Evaluation of Water Quality Changes for Two Tributaries with Basins Having Undergone Residential Septic-to-Sewer Conversions, Duval County, FL

Leel Knowles, Jr.

U.S. Geological Survey
in cooperation with
City of Jacksonville

USGS
science for a changing world

Problem

Fecal Coliform Bacteria in Jacksonville's Tributaries

- 51 of 76 tributary basins sampled by the City Of Jacksonville are identified as "impaired" due to fecal coliform bacteria, most likely from septic sources
- Effect of removing septic-tank systems on receiving ground and surface waters is not well documented

USGS
science for a changing world

Purpose

- Provide “real-life” empirical data describing pollution load reduction from reducing septic-tank influences
- Assist in TMDL implementation and Basin Management Action Plan (B-MAP) development
- Water-quality based justification for supporting centralized sewer conversion of septic-tank failure areas

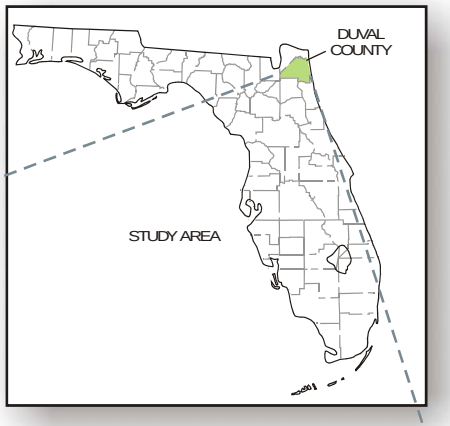
USGS
science for a changing world

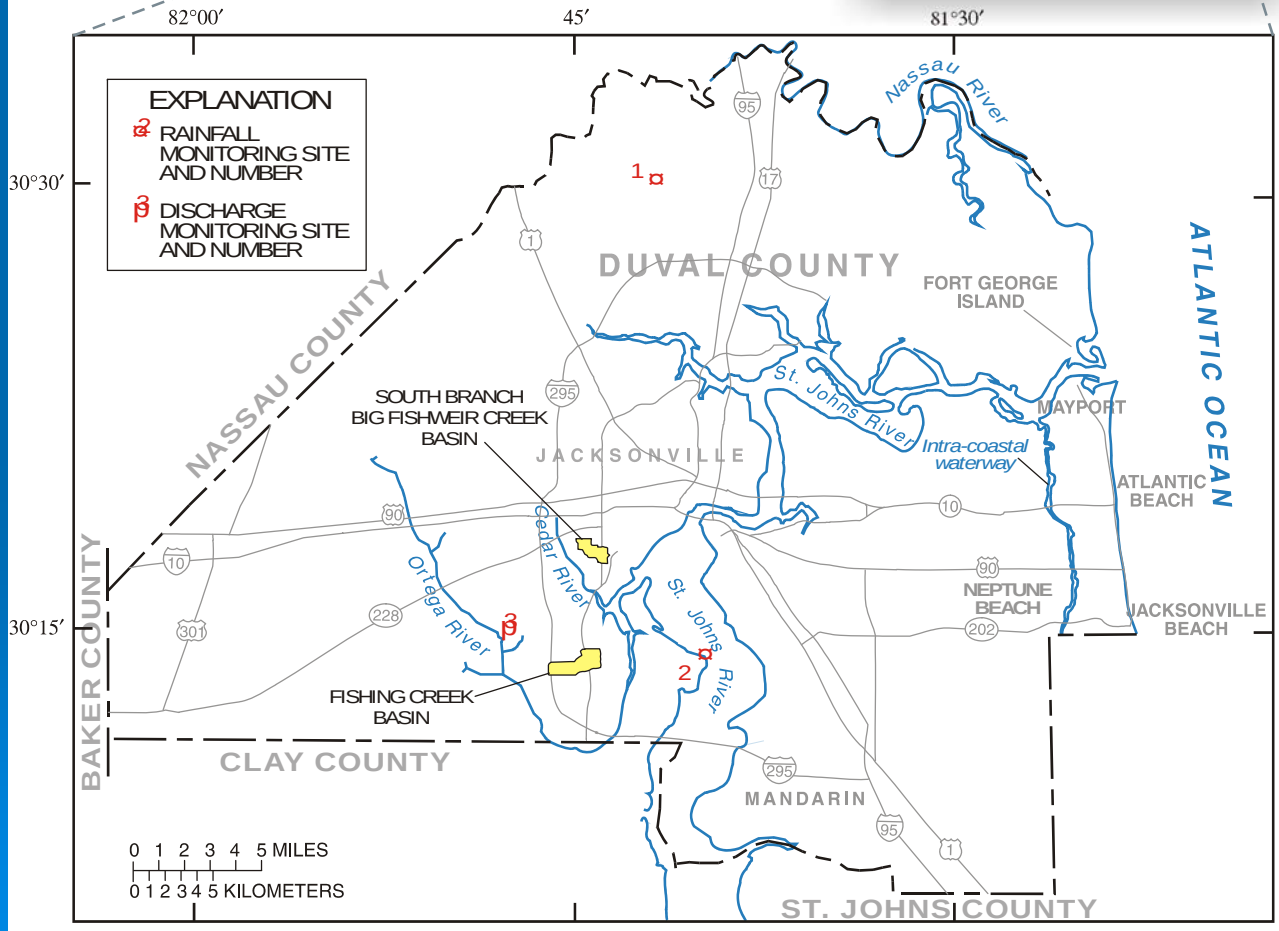
Study Objectives

- Compile basin characteristics to facilitate the transferability of results to other locations (Phase I)
- Document baseline stream water-quality conditions prior to connection of target areas to a centralized sewer system (Phase I)
- Document changes in water quality that may result from septic to sewer system conversion (Phase II)

USGS
science for a changing world

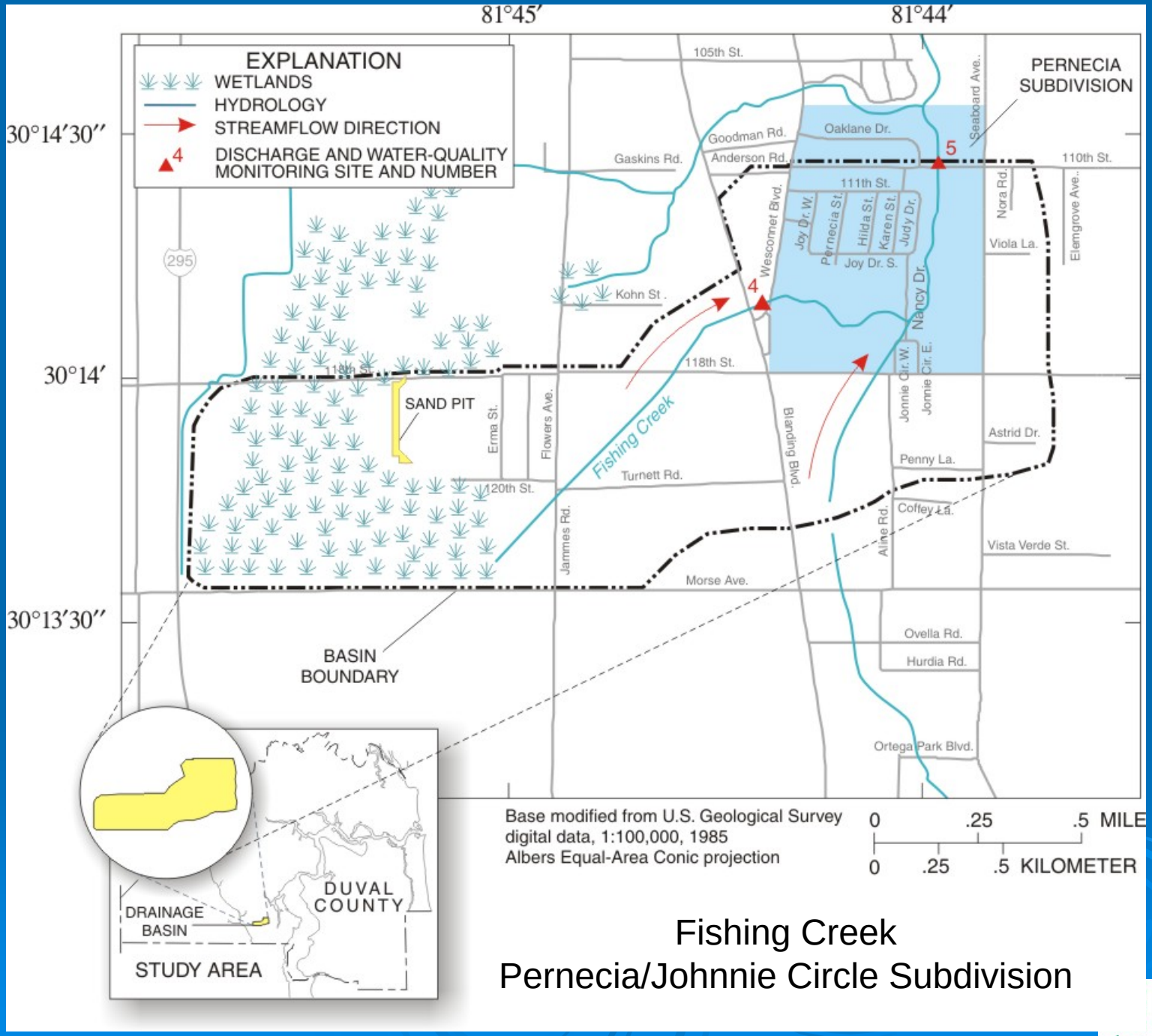
Location of Study Sites





Base modified from U.S. Geological Survey digital data, 1:100,000, 1985
Albers Equal-Area Conic projection

USGS science for a changing world



Fishing Creek
Pernecia/Johnnie Circle Subdivision

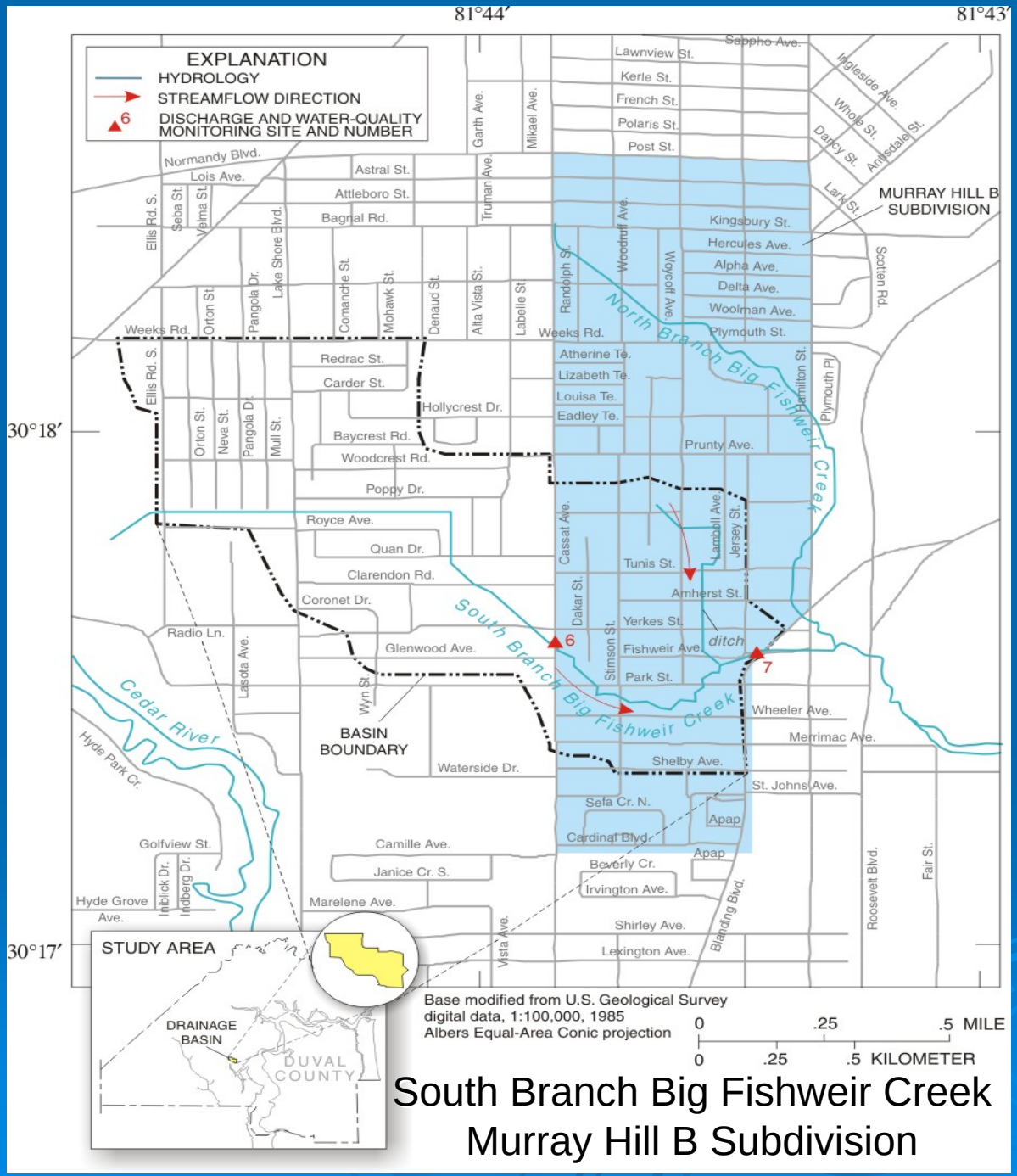
USGS
science for a changing world

Fishing Creek
Upstream site at Wesconnett Blvd.

USGS
science for a changing world

Fishing Creek
Downstream site at 110th St.

USGS
science for a changing world



South Branch Big Fishweir Creek
Murray Hill B Subdivision

USGS science for a changing world

South Branch Big Fishweir Creek
Upstream site at Cassat Ave. (Phase I)

USGS
science for a changing world

South Branch Big Fishweir Creek
Upstream site at Yerkes St.
(Phase II)

USGS
science for a changing world

South Branch Big Fishweir Creek
Upstream site at Yerkes St.
during Tropical Storm Fay (Aug. 22, 2008)

USGS
science for a changing world

South Branch Big Fishweir Creek
Downstream site at Blanding Blvd.
(Upstream side)

USGS
science for a changing world

South Branch Big Fishweir Creek
Downstream site at Blanding Blvd.
(Downstream side)

USGS
science for a changing world

South Branch Big Fishweir Creek
Downstream site at Blanding Blvd.
during Tropical Storm Fay (Aug. 22, 2008)

USGS
science for a changing world

Subdivision and Basin Characteristics

- Approximately 155 acres in each subdivision drains to a receiving stream
- Greater than 90 percent of the land-use in each basin is single- or multi-family residences

Subdivision	Basin	Drainage area (acres)	Subdivision			
			Area (acres)	Population (count)	Residences (count)	Septic tanks (count)
Pernecia/Johnnie	Fishing Creek	812.8	193.2	522	246	251
Murray Hill B	South Branch Big Fishweir Creek	428.8	464.8	2,766	1,077	1,245

USGS science for a changing world

Data Collection

- Physical water properties (temperature, dissolved oxygen, pH, specific conductance, turbidity)
- Streamflow measurements
- Water samples
  - Nutrients (nitrogen and phosphorus)
  - 63 organic wastewater compounds (caffeine, camphor, DEET, fragrances, menthol, phenol, etc.)

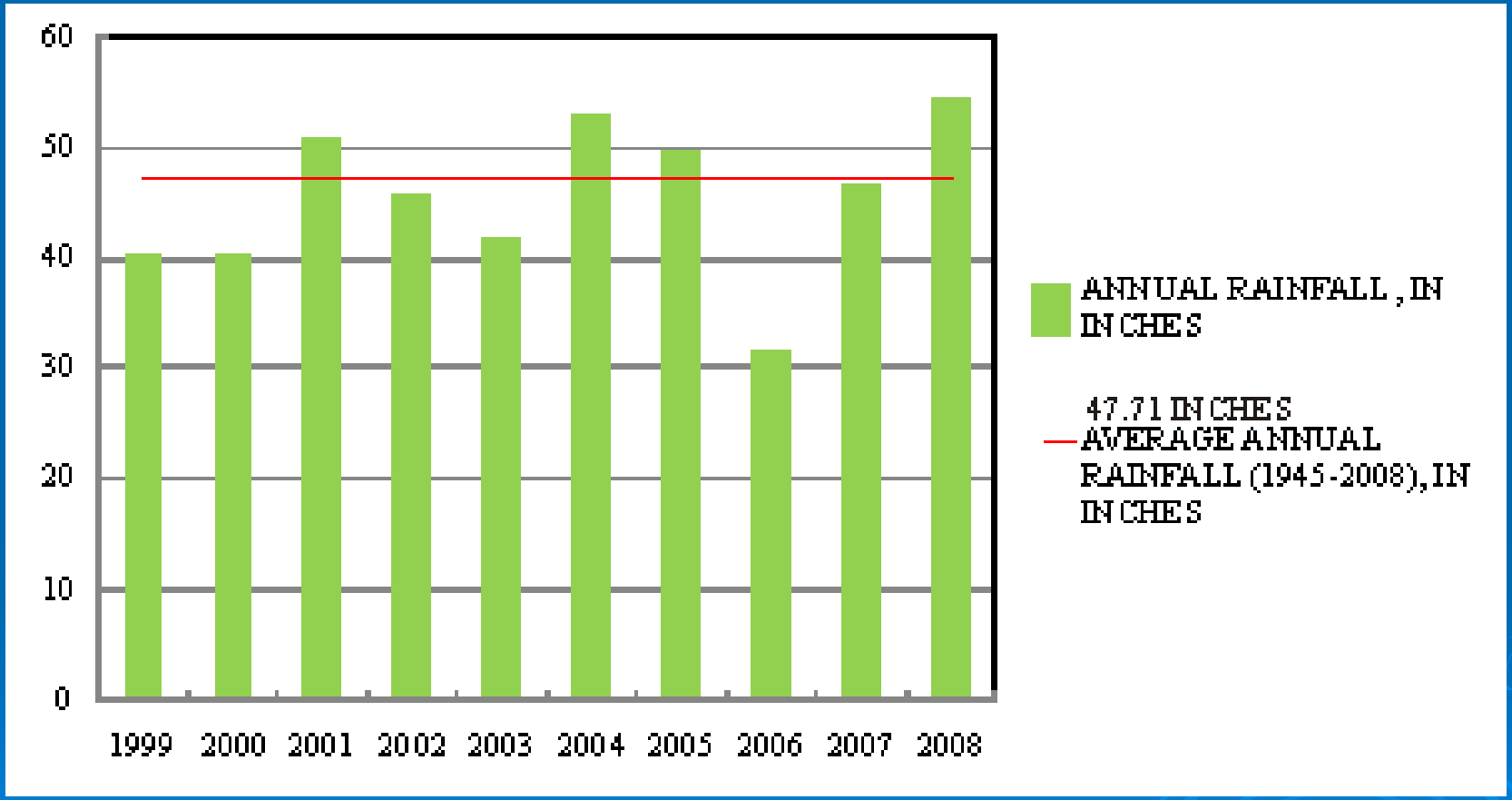
USGS
science for a changing world

Data Collection (cont…)

- Water Samples (cont…)
  - Fecal coliform bacteria (Phase I)
    - Most probable number per 100 mL
    - Classification of bacteria sources using antibiotic resistance pattern testing
  - Fecal coliform bacteria (Phase II)
    - Counts per 100 mL by membrane filtration method
    - Detection and quantification of the Fecal *Bacteroidetes* and *Enterococcus faecium* esp human-gene biomarker for human fecal contamination by Real-Time Quantitative Polymerase Chain Reaction (qPCR) DNA Analytical Technology

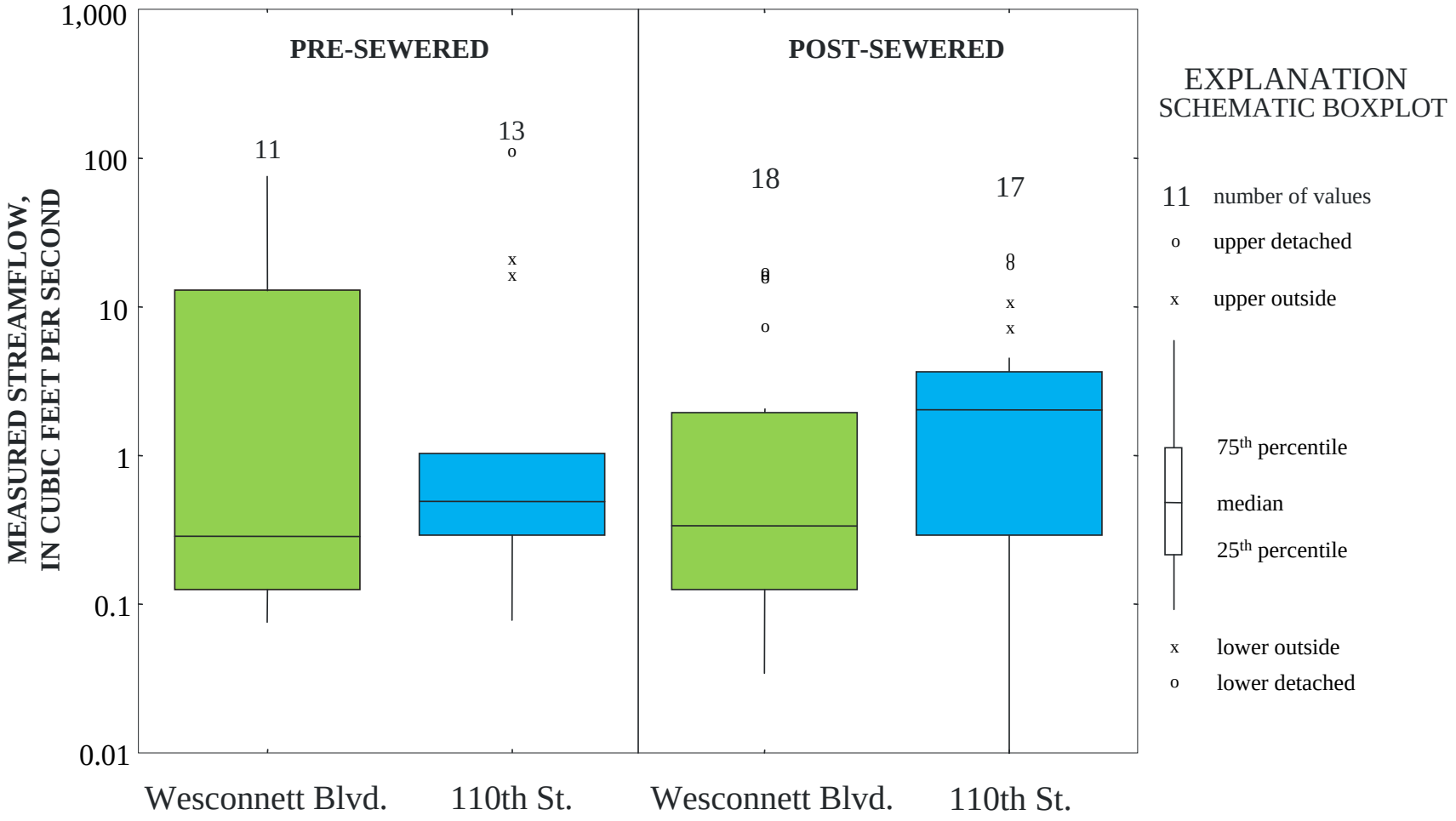
USGS science for a changing world

Rainfall at Jacksonville NAS



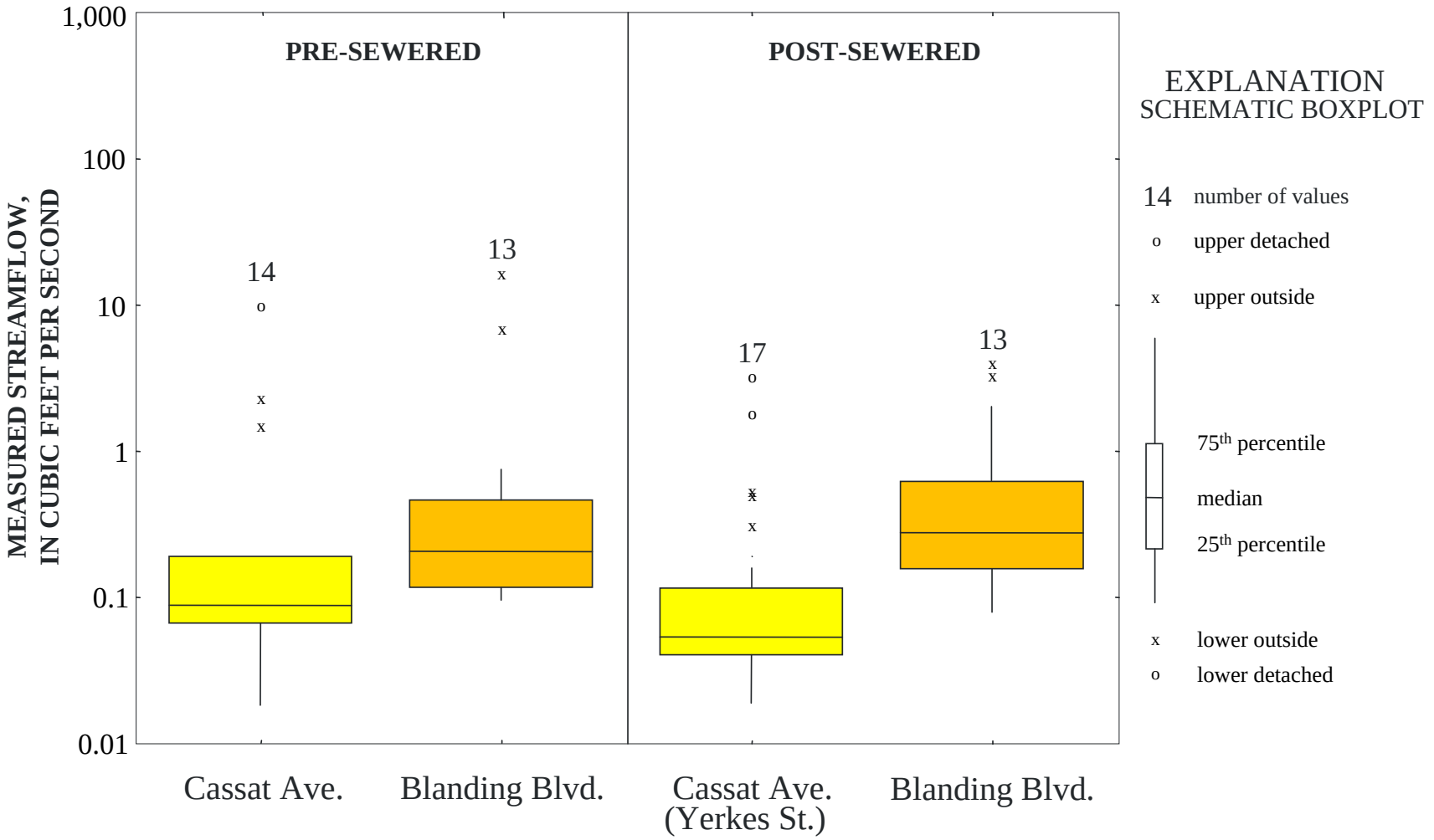
USGS
science for a changing world

Measured Streamflow Fishing Creek



USGS science for a changing world

Measured Streamflow
South Branch Big Fishweir Creek



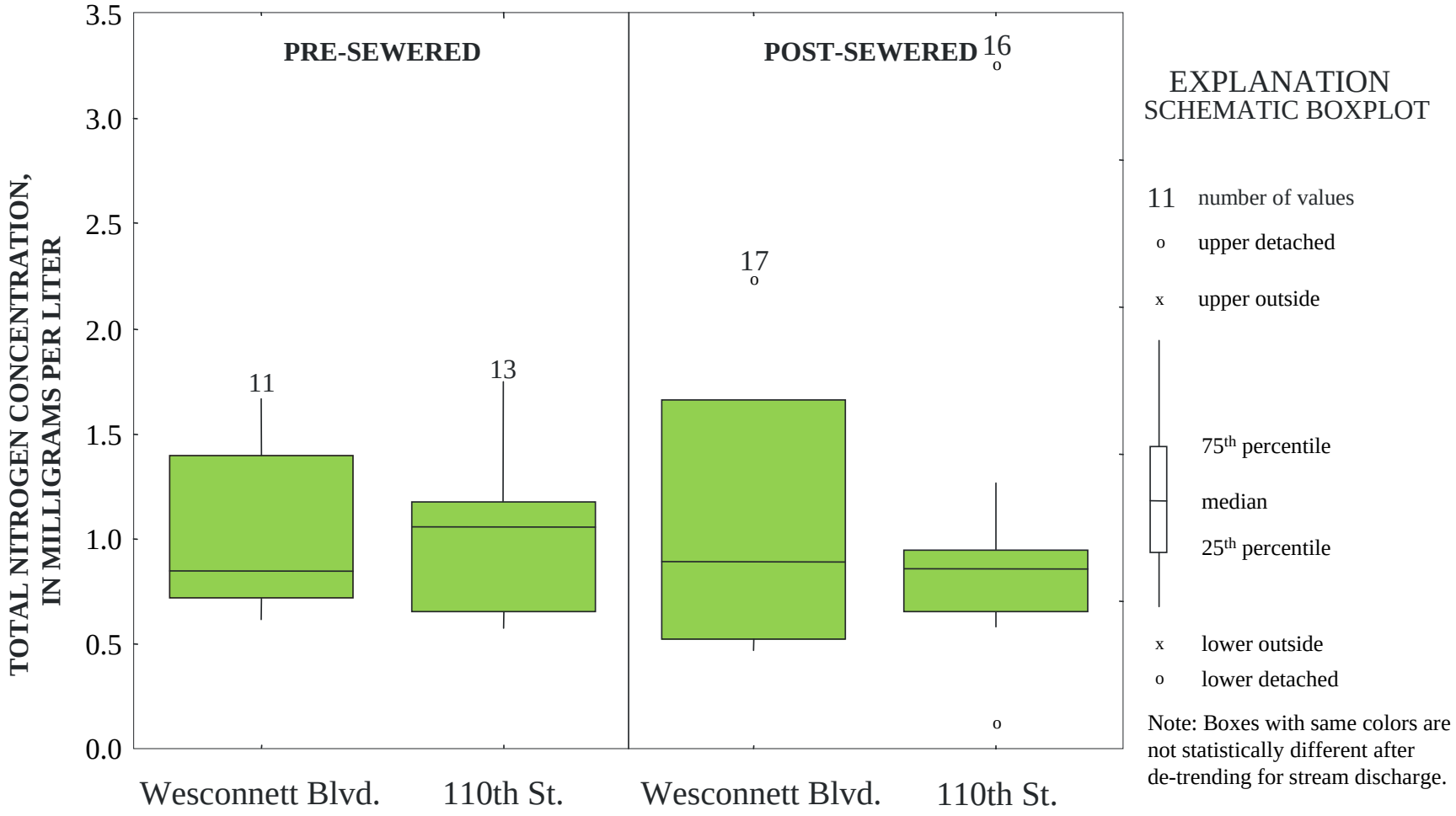
USGS science for a changing world

Results

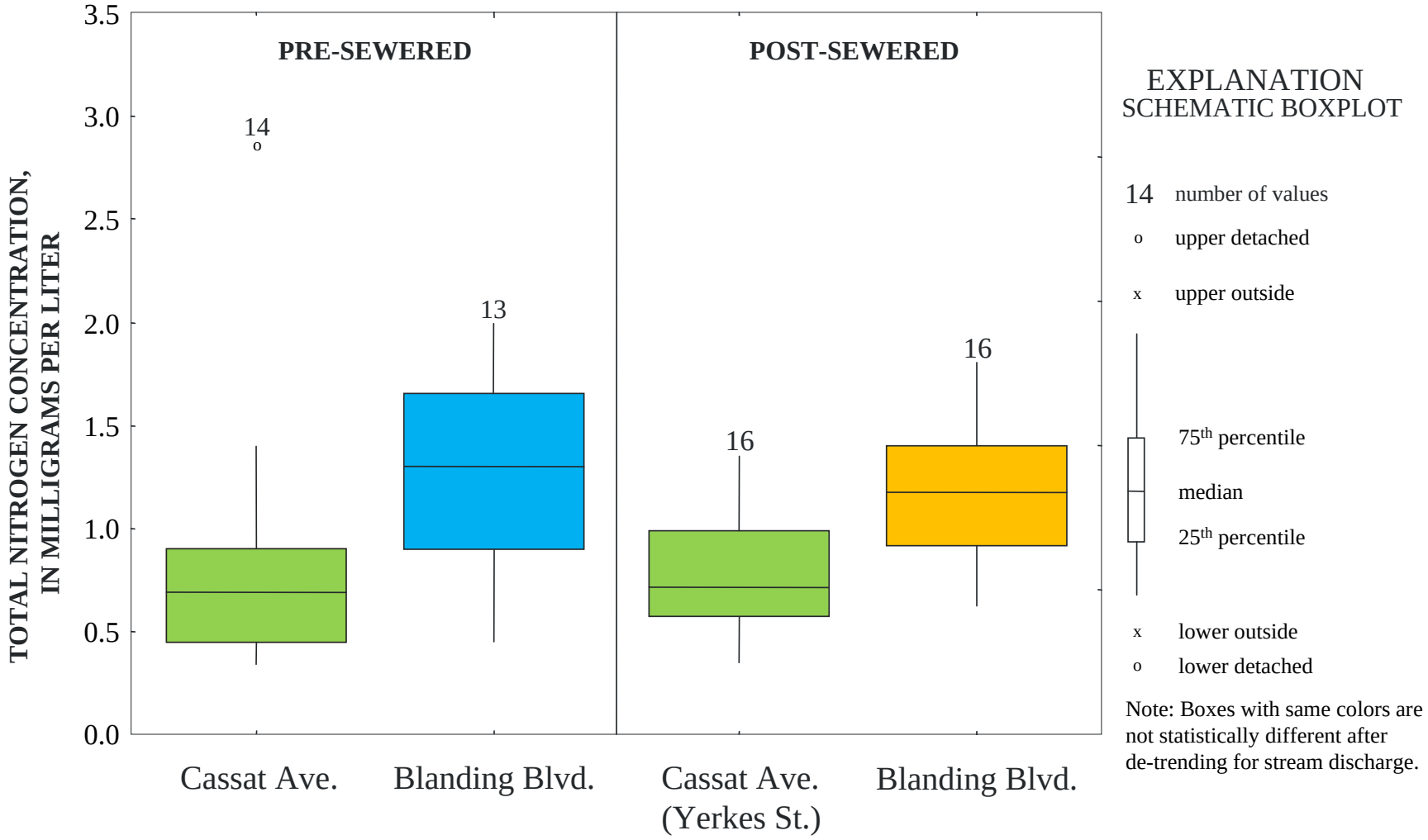
- Nutrients exceeded EPA Ecoregion XII criteria
  (concentration - 25 percentile based)
- PHASE I
  - 49 percent of 51 total nitrogen samples (0.9 mg/L)
  - 96 percent of 51 total phosphorus samples (0.04 mg/L)
- PHASE II
  - 51 percent of 65 total nitrogen samples
  - 89 percent of 65 total phosphorus samples

USGS
science for a changing world

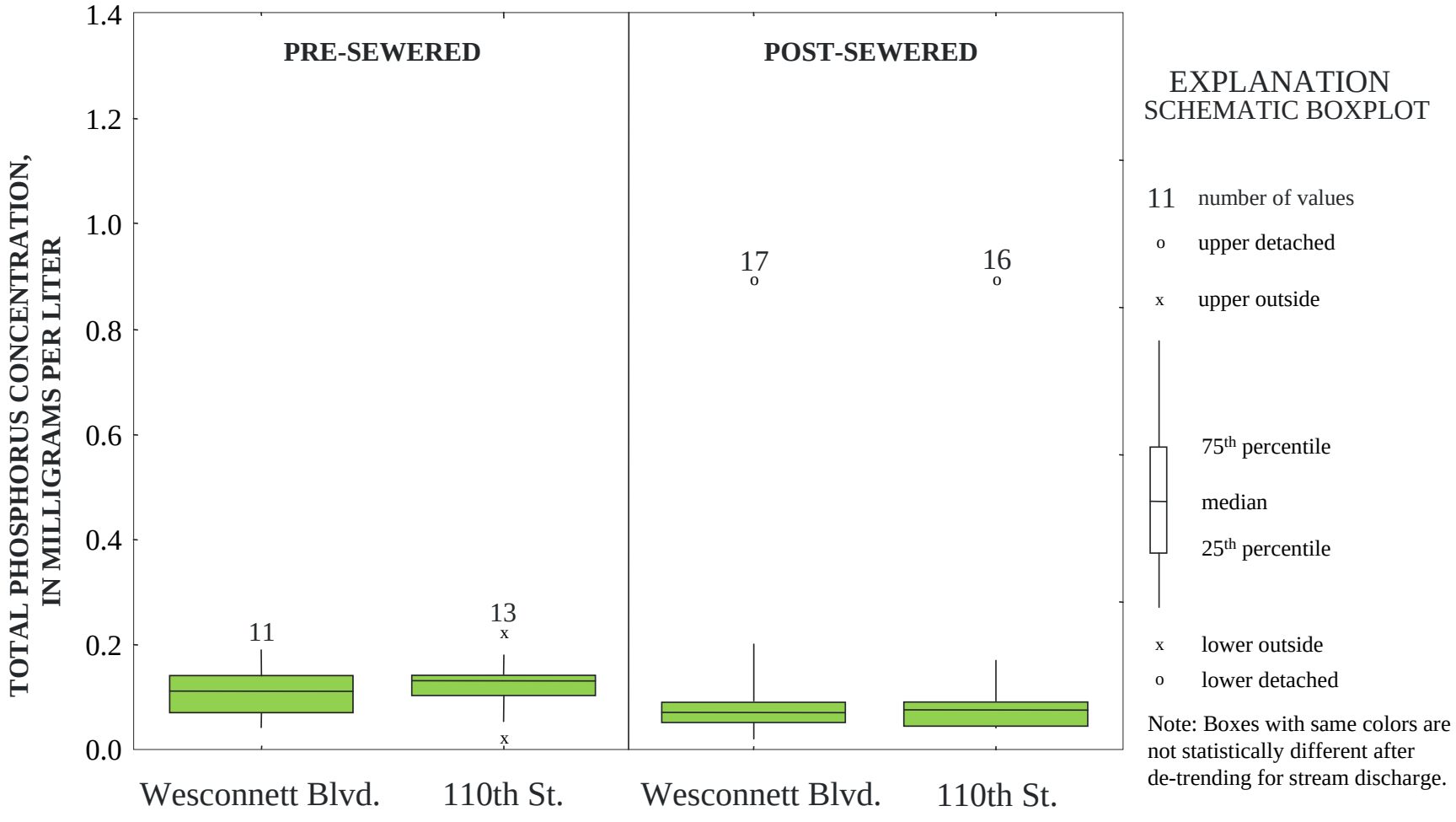
Total Nitrogen Concentration Fishing Creek



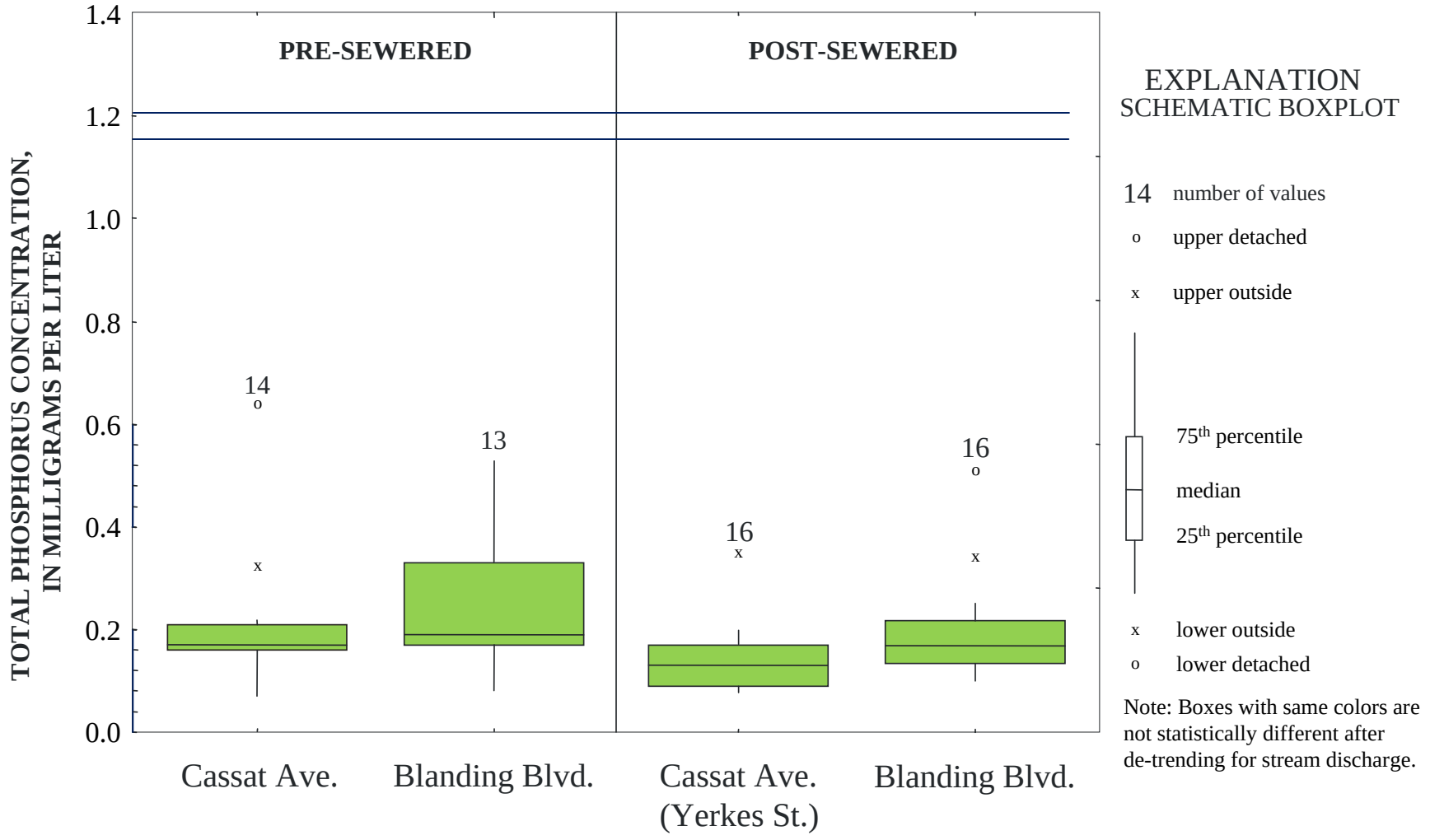
Total Nitrogen Concentration
South Branch Big Fishweir Creek



Total Phosphorus Concentration
Fishing Creek



Total Phosphorus Concentration South Branch Big Fishweir Creek



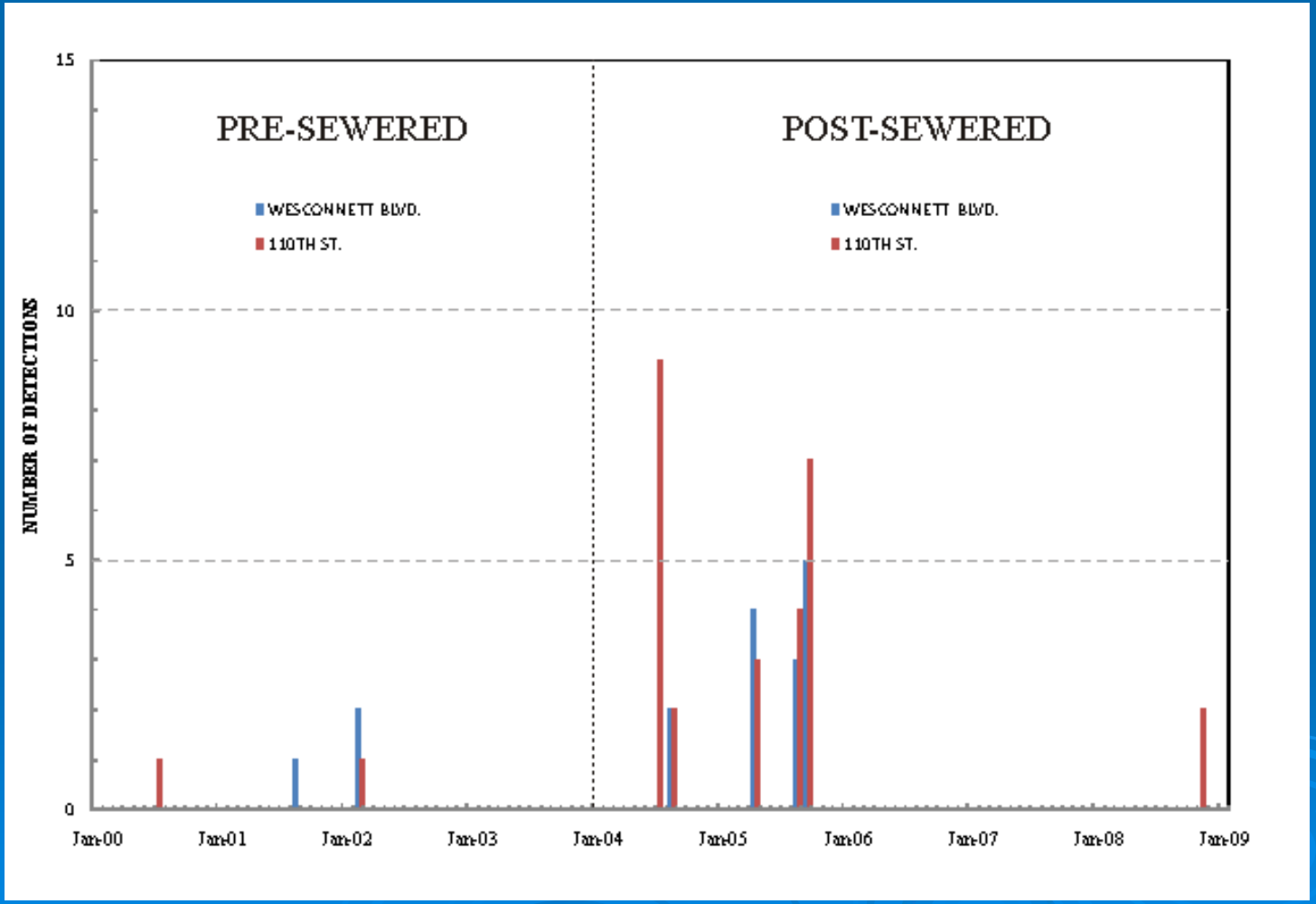
Results

- Organic Wastewater Compounds detected at or above the lab reporting level
- PHASE I
  - Detergents, Fragrances, Antioxidants, Flame Retardants, Polycarbonate Resins, Industrial Solvents, DEET, Caffeine, and Nicotine
- PHASE II
  - DEET, Caffeine, Camphor, Phenol, Antioxidants*, Industrial Solvents*, Fragrances, Pesticides, Herbicides, Flame Retardants, and Combustion Products

    *SB Big Fishweir Creek only

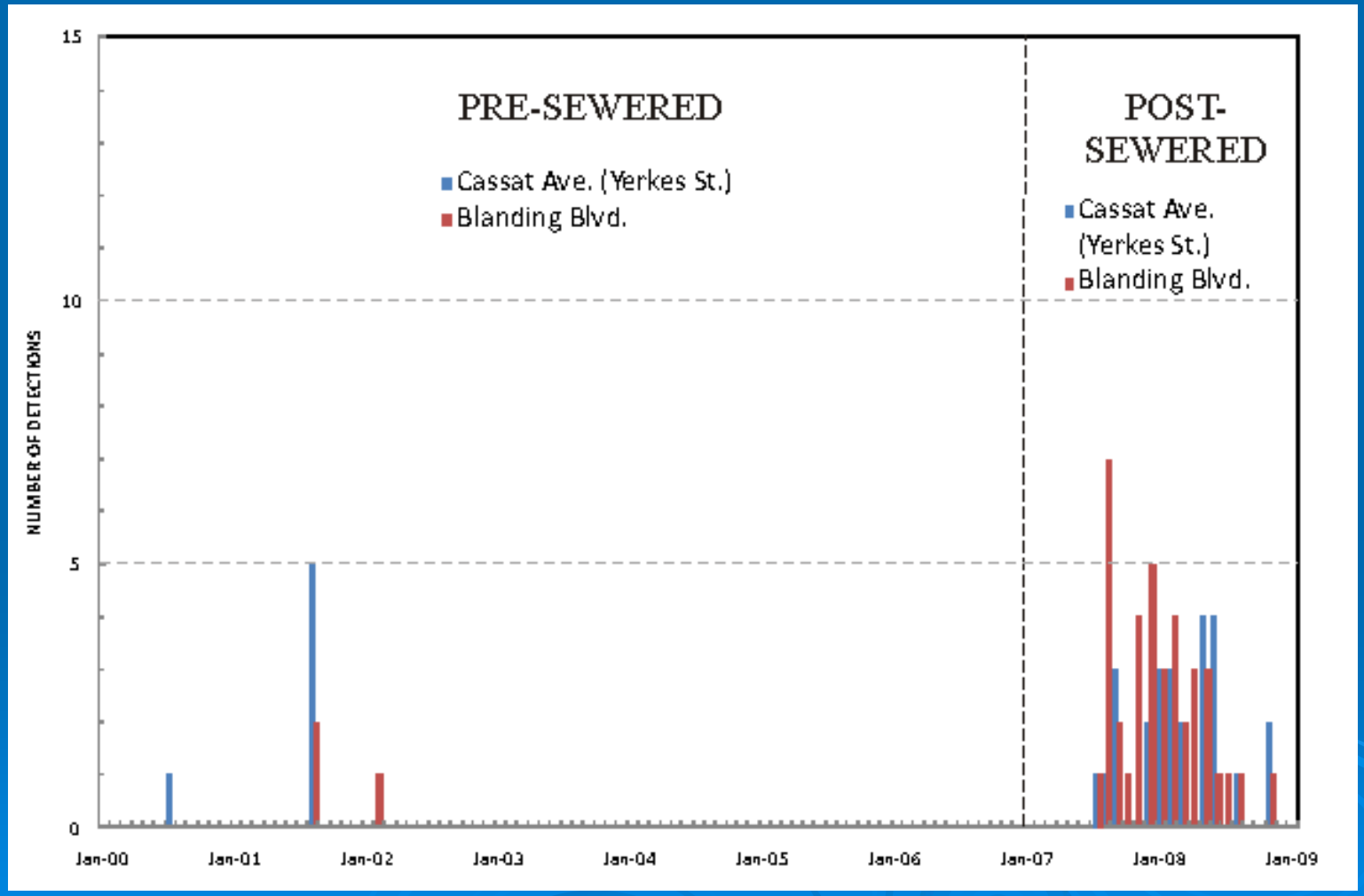
USGS science for a changing world

Detections of Organic Wastewater Compounds At or Above the Minimum Laboratory-Reporting Level Fishing Creek



USGS science for a changing world

Detections of Organic Wastewater Compounds At or Above the Minimum Laboratory-Reporting Level South Branch Big Fishweir Creek



USGS
science for a changing world

Results

- Fecal Coliform Bacteria
- PHASE I
  - 63 percent of 115 samples exceeded State of Florida Class III water standards for E. Coli (800 counts/100mL)
  - 100 percent of 16 MST samples detected human fecal pollution: 67 percent of the overall fecal pollution from human sources
- PHASE II
  - 77 percent of 65 samples exceeded State of Florida Class III water standards for E. Coli – all 33 samples exceeded standard at SB Big Fishweir Creek
  - 47 percent of 30 MST samples detected human fecal pollution at SB Big Fishweir Creek: 43 percent of the overall fecal pollution from human sources

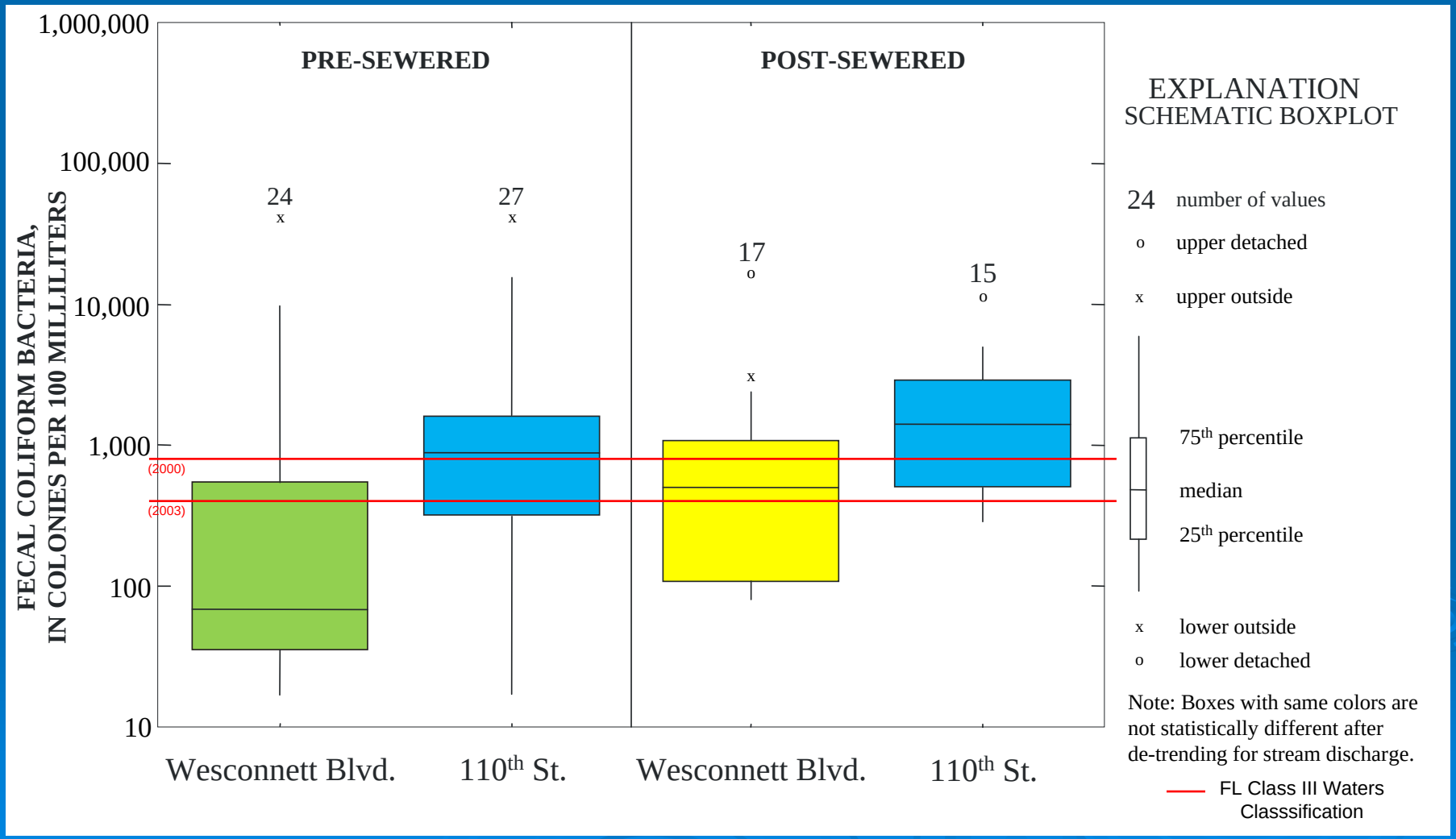
USGS science for a changing world

Results

- Fecal Coliform Bacteria
- PHASE II (cont …)
  - 1 of 2 samples detected human fecal pollution at Fishing Creek (Wesconnett Blvd upstream site): 95-100 percent of the overall fecal pollution from human sources
  - E. Coli (total) concentrations generally were lower with lower rainfall (winter) and higher (post storm) streamflows
  - *Bacteroidetes* human-gene biomarkers were detected in 6 of 15 sampling months indicating recent human fecal pollution in SB Fishweir Creek
  - Human fecal pollution in SB Big Fishweir Creek seems to appear for up to several days following significant rainfall (greater than 0.5 inches)

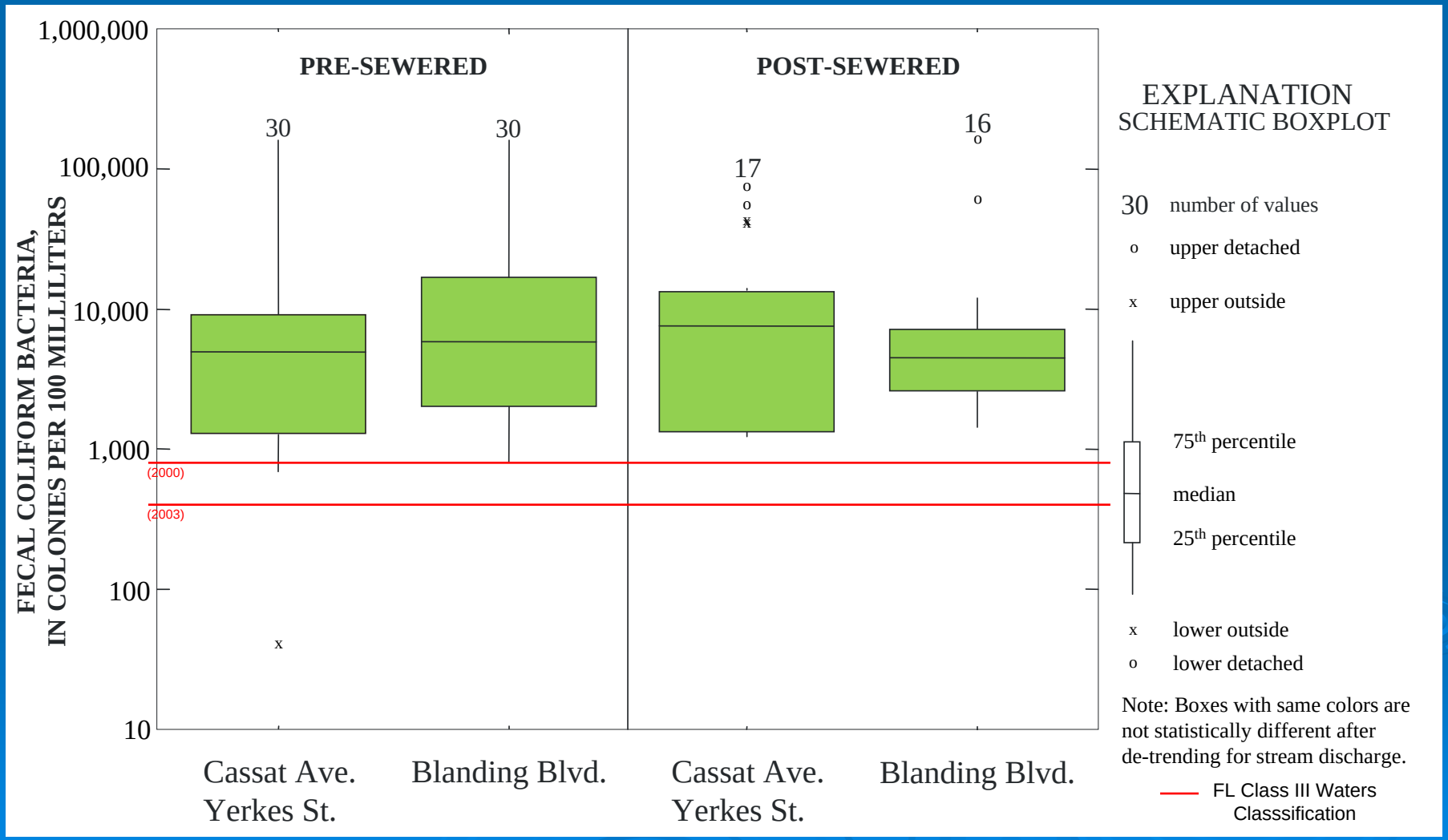
USGS science for a changing world

Fecal Coliform Bacteria
Fishing Creek



USGS science for a changing world

Fecal Coliform Bacteria
South Branch Big Fishweir Creek



USGS science for a changing world

Estimates of Ground-Water Flow Travel Times

Average Linear Pore-Water Velocity

(not considering attenuating factors e.g., adsorption or degradation)						using doubled values of porosity and conductance					
For:	closest septics (within 100 ft of trib; dry conditions)				Best Estimate:					Best Estimate:	
L [ft]	100	100	100	100		100	100	100	100		
ΔH [ft]	0.1	0.1	0.1	0.1		0.1	0.1	0.1	0.1		
n	0.1	0.2	0.1	0.2		0.2	0.2	0.4	0.4	Values of n from "Soil Survey of City of Jacksonville, Duval County, Florida" by USDA in 1998; reported as liquid limit in Table 15, ranged 0-45%.	
K [ft/d]	1	1	10	10		20	40	20	40		
v [ft/d]	0.01	0.005	0.1	0.05		0.1	0.2	0.05	0.1		
t [d]	10000	20000	1000	2000	1000-2000 days	1000	500	2000	1000	500-2000 days	
t [hr]	240000	480000	24000	48000		24000	12000	48000	24000		
t [yr]	27.37850787	54.75702	2.737851	5.475702		2.737851	1.368925	5.475702	2.737851		
t [min]	14400000	28800000	1440000	2880000		1440000	720000	2880000	1440000		
For:	closest septics (within 100 ft of trib; wet conditions)				Best Estimate:					Best Estimate:	Median Travel Time for 100ft: 0.7 years
L [ft]	100	100	100	100		100	100	100	100		
ΔH [ft]	5	5	5	5		5	5	5	5		
n	0.1	0.2	0.1	0.2		0.2	0.2	0.4	0.4		
K [ft/d]	1	1	10	10		20	40	20	40		
v [ft/d]	0.5	0.25	5	2.5		5	10	2.5	5		
t [d]	200	400	20	40	20-40 days	20	10	40	20	10-40 days	
t [hr]	4800	9600	480	960		480	240	960	480		
t [yr]	0.547570157	1.09514	0.054757	0.109514		0.054757	0.027379	0.109514	0.054757		
t [min]	288000	576000	28800	57600		28800	14400	57600	28800		
For:	furthest septics (1,500 ft from trib; dry conditions)				Best Estimate:					Best Estimate:	
L [ft]	1500	1500	1500	1500		1500	1500	1500	1500		
ΔH [ft]	5	5	5	5		5	5	5	5		
n	0.1	0.2	0.1	0.2		0.2	0.2	0.4	0.4		
K [ft/d]	1	1	10	10		20	40	20	40		
v [ft/d]	0.033333333	0.016667	0.333333	0.166667		0.333333	0.666667	0.166667	0.333333		
t [d]	45000	90000	4500	9000		4500	2250	9000	4500		
t [hr]	1080000	2160000	108000	216000		108000	54000	216000	108000		
t [yr]	123	246	12	25	12-25 years	12.32033	6.160164	24.64066	12.32033	6-25 years	
t [min]	64800000	1.3E+08	6480000	12960000		6480000	3240000	12960000	6480000		
For:	furthest septics (1,500 ft from trib; wet conditions)				Best Estimate:					Best Estimate:	Median Travel Time for 1,500ft: 8.2 years
L [ft]	1500	1500	1500	1500		1500	1500	1500	1500		
ΔH [ft]	15	15	15	15		15	15	15	15		
n	0.1	0.2	0.1	0.2		0.2	0.2	0.4	0.4		
K [ft/d]	1	1	10	10		20	40	20	40		
v [ft/d]	0.1	0.05	1	0.5		1	2	0.5	1		
t [d]	15000	30000	1500	3000		1500	750	3000	1500		
t [hr]	360000	720000	36000	72000		36000	18000	72000	36000		
t [yr]	41	82	4	8	4-8 years	4.106776	2.053388	8.213552	4.106776	2-8 years	
t [min]	21600000	43200000	2160000	4320000		2160000	1080000	4320000	2160000		

USGS
science for a changing world

USGS Online Reports

- http://fl.water.usgs.gov/publications/online/online.html
- Wicklein, Shaun M., 2004, WRIR 03-4299

USGS science for a changing world