- Mission: Stormwater Management Technology
- Pilot Projects, Monitoring, Modeling, Manuals, Training, Education

The Low Impact Development Center, Inc.

South Carolina LID Conference

2003

Balancing Growth and Environmental Integrity

Low Impact Development (LID)

Stormwater Management
Ecosystem Based Functional Design

"Uniformly Distributed Small-scale Controls"
"Integration of Controls with Sites, Streets and Architecture "

*** Low Cost & Low Impacts ***

Prince George's County, MD

LID National Design Manual 1999

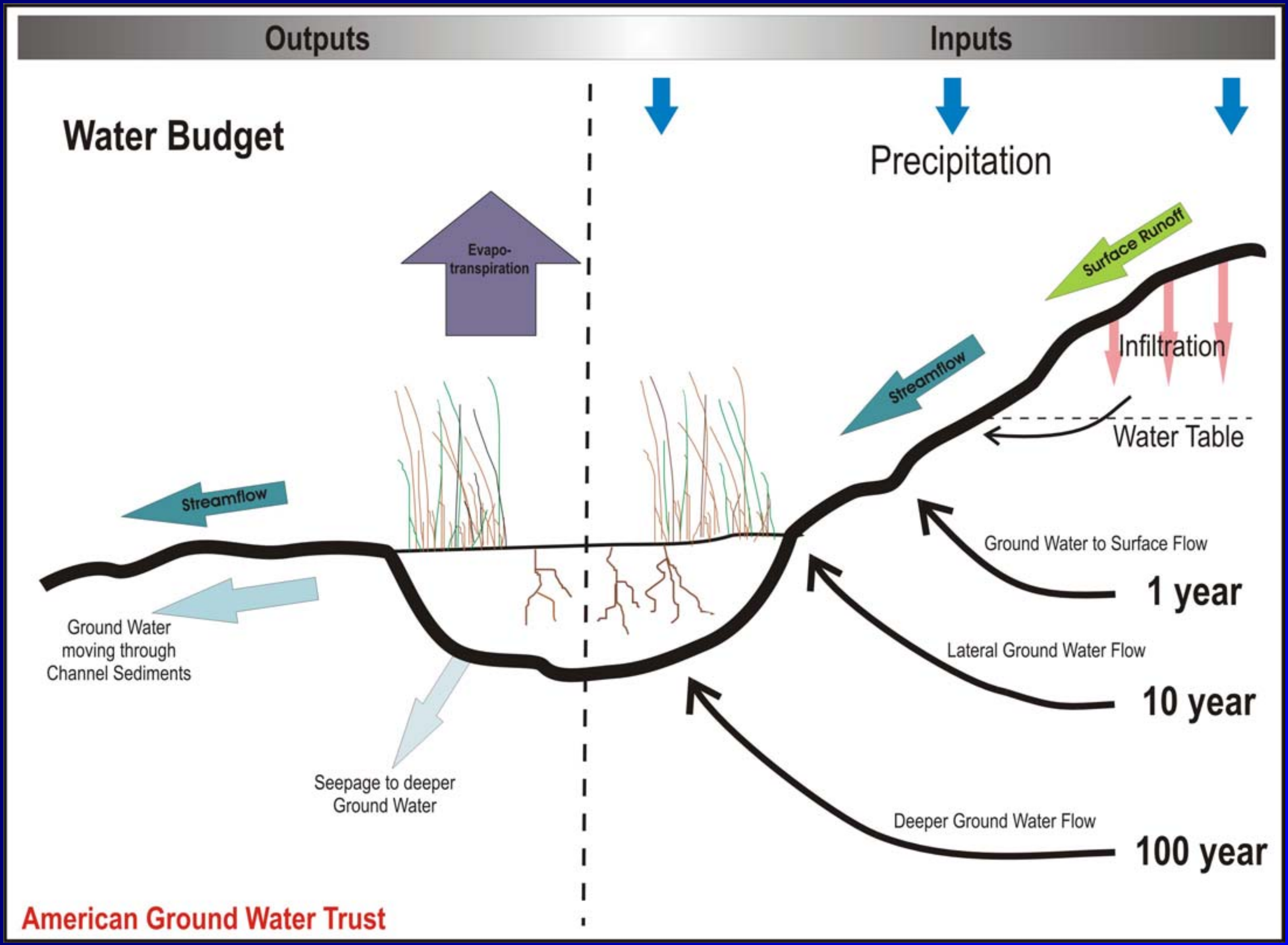
"Centralized versus Decentralized Controls"

How LID Began!

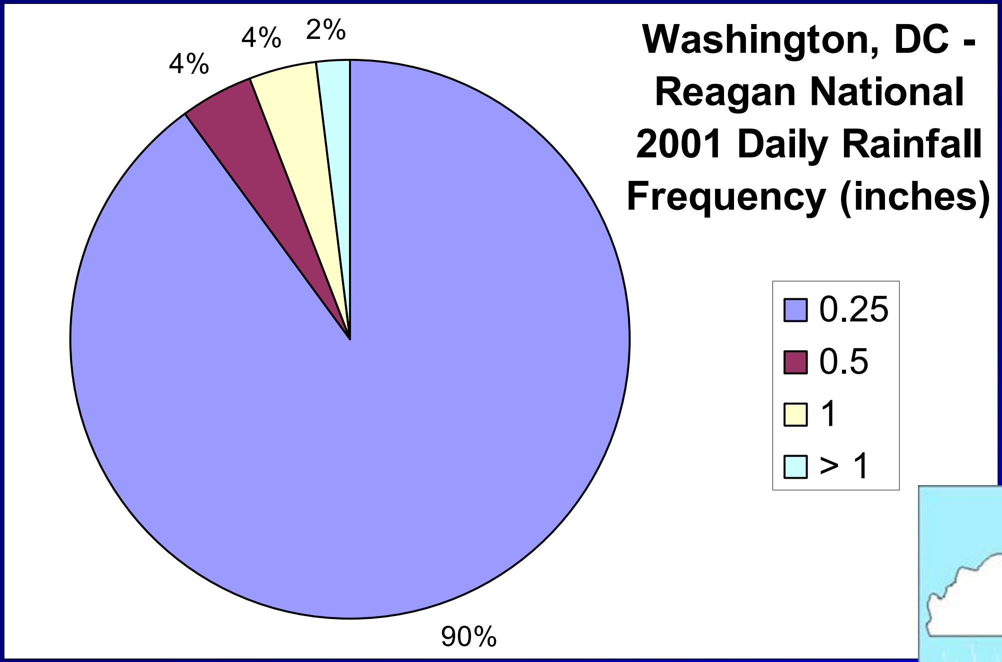
1200 Years and Still Working !!!

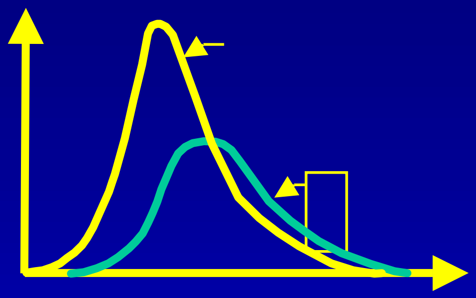
Buttermilk off North Shore

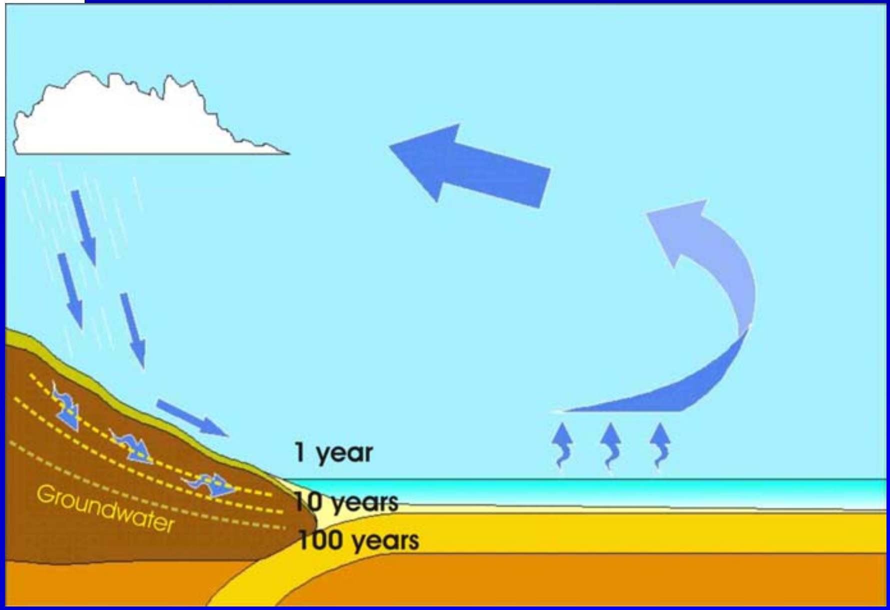
Buttermilk off Ring Road



Compliance by Working with Natural Processes







Address Frequently Occurring Events and Loads While Insuring Flood Protection

LID – Examples of Where and Who

Where

- Chesapeake Bay Watershed
- Great Lakes States
- Puget Sound
- Oregon
- New England
- Florida
- Minnesota
- Pennsylvania
- New Jersey
- Delaware
- North Carolina
- New Zealand
- Australia

Who

- ASCE
- EPA
- NRDC
- NAHB
- Harvard Design School
- Universities
- Watershed Groups
  - Rappahannock
  - Upper Nuse
  - Chagrin
- Professional Groups
- Consultants
- DOT's
- U.S. Congress
- DOD

Why - LID

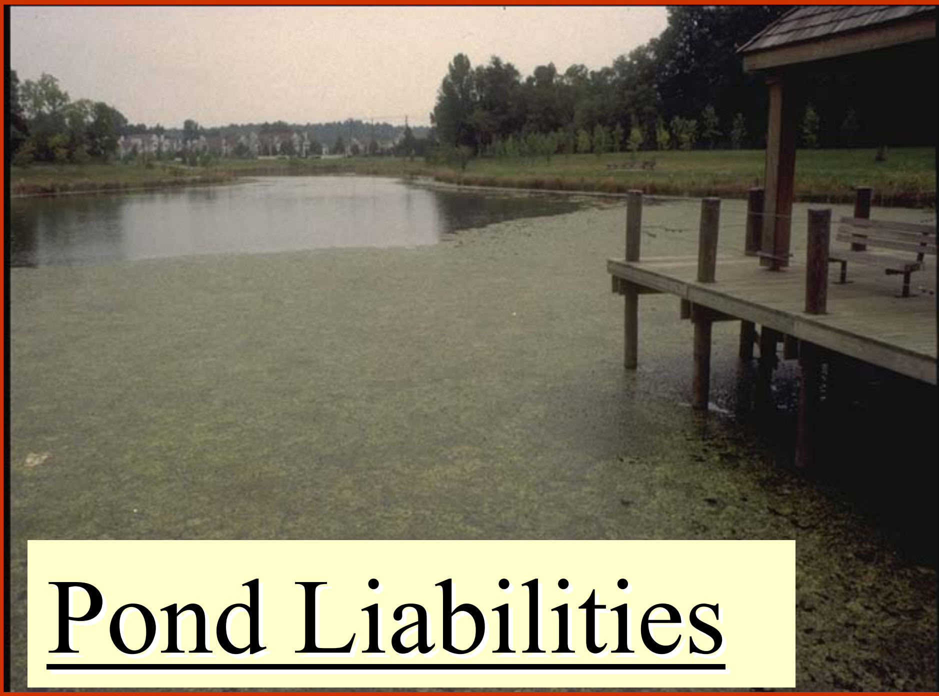
- Water Supply
- Wastewater
- Stormwater
  - Flood Control
  - Ecological Health
  - Human Use
  - Regulations

Important Concepts

- Terrestrial / aquatic ecosystem linkages
- Ecosystem functions
- Using nature to mitigate its own forces
- Mimic the water balance
- Hydrology as an organizing principle
- Multiple systems
- Volume / Frequency / Timing
- Ecological functions of the built environment

Limitations of Conventional Stormwater Approaches

- Economics
  - Cost of Maintaining a Growing / Aging Infrastructure
- New Objectives (Public Health / Ecological)
  - Source Water, CSO’s, Living Resources / Streams
  - Regulations
    - NPDES / TMDL’s / ESA



Limitations

- Safety / Health
- Inspection / Maintenance
- Inefficient Pollutant Removal
- Temp / Sediment / Frequency / Volume


Issues
West Nile Virus
Safety
Maintenance
Sediments
Nutrients


Values / Functions / Goals
What is the Role of Technology?

Your understanding of the state of technology is key to:

- Setting Goals
- Prioritizing protection / restoration strategies
- Determining cost of protection programs
- Promoting / discouraging development

"Technology can be Apolitical"

Paradigm Shifts

- Watersheds to **Ecosystems**
- Flow Centric to **Volume Centric**
- Centralized Control to **Decentralized Control**
- Uni-functional to **Multifunctional**
- Impact Reduction to **Functional Restoration**
- Good Drainage to **Functional Drainage**
- One Size Fits All to **Unique Design**
- Unsustainable to **Sustainable**

Emerging Technology Debate

The Efficacy of

Centralized

Versus

Decentralized Controls

CHAPTER 26 CFR - WATER POLLUTION PREVENTION AND CONTROL

SUBCHAPTER I - RESEARCH AND RELATED PROGRAMS

- § 1251. Congressional declaration of goals and policy.

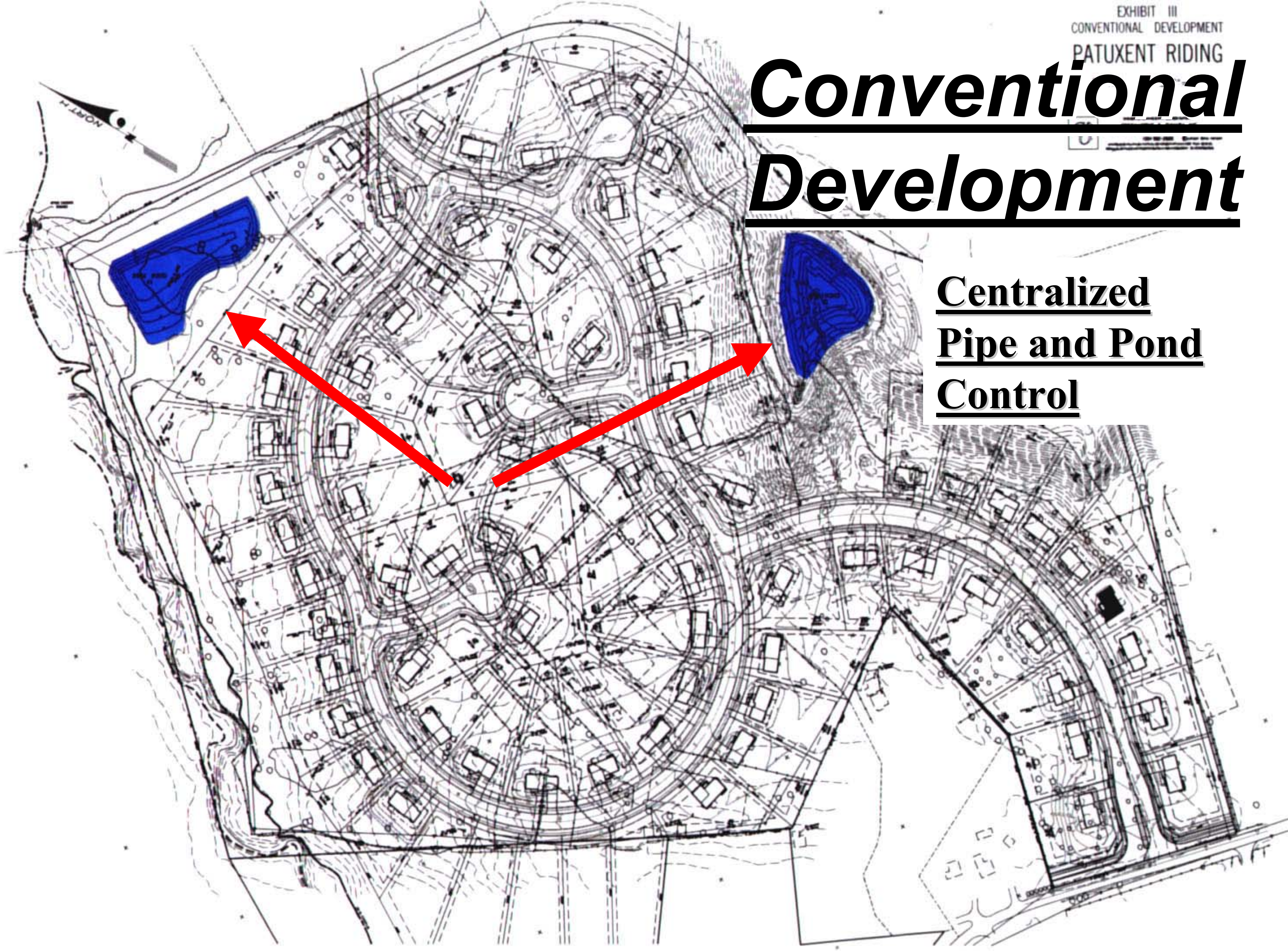
(a) Restoration and maintenance of chemical, physical and biological integrity of Nation's waters; national goals for achievement of objective.

- Ecosystems Based
- Technology-forcing
- Comprehensive Research
- Total Maximum Daily Load

Limitations of Conventional Stormwater Approaches

- Technology Gaps
  - Cumulative impacts
  - Not an anti-degradation strategy
  - Allows hydrodynamic modifications
  - Allows continued stream degradation
  - Limited use for urban retrofit
  - Unsustainable maintenance burdens

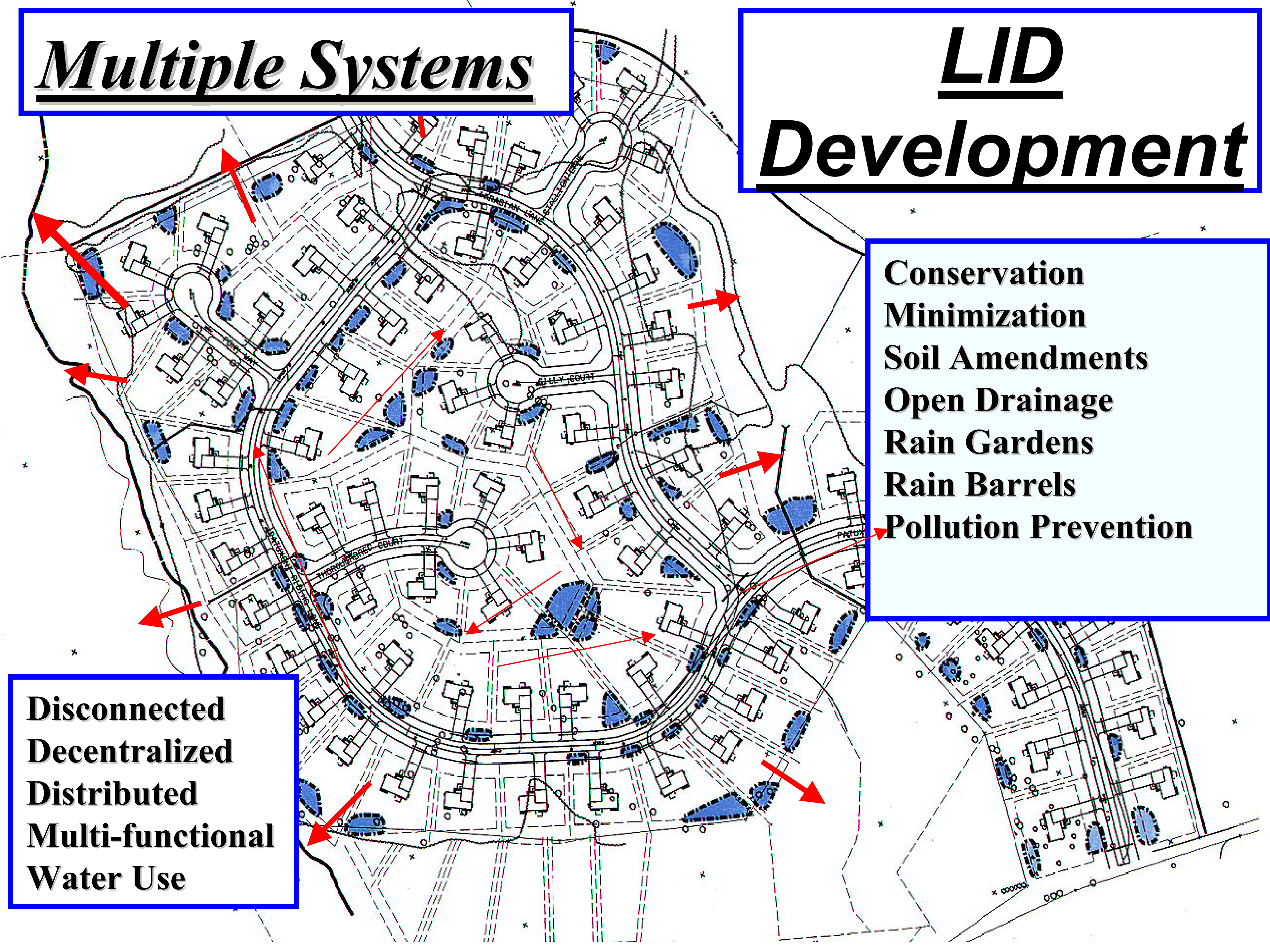
Conventional Development



Centralized Pipe and Pond Control

Multiple Systems

LID Development



Conservation
Minimization
Soil Amendments
Open Drainage
Rain Gardens
Rain Barrels
Pollution Prevention

Disconnected
Decentralized
Distributed
Multi-functional
Water Use


Conventional
Low Impact
Good Drainage
Functional Lanscape Design

Ecosystem Protection

Protecting or restoring the natural function, structure, and species composition of an ecosystem, recognizing that all components are interrelated.

-- U.S. Fish and Wildlife Service

Applied ecology, science and engineering to ensure homeostasis between the terrestrial and aquatic ecosystems.

New Objectives

Small Stream and Living Resource Protection

Ecological Integrity Protection

Species – Fauna / Flora

Structure – Spatial / Temp / Distribution

Processes – Cycling (Energy / Materials / Nutrients)

Minimize / lesson impacts

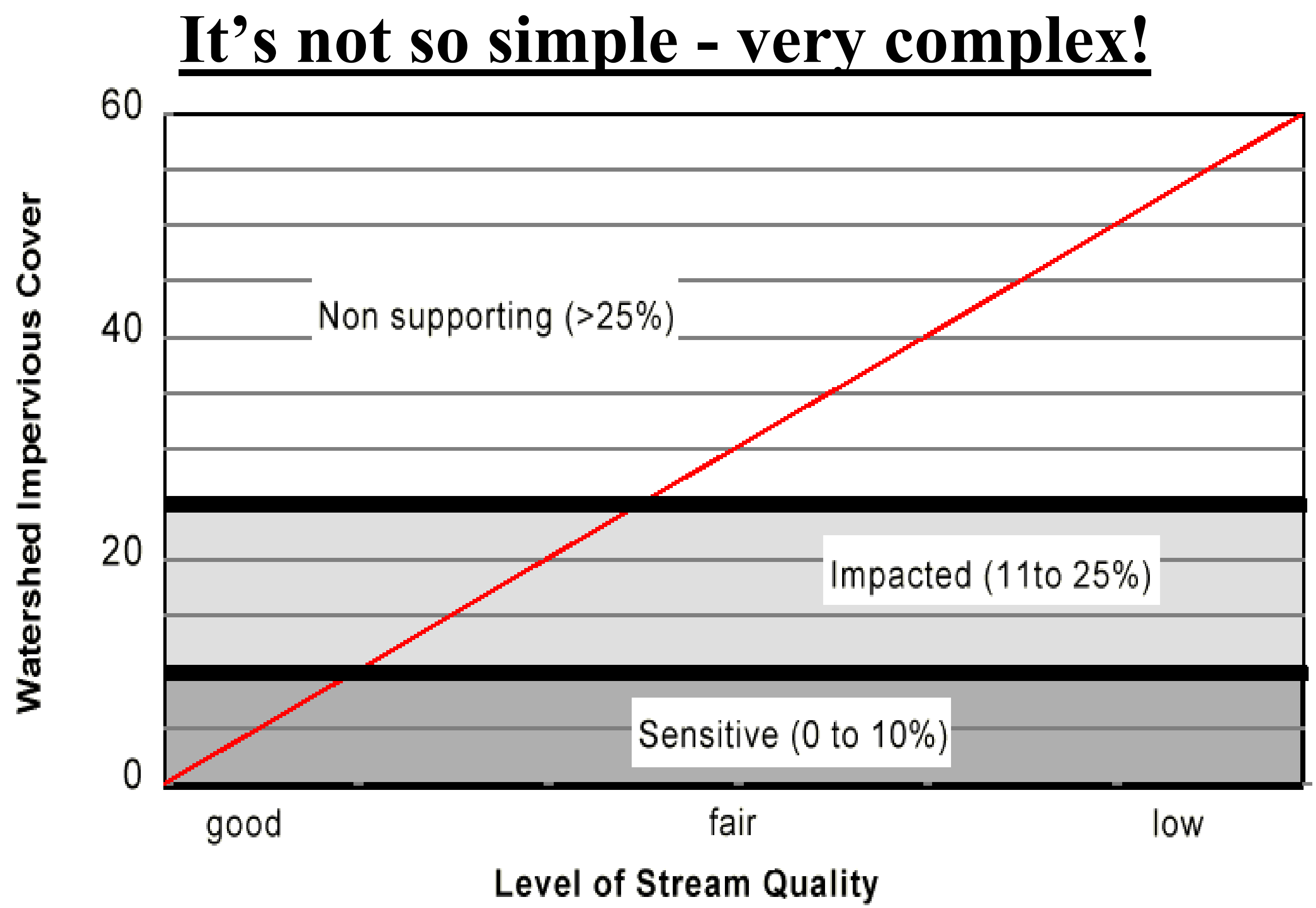
We should

Restore / maintain functions

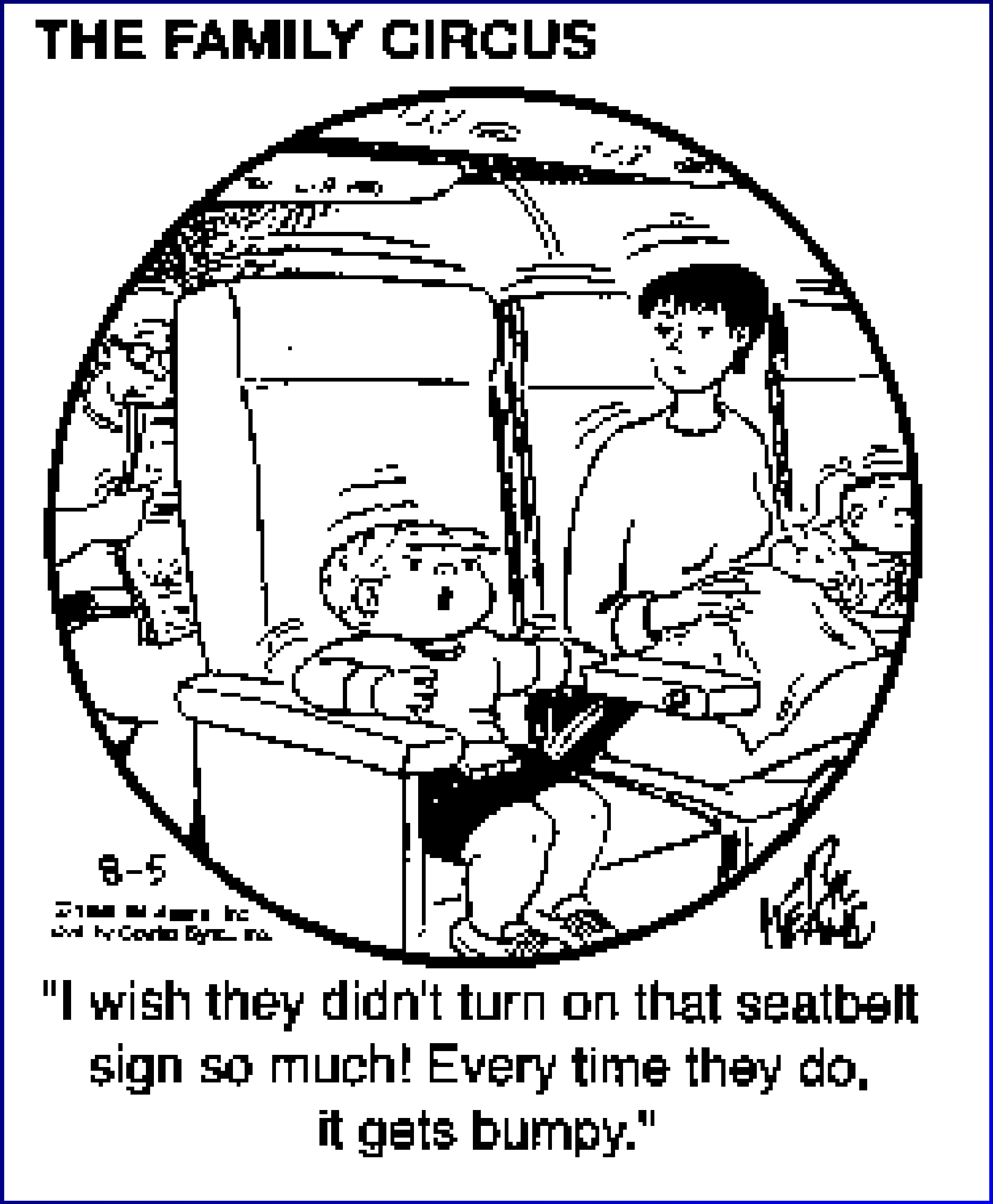
Ecological Factors

1. Hydrology / Hydraulics
2. Habitat Structure
3. Water Quality
4. Energy Sources
5. Biotic Interactions

Imperviousness & Threshold Theories



Source: Schueler and Claytor, 1995


THE FAMILY CIRCUS
8-5
"I wish they didn't turn on that seatbelt sign so much! Every time they do, it gets bumpy."

Good Science or Good Sense? Correlation or Causation

- Correlation "mutual relation between two or more things"
  - Most accidents take place within 25 miles of home.
    - Therefore it is more dangerous to drive near your home.
  - Failure of your main and reserve almost always results in death.
    - Therefore parachute failures cause death.
  - Increased imperviousness results in decreased biological integrity.
    - Therefore impervious surfaces causes stream impairment.
- Correlation is not necessarily causation.
- Faulty conclusions drawn from scientific research.

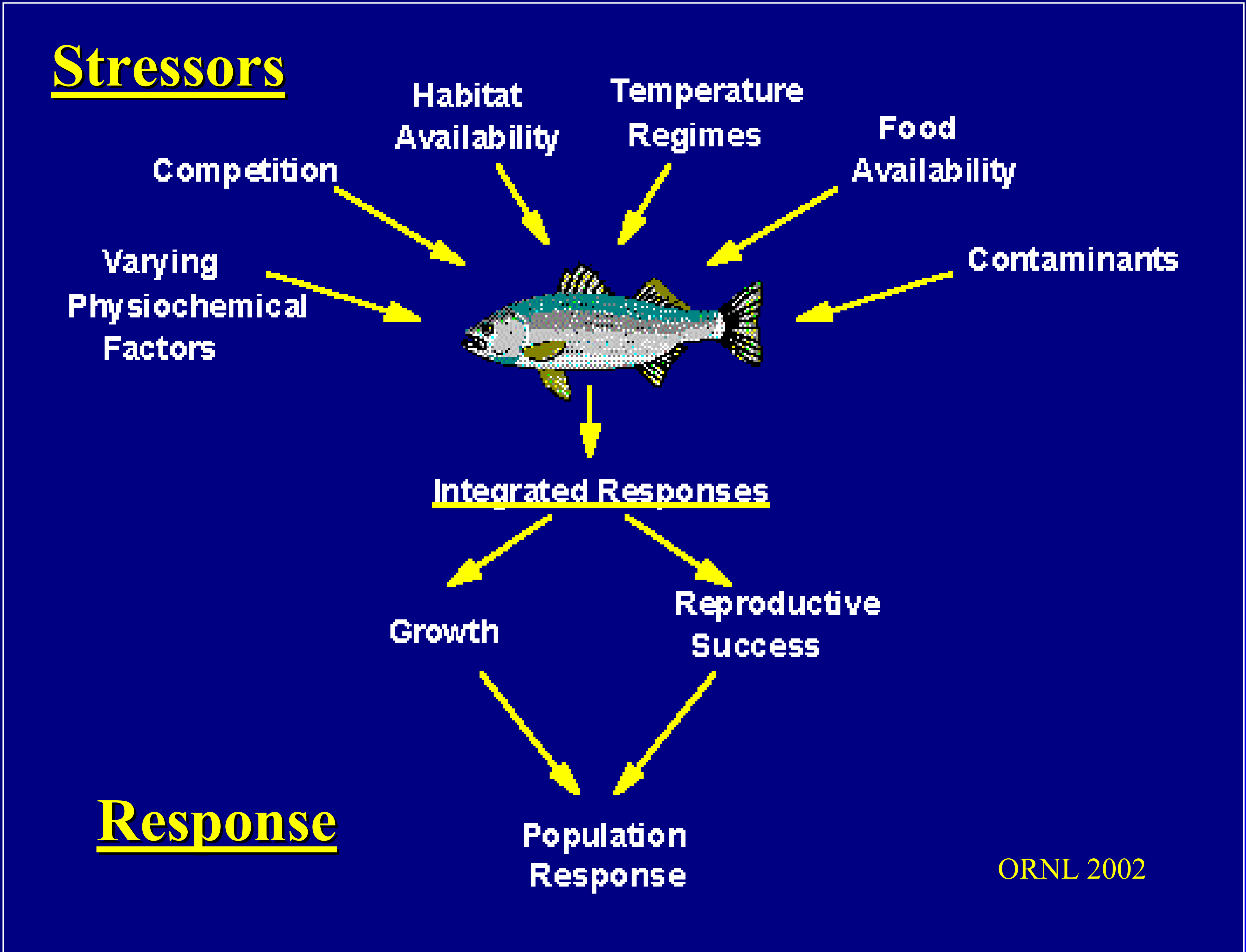
Good Science or Good Sense? “Correlation or Causation”

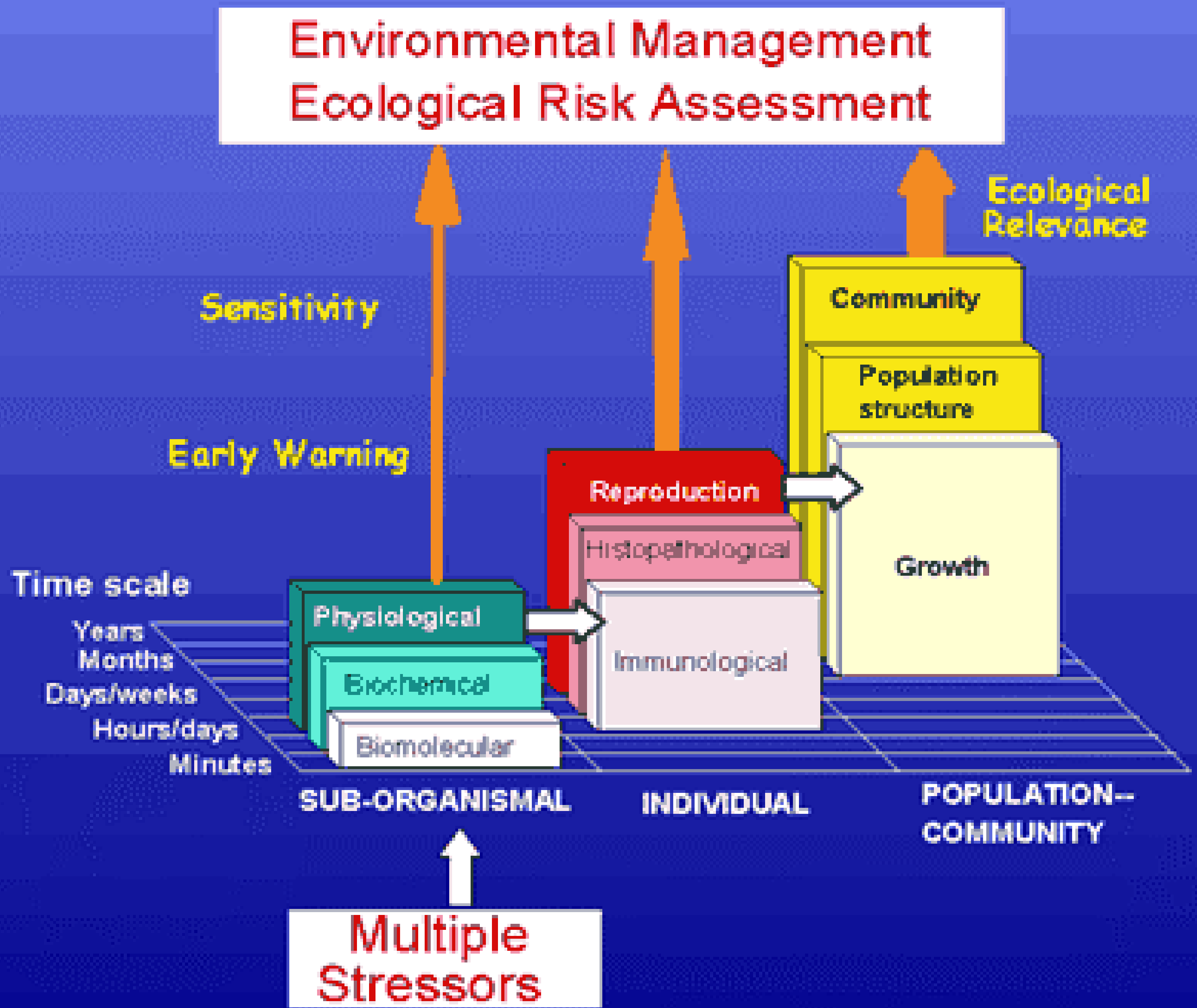
- Causation "causing or producing an effect“
- Confounding Problems
- What is the “Proximate Cause” of stream degradation in urban areas (or any disturbed land).

Causal Effects of Urbanization

Changes in Ecosystem Functions such as:

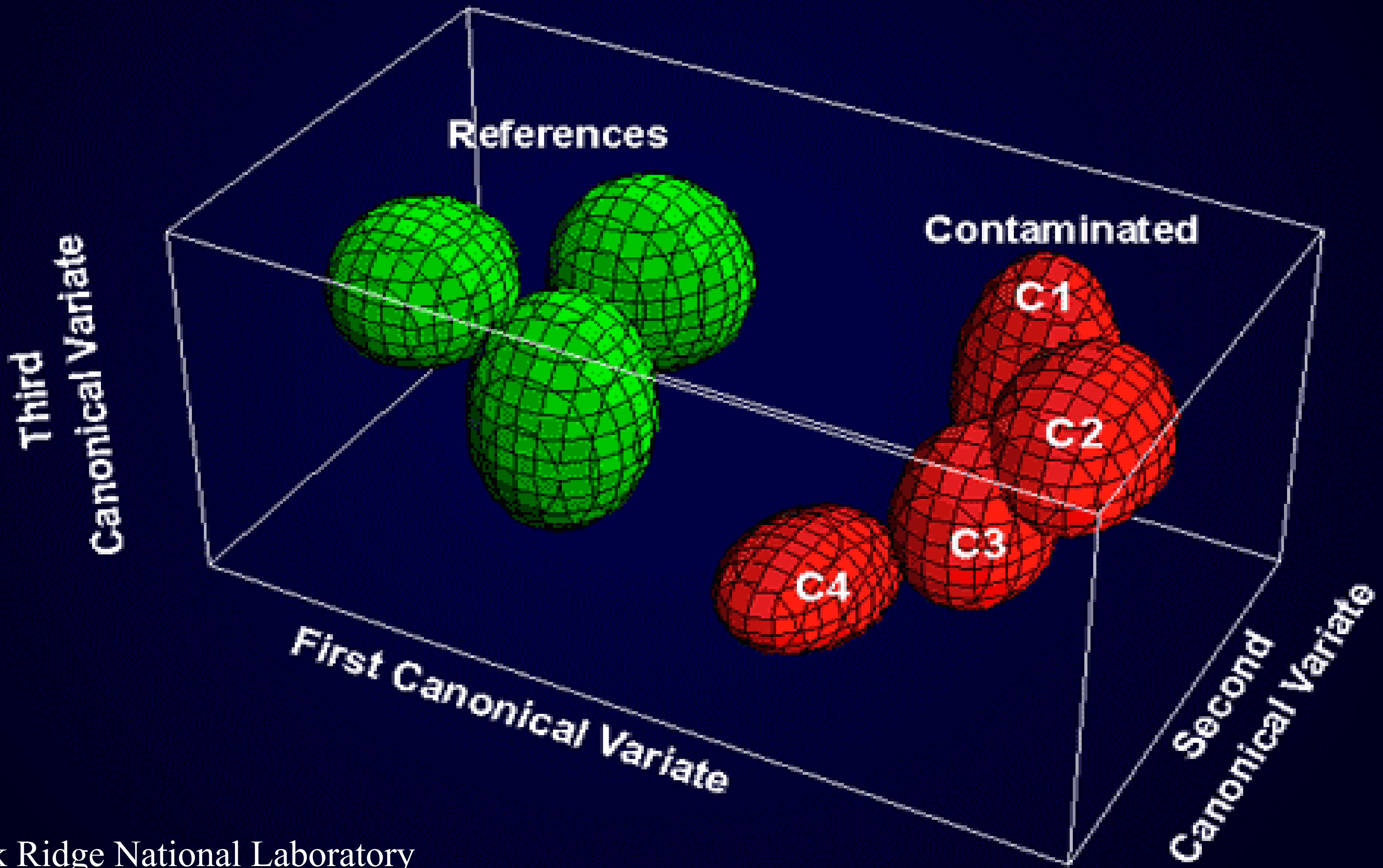
Velocity / Frequency / Habitat Structure / Nutrient Cycles / Chemistry / Energy / Temperature / Base flow


Stressors
Habitat Availability
Temperature Regimes
Food Availability
Competition
Varying Physiochemical Factors
Contaminants
Integrated Responses
Growth
Reproductive Success
Response
Population Response
ORNL 2002



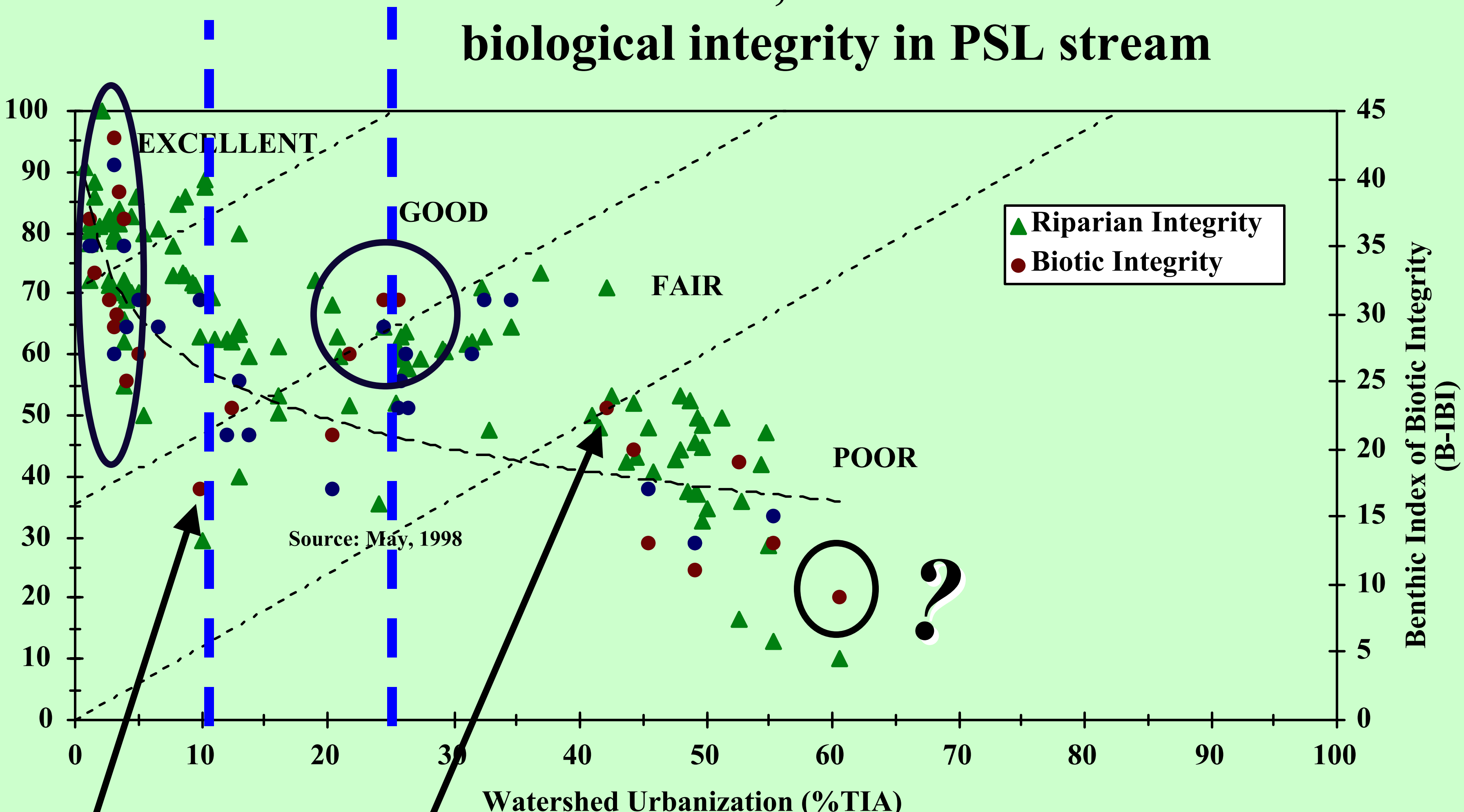
Oak Ridge National Laboratory

Integrated Bioindicator Site Responses in East Fork Poplar Creek



Oak Ridge National Laboratory

Relationship between basin development, riparian buffer width, and biological integrity in PSL stream

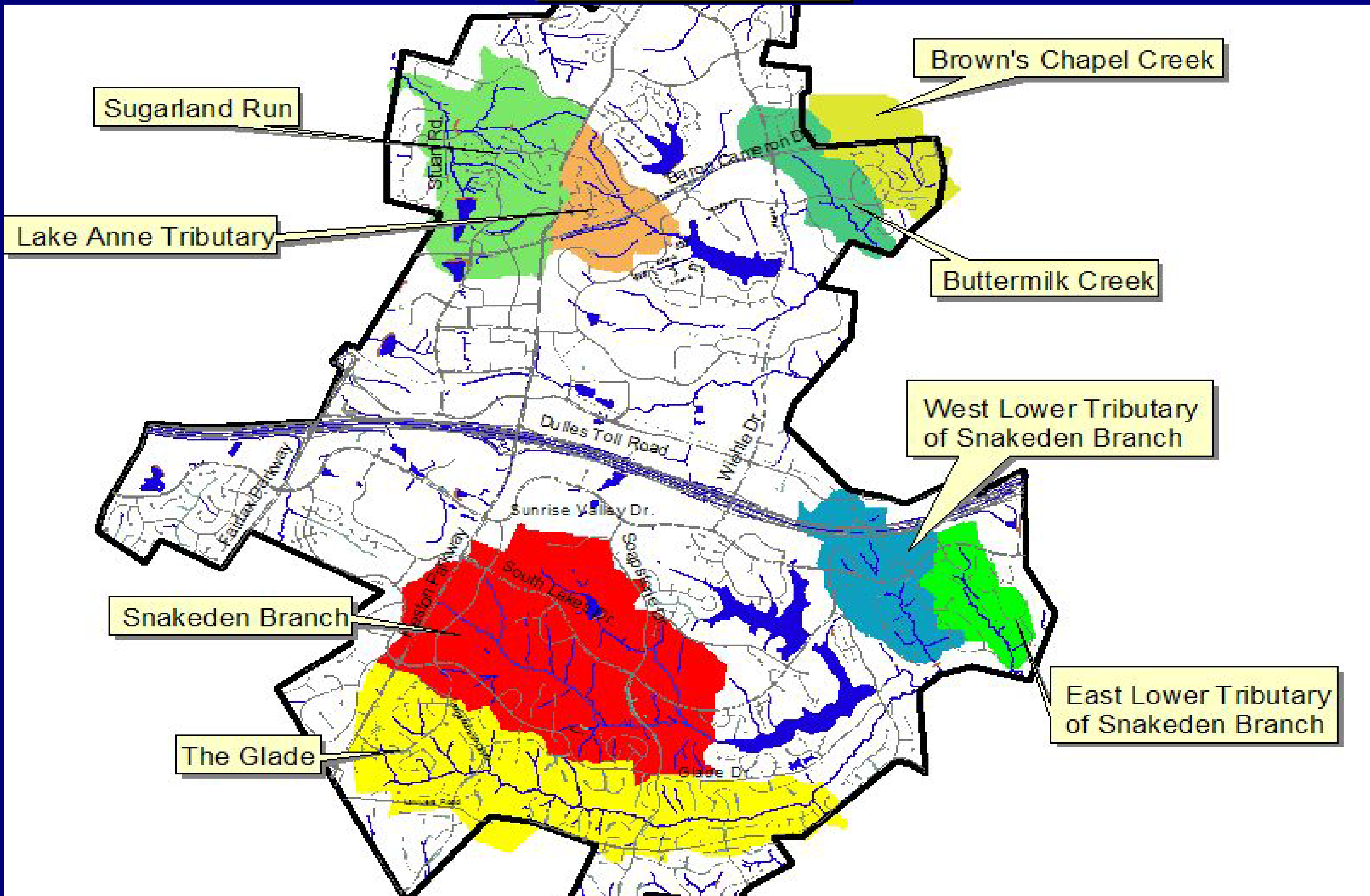


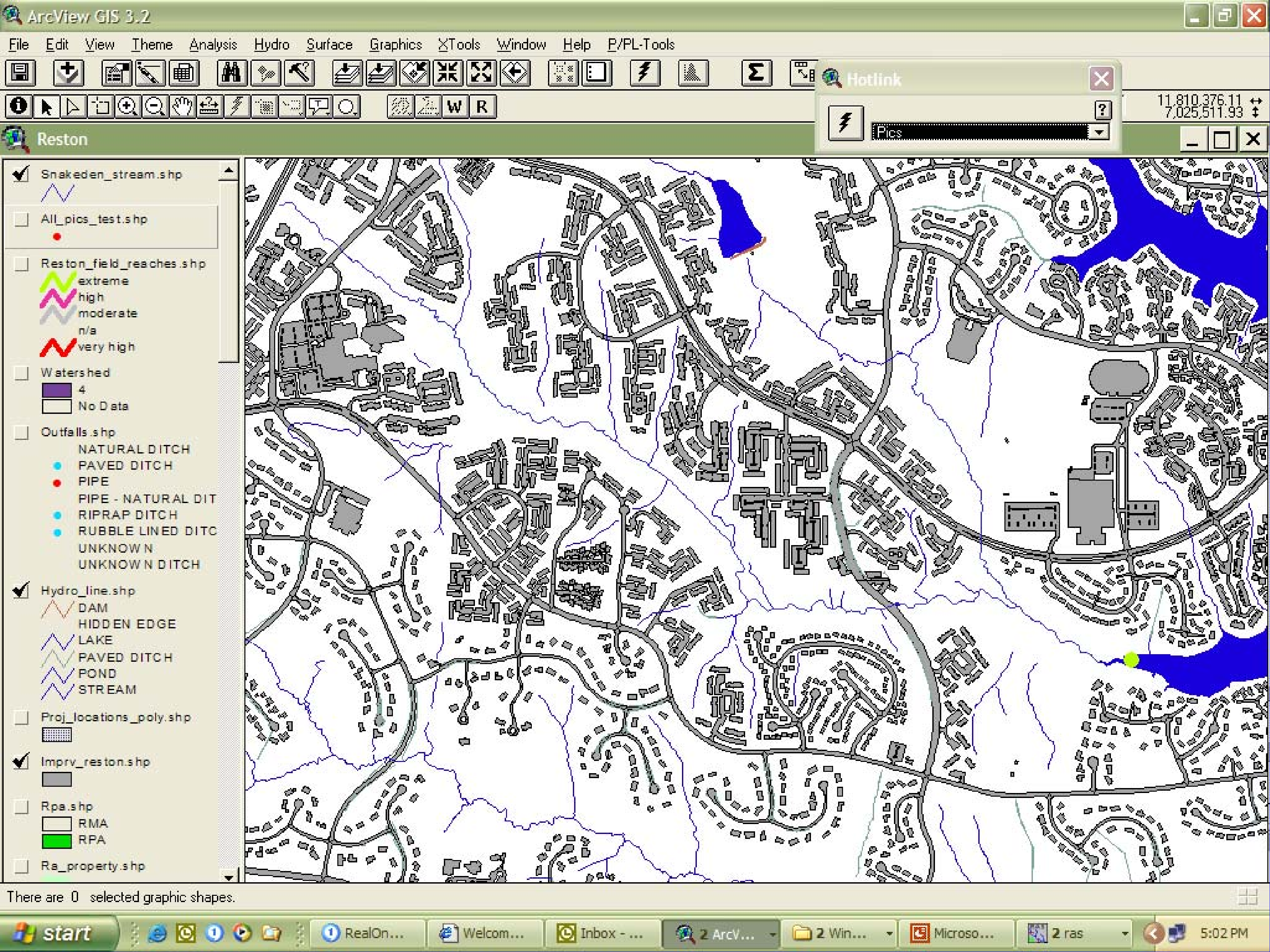
High Imperviousness (40%) Fair Integrity

Low Imperviousness 9% Fair Integrity

Chris May, 1998

Reston Watershed Management Planning

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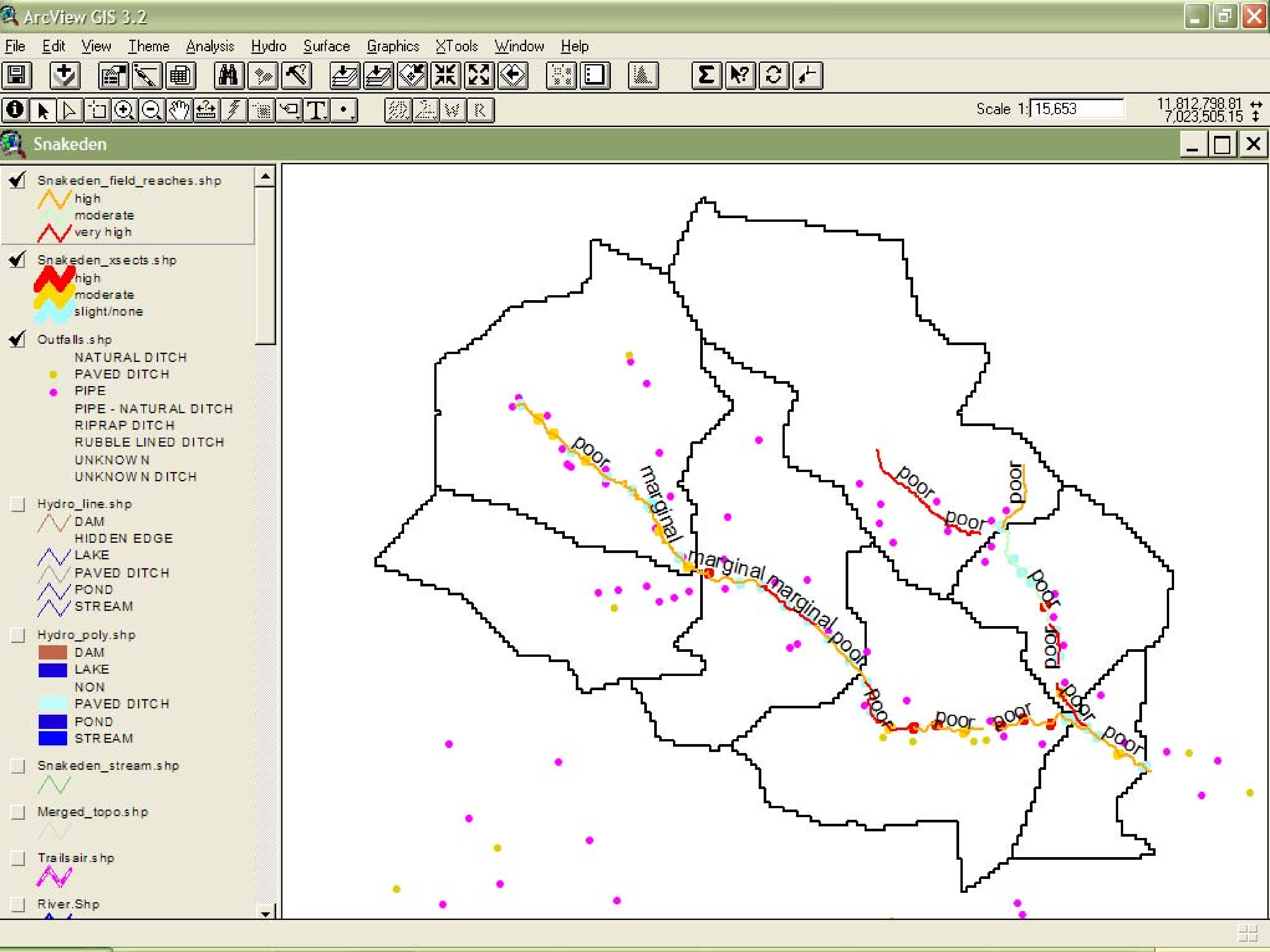
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PAVED DITCH
PIPE
PIPE - NATURAL DITCH
RIPRAP DITCH
RUBBLE LINED DITCH
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HIDDEN EDGE
LAKE
PAVED DITCH
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PAVED DITCH
POND
STREAM
Snakeden_stream.shp
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Trailsair.shp
River.Shp
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poor

Buttermilk off North Shore

Buttermilk off Ring Road

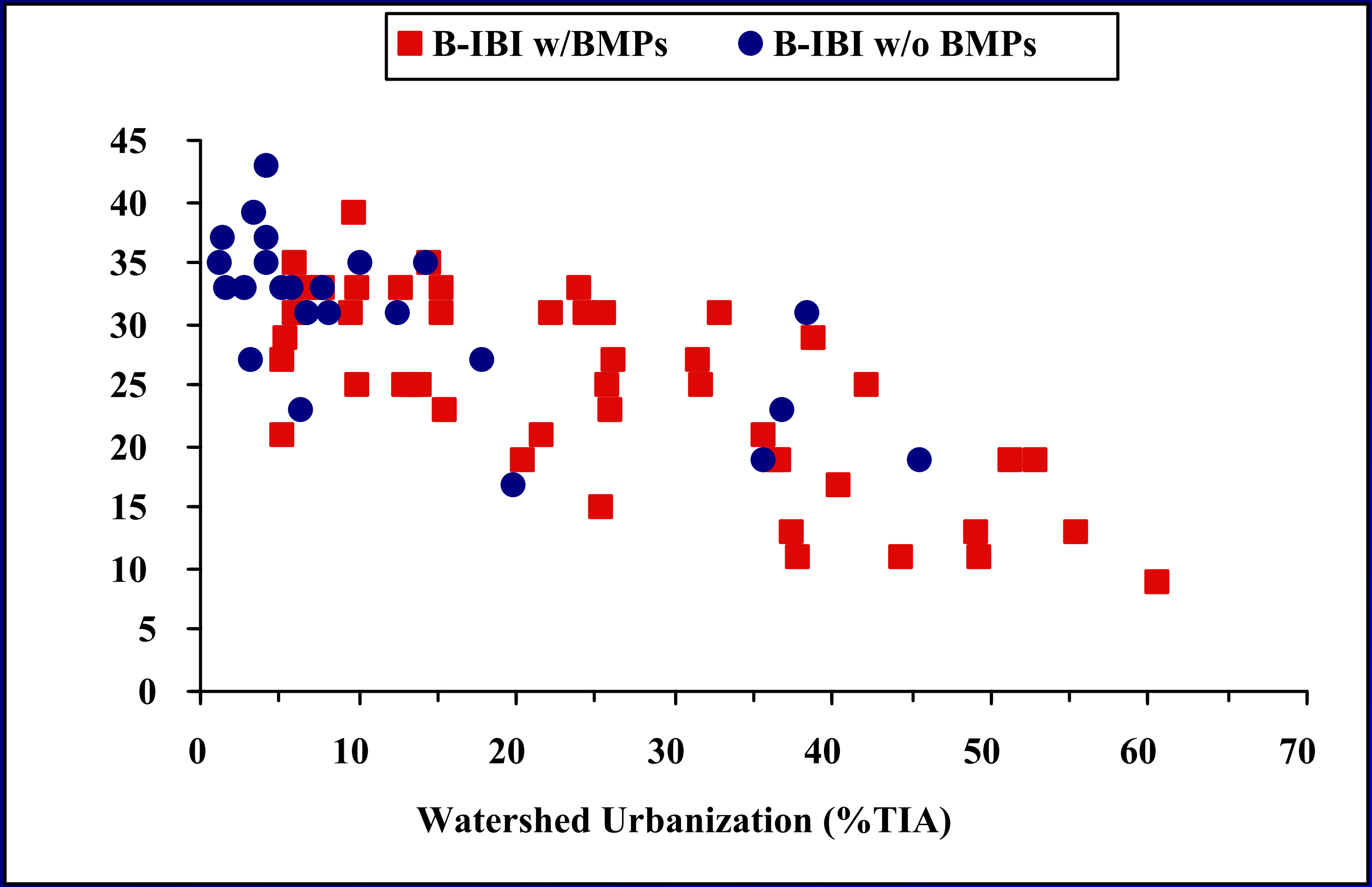
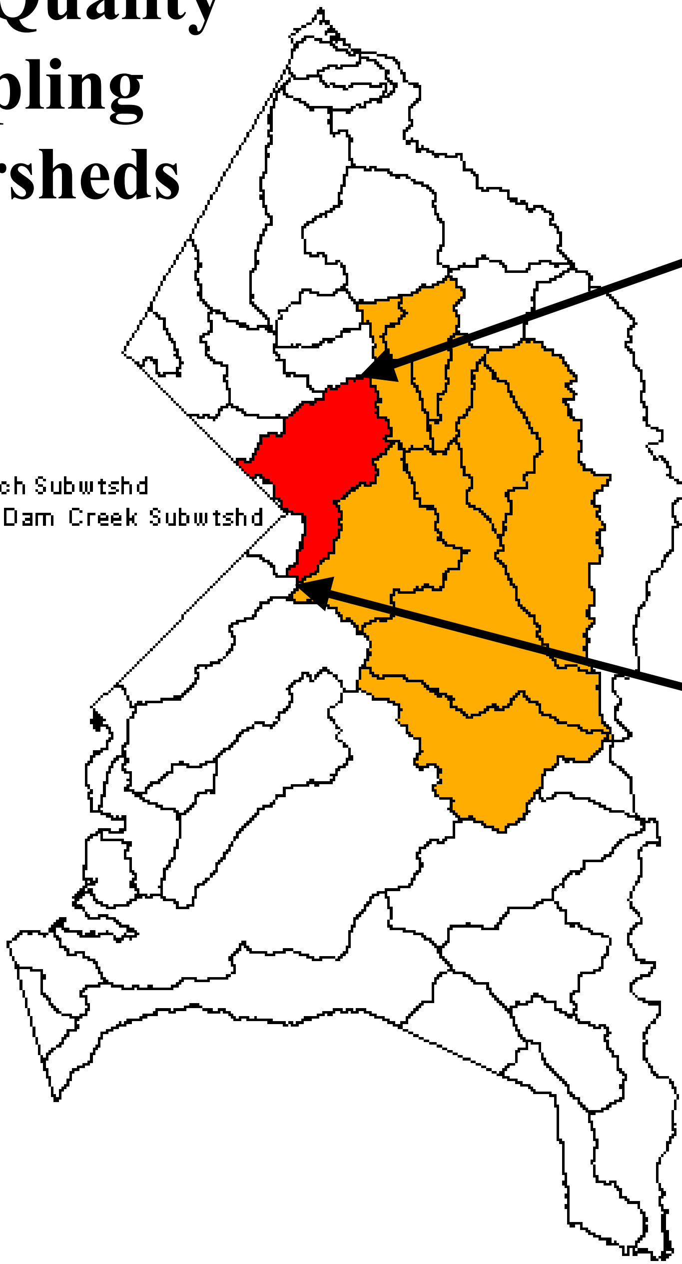
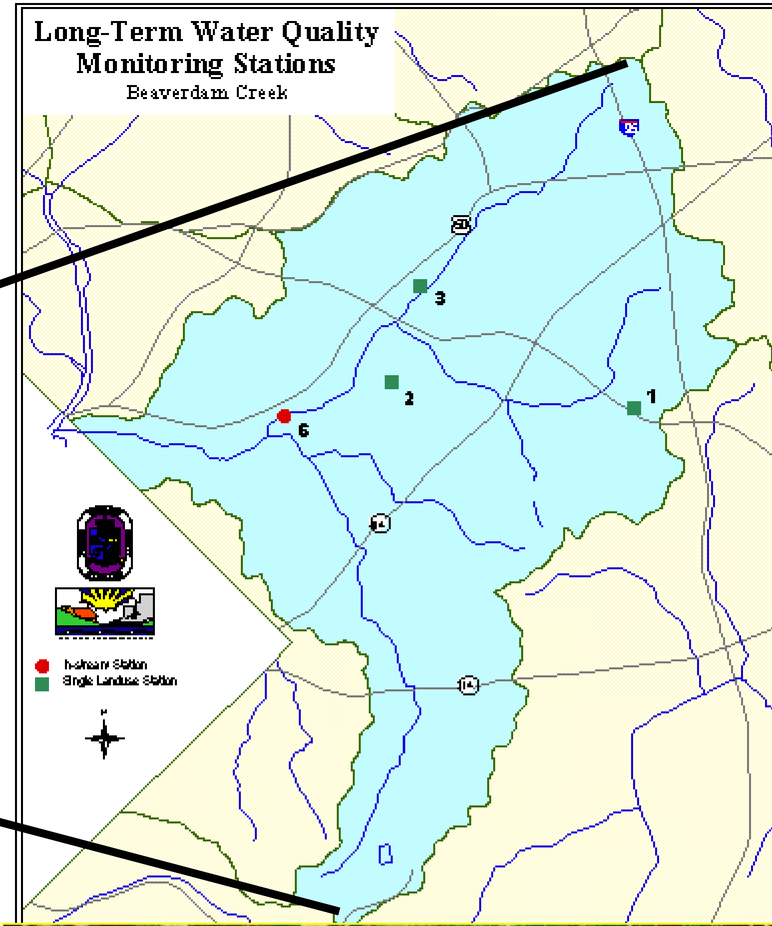


Figure 2: Showing the lack of mitigating influence of structural BMPs on biologic conditions in Puget Sound lowland streams (Horner and May, 2000). Note, "w/BMPs" refers to structural facilities only. [Honer / May 2001]

Water Quality Sampling Watersheds

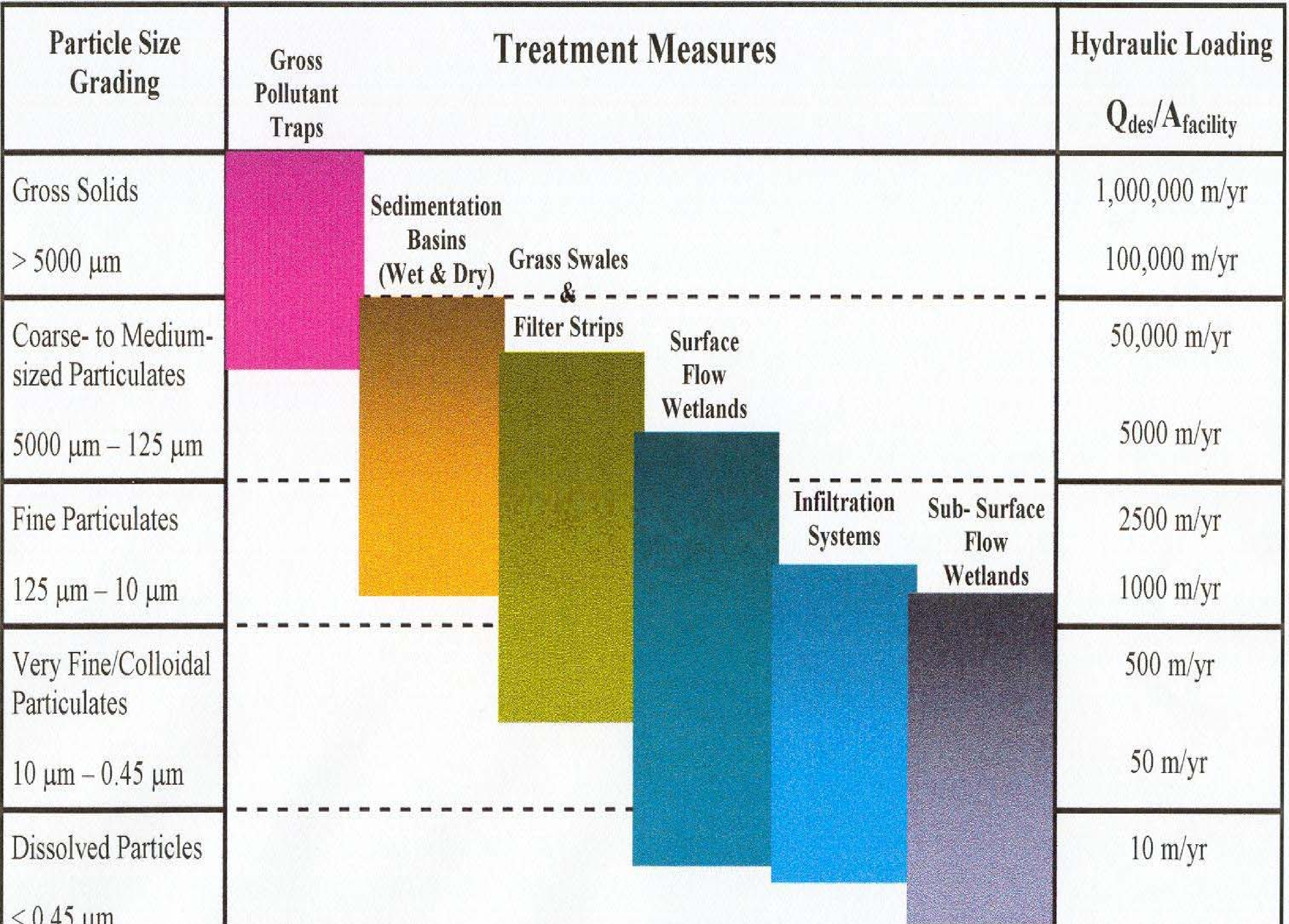




Wet Weather Monitoring

Maximum Concentrations at In-stream Stations

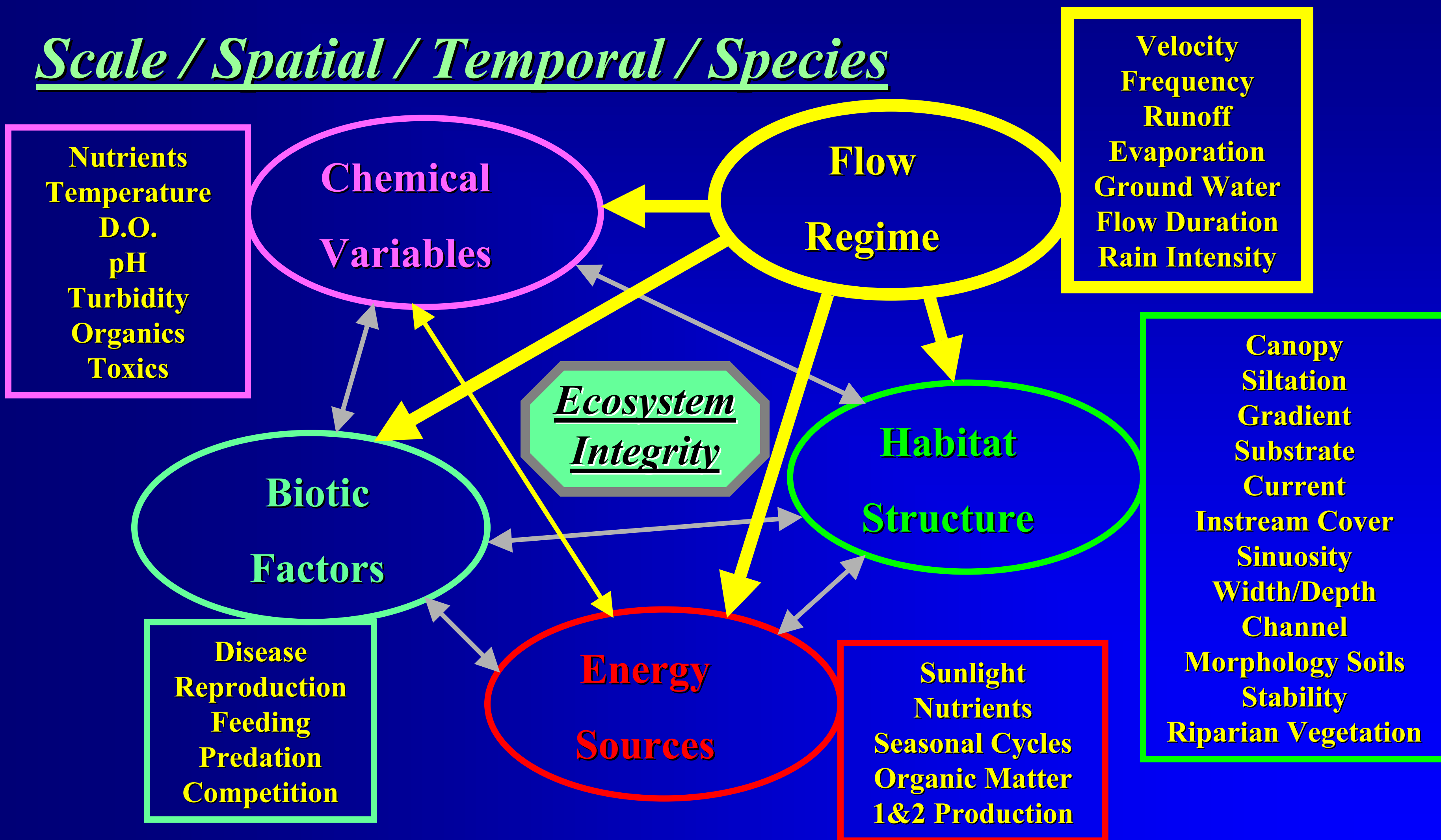
Parameter	EPA Criteria		L. Beaver-dam Cr.	Western Branch	Collington Branch
	chronic	acute			
Cadmium (*ug*/l)	1.1	3.9	40	1.0	10
Copper (*ug*/l)	12	18	470	30	57
Lead (*ug*/l)	3.2	83	1700	66	34
Zinc (*ug*/l)	110	120	5400	160	330
Total P (mg/l)	0.1		3.2	0.74	3.4
TKN (mg/l)	--		6.0	7.2	9.9
Nitrate (mg/l)	10		2.5	1.0	1.8
BOD (mg/l)	7		71	57	27
TSS (mg/l)	500		4800	910	2500
Fecal Coliform (org/100 ml)	200		220000	13000	17000
Oil/Grease (mg/l)	--		7	BDL	BDL



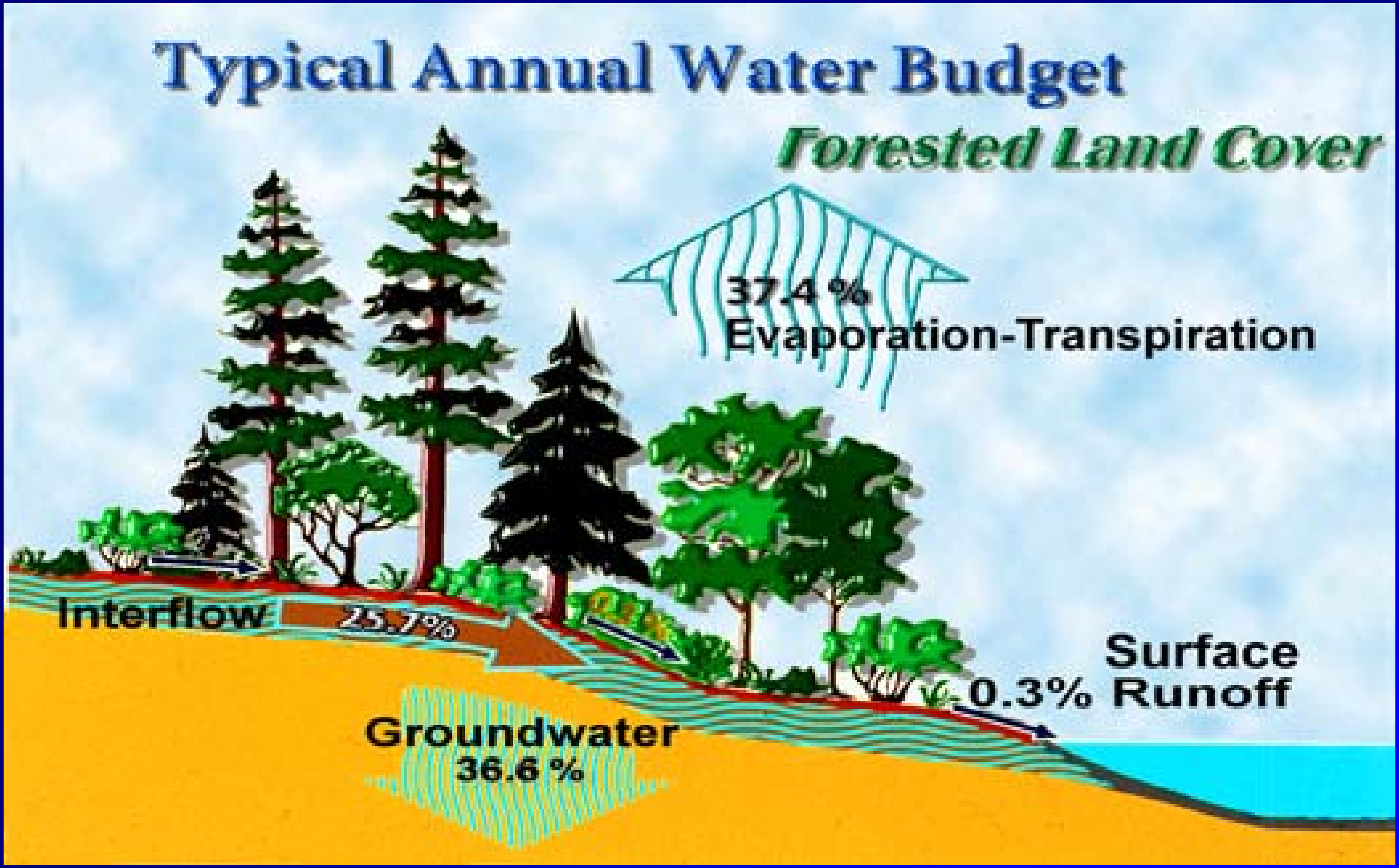
Courtesy Wong, 2001

How well do we maintain the ecological integrity (functions) of aquatic systems (small streams)?

Scale / Spatial / Temporal / Species

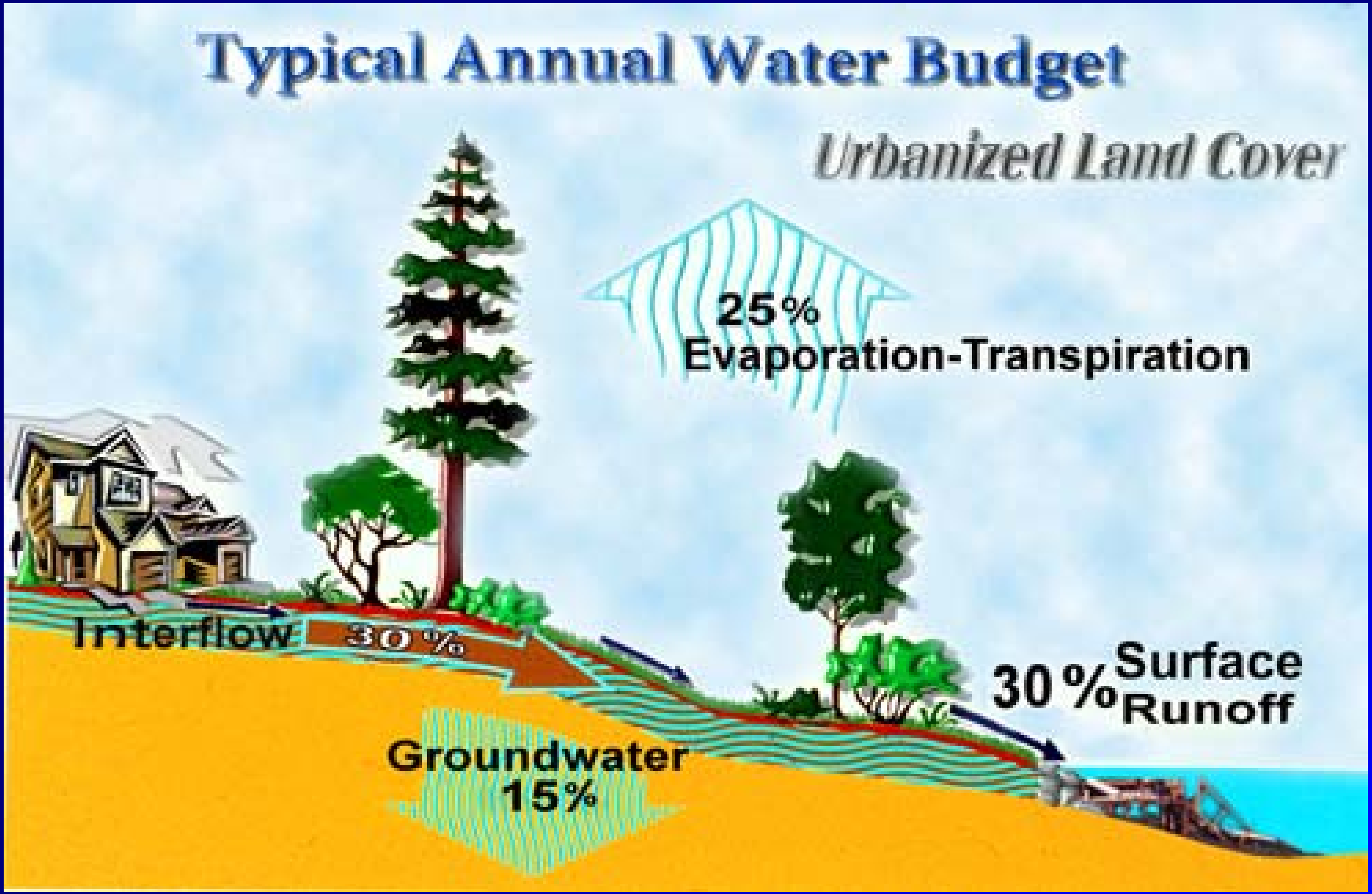


Natural Conditions



Courtesy May, U of W

Developed Conditions



Courtesy May, U of W


The Problem: Conventional Site Design
Collect
Concentrate
Convey
Centralized
Control
Good Drainage Paradigm

Hydrologically Connected

Ecologically Dysfunctional

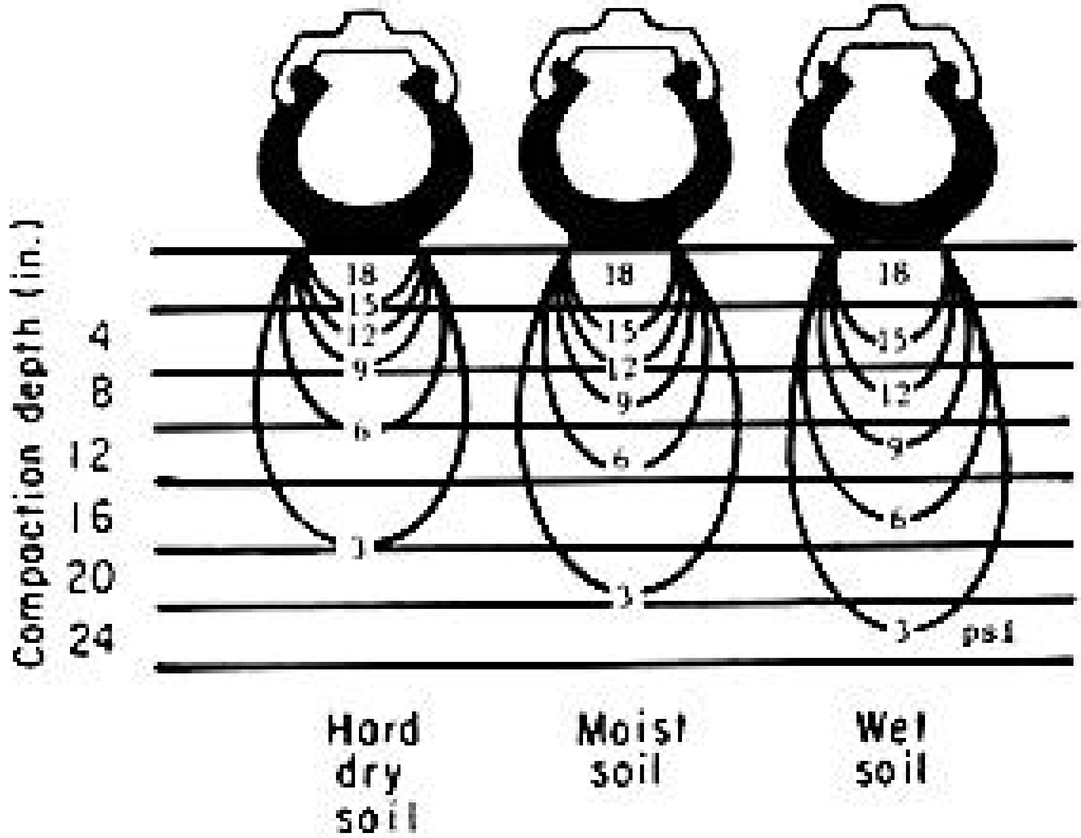


Figure 3. How soil moisture affects soil compaction. The lines in the soil under the tire represent curves of equal pressure. In all three situations the tire size was 11 x 28, the load was 1,650 pounds and the pressure 12 psi. On wet soil, pressures were transmitted to depths of more than 24 inches. (Source—Soehne, Jour. of Agr. Eng., May 1958.)

Background

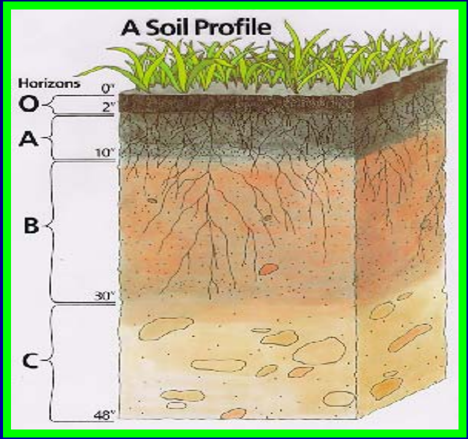
Soil Ecosystem Functions

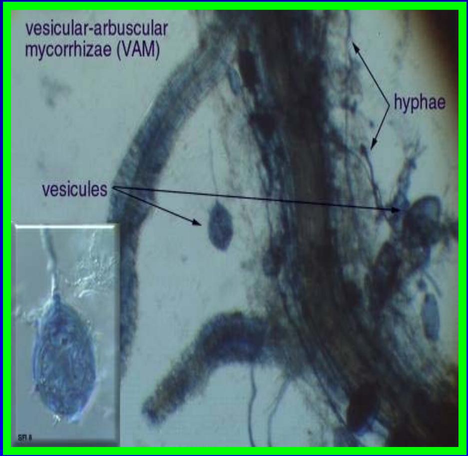
Physical / Chemical / Biological

1. *Hydrology*
   storage / evaporation / recharge / detention
2. *Storing Cycling Nutrients (bacteria / fungi)*
   phosphorous / nitrogen / carbon
3. *Plant Productivity (vigor)*
4. *Water Quality*

   filter / buffer / degrade / immobilize
   detoxify organic and inorganic materials

"Most diverse ecosystem in the world"






1

Conventional Pipe and Pond Centralized Control

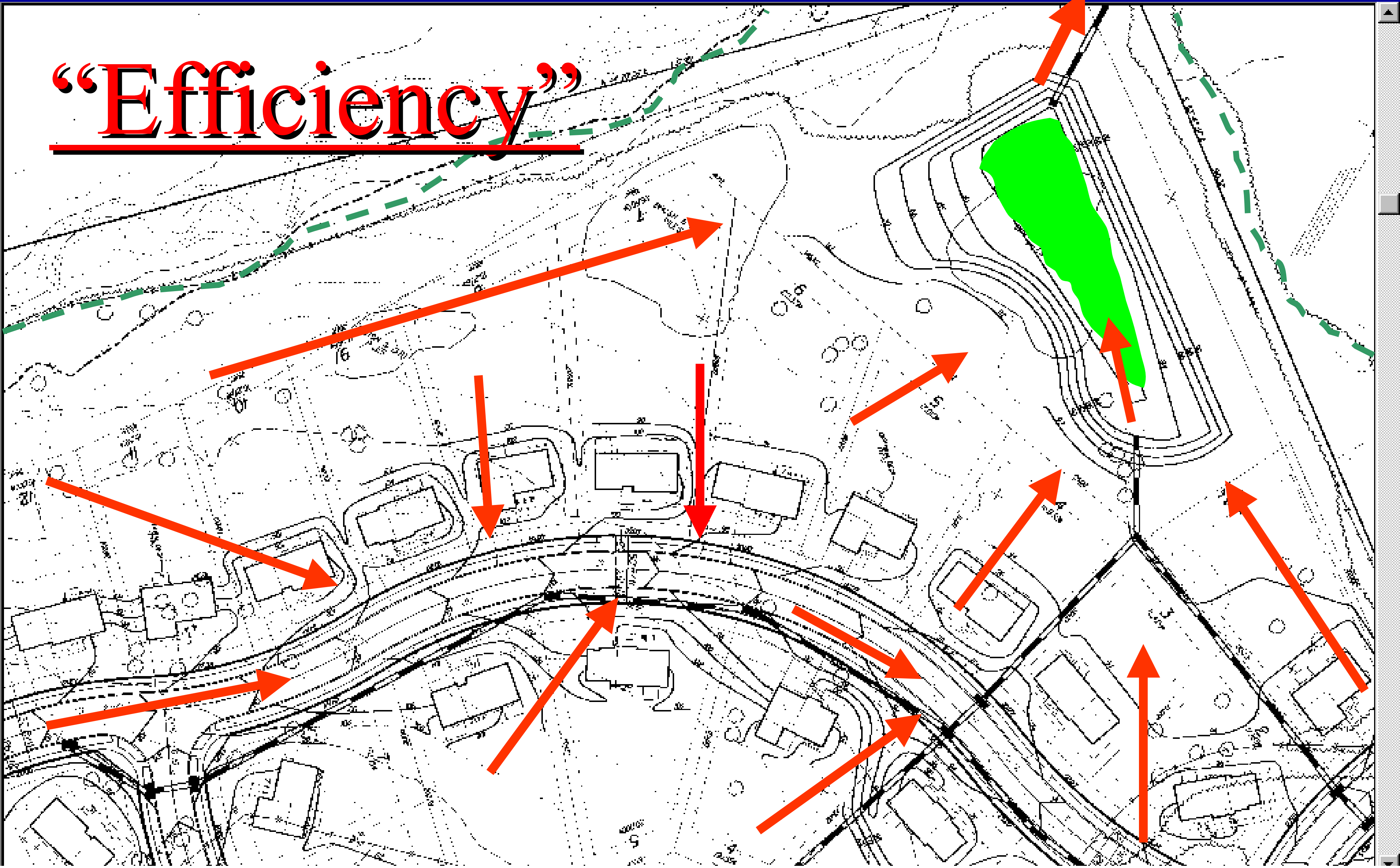
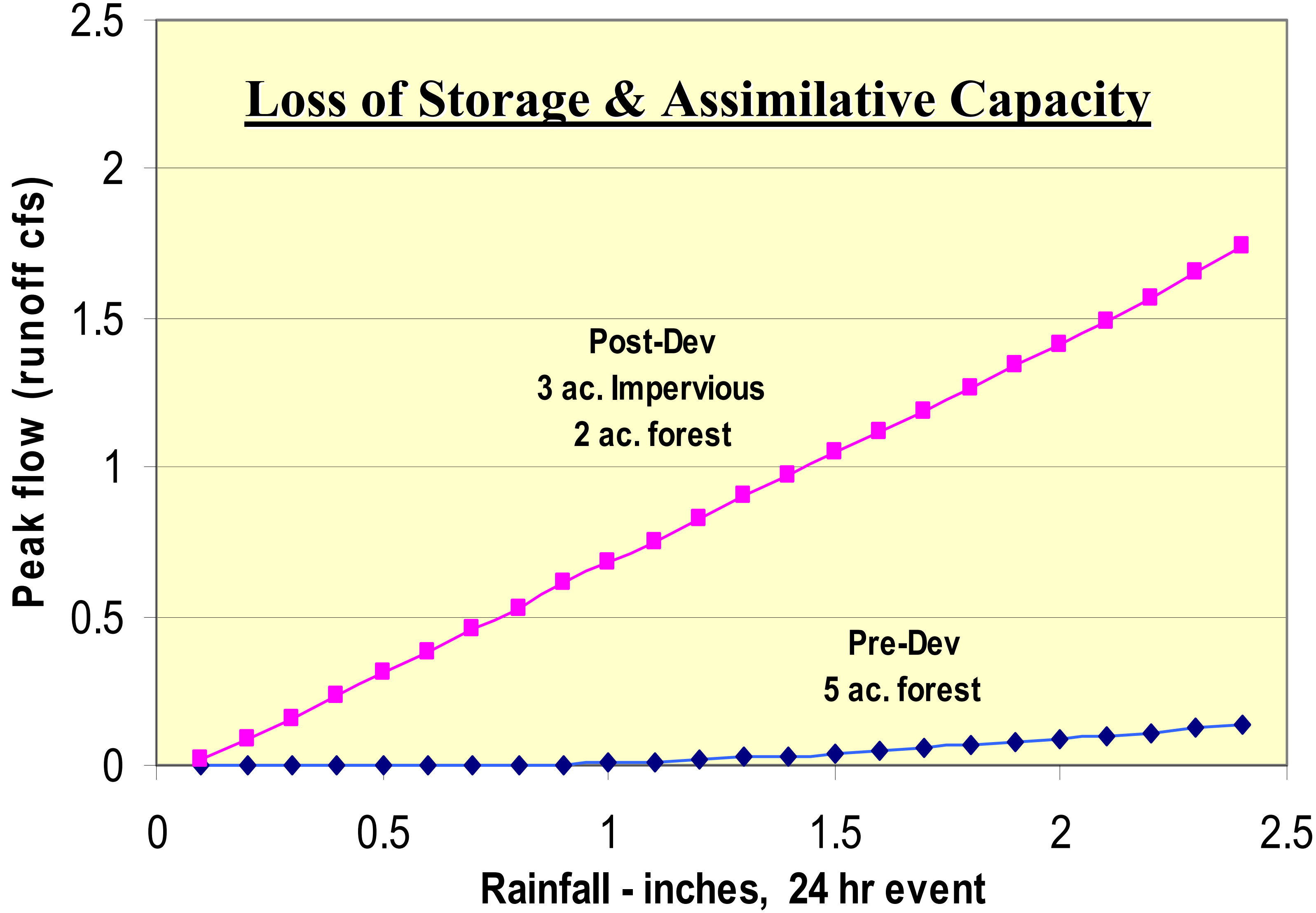
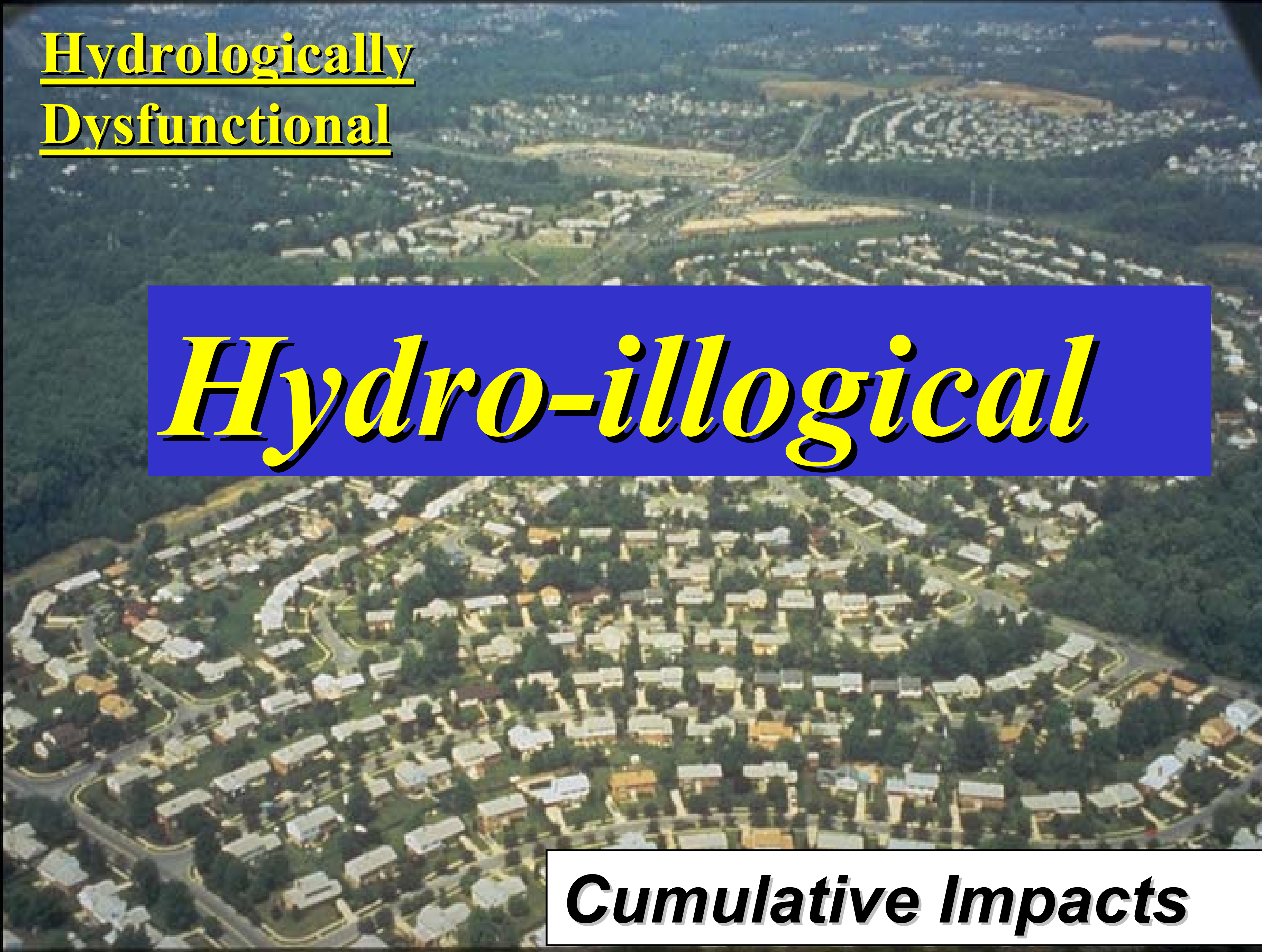


Figure I.6.2 Pre / Post development comparison

(Source: SBUH method, perv. Cn 70/imp. Cn 99, 5 acre site)




Hydrologically
Dysfunctional
Hydro-illogical
Cumulative Impacts

LID Basics

Principles
and
Practices

It's not what but how you do it!

- Hydrologically Functional Designs
- Increasing Assimilative Capacity
- Multifunctional / Beneficial Landscape and Architecture

LID Provides Powerful New tools for Urban Stormwater Management

How Does LID Maintain or Restore The Hydrologic Regime?

- **Creative ways to:**
  - **Maintain / Restore Storage Volume**
    - **interception, depression, channel**
  - **Maintain / Restore Infiltration Volume**
  - **Maintain / Restore Evaporation Volume**
  - **Maintain / Restore Runoff Volume**
  - **Maintain Flow Paths**
- **Engineer a site to mimic the natural water cycle functions / relationships**

Key LID Principles

"Volume"

"Hydrology as the Organizing Principle "

- Unique Watershed Design
  - Match Initial Abstraction Volume
  - Mimic Water Balance
- Uniform Distribution of Small-scale Controls
- Cumulative Impacts of Multiple Systems
  - filter / detain / retain / use / recharge / evaporate
- Decentralized / Disconnection
- Multifunctional Multipurpose Landscaping & Architecture
- Prevention

Defining LID Technology

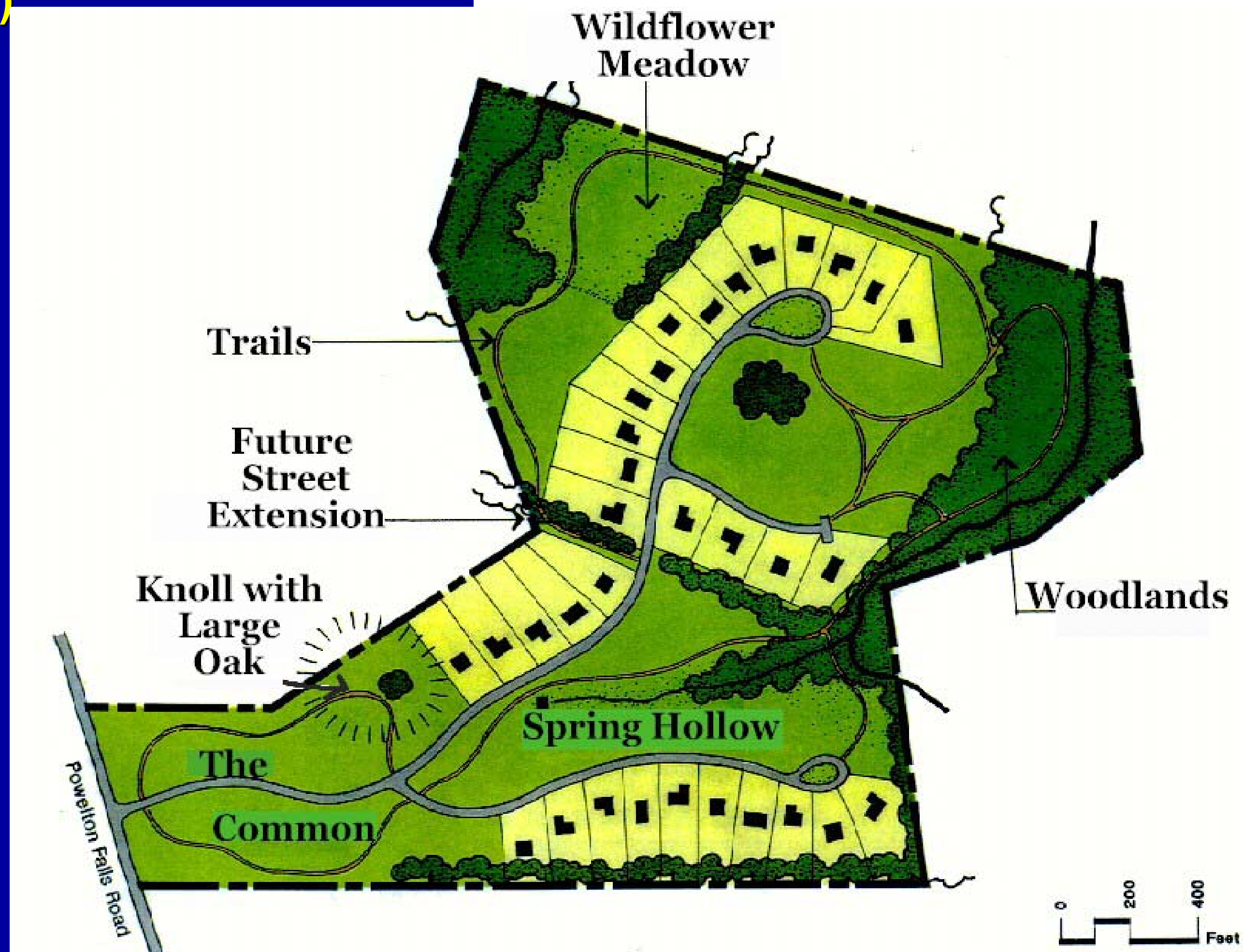
Major Components

1. Conservation (Watershed and Site Level)
2. Minimization (Site Level)
3. Strategic Timing (Watershed and Site Level)
4. Integrated Management Practices (Site Level)
   Retain / Detain / Filter / Recharge / Use
5. Pollution Prevention
   Traditional Approaches

1. Conservation Plans / Regulations

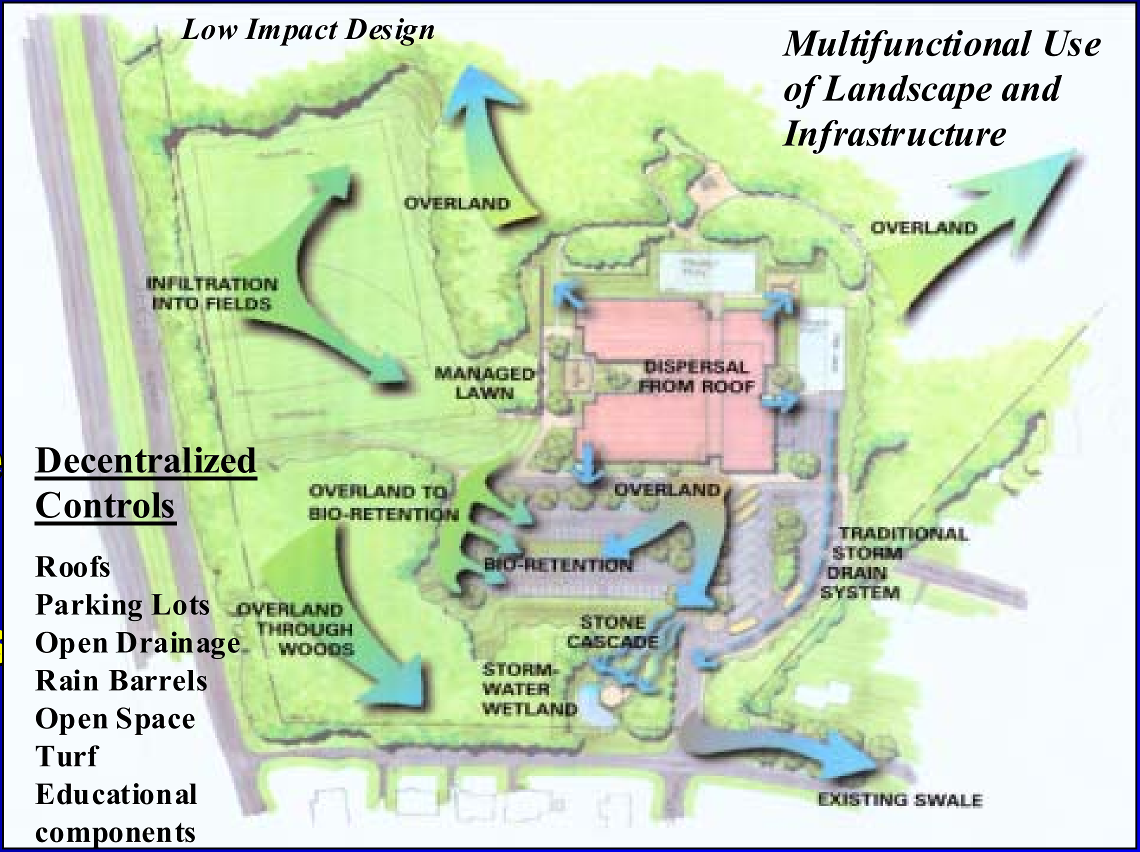
- Local Watershed and Conservation Plans
  - Forest (Contiguous and Interior Habitat)
  - Streams (Corridors)
  - Wetlands
  - Habitats
  - Step Slopes
  - Buffers
  - Critical Areas
  - Parks
  - Scenic Areas
  - Trails
  - Shorelines
  - Difficult Soils
  - Ag Lands
  - Minerals

Large and Small Scale

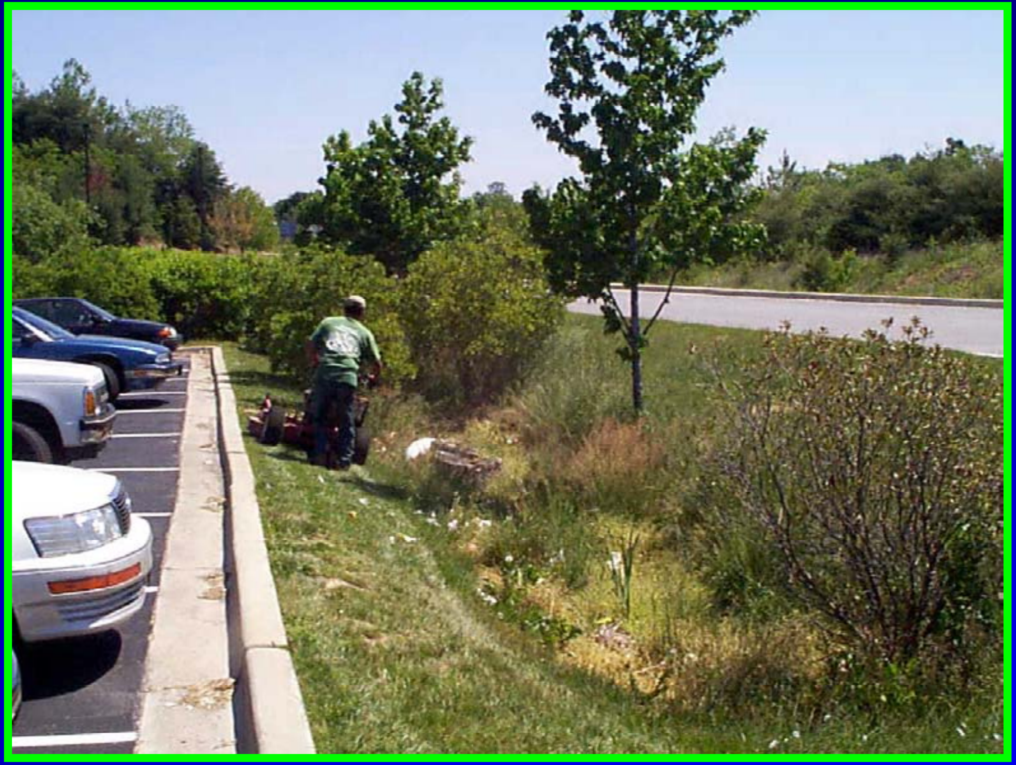


2. Minimize Impacts

- Minimize clearing
- Minimize grading
- Save A and B soils
- Limit lot disturbance
- * Soil Amendments
- Alternative Surfaces
- Reforestation
- Disconnect
- Reduce pipes, curb and gutters
- Reduce impervious surfaces



3. Maintain Time of Concentration



- Open Drainage
- Use green space
- Flatten slopes
- Disperse drainage
- Lengthen flow paths
- Save headwater areas
- Vegetative swales
- Maintain natural flow paths
- Increase distance from streams
- Maximize sheet flow

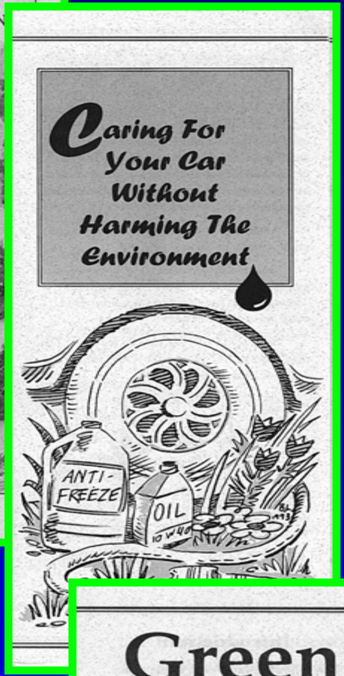
4. Storage, Detention & Filtration "LID IMP's"

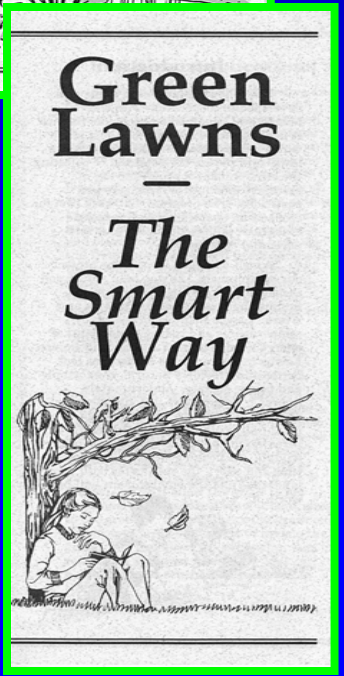
- Uniform Distribution at the Source
  - Open drainage swales
  - Rain Gardens / Bioretention
  - Smaller pipes and culverts
  - Small inlets
  - Depression storage
  - Infiltration
  - Rooftop storage
  - Pipe storage
  - Street storage
  - Rain Water Use
  - Soil Management**

5. Pollution Prevention

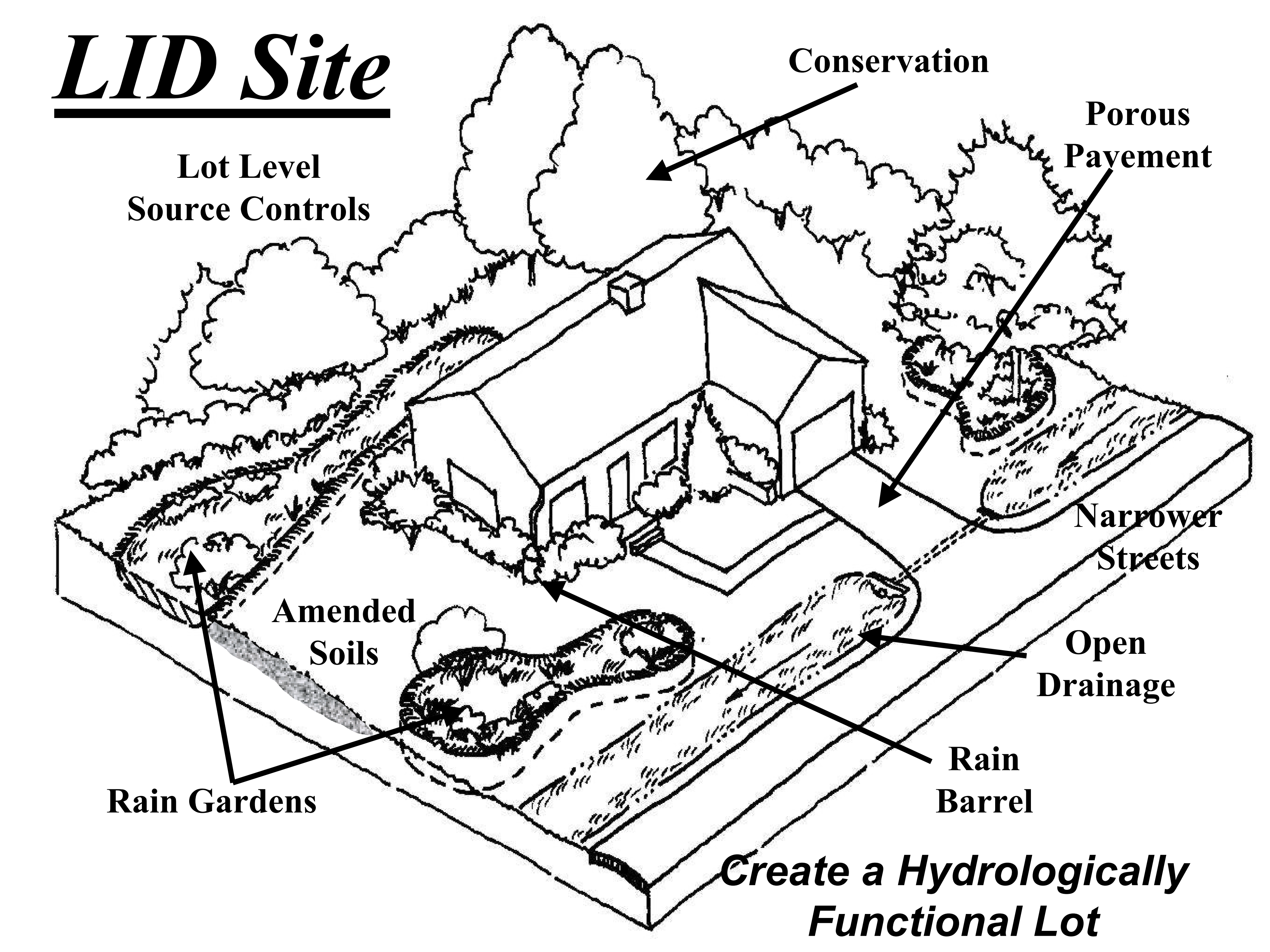
30 - 40% Reduction in N&P

Kettering Demonstration Project

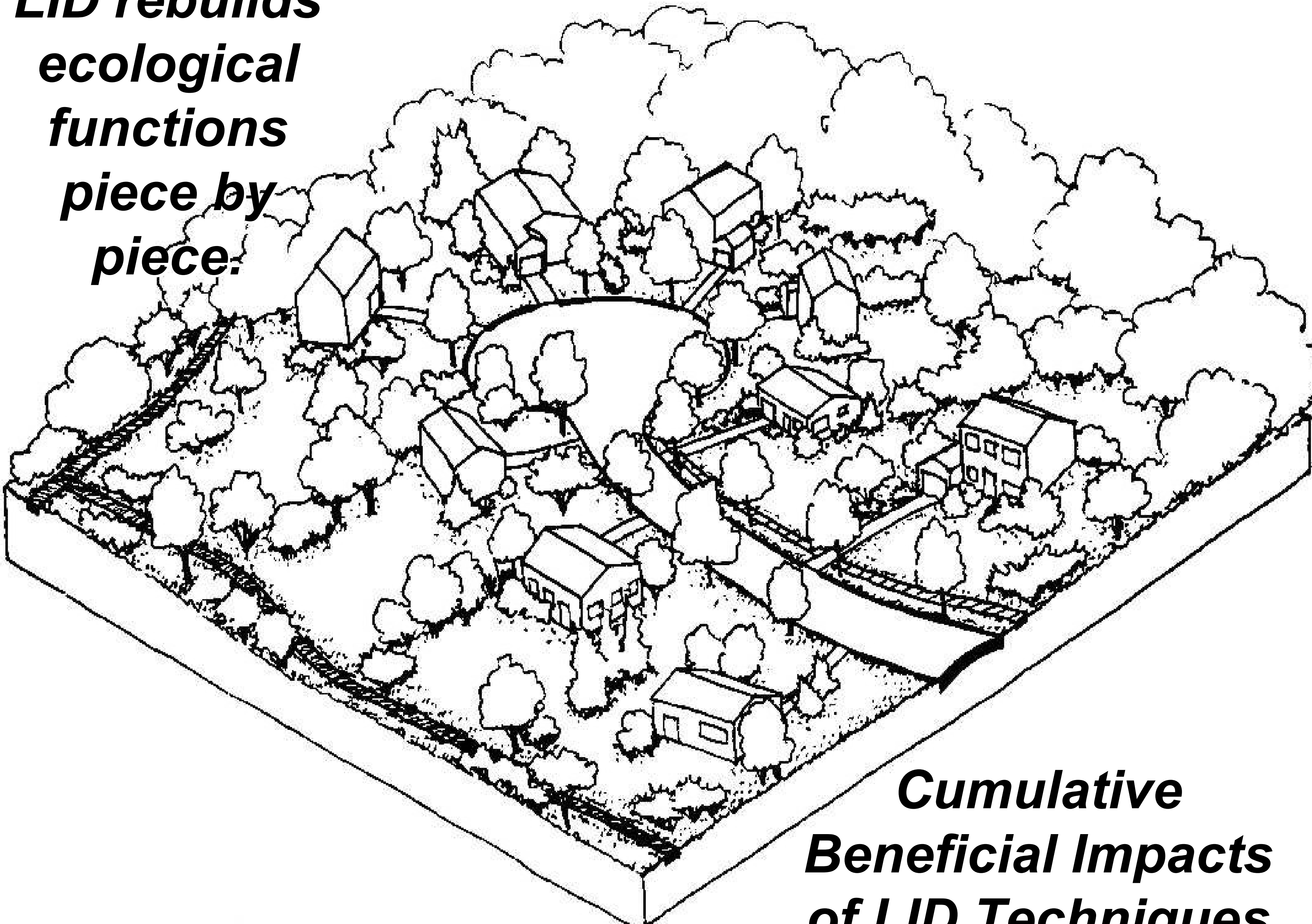




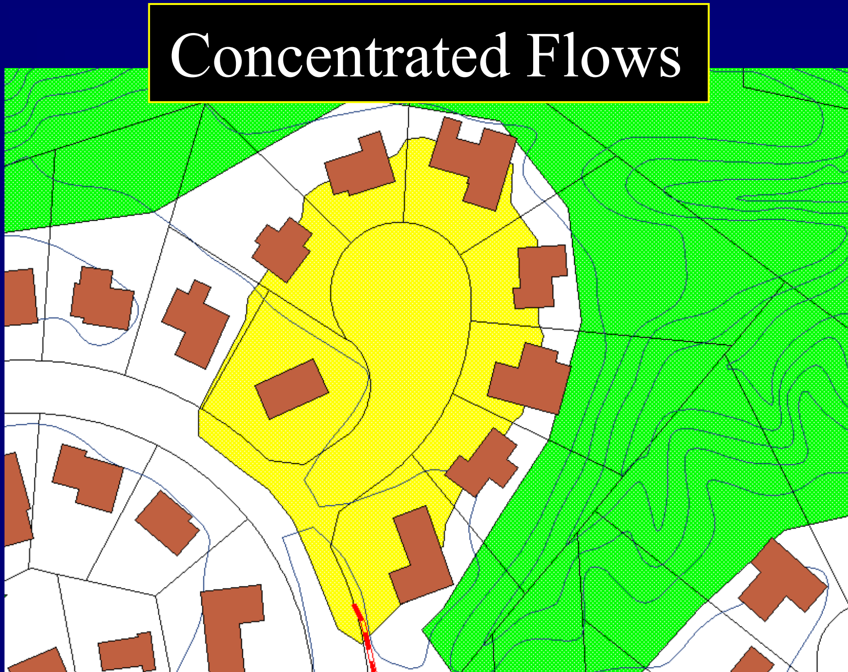
- Maintenance
- Proper use, handling and disposal
  - Individuals
    - Lawn / car / hazardous wastes / reporting / recycling
  - Industry
    - Good house keeping / proper disposal / reuse / spills
  - Business
    - Alternative products / Product liability

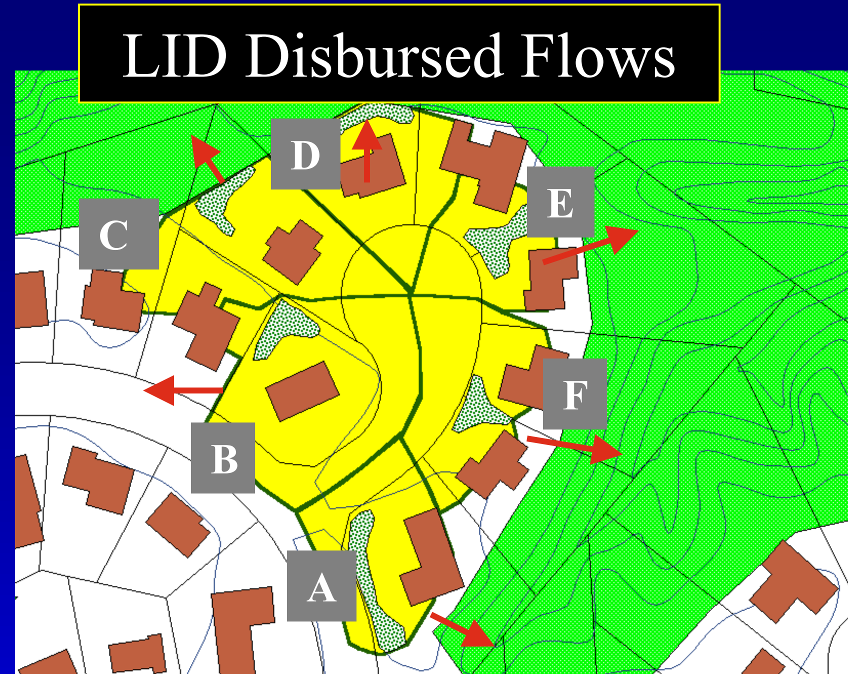

LID Site
Lot Level
Source Controls
Conservation
Porous
Payement
Narrower
Streets
Amended
Soils
Open
Drainage
Rain
Barrel
Rain Gardens
Create a Hydrologically
Functional Lot

LID rebuilds ecological functions piece by piece.



Cumulative Beneficial Impacts of LID Techniques





Peak Flow Rate

$Q_{10} = C\ I_{10}\ A$

$Q_{10} = .38 * 5.88 * 2$

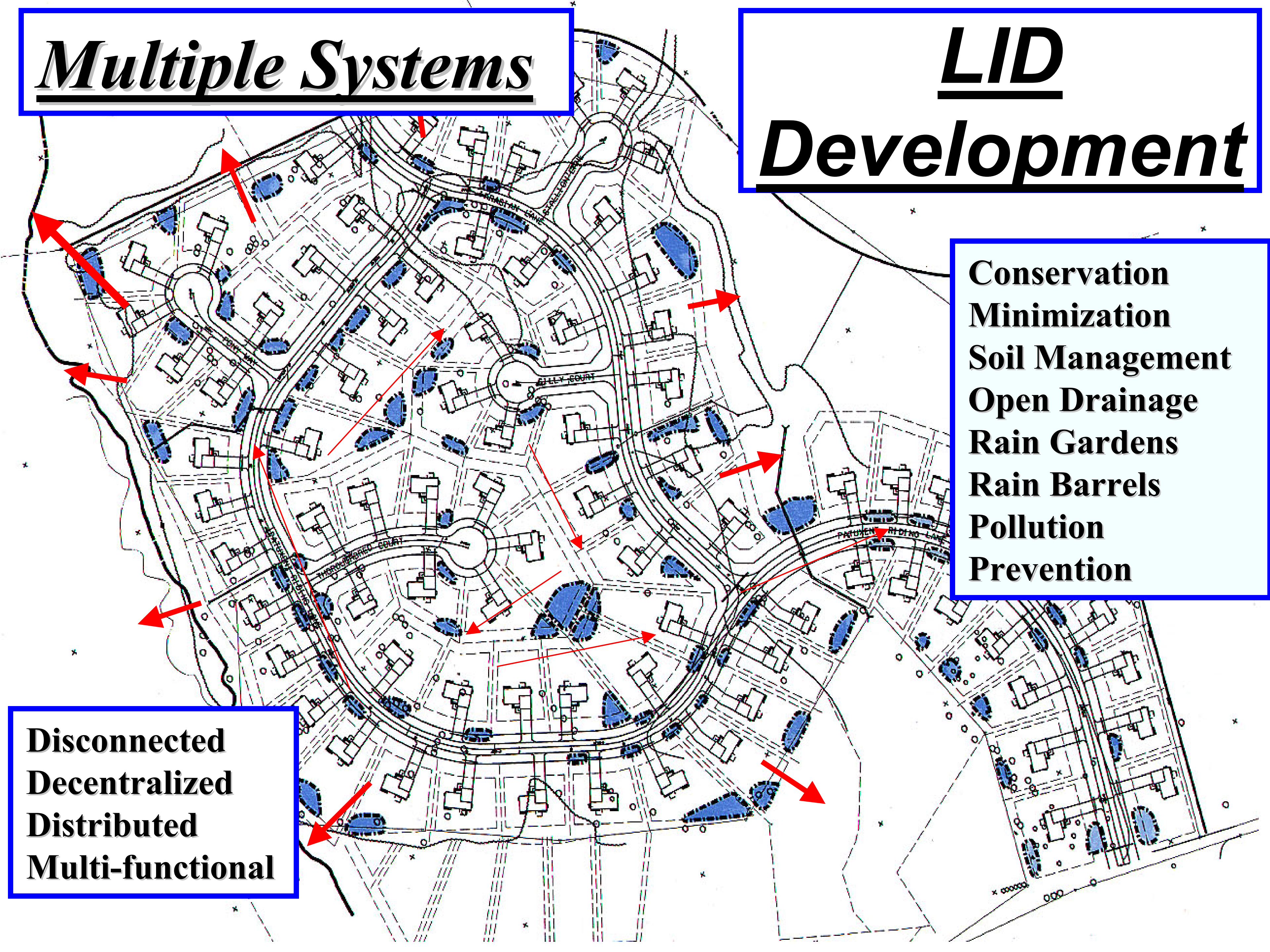
$Q_{10} = 4.47$cfs

DA = 1.9ac

Peak Flow Rates
A = 1.18cfs
B = 0.65cfs
C = 0.39cfs
D = 0.41cfs
E = 0.45cfs
F = 0.45cfs
Total = 4.09cfs
DA = 2.47ac

Multiple Systems

LID Development



Conservation
Minimization
Soil Management
Open Drainage
Rain Gardens
Rain Barrels
Pollution
Prevention

Disconnected
Decentralized
Distributed
Multi-functional

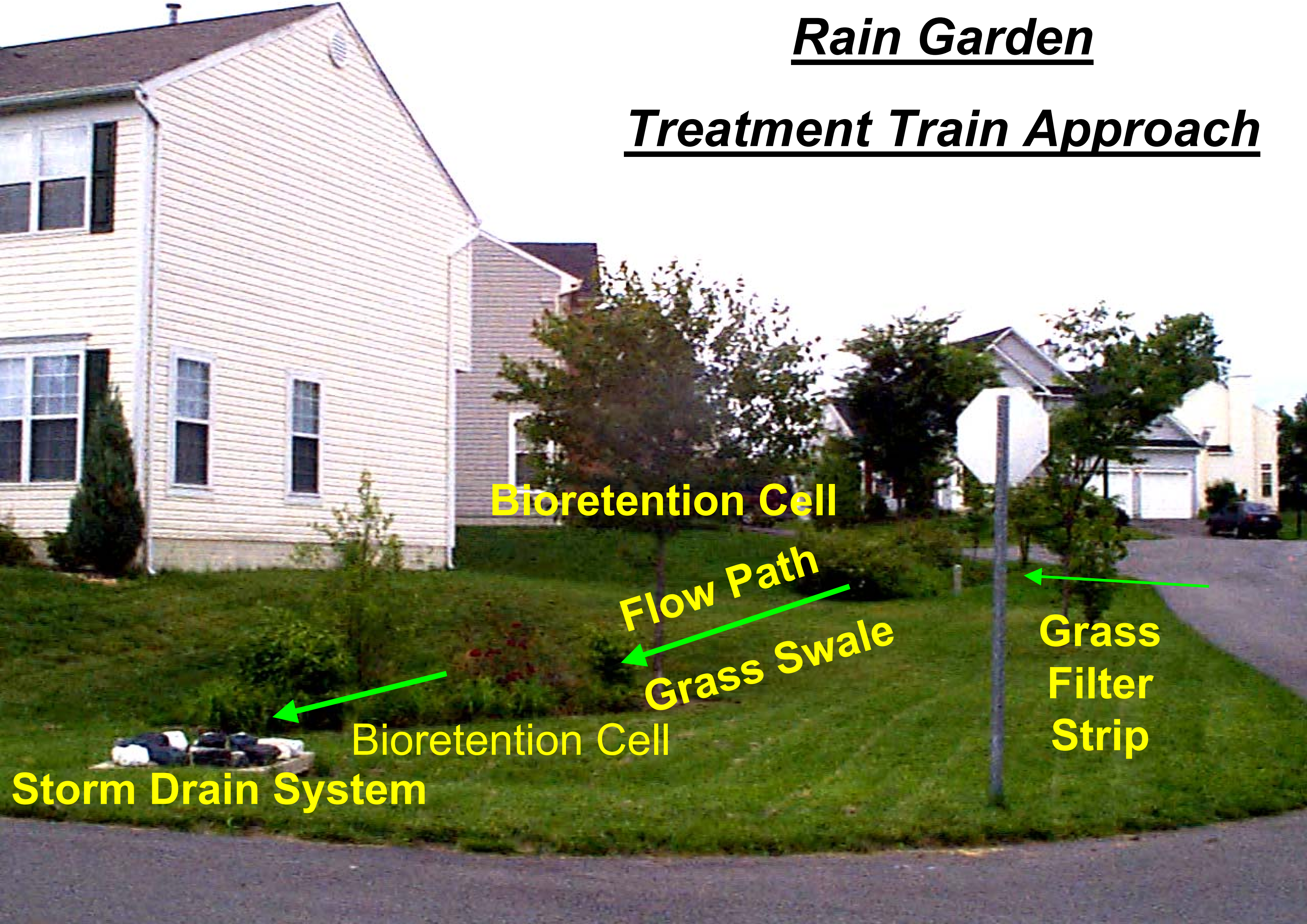
Construction Cost Comparison

	Conventional	Low Impact
Grading/Roads	**$569,698**	**$426,575**
Storm Drains	**$225,721**	**$132,558**
SWM Pond/Fees	**$260,858**	**$ 10,530**
Bioretention/Micro	**—**	**$175,000**
Total	$1,086,277	$744,663
Unit Cost	$14,679	$9,193
Lot Yield	74	81


Rain
Gardens
Typical Landscape Maintenance Practices

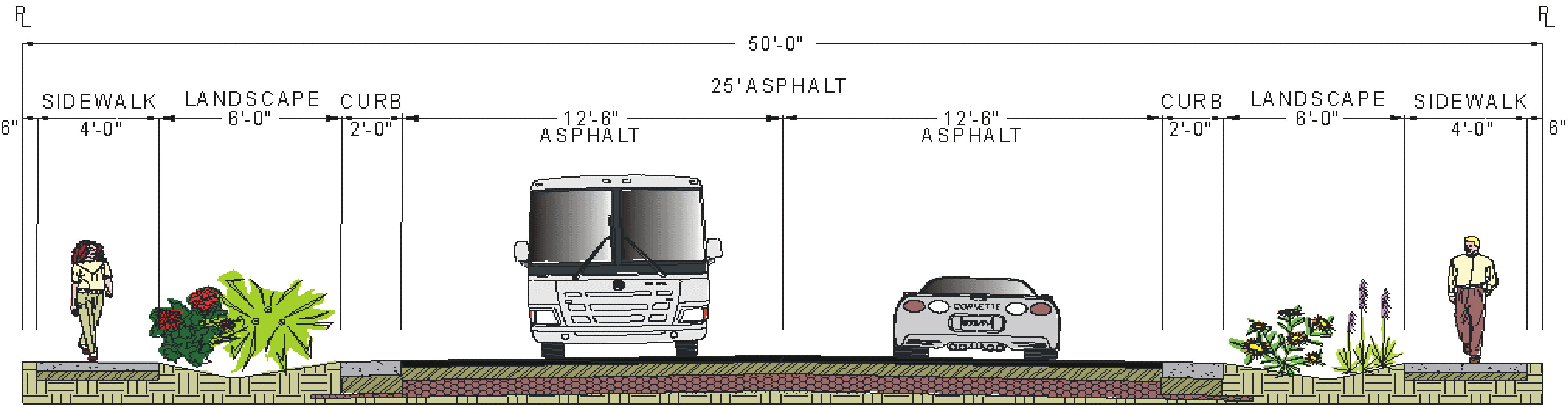
Rain Garden

Treatment Train Approach



NEW 50' RIGHT-OF-WAY

SERVICE UP TO 25 RESIDENCES



LOW IMPACT RESULTS

- 17% LESS ASPHALT SURFACE
- 5-8% STORM WATER RUNOFF REDUCTION
- 86% INCREASE IN GREEN SPACE


SPEED
LIMIT
25

VIEW OF LOT WITH STORAGE AND BIORETENTION

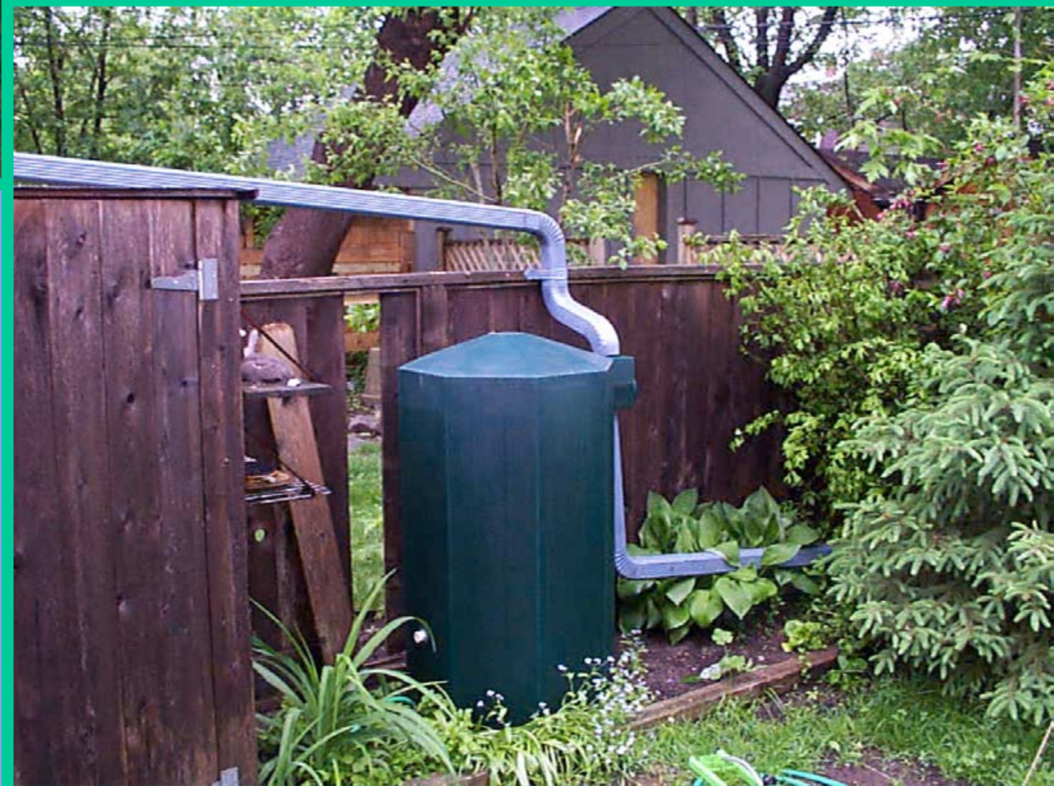

SOLOMONS
LANDING

Total Water Management

Runoff Use

Consumption Reduction

Save $100 / yr.




Caring For Your Car Without Harming The Environment
ANTI-FREEZE
OIL
Rain Gardens
THE NATURAL SOLUTION
Green Lawns
The Smart Way
pollution prevention
it's everyone's business


ANTIFREEZE


LITTER


Corbis.com

Did You Know:

Kettering residents discharge approximately 1,277 quarts of detergents each year to the local stream from car washing alone?

Approximately 2,533 quarts of oil are disposed of improperly in Kettering each year and have the potential to contaminate the stream?

Approximately 2,992 quarts of antifreeze are drained onto the streets of Kettering where it then runs directly into the stream?

Approximately 23,643 pounds of nitrogen have the potential of being washed off of Kettering lawns each year from fertilizer applications?

Approximately 80% of Kettering residents apply some form of chemical pesticides to their yards each year?

When our environmental education program began last summer, 58% of Kettering residents did not know that neighborhoods like Kettering cause water pollution?

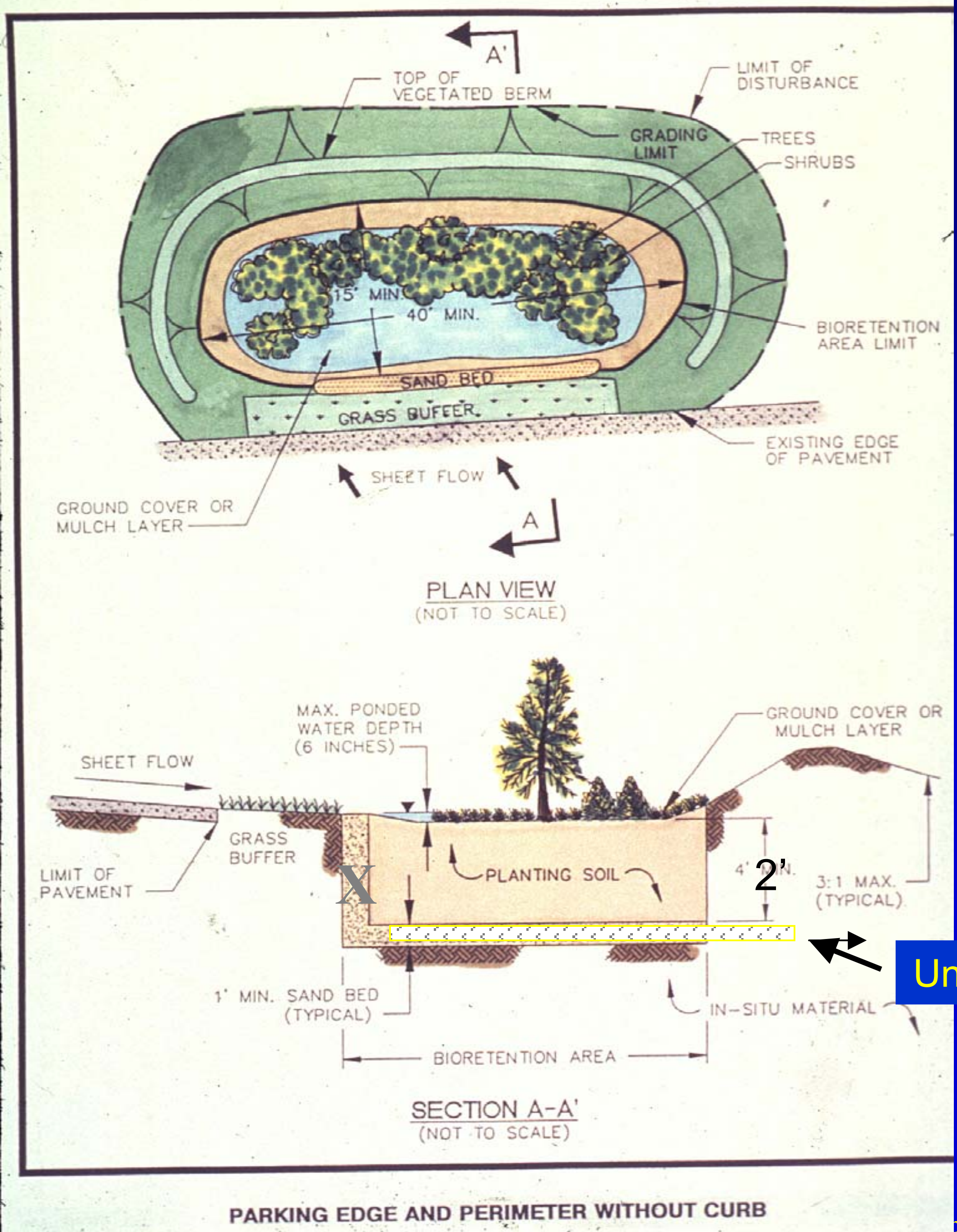
The stream that flows through the eastern part of Kettering into the Northeast Branch is so polluted that it can support almost no aquatic life?

What is Bioretention?

"Filtering stormwater runoff through a terrestrial aerobic (upland) plant / soil / microbe complex to remove pollutants through a variety of physical, chemical and biological processes."

The word "bioretention" was derived from the fact that the biomass of the plant / microbe (flora and fauna) complex retains or uptakes many of the pollutants of concern such as N, P and heavy metals.

It is the optimization and combination of bioretention, biodegradation, physical and chemical that makes this system the most efficient of all BMP's



Bioretention

- Shallow Ponding - 4” to 6”
- Soil Depth 2’ - 2.5’
- Sandy Top Soil
  - 65% Sand
  - 20% Sandy Loam
  - 15% Compost
- Under Drain System
- Plant Selection

Aesthetic Value / Habitat Value

Property Value / Low Cost

Low Maintenance

LID Practices (No Limit!)

"Creative Techniques to Treat,Use, Store, Retain, Detain and Recharge"

- Bioretention / Rain Gardens*
- Strategic Grading*
- Site Finger Printing
- Conservation*
- Flatter Wider Swales
- Amended Soils*
- Long Flow Paths
- Tree / Shrub Depression
- Turf Depression
- Landscape Island Storage
- Rooftop Detention /Retention
- Disconnection*
- Parking Lot / Street Storage
- Smaller Culverts, Pipes & Inlets
- Alternative Surfaces
- Reduce Impervious Surface
- Surface Roughness Technology
- Rain Barrels / Cisterns / Water Use*
- Catch Basins / Seepage Pits
- Sidewalk Storage
- Vegetative Swales, Buffers & Strips*
- Infiltration Swales & Trenches
- Eliminate Curb and Gutter
- Shoulder Vegetation
- Maximize Sheet flow
- Maintain Drainage Patterns
- Reforestation……………….
- Pollution Prevention………….


Urban Development
Washington D.C.
Potomac
River
Anacostia
River

LID Urban Retrofit
"First Define Your Goals!"

Water Quality

Water Supply

Fisheries

Recreational Use

ESA

CSO

Flood Control

Urban LID Lot Level Control Opportunities

- Roofs
- Buildings
- Down Spouts
- Yards
- Sidewalks
- Parking Lots
- Landscape Areas
- Open space
- Amended Soils

Multifunctional Infrastructure

Retention

Detention

Filtration

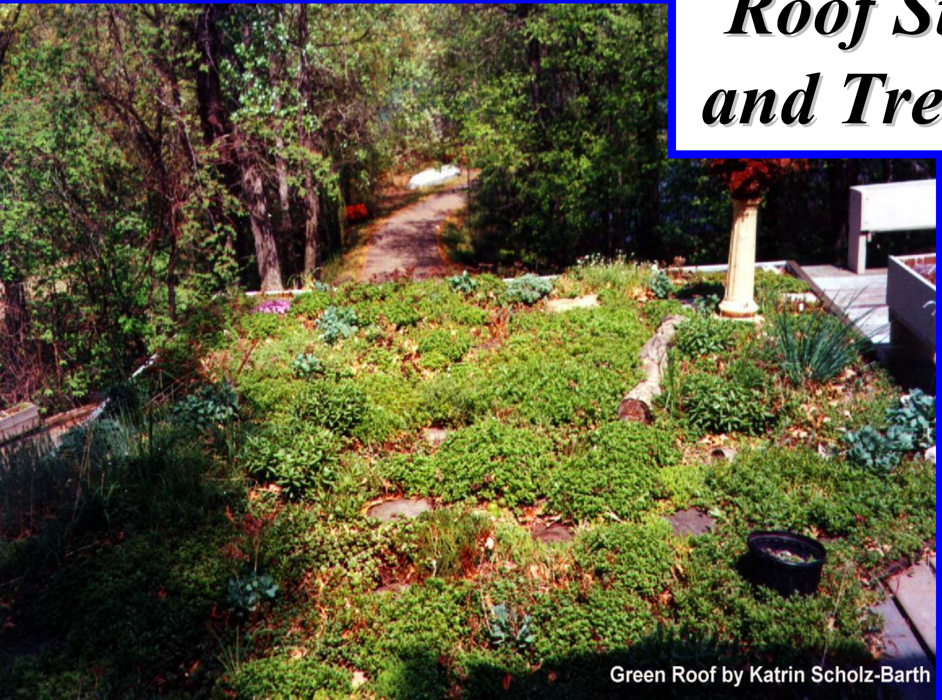
Infiltration

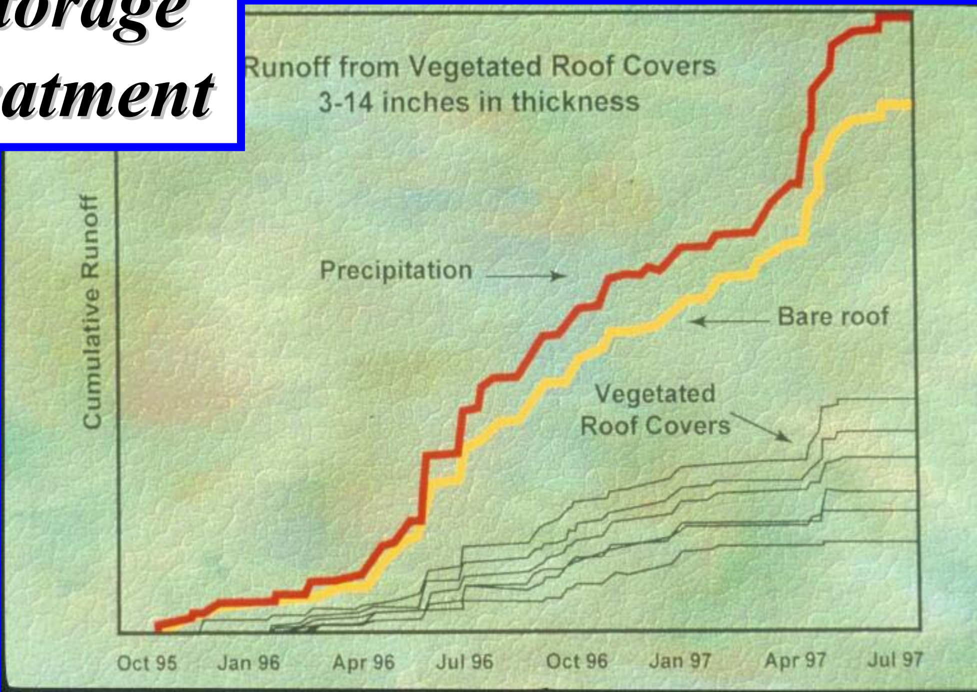
Timing

Water Use

Prevention

Roof Storage and Treatment






MAY 29 2001

Buildings Design

Downspouts Disconnect / Water Use


Rain
Barrels

Increasing Surface Area

Urban Canopy

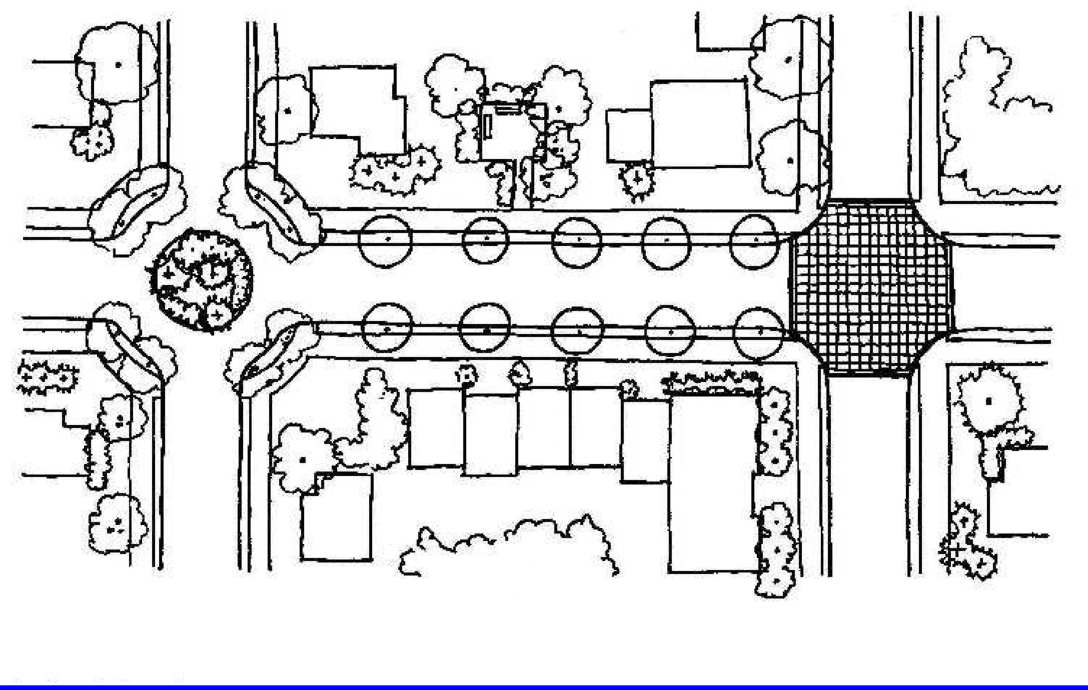
Weep Wall Filter

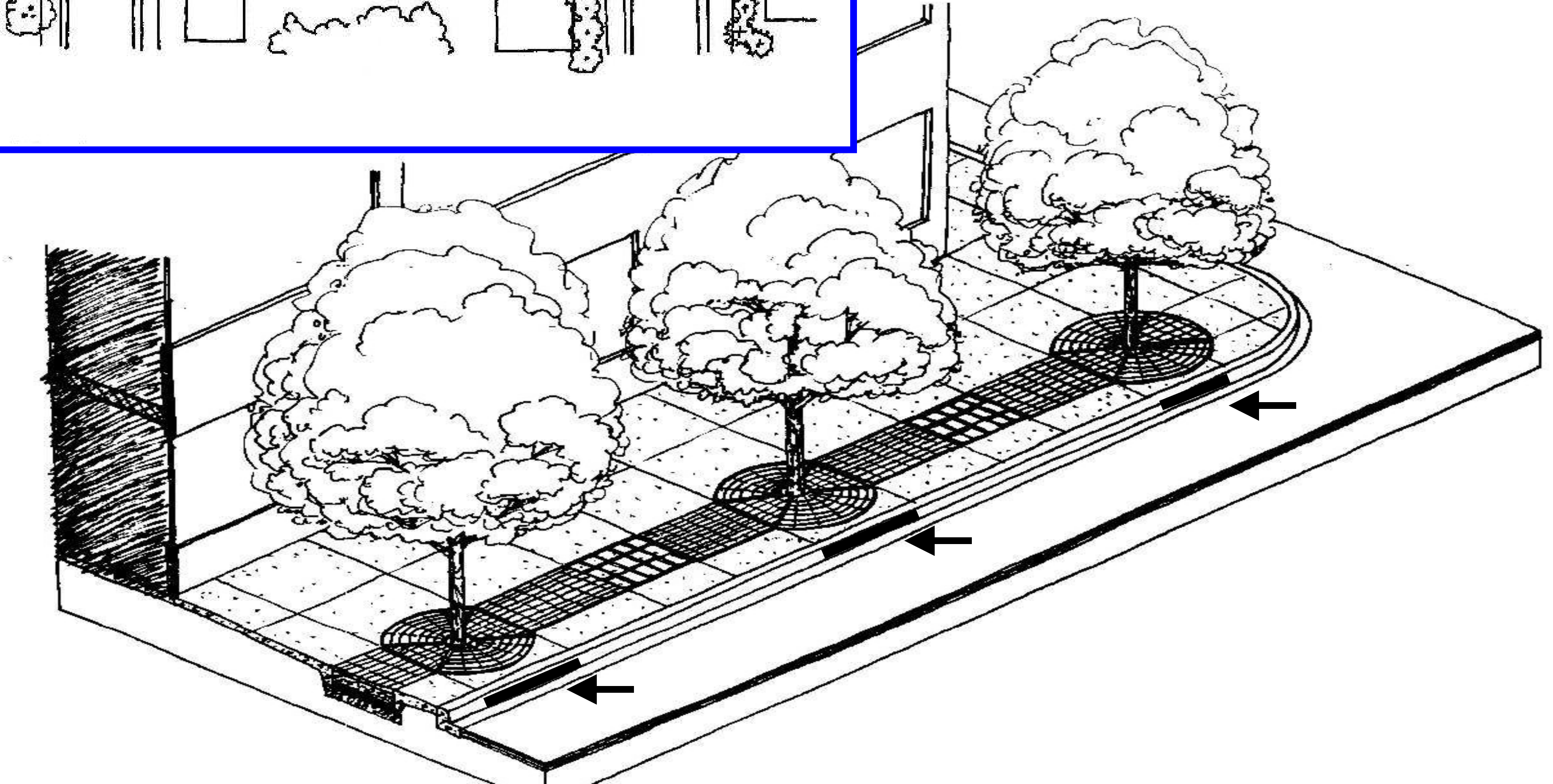

NORTHWESTERN HIGH SCHOOL
7000 ADELPHI ROAD

Buckman Heights courtyard with infiltration garden

Rain Gardens

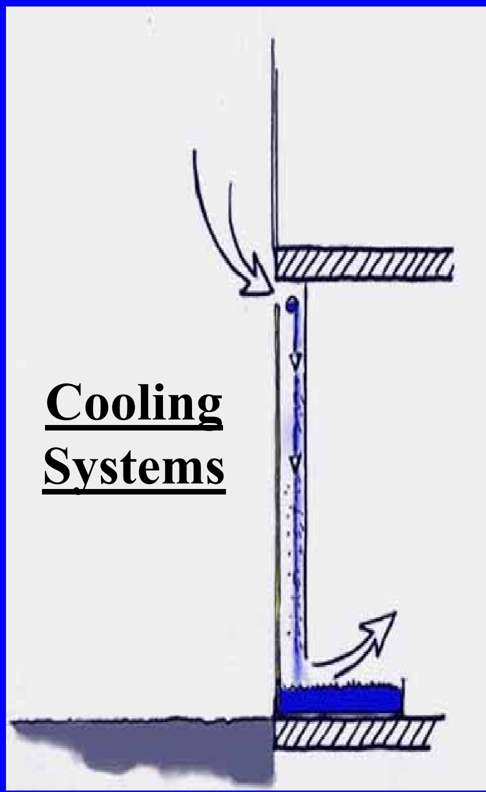
Street Tree / Shrub Filters



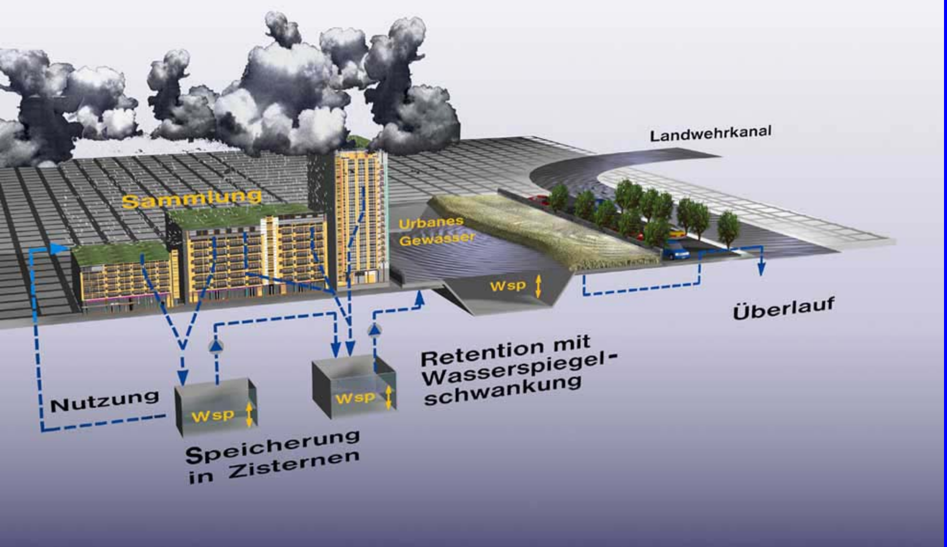


Tree and Shrub Box

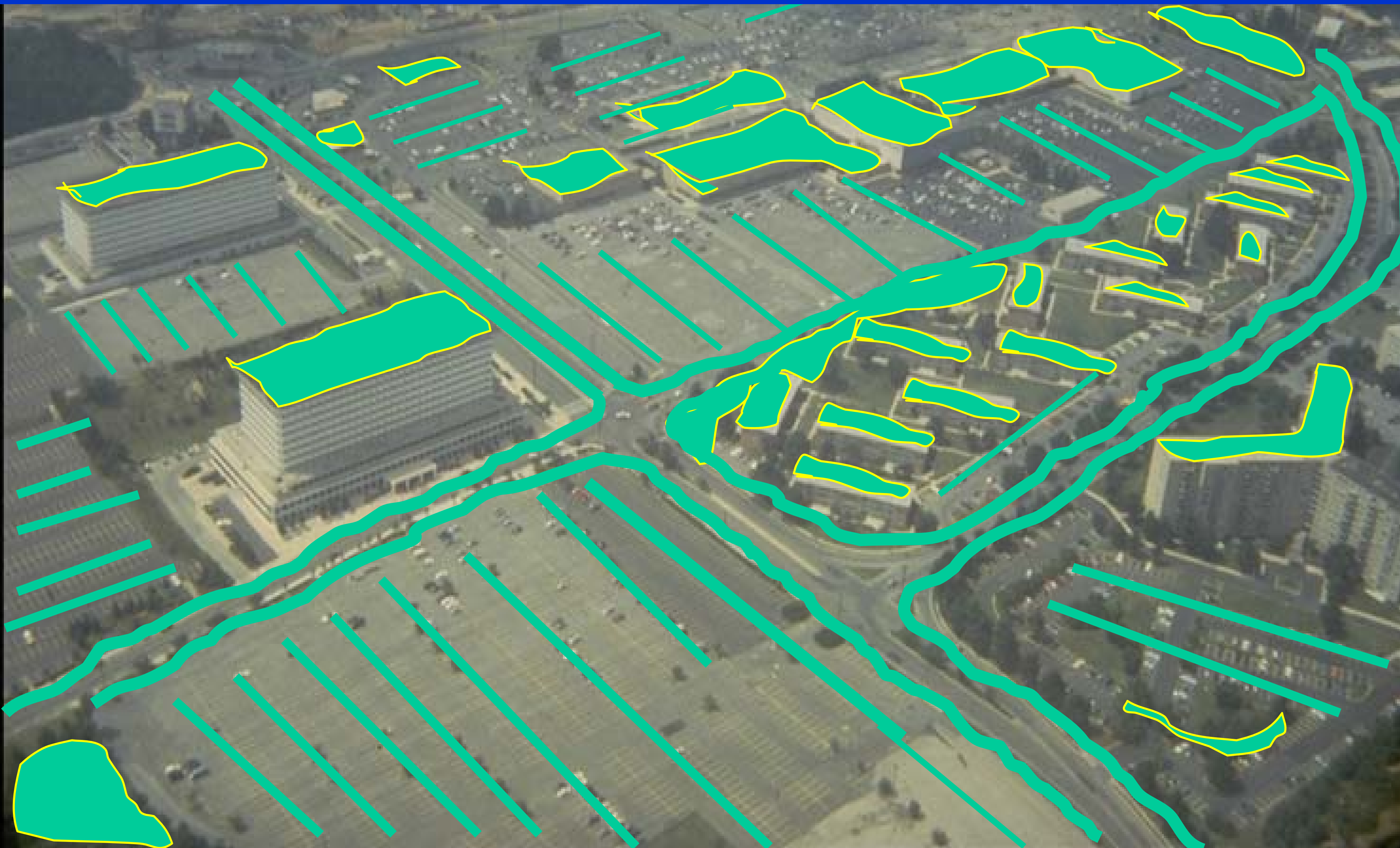
Runoff Use / Filter



Herbert Dreiseitl - www.dreiseitl.de

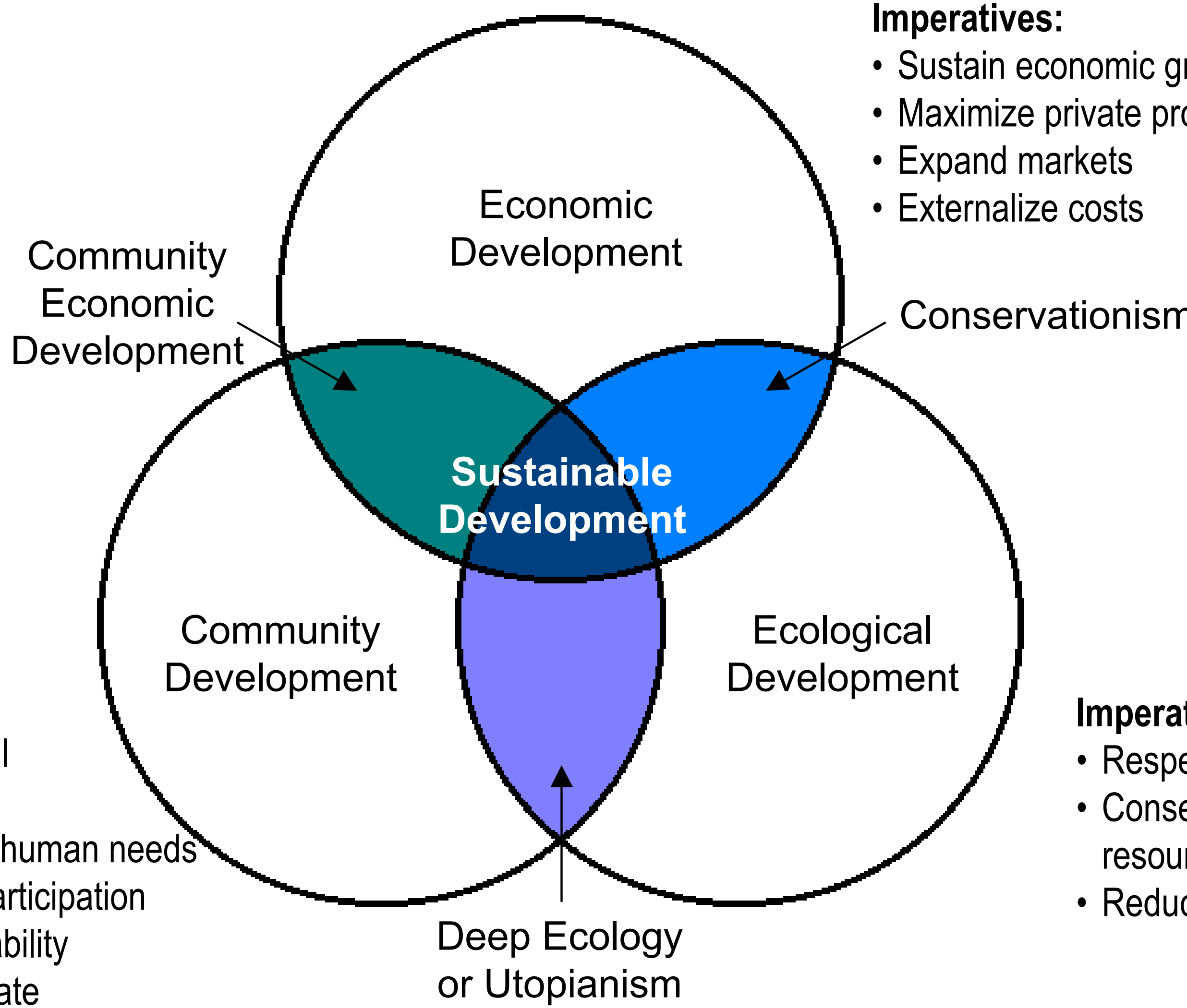


Urban LID -- Rooftop Storage, Bioretention Landscaping, Parking Lot Storage, Longer Flow Paths, Swales, Water Use, Pollution Prevention …………



Runoff Use

<u>Possibilities & Opportunities</u>



Imperatives:
- Sustain economic growth
- Maximize private profit
- Expand markets
- Externalize costs

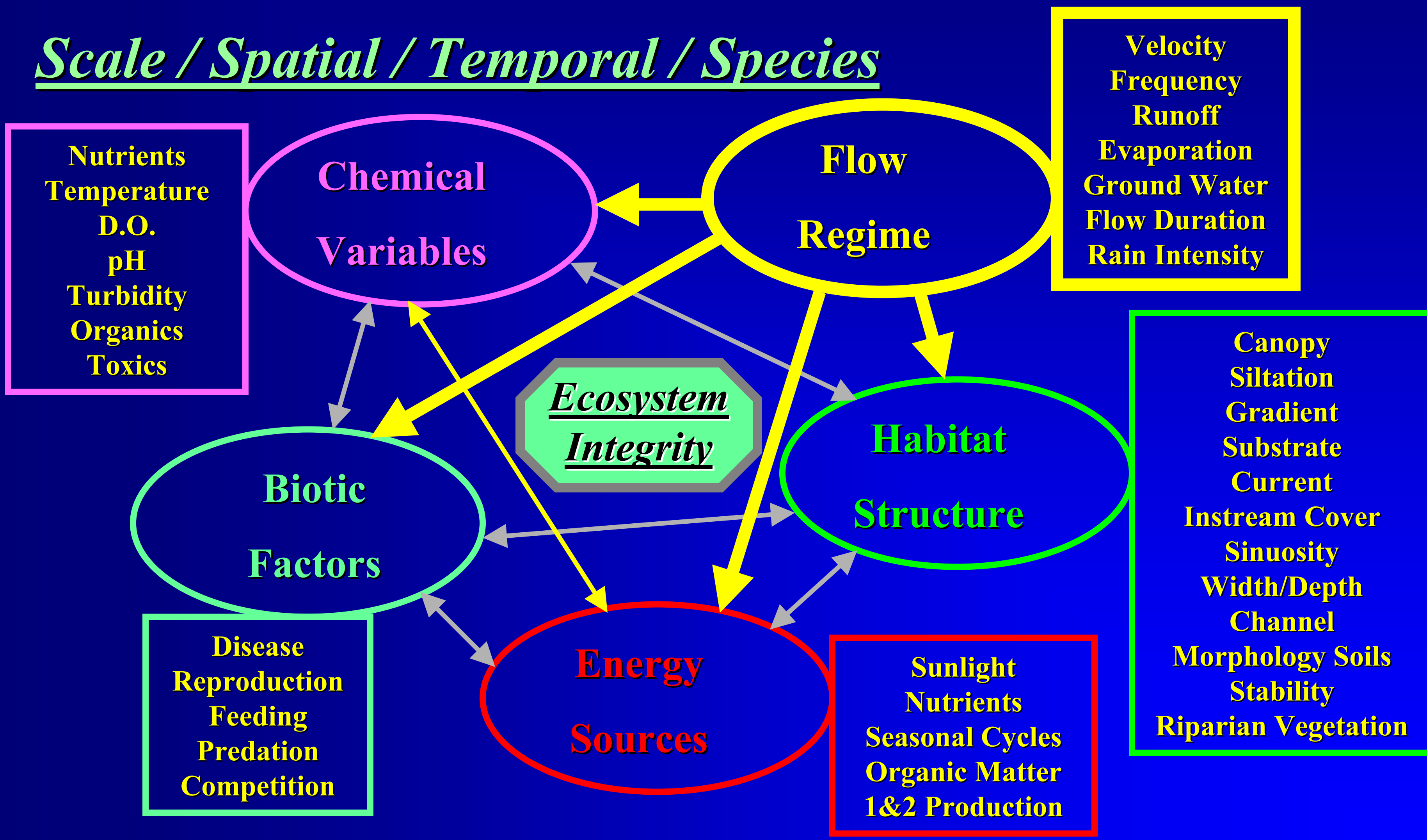
Imperatives:
- Increase local self-reliance
- Satisfy basic human needs
- Guarantee participation and accountability
- Use appropriate technology

Imperatives:
- Respect carrying capacity
- Conserve and recycle resources
- Reduce waste

Courtesy ICLEI, 1999

Stormwater Management!!!

How well do we maintain the ecological integrity (functions) of aquatic systems (small streams)?



Key LID Principles "Volume"

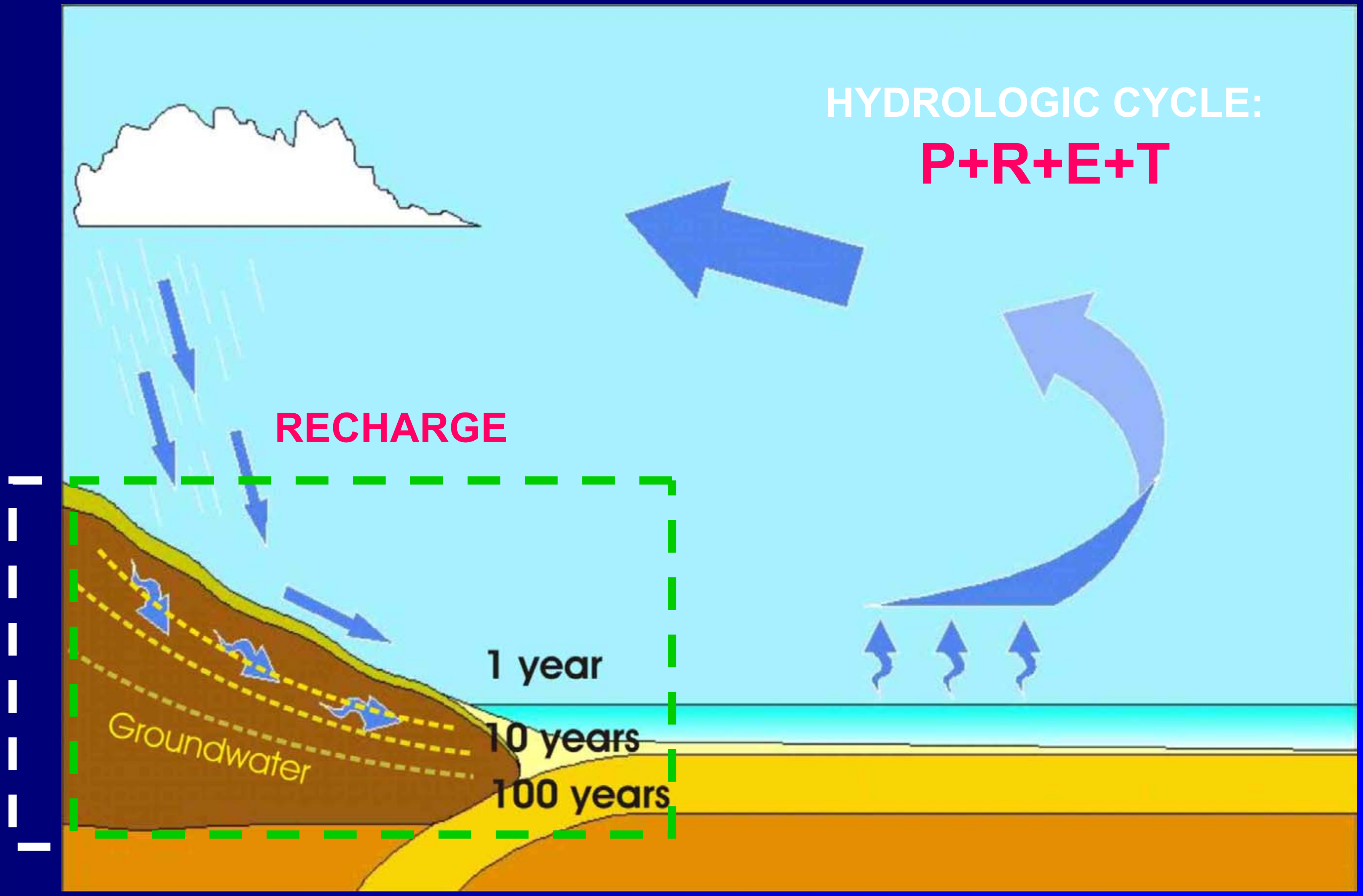
"Hydrology as the Organizing Principle "

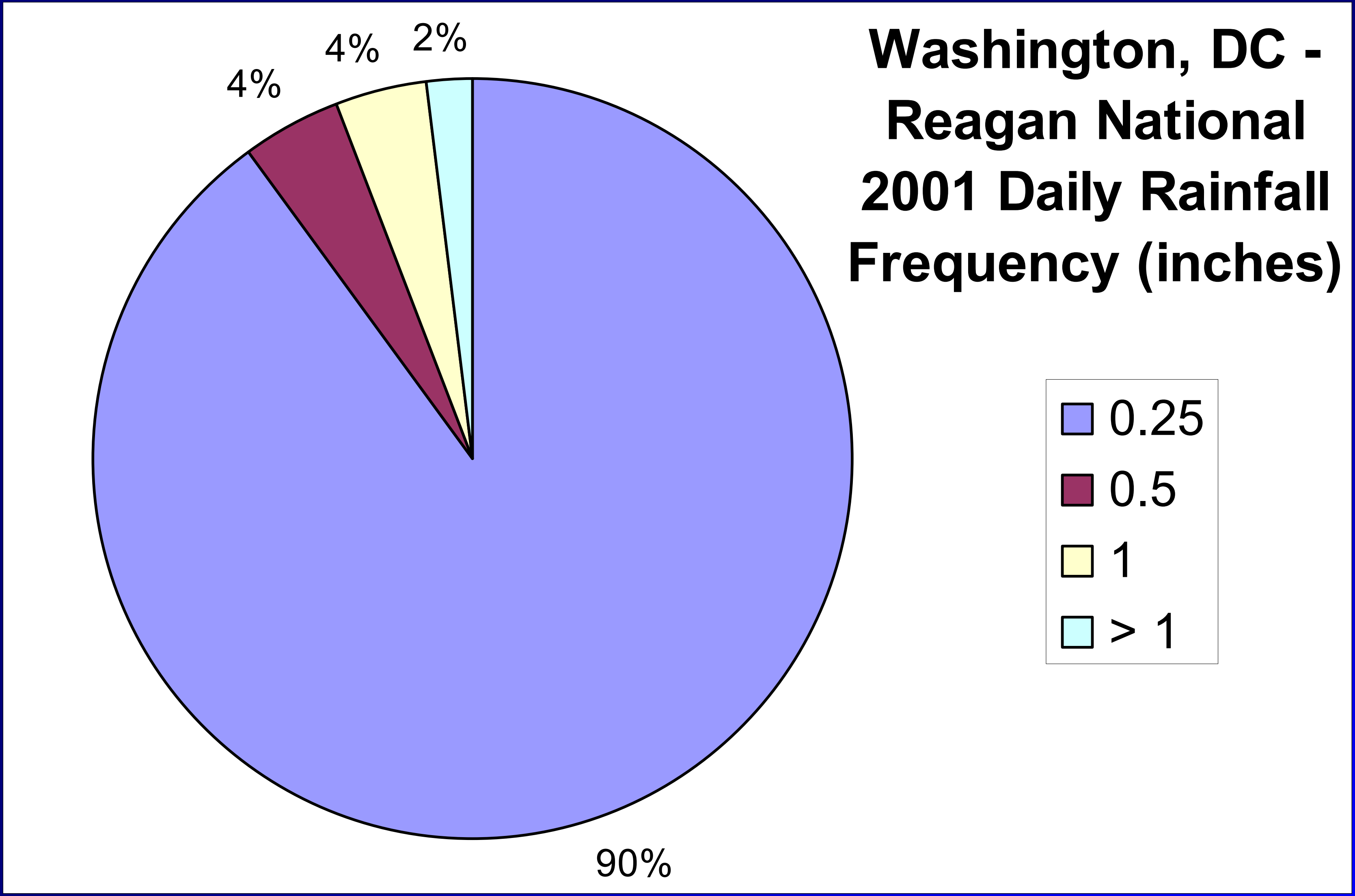
- Unique Watershed Design
  - Match Initial Abstraction Volume
  - Mimic Water Balance
- Uniform Distribution of Small-scale Controls
- Cumulative Impacts of Multiple Systems
  - filter / detain / retain / use / recharge / evaporate
- Decentralized / Disconnection
- Multifunctional Multipurpose Landscaping & Architecture
- Prevention

It's not <u>what</u> but <u>how</u> you do it!

- Hydrologically Functional Designs
- Increasing Assimilative Capacity
- Multifunctional / Beneficial Landscape and Architecture

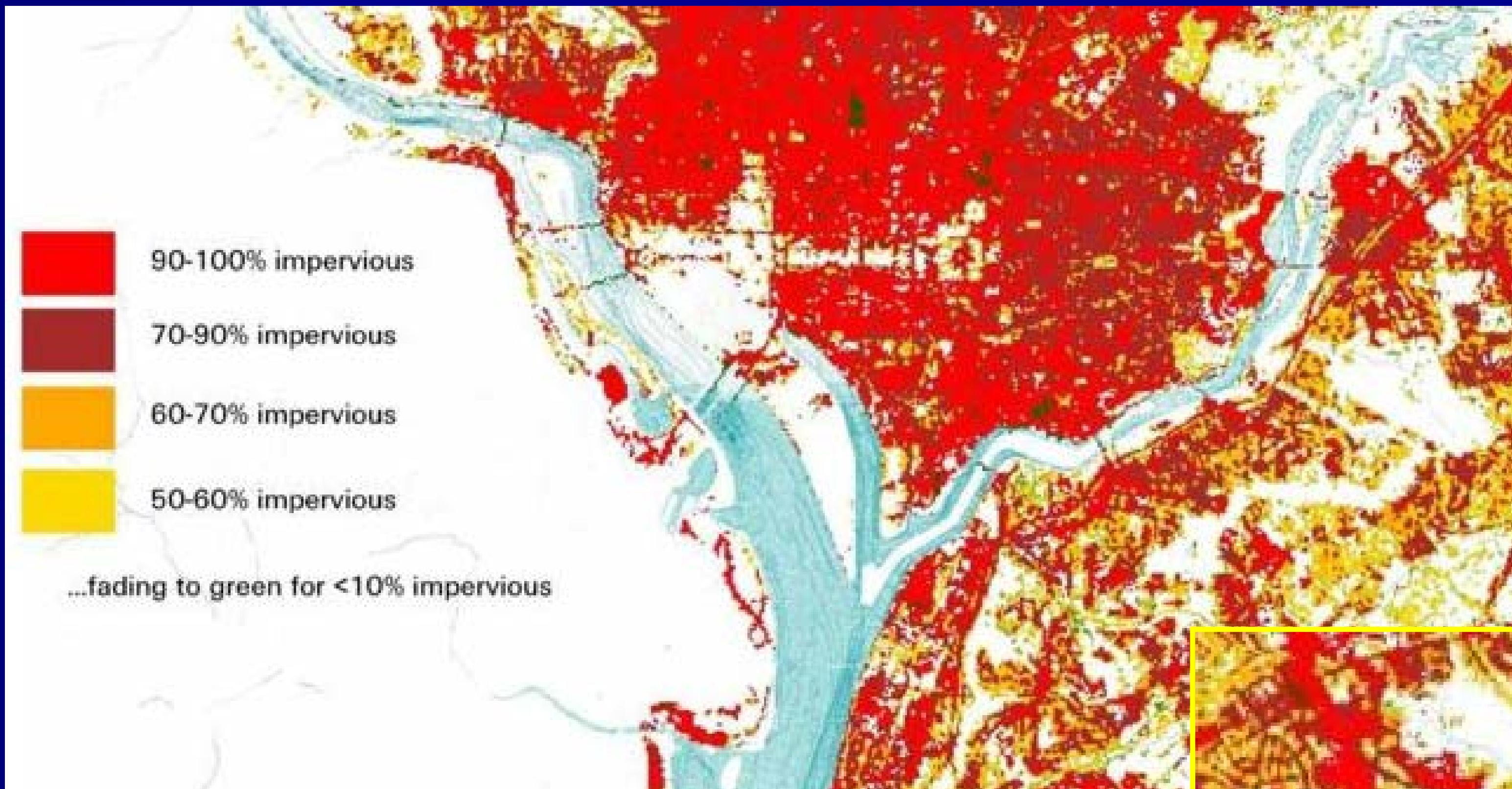
<u>LID Provides Powerful New tools for Urban Stormwater Management</u>


HYDROLOGIC CYCLE:
P+R+E+T
RECHARGE
1 year
10 years
100 years
Groundwater



Volume/Frequency

An estimate of imperviousness can be derived directly from the satellite image for developed areas. (Water bodies from the USGS topographic maps are overlaid for orientation, and areas identified as undeveloped in the National Land Cover dataset are left white.)

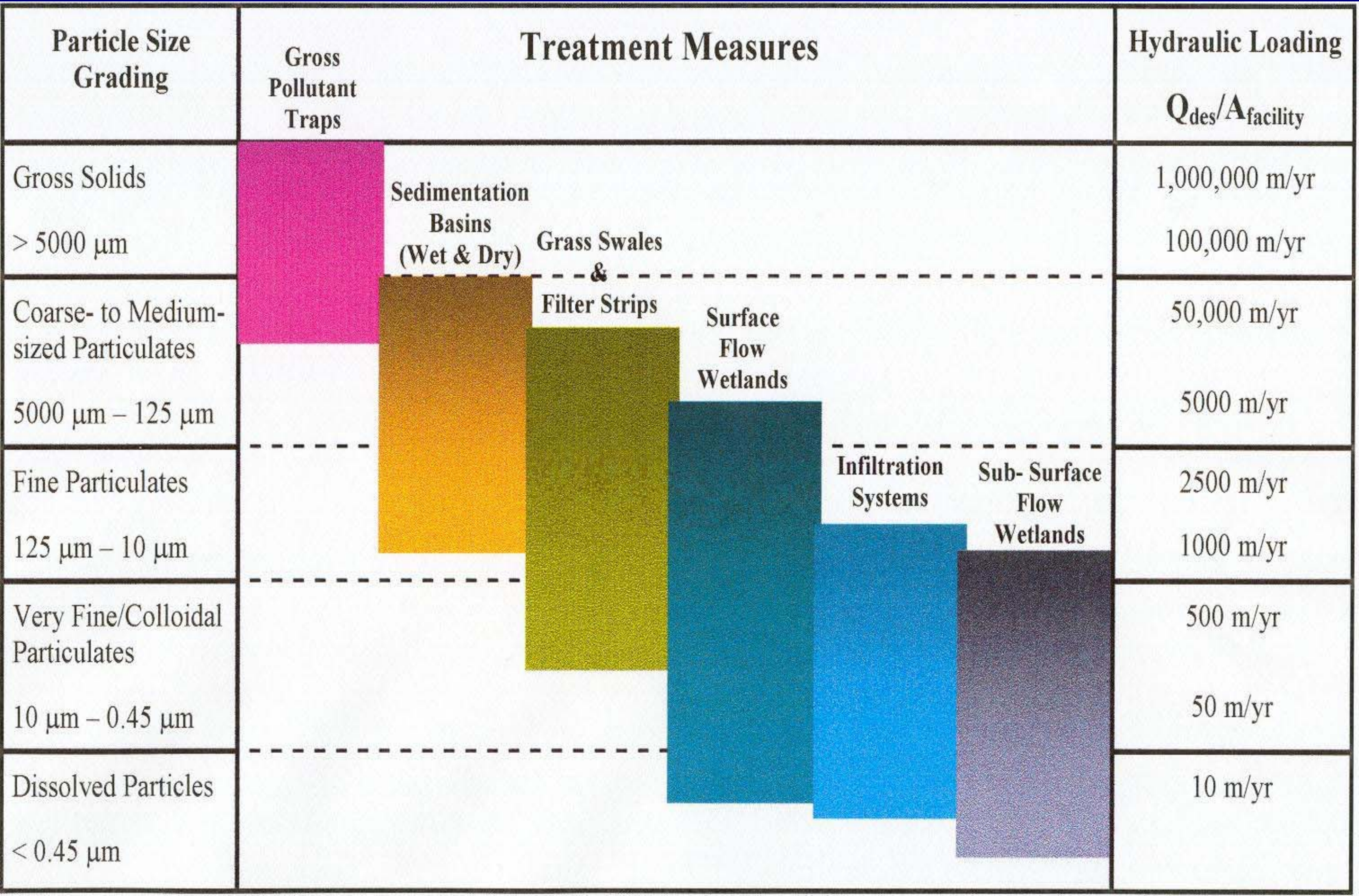


Soil Modific

- Clear Ve
- Remove
- Compac
- Change
- Modify D
- Destroy Biological Activity
- Destroy Soil Structure / Function

Urban Stormwater Art

Multiple Systems to Deal Wide a Range of Problems



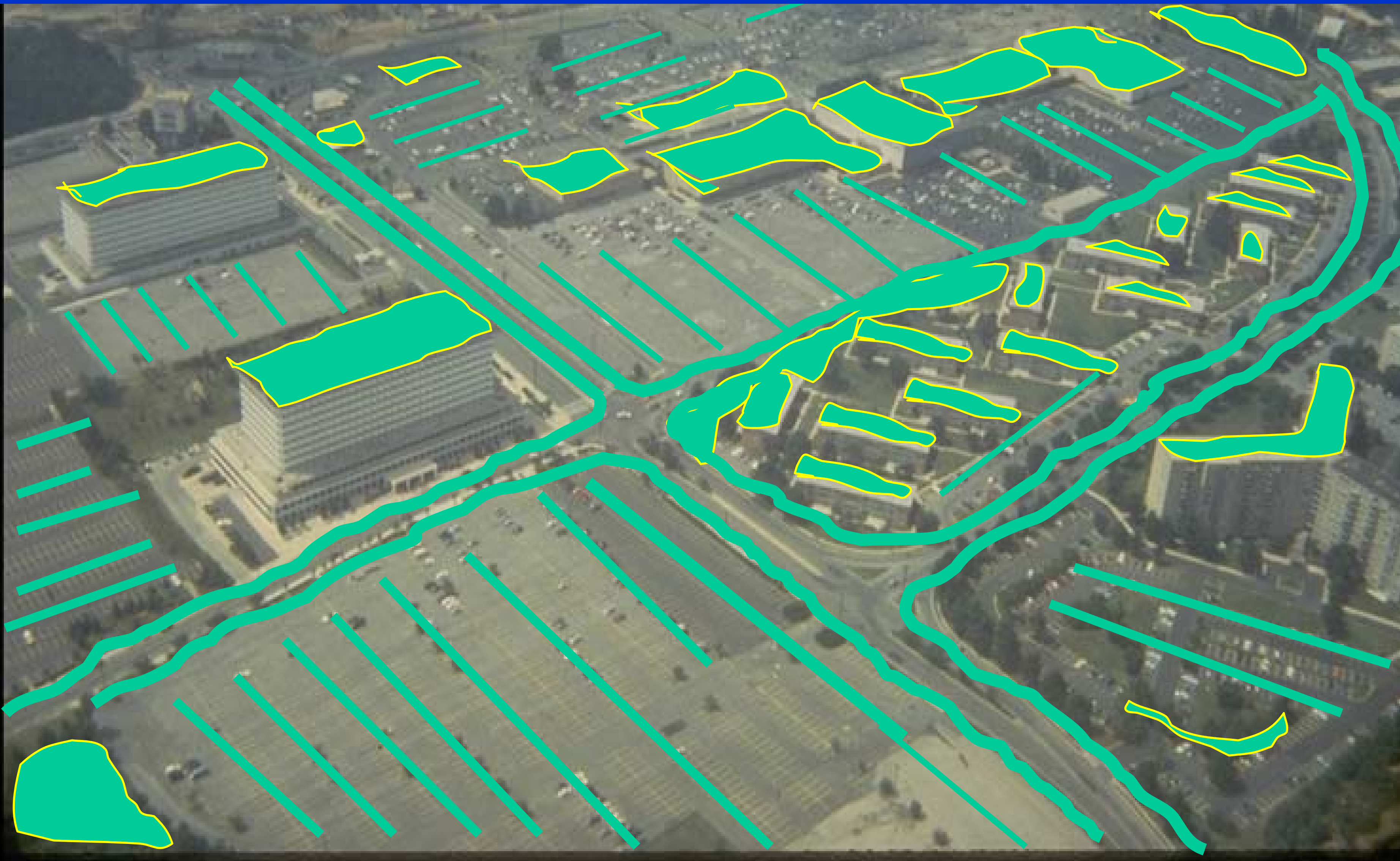
Where's the ~~Beef~~ Buffer?

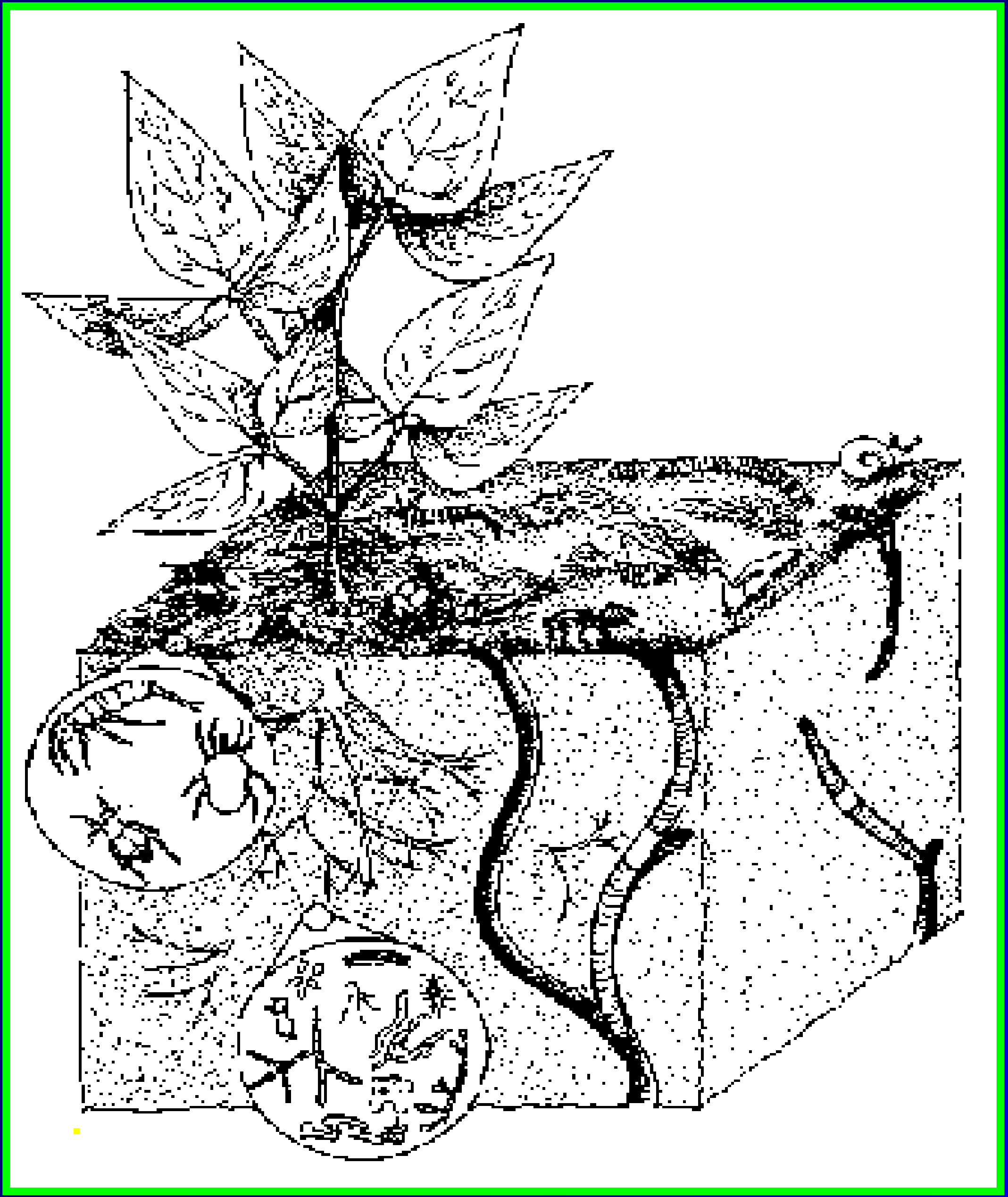
Anacostia Tributary

Canadian
TMDL Goose

Engineers Fountain Design

Urban LID -- Rooftop Storage, Bioretention Landscaping, Parking Lot Storage, Longer Flow Paths, Swales, Water Use, Pollution Prevention …………





Bioretention

A Dynamic Living Ecosystem Cycling Nutrients, Chemicals and Organic energy Sources

Plants

Bacteria

Protozoa

Fungus

Worms

Insects

Mammals