Tracking the Primary Sources of Fecal Pollution in the Recharge and Contributing Zones of Edwards Aquifer in Bexar County, TX using Molecular Tools

Vikram Kapoor, PhD

Drew Johnson, PhD, PE

Civil & Environmental Engineering

University of Texas at San Antonio

Project Overview/Scope

- The primary goal of this project is to **design and implement an efficient fecal source tracking and evaluation program for the Recharge and Contributing Zones of Edwards Aquifer in Bexar County, TX**.

Project Deliverables

- Monitoring datasets
- Identification of sources of fecal bacteria, including municipal waste/runoff and animal waste
- Resolution of spatiotemporal fecal input, including source identification, and factors that contribute to seasonable variability of microbial concentrations
- Public outreach, to include educational and outreach activities about non-point source pollution
- Publication of findings in scientific publications, and presentations at scientific meetings
- Incorporation of study results into UTSA Civil and Environmental Engineering Department undergraduate coursework

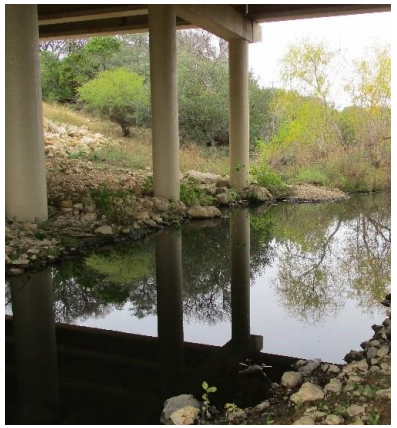
Questions Project Will Answer

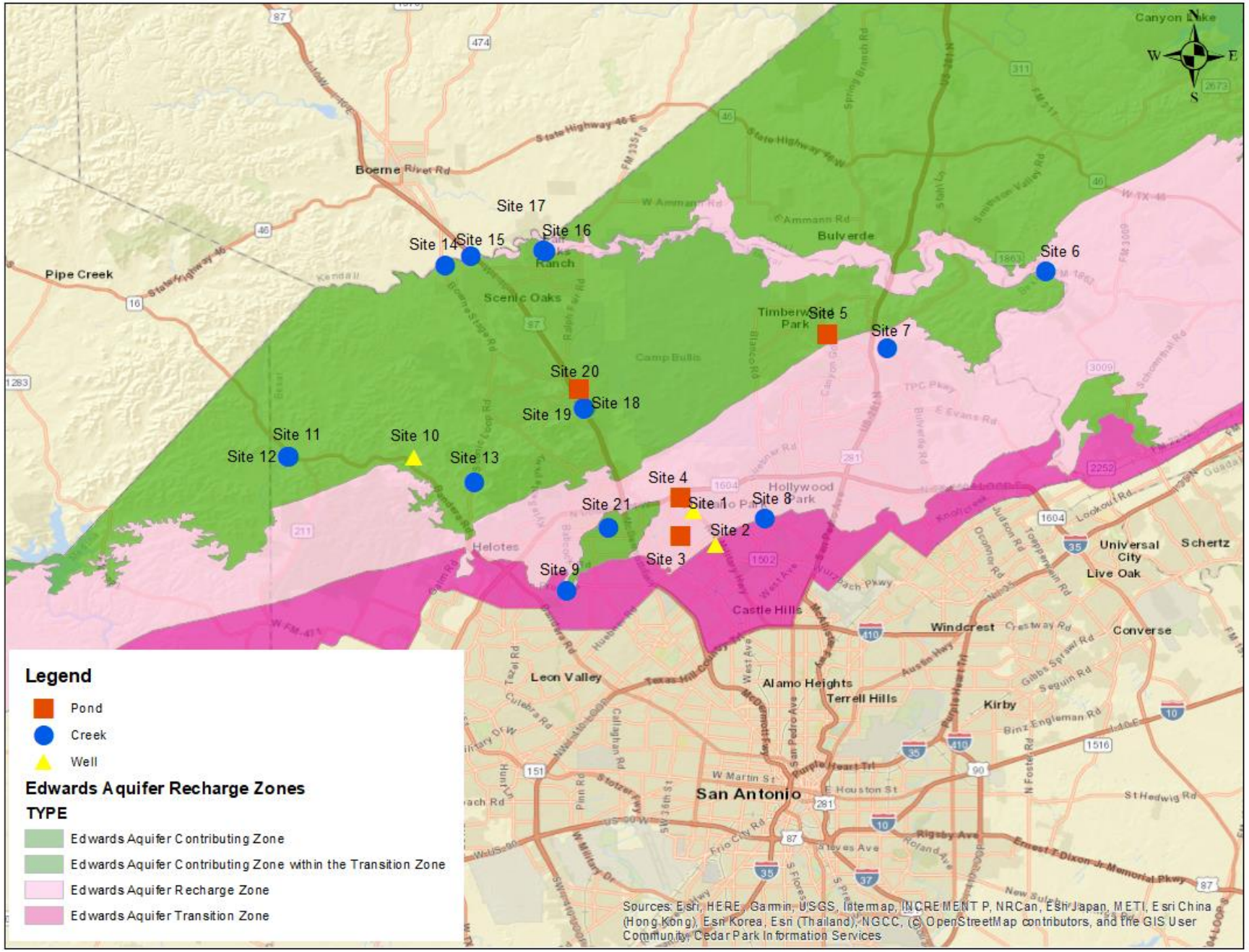
- What, if any, are the primary sources of human fecal pollution in the recharge and contributing zones of Edwards Aquifer in Bexar County, Texas?
- What, if any, are the primary sources of non-human fecal contamination (major animal sources) in the region?
- What, if any, are the different factors that contribute to fecal pollution of water entering the aquifer?
- What, if needed, are the types of BMPs that can be implemented to reduce the levels of fecal bacteria entering the aquifer’s water?

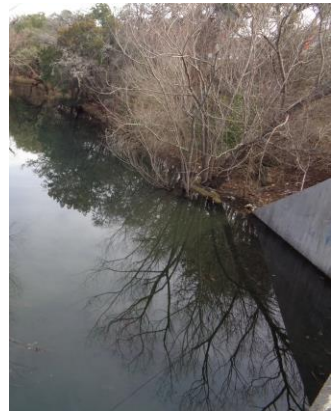
Project Cost: $692,452	2017		2018				2019				2020				2021			
Project Timeline	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Initial Materials and Disposables Purchasing																		
Sample Sites: GIS Map Synthesis, Site Identification, and Site Assessment																		
Begin Sample Collection																		
Begin DNA Extraction and PCR Optimization of Samples																		
Routine Sample Collection, DNA Extraction, and PCR																		
Test Water Quality Parameters																		
Full-day Storm Events Sample Collection																		
PCR and qPCR																		
Data Analysis and Dissemination of Results																		
Recommendations of BMPs and Public Outreach																		

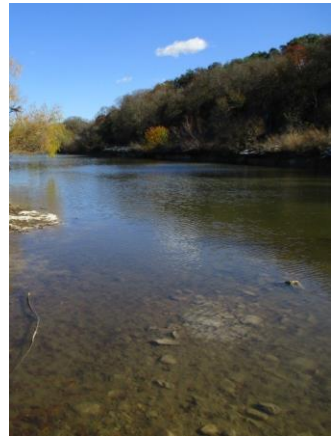
Methods

- Sampling
  - 20 sites – creeks, wells, and pond sites
  - Water samples collected bi-weekly over 27 months ($n \geq 1{,}200$)
  - Water quality parameters – pH, temperature, DO, nitrate/nitrite/ammonia
- qPCR
  - Filtration and DNA extraction
  - Eleven molecular markers – Universal Bacteroidales, *E. coli*, Enterococci, human (HF183 and BacHum), avian (Chicken/Duck-Bac and GFD), dog (BacCan), bovine (BacCow and Rum2Bac), swine (Pig-1-Bac), *E. coli* O157:H7
- Stormwater event-related sampling
  - Samples for before, during and after rain
  - 10 stormwater events at selected sites
  - Weather dependent




Site 17
Site 14
Site 15
Site 16
Site 6
Site 5
Site 7
Site 20
Site 18
Site 19
Site 11
Site 12
Site 10
Site 13
Site 4
Site 1
Site 8
Site 21
Site 2
Site 3
Site 9
Pipe Creek
Boerne River Rd
Scenic Oaks
Bulverde
Ranch
Timberwood Park
Camp Bullis
Helotes
Hollywood Park
Castle Hills
Windcrest
Converse
Universal City
Schertz
Live Oak
Leon Valley
Alamo Heights
Terrell Hills
Kirby
San Antonio
Canyon Lake
Legend
Pond
Creek
Well
Edwards Aquifer Recharge Zones
TYPE
Edwards Aquifer Contributing Zone
Edwards Aquifer Contributing Zone within the Transition Zone
Edwards Aquifer Recharge Zone
Edwards Aquifer Transition Zone
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community Cedar Park Information Services





Detection of markers at study sites

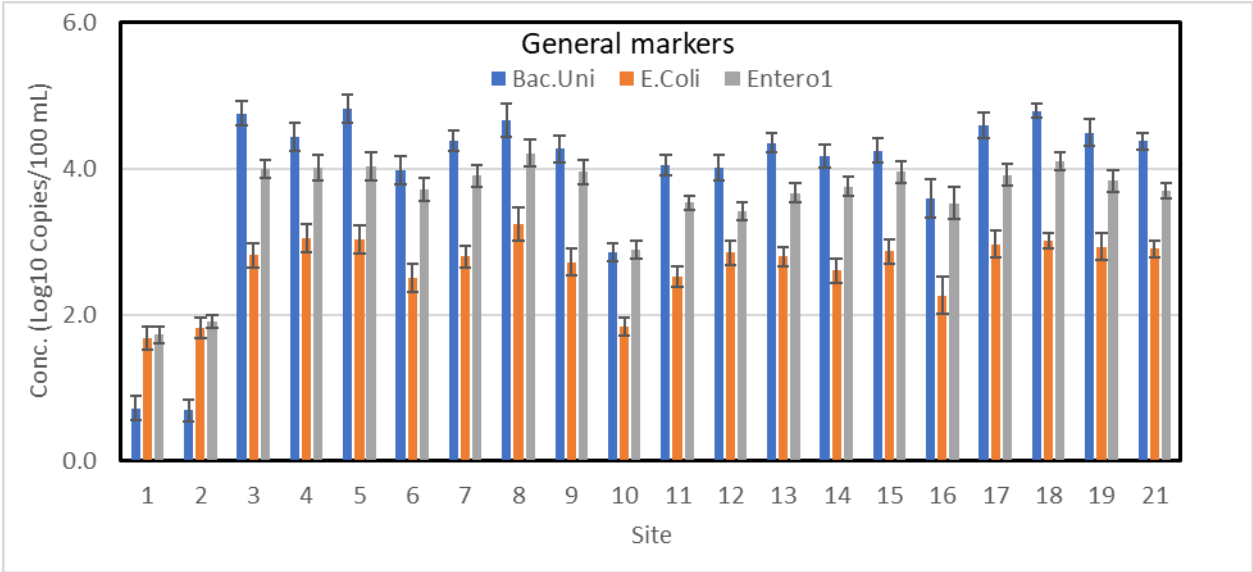
Site	% of tested water samples positive for marker										No. of samples tested
	BacUni	E. coli	Entero1	BacCow	BacCan	Chicken/Duck-Bac	Rum2Bac	GFD	HF183	BacHum	
1	40	83	90	19	17	6	67	29	2	0	48
2	38	87	94	15	23	2	68	13	2	6	53
3	96	93	100	66	55	59	66	91	9	14	56
4	93	95	96	71	58	64	67	95	2	13	55
5	95	96	96	87	78	80	69	91	7	7	55
6	93	94	98	50	33	19	67	91	9	9	54
7	98	95	100	66	38	11	73	98	18	23	56
8	93	93	96	61	48	33	61	83	30	39	54
9	94	96	98	56	39	17	69	93	19	19	54
10	96	86	100	20	22	4	64	86	2	4	50
11	98	98	100	58	13	9	66	96	8	15	53
12	94	98	100	67	42	33	65	94	12	15	52
13	98	96	100	65	36	20	67	95	29	44	55
14	94	100	98	50	30	15	69	94	4	9	54
15	96	100	100	57	36	15	62	98	11	19	53
16	81	84	89	42	35	35	60	82	9	9	57
17	94	98	98	78	43	33	74	94	22	24	54
18	100	100	100	70	56	56	72	96	13	20	54
19	93	96	96	63	52	36	70	91	25	27	56
21	100	100	100	46	41	11	63	94	11	17	54

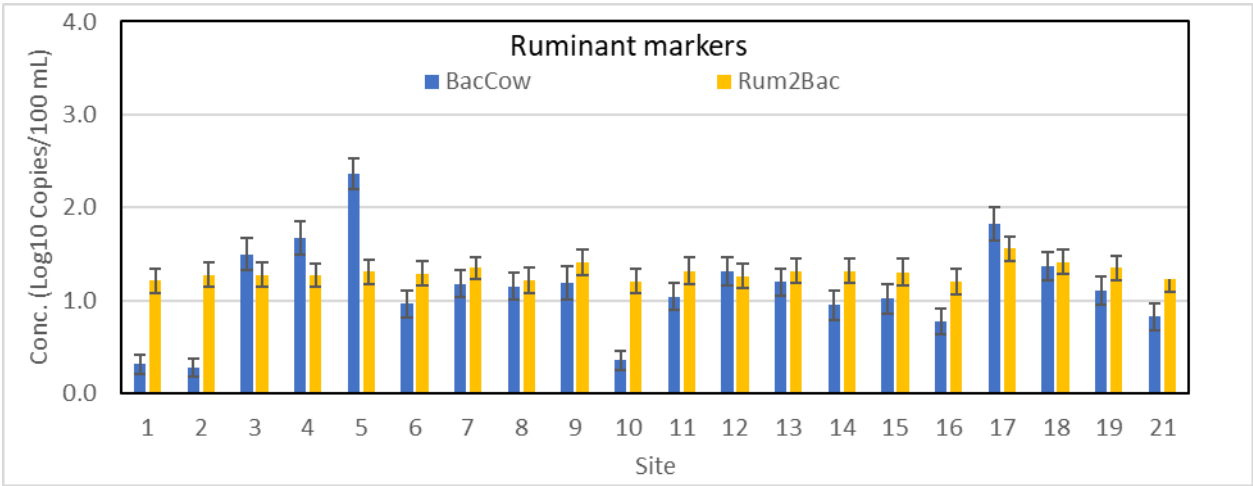
Results

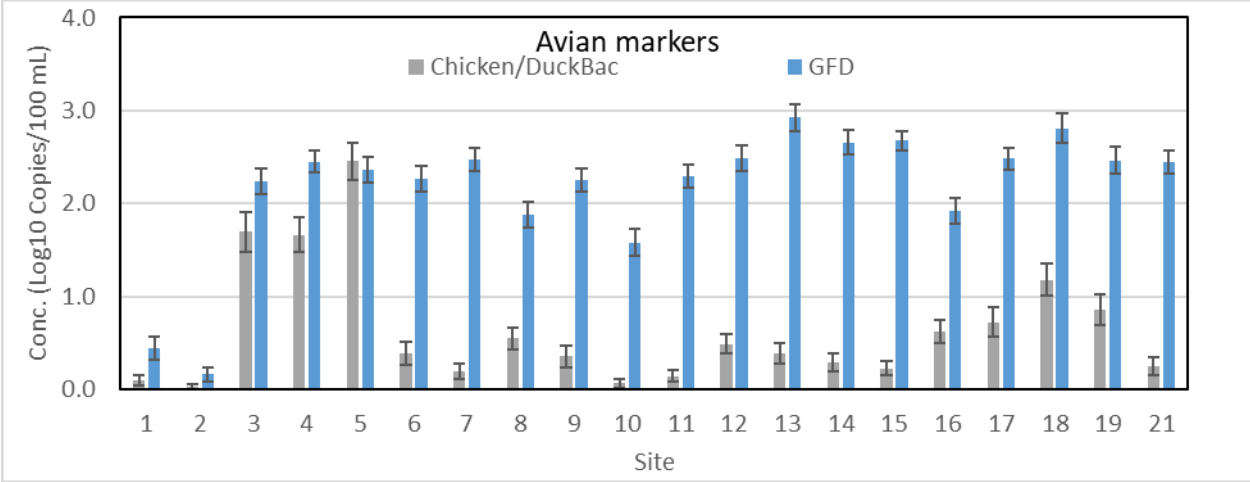
The predominant sources of fecal contamination identified in the Edwards Aquifer study area were, in ranked decreasing order of presence:

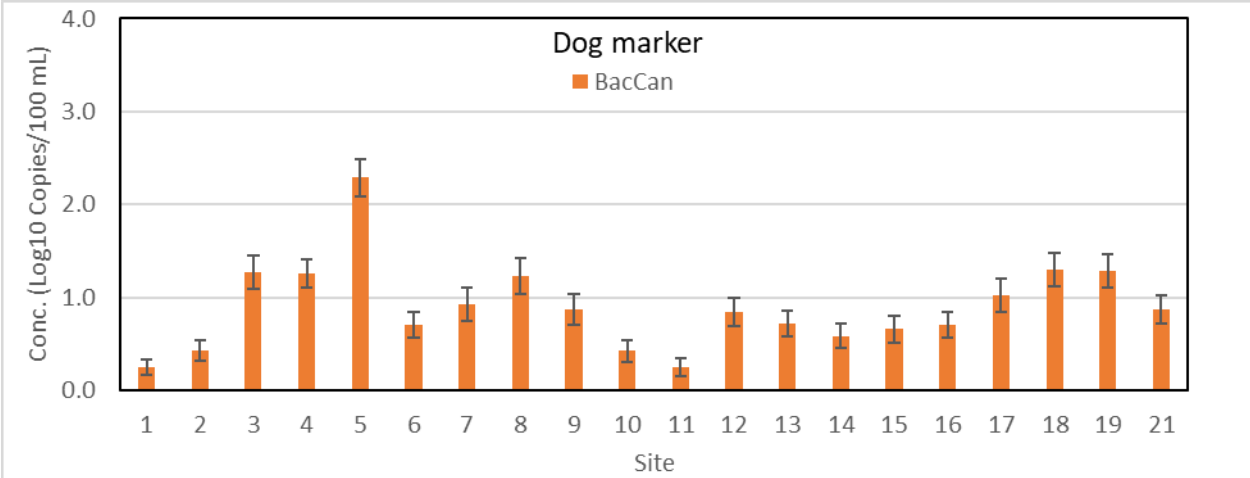
- avian including gull, ducks etc. (85%)
- ruminant including cattle and deer (67%)
- dog (40%)
- human-derived (17%)

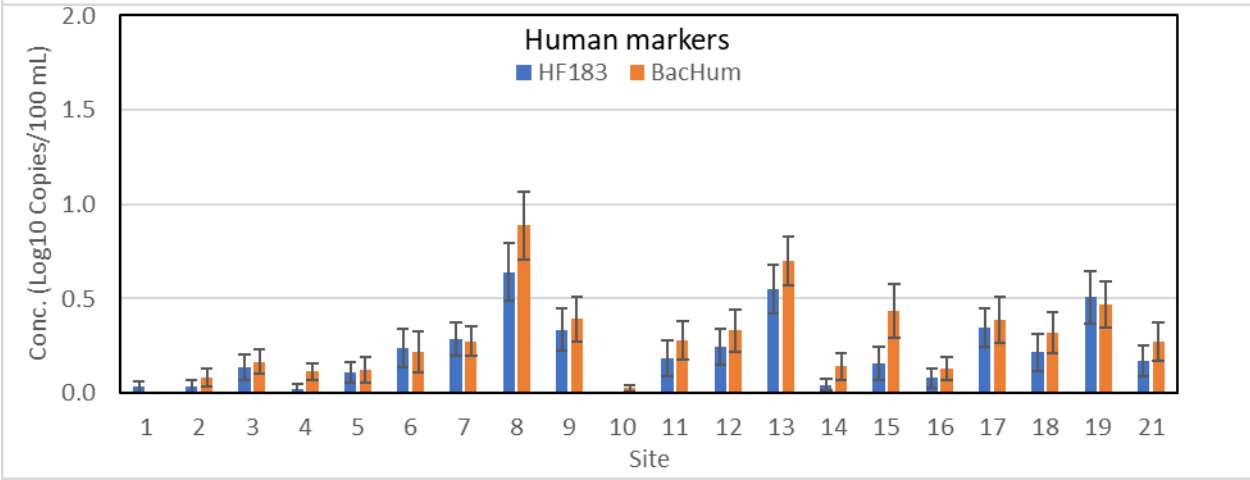
Spatial variation of markers











Results

- Highest fecal bacterial levels based on general markers were observed for sites 5 and 18.
  - Site 5 is a pond site in the contributing zone nearby a densely populated subdivision while site 18 is on Leon Creek in the contributing zone located next to Interstate-10.
- Lowest fecal bacterial levels were observed for well water sites (Sites 1, 2 and 10) indicating that the natural biogeochemical processes are somewhat effective in decreasing the concentrations of surface-derived microbial contaminants in the groundwater.

Results

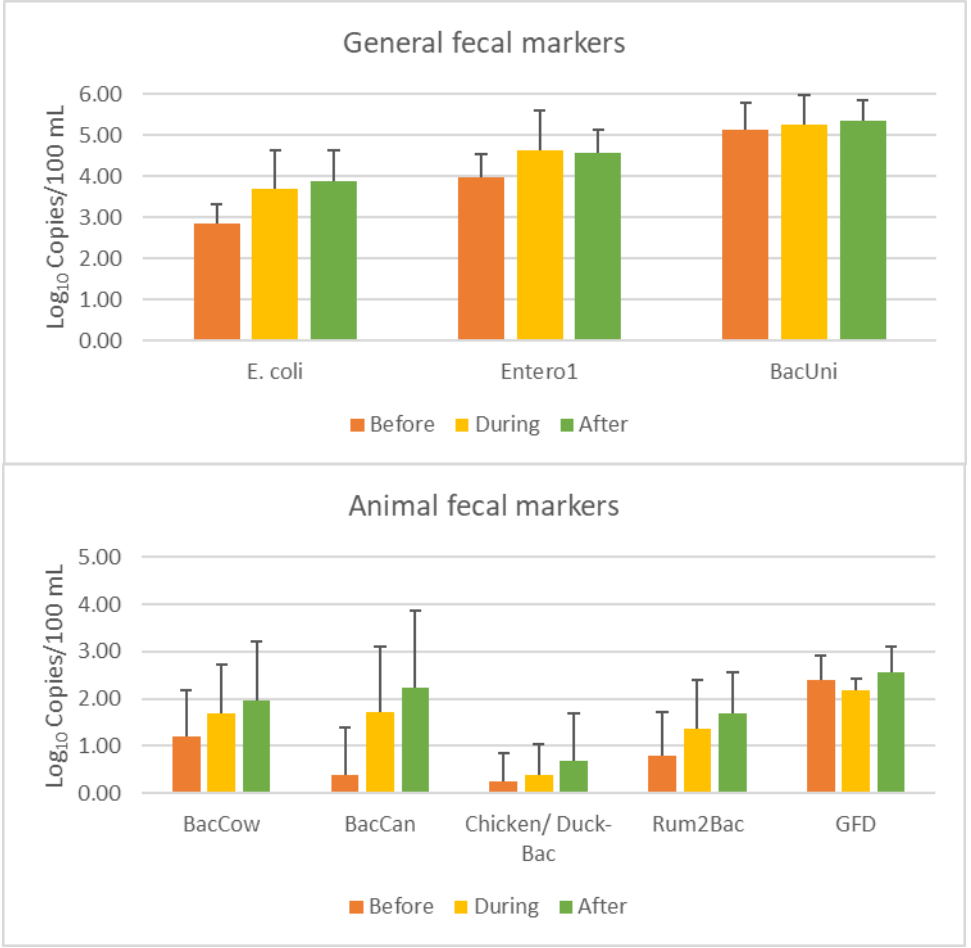
- The concentrations of the GFD genetic marker were relatively higher at all surface water sites (except for well sites) suggesting that bird fecal pollution is a major source of concern for Edwards Aquifer.
- The Chicken/Duck-Bac marker was consistently higher in the pond sites as compared to creek sites.
- The cow/ruminant marker concentrations were higher for Balcones Creek sites due to farms and ranches in the area.
- Higher levels of canine-derived contamination was observed for pond sites near residential areas and Leon Creek sites.

Results

- Human-associated markers were detected mostly at surface water sites near densely populated urban areas and/or rural areas with high septic tank density, suggesting that their presence is the result of larger human population served by septic tanks or sewer infrastructure.
- Absence of pathogenic *E. coli* O157:H7 from the water samples collected from all the sampling sites.
- Negligible levels of swine marker in the study area (discontinued after first year).

Effect of stormwater

- 13 storm event-related samples
- Increase in concentration for most fecal markers after the rain
- BacCan showed highest concentration difference
- Storm events can significantly increase fecal pollution in the water bodies over the Edwards Aquifer



Public outreach

- Lab exhibits for high school students showcasing the Edward's Aquifer project
  - March 2019 and Feb 2020

UTSA Education

- CE 2633 Environmental Engineering (undergrad)
  - Presentation was developed covering the basics of fecal source tracking, study sites and methods, and the importance of the study for Edwards Aquifer Water Protection, and delivered as part of regular lecture in the Water and Wastewater Module. (Fall 2019 – Spring 2024)
- CE 5683 Biological Phenomenon in Environmental Engineering (grad)
  - Presentation was developed covering the basics of fecal source tracking, study sites and methods, and the importance of the study for Edwards Aquifer Water Protection, and delivered as part of regular lecture in the Microbial Water Quality section. (Fall 2019 – ongoing)

Educational flyers

WHY BE A POOPER SCOOPER?

Don't like to pick up your dog's waste?

Not cleaning up after your pet can have serious consequences - for you as well as the environment.

A recent study by researchers at UTSA found high concentrations of bacteria from dog waste in creeks in urban areas of the Edwards Aquifer Recharge Zone.

The recharge zone is where water from land surfaces trickles down into our groundwater supply.

Think about it!

The dog waste that's left on land surfaces or gets washed away into a nearby creek can get down into the groundwater where we get our drinking water.

Dog waste that isn't disposed of can get into the ground and wash away into rivers and streams.

This means that disease-causing bacteria and parasites in dog waste can contaminate lawns, gardens, parks and waterways when the waste decomposes.

Not picking up after your pets can also result in some hefty fines.

In San Antonio the fines for not picking up dog waste range from $100 to $2000.

Let's keep our water clean!

Next time you take your furry friends for a walk, make sure you dispose of their waste properly by bagging it and placing it in a trash receptacle.

For more information on the Pooper Scooper Law in San Antonio visit https://www.sanantonio.gov/Remember-the-River/Residential/Scoop-Your-Pets-Poop.

Animal Waste Management

Application of animal waste to pasture lands

Animal waste is a source of fertilizer and a convenient method of waste disposal. If left under-managed, it can impact drinking water sources.

UTSA® Research Findings

Cows' waste being applied as fertilizers to nearby farmlands contributed to high concentrations of bacteria in Balcones Creek.

Balcones Creek is a recharge zone for Edwards Aquifer (San Antonio's primary drinking water source).

Why care?

The microscopic organisms in animals' waste, such as E. coli , can be disease-causing.

As it rains, the runoff from manured lands can reach rivers and streams.

Here's what farmers can do

Use pasture or forest buffer strips and vegetative filters between areas with applied animal waste and streams or their tributaries.

Apply liquid manure instead of solid spreading, ideally, 24 - 72 hours before a rain event.

Apply site selection criteria for waste application sites away from streams.

Use larger waste storage facilities to limit the contact of manure with stormwater.

Let's keep our water clean!

Consider managing your manured lands to avoid the risk of loading our drinking water sources with disease-causing contaminants.

For more information on Animal Waste Impacts and Management please visit https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/?&cid=nrcs143_014211

Recommendations for the City

- Domestic Pet Waste - Education and outreach to homeowners regarding proper disposal of domestic pet waste.
- Urban Wildlife Populations – Education and outreach to homeowners about practices that discourage attraction of urban wildlife, particularly ruminant animals.
- Bird Fecal Waste – Identify birds that are polluting the water and develop bird relocation efforts to reduce hazards associated with large bird populations.
- On-Site Septic Systems
  - Ongoing homeowner education regarding septic system maintenance and homeowner inspections of septic systems.
  - Investigate, identify, and repair or replace problematic septic systems in the contributing zone.

Recommendations for the City

- Improve storm water management programs, including the promotion of Low Impact Development (LID) such as the reduction of effective impervious surfaces, dispersion of storm water runoff to vegetated areas, and Best Management Practices that are appropriate to the site-specific conditions.
- Future studies focusing on a more detailed assessment of rural and urban areas associated with clusters of OSSFs and underground sewer infrastructure are recommended to determine appropriate measures for mitigating human fecal pollution from these sources.

Products from the Project

- Journal articles and conference proceedings: 2
  - Hinojosa, J., Green, J., Estrada, F., Herrera, J., Mata, T., Phan, D., Tanvir Pasha, A. B. M., Matta, A., Johnson, D., & **Kapoor, V.** (2020). Determining the primary sources of fecal pollution using microbial source tracking assays combined with land-use information in the Edwards Aquifer. *Water Research*, *184*, 116211.
  - Phan, D., Hinojosa, J., Moghadam, S. V., Jafarzadeh, A., Green, J., Matta, A., Johnson, D., & **Kapoor, V.** (2021) Fecal Pollution Source Characterization in Environmental Waters of the Edwards Aquifer. *Proceedings of the Water Environment Federation Technical Exhibition & Conference, 2021.*
- Conference presentations: 5 (ASM, IWA, WEFTEC)
- Students supported: 5 grads, 4 undergrads, 2 postdocs

Questions