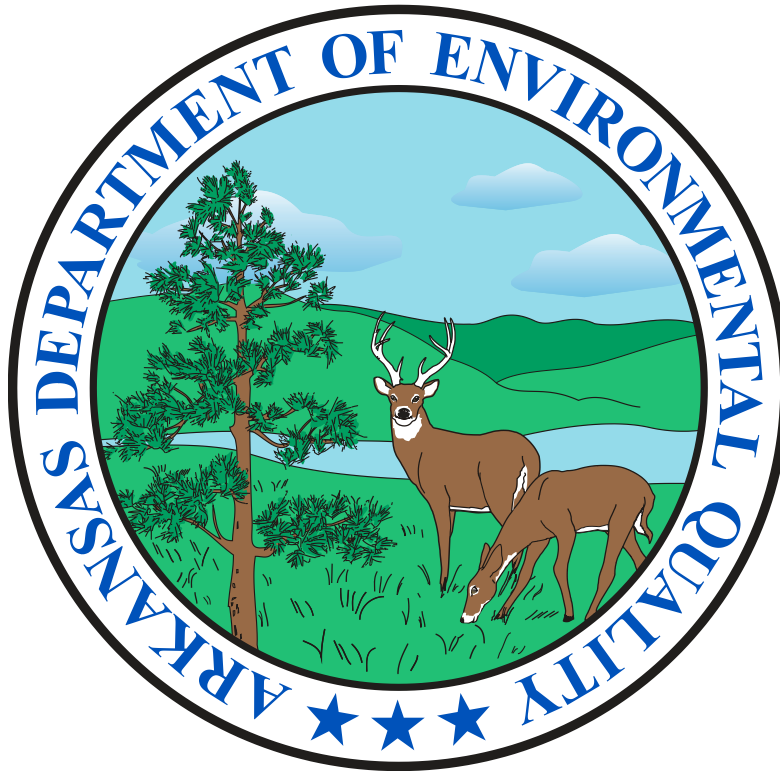


Evaluation of *Escherichia coli* (*E. coli*) Concentrations in Mill Creek, Newton Co., Arkansas



**Office of Water Quality
Planning Branch**

WQ18-5-01

Introduction

Point and non-point source water quality threats are well established in Mill Creek (Newton Co.), which is a tributary of the Buffalo National River. Maner and Mott (1991) provided the first comprehensive water quality study of Mill Creek watershed and found factors contributing to water quality degradation in the Buffalo River included elevated fecal coliform concentrations and nutrient concentrations. Secondary and tertiary concerns of note which may cause degraded conditions in the Buffalo River were bank erosion, sedimentation. Lastly, Maner and Mott (1991) stated water quality impacts from Marble Falls wastewater treatment facility Sewer Improvement District (SID) were insignificant due to minimal flow and low concentrations of pollutants.

Maner and Mott's study hypothesized that elevated bacteria and nutrient concentrations were possibly due to groundwater infiltration. Mott et al. (1999; 2000) tested an interbasin water transfer hypothesis using dye studies to delineate groundwater recharge areas confirmed that waters geographically originating in the Crooked Creek basin enter Mill Creek basin through connection of karst features and springs. Mott et al. (1999) proposed that elevated bacteria and nitrogen concentrations in Mill Creek originate in the Crooked Creek watershed due to land use practices between the two watersheds.

Permitted Facilities

Constructed in the 1960s to serve the Dogpatch U.S.A. theme park, Marble Falls Sewer Improvement District (SID) (AR0034088) is the only NPDES permitted facility discharging to Mill Creek. Currently, the Marble Falls SID serves approximately 30 accounts that include a private residences, post office, recreation center, restaurant, hotel, and conference center, which receive moderate tourism visitation during summer months.

In 1992, Arkansas Department of Environmental Quality (ADEQ) entered into a Consent Administrative Order (CAO 92-007) requiring Marble Falls SID to conduct a 12-month study of the polishing pond and ensure that the pond met the Ten States Standards (Great Lakes 2012). In 2001, ADEQ issued a Notice of Violation (NOV) (LIS No. 01-217) because the 1992 CAO requirements were not completed. The NOV reinforced requirements for Marble Falls SID to conduct a 12-month study of the polishing pond and ensuring that the pond met the Ten States Standards with the additional requirement to submit monthly progress reports. ADEQ entered into a Consent Administrative Order (CAO 03-049) in 2003 with Marble Falls SID setting certain monitoring requirements for plant effluent at the discharge point prior to entering the pond. Additionally, this CAO required a report by a professional engineer demonstrating that the pond meets the Ten States Standards.

In 2009, Marble Falls SID suffered multiple equipment failures and coupled with an aging infrastructure led to raw influent infiltrating groundwater and subsequently surface waters for nearly a year. Usrey (2010) reported an increase *E. coli* arithmetic mean from 53 colony forming

units (cfu)/100 mL upstream of Marble Falls SID to 150 cfu/100mL at the lowest Mill Creek monitoring point in 2010. During 2010, Mill Creek at Pruitt (BUFT04) had 13 of 74 (18%) exceed 298cfu/100 mL. Late 2010 brought a consent decree and settlement between ADEQ and Marble Falls SID (Case No. CV 2010-10-1) and an agreement that Marble Falls SID would implement phased infrastructure and facility remediation. However, contempt of the 2010 consent decree was filed in 2015, and Marble Falls SID is still considered out of compliance with their NPDES permit and required to submit quarterly monitoring reports to ADEQ Office of Water Quality Enforcement. As of 2017, Marble Falls SID has repaired damaged transfer lines, closed inoperable transfer lines, and replaced damaged equipment.

Bacteria Water Quality Standards

E. coli is common indicator of fecal contamination of freshwater because it constitutes more than 90% of bacteria found in warm blooded animal excrement (US EPA 1986). Indicators such as fecal coliform are used less frequently as indicators of contamination because poor correlation with swimming related illness, whereas *E. coli* presence has a much stronger relationship (US EPA 1986). Many states, including Arkansas, utilized fecal coliform as the primary analyte until the early 2000s. It was not until 2004 that Arkansas switched to utilizing *E. coli* as the primary indicator for monitoring recreational contact.

Arkansas's water quality standards are established by the Arkansas Pollution Control and Ecology Commission Regulation No. 2 (APC&EC 2017). Regulation No. 2.507 (Bacteria) defines primary contact recreation season as May 1 to September 30 and establishes bacteria criteria for primary and secondary contact seasons for Extraordinary Resource Waters (ERWs) and Ecological Sensitive Water (ESWs), lakes/reservoirs, and all other waters. Mill Creek is classified as "all other water" and thus has an *E. coli* individual sample criteria of 410 colonies/100mL primary contact season. Data quality requirements necessitate that eight (8) samples be collected from May 1 through September 30 and cannot exceed 410 colonies/100mL more than 25% of the time (i.e. more than 2 of 8 samples). For all streams with watersheds less than ($\leq$) 10mi², primary contact shall not be designated for primary contact unless site verification indicates that such use is attainable. Fecal coliform individual sample and geometric mean criteria of 400 and 200 cfu/100 mL, respectively, apply to ERWs, ESWs, lakes/reservoirs, and all other waters.

In an effort to protect public health, NPS applies ERW criteria to waters within the NPS boundary even though not all waters within the NPS boundary are designated as an ERW. For the NPS monitoring program, if *E. coli* concentrations exceed an individual-sample value of 298 colonies/100mL, then the NPS will increase sampling efforts to five (5) samples per month. During this high frequency sampling, if a 30-day geometric mean exceeds 126 colonies/100mL, then NPS staff will erect signage advising public caution, issue health advisories on their website, and contact Arkansas Department of Health and ADEQ (NPS Pers. Communication, Figure 1).

Impairment Concerns

In 2015, the NPS submitted a letter and supporting data to ADEQ requesting Mill Creek be placed on the 2016 impaired waterbodies list pursuant to Section 303(d) of the Clean Water Act for violation of fecal coliform bacteria water quality standards (Cheri 2015). In this letter, NPS also requested assistance from ADEQ in determining the source(s) of the fecal coliform contamination so it could be reduced or eliminated. The NPS presented data for Mill Creek sampling station BUFT04 during summer 2015. Five samples were collected within a 30-day period for calculation of geometric means (APC&EC Reg. 2.507). Summer 2015 *E. coli* geometric means ranged from 120 most probable number (MPN) /100mL in June to 392 MPN/100mL in July.

ADEQ received over 150 comments during the 2016 303(d) list public comment period requesting that Mill Creek and additional Buffalo River tributaries be added to the list of impaired waterbodies. Commenters were concerned that *E. coli* concentrations in Mill Creek exceeded the state water quality standard and were degrading water quality of the Buffalo River. ADEQ's 2016 303(d) Responsiveness Summary noted that the NPS data received did not satisfy 2016 Assessment Methodology temporal requirements and thus were unable to be used for Clean Water Act attainment decisions (ADEQ 2016). On July 19, 2017, US EPA approved Arkansas's 2010, 2012, 2014, and 2016 303(d)/305(b) Integrated Reports (EPA 2017).

Objective

In 2016, ADEQ Office of Water Quality (OWQ) initiated a two-year bacteria monitoring study in the Mill Creek watershed to determine if the primary contact recreation designated use was being supported per APC&EC Regulation 2.507.

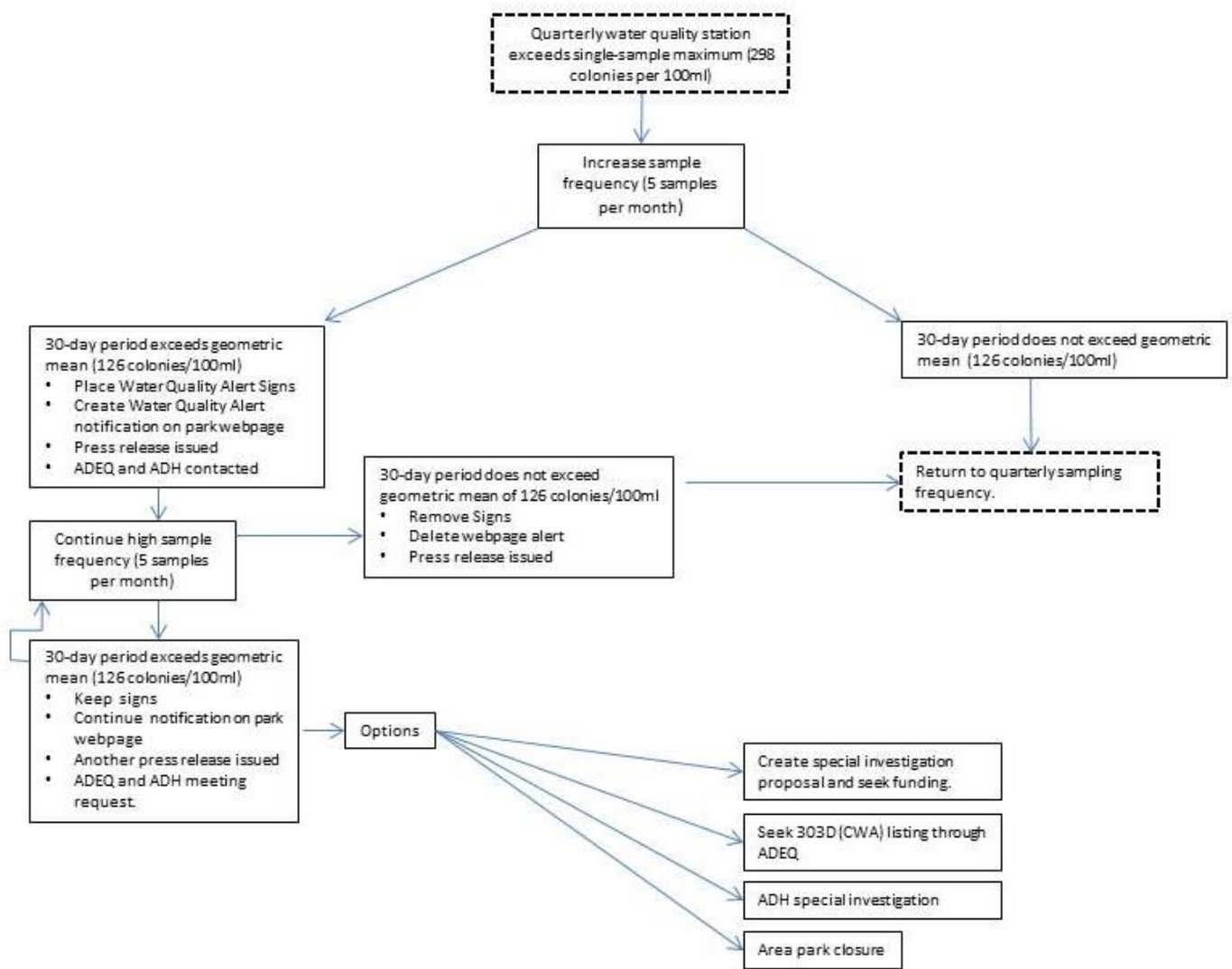


Figure 1. Buffalo National Park bacteria advisory decision matrix (NPS, personal comm.).

Methods

Study Area

Located in the Ozark Highlands Ecoregion of Arkansas, Mill Creek (watershed area = 21.3mi²) originates in south central Boone County and flows south into Newton County for 5.2 river miles to its confluence with the Buffalo National River. Mill Creek is a perennial, 3rd order, high

gradient, Ozark stream with riffle, run, pool sequencing. Karst features are present throughout the watershed, including springs and subsurface drainage. Watershed land use is predominantly forested (77%) with some pasture (18%). Developed land (5%) includes the abandoned theme park, Dogpatch USA (now Heritage USA), and the rural community of Marble Falls. Two impoundments on Mill Creek were constructed within the boundaries of theme park in the late 1960s and served as trout fisheries until abandonment in the mid-1990s. The impoundments dam inflow from two springs, commonly referred to as Upper Dogpatch Spring and Lower Dogpatch Spring.

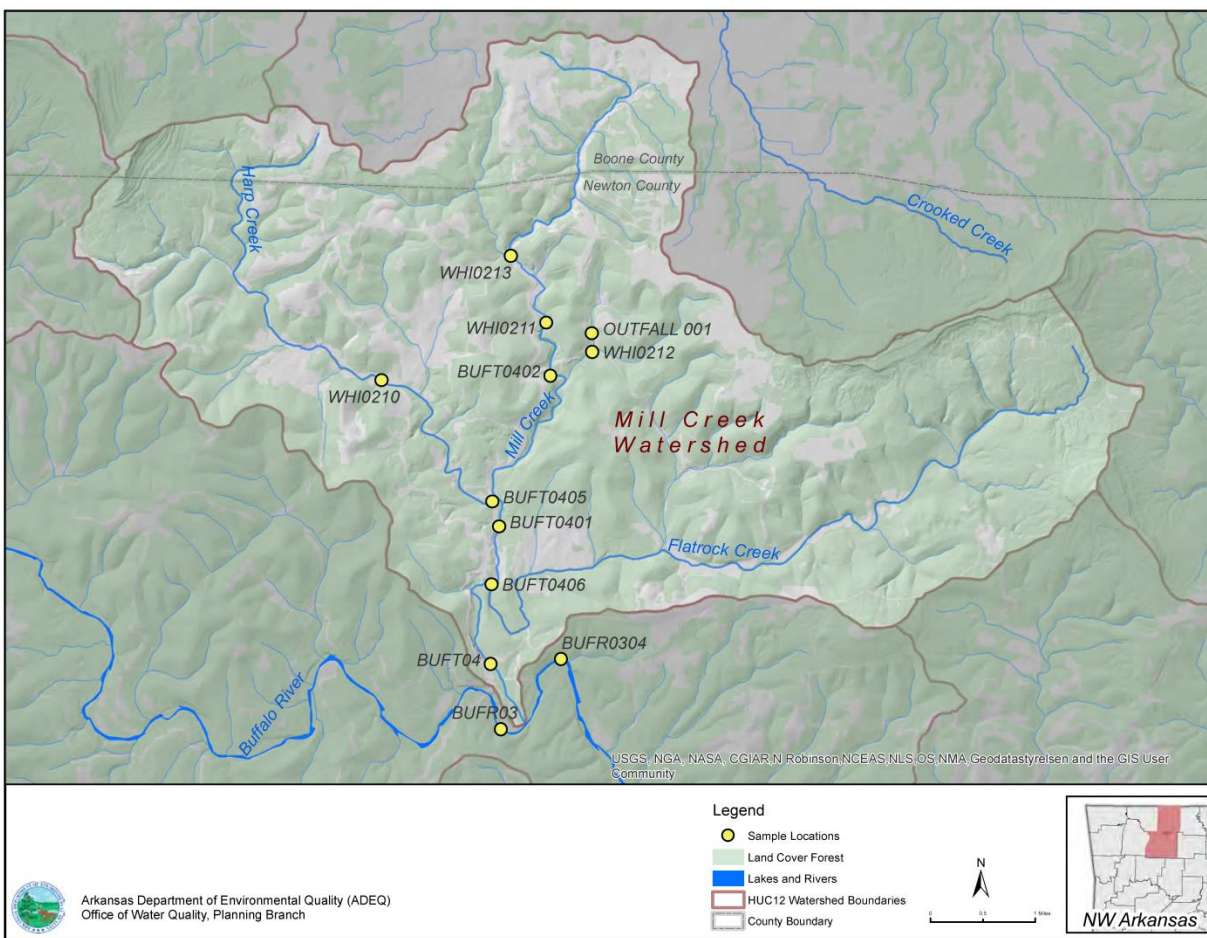


Figure 2. Distribution of sample locations throughout the Mill Creek (Newton Co.) watershed.

Bacteria Collection and *In-situ* Water Quality

During the summers of 2016 and 2017, Mill Creek watershed was sampled for *E. coli* and *in situ* water quality parameters: dissolved oxygen (mg/L), temperature (°C), and specific conductance (µS/cm). Twelve collection sites were established throughout the watershed (Table 1; Figure 1). One tributary collection site (BUFT0406) was discontinued in 2017 due to ephemeral flow. Nine sampling events per year were distributed throughout the primary contact season, as defined in

APC&EC Reg. 2.507 (May 1-September 30). Sample container was triple rinsed with native water. Water samples were collected from mid-channel and a 100mL aliquot of ambient water was transferred to a sterile plastic container. Dechlorination tablets (sodium thiosulfate) were added if treated effluent samples were collected. Containers were labeled with sampling station identifiers and immediately placed on ice until processing at ADEQ Environmental Media Laboratories. *E.coli* processing and colony counts followed EPA Method 1603 (2014) and ADEQ's approved 2014 Quality Assurance Project Plan. Data were reported as cfu/100mL.

In situ water quality parameters were measured with a YSI ProDSS, YSI 550A, YSI 100, or YSI 556 meters. Meters were calibrated per manufacturer's instructions and calibration values were recorded. All *in situ* measurements were collected and recorded after decanting a 100mL aliquot of water from the container for *E. coli* analysis. *In-situ* readings were recorded on ADEQ's sample requisition form.

Table 1. Sampling site name, coordinates, and brief site description.

ADEQ Site Name	Latitude	Longitude	Description
WHI0213	36.110139	-93.134696	Mill Creek north of Dogpatch
WHI0211	36.102643	-93.129786	Mill Creek directly below Dogpatch and Marble Falls relief 1
BUFT0402	36.096730	-93.129246	Mill Creek at Spring Valley Rd.
WHI0212	36.099370	-93.123474	Unnamed tributary south of Outfall 001.
OUTFALL 001	36.101448	-93.123498	Marble Falls SID permitted outfall.
BUFT0405	36.082677	-93.137270	Harp Creek prior to merging with Mill Creek (Lower)
WHI0210	36.096233	-93.152637	Harp Creek below James Spring (Upper)
BUFT0401	36.07988	-93.136333	Mill Creek at Mill Creek Campground
BUFT04	36.064516	-93.137514	Mill Creek at Pruitt-Yardell Rd bridge upstream of spring outfall
BUFR03	36.057279	-93.136073	Buffalo River upstream of merging with Mill Creek (Pruitt)
BUFR0304	36.065101	-93.127768	Buffalo River downstream of Mill Creek at Crow Hole

Table 2. ADEQ monitoring site, associated watershed size, and individual sample (IS) *E. coli* criteria, and results of primary contact site evaluation.

ADEQ Site Name	Watershed Size (mi ²)	Critical Season IS <i>E. coli</i> Criteria	Site Verification for Primary Contact
WHI0213	2.18		Primary contact unlikely
WHI0211	3.9		Primary contact unlikely
BUFT0402	4.26	410	*Yes
WHI0212	1.32		Primary contact unlikely
Marble Falls SID 00	-	-	NA
BUFT0405	6.19	410	*Yes
WHI0210	4.08	410	Primary contact unlikely
BUFT0401	12.3	410	NA
BUFT0406	8.36	410	*Yes
BUFT04	21.3	410	NA
BUFR03	19.1	298	NA
BUFR0304	21.3	298	NA

*Regulation 2.507, “For the purpose of this regulation, all streams with watersheds less than 10mi² shall not be designated for primary contact unless and until site verification indicates that such use is attainable.”

Results

Mean primary contact season water temperatures in 2016 were 2°C warmer than in 2017. Mean combined temperature data for 2016 was 22.3(±3.5)°C compared to 2017 of 20.2 (±3.3)°C. Mean water temperatures for 2016 ranged from 16.82 (±0.8)°C at Mill Creek at Highway 7 (WHI0213) to 27.78 (±1.81)°C at Buffalo River at Pruitt (BUFR03). Mean 2017 temperatures ranged from 16.66 (±1.5)°C at WHI0213 to 24.67 (±3.1)°C for BUFR03 (Table 3). Lowest mean pH values for 2016 and 2017 were recorded at WHI0213 (Table 3). Highest mean dissolved oxygen was observed at WHI0213 for 2016 and second highest mean dissolved oxygen during 2017, only behind Upper Harp Creek (WHI0210) (Table 3). Specific conductance was variable across sites and years; however, for both years highest and lowest mean specific conductance values were at WHI0212 (Unnamed tributary to Mill Creek) and BUFR03, respectively (Table 3).

ADEQ Office of Water Quality staff collected 297 *E. coli* samples between 2016 and 2017 primary contact seasons. Highest mean *E. coli* concentrations were observed at WHI0210 (Upper Harp Creek) (451 ± 418) and BUFT0401 (Mill Creek Campground) (476 ± 781) for 2016 and 2017, respectively (Table 4; Figures 3, 4). Highest variability among *E. coli* concentrations was observed at BUFR03 (Buffalo River at Pruitt) in 2016 and WHI0211 (Mill Creek below Dogpatch) in 2017 (Table 4). Lowest mean *E. coli* was observed at BUFR03, BUFR0304, and WHI0211 (Buffalo River at Pruitt, Buffalo River at Crow Hole and Mill Creek below Dogpatch) through both years (Figures 3, 4).

Evaluation of individual samples to the applicable water quality criteria indicate that only one exceedance of ERW criterion of 298 cfu/100 mL was observed in 2016. In 2017, Mill Creek at

Mill Creek Campground (BUF0401) and Lower Harp Creek (BUFT0405) each had two exceedances of the 410 cfu/100 mL criterion and BUFT0402 (Mill Creek at Spring Valley Rd.) and BUFT04 (Mill Creek at Pruitt) each had one exceedance above 410 cfu/100 mL.

Table 3. Mean *in situ* water quality parameters collected during 2016 and 2017.

ADEQ Site Name	2016				2017			
	Dissolved Oxygen (mg/L)	pH	Water Temp °C	Sp. Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH	Water Temp °C	Sp. Conductance (µS/cm)
WHI0213	9.32	6.72	16.82	415.12	9.79	6.96	16.66	432.14
WHI0211	9.04	7.22	21.54	407.04	9.53	7.19	19.20	398.05
BUFT0402	8.39	7.41	20.82	398.58	9.59	7.59	18.76	389.13
WHI0212	6.63	7.27	19.09	533.00	7.57	7.30	18.20	495.30
BUFT0405	8.36	7.46	21.98	401.41	9.36	7.66	20.24	384.92
BUFT0401	8.87	7.64	21.69	387.99	9.49	7.79	20.19	316.67
WHI0210	8.81	7.67	23.98	469.51	9.89	7.71	21.46	455.30
BUFT04	8.19	7.75	23.17	368.32	9.26	7.74	21.16	364.13
BUFR03	7.79	7.83	27.78	205.31	8.28	7.69	24.67	179.03
BUFR0304	8.18	7.84	26.94	229.27	8.38	7.74	24.35	191.61

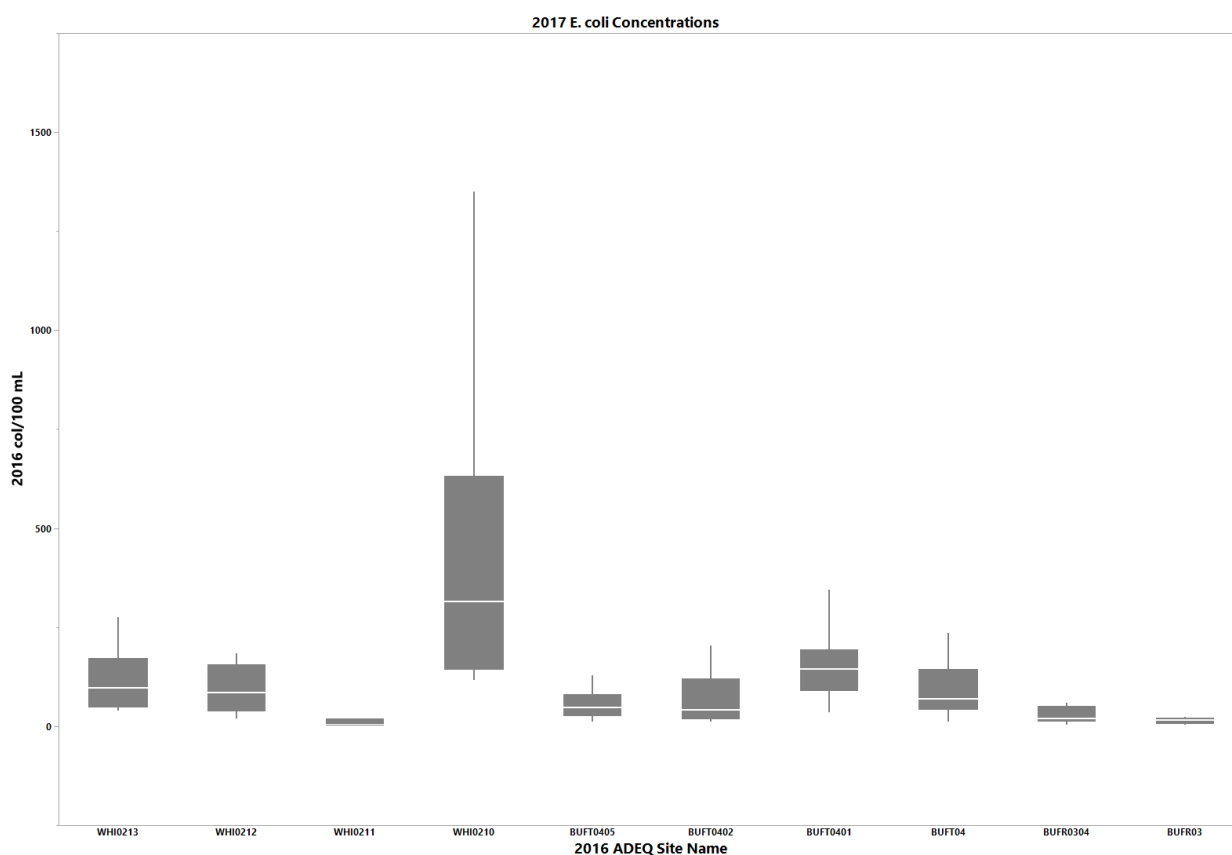


Figure 3. Box plots of *E. coli* concentrations from Mill Creek and Buffalo River during 2016 monitoring period with quartile distributions representing minimum, first quartile, median, third quartile, and maximum.

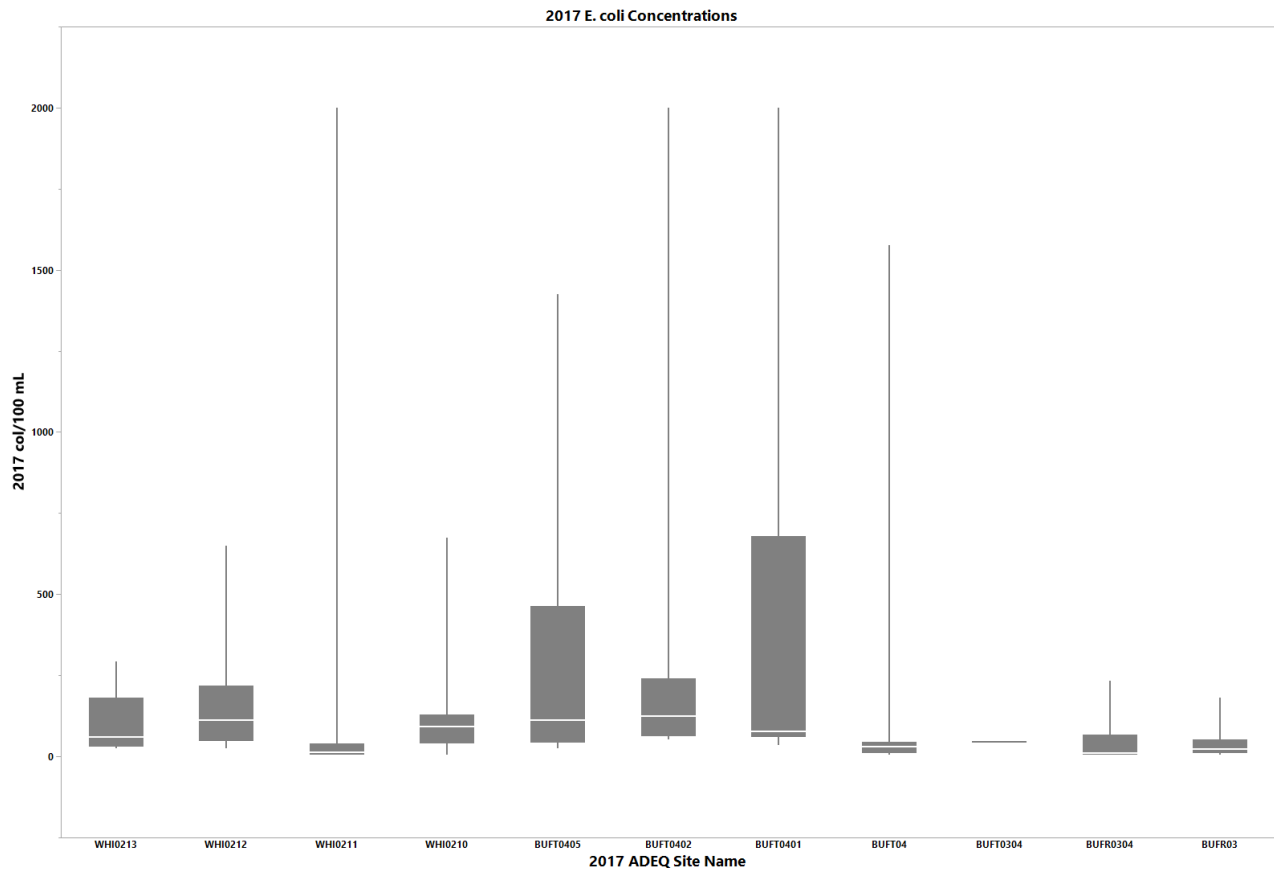


Figure 4. Box plots of *E. coli* concentrations from Mill Creek and Buffalo River during 2017 monitoring period with quartile distributions representing minimum, first quartile, median, third quartile, and maximum.

Table 4. Calculated geometric and arithmetic means (cfu/100 mL $\pm$ SD) for 2016 and 2017 and exceedances of applicable bacteria criterion. Not applicable (NA) applies for stations with watersheds less than 10mi² (APC&EC Reg. 2.507).

ADEQ Site Name	2016				2017			
	Geomean (cfu/100mL)	Mean (cfu/100mL)	Stdev.	No. Exceedance	Geomean (cfu/100mL)	Mean (cfu/100mL)	Stdev.	No. Exceedance
WHI0213	103	160	200	NA	69	101	97	NA
WHI0211	10	30	62	NA	18	236	662	NA
BUFT0402	46	73	70	0	149	322	597	1
WHI0212	90	232	475	NA	112	177	201	NA
BUFT0405	44	55	34	0	125	341	541	2
BUFT0401	130	154	90	0	159	476	781	2
WHI0210	319	451	418	NA	69	140	204	NA
BUFT04	68	91	69	0	32	182	490	1
BUFR03	19	176	487	1	22	43	56	0
BUFR0304	24	53	90	0	18	47	73	0

Conclusions

The objective of this two year study was to determine whether Mill Creek was in compliance with applicable state water quality criteria for bacteria and supporting its primary contact recreation designated use. Data collected during 2016 and 2017 indicate an acceptable level of exceedances of applicable bacteria criteria; thus, Mill Creek supports its primary contact recreation designated use per APC&EC Reg. No. 2.507.

However, the NPS has applied the definition of APC&EC Reg. No. 2.302(A) (Extraordinary Resource Waterbody) to all tributaries of the Buffalo River and subsequently applied ERW specific *E. coli* criteria for protection of primary contact recreation within NPS boundaries. Review of ADEQ's 2016 and 2017 data compared to the individual sample ERW criterion of 298 cfu/100mL, only six of the ten monitoring location met applicable watershed threshold of >10 mi². In the main stem of the Buffalo River, one ERW *E. coli* criterion exceedance was observed at BUFR03 in 2016, and no exceedances were observed at BUFR03 in 2017 or at BUFR0304 in 2016 or 2017. In 2016, BUFT0401 (Mill Creek at the campground) was the only site with one exceedance outside of the main stem Buffalo River site. In 2017 BUFT0401 (Mill Creek at the campground), BUFT0402 (Mill Creek downstream of Dogpatch), and BUFT0405 (lower Harp Creek) all had at least two samples exceed the criteria. Comparisons of *E. coli* data to the applicable water criterion as well as the more stringent NPS approach suggests that the

number of exceedances observed during 2016 and 2017 support attainment of Mill Creek's primary contact recreation designated use.

In 2010, the NPS reported highest arithmetic mean concentrations (273cfu/100mL) from Harp Creek (BUFT0405) and lowest mean (72 cfu/100mL) from Spring Valley Road (BUFT0402). Interestingly, NPS reports that the Mill Creek Campground site (BUFT0401) and Harp Creek (BUFT0405) had higher *E. coli* concentrations during base flow events than storm flow, indicating more localized bacteria sources.

Since 1985, the NPS has routinely collected bacteria from Mill Creek near the mouth (BUFT04). Arkansas Watershed Conservation Resource Center (AWCRC) (2017) summarized 27 years of fecal coliform data for Buffalo River and tributaries. Arithmetic mean and geometric mean were calculated for 62 samples during base flow conditions, which were 43.4 and 8.7 cfu/100mL, respectively. The 2017 AWCRC report also compared fecal coliform geometric mean from 1985-1994 (Mott 1997) and 1995-2011. Mott (1997) reported fecal coliform geometric mean from 1985-1994 as 14 cfu/100mL, while the 1995-2011 geometric mean increased by 3.7 cfu to 17.7cfu/100mL. The individual sample criterion for fecal coliform in non-ERW waterbodies is 400 for primary contact season and 2,000 cfu/100mL for secondary contact (APC&EC 2017).

Fecal coliform and *E. coli* concentrations are generally correlated in freshwaters (Francy et al. 1993); however, the NPS dataset lacks paired bacteriological samples to evaluate the relationship between the two indicators in Mill Creek or the Buffalo River.

Findings from ADEQ's two year study are consistent with Maner and Mott (1991) and NPS (2010), in which highest bacteria concentrations were observed in the vicinity of the Mill Creek Campground and the confluence of Harp Creek. The NPS reported that bacteria sources in Mill Creek are still unclear, but speculate that bedrock features within this vicinity may preclude septic infiltration into the soils, thus leading to chronic bacteria contamination. In an effort to determine bacteria as well as nutrient sources, ADEQ and the United States Geological Survey (USGS) have partnered to study what, if any, anthropogenic or agricultural sources can be detected in Mill Creek. The study is designed to sample base and storm flow events while analyzing for multiple constituents indicative of both forms of non-point source contributions. In doing so, multiple lines of supporting evidence can be provided to document bacteria and nutrient source contributions to Mill Creek.

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