Geosyntec consultants

# The State of the Practice for Identifying Bacteria & Nutrient Sources in Urban Waters

Merrimack Valley Mayors & Managers Coalition
DPW Directors/Stormwater Collaborative Meeting
October 4, 2017

Merrimack Valley Stormwater Collaborative
COMMUNITIES WORKING TOGETHER FOR A CLEANER ENVIRONMENT

# Total Maximum Daily Load (TMDL)

- TMDLs determine the amount of a pollutant that a waterbody can safely assimilate without violating water quality standards.
- The TMDL process **establishes the maximum allowable loading** of pollutants or other quantifiable parameters for a water body based on the relationship between pollutant sources and instream conditions.

# MA Year 2016 Integrated List of Waters

- Bacteria TMDLs (from report):
- "In 2006 MassDEP began working closely with the EPA Region 1 to develop "bundled" bacteria cleanup plans for all of Massachusetts' major watersheds... Since 2007, MassDEP has received the EPA's approval of watershed-wide bacteria TMDLs for the Charles and Taunton watersheds and the Buzzards Bay, Cape Cod, Three Bays (Barnstable), Mount Hope/Narragansett Bay, North Shore and South Shore coastal drainage systems. **The plan for FY2017 through FY2018 is to continue to work, as resources allow, toward the finalization of bacteria TMDLs for the following coastal watersheds: Merrimack**, Ipswich, Parker and the Islands."

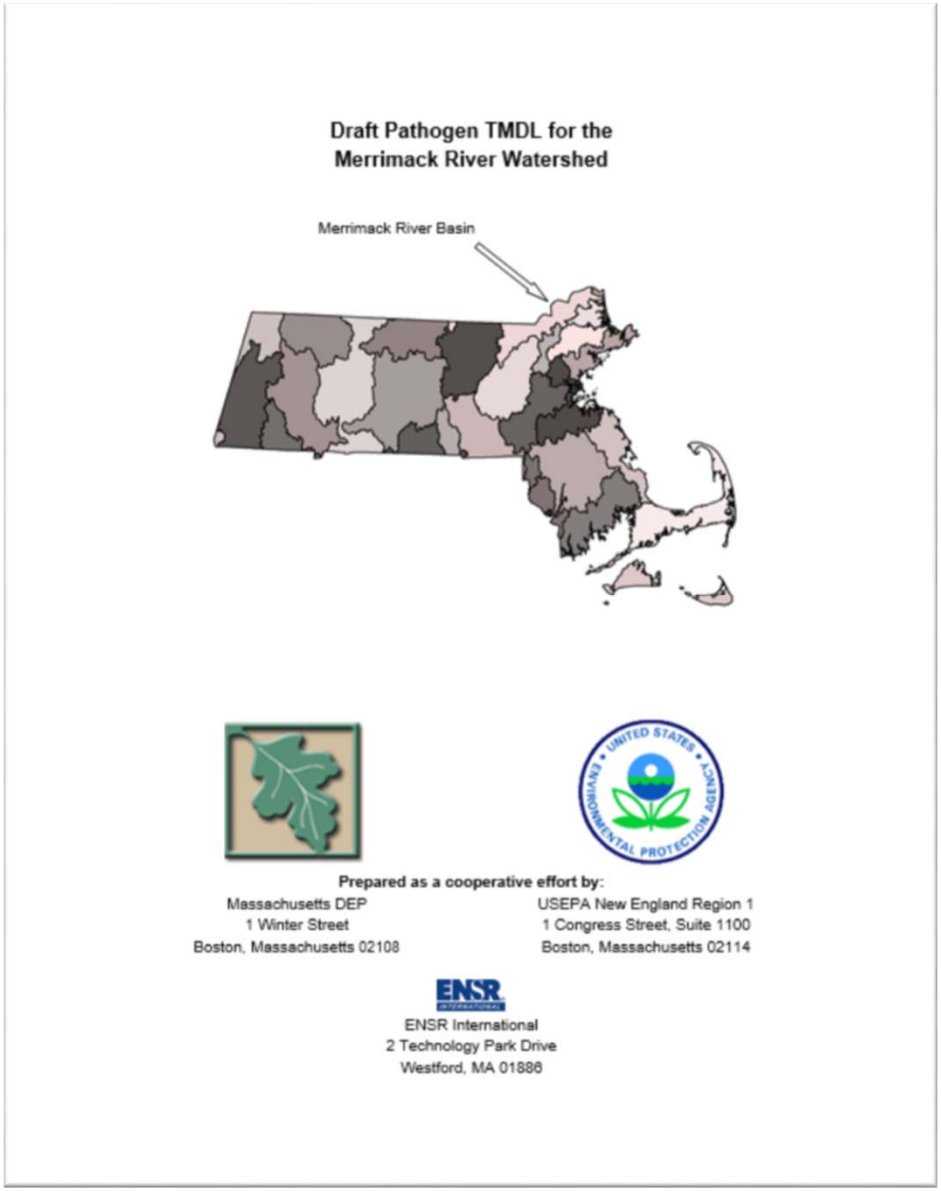
# MA Year 2016 Integrated List of Waters

**Table 4.** Total Maximum Daily Loads (TMDLs) scheduled by the MassDEP for development during FY2017 – FY2018.

| Project | TMDL Count | Req'd Public Mtg. Held? | Draft Tech Report[1] | Final Tech Report[1] | Draft TMDL | Projected EPA Approval of Final TMDL |
|---|---|---|---|---|---|---|
| **Bacteria TMDLs** | | | | | | |
| Boston Harbor | 33 | yes | N/A | N/A | Completed | FY-17 |
| Islands | 15 | yes | N/A | N/A | Completed | FY-18 |
| Merrimack River | 22 | yes | N/A | N/A | Completed | FY-18 |
| Ipswich River | 9 | yes | N/A | N/A | Completed | FY-18 |
| Parker River | 10 | yes | N/A | N/A | Completed | FY-18 |
| Blackstone | 10 | yes | N/A | N/A | Completed | TBD |
| Nashua | 12 | yes | N/A | N/A | Completed | TBD |
| SuAsCo | 13 | yes | N/A | N/A | Completed | TBD |
| Ten Mile River | 5 | no | N/A | N/A | To be completed | TBD |
| Connecticut | 9 | no | N/A | N/A | To be completed | TBD |
| Deerfield | 3 | no | N/A | N/A | To be completed | TBD |
| Hoosic | 6 | no | N/A | N/A | To be completed | TBD |
| Housatonic | 6 | no | N/A | N/A | To be completed | TBD |
| Westfield | 3 | no | N/A | N/A | To be completed | TBD |
| Chicopee | 8 | no | N/A | N/A | To be completed | TBD |
| F&Q | 6 | no | N/A | N/A | To be completed | TBD |
| Millers | 9 | no | N/A | N/A | To be completed | TBD |
| **Subtotal Bacteria** | 179 | | | | | |

**The good news:**
Funding priority for Section 319 grants and SRF loans will be given to watershed cleanup projects that advance TMDL program requirements!

# Draft Pathogen TMDL for the Merrimack River Watershed




- This report represents a TMDL for **pathogen indicators (e.g. fecal coliform, E. coli, and enterococcus bacteria).** Certain bacteria are indicators of contamination from sewage and/or the feces of warm-blooded wildlife (mammals and birds). Such contamination **may pose a risk to human health.** Therefore, in order to prevent further degradation in water quality and to ensure that waterbodies within the watershed meet state water quality standards, the **TMDL establishes indicator bacteria limits** and outlines corrective actions to achieve that goal.

http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/merimac1.pdf

# Potential Sources

- Some dry weather sources include:
  - leaking sewer pipes,
  - storm water drainage systems (illicit connections of sanitary sewers to storm drains),
  - failing septic systems,
  - recreational activities,
  - wildlife (including birds), and
  - illicit boat discharges.
- Some wet weather sources include:
  - wildlife and domesticated animals (including pets),
  - storm water runoff including municipal separate storm sewer systems (MS4),
  - combined sewer overflows (CSOs), and
  - sanitary sewer overflows (SSOs).

# Recommendations

- Recommended TMDL implementation measures include identification and **elimination of prohibited sources** (such as leaky or improperly connected sanitary sewer flows) and **best management practices to mitigate storm water runoff** volume.

# MA MS4 Permit Requirements

- Appendix F:
- Any permittee that discharges to a waterbody with a **Bacteria or Pathogen TMDL** must implement Enhanced BMPs:
  - Public Education
  - Illicit Discharges: Catchments draining to any waterbody impaired for bacteria or pathogens shall be designated either Problem Catchments or HIGH priority in implementation of the IDDE program.

# MA MS4 Permit Requirements

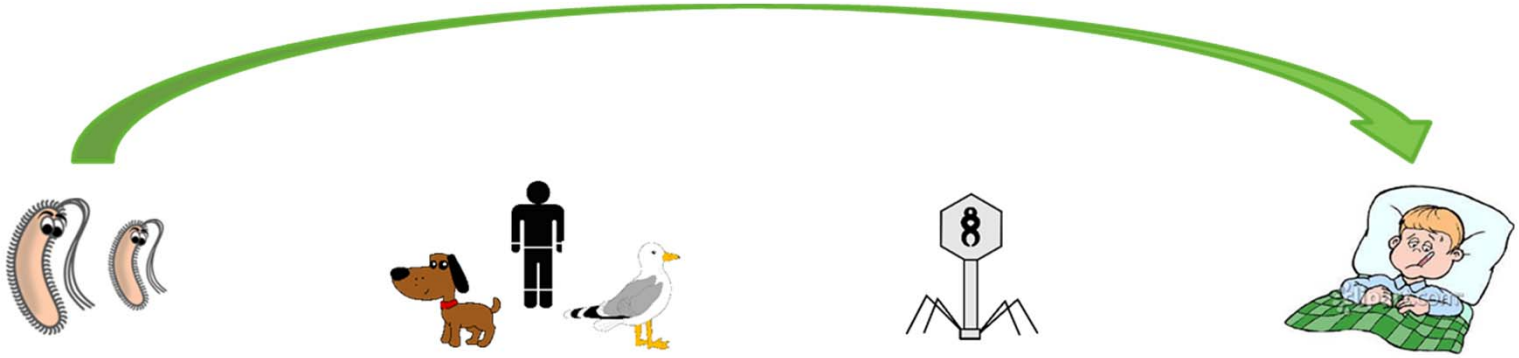
- Appendix H:
- Any permittee that discharges to a waterbody with a **Bacteria or Pathogen impairment (without an EPA approved TMDL)** must implement Enhanced BMPs:
  - Public Education
  - Illicit Discharges: Catchments draining to any waterbody impaired for bacteria or pathogens shall be designated either Problem Catchments or HIGH priority in implementation of the IDDE program.

No change in permit language – same requirements apply for TMDL approved or non-TMDL approved waterbodies

# Presentation Outline

- Background
- Tools Available for Bacteria and Nutrient Source Tracking Investigations
  - Conventional Tools
  - Advanced Forensic Tools
- Case Studies:
  1. Boston /Charles River Nutrient and Bacteria Source Tracking
  2. Santa Barbara Area Beaches Microbial Source Tracking
  3. Ventura River Watershed Nutrient Source Tracking
- Components of a Successful Source Tracking Strategy
- Recommendations & Conclusions

# Fecal Indicator Paradigm: Presumptive Linkages



Fecal Indicator Bacteria (FIB) have been linked to an increased occurrence of gastrointestinal illness, however this linkage may not be appropriate for non-sewage impacted waters

<u>How to measure each step in this linkage:</u>

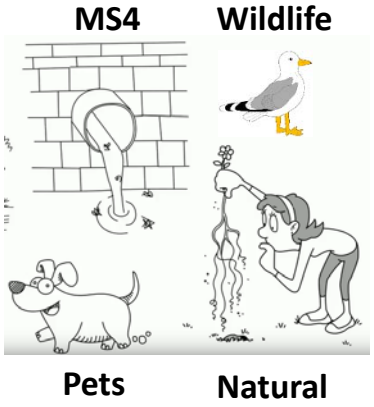
| | | | |
|---|---|---|---|
| Culturable FIB | **Fecal DNA Markers (MST)** | Direct pathogen enumeration (needed for **QMRA**) | Epidemiology studies |

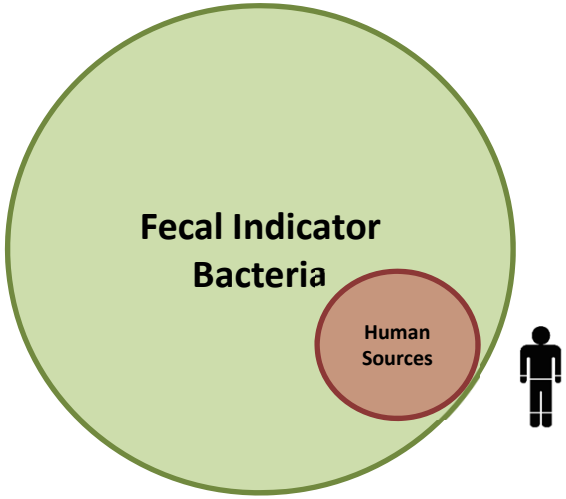
# Common Sources of Bacteria in Urban Waters

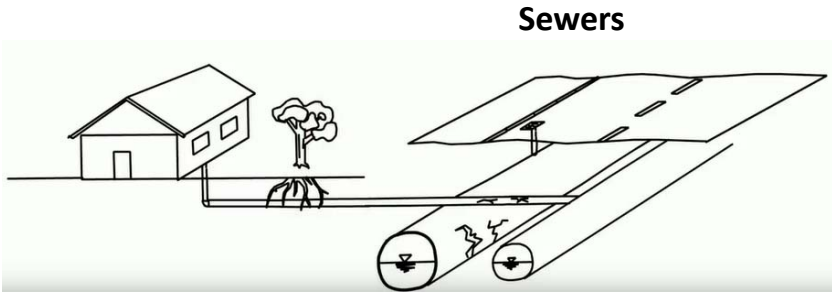
| Human Waste Sources | Non-Human Sources Related to Human Activities | Non-Human Sources Independent of Human Activity |
|---|---|---|
| Sanitary Sewer Overflows (SSOs) | Pets (Dogs, Cats, etc.) | Wildlife (Raccoons, Birds, Deer, Coyote, etc.) |
| Leaky Sewer Pipes (Exfiltration) | Livestock (Horses, Cows, etc.) | Decaying Plants |
| Illicit Connections to MS4 | Rodents (Mice, Rats, etc.) | Algae and Biofilms |
| Leaky or Failing Septic Systems | Birds (Gulls, Pigeons, etc.) | Soil/Sediment |
| Porta-Potties | Dumpsters and Trash Cans | |
| Bathers and Open Defecation | Garbage Trucks | |
| Boats and RVs | Animal Manure/Compost | |
| Dumpsters and Trash Cans | Washwater | |
| Garbage Trucks | Green Waste | |
| Illegal Dumping | Litter | |
| Illegal Discharges | Grease Bins/Traps | |
| Gray Water Discharges | Irrigation Runoff | |
| Pools and Hot Tubs | | |

# Bacteria and Nutrient Sources

In general, where contributions from human waste (e.g., sewer leaks, illicit connections, etc.) are small, the primary **sources of FIB and human waste markers differ**, so control strategies differ



# Bacteria and Nutrient Source Tracking Tools

## Relative strengths/weaknesses

| Tool | Description | Cost |
|---|---|---|
| Visual Surveys | For outfall screening to identify flowing outfalls, nearby sources (e.g., homeless encampments, dog parks, porta-potties), and indications of sewage (e.g., toilet paper, odors). | $ |
| GIS | Support tool essential for interpreting sampling results and for planning follow-on network investigation, e.g., by identifying sewer-stormdrain crossings and sewers/septics near surface waters. | $ |
| Fecal indicator bacteria | Basic indicator of sewage/septage contamination tied to regulatory criteria, correlated with markers when human waste is present (prone to false positives otherwise). | $ |
| Basic Chemical Indicators | Includes detergents/surfactants, fluoride, ammonia, and potassium. Low-cost field kits may be useful in MS4 networks for instant results. | $ |
| Canine Scent Tracking | Trained dogs used to identify sewage leaks. Useful when real time results and broad spatial coverage are needed, such as in large storm drain networks. Prone to low sensitivity, low specificity compared with human markers. | $ |
| Dye Testing | Visual or fluorimeter based detection of dye. Essential for confirming and locating illicit connections and leakage from sewers (e.g., to storm drains or nearby groundwater/surface water). | $/$$ |
| CCTV | Cameras used in the MS4. Useful for locating illicit connections, sewer leaks into stormdrains, and tracking flow sources within networks, except where network is submerged. | $$ |
| **Advanced Chemical Indicators** | **Includes sucralose, caffeine, and cotinine, as well as many contaminants of emerging concern. Useful as a second line of evidence for sewage sources, or for tracking conservative solutes (e.g., nitrate).** | **$$$** |
| **Human Markers** | **Most sensitive and specific tool for quantifying magnitude of human waste in all water types (e.g., MS4 network or outfalls, surface receiving waters, and groundwater). Like fecal indicator bacteria and pathogens, subject to decay.** | **$$$** |
| **Non-Human Markers** | **Sensitive and specific tools for identifying non-human sources of waste including cows, dogs, birds, deer, and others. Most informative after human waste has been ruled out. Like fecal indicator bacteria and pathogens, subject to decay.** | **$$$** |
| **Stable Isotopes** | **Isotopic ratios of nitrogen and oxygen in nitrate, or hydrogen and oxygen in water, to identify sources of nitrate and flow sources, respectively.** | **$$$** |

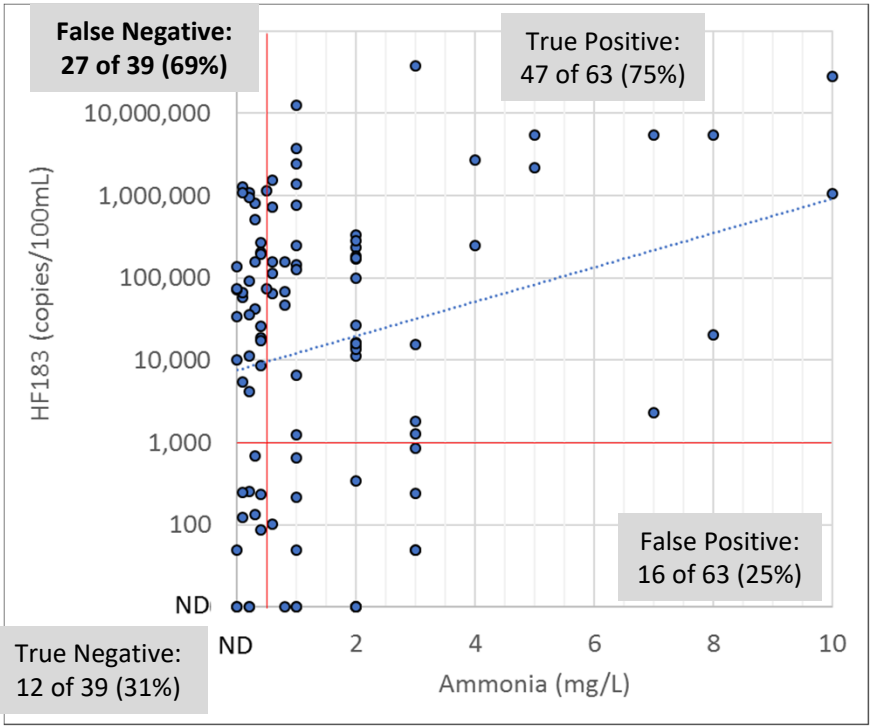
# Bacteria and Nutrient Source Tracking Tools

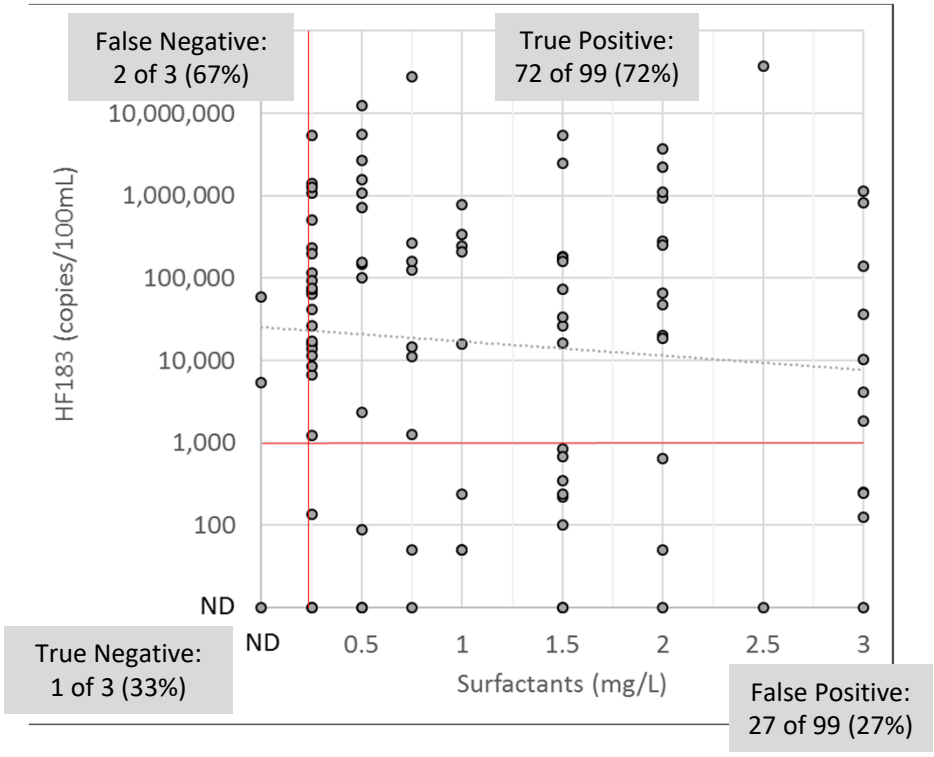
When to use each for advanced IDDE in MS4s

| Tool | Reliable for MS4 Outfall Screening/Prioritization? | Useful for MS4 Network Investigation Above Priority Outfalls? | Sensitivity for human waste? | Specificity to human waste? | Cost |
|---|---|---|---|---|---|
| Visual Surveys | YES | YES | VERY LOW | VERY LOW | $ |
| GIS | | YES | | | $ |
| Fecal indicator bacteria | ? | ? | LOW | LOW | $ |
| Basic Chemical Indicators | ? | ? | LOW | LOW | $ |
| Canine Scent Tracking | | ? | LOW | LOW | $ |
| Dye Testing | | YES | | | $/$$ |
| CCTV | | YES | | | $$ |
| **Advanced Chemical Indicators** | **?** | **?** | **HIGH (for some)** | **HIGH (for some)** | **$$$** |
| **Human Markers** | **YES** | **IN SOME CASES** | **VERY HIGH** | **VERY HIGH** | **$$$** |
| **Non-Human Markers** | | | | | **$$$** |
| **Stable Isotopes** | | | | | **$$$** |

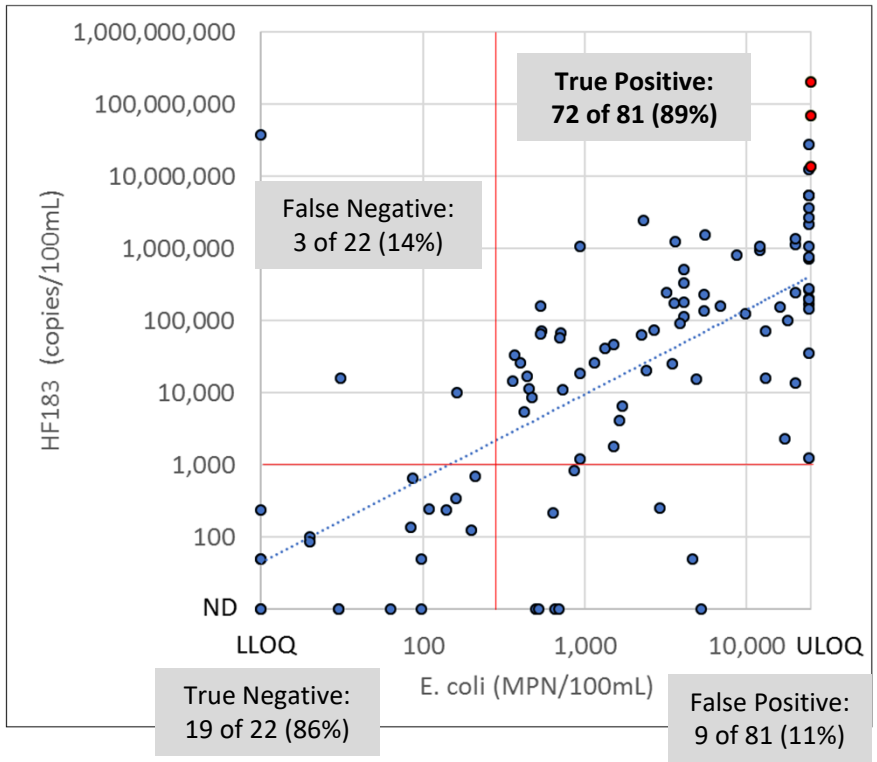
Definitions:
"sensitivity" refers to ability to detect low concentrations of waste
"specificity" refers to ability to differentiate human waste vs non-human

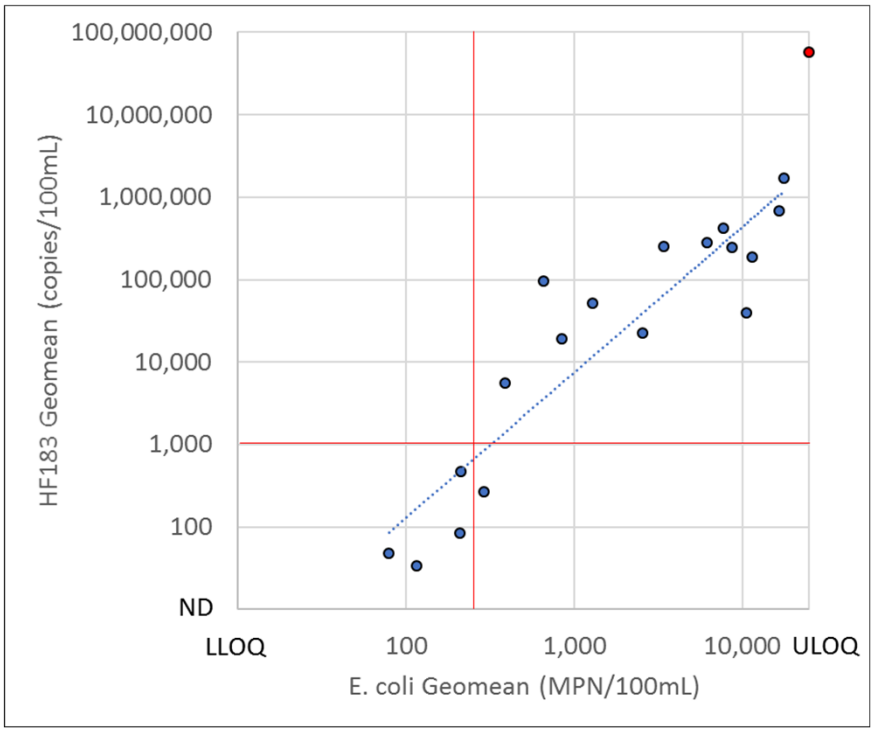
# Ammonia and Surfactants vs HF183



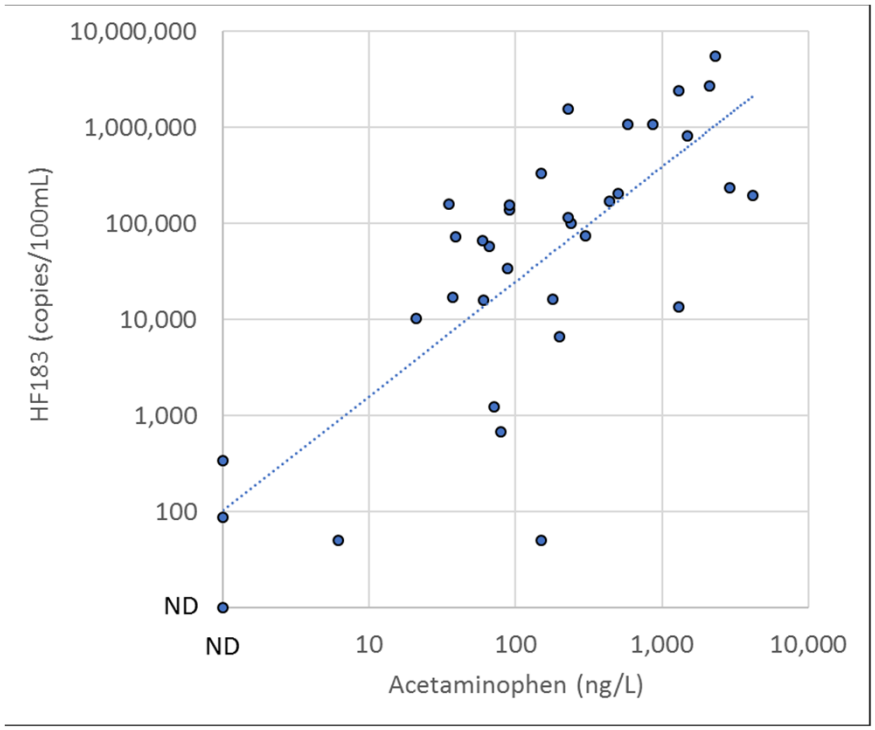



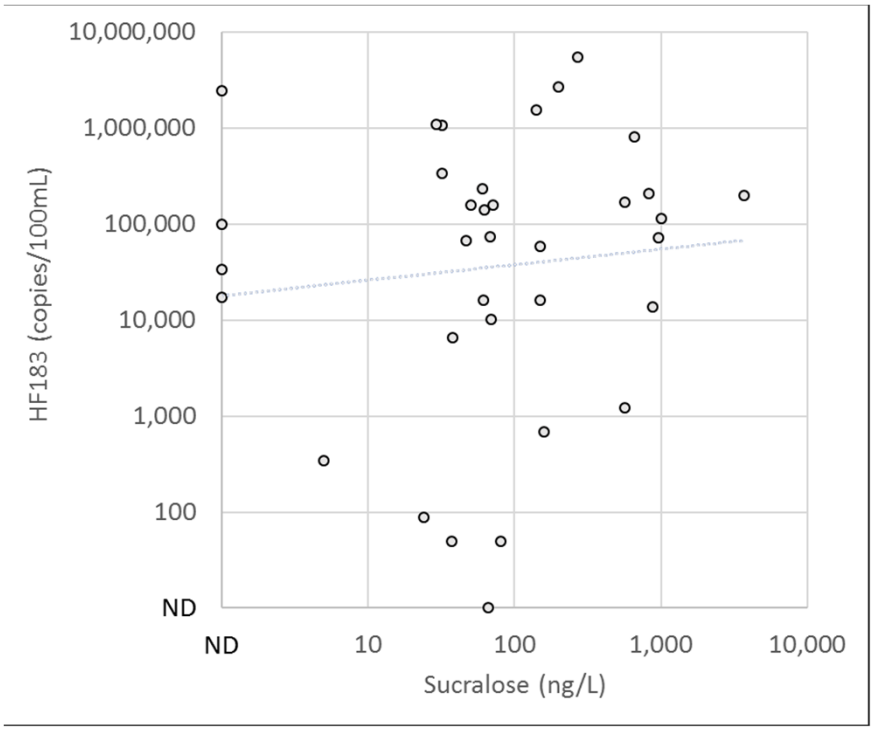
# *E. coli* vs HF183 (dry weather outfall samples)



# PPCPs vs HF183 (dry weather outfall samples)



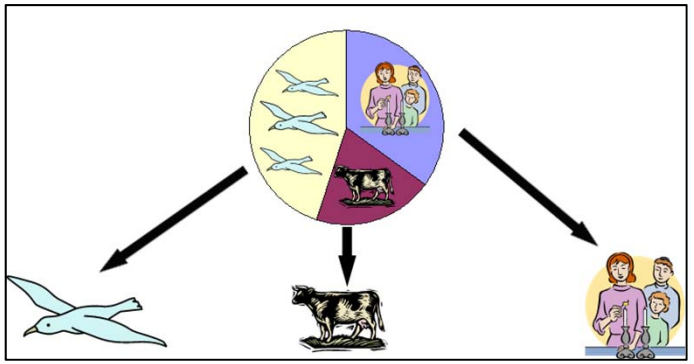
# Traditional Source Tracking Tools

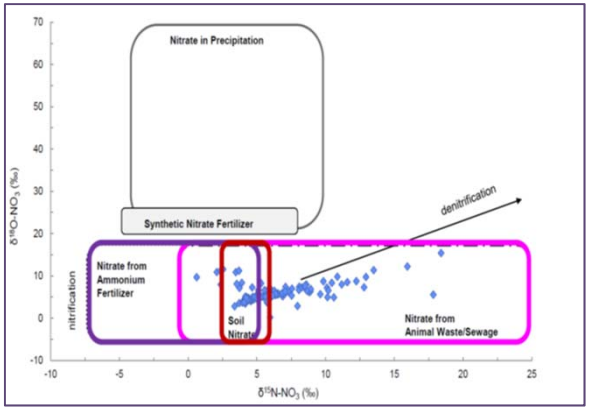
- Most conventional tools give no indication of the source of contamination
  - A problem is identified (e.g., nutrients or bacteria are elevated), but the source cannot be reliably identified
- However, traditional tools generally have lower costs and may be useful in combination with advanced tools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

Photo: Jill Murray, City of Santa Barbara

# Advance Forensic 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 potentially impacted by these sources
  - Analytes include artificial sweeteners (e.g., sucralose), pain relievers (e.g., acetaminophen), caffeine, cotinine, and many others
- DNA-based Microbial Source Tracking Markers
  - Markers have been lab and field tested as part of multi-laboratory validation studies
  - Sensitive and specific to human, dog, gull, cow, horse, and other sources
  - CA Microbial Source ID Manual
  - EPA method for human markers coming soon
- Stable Isotope Analysis
  - Allows for differentiation of nutrient source(s) based on the isotopic ratios of nitrogen and oxygen
  - Sources with distinct signatures include: Fertilizers, Sewage/Animal Waste, Soils, and Atmospheric






USGS, 2014

# Case Study: Boston, MA

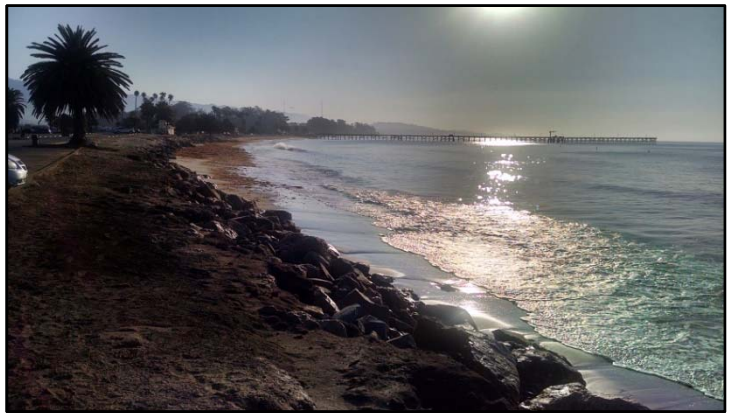
- Regulatory Driver - USEPA Consent Decree & multiple TMDLs (Charles River and Boston Harbor)
  - Requires enhancement to their MS4 IDDE program to more effectively identify and eliminate sources of bacteria and phosphorous
- Project Objectives:
  - Identify sources of bacteria and phosphorous to the City of Boston's MS4 in terms of both location (above ground runoff vs below ground illicit connections and sewer leaks) and type (human vs non-human)
  - Evaluate current IDDE program effectiveness (uses conventional screening parameters) and provide recommended improvements
- Approach
  - Hypothesis-driven study design
  - Use of multiple DNA markers and PPCPs
  - Sampling of 30 outfalls during wet and dry weather, as well as surface runoff, catchbasin sediments and illicit discharges

# Case Study: Boston, MA

- Preliminary Project Outcomes:
  - Identification of subcatchments / outfalls where human waste sources are not present or minimal and subcatchments where human waste sources remain
  - Human waste is a significant source of FIB and P in outfalls during dry weather, while non-human sources are likely contributing during wet weather
  - Some conventional parameters (e.g., *E. coli*) are correlated with human waste sources *when sewage is present*
  - Recommendations for IDDE program improvements to identify remaining human waste sources
  - Demonstration of increased sensitivity and specificity of human markers for detection of human sources

# Case Study: Santa Barbara, CA

- State Clean Beach Initiative (CBI) funded project
  - 3 beaches 303(d) listed as impaired due to FIB (no bacteria TMDLs)
  - Beaches are on CBI priority list due to historical FIB exceedances
- Project Objective
  - Perform microbial source tracking at three Santa Barbara area beaches to identify fecal bacteria sources and improve water quality and public health
- Approach
  - Hypothesis-driven study design targeting multiple potential sources including: sewage, stormwater, dogs, birds, groundwater, bathers, open defecation, boats, beach sands, and sediments
  - Conventional tools including FIB and dye testing of sewer infrastructure
  - Advanced tools including human, dog, and gull MST markers and pathogens
  - Sampling of 50+ locations across three beaches including: surf, zone streams, nearshore, offshore, sediments, groundwater, and stormwater

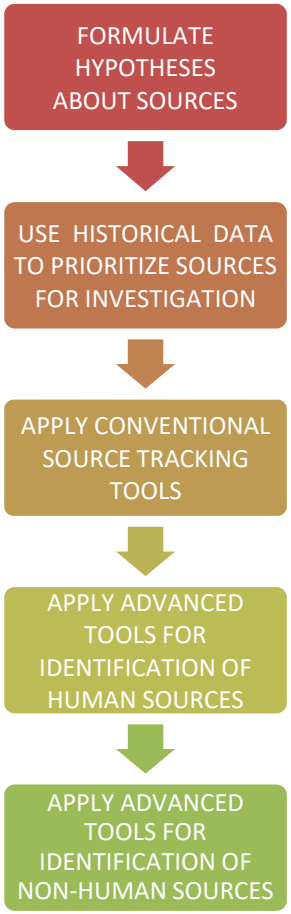


# Case Study: Ventura County, CA

- Regulatory Driver - Ventura River Algae/Nutrient TMDL
  - Load Allocations specified for septic systems (50% reduction of TN)
  - Provision for special study to investigate the influence of septic systems on surface water nitrogen
- Project Objective
  - Define the geographic extent of septic systems that are contributing nutrients to the Ventura River and its tributaries
- Approach
  - Use of PPCPs and nitrate isotopes to identify nitrogen sources
  - Sampling of surface waters downstream from septics
  - Sampling of groundwater at existing wells between septics and impaired surface waters

# Source Tracking Study Design

- Use local resources to identify potential waste sources, including:
  - Consultation with stakeholders
  - Analysis of historical sampling data
  - Desktop GIS and mapping analysis
  - First hand observational/reconnaissance visits
- Define specific questions (hypotheses) that will be tested through sampling and analysis and base the study design on these questions
  - Number of samples and locations
  - Frequency and timing of collection
  - Analytical methods and analysis of results
- Use a tiered investigation approach to most efficiently identify sources
- Consult with source tracking practitioners experienced in:
  - Study design considerations, including field sampling procedures, analytical methods, and QA/QC necessary to produce high quality results
  - Data analysis and interpretation of results to determine the contributing source(s), the extent of contamination, and successful management strategies and regulatory pathways




**Tiered Source Tracking Approach (adapted from Griffith, 2013)**

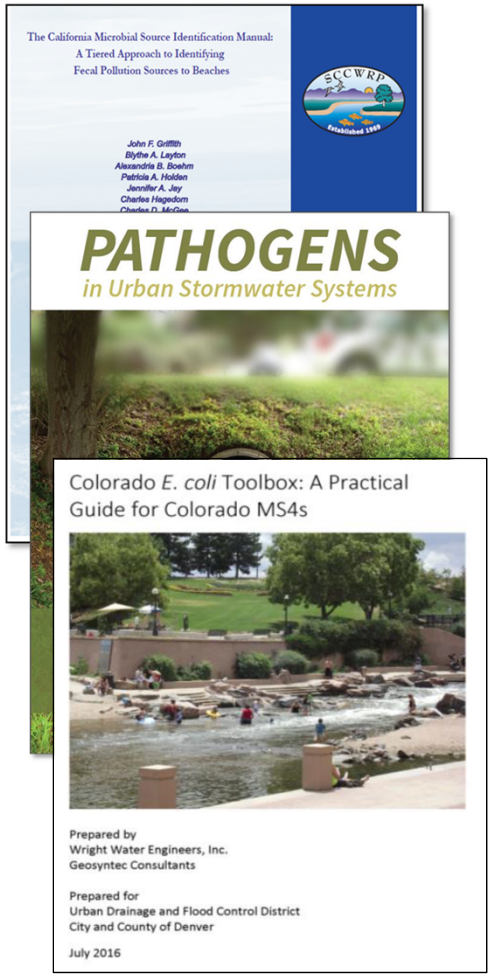
# Recommendations

- Use the right tool for the job
  - Receiving water and outfall screening/prioritization can now be as specific/sensitive as you want it to be based on your drivers (e.g., MS4 permit IDDE requirements, bacteria TMDLs, IDDE Consent Decree, beach report card scores, agency proactiveness)
  - Also weigh the time costs of cheaper analyses – taking actions in response to false positives/negatives is an unnecessary cost to MS4 permit compliance programs
- Seek advance consensus with regulators on what desired outcomes are – e.g., reduction of bacteria/nutrients or illnesses/eutrophication?
  - Assuming it's the latter, inquire into whether advanced markers can *replace* conventional ones to better achieve these desired outcomes
  - We can help facilitate this conversation
- Seek assistance from experts that have proven experience using/interpreting these advanced markers and negotiating lower cost solutions with regulators

# Conclusions

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

- Improved water quality outcomes that are directly connected to beneficial use endpoints – e.g., recreational public health protection through abatement of highest risk sources (human)
- Compliance with TMDL, MS4 permit and Consent Decree requirements, reduction of litigation risks (increasingly common), and access to alternative compliance pathways (e.g., site-specific criteria)
- Lower cost means of water quality improvement – greater bang for buck ($ per load reduction) to control waste sources than to capture/treat stormwater using Green Infrastructure
- Demonstrated commitment to solving water quality problems and leadership in applying innovative solutions – helps secure trust/credibility with regulators and other stakeholders



# Thank you for your Time!
# Questions?

Andrea Braga
617-992-9059
abraga@geosyntec.com

and

Brandon Steets, PE
805-979-9122
bsteets@geosyntec.com

Geosyntec consultants