Development of Regression-Based Models to Predict Fecal Indicator Bacteria at the Illinois River Basin, Arkansas and Oklahoma

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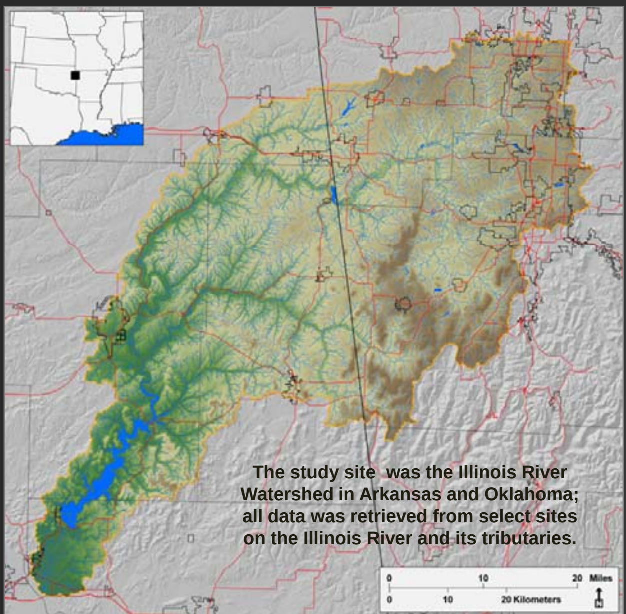
Introduction

- **Fecal bacteria enter the aquatic environment through direct deposition, runoff from fields receiving manure application and municipal wastewater treatment plant effluent discharges.**
- **The presence of fecal bacteria, particularly E. Coli, in aquatic systems is an indicator of pathogens, as well as a potential or possible health risk for humans exposed to the water.**
- **Fecal bacteria presence and transport in the fluvial channel can be difficult and expensive to intensively monitor; however,** some studies have shown that real-time monitoring of surrogates can be used to predict fecal bacteria numbers in streams.

Methods

- **Archived water quality data from the USGS NWIS database was separated by flow conditions using Base Flow Index (BFI Model) .**
- **Base flow samples were defined as samples collected when base flow discharge was greater than or equal to 70% of mean daily discharge (total stream flow); storm flow samples represented other data.**
- **Several water quality parameters (e.g., conductivity, DO, temperature, sediment, etc.) were compared with bacteria concentrations (i.e., fecal coliform and E. Coli) at base flow and storm event conditions.**
- **A synthetic model was developed to identify the relationships between fecal bacteria and other measured physico-chemical parameters using all data, and that separated by flow conditions.**



The study site was the Illinois River Watershed in Arkansas and Oklahoma; all data was retrieved from select sites on the Illinois River and its tributaries.

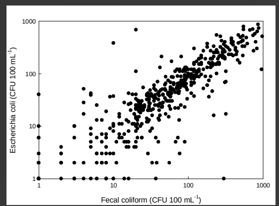
Objectives

- **Develop regression models that accurately predict fecal bacteria concentrations in the Illinois River Watershed using parameters measured in real-time during base flow and storm even conditions.**


Surface runoff (Left) and base flow (Right) conditions at Baron Fork Creek at Eldon, Oklahoma in the Illinois River Watershed during 2001.

Results

- **Fecal bacteria and E. coli concentrations were highly correlated during baseflow and storm events, except at low numbers.**
- **Fecal bacteria numbers were generally low during base flow conditions (see Tables below).**
- **Across the Illinois River and its tributaries, fecal bacteria numbers increased during surface runoff conditions, where fecal bacteria increased with increasing Q.**



Relationship between fecal coliform and E. coli at all sites during base flow and surface runoff event conditions.

- **The percent of samples with fecal bacteria numbers exceeding WQS was greatest at surface runoff.**

USGS Site Number	Flow	n	Escherichia coli (CFU/100 mL) Min	Max	Mean	Median	Primary Exceedence	Secondary Exceedence
07194800	ALL	48	4	5100	500	300	60.4%	8.3%
07195000	ALL	46	12	540	200	100	37.0%	0.0%
07195430	ALL	73	5	72000	4350	1600	43.8%	34.2%
07195500	ALL	36	1	13000	1700	200	22.2%	13.9%
07195865	ALL	60	1	19000	435	30	8.3%	1.7%
07196000	ALL	77	1	40000	1850	100	31.2%	19.5%
07196090	ALL	39	1	20000	3050	2200	56.4%	46.2%
07196500	ALL	80	1	15000	950	200	33.8%	26.3%
07196900	ALL	50	8	14000	550	200	48.0%	12.0%
07197000	ALL	75	1	41000	1500	100	29.3%	21.3%
07197360	ALL	56	1	6400	260	100	12.5%	5.4%
07194800	BF	29	4	750	200	200	51.7%	0.0%
07195000	BF	34	17	540	200	100	35.3%	0.0%
07195430	BF	36	12	210	100	70	8.3%	0.0%
07195500	BF	25	1	300	100	30	8.0%	0.0%
07195865	BF	33	1	900	70	30	9.1%	0.0%
07196000	BF	35	1	1500	100	40	11.4%	0.0%
07196090	BF	14	2	16000	1200	20	14.3%	7.1%
07196500	BF	35	1	2000	100	30	5.7%	0.0%
07196900	BF	16	29	660	200	100	31.3%	6.3%
07197000	BF	33	1	440	100	30	6.1%	0.0%
07197360	BF	31	1	88	20	10	0.0%	0.0%
07194800	SRO	19	84	5100	800	300	73.7%	21.1%
07195000	SRO	12	12	450	200	100	41.7%	0.0%
07195430	SRO	37	5	72000	8600	3200	78.4%	67.6%
07195500	SRO	11	1	13000	3300	300	54.5%	45.5%
07195865	SRO	27	1	19000	800	30	7.4%	3.7%
07196000	SRO	42	2	40000	3600	200	47.6%	35.7%
07196090	SRO	25	1	20000	4900	4400	80.0%	68.0%
07196500	SRO	45	3	15000	1800	300	55.6%	46.7%
07196900	SRO	34	8	14000	900	200	55.9%	14.7%
07197000	SRO	42	1	41000	2900	100	47.6%	38.1%
07197360	SRO	25	1	6400	500	100	28.0%	12.0%

USGS Site Number	Flow	n	Fecal Coliform (CFU/100 mL) Min	Max	Mean	Median	Primary Exceedence	Secondary Exceedence
07194800	ALL	48	17	4500	400	200	45.8%	8.3%
07195000	ALL	46	10	520	150	100	32.6%	0.0%
07195430	ALL	73	4	110000	4400	2000	41.1%	32.9%
07195500	ALL	36	1	18000	2300	100	22.2%	13.9%
07195865	ALL	42	1	17000	575	40	9.5%	2.4%
07196000	ALL	59	1	42000	2450	200	37.3%	30.5%
07196090	ALL	39	2	21000	3400	1600	56.4%	41.0%
07196500	ALL	62	1	19000	1500	400	46.8%	30.6%
07196900	ALL	49	4	7400	400	200	42.9%	8.2%
07197000	ALL	58	1	50000	2200	300	37.9%	24.1%
07197360	ALL	56	1	4200	200	25	10.7%	3.6%
07194800	BF	29	17	470	200	100	34.5%	0.0%
07195000	BF	34	10	520	100	100	32.4%	0.0%
07195430	BF	36	6	220	100	40	2.8%	0.0%
07195500	BF	25	1	510	100	30	8.0%	0.0%
07195865	BF	25	1	250	50	30	8.0%	0.0%
07196000	BF	25	1	560	100	30	4.0%	4.0%
07196090	BF	14	3	18000	1300	10	14.3%	7.1%
07196500	BF	26	1	360	50	20	7.7%	3.8%
07196900	BF	16	20	1100	200	100	18.8%	0.0%
07197000	BF	26	1	250	40	20	7.7%	0.0%
07197360	BF	31	1	120	20	10	0.0%	0.0%
07194800	SRO	19	62	4500	600	300	63.2%	21.1%
07195000	SRO	12	17	430	200	100	33.3%	0.0%
07195430	SRO	37	4	110000	8700	3900	78.4%	64.9%
07195500	SRO	11	5	18000	4500	200	54.5%	45.5%
07195865	SRO	17	1	17000	1100	40	11.8%	5.9%
07196000	SRO	34	6	42000	4800	300	61.8%	50.0%
07196090	SRO	25	2	21000	5500	3200	80.0%	60.0%
07196500	SRO	36	2	19000	3000	800	75.0%	50.0%
07196900	SRO	33	4	7400	600	200	54.5%	12.1%
07197000	SRO	32	1	50000	4400	500	62.5%	43.8%
07197360	SRO	25	1	4200	400	40	24.0%	8.0%

Fecal coliform (left) and E. coli (right) concentrations during combined (ALL), base flow (BF), and surface runoff events (SRO). Primary % exceedence: bacteria > 200 CFU per 100 mL. Secondary % exceedence bacteria > 100 CFU per 1000 mL.

Results

- **These tables detail the regression models developed in this study.**

USGS[b] Site Number	Flow	n	Stepwise linear regression equation	R^2	*p*
07194800	ALL	48	$0.443\log_{10}Qi + 0.669\log_{10}T - 2.83\log_{10}SC - 1.71\log_{10}DO + 9.16$	0.67	0.06
07195000	ALL	46	$0.980\log_{10}T - 1.92\log_{10}SC - 2.27\log_{10}DO + 8.13$	0.59	0.01
07195430	ALL	72	$1.58\log_{10}Qi + 2.65\log_{10}SS - 2.48\log_{10}DO - 4.82$	0.73	0.04
07195500	ALL	36	$1.87\log_{10}Qi - 2.68\log_{10}DO - 0.639$	0.62	0.05
07195865	ALL	40	$0.773\log_{10}Qi - 2.18\log_{10}DO + 2.85$	0.19	0.07
07196000	ALL	39	$0.770\log_{10}SS + 2.21\log_{10}pH - 20.0\log_{10}DO + 20.5$	0.64	<0.01
07196090	ALL	39	$1.27\log_{10}Qi - 13.2\log_{10}pH + 10.1$	0.75	0.06
07196500	ALL	62	$1.22\log_{10}Qi - 3.11\log_{10}DO + 1.34$	0.67	<0.01
07196900	ALL	41	$0.823\log_{10}T + 2.04\log_{10}SS - 2.78$	0.19	0.05
07197000	ALL	56	$282\log_{10}T - 98.1\log_{10}SC - 4440\log_{10}pH + 48800$	0.32	0.05
07194800	BF	29	$0.630\log_{10}Qi + 0.933\log_{10}T - 1.45\log_{10}DO + 1.41$	0.52	0.09
07195000	BF	34	$0.970\log_{10}T - 1.83\log_{10}SC - 2.07\log_{10}DO + 7.70$	0.54	0.05
07195430	BF	35	$-1.56\log_{10}DO + 3.19$	0.29	0.79
07195500	BF	25	No Model Developed	-	-
07195865[e]	BF	23	No Model Developed	-	-
07196000[e]	BF	22	$-25.7\log_{10}DO + 24.7$	0.21	0.03
07196090	BF	14	$-17.5\log_{10}SC + 45.0$	0.38	0.02
07196500	BF	26	$-2.85\log_{10}DO + 4.16$	0.23	0.01
07196900[e]	BF	13	No Model Developed	-	-
07197000	BF	25	$-3.80\log_{10}DO + 5.03$	0.33	<0.01
07194800[c]	SRO	19	$-4.86\log_{10}SC - 2.26\log_{10}DO + 16.1$	0.76	0.20
07195000	SRO	12	$-4.18\log_{10}DO + 6.27$	0.70	<0.01
07195430	SRO	37	$1.36\log_{10}Qi + 5.46\log_{10}SS - 11.8$	0.63	<0.01
07195500	SRO	11	$2.61\log_{10}Qi - 5.59$	0.76	<0.01
07195865	SRO	17	$1.72\log_{10}Qi - 2.78\log_{10}DO + 2.57$	0.64	0.06
07196000	SRO	17	$1.49\log_{10}SS + 2.71\log_{10}pH + 2.47$	0.86	<0.01
07196090	SRO	25	$2.23\log_{10}Qi + 4.47\log_{10}SC - 13.5\log_{10}pH - 3.34$	0.78	0.10
07196500	SRO	36	$1.29\log_{10}Qi - 3.36\log_{10}DO + 1.33$	0.62	0.01
07196900	SRO	28	$4.34\log_{10}SS - 1.60\log_{10}DO - 4.84$	0.24	0.07
07197000	SRO	31	$-32.0\log_{10}pH + 30.1$	0.36	0.61

USGS[b] Site Number	Flow	n	Stepwise linear regression equation	R^2	*p*
07194800[c]	ALL	48	No Model Developed	-	-
07195000	ALL	46	$0.709\log_{10}T - 2.04\log_{10}SC - 2.21\log_{10}DO + 8.57$	0.46	0.07
07195430	ALL	72	$1.09\log_{10}Qi + 2.05\log_{10}SS - 3.01\log_{10}SC - 2.59\log_{10}DO + 5.10$	0.76	0.10
07195500	ALL	36	$1.84\log_{10}Qi - 4.06\log_{10}DO + 0.784$	0.62	<0.01
07195865	ALL	40	$0.764\log_{10}Qi - 2.99\log_{10}DO + 3.49$	0.18	0.04
07196000	ALL	39	$0.734\log_{10}SS + 2.44\log_{10}pH - 20.0\log_{10}DO + 20.6$	0.51	0.02
07196090	ALL	39	$1.31\log_{10}Qi - 13.3\log_{10}pH + 10.0$	0.75	0.06
07196500	ALL	62	$1.38\log_{10}Qi - 2.91\log_{10}DO + 0.678$	0.63	<0.01
07196900	ALL	40	$-0.934\log_{10}DO + 2.84$	0.08	0.08
07197000	ALL	56	$334\log_{10}T - 124\log_{10}SC - 4930\log_{10}pH + 56800$	0.35	0.06
07194800	BF	29	$0.472\log_{10}Qi + 0.889\log_{10}T + 5.62\log_{10}pH - 1.16\log_{10}DO - 3.69$	0.70	0.04
07195000	BF	34	$-3.25\log_{10}DO - 2.49\log_{10}SC + 11.6$	0.40	0.13
07195430	BF	35	$-2.15\log_{10}SC - 1.81\log_{10}DO + 8.74$	0.36	0.04
07195500	BF	25	$1.46\log_{10}T - 0.416$	0.21	0.02
07195865[e]	BF	23	No Model Developed	-	-
07196000	BF	22	$-25.9\log_{10}DO + 24.7$	0.14	0.09
07196090	BF	14	$-17.2\log_{10}SC + 44.2$	0.37	0.02
07196500	BF	26	$-2.75\log_{10}DO + 3.83$	0.17	0.04
07196900	BF	13	$-0.264\log_{10}Qi + 0.362\log_{10}T - 3.82\log_{10}SC + 11.2$	0.90	<0.01
07197000	BF	25	$-4.04\log_{10}DO + 5.06$	0.36	<0.01
07194800	SRO	19	$-1.86\log_{10}SS - 4.34\log_{10}SC - 1.93\log_{10}DO + 18.2$	0.70	0.06
07195000	SRO	12	$-3.34\log_{10}DO + 5.44$	0.65	<0.01
07195430	SRO	37	$1.48\log_{10}Qi + 5.26\log_{10}SS - 11.9$	0.65	<0.01
07195500	SRO	11	$2.62\log_{10}Qi - 5.58$	0.77	<0.01
07195865	SRO	17	$1.57\log_{10}Qi - 3.73\log_{10}DO + 3.50$	0.47	0.07
07196000[c]	SRO	17	No Model Developed	-	-
07196090	SRO	25	$1.02\log_{10}Qi - 4.02\log_{10}T - 9.11\log_{10}DO + 12.8$	0.82	<0.01
07196500	SRO	36	$1.38\log_{10}Qi + 0.992\log_{10}T + 9.89\log_{10}SS - 22.4$	0.61	0.06
07196900	SRO	27	$9.91\log_{10}pH - 2.38\log_{10}DO - 4.69$	0.26	0.08
07197000	SRO	31	$-3.84\log_{10}SC - 28.1\log_{10}pH + 35.4$	0.48	0.03


Summary

- **The regression models were somewhat different across the sites and the databases used (all data, base flow data, and surface runoff data) at the Illinois River and its tributaries.**
- **The predictive abilities of these regression models was limited during base flow conditions, as several sites showed that no regression model could be developed using these parameters.**
- **The ability of the regression models to predict changes in fecal bacteria numbers differed across sites, where the regression models explained between 8 and 86% of the variation in bacterial numbers.**
- **Several other studies across the south-central USA have developed regression models to predict fecal bacteria numbers, and these models collectively suggest that turbidity should be included.**