Microbial Source Tracking to battle *E. coli* pollution in the District of Columbia

Amir Sharifi, PhD

Nov 21 2019

DEPARTMENT OF ENERGY & ENVIRONMENT

GOVERNMENT OF THE DISTRICT OF COLUMBIA
MURIEL BOWSER, MAYOR

Presentation overview

1. Microbial Pollution in the District of Columbia
2. MST basics
3. DOEE / EPA MST Project

Fecal Pollution is a Nationwide Challenge

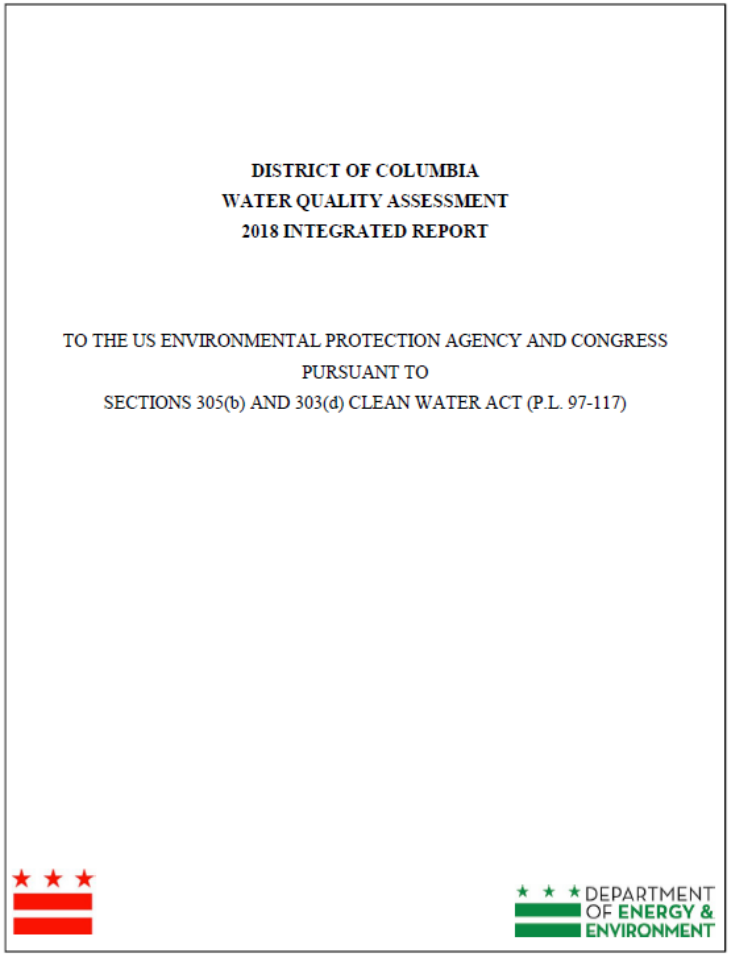
Pathogens are the No.1 cause of impairments to the Rivers/streams of the US.

National Summary
Causes of Impairment in Assessed Rivers and Streams

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
Mercury	72,554

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

Microbial Pollution in the District of Columbia



DISTRICT OF COLUMBIA
WATER QUALITY ASSESSMENT
2018 INTEGRATED REPORT

TO THE US ENVIRONMENTAL PROTECTION AGENCY AND CONGRESS
PURSUANT TO
SECTIONS 305(b) AND 303(d) CLEAN WATER ACT (P.L. 97-117)

DEPARTMENT OF ENERGY & ENVIRONMENT

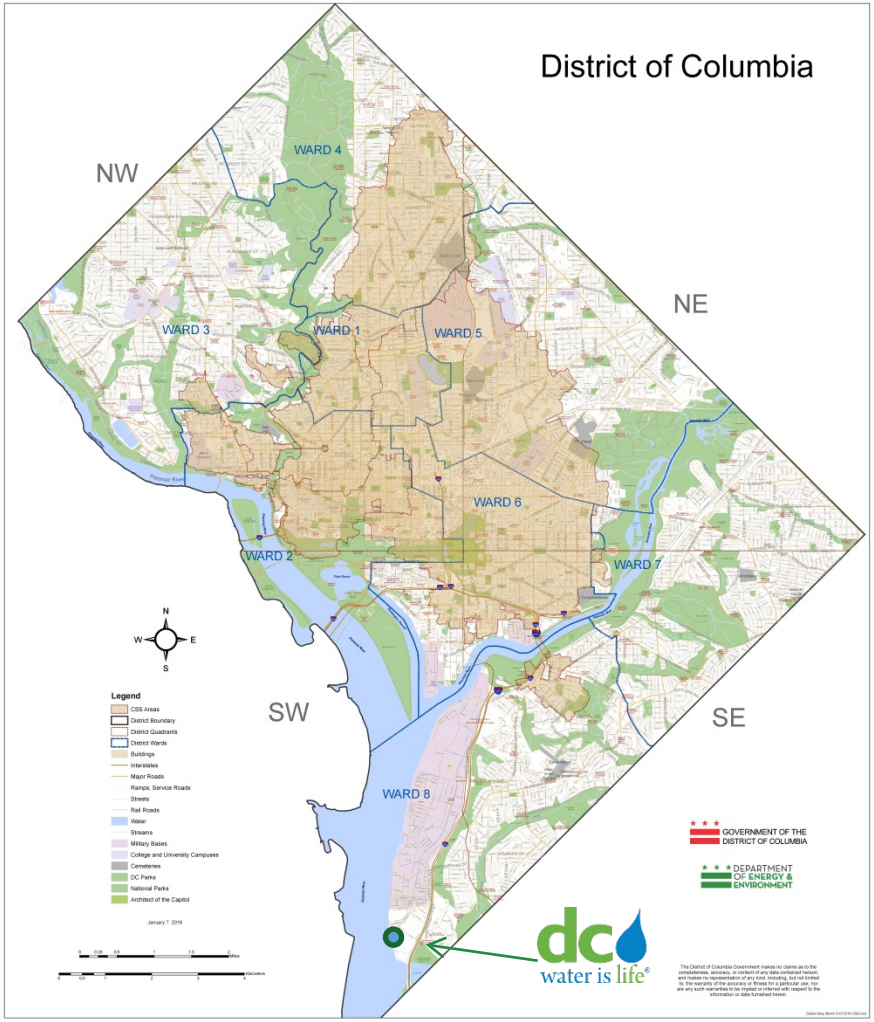
Table 3.6 Total Number of Waterbody Segments Impaired by Various Causes

Parameter Causing Impairment	Number Effected Cause	Meeting Criteria	Observed Effect	Total
ESCHERICHIA COLI (*E. COLI*)	36	0	0	36
POLYCHLORINATED BIPHENYLS (PCBS)	36	0	0	36
TOTAL SUSPENDED SOLIDS (TSS)	21	0	0	21
DIELDRIN	19	0	0	19
HEPTACHLOR EPOXIDE	16	0	0	16
CHLORDANE	14	0	0	14
FLOW REGIME MODIFICATION	10	0	0	10
ARSENIC	9	0	0	9
DISSOLVED OXYGEN	9	0	0	9
PH	9	0	0	9
PAHS POLYCYCLIC AROMATIC HYDROCARBONS (AQUATIC ECOSYSTEMS)	8	0	0	8
HABITAT ASSESSMENT	8	0	0	8
DDT (DICHLORODIPHENYLTRICHLOROETHANE)	5	0	0	5
DDE (DICHLORODIPHENYLDICHLOROETHYLENE)	5	0	0	5
CHLOROPHYLL-A	5	0	0	5
COPPER	4	0	0	4

Microbial Pollution in the District of Columbia

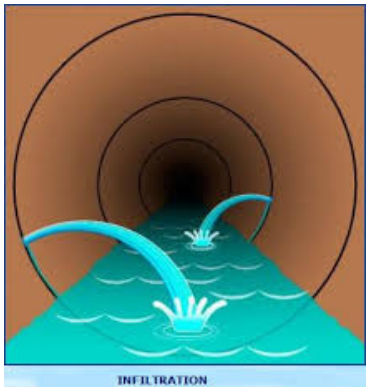
- Blue Plains WTP and CSO (Combined Sewer Overflow) ~95% bacterial load
- MS4 (Municipal Separate Storm Sewer System)

~ 5% bacterial load



Common sources of *E. coli* in MS4

- Illegal sanitary sewer connections to the storm drain
- Sanitary sewer exfiltration via groundwater seepage
- Wildlife, such as birds and deer
- Pets - especially dogs

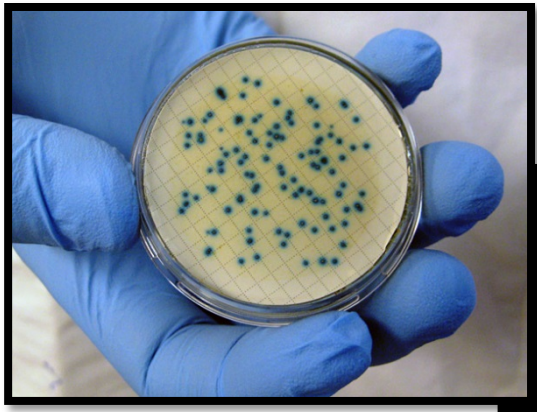


DC Water Quality Standards for *E. coli*

Water quality standards for *E. coli* in District specify that:

- No single sample shall exceed **410 MPN/100 mL**
- The 30-day geometric mean should not exceed **126 MPN/100 mL**

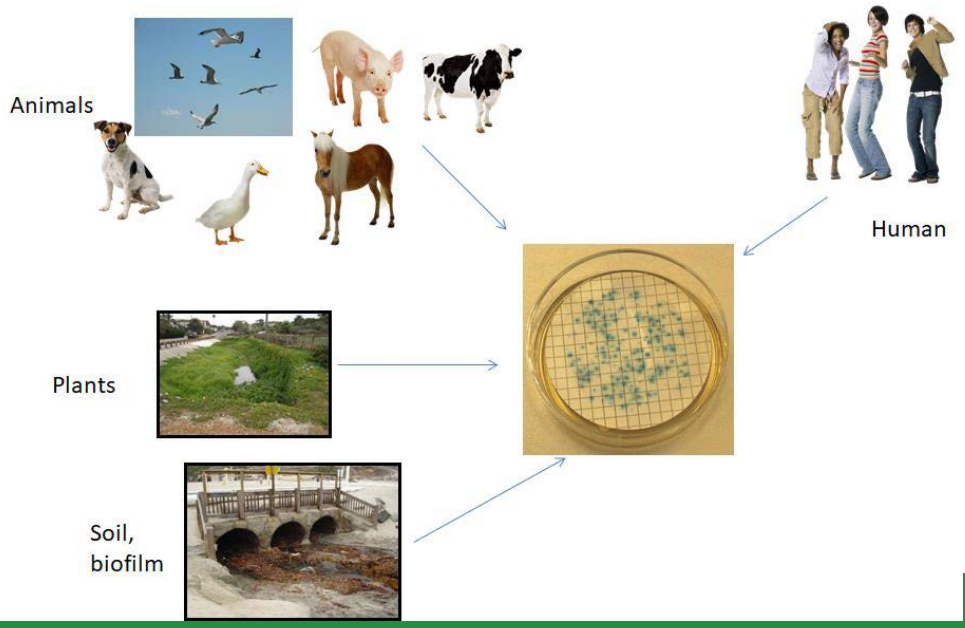
Categories of Uses that Determine Water Quality Standards	**Classes of Water**
Primary contact recreation	A
Secondary contact recreation and aesthetic enjoyment	B
Protection and propagation of fish, shellfish, and wildlife	C
Protection of human health related to consumption of fish and shellfish	D
Navigation	E



https://www.epa.gov/wqs-tech/water-quality-standards-regulations-washington-dc

Source of Fecal Pollution is Important

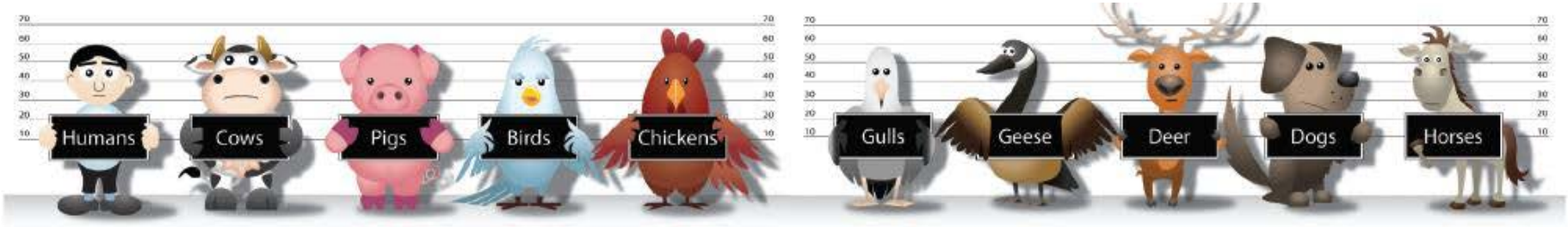
- *E. coli* data alert to the total pollution level, however, does not provide information about the cause or source of pollutants
- Public health risk can vary by source
- Mitigation strategies can vary by source
- Source information improves water quality management and public safety



DNA-Based Microbial Source Tracking

- There are specialist microbes closely associated with a given pollution source
  - Host and gut microbes co-evolve
    - Physiological differences of the gut
    - Dietary differences between hosts

- MST provides a set of tools to characterize sources of contamination

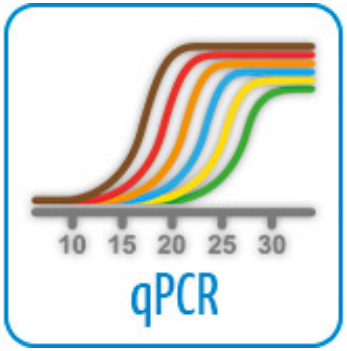


Advantages of qPCR for MST

qPCR = quantitative Polymerase Chain Reaction

Procedure for the measurement of host-associated gene sequences isolated from environmental water samples

- "Gold standard" for MST
- No cultivation requirement
- Highly reproducible when standardized
- Established quality control guidelines
- Specialized reagents for environmental testing



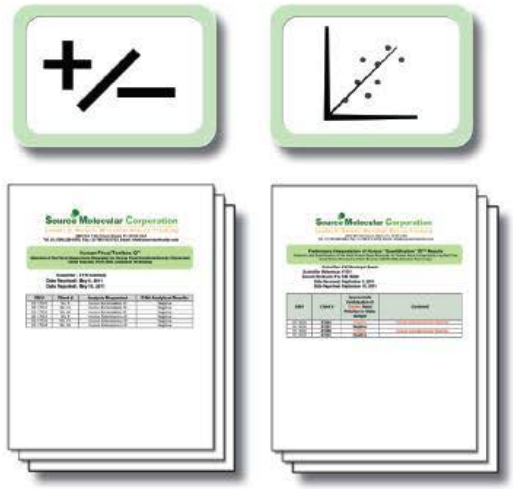
EPA Nationally Validated Methods

Method 1697: Characterization of Human Fecal Pollution in Water by HumM2 TaqMan® Quantitative Polymerase Chain Reaction (qPCR) Assay®

Method 1696: Characterization of Human Fecal Pollution in Water by HF183/BacR287 TaqMan® Quantitative Polymerase Chain Reaction (qPCR) Assay

Dr. Orin Shanks
U.S. EPA Office of Research & Development (ORD)

MST with Quantitative real-time PCR (qPCR)



Sample Collection → Sample Concentration → DNA Isolation → qPCR Amplification → Data Analysis

DEPARTMENT OF ENERGY & ENVIRONMENT

TETRA TECH

U.S. EPA- ORD
Cincinnati, OH

DC MST Study Objectives

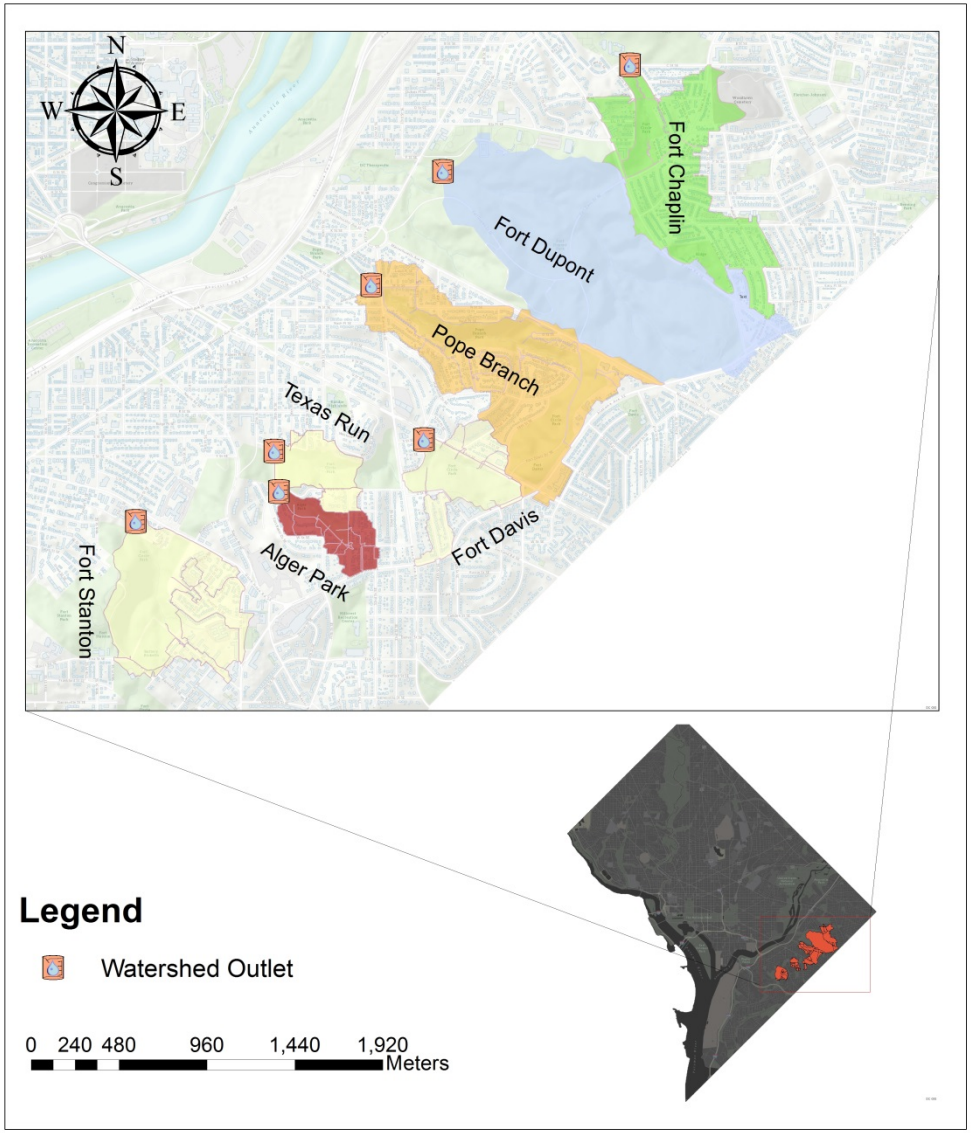
1. Characterize fecal source trends in select District outfalls to improve urban stormwater management

2. Develop procedure for future MS4 outfall fecal pollution source characterization with MST qPCR
    - District
    - EPA Region 3
    - National



Selected Sites

- East side of Anacostia River
- First order catchments
- Size 13 to 123 ha
- 32 MS4 outfalls across sites
- Historic *E. coli* data (n = 202; since 2008)
- Chronic fecal pollution
  (median *E. coli* geometric mean > 126 MPN/100ml)
- No known CSO impact
- Range of land use
  (100% parkland to 100% urban)
- Dry weather MS4 outflows at most sites



Sampling Plan

Dry weather

- ❑ 12-16 months
- ❑ 2x per month
- ❑ Receiving water
- ❑ MS4 dry flow outfalls

Wet weather

- ❑ 6-8 events
- ❑ Receiving water
- ❑ MS4 dry flow outfalls only

- Precipitation
- Flow Information
- Water Quality Metrics
  - *E. coli* (IDEXX Colilert)
  - Turbidity, Temperature, DO, pH
- MST qPCR Methods
  - Human-associated (HF183/BacR287 and HumM2)
  - Ruminant-associated (Rum2Bac)
  - Dog-associated (DG3)
  - Avian-associated (GFD)

Evidence-Based Hypothesis Testing

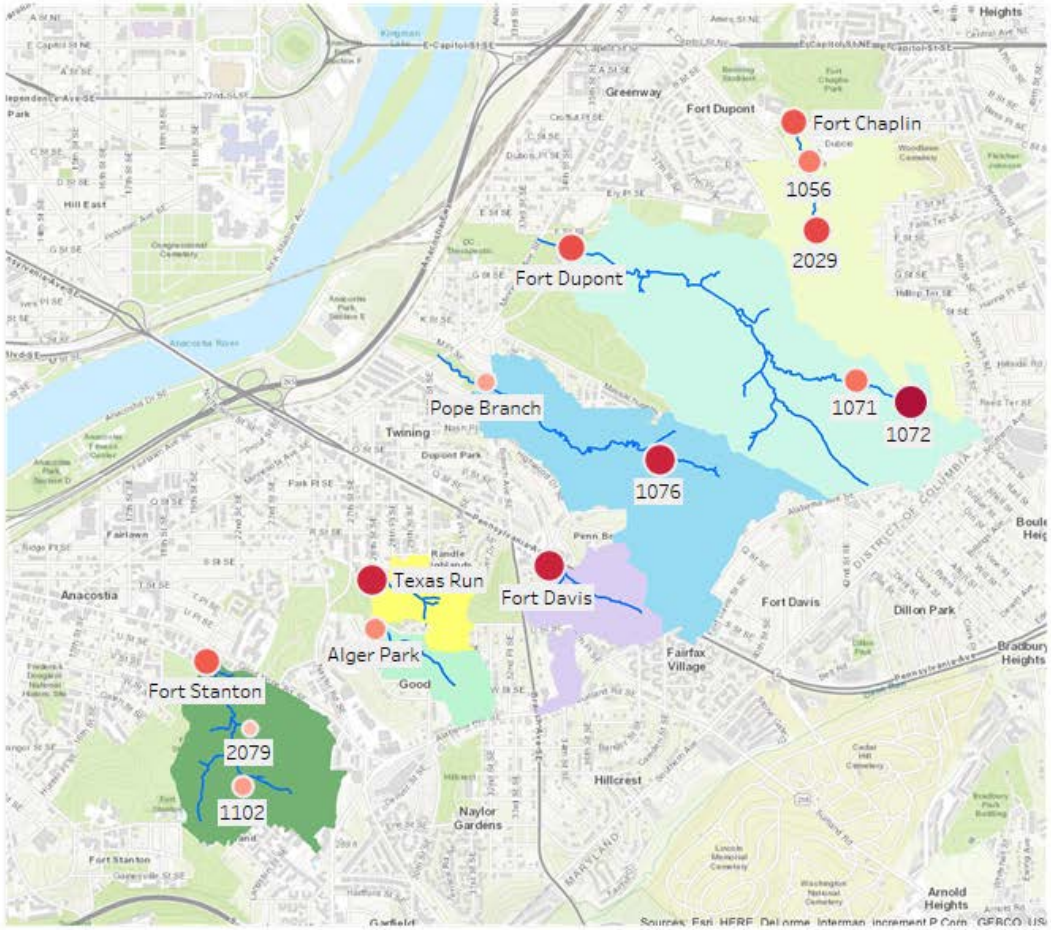
H_1: *E. coli* concentrations downstream of MS4 outfalls will be higher during wet weather compared to dry weather conditions

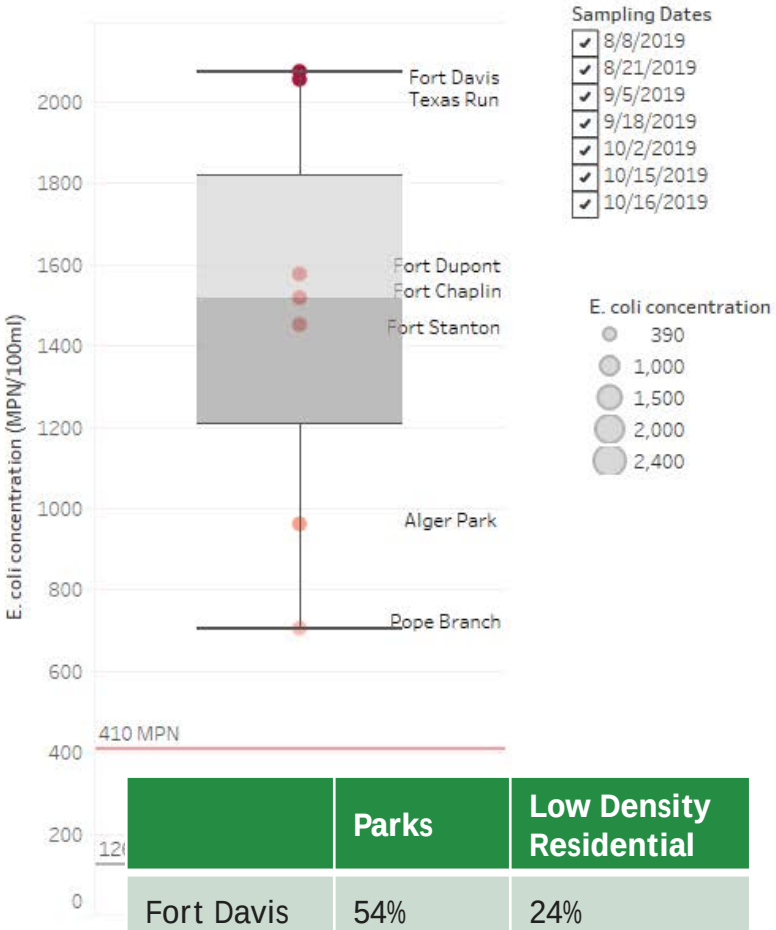
H_2: Human sources will be more prevalent during dry weather outfalls compared to wet weather

H_3: Non-human sources will be more prevalent during wet weather outfalls compared to dry weather conditions

H_4: Spatial and temporal trends will vary by pollution source and subwatershed land use practices

E. coli monitoring, 7 events

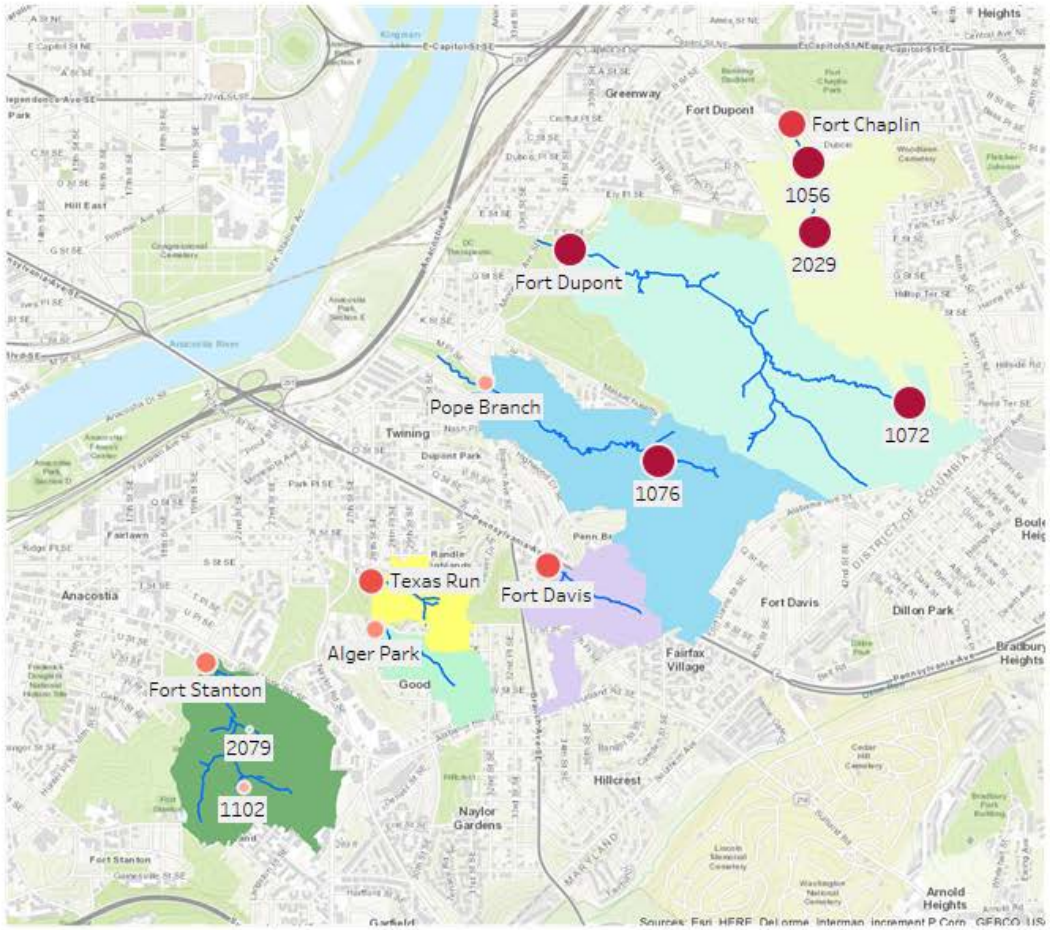


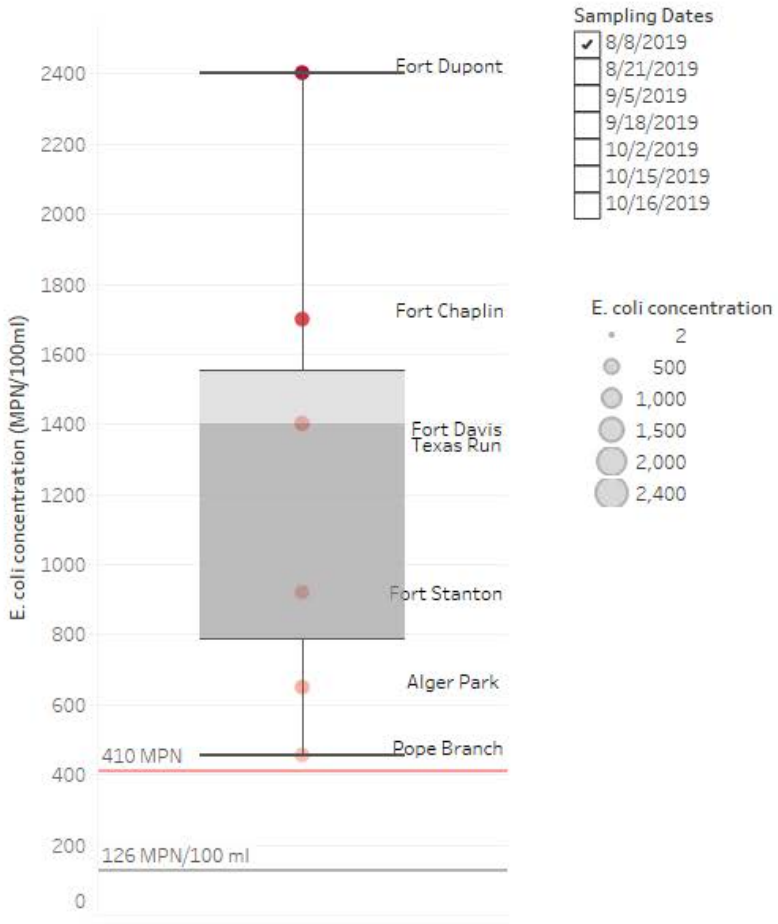


	Parks	Low Density Residential
Fort Davis	54%	24%
Texas Run	60%	18%

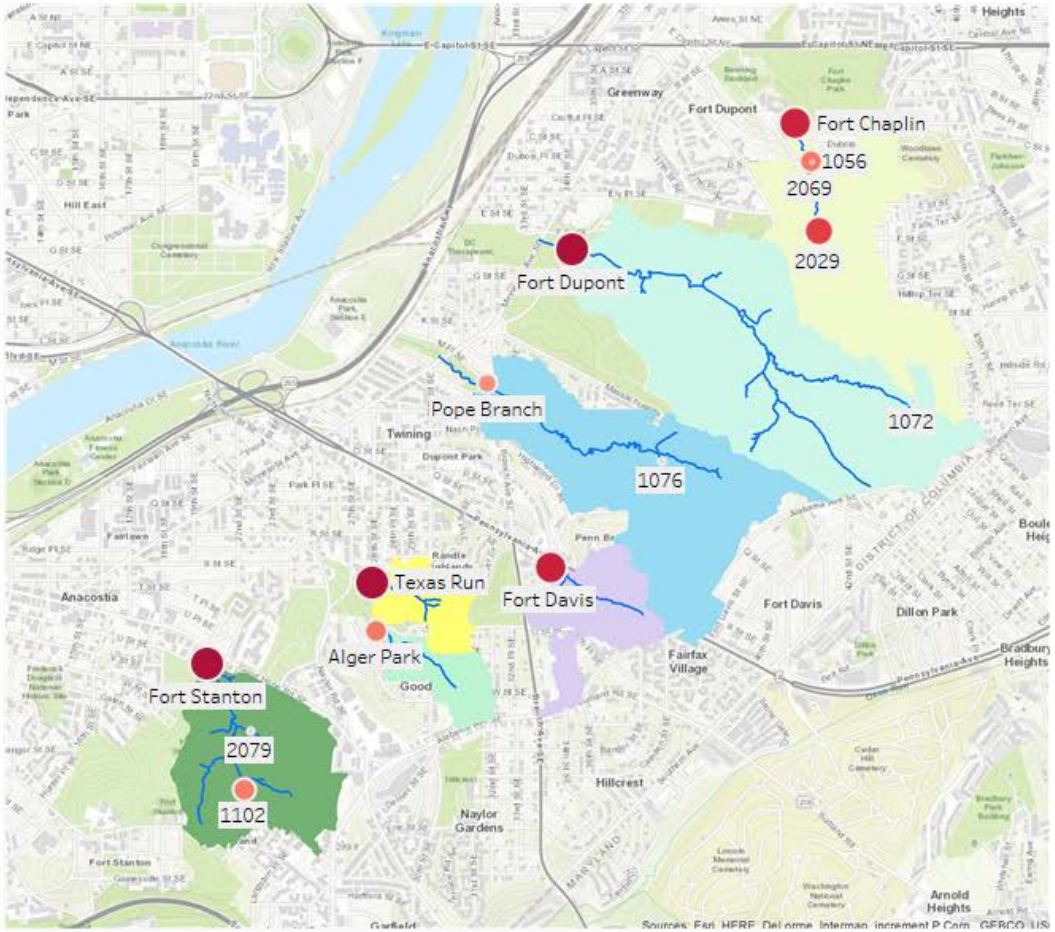
https://public.tableau.com/profile/amir.sharifi3095#!/vizhome/Graphs-mst/Dashboard2

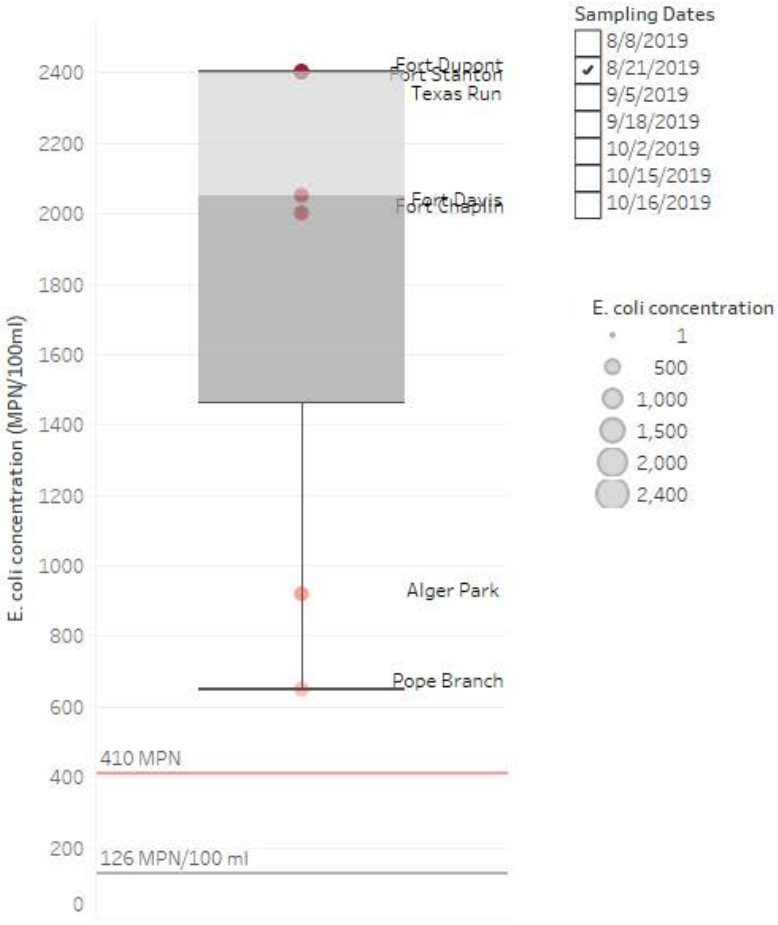
E. coli monitoring, 08-08-2019



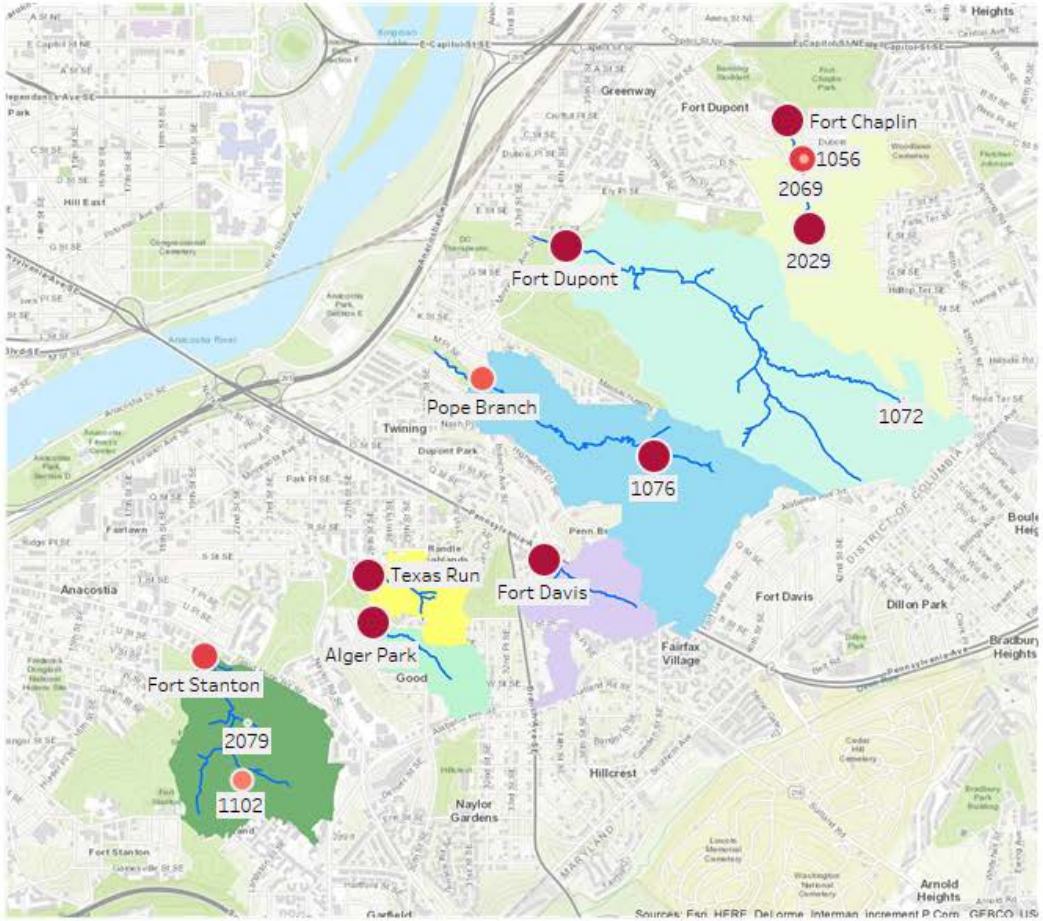


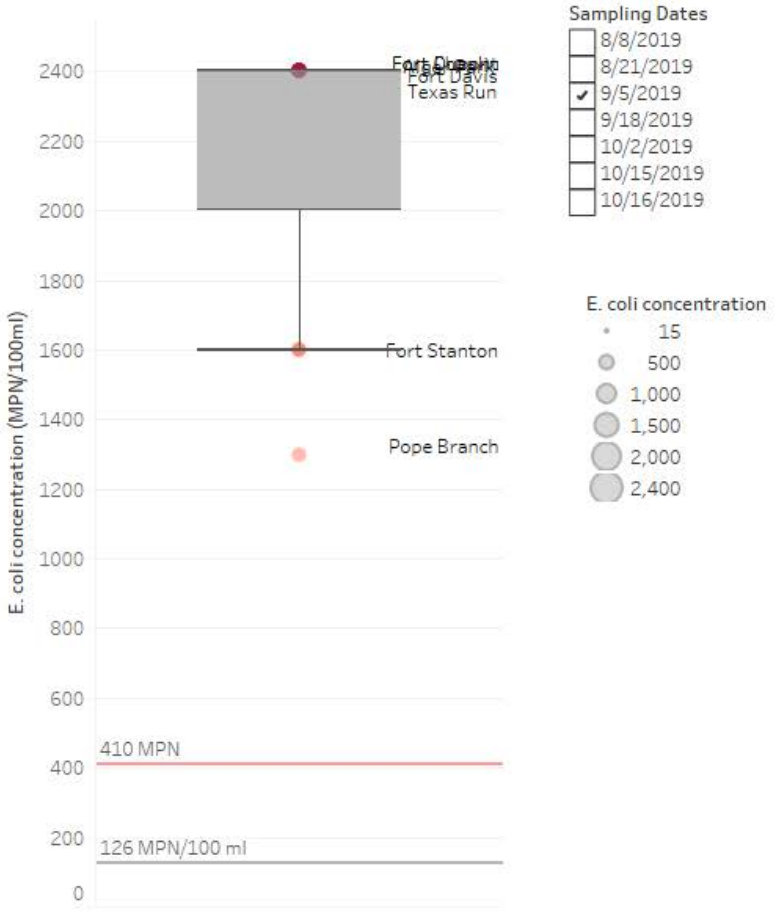
E. coli monitoring, 08-21-19



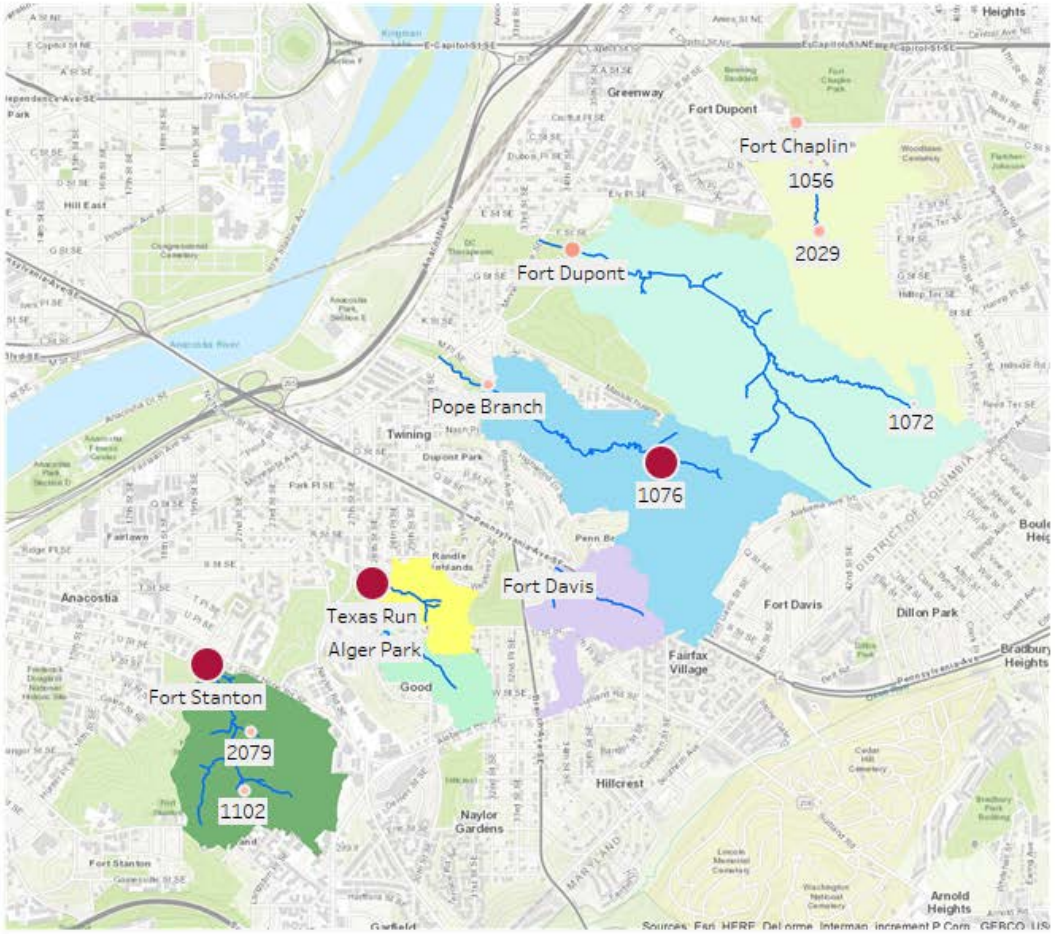


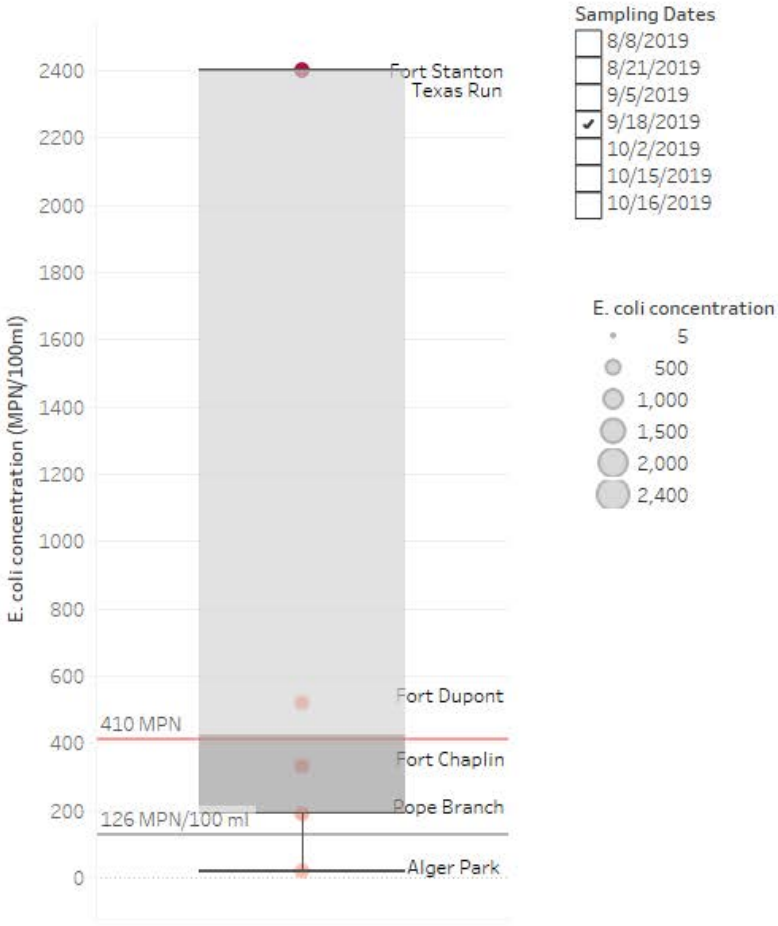
E. coli monitoring, 09-05-2019



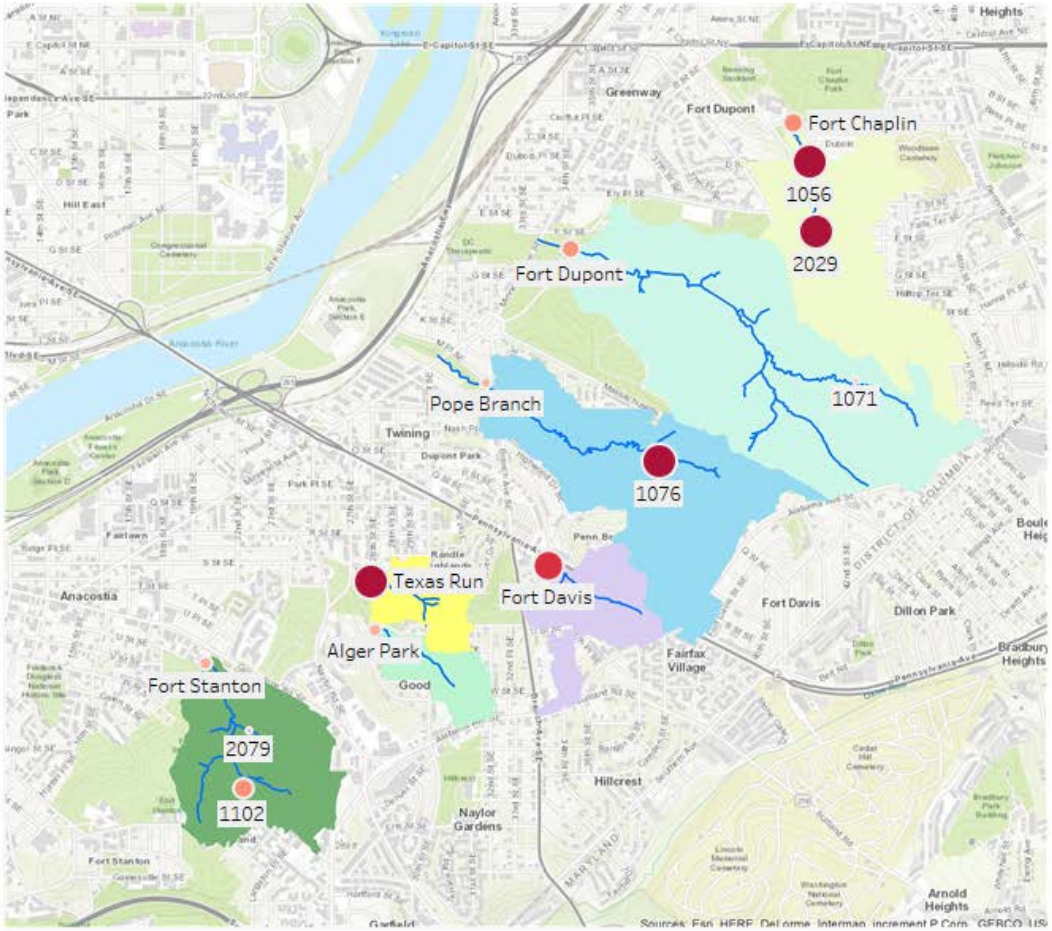


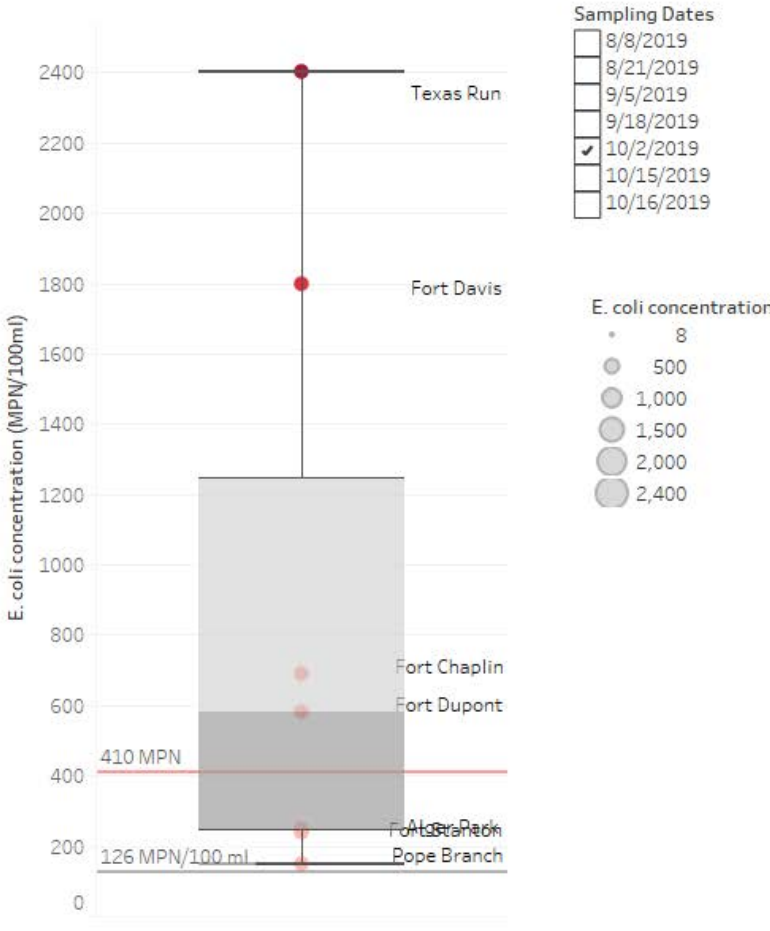
E. coli monitoring, 09-18-19



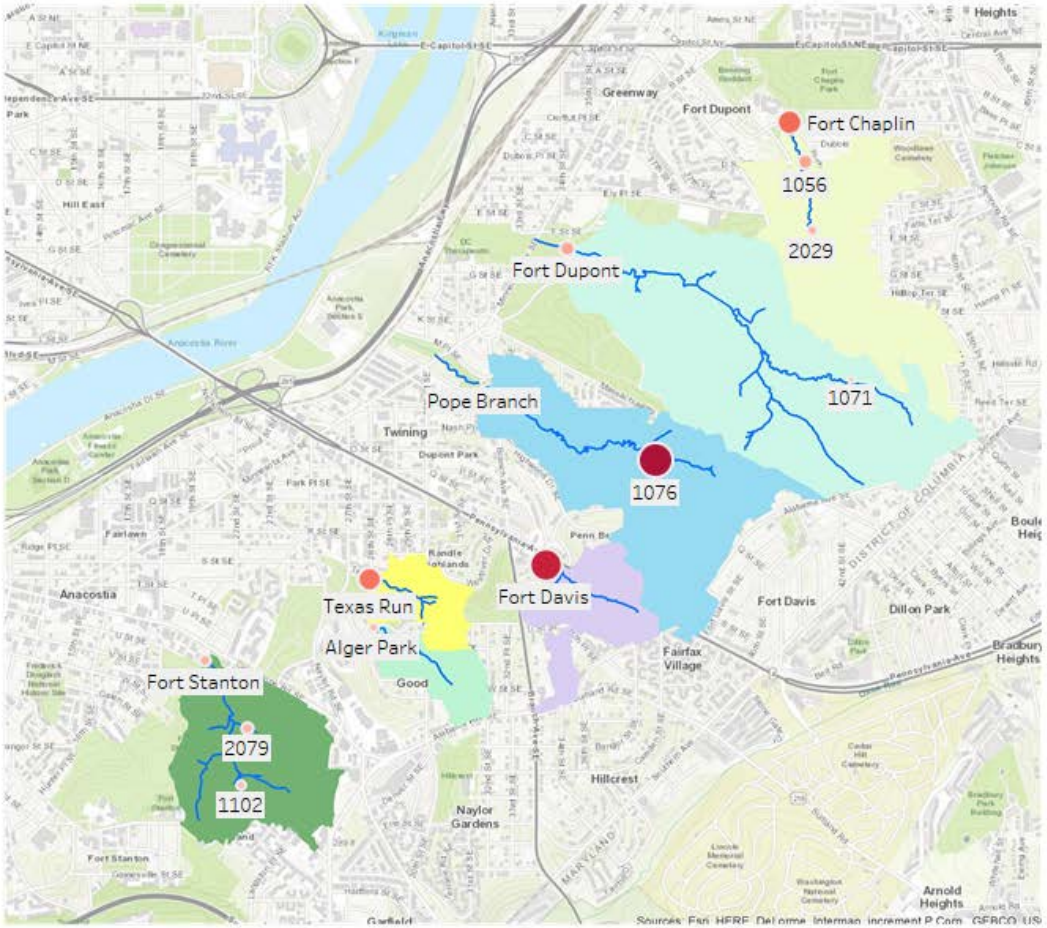


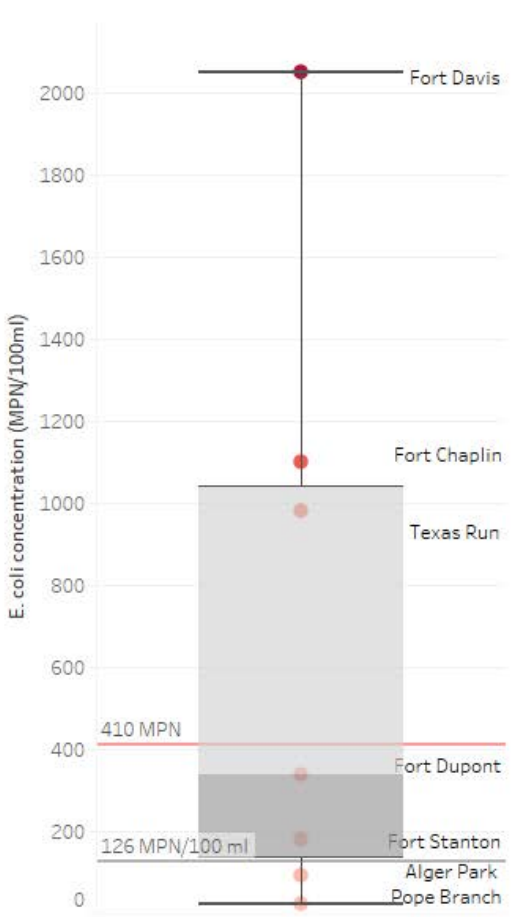
E. coli monitoring, 10-02-19

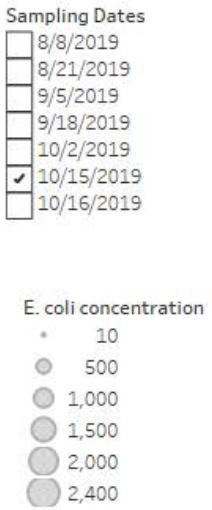




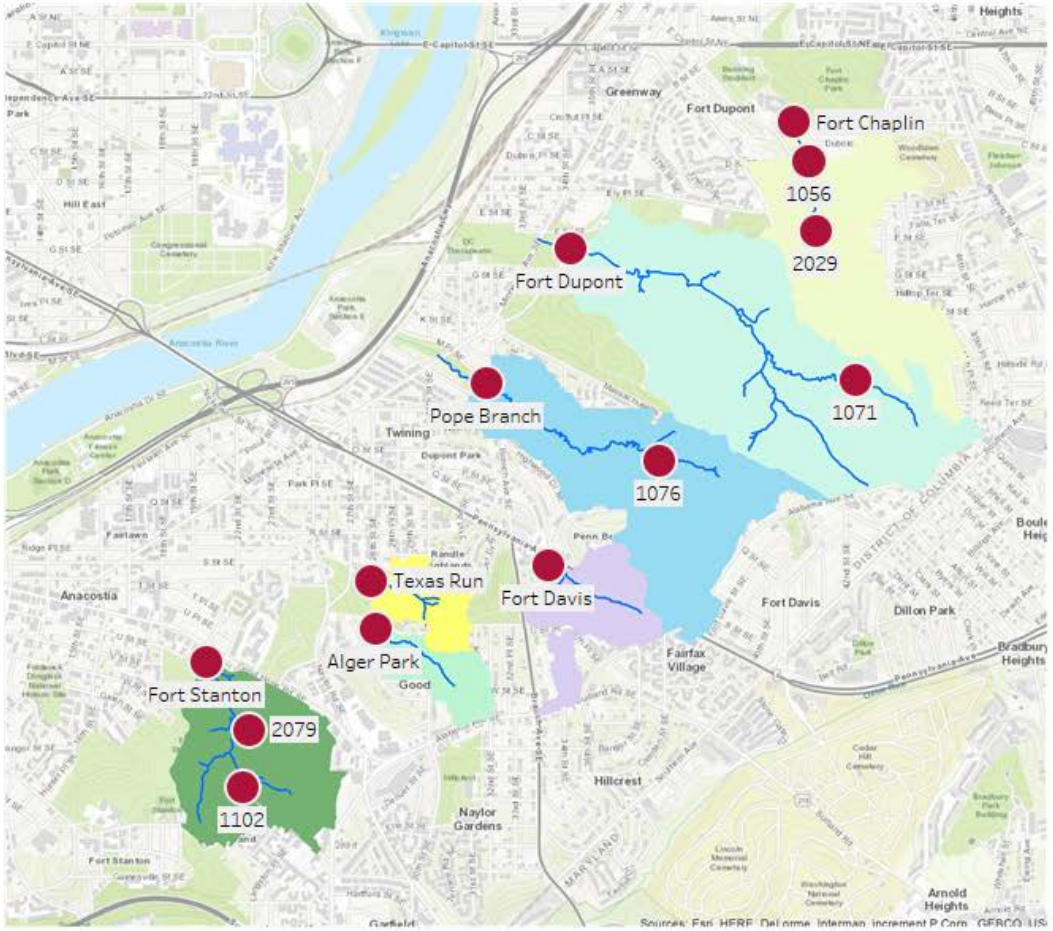
10-15-19

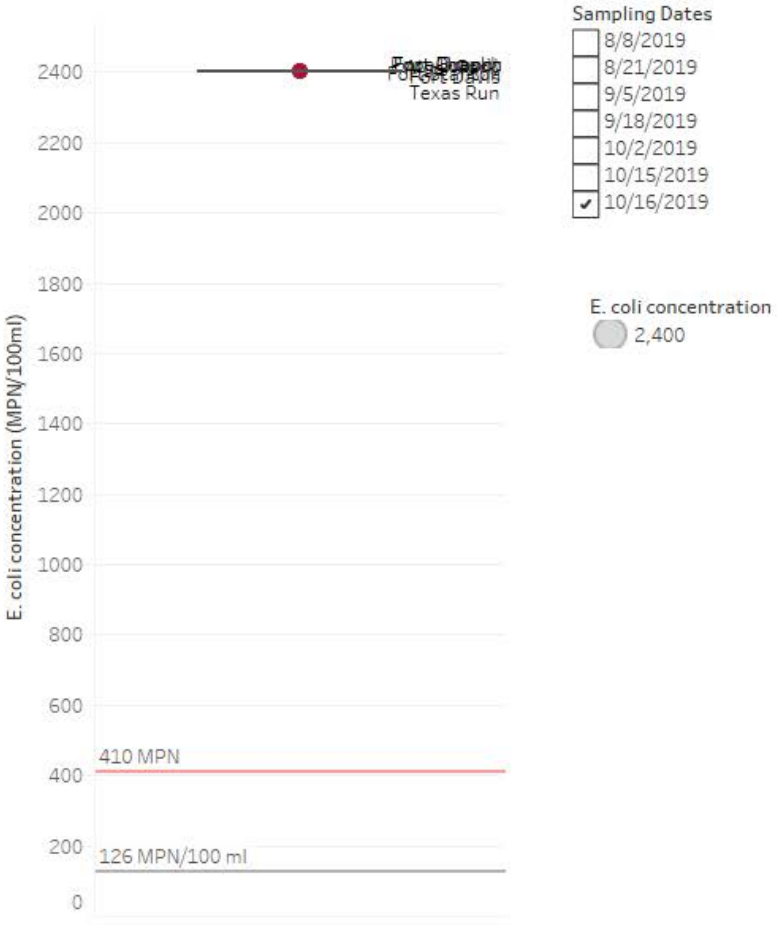

Fort Chaplin
1056
2029
Fort Dupont
1071
Pope Branch
1076
Texas Run
Fort Davis
Alger Park
Fort Stanton
2079
1102
Anacostia
Fairlawn
Greenway
Hill East
Twining
Dupont Park
Randle Highlands
Good
Fairfax Village
Dillon Park
Hillcrest
Naylor Gardens
Arnold Heights
Bradbury Heights
Garfield


E. coli concentration (MPN/100ml)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
410 MPN
126 MPN/100 ml
Fort Davis
Fort Chaplin
Texas Run
Fort Dupont
Fort Stanton
Alger Park
Pope Branch


Sampling Dates
8/8/2019
8/21/2019
9/5/2019
9/18/2019
10/2/2019
10/15/2019
10/16/2019
E. coli concentration
10
500
1,000
1,500
2,000
2,400

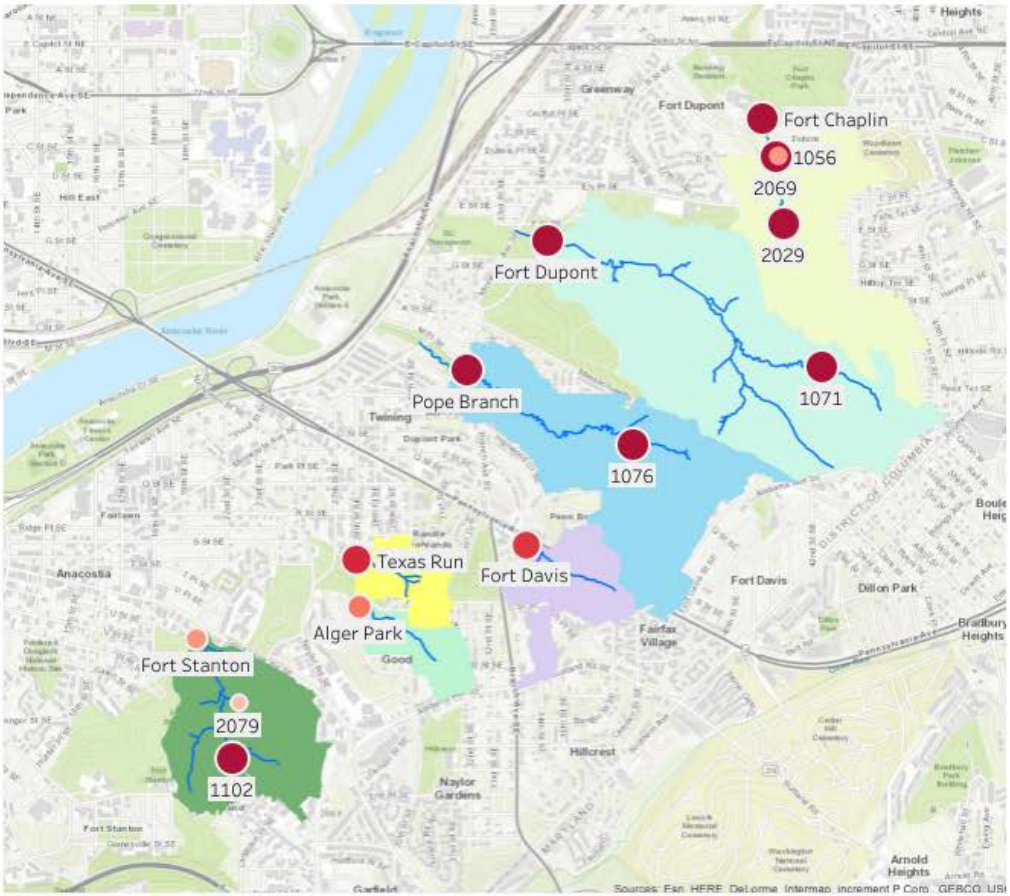
E. coli monitoring, 10-16-19 (wet weather event)

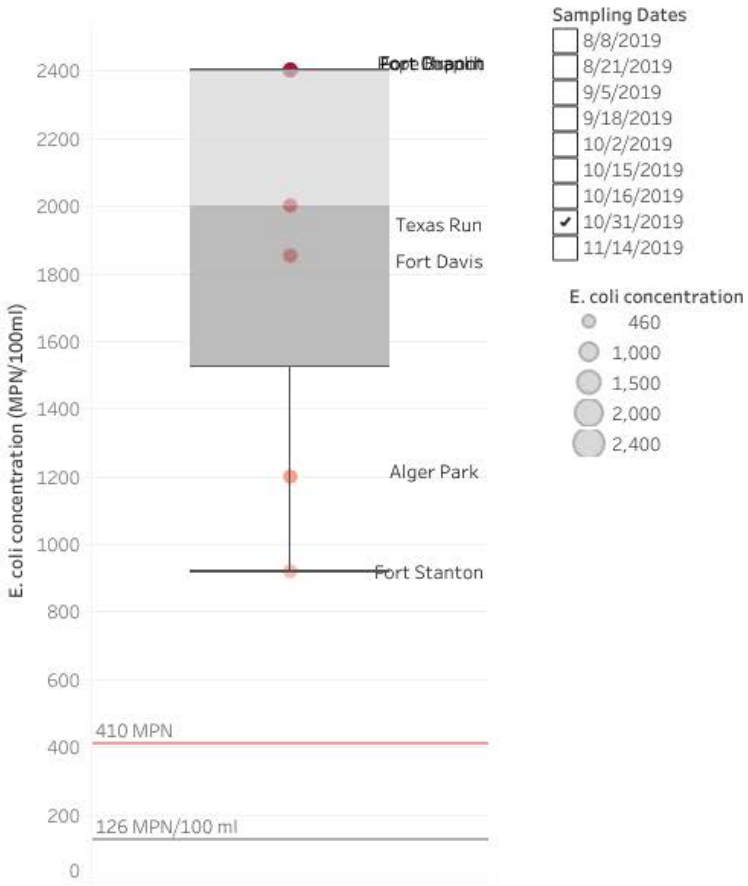




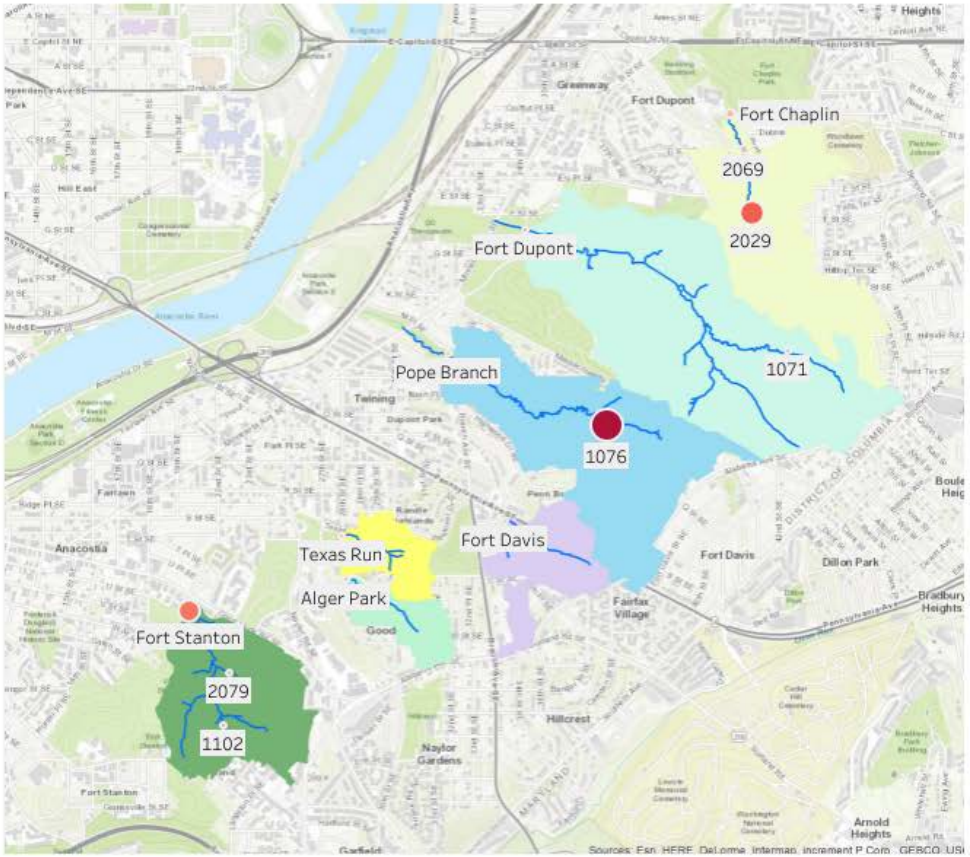
1.35” total rainfall

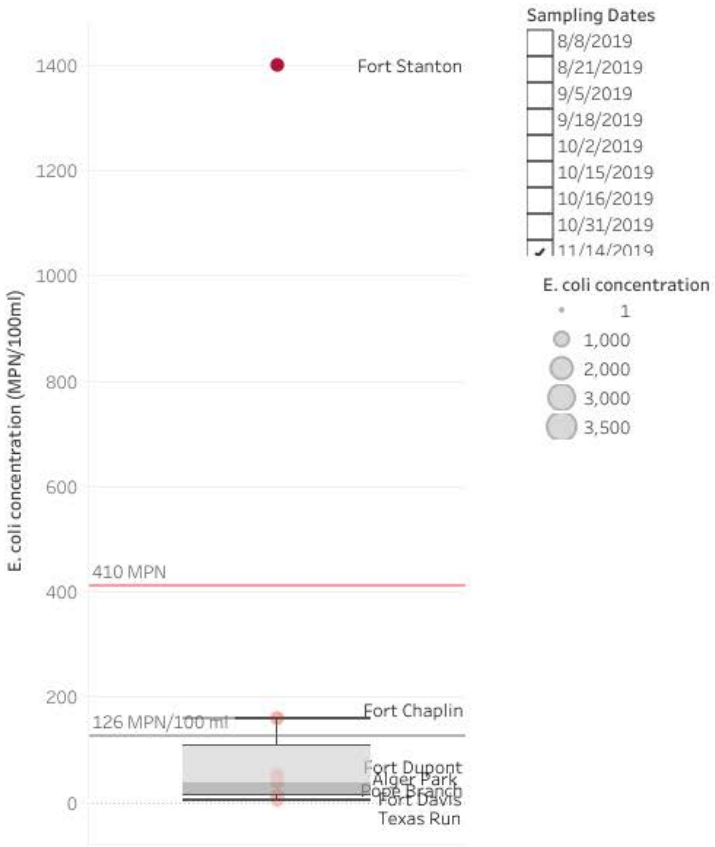
E. coli monitoring, 10-31-19





E. coli monitoring, 11-14-19

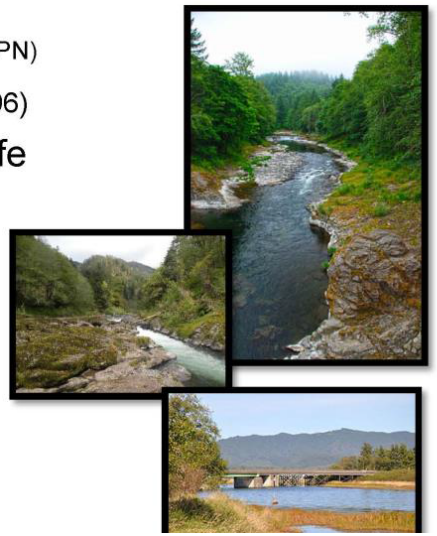




Case Study: Tillamook Basin, OR

Goal: Identification of fecal pollution source spatial and temporal trends contributing to water impairment

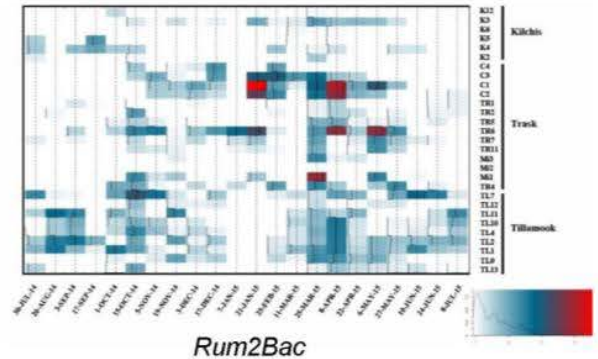
- 29 sites in Tillamook Basin, OR
- Chronic water quality impairment (*E. coli* MPN)
- Bimonthly sampling for 12-months (n = 696)
- Urban, residential, agricultural and wildlife pollution sources
- Land use high resolution mapping
- 8 MST qPCR assays
- Partners
  - EPA Region 10 Laboratory
  - Oregon Department of Agriculture
  - Oregon Department of Environmental Quality
  - Tillamook Estuaries Partnership



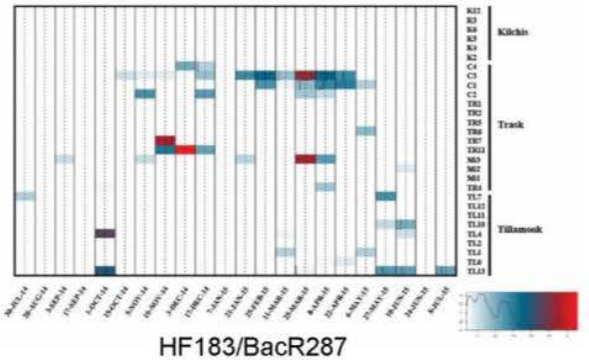
Applied **human-associated** qPCR methods (HF183/BacR287 and HumM2), along with procedures for **ruminant** (Rum2Bac), **cattle** (CowM2 and CowM3), **canine** (DG3 and DG37), and **avian** (GFD) fecal pollution sources to characterize trends in fecal pollution sources in the research area.

Li X, Sivaganesan M, KeltyCA, Zimmer-FaustA, ClintonP, ReichmanJR, et al. (2019)Large-scaleimplementationof standardizedquantitative real-timePCR fecal sourceidentificationprocedures in the TillamookBayWatershed.PLoSONE 14(6):e0216827.https://doi.org/10.1371/journal.pone.0216827

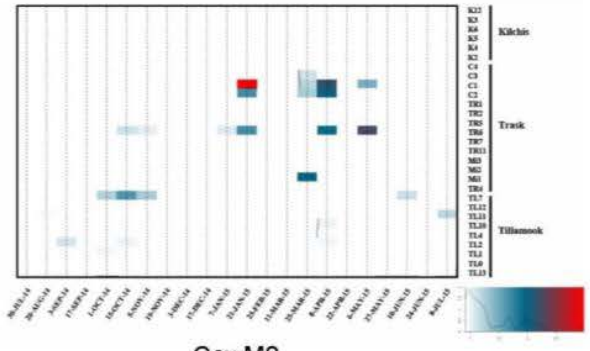
- Spatial trends
  - *Land use*
  - *Waste management practices*
- Temporal trends
  - *Weather conditions*
  - *Agricultural practices*
  - *Wildlife activities*
- Varies by assay



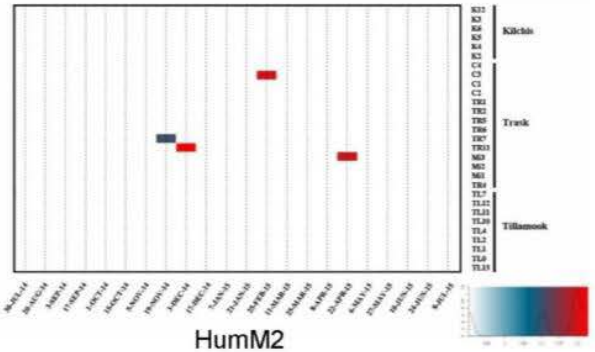
Rum2Bac



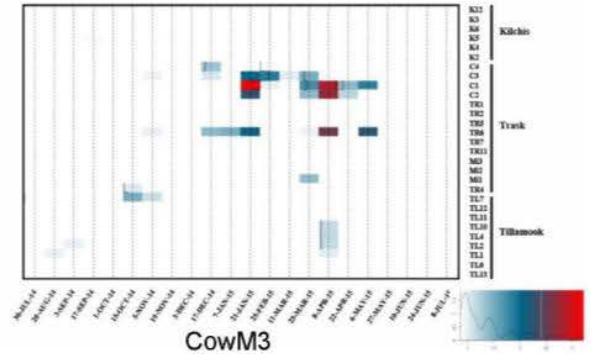
HF183/BacR287



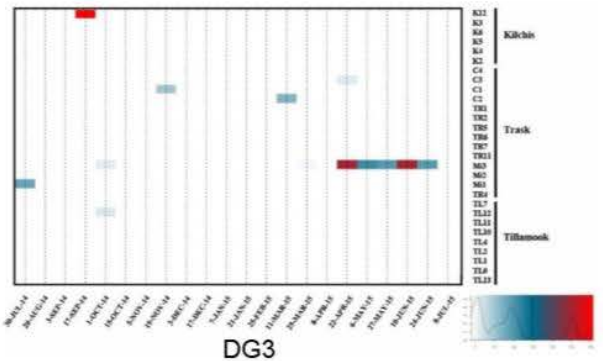
CowM2



HumM2

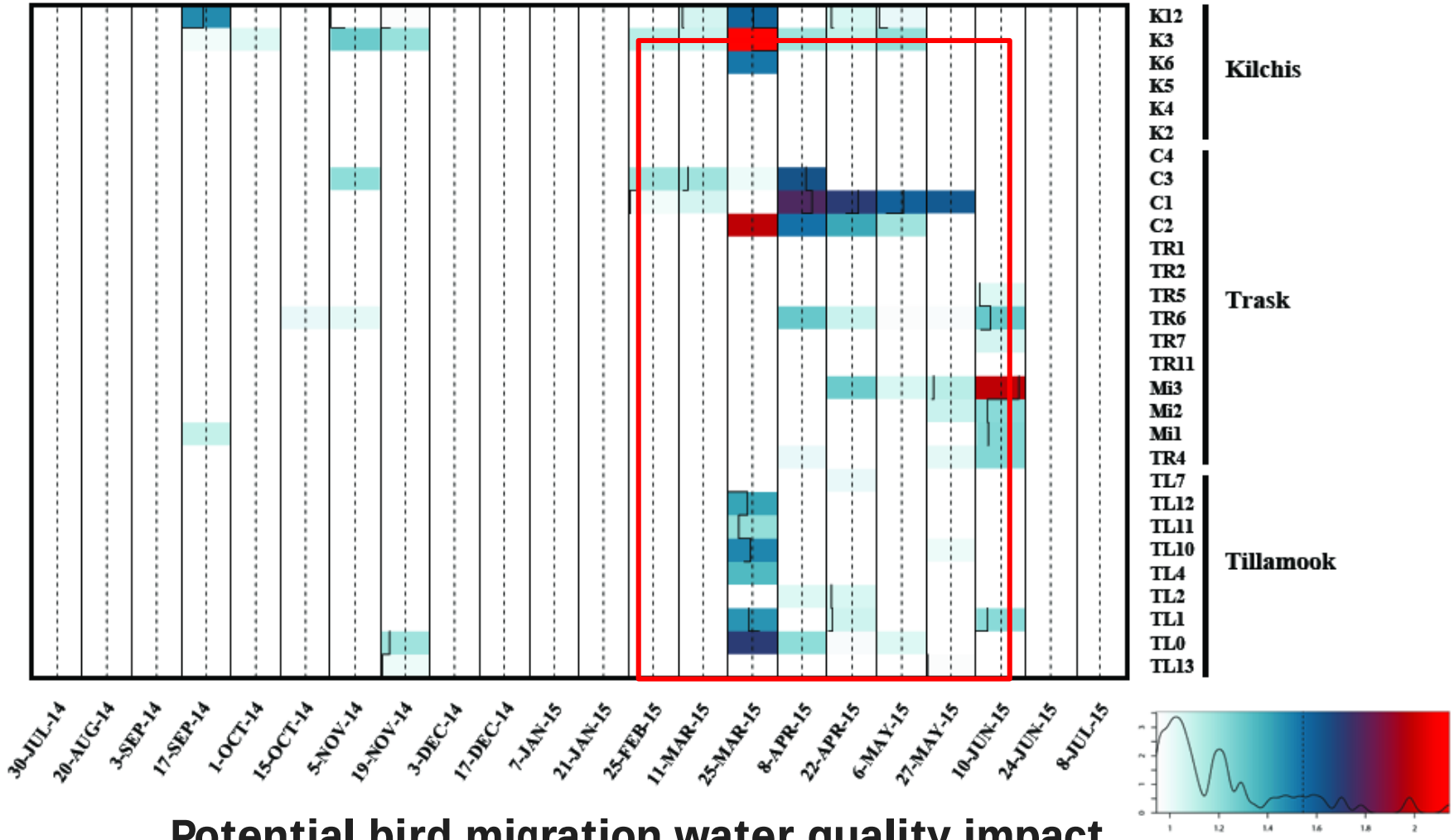


CowM3



DG3

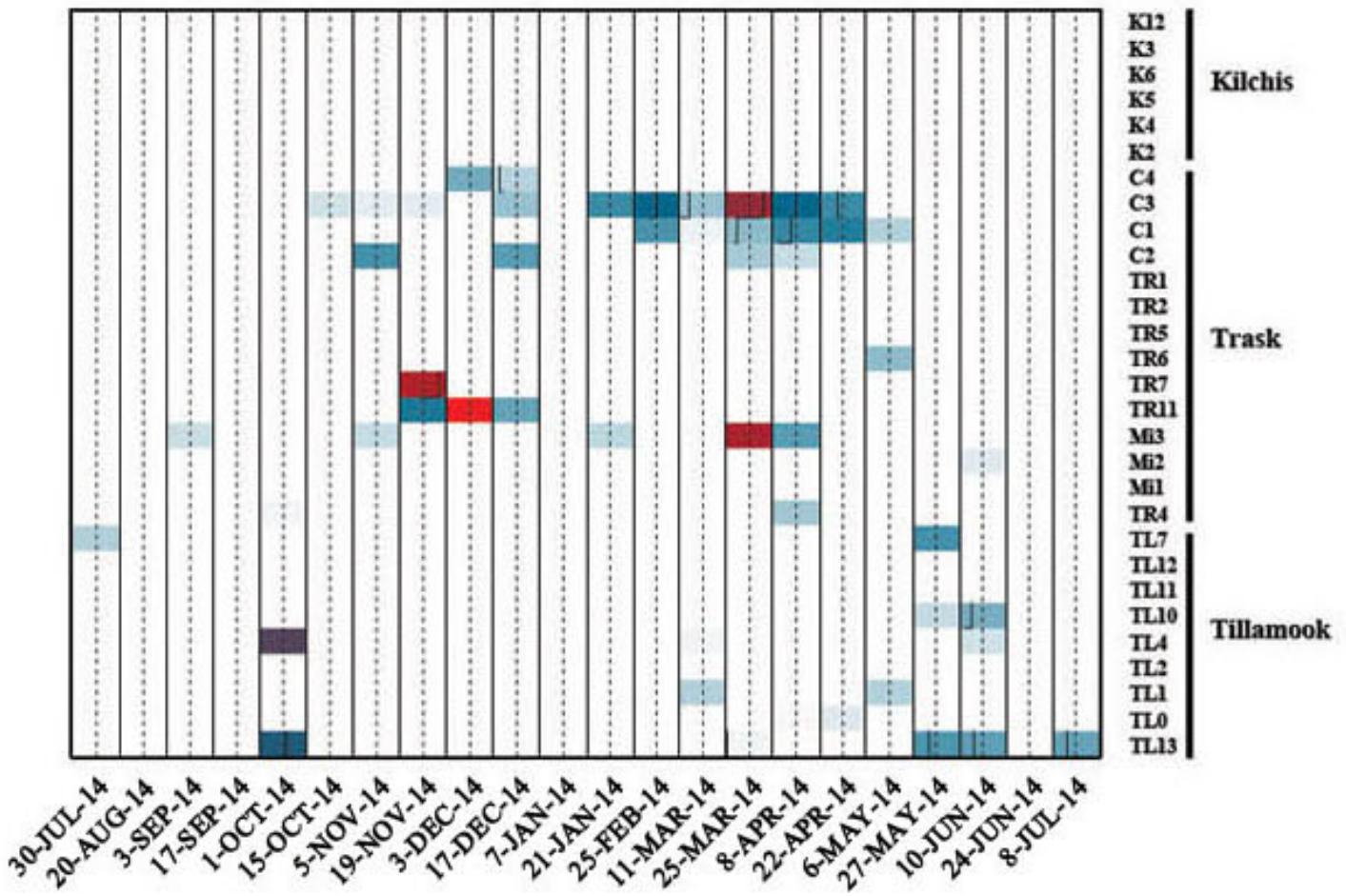
Avian Pollution Spatial and Temporal Trends



Potential bird migration water quality impact

Heat map: estimated $\log_{10}$ copies per reaction color coding and frequency information.

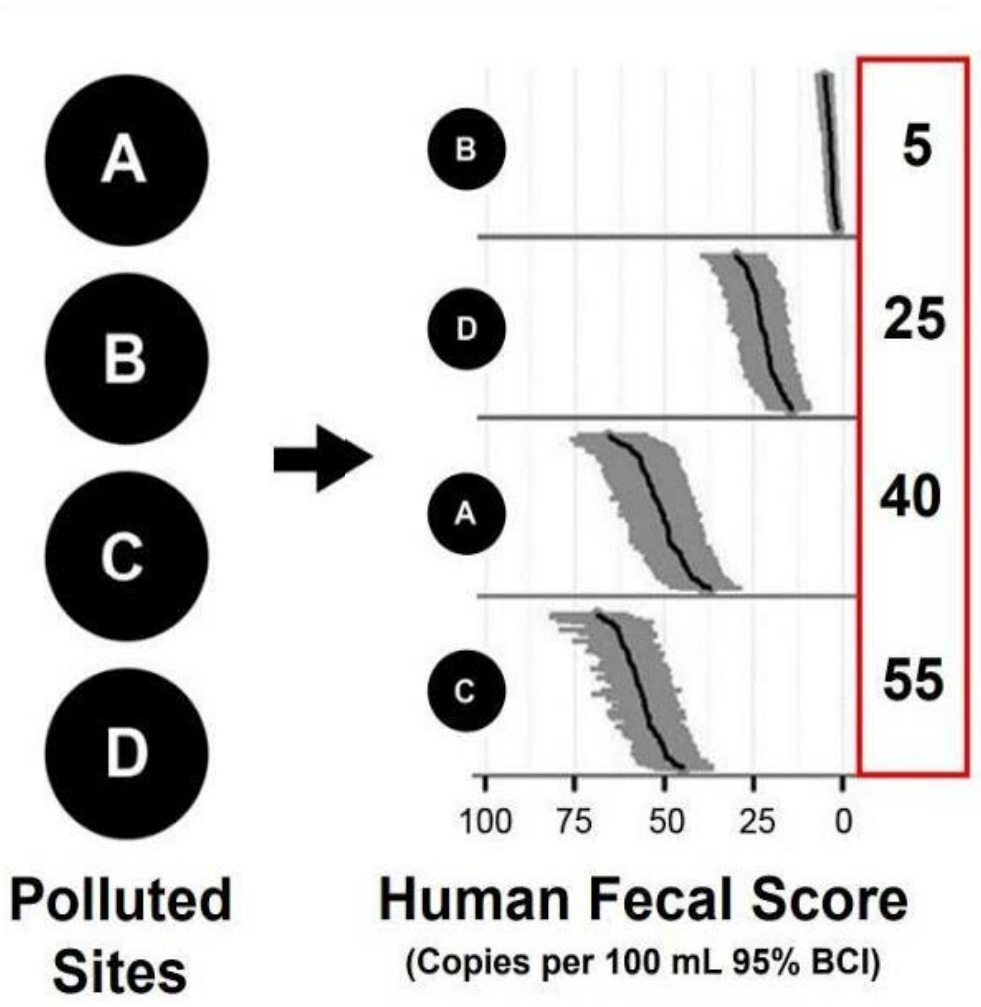
Human Pollution Spatial and Temporal Trends



River systems exhibit different temporal trends

Human Fecal Contamination Score (HFS)

Project Level Probabilistic Modeling that can be used to prioritize sampling sites for remediation based on measured human waste levels.



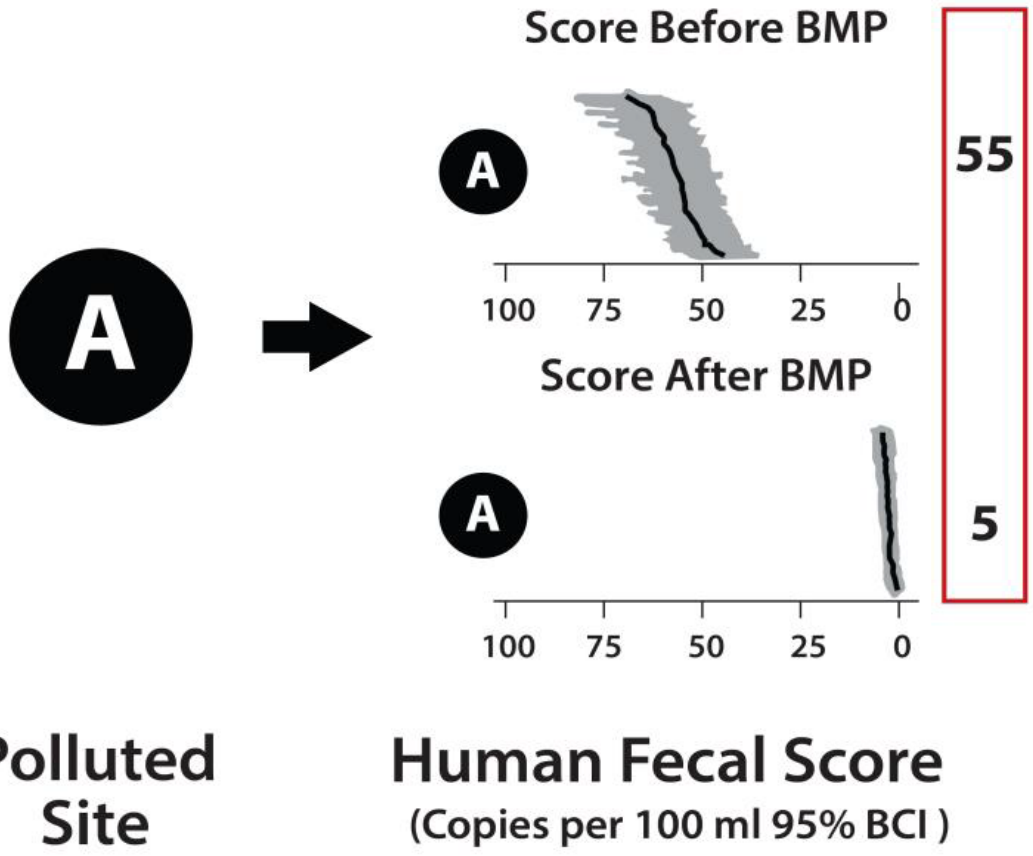
A human fecal contamination score for ranking recreational sites using the HF183/BacR287 quantitative real-time PCR method

Yiping Cao [a], Mano Sivaganesan [b], Catherine A. Kelty [b], Dan Wang [c], Alexandria B. Boehm [c], John F. Griffith [a], Stephen B. Weisberg [a], Orin C. Shanks [b,*]

[a] Southern California Coastal Water Research Project Authority, Costa Mesa, CA 92626, USA
[b] U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH 45268, USA
[c] Department of Civil and Environmental Engineering, Stanford University, Stanford CA 94305, USA

Human Fecal Contamination score (HFS)

BMP performance can assessed through HFS



Thank you for your attention!

GOVERNMENT OF THE DISTRICT OF COLUMBIA
DEPARTMENT OF ENERGY & ENVIRONMENT

Amir Sharifi, Ph.D.
Environmental Protection Specialist
Water Quality Division

1200 First Street NE, 5th Floor
Washington, DC 20002
doee.dc.gov

Office: (202) 671-5122
amirreza.sharifi@dc.gov