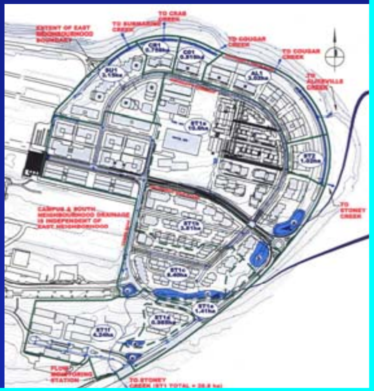
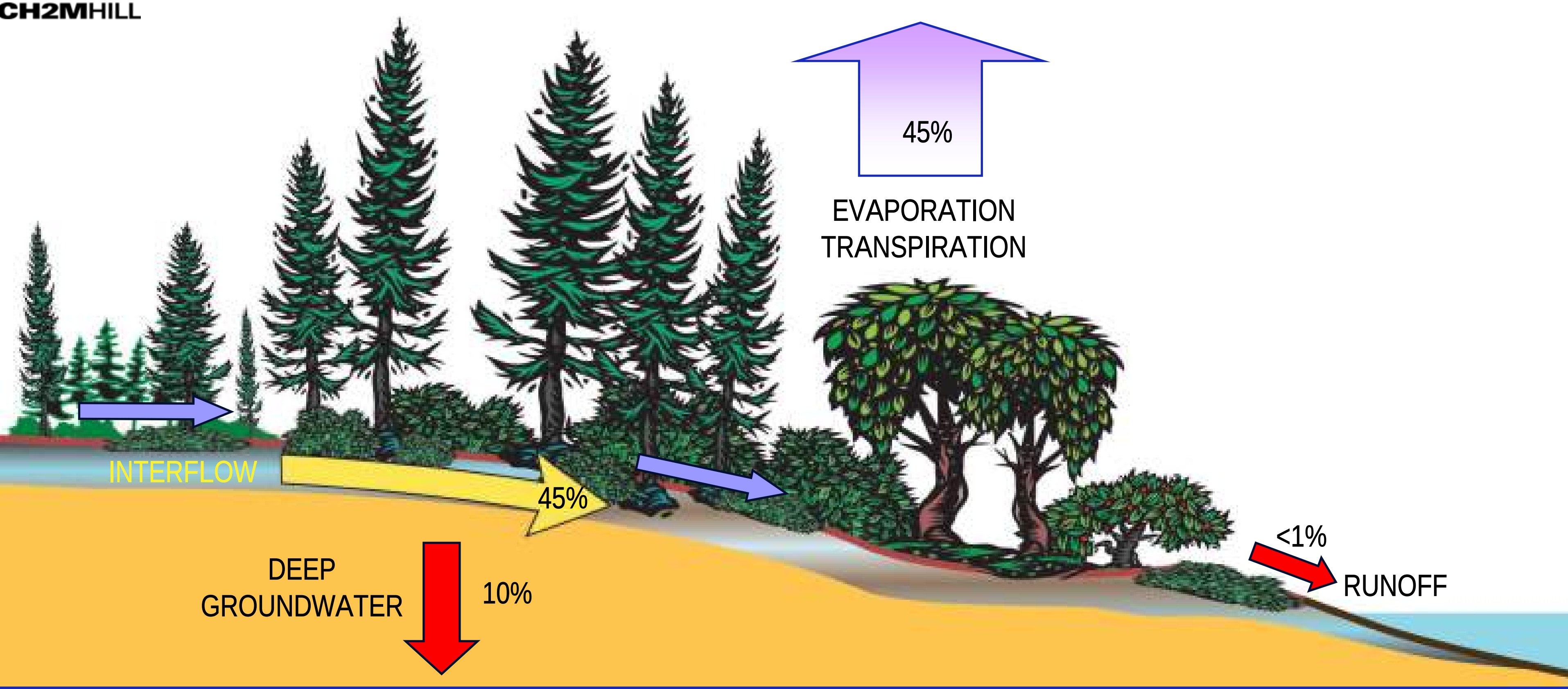
Sustainable Stormwater Management Using Low Impact Development



By:
Dan Medina
CH2MHILL

February 6, 2006

Under Natural Conditions Runoff is Limited



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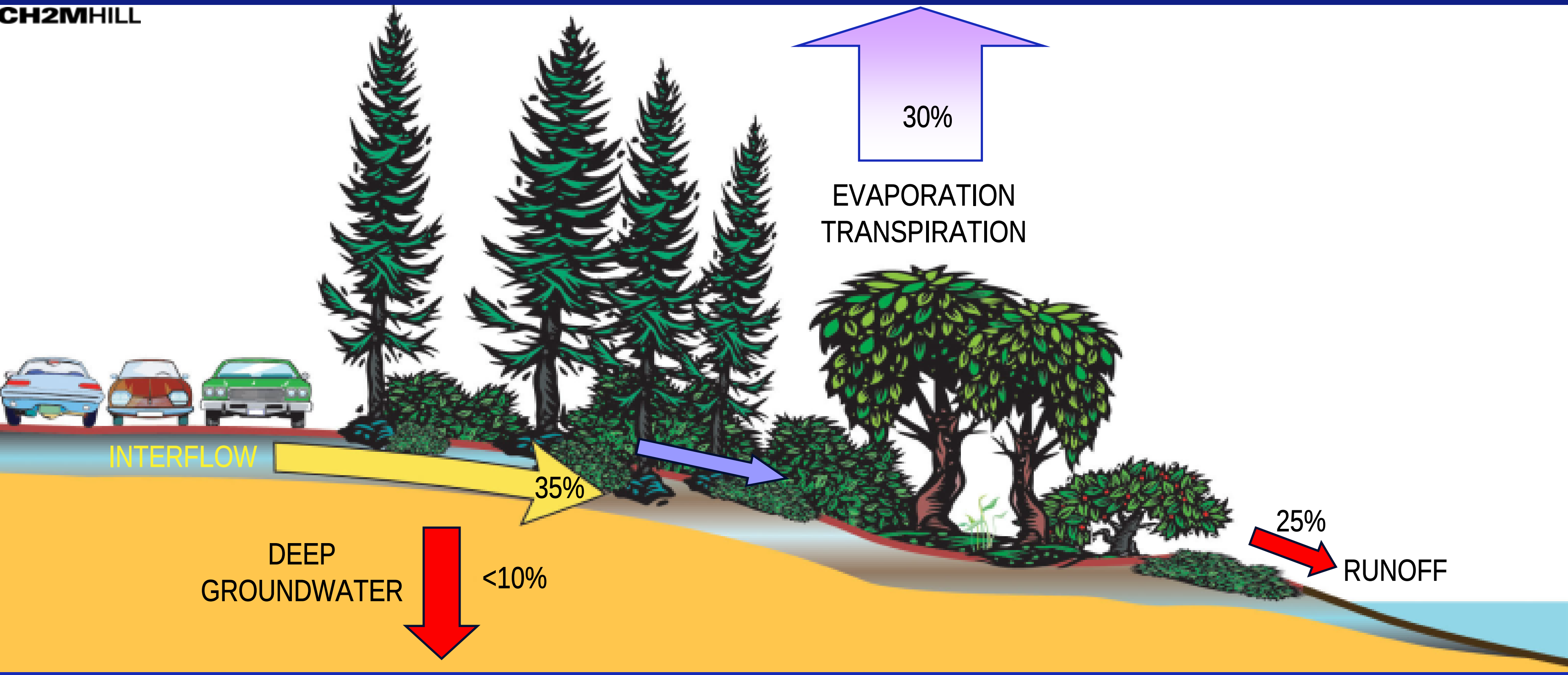
After Development, Runoff is High



How do we make this…

function like this?

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What is LID?

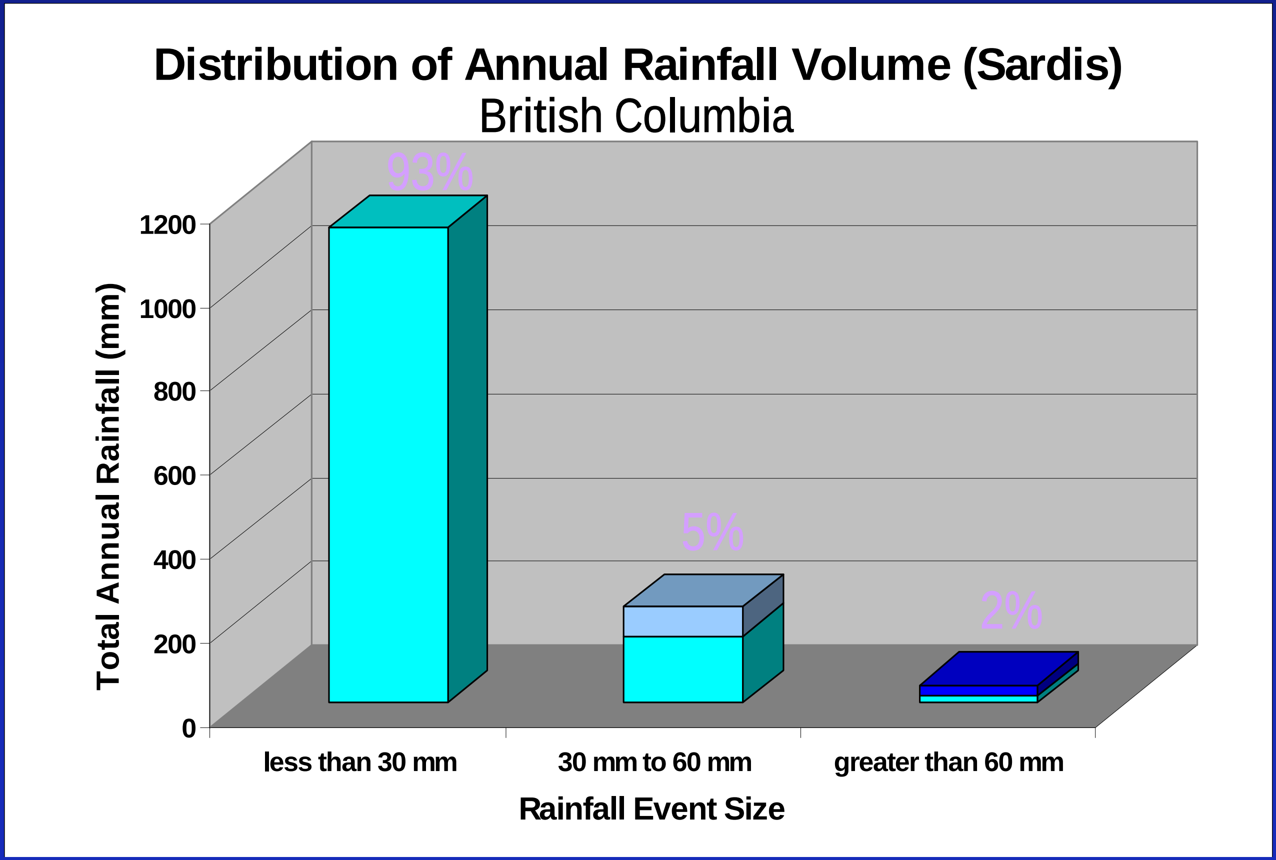
- Low Impact Development (LID), Sustainable Urban Drainage Systems (SUDS), better site design, Natural Drainage Systems (NDS)
- Hydrologically functional site design combined with pollution prevention measures to compensate for land development impacts on hydrology and water quality
- Decentralized stormwater micro-management techniques to mimic the original hydrologic regime
- Based on runoff volume control

LID Site Planning Principles

- Use hydrology as the basis for site design
- Think small (small storms, small drainage areas, small controls)
- Control runoff volume at the source
- Simple is safe
- Hydrologically functional landscape: more than just pretty plants

LID Site Planning Principles

- Think small
  - Small storms
  - Small drainage subareas
  - Small controls



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LID Conceptual Basis

- Preserve ecosystem functions in the built environment
- Use nature to mimic the natural water balance
- Use hydrology as fundamental design guide
- Deploy multiple systems
- Preserve runoff volume, frequency, and timing

Volume Control vs. Peak Flow Control

	Peak Flow Control	Volume Control
Impervious cover	Maximized to speed drainage	Minimized
Time of concentration	Shortened to speed drainage	Maximized
Runoff volume	Increased, not controlled	Controlled for most storms
Peak discharge	Controlled for a few events	Controlled for most storms
Runoff frequency	Increased for small storms	Maintained for all storms
Runoff duration	Increased for all storms	Maintained for all storms
Groundwater recharge	Reduced	Maintained for all storms
Water quality	Controlled for a few events	Controlled for all storms
Stream ecology	Degraded	Sustained for all storms
Flooding	Reduced on site but perhaps increased downstream	Controlled for most storms on site and elsewhere

- Site cleared and grubbed
- Non native vegetation planted
- Soils compacted
- Fast drainage
- One central pond treatment
- No groundwater recharge

- Site "fingerprinted"
- Native vegetation preserved
- Soils protected
- Slow drainage
- Decentralized treatment
- Groundwater recharge encouraged

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Soil Compaction

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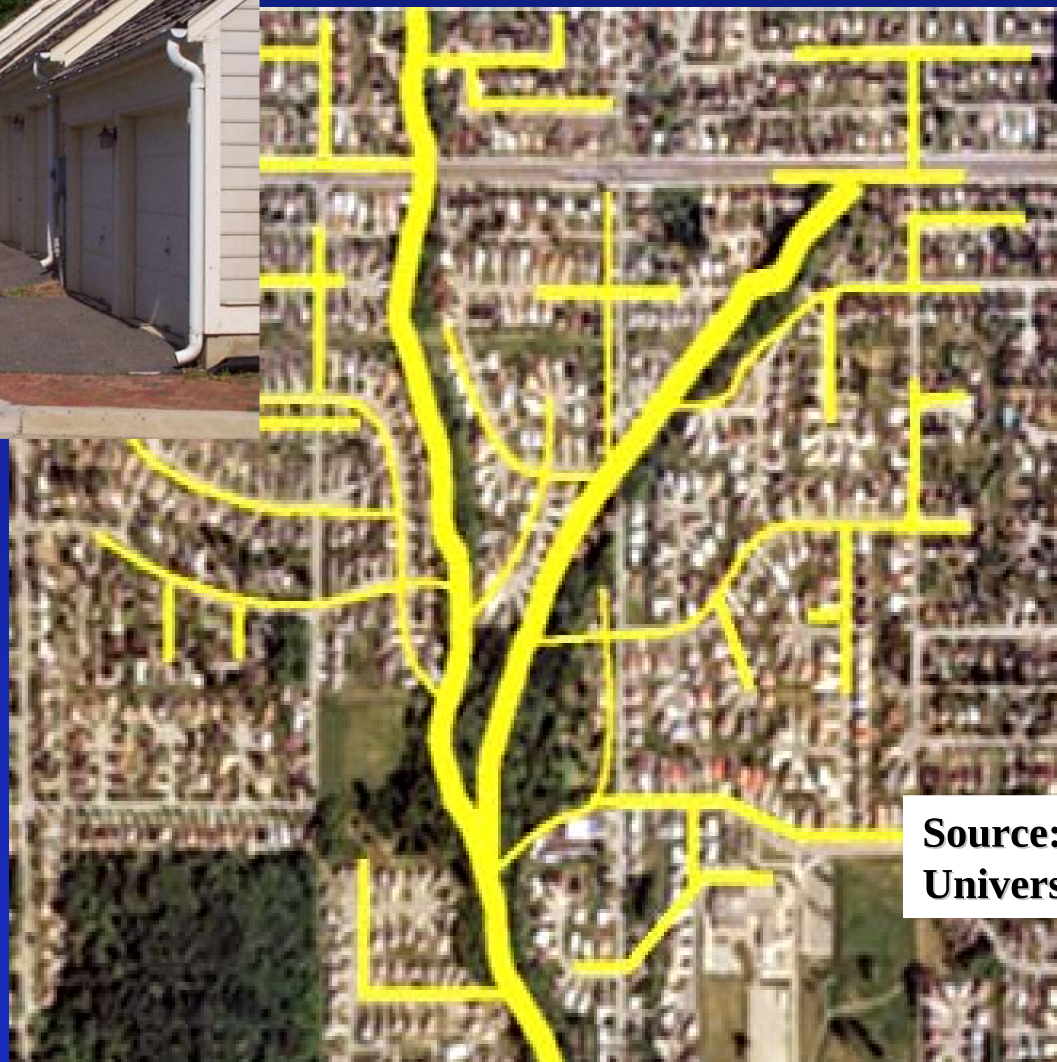
The street system and the stream system are one system!



Source: Patrick Condon, University of British Columbia

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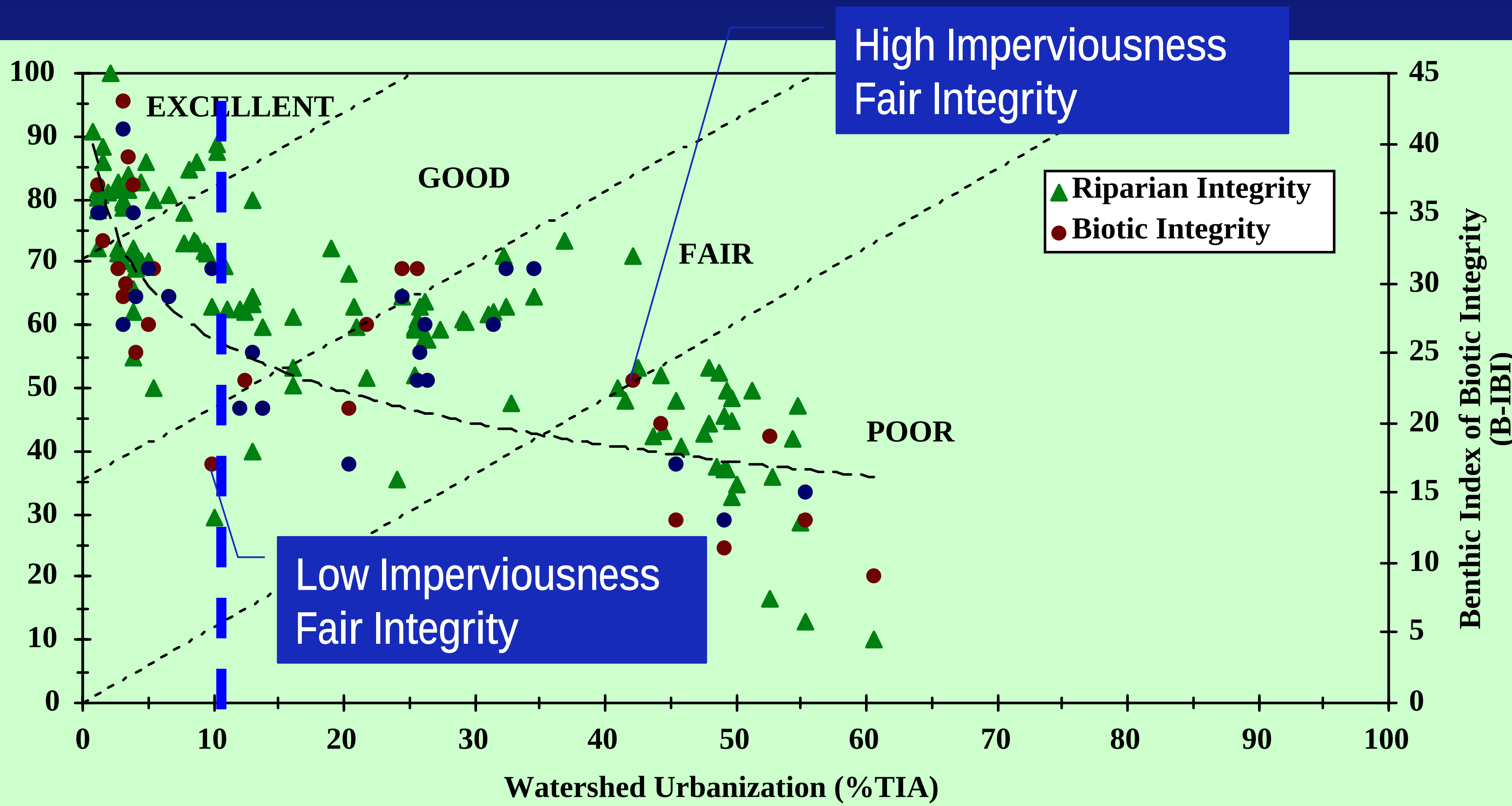
Is Imperviousness the Culprit?



May, C., et al. 1997. "Effects Of Urbanization On Small Streams in the Puget Sound Ecoregion" in Watershed Protection Techniques, 2(4), p. 483-494.

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Is not what we do but how we do it!

- Hydrologically functional land design
- Engineer the site to mimic original hydrologic regime
- Distribute and increase assimilative capacity
- Build redundancy
- Multifunctional landscape and buildings

LID vs. Conventional Stormwater Management

- Economics
  - Infrastructure maintenance cost
- New drivers
  - Public health (open water liability, West Nile virus)
  - Ecosystem protection
  - Source water protection
  - CSOs
  - Urban densification
  - Regulations (NPDES, TMDL, ESA)

Source: Larry Coffman

Limitations of Conventional Stormwater Management

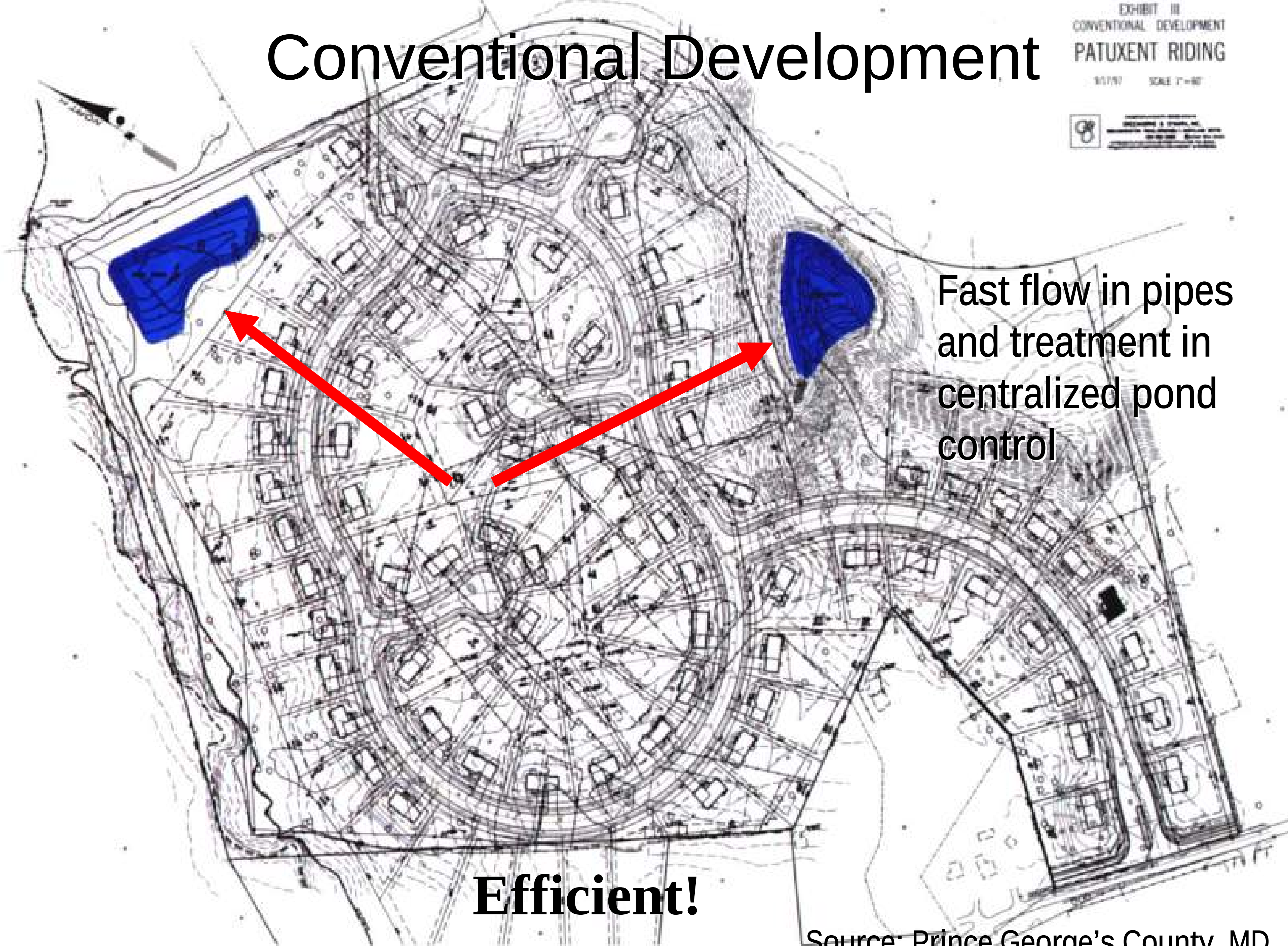
- Alters hydrologic regime (hydromodification)
- Does not prevent stream degradation
- Limited use for urban retrofit
- Excessive maintenance

Conventional Stormwater Management is not Working

Reston, VA: stormwater managed with system of regional ponds

Source: Larry Coffman

Conventional Development

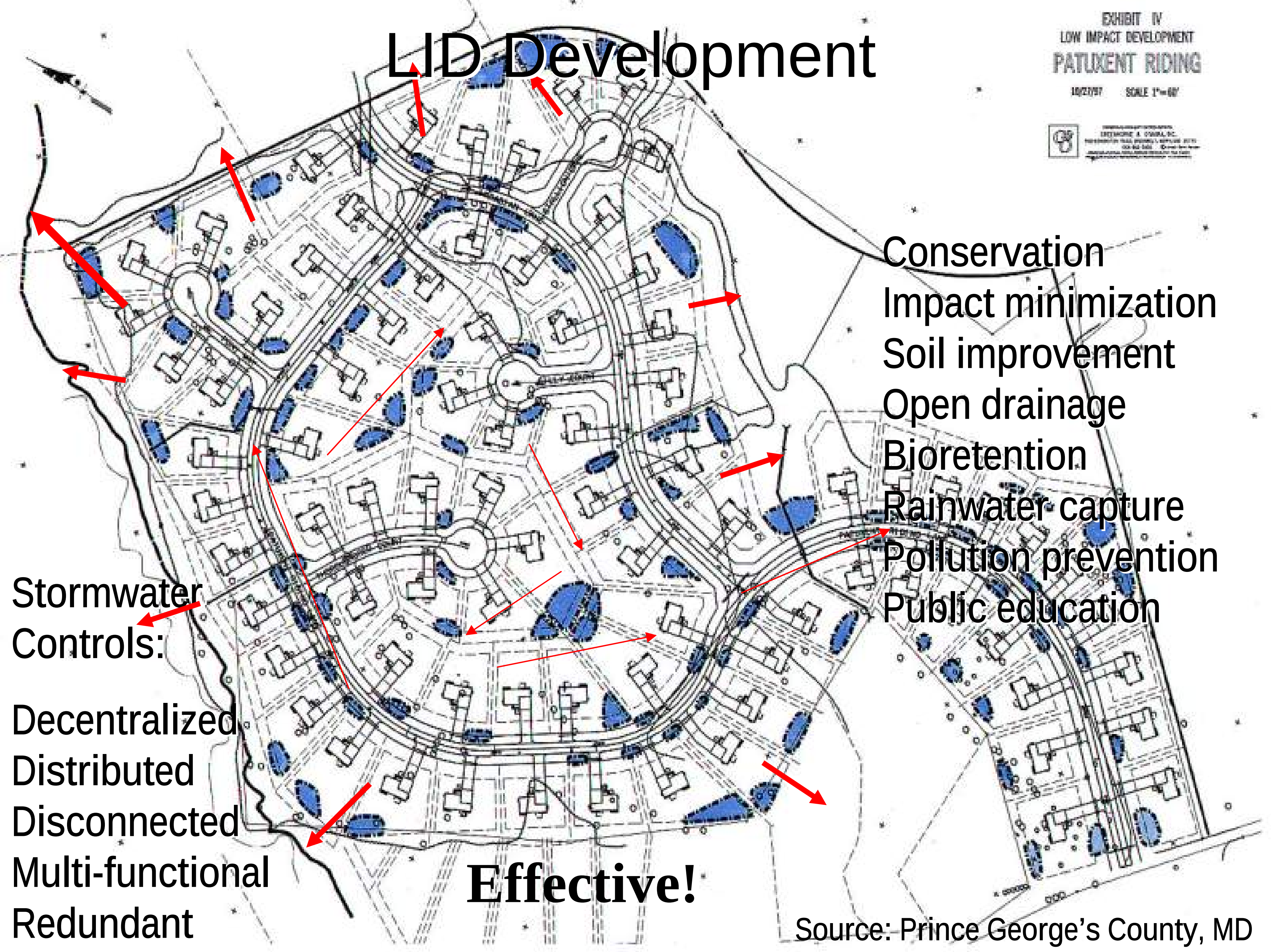


Fast flow in pipes and treatment in centralized pond control

Efficient!

Source: Prince George's County, MD

LID Development



Conservation
Impact minimization
Soil improvement
Open drainage
Bioretention
Rainwater capture
Pollution prevention
Public education

Stormwater Controls:

Decentralized
Distributed
Disconnected
Multi-functional
Redundant

Effective!

Source: Prince George's County, MD

Conventional Site Design

Concentrate flow and convey to centralized control

Fast Drainage

Source: Larry Coffman

LID Site Grading

Source: Mike Clar, Ecosite, Inc.

Site Fingerprinting

Source: Mike Clar, Ecosite, Inc.

Tree Preservation

Source: Mike Clar, Ecosite, Inc.

Imperviousness Minimization

Source: Mike Clar, Ecosite, Inc.

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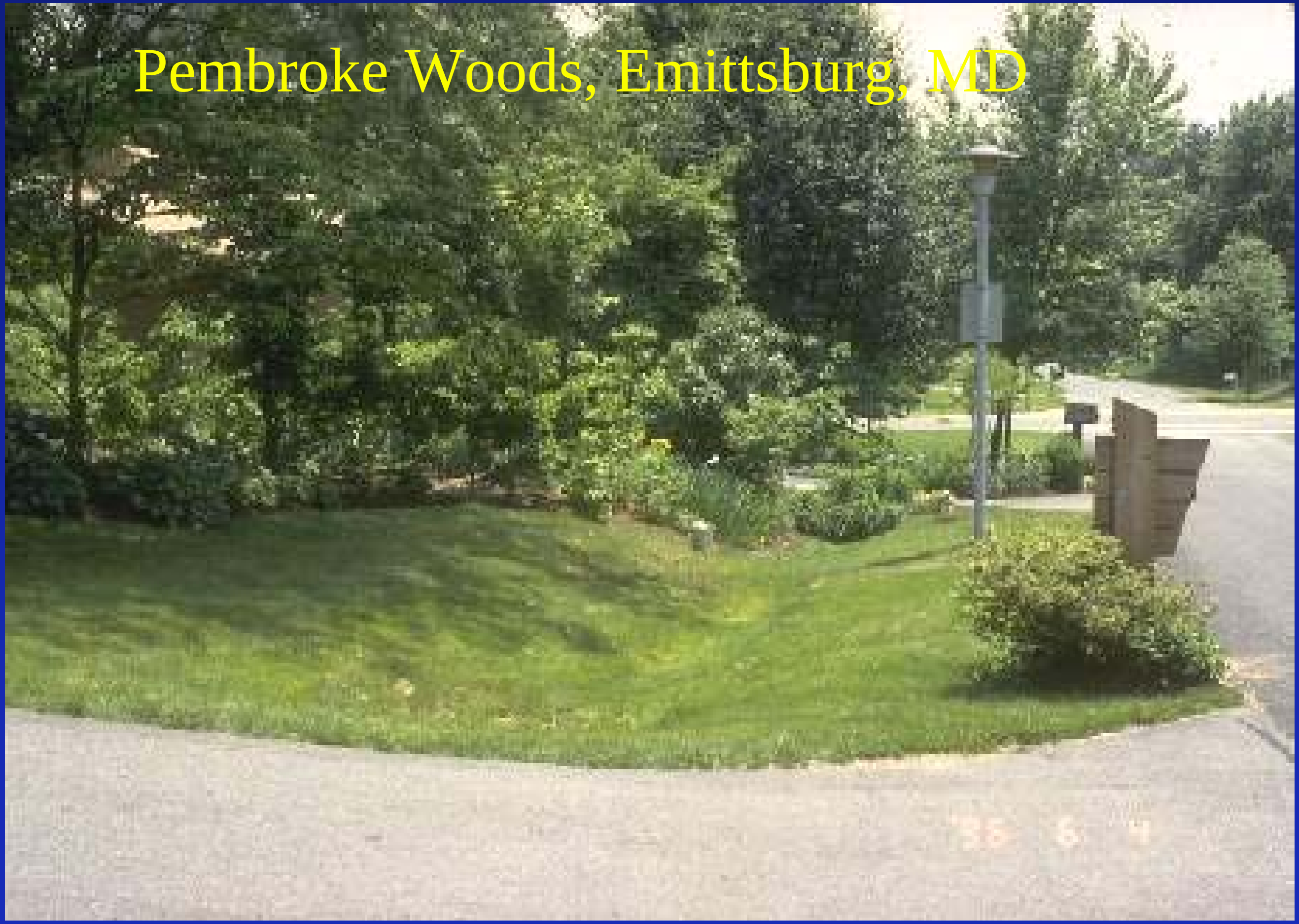
Open Drainage



Source: Mike Clar, Ecosite, Inc.

Construction Cost Comparison

Somerset Development, Prince George's County, Maryland

	Conventional	Low Impact
Grading and roads	$569,698	$426,575
Stormdrain system	$225,721	$132,558
SWM pond/Fees	$260,858	$ 10,530
Bioretention	—	$175,000
Total	$1,086,277	$744,663
Unit Cost	$14,679	$9,193
Lot Yield	74	81

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Challenges to LID Implementation

- Regulators must approve new approaches
  - New road standards
  - Clustering
- Professionals must change their designs standards
- Life cycle cost of BMPs must be considered
- Reviewers must have procedures in place and be trained in LID
- Developers must recognize the validity and marketability of LID
- The public must become more educated in stormwater management
- Research is needed on LID controls
- Need suitable models

Categories of LID Controls

- Runoff Minimization
- Rainwater Capture
- Landscaping
- Infiltration
- Conveyance

Runoff Minimization

- Imperviousness disconnection
- Sidewalk minimization
- Permeable pavement
- Vertical construction

Roof Leader Disco
(Chincoteage, VA)


Anacostia, Washington DC

Runoff Minimization

- Imperviousness disconnection
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EcoVillage at Ithaca
(Ithaca, NY)

Runoff Minimization

- Imperviousness disconnection
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Source: http://www.uni-groupusa.org/

Rainwater Capture

- Rainfall harvesting
- Rooftop detention
- Green roofs
- Subsurface storage
- Median storage

Source: American Rainwater Catchment Systems Association
www.arcsa-usa.org

Rainwater Capture

Vancouver, British Columbia

- Rainfall harvesting
- Rooftop detention
- Green roofs
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Rainwater Capture

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Kennedy Center,
Washington, DC

Rainwater Capture

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Landscaping

- Bioretention
- Stormwater planters
- Lawn replacement
- Created wetlands

Maryland Department of the Environment, Baltimore, MD

Landscaping

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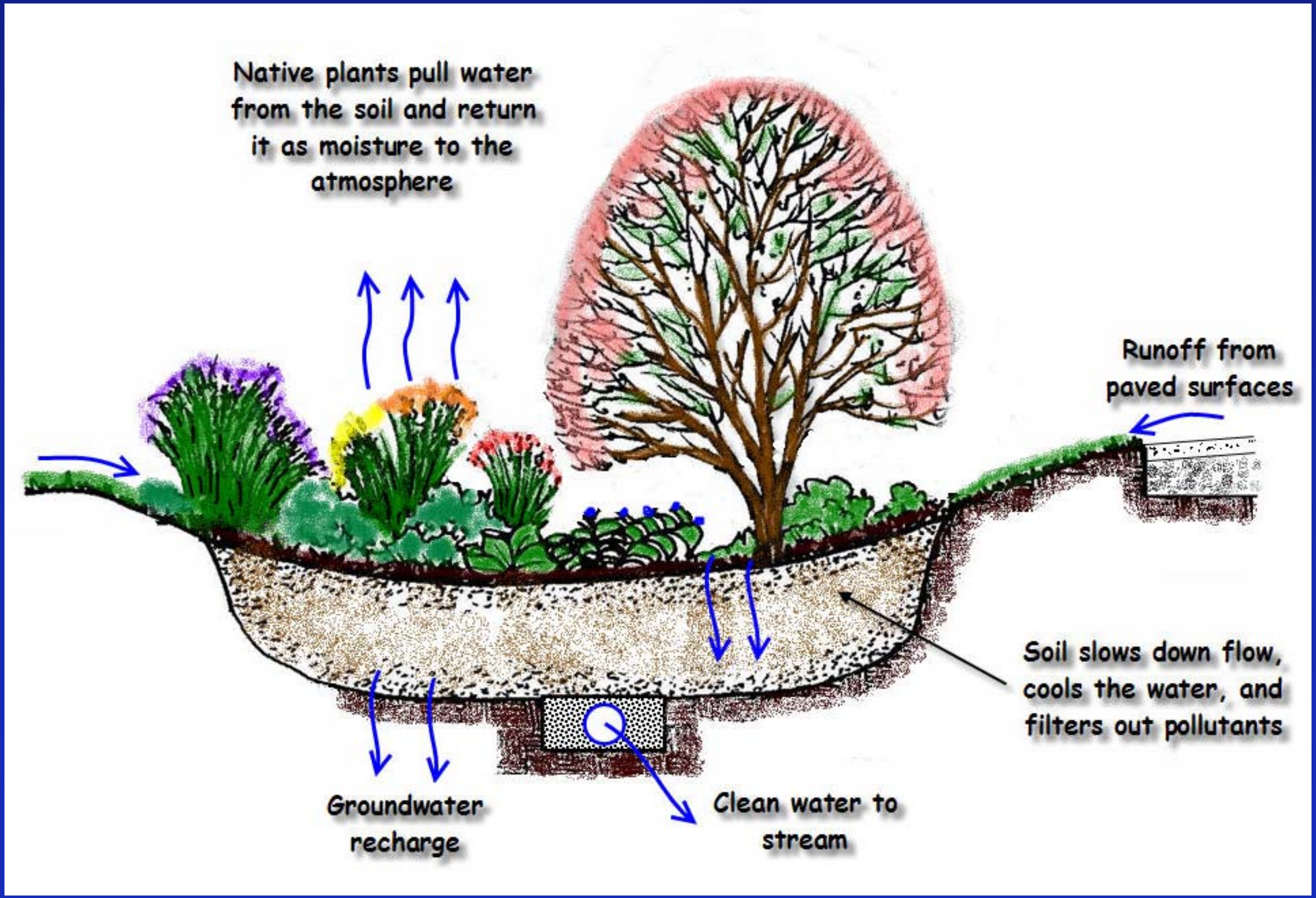

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Source: City of Portland, OR

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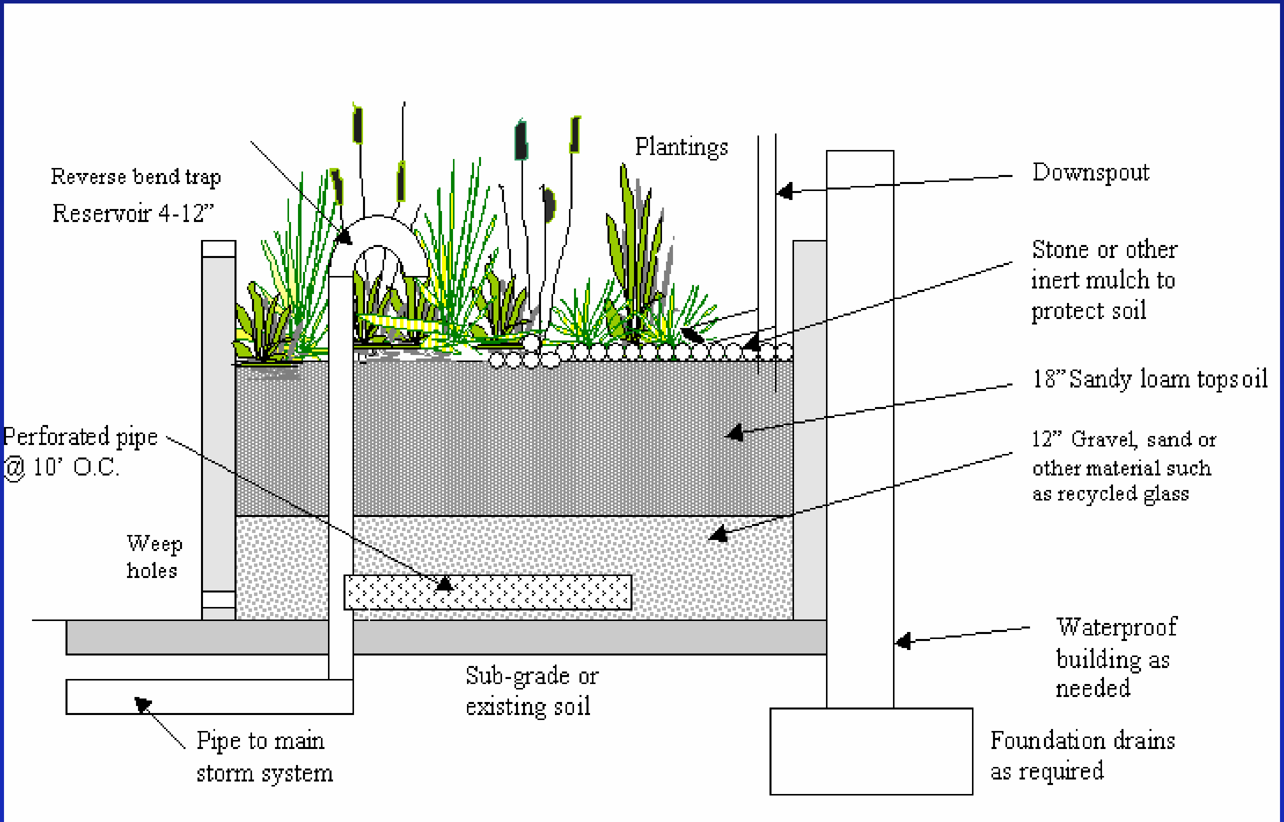


Source: City of Portland, OR

Infiltration

- Infiltration trenches
- Permeable pavement

UniverCity, Burnaby, British Columbia

Conveyance

- Swales
- Bioswales

Pembroke subdivision, MD. Design by Ecosite, Inc.

Maintenance

- Most planning control measures need no maintenance:
  - Clustering
  - Site fingerprinting
  - Imperviousness reduction
  - Imperviousness disconnection
  - Preservation of open areas
  - Tree preservation
  - Minimization of soil compaction
  - Preservation of riparian buffers
  - Wetland protection & enhancement
  - Open road drainage
  - Strategic grading
  - Pollution prevention
    - » Public education
    - » Fertilizer and pesticide reduction

Maintenance

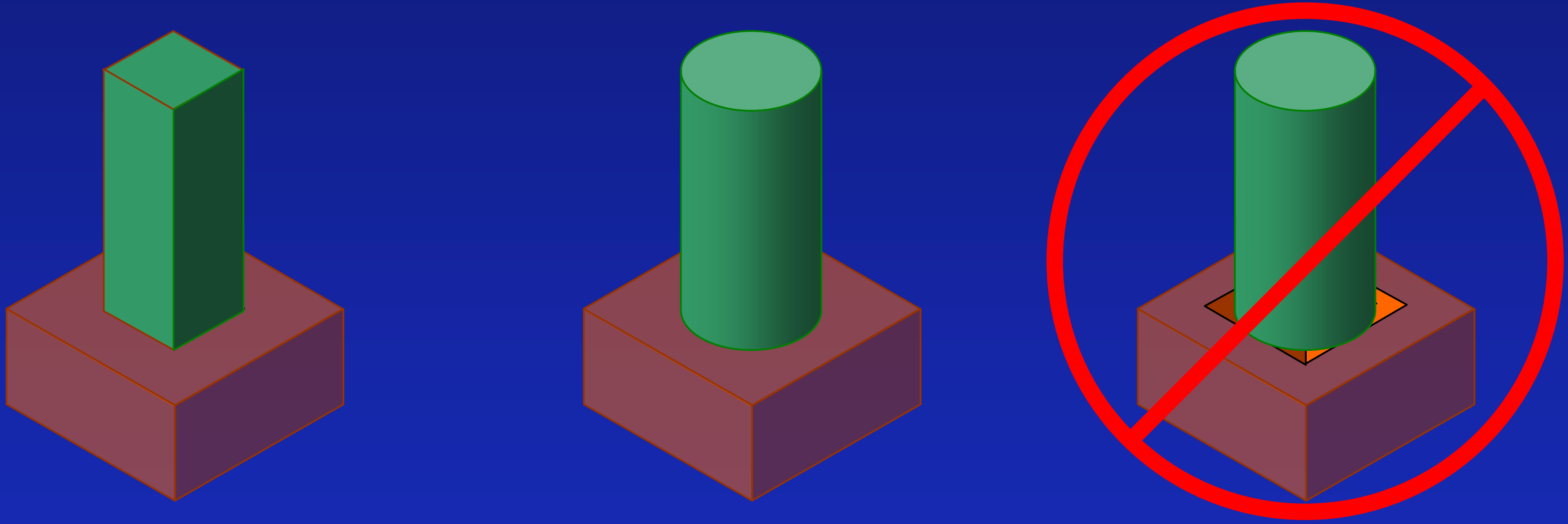
- Bioretention/Planters/Green Roofs
  - Landscaping O&M
- Permeable pavement
  - Vacuum sweeping
- Reinforced turf / Grassed swales / Filter strips
  - Mowing
- Infiltration practices (trenches, dry wells)
  - Replacement of surficial layer
- Rain cisterns
  - Periodic inspection
  - Drainage
- Amended soils / turf replacement
  - None

Conventional Hydrologic Models

- Developed for flooding (large storms), suitable mainly for peak flows
- Intended for large drainage areas
- Lump parameters, do not allow for precise placement of stormwater controls
- Weak infiltration modeling

Select a model to suit the problem

The Round-Peg-Square-Hole Syndrome



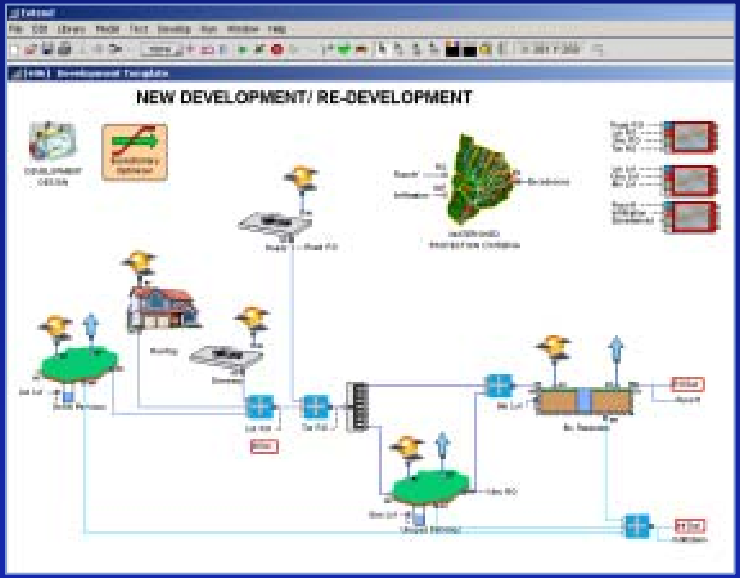
Model that fits the problem

Model that does not fit the problem

Problem fitted to the model

LIFE™:
Low Impact Feasibility Evaluation Model

- Specifically developed to simulate LID microhydrology
- Models water quantity (volume, peak flows) and water quality
- Physically-based, continuous simulation
- New development and redevelopment



- Numerous controls: bioretention, green roofs, rainwater cisterns, pervious pavements, infiltration devices...
- Optimization module balances competing priorities
- Drag-and-drop user friendly interface, GIS linkage

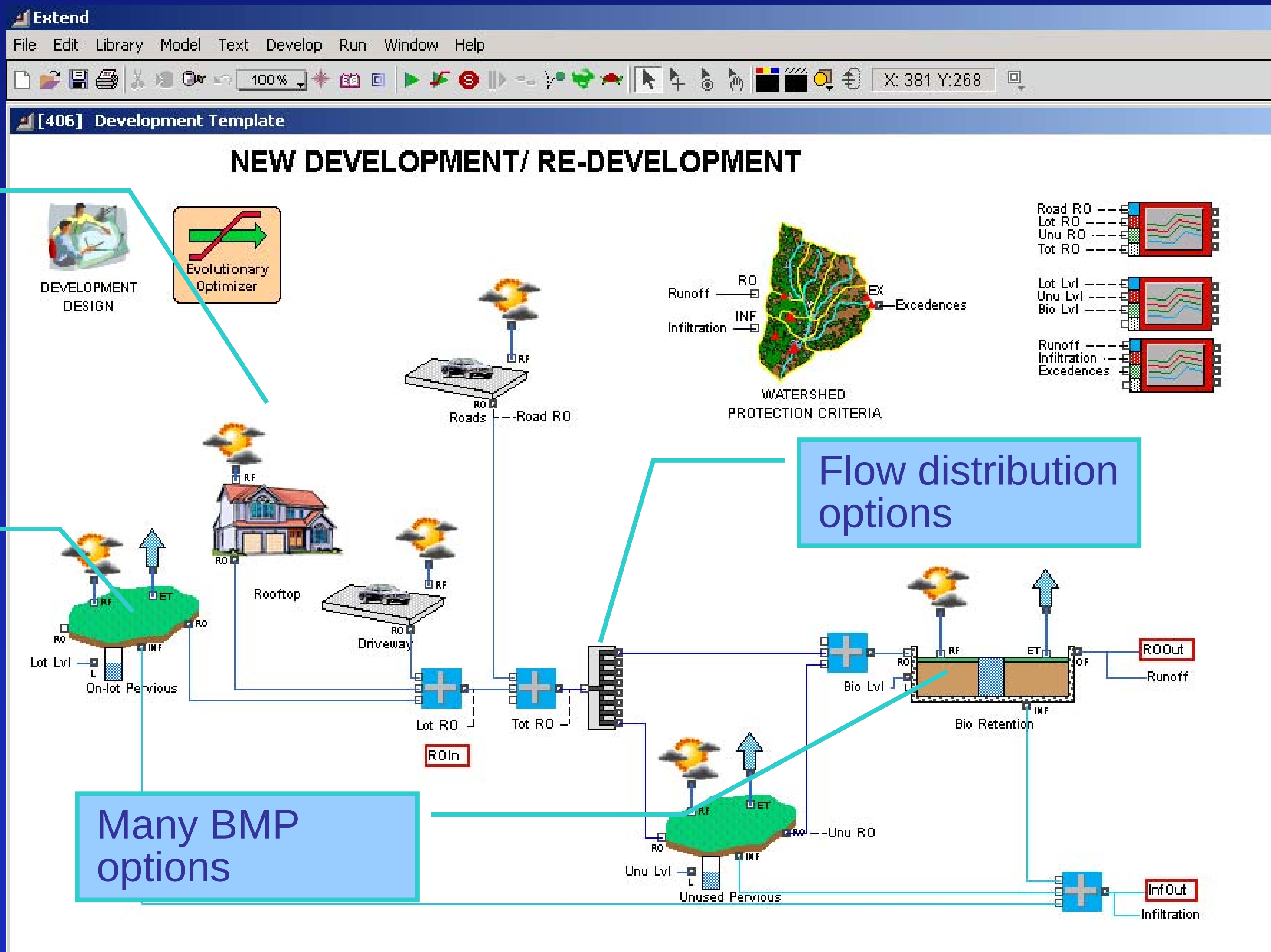
Precision in site definition

Resolution in impervious areas: roofs, roads, parking

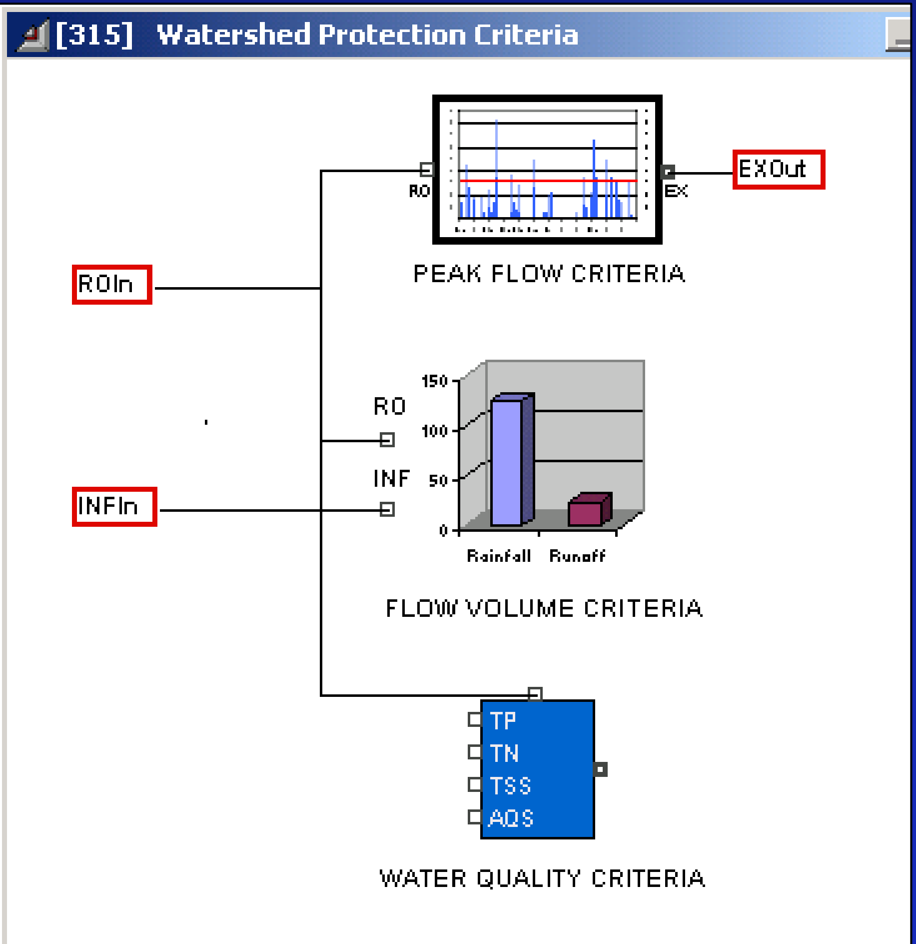
Proper accounting of open space

Many BMP options

Flow distribution options

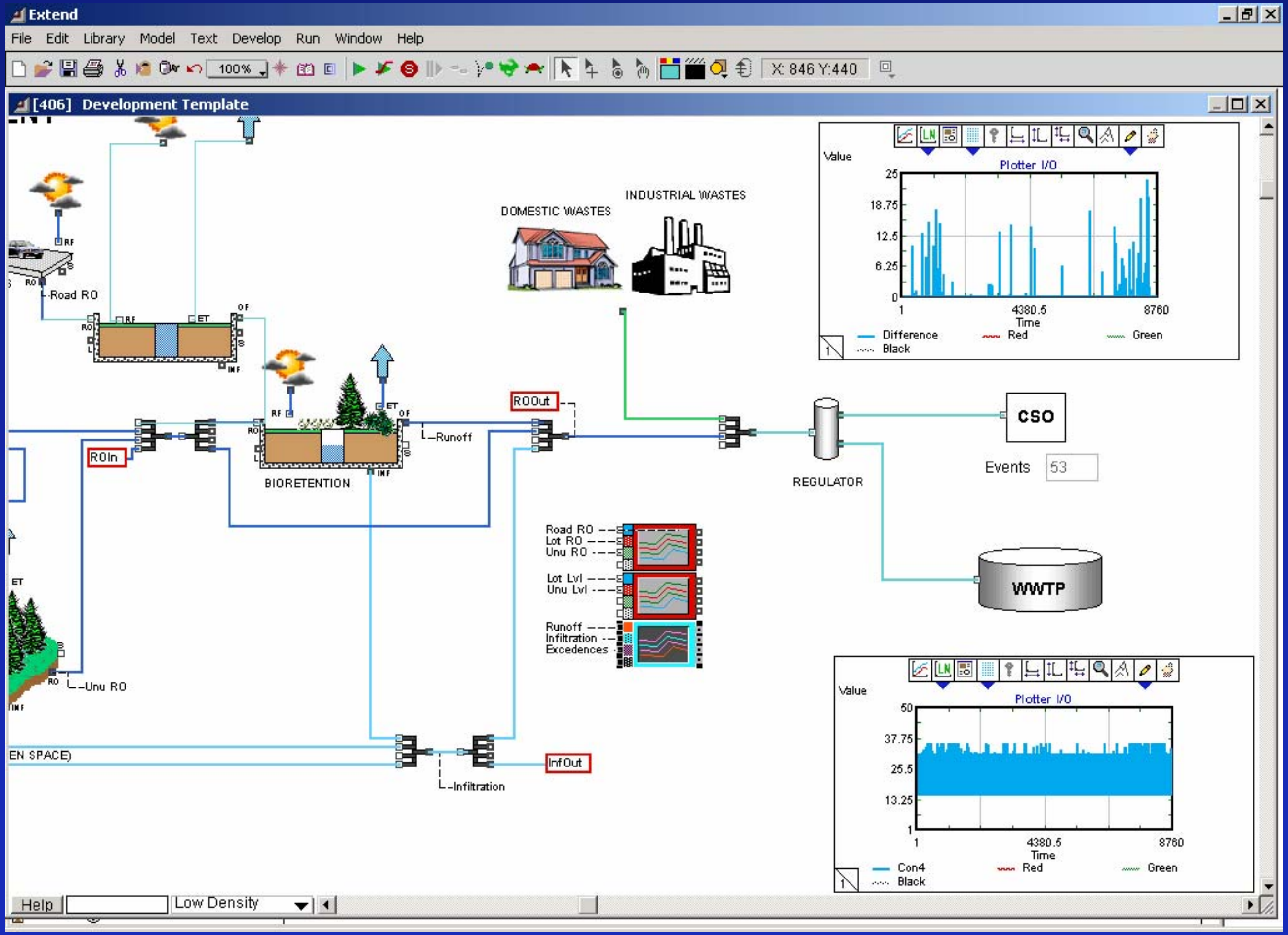


Watershed protection criteria



- **Peak Flow Criteria:** e.g., Match pre- & post-development peaks for 10-year storm
- **Volume Criteria:** e.g., capture volume from 1-year storm
- **Water Quality Criteria:** e.g., 85% Total Suspended Solids removal

CSO Modeling Capabilities



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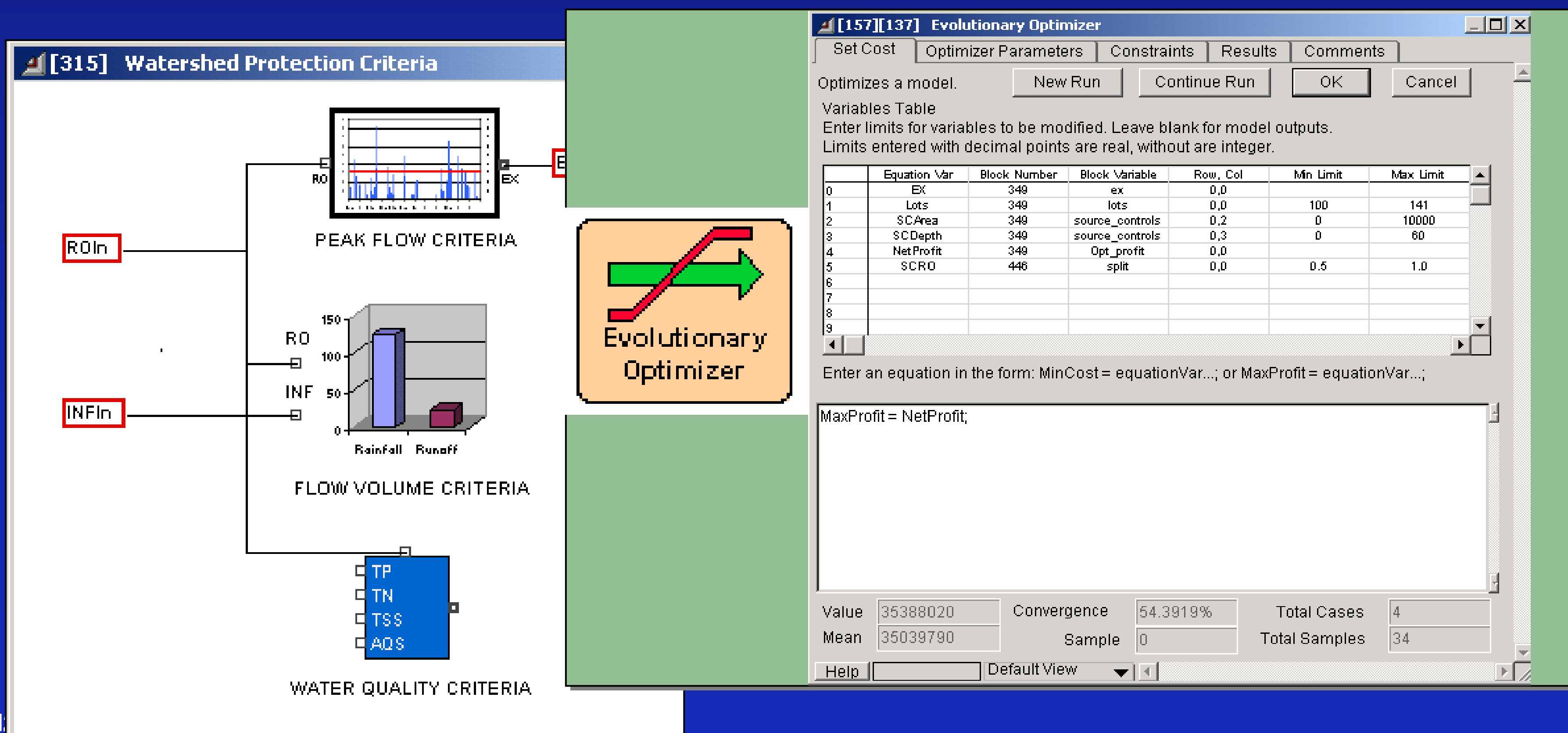
BMP Optimization

- Genetic algorithms optimize BMP sizing to meet watershed criteria: volume, flow, and water quality



LID Controls and Pollutant Removal

- Several studies conducted
  - University of Maryland
  - North Carolina State University
  - European universities (e.g., University of Tronheim, Norway)

Bioretention Pollutant Removal

University of Maryland

Cumulative Depth	Cu	Pb	Zn	P	TKN	NH4	NO3
1’	90	93	87	0	37	54	-97
2’	93	99	98	73	60	86	-194
3’	93	99	99	81	68	79	23
Field	**97**	**96**	**95**	**65**	**52**	**92**	**16**

Dr. Allen Davis, University of Maryland

Bioretention Pollutant Removal

North Carolina State University

- TN removal: 40%
- NO_3 (aerobic): 13%
- NO_3 (anaerobic): 75%
- TP (high P-index soil): -242%
- TP (low P-index soil): 65%
- Zn and Cu: 98%
- Pb: 80% (inflow concentration was low)
- Fe: increased due to iron-rich soils

Dr. Bill Hunt, NCSU

Sample Projects

- Seattle urban stormwater retrofits
- New River Marine Corps Air Station, North Carolina

Seattle LID Urban Retrofit

- Seattle Public Utilities SEA Street Edge Program
- LID retrofits that use a variety of controls maximize the use of limited space

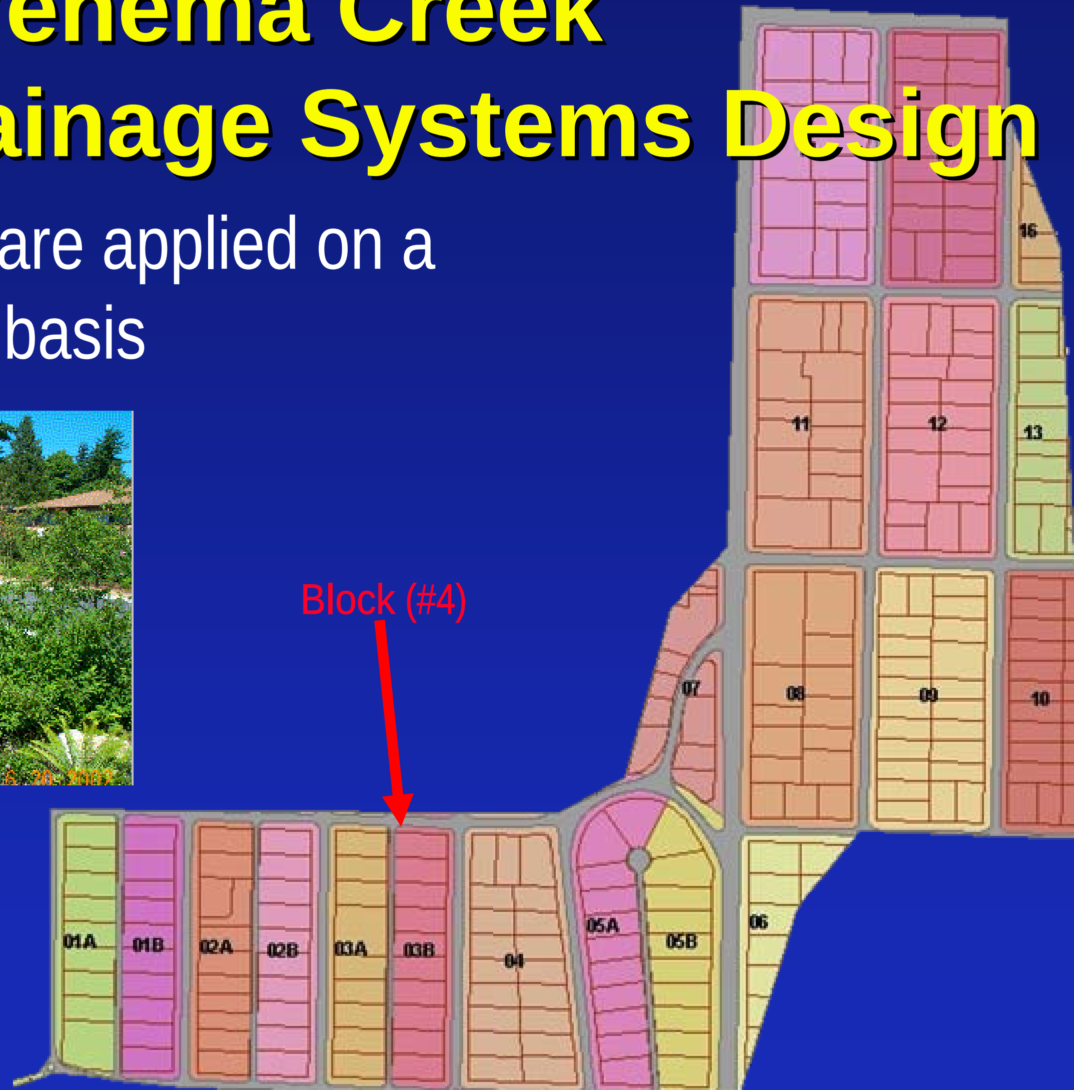
Photos by Seattle Public Utilities

Venema Creek
Natural Drainage Systems Design

- Effective use of the right-of-way avoids private property issues while meeting all safety standards

Venema Creek
Natural Drainage Systems Design

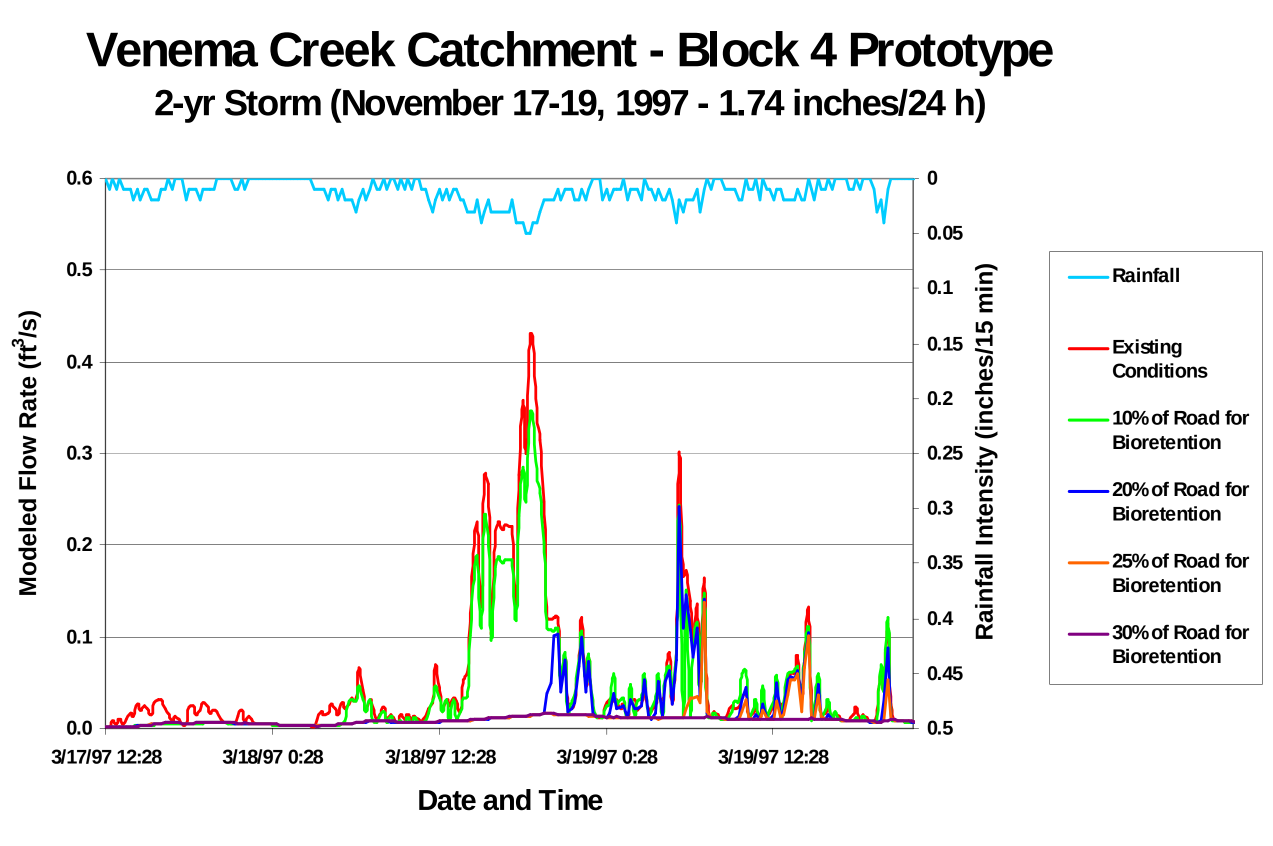
- Micro-controls are applied on a block-by-block basis



0 190 380 760 1,140 1,520
Feet

Venema Creek
Natural Drainage Systems Design

- The LIFE™ model was applied to simulate LID hydrology at several scales



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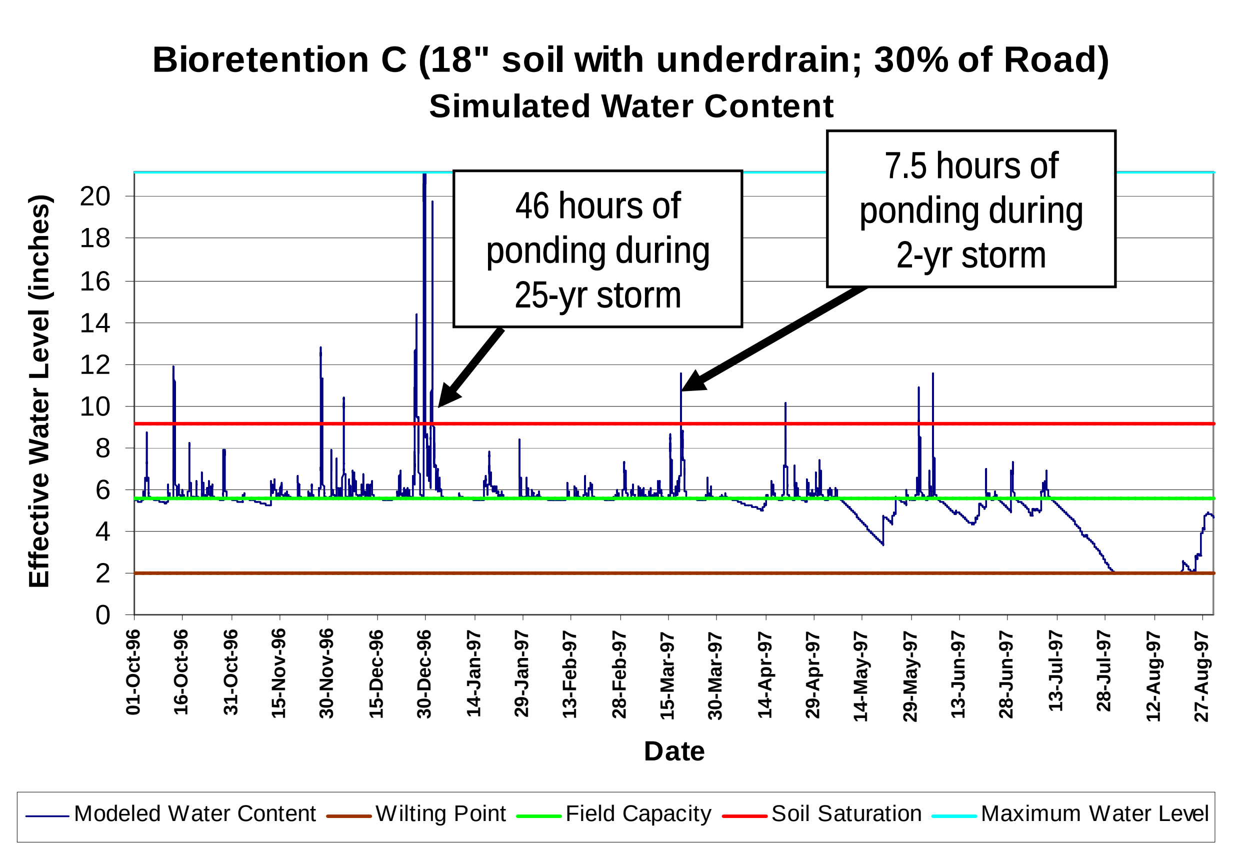
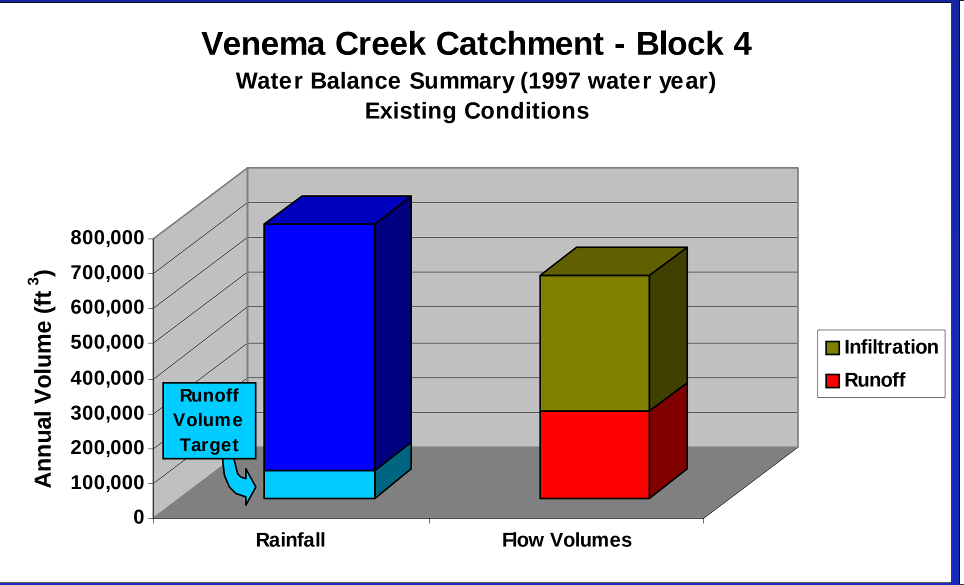
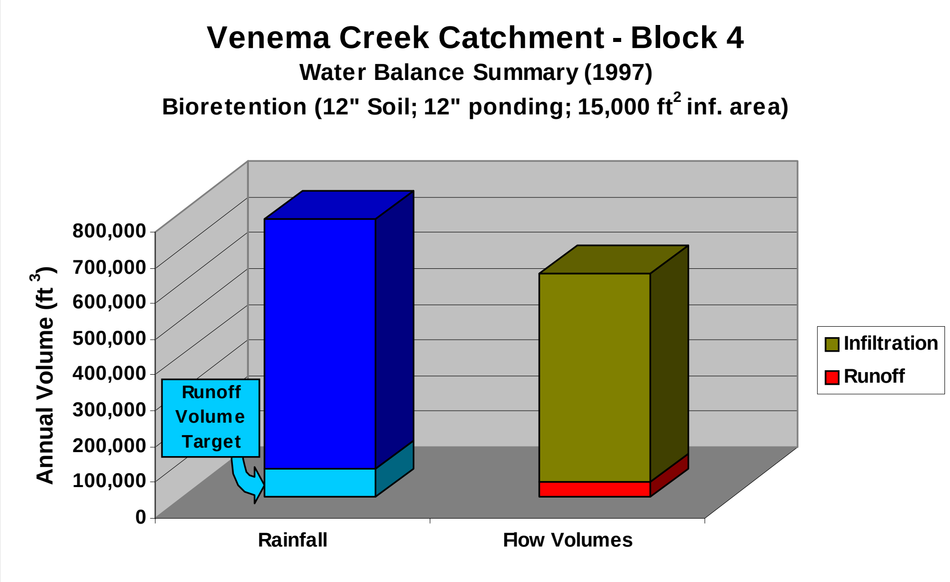


Venema Creek
Natural Drainage Systems Design

- A sound monitoring plan allows for adaptive management and builds public support
- Performance exceeded design criterion for rainfall capture:
  Target: 10% runoff,   Actual: 0-2% runoff





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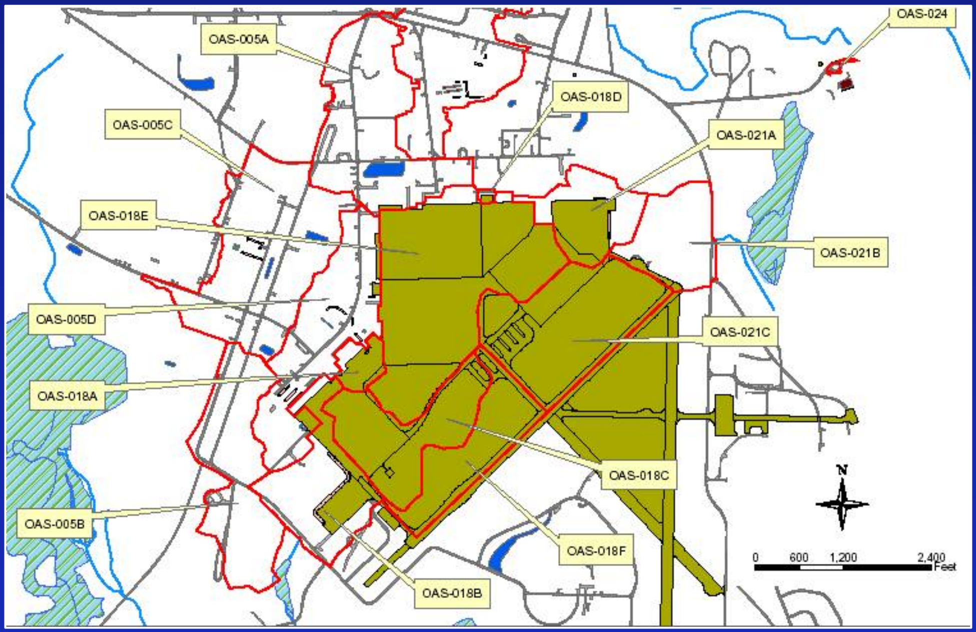
LID retrofit for New River Marine Corps Air Station, Jacksonville, NC

- LID retrofit feasibility study
  - Rainwater capture
  - Bioretention
  - Permeable pavers
  - Stormwater planters



- Two LID pilot projects built
  - Stormwater planters
  - 5 bioretention cells in parking lot
- Monitoring being conducted by NCSU

LID retrofit for New River Marine Corps Air Station

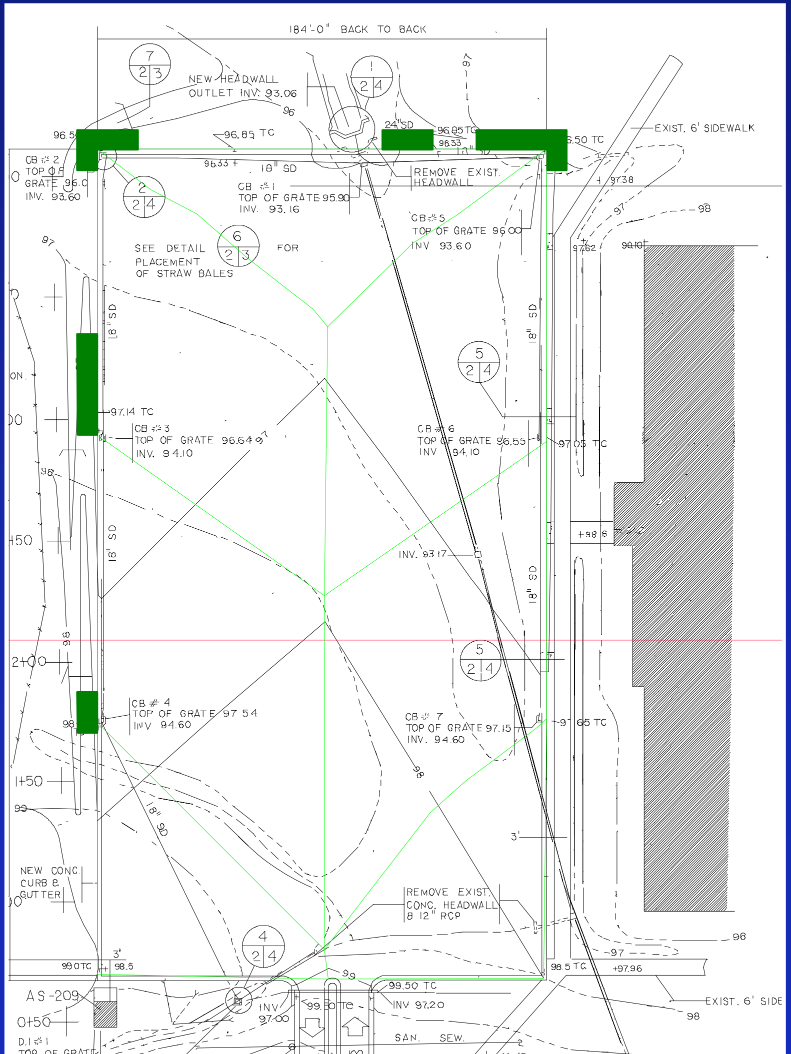
Stormwater planters at Officers' Club

LID retrofit for New River Marine Corps Air Station

Stormwater planters at Officers' Club

LID retrofit for New River Marine Corps Air Station

Bioretention retrofit at HQ parking lot



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CAUTION


CAUTION