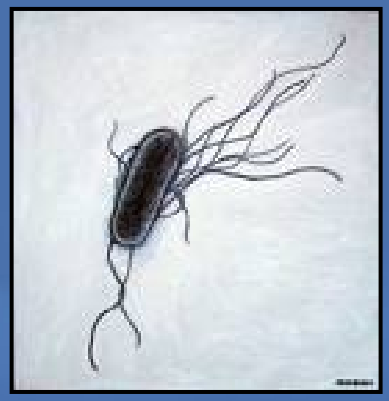
A Tool to Identify and Remediate Sources of Fecal Contamination in Surface Waters

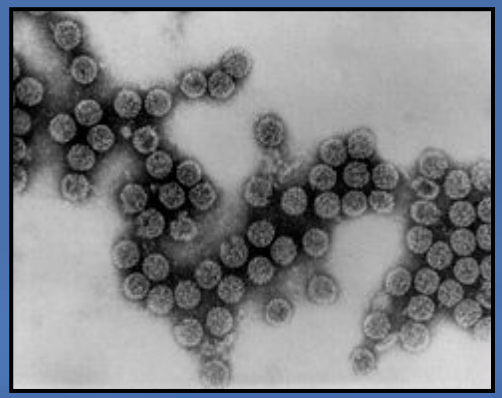
Cheryl M. Wapnick

Indicator Organisms (IOs)

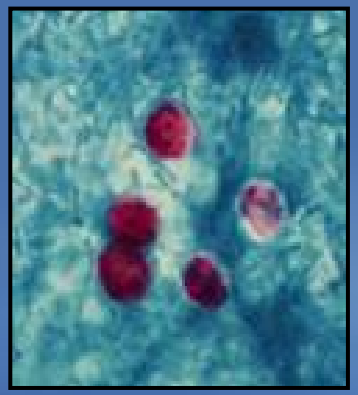
- Bacteria present in the GI tract of warm-blooded animals
- Used to identify fecal contamination
- Not pathogenic
- In theory, predictive of human pathogens



Bacterial Pathogens



Viral Pathogens

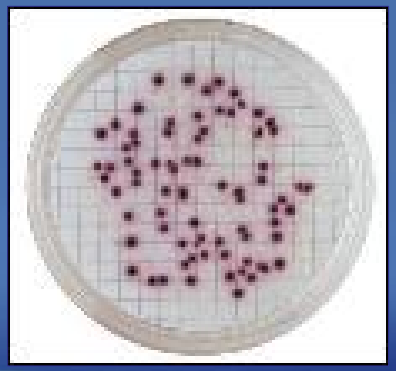


Protozoan Pathogens

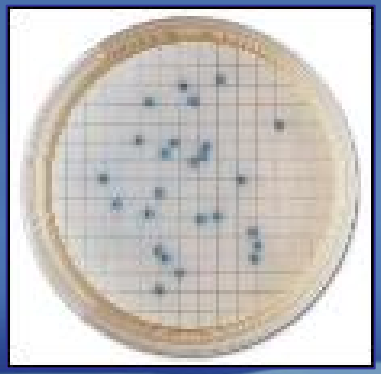
Currently Recognized IOs

- Fecal coliforms – thermotolerant coliforms of fecal origin
- *Escherichia coli* – the dominant fecal coliform species
- Enterococci – also of fecal origin; more salt-tolerant than fecal coliforms

Fecal coliforms



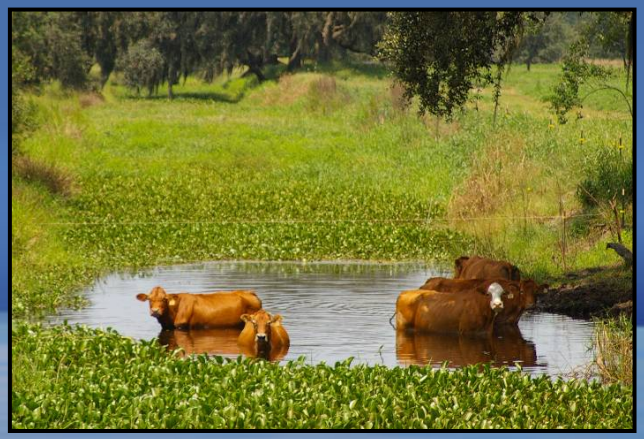
E. coli



enterococci

Possible Sources of IOs

- Aging sanitary sewer infrastructure
- Onsite wastewater disposal systems (septic)
- Surface runoff
- Agriculture
- Wild animals
- Soil/sediments



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Human Health Risk

- **High risk:**
  - Human sewage, carries human-specific pathogens
- **Definite risk:**
  - *E. coli* 0157:H7 in cattle
  - *Salmonella* in chickens
- **Unknown risk:**
  - Wildlife, pets

Bacteria Decision-Support Tool

- Designed to:
  - Prioritize basins for management action
  - Identify sources of fecal pollution
  - Track the effectiveness of management actions
- Methodology developed in Florida, but can be applied anywhere

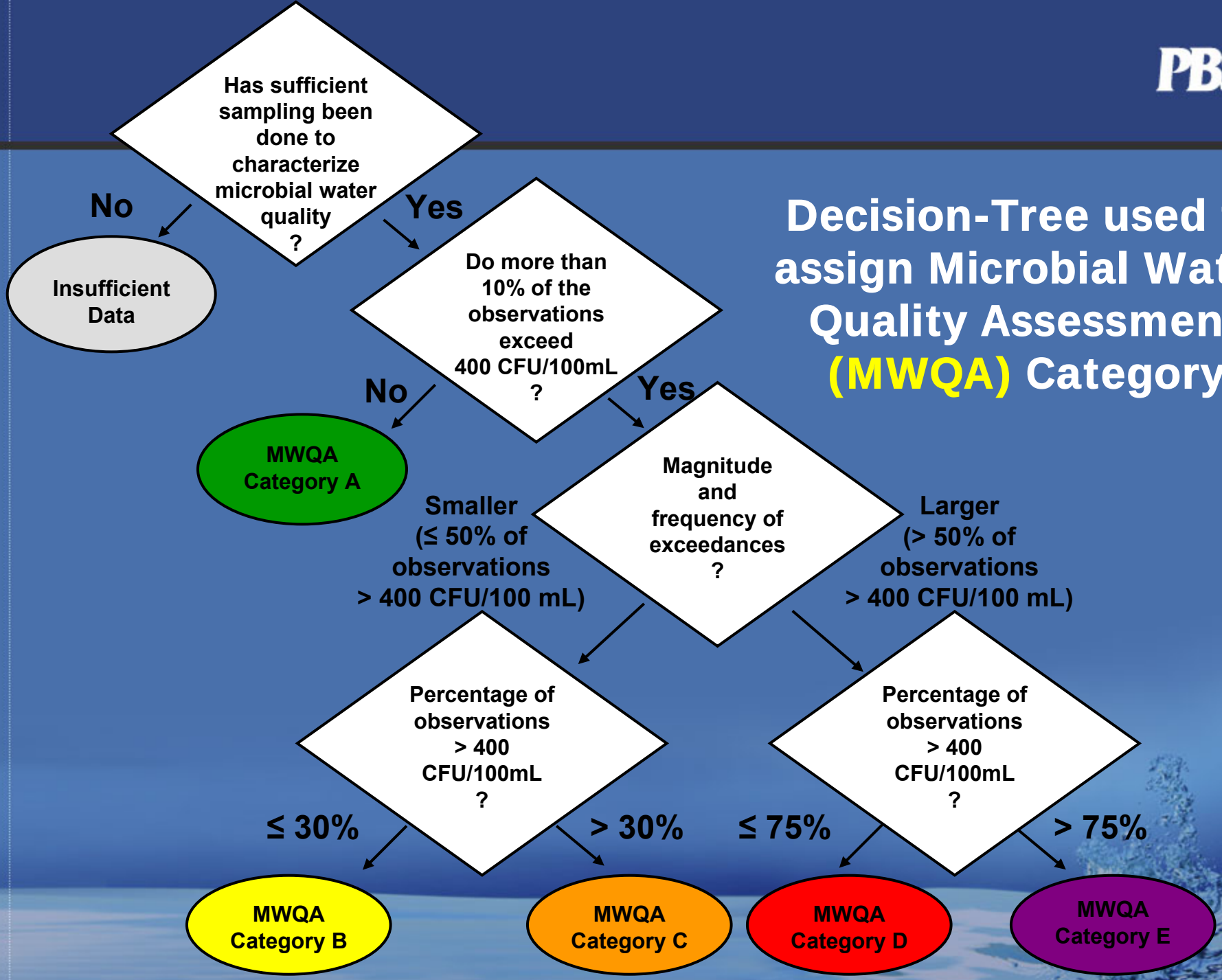
Bacteria Decision-Support Tool

- **Based on:**
  - **"Annapolis Protocol" recommended by WHO (2003)**
  - **"Phased monitoring approach" recommended by NRC (2004)**
- **Acknowledge limitations of existing bacteria water quality indicators to protect public health**
  - **Use a "weight-of-evidence" approach to compensate for limitations**

Bacteria Decision-Support Tool: *Step 1*

- Categorize microbial water quality conditions within each waterbody based on fecal indicator bacteria from existing monitoring data
  - A decision-tree is used to assign a **"microbial water quality assessment" (MWQA)** category to monitoring stations
  - MWQA categories are based on the exceedance of the fecal indicator bacteria criterion

Decision-Tree used to assign Microbial Water Quality Assessment (MWQA) Category



Location	Sta. No.	No. Samples (*N*)	% >400 CFU/ 100 mL ($\hat{P}$)	MWQA category	Geometric mean fecal coli. (CFU/ 100 mL)	Geometric mean enterococci (CFU/ 100 mL)
Turkey Creek at SR 60	111	77	84%	E	1,212.0	1,426.0
Bullfrog Creek at Symmes Rd	132	78	83%	E	1,134.8	2,658.9
Sweetwater Creek at Hillsborough Ave	104	84	69%	D	786.4	849.9
Delaney Creek at 36th Ave	138	84	54%	C	443.3	642.2
Delaney Creek at US 41	133	84	42%	C	376.7	596.8
Little Manatee River at CR 579	140	84	31%	B	283.6	664.9
English Creek at SR 60	154	83	30%	B	266.6	487.7
Mill Creek at I-4	149	81	37%	B	258.0	578.7
Little Manatee River at US 301	113	84	20%	B	250.8	664.0
Rocky Creek at Hillsborough Ave	103	84	26%	B	242.6	285.2
Hillsborough River at Sligh Ave	152	84	27%	B	239.8	182.8
Bullfrog Creek at US 41	144	84	37%	B	233.7	254.7
Little Manatee River at CR 674	129	84	24%	B	218.5	704.0
Baker Creek at Thonotosassa Rd	107	84	35%	B	216.5	508.7
Hillsborough River at Rowlett Pk	105	84	26%	B	208.7	127.7
Rocky Creek at Waters Ave	141	84	26%	B	205.8	343.4
Hillsborough River at Columbus Ave	137	84	33%	B	195.5	153.7
Flint Creek at US 301	148	84	25%	B	191.2	359.8
Double Branch Creek at Hillsborough Ave	101	84	27%	B	185.1	222.6
Blackwater Creek at SR 39	143	82	21%	B	156.9	284.2
Trout Creek at CR 581	145	65	18%	B	152.9	281.8
Sweetwater Creek at Anderson Rd	142	84	20%	B	152.2	764.8
Turkey Creek at Durant Rd	151	82	26%	B	142.0	322.6
Alafia River South Prong at Bethlehem Rd	139	83	16%	B	138.8	215.7
Alafia River at Bell Shoals Rd	114	84	18%	B	136.4	240.7
Cypress Creek at CR 581	120	72	19%	B	132.9	261.9
Alafia River at US 301	153	83	14%	A	152.7	209.7
Hillsborough River at US 301	108	83	11%	A	101.7	159.4
Alafia River North Prong ab confluence	115	84	11%	A	100.4	267.3
Alafia River South Prong ab confluence	116	84	10%	A	80.6	207.3
Channel A at Hillsborough Ave	102	84	14%	A	63.2	63.1
L. Thonotosassa at Flint Creek	118	82	2%	A	46.8	68.5
Hillsborough River at Fowler Ave	106	84	5%	A	46.6	96.4
TBC at Fowler Ave	146	82	7%	A	40.5	51.0
Palm River at US 41	109	84	7%	A	39.1	36.4
Little Manatee River at US 41	112	84	5%	A	34.6	55.1
L. Thonotosassa middle	135	82	2%	A	32.9	41.7
TBC at MLK Blvd	147	84	6%	A	31.9	31.0

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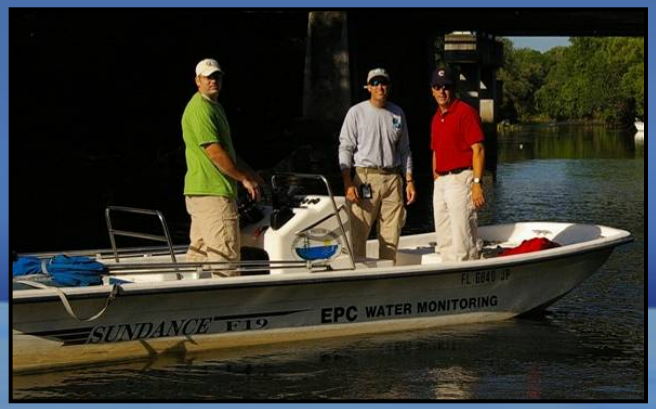
county-wide, sampling site prioritization using MWQA scores

(based on fecal coliform data from EPCHC monitoring stations 2001-2007)

Bacteria Decision-Support Tool: *Step 2*

- Use "weight-of-evidence" approach to assess potential sources of fecal contamination
  - Data analysis
  - "One-on-one meetings" with stakeholders
  - "Maps on the table" workshops
  - Field reconnaissance
  - Microbial Source Tracking (MST), if necessary
- Classify sites based on potential for human health risks using **contaminant source survey (CSS)** categories



Contaminant Source Survey (CSS) categories

1. **Very Low:** No visual evidence of potential sources of human pathogens; natural environment; no or minimal anthropogenic land uses; wildlife present (any density)
2. **Low:** Low density agricultural and residential sources, including pets, livestock (without direct access to surface waters), or poultry operations; residences on septic systems
3. **Moderate:** Urban stormwater sources (including pet waste) present; well-functioning wastewater infrastructure (both sewer and septic); episodic/low volume sanitary sewer overflows (SSOs) reaching surface waters; moderate-density livestock with little direct access to surface waters; Class A residual and/or septage spreading areas may be present
4. **High:** Major stormwater outfalls present; history of failing wastewater infrastructure (central sewer or onsite systems); episodic or chronic/high volume SSOs reaching surface waters; concentrated livestock without direct access to surface waters; residual/septage spreading (Class B)
5. **Very High:** Current failing wastewater infrastructure; chronic/high volume SSOs reaching surface waters; concentrated livestock with direct access to surface waters; evidence of direct sewage inputs (e.g., confirmed illicit discharges)

Classification Matrix:
Annapolis protocol approach

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		MWQA Group (based on binomial assessment of frequency of 400 CFU/100 mL fecal coliform exceedances)					Exceptional Circumstance (e.g., sewer line break) [c]
		A (≤ 10%)	B (>10% - 30%)	C (>30% - 50%)	D (>50% - 75%)	E (>75%)	
Contaminant Source Survey (CSS) Assessment Category (likelihood of fecal contamination posing human health risks)	1. Very Low	A1	B1	C1[a]	D1[a]	E1[a]	Immediate Action
	2. Low	A2 [b]	B2	C2	D2[a]	E2[a]	
	3. Moderate	A3[b]	B3	C3	D3	E3	
	4. High	A4[b]	B4[b]	C4	D4	E4	
	5. Very High	A5[b]	B5[b]	C5[b]	D5	E5	
	Exceptional Circumstance (e.g., sewer line break) [c]	Immediate Action					

Notes:

a) These outcomes imply that the CSS may be providing an overly optimistic rating of water quality, or the fecal coliform sources in the area may be relatively low-risk or primarily environmental (e.g., wildlife, sediments, soils, vegetation), and the cause(s) of the discrepancy should be verified.

b) These outcomes imply that the fecal coliform indicator may be providing an overly optimistic MWQA rating, or the CSS may be providing an overly negative assessment, and the cause(s) of the discrepancy should be verified.

c) As explained by WHO (2003), exceptional circumstances involve acute situations known to be associated with higher public health risks, such as sewer line breaks and other SSOs that contaminate surface waters, which require immediate remedial action.

Bacteria Decision-Support Tool: Results of *Steps 1 and 2*

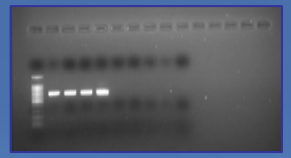
- Narrow focus of the investigation to discrete sources in specific areas
- Take corrective action as appropriate
- Identify appropriate MST techniques for use in those areas that require additional investigation or confirmation of human/non-human sources

Bacteria Decision-Support Tool: *Step 3*

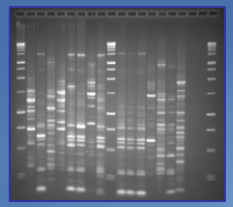
- **Microbial Source Tracking (MST),** if necessary, is used in those watersheds with highest frequency and magnitude of exceedance
  - To minimize cost & time, use lower-cost more basic analytic methods first, followed by higher-cost, more sophisticated methods

Central Hypothesis of MST

- Certain microbial species or types are associated with the gastrointestinal tract of specific animal hosts
- This association can be used to “track” the fecal microorganism back to its host
- “Toolbox approach” – methods constantly evolving



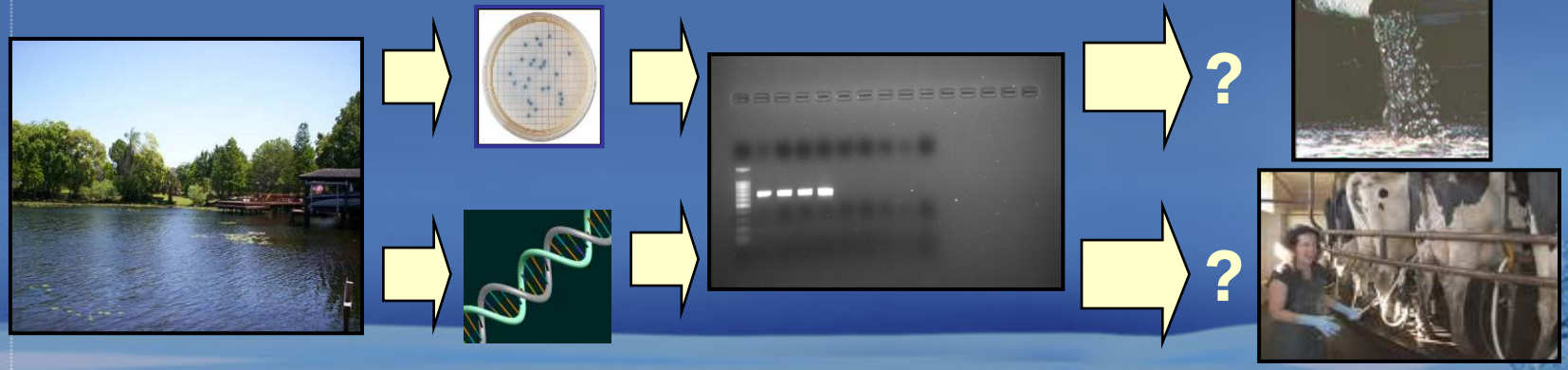
Library-independent MST



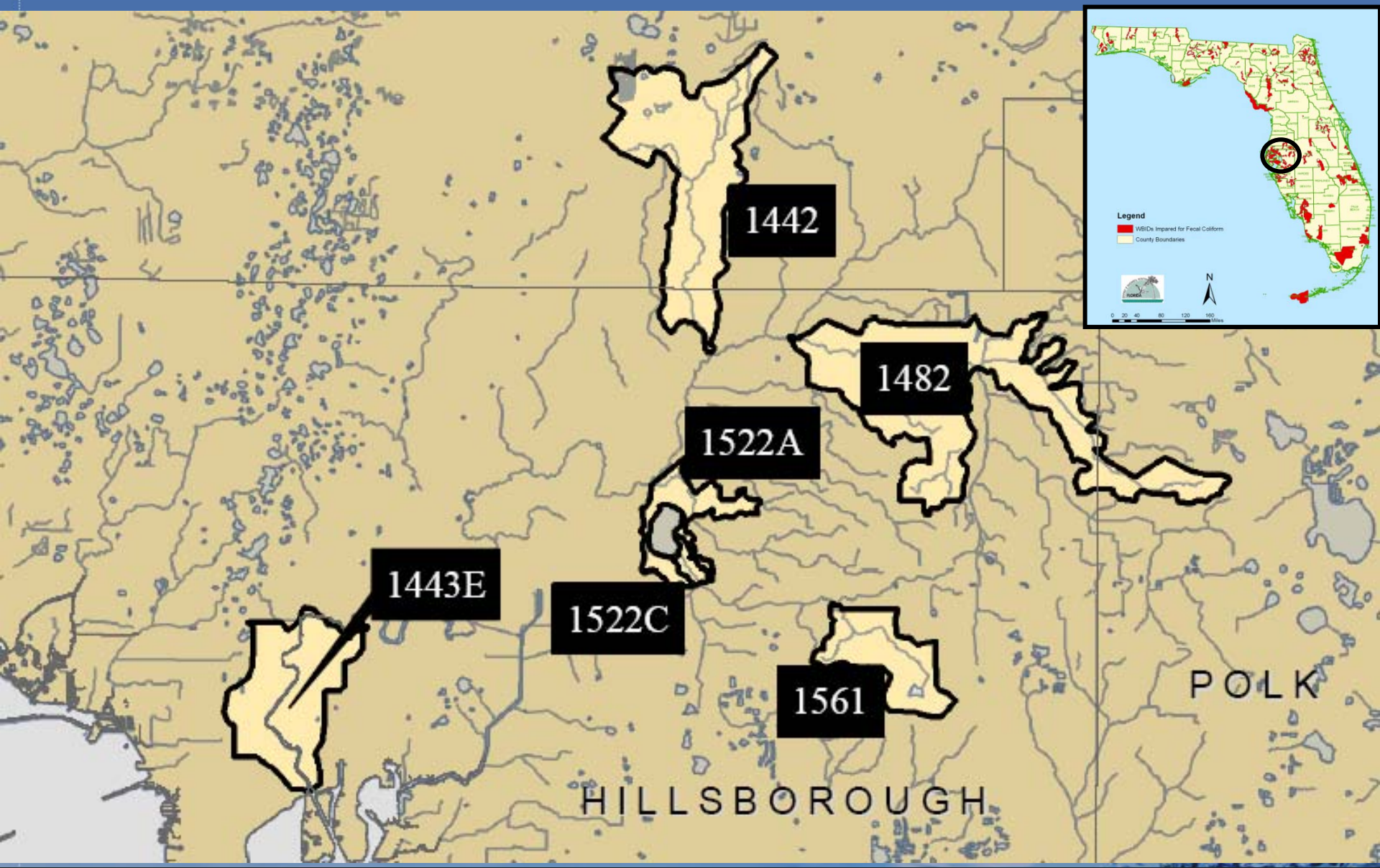
Library-dependent MST

Library-Independent MST Methods

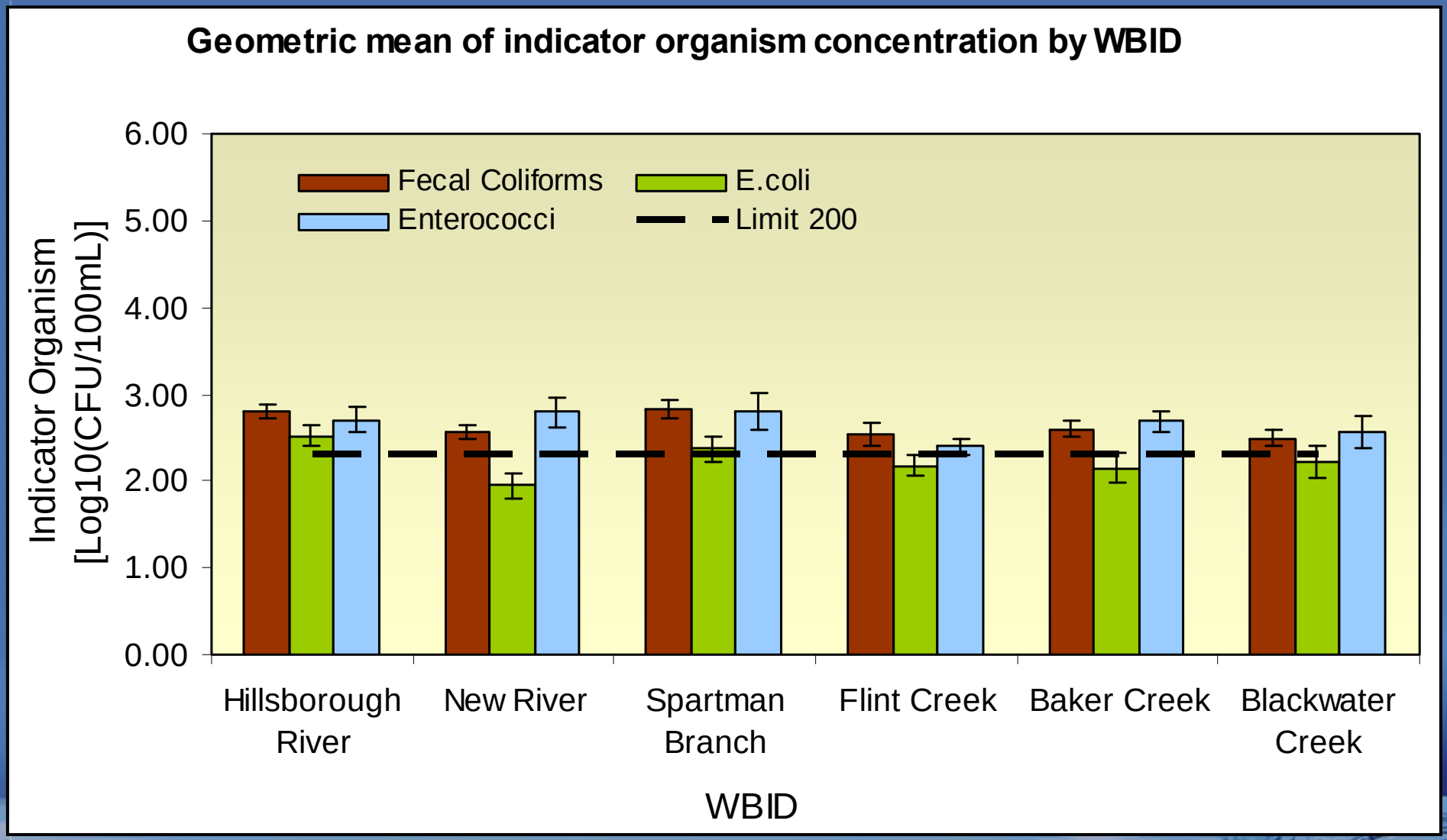
- **Human polyomavirus (qPCR)**
  - Nonpathogenic (harmless) virus shed in urine; high carrier rate in human population & ubiquitous in sewage
- ***esp* gene of *Enterococcus faecium* (qPCR)**
  - Enterococcal surface protein – virulence factor associated with human hosts
- ***Bacteroides* (PCR / qPCR)**
  - Fecal anaerobe that tends to co-evolve with host
  - Several markers: human, ruminant, horse



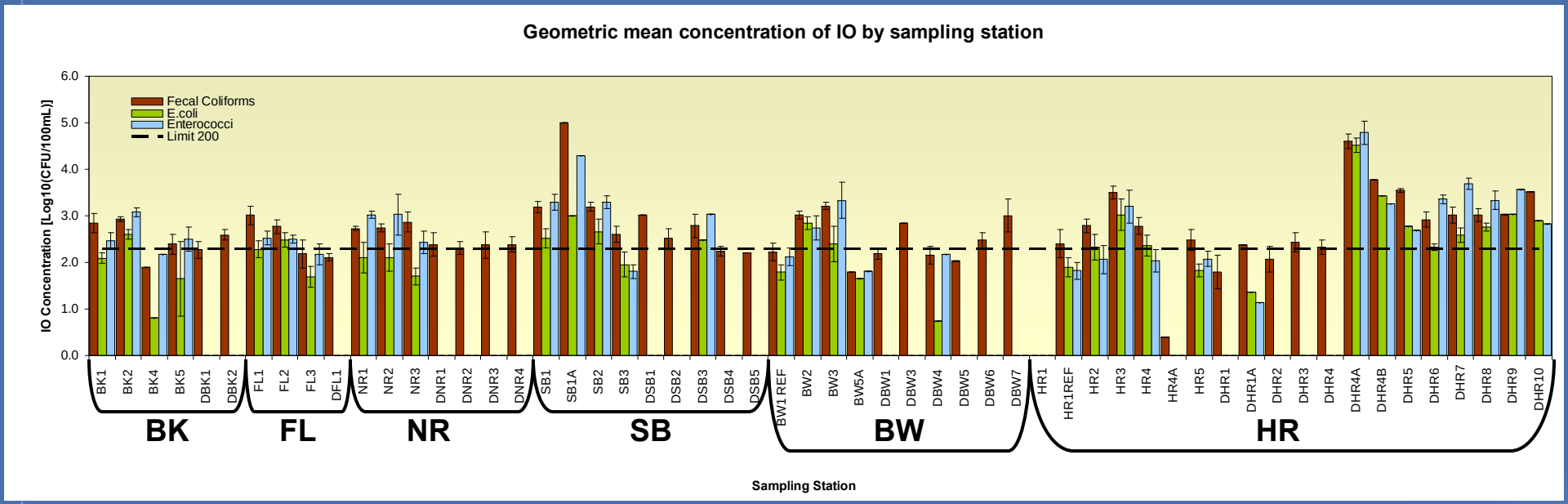
Full Implementation Example: Hillsborough River Watershed



Geometric Mean Concentration of Indicator Organism by WBID

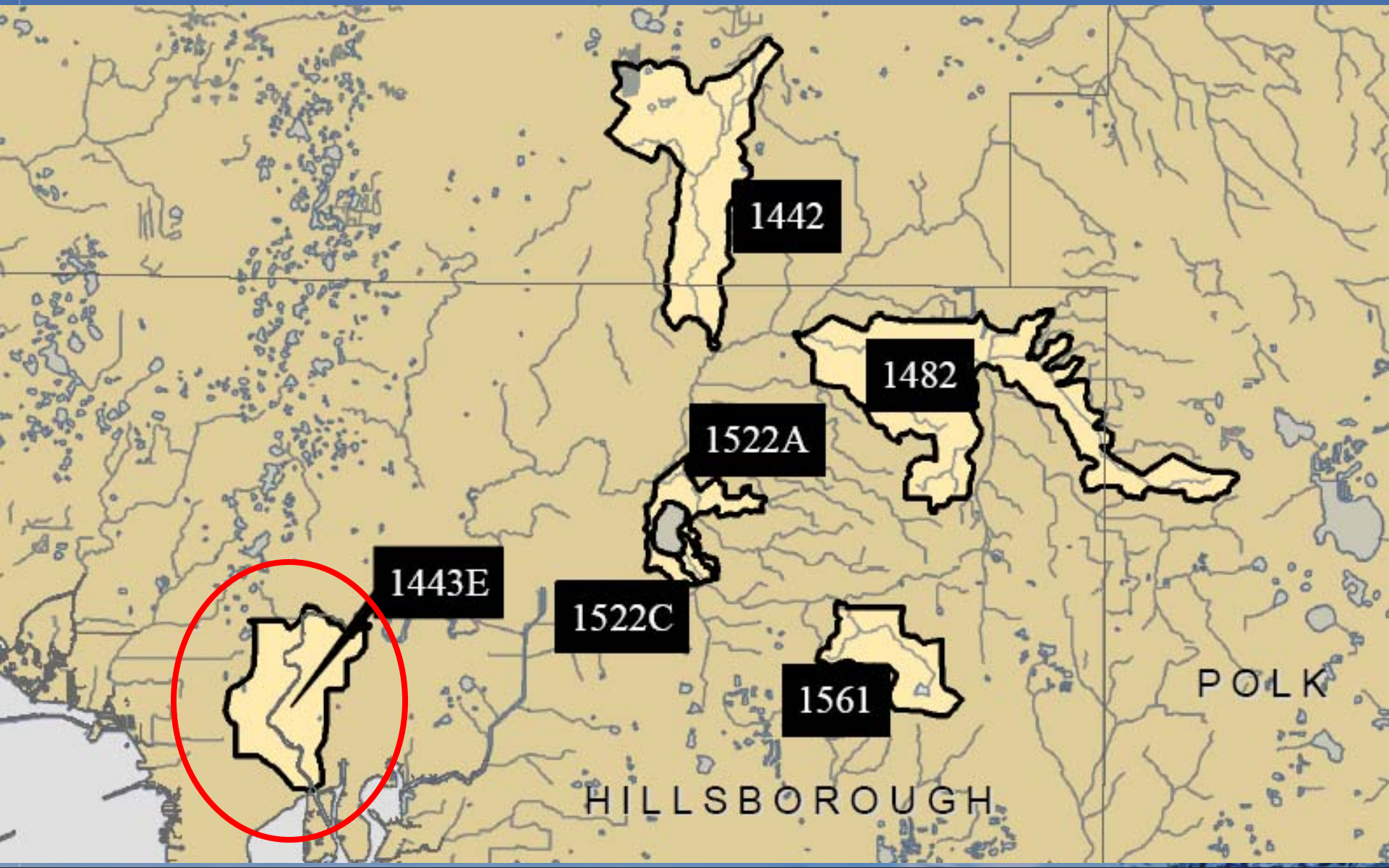


Geometric Mean Concentration of Indicator Organism by Sampling Station



Evaluating data from individual stations allows you to target those areas within a watershed that are most impaired

Lower Hillsborough River



Lower Hillsborough River

HR1 Ref

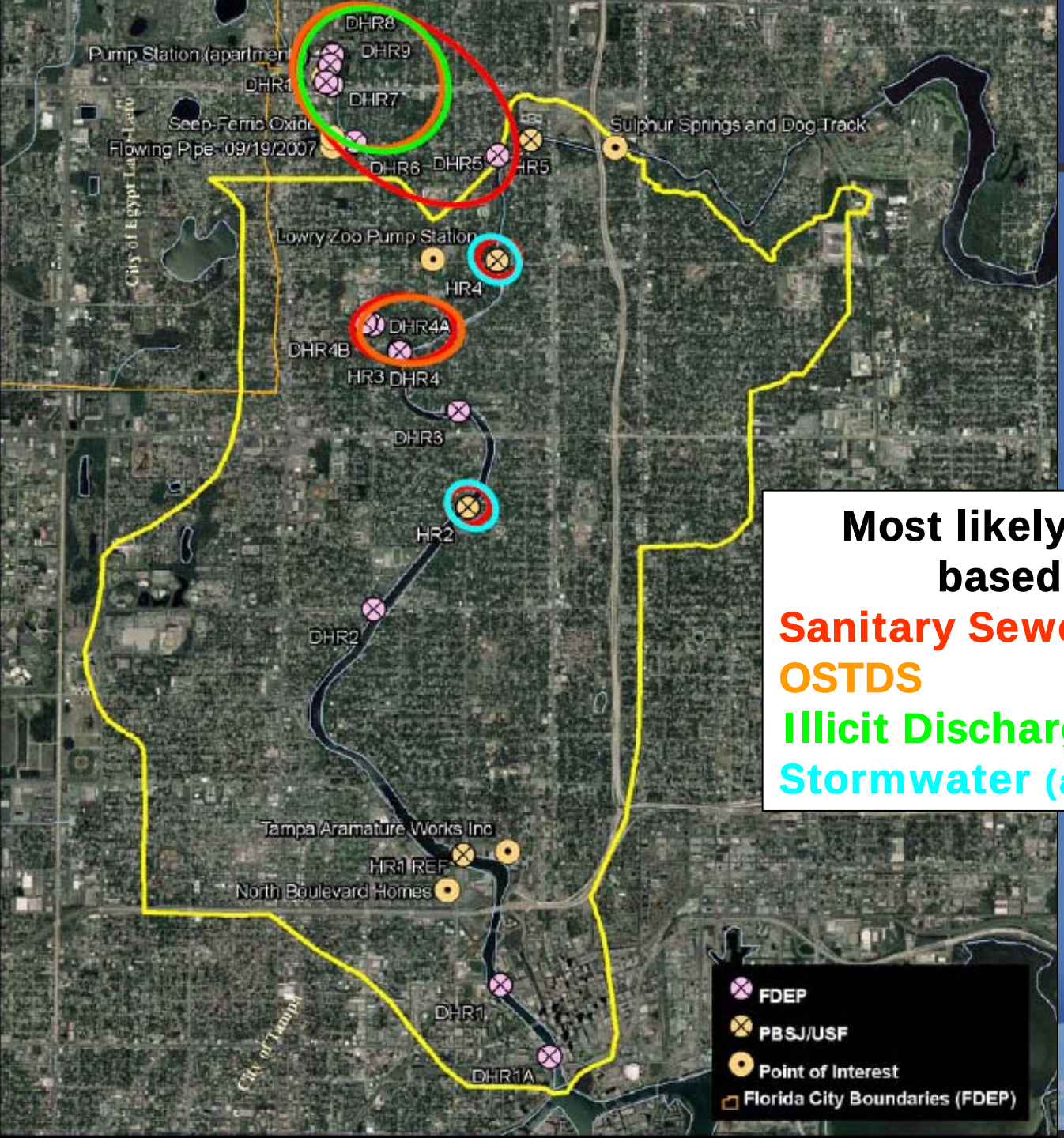
HR2

HR3

DHR4a

Lower Hillsborough River

Monitoring Location	Fecal Source(s) of Concern	% of Sampling Dates Markers Detected	Most Probable Source Categories and Recommended Management Actions
DHR4A	Human	100 %	Septic and possibly sanitary sewer; confirm and address specific source locations and provide public outreach explaining potential presence of health risk at site
HR3	Human	80 %	Septic and sanitary sewer; confirm and address specific source locations and provide public outreach explaining potential presence of health risk at site
DHR8	Human	50 %	Multiple sources suspected; identify and address specific source locations; provide public outreach explaining potential presence of health risk at site
DHR5	Human	50 %	Multiple sources suspected; identify and address specific source locations; provide public outreach explaining potential presence of health risk at site
HR2	Human	67 %	Sanitary sewer and stormwater; identify and address specific source location(s)
HR4	Human	67 %	Sanitary sewer and stormwater; identify and address specific source location(s)
DHR7	Human	60 %	Multiple sources suspected; identify and address specific source locations
DHR6	Human	33 %	Unknown; identify and address specific source location(s)
DHR 9	Human	0 %	Unknown; identify specific source location(s)
HR1 REF	Human	100 %	Homeless camp, sanitary sewer and possibly stormwater; confirm and address specific source locations
HR5	Human	60 %	Sanitary sewer; confirm and address specific source locations
DHR10	Human	100 %	Multiple sources suspected; identify and address specific source locations
DHR4B	Human	0 %	Unknown; identify specific source location(s)



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Lower Hillsborough River Tampa, FL

Most likely bacteria sources, based on MST results:

Sanitary Sewer & SSOs

OSTDS

Illicit Discharges

Stormwater (as a conveyance system)

Bacteria Remediation: *tracking & reporting results*

	Monitoring Location			
Year	1	2	3	4
2004	D4	A1	B1	C3
2005	C4	B1	B1	C3
2006	D4	B1	C1	B3
2007	C3	A1	B1	B2
2008	C3	A1	A1	B2

Benefits of the Bacteria Decision-Support Tool

- **Saves time and money** – Screening tool is used to prioritize bacterial impairments at the station and waterbody levels
- **Increases efficiency and effectiveness** – Uses both the level of impairment and potential human health risk to prioritize identification of sources
- **Helps to coordinate and leverage available resources** – Active stakeholder involvement builds consensus for addressing sources
- **Ensures that projects can be expected to address impairments and in the most effective way** – The tool can be used to evaluate the "sufficiency of effort" of the projects identified in the management plan to restore water quality

Cost Estimate
6 tributaries, 3-8 stream miles each

- **Implementation of Tool: Steps 1 and 2**

  ~$123,000 for 6 tributaries

  ~$20,000 per tributary

- **Estimated Cost of Adding Step 3**

  ~$285,000 for 6 tributaries

  ~$48,000 per tributary

Does not include expenses associated with travel

Acknowledgements

- Florida Department of Environmental Protection (FDEP)
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More Information

Cheryl M. Wapnick
Senior Scientist
(904) 363-8443
cmwapnick@pbsj.com