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Leveraging State of the Science Tools to Identify Bacteria and Nutrient Sources in Urban Waters

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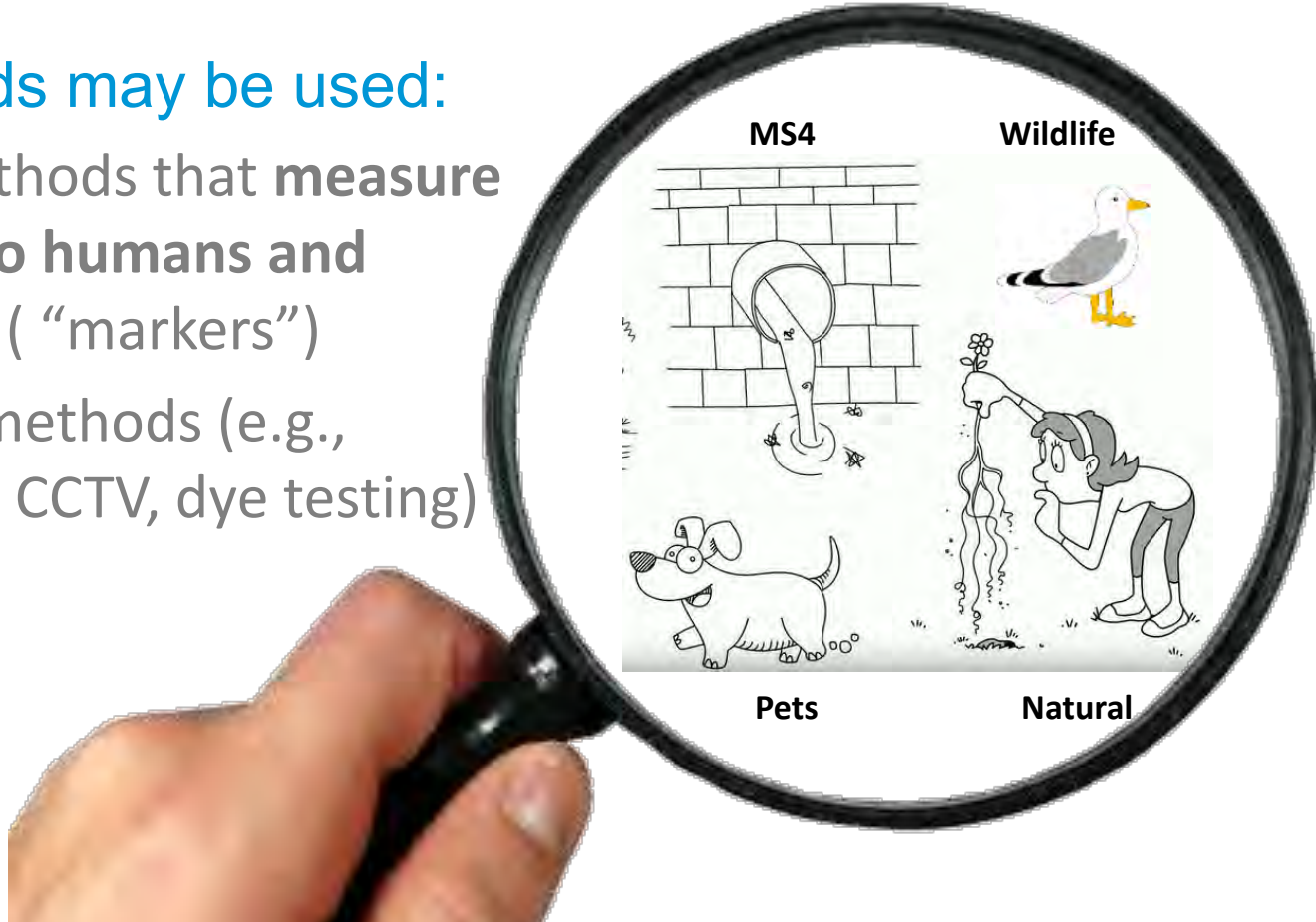
What is MST/NST?

- Microbial source tracking (MST) and nutrient source tracking (NST) are approaches to identify and locate **specific** sources of bacteria and nutrients

- Multiple methods may be used:
  - laboratory methods that **measure DNA specific to humans and other animals** (“markers”)
  - conventional methods (e.g., smoke testing, CCTV, dye testing)



Why is MST/NST Needed?

- Pathogen/nutrient contamination of surface waters is a massive problem nationwide
- MST/NST allows effective source control with a more exact, lower cost approach to meet MS4 and TMDL requirements

National Summary
Causes of Impairment in Assessed Rivers and Streams

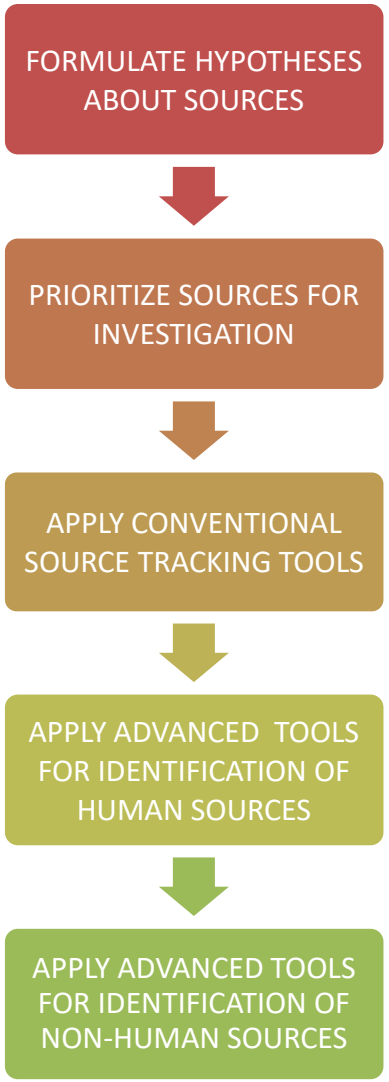
Description of this table

Cause of Impairment Group	Miles Threatened or Impaired
Pathogens	187,872
Sediment	138,874
Nutrients	118,831
Organic Enrichment/Oxygen Depletion	98,037
Temperature	94,488
Metals (other than Mercury)	94,384
Polychlorinated Biphenyls (PCBs)	82,311

https://ofmpub.epa.gov/waters10/attains_nation_cy.control

MST/NST Study Design

- Use local resources to identify potential sources, including:
  - Consultation with local stakeholders
  - Analysis of historical water quality data
  - Desktop GIS and mapping analysis
  - First hand observational/reconnaissance visits
- Define specific questions (hypotheses) that will be tested through sampling and analysis and dictate the study design
  - Number of samples and locations
  - Frequency and timing of sample collection
  - Analytical methods and analysis of results
- Use a tiered investigation approach to most efficiently identify sources



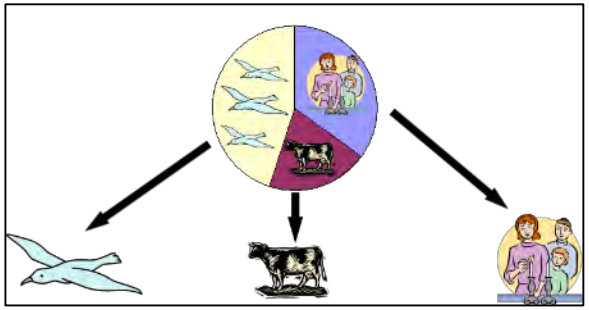
Tiered Source Tracking Approach (adapted from Griffith, 2013)

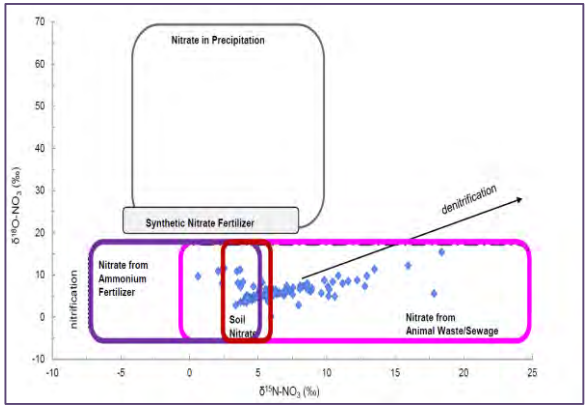
Traditional Source Tracking Tools

- Most conventional tools give no indication of the source of contamination
  - A problem is identified (e.g., nutrients or bacteria are elevated), but the source cannot be reliably identified or located
- However, these tools generally have lower costs and may be useful in combination with advanced tools
  - Source surveys can provide information on potential sources to help with development of study hypotheses
  - FIB and nutrient patterns can help identify areas for use of advanced tools
  - Dye testing can be used to conclusively demonstrate a hydraulic connection (or rule out a source where non is found)
  - CCTV can be used to track illicit discharges in the stormdrain system

Advanced Source Tracking Tools

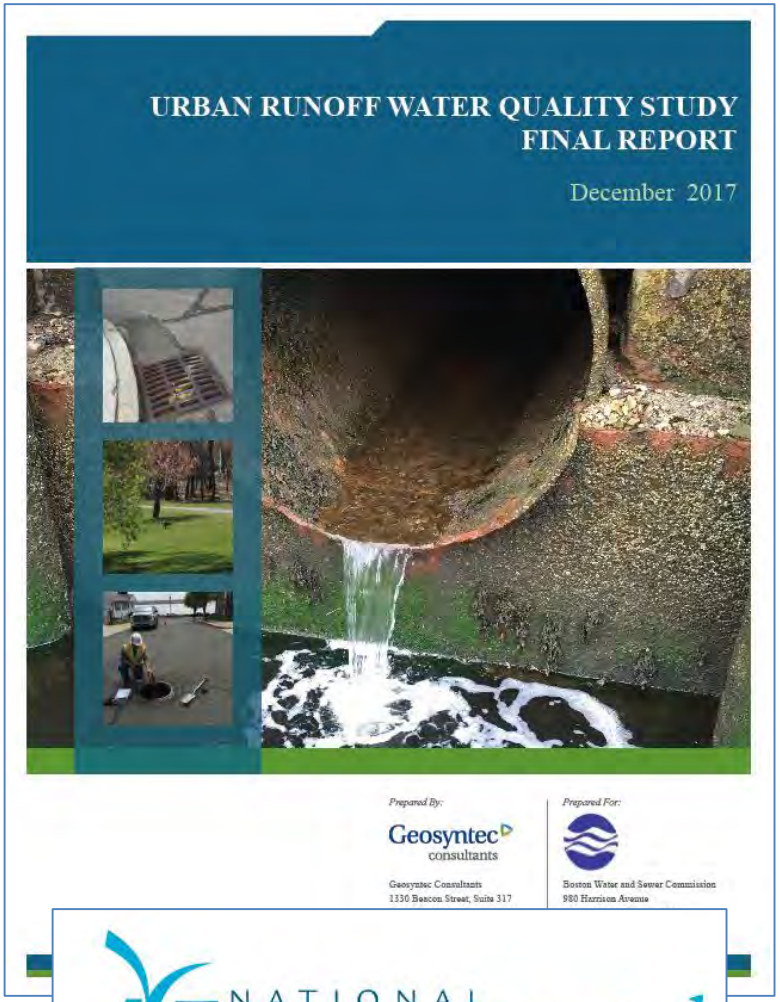
- Chemical Sewage Indicators / Pharmaceuticals and Personal Care Products (PPCPs)
  - A suite of analytes persistent in the environment and specific to human waste can be analyzed on surface and/or groundwater
  - Analytes include artificial sweeteners (e.g., sucralose), pain relievers (e.g., acetaminophen), caffeine, cotinine, and many others
- DNA Markers
  - Markers have been lab and field tested as part of multi-laboratory validation studies
  - Sensitive and specific to waste sources including human, dog, gull, cow, and horse
- Stable Isotopes
  - Differentiation of nutrient source(s) based on the isotopic ratios of nitrogen and oxygen
  - Sources with distinct signatures include: synthetic fertilizers, sewage/animal waste, natural soils, and atmospheric deposition





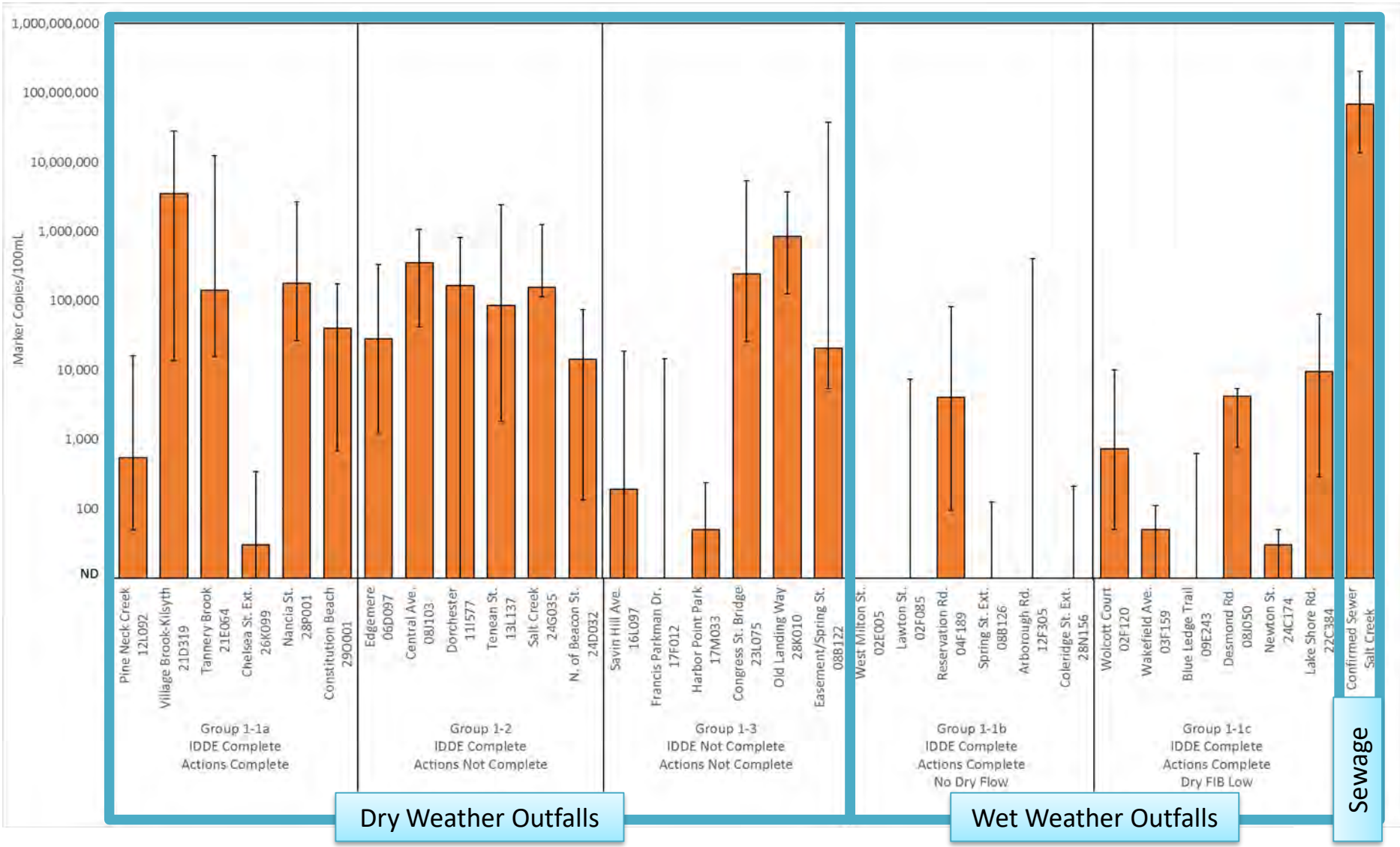
Case Study: Boston (BWSC)

- Regulatory Drivers
  - MS4 Permit
  - Consent Decree
  - Bacteria (FIB) & Phosphorous (P) TMDLs
- Study Objectives
  - Determine whether elevated FIB and P at representative outfalls are due to human or non-human sources
  - Evaluate the relative contribution of FIB and P from various sources, during dry and wet weather
- Approach:
  - 30 MS4 outfalls sampled across 6 events (dry and wet weather)
  - Analysis for FIB, P, HF183, Field Kits, PPCPs, and non-human DNA markers



2018 NACWA Award Winning Project

Case Study: Boston (BWSC)



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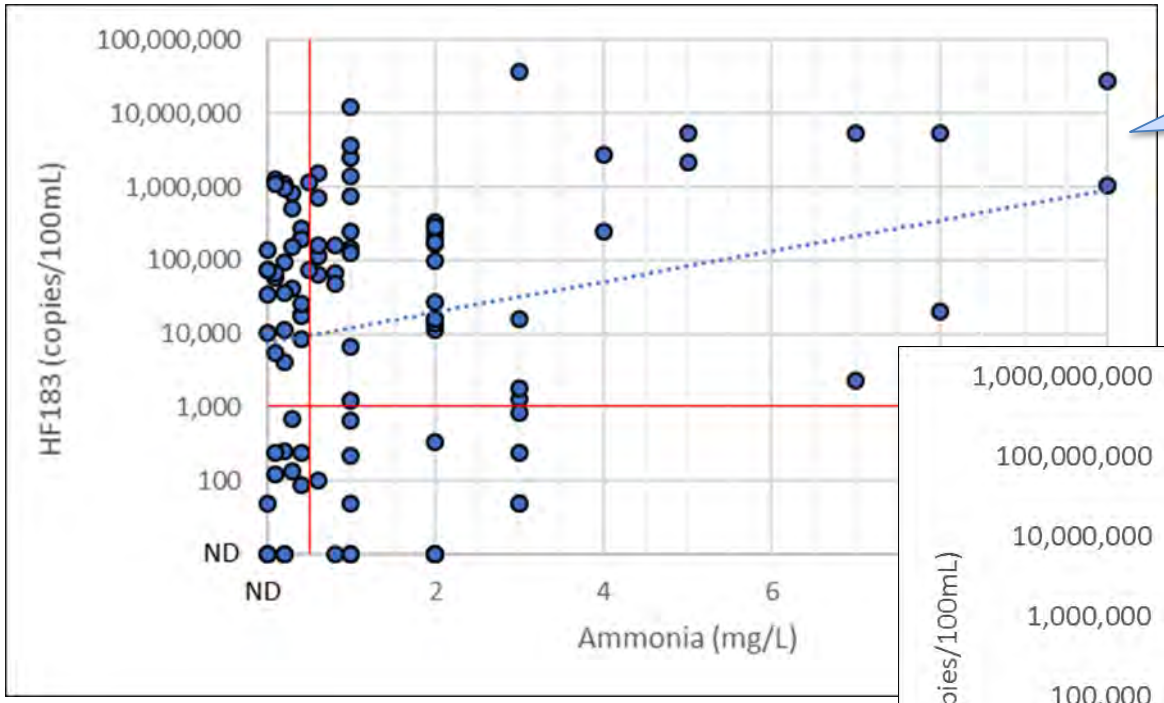
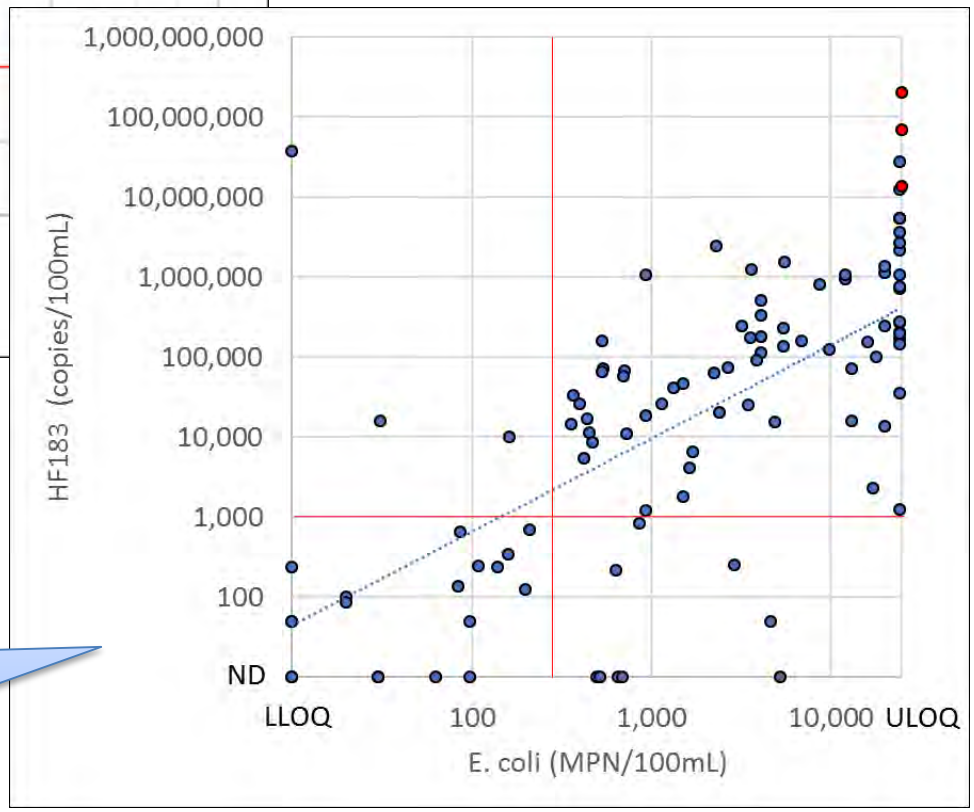


No significant correlation between Ammonia and HF183 (dry or wet)



E. Coli highly correlated with HF183 during dry weather (not wet)

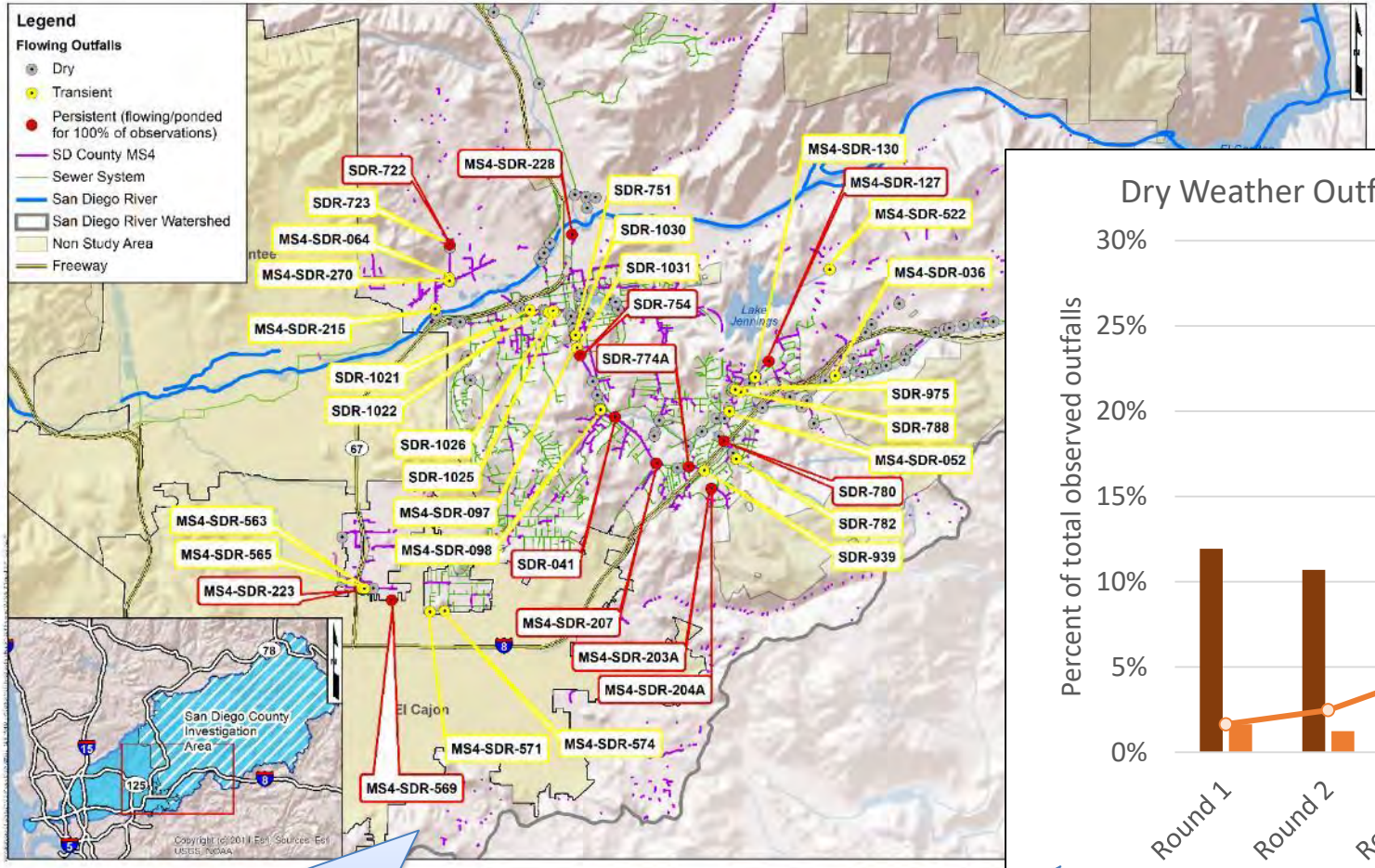
Case Study: Boston (BWSC)

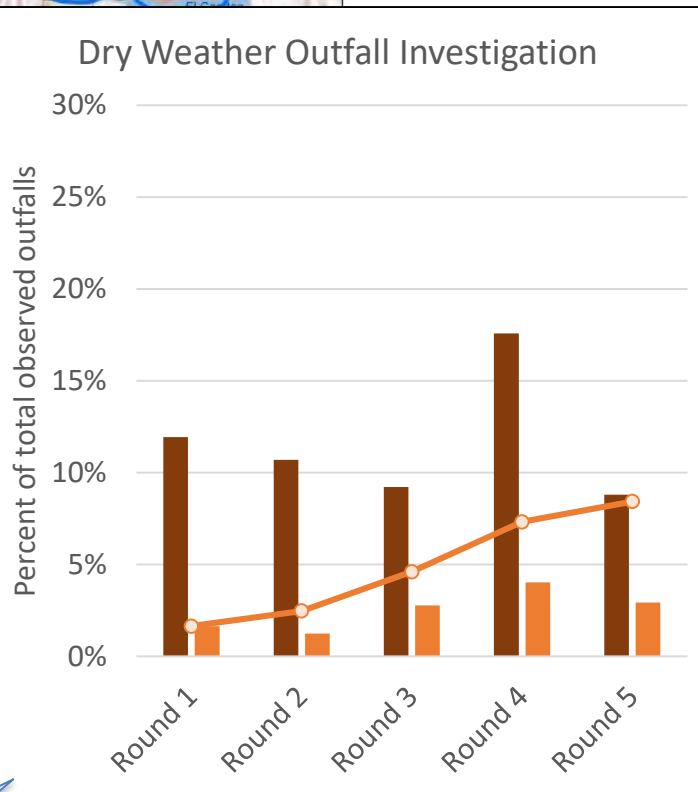
- Key Results/Findings
  - Human waste was a significant source of TMDL pollutants (FIB and P) in MS4 discharges during dry weather, while non-human sources were more significant during wet weather
  - Rapid indicators (ammonia, surfactants, chlorine) were not able to effectively detect human waste impacted discharges in dry or wet weather
  - FIB (*E. coli* and Enterococcus) were well correlated with the human waste marker (HF183) during dry weather
  - Advanced IDDE procedures were recommended to locate remaining sewage sources, including:
    - Within network FIB and/or HF183 sampling
    - Expanded use of CCTV (within the MS4) and dye testing

Case Study: San Diego County MS4

- Regulatory Driver:
  - MS4 Permit
  - Bacteria TMDL
- Study Objective:
  - Identify sources of dry weather flow and human waste to County MS4 outfalls
- Approach:
  - Screen all County outfalls (>500) multiple times each year
  - Sample flowing and ponded outfalls for HF183
  - Perform follow up investigation and abatement actions (e.g., above ground flow tracking and source survey, belowground CCTV) at outfalls with HF183 > 500 copies/100mL

Case Study: San Diego County MS4





Persistent and Intermittently flowing outfalls identified

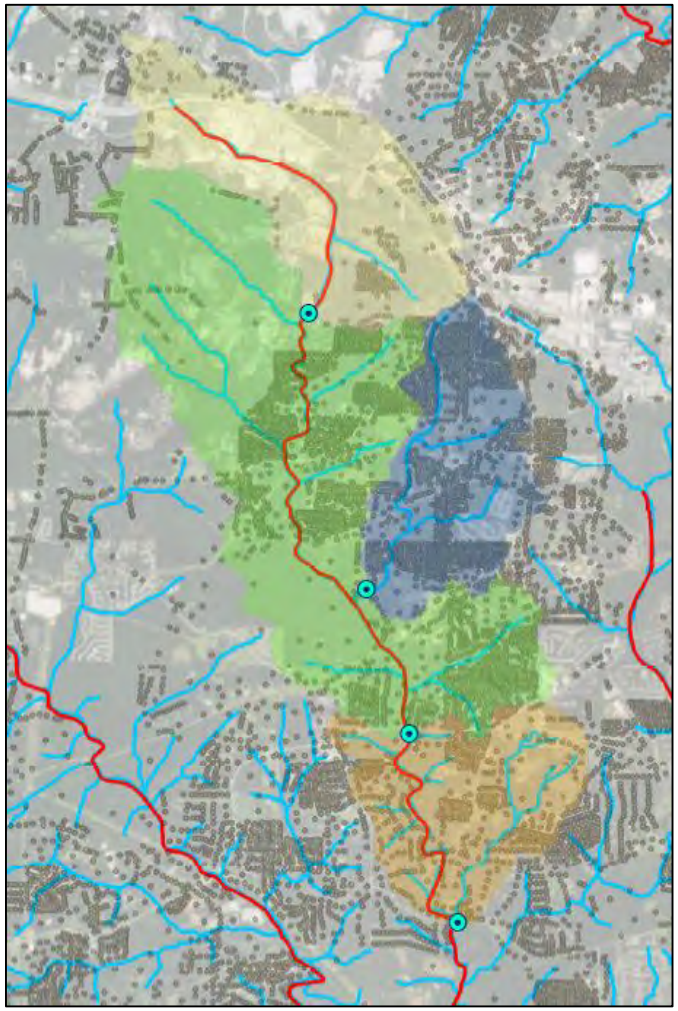
Most HF183 detections are intermittent

Case Study: San Diego County MS4

- Key Results/Findings
  - A majority of County MS4 outfalls were dry during all observations, suggesting that most outfalls were not a source of discharge during dry weather, and thus not a source of bacteria to surface waters
  - Most human impacted outfalls have intermittent detections
  - Multiple rounds of observations and sampling are required to address outfalls with transient flows and not miss intermittent human waste impacts
  - Irrigation overspray was the most common source of flow in dry weather based on above ground flow tracking
  - Further investigation (e.g., CCTV and dye testing) is required to identify belowground sources of flow/bacteria

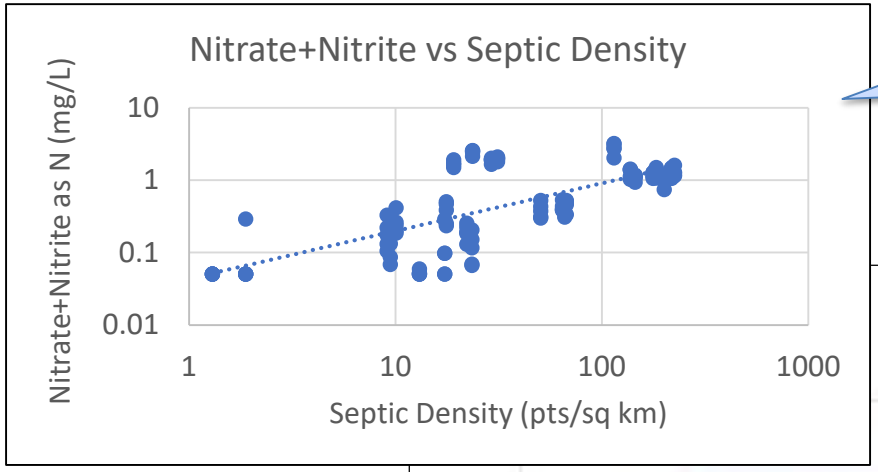
Case Study: Atlanta Septic Evaluation

- **Regulatory Driver:**
  - 303(d) listed streams for fecal coliform (FC) and lakes for nutrients (total nitrogen)
  - Bacteria and nutrient TMDLs identify septic systems as a source (estimated 450,000 septics in 15 County region)
- **Study Objective:**
  - Investigate the impacts of septic systems on surface waters in the Atlanta region
- **Approach:**
  - Sampling across 10 subwatersheds with varying septic densities
  - 5 dry weather events at 31 stream locations
  - Analysis of HF183, FC, and nutrients

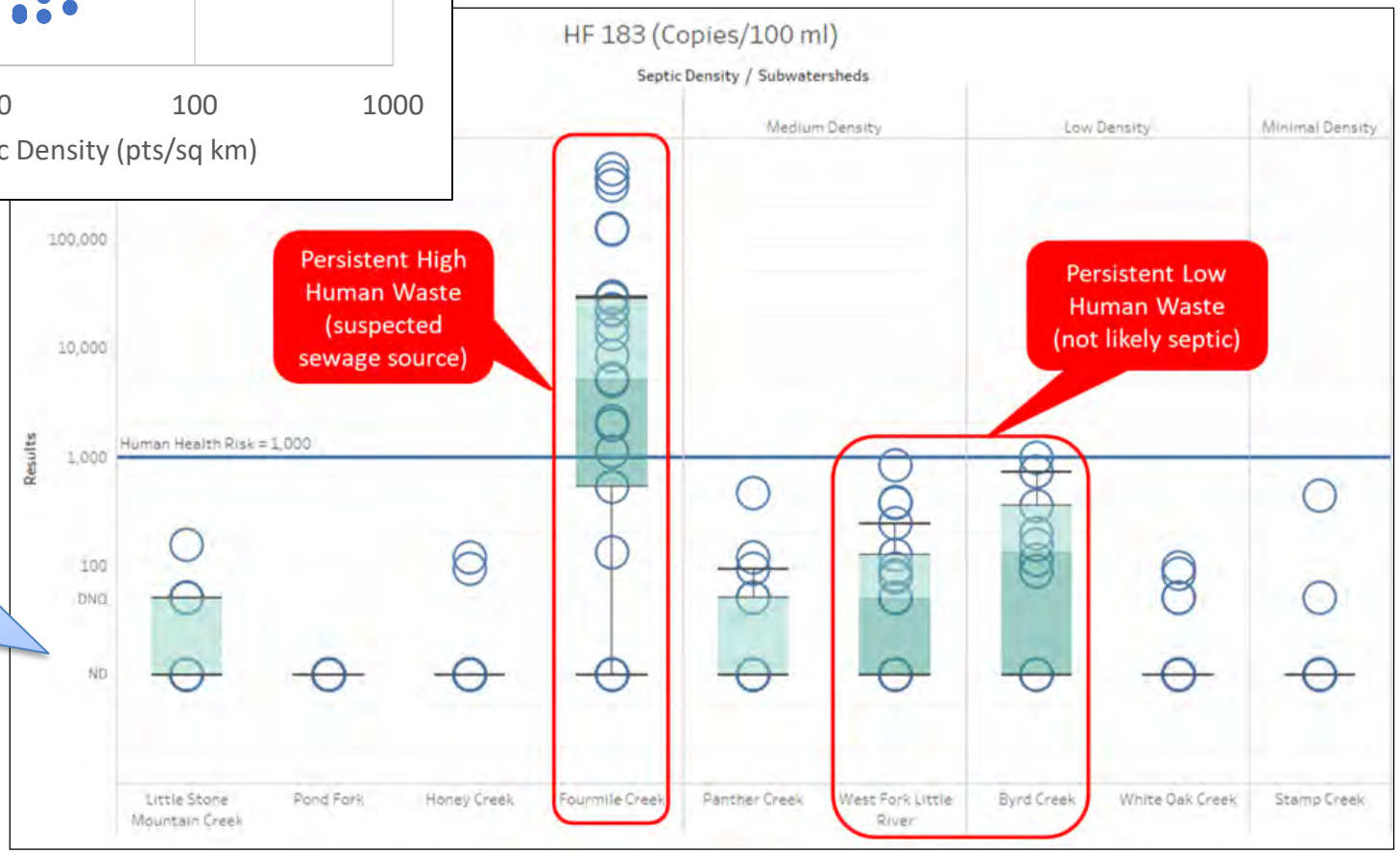


Honey Creek subwatershed

Case Study: Atlanta Septic Evaluation



Significant correlation between septic density and Nitrate concentration



No trends between septic density and HF183

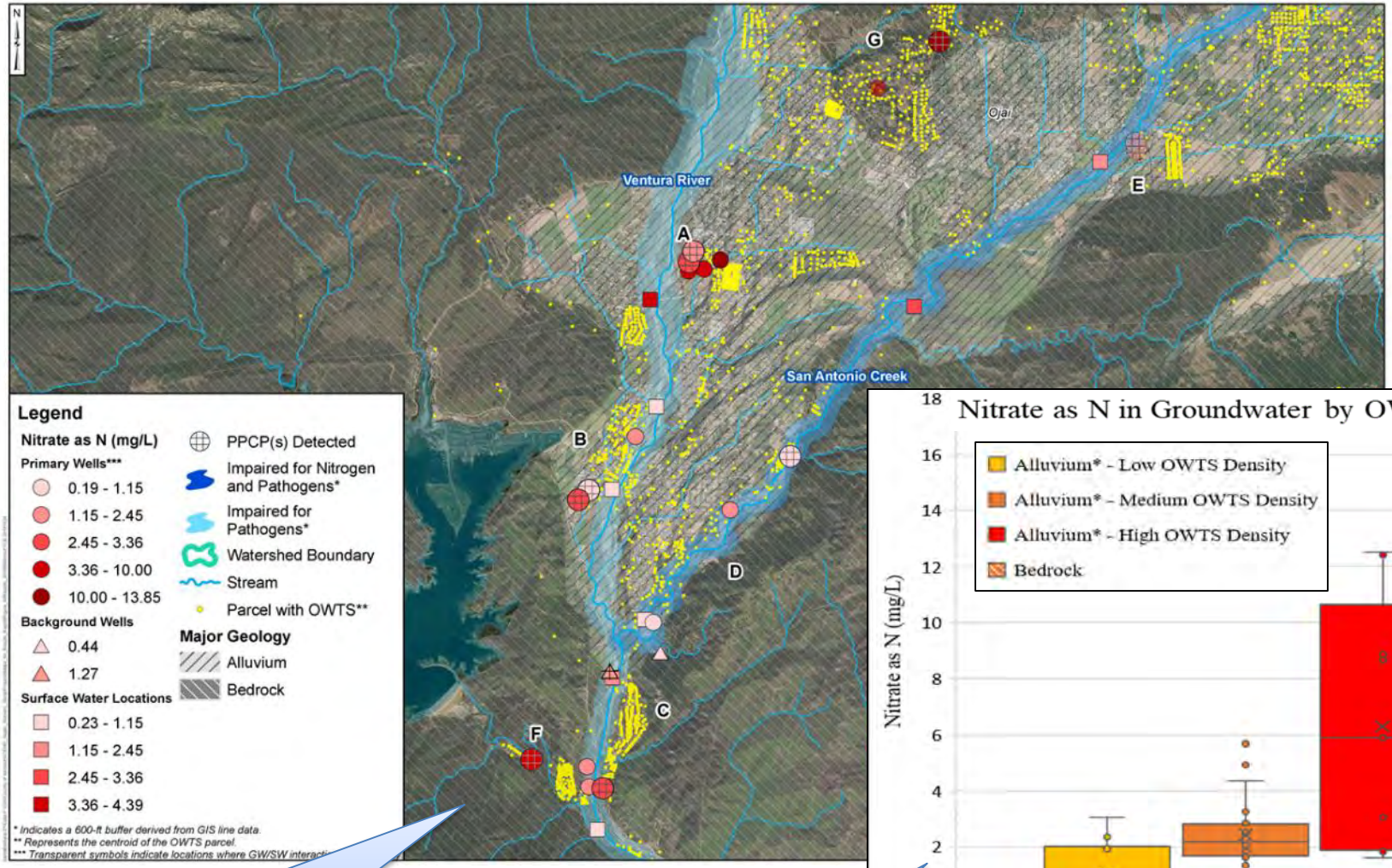
Case Study: Atlanta Septic Evaluation

- Key Results/Findings
  - Septic systems were not a significant source of bacteria during dry weather
    - Wet weather is expected to be different
  - Septic systems can be a significant source of nitrogen (primarily nitrate) during dry weather
    - Impacting streams and downstream lakes with nutrient TMDLs
    - Could also be a source of dissolved phosphorous, although this was not found in the Atlanta study
  - Agriculture was a likely source of bacteria and nutrients to surface waters in the Atlanta region
  - Low level human marker was detected even in areas with minimal development

Case Study: Ventura River Septic Study

- **Regulatory Driver:**
  - 303(d) impairments for nitrogen, algae, and eutrophic conditions
  - Algae TMDL identifying all septic systems in the watershed as a nitrogen source and requiring a 50% load reduction for nitrogen
- **Study Objective:**
  - Identify the area of septic systems contributing to elevated nitrogen in the river
- **Approach:**
  - 3 groundwater and surface water sampling events at 29 locations downgradient of varying septic densities
  - Analysis of nutrients, PPCPs, and nitrate isotopes

Case Study: Ventura River Septic Study

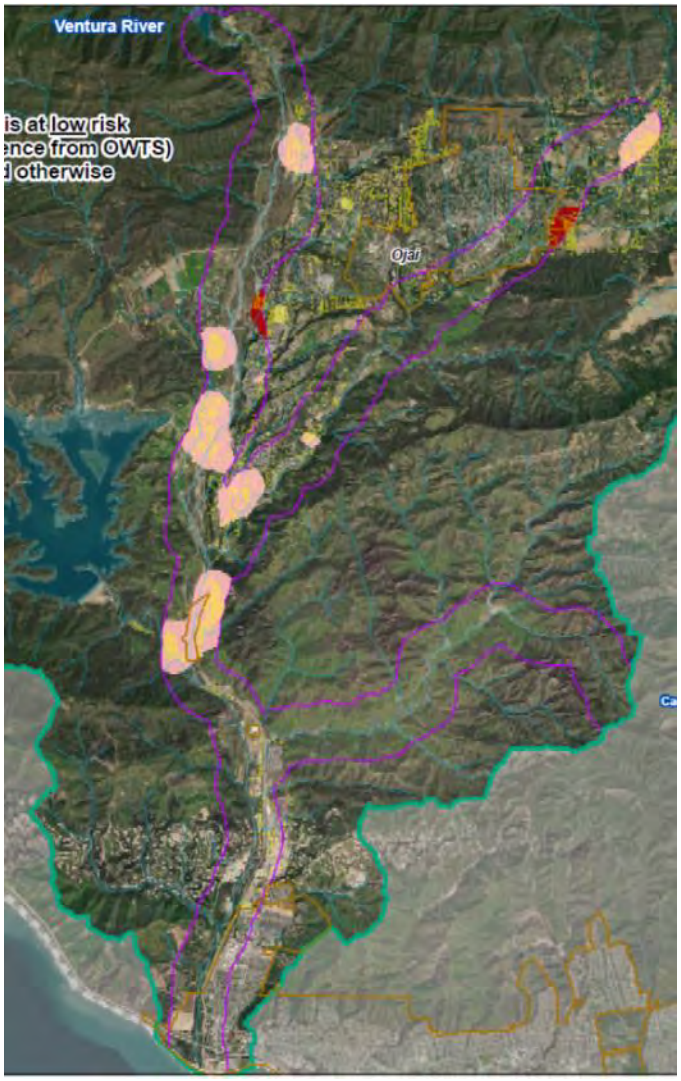


Elevated nitrate & PPCPs detected downgradient of Septic areas

Septic density correlated with Nitrate

Case Study: Ventura River Septic Study

- Key Results/Findings
  - Nitrate levels in GW were elevated downgradient of areas with OWTS
  - PPCPs and nitrate isotopes supported OWTS as a source
  - Surface water impacts were dependent on OWTS density and distance to the stream
  - Study identified which septic systems were contributing the greatest load of nitrogen to surface waters to support TMDL modification and sewering



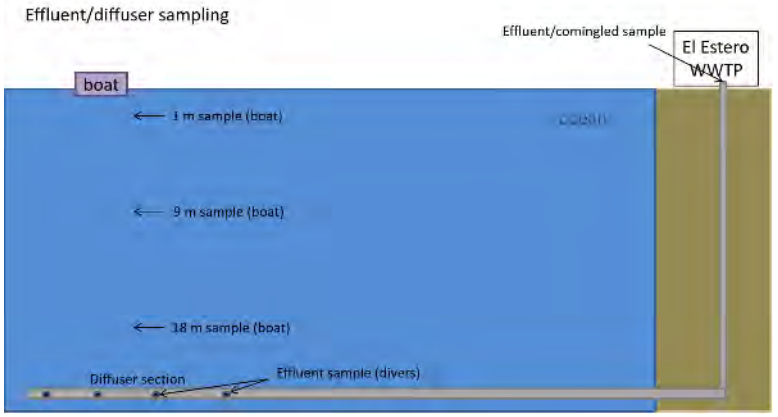
Ventura River Septic Risk Analysis

Case Study: Santa Barbara Beaches

- **Regulatory Driver:**
  - 303(d) listed for bacteria/pathogens
  - Periodic beach warnings
- **Study Objective:**
  - Perform microbial source tracking (MST) at three Clean Beaches Initiative (CBI) priority beaches in the Santa Barbara region to identify fecal bacteria sources and improve water quality and public health
- **Approach:**
  - Over a dozen source hypotheses tested over 3 years including
  - Conventional (dye testing, indicator bacteria) and advanced (DNA markers, pathogens) analytes/tools used
  - Sampling of 50+ locations across three beaches including: surf, streams, nearshore, offshore, harbor, sediments, groundwater, and stormwater

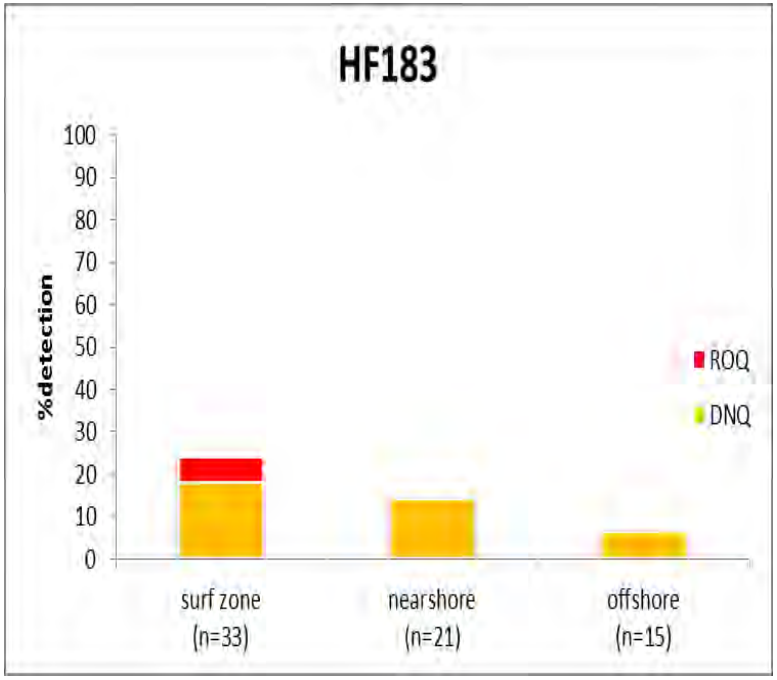
Case Study: Santa Barbara Beaches

- Source Hypotheses Tested
  1. Background/Natural Sources
  2. Flowing MS4 Outfalls
  3. Sanitary Sewers
  4. Septic Systems
  5. Dogs and Birds
  6. Creeks and Creek Sediments
  7. Submarine Groundwater
  8. Supratidal and Intertidal Sands
  9. Marine Sediments
  10. WWTP Effluent
  11. Boats (Harbor and Offshore)
  12. Stearns Wharf Infrastructure
  13. Open Defecation
  14. Bather Shedding



Case Study: Santa Barbara Beaches

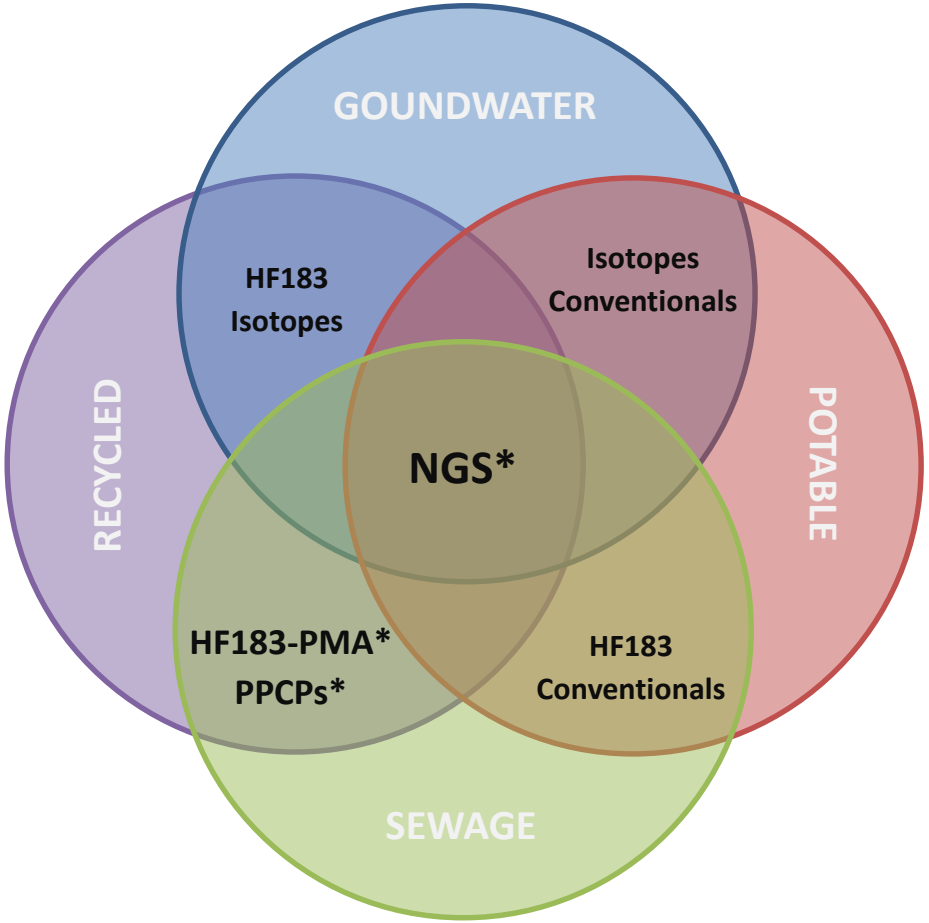
- Key Results/Findings
  - Infrastructure related and watershed based sources of fecal bacteria to the surf zone were ruled out during dry weather/recreational season
  - Bathers were a quantifiable source of human DNA marker to the surf zone, while indicator bacteria were primarily from birds and dogs
  - Study identified human marker levels achievable at urban beaches when all non-bather sources have been eliminated
  - Demonstrated how rigorous hypothesis based MST can be used to systematically test sources in a complex urban area



Other Methods Being Investigated

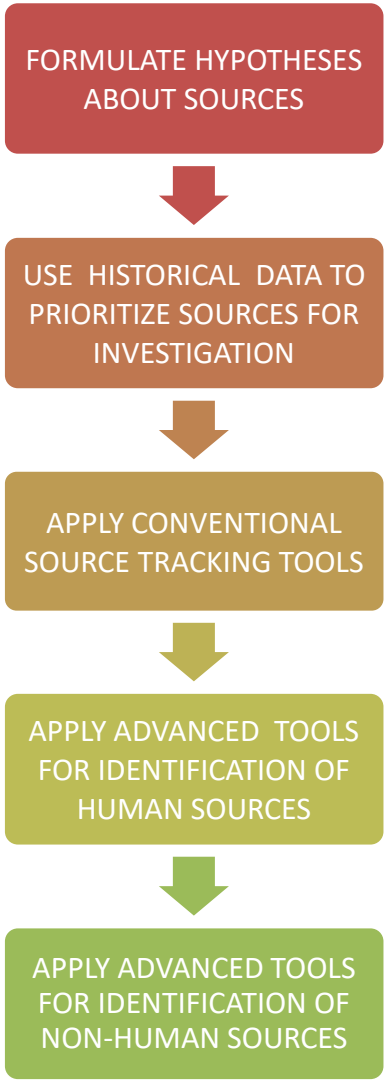
- HF183-PMA
  - Sampling treated with propidium monoazide prior to HF183 analysis to distinguish viable from non-viable DNA
- Next Generation Sequencing (NGS)
  - Community analysis to identify source signature based on all bacteria in a sample

➢ These methods are being pilot tested in MS4 discharges and receiving waters in Southern California



Recommendations

- Apply hypothesis-driven study design
- Select the right tool for the job
- Use validated laboratories performing standardized methods
- Consult experienced source tracking experts
- Seek consensus with regulators on study design and desired outcomes



Tiered Source Tracking Approach (adapted from Griffith, 2013)

Takeaway Message

Successful source tracking of bacteria and nutrient sources can result in:

1. Improved water quality outcomes
2. Compliance with TMDL and MS4 permit requirements
3. Lower cost means of water quality improvement
4. Demonstrated commitment to solving water quality problems

Thank you for your time!

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