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State of the Practice for Bacteria TMDL Implementation and Source Tracking

Denver E. coli Symposium
March 12, 2019

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Agenda

- Part 1: Bacteria Reduction Through Human Waste Source Control
- Part 2: Microbial Source Tracking Case Studies

But first, two sidebars…

Takeaways from 15 Years of CA Bacteria TMDL Implementation

- Compliance demonstration approaches vary, for example:
  1. Numeric effluent and receiving water limits
     - Strict single sample and GM Water Quality Standards (eg, Central Coast)
     - Reference system / antideg (eg, LA & SD)
     - Natural source exclusion (eg, SD… but policy never used)
  2. Alternative compliance (Reasonable Assurance Analysis)
     - Plan-based (eg, SD)
     - Plan plus numeric limits (eg, LA)
- Both have led to massive Green Infrastructure planning/implementation for wet weather (huge cost)
  - Similar for dry weather, disinfection/diversion key structural tool
- New option: human waste source control
  - Focus on pathogens, public health, and control at the source
  - May require site specific criteria

Homeless as a Unique & Challenging Source

- Larger societal problem, multiple/complex causes, multi-agency coordination required to address it (to the extent controllable)
- Many solutions being tested, e.g.,
  - Increased housing, access to sanitation facilities
  - Direct subsidies for trash collection (eg, San Jose)
  - Coordination with social NGOs to support outreach
  - Increased enforcement
- Following hepatitis outbreak and Surfer Health Study results, San Diego issued precedent-setting Investigative Order to quantify wet weather contributions from:
  - Public sewers and private laterals
  - Septics
  - Homeless
- Other studies of the issue:
  - Santa Barbara MST study investigated homeless contributions at beaches
  - SoCal MST studies detecting waste markers below encampments
  - Santa Ana River study on homeless impacts to bacteria/habitat
  - Possible project by California Stormwater Quality Association (CASQA)

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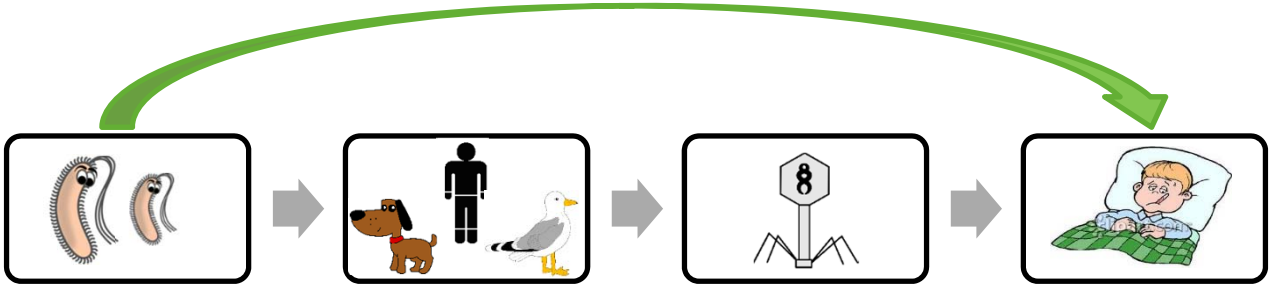
Part 1: Bacteria Reduction Through Human Waste Source Control

Part 1 Outline

- Bacteria and pathogens 101
- Basis for a new approach
- Approach overview
- Conclusions & where is Southern California headed?

Bacteria and Pathogens 101

Fecal Indicator Framework and Basis for Special Studies:



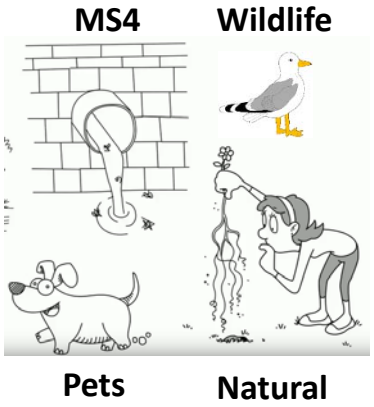
Fecal Indicator Bacteria (FIB) have been linked to an increased occurrence of gastrointestinal illness, however this linkage may not be appropriate for non-sewage impacted waters

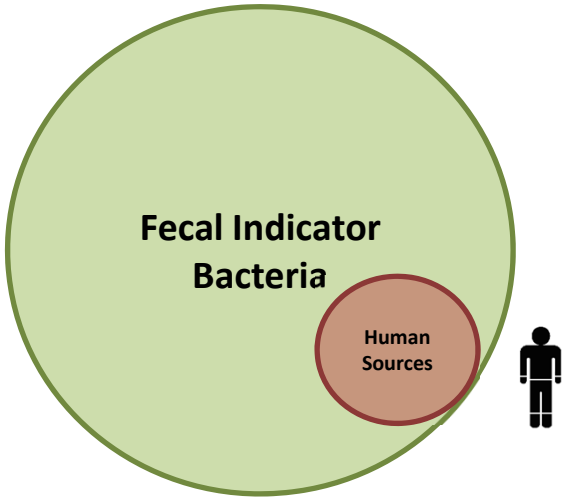
<u>How to measure each step in this linkage:</u>

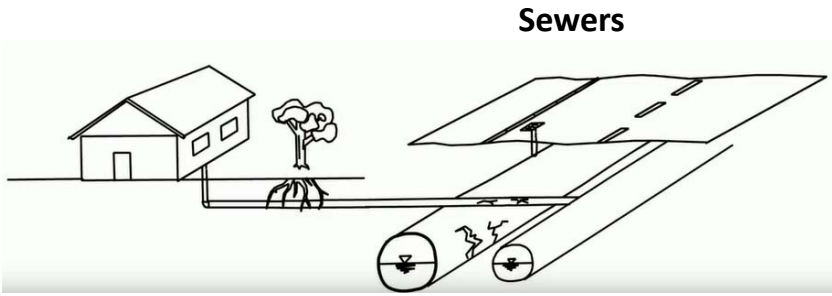
Culturable FIB	**Fecal DNA Markers (MST)**	Direct pathogen enumeration (needed for **QMRA**)	Epidemiology studies

Bacteria and Pathogens 101

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.

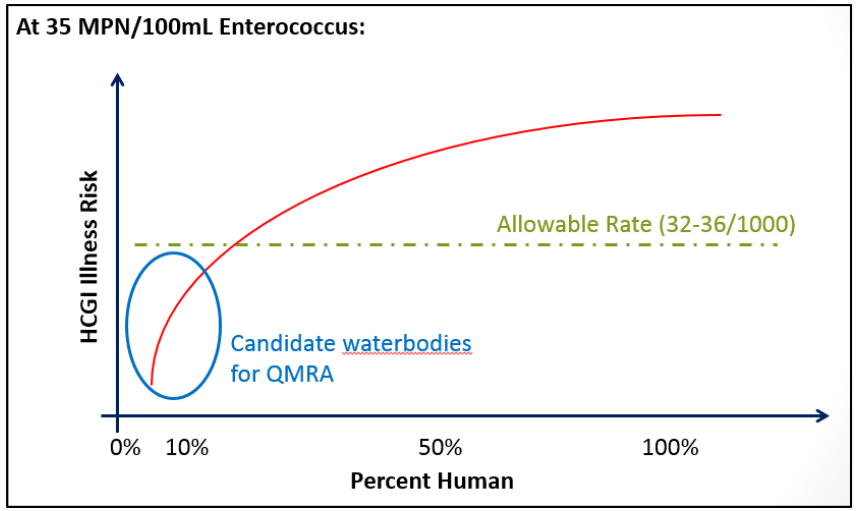


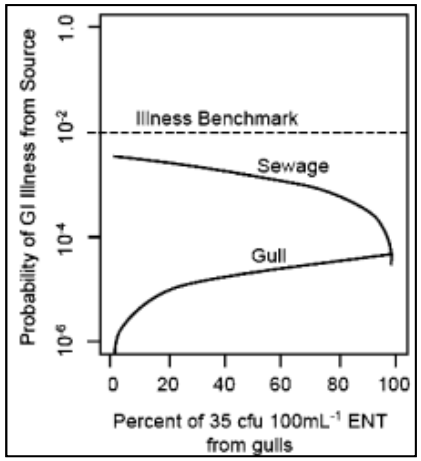




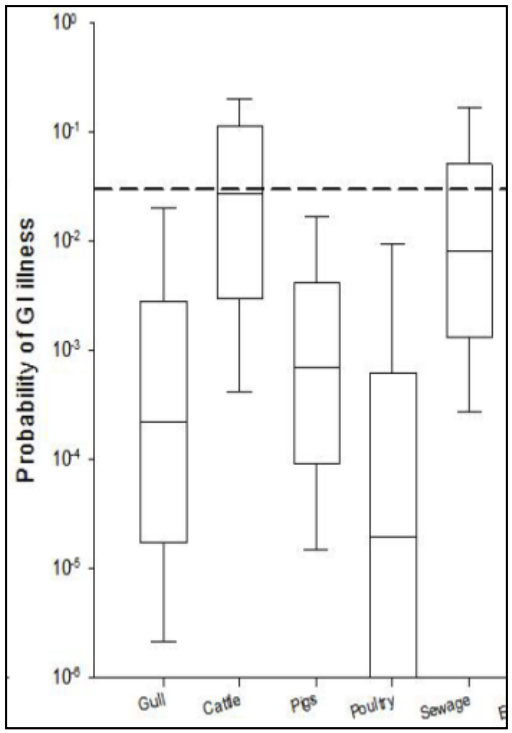
Bacteria and Pathogens 101

Furthermore, **illness risks vary by source**, so some sources are more important to control than others, which is what allows us to focus on a human waste control strategy.





Source: Schoen & Ashbolt, 2010



Source: Soller et al, 2010

New Questions Raised

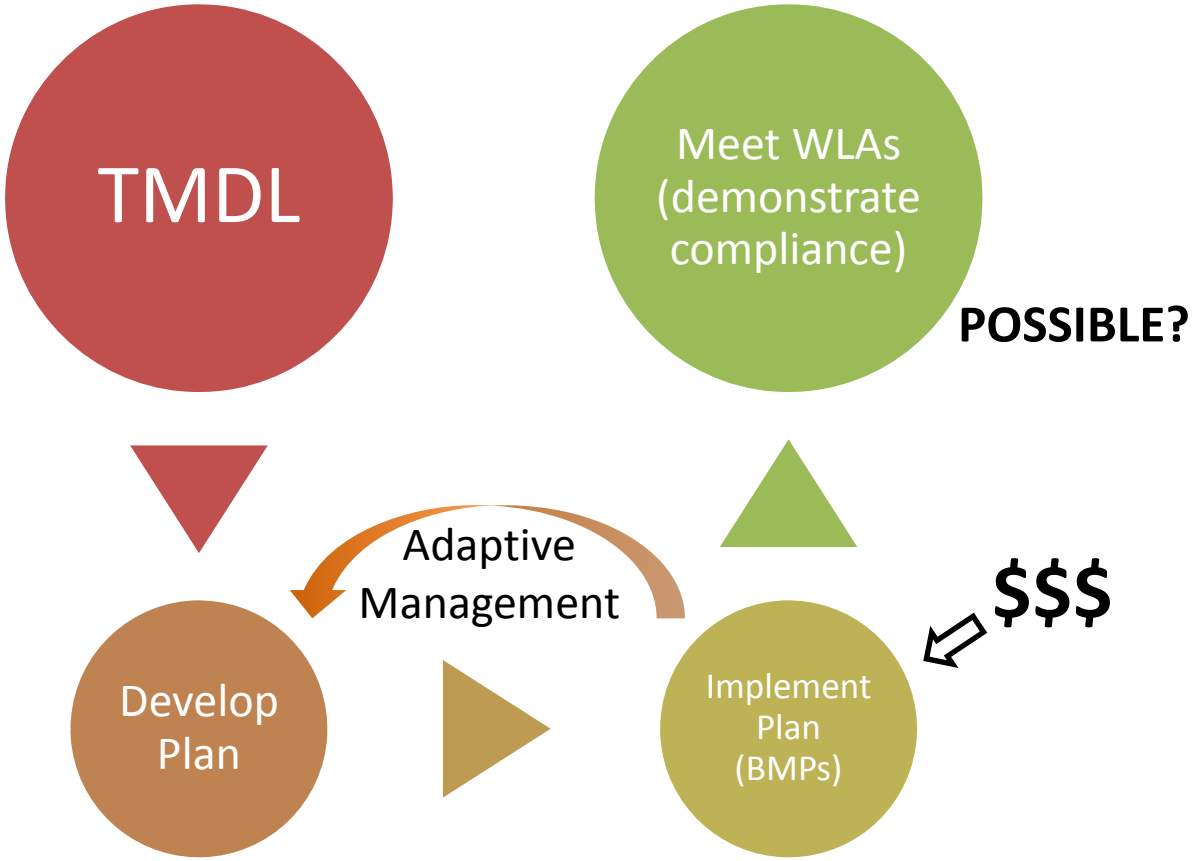
- Are the structural BMPs in MS4 implementation plans designed to capture stormwater impacted by below-ground infrastructure leaks/connections? And/or were they sited downstream of known homeless areas?
- If not, based on new information, should we reevaluate some of these huge planned investments to better protect public health?

Green streets typically miss below-ground infrastructure contamination

Other Considerations

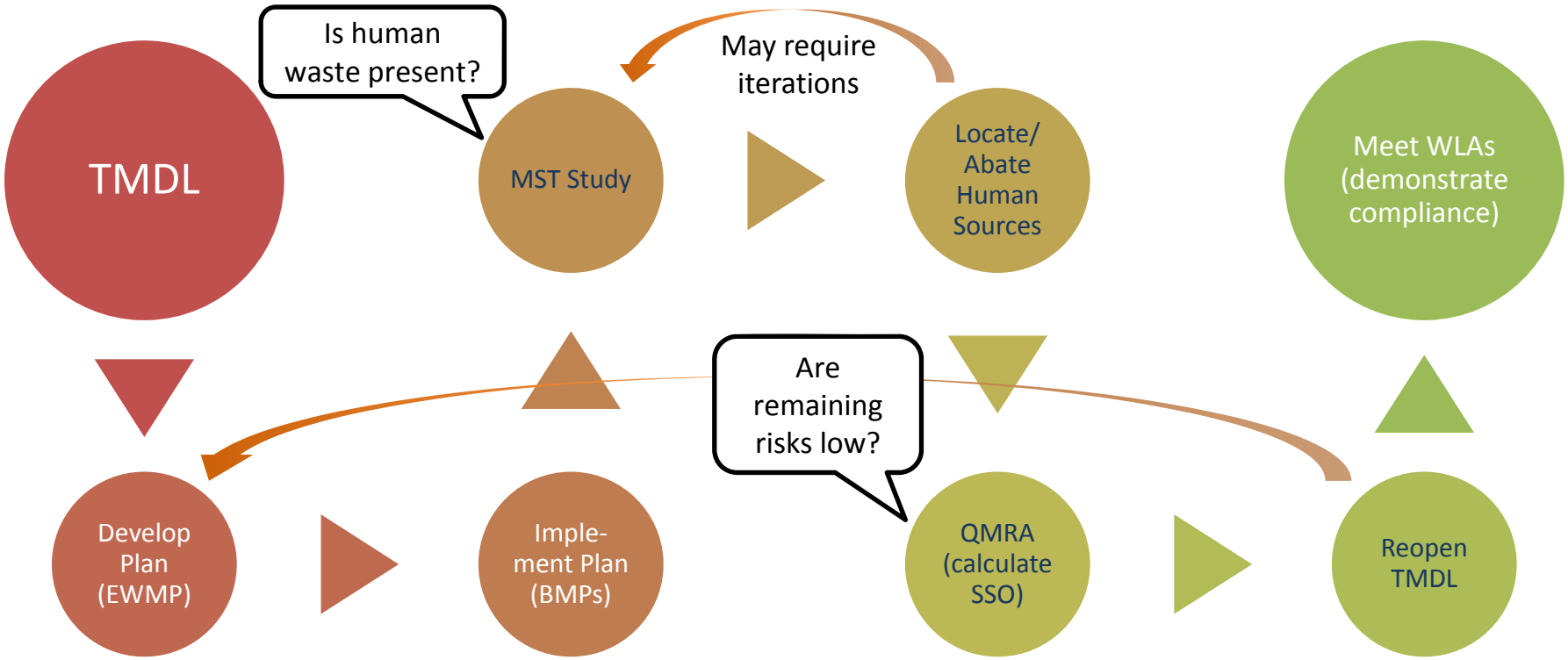
- After all the $$B is spent on Green Infrastructure, are we confident bacteria limits will be met?
  - If not, we'll be back at this point anyway.
- Even reference beaches/streams exceed the allowable exceedance rates half the years
  - Could a fully mitigated urban watershed do any better?

Traditional TMDL Compliance Process



Alternative Bacteria TMDL Compliance Process

Where WLAs can't be met:



- Remains theoretical (tests are in the pipeline)… steps 3/4 are the roadblock
- Process (steps 4-7) may require 4-6 years, so advanced planning is needed

Traditional vs Alternative Approach

Traditional Compliance Approach

Focuses on *FIB* reduction,

with

structural stormwater controls

as the primary implementation strategy (perhaps incorporating MST as an ancillary "special study")

Alternative Compliance Approach

Focuses on *health risk* reduction,

with

human waste control

as the primary implementation strategy (using MST as an implementation tool to comprehensively identify/locate human waste sources)

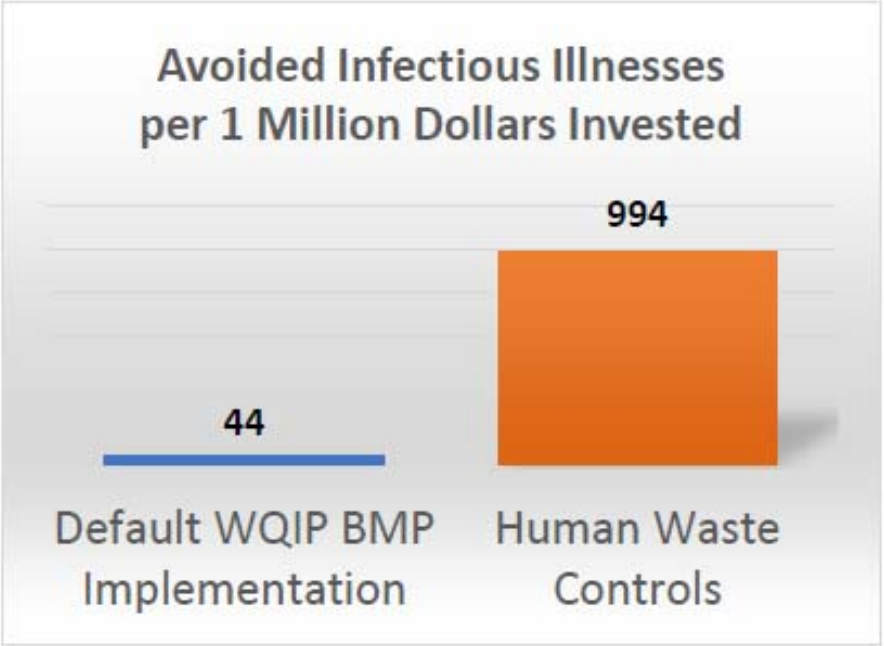
Example: South Orange County WQIP (approved in 2018)

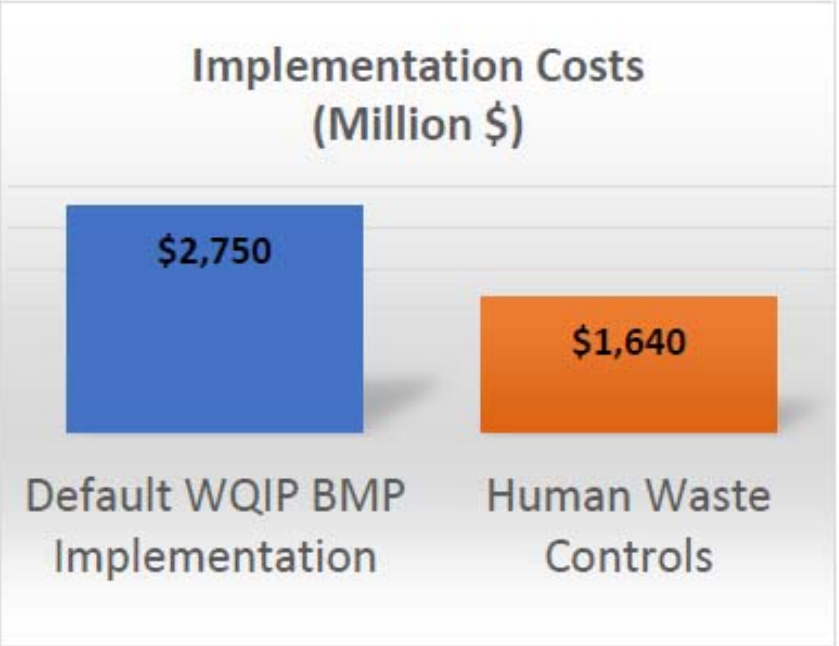
Other plans may be following suit.

State of the science (MST) makes the human waste control option viable.

SD Bacteria TMDL Cost Benefit Analysis

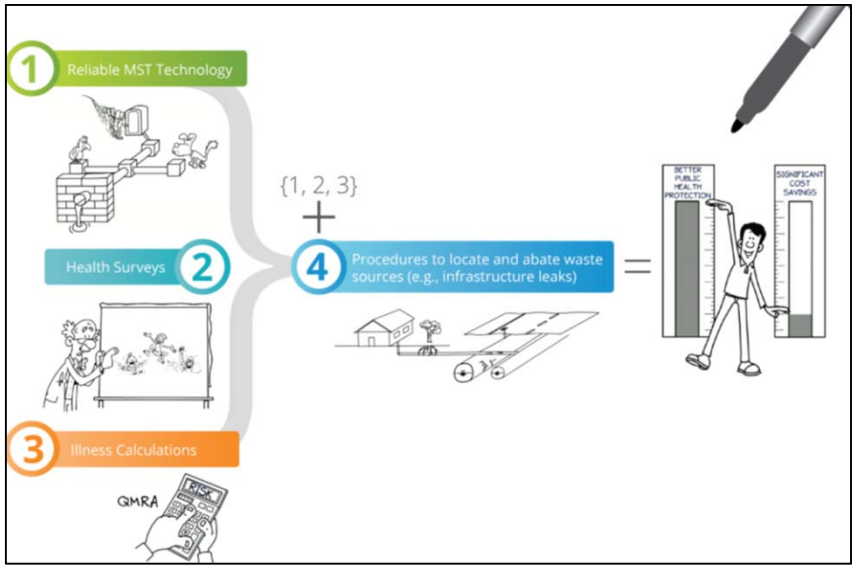
Results confirm intuition:





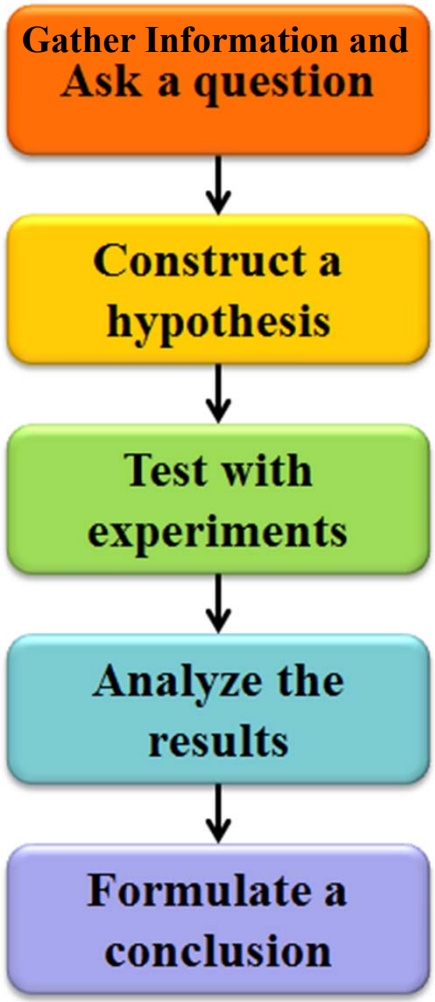
Advantages

- Greater Health Risk Reduction
  - Targets human waste sources that are both higher risk and more controllable than non-human sources of fecal indicator bacteria
- Lower Implementation Cost
  - Requires less public funding by de-emphasizing structural BMPs that were not selected to reduce illness risk
- In-line with USEPA's movement towards health-based criteria and consistent with ongoing efforts across the region
  - E.g., wet weather Surfer Health Study, QMRAs, and Cost Benefit Analysis
- Structural stormwater BMPs can remain as a backup plan



MST Study Planning Begins with Hypothesis Testing…

- Identify potential sources through stakeholder consultation and review of historical data
- Define specific questions (hypotheses) that will be tested through sampling and analysis
- Develop a robust study design to test hypotheses
- Analyze data to conclusively accept or reject each hypothesis with statistical confidence
- Make conclusions, including identifying new hypotheses for further study



…And Development of a Conceptual Site Model (CSM)…

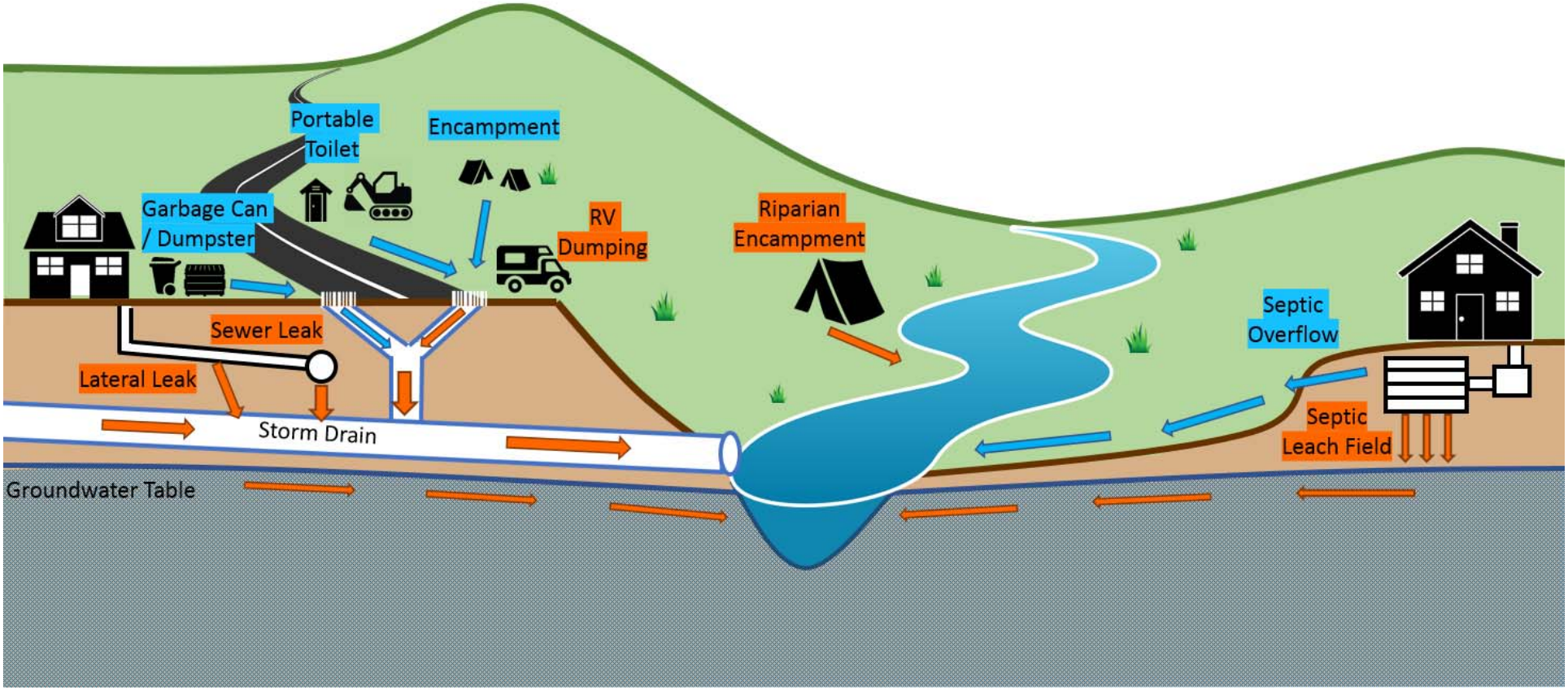
Proper CSM, with source hypothesis testing, should be the basis for any study design

- **Dry Weather Sources should be controlled before Wet Weather Source investigations:** Belowground infrastructure sources more effectively detected and located during dry weather. Then once dry weather sources are abated, wet weather sources, which add overland sources from the entire watershed, can be investigated and controlled.

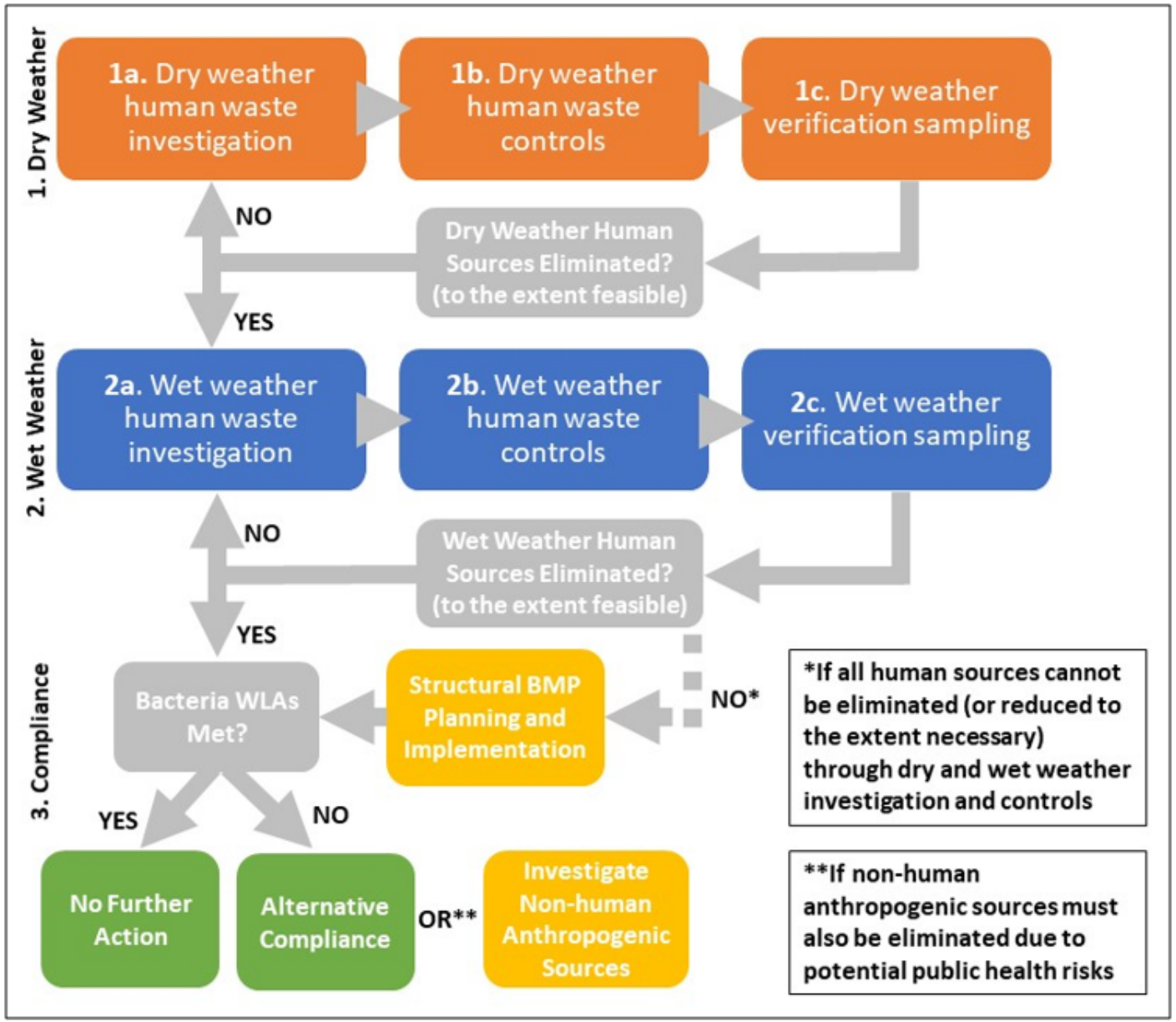
Legend

Source contributes during **wet and dry weather**

Source contributes during **wet weather only**



…Which Suggest a Dry-Then-Wet Phased Study Approach is Most Efficient



So Where is Southern California Headed?

Possibly toward a human waste control approach to address bacteria TMDLs. It will require implementation creativity and regulatory flexibility.

More "proofs of concept" are needed.

- Recent analyses have shown this approach to result in greater public health protection at much lower cost, lending it further credibility
- EPA and State/Regional Board staff continue to express openness to a QMRA-based site specific criteria compliance approach
- The site specific criteria process in CA is lengthy, and the bar is initially being set high, but it may be the only cost-saving alternative available for achieving TMDL compliance
- The pathway potentially represents a win-win-win solution for the recreating public and environmental NGOs, MS4 agencies, and regulators

For other regions and states, alternative implementation or compliance demonstration language in the permit may be preferable over this lengthy MST-plus-QMRA site specific criteria approach.

GI not completely off the table. Necessary for other pollutants and as backstop for bacteria, for example where sources can't be found or are infeasible to control (e.g., certain high density homeless areas).

Full Disclosure: Key Questions Remain

1. Can we get an urban creek/river or beach to an acceptably low level of human marker non-detects? What are the limits of infrastructure fixes in terms of receiving water MST results?

2. Where MS4 compliance goes through Reasonable Assurance Analysis (RAA): Can RAA modeling guidelines be made more flexible to accommodate the approaches/assumptions needed to model human waste control approach? And could they accept demonstration of illness reduction benefits over strict bacteria-based WQS compliance?

3. Will CA Regional Board members be willing/able to pass a recreational WQS adjustment?

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Part 2: Microbial Source Tracking Case Studies

Part 2 Outline

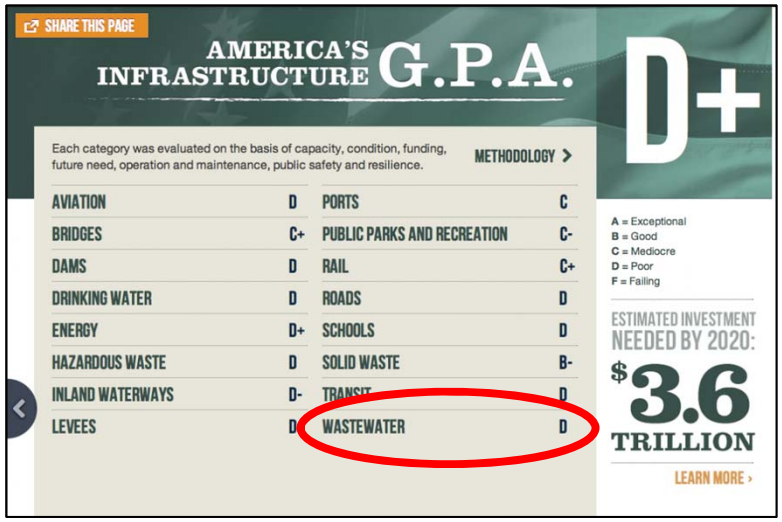
- What is MST?
- Why is it needed?
- What establishes its credibility?
- Case studies
- Q&A

What is MST? (Including NST too)

- Microbial source tracking (MST) and nutrient source tracking (NST) leverage state of the science forensic tools to discriminate sources, e.g.,
  - Human waste (sewage, septic effluent)
  - Non-human waste (pets, livestock, birds, other wildlife)
  - Non-fecal (natural environmental sources, chemical fertilizer)
- Analytical tools (DNA markers, isotope ratios) have recently become more *sensitive* (detect to highly diluted levels) and *specific* (reliable, with very little cross-reactivity), enabling:
  - more conclusive outcomes (critical for litigation needs)
  - standardization and regulator acceptance (critical for regulatory needs)
- Often combined in field with other traditional tools (CCTV, smoke testing, dye testing, conventional water quality parameters) in toolbox approach to locate and abate specific sources

Why is it Needed?

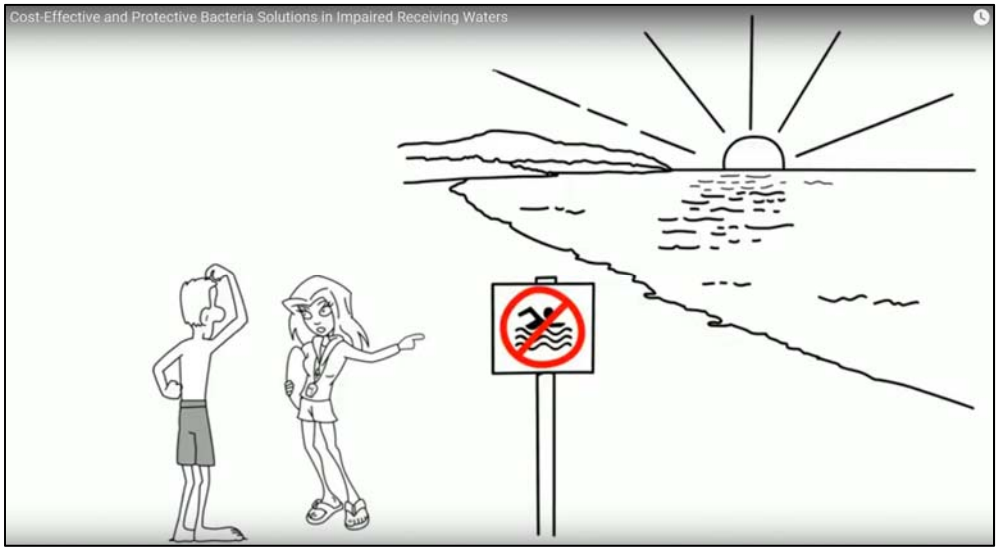
1. Bacteria and nutrient pollution is a massive problem in need of a solution
   - These are #1 and #3 sources of 303(d) impairment nationwide
   - Southern CA municipalities facing $Bs to meet bacteria TMDLs
   - USEPA recognizes bacteria WQS are overly conservative when sources are mostly non-human, and allows site specific criteria
   - Harmful algal blooms (HABs) are a growing problem in all U.S. coastal and Great Lakes states, and have upped the ante on excessive nutrient loading to surface waters
   - Infrastructure deterioration is also a growing concern nationwide



Why is it Needed? (cont'd)

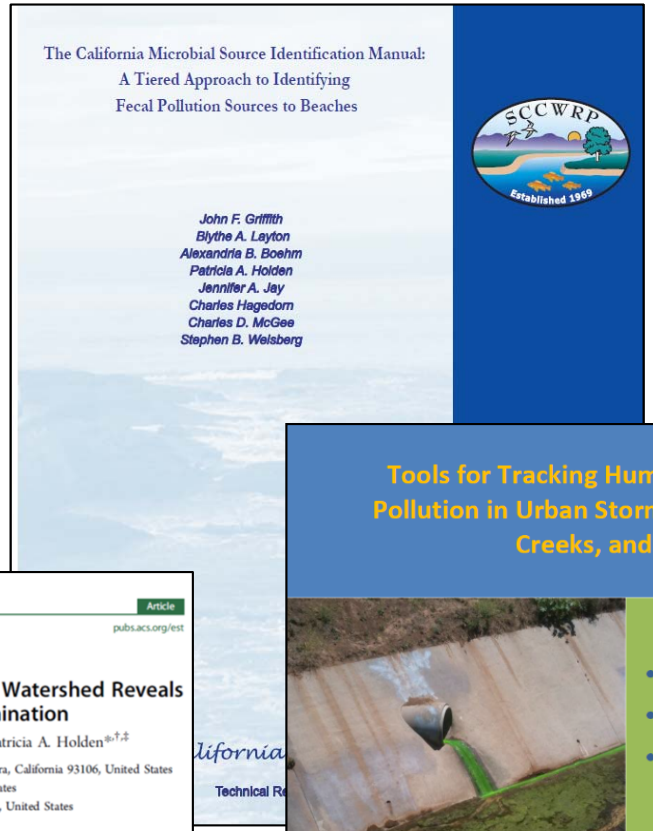
2. These tools allow effective source control, which is a more surgical, lower cost approach than stormwater capture/treatment, and more directly targets illness/HAB driving pollutants
   - Pathogens
   - Bioavailable nutrients

YouTube whiteboard video describes this: youtu.be/psXkqTc9eeE



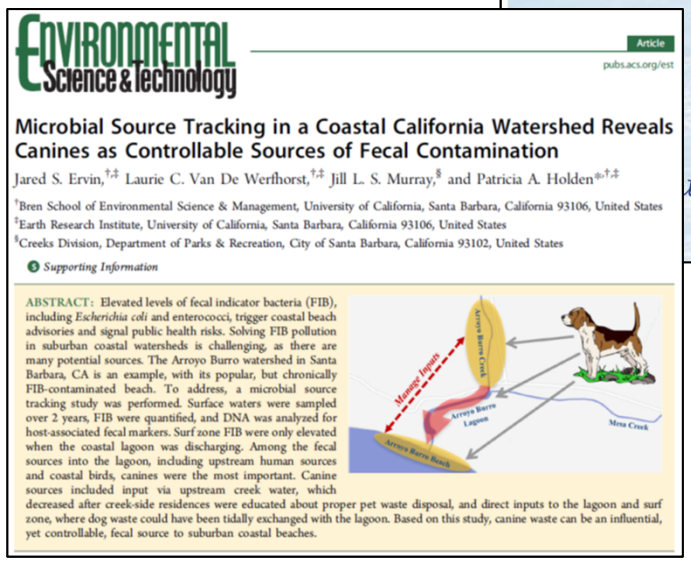
What establishes its credibility?

- California MST Manual (for State Water Board)
- USEPA Standard Method
- Peer-reviewed publications
- Practice guidance


The California Microbial Source Identification Manual:
A Tiered Approach to Identifying
Fecal Pollution Sources to Beaches

John F. Griffith
Blythe A. Layton
Alexandria B. Boehm
Patricia A. Holden
Jennifer A. Jay
Charles Hagedorn
Charles D. McGee
Stephen B. Weisberg

SCCWRP
Established 1969


Environmental Science & Technology

Article

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Microbial Source Tracking in a Coastal California Watershed Reveals Canines as Controllable Sources of Fecal Contamination

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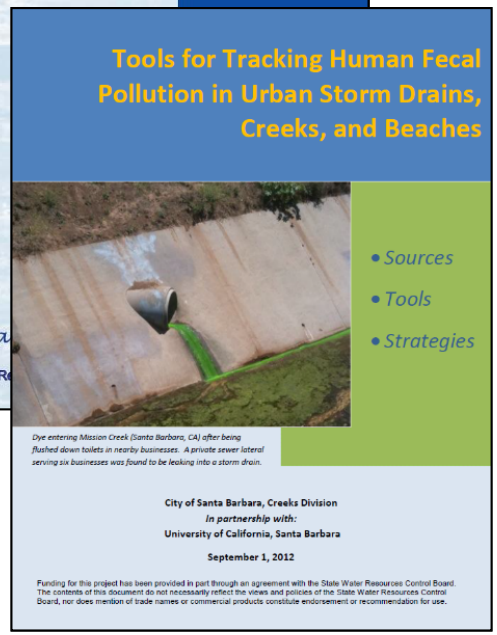
Supporting Information

ABSTRACT: Elevated levels of fecal indicator bacteria (FIB), including *Escherichia coli* and enterococci, trigger coastal beach advisories and signal public health risks. Solving FIB pollution in suburban coastal watersheds is challenging, as there are many potential sources. The Arroyo Burro watershed in Santa Barbara, CA is an example, with its popular, but chronically FIB-contaminated beach. To address, a microbial source tracking study was performed. Surface waters were sampled over 2 years, FIB were quantified, and DNA was analyzed for host-associated fecal markers. Surf zone FIB were only elevated when the coastal lagoon was discharging. Among the fecal sources into the lagoon, including upstream human sources and coastal birds, canines were the most important. Canine sources included input via upstream creek water, which decreased after creek-side residences were educated about proper pet waste disposal, and direct inputs to the lagoon and surf zone, where dog waste could have been tidally exchanged with the lagoon. Based on this study, canine waste can be an influential, yet controllable, fecal source to suburban coastal beaches.


Tools for Tracking Human Fecal Pollution in Urban Storm Drains, Creeks, and Beaches

- Sources
- Tools
- Strategies

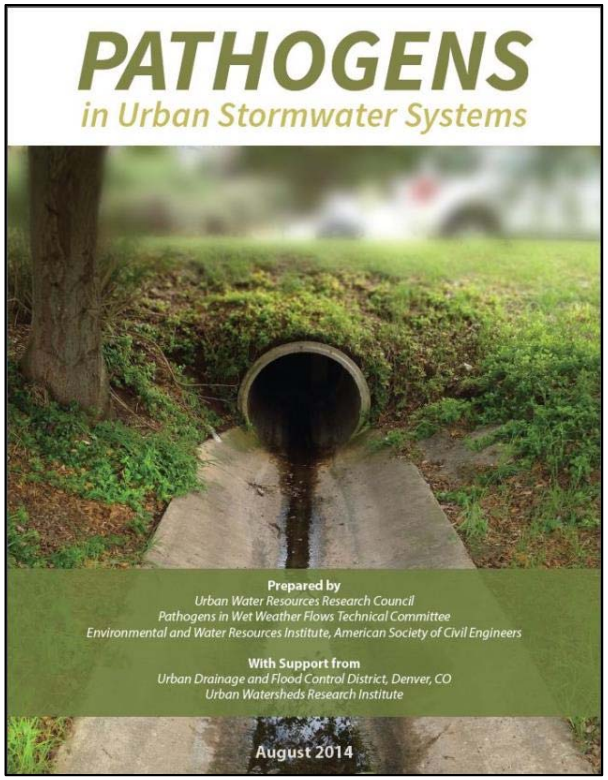
Dye entering Mission Creek (Santa Barbara, CA) after being flushed down toilets in nearby businesses. A private sewer lateral serving six businesses was found to be leaking into a storm drain.

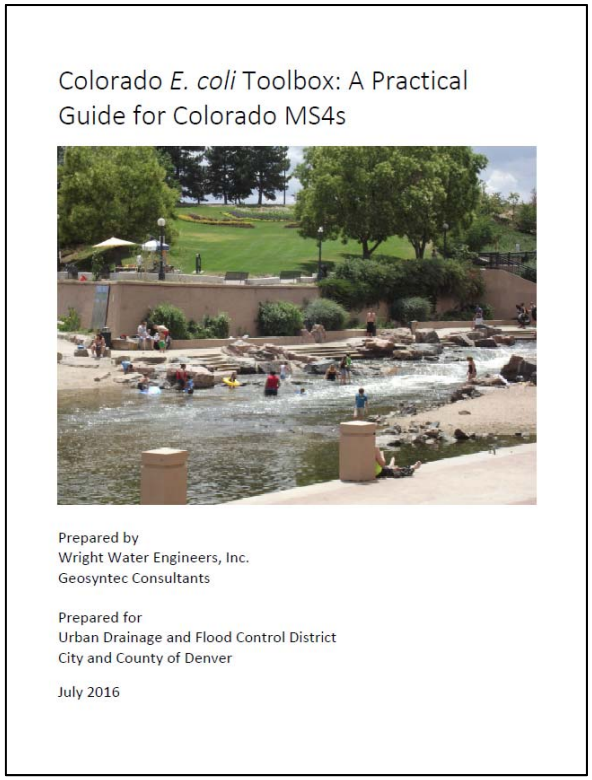
City of Santa Barbara, Creeks Division
In partnership with:
University of California, Santa Barbara

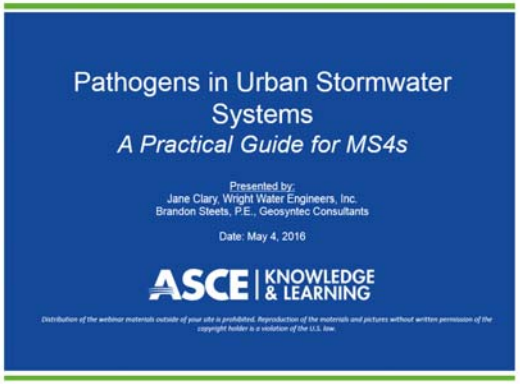
September 1, 2012

Funding for this project has been provided in part through an agreement with the State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Example Practice Guidance

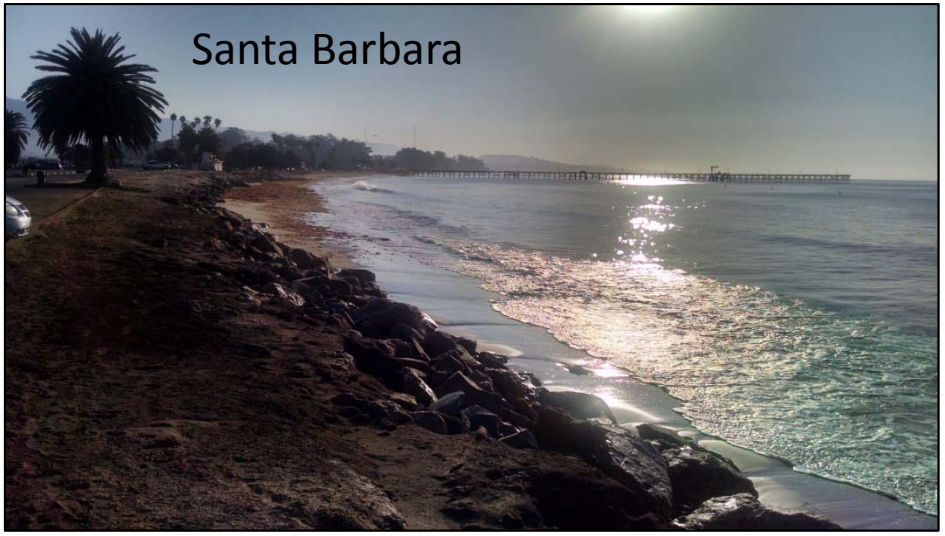


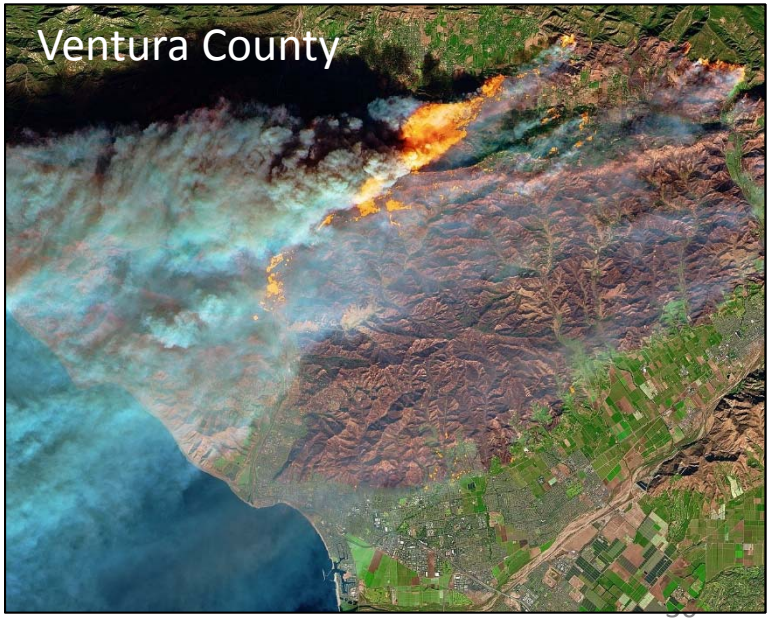




These help to establish "standard practice" for addressing bacteria, including guidance on MST

Case Studies

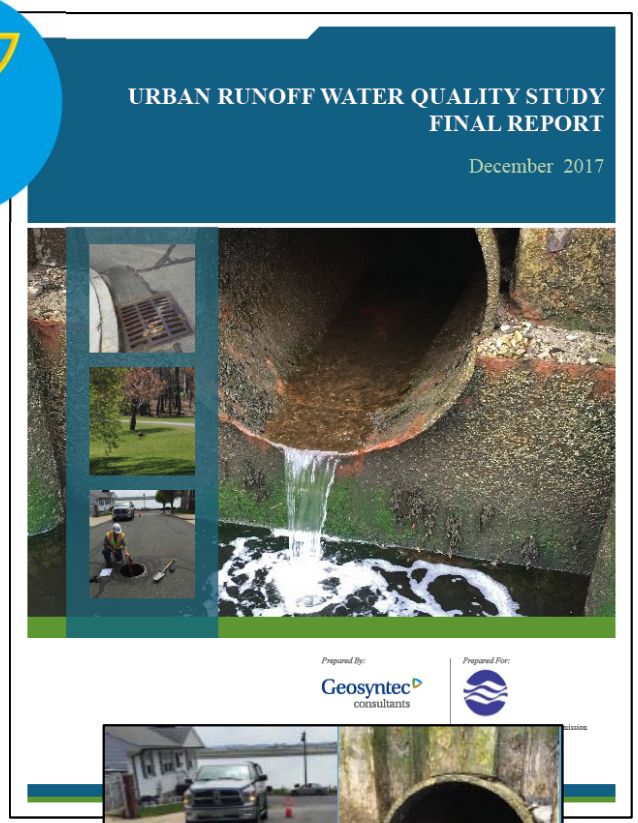




BWSC IDDE Study

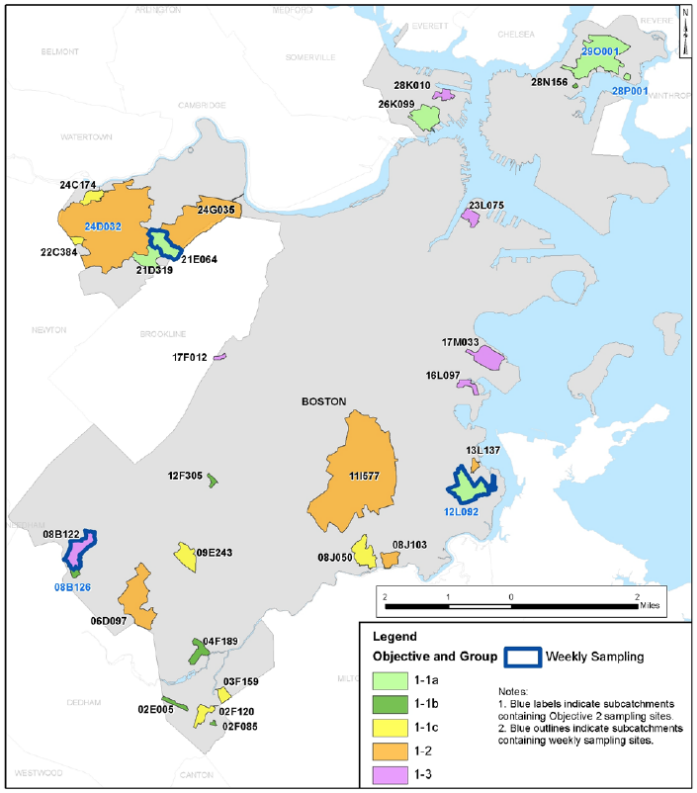
- **Regulatory Drivers**
  - MS4 Permit
  - Consent Decree
  - Phosphorus and Bacteria TMDLs
- **Scientific Advancement**
  - 1st ever evaluation of a major IDDE program using state-of-the-science MST tools
- **Results**
  - Wet weather outfall FIB sampling not meaningful for FIB (possible new MS4 permit requirement)
  - Sewage sources remain (continued illicit discharge pursuit warranted)
  - IDDE procedure enhancements recommended
  - Further IDDE refinement will yield further Phosphorus and Bacteria reduction (warrants greater credit toward TMDL?)

2018 NACWA award



BWSC IDDE Study

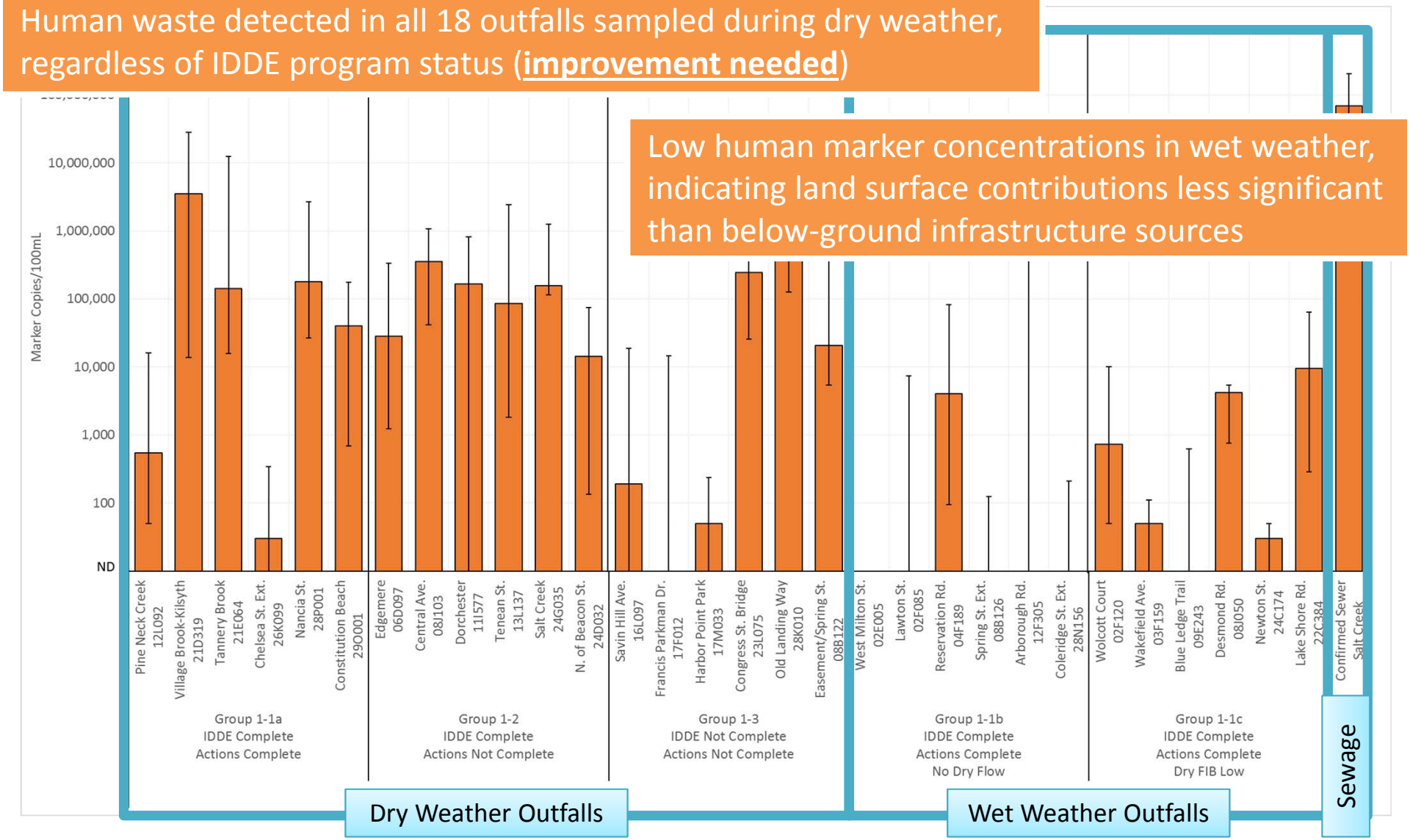
- Benefits
  - New awareness of extent of remaining sewage sources
  - Procedure enhancements that will improve program effectiveness (more efficient sewage elimination and phosphorus/bacteria load reduction)
  - Demonstration to regulators and NGOs that BWSC is proactively addressing water quality issues (Consent Decree, TMDLs)
  - Demonstration to public of BWSC's commitment to innovation (NACWA award as demonstration)



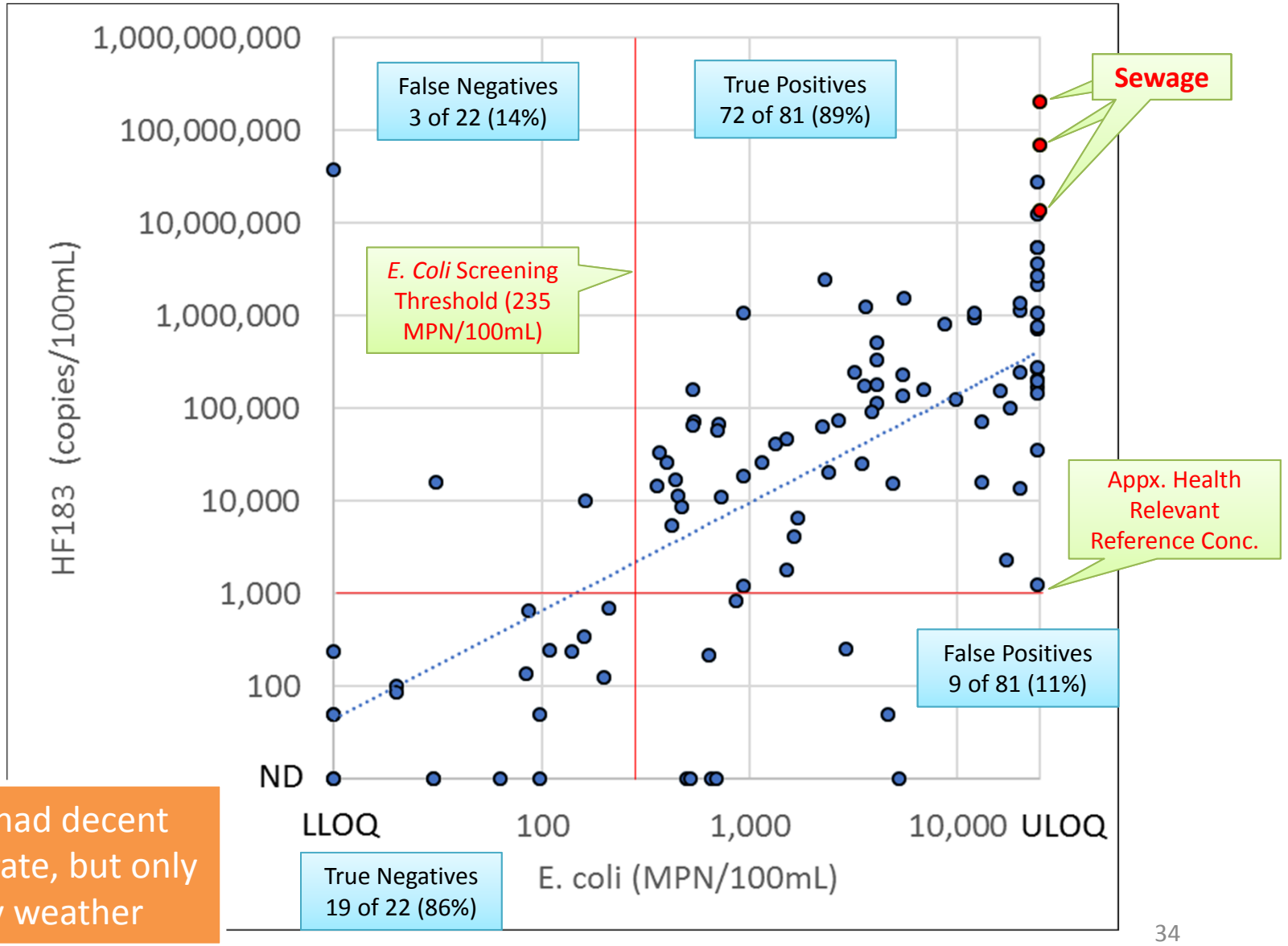
Sewage Sources Remain, Despite Status of Prior IDDE Work

Human waste detected in all 18 outfalls sampled during dry weather, regardless of IDDE program status (**improvement needed**)

Low human marker concentrations in wet weather, indicating land surface contributions less significant than below-ground infrastructure sources

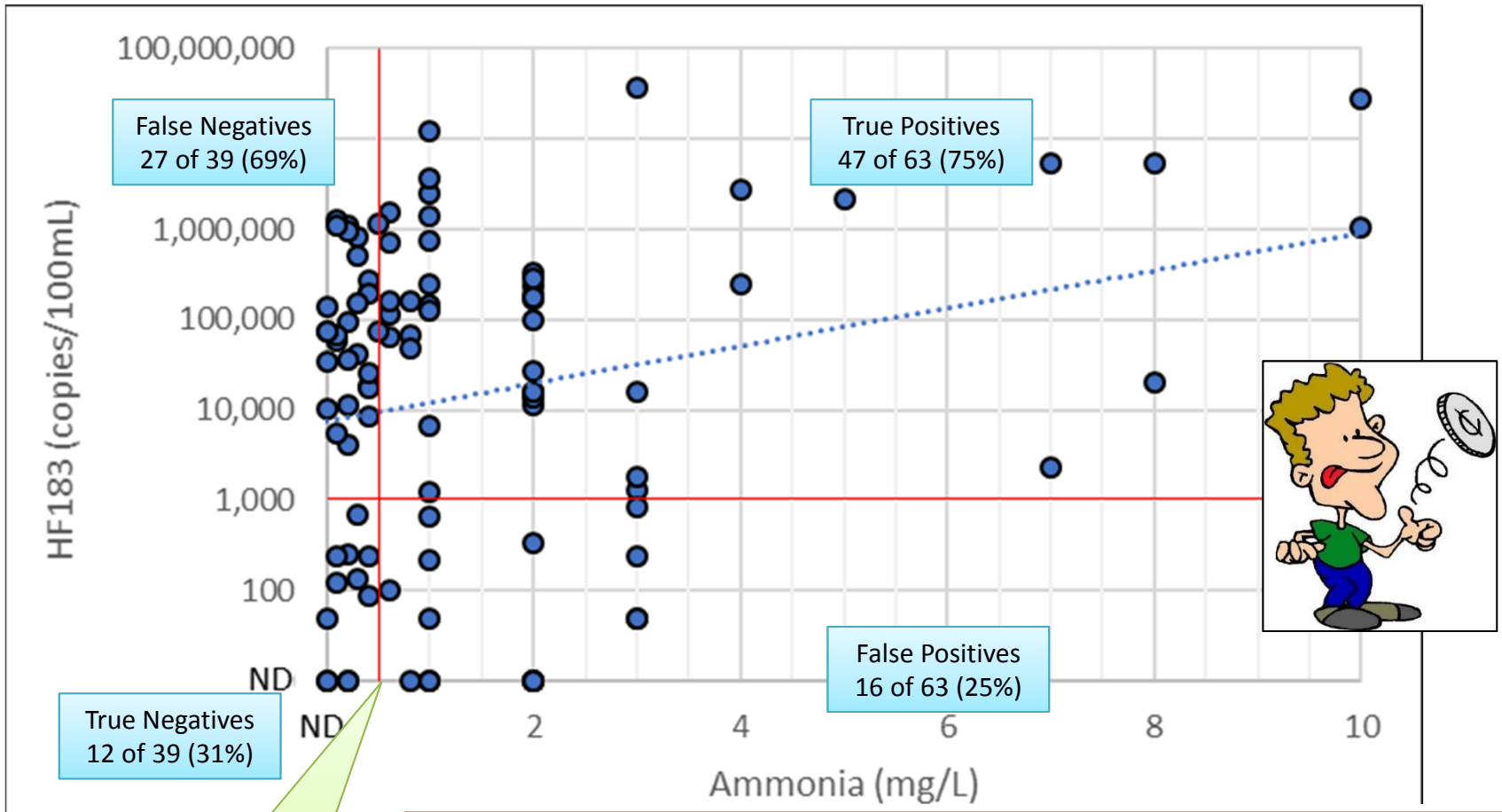


Outfall Prioritization is Working (During Dry Weather)



E. Coli had decent success rate, but only in dry weather

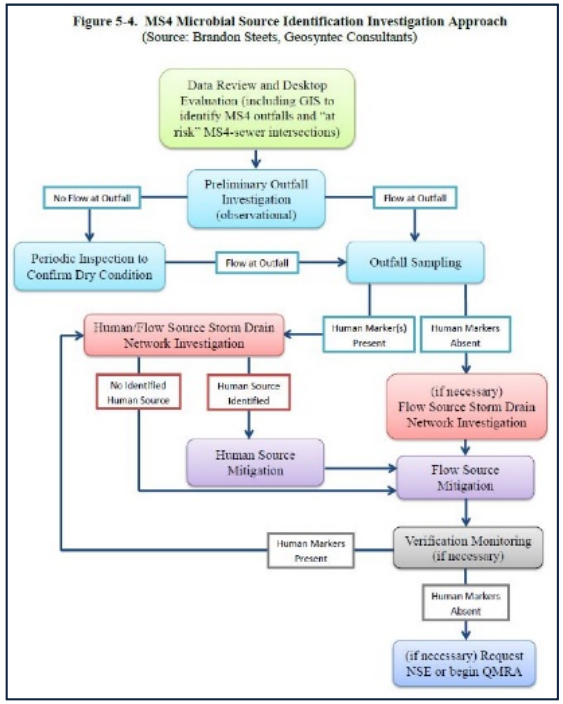
Network Investigation is Where Improvement is Needed



Test kit parameters (ammonia, surfactants, and chlorine) not correlated with human marker and prone to false negative and false positive results at outfalls… this comes at a cost

San Diego County MS4 MST Study

- Purpose: implement Water Quality Improvement Plan, demonstrate compliance with TMDL requirements, and support response to recent Investigative Order
- Extensive MST survey of ~500 MS4 outfalls during dry weather
- Human marker detections prompted CCTV investigations to locate flow sources into MS4s and guide management actions



San Diego County MS4 HF183 Results

San Luis Rey and San Diego Creek Watersheds

	2014/15	2018/19
# MS4 Outfalls Inspected	**239** (sewered areas only)	**496** (unsewered + incorporated areas added)
# Sampling Rounds Performed	**1**	**5**
# MS4 Outfalls Sampleable	**42** (18%)	**69** (14%)
# with HF183 Quantified	**2** (5% of flowing outfalls, using qPCR)	**26** (38% of flowing outfalls, using ddPCR)
Human Sources Identified After CCTV	• **Leaky infrastructure ruled out** (both networks CCTV'ed, no below-ground flow inputs found) • **Homeless encampment** above one outfall • **Runners** (open defecation) suspected at other outfall (running trail adjacent)	Not completed yet

Conclusions:

- Multiple rounds needed to identify human waste-impacted outfalls
- ddPCR technology allows more sensitive detection/quantification ability
- Detected levels in discharges are relatively low (<100-1000 cp/100mL)
- Outfall-based sampling using HF183 is an efficient means of (sewage) IDDE
- Infrastructure contributions were infrequent (Q: will 2018/19 corroborate this?)
- Open defecation may be a social and public health issue requiring more attention

Santa Barbara Beaches MST Study

- Purpose: to improve public health protection at three popular beaches
- Builds off prior investigations, which were first to document and publish on sewer exfiltration into stormdrains, shedding new light on this important source for agencies nationwide
- Rigorous testing of every proposed source hypothesis, including infrastructure and homeless
- DNA markers used in combination with conventional tools (dye + fluorimeter, GIS)

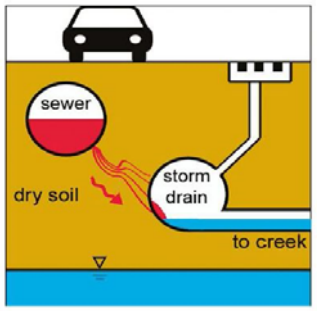


Figure 3-1. Leaking Sanitary Sewer Exfiltrating to Storm Sewer (Source: Sercu et al. 2011[4])

Hypothesis Testing Matrix

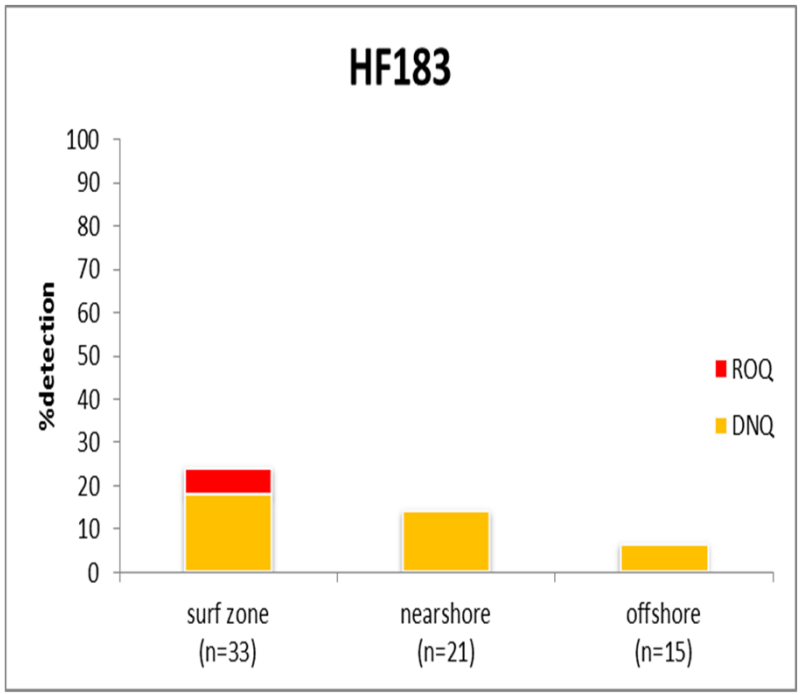
Hypothesis	Dye Testing	Surf Zone Sampling	Offshore Sampling	Watershed Sampling	Sand/Sediment Sampling	Groundwater Sampling
Creeks		✓		✓		
Scour Ponds	✓	✓		✓		✓
MS4 Outfalls		✓		✓		✓
Sewers/Septic	✓	✓		✓		✓
Background		✓		✓	✓	
Creek Sediments		✓		✓	✓	
Marine Sediments		✓	✓		✓	
Intertidal/ Supratidal		✓			✓	
Stearns Wharf	✓					
Moored Boats		✓	✓			
WWTP Effluent		✓	✓			
Water Defecation		✓				
Bather Shedding		✓			✓	

Study Findings

- Shorebirds were a significant source of surf zone FIB in dry weather, based on gull marker-FIB correlations
- Consistent low level human markers (and less frequently, pathogens) were present in the surf zone
- Creek outlets were also human fecal impacted (possibly from open defecation and/or compromised infrastructure) but were non-transmissive to the surf zone, based on beach dye studies and groundwater sampling
- Beach-area sanitary infrastructure (sewers, bathrooms, and a septic system) were not fecal sources to the surf zone, again based on dye studies and groundwater sampling

Study Findings (cont'd)

- Open defecation was not a source; although deposits were observed, beach sands were devoid of human markers
- Offshore POTW outfall was not a source, based on plume modeling
- Off- to onshore synchronized sampling suggested human-associated DNA markers originated in the surf zone
- Bathers were the primary source of surf zone human markers, based on swimmer-marker correlations and higher marker levels in afternoons



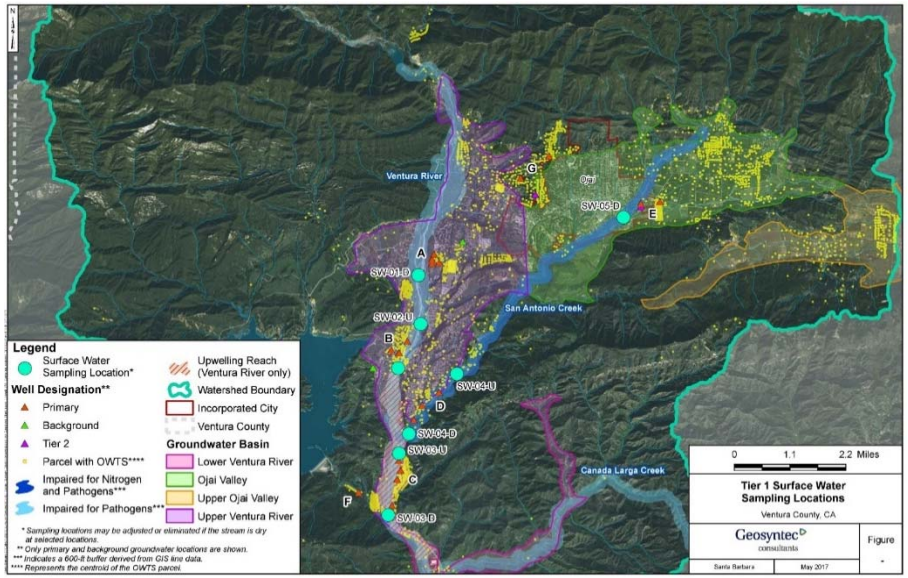
Project Significance

1. (To our knowledge) First time urban beaches in CA have been conclusively demonstrated to have no significant infrastructure or homeless impacts to surf zone water quality

2. Provides demonstration that bather shedding from normal recreational use can cause low level human marker detections in the surf zone at high use beaches

Ventura River Septic Nutrient Study

- Driver: Algae TMDL and statewide septic policy require watershed-wide upgrades to costly OWTS
- Purpose: to geographically define septics that are contributing to elevated nutrients in surface water
- Approach:
  - GW/SW sampling of nitrate, nitrate isotopes and chemical sewage markers
  - Representative sampling locations selected based on travel time and geology
- Related project includes GW-SW modeling to quantitatively evaluate sources and effects of water management activities and Thomas fire
- **Result: 70%** of septics excluded from contributing, management actions can now focus on narrower group, potential TMDL modification next



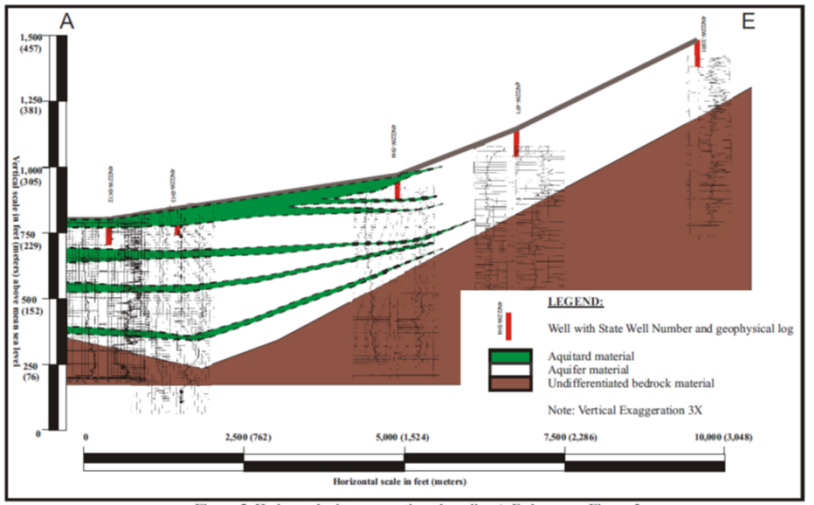


Figure 5. Hydrogeologic cross section along line A-E shown on Figure 3 (view looking north along central portion of Ojai Valley)

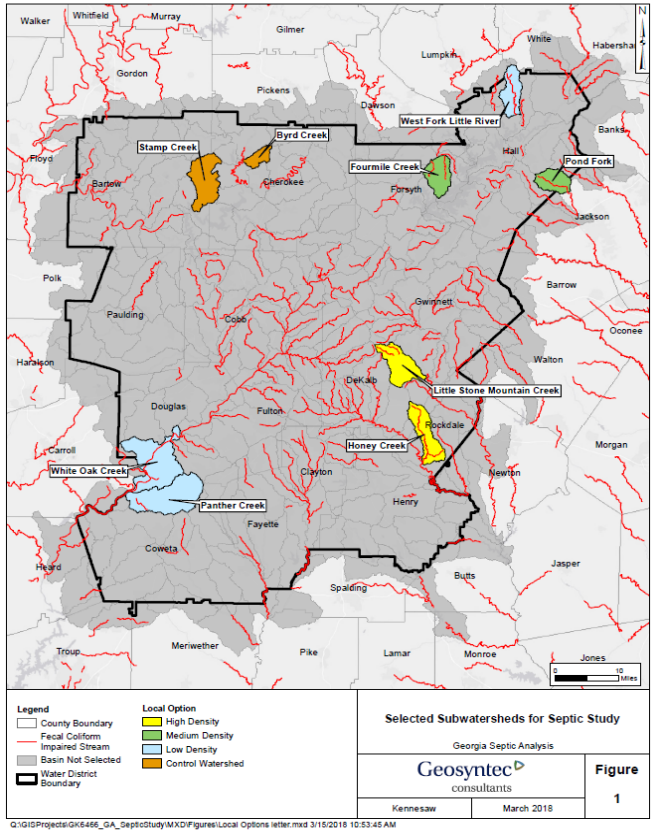
Septic Impacts to Surface Waters in Atlanta Region

Background

- Metropolitan North Georgia Water Planning District (MNGWPD) covers 6 major river basins and represents 15 counties, 95 Cities, and >50 water and wastewater providers
- Over **450,000** septic systems in the district
- Stream and lake impairments due to bacteria and nutrients

Project Purpose

- Investigate impacts of septics on bacteria and nutrients in surface waters
- Proactively address 303(d) listings and avoid future TMDLs if possible



Septic Impacts to Surface Waters in Atlanta Region

Study Questions / Hypotheses

1. Are human marker concentrations higher in fecal coliform impaired reaches with high septic densities?
2. Are fecal coliform and nutrient concentrations higher in stream reaches where human markers are detected?

Study Design

- 5 dry weather sampling events at 31 stream locations across 10 subwatersheds with varying septic densities
- Samples analyzed for human marker, FIB and nutrients

Expected Outcome

- Determine whether/where new septic management actions are necessary

Other Example Geosyntec MST Applications

1. Impact assessment of major sanitary sewer overflow into creek (enforcement response)
2. Impact assessment of emergency mud disposal onto beach (debris flow disaster response)
3. Septic impact study (response to Investigative Order)
4. CAFO impact investigation (response to enforcement order)
5. Assessment of hog farm impacts after Hurricane Michael
6. Identification of illicit discharges into private industrial stormdrain (under USDOJ Consent Decree)
7. Supporting defense (CA DOJ) against allegations from impacted shellfish bed owner
8. Non-industrial source demonstration (pathway incorporated into 3rd party settlement agreements)

Closing Thoughts on MST

- MST projects have many different drivers
  - Improved public health protection and public relations
  - TMDL compliance, modification, or avoidance
  - Reducing higher cost Green Infrastructure obligations
  - MS4 IDDE enhancement or Consent Decree compliance
  - Health departments evaluating need for costly septic upgrade, or making beach closure/warning decisions
  - Determining liability for bacteria/nutrient impairments and responding to CWA enforcement action allegations of impact
  - Non-industrial source demonstration for industrial stormwater permit compliance and settlement offramp tool
- The analytical tools are highly sensitive, so expect some degree of waste detection in urban receiving waters. But sources can be found and fixed!

Q & A

Thank you for your time!

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