Performance Results from Small- and Large-Scale System Monitoring and Modeling of Intensive Applications of Green Infrastructure in Kansas City

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1

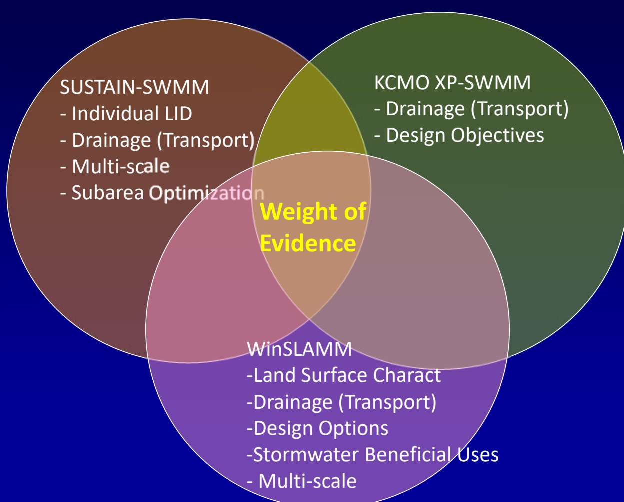
Kansas City's CSO Challenge

- Combined sewer area: 58 mi^2
- Fully developed
- Rainfall: 37 in./yr
- 36 sewer overflows/yr by rain > 0.6 in; reduce frequency by 65%.
- 6.4 billion gal overflow/yr, reduce to 1.4 billion gal/yr
- Aging wastewater infrastructure
- Sewer backups
- Poor receiving-water quality

2

2

KC's Modeling Connections



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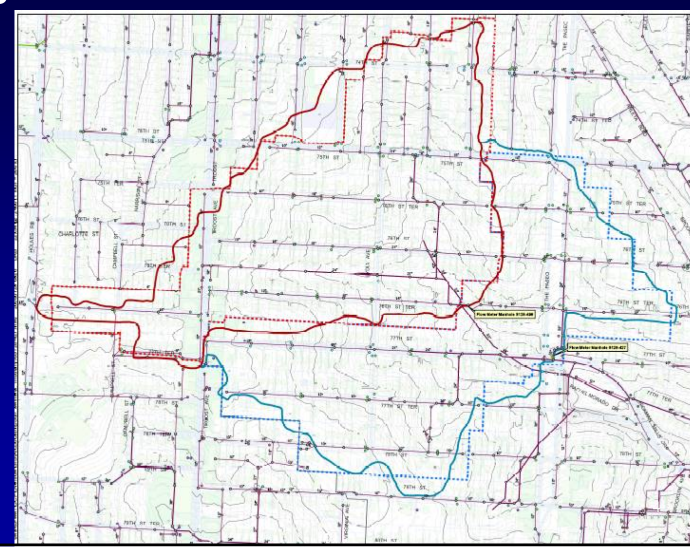
Adjacent Test and Control Watersheds



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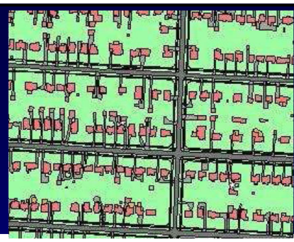
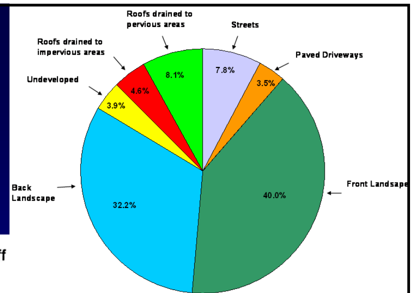
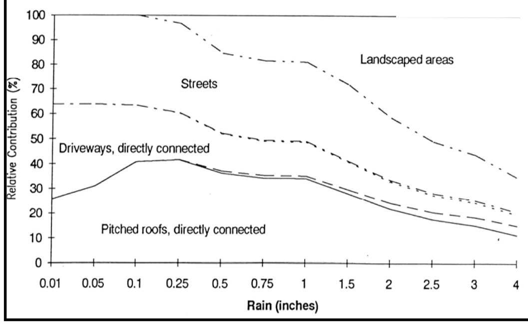




Medium Density Residential Area, Runoff



Surveys were conducted for each house and lot in the study area. This information was used with the GIS data and WinSLAMM to determine the sources of the runoff during different rain conditions

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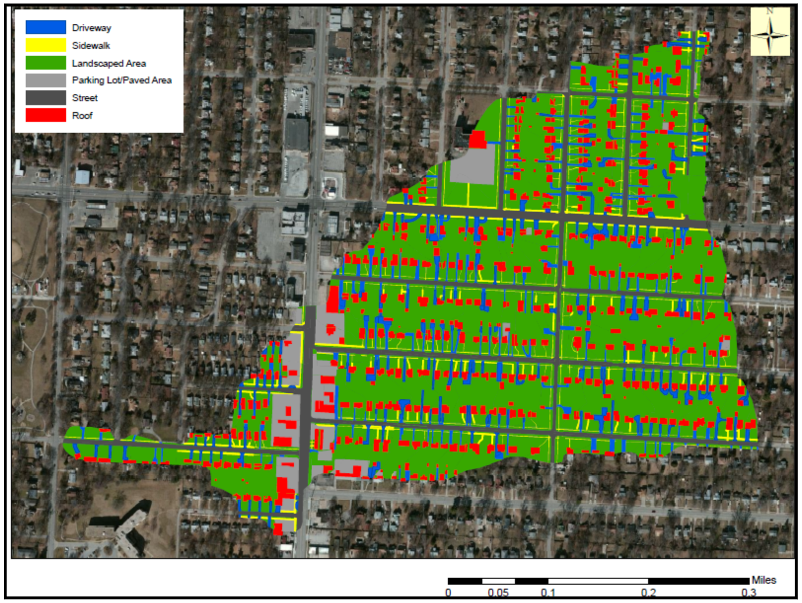


6

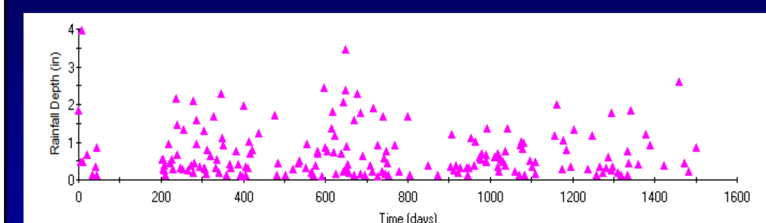
Major Land Use Components in Residential Portion of Study Area (% of area and % of total annual flow contributions)

	Roofs	Drive-ways	Side-walks	Park-ing	Streets	Land-scaped	Total
Directly connected	2 (6)	4 (9)	1 (3)	2 (5)	9 (21)		18 (44)
Disconnected	11 (7)	4 (3)	1 (1)				16 (11)
Landscaped						66 (45)	66 (45)
Total area	13 (13)	8 (12)	2 (4)	2 (5)	9 (21)	66 (45)	100

Based on KCMO GIS mapping and detailed site surveys, along with WinSLAMM calculations.

7

September 2, 2008 to October 12, 2012 Rains Monitored in the Kansas City Green Infrastructure Test Area



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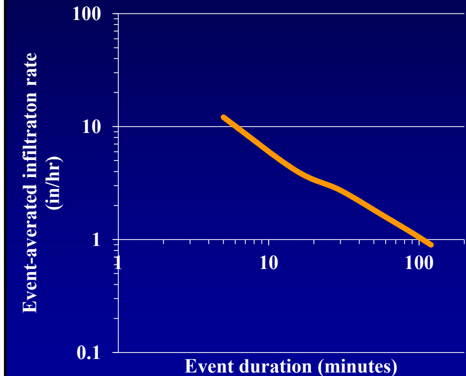
Varying-duration Site Infiltration Rates



This plot shows the time-averaged infiltration rates based on the individual incremental values. The surface infiltration rates are less than 25 mm/hr for rains about 2 hrs long and longer.

Additional site measurements and deep soil profiles have indicated that infiltration rates may be low for most of the area during the large and long-duration critical events for overflows.

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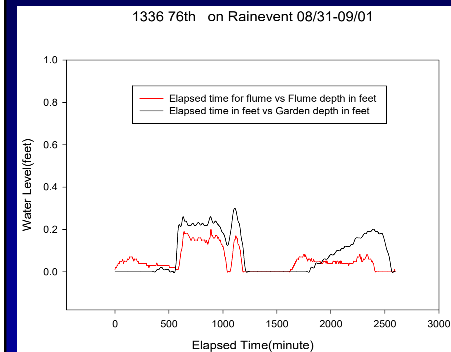
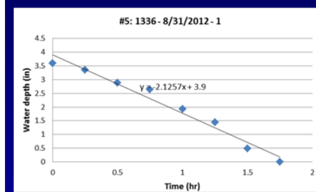
Example Water Level in Influent Flume and Water Stage Recordings in Biofilter used for Calculating Infiltration Rates during Rains





Example plot of recession limbs and infiltration rate calculation (after influent flows ceased).

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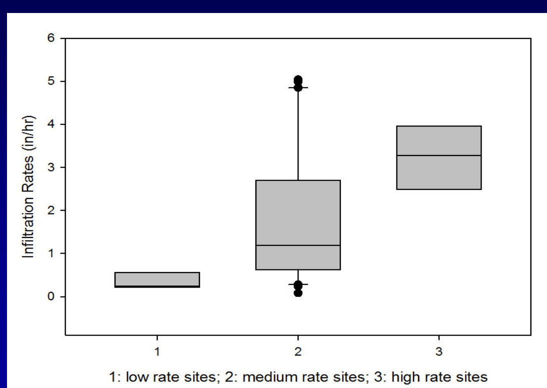
10

Measured Biofilter Infiltration Rates During Actual Rains, Separated into Three Categories



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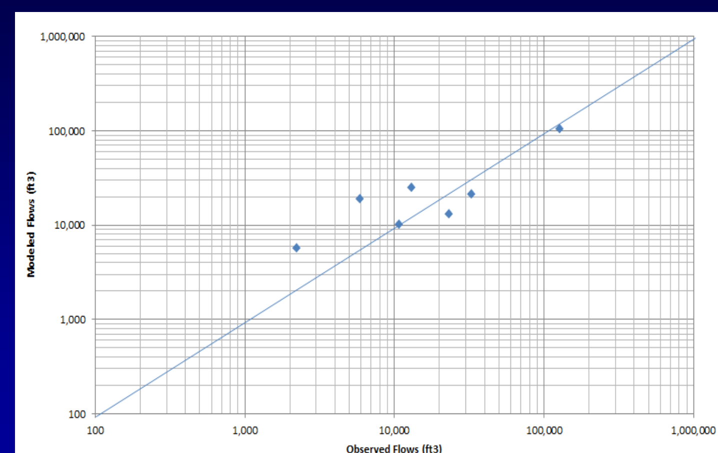
11

Observed vs. Modeled Flows during Final Baseline Conditions



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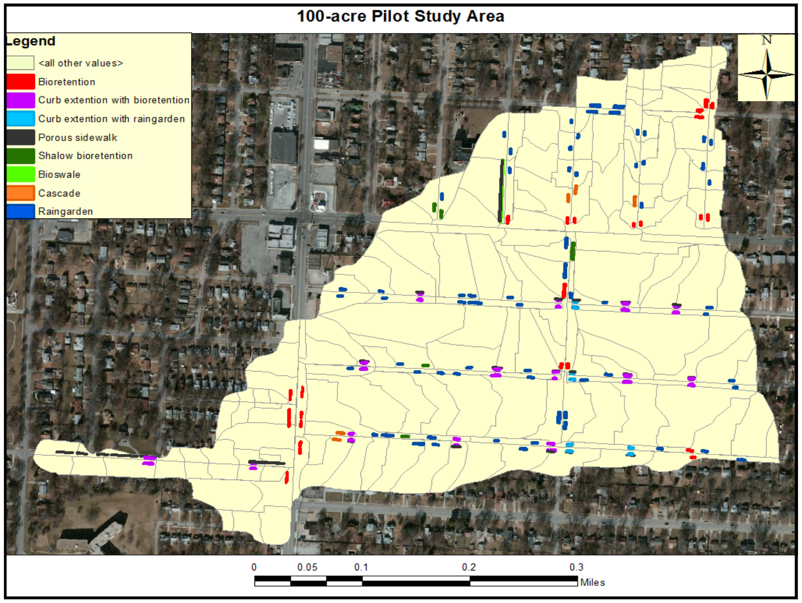

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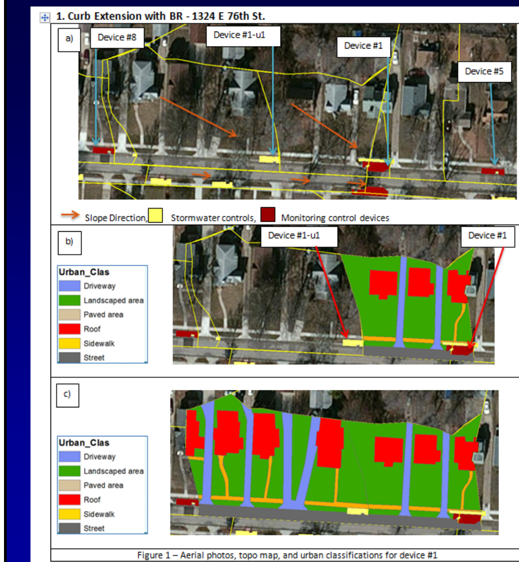


Example micro flow and drainage area analysis for a set of stormwater controls in the test area, examining both direct runoff area to biofilters and overflows from upgradient biofilters.

14

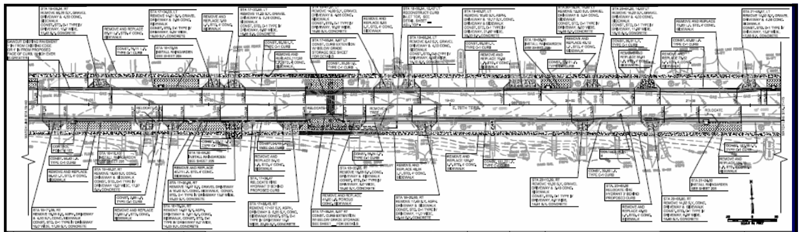
14

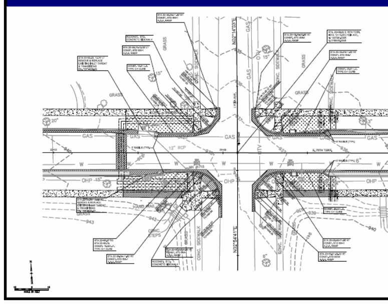
15

Characteristics of Areas Draining to Stormwater Controls vs. Areas without Controls

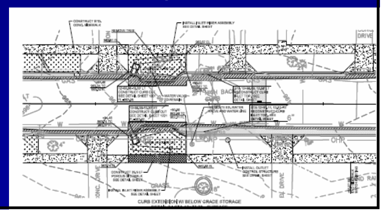
Land Component	Area in subwatersheds with no devices		Area in subwatersheds with stormwater control devices	
	Area (acres)	Percent of subarea	Area (acres)	Percent of subarea
Impervious, directly connected	8.09	17.7	15.02	27.6
Impervious, draining to pervious areas	9.04	19.7	9.38	17.2
Pervious areas	28.70	62.6	30.00	55.2
Total area:	45.83	100.0	54.40	100.0

16





Examples from “95%” plans prepared by URS for project streets. Plans reviewed and modeled by project team, and construction completed in Summer 2012. Initial monitoring until October 2012, extended monitoring thru Fall 2013.



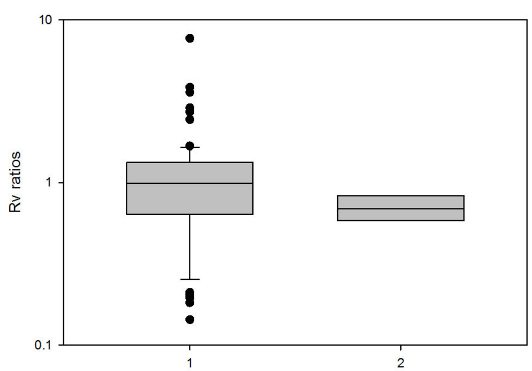
17

Summary of Constructed Stormwater Controls in Test Area

Design plan component	Number of this type of stormwater control units in 100 acre test (pilot) area	Device as a % of the drainage area	Average drainage area for each unit (ac)	Total area treated by these devices (ac)
Bioretention	24 (no curb extensions)	1.6	0.40	9.6
	28 (with curb extension)	1.5	0.40	11.2
	5 (shallow)	1.6	0.40	2.0
Bioswale	1 (vegetated swale)	8.9	0.50	0.5
Cascade	5 (terraced bioretention cells in series)	1.9	0.40	2.0
Porous sidewalk or pavement	18 (with underdrains)	100.0	0.015	0.3
	5 (with underground storage cubes)	99.9	0.015	0.1
Rain garden	64 (no curb extensions)	2.8	0.40	25.6
	8 (with curb extension)	1.5	0.40	3.2

18

Preliminary Test to Control Area Runoff Flow Ratios during Different Monitoring Periods



1) Pre-construction test area 1/control area 2a Rv ratios
2) Post-construction test area 1/control area 2a Rv ratios

19

19

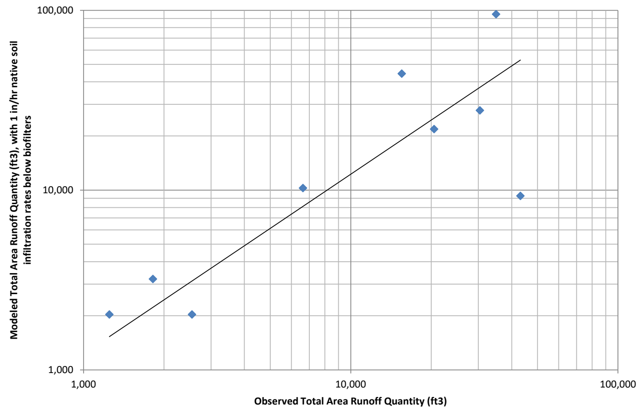
Preliminary Test and Control Watershed Flow Comparisons

Mann-Whitney Rank Sum Test				
Group	N	Median	25%	75%
Pre-construction pilot area to control area Rv ratio	78	0.99	0.64	1.33
Post-construction pilot area to control area Rv ratio	8	0.69	0.59	0.83
Mann-Whitney U Statistic= 206				
T = 242; n (small) = 8; n (big) = 78; (p = 0.12)				

- Therefore the difference is not significant at the 0.05 level for the number of sample pairs available (p = 0.12).
- The apparent change between the initial monitoring period and the after construction monitoring period is about 30%. Individual biofilter monitoring and modeling suggest differences of 50+%.
- Therefore, need to detect a difference of at least 30% between the two groups. With a COV of about 0.4, this would require about 25 sample sets (for 95% confidence and 80% power).
- These preliminary analyses focused on the 8 sets of data after construction in the current year (compared to the initial 78 data sets); many more events will be monitored before the end of the project period when the final analyses will be conducted. 20

20

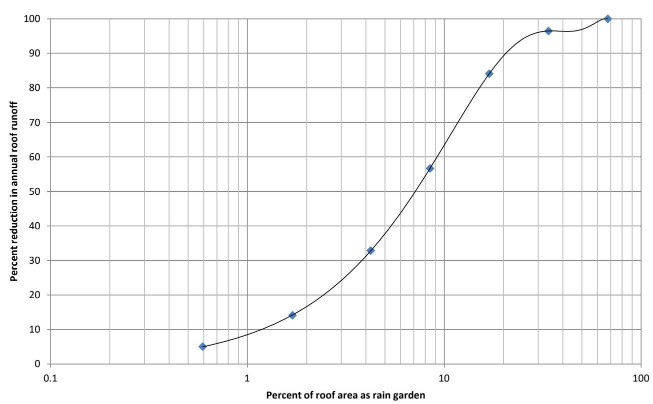
Observed and Modeled Flows in the Test Watershed after Construction of Stormwater Controls



21

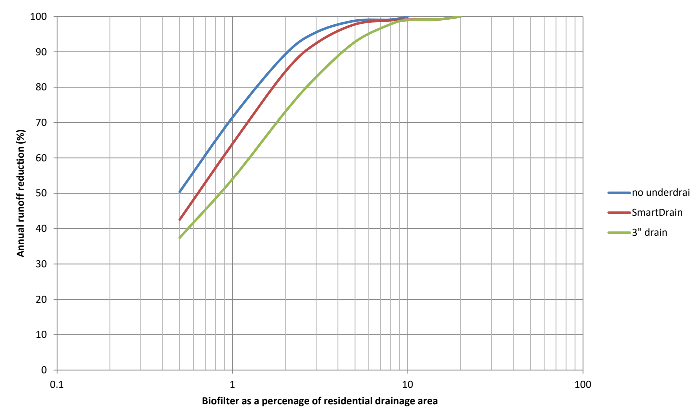
22

Percentage Reductions of Annual Runoff Flows with Rain Gardens



23

Effects of Underdrains in Biofilters on Annual Runoff Reductions (0.5 in/hr subsurface soil infiltration rates)



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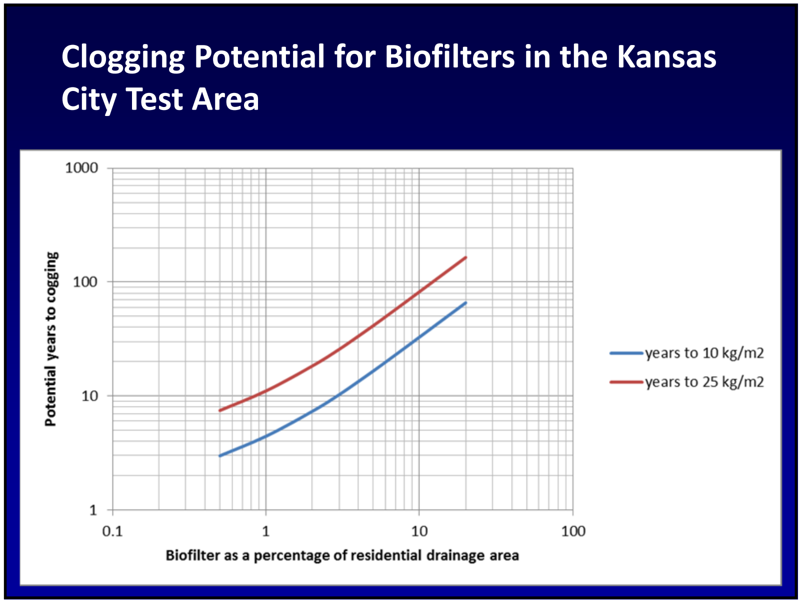
Clogging Potential for Biofilters in the Kansas City Test Area
1000
100
10
1
0.1
1
10
100
Potential years to cogging
Biofilter as a percentage of residential drainage area
years to 10 kg/m2
years to 25 kg/m2

25


1324 76th St. monitoring location, biofilter and adjacent porous concrete sidewalk
26

26


Other Stormwater Controls in Test Area
27

27


Curb extension rain garden
Other Stormwater Controls in Test Area

28

Conclusions

- There are a large number of infiltration-based stormwater controls that can be applied to a variety of land uses to reduce the volume and rates of stormwater discharged to combined sewers.
- Beneficial uses of stormwater can also be a useful tool to reduce these discharges, while still conserving important resources.
- Continuous WinSLAMM simulations can calculate the benefits of these controls in many combinations for an area.

29

29

Collaborations for Kansas City

- US EPA: National Risk Management Research Laboratory (NRMRL), Office of Research and Development (ORD), Region 7, Office of Wastewater Management (OWM), Office of Enforcement and Compliance Assurance (OECA)
- KCMO Water Services Department
- Tetra Tech, Inc.
- University of Missouri, Kansas City
- University of Alabama
- Mid-America Regional Council (MARC)
- Bergmann Associates
- Partnerships at neighborhood, watershed and regional levels

30