

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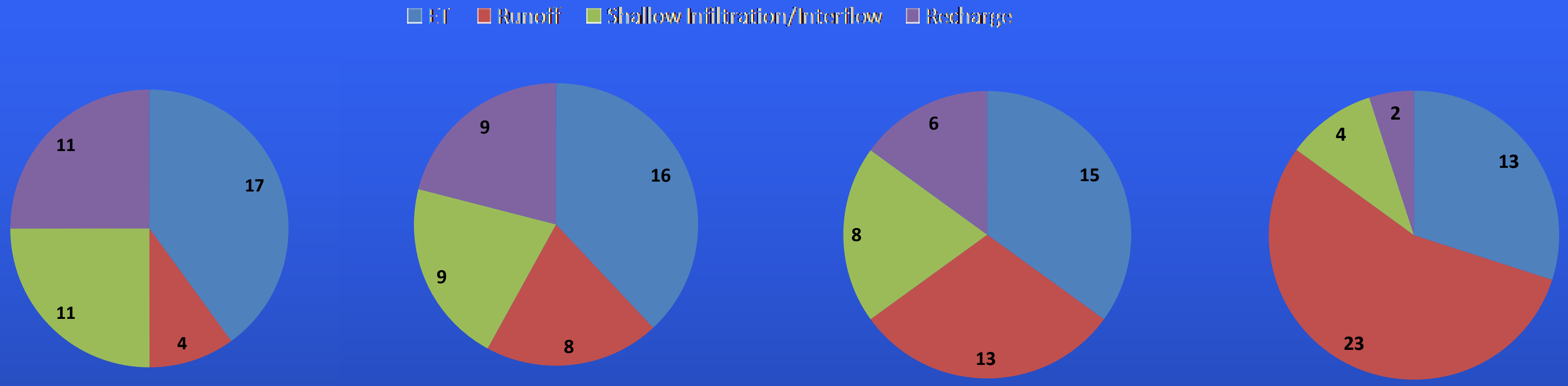
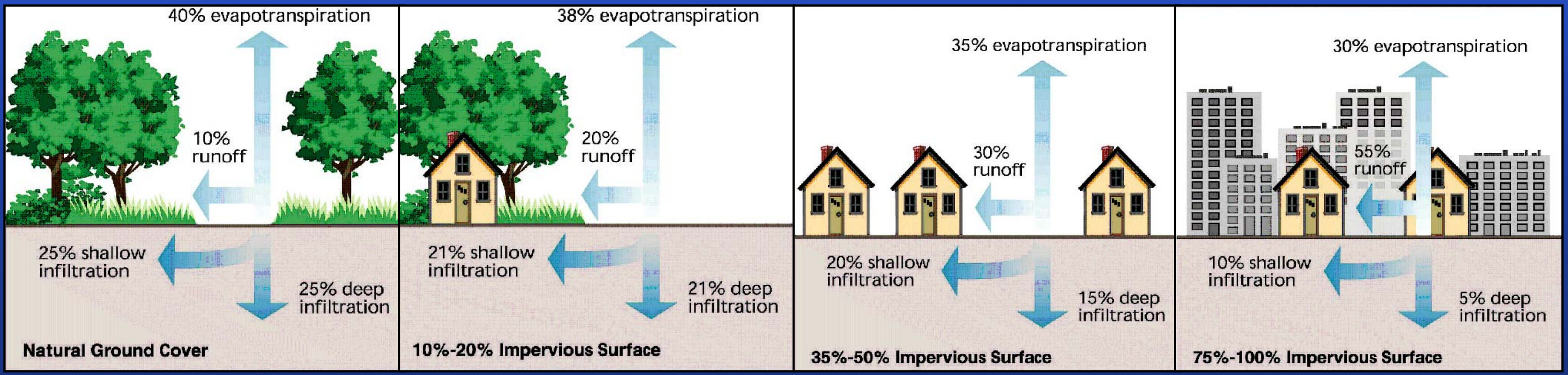
Urban Impacts-Hydrologic Cycle





Source: Stream Corridor Restoration, 1998

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Resultant Impacts on Streams

- Increased Runoff Volume
- Increased Runoff Peak
- Increased streambank erosion and deposition
- Loss of Riparian Buffers, loss of overbank storage
- Loss of wetland storage
- Sediment Load increase
- Base flows/Stream lengths decrease

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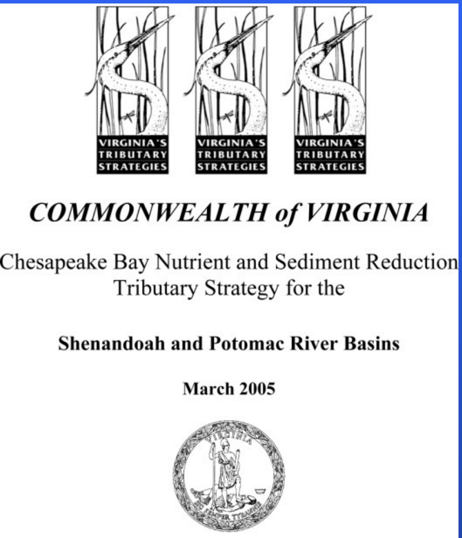
Tributary Strategies

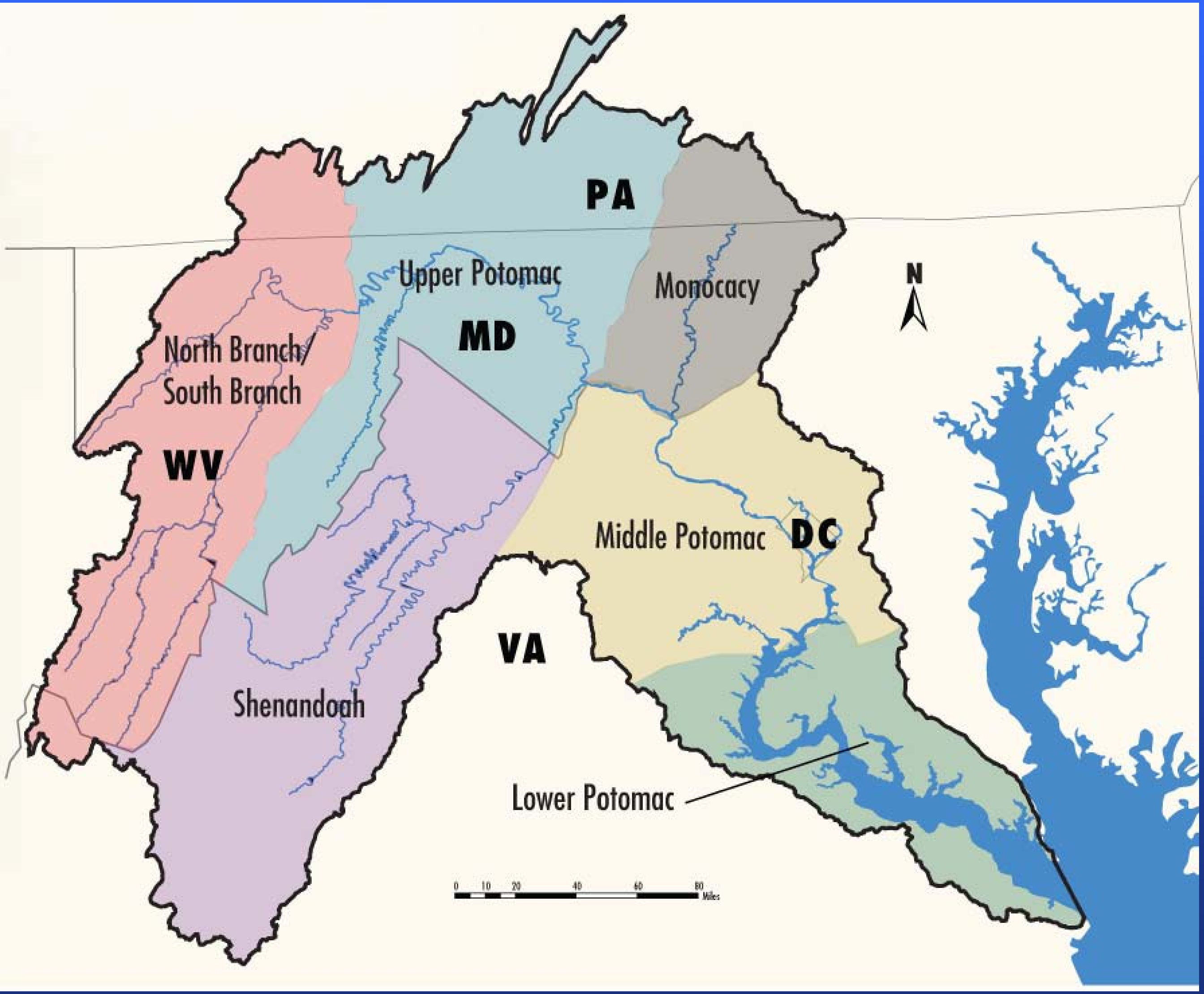

VIRGINIA'S TRIBUTARY STRATEGIES VIRGINIA'S TRIBUTARY STRATEGIES VIRGINIA'S TRIBUTARY STRATEGIES

COMMONWEALTH of VIRGINIA

Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the

Shenandoah and Potomac River Basins

March 2005



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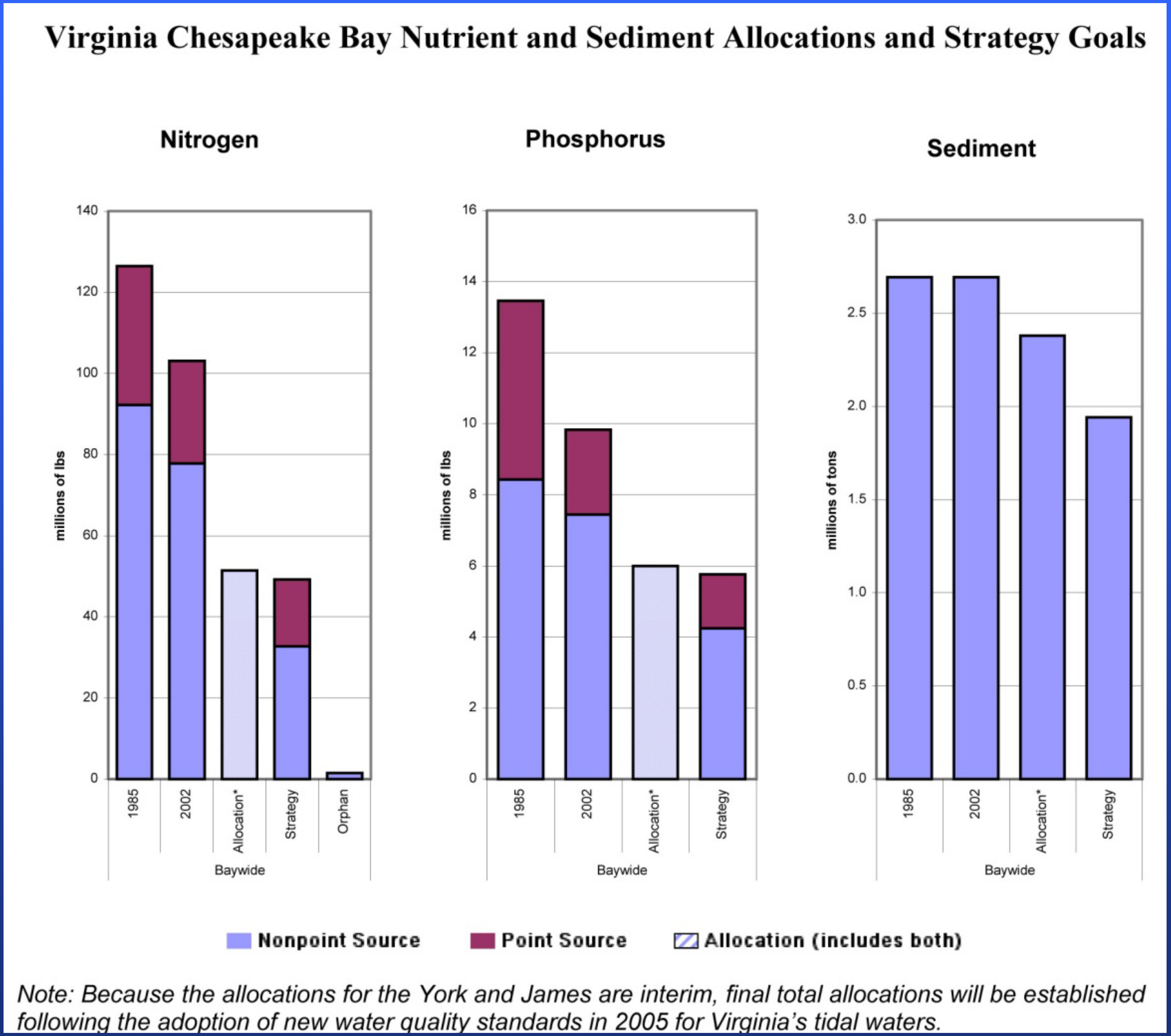
Sources: Commonwealth of Virginia Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the Shenandoah and Potomac River Basins, March 2005 and Source: Commonwealth of Virginia (2001) Achieving the Nonpoint Source Pollution Reduction Goal for the Shenandoah and Potomac Rivers in Virginia, Report prepared by the Virginia Department of Conservation and Recreation Commonwealth of Virginia, Richmond March 30, 2001

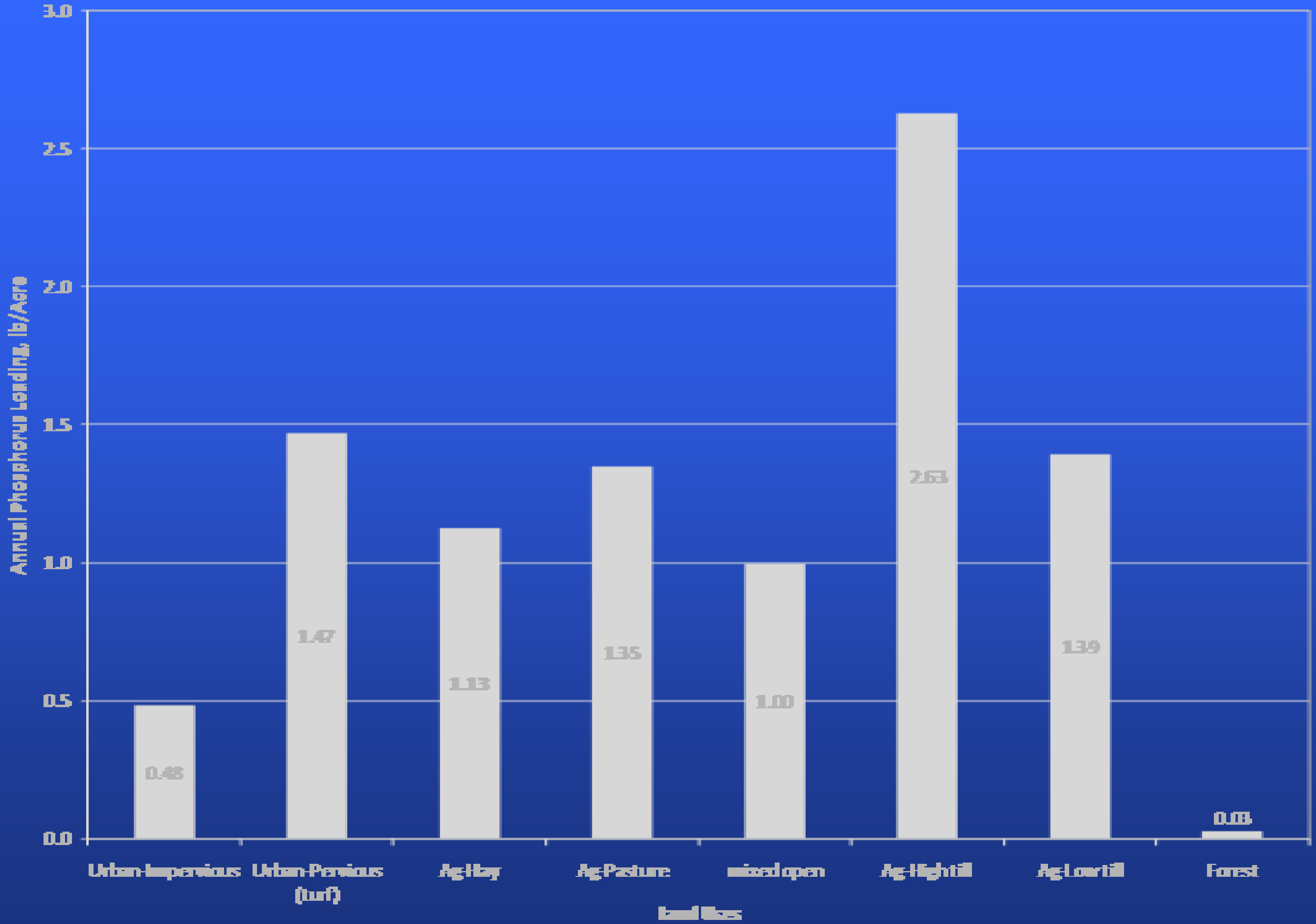
Tributary Strategies- the Numbers



CENTER for WATERSHED STUDIES at VIRGINIA TECH

Source: Commonwealth of Virginia Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the Shenandoah and Potomac River Basins, March 2005

Tributary Strategies



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Source: Commonwealth of Virginia Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the Shenandoah and Potomac River Basins, March 2005

2007 Reporting Results

Source Type	% of Action Stragegy Reached		
	[illegible]	[illegible]	[illegible]
Point Sources	69	87	NA
Agricultural Sources	48	51	48
Urban Stormwater	-83	-73	-62

- Growing Urban Population
- Forest Conversion to Development
- New Strategy for Urban Stormwater Needed

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Sources: Chesapeake Bay Program. 2007. Chesapeake Bay: Health & Restoration Assessment, A Report to the Citizens of the Bay Region, www.chesapeakebay.net, EPA-903-R-08-002 and the Potomac Conservancy (2007) State of the Nation's River.

Virginia Stormwater Criteria

Existing

Based upon Peak Runoff Control:

- Water Quality Volume-1 inch/30 hours
- Channel Protection, 1-year storage for 24 hours & evaluate velocity at 2-year, conveyance at 10.
- Flood protection, 10-year

Proposed

Based upon an Iterative Land Development Process:

- Environmental Site Design-minimize impervious surfaces
- Runoff Reduction-Increase infiltration through LID
- Pollutant Removal-Treat remaining runoff to remove Phosphorus
- Potential Channel "work" to remain constant

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Virginia Stormwater Management Handbook (1999), graphic from Georgia Stormwater Manual (2001)

Source: Technical Memorandum: The Runoff Reduction Method, April 18, 2008, Center for Watershed Protection

Meeting Goals with Environmental Site Design (ESD)

- Forest conservation
- Soil restoration
- Minimize Impervious cover
- Conservation Subdivisions

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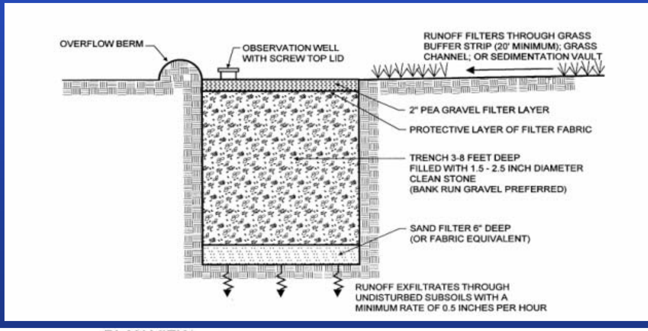
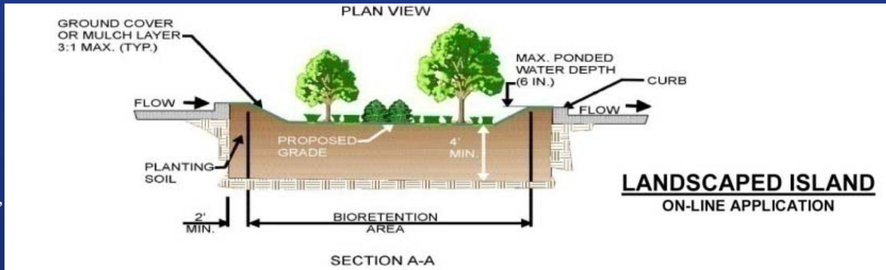
Sources: Technical Memorandum: The Runoff Reduction Method, April 18, 2008, Center for Watershed Protection, Washington County Maryland at ww.washco-md.net/planning/forest.shtm, Town of Cary, North Carolina Planning Dept., at townofcary.org.

Meeting Goals with Runoff Reduction (RR)

- Sheetflow to open space
- Rooftop Disconnects
- Green Roofs
- Porous Pavement
- Bioretention
- Dry Swales
- Infiltration
- Wet Swales
- Extended Detention





CENTER for WATERSHED STUDIES at VIRGINIA TECH

Source: Technical Memorandum: The Runoff Reduction Method, April 18, 2008, Center for Watershed Protection

Comparative P Removal Efficiencies

Practice	Runoff Reduction (RR) (%) (Appendix B)	Pollutant Removal (PR)[1] - Total Phosphorus (%) (Appendix C)	Total Removal (TR) [2]	NPRPD – Median to 3rd quartile (Q3)
Green Roof	*45 to 60*	*0*	*45 to 60*	*NR*
Rooftop Disconnection	*25 to 50*	*0*	*25 to 50*	*NR*
Raintanks and Cisterns	*40*	*0*	*40*	*NR*
Permeable Pavement	*45 to 75*	*25*	*59 to 81*	*NR*
Grass Channel	*10 to 20*	*15*	*23 to 32*	*24 to 46* [3]
Bioretention	*40 to 80*	*25 to 50*	*55 to 90*	*5 to 30*
Dry Swale	*40 to 60*	*20 to 40*	*52 to 76*	*NR*
Wet Swale	*0*	*20 to 40*	*20 to 40*	*NR*
Infiltration	*50 to 90*	*25*	*63 to 93*	*65 to 96*
ED Pond	*0 to 15*	*15*	*15 to 28*	*20 to 25*
Soil Amendments[4]	*50 to 75*	*0*	*50 to 75*	*NR*
Sheetflow to Open Space	*50 to 75*	*0*	*50 to 75*	*NR*
Filtering Practice	*0*	*60 to 65*	*60 to 65*	*59 to 66*
Constructed Wetland	*0*	*50 to 75*	*50 to 75*	*48 to 76*
Wet Pond	*0*	*50 to 75*	*50 to 75*	*52 to 76*
Range of values is for Level 1 and Level 2 designs – see Section 9 & Appendix D				

[1] EMC based pollutant removal
[2] TR = RR + [(100-RR) * PR]
[3] Includes data for Grass Channels, Wet Swales and Dry Swales
[4] Numbers are provisional and are not fully accounted for in Version 1 of the BMP Planning spreadsheet (Appendix A); however future versions of the spreadsheet will resolve any inconsistencies.
NR= Not Researched

Source: Technical Memorandum: The Runoff Reduction Method, April 18, 2008, Center for Watershed Protection

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Comparative N Removal Efficiencies

Practice	Runoff Reduction (RR) (%) (Appendix B)	Pollutant Removal (PR)[1] - Total Nitrogen (%) (Appendix C)	Total Removal (TR) [2]	NPRPD – Median to 3rd quartile (Q3)
Green Roof	45 to 60	0	45 to 60	NR
Rooftop Disconnection	25 to 50	0	25 to 50	NR
Raintanks and Cisterns	40	0	40	NR
Permeable Pavement	45 to 75	25	59 to 81	NR
Grass Channel	10 to 20	20	28 to 36	56 to 76 [3]
Bioretention	40 to 80	40 to 60	64 to 92	46 to 55
Dry Swale	40 to 60	25 to 35	55 to 74	NR
Wet Swale	0	25 to 35	25 to 35	NR
Infiltration	50 to 90	15	57 to 92	42 to 65
ED Pond	0 to 15	10	10 to 24	24 to 31
Soil Amendments[4]	50 to 75	0	50 to 75	NR
Sheetflow to Open Space	50 to 75	0	50 to 75	NR
Filtering Practice	0	30 to 45	30 to 45	32 to 47
Constructed Wetland	0	25 to 55	25 to 55	24 to 55
Wet Pond	0	30 to 40	30 to 40	31 to 41
Range of values is for Level 1 and Level 2 designs – see Section 9 & Appendix D				

[1] EMC based pollutant removal
[2] TR = RR + [(100-RR) * PR]
[3] Includes data for Grass Channels, Wet Swales and Dry Swales
[4] Numbers are provisional and are not fully accounted for in Version 1 of the BMP Planning spreadsheet (Appendix A); however future versions of the spreadsheet will resolve any inconsistencies.
NR= Not Researched

Source: Technical Memorandum: The Runoff Reduction Method, April 18, 2008, Center for Watershed Protection

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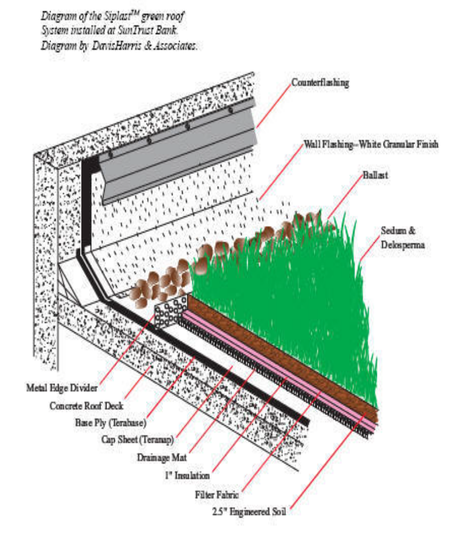
Green Roofs (RR)



- Designed to provide modest storage
- Converts some water to ET
- Reduces Energy Loss/LEEDS
- Aesthetically pleasing
- Typically addresses small storms, <.25-0.5 inches
- Extensive-Intensive
- Ex: SunTrust Bank, Richmond

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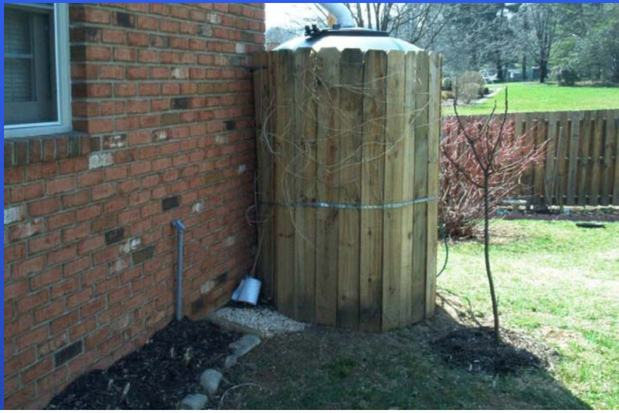
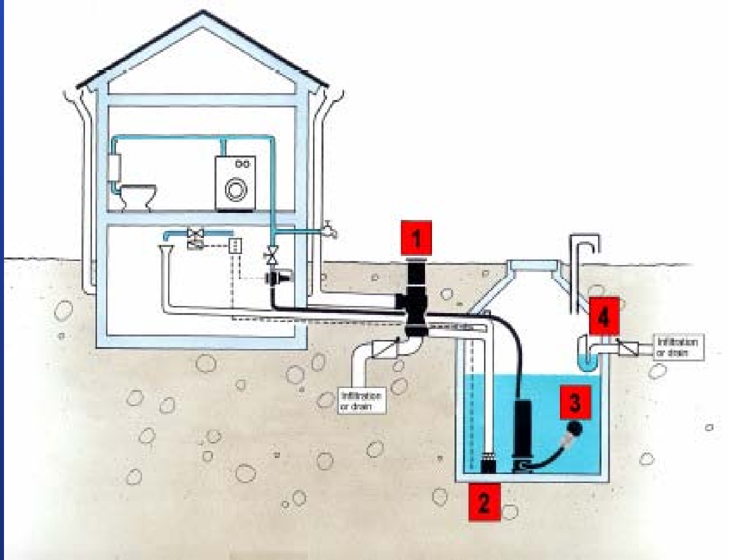
Source: Richmond Regional Planning and Development Council at http://www.richmondregional.org/Planning/Stormwater/green_roof.htm

Rainwater Harvesting/Cisterns (RR)

- Captures impervious runoff
- Underground/Above
- Reuse-can be Outdoor or indoor
- Supplements water supply
- Volume benefits-maximize if managed





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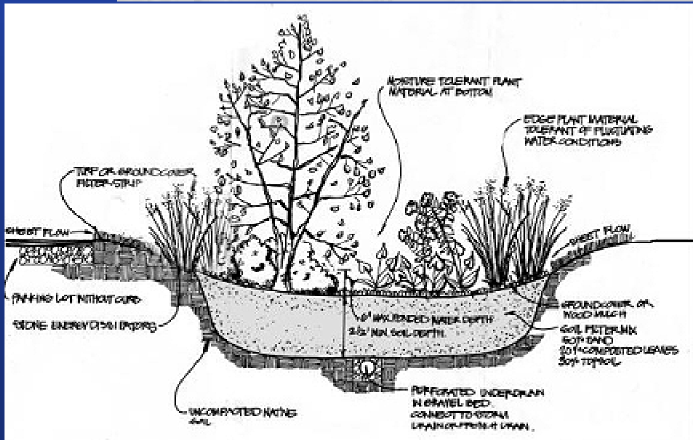
Source: Virginia Rainwater Harvest Manual, at www.CabellBrandCenter.org and WSSI/Wetland Studies and Solutions, Inc., at http://www.wetlandstudies.com.

Bioretention/Rain Gardens (RR, PR)

- Aka “Rain Gardens”
- With and without Underdrains
- Peak/Volume Benefits
- Pollutant Removal
- Issues:
  - Keep Small (5-10%) DA
  - Sediment Pretreatment
  - Soils/Media



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Source: www.stormwatercenter.net, William Hunt’s web site at www.bae.ncsu.edu/stormwater, and WSSI/Wetland Studies and Solutions, Inc., at http://www.wetlandstudies.com.

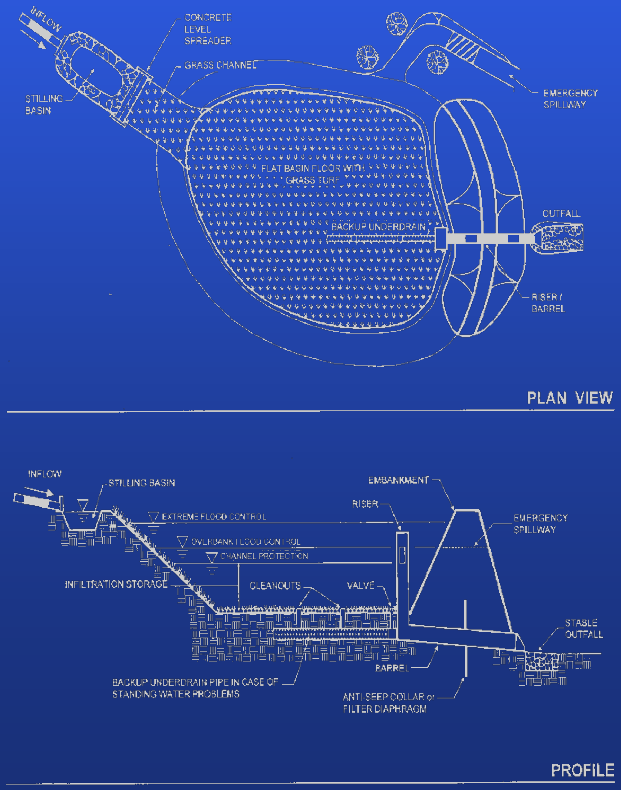
Permeable Pavement (RR)

- Paver/block systems
- Porous concrete
- Provides storage by eliminating use of fine materials
- Heavy traffic areas may not be suited
- Must keep sediment off!
- Reduce/attenuates small storm runoff depending upon substrate

Source: William Hunt's web site at www.bae.ncsu.edu/stormwater and WSSI/Wetland Studies and Solutions, Inc., at http://www.wetlandstudies.com/

Infiltration Basins (RR, PR)

- Provides storage within voids
- Surface can be used for passive storage
- Provides RR (if soil permits), attenuation, and PR
- Must be careful to avoid pervious runoff
- Maintenance costs high/clogging



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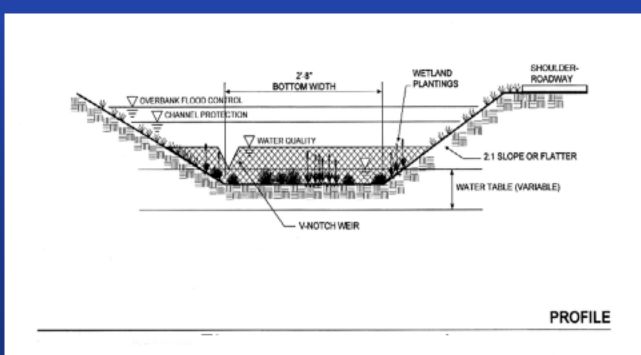
Source: www.stormwatercenter.net, and WSSI/Wetland Studies and Solutions, Inc., at http://www.wetlandstudies.com.

Wet Swales (PR)

- Similar to “roadside swales, however much larger
- Vegetation/wet pool provides WQ treatment
- Not recommended and steep slopes
- Lower capital cost, higher maintenance costs



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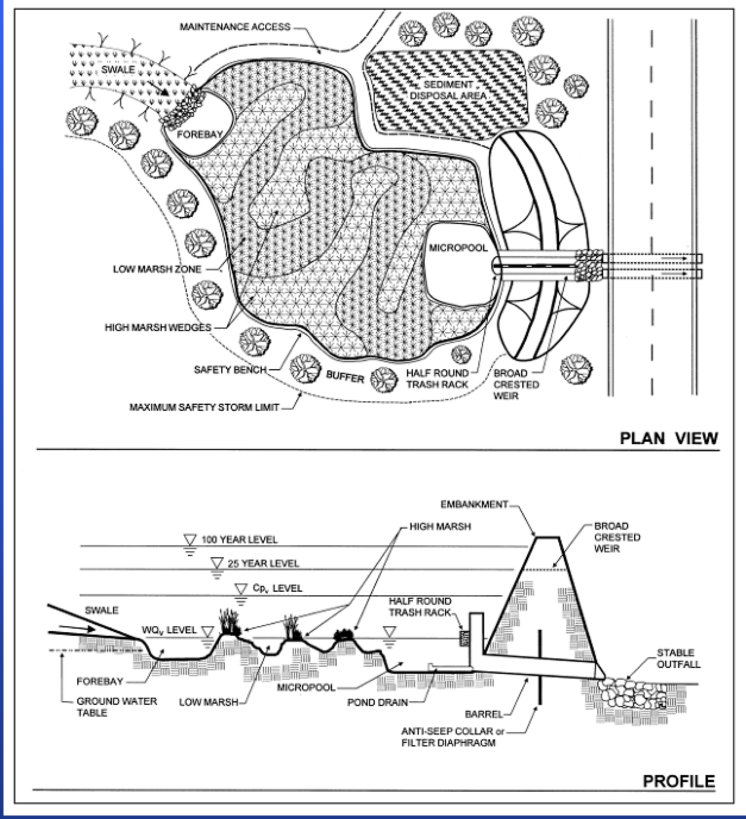
Source: Bottom Right, www.stormwatercenter.net, Bottom Left, WSSI/Wetland Studies and Solutions, Inc., at http://www.wetlandstudies.com, Top Left, University of Vermont, BMP toolbox, at: http://www.uvm.edu/~ran/ran/toolbox/bmp/vegetatedswales.php, Top right, http://www.unh.edu/erg/cstev/fact_sheets/veg_swale_fact_sheet_08.pdf

Stormwater Wetlands (PR)

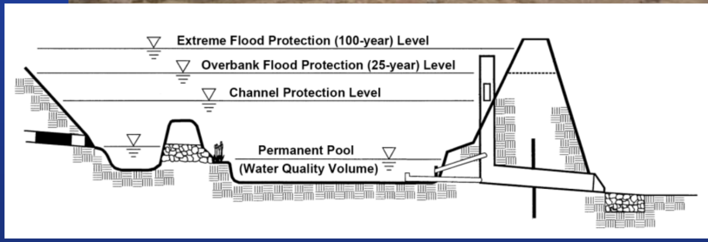
- Provides excellent nutrient removal
- Must have continuous base flow
- Large land area required
- Low maintenance
- New focus on emergent and forested wetlands



Source: www.stormwatercenter.net, and William Hunt's web site at www.bae.ncsu.edu/stormwater

Wet Ponds (PR)

- Provides nutrient and sediment removal
- Can provide flood control benefits
- Must have base flow
- Maintenance can be high
- Discharge energy can be problematic



Source: Georgia Stormwater Manual (2003), *http://www.unh.edu/erg/cstev/fact_sheets/ret_pond_fact_sheet_08.pdf*

What we Need to Know About Green Infrastructure

Measuring Performance

- Large degree of uncertainty
- Inflow/Outflow, issues with inflow
- Capture of total mass
- Statistical methods
- New ASCE Handbook

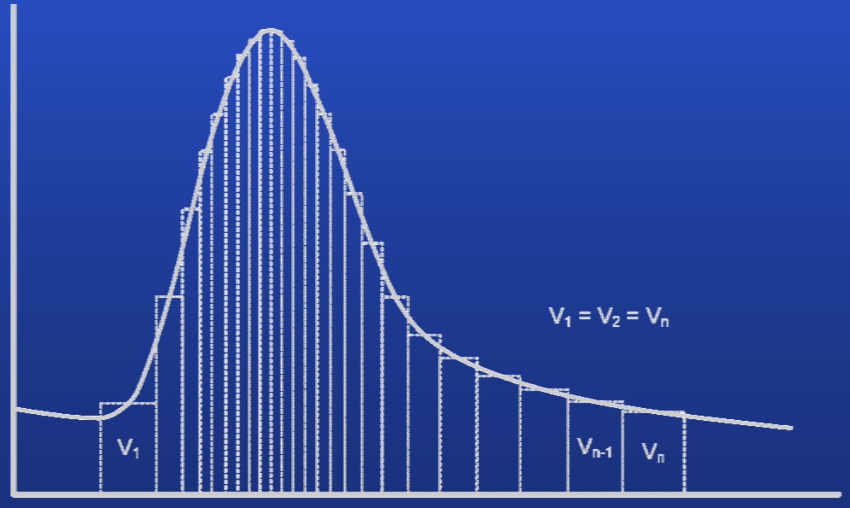


Figure 11. Schematic of flow-weighted compositing methodology.

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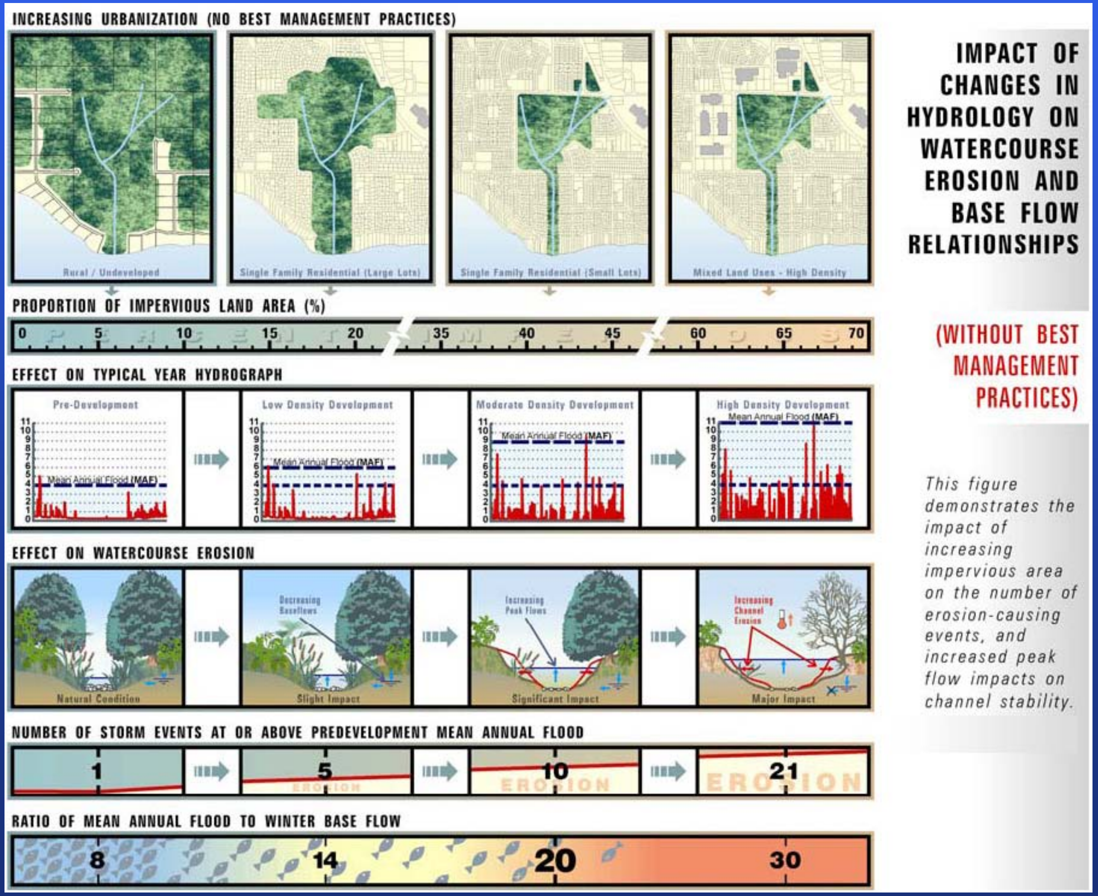
Predicting Costs

- Types of Costs
  - Capital
  - Land/Opportunity Costs
  - Operation/Maintenance-Regular
  - Operation/Maintenance-Special
  - Retirement
- Lack of Centralized Data Collection
- Partnership between EPA and Local
- WERF Project
- VT Project

Aggregation and Uncertainty

- How do we aggregate these techniques, and can we measure effectiveness within a watershed?
- How do they integrate with stream programs
- Ongoing USGS research on Fairfax Implementation



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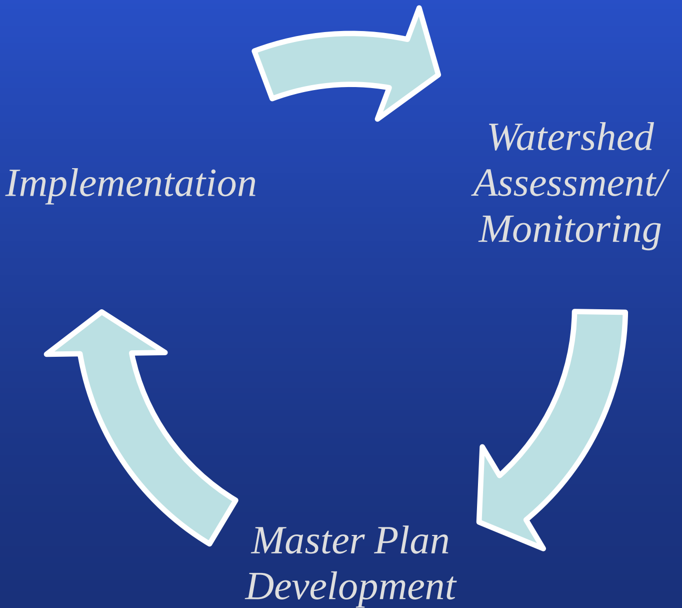
Source: Metropolitan North Georgia Water Planning District (2003) District-Wide Watershed Management Plan

Barriers to Implementation

- Potentially large numbers to manage
- Lack of legal mechanisms for control and maintenance
- Lack of integration with other mitigation practices
- Lack of understanding what maintenance is required, what frequency
- Lack of experience with controls
- Concerns over resiliency

Monitoring and its Role in Adaptive Management

- Local governments
  - Focus upon implementation with limited $
  - Impressive investments in planning and implementation
- State Agencies
  - Focus upon implementation with limited $
- Federal Agencies
  - ARRA-focus upon implementation



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Active Research Areas

Stormwater Treatment Wetland

- City of Fairfax-Ashby Road Pond
- Proposed as a traditional wet pond retrofit
- Current proposal for NFWF/Chesapeake Bay Grant funding for conversion to wet pond/wetland
- Cost: $650k
- Projected Annual Benefits:
  - TSS, 10 tons
  - P, 73 lbs
  - N, 320 lbs
  - Stream TSS, 2 tons

Source: Technical Memorandum: The Runoff Reduction Method, April 18, 2008, Center for Watershed Protection and The Louis Berger Group, Inc. and Gannett Fleming, Inc., (2005) City of Fairfax, Virginia City of Fairfax, Virginia Ashby Road Pond Feasibility Study, Final Report July 2005, Washington, DC.

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LID Design/Implementation
Science Museum, Richmond

- Bioretention
- Permeable pavement
- Grass Channels
- Wetland
- Infiltration
- Dry Swales

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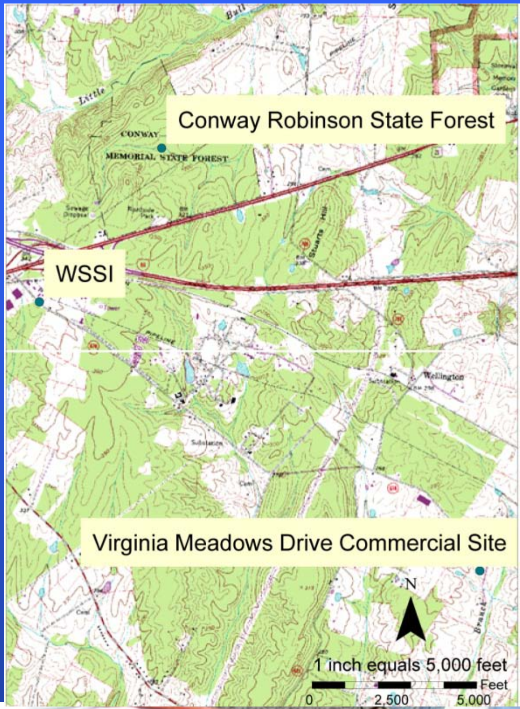
LID Performance Evaluation, NOVA

- Multiple LID devices including Bioretention, permeable pavement, swales, infiltration, green roof, cistern
- Need to assess performance/publish results
- Paired watershed study



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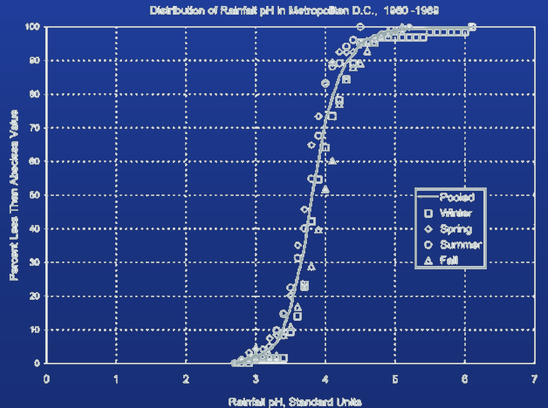
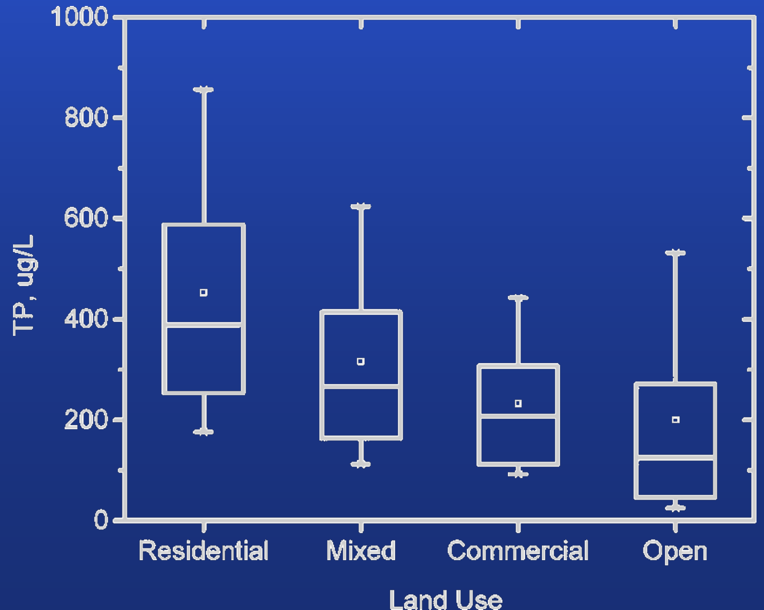
Alternative Media

- Proposed Test Sites
  - Large Bioretention
  - Infiltration Basin
- Alternative Media Examples
  - Fly Ash (amended)
  - Compost and Mix
  - Steel Slag (note pH)



Phosporus Testing Protocol for MTDs

- Proposed stormwater rules in VA, focus upon Phosphorus
- Manufactured devices proliferating, data on sediment, not P
- Developing testing procedures, balancing # of samples, protocols



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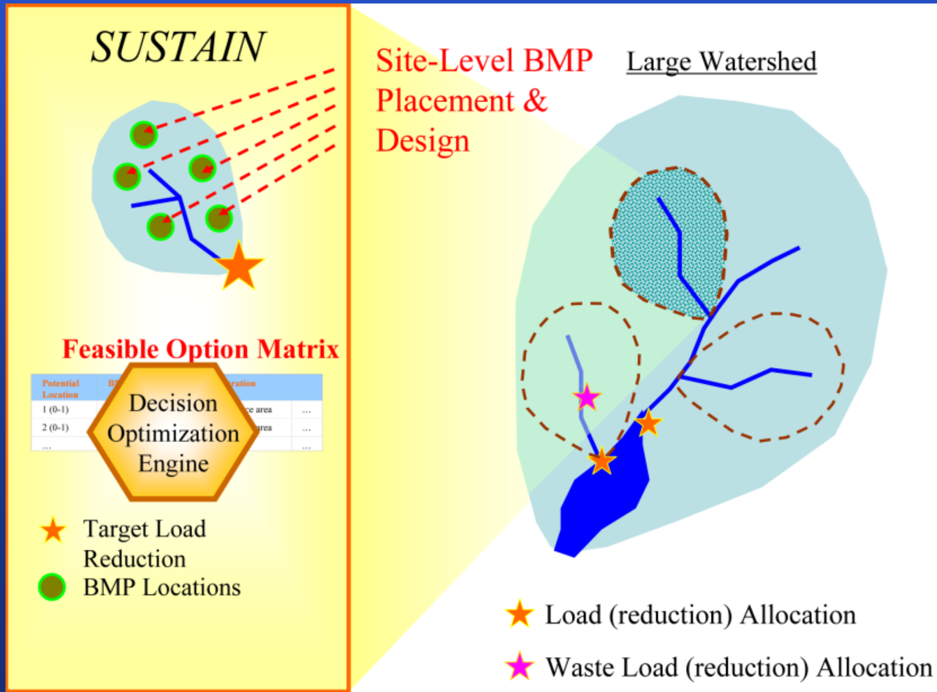
Watershed Evaluation of LID Implementation

- Assessing effects of aggregation
- New modeling/optimization tools available
- Integrating with master planning and stream restoration



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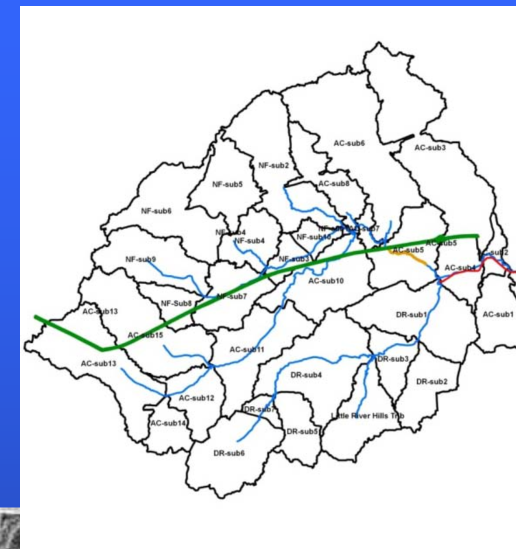
Fairfax Blvd Redevelopment



Source: City of Fairfax (2007) Fairfax Boulevard Redevelopment Master Plan.

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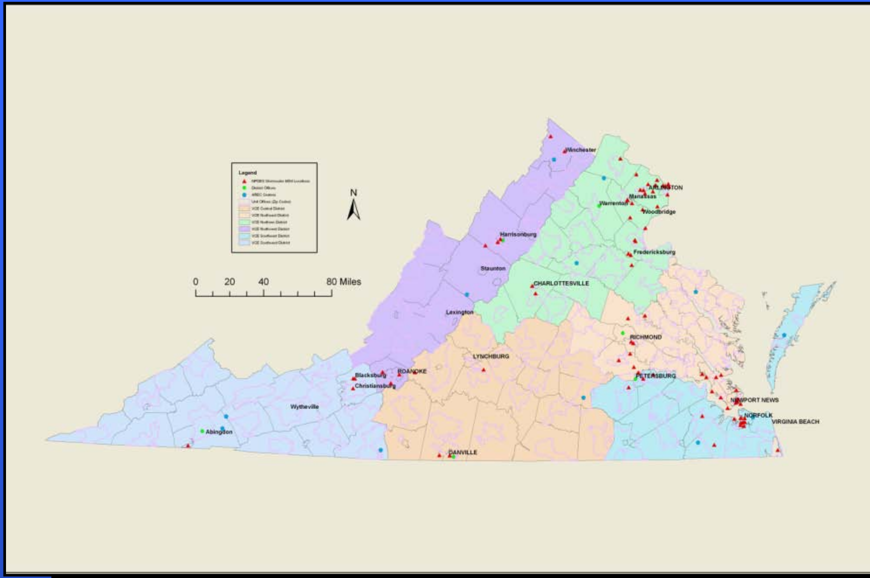
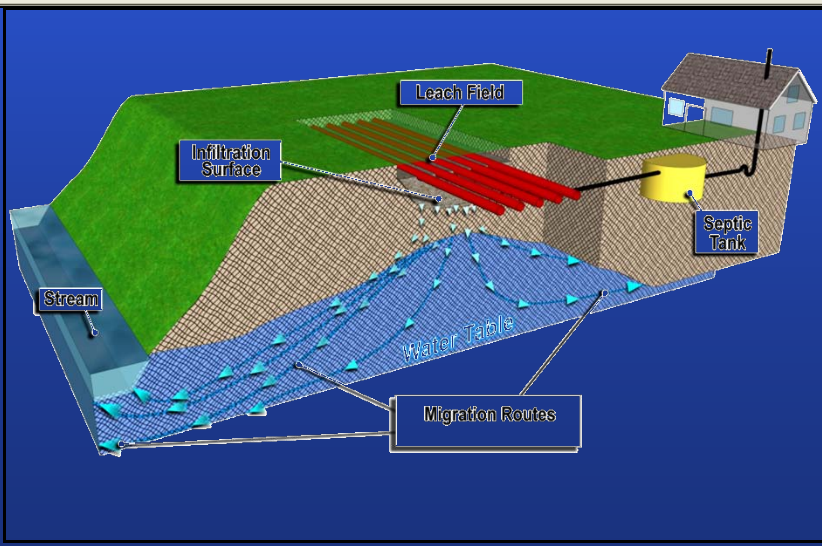
Extension Activities

- Supporting DCR in Virginia SW Program, BMP Clearinghouse, development of Fact Sheets, internal training and support
- Developing an educational and training programs for Virginia municipalities implementing permitted SW programs
- Developing outreach programs for best practices for detection of Failing Septic Systems





Questions?

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