



Green Infrastructure Webcast Series

Models and Calculators
Louisville Case Study



Guide to Our Webcasts

For Technical Support click the “*Help*” button

- *To Ask a Question* – Type your question in the text box located in the lower left-hand corner of your screen and click on the “Submit Question” button
- *To Answer a Poll Question* – Click on the radio button to the left of your choice and click submit. Do not type your answer in the “Ask a Question” box
- *To See Closed Captioning* – Turn your pop-up blocker off and click on the “closed captioning” button
- *To Complete the Survey* – Turn off your pop-up blocker
- *To Obtain a Certificate* – Watch 1 hour and 30 minutes of the webcast and then click “Download Certificate.” If you are in a room with multiple attendees please wait until the last slide to obtain the URL to customize your own certificates



Green Infrastructure Webcast Series

Tuesday, May 12, 2009

- Site Planning & Design Considerations
- Costs and WERF Cost Tool

Tuesday, June 23, 2009

- Funding & Incentives
- Brownfield Redevelopment

Tuesday, July 28, 2009

- Retrofits: Green Streets
- Operation & Maintenance

Green Infrastructure Website

www.epa.gov/greeninfrastructure

The screenshot shows the EPA website interface for the NPDES program. The main heading is "Managing Wet Weather with Green Infrastructure". The page is organized into several sections:

- Basic Information:** Includes links for Green Infrastructure Policies, Benefits of Green Infrastructure, Glossary of Terms, and Green Infrastructure Bulletin.
- Case Studies:** Lists Green Municipalities Case Studies, Green Campuses Case Studies, Green Capitals Case Studies, and Regulatory Integration.
- Our Partnership:** Provides links to Join our Partnership and Partnership Contacts.
- Technical Information:** Offers links to Technologies and Approaches, Research Reports and Publications, and Models and Calculators.
- Funding:** Includes Sources of Funding and Funding Tools.
- Links:** Points to Green Infrastructure in the News and Additional Webinars.

There is also a sidebar on the left with navigation options like "Types, Applications, & Design Approaches", "Case Studies", "News", "Green Infrastructure Partnership", "Policies & Regulations", "Research", "Models & Calculators", "Municipal Handbook", "Funding Opportunities", "Links", "Training & Conferences", and "Contacts".

- General Information
- Key Resources
- Case Studies
- Performance Data
- Partnership Contacts
- Statement of Support

NEW! Click on Trainings and Conferences to download previous webcasts from the series and for info on upcoming workshops

Green Infrastructure: Models and Calculators

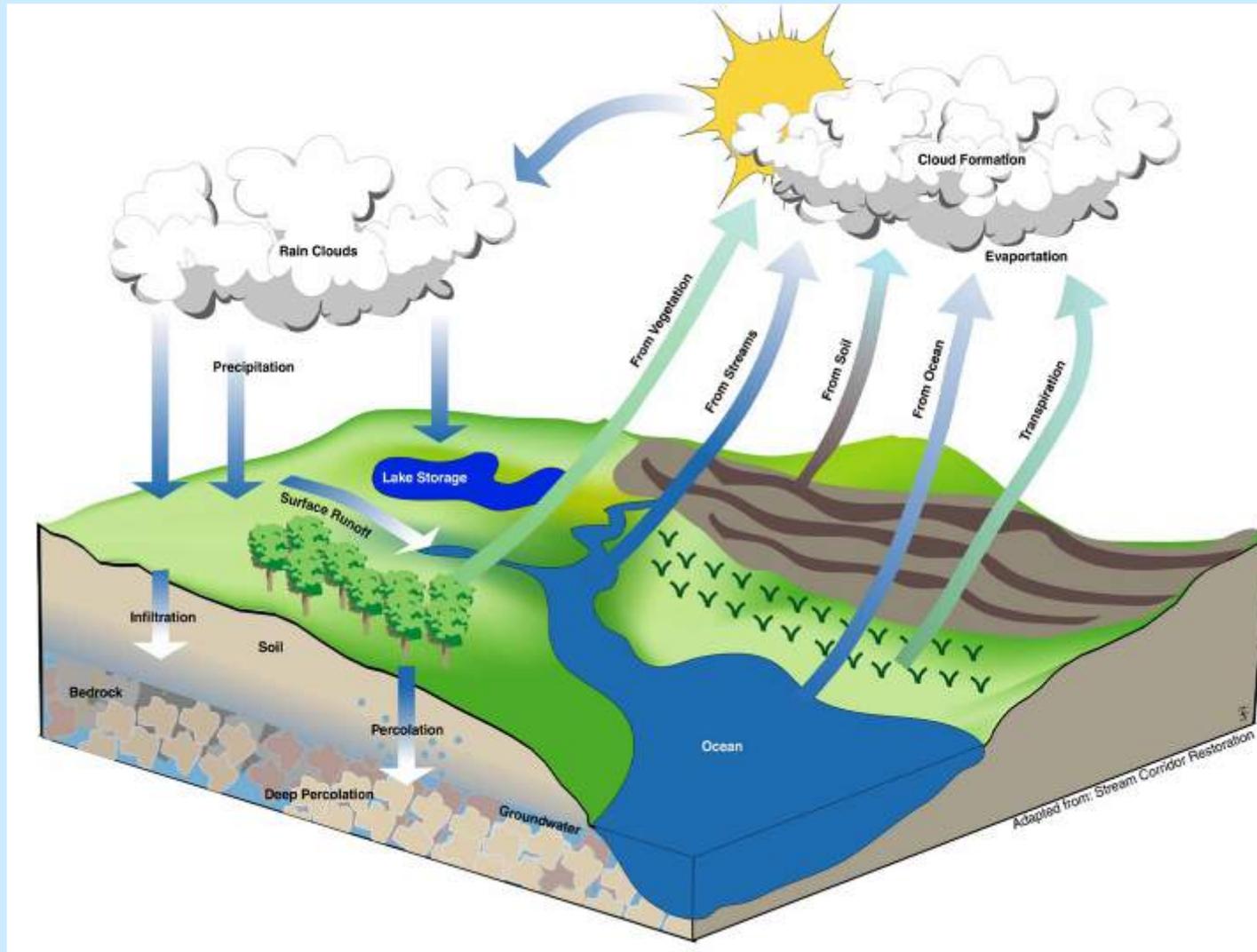
EPA Green Infrastructure Webcast
April 28, 2009

Brian Busiek, P.E.

Introduction

- **Objective**
 - Provide overview of available green infrastructure calculators and models
 - Highlight specific green infrastructure modeling activities in other cities
- **Overview**
 - Background
 - Simple models and calculators
 - More complicated models

The Water Balance



Why Use a Model or Calculator

- **Applications**

- Large scale planning level
- Site or lot level

- **Purpose**

- Determine stormwater runoff reductions (total and peak)
- Determine pollutant load reductions and water quality benefits
- Monetize costs and benefits
- Facilitate design

Choosing a Model or Calculator

- **Understand your objective**
- **Understand information and data requirements**
- **Use simplest method that can meet the objective**
- **Weigh whether increased accuracy is worth increased effort**
- **Do not forget assumptions underlying the model**
- **Understand significance of model results**

Simple Models and Calculators

- **Uses**

- Scoping level tools that you can use to help approximate stormwater benefits
- Preliminary design and sizing estimations

- **Limitations**

- Mathematical abstractions
- Only as good as the data you have and assumptions you make
- Often use local or regional assumptions
- Typically single event calculations

Simple Models and Calculators

- **Common Calculation Methods**

- Runoff Volume
 - Runoff Curve Number Method (TR-55)
 - Small Storm Hydrology Method
 - Infiltration Models
- Peak Runoff Rate
 - NRCS Unit Hydrograph Method
 - Rational Method
- Pollutant Loading
 - Simple Method

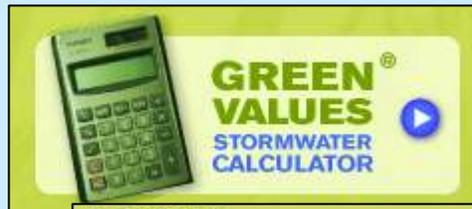
- **Typical Data Needs**

- Land use
- Soil types
- Rainfall data



Green Values Stormwater Calculator

Center for Neighborhood Technology



Calculator

Green Interventions:

- Roof Drains to Raingardens at All Downspouts:
- Half of Lawn Replaced by Garden with Native Landscaping:
- Porous Pavement used on Driveway, Sidewalk and other non-street pavement:
- Green Roofs:
- Provide Tree Cover for an Additional 25% of Lot:
- Use Drainage Swales instead of Stormwater Pipes:

Site Statistics:

- Select a scenario:
Custom
- Is this an existing site:
- Total size of site: 1.5 acres
- Number of lots: 1
- Average Roof Size, including Garage: 1200 ft.²
- Average Number of Trees on Lot: 0

- **Web-enabled application**
- **Planning tool with lot and neighborhood level calculations**
 - Hydrologic
 - Financial
- **Evaluate range of green infrastructure practices**

- **Pre-defined or custom inputs**
 - Landscape details
 - Cost elements
- **Integrated pop-up help screens**

Green Values Stormwater Calculator

Results

- Compare results for conventional system and chosen green intervention
 - Hydrologic
 - Financial

Hydrologic Results				
Lot Level Improvements:	Conventional	Green		Reduction
Lot Discharge (cf)	1,968	1,320		33.0%
Lot Peak Discharge (cfs)	0.48	0.30		37.4%
Total Site Improvements:	Conventional	Green		Reduction
Total Peak Discharge (cfs)	56.79	41.08		27.7%
Detention Size Improvements:	Conventional	Green		Reduction
Total Detention Required (ft ³)	148,908	90,075		40%
Annual Discharge Improvements:	Conventional:	Green:		Average Annual Ground Water Recharge Increase:
Average Annual Discharge (acre ft)	43.57	31.52		7.54

Financial				
Costs				
Present Value Over 100 Year Life Cycle:	Conventional	Green		Reduction
Per Lot Life Cycle Costs	\$89,171	\$76,092		\$13,079
Total Life Cycle Costs	\$7,133,706	\$6,087,390		\$1,046,316
First Year Site Construction and Maintenance Costs:	Conventional	Green		Reduction
Per Lot Costs	\$24,001	\$19,393		\$4,608
Total Costs	\$1,920,065	\$1,551,415		\$368,650
See how costs are calculated.				
Benefits				
Present Value Over 100 Year Life Cycle:	Conventional	Green		Increase
Per Lot Life Benefits	\$0	\$4,140		\$4,140
Total Life Benefits	\$0	\$331,165		\$331,165
See how benefits are calculated.				

Green Values Stormwater Calculator

Methods and Calculations

HYDROLOGIC

- **Lot discharge**
 - TR-55 Runoff Curve Number Method
 - 2-year, 24 hour storm
- **Lot peak discharge**
 - Rational Method

FINANCIAL

- **Life Cycle Costs**
- **Unit costs and lifespan data from literature review**
- **Monetized benefits from literature review**

All calculations and assumptions fully documented

Supporting calculations are provided in separate detail tabs

National Green Values Calculator

Center for Neighborhood Technology



Calculator

Getting Started | Lot Information | Predevelopment | Runoff

Green Improvements

- Green Roof
- Planter Boxes (disconnect downspout)
- Rain Garden (disconnect downspout)
- Cisterns / Rain Barrels (disconnect downspout)

- Native Vegetation
- Vegetation Filter Strips
- Amended Soil
- Roadside Swales (elimination of curb and gutter)
- Trees

- Swales in Parking Lot
- Reduced Street Width
- Permeable Pavement on Parking
- Permeable Pavement on Driveways and Alleys
- Permeable Pavement on Sidewalks

- Expanded calculator
- Limited to site level
- Contains broader range of green practices
- Calculates runoff volume reduction (no peak flow)
- Uses historic precipitation data, not design storms
- Compare against specific management goal
- Expected to be released later this spring

LID Quicksheet

Milwaukee Metropolitan Sewerage District

LID Quicksheet 1.1		SITE SUMMARY		Enter data into the shaded boxes only.	
PRECIPITATION and DRAINAGE AREA					
Line 1a	100	years	Return period for this storm event.		
1b	NRCS Type II		Rainfall distribution. See RainDistribution sheet to change.		
2a	P	5.88	inches	Total precipitation.	
2b	A	100.0	acres	Drainage area.	
2c	CN minimum	25		CNs must be greater than this value to generate runoff.	
NoLID DESIGN					
3a	CN	85		Area-weighted average for the NoLID site design.	
3b	Tc	30	minutes	Cannot be less than 5 minutes.	
LID DESIGN					
<u>Standard CN Determination</u>					
4a	CN	78		Area-weighted average for the LID site.	
<u>Optional CN Determination</u> If option not used, enter zeroes in Lines 4b-4d.					
4b	CN _p	70		Composite CN _p for pervious areas alone.	
4c	P _{imp}	30%		Actual percent impervious.	
4d		0.2		Decimal <= 1.0. Ratio of unconnected impervious area to total impervious area. (Enter "0" as the ratio if total impervious area is greater than 30% of site.)	
4e	CN result:	77		(The "CN _p " in TR-55 Appendix F)	
4f	Selected CN	77		Enter the value from Line 4a or Line 4e.	
4g	Tc	45	minutes	Cannot be less than 5 minutes.	
LID Retention Features For individual features, compare the contributing runoff with the capacity, and take the lesser of the two. Summarize on SubareaCheck sheet.					
Rain Garden Capacity					
5a		8.0	inches	Average ponding depth.	
5b		18.0	inches	Average soil mix depth available for retention (24 inches or less).	
5c		0.2	(unitless)	Average fillable porosity.	
5d		9.2	inches	Storage per unit area.	
5e	Rain Garden Coverage	4.0%	of drainage area used for rain gardens.	Design	Volume
5f		174240	sq.ft. (average of top and bottom areas)	acre-feet	gallons (thousand)
6a	Rain Barrels	55.0	gallons	3.07	999
6b		100	Number of rain barrels.	0.02	6
7a	Green Roofs	3.0	inches	Maximum Water Capacity (MWC).	
7b		0.50		Multiplier between 0.33 and 0.67.	
7c		10000	sq.ft.	0.03	9
8	Cisterns	1000	cu.ft.	0.02	7
9a	Permeable Pavement	5.0	inches	Storage depth, or capacity per unit area.	
9b		1600	sq.ft.	0.02	5
10	Other	80000	cu.ft.	1.84	598
Total				4.99	1625

- Excel spreadsheet
- Evaluates various green infrastructure features on a development site to reduce detention requirements
- Can evaluate 2-year and 100-year, 24 hour storm events
- Practices include:
 - Rain gardens
 - Rain barrels
 - Green roofs
 - Cisterns
 - Permeable pavement

RECARGA

University of Wisconsin-Madison

RECARGA Version 2.3
Bioretention/Raingarden Sizing Program

Units: Metric

Planview Data

Facility Area	404.8327 [m ²]
Tributary Area	4046.9 [m ²]
Percent Impervious	30
Pervious CN	80

Files

Regional Ave. ET	0.3302 [cm/day]
Simulation Type	Continuous
Input File Length	266 days
Precip. File Name	Med1981
Output File Name	MedXXXXXX

Facility Inputs

Soil Texture	Infiltration Rate [cm/hr]	Depth [cm]
Depression		15.24
Root Layer (Loamy Sand)	10.0076	60.96
Storage Layer (Sand)	15.0114	0
Native Soil Layer (Silt Loam)	0.3302	

Underdrain

Flowrate	0 [cm/hr]
Diam.	0 [mm]

Raingarden Water Balance

	[cm]	%
Runon	0	0
Runoff	0	0
Recharge	0	0
Evaporation	0	0
Underdrain	0	0
Soil Moisture	0	0
Stay-on	0	0

Target Stay-on: 66.04 cm

Wisconsin-Madison Water Resources Group (L. Severson)

- MATLAB application
- Design tool for evaluating performance of bioretention facilities and infiltration basins
- Model can simulate continuous rainfall, a single-event, or user specified volume

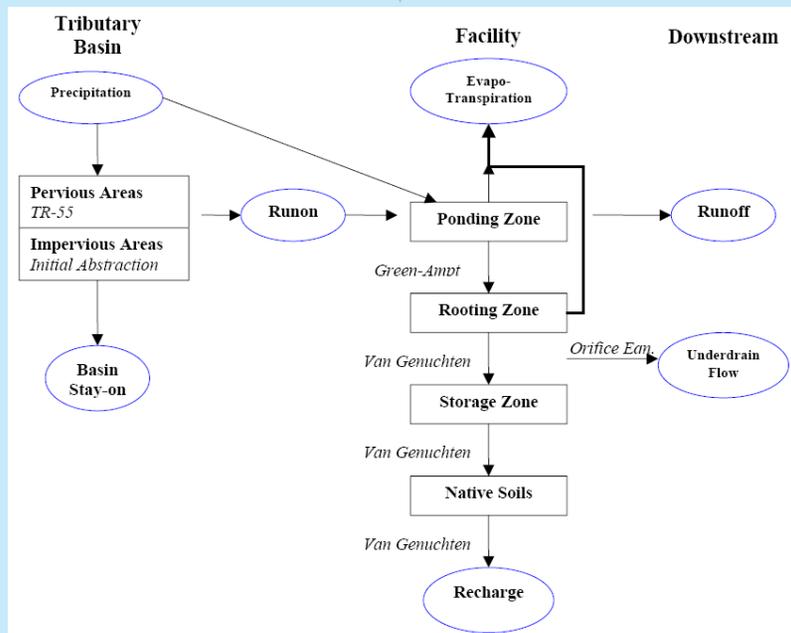
- User inputs
 - Rainfall and evaporation file
 - Drainage area characteristics
 - Layer characteristics

RECARGA

Calculations and Results

- Model calculates movement of water through facility and water balance at each time step

- Results shown in application
 - Plant Survivability
 - Tributary Runoff
 - Rain Garden Water Balance
- Summary output text file
- Record file output with water balance quantities for each time step



Results		
Plant Survivability		
(Less than 48 hours max. ponding is desirable)		
	max.	Total
Hrs. Ponded	<input type="text" value="0"/>	<input type="text" value="0"/>
Number of overflows	<input type="text" value="0"/>	
Tributary Runoff [cm]		
Precipitation	<input type="text" value="0"/>	
Impervious Runoff	<input type="text" value="0"/>	
Pervious Runoff	<input type="text" value="0"/>	
Raingarden Water Balance [cm] %		
Runon	<input type="text" value="0"/>	<input type="text" value="0"/>
Runoff	<input type="text" value="0"/>	<input type="text" value="0"/>
Recharge	<input type="text" value="0"/>	<input type="text" value="0"/>
Evaporation	<input type="text" value="0"/>	<input type="text" value="0"/>
Underdrain	<input type="text" value="0"/>	<input type="text" value="0"/>
Soil Moisture	<input type="text" value="0"/>	<input type="text" value="0"/>
Stay-on	<input type="text" value="0"/>	<input type="text" value="0"/>

Long-Term Hydrologic Impact Assessment Model

Local Government Environmental Assistance Network

LAND USE	SCENARIO 1		HYD. SOIL GROUP (View Maps)	SELECT Land use Similar to the Custom Land use	Modify EMC Values if Desired (all concen				
	Area				Nitrogen	Phosphorou	Susp Solids	Lead	Copper
Residential 1/4 acre	500		C	SELECT LANDUSE	1.82	0.57	41	0.009	0.009
Residential 1/8 acre	400		A	SELECT LANDUSE	1.82	0.57	41	0.009	0.009
Parking/Paved Spaces	150		D	SELECT LANDUSE	1.82	0.57	41	0.009	0.009
Residential 1/2 acre	275		A	SELECT LANDUSE	1.82	0.57	41	0.009	0.009
Grass/Pasture	1000		A	SELECT LANDUSE	0.7	0.01	1	0.005	0.010
SELECT LANDUSE			A	SELECT LANDUSE					
SELECT LANDUSE			A	SELECT LANDUSE					
SELECT LANDUSE			A	SELECT LANDUSE					
SELECT LANDUSE			A	SELECT LANDUSE					
SELECT LANDUSE			A	SELECT LANDUSE					

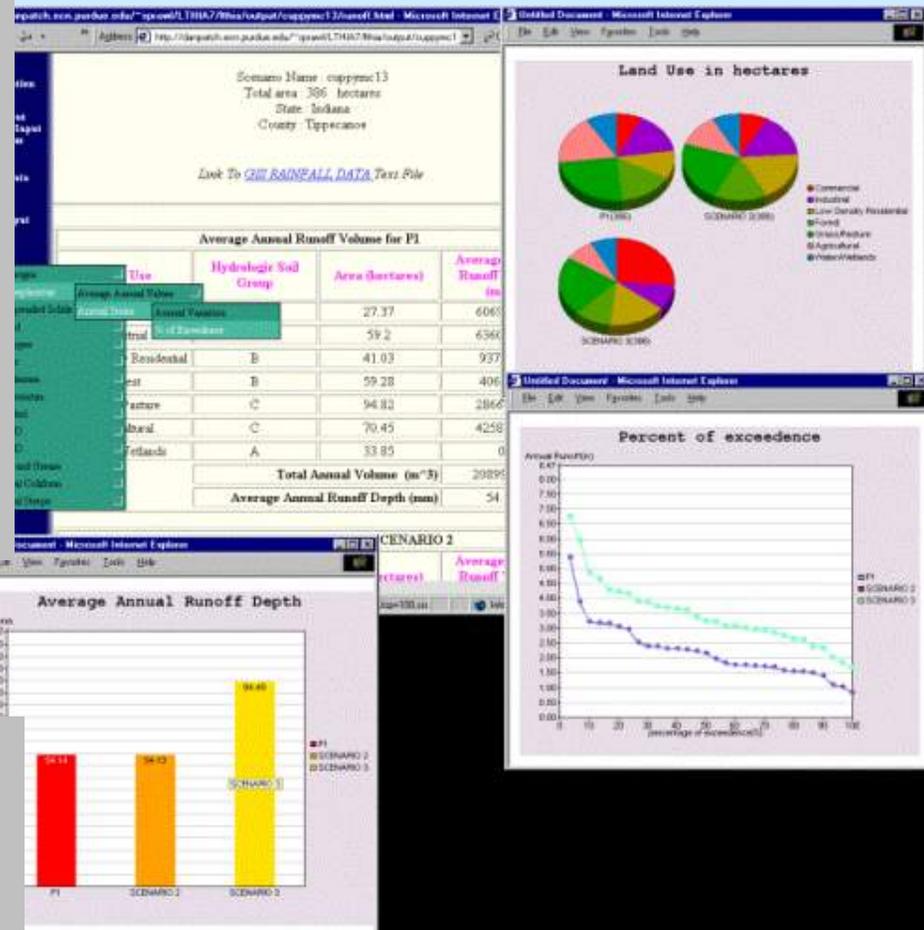
Land Use ?	Soil Type ?	Area ?	Current	Scenario 1	Scenario 2
(Use as many as necessary)	Check Map				
Commercial	B		10	15	0
Industrial	C		20	35	0
Agricultural	A		40	20	0
High Density Residential	B		10	20	0
Forest	A		20	10	100
SELECT LAND USE	A				
SELECT LAND USE	A				
SELECT LAND USE	A				
SELECT LAND USE	A				
Total Area:			100	100	100

- **Web enabled tool**
- **Used to quantify the impact of land use change on water quantity and quality**
- **Five versions:**
 - **Basic L-THIA**
 - **Impervious L-THIA**
 - **GIS L-THIA**
 - **Detailed Input L-THIA**
 - **Advanced Input L-THIA**

Long-Term Hydrologic Impact Assessment Model

Calculations and Results

- Uses Runoff Curve Number approach
- Uses 30 years of precipitation data to predict yearly runoff
- Event Mean Concentrations are used to estimate pollutant loading



- Provides graphical and tabular runoff volumes and associated pollutant loads

Pollutant Load and Reduction Model

Comprehensive Environmental Inc (CEI)

- Excel-based tool
- Site level calculations of pollutant load reductions based on BMPs
- Assign area, landuse category, and BMPs to each watershed

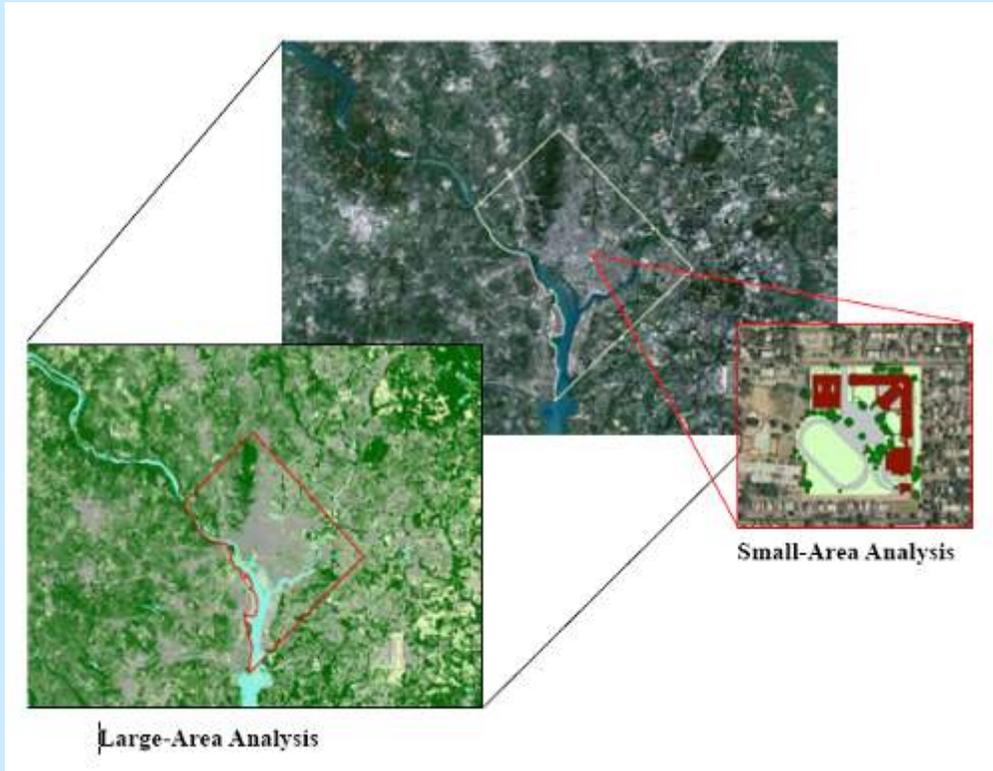
- Literature values for
 - % impervious
 - Pollutant loading
 - Pollutant removal efficiency
- Uses Simple Method to calculate pollutant removal results
 - Annual TSS removed
 - Annual TP removed
 - Annual TN removed

No.	Watershed Name	Landuse	Area (acres)
1	AF-1	Industrial	450.00
2	AF-2	Commerical	122.00
3	AF-3	Residential-Low Density	380.00
4	AF-4	Residential-High Densiv	226.00
5	LG-6	Comr	
6			
7			

No.	Watershed Name	BMP Type	BMP Drainage Area (acres)	TSS Removal (%)	TP Removal (%)	TN Removal (%)	Annual TSS Removed (lbs)	Annual TP Removed (lbs)	Annual TN Removed (lbs)
1	AF-1	Constructed Wetland		80%	55%	30%	0	0.00	0.0
2	#REF!	Infiltration - 1"		90%	65%	58%	0	0.00	0.0
3	AF-2	Raingarden - 1"		90%	65%	58%	0	0.00	0.0
4	AF-3	Baffle Tank		70%	30%	0%	0	0.00	0.0
5	LG-6	Constructed Wetland		80%	55%	30%	0	0.00	0.0
6							0	0.00	0.0

CityGreen

American Forests



- ArcGIS extension (not free)
- Analyzes ecological and economic benefits of tree canopy and other green space for any size area
- Analyzes user provided land cover raster data

CityGreen

Calculations and Results

- **Stormwater Runoff**

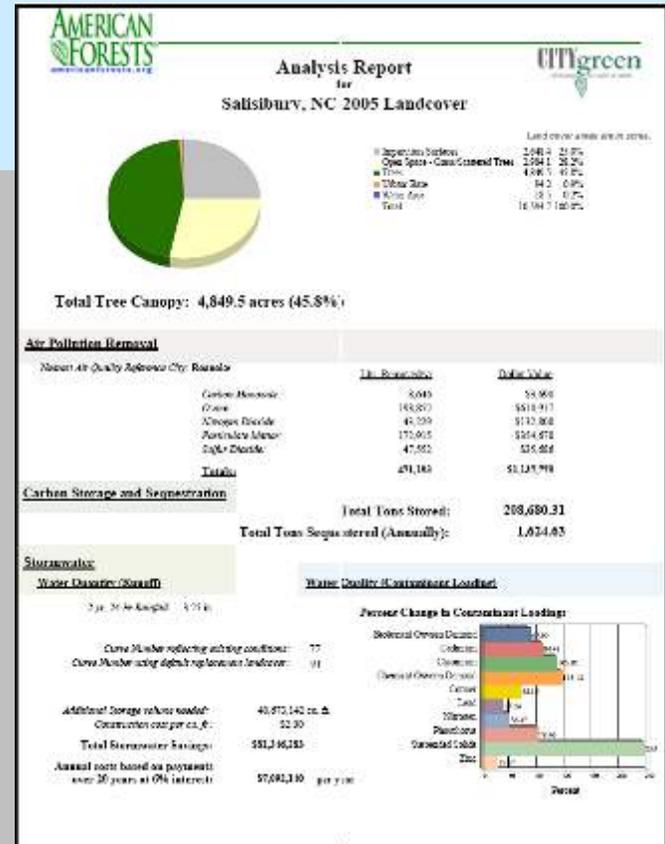
- Calculates runoff volume based on 2-year, 24-hour storm
- Based on Runoff Curve Number (TR-55)

- **Air Pollution Removal**

- Calculates pollutant removal capacity of tree canopy and financial benefit
- Based on US Forest Service air pollution model

- **Carbon Storage and Sequestration**

- Calculates amount of carbon stored in trees and annual carbon removal
- Based on US Forest Service model



- **Additional free web-based air pollution calculator**

GreenSave Calculator

Green Roofs for Healthy Cities



Configuration Page | **LCC Assumptions & Results** | Scenario #1 Calculator | Scenario #2 Calculator | Scenario #3 Calculator | Roof Durability Module | Energy Use Module

Heat Island Module | Development Fees Module | Saleability/Rentability | Tenant Health & Productivity

GreenSave Calculator - LCC Assumptions & Results
 developed by the Athena Institute for Green Roofs for Healthy Cities (GRHC)

The light yellow "shaded" cells are entered directly by the user, while the darker yellow "shaded" cells are copied "referenced" from worksheet modules
 violet "shaded" cells are calculated by model
 orange "shaded" cells represent default values, but may be changed by the tool user

Hide Header

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	Conventional Mod. Bit	PVC Single Ply Cool Roof	Extensive Green Roof
Date (MM-DD-YYYY)	06-01-2007	06-01-2007	06-01-2007
Completed by:	Jamie Meil	Jamie Meil	Jamie Meil
Company	Athena Institute	Athena Institute	Athena Institute
Contact phone number	613.722.8075	613.722.8075	613.722.8075
Contact email	jamie.meil@athenasmi.ca	jamie.meil@athenasmi.ca	jamie.meil@athenasmi.ca
Project Initiation year	2007	2007	2007
Study Period in years	25.00	25.00	25.00
Applicable discount (hurdle) rate (%)	8.0000	8.0000	8.0000
General price inflation factor (%)	2.0400	2.0400	2.0400
Thermal fuel energy price inflation factor (%)	9.0000	9.0000	9.0000
Electricity price inflation factor (%)	3.0000	3.0000	3.0000
INVESTMENT DATA			
Investment Name (description)	Conventional Mod. Bit	PVC Single Ply	Extensive Green Roof
Total Installed Capital Cost (excluding grants or subsidies)	\$ 49,728.00	\$ 41,440.00	\$ 103,600.00
Annual Electricity Energy Cost	\$ 250.02	\$ 232.56	\$ 232.47
Annual Heating Energy Cost	\$ 2,653.00	\$ 2,653.00	\$ 2,600.00

- Web-enabled tool (registration required)
- Life-cycle costing tool used to compare cost of green roof with conventional roof
- Option to publish data to Case Study database
- Modules with minimum and optional detailed data inputs
 - Roof durability
 - Energy use
 - Stormwater
 - Heat island
 - Development fees
 - Saleability/rentability
 - Tenant health and productivity

GreenSave Calculator

Results

GreenSave Calculator - Scenario #1									
Project Name: Conventional Mod. Bit. Scenario Name: Conve									
Hide Header									
Project Initiation year	2007		Periodic Salvage / Resale value (\$)	0.00					
Discount (Hurdle) Rate (%)	8.0000		Replacement Cost(\$)	59,046.50					
General Price Inflation (%)	2.0400		End-of-life Residual Value(\$)	27,972.00					
Thermal fuel price inflation (%)	9.0000		Replacement time (at year)	0.00					
Electricity Price Inflation (%)	3.0000								
Study Period (years)	25.00								
		(49,728.00)	(761.00)	(2,653.00)	(250.00)	0.00	0.00	0.00	
Year	Num.	Initial Equity Investment	Annual Maintenance	Annual Thermal Fuel Cost	Annual Electricity Cost	Rental Income	Inc. Health Productivity	Other Annual Benefit or (Cost)	Per Cos
	0.00	(49,728.00)							
2007	1.00	0.00	(776.52)	(2,891.46)	(257.52)	0.00	0.00	0.00	0.00
2008	2.00	0.00	(792.37)	(3,151.70)	(265.25)	0.00	0.00	0.00	0.00
2009	3.00	0.00	(808.53)	(3,435.35)	(273.20)	0.00	0.00	0.00	0.00
2010	4.00	0.00	(825.02)	(3,744.53)	(281.40)	0.00	0.00	0.00	0.00
2011	5.00	0.00	(841.85)	(4,081.54)	(289.84)	0.00	0.00	0.00	0.00
2012	6.00	0.00	(859.03)	(4,448.88)	(298.54)	0.00	0.00	0.00	0.00
2013	7.00	0.00	(876.55)	(4,849.28)	(307.49)	0.00	0.00	0.00	0.00
2014	8.00	0.00	(894.43)	(5,285.71)	(316.72)	0.00	0.00	0.00	0.00
2015	9.00	0.00	(912.68)	(5,761.42)	(326.22)	0.00	0.00	0.00	0.00
2016	10.00	0.00	(931.30)	(6,279.95)	(336.01)	0.00	0.00	0.00	0.00
2017	11.00	0.00	(950.30)	(6,845.15)	(346.09)	0.00	0.00	0.00	0.00
2018	12.00	0.00	(969.68)	(7,461.21)	(356.47)	0.00	0.00	0.00	0.00
2019	13.00	0.00	(989.47)	(8,132.79)	(367.16)	0.00	0.00	0.00	0.00

- Compare up to three roofing configurations
- Results table includes:
 - Annual cash flows by cost/savings element
 - Resultant total cash flow for individual years on both a nominal and discounted basis
 - Calculated life cycle cost results for investment over the expected life

Other Simple Models and Calculators

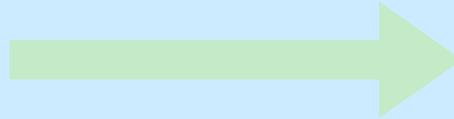
- **LTCP-EZ (EPA, LimnoTech)**
- **TSA Design Tools (T.E. Scott and Associates)**
- **Site Evaluation Tool (SET) (Tetra Tech)**
- **Storm Water Runoff Volume Calculator (UC Davis Extension)**
- **Urban Forest Effects Model (UFORE) (USDA Forest Service)**
- **Street Tree Management Tool for Urban Forest Managers (STRATUM) (Center for Urban Forest Research)**
- **Rainwater Harvester Design Model (NC State Cooperative Extension)**
- **Bioretention Thermal Model (NC State Cooperative Extension)**
- **Watershed Treatment Model (Center for Watershed Protection)**

- **MORE?**

More Complicated Models

Hydrologic Model

- Simulates flow of water over land surface



Hydraulic Model

- Simulates flow of water through pipe network

- EPA Stormwater Management Model (SWMM)
- EPA System for Urban Stormwater Treatment and Analysis INtegration (SUSTAIN)
- Model for Urban Sewers (MOUSE)
- Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds (P8)
- Hydrological Simulation Program – Fortran (HSPF)
- Hydrologic Modeling System (HEC-HMS)
- Source Loading and Management Model (WinSLAMM)
- Better Assessment Science Integrating Point and Nonpoint Sources (BASINS)
- Prince George's County (MD) Best Management Practice Decision Support System (PG BMP-DSS)

More Complicated Models

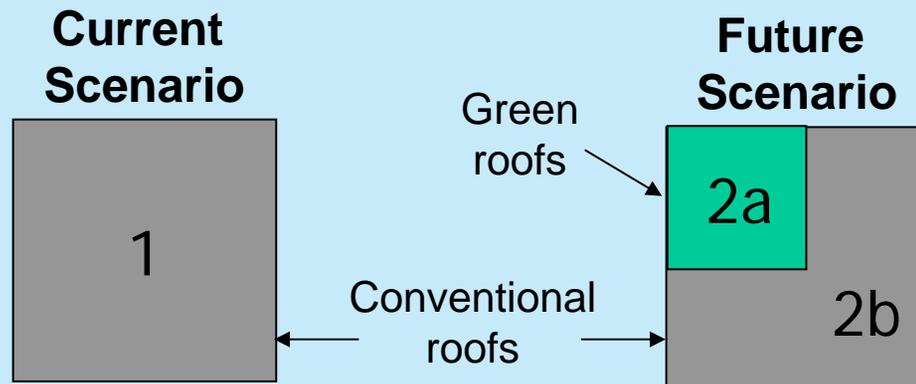
- **Uses**

- Evaluate watershed impacts of land use decisions
- More accurately approximate stormwater benefits of green infrastructure
- Can be used for single-event or continuous simulation

- **Limitations**

- Data intensive
- Require specific expertise to utilize

More Complicated Models



- **Create catchments based on land use or surface type**
- **Assign parameter values to each catchment**
 - Infiltration rates
 - Slopes
 - Dimensions/travel time
 - Surface roughness
 - Depression storage

- **Typical Data Needs**

- Topography
- Soil types
- Meteorological records
- Evapotranspiration rates
- Built structures (roads, buildings, other impervious, etc.)
- Pipe network and control structures
- Flow meter data

Washington, DC

Green Build-out Model Overview



- **Objective**

- Quantify the contribution that green infrastructure could make towards reducing storm-water runoff and volumes and frequencies of discharge to the District's rivers

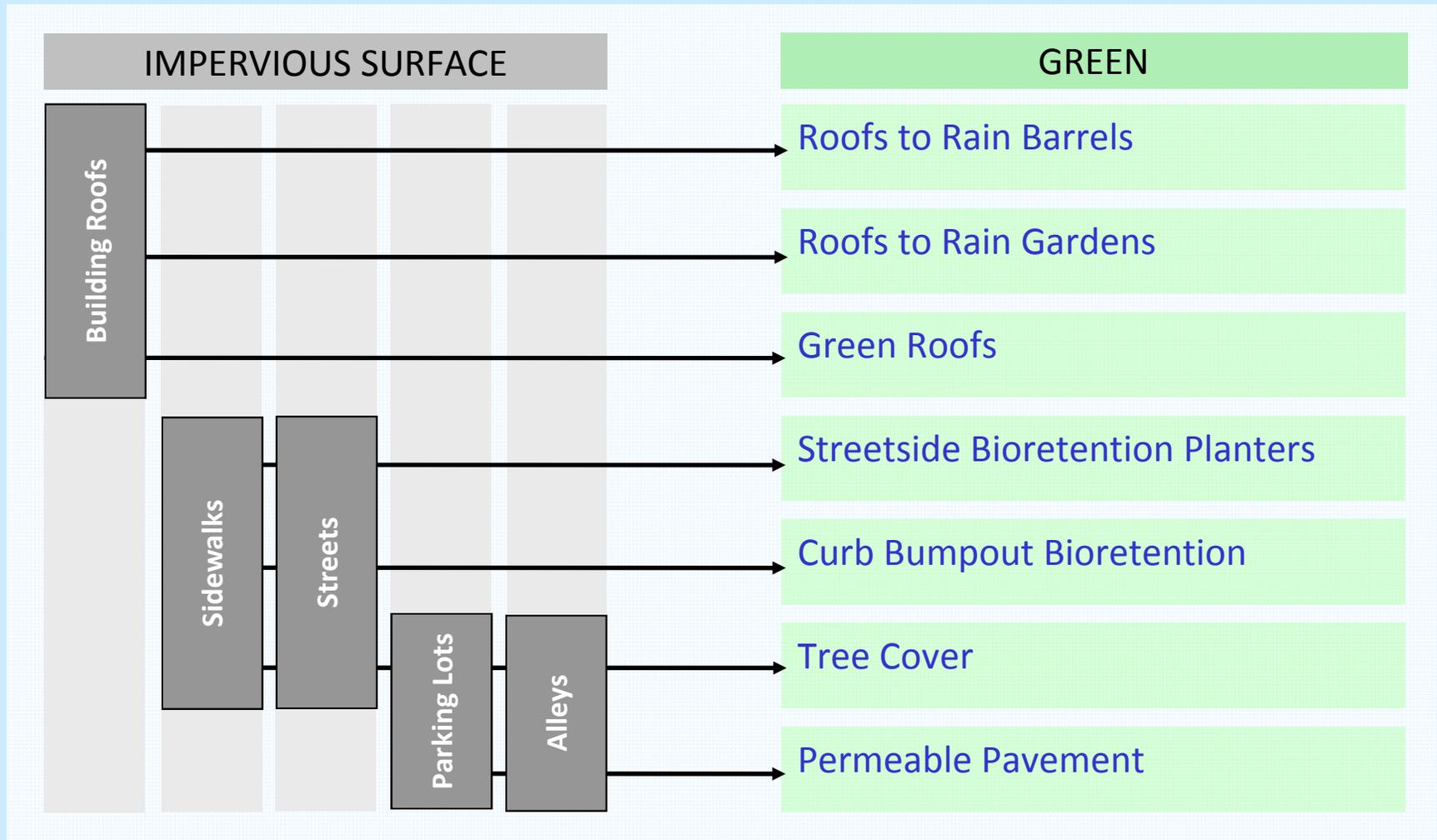


- **Approach**

- Developed conceptual plan for integrating green infrastructure into landscape
- Performed detailed GIS analysis to identify opportunities for green infrastructure retrofits
- Modified existing H&H model for the District (MOUSE)

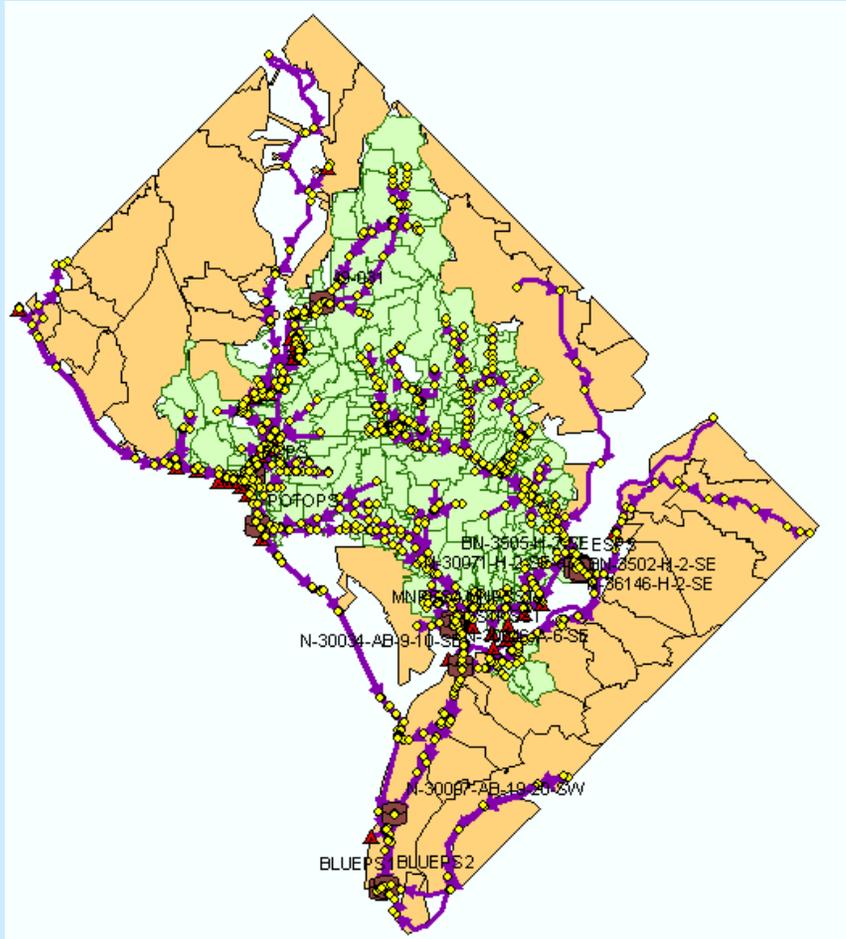
Washington, DC

Conceptual Plan and Opportunity Analysis



Washington, DC

Model Details

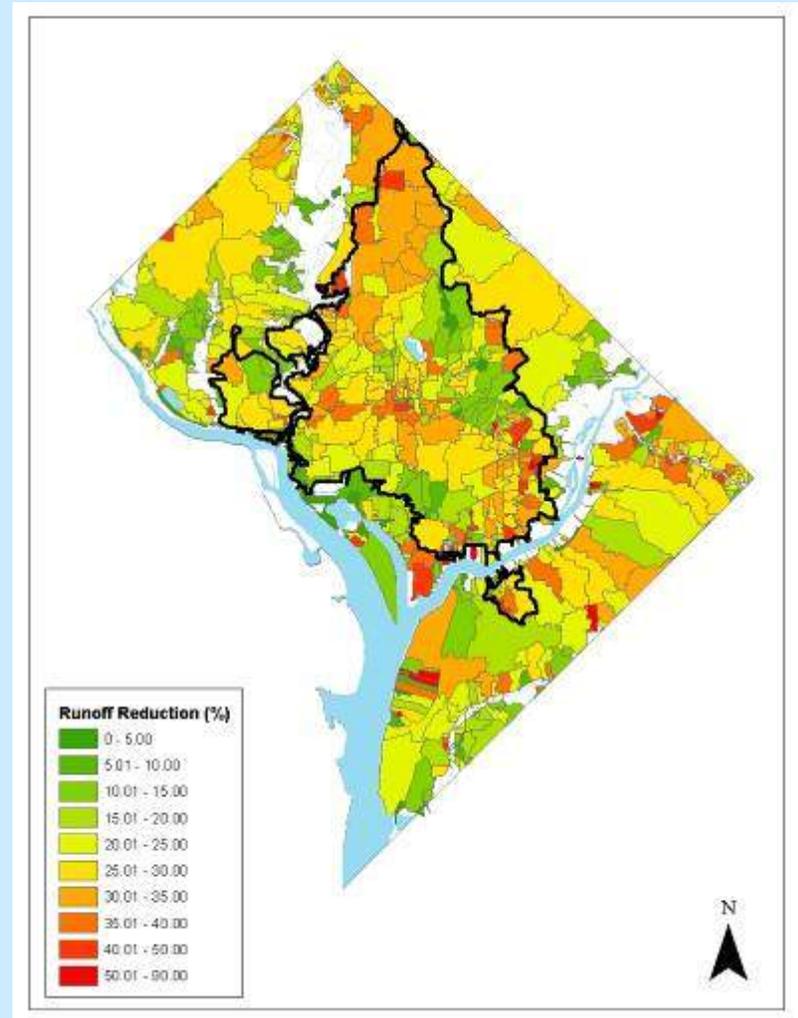


- H&H model used by WASA for LTCP development
- Calibrated to actual flow data
- Add MS4 area to model
- Modify inputs to mimic green infrastructure
 - Storage
 - Infiltration
 - Surface roughness
 - Potential evapotranspiration
- Continuous simulation, hourly precipitation data, average year

Washington, DC

Model Results

- **Annual reduction of runoff**
 - District wide - 4.3 billion gallons (26%)
 - Greater than 50% reductions in individual sewersheds
- **Annual reduction of discharges to rivers**
 - District-wide - 3 billion gallons (30%)
 - CSS area - 1 billion gallons (43%)



Cincinnati

MSDGC LID Assessment

- **Objective**
 - “Derive a preliminary estimate of LID control requirements and effectiveness over a range of reasonable LID implementation scenarios within MSDGC’s CSO area”



Photo: AP/Al Behrman



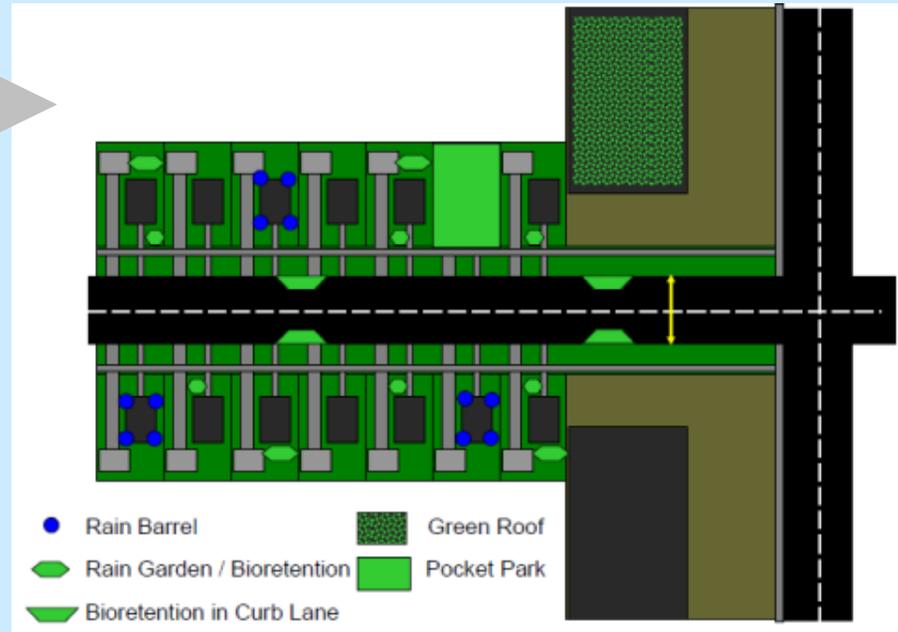
- **Approach**
 - Performed detailed land use characterization
 - Identified LID opportunities
 - Modeled representative CSO sewershed (Lick Run)
 - Applied modeled sewershed findings to entire CSO area

Cincinnati

LID Opportunities in Lick Run Sewershed

- **LID Opportunities**

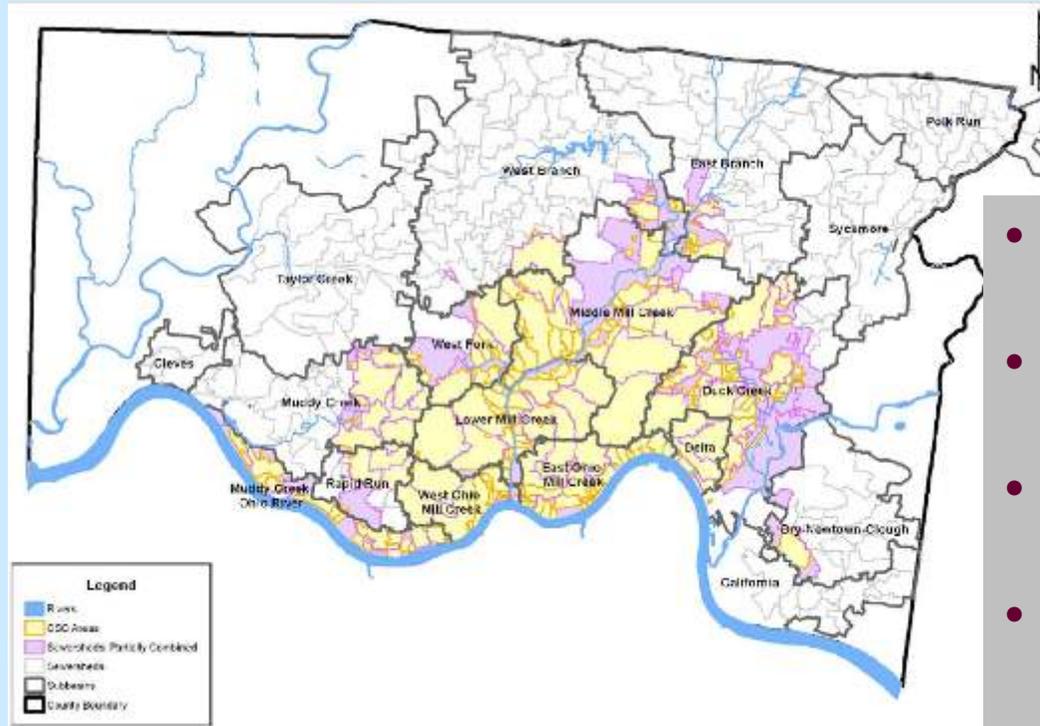
- Roof tops
 - Green roofs and roof top storage
 - Roof leader disconnection and bioretention
- Parking/driveways
 - Bioretention
 - Permeable pavement
- Streets
 - Curb-side bioretention
 - Infiltration swales



- **Land Use Characterization**
- **Scenario Development**

Cincinnati

Model Details



- Used SWMM-based System Wide Model
- Modified subcatchments for base model and recalibrated
- Added subcatchments with green infrastructure practices
- Modeled three rainfall events and continuous simulation of typical year
- Spreadsheet evaluation to examine benefits across CSO area

Cincinnati

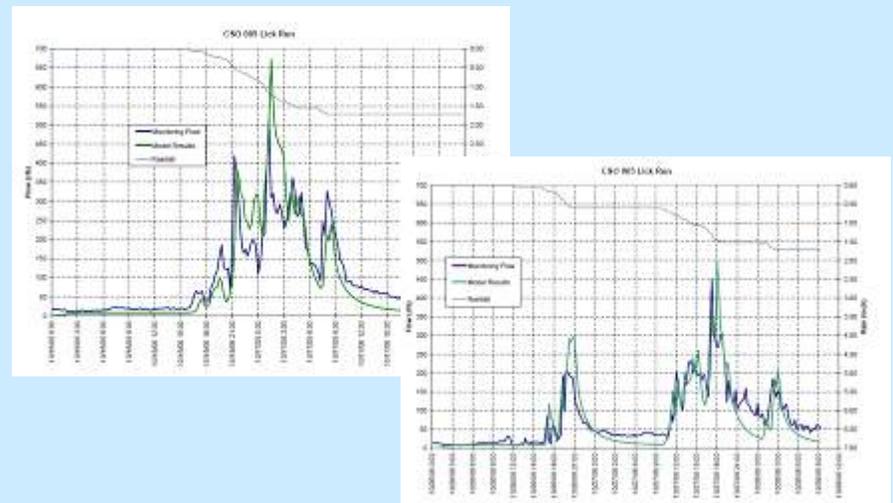
Model Results

- **Lick Run Model Results**

- Single event evaluations
 - 10% reduction in peak flow rates
 - 4 to 7% reduction in overflow volume
- Typical year evaluations
 - Capture volume scenario = 8.9-12.6% reduction in overflow volume
 - Managed impervious surface scenario = 7.2 to 17.5% reduction in overflow volume

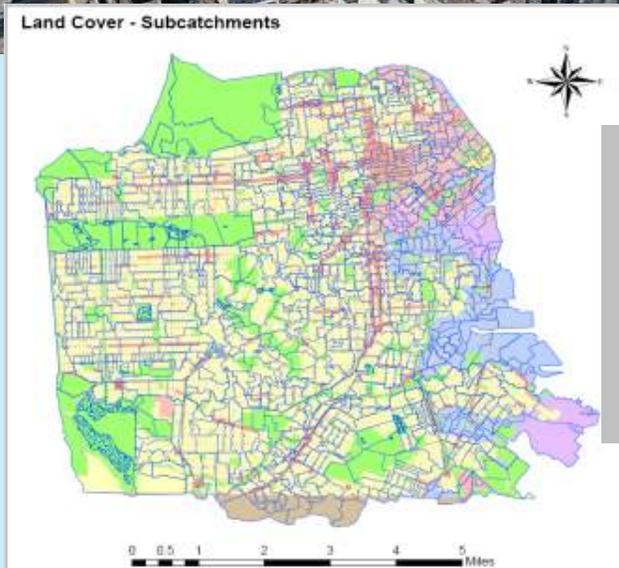
- **CSO Area**

- Typical year evaluations
 - Low LID implementation = 1.5% to 13.5% runoff reduction
 - High LID implementation = 3.4 to 30.6% runoff reduction



San Francisco

Green Evaluation with InfoWorks



- **Objectives**

- Identify the extent that LID techniques could be implemented
- Calculate the drainage improvements that could be achieved by installing LID facilities throughout the city

- **Approach**

- Identified LID opportunities through GIS analysis
- Modeled LID practices

San Francisco

LID Opportunity Analysis



- **Performed infiltration potential analysis**
- **Created parking lot and rooftop coverage**
- **Applied siting constraints**

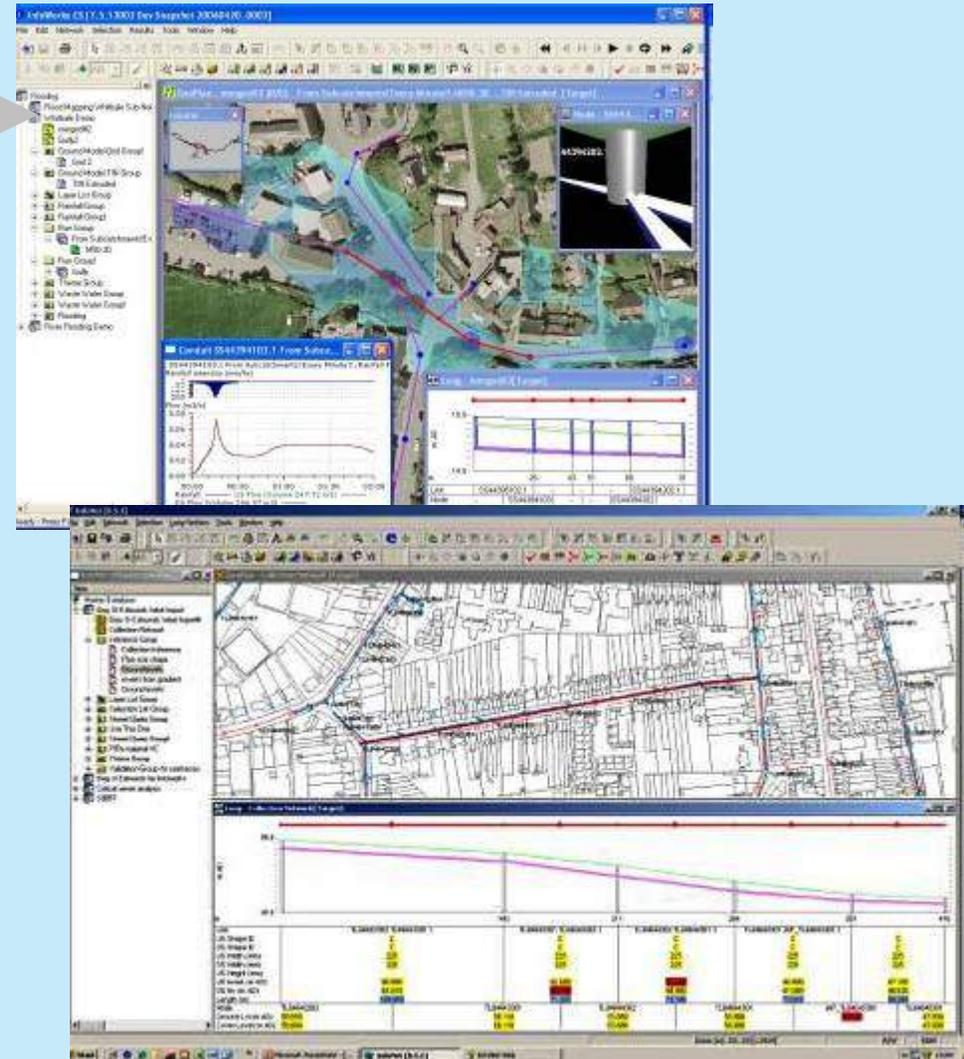
- **LID Opportunities**

- Roof tops
 - Green roofs
 - Roof disconnection
- Streets/sidewalks/parking lots
 - Tree planting
 - Lined bioretention
 - Permeable pavement

San Francisco

Model Details

- Used existing InfoWorks collection system model
- High and low performance measures were used
- Model integration
 - Green roofs - modified roughness and depression storage
 - Rooftop disconnection - removed roof area
 - Trees - modified interception storage
 - Lined bioretention and permeable pavement – modified detention storage



San Francisco

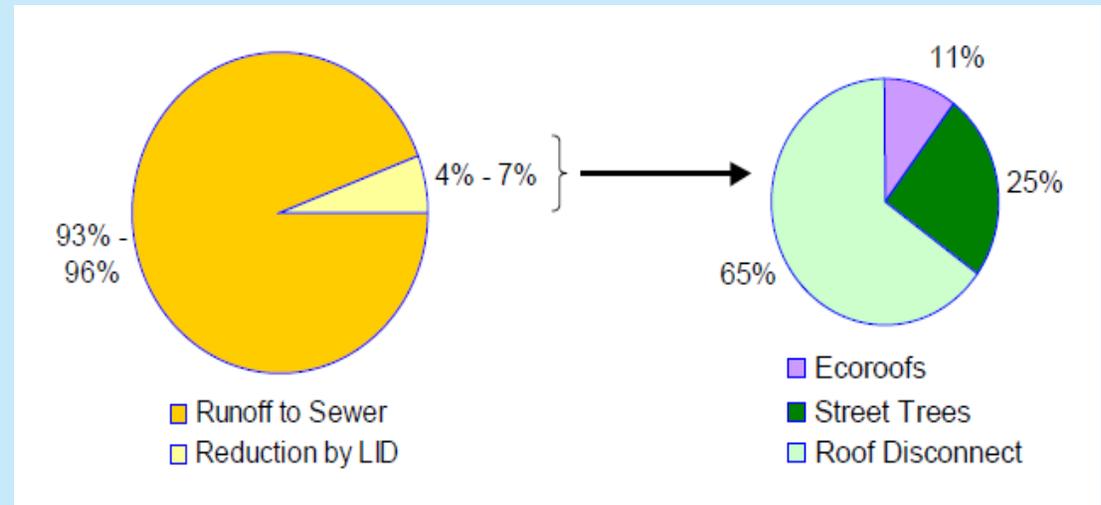
Model Results

- **Runoff volume**

- Annual reduction of 400 to 700 MG (4 to 7%)
- Green roofs = 5 to 6 gal per sq ft
- Trees = 1,100 to 1,500 gal per tree
- Roof disconnect = 7 to 14 gal per sq ft

- **Peak flow rate**

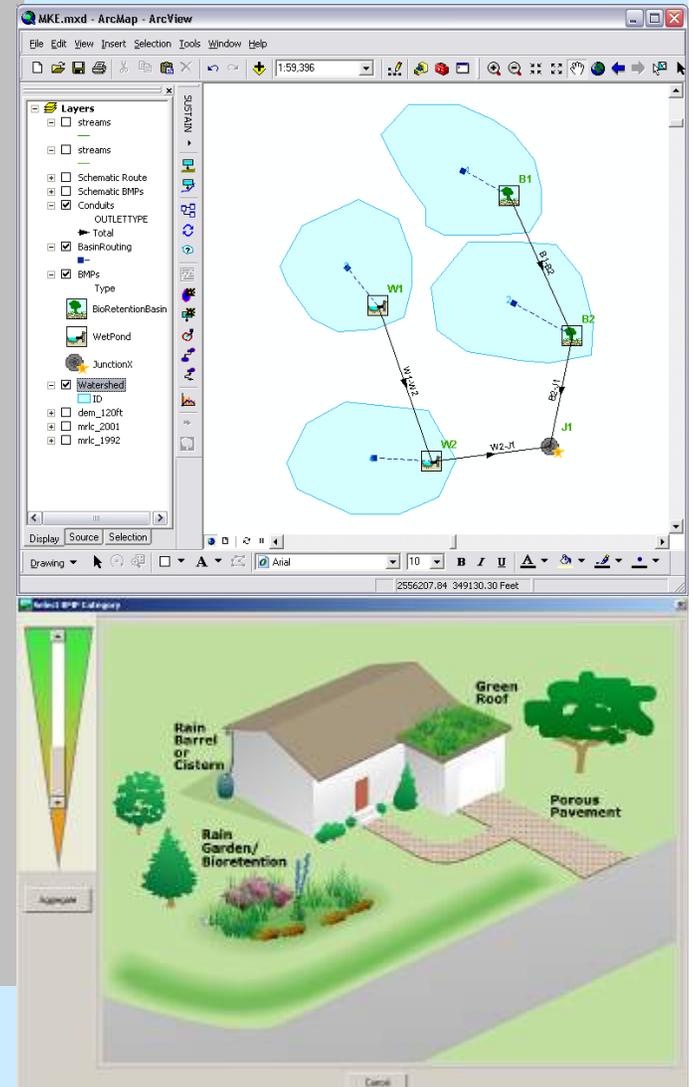
- 3-month, 24-hour = 11.3 to 15.1%
- 1-year, 24-hour = 10.7 to 14.6%



- **Lined bioretention and permeable pavement do not affect runoff volume but do affect peak flow rates**

EPA System for Urban Stormwater Treatment and Analysis INtegration (SUSTAIN)

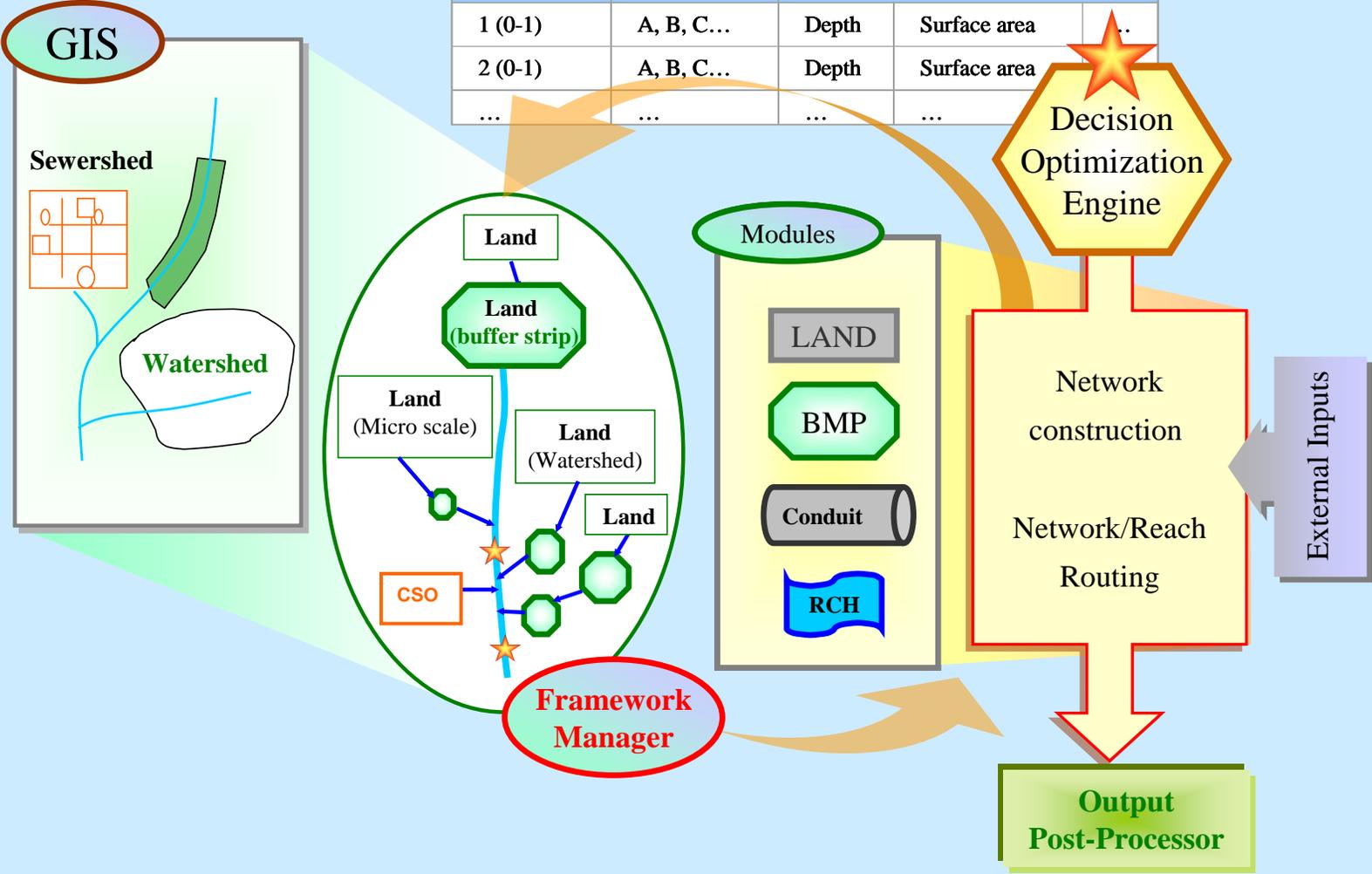
- A GIS-based framework designed to support decision-making
- Answers key questions
 - How effective are BMPs or green infrastructure techniques in reducing runoff and pollutant loadings?
 - What are the most cost effective solutions to meet water quantity and quality objectives?
 - Where, what type, and how large should they be?
- Will be released after June '09



SUSTAIN Framework Manager

Decision Matrix

Potential Location	BMP types	BMP configuration		
1 (0-1)	A, B, C...	Depth	Surface area	..
2 (0-1)	A, B, C...	Depth	Surface area	..
...



Platform: ArcGIS 9.x

Conclusions

- **Understand your objective**
- **Understand information and data requirements**
- **Use simplest method that can meet the objective**
- **Weigh whether increased accuracy is worth increased effort**
- **Do not forget assumptions underlying the model**
- **Understand significance of model results**

Questions?

Contact information

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LimnoTech

1705 DeSales Street NW, Ste 600

Washington, DC 20036

202-833-9140

bbusiek@limno.com



Louisville: The Green City

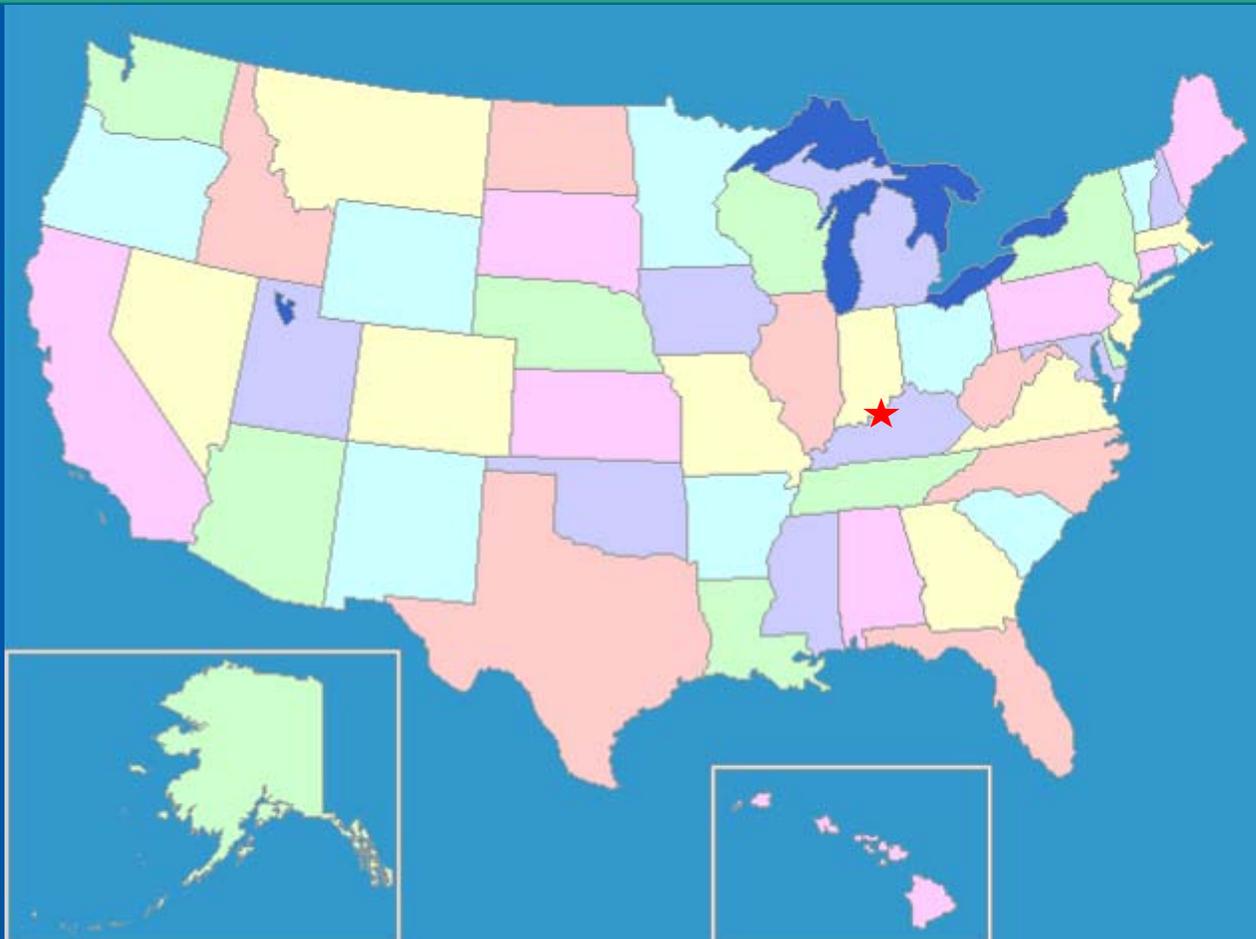
From Raindrops to Rivers: A Vision for Integrating Green Solutions Into CSO Management



CLEAN, GREEN, GROWING COMMUNITY



Louisville, Kentucky



CLEAN, GREEN, GROWING COMMUNITY



Acknowledgements



Hagerty Engineering, Inc.



CLEAN, GREEN, GROWING COMMUNITY



Green Program Objectives

- **Augment traditional “gray” engineering solutions**
 - Comprehensive CSS evaluation drives site specific solutions
 - Focus on quantity (i.e reduce runoff)
- **Assist in achieving regulatory compliance**
 - **Sewer overflow Consent Decree**
- **Cost effective**
 - green commitments based on a “business case”
- **Provide supplemental benefits**
 - habitat, air quality, urban beautification
 - public amenities (i.e community connectivity)
 - builds upon the current planning and priority initiatives of Metro Government

Green Infrastructure Strategy

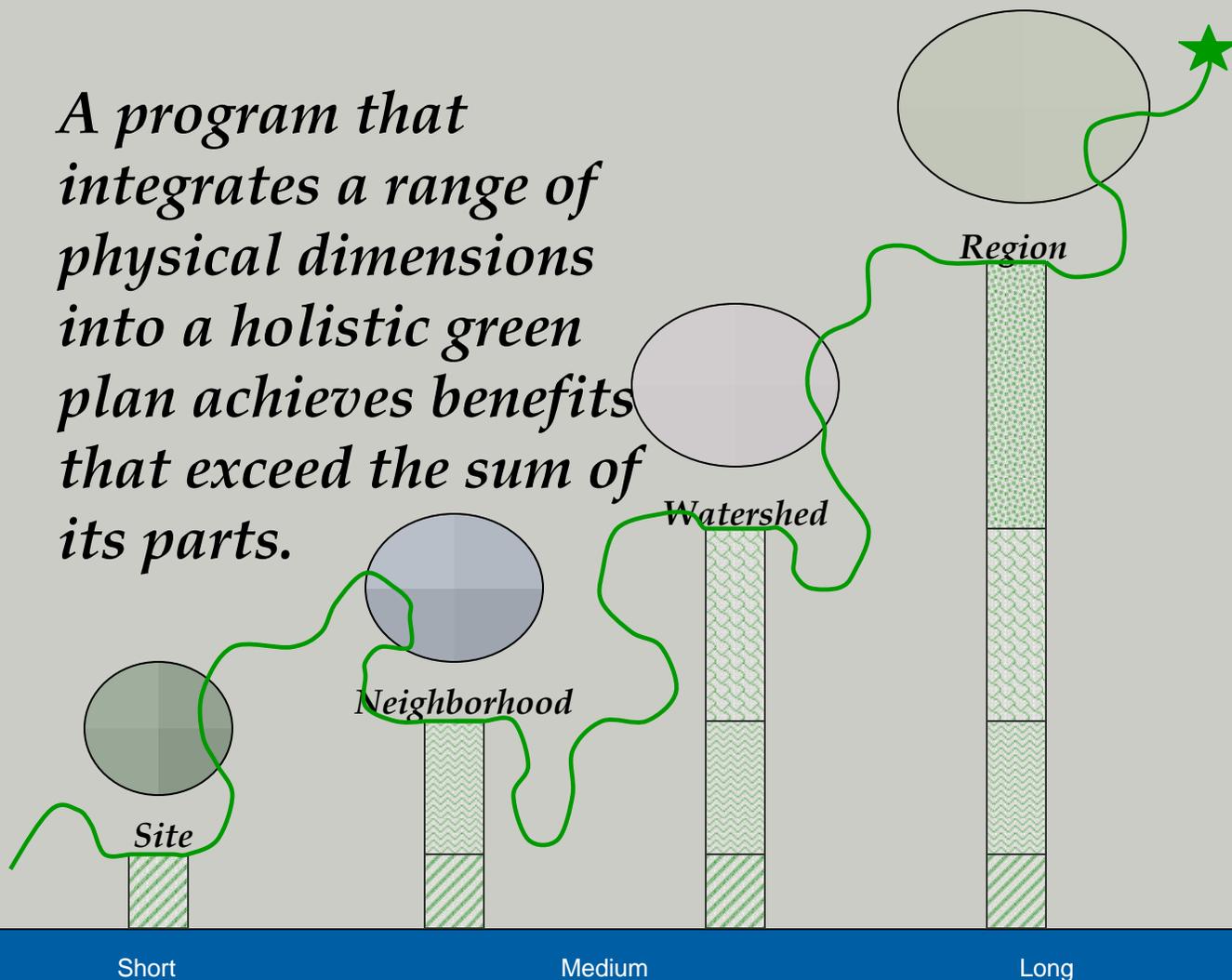
Relative Impact

High

Medium

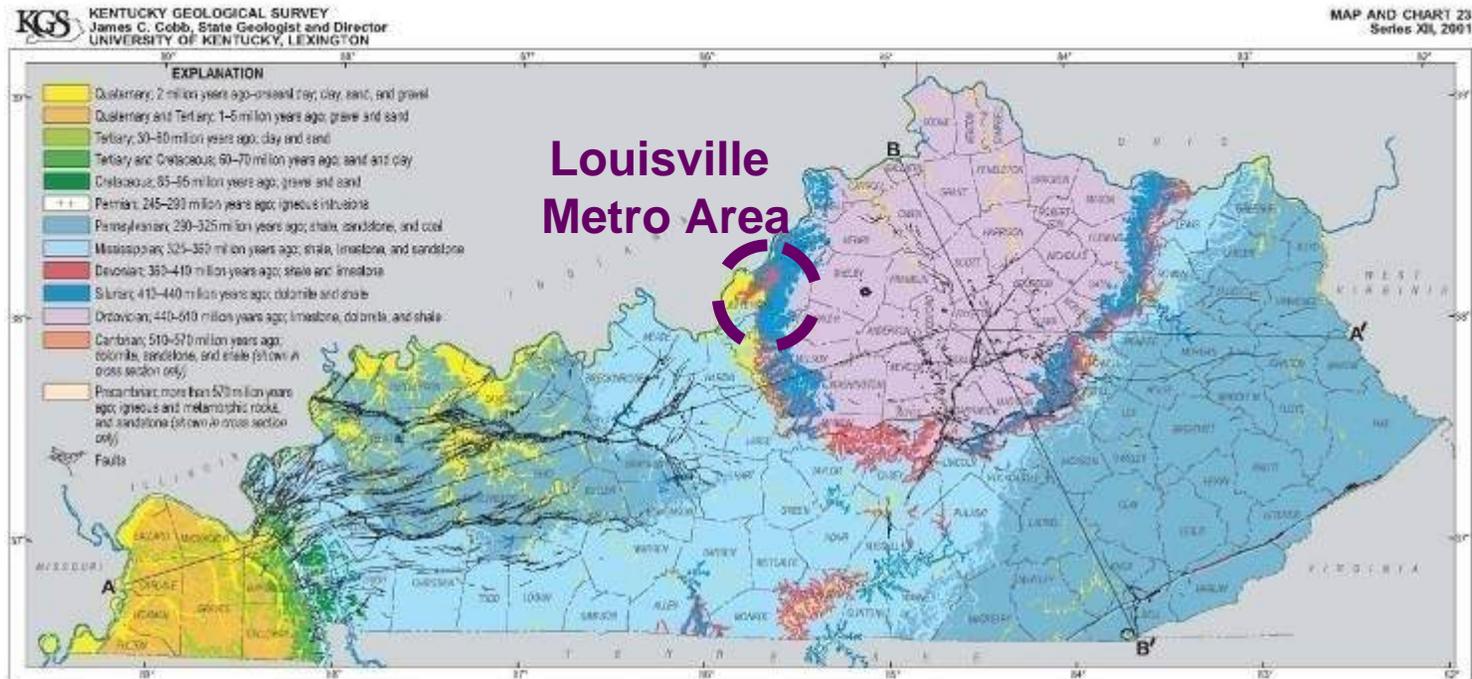
Low

A program that integrates a range of physical dimensions into a holistic green plan achieves benefits that exceed the sum of its parts.

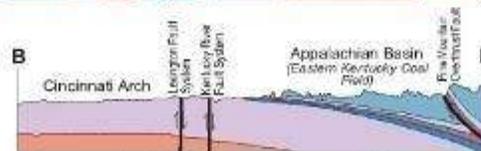
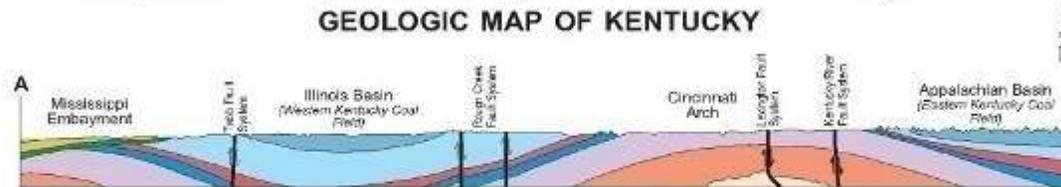


Time Frame

State Geology



GEOLOGIC MAP OF KENTUCKY



Generalized geologic cross sections

Cross sections are diagrammatic;
not to scale

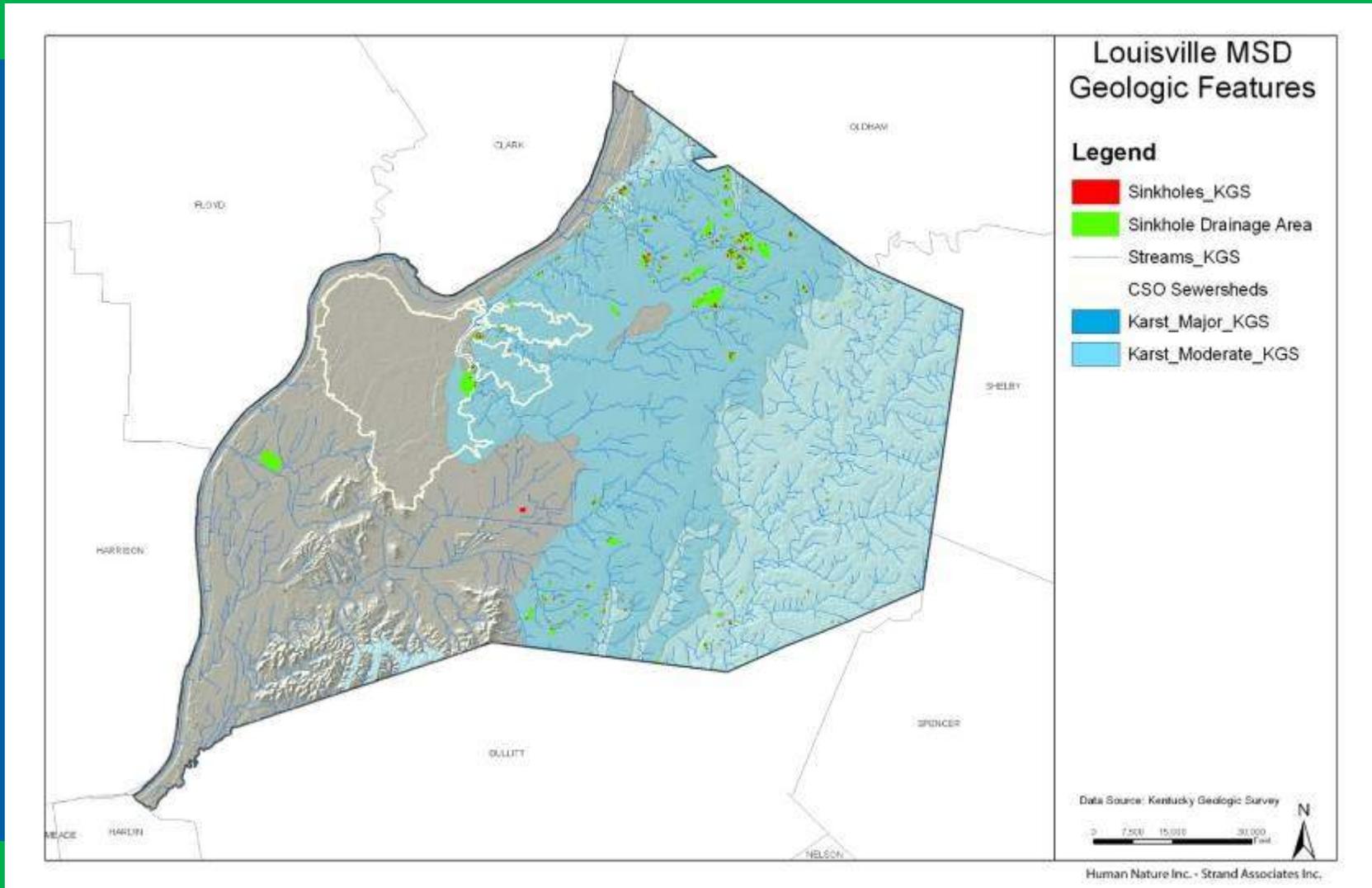
Copyright © 2001
University of Kentucky
Kentucky Geological Survey

Compiled from Noger, M.C., 1988, Geologic map of
Kentucky, U.S. Geological Survey, scale 1:600,000.
Cartography by Terry Rowland

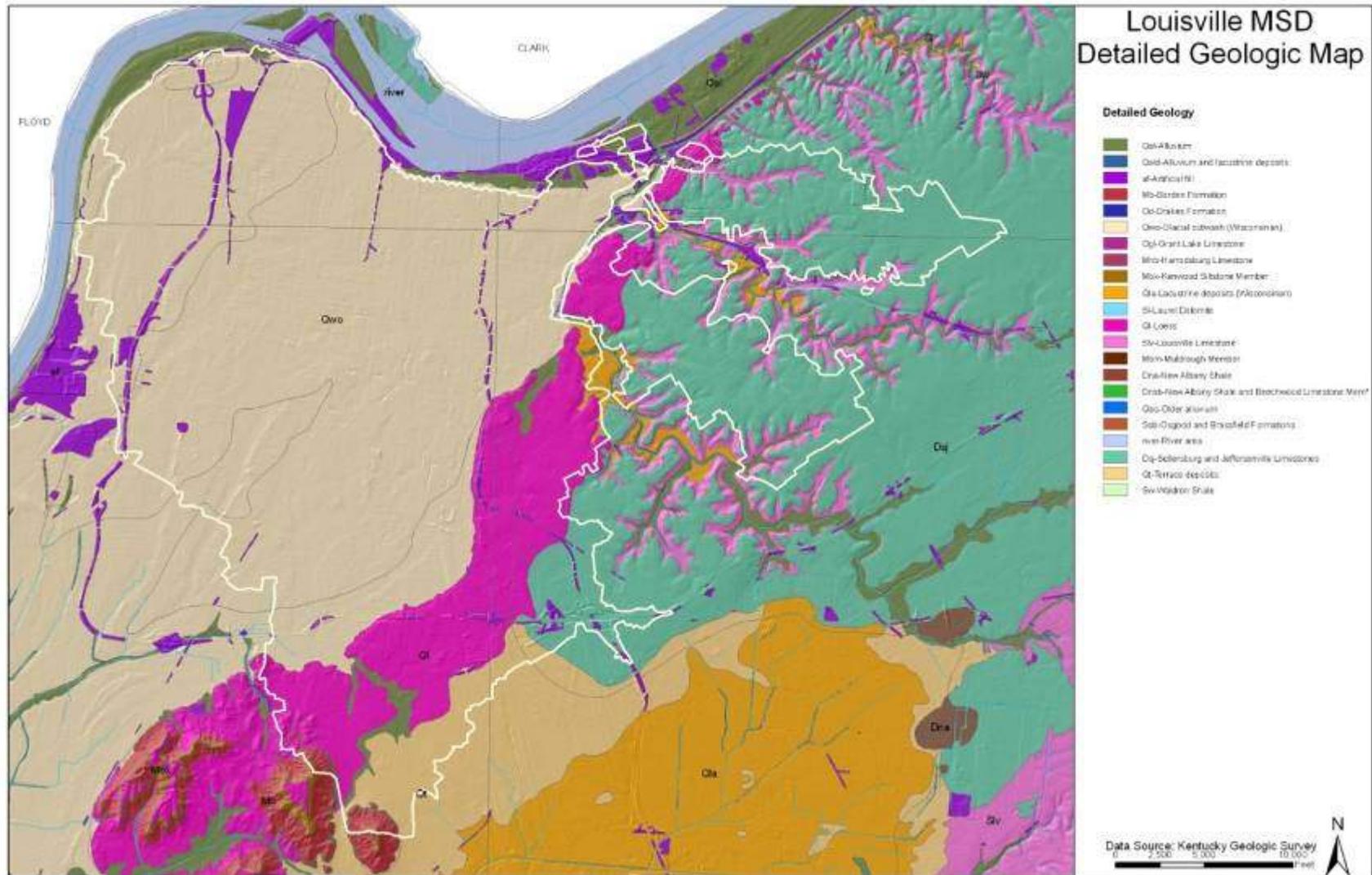
View the KGS World Wide Web site at
www.uky.edu/kgs

For information on obtaining copies of
this map and other Kentucky Geological
Survey maps and publications call:
Publication Sales
(859) 257-3898

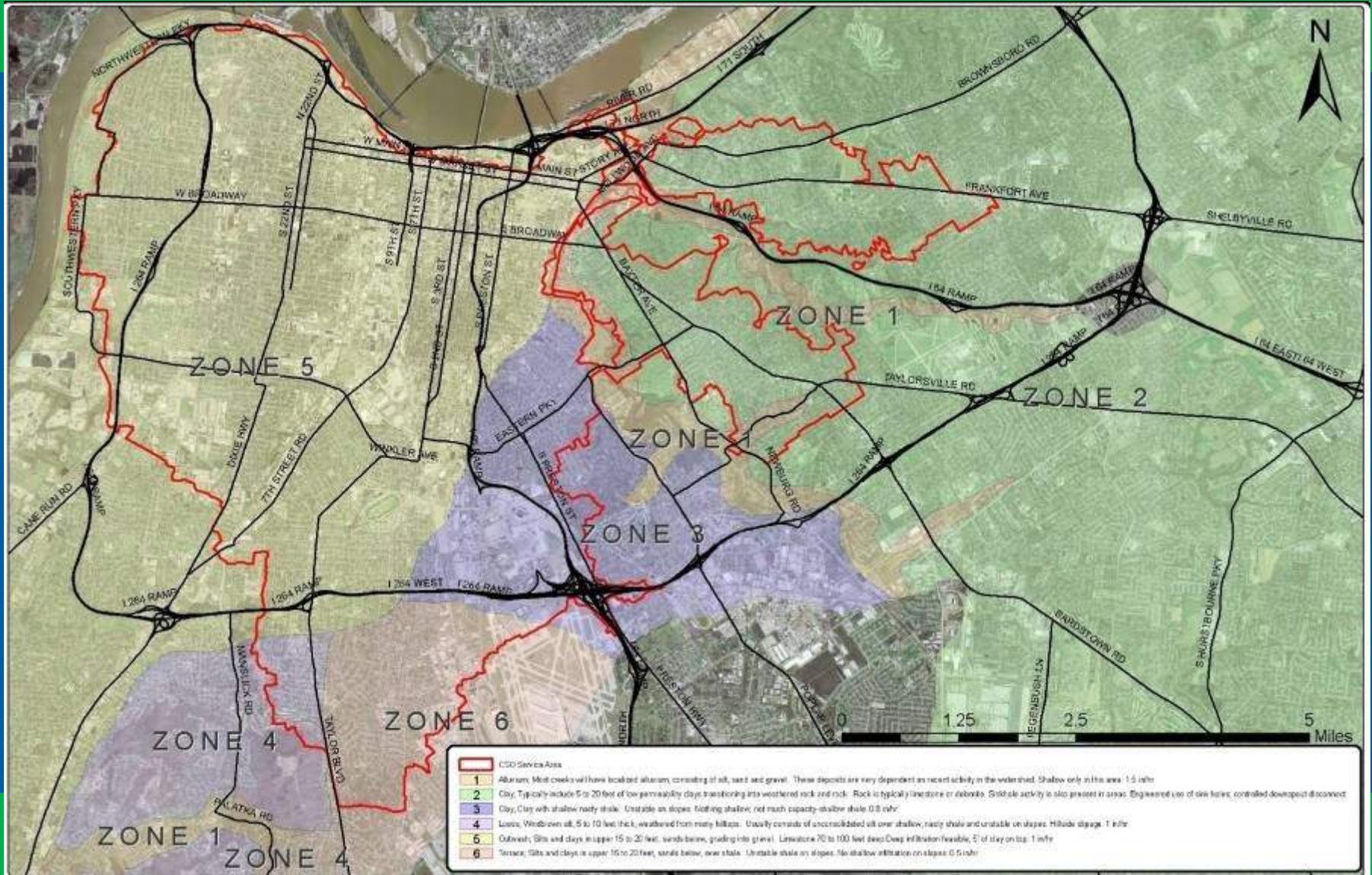
Metro/County Karst Geology



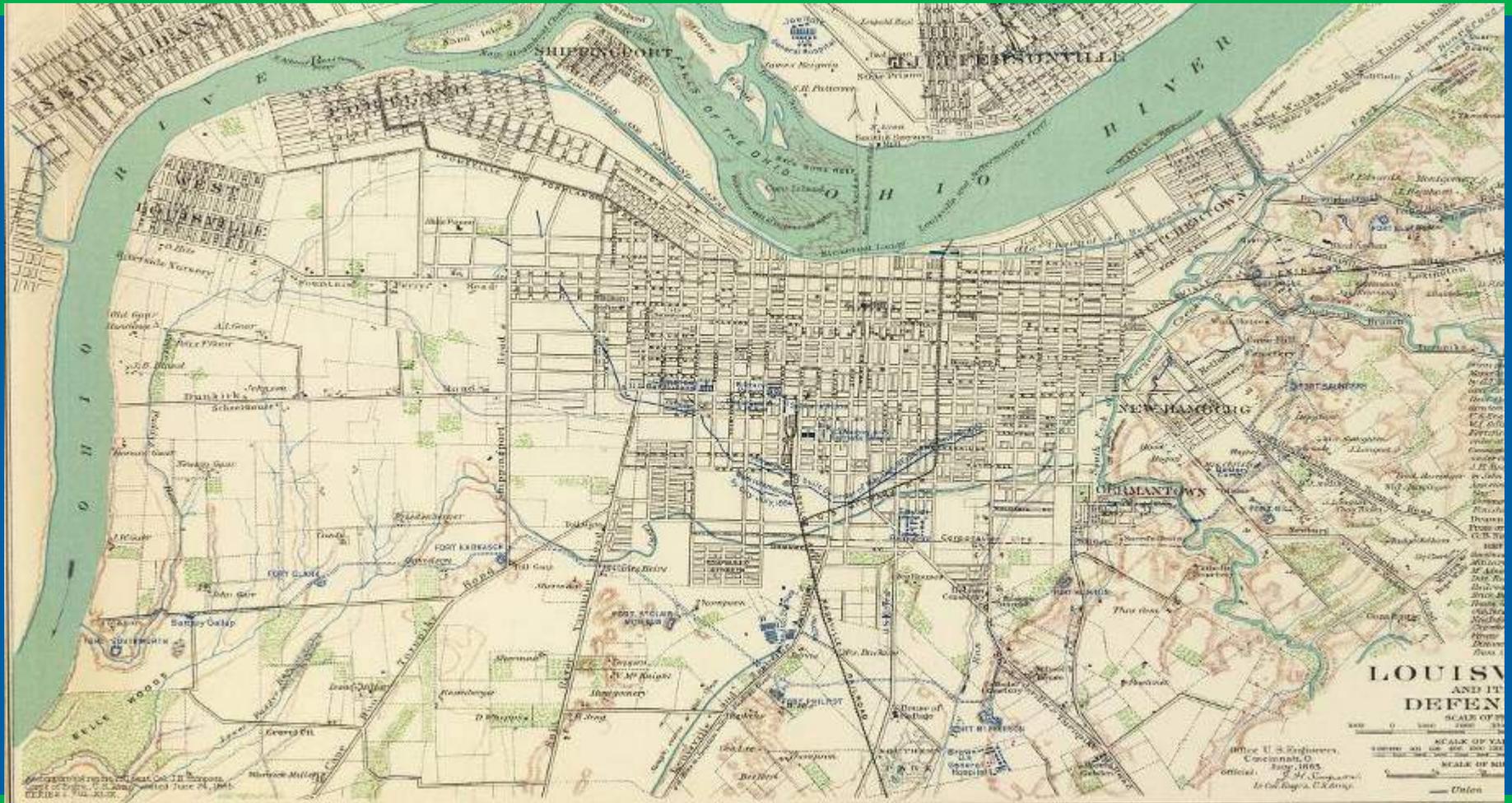
CSO Area Geology



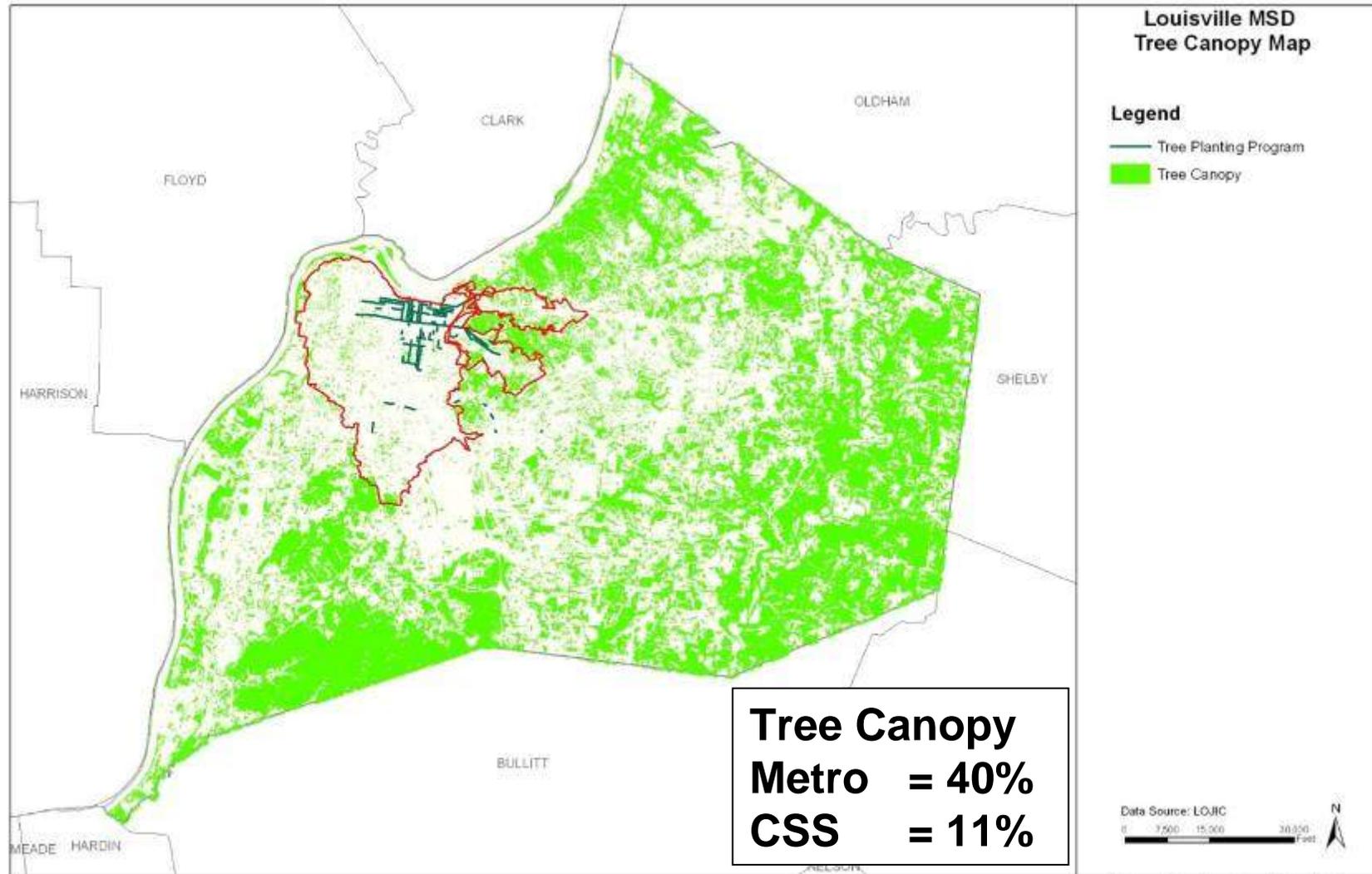
Metro/County Geology and Soils



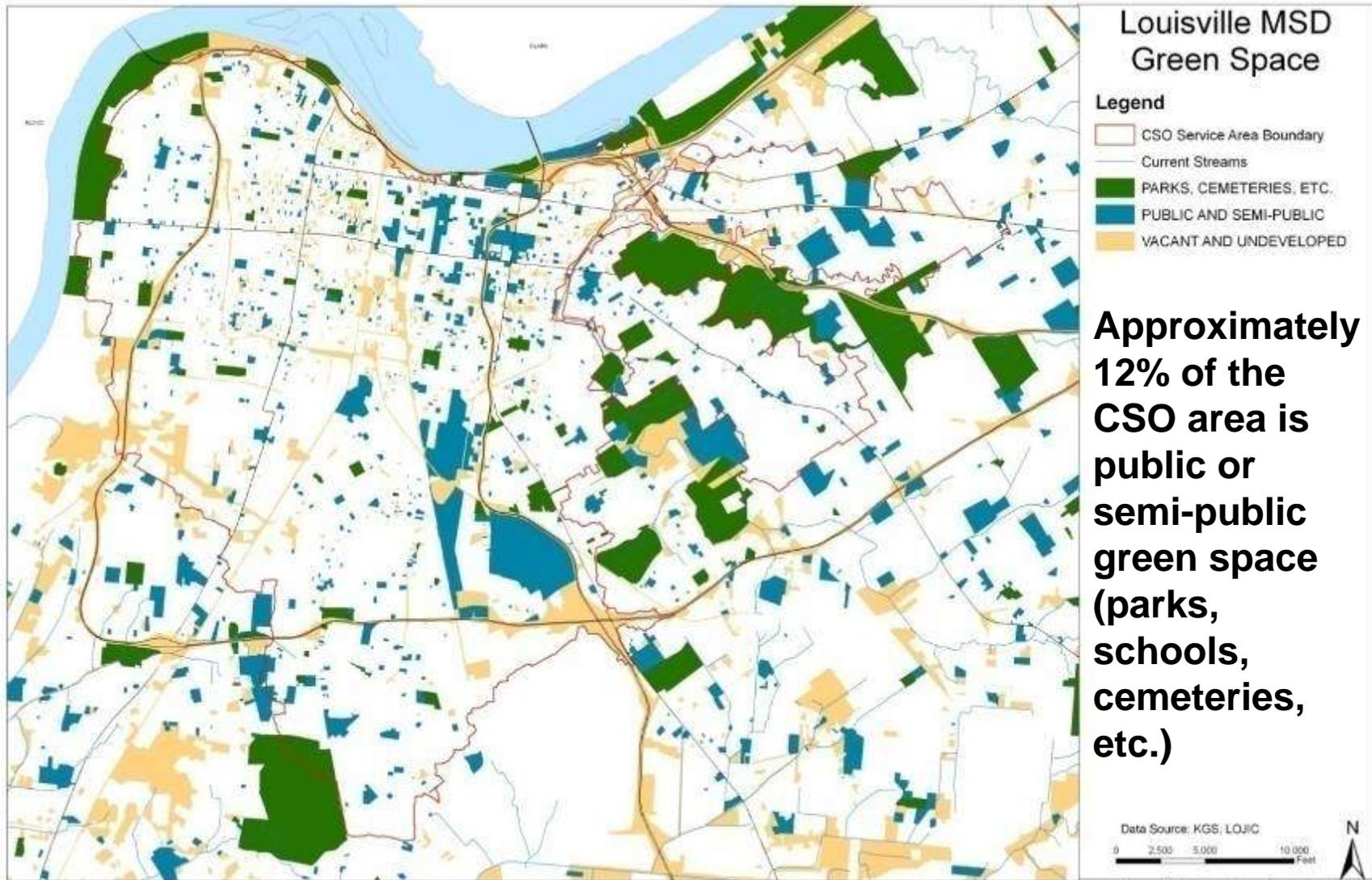
CSO Area Historic Streams



Metro/County Canopy Coverage



CSO Area Greenspace



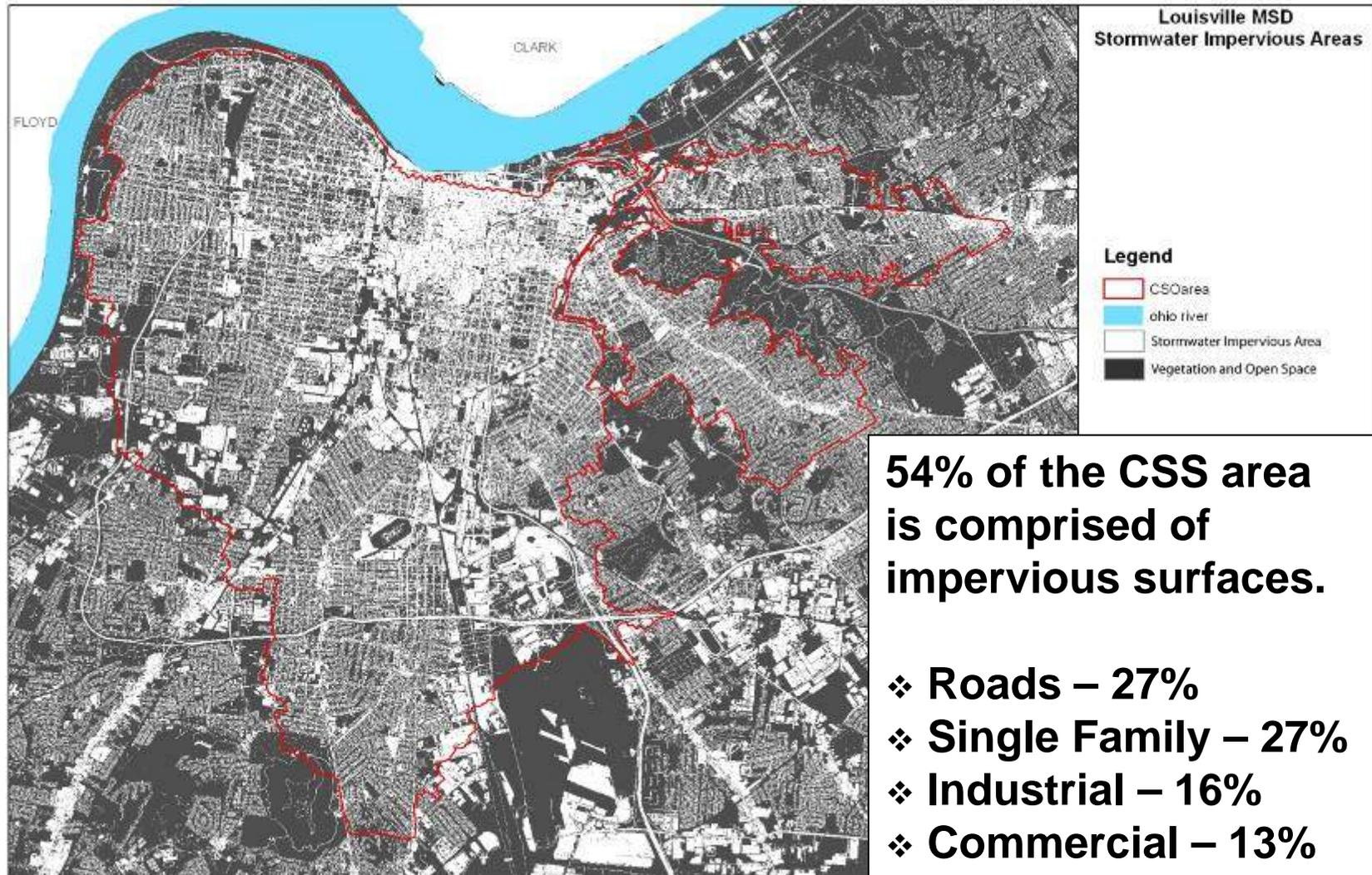
Approximately 12% of the CSO area is public or semi-public green space (parks, schools, cemeteries, etc.)

Data Source: KGS, LOJ/C

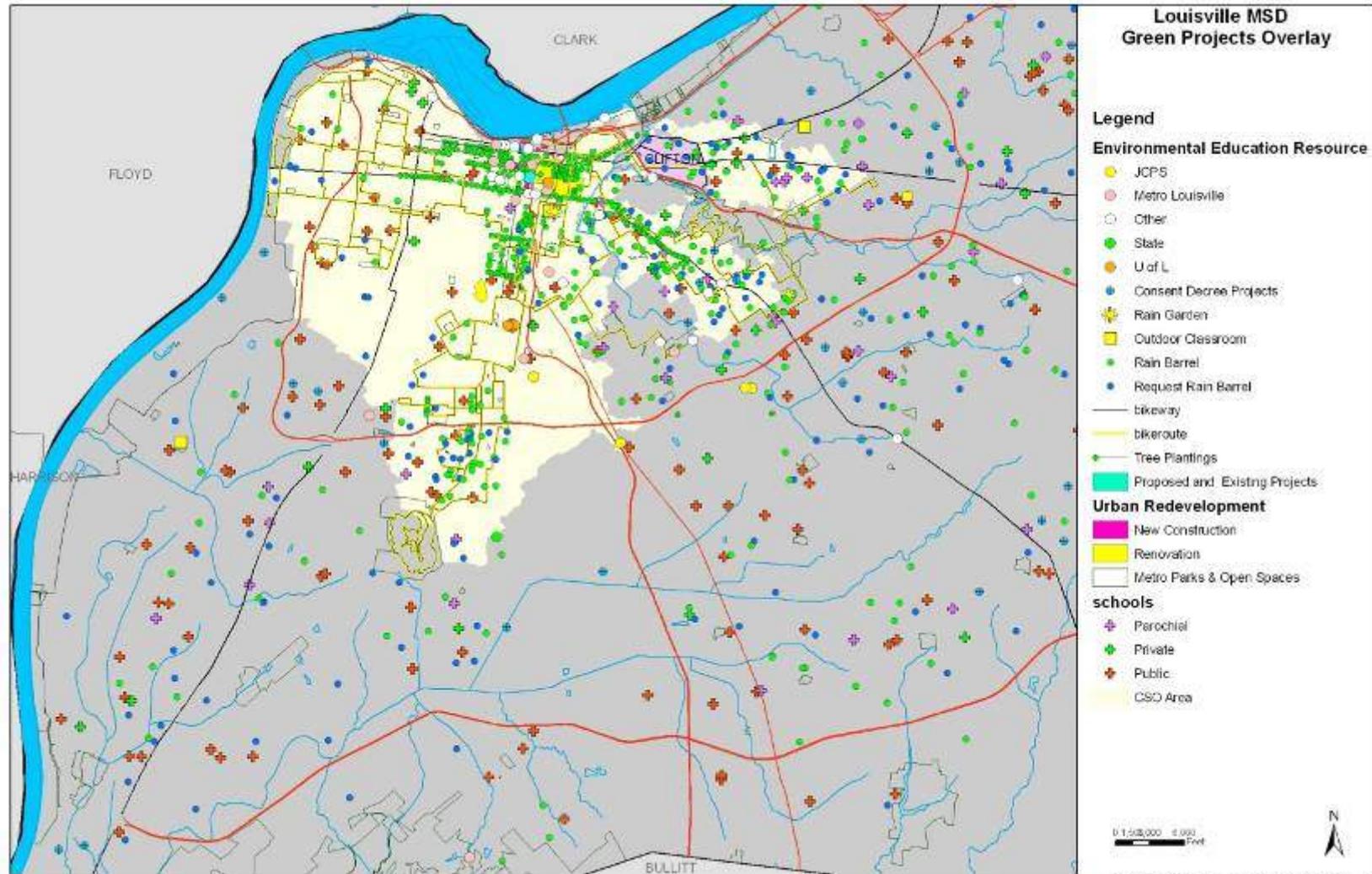
0 2,500 5,000 10,000 Feet

Human Nature Inc. - Strand Associates Inc.

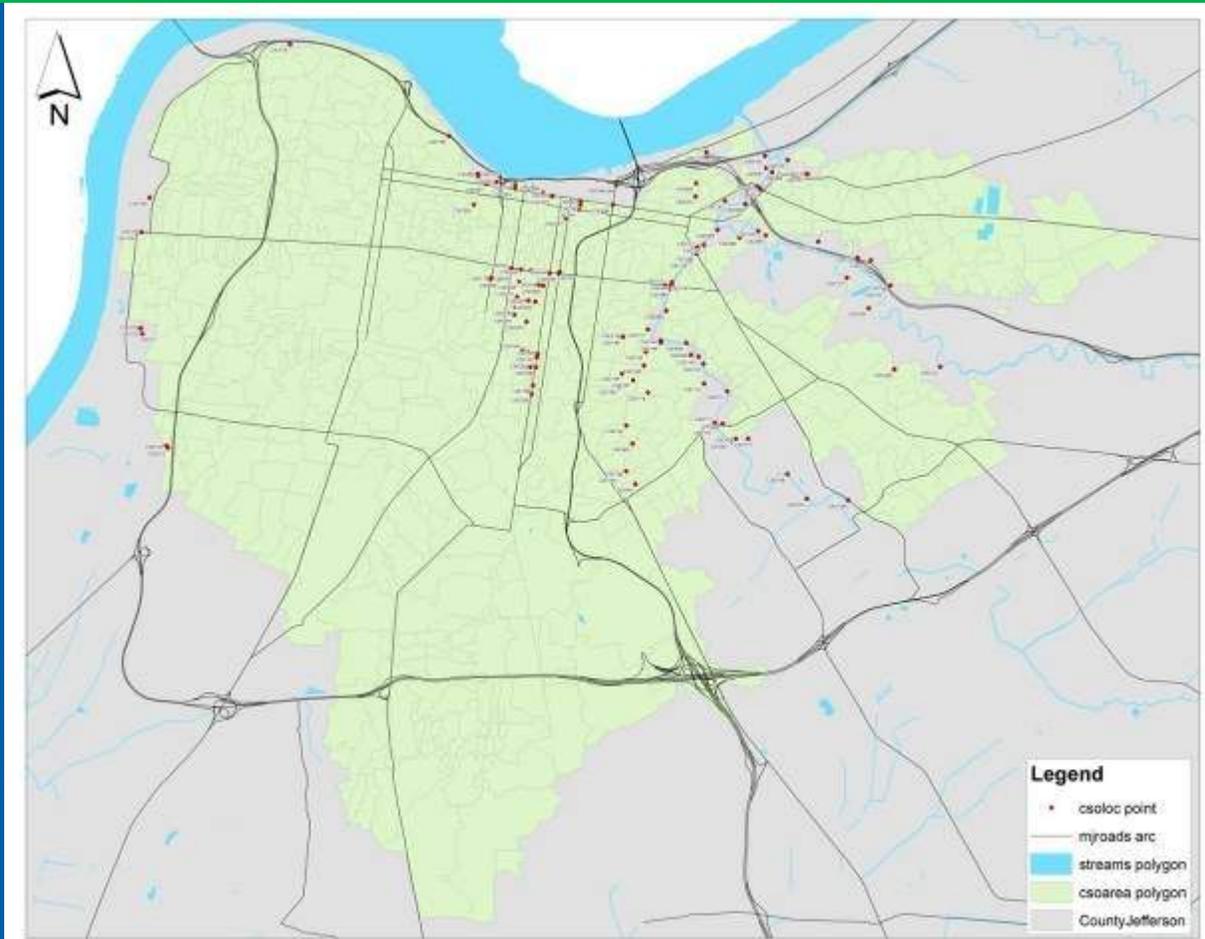
Impervious Area in CSS



Current Green Projects/Programs



CSO Sewershed Evaluations

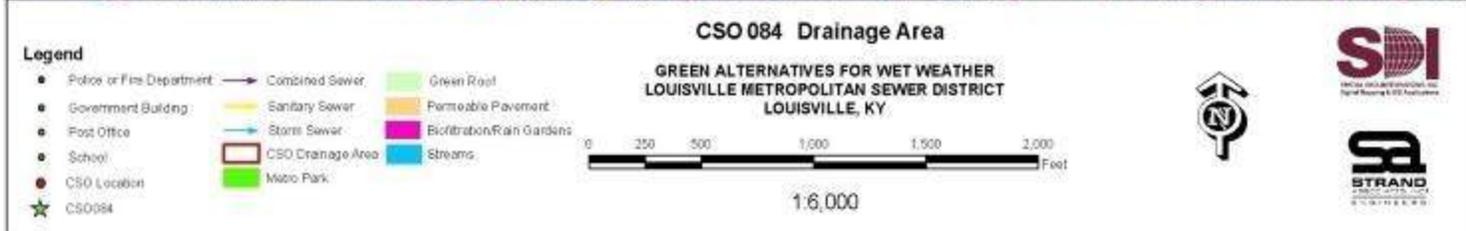


- Impervious area distribution
- Land use distribution
- Public green space
- Alleys and ROW
- Public parking lots and buildings
- Number of catch basins
- Residential properties

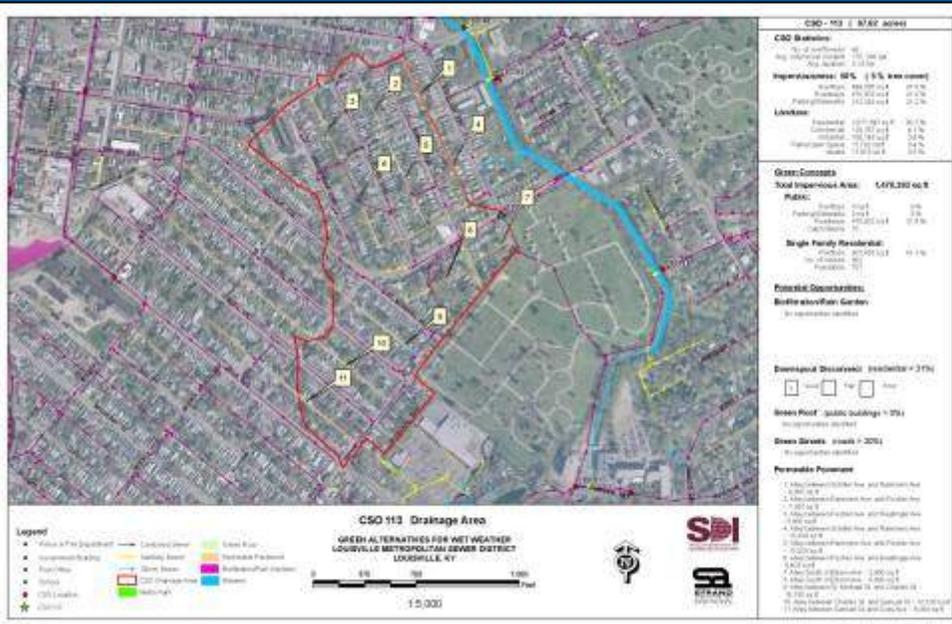
Sewershed Evaluations



CSO - 084 (125.06 acres)	
CSO Statistics:	
No. of overflows:	15
Avg. volume per incident:	140,000 gal
Avg. duration:	1.2 hrs
Imperviousness: 64% (4% tree cover)	
Roofs:	1,299,139 sq ft 37.2%
Roadways:	810,331 sq ft 23.2%
Parking/Sidewalks:	1,379,053 sq ft 39.5%
Landuse:	
Residential:	2,849,102 sq ft 52.3%
Commercial:	2,200,898 sq ft 40.4%
Industrial:	196,114 sq ft 3.6%
Parks/Open Space:	98,067 sq ft 1.8%
Vacant:	103,505 sq ft 1.9%
Green Concepts	
Total Impervious Area:	3,488,496 sq ft
Public:	
Roofs:	88,644 sq ft 2.5%
Parking/Sidewalks:	135,233 sq ft 3.9%
Roadways:	810,331 sq ft 23.2%
Catch Basins:	123
Single Family Residential:	
Roofs:	420,795 sq ft 12.1%
No. of houses:	385
Population:	495
Potential Opportunities:	
Biofiltration/Rain Garden	
1. Public Building Green Space	
2. Eastern Star Property	
Downspout Disconnect (residential = 12%)	
<input type="checkbox"/> Good <input checked="" type="checkbox"/> Fair <input type="checkbox"/> Poor	
Green Roof (public buildings = 3%)	
3. Urban Metro Govt Center	
4. Louisville Metro Air Pollution Control	
5. Police Department	
6. Barber Post Office	
Green Streets (roads = 23%)	
Permeable Pavement	
7. Public Building Parking Lots - 135,233 sq ft	
8. Alley between Debar and St. Anthony - 4,444 sq ft	

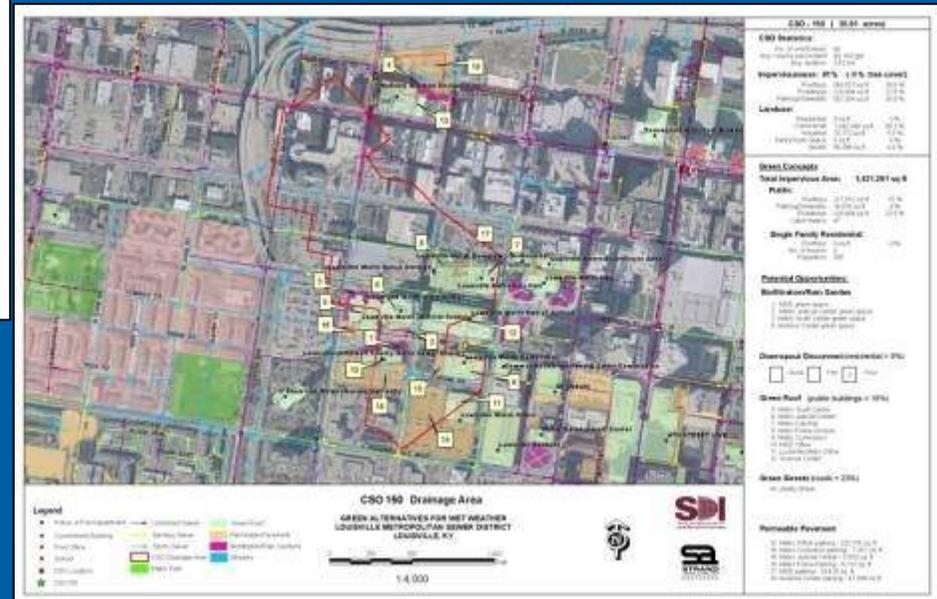


Site Specific Strategies



95 % of Land Use = Commercial/Industrial

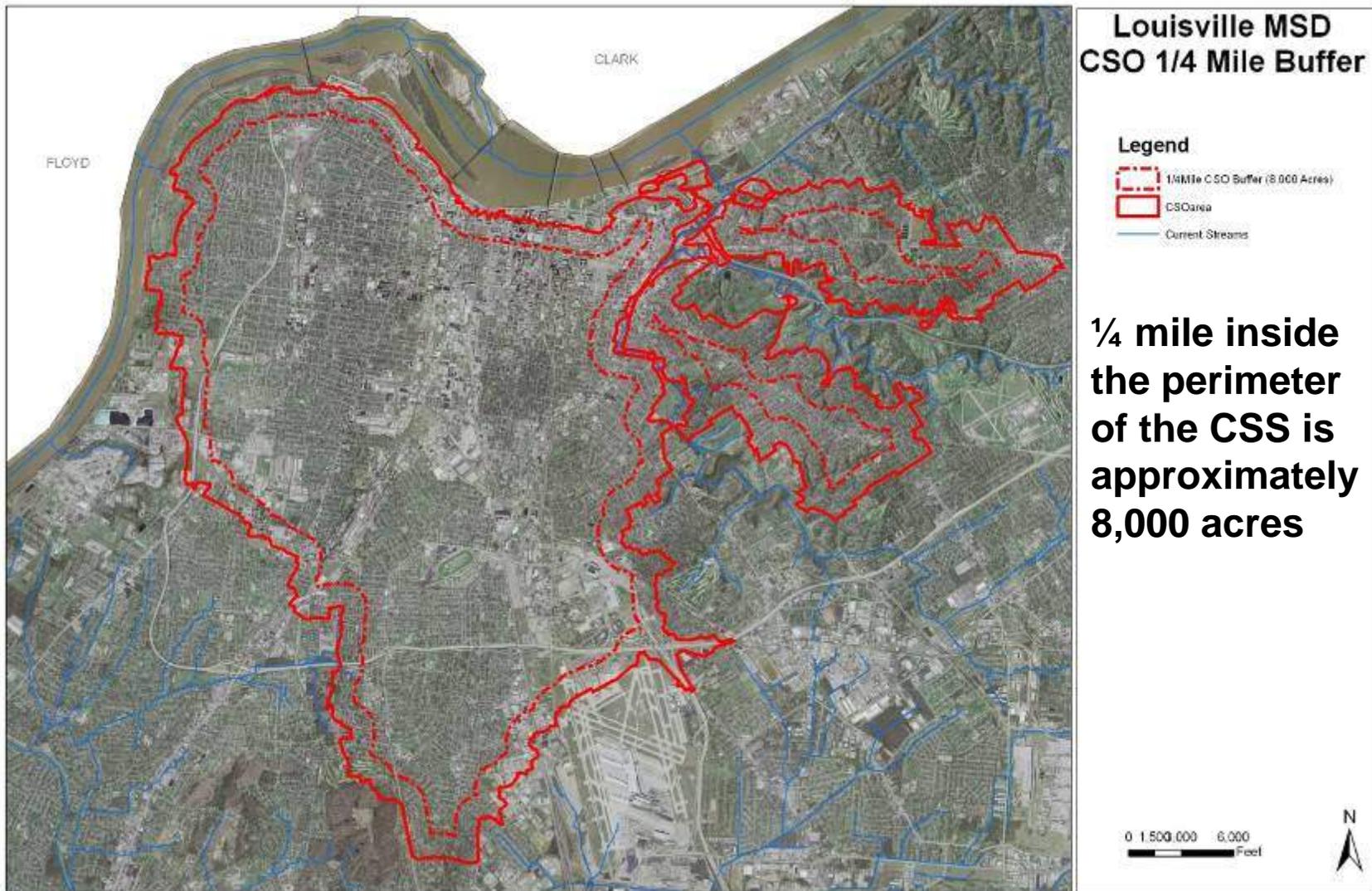
- Impervious Area
 - Rooftops 39%
 - Parking Lots 39%



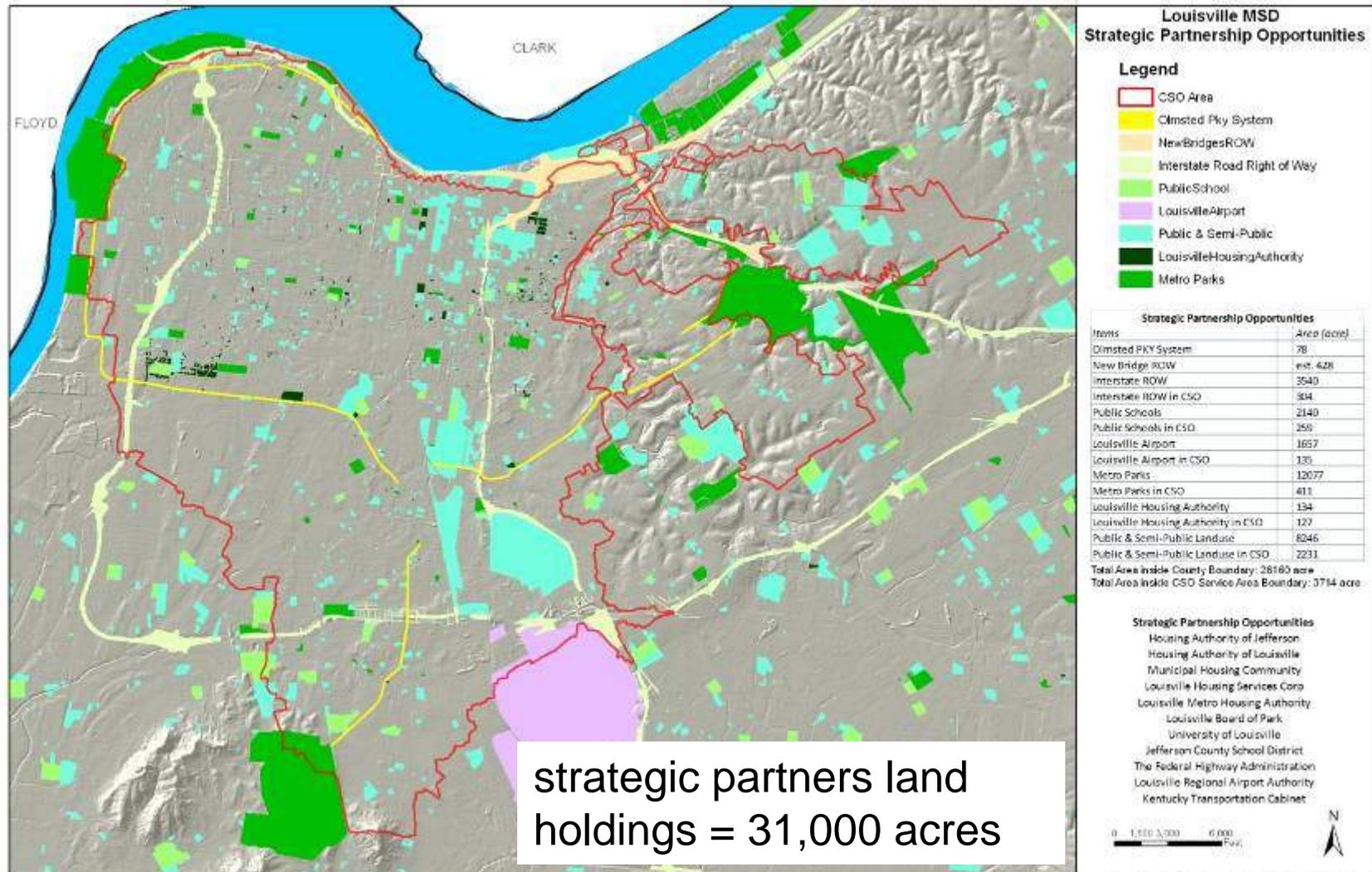
91% of Land Use = Residential

- Rooftops are 41% of the Impervious Area

CSO PERIMETER OFF-LOADING



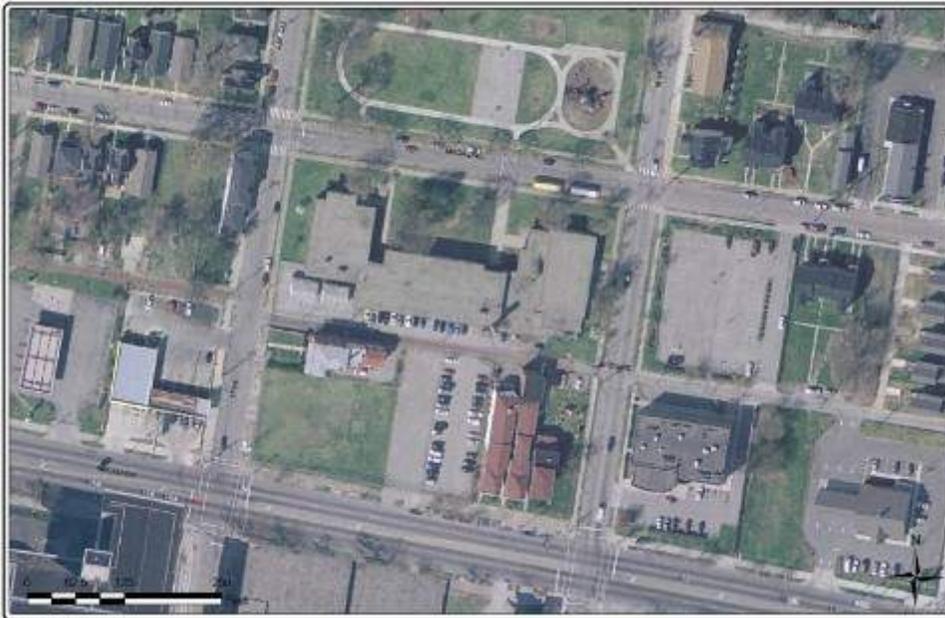
Strategic Partnerships



strategic partners land holdings = 31,000 acres

Strategic Partnerships

JEFFERSON COUNTY PUBLIC SCHOOLS



Current Site

Proposed Green Concept Plan



Strategic Partnerships

METRO PUBLIC WORKS

Louisville MSD
Board 1: City-wide Green Street Opportunities

City of Parks & Recreation
CLEAN WATER • GREEN ENVIRONMENT • GROWING COMMUNITY

4th Street Case Study Area (See Board 2)

A Parkway - Northwestern Parkway
B Suburban Residential - Fleming Avenue & Engin Avenue
C Downtown Residential - Broadway
D Downtown Residential - Victory Park
E Suburban Residential - Fleming Avenue & Engin Avenue
F Interstate I-64 / Cincinnati Drive Interchange
G Suburban Commercial Corridor - Barkdown Road
H Downtown Residential - Broadway

1. Storm Apical
2. Green Roof
3. Drywell
4. Rainwater Harvest
5. Storm Retention
6. Permeable Pavement
7. Stormwater Infiltration
8. Bioswale
9. Stormwater Quality Treatment
10. Stormwater Conveyance
11. Stormwater Detention
12. Stormwater Storage
13. Stormwater Treatment
14. Stormwater Management

MSD
Louisville and Jefferson County
Metropolitan Sewer District

Human Nature Inc. - Strand Associates

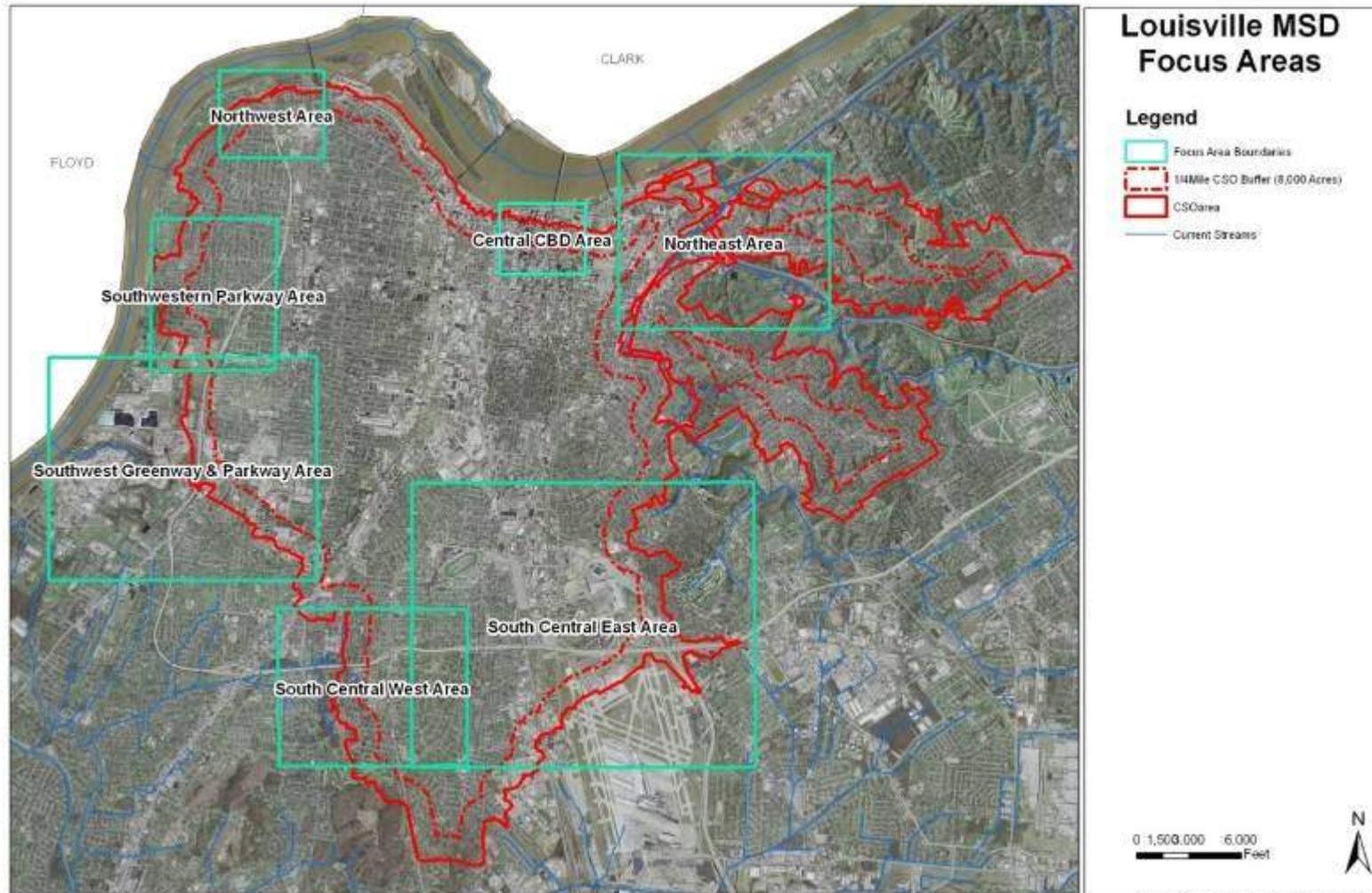
January 2008

Strategic Partnerships

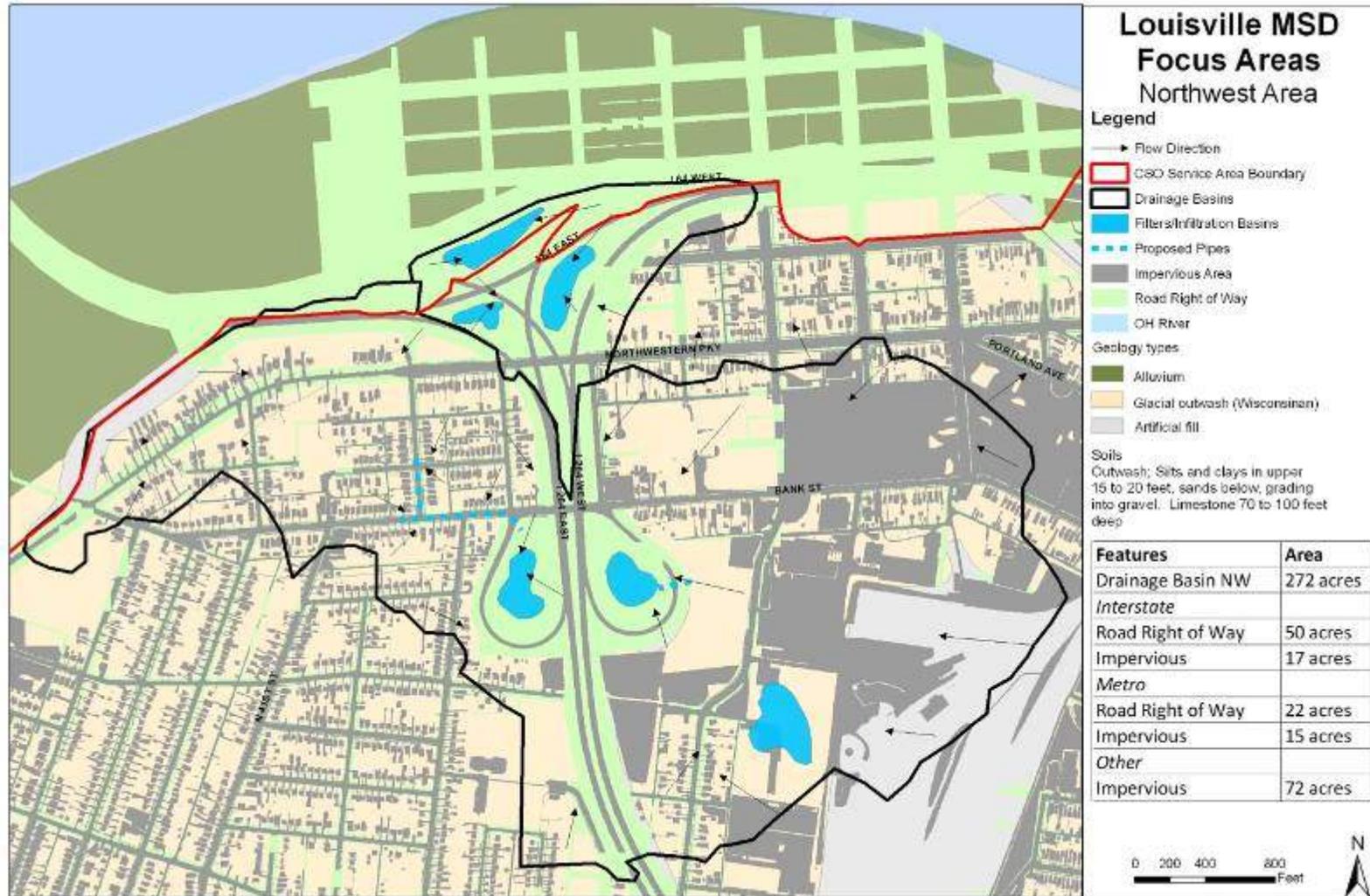
Kentucky Transportation Cabinet



Regional Evaluation Identifies Focus Areas



Northwest Focus Area



Proposed GI Program Elements

System Wide Implementation

Program Components

- Downspout Disconnection Program
- Vegetated Roof Program
- Residential Rain Garden Program
- Rain Barrel Program
- Urban Reforestation



STRAND ASSOCIATES, INC. GREEN INFRASTRUCTURE COST PLANNING TOOL

ROOFTOPS

Land Use Type	Acres(ac)	BMP Type	Implementation
Public	15	Extensive Vegetated Roof	0.0%
		Tray System Vegetated Roof	0.0%
Commercial	16	Extensive Vegetated Roof	0.0%
		Tray System Vegetated Roof	0.0%
Industrial	15	Extensive Vegetated Roof	0.0%
		Tray System Vegetated Roof	0.0%
Residential	121	Downspout Disconnection	0.0%
		Rain Barrel Installation	0.0%

ROADWAYS

Land Use Type	Acres(ac)	BMP Type	Implementation
Paved Roads	110	Green Street	0.0%
		Urban Reforestation (No. Trees)	0
		Biofiltration Techniques	0.0%
Alleys	9	Porous Alleys	0.0%

PARKING LOTS, DRIVEWAYS, AND SIDEWALKS

Land Use Type	Acres(ac)	BMP Type	Implementation
Public	19	Biofiltration Techniques	0.0%
Commercial	21	Biofiltration Techniques	0.0%
Industrial	48	Biofiltration Techniques	0.0%
Residential	51	Biofiltration Techniques	0.0%

LOCATION SPECIFIC INFORMATION

Typical Annual Rainfall (in)	42.83
Green Program Length (years)	15
Program Administration	5.0%

Calculate

Reset

GREEN PROGRAM SUMMARY

Annual Gallons Removed from CSS
 Annual Reduction in AAOV
 Annual Green Program Cost
 Annual Cost per Gallon Removed



Green Cost Tool: Community Specific Considerations

- Unit benefit costs
- Programmatic costs
- BMP type
- Drainage areas
- Performance
 - Rainfall
 - Soils
 - Geology
- Annual vs. design storm
- Program duration

Downspout Disconnect Program

- Limited to target areas as soils permit
- Utilized scoring matrix based on participation/ effectiveness factors
- Projected SW reduction = 124MG @ 10% implementation level

LOUISVILLE MSD GREEN EVALUATION				
		Residential Downspout Disconnection Program Matrix		
Participation	High	15%	30%	40%
	Medium	10%	20%	30%
	Low	5%	10%	15%
		Low	Medium	High
		Effectiveness		

Vegetated Roof Program

- Determine effectiveness of green roofs at reducing runoff (\$/gallon)
- Proposing to establish a green roof incentive program.
- Projected SW reduction = 45MG @ 4% implementation level



Residential Rain Garden Program

- Target Neighborhood Groups
- Augment effectiveness of downspout disconnect
- Address street runoff where public green space is available
- Projected SW reduction = 52 MG
@ 0.5% implementation level



Rain Barrel Program

- Service area wide
- Augment effectiveness of downspout disconnect where appropriate.
- Used to promote awareness and personal responsibility
- Develop two standard details:
 - One that overflows to surface
 - One that overflows to CSS



Urban Reforestation Program

- Leaves and branches intercept rainwater
- Dissipates rainwater by evapotranspiration
- Increases soil infiltration
- Reduce volume of stormwater and increases time of concentration runoff



Urban Reforestation Program

Recommended Tree Canopy Coverage and Benefits

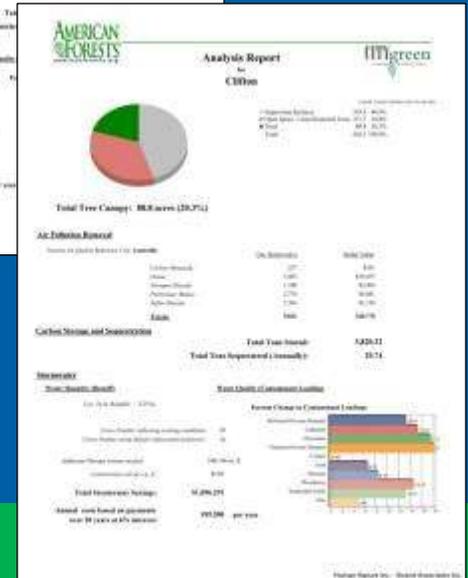
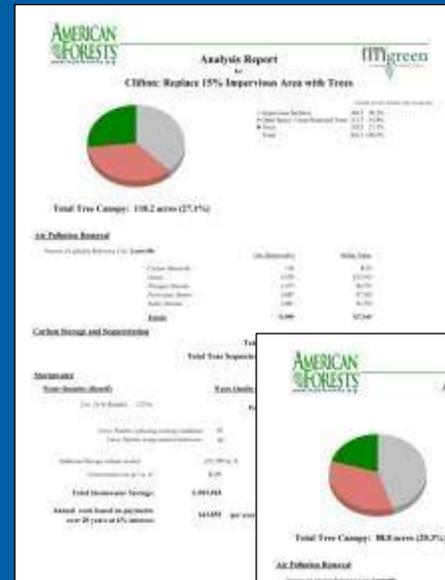
CSO Area

- Current canopy coverage 11%
- Increase Tree Canopy by 15%

Additional Stormwater Reduction =
7,166,019 cubic feet
(or over 53 million gallons)

Additional Benefits;

- Carbon Stored 196,364 tons
- Carbon Sequestered annually 1,528 tons per year
- Air pollution removal 463,724 lbs removed per year



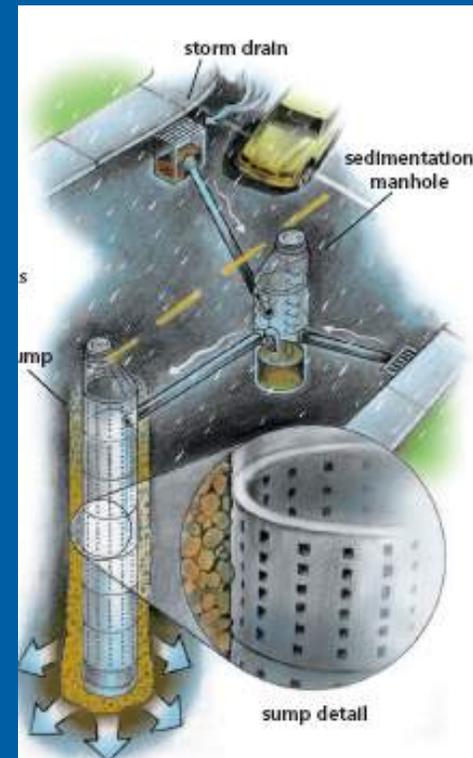
Green Infrastructure Demonstration Projects

Project Components

- Rain Gardens
- Dry Wells
- Green Alley
- Green Streets
- Green Parking Lots
- Off-loading to natural systems

Dry Wells

- Identify demonstration project locations
- Develop standards for three locations:
 - residential
 - single inlet
 - multi-inlet
- Establish a cost/gallon relationship



Green Alleys

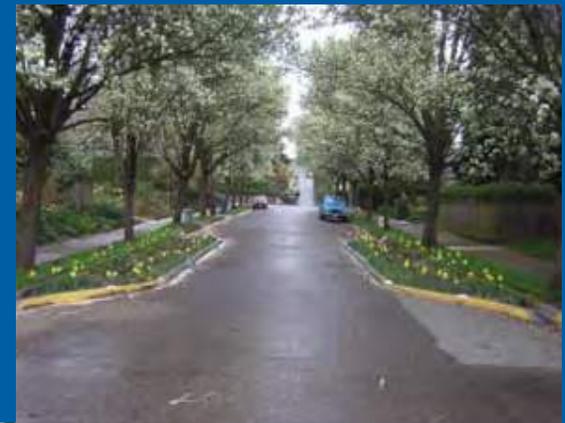
- Identify demonstration sites
- Develop 2 standard designs
- Coordinate with Public Works
- Projected SW reduction = 24 MG @ 10% implementation level



Chicago, IL

Green Streets

- Identify 2 demonstration sites
- Coordinate with Public Works
- Develop standard detail for Louisville
- Projected SW reduction = 246 MG @ 1% implementation level



Portland, OR

Green Infrastructure Vision

Louisville MSD Regional Green Infrastructure Concept Plan

From Raindrops to Rivers: A Vision for Integrating Green Solutions into Stormwater Management



QUESTIONS?



John Lyons, P.E.

Participation Certificate

- If you would like to obtain participation certificates for multiple attendees, click the link below
- You can type each of the attendees names in and print the certificates

http://www.epa.gov/npdes/webcasts/certificate/gi_models&calcs.pdf



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