Green Infrastructure Components to Reduce Combined Sewer Overflows

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To be presented in three parts, with the following general topics:

- **Part 1: An Overview of the Problem**
- **Part 2: Soil Issues and Bioretention and Biofiltration Applications**
- **Part 3: Large Scale Applications**

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Part 1 of Green Infrastructure Components to Reduce Combined Sewer Overflows – An Overview of the Problem

- Short historical perspective of urban water
- Water consumption and shortages
- Wastewater reuse example
- Risks
- Receiving water effects of stormwater discharges
- Watershed-based stormwater controls
- Roof runoff options and simple beneficial uses

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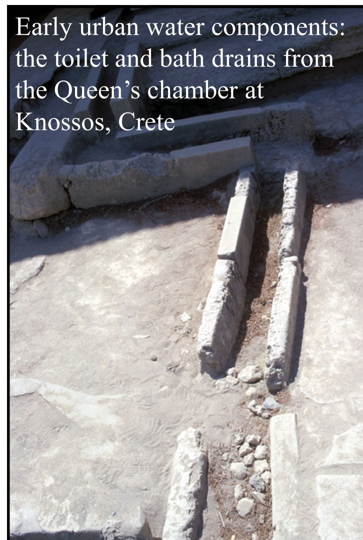
Early urban water components: the toilet and bath drains from the Queen's chamber at Knossos, Crete



Ancient temple drains at Knossos, Crete (Minoan 2600 to 1000 BC)

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Ancient clay pipe from reservoir at Knossos, Crete (Minoan 2600 to 1000 BC)

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Ancient temple site at top of hill that had roof runoff cistern, Kamiros, Rhodes (ancient Greece, 7th century BC)

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The homes of important officials had water delivered through clay pipes

Ancient clay pipe at Kamiros, Rhodes (ancient Greece, 7th century BC)

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Regular citizens had to hand carry water from the cistern at the top of the hill back down to their homes

Cistern tank, Kamiros, Rhodes, collected roof runoff from adjacent temple located at top of the hill.

Steps alongside cistern allowing jugs to be filled from holes in wall to cistern.

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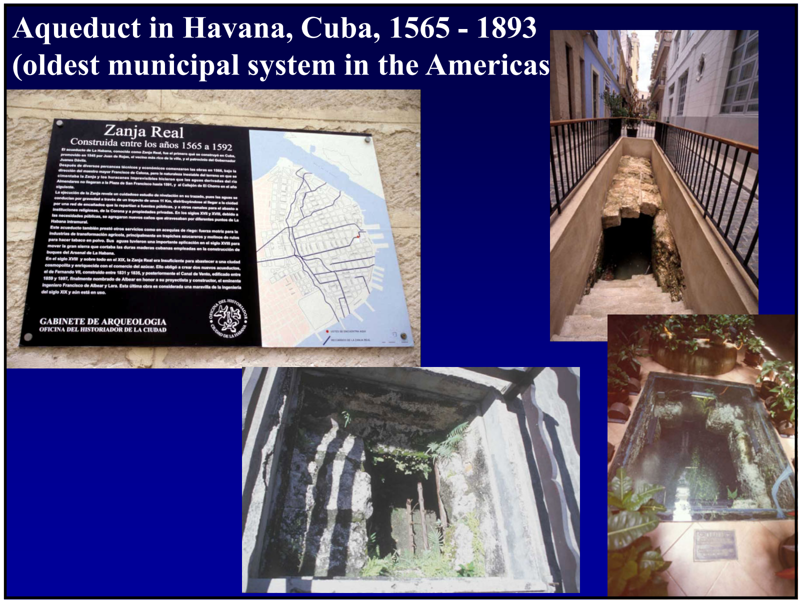
Aqueduct in Havana, Cuba, 1565 - 1893
(oldest municipal system in the Americas
Zanja Real
Construida entre los años 1565 a 1592
GABINETE DE ARQUEOLOGIA
OFICINA DEL HISTORIADOR DE LA CIUDAD

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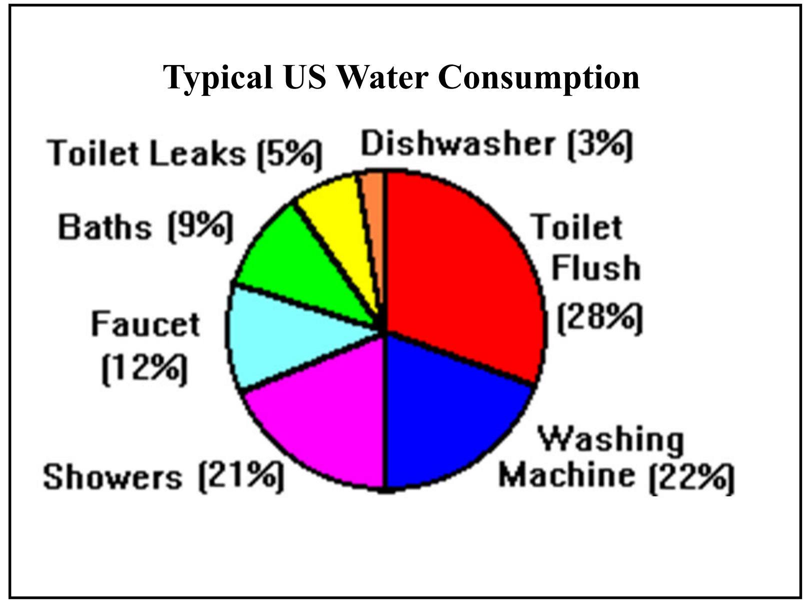
Typical US Water Consumption
Toilet Leaks (5%)
Dishwasher (3%)
Baths (9%)
Toilet Flush (28%)
Faucet (12%)
Showers (21%)
Washing Machine (22%)

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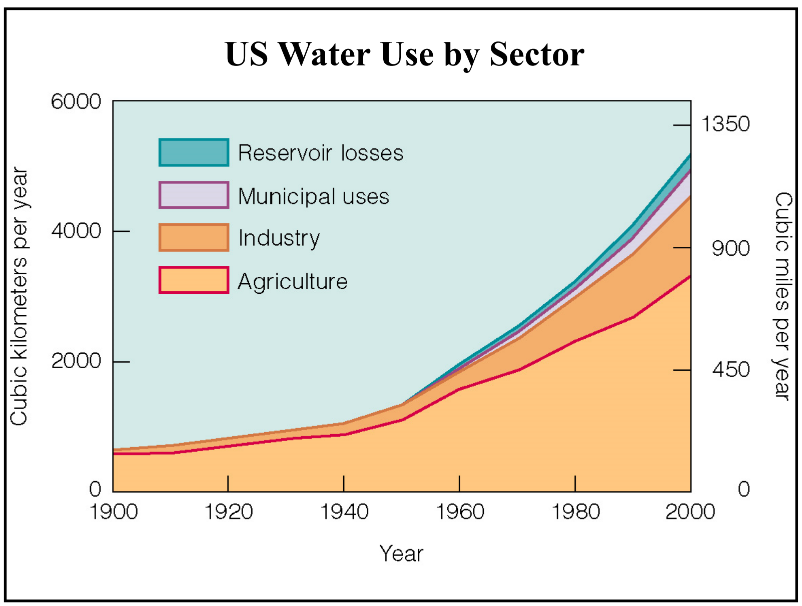
US Water Use by Sector
Reservoir losses
Municipal uses
Industry
Agriculture
Cubic kilometers per year
Cubic miles per year
Year
6000
4000
2000
0
1350
900
450
0
1900
1920
1940
1960
1980
2000

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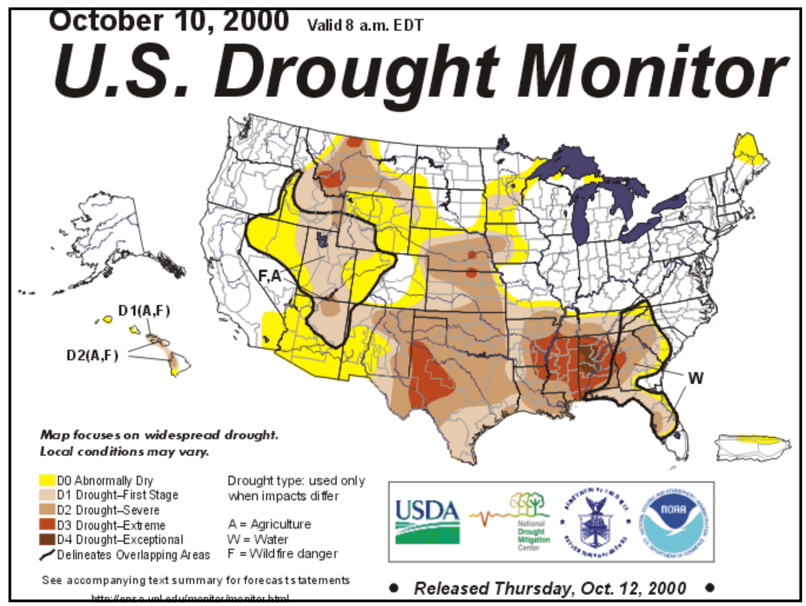
October 10, 2000
Valid 8 a.m. EDT
U.S. Drought Monitor
F,A
D1(A,F)
D2(A,F)
W
Map focuses on widespread drought.
Local conditions may vary.
D0 Abnormally Dry
D1 Drought–First Stage
D2 Drought–Severe
D3 Drought–Extreme
D4 Drought–Exceptional
Delineates Overlapping Areas
Drought type: used only when impacts differ
A = Agriculture
W = Water
F = Wildfire danger
USDA
NOAA
See accompanying text summary for forecast statements
Released Thursday, Oct. 12, 2000

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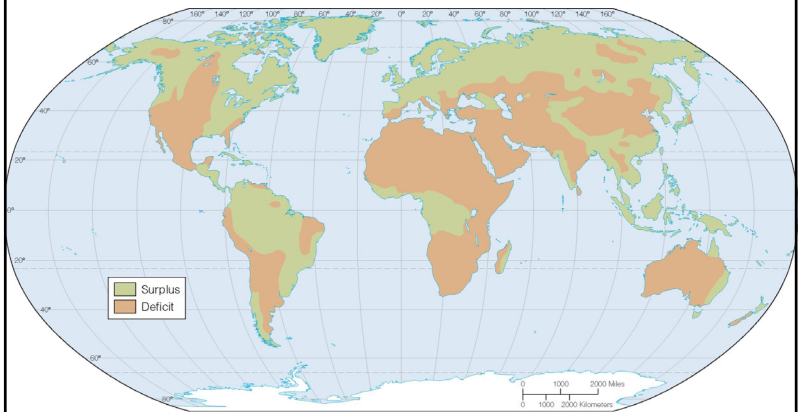
Worldwide Water Surplus and Deficit Conditions



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Water Deficits in Key Countries and Regions, Mid-1990s

Country/Region	Estimated Annual Water Deficit (billion cubic meters per year)
India	104.0
China	30.0
United States	13.6
North Africa	10.0
Saudi Arabia	6.0
Other	unknown
Minimum Global Total	163.6

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Water Supply and Water Quality

- Conservation easiest to develop and cheapest new water source
- Water quality problems becoming better understood
- Habitat destruction becoming recognized as serious issue

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In El Paso, Texas, pricing and educational efforts are credited with a substantial reduction in water use. Conservation meets about 15 to 17% of the city's future water needs. Besides slowing the rate of depletion of the groundwater supply, the conservation measures cost about 8% less than the cost of existing water supplies (about \$135 per 1,000 m^3).

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Water Factory 21, Orange County, California, was the US's large-scale example to highly purify sanitary sewage for groundwater injection and reuse (operated from 1975 to 2004, replaced with new facility in 2007, the Groundwater Replenishment System that utilizes microfiltration, RO, and UV disinfection. There are about 15 large reuse treatment facilities in the US now).

Facilities of **Water Factory 21** include: a 15 million gallon per day (MGD) (56,775 m^3/d) advanced wastewater reclamation plant that provides chemical clarification, air stripping, recarbonation, multi-media filtration, carbon adsorption and chlorination; and a 5 MGD (18,925 m^3/d) reverse osmosis (RO) demineralization plant. Twenty-three multiple-point wells inject the water into the underground aquifers, creating a coastal barrier to prevent seawater intrusion.

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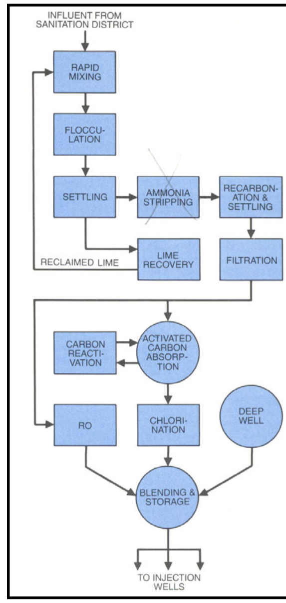

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OCWD's recharge channel in the Santa Ana River helps refill the groundwater basin.

The Orange County Water District also encourages infiltration in man-made meandering channels in the Santa Ana River.

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Myths of Pollution Control

(McKinney and Schoch)

- **Myth of Purity in Nature**: virtually nothing is "pure" in nature. There are many naturally occurring contaminants, and highly polluted air or water contains only tiny fractions of contaminants (ppm, ppb)
- **Myth of Zero Pollution**: zero pollution is an unrealistic goal. Modern society produces pollutants and everything must go somewhere.
- **Myth of Zero Risk**: every activity has risk. Can only minimize, not eliminate, total risks we face. Hindered by inaccurate perceptions of risk.

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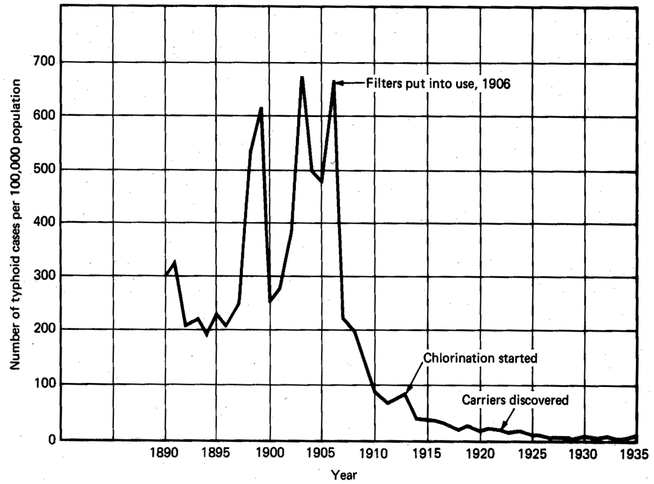
Typhoid cases in Philadelphia, Pennsylvania, showing rapid decrease concurrent with water filtration, and further decreases with chlorination.



http://www.p2pays.org/ref/20/images/Nf505.jpg

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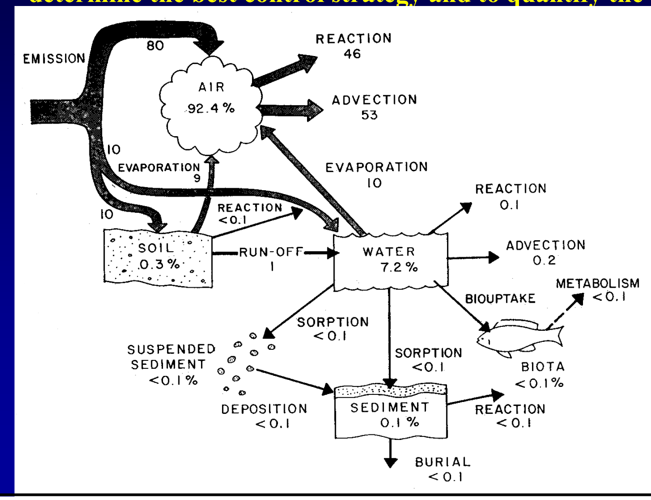
Where did that Chemical Go?

Fate/mass balance analysis for trichloroethylene is needed to determine the best control strategy and to quantify the effects



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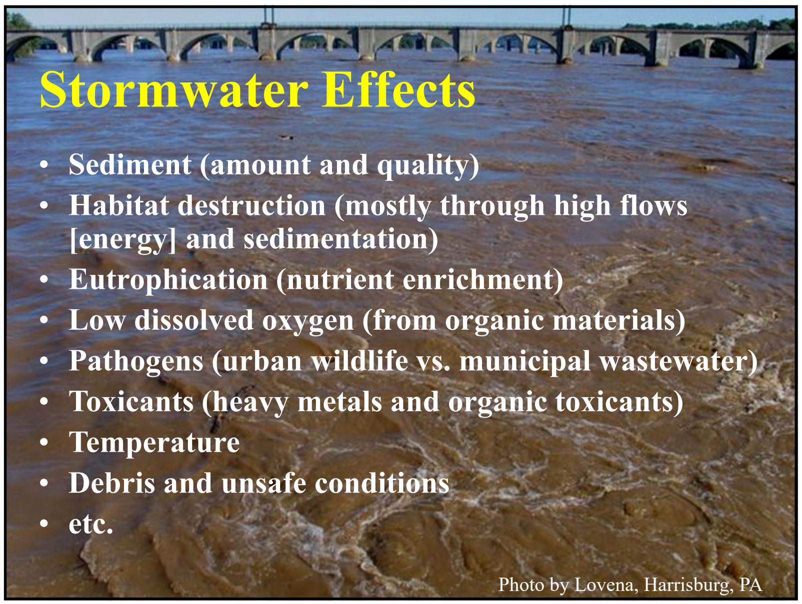

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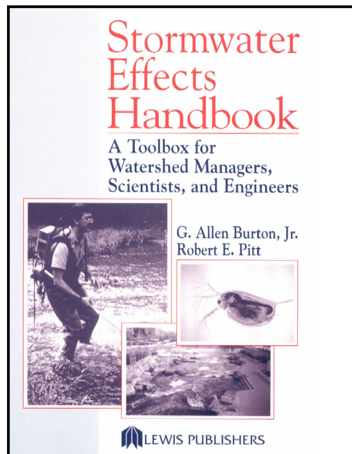

Need to obtain local data concerning effects and sources. We wrote this book to provide detailed descriptions of how to select constituents to measure, how many samples to obtain, how to collect samples, how to do analytical work, how to analyze data, etc.

Burton, G.A. Jr., and R. Pitt. *Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers*. ISBN 0-87371-924-7. CRC Press, Inc., Boca Raton, FL. 2002. 911 pages.

Can be downloaded at:

http://unix.eng.ua.edu/~rpitt/Publications/Publications.shtml

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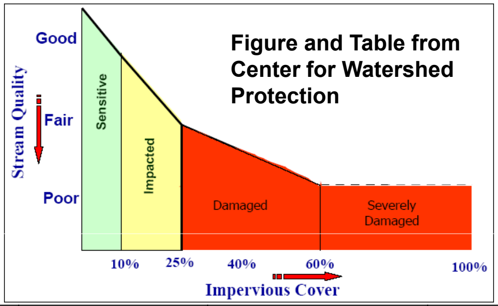

Urban Steam Classification	Sensitive 0 – 10% Imperviousness	Impacted 11– 25% Imperviousness	Damaged 26–100% Imperviousness
Channel Stability	Stable	Unstable	Highly Unstable
Aquatic Life Biodiversity	Good/Excellent	Fair/Good	Poor

Can therefore calculate benefits of stormwater controls relating to runoff characteristics

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Historical concerns focused on increased flows during rains and associated flooding. However, decreased flows during dry periods are now seen to also cause receiving water problems.

WI DNR photo

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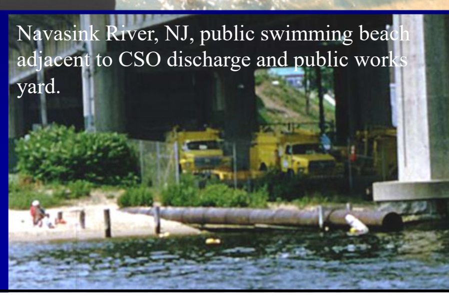
Urban Wildlife and Sewage Contamination

Potential health effects due to exposure to pathogens in urban receiving waters.

However, kids still play in urban creeks and swim near outfalls

WI DNR photo



Navasink River, NJ, public swimming beach adjacent to CSO discharge and public works yard.

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Fishing in urban streams and rivers also common for both recreation and food.

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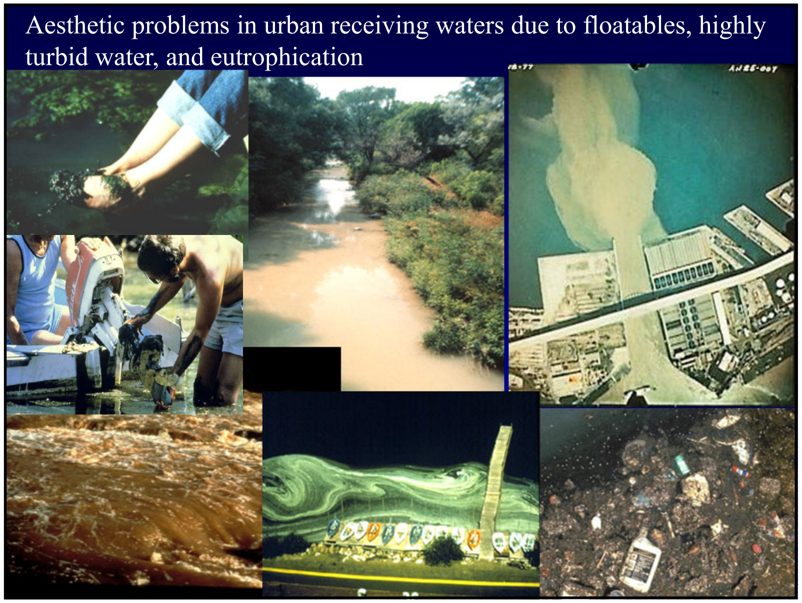
Aesthetic problems in urban receiving waters due to floatables, highly turbid water, and eutrophication

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Many types of runoff monitoring have been used to understand their transport and fate, from small source areas to outfalls.

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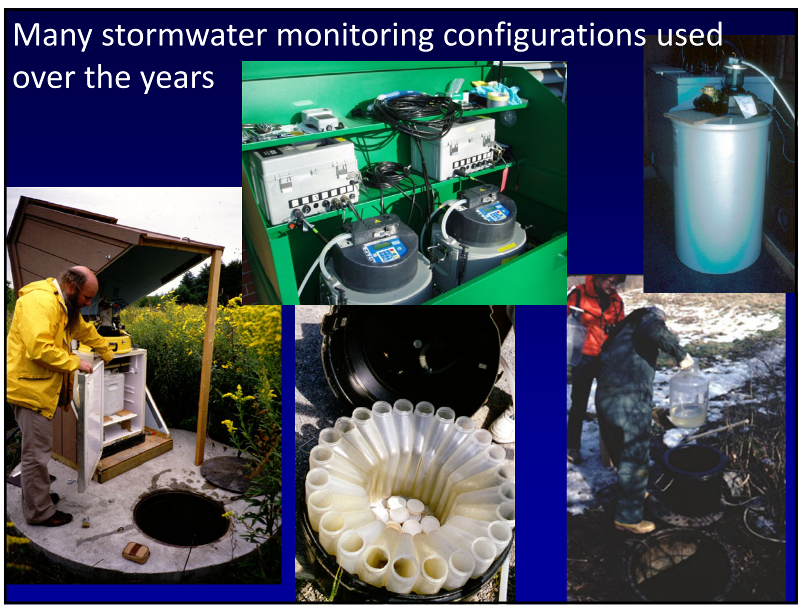
Many stormwater monitoring configurations used over the years

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Fate of stormwater pollutants and actual receiving water effects need to be directly monitored

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Watershed-Based Stormwater Controls

Multiple names for a similar goal/design process:

- Low Impact Development (LID)
- Conservation Design
- Water Sensitive Urban Design (WSUDs)
- Sustainable Urban Drainage Systems (SUDS)
- Distributed Runoff Controls (DRC)

These approaches emphasize infiltration, however, other stormwater treatment approaches will also likely be required to meet the wide range of beneficial use objectives of urban receiving waters.

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Conservation Design Approach for New Development

- **Better site planning to maximize resources of site**
- **Emphasize water conservation and water reuse on site**
- **Encourage infiltration of runoff at site but prevent groundwater contamination**
- **Treat water at critical source areas and encourage pollution prevention (no zinc coatings and copper, for example)**
- **Treat runoff that cannot be infiltrated at site**

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Roof Runoff Control

- Runoff disconnections
- Rain gardens for roof runoff
- Green roofs to reduce flows and to provide benefits to the building
- Capture of roof runoff for beneficial uses

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One of the simplest and most effective approaches for the control of stormwater is to reduce the amount of impervious areas that are directly connected to the drainage system. This can be accomplished by using less paved and roof areas (hard to do and meet design objectives), disconnect the impervious areas, or reduce the runoff from the impervious areas by infiltration, or other, methods. Reducing the runoff volume also reduces the pollutant discharges, reduces peak flows, and reduces combined sewer overflows.

Disconnected roof drain

Directly connected roof drain

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Roof drain disconnections

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Calculated Benefits of Various Roof Runoff Controls (compared to typical directly connected residential pitched roofs)

Annual roof runoff volume reductions	Birmingham, Alabama (55.5 in. annual rain)	Seattle, Wash. (33.4 in.)	Phoenix, Arizona (9.6 in.)
Flat roofs instead of pitched roofs	13%	21%	25%
Cistern for reuse of runoff for toilet flushing and irrigation (10 ft. diameter x 5 ft. high)	66	67	88
Planted green roof (but will need to irrigate during dry periods)	75	77	84
Disconnect roof drains to loam soils	84	87	91
Rain garden with amended soils (10 ft. x 6.5 ft.)	87	100	96

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On-going Millburn, NJ, Monitoring Project to Evaluate Performance and Groundwater Problems Associated with Required Dry Wells

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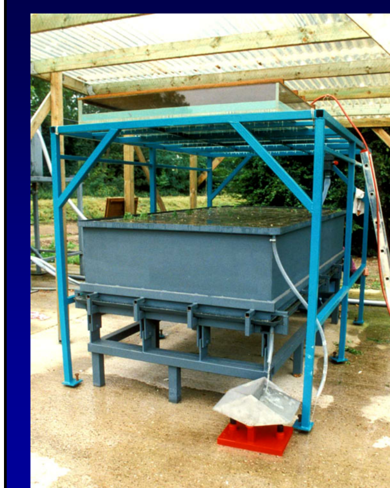
Wolfgang Geiger's Porous Paver Test Rig, Essen, Germany



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Green Roofing

Extensive Green Roof

- Lighter
- ≤6" media depth
- Planted with sedums or native plant species
- Saturated weights from 12-50lbs/sq.ft.

Intensive Green Roof

- Heavier
- ≥12" media depth
- Wider variety of plants which need more care and irrigation
- Saturated weights from 80-100lbs/sq.ft.

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Benefits of Green Roofing

- Reduce Heat Island Effect
- Reduce Air Pollution and Greenhouse Gas Emission
- Improved human health and comfort
- Enhanced Stormwater Management and Water Quality
- Improved Quality of Life

Information courtesy of the Environmental Protect Agency – http://www.epa.gov/heatisland/mitigation/greenroofs.htm

http://www.coolflatroof.com/pics/green-roof-blocks.jpg

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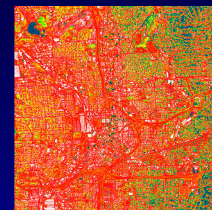
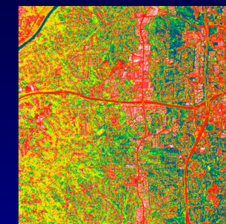
Urban Heat Island Effect – Atlanta, GA

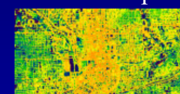


Urban Temp. - Day

Can a green roof make the urban look like the suburban?

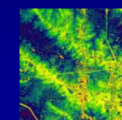


Suburban Temp. - Day

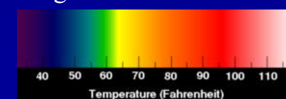


Urban Temp. - Night

→



Suburban Temp. - Night



Images Courtesy of NASA

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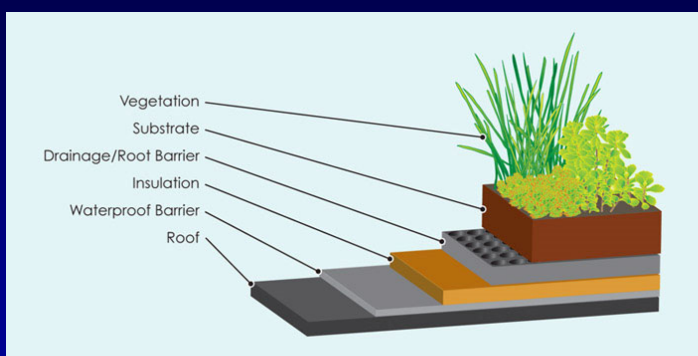
Green Roof Design



Cross-section of a typical green roof illustrating the key components

http://www.greensulate.com/green_roofs_intensive.php

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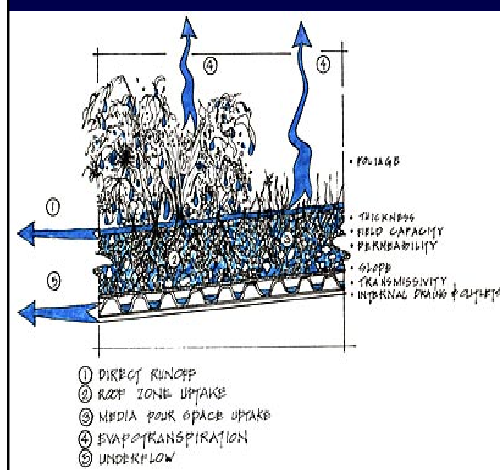
Function of a Green Roof



- The storage of water in the substrate
- Absorbing water in the root zone
- Capturing and holding precipitation in the plant foliage where it is returned to the atmosphere through transpiration and evaporation
- Slowing the velocity of direct runoff as it infiltrates through layers of vegetated cover

http://www.lid-stormwater.net/greenroofs_benefits.htm

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Central Alabama	Average daily ET_o reference conditions (inches/day) (irrigated alfalfa)
January	0.035
February	0.048
March	0.072
April	0.102
May	0.156
June	0.192
July	0.186
August	0.164
September	0.141
October	0.096
November	0.055
December	0.036

Evapotranspiration (ET) is the major rain abstraction mechanism available for green roofs, besides some detention storage and evaporation.

Plant	Crop Coefficient Factor (Kc)	Root Depth (ft)
Cool Season Grass (turfgrass)	0.80	1
Common Trees	0.70	3
Annuals	0.65	1
Common Shrubs	0.50	2
Warm Season Grass	0.55	1
Prairie Plants (deep rooted)	0.50	6

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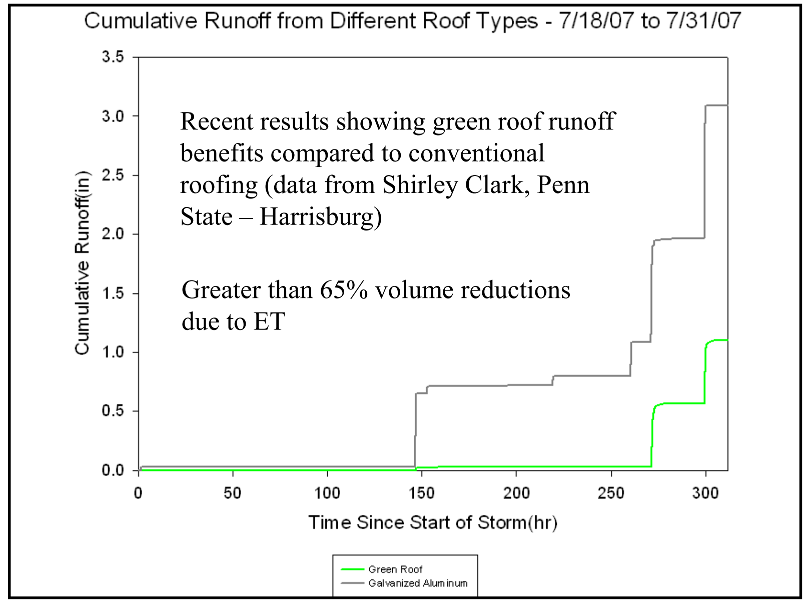

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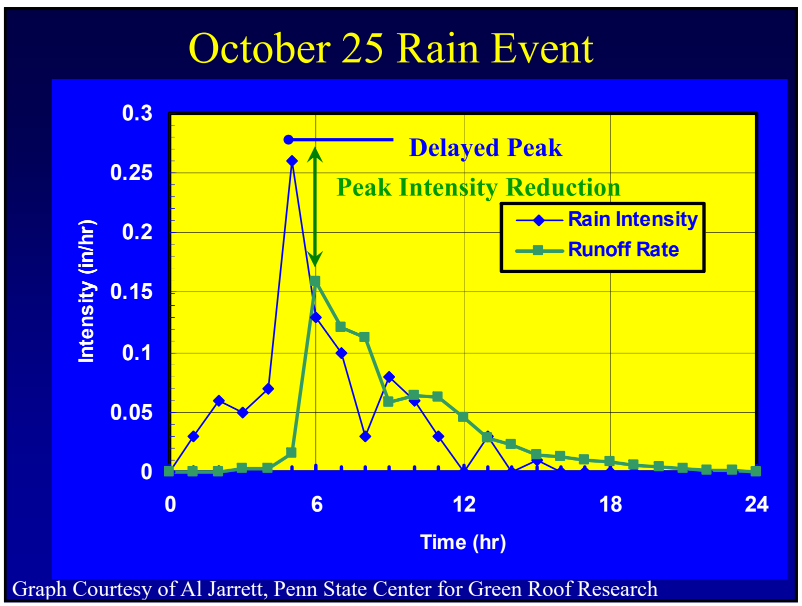

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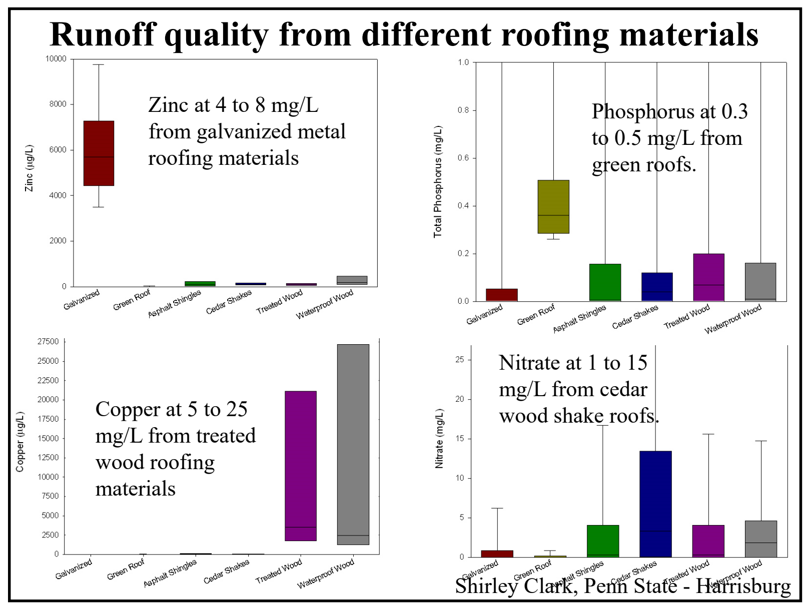

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Beneficial use of stormwater as a local resource needs to be seriously considered

Prince George's County photo

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The water tank cisterns modeled for the Kansas City area were about 10 ft in diameter and 10 ft tall. The expected per household water use (gallons/day) from cisterns for toilet flushing and outside irrigation (ET deficit only) for the KC study area is:

January	113 gal/day	July	428
February	243	August	479
March	126	September	211
April	175	October	71
May	149	November	71
June	248	December	71

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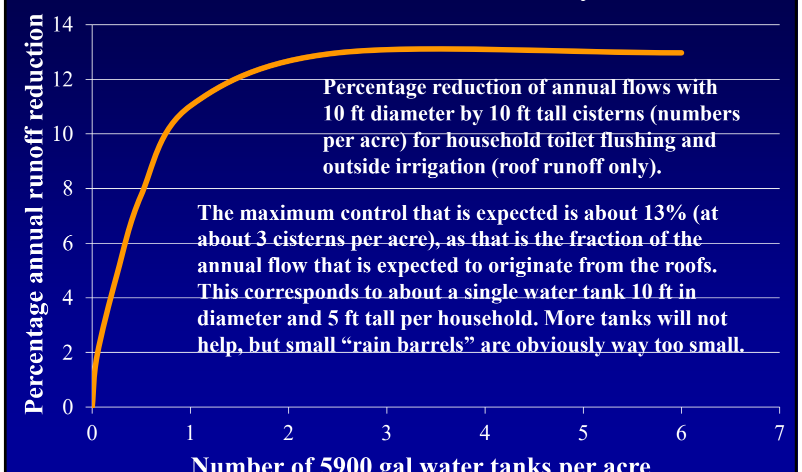
Number of water tanks and annual flow volume reductions for Kansas City test area



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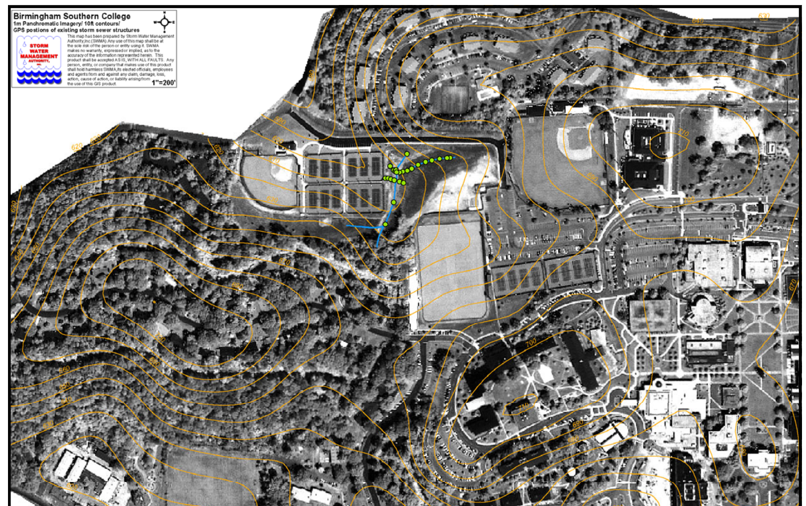

Birmingham Southern College Campus

(map by Jefferson County Stormwater Management Authority)

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Birmingham Southern College Fraternity Row (new construction at existing site)

	Acres	% of Total
Roadways	0.24	6.6%
Parking	0.89	24.5
Walks	0.25	6.9
Roofs	0.58	16.0
Landscaping	1.67	46.0
Total:	3.63	100.0

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Supplemental Irrigation

	Inches per month (example)	Average Use for 1/2 acre (gal/day)
Late Fall and Winter (Nov-March)	1 to 1-1/2	230 - 340
Spring (April-May)	2 to 3	460 - 680
Summer (June-August)	4	910
Fall (Sept-Oct)	2 to 3	460 - 680
Total:	28 (added to 54 inches of rain)	

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Capture and Reuse of Roof Runoff for Supplemental Irrigation

Tankage Volume (ft^3) per 4,000 ft^2 Building	Percentage of Annual Roof Runoff used for Irrigation
1,000	56%
2,000	56
4,000	74
8,000	90
16,000	98

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