Disclaimer

Notice: This presentation has been provided as part of this U.S. Environmental Protection Agency Webinar. This document does not constitute EPA policy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. Links to non-EPA web sites do not imply any official EPA endorsement of or a responsibility for the opinions, ideas, data, or products presented at those locations or guarantee the validity of the information provided. Links to non-EPA servers are provided solely as a pointer to information that might be useful to EPA staff and the public.





Implementing Section 438 of the Energy Independence & Security Act

Stormwater's Effect on National Water Quality

Water Body Type	Stormwater's Rank as Pollution Source	% of Impaired Waters Affected
Ocean shoreline	1st	55% (miles)
Estuaries	2nd	32% (sq. miles)
Great Lakes shoreline	2nd	4% (miles)
Lakes	3rd	18% (acres)
Rivers	4th	13% (miles)

Energy Independence and Security Act of 2007

"Sec. 438. Storm Water Runoff Requirements for Federal Development Projects. The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

Section 438 Guide

To assist Agencies and outline performance requirements, EPA drafted a guidance document, which includes:

- Stormwater management requirements;
- Appropriate control techniques;
- Benefits of complying with Section 438;
- Modeled compliance scenarios.

Performance Requirements

METF = Maximum Extent Technically Feasible

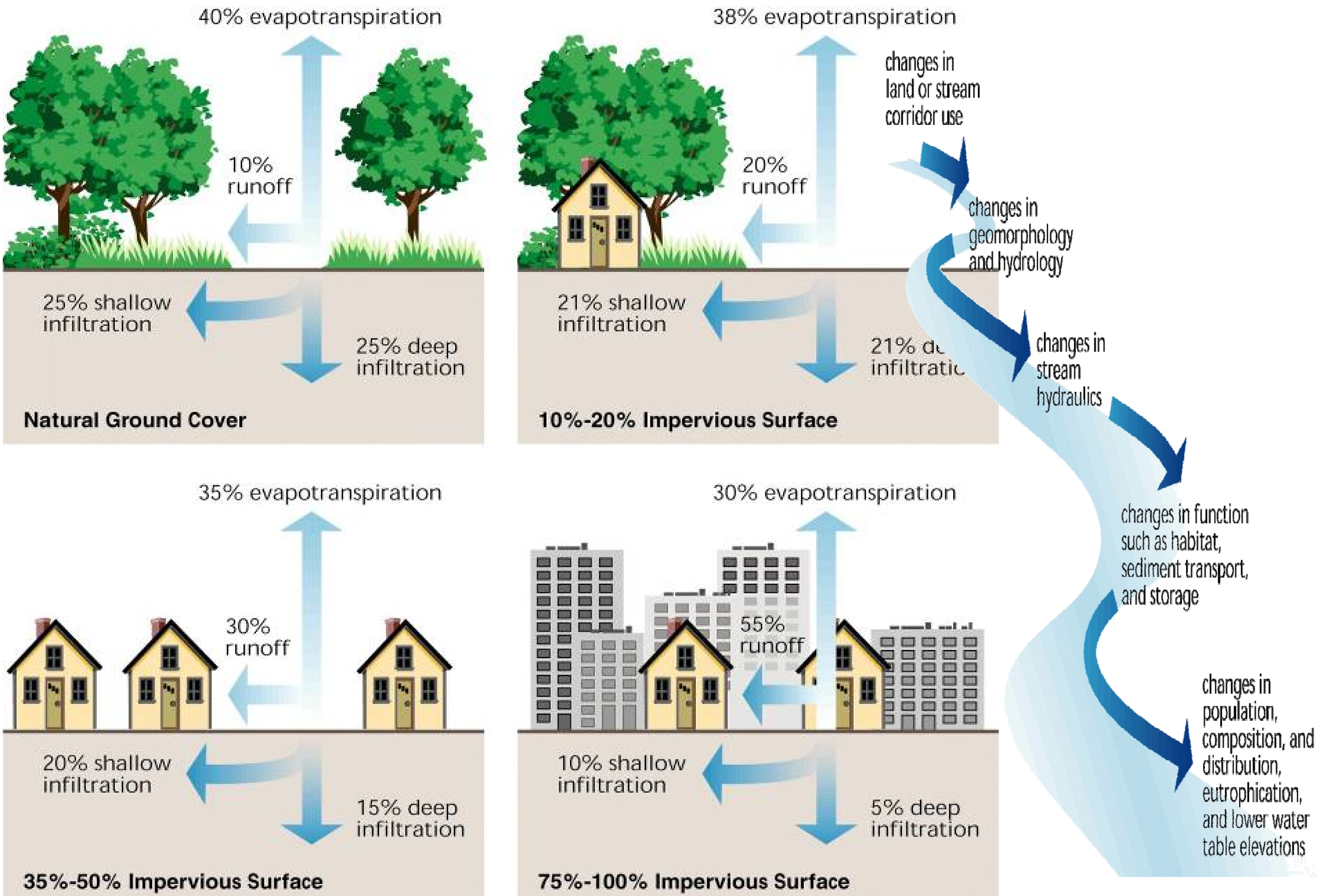
Predevelopment Hydrology

Volume, Rate, Duration, Temperature

Applicability

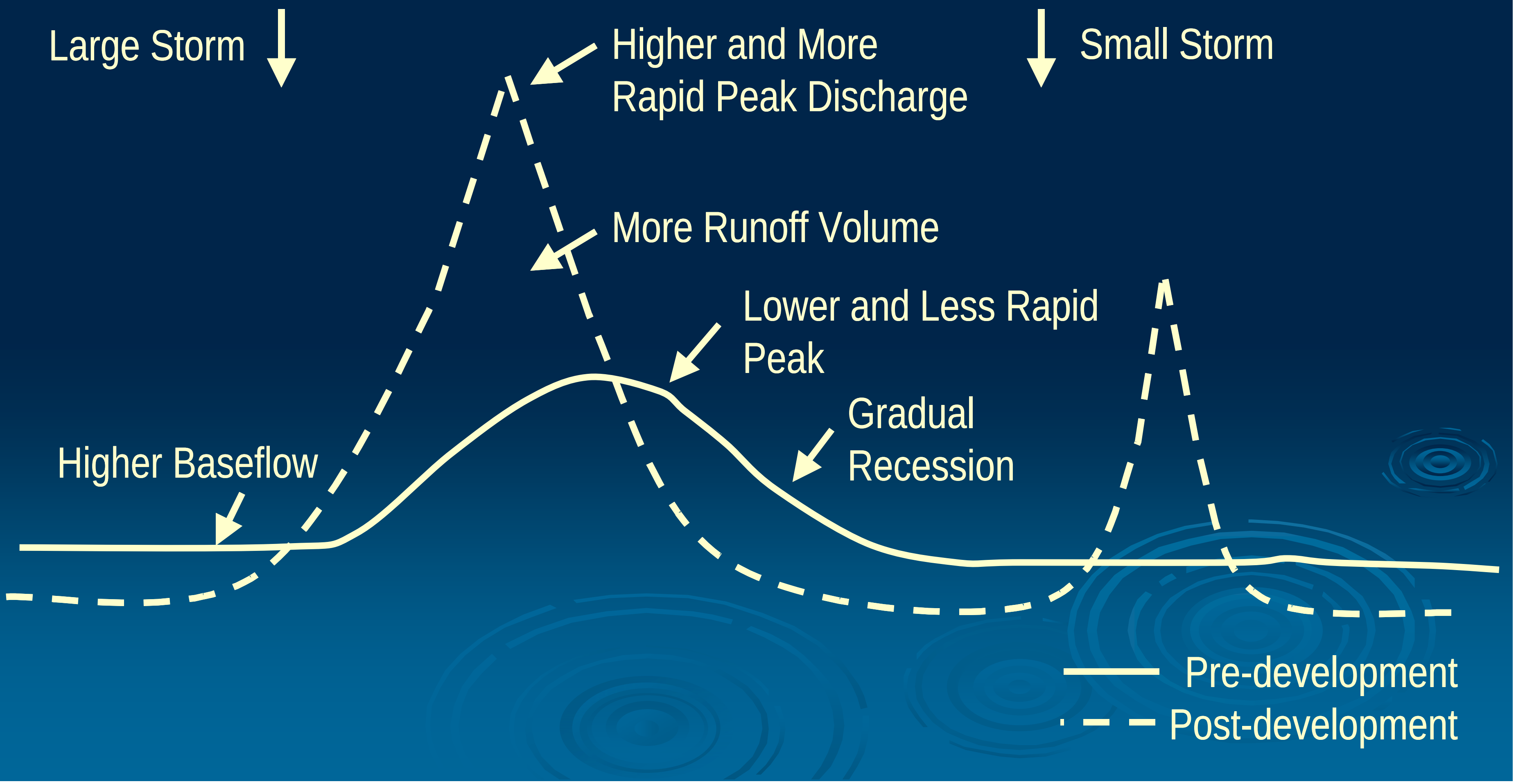
- All facility related construction, i.e., projects associated with buildings and associated infrastructure, e.g., parking lots and access roads

- New development and redevelopment



Source: FISRWG 2001

Consequences of Development to Urban Streams

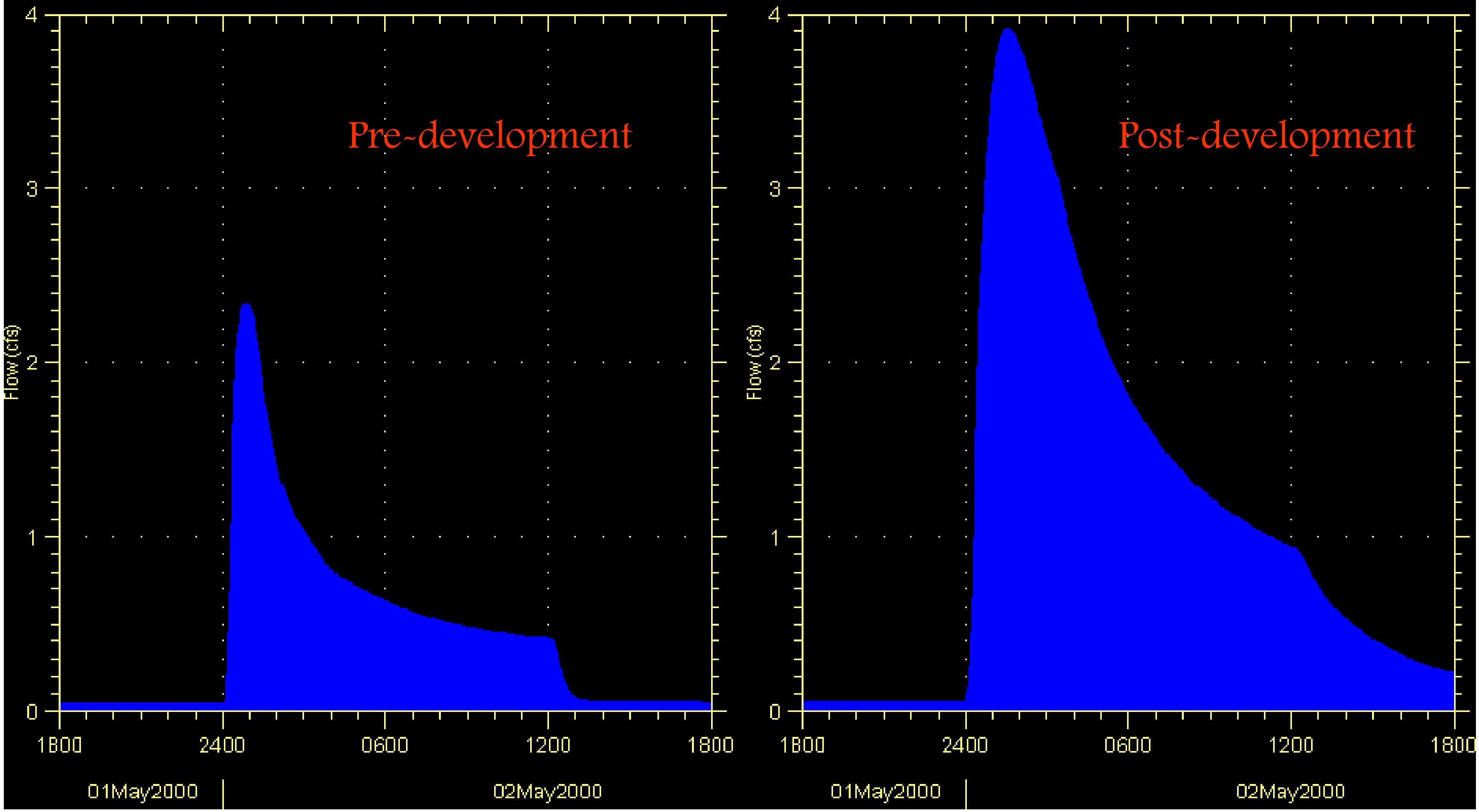


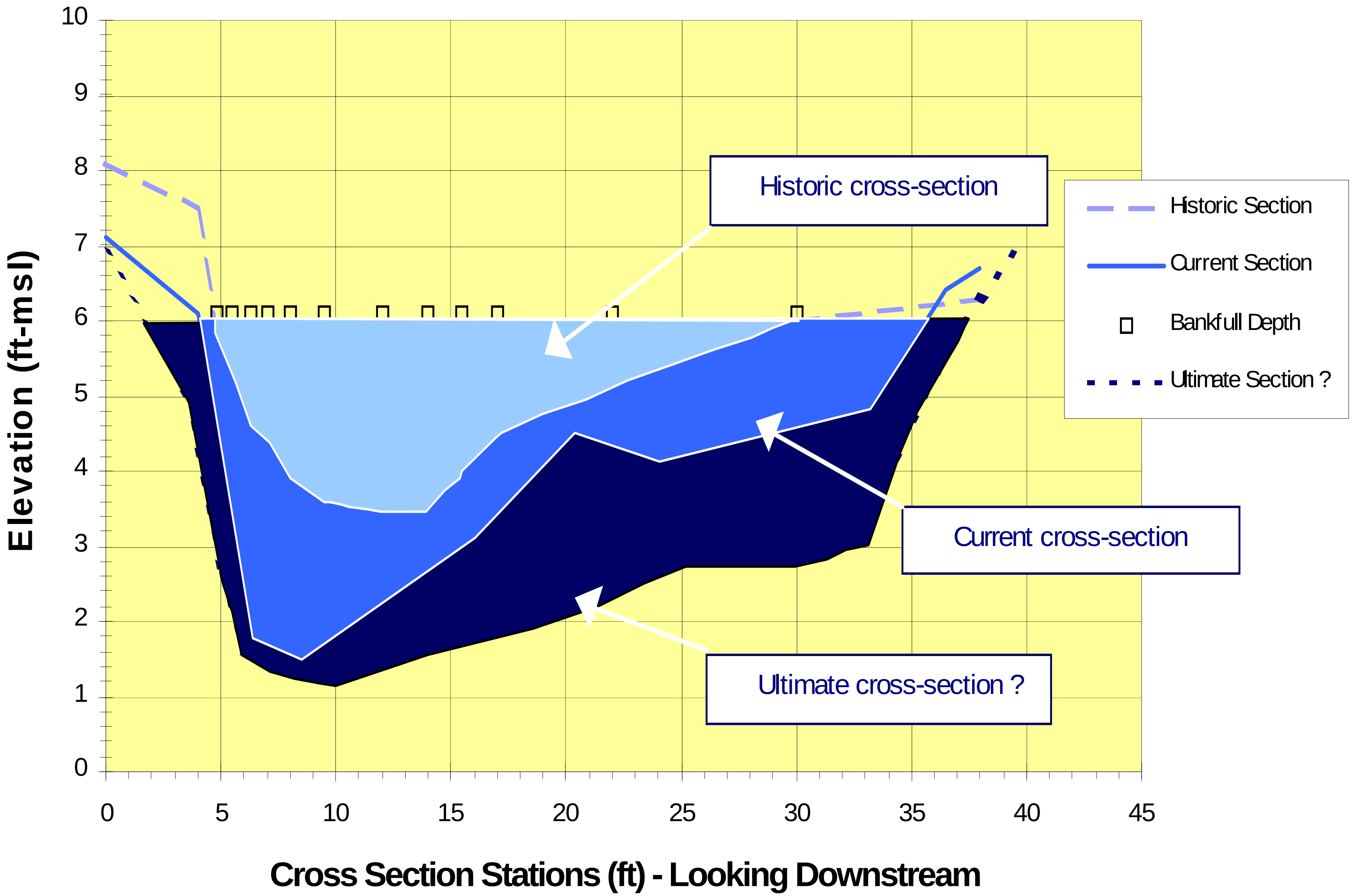
Blakeslee Creek, Michigan

70% increase in peak flow.

170% increase in runoff volume.

Former instantaneous peak flow now lasts ~4 hours.





Increased rates and volumes of storm water discharges lead to stream widening and down-cutting, or incision.

Era of the Big Basin

Stormwater management designs that manage only discharge rates often exacerbate the problem.

Natural systems respond to runoff volumes, frequencies, durations and temperatures as well.

Green Infrastructure Approaches to Wet Weather Flow Management

- Good Site Design
- Good Neighborhood and Community Design
- Water Conservation & Reuse

Infiltration ~ Evapotranspiration ~ Capture & Use

Green Infrastructure

- Green infrastructure - vegetation and soils are used to manage and treat precipitation naturally rather than collecting it in pipes.

- Natural systems are preserved and green roofs, trees, rain gardens, permeable pavements and vegetated swales are used to mimic natural functions.

What is "Green Infrastructure"?

An interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife

Benedict & McMahon, 2006

Green Infrastructure Linking Landscapes and Communities

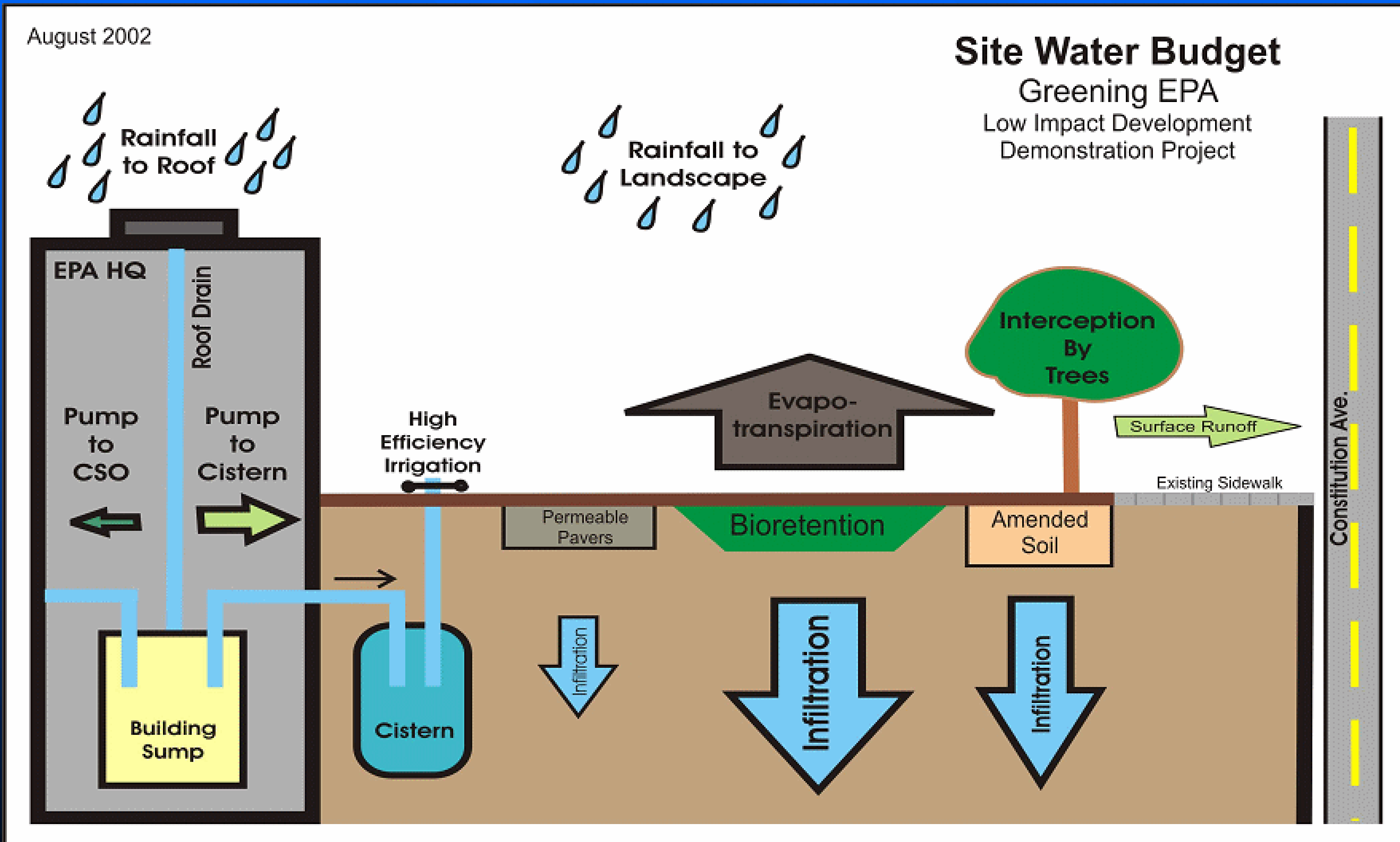
Multiple Benefits

- Reduced hydrological impacts on streams and streambanks
- Reduced pollutant discharges
- Reduced flooding
- Increased groundwater recharge and baseflow
- Reduced energy consumption
- Improved air quality
- Reduced urban heat island impacts
- Enhanced property values
- Community benefits of green space
- Green roofs last longer than traditional roofs, and conserve resources
- Carbon sequestration
- Aesthetic benefits
- Public Health benefits

Green Infrastructure Practices

- Amended soils
- Impervious cover removal
- Bioretention
- Permeable pavements
- Green roofs
- Cisterns & rain barrels
- Trees & expanded tree boxes
- Reforestation & restoration
- Redevelopment and infill development
- Alternative parking & street designs
- Water and energy conservation

Cisterns – Basic Design



Keeping Water Out of Pipes





Bioretention

Open Swales




Parking Lot Island Infiltration Areas

Rain Gardens

Permeable and Porous Pavements

Green Roofs







Soil Amendment & Structuring



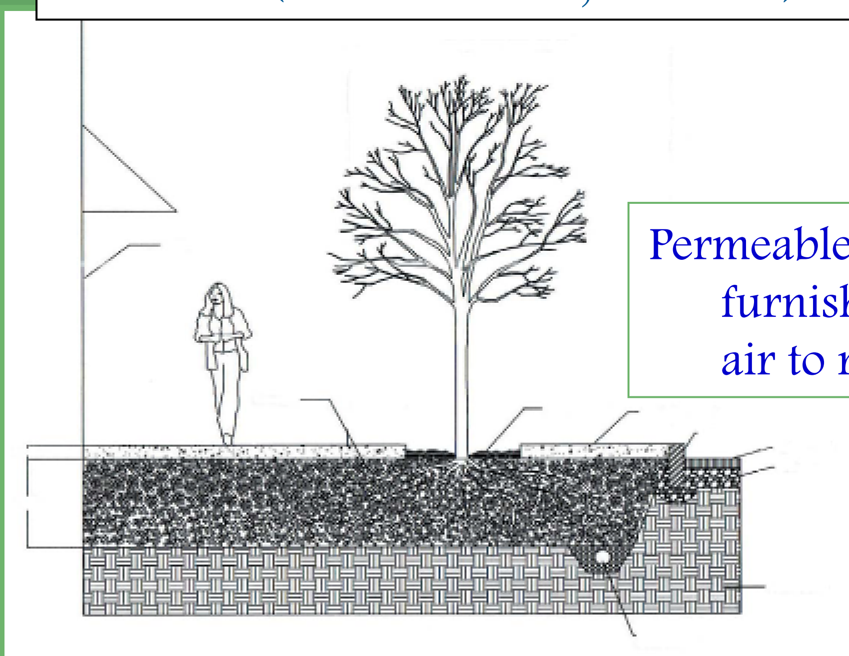



Planters

Expanded Tree Boxes for Street Trees and Plazas

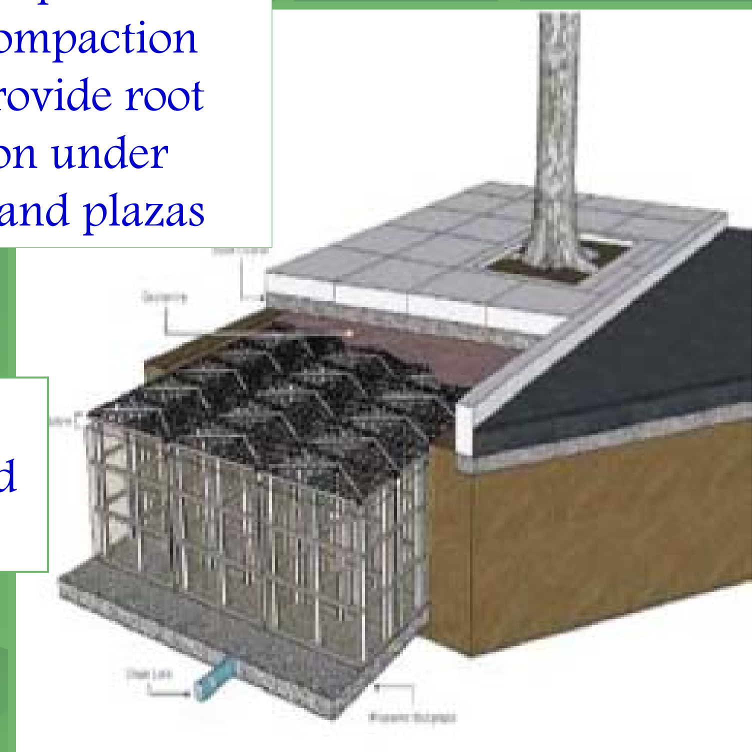
Design roof drains and streets to drain into tree boxes (after treatment, if needed)

Engineered systems prevent root compaction and provide root aeration under roads and plazas



Permeable pavements furnish rainwater and air to roots

Source: *Using CU-Structural Soil in the Urban Environment, Cornell University*



Source: Marquette Avenue and Second Avenue South Transit Project, Minneapolis Public Works, Silva Cell™ Installation

Draft Section 438 Guidance

- Purpose and Organization of Guidance
- Part I: Implementation Framework
  - Background
  - Benefits
  - How to Comply with Section 438
  - Applicability and Definitions
  - Meeting the Performance Requirements (METF)
  - Calculating the 95th Percentile Rainfall Event
- Part II: Case Study Examples

Performance Options

Option 1: Control 95th Percentile Rainfall Event

- Manage rainfall onsite
- Infiltrate, Evapotranspire, Harvest and Reuse Runoff

Note: The 95th percentile rainfall event is the event whose precipitation total is greater than or equal to 95 percent of all 24-hour storms on an annual basis.

Performance Options

Option 2: Preserve predevelopment hydrology (rate, volume, duration & temperature)

- Conduct hydrologic and hydraulic analyses
- Quantify post-construction hydrographs for the following storm sizes:
  - 1, 2, 10 and 100 year 24 hour storm events
- Maintain pre-development hydrographs for these storm events

Maximum Extent Technically Feasible

- Stormwater control practices that are effective in reducing the volume of stormwater discharge must be used.
- Use available and reasonable methods of stormwater retention and/or reuse to prevent the off site discharge of stormwater runoff consistent with the performance standard.
- In cases when a facility seeks or claims an exception, it is expected that there will be a serious and documented attempt to comply.

Process for Accountability

Each Agency or Department is responsible for ensuring compliance. The final design and as-built drawings of each facility shall be reviewed by a registered professional engineer. The Agency or Department shall develop and maintain documentation of the following design criteria:

- Site evaluation and soils analysis
- Calculations for the 95th percentile rainfall event or the pre-development runoff volumes
- The site design and stormwater management practices employed on the site
- Design calculations for each stormwater management practice
- The respective volume of stormwater managed by each practice
- Operations and maintenance protocols

Performance Options

What do you do if Options 1 and 2 are not technically feasible?

- Site evaluation and assessment
- Site conditions or other factors preclude achievement of Options 1 or 2, i.e., neither is technically feasible
- Agency/Department follows process to employ onsite practices to the METF
- Agency/Department documents appropriate design based on METF and other factors

What is a Defensible METF for Redevelopment Sites or Sites with Confounding Factors?

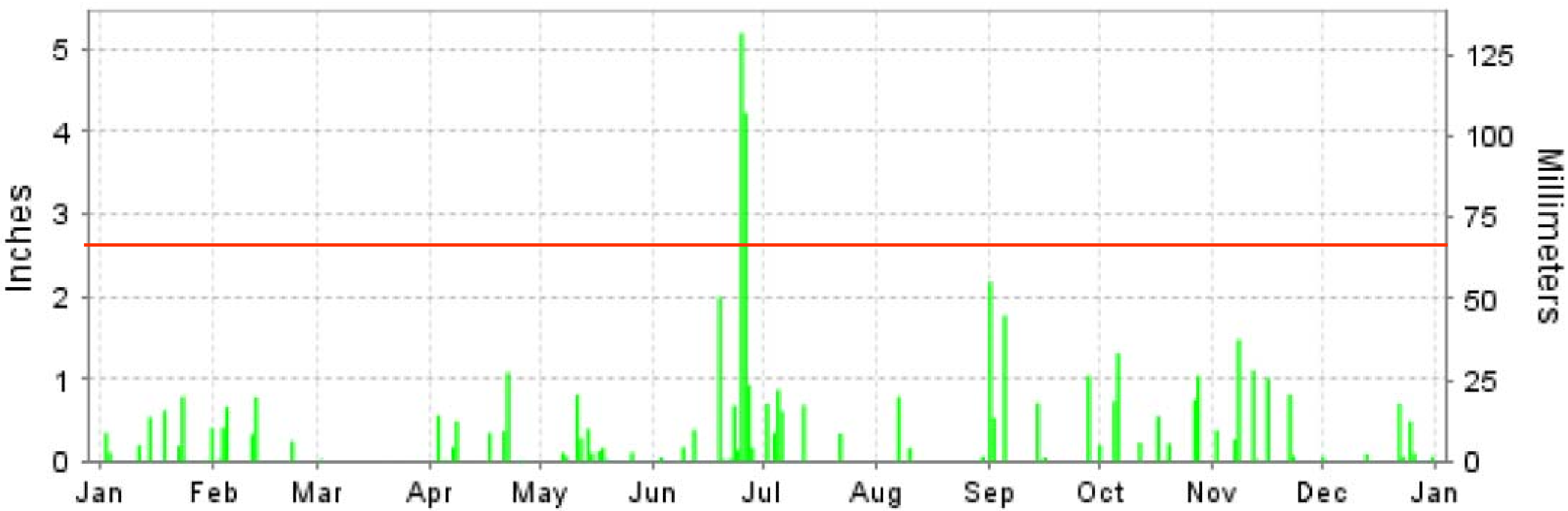
- Standard analytical process
- Design is justifiable and credible given the site specific factors
- Other public goals and benefits achieved through the design
- Mitigation of impacts elsewhere in the watershed/subwatershed

Design to Control a Specified Volume

% Average Annual Rainfall Approach

	90%	95%	99%
Washington DC	1.2”	1.7”	2.4”
Seattle WA	1.3”	1.6”	1.7”
Salt Lake City UT	0.6”	0.8”	1.2”

2006 Precipitation
Washington DC

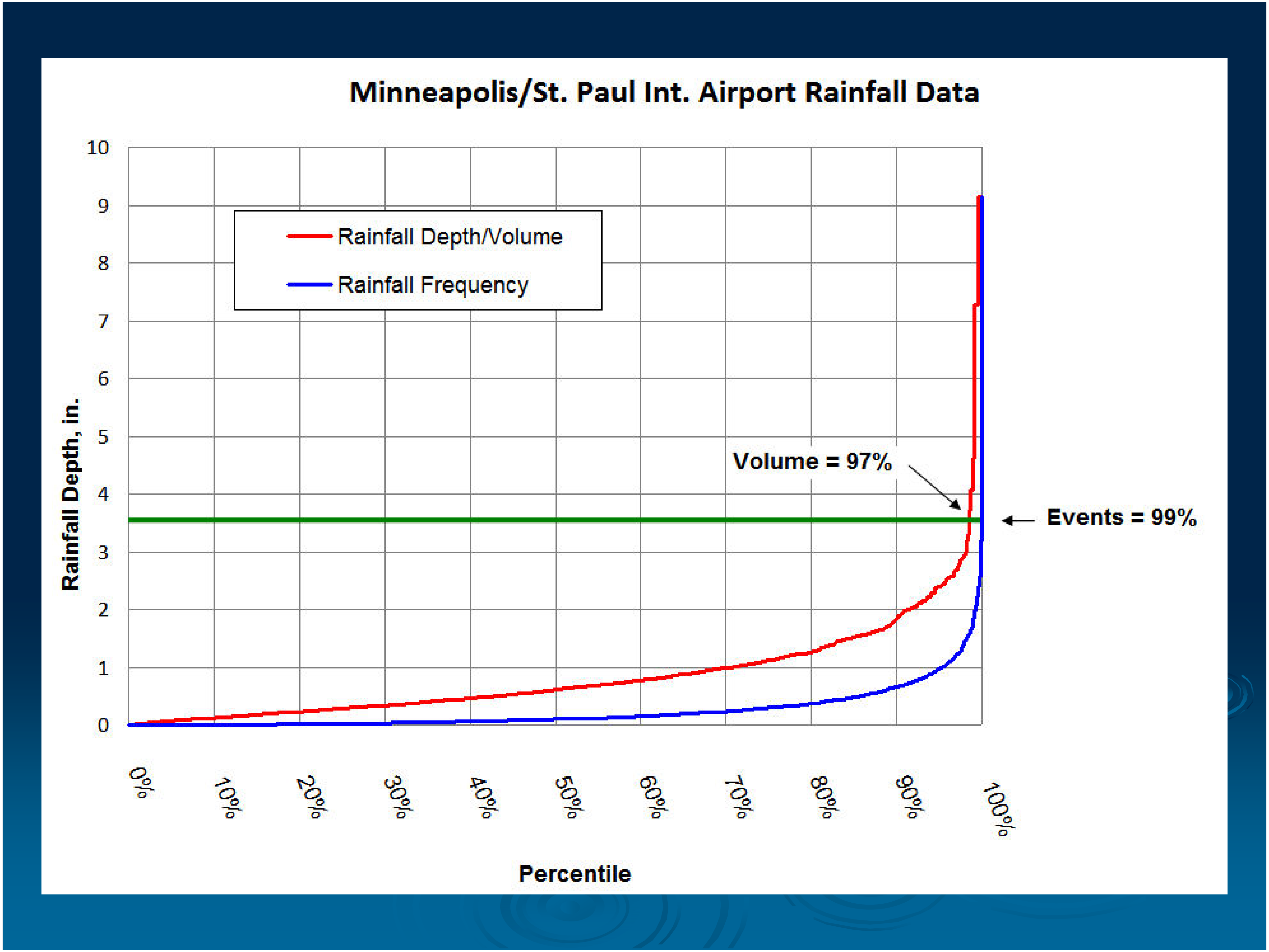


95th Percentile Event = 1.7"

Precipitation Data, NOAA, Reagan National Airport, Arlington VA

Example 95th Percentile Storms

City	95th Percentile Event Rainfall Total (in)	City	95th Percentile Event Rainfall Total (in)
Atlanta, GA	1.8	Kansas City, MO	1.7
Baltimore, MD	1.6	Knoxville, TN	1.5
Boston, MA	1.5	Louisville, KY	1.5
Buffalo, NY	1.1	Minneapolis, MN	1.4
Burlington, VT	1.1	New York, NY	1.7
Charleston, WV	1.2	Salt Lake City, UT	0.8
Coeur D'Alene, ID	0.7	Phoenix, AZ	1.0
Cincinnati, OH	1.5	Portland, OR	1.0
Columbus, OH	1.3	Seattle, WA	1.6
Concord, NH	1.3	Washington, DC	1.7
Denver, CO	1.1		



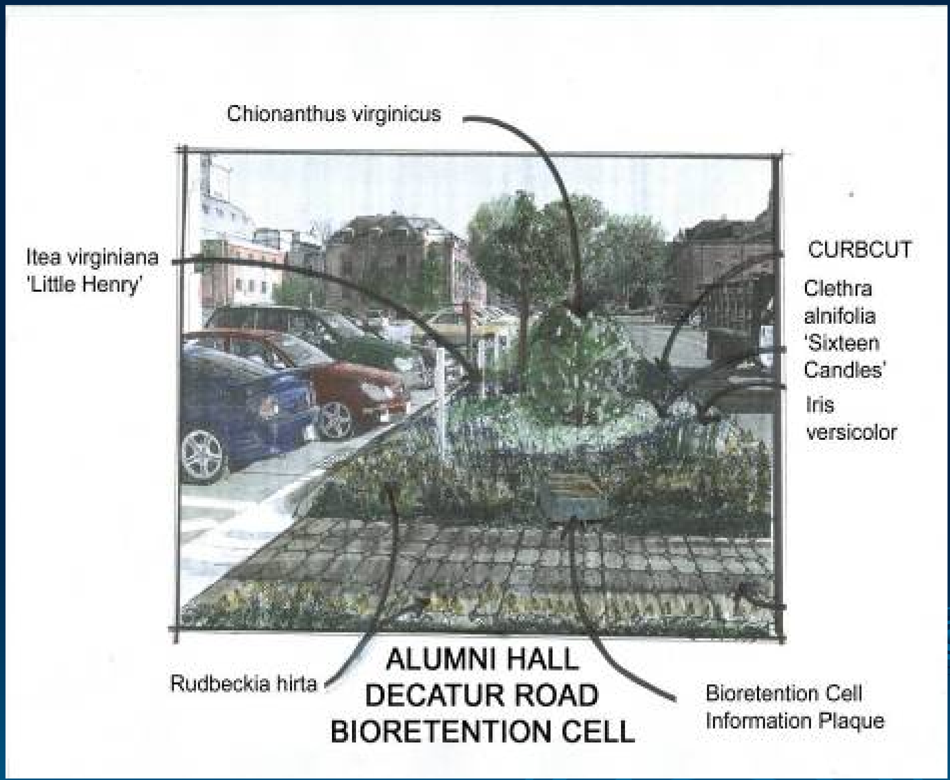
Minneapolis/St. Paul Int. Airport Rainfall Data
Rainfall Depth/Volume
Rainfall Frequency
Volume = 97%
Events = 99%
Rainfall Depth, in.
0
1
2
3
4
5
6
7
8
9
10
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentile

Other Relevant Policies

- Greening Federal Facilities Executive Orders
- Chesapeake Bay Executive Order
- Navy LID Policy for Stormwater Management (November 16, 2007)

Stormwater Management Techniques

- Performance standard not technology standard
- Design flexibility for compliance



Modeling Scenarios

- Demonstrate how to calculate 95th percentile event.
- Show procedure for site assessment and determining appropriate control techniques.
- Provide modeling protocols and outputs to demonstrate verification of compliance.
- Give general performance capabilities of control techniques.

The challenge:

make these… **…function like this**

Analyses of 95% Event Volumes

Location	95% Rainfall Events (in)
Charleston, WV	1.23
Denver, CO	1.07
Cincinnati, OH	1.45
Portland, OR	1.00
Phoenix, AZ	1.00
Boston, MA	1.52
Atlanta, GA	1.77

Denver, Colorado

Total Area (acres)	4.5	
Estimated Imperviousness (%)	55%	
95^{th} Percentile Rainfall Event (inches)	1.07	
Expected Runoff for the 95^{th} Percentile Rainfall Event (inches)	0.53	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination method (acres)	0.16	0.3
Bioretention estimated by Rational Method (acres)	0.16	0.28
Off-site storage necessary to control the 10-yr event of 3.2 inches (acre-ft)	0.35	0.52

Total Area (acres)	19	
Estimated Imperviousness (%)	51%	
95^{th} Percentile Rainfall Event (inches)	1.45	
Expected Runoff for the 95^{th} Percentile Rainfall Event (inches)	0.68	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.8	1.3
Off-site storage necessary to control the 10-yr event of 4.2 inches (acre-ft)	2.42	3.24

Cincinnati, Ohio

Total Area (acres)	27	
Estimated Imperviousness (%)	95%	
95th percentile Rainfall Event (inches)	1.00	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.86	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Paver block area estimated by Direct Determination (acres)	1.4	3.5*
Bioretention estimated by Direct Determination (acres)	0.4	
Green Roof estimated by Direct Determination (acres)	1.7	
Cistern volume estimated by Direct Determination (gallons)	50,000	
Off-site storage necessary to control the 10-yr event of 3.7 inches (acre-ft)	5.37	5.62

Portland, Oregon

Phoenix, Arizona

Total Area (acres)	2	
Estimated Imperviousness (%)	47%	
95th Percentile Rainfall Event (inches)	1.00	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	0.42	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.06	0.1
Off-site storage necessary to control the 10-yr event of 2.4 inches (acre-ft)	0.05	0.12

Atlanta, Georgia

Total Area (acres)	21	
Estimated Imperviousness (%)	70%	
95th Percentile Rainfall Event (inches)	1.77	
Expected Runoff for the 95th Percentile Rainfall Event (inches)	1.17	
Stormwater Management Area Required	Hydrologic Soil Group	
	B	C
Bioretention estimated by the Direct Determination (acres)	0.9	
Paver block area estimated by the Direct Determination (acres)	0.9	3.2*
Bioretention estimated by TR-55	0.8**	0.9
Paver block area estimated by TR-55	0**	1.84
Off-site storage necessary to control 10-yr event of 6.0 inches (acre-ft)	5.85	6.62

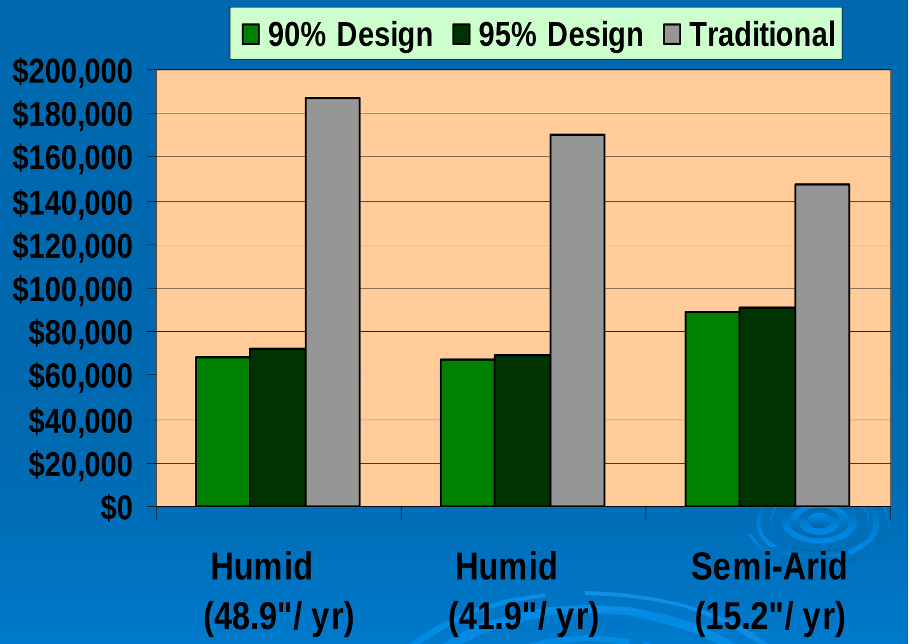
Preliminary Cost Estimates

Site A: Single Family Residential Development (40% imperviousness)

5.2 acre site
22 ¼ acre lots

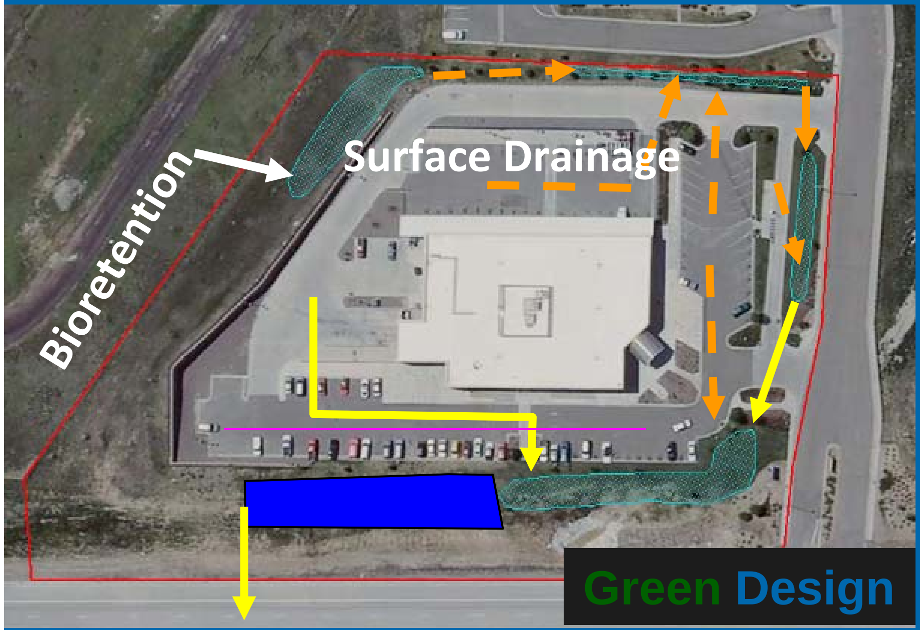
Cost Comparison

(capital costs for entire site)



Note: All sites use traditional development patterns and do not represent innovative green designs

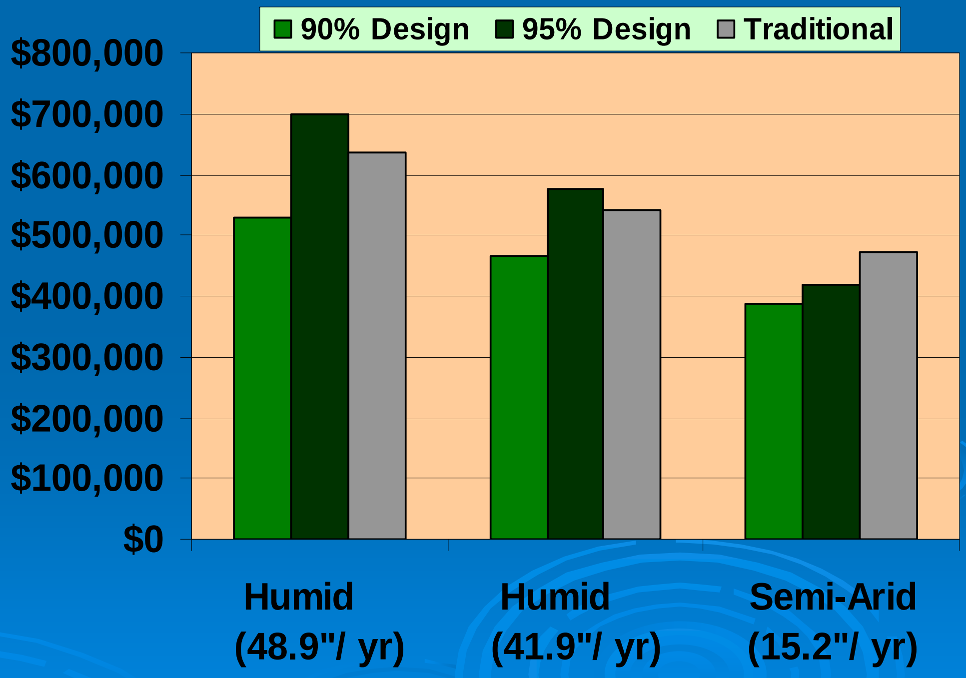
Site B: Commercial Development (55% imperviousness)



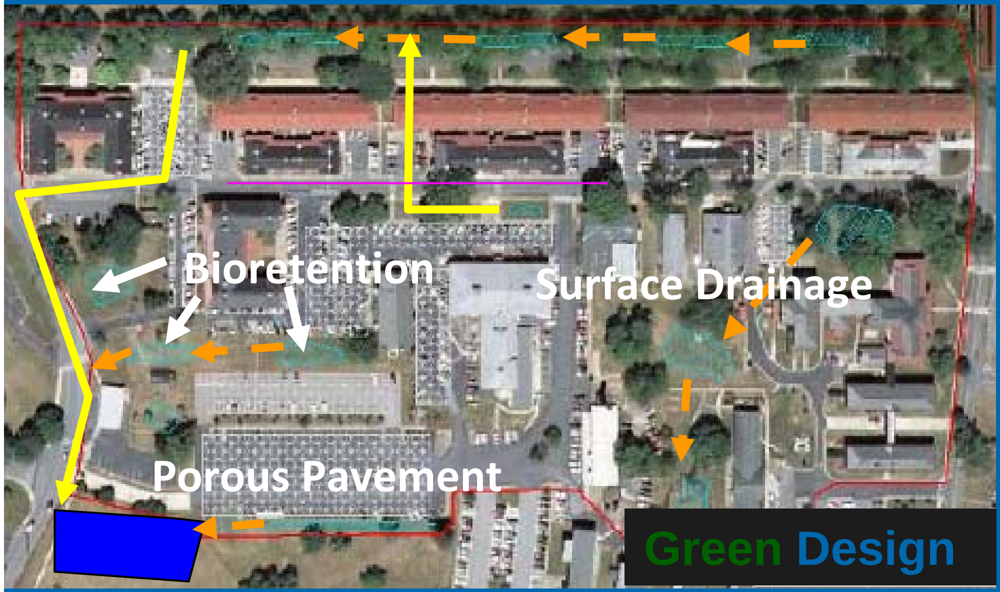
4.5 acre site

Cost Comparison

(capital costs for entire site)



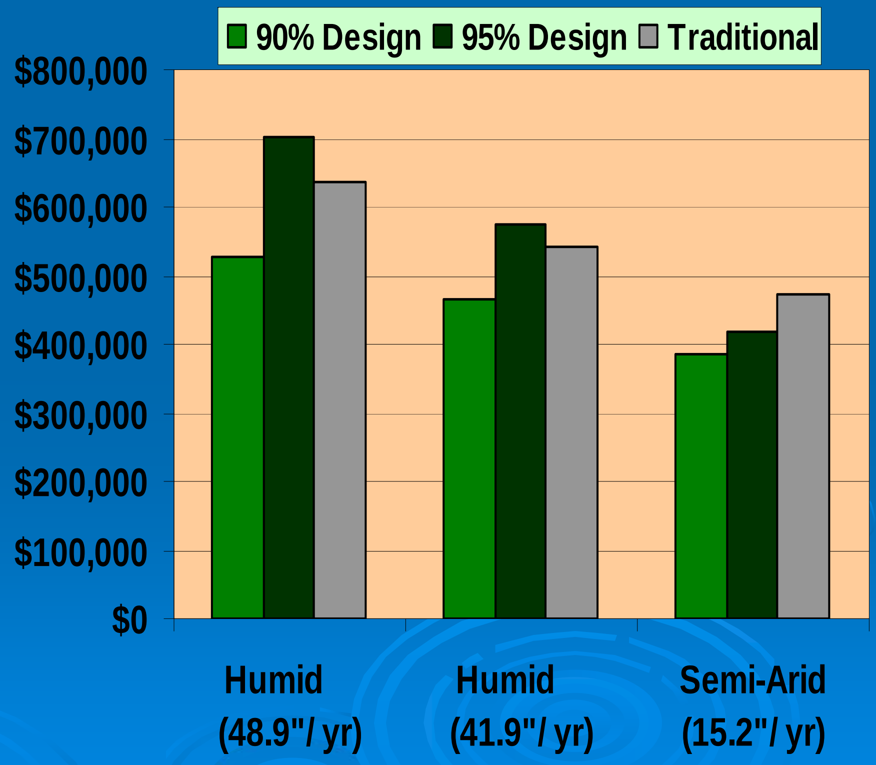
Site C: High Density Residential Development (70% imperviousness)



22 acre site

Cost Comparison

(capital costs for entire site)



LID Feasibility Analysis
Cincinnati, Ohio

Andrew W. Breidenbach Environmental Research Center (AWBERC)

Cincinnati AWBERC

- 862,488 SF site in Hamilton County, Ohio
- 68,000 SF building foot print (8% of site)
- 310,000 SF pavement surfaces (36% of site)
- 485,000 SF open space (56% of site)

Courtesy of Lisa Biddle - ERG

Runoff Analysis for AWBERC—Overview

- Assess rainfall distribution
- Perform runoff analysis for three types of storm events
  - 95^{th} percentile storm event
  - 2-year, 24-hour storm
  - 10-year, 24-hour storm

Courtesy of Lisa Biddle - ERG

Runoff Assessment of Three Storm Scenarios

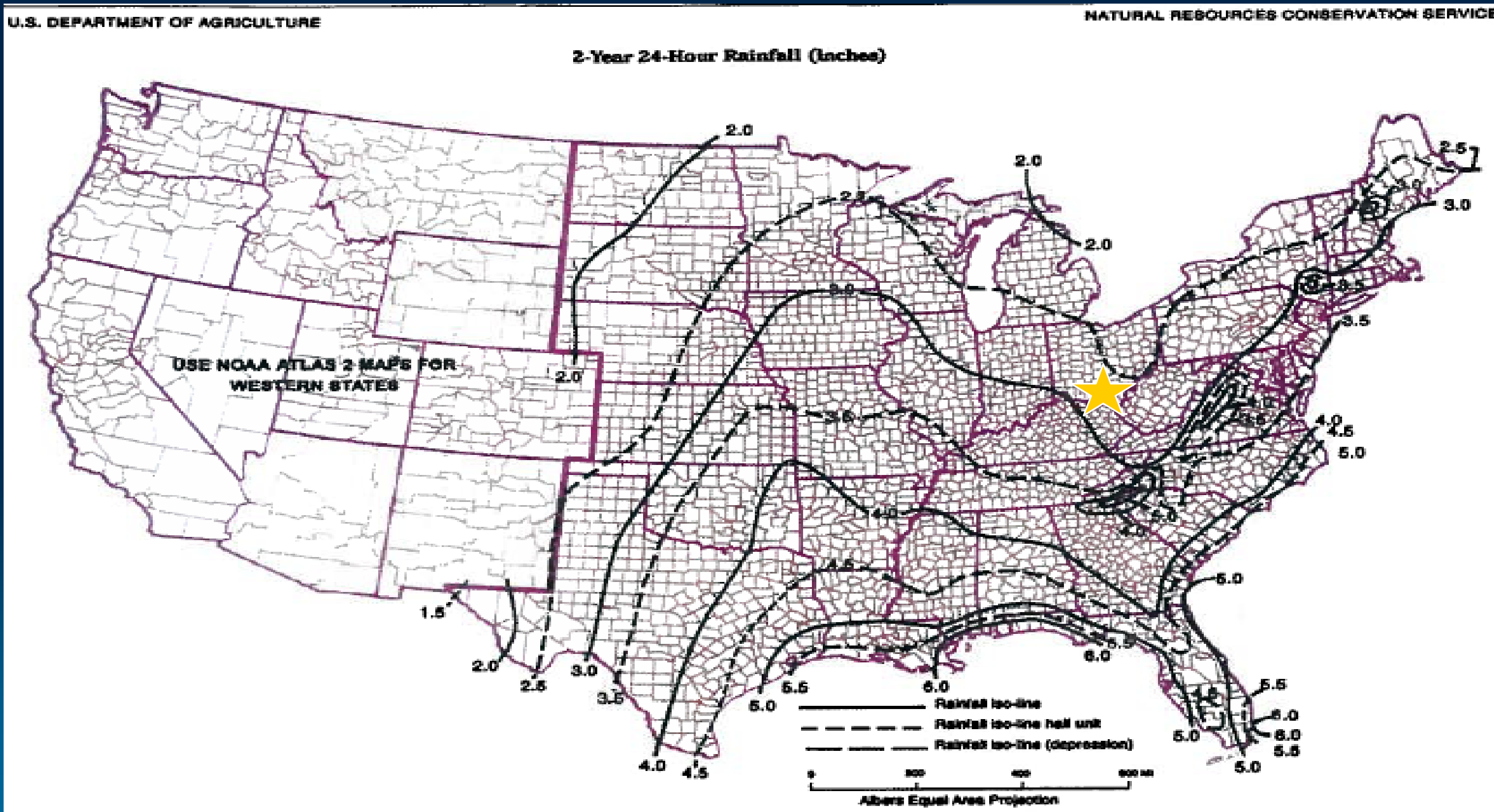
Type of Storm Event	Goal	Results*
95th percentile storm event	To meet Section 438 (EISA 2007) requirements, EPA's draft implementation instructions advise ensuring that LID strategies can manage the 95th percentile 24-hour rainfall amount with no measurable off-site discharge	1.34 inches
2-year, 24-hour storm	Channel protection	3 inches
10-year, 24-hour storm	Flood protection	4 inches

** The methods used to obtain the results are depicted on the following slides.*

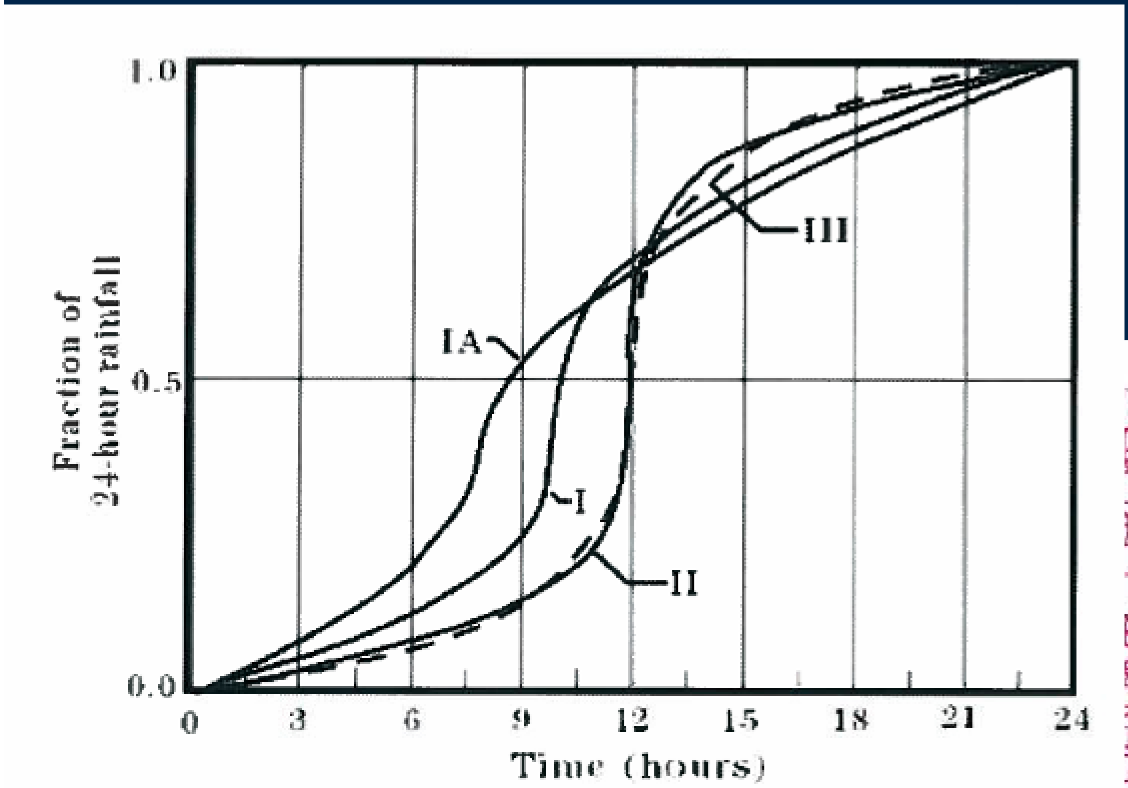
Find the Rank of the 95th Percentile Amount

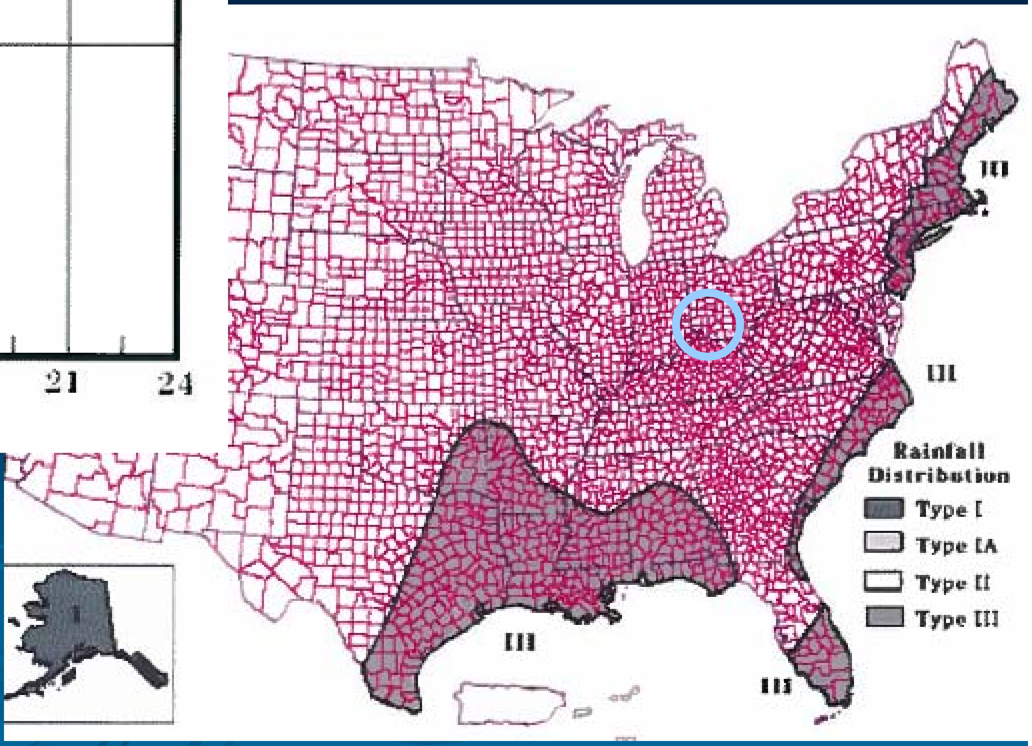
Rank	Cum Frequency	Event Date	Daily Precip (Inches)	Rank	Cum Frequency	Event Date	Daily Precip (Inches)	Rank	Cum Frequency	Event Date	Daily Precip (Inches)
1	100.00%	2/12/1979	4.06	108	96.02%	5/11/1996	1.5	2658	1.08%	8/18/2003	0.1
2	99.96%	7/20/1998	3.82	109	95.98%	7/14/1994	1.5	2659	1.04%	7/7/2003	0.1
3	99.93%	8/6/1995	3.66	110	95.94%	9/1/1993	1.5	2660	1.01%	6/11/2003	0.1
4	99.89%	8/31/2005	3.36	111	95.90%	11/16/1989	1.5	2661	0.97%	4/8/2003	0.1
5	99.85%	5/11/2003	3.14	112	95.87%	1/20/1988	1.5	2662	0.93%	12/12/2002	0.1
6	99.81%	9/28/1996	3.07	113	95.83%	8/5/1982	1.5	2663	0.89%	8/14/2002	0.1
7	99.78%	4/16/1998	2.96	114	95.79%	8/6/1976	1.5	2664	0.86%	5/1/2002	0.1
8	99.74%	4/29/1996	2.87	115	95.76%	4/8/1998	1.47	2665	0.82%	2/26/2002	0.1
9	99.70%	10/13/1983	2.8	116	95.72%	10/25/2002	1.46	2666	0.78%	8/26/2001	0.1
10	99.66%	9/27/2002	2.79	117	95.68%	7/20/1988	1.46	2667	0.74%	8/4/2001	0.1
11	99.63%	5/8/1986	2.72	118	95.64%	7/12/1987	1.46	2668	0.71%	4/11/2001	0.1
12	99.59%	1/4/2000	2.69	119	95.61%	9/12/1986	1.46	2669	0.67%	12/13/2000	0.1
13	99.55%	6/12/1998	2.63	120	95.57%	6/8/1982	1.46	2670	0.63%	12/12/2000	0.1
14	99.52%	4/29/1989	2.56	121	95.53%	10/18/1980	1.46	2671	0.60%	7/4/2000	0.1
15	99.48%	9/14/1979	2.52	122	95.50%	11/24/1979	1.46	2672	0.56%	5/17/2000	0.1
16	99.44%	9/4/1988	2.48	123	95.46%	4/3/1977	1.46	2673	0.52%	5/14/2000	0.1
17	99.40%	10/24/2001	2.44	124	95.42%	8/23/1989	1.42	2674	0.48%	7/2/1999	0.1
18	99.37%	4/1/1996	2.44	125	95.38%	2/2/1981	1.42	2675	0.45%	6/9/1999	0.1
19	99.33%	6/9/1982	2.4	126	95.35%	2/18/1976	1.42	2676	0.41%	4/22/1999	0.1
20	99.29%	10/13/1978	2.4	127	95.31%	6/15/2005	1.4	2677	0.37%	1/17/1999	0.1
21	99.26%	11/15/2005	2.39	128	95.27%	5/8/2002	1.4	2678	0.34%	3/10/1998	0.1
22	99.22%	6/8/1992	2.36	129	95.23%	5/13/2002	1.39	2679	0.30%	11/3/1997	0.1
23	99.18%	12/6/1977	2.36	130	95.20%	4/22/1984	1.38	2680	0.26%	11/3/1993	0.1
24	99.14%	7/12/1992	2.32	131	95.16%	12/9/1978	1.38	2681	0.22%	8/2/1993	0.1
25	99.11%	10/4/1990	2.32	132	95.12%	1/1/2003	1.35	2682	0.19%	12/3/1992	0.1
26	99.07%	2/19/2000	2.3	133	95.09%	6/27/1999	1.34	2683	0.15%	5/4/1977	0.1
27	99.03%	8/29/1994	2.28	134	95.05%	7/8/1991	1.34	2684	0.11%	12/20/1976	0.1
28	98.99%	4/22/2002	2.26	135	95.01%	9/19/1990	1.34	2685	0.07%	4/11/1976	0.1
29	98.96%	5/16/1990	2.24	136	94.97%	8/30/1989	1.34	2686	0.04%	1/9/1974	0.1

2~Year 24~Hour Storm (3 Inches)



SCS Rainfall Distribution Curve





Type II Rainfall Distribution Curve

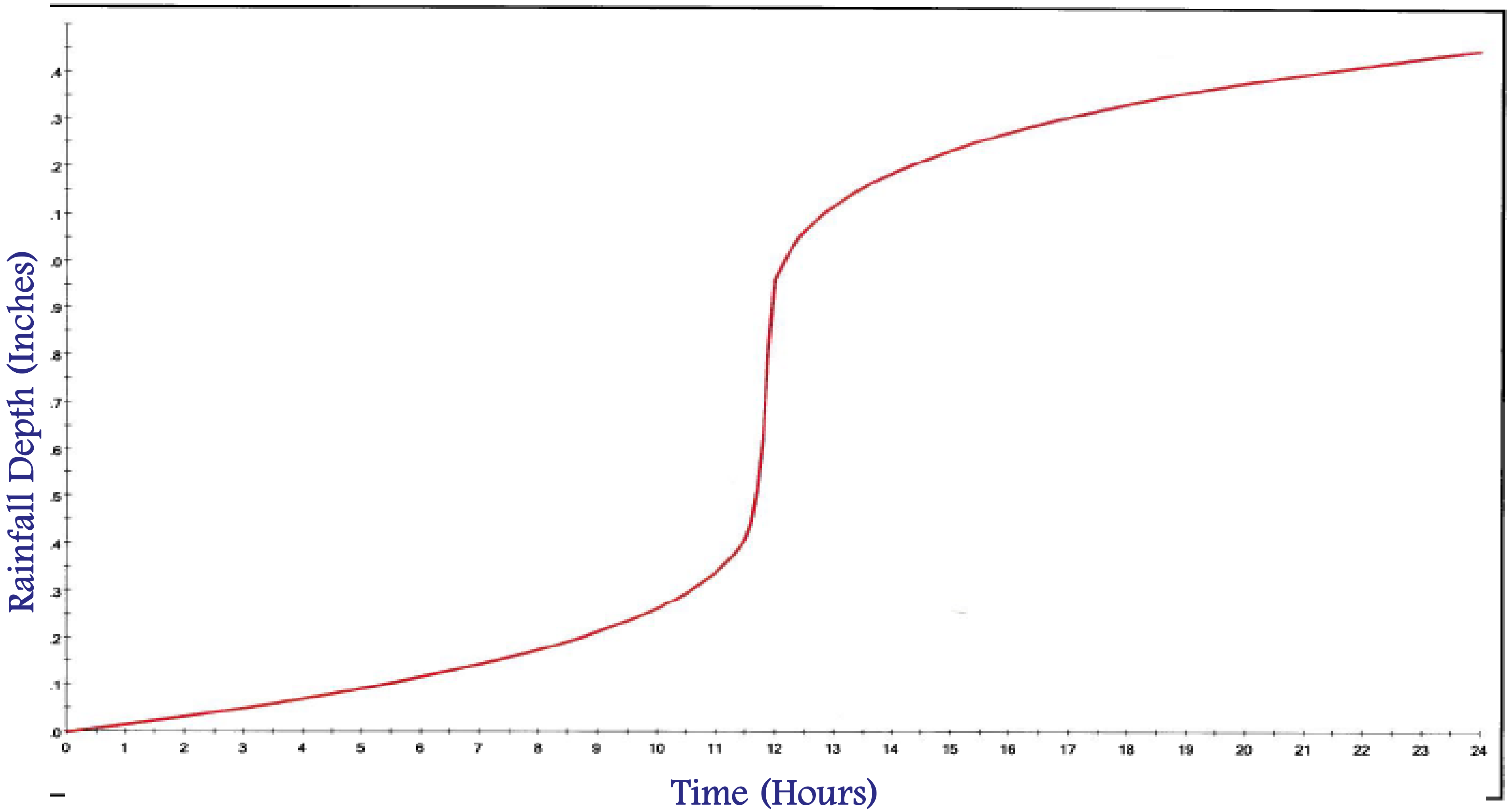
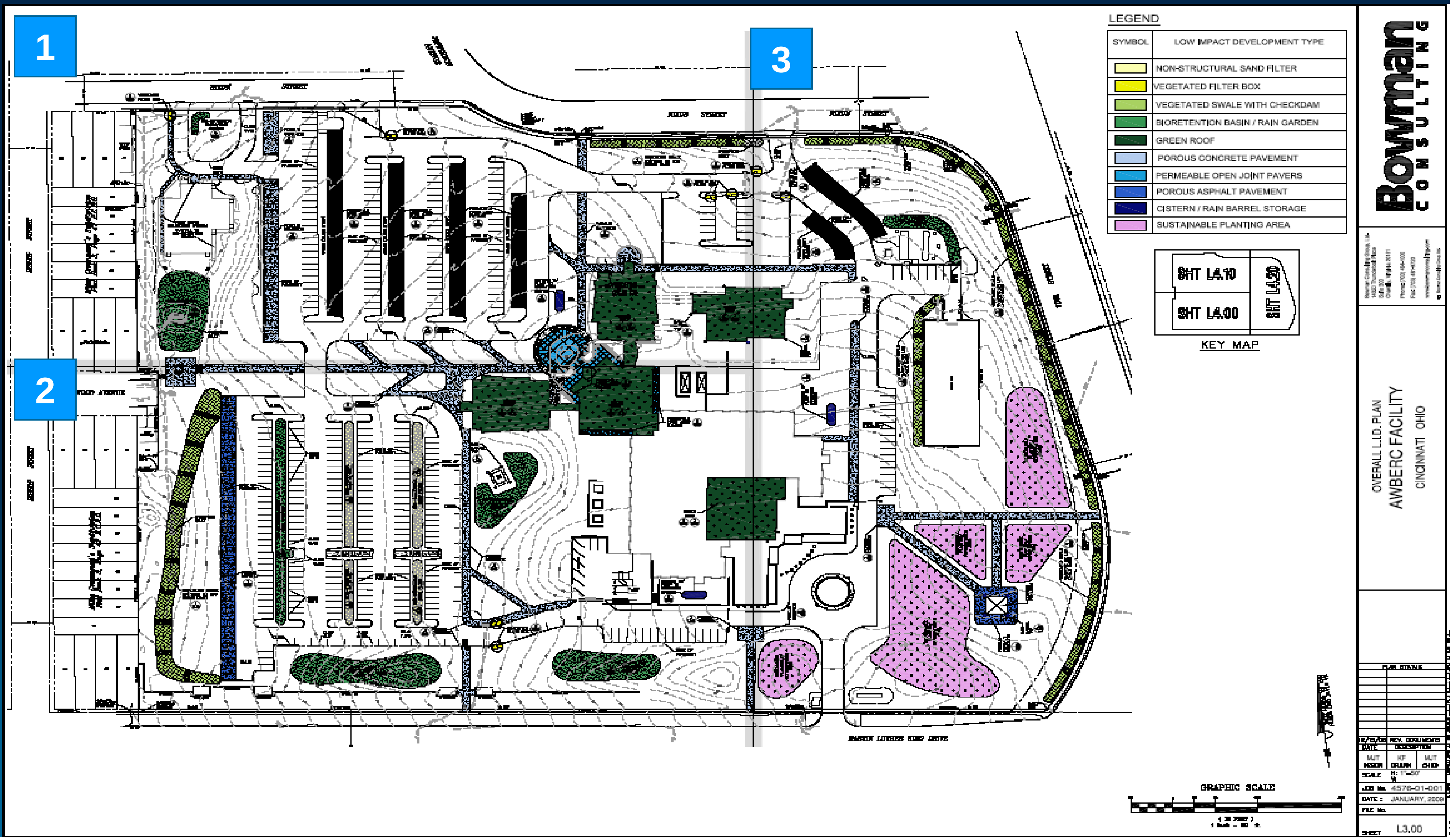


Figure 4. Type II 24hr Rainfall Distribution for 95% Storm Event in Cincinnati, OH.

Next Steps

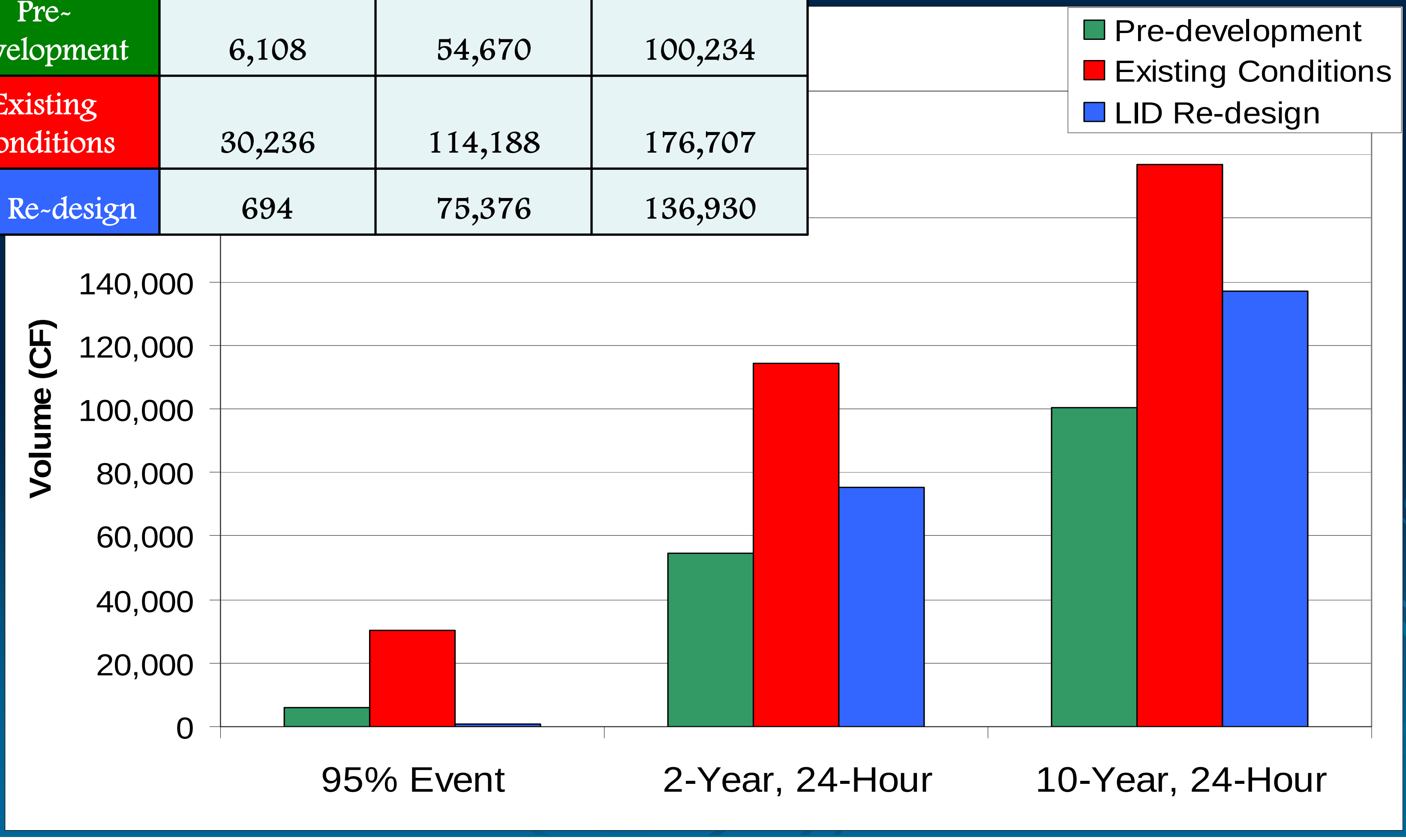
- Select on-site LID options to capture the 95th percentile rainfall runoff
- Determine whether additional state or local requirements are more stringent
- Determine whether additional considerations and analysis should be performed to ensure sufficient flood control is provided

Cincinnati AWBERC
LID Re-Design Exercise



Runoff Volume Analysis

Runoff Volume (CF)			
	95% Event (1.34 inches)	2-yr Event (3.00 inches)	10-yr Event (4.00 inches)
Pre-development	6,108	54,670	100,234
Existing Conditions	30,236	114,188	176,707
LID Re-design	694	75,376	136,930



Cincinnati LID Re-Design—Runoff Managed

LID Re-Design				
Type	#	Units*	Acres Managed	Volume Treated (CF)
LID Features:				
Tree Box Filters	8	EA	2.3	8,470
Porous Pavement	1,278	SY	1.9	7,410
Pervious Pavers	2,125	SY	1.7	10,483
Bio-Retention Basin/ Rain Garden	451	CY	4.5	15,106
Vegetated Swale	417	CY	4.5	10,264
Green Roof - Extensive	4,162	SY	**0.86**	10,825
Cistern	3	EA	0.7	1,372
Non-structural Sand Filter	52	SY	0.9	4,083
Total				**63,930**

* EA = each CY = cubic yard AC = acre LS = lump sum SY=square yard

Cincinnati LID Re-Design—Implementation Costs

LID Re-Design Scenario (cost details)				
Type	**#**	**Units***	**Each**	**Total**
LID Features:				
Tree Box Filters	8	EA	$2,600	$20,800
Porous Pavement	1,278	SY	$34	$43,452
Pervious Pavers	2,125	SY	$102	$216,750
Bio-Retention Basin/ Rain Garden	451	CY	$76	$34,276
Vegetated Swale	417	CY	$76	$31,692
Cistern	3	EA	$4,500	$13,500
Rain Barrel	9	EA	$150	$1,350
Non-structural Sand Filter	52	SY	$22	$1,144
Reforestation	0.91	AC	$45,000	$40,950
Subtotal LID Controls				$403,914
Traditional Infrastructure Components:				
Storm Sewer (for unmanaged area and conveyance of larger storms)		LS		$122,900
Streets and Parking Lots (includes non-porous pavement)		LS		$704,375

* EA = each CY = cubic yard AC = acre LS = lump sum

Cincinnati LID Re-Design— Cost Comparison

LID Re-Design Scenario	
Subtotal LID Components	$403,914
Subtotal Traditional Infrastructure Components	$827,275
Total LID Re-Design	**$1,231,189**

Existing Conditions (Non-LID) Design Scenario	
Storm Sewer	$431,298
Streets and Parking Lots	$862,138
Total Existing Conditions (Non-LID)	**$1,293,436**

Draft Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act

EPA Contacts:

- Jenny Molloy

  molloy.jennifer@epa.gov
  (202) 564-1939

- Robert Goo

  goo.robert@epa.gov
  (202) 566-1201