The Ohio State University

Measuring the Impacts of Green Infrastructure Implementation: Blueprint Columbus

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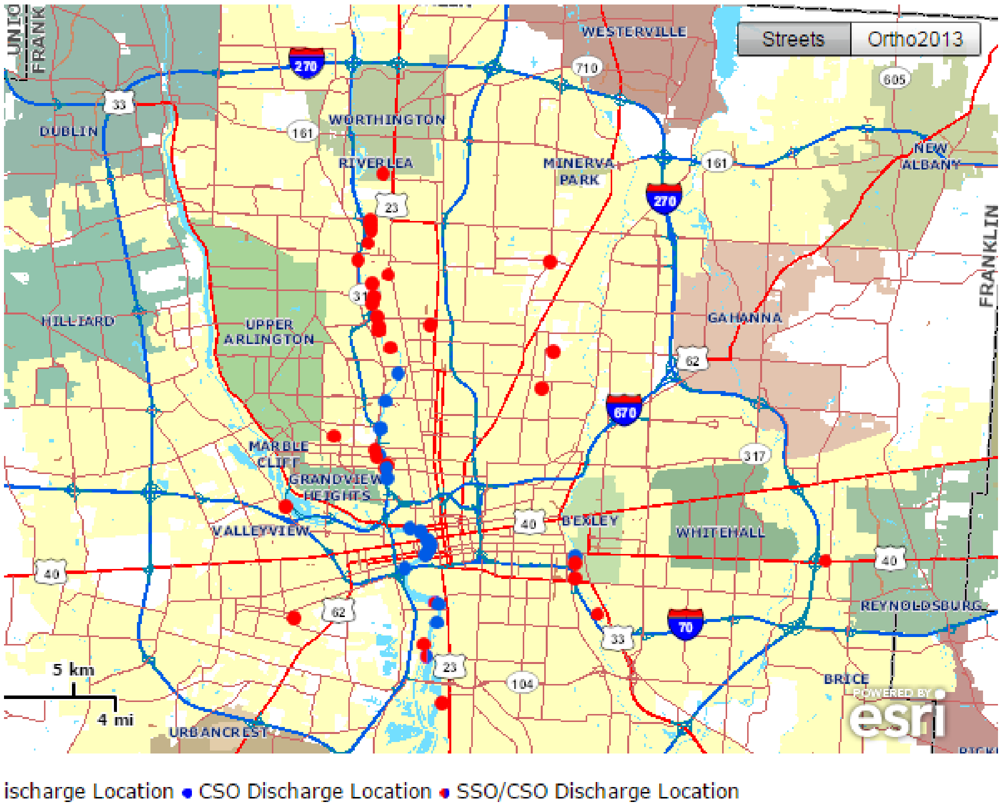
Today's Outline:

1. Goals and Motivation
2. Blueprint Columbus: Clintonville plans
3. OSU Research

BLUEPRINT COLUMBUS
Clean streams.
Strong neighborhoods.

SSOs/CSOs in Columbus



Source: https://eapp.columbus.gov/ssocso/mnmap.aspx

- In 2016:
  - 34 SSOs outfalls
    - 97 events
    - All but 5 outfalls
  - 20 CSO outfalls
    - 188 events
    - All but 4 outfalls
- Most outfalls discharge to Olentangy River

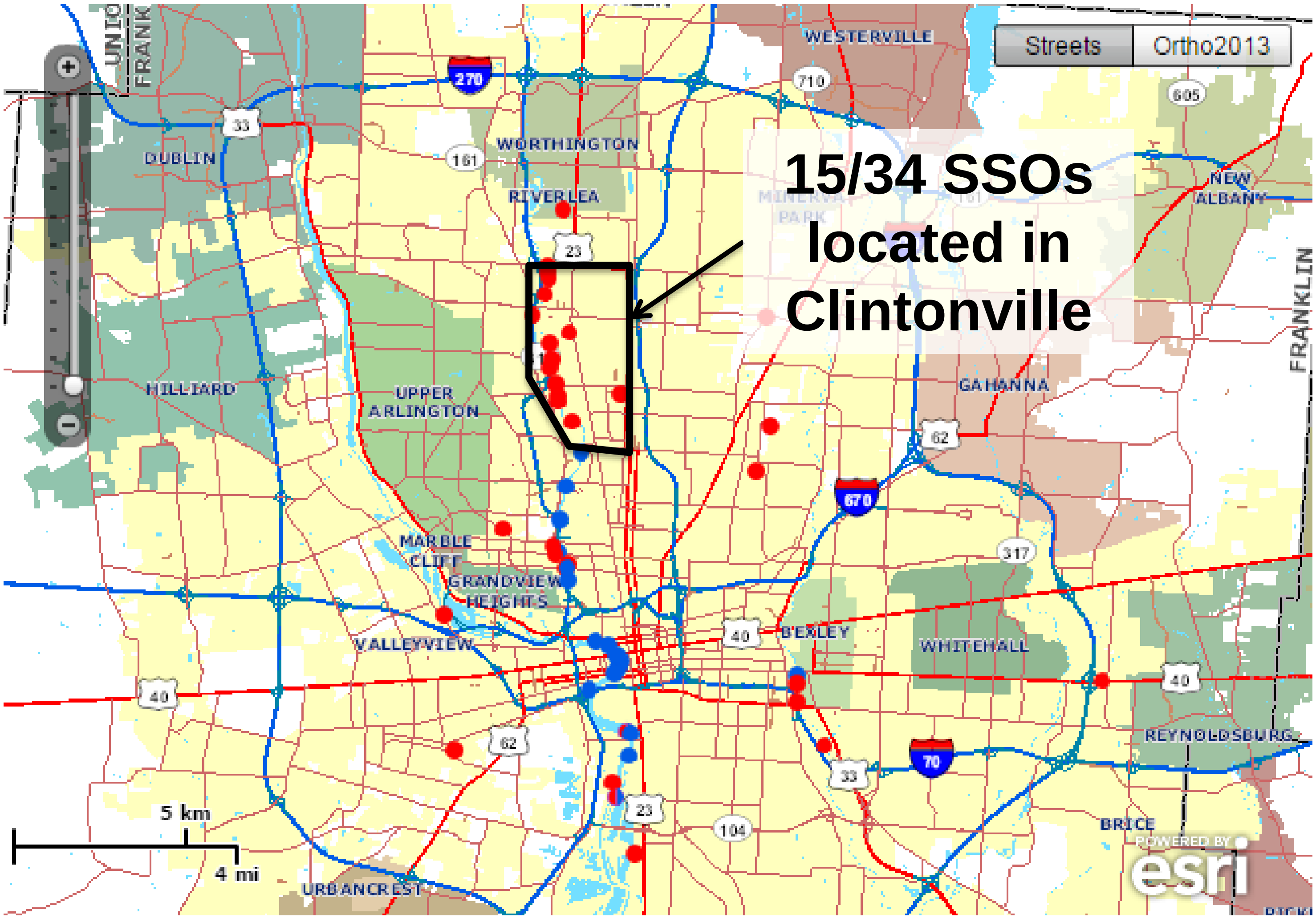
SSO Mitigation: 2 Options

- Blueprint Columbus
  - $1.7B USD capitol costs
  - Includes green infrastructure, downspout disconnection, lateral lining, sump pumps
  - Reduce I/I by 30%
- Gray Solutions
  - $1.6B USD capitol costs
  - Two SSO tunnels
  - Pipe upsizing, rehab, and replacement

- Grey solutions = no impact on stormwater quality
- Modeling in SWMM showed greater reduction in overall SSOs for green solutions
- Ecosystem and community services

SSO Mitigation

Blueprint Columbus



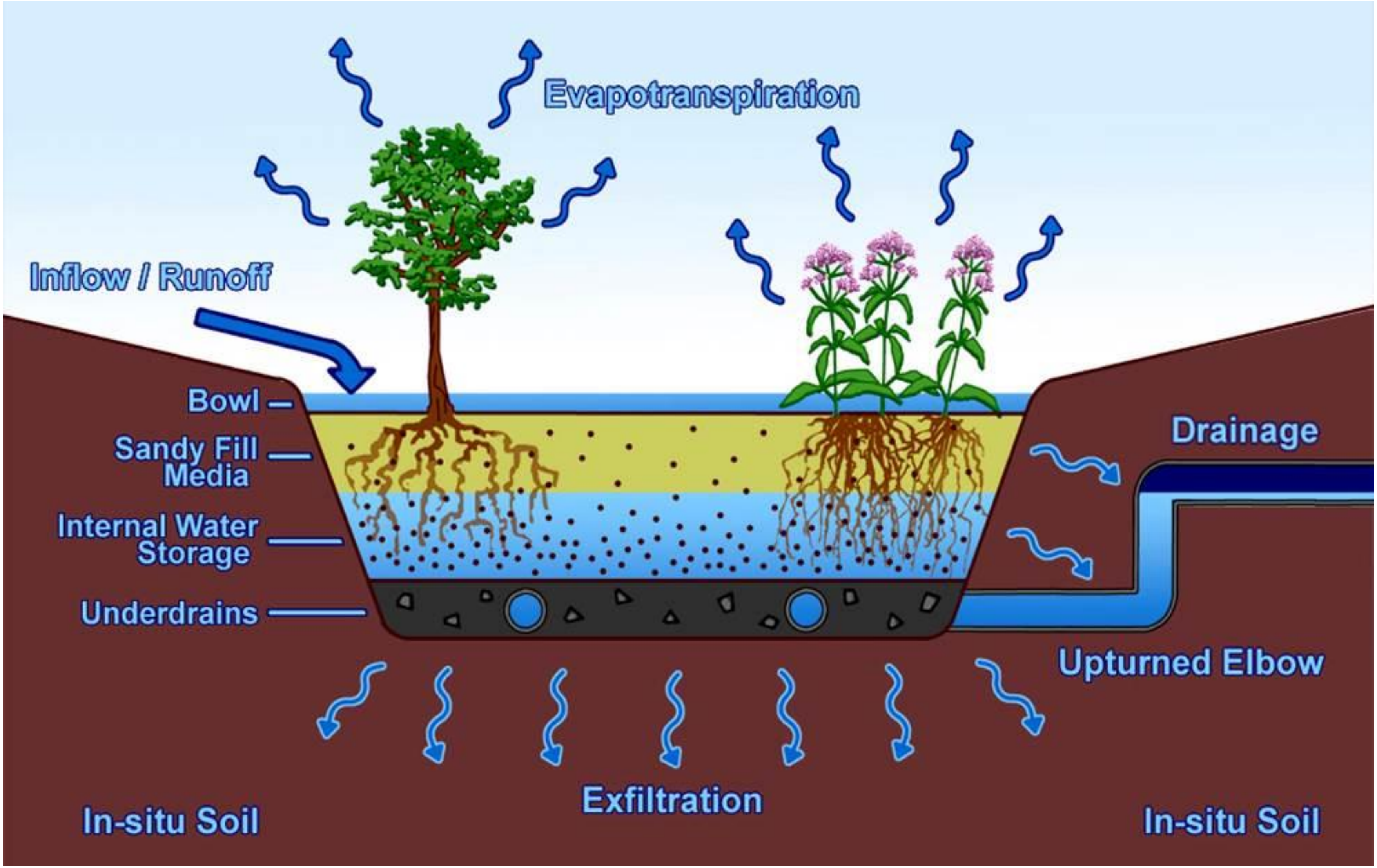
● SSO Discharge Location ● CSO Discharge Location ● SSO/CSO Discharge Location

Source: https://eapp.columbus.gov/ssocso/mnmap.aspx

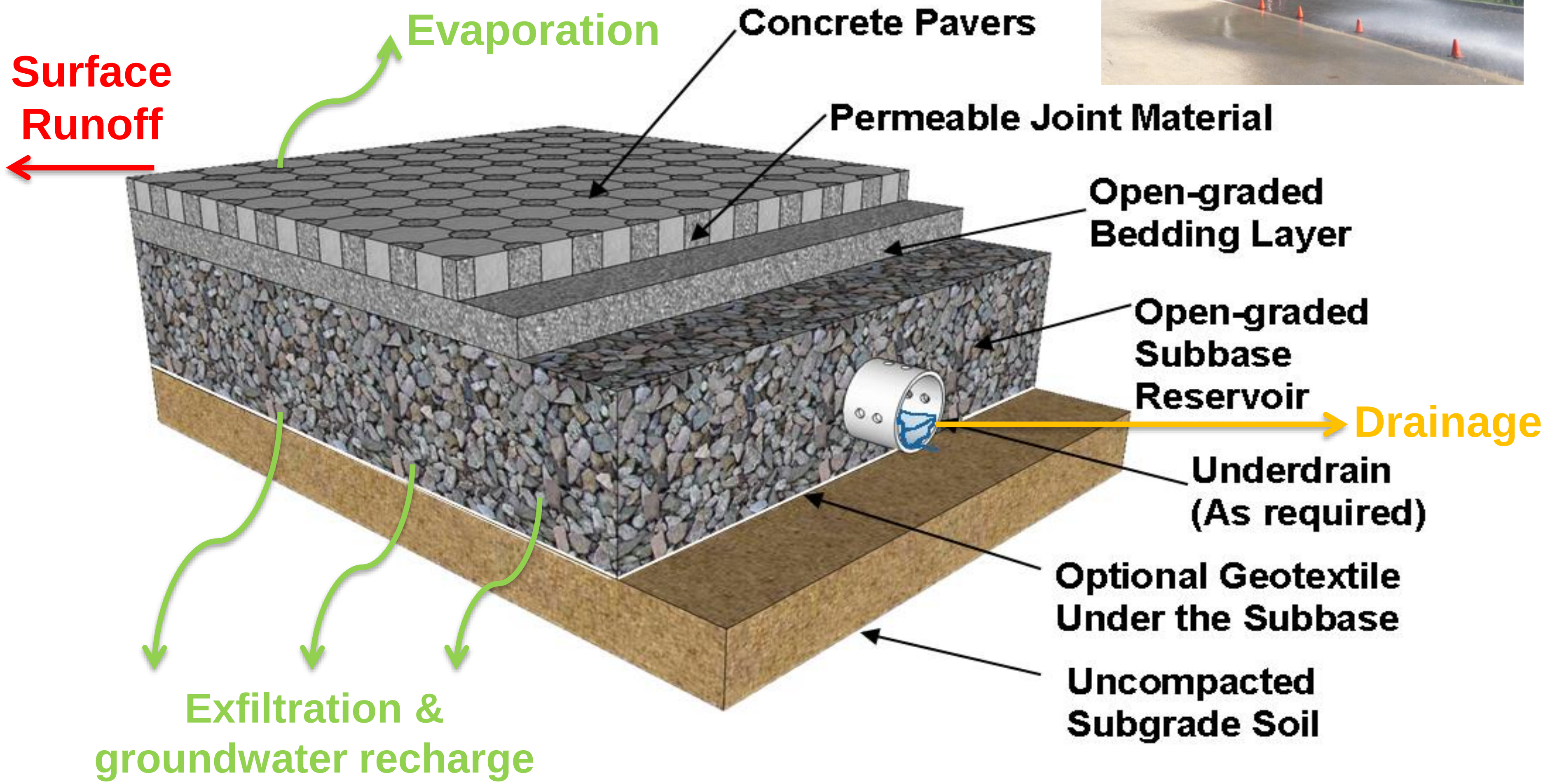
Clintonville Pilot Area

- Mandatory lateral lining and sewer main lining
  - Reduce I/I by 30% (thereby reducing SSOs)
- Redirect runoff from rooftops to lawns instead of directly to sewers or foundation drains
- Sump pump installation (reduce flow to foundation drains)
- Green Infrastructure for stormwater management

Bioretention Typical Cross-Section

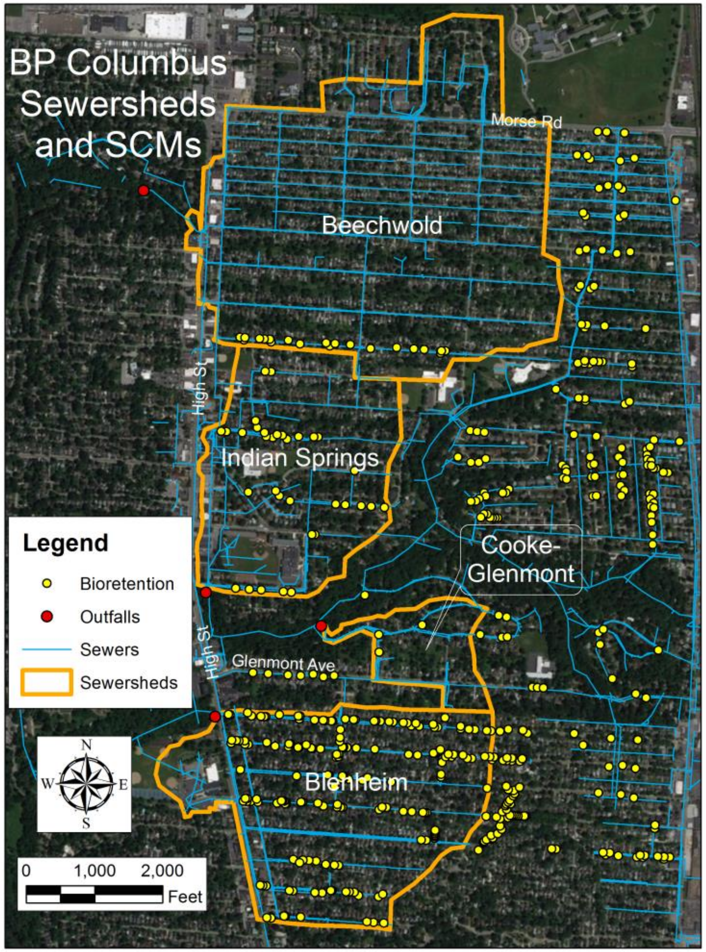


Permeable Pavement Cross-Section

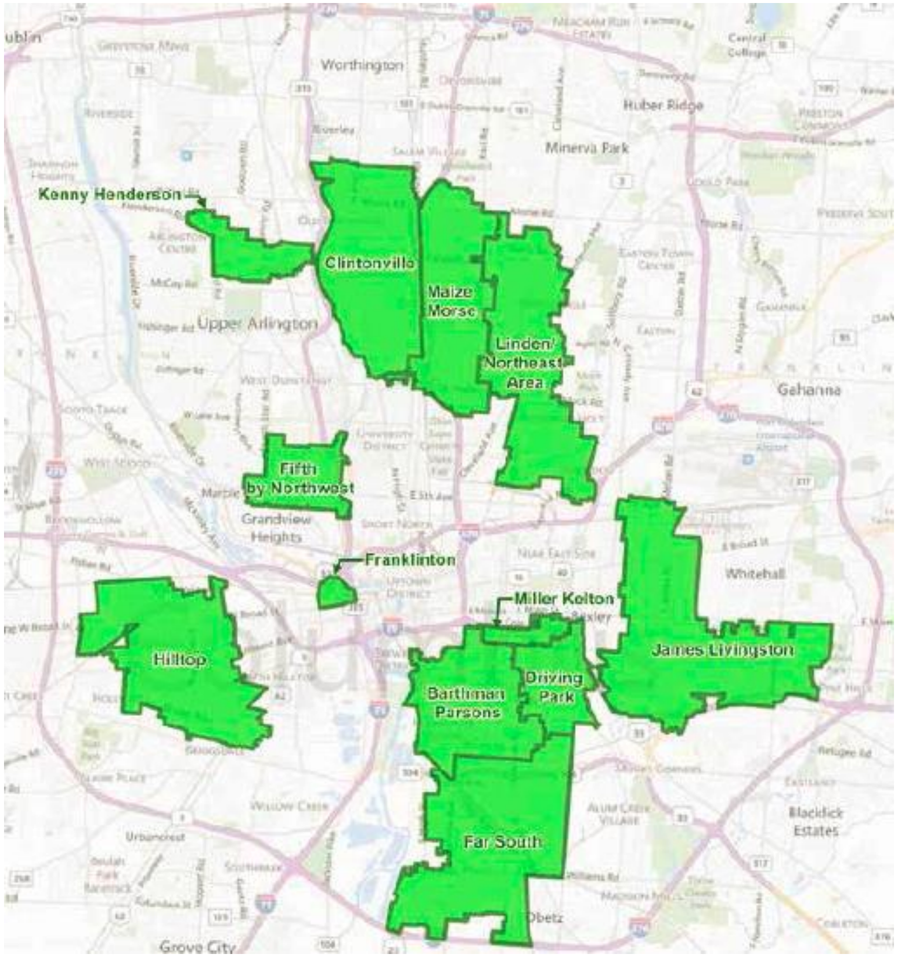


Why Monitor?

- Watershed planning
- Watershed-scale BMP implementation
  - Impacts at outfall to surface waters



Long-Term Plan: City-wide Implementation



Source: CDM Smith

Statement of Needs

- We have excellent data on how single stormwater practices perform (BR, PP, Swales, Wet Ponds, etc.)
- How do these systems, implemented watershed (catchment) – wide, affect hydrology and WQ?
- What %age of catchment needs to be retrofitted before a change is observed?
- How do we best locate SCMs and compare gray vs. green

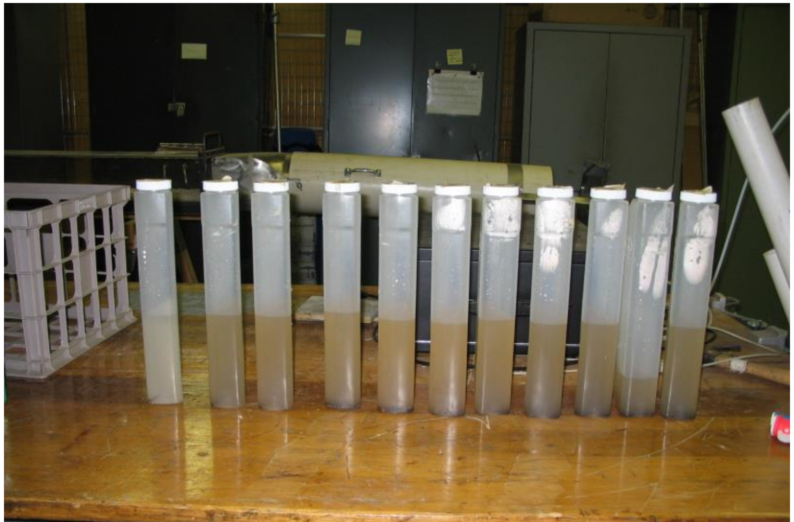
Blueprint Goals & OSU Research 2016-22:

1. Reduce sewer overflows
   - Analyze storm flows
2. Improve water quality
   - Analyze water quality
3. Provide habitat
   - Analyze species in gardens
4. Improve property values
   - Track home prices
5. Stabilize neighborhoods
   - Survey residents

BLUE PRINT COLUMBUS
Clean streams.
Strong neighborhoods.

Quantify changes in volume and quality of flow during:

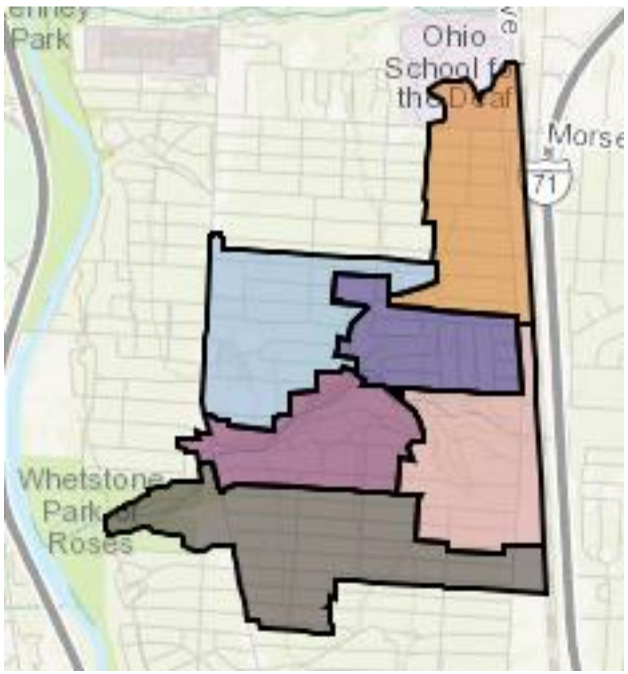
1. Simulated storm events in individual bioretention systems
2. Real events at catchment scale
   - Analyze quality samples for TSS, nutrients, fecal indicator bacteria, metals, BOD, oil and grease (began 2016)



Blueprint: Clintonville Plans

Six Project Areas

Phased Construction
2017-2019



BLUE PRINT COLUMBUS
Clean streams. Strong neighborhoods.

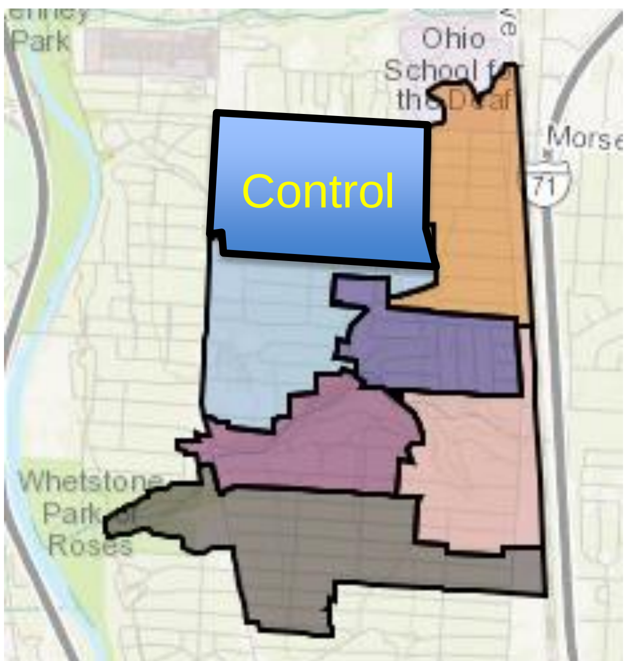
Blueprint Columbus - Clintonville
Potential Green Infrastructure Locations
(Not all will be constructed)

0 500 1,000 2,000
Feet

Potential Monitoring Locations

Control Sewershed

- Beechwold – no GI implementation
- Neighborhood characteristics similar



BLUE PRINT COLUMBUS
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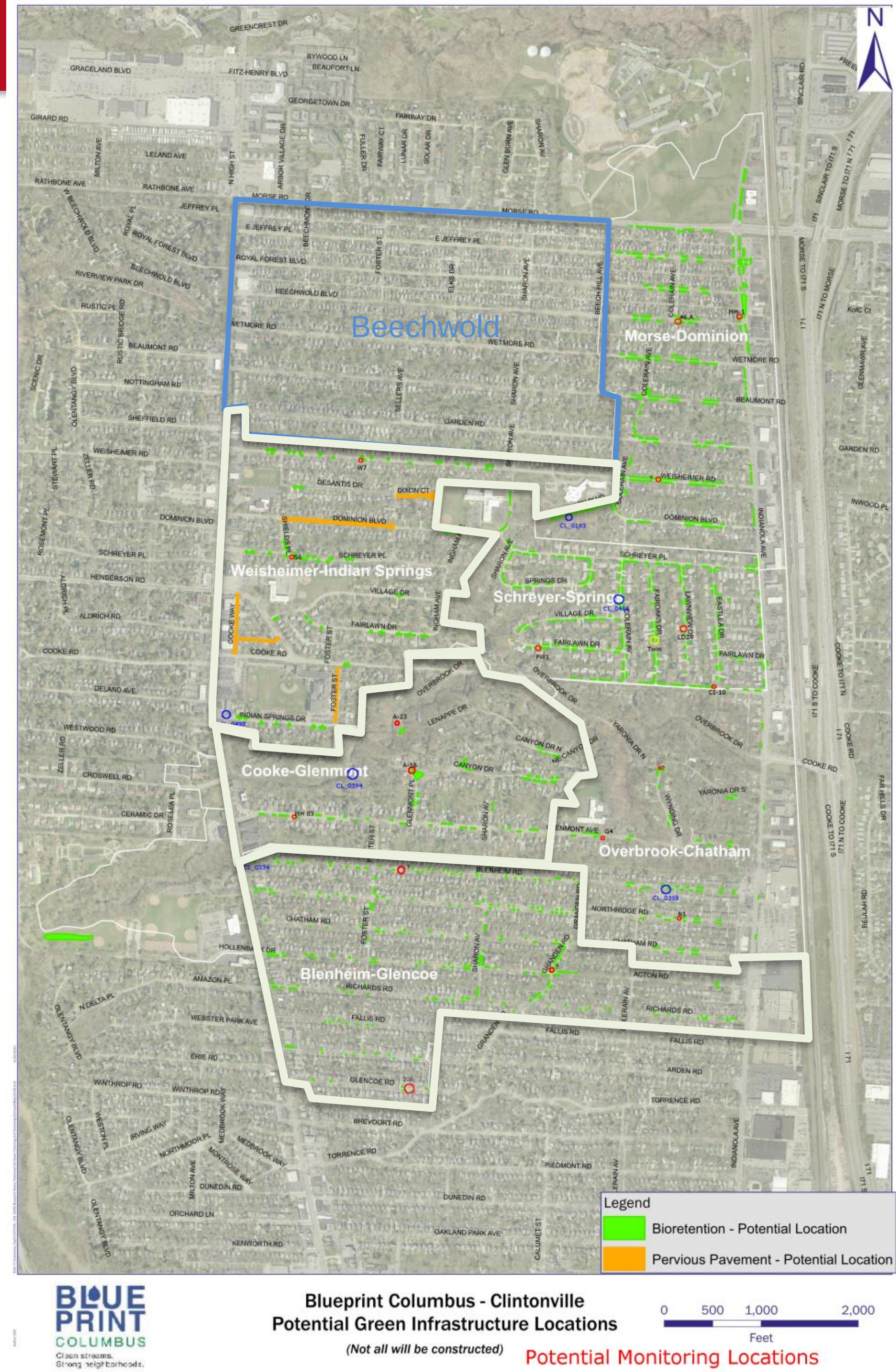
Blueprint Columbus - Clintonville
Potential Green Infrastructure Locations
(Not all will be constructed)

0 500 1,000 2,000
Feet

Potential Monitoring Locations

Treatment Sewersheds

- Weisheimer-Indian Springs
  - Extensive permeable pavement installation
- Cooke Glenmont
  - Lowest GI installation
  - Larger facilities
- Blenheim Glencoe
  - Moderate GI implementation

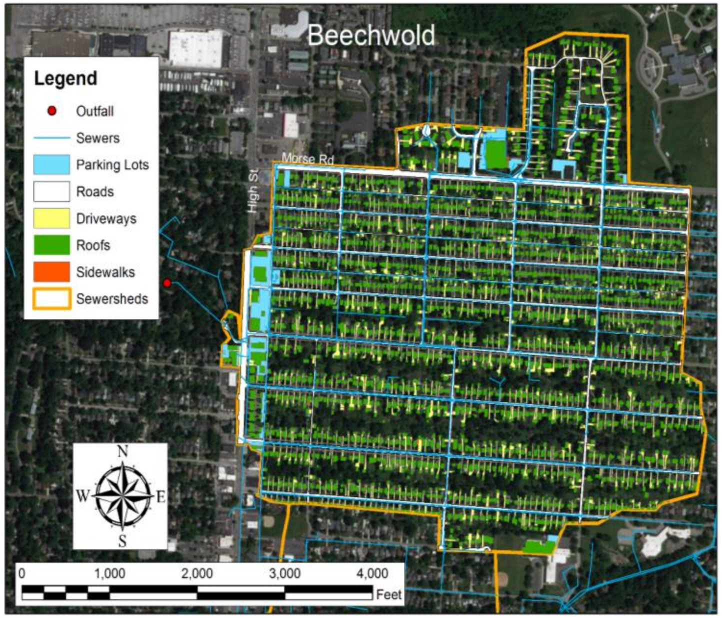


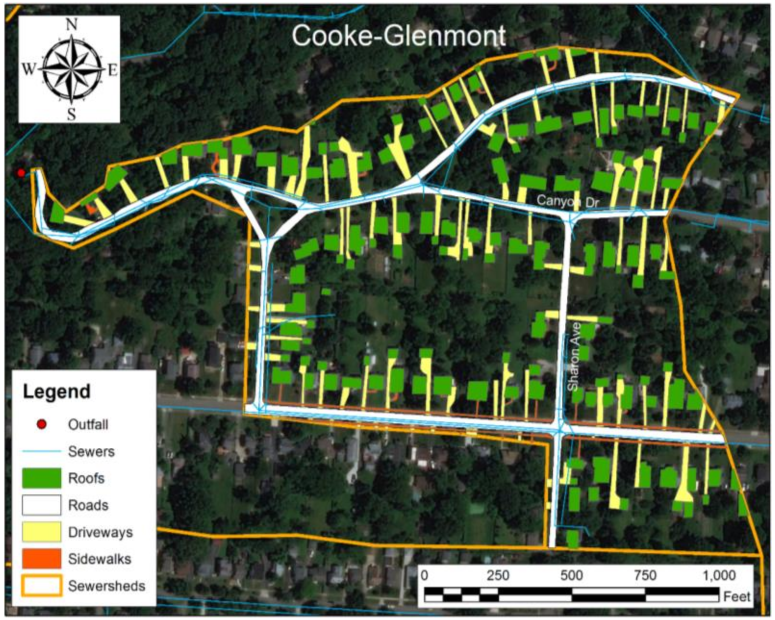
Sewershed Land Use

Sewershed	Area (ac)	Land Use (%)		
		Residential	Commercial	Institutional
Beechwold	276	95.7	3.6	0.7
Blenheim	151	88.6	4.9	6.5
Cooke-Glenmont	29	100	0	0
Indian Springs	118	75.0	7.6	17.4

Imperviousness

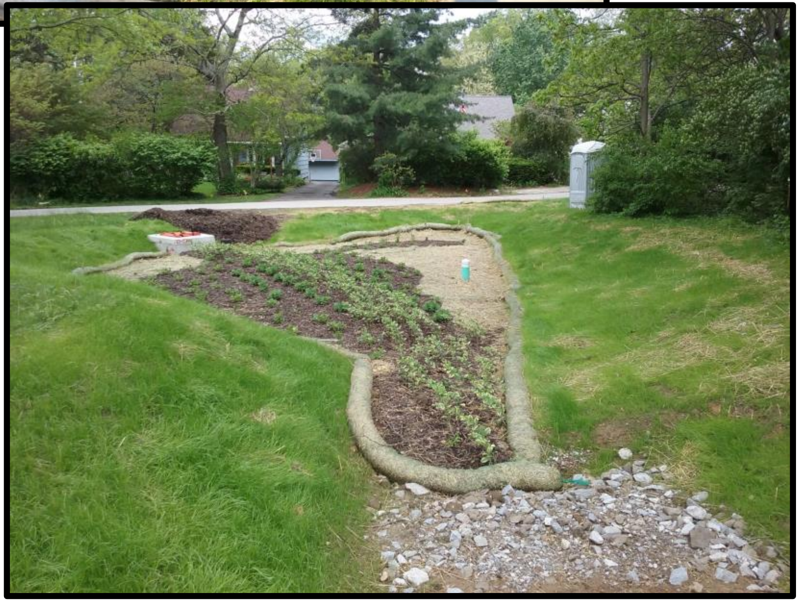
Sewershed	Units	Impervious	Roofs	Roads	Sidewalks	Driveways	Parking Lots	Pervious
Beechwold	% of total area	38.2	15.2	11.0	2.1	8.3	1.6	61.8
Blenheim		44.5	16.7	9.9	4.8	9.9	3.2	55.5
Cooke-Glenmont		30.9	12.5	9.3	1.2	8.0	0.0	69.1
Indian Springs		40.3	15.7	8.6	2.7	6.4	7.0	59.7





Construction of SCMs

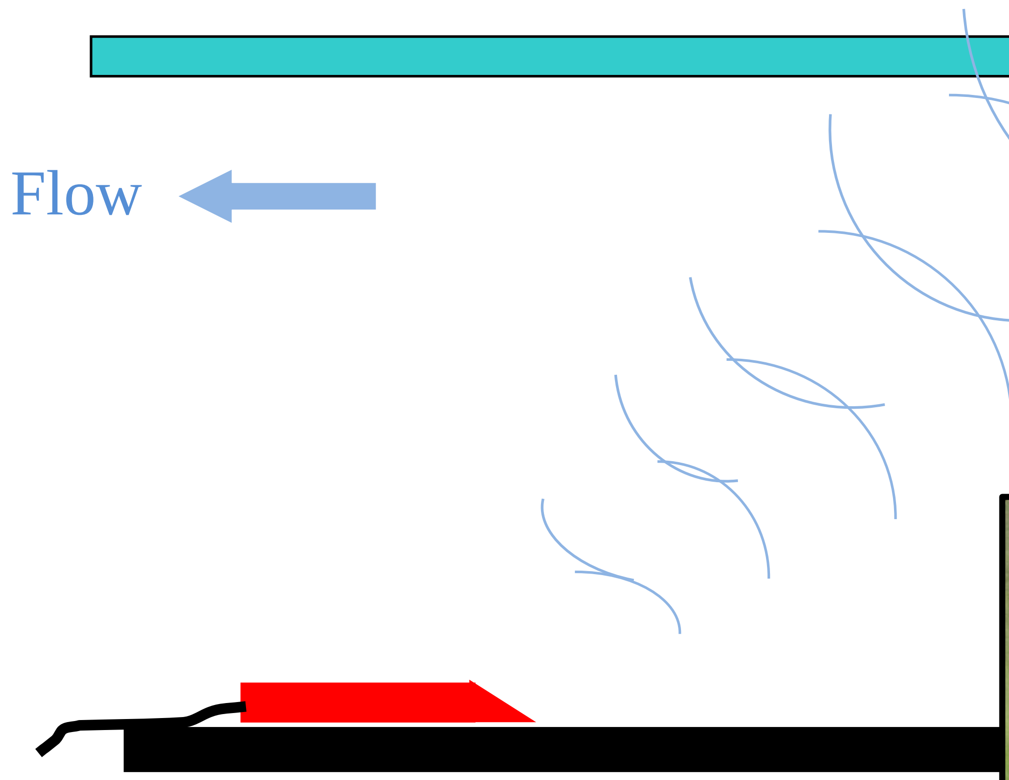
- Construction began summer 2017
- Data sets collected 2016-2017
- Existing conditions data thus far, no post-SCM implementation data

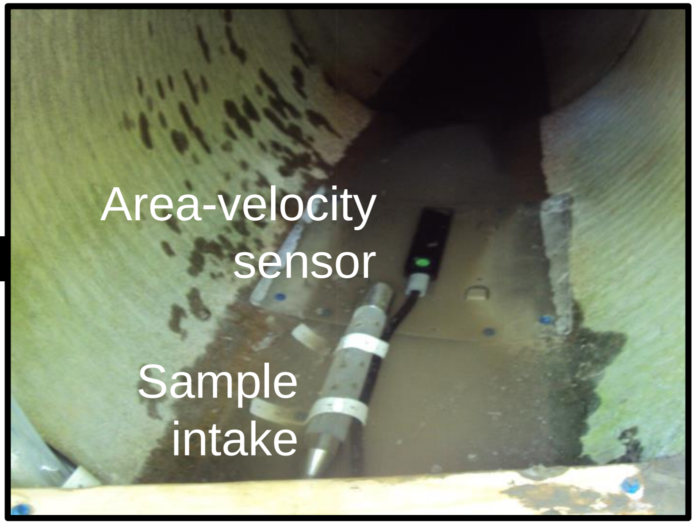


Stormwater Monitoring

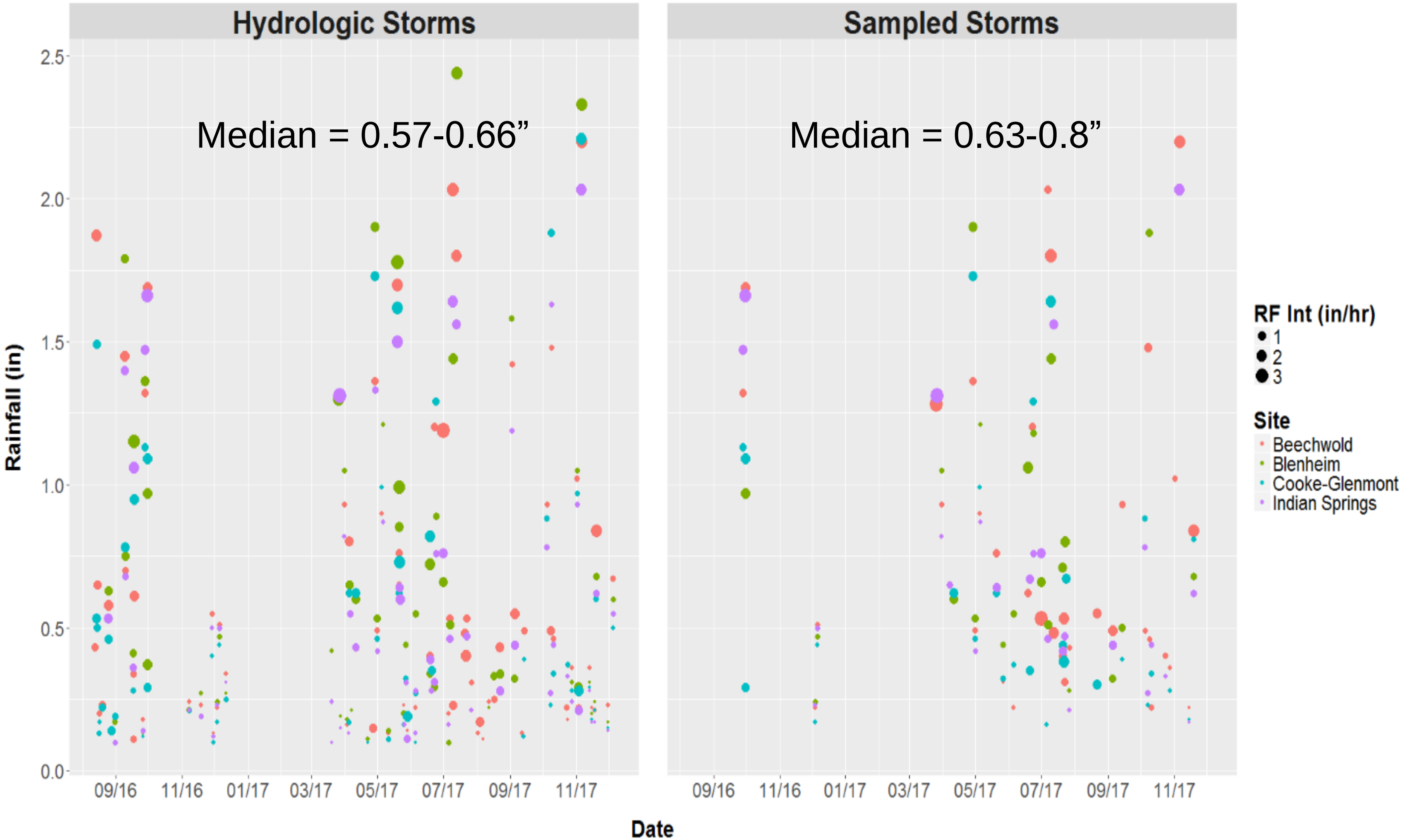
- Continuous rainfall and flow monitoring (baseflow and stormflow)
- ISCO 6712 samplers used to obtain flow proportional, composite samples
- Analyze for nutrients, sediment, metals, bacteria

Flow Measurement with Area Velocity Sensors





Rainfall Events



Rainfall/Flow Seasonality

Rainfall

Site	Parameter	Differences
Beechwold	Peak Rainfall Intensity	Summer>Fall
		Summer>Spring
	Average Rainfall Intensity	Summer>Fall
Blenheim	Peak Rainfall Intensity	Summer>Fall
	Average Rainfall Intensity	Summer>Fall
Cooke-Glenmont	Peak Rainfall Intensity	Spring>Fall
		Summer>Fall
Indian Springs	Peak Rainfall Intensity	Summer>Fall
		Summer>Spring
	Average Rainfall Intensity	Summer>Fall

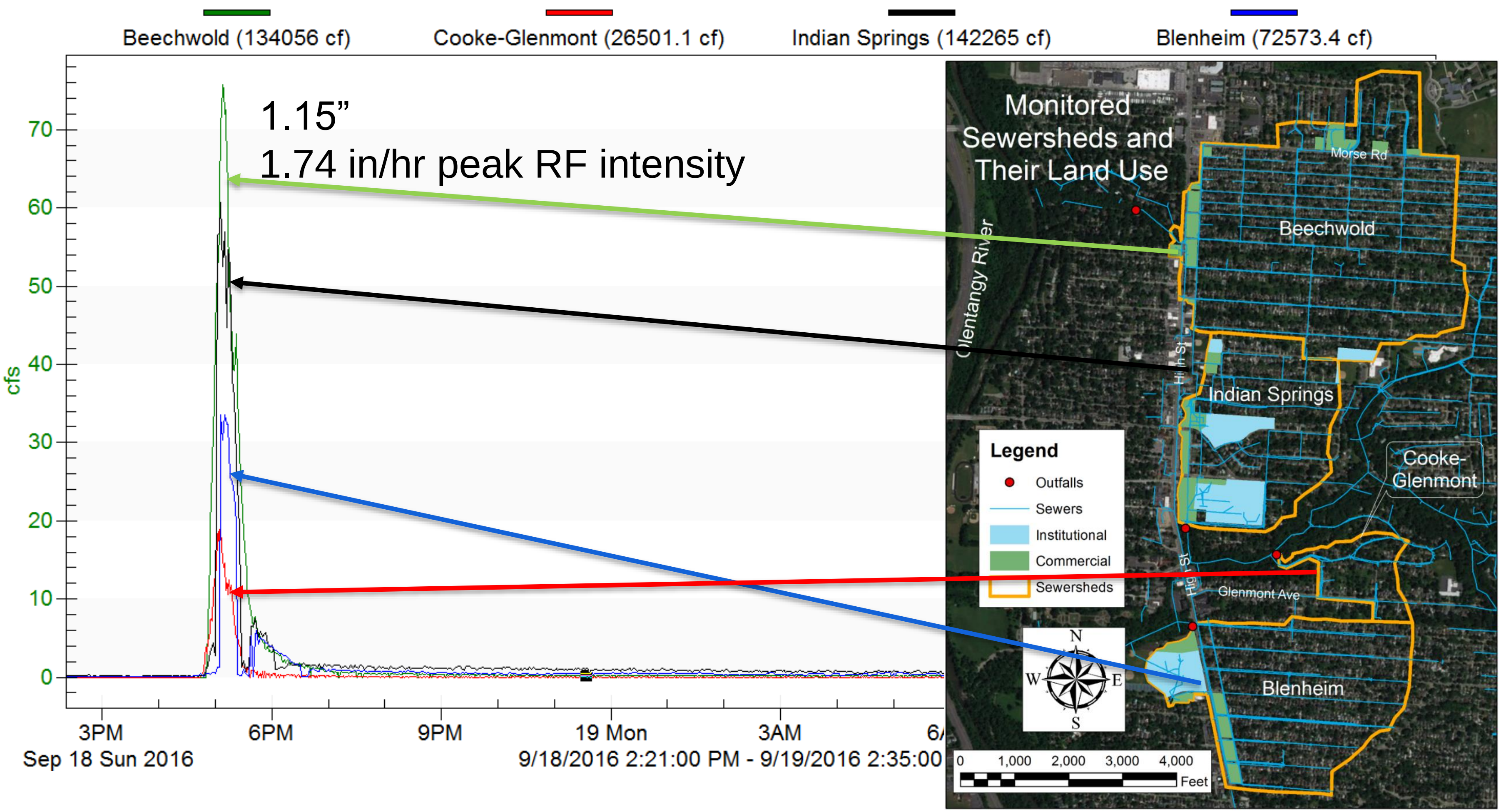
- Summer intensity generally > other seasons
- No difference in rainfall depth

Flow

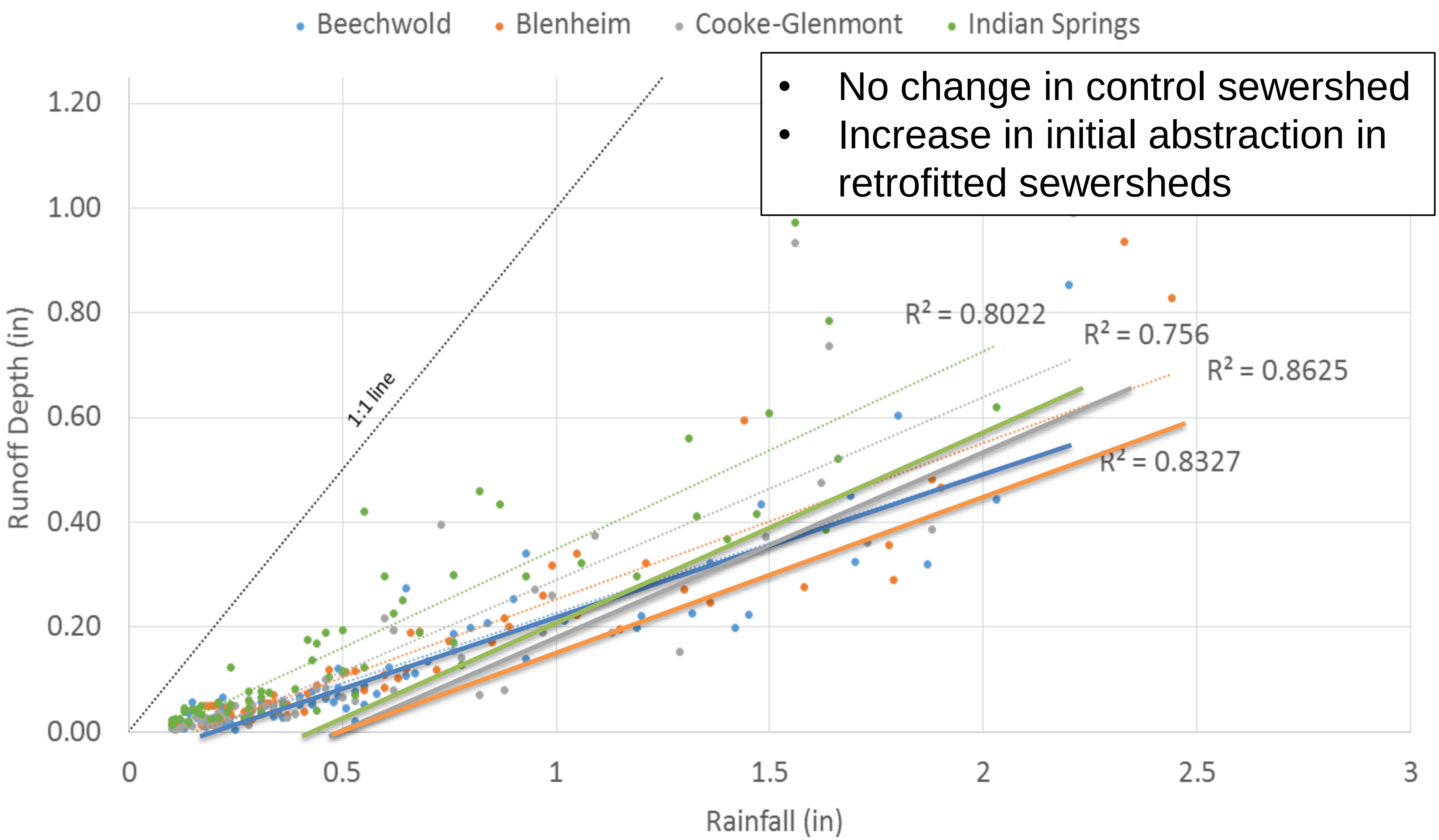
Site	Parameter	Differences
Beechwold	Lag-to-Peak	Fall>Summer
	Flow Duration	Fall>Summer
		Spring>Summer
	Time to Peak	Fall>Spring
		Fall>Summer
	Normalized Peak Flow	Summer>Fall
Blenheim	Normalized Peak Flow	Summer>Fall
Cooke-Glenmont	Lag-to-Peak	Fall>Summer
	Time to Peak	Fall>Spring
		Fall>Summer
	Normalized Peak Flow	Summer>Fall
Indian Springs	Time to Peak	Fall>Summer
	Normalized Peak Flow	Summer>Fall

- Durations longer in non-summer
- Peak flows higher in summer

Example Storm Event



Runoff Hydrology

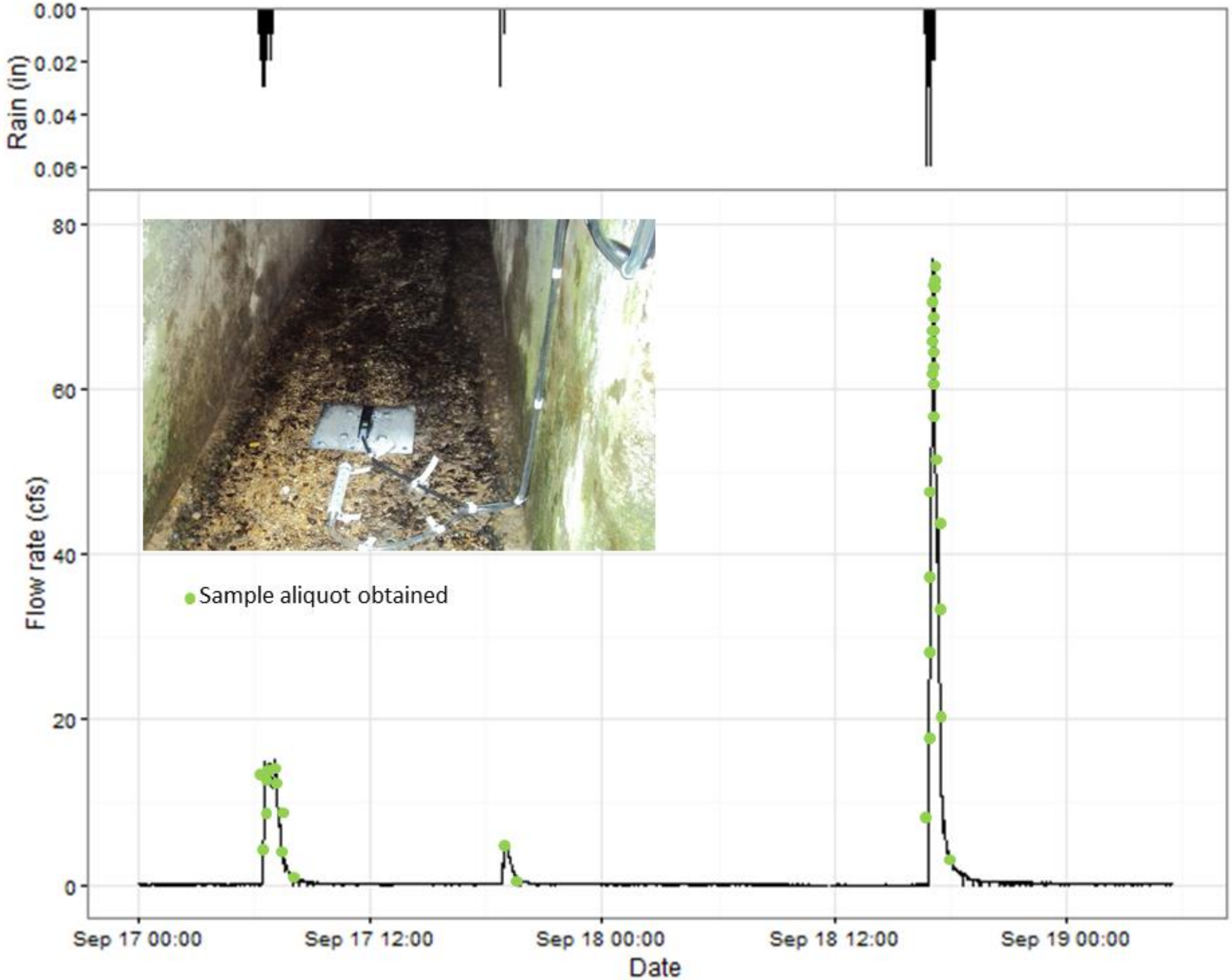


- No change in control sewershed
- Increase in initial abstraction in retrofitted sewersheds

Comparison to Past Residential Runoff Studies

Sewershed or Reference	Runoff Coefficient	Percent Impervious	Soil Texture	Drainage Area (mi^2)
Beechwold	0.2	38.2	Silt Loam	0.43
Blenhheim	0.23	44.5	Silt Loam	0.24
Cooke-Glenmont	0.24	30.9	Silt Loam	0.05
Indian Springs	0.33	40.3	Silt Loam	0.18
Page et al (2015b)	0.38	60	Sandy	0.002
Line and White (2007)	0.55	53	Clayey	0.015
Leopold (1991)	0.35	40	No data	0.25
Leopold (1991)	0.18	27	No data	1.17
Barrett et al. (1998)	0.4	37.6	No data	0.04
Hood et al. (2007)	0.19	29	Sandy Loam	0.021
Hood et al. (2007)	0.24	32	Sandy Loam	0.008

Flow Weighted Sampling

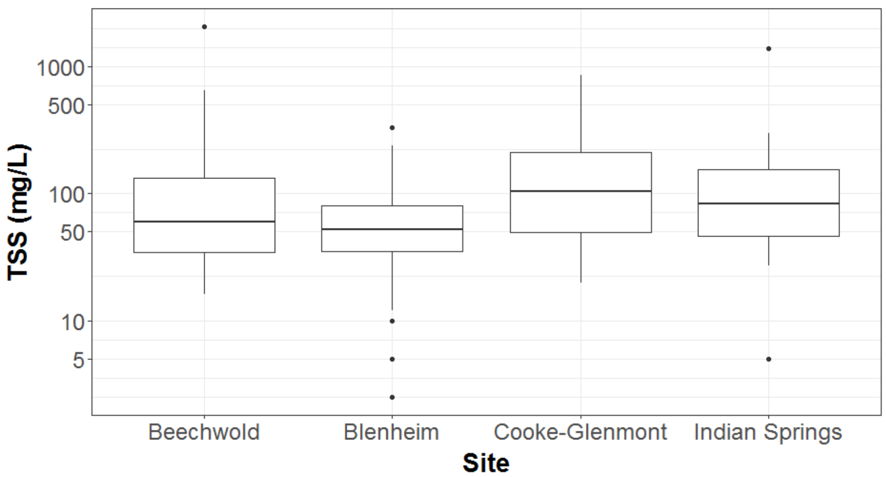


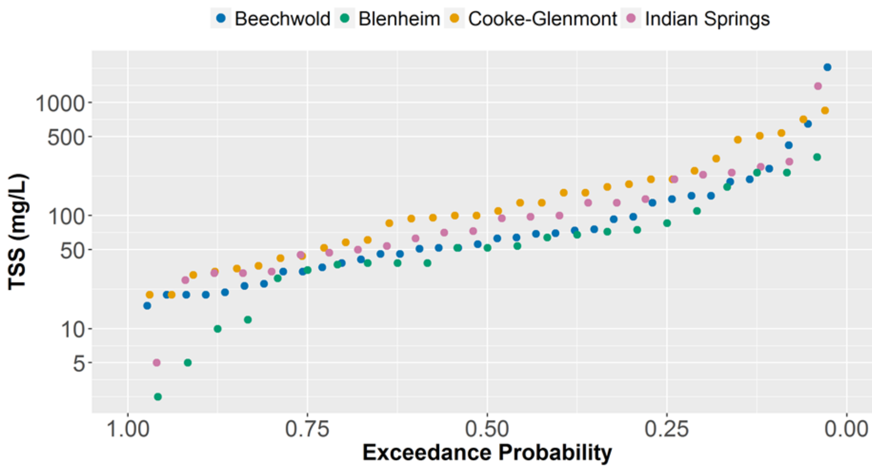
Pollutants Analyzed

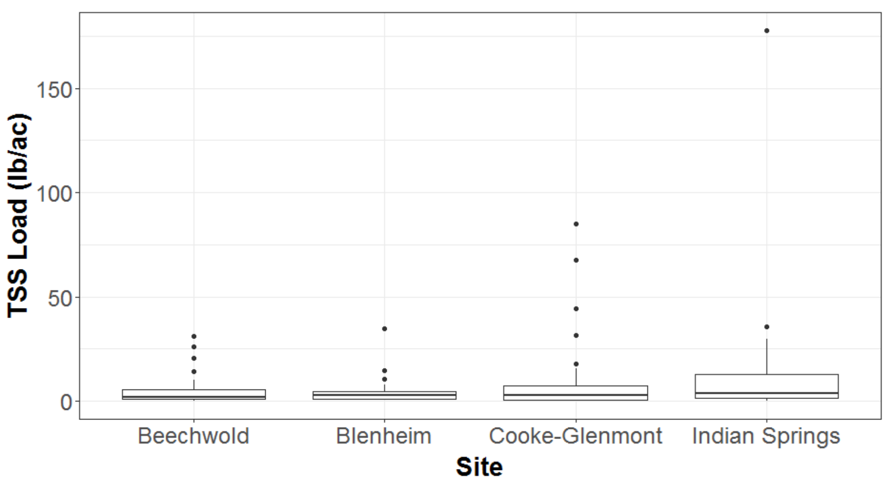
Ammonia (mg/L)	Total Phosphorus (mg/L)
BOD 5 Day (mg/L)	Alkalinity (mg/L)
cBOD, 5 Day (mg/L)	TSS (mg/L)
COD (mg/L)	Total Cd (ug/L)
Cyanide (mg/L)	Total Cr (ug/L)
Hardness (mg/L)	Total Cu (ug/L)
Total Kjeldahl Nitrogen (mg/L)	Total Ni (ug/L)
Nitrate (mg/L)	Total Pb (ug/L)
Nitrite (mg/L)	Total Zn (ug/L)
Total Nitrogen (mg/L)	*E. coli* (cfu/100mL)
Orthophosphate (mg/L)	Oil and Grease (mg/L)

TSS

Typical parking lot/road runoff concentration 50-200 mg/L







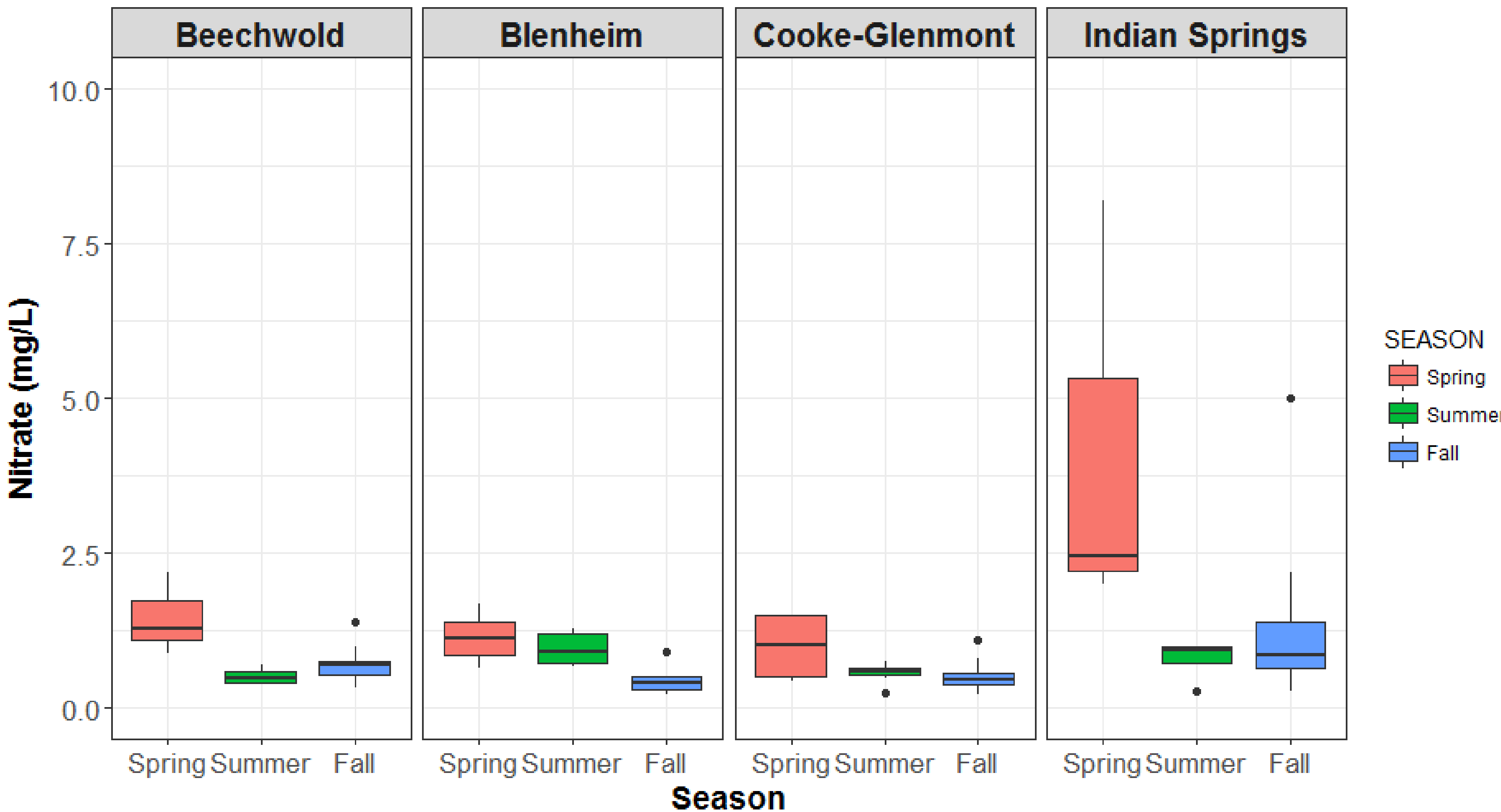
Site	Concentration (mg/L)				Load (lb/ac)			
	Min	Med	Mean+/-SD	Max	Min	Med	Mean+/-SD	Max
Beechwold	16	57	151+/-336	2000	0.11	1.76	4.89+/-7.6	31.2
Blenheim	2.5	45	77.7+/-84.8	330	0.35	2.88	5.4+/-8.3	34.9
Cooke-Glenmont	20	100	183+/-202	850	0.10	2.83	12+/-21.7	85.1
Indian Springs	5	84	161+/-277	1400	0.03	3.58	15.8+/-37.6	177.6

Comparison to Past Studies on Residential Runoff

Pollutant	Beech.	Blen.	Cooke.	I.S.	Page et al. (2015a)	Page et al. (2015a)	Line et al. (2002)	Bedan and Clausen (2009)	Bedan and Clausen (2009)	USEPA (1983)*
TKN	1.10	1.10	1.40	1.10	1.14	1.35	1.48	1.1	1	1.9
$NO_{2\text{-}3}$	0.71	0.84	0.62	1.03	0.14	0.26	0.49	1.1	0.3	0.74
TAN	0.09	0.08	0.10	0.13	0.06	0.04	0.34	0.16	0.15	-
TN	1.7	1.43	2.04	1.9	1.36	1.39	1.97	2.2	1.3	2.64
TP	0.24	0.2	0.33	0.21	0.22	0.21	0.4	0.16	0.19	0.38
OP	0.12	0.13	0.11	0.10	0.11	0.11	-	-	-	0.14
TSS	60	52	105	84	42	54	42	22	24	101
Cu	12	10	12	12	13	14	-	9	7	33
Pb	6	8	8	5	35	14	-	1	1	144
Zn	68	55	50	52	70	65	-	36	42	135

Nutrient, sediment, & metals similar to past studies

Seasonality in Concentration



Seasonality

Concentrations

Site	Pollutant	Differences
Beechwold	Hardness	Spring>Fall
		Spring>Summer
	Nitrate	Spring>Summer
	Nitrite	Summer>Fall
	Alkalinity	Spring>Fall
		Spring>Summer
Blenheim		
Cooke-Glenmont		
Indian Springs		
	Ni	Spring>Summer

		…ences
		…g>Fall
		…er>Fall
		…er>Fall
		…g>Fall
		…Summer
		…g>Fall
		…Summer
		…g>Fall
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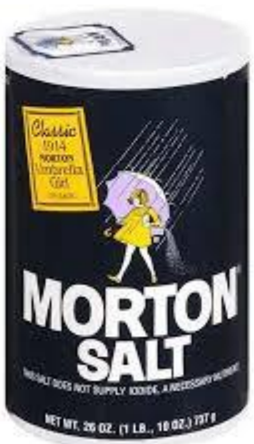
		…Summer
		…g>Fall
		…g>Fall
		…Summer
		…g>Fall
		…Summer
		…g>Fall
		…Summer
	Pb	Spring>Summer

Cause?

Dispersion of Soil

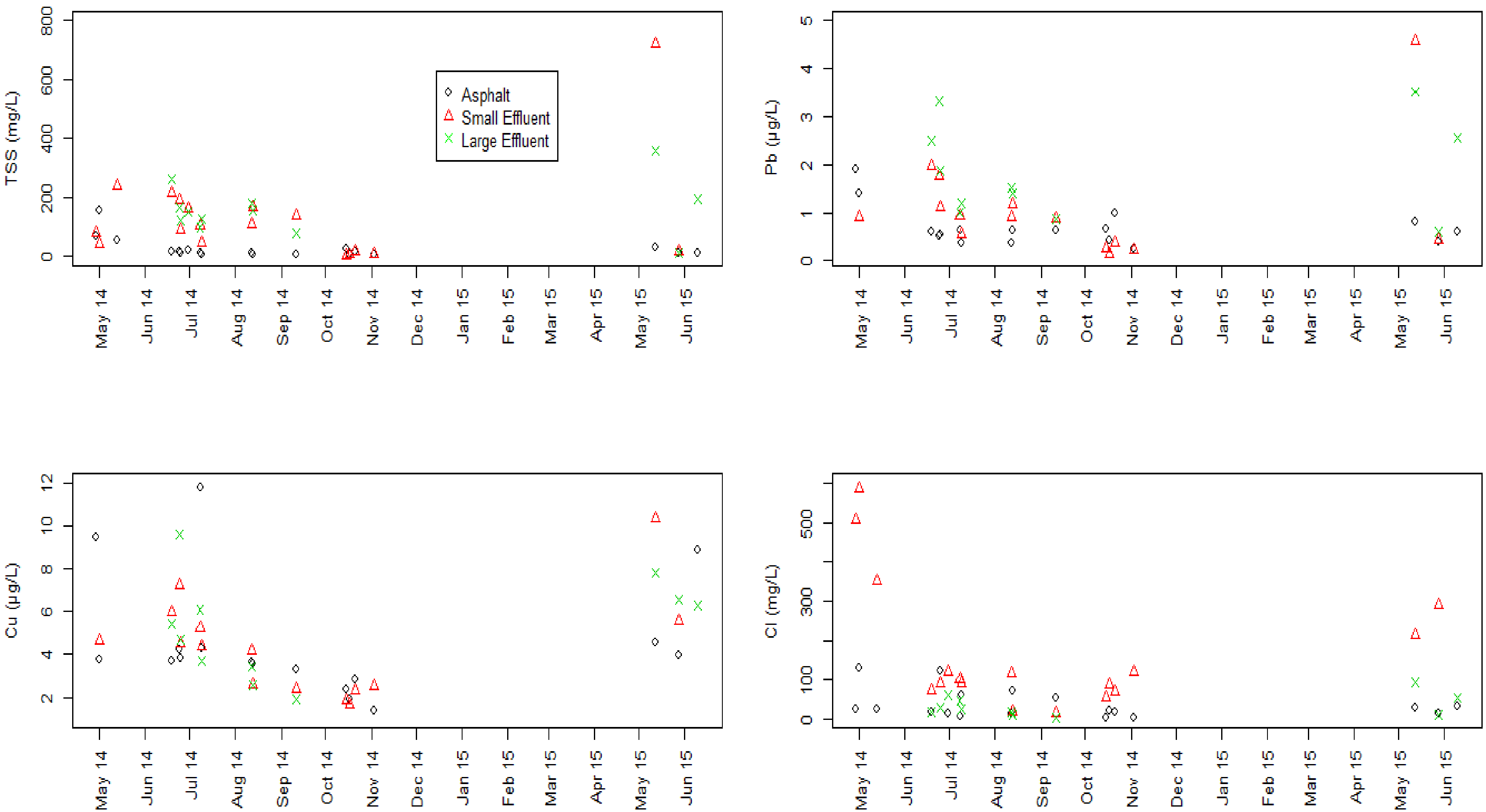
Courtesy:
Lanfaxlabs.com



Test underlying soil at 500 mg/L Cl^-

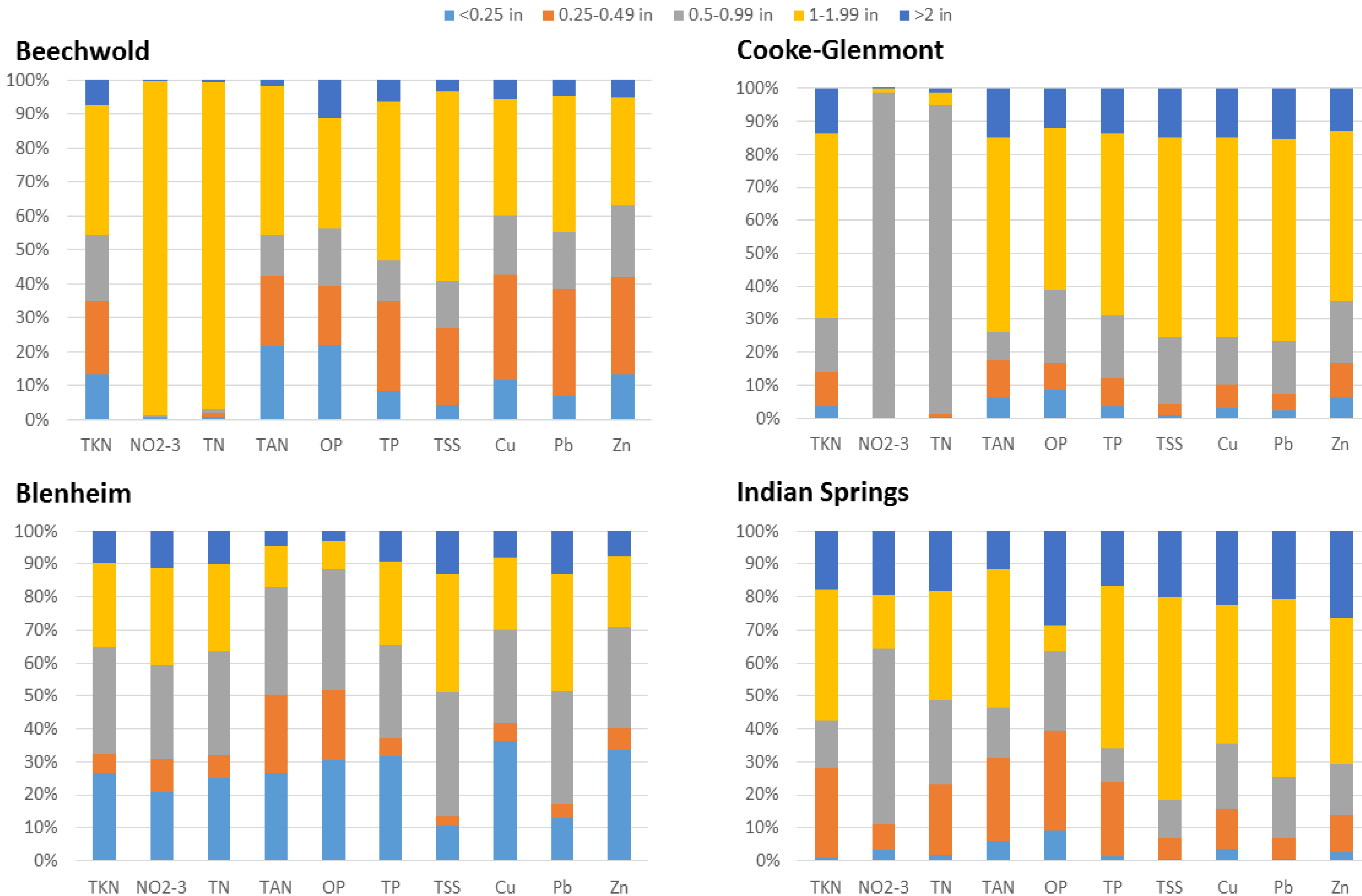
Porous Pavement

Willoughby Hills, Ohio

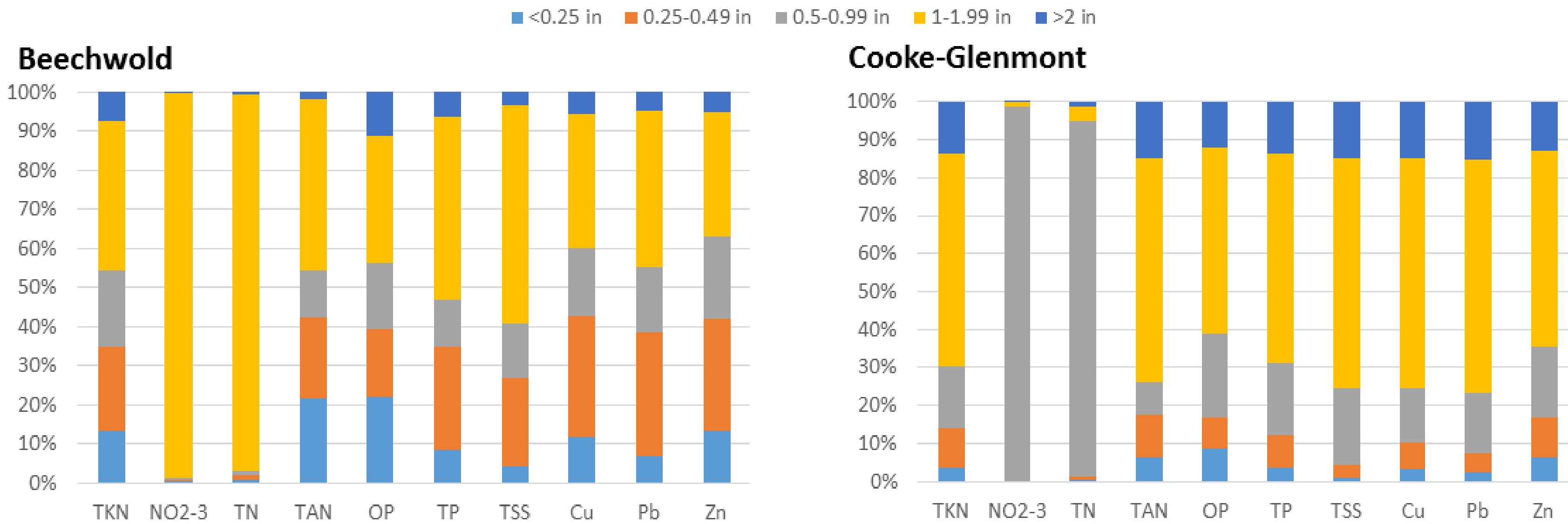


Winston et al. 2016; *Water, Air and Soil Pollution*

Pollutant Load by Rainfall Depth



Pollutant Load by Rainfall Depth



Percent of pollutant load treated with a 0.75" design storm assuming entire sewershed is treated by SCMs

	TAN	TKN	NO_{2-3}	OP	TP	TSS	TN	Cu	Pb	Zn
Average across all sites	75	72	75	78	71	65	74	72	67	73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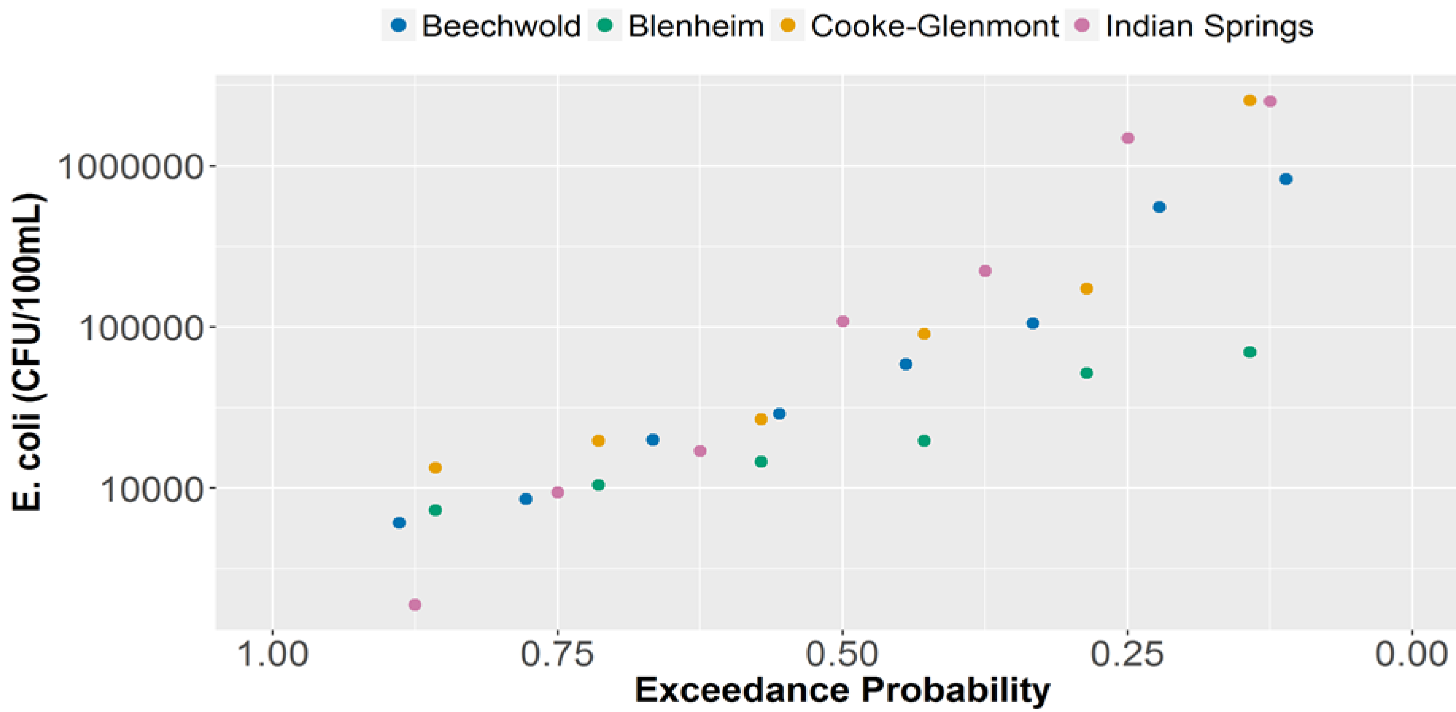
Bacteria making some Ohio beaches no vacation

28 beaches are under health advisories for E. coli

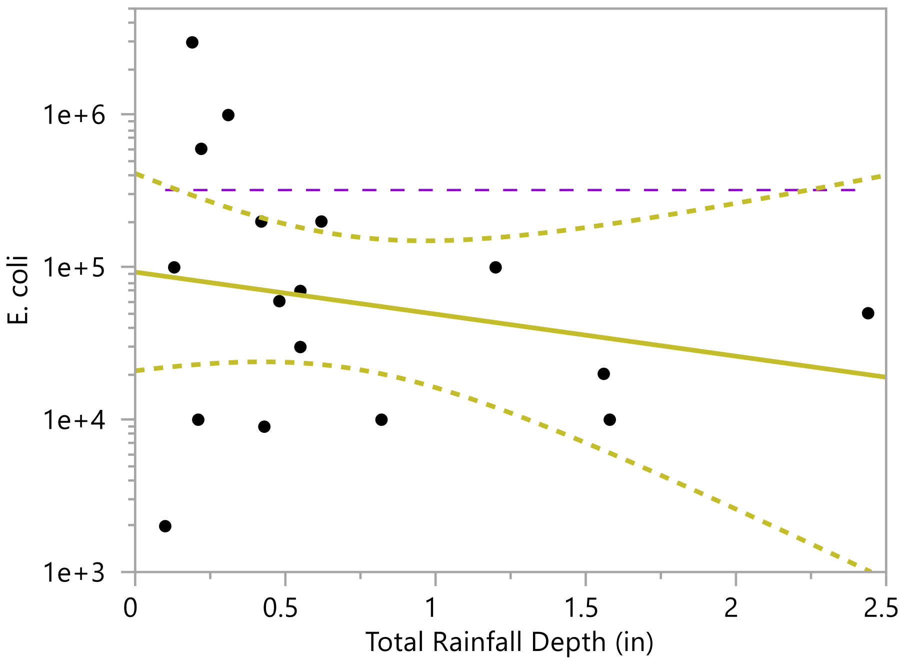
Public Health

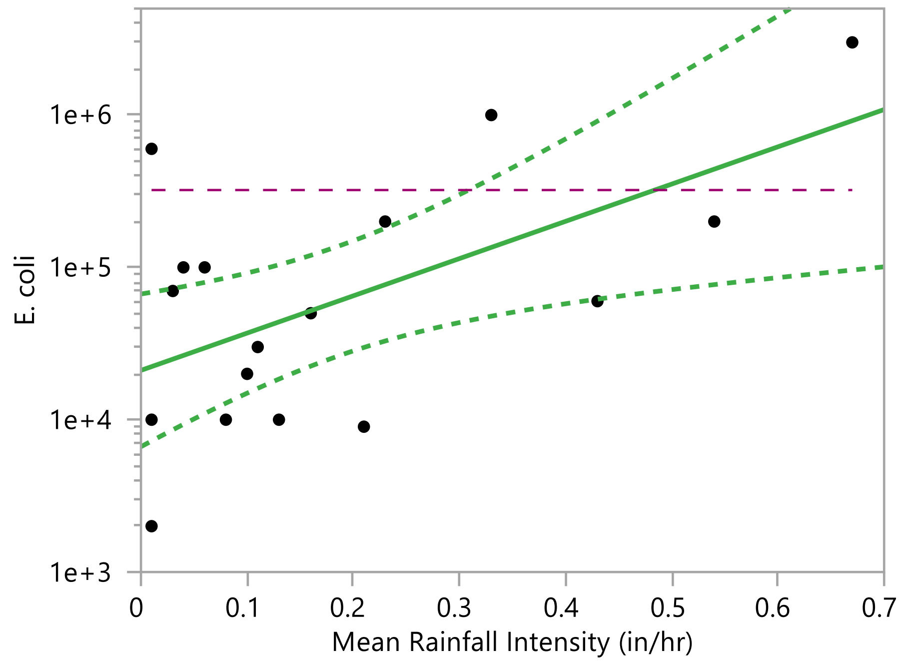
Indicator Bacteria



- Substantial variability in *E. coli* concentrations
- Max concentrations 2.5×10^8 CFU/100mL

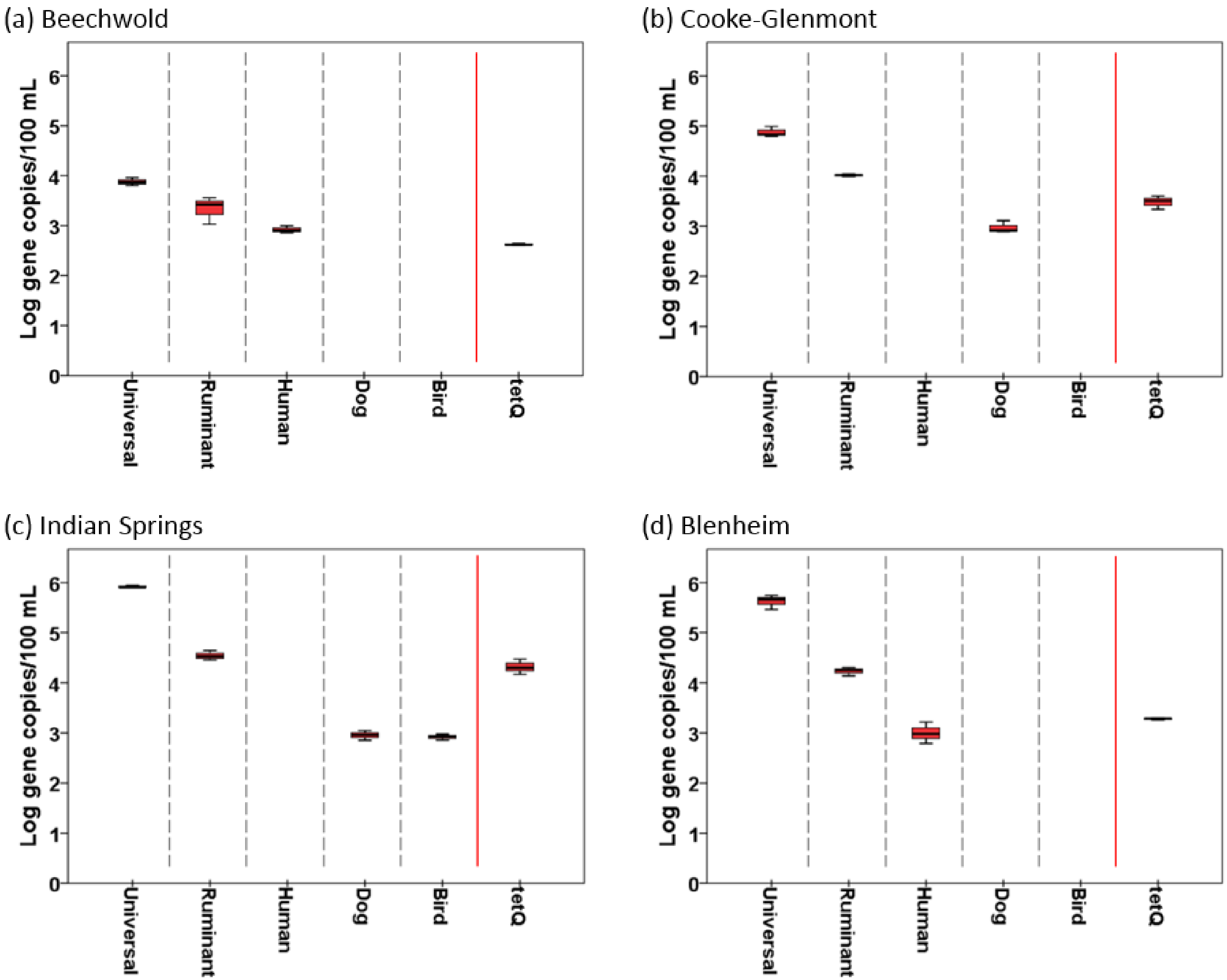
E. Coli Relationships





Public Health

Microbial Source Tracking

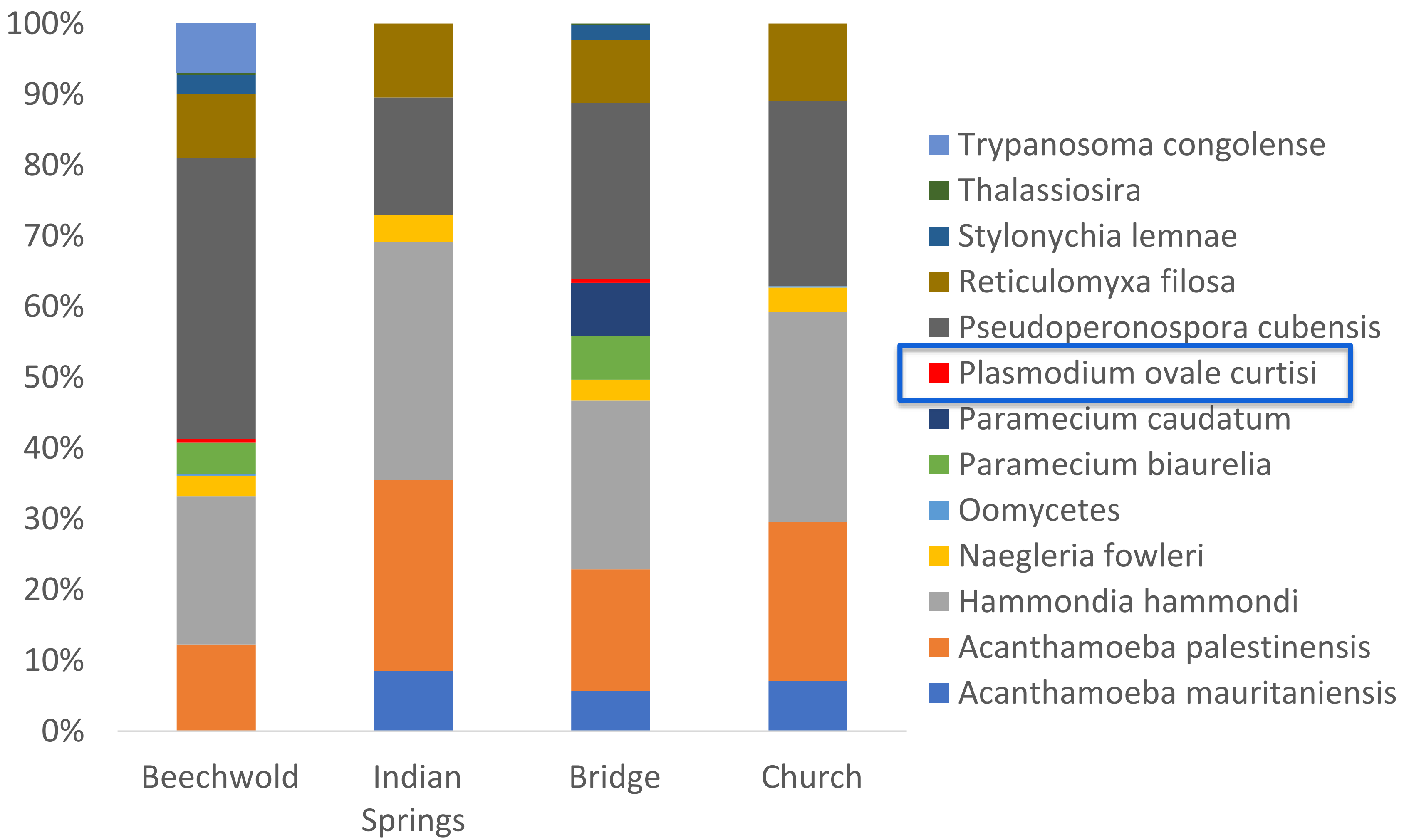


<u>MST suggests:</u>

- Cross-connection or I/I between storm and sanitary
- Deer, dogs, birds also sources
- Antibiotic resistance genes are present

<u>NSF Env. Sustain.</u> proposal to investigate stormwater microbiome

Protist Species



Metagenomic Analysis

Blueprint Goals & OSU Research:

1 Reduce sewer overflows
- Analyze storm flows

2 Improve water quality
- Analyze water quality

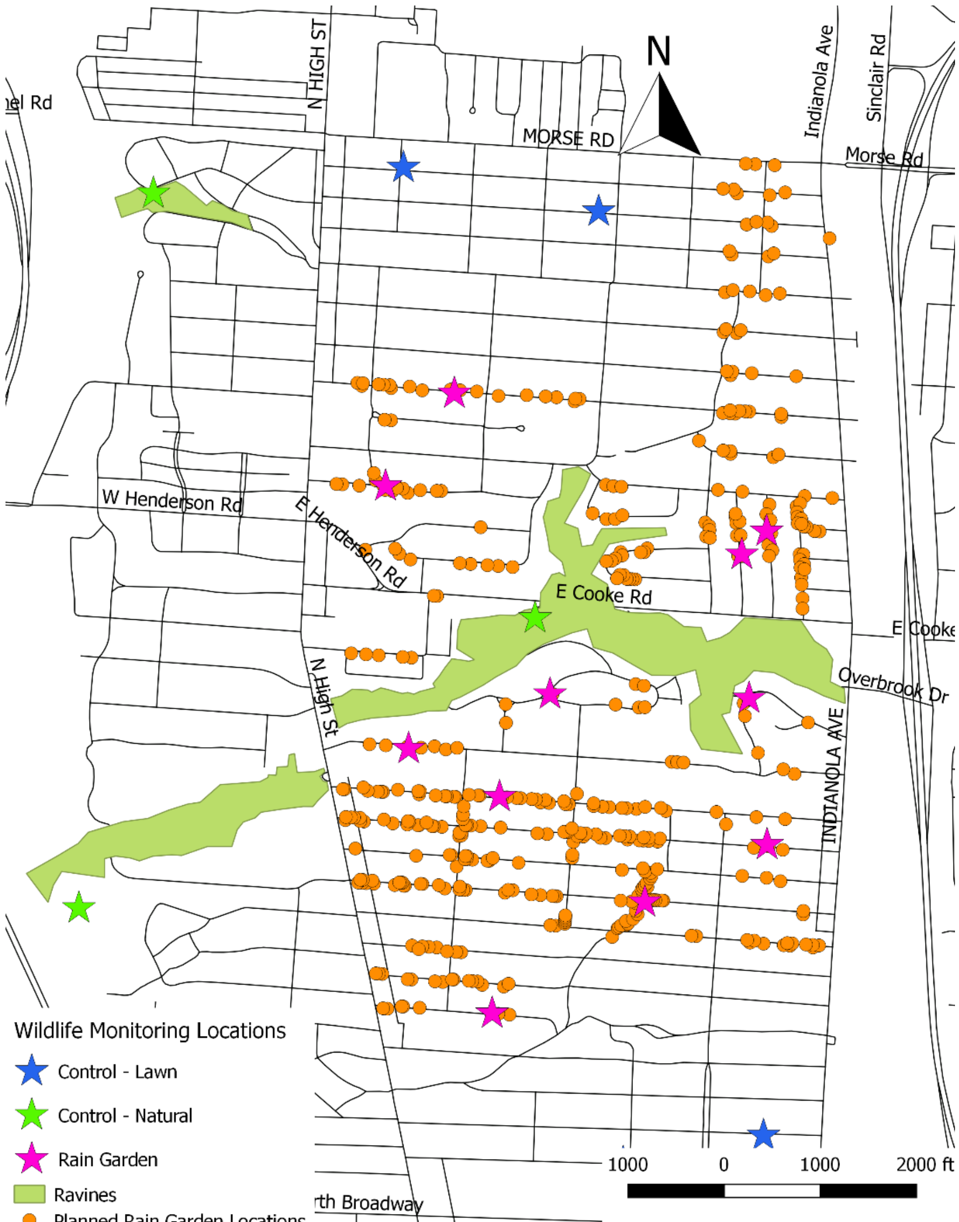
3 Provide habitat
- Analyze species in gardens

4 Improve property values
- Track home prices

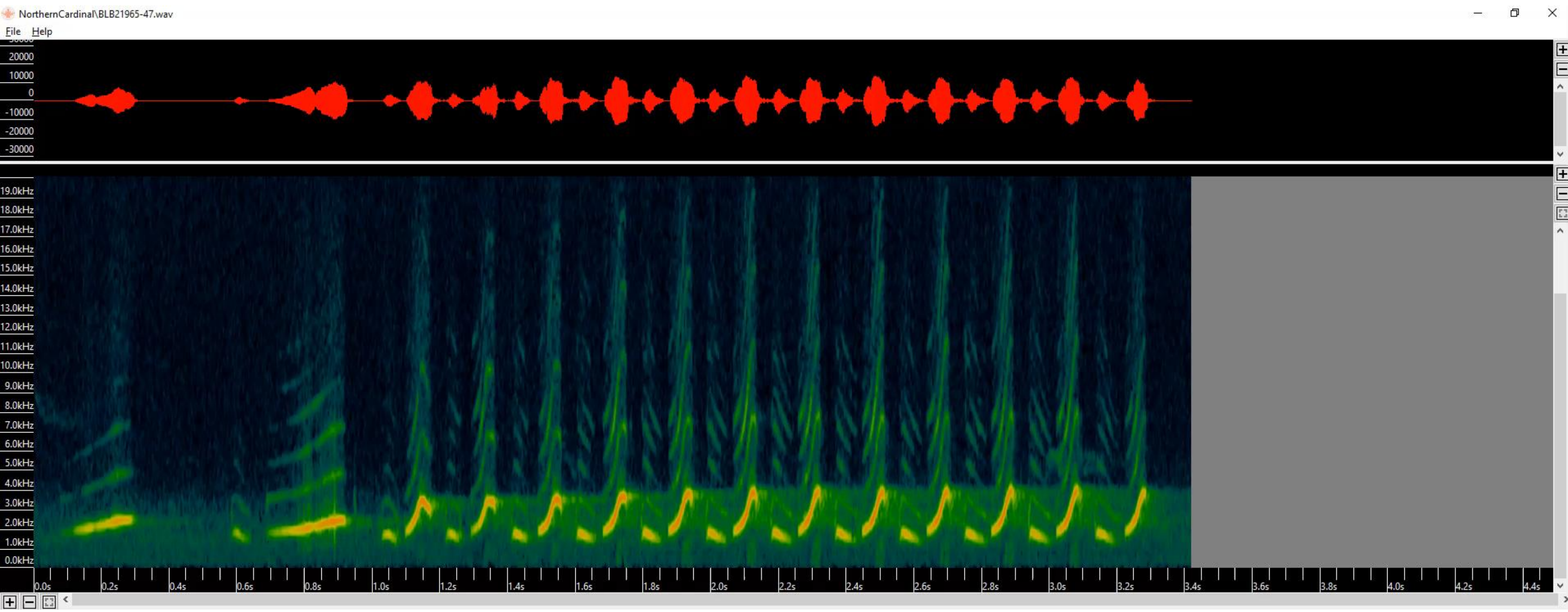
5 Stabilize neighborhoods
- Survey residents

- Ground foraging insects and birds surveyed with pitfall traps and acoustic sensors in 2 systems per subarea and in control areas

Wildlife Acoustics Songmeter SM4

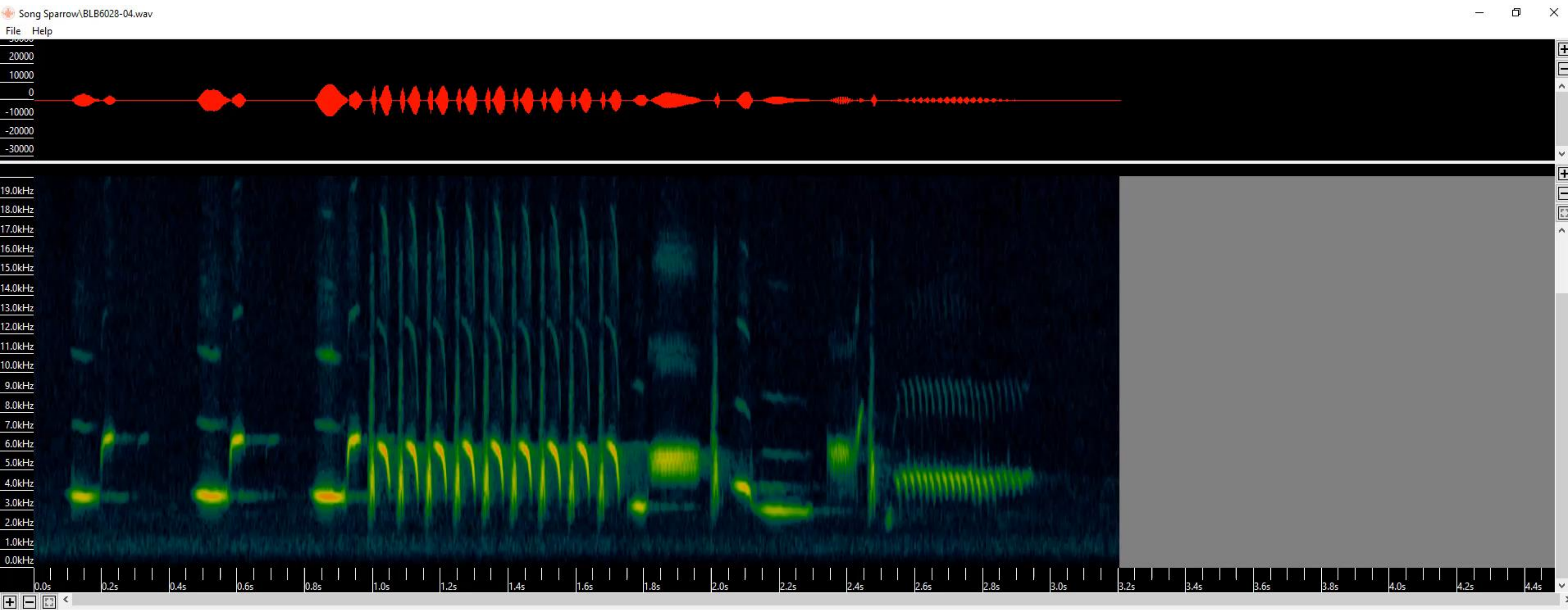

N HIGH ST
MORSE RD
N
Indianola Ave
Sinclair Rd
Morse Rd
W Henderson Rd
E Henderson Rd
E Cooke Rd
E Cooke
Overbrook Dr
N High St
INDIANOLA AVE
1000 0 1000 2000 ft
Wildlife Monitoring Locations
Control - Lawn
Control - Natural
Rain Garden
Ravines
Planned Rain Garden Locations

Call Examples



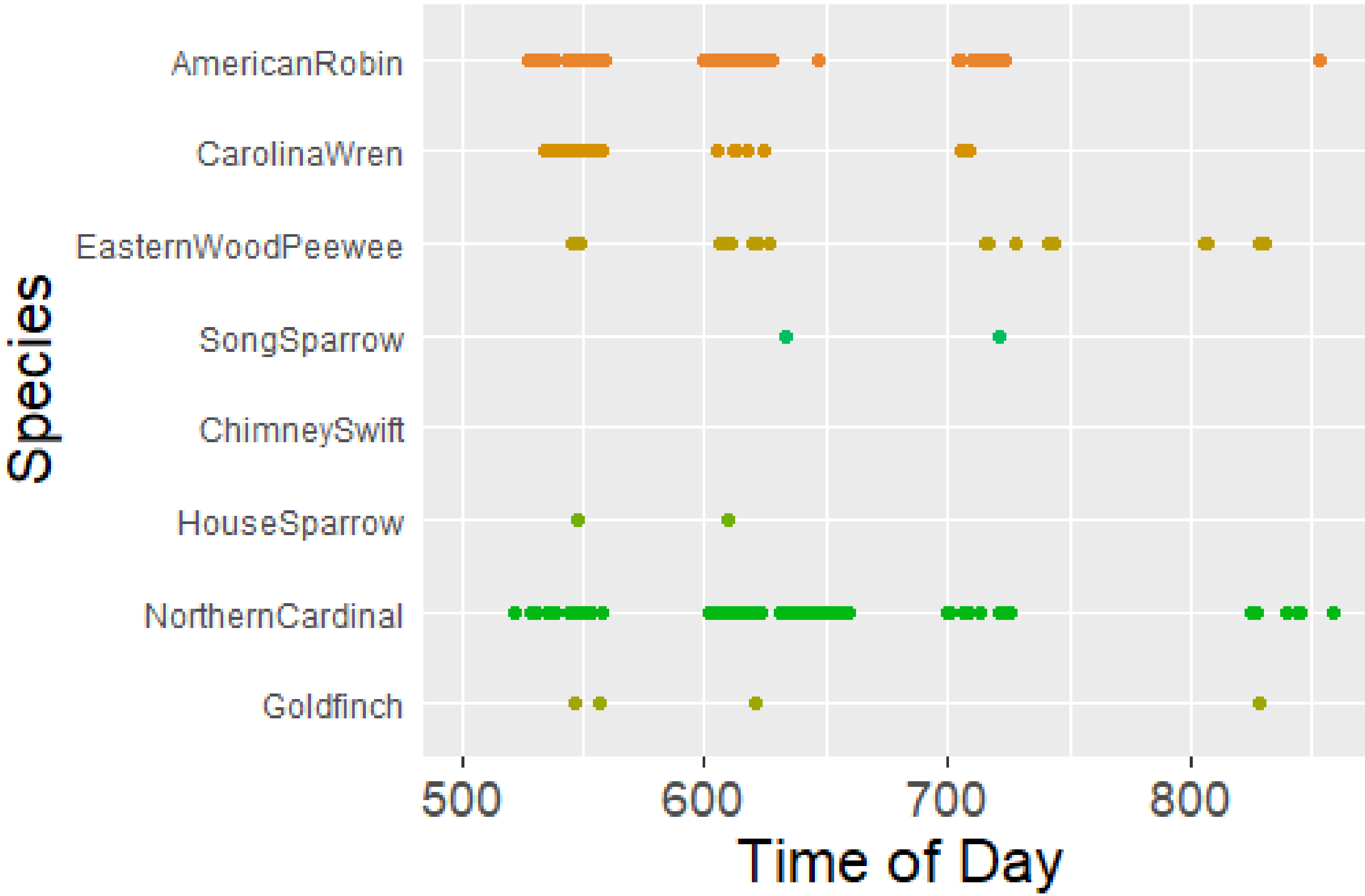
Northern Cardinal

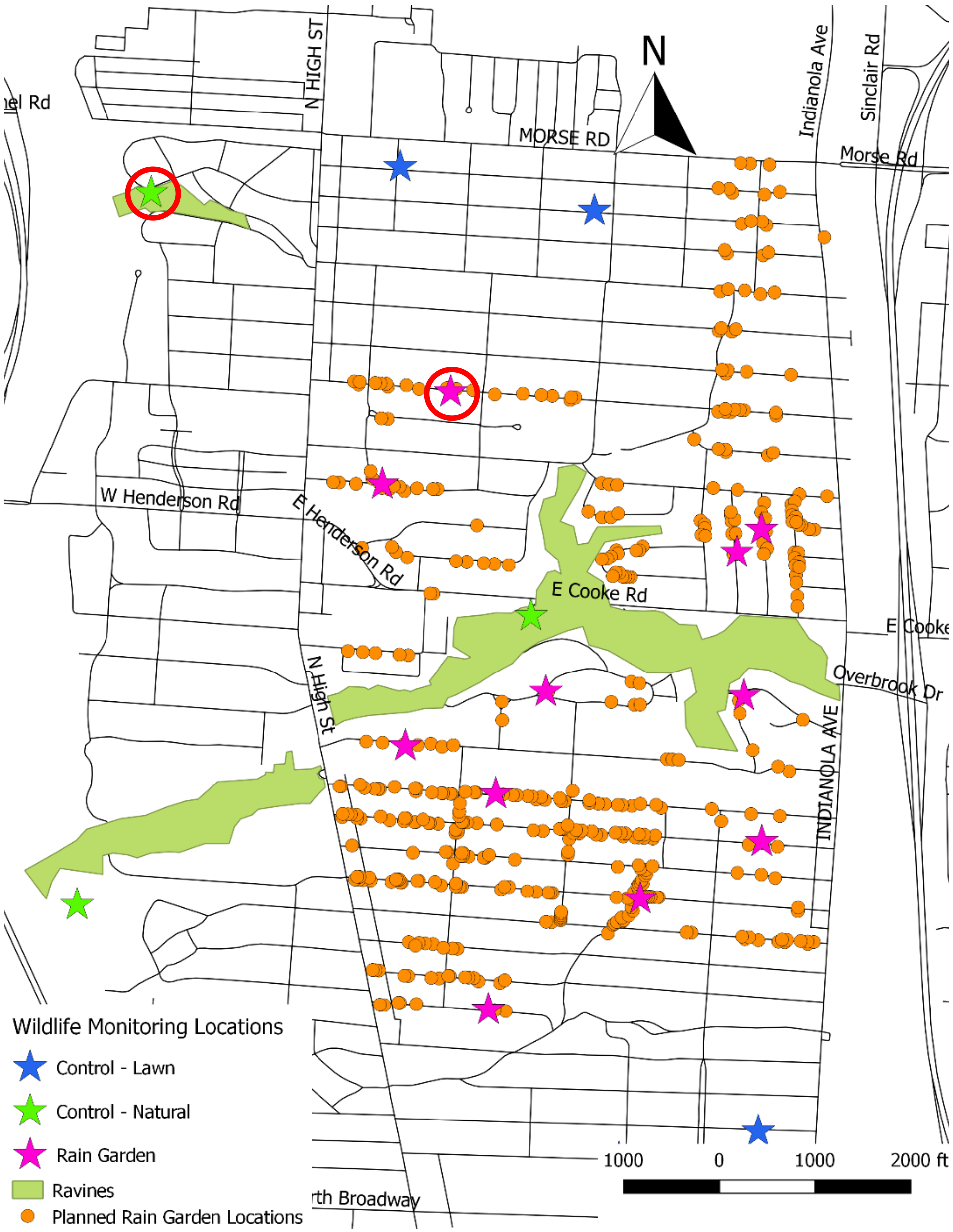
Call Examples



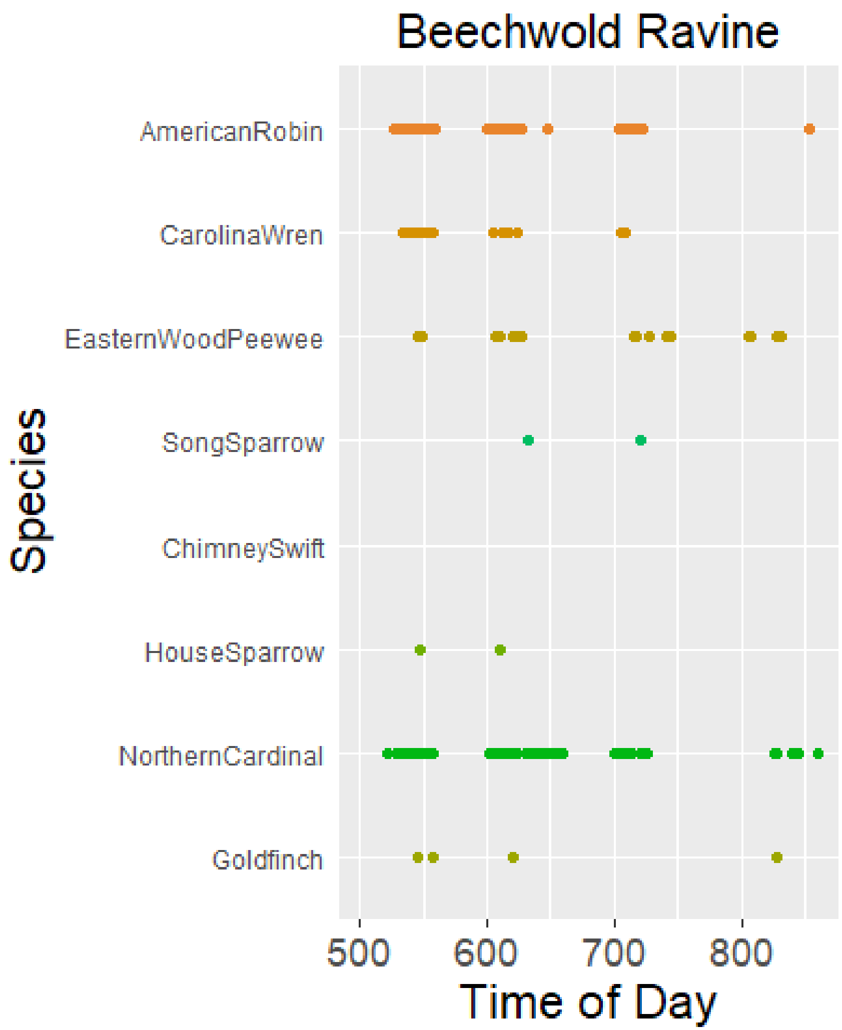
Song Sparrow

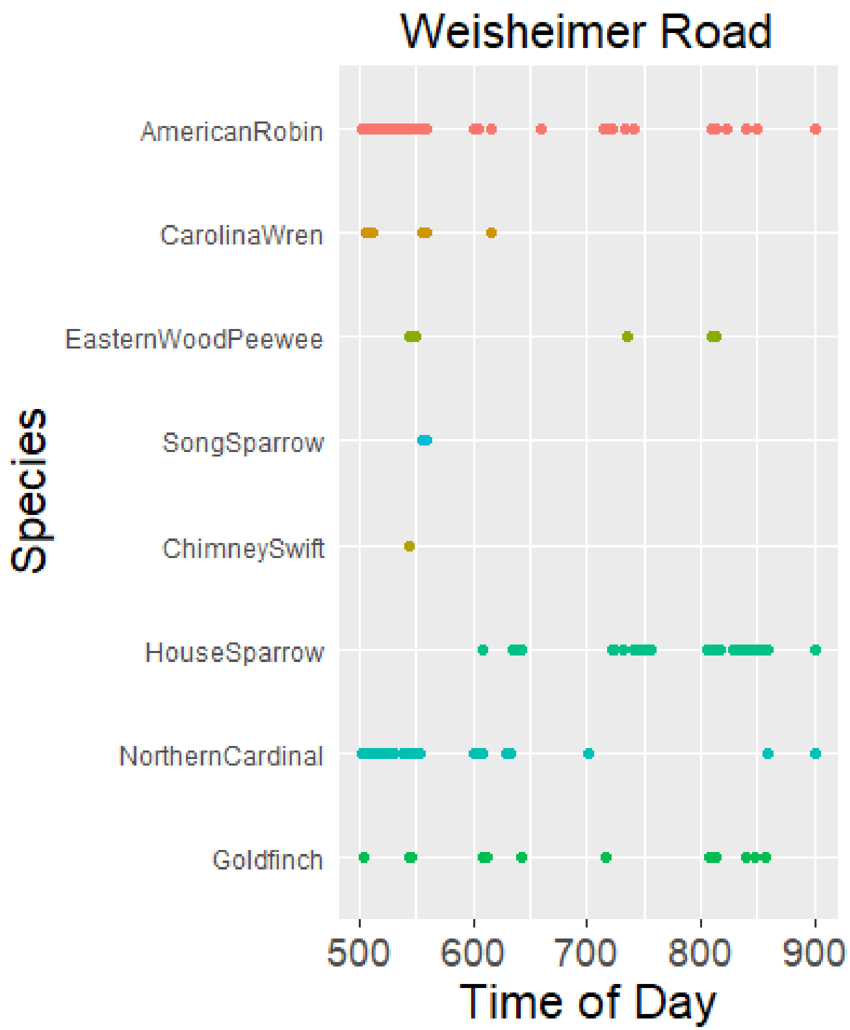
One Morning at the Beechwold Ravine




N
MORSE RD
N HIGH ST
Indianola Ave
Sinclair Rd
Morse Rd
W Henderson Rd
E Henderson Rd
E Cooke Rd
E Cooke
Overbrook Dr
N High St
INDIANOLA AVE
rth Broadway
1000 0 1000 2000 ft
Wildlife Monitoring Locations
Control - Lawn
Control - Natural
Rain Garden
Ravines
Planned Rain Garden Locations

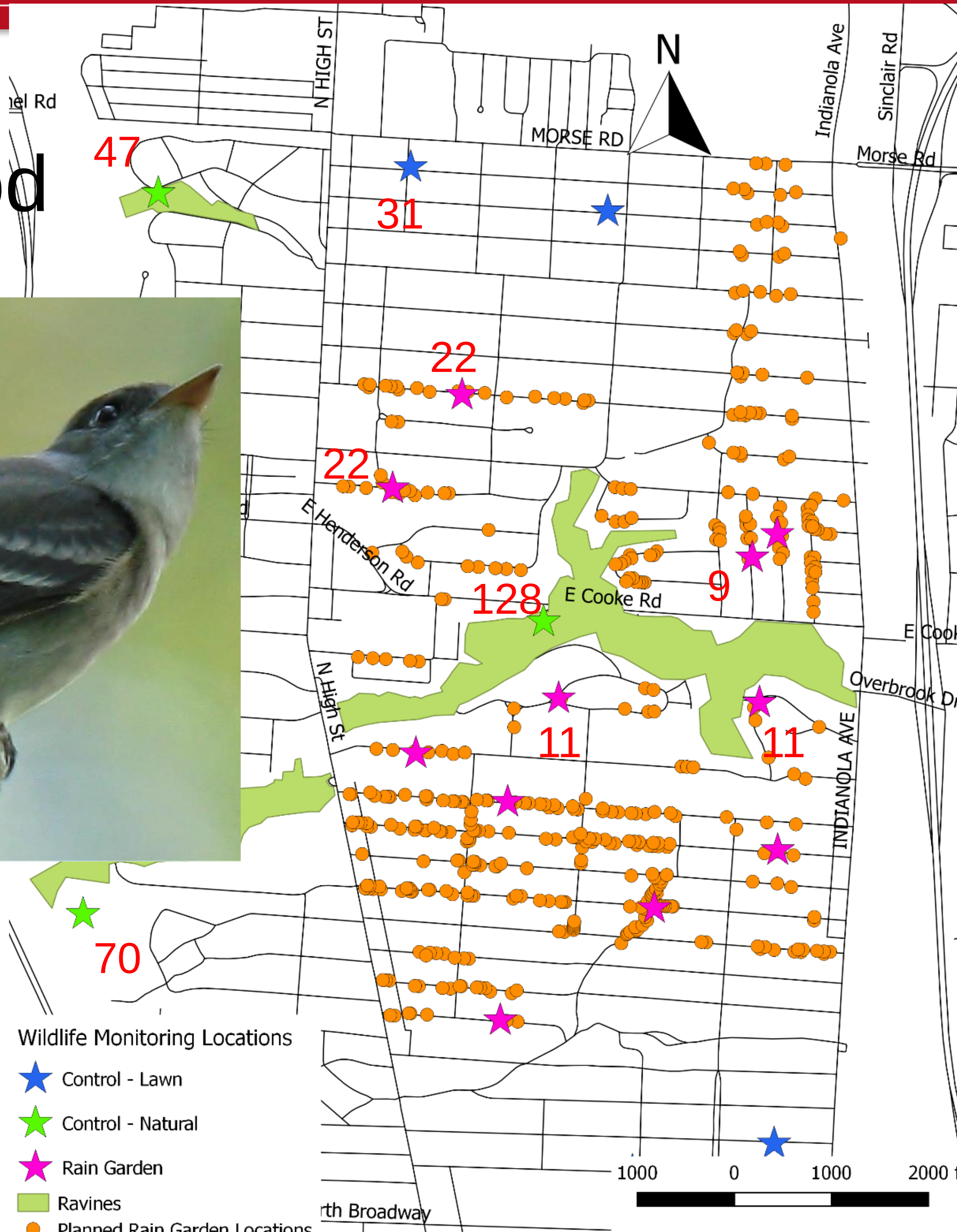
Comparison


Beechwold Ravine
AmericanRobin
CarolinaWren
EasternWoodPeewee
SongSparrow
ChimneySwift
HouseSparrow
NorthernCardinal
Goldfinch
Species
500
600
700
800
Time of Day


Weisheimer Road
AmericanRobin
CarolinaWren
EasternWoodPeewee
SongSparrow
ChimneySwift
HouseSparrow
NorthernCardinal
Goldfinch
Species
500
600
700
800
900
Time of Day

Eastern Wood Pewee

“Eastern Wood-Pewee” by Andy Reago and Chrissy McClarren



Blueprint Goals & OSU Research:

1 Reduce sewer overflows
- Analyze storm flows

2 Improve water quality
- Analyze water quality

3 Provide habitat
- Analyze species in gardens

4 Improve property values
- Track home prices

5 Stabilize neighborhoods
- Survey residents

Quantify changes in property values:
1. Housing values from auditors website
2. Hedonic regression to account for variables (i.e. distance to garden)

Stabilize neighborhoods:
1. Surveys of Blueprint residents and control area
2. Analyze satisfaction with GI, habits (i.e walking, water use & management, cooperation)

Round 1: Mean response: Support for Rain Gardens
(1-5; strongly disagree – strongly agree)

Question	C'ville	Linden
In general, I like rain gardens	4.23	3.15
Rain gardens…would increase the value of my property...	3.70	3.00
I would like it if the city installed rain gardens on my property or the property immediately bordering my own	3.39	2.62
I would like it if the city installed rain gardens in my neighborhood, but not on my property or the property immediately bordering my own	2.97	3.18
Existing storm sewers are adequate	2.04	2.92
Rain gardens would be effective in reducing storm water runoff	4.05	3.42
I prefer the city build more storm sewers instead of rain gardens	2.48	3.42

Round 2: Environmental Behaviors/actions
Lots of room for improvement

Question	Blenheim	Schreyer	Weisheimer	Morse	Overbrook
I consciously try to limit the amount of water I use for activities around my home… (1-5; agree – disagree)	3.88	3.72	3.86	3.82	3.74
Rain gardens **(% who <u>don't</u> plan on using)**	76%	76%	67%	71%	78%
Rain Barrels **(% who <u>don't</u> plan on using)**	35%	66%	47%	67%	61%
Using low N/P fertilizers or pesticides **(% who <u>don't</u> plan on using)**	48%	39%	44%	80%	86%
Conservation landscaping **(% who <u>don't</u> plan on using)**	56%	61%	44%	62%	59%

Round 2: Mean response - Walking

(number of times per…)

Lots of room for improvement here too

Question	Blenheim	Schreyer	Weisheimer	Morse	Overbrook
Walk to place of employment (per week)	0.40	0.11	0.02	0.09	0.36
Walk children to school (per week)	0.12	0.19	0.18	0.15	0.09
Walk to an appointment (per month)	0.17	0.01	0.16	0.09	0.05
I would walk more in my neighborhood if there were more greenery	2.47	2.27	2.58	2.54	2.54
Socialize with a neighbor at their house or yours (1- 5, daily, weekly, monthly, every few months, once or twice a year, never)	2.73 (weekly – monthly)	2.39	2.63	1.88	2.57

Summary

- Characterized baseline hydrology (continuous) and water quality (storm and base flow)
  - Continuing to collect data as SCMs are installed
  - Data collection through 2022
- Quantifying ecosystem services of SCMs
- Evaluate effects of green infrastructure on property values and neighborhoods

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BLUE PRINT COLUMBUS
Clean streams. Strong neighborhoods.

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BORROR LABORATORY OF BIOACOUSTICS

Any Questions?

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