Total Maximum Daily Load for:
Escherichia coli (*E. coli*) in Oak Creek and Spring Creek

in

Oak Creek Watershed

March 2026

Open File Report **[TBD]**

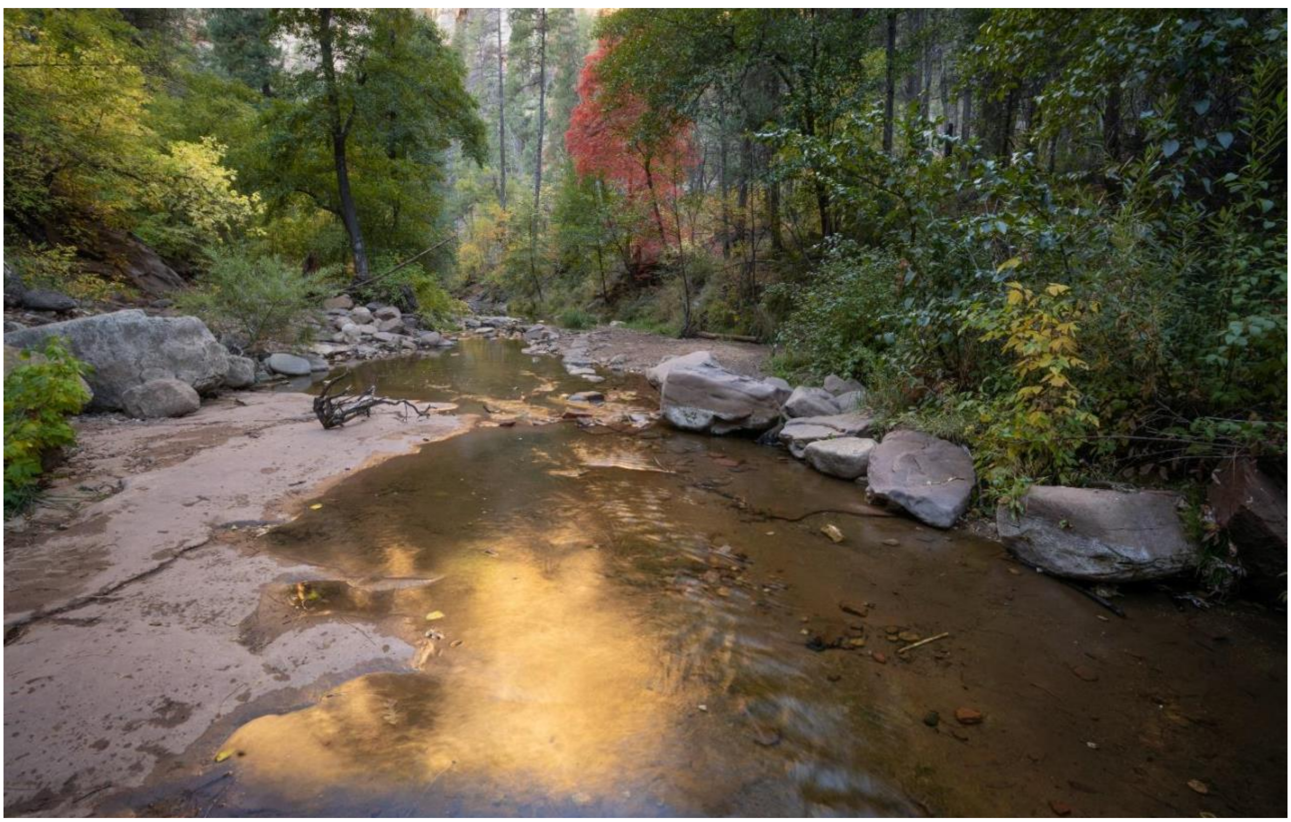

Photo by Richie Graham Photography, courtesy of the National Forest Foundation.

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Abbreviated Terms

A.A.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADOT	Arizona Department of Transportation
ASU	Arizona State University
AZGFD	Arizona Game and Fish Department
AZPDES	Arizona Pollution Discharge Elimination System
ASPT	Arizona State Parks & Trails
BMPs	Best Management Practices
cfs	Cubic feet per second
CFU/100 mL	Colony Forming Units per 100 milliliters
CGP	Construction General Permit
cms	Cubic meters per second
CWA	Clean Water Act
DMR	Discharge Monitoring Report
E. coli	*Escherichia coli*
FBC	Full Body Contact
FDC	Flow Duration Curve
G-CFU/day	Giga-CFU/day
IR	Integrated Report
LA(s)	Load Allocation(s)
LDCs	Load Duration Curves
MGD	Million Gallons per Day
mg/L	Milligrams per Liter
MSGP	Industrial Stormwater Multi-Sector General Permit
MOS	Margin of Safety
MPN/100 mL	Most Probable Number per 100 milliliters
MS4	Municipal Separate Stormwater Sewer System
n.d.	No date
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information Service
NB	Natural background
NPS	Non-Point Source
NAU	Northern Arizona University
OAW	Outstanding Arizona Water
OCWC	Oak Creek Watershed Council
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PBC	Partial Body Contact
SSM	Single Sample Maximum
mi^2	Square miles
SWMP	Stormwater Management Program
SWPPP	Stormwater Pollution Prevention Plan
TMDL	Total Maximum Daily Load
USFS	United States Forest Service
USGS	United States Geological Survey
WLA(s)	Waste Load Allocation(s)
WOTUS	Waters of the United States
WWTP	Wastewater Treatment Plant
WQP	Water Quality Portal Database
WQS	Water Quality Standard

Section 1 Introduction

Every two years, the Clean Water Act (CWA) § 305(b) and § 303(d) requires the Arizona Department of Environmental Quality (ADEQ) to assess the health of Arizona surface waters against established standards. ADEQ combines these requirements into an Integrated Report (IR) that is submitted to the United States Environmental Protection Agency (EPA). Additionally, the CWA requires states to establish a priority ranking for impaired waters and to develop and implement a Total Maximum Daily Load (TMDL) for each § 303(d)-listed impairment. Regulations at 40 Code of Federal Regulations (C.F.R.) § 130.7(c)(1) further require that "[e]ach State shall establish TMDLs for the water quality limited segments identified" in its IR. TMDLs must be established for impaired waters within 15 years of their initial identification on the § 303(d) list per regulations at 40 C.F.R. § 130.28.

A TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. It is defined as the sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources (NPSs), plus natural background (NB) levels (40 C.F.R. § 130.2). The purpose of a TMDL is to identify the pollutant load reductions needed to return a waterbody to attainment with water quality standards, thereby supporting its designated use(s). Typically, a TMDL involves identifying the pollutant of concern, estimating the waterbody's assimilative capacity, estimating the existing pollutant loads from sources in the watershed, determining the allowable loading from the sources and the reductions needed to meet water quality standards, and allocating the pollutant load among the sources.

Six segments of Oak Creek (Headwaters to West Fork [-019], West Fork to Slide Rock State Park [-018A], At Slide Rock State Park [-018B], Below Slide Rock State Park to Dry Creek [-018C], Dry Creek to Spring Creek [-017], Spring Creek to Verde River [-016]) and one segment of Spring Creek (Coffee Creek to Oak Creek [-022]) are impaired for *Escherichia coli* (*E. coli).* ADEQ added all but one of the above segments (-016) to the § 303(d) list in 2008 (ADEQ, 2008) and a TMDL was developed for each segment in 2010. This TMDL report revises and updates the previous TMDLs from 2010 and incorporates the additional downstream impaired reach from Spring Creek to Verde River that was listed as impaired in 2016 — six years after the development of the previous TMDL (Figure 1).

E. coli is a pathogen indicator parameter for the presence of fecal contamination in freshwater systems. While most strains of *E. coli* are not human pathogens and do not cause human illness, the parameter's reliable co-occurrence with fecal contamination makes it a strong predictor of the presence of human pathogens in the waterbody and of gastrointestinal illnesses in people engaging in water recreation (EPA, 2012).

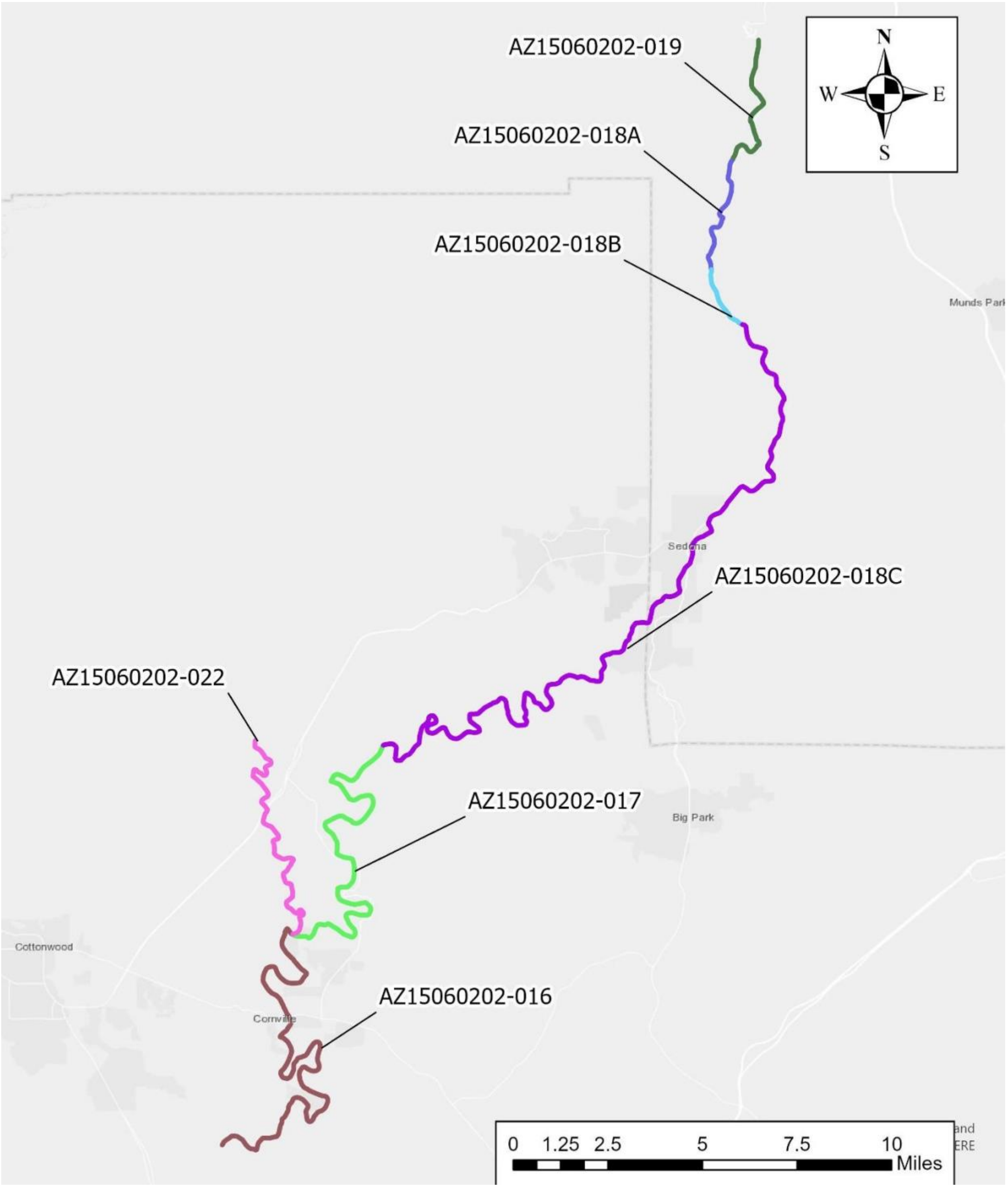


Figure 1. Impaired Segments within Oak Creek Watershed Addressed in the 2024 TMDL Update

This TMDL report contains the following sections:

- **Problem Statement** describes the impairment(s) to be addressed by these TMDLs (Section 2)
- **Setting** presents the physical conditions in and around the Oak Creek and Spring Creek segments that influence pollutant loading conditions (Section 3)
- **Water Quality Standards and Numeric Endpoint Targets** identify the applicable designated uses and criteria that are used for data assessment and TMDL calculations (Section 4)
- **Data Evaluation** presents a review of available water quality, and a comparison to applicable criteria (Section 5)
- **Source Assessment** identifies potential sources of the pollutant of concern (Section 6)
- **Technical Approach** presents the options and the selected approach for TMDL development (Section 7)
- **Linkage Analysis** describes the methodology and analyses conducted to calculate the relationship between pollutant sources and receiving water conditions (Section 8)
- **TMDL Development** presents the loading capacity and allocations, the identified margin of safety (MOS), and seasonality and critical conditions (Section 9)
- **Implementation Planning** describes the regulatory and non-regulatory mechanisms by which the relevant stakeholders may achieve compliance with the TMDL allocations (Section 10)
- **Public Participation** describes the activities undertaken to ensure adequate participation in the TMDL development process by members of the public and any significant comments on the TMDL from members of the public (Section 11)

Section 2 Problem Statement

Spring Creek and Oak Creek are within the Oak Creek watershed and are listed as impaired due to exceeding the *E. coli* water quality standard (ADEQ, 2022a). One segment of Spring Creek and five segments of Oak Creek were first listed as impaired in 2008 with an additional Oak Creek segment listed as impaired in 2016. *E. coli* has caused or contributed to the non-attainment of the Full-Body Contact (FBC) designated use within these segments as shown in Table 1.

Table 1. Impaired Waterbody, Pollutant, Uses, and Causes of Impairment

Waterbody Assessment Unit	Pollutant	Impaired Uses	Year Listed	303(d) /305(b) Category Priority [1]
Oak Creek – Headwaters to West Fork 15060202-019	*E. coli*	FBC	2008	4A
Oak Creek – West Fork to Slide Rock State Park 15060202-018A	*E. coli*	FBC	2008	4A
Oak Creek – Slide Rock State Park 15060202-018B	*E. coli*	FBC	2008	4A
Oak Creek – Below Slide Rock State Park to Dry Creek 15060202-018C	*E. coli*	FBC	2008	4A
Oak Creek – Dry Creek to Spring Creek 15060202-017	*E. coli*	FBC	2008	4A
Oak Creek – Spring Creek to Verde River 15060202-016	*E. coli*	FBC	2016	5 (High Priority)
Spring Creek – Coffee Creek to Oak Creek 15060202-022	*E. coli*	FBC	2008	4A
Potential Pollutant Sources				
• Recreation and tourism (non-boating) • On-site treatment systems (septic systems and similarly decentralized systems) • Wastes from pets • Wildlife other than waterfowl				

[1]More information on Category is available at epa.gov/sites/default/files/2018-09/documents/attains_calculations_of_epa_ir_categories_2018-08-31.pdf and on assessing TMDL priority at azleg.gov/ars/49/00233.htm

These segments of the Oak Creek watershed were prioritized for a TMDL revision because of the watershed's recreational significance and the absence of a TMDL for the segment identified as impaired in 2016. ADEQ completed a Pathogen TMDL in 1999 for Slide Rock State Park, which called for a 30 percent reduction in summer recreational season *E. coli* values to attain the water quality standard of 580 colony forming units per 100 milliliters (CFU/100 mL) (ADEQ, 1999). Subsequently, the water quality standard was revised to its current Single Sample Maximum (SSM) value of 235 CFU/100 mL and geometric mean of 126 CFU/100 mL. However, continued exceedances of the *E. coli* water quality standard led ADEQ to undertake revisions to the TMDL report in 2003 and again in 2010 to include TMDLs for additional impaired segments in the watershed. In subsequent years, ADEQ conducted water body sampling during high visitation weekends, during stormwater runoff and snowmelt events, and under baseflow conditions. The TMDLs calculated in this document supersede and replace the 2010 Pathogen (fecal coliform and *E. coli*) TMDL for Oak Creek and Spring Creek.

Section 3 Setting

Oak Creek and one of its tributaries, Spring Creek, are located in north-central Arizona (Figure 2). Oak Creek's headwaters are located approximately 20 miles south of Flagstaff, flowing south towards its confluence with the Verde River. Spring Creek's headwaters are located approximately 25 miles southwest of Flagstaff and it flows south before joining Oak Creek's lower segments. Sedona is the largest city located within the Oak Creek watershed, with an estimated population of 9,790 (U.S. Census Bureau, 2023). Smaller communities located within the basin include Mountainaire, Kachina Village, Munds Park, Page Springs, and Cornville. The Red Rock Secret Mountain Wilderness Area is located within the west central portion of the watershed and encompasses approximately 75 square miles (mi^2). Approximately half (14 mi^2) of the Munds Mountain Wilderness Area is located in the east-central portion of the watershed.

The Oak Creek watershed has a drainage area of approximately 465 mi^2, and fully encompasses the approximately 48 mi^2 Spring Creek subwatershed. Total stream miles within the Oak Creek watershed equal approximately 632 miles. Perennial flow in Oak Creek originates from springs located above the Sterling Springs Fish Hatchery. Segments of Pumphouse Wash, West Fork Oak Creek, Munds Canyon, and Spring Creek also have perennial flow. Total intermittent flow is approximately 61 stream miles. Ephemeral streams, including Dry Creek, equal approximately 344 miles. Pumphouse Wash is either an ephemeral or intermittent stream that flows into Oak Creek below Sterling Springs Fish Hatchery.

Historic flow data from two United States Geological Survey (USGS) flow gages in the watershed indicate that above average flow occurs throughout Oak Creek during two periods of the year. The first typically occurs during December to early April, in response to the winter storm season and snow melt. The second increased period of flow occurs in late July to early September during the summer monsoon.

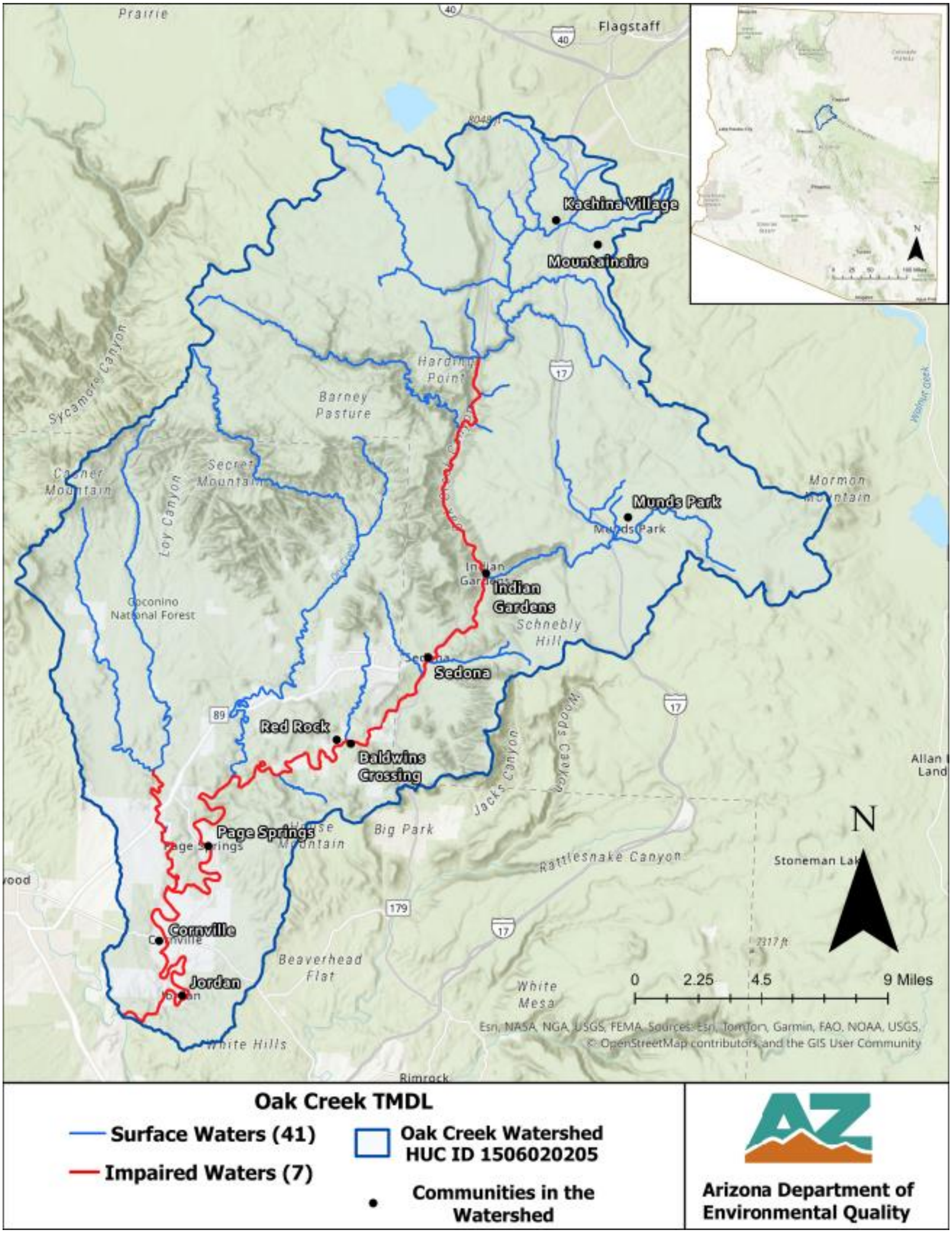


Figure 2. Map of the Oak Creek Watershed for a General Overview

3.1 Geology and Topography

The elevation of the watershed varies from approximately 7,500 feet in the upper region 20 miles south of Flagstaff, to 3,200 feet in the lower region at the confluence of Oak Creek and the Verde River, 17 miles southwest of Sedona. Figure 3 displays the topography of the Oak Creek watershed. The upper segments of Oak Creek formed a canyon because of extensional faulting and the erosion of the uplifted Colorado Plateau by the waters of Oak Creek. The western edge of the Mogollon Rim, which is located near the City of Sedona, is a part of the larger Arizona Transition Zone that stretches diagonally across the state from northwest to southeast. It forms the geological transition in Arizona between the Colorado Plateau and the Basin and Range Province of the west and southwest United States. As Oak Creek flows south, it transitions from a steep sided, narrow canyon to a wide floodplain south of Sedona (USGS, 2005).

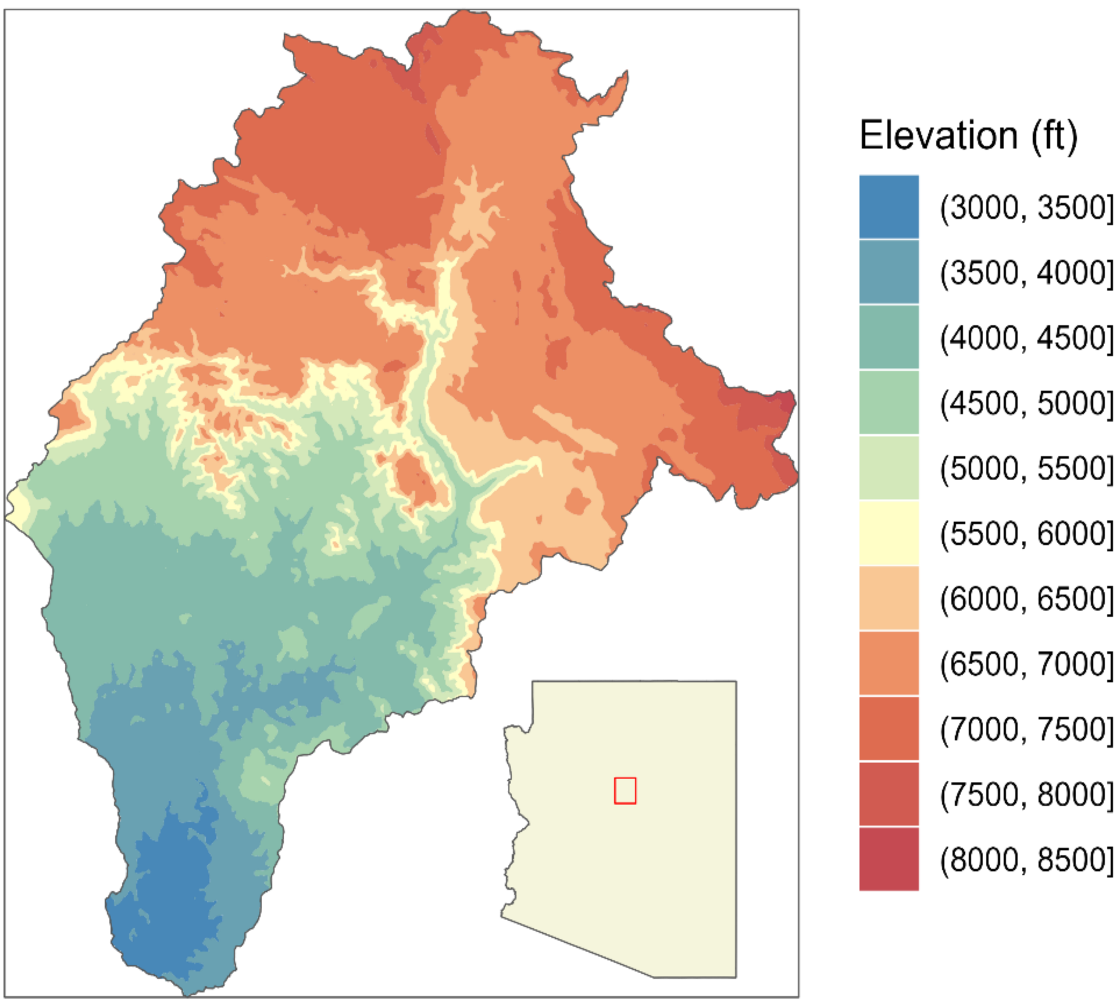


Figure 3. Topography of the Oak Creek Watershed

3.2 Climate

Warm summers and mild winters characterize the general climate of the Oak Creek watershed. Higher elevations of the watershed experience harsher winter conditions. Sedona has an average high temperature of 75.5°F and average low temperature of 46°F (WRCC, 2010). Precipitation in July and August is often from high intensity, short duration storms associated with the summer monsoon. A second storm season occurs during the winter months (December through March), and these precipitation events are less intense, but longer in duration and larger in extent. Snow typically only accumulates in the upper watershed resulting in increased flows as melting occurs in late winter and early spring.

To assess changes in precipitation since the 2010 TMDL, Parameter-elevation Regressions on Independent Slopes Model (PRISM) data for the period 1980 – 2022 (PRISM Climate Group, 2023) were used to estimate total annual precipitation for the watershed, as shown in Figure 4. The average annual precipitation total from 1980 – 2022 was 16.47 inches per year. Over that period, average annual precipitation has declined approximately 0.187 inches per year. Rainfall totals for the post-2010 period (14.27 inches per year; 2011 – 2022) are approximately the same as those occurring in the decade prior (14.04 inches per year; 2000 – 2010).

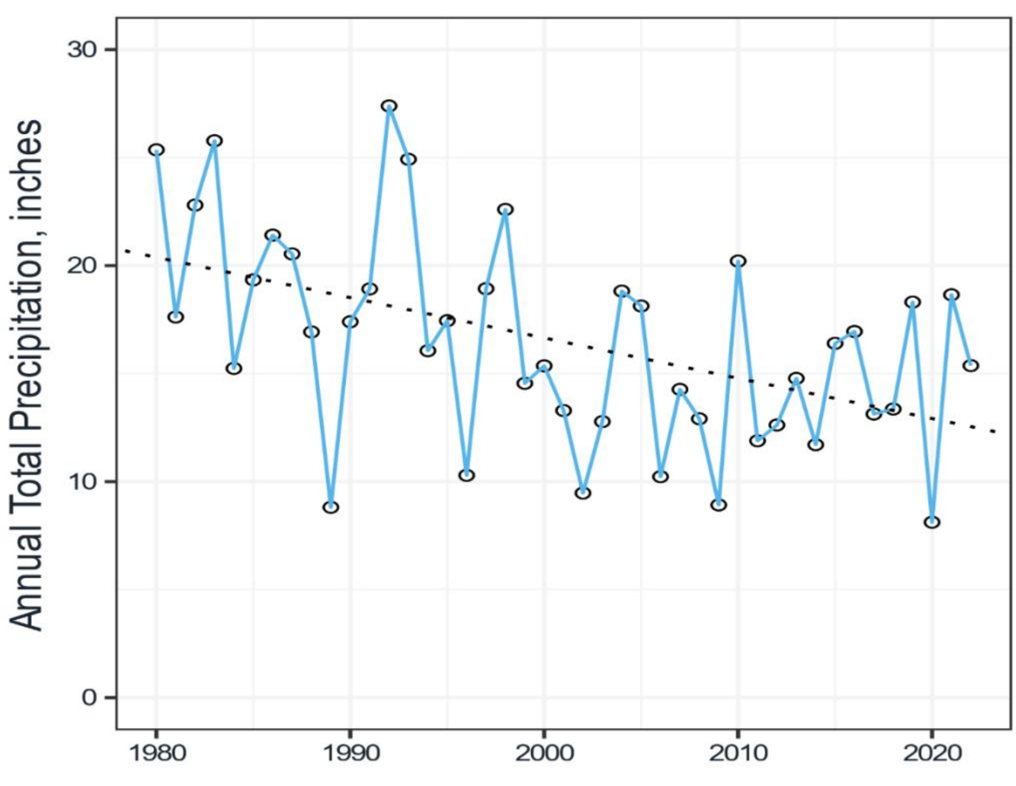


Figure 4. PRISM Annual Total Precipitation

Dotted line shows linear trend line. $R^2 = 0.24$; Slope = -0.187 inches/yea

3.3 Land Use/Cover

Oak Creek Canyon is a popular area for recreational activities during the summer months. Improved campgrounds and day use areas are managed by the U.S. Forest Service (USFS), while Slide Rock State Park is managed by Arizona State Parks & Trails (ASPT). Private communities are scattered throughout the canyon.

The National Land Cover Database (NLCD) was used to assess changes in land use and cover since the 2010 TMDLs were established. NLCD data from 2008 and 2021 for the Oak Creek watershed were compared, as shown in Figure 5 (Dewitz, 2021). As shown in Table 2, the two dominant land cover classes in the watershed are evergreen forest (approximately 58 percent of the watershed in 2008) and shrub/scrub land (33 percent in 2008). According to the 2021 data, little has changed regarding land use, except that approximately 100 square kilometers (39 mi^2) of evergreen forest (approximately 8 percent of the watershed) has been converted to shrub/scrub land and herbaceous land cover. The conversion of evergreen forest into non-forested undeveloped terrain may be due to wildfires in the watershed. For example, the Slide Fire[2] burned approximately 85 square kilometers (33 mi^2) of land north of Sedona from May 20 to June 4, 2014. The alteration of land cover reduces the filtering ability of the natural forest vegetation and surface litter. Additionally, without natural vegetation, groundwater infiltration rates are reduced, resulting in increased runoff to downstream water bodies.

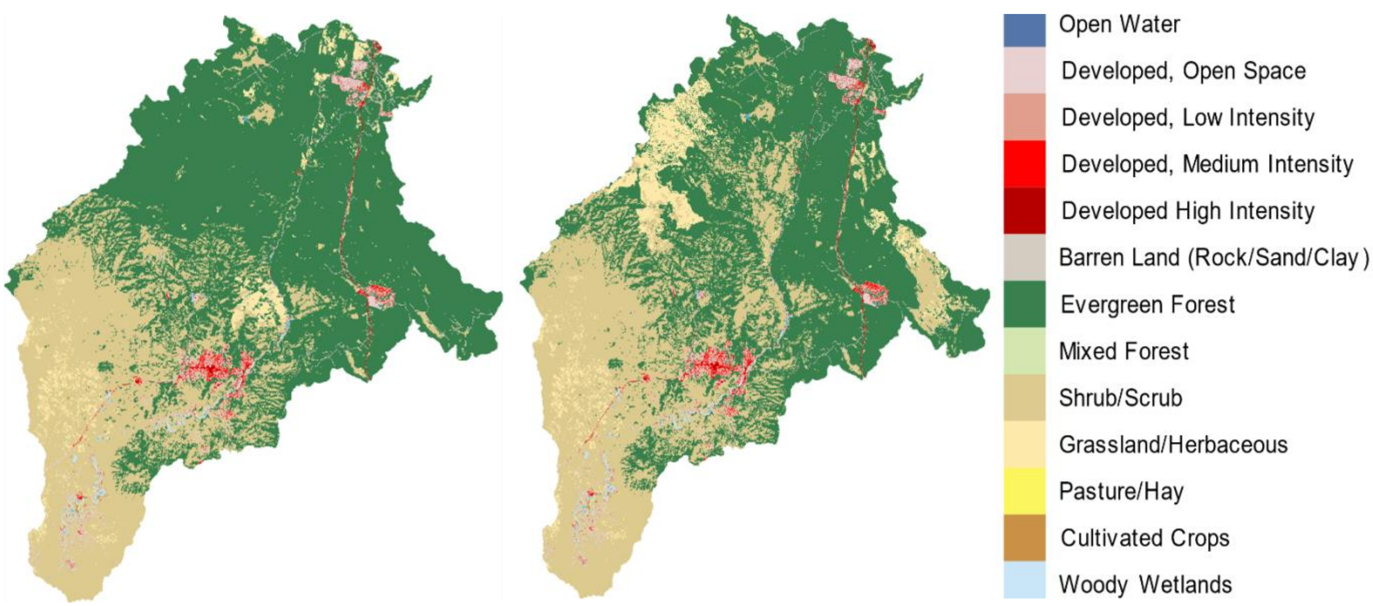


Figure 5. 2008 NLCD (left) and 2021 NLCD (right) for the Oak Creek Watershed

[2]See the following link for additional information: fs.usda.gov/detail/coconino/fire/?cid=stelprd3802894

Table 2. Land Cover and Land Use within the Watershed in 2008 and 2021

NLCD Land Cover Class	Area (km^2)		2008 to 2021 Change (km^2)	2008 to 2021 Change (%)
	2008	2021		
Open Water	0.13	0.19	0.06	46.1
Developed, Open Space	26.46	25.52	-0.94	-3.55
Developed, Low Intensity	15.86	15.82	-0.04	-0.25
Developed, Medium Intensity	8.03	9.29	1.3	16.3
Developed, High Intensity	0.97	1.21	0.2	20.0
Barren Land	1.11	0.23	-0.9	-81.8
Evergreen Forest	704.76	601.32	-103.4	-14.7
Mixed Forest	0.13	0.13	0.0	0.0
Shrub/Scrub	399.87	460.7	60.8	15.2
Herbaceous	41.49	84.38	42.9	103.4
Hay/Pasture	0.2	0.2	0.0	0.0
Cultivated Crops	0.21	0.22	0.01	4.76
Woody Wetlands	4.9	4.9	0.0	0.0
Emergent Herbaceous Wetlands	1.48	1.48	0.0	0.0
Total	**1205.6**	**1205.6**	**--**	**--**

Multi-Resolution Land Characteristics Consortium, 2021

Section 4 Water Quality Standards and Numeric Endpoint Targets

Water quality standards are legal standards promulgated by the State of Arizona and can be found in Title 18, Chapter 11 of the Arizona Administrative Code (A.A.C. R18-11). These standards establish designated uses for waters of the state, along with rules and criteria for the protection of those uses. Water quality standards are composed of three elements:

1. Designated Uses
2. Narrative and/or Numeric Water Quality Criteria
3. Antidegradation Policy

A numeric endpoint target identifies the specific goal or endpoint for the TMDL, which signifies attainment of the waterbody's assigned designated uses. The numeric target may be equivalent to a numeric water quality criterion (if one exists), or it may represent a numeric translation of a narrative water quality standard. These elements are described in greater detail in the following subsections. This section identifies the water quality standard(s) and designated use(s) applicable to the waterbody and identifies appropriate numeric endpoint targets for *E. coli* TMDLs in six segments of Oak Creek and one segment of Spring Creek.

4.1 Water Quality Standards

Six segments of Oak Creek and one segment of Spring Creek are listed as impaired due to their SSM exceedance of *E. coli* criterion. This criterion protects against gastrointestinal illness, and exceedance of the criteria does not meet the FBC designated use.

4.1.1 Designated Uses

40 C.F.R. § 131.3(f) defines designated uses as "those uses specified in the water quality standards regulations for each waterbody or segment whether or not they are being attained." The State has established nine designated uses at A.A.C. R18-11-104, as well as narrative and numeric criteria for protection of those uses. Waterbodies and their designated uses are listed in A.A.C. R18-11, Appendix B. Waterbodies not listed in A.A.C. R18-11, Appendix B, but which are a tributary to a listed waterbody, are assigned designated uses according to the Tributary Rule at A.A.C. R18-11-105. Designated uses for these waterbodies that are relevant to a bacteria TMDL are listed in Table 3.

Table 3. Relevant Designated Uses Applicable to the Segments of Oak and Spring Creek

Designated Use	Description
Full-Body Contact (FBC)	The use of a surface water for swimming or other recreational activity that causes the human body to come into direct contact with the water to the point of complete submergence. The use is such that ingestion of the water is likely and sensitive body organs, such as the eyes, ears, or nose, may be exposed to direct contact with the water.

4.1.2 Water Quality Criteria

Arizona has promulgated water quality criteria applicable to *E. coli* in Oak Creek and Spring Creek at A.A.C. R18-11, Appendix A; EPA approved the criteria in 2003, and they are summarized in Table 4.

Table 4. Applicable Water Quality Criteria for *E. coli*

Designated Use	Parameter	Criterion
Full-Body Contact	*E. coli*	126 CFU/100 mL (Geometric Mean) 235 CFU/100 mL (Single Sample Maximum)

4.1.3 Antidegradation Policy

The Antidegradation regulations promulgated in A.A.C. R18-11-107(B) state:

> *Tier 1: The level of water quality necessary to support an existing use shall be maintained and protected. No degradation of existing water quality is permitted in a surface water where the existing water quality does not meet the applicable water quality standards.*

Tier 1 antidegradation protection applies to surface waters listed on the State's § 303(d) list, including those covered under this TMDL, for the pollutant that resulted in the listing. Based on the above provision, the Antidegradation Regulations prohibit any water quality degradation which would interfere with or prevent attainment with existing designated uses. Therefore, to abide by the Antidegradation Regulations, this TMDL will identify numeric endpoint targets for each of the seven reaches of Oak and Spring Creek that will facilitate the attainment of their existing FBC designated use.

Section 5 Data Evaluation

An important step in the TMDL development process is the review of existing water quality monitoring data. Examination of these data assists in defining the impairment that the TMDL will address and provides a basis for future implementation efforts by identifying potential pollutant sources through pattern analysis. This section provides a review of the available surface water quality and streamflow data in and around impaired segments of Oak Creek and Spring Creek.

5.1 TMDL Numeric Endpoint Targets

A numeric target is the quantitative value used to calculate the loading capacity and evaluate whether the applicable designated uses are attained. Load Duration Curves (LDCs) were used to determine the TMDL numeric target by five flow conditions[3] for Oak Creek segments -016, -017, -018A, -018B, -018C, -019; as shown in Table 5a and

Table 6a. The full flow range (cfs) for each flow condition can be found in Table 5b and

Table 6b. These numeric targets and flow ranges were calculated using streamflow data taken from two USGS gauges on the Oak Creek watershed (USGS 09504500 and USGS 09504420). The USGS gauges and the technical approach for LDC development are discussed in more depth in Section 7.2.

Table 5a. TMDL Numeric Targets for -019, -018A, and -018B

Flow Condition	TMDL Numeric Target (G-CFU/day)
High (0 – 10%)	1,190
Wet (10.01 – 40%)	204
Mid (40.01 – 60%)	179
Dry (60.01 – 90%)	166
Low (90.01 – 100%)	151

Table 5b. Flow Condition Ranges for -019, -018A, and -018B

Flow Condition	Maximum Flow Rate (cfs)	Minimum Flow Rate (cfs)
High (0 – 10%)	9470	86
Wet (10.01 – 40%)	85.9	32.3
Mid (40.01 – 60%)	32.2	30.3
Dry (60.01 – 90%)	30.2	27.2
Low (90.01 – 100%)	27.1	17.2

Table 6a. TMDL Numeric Targets for -018C, -017, and -016

Flow Condition	TMDL Numeric Target (G-CFU/day)
High (0 – 10%)	1,371
Wet (10.01 – 40%)	236
Mid (40.01 – 60%)	188
Dry (60.01 – 90%)	144
Low (90.01 – 100%)	114

[3] Available flow rate data are collected and sorted from highest to lowest and ranked. The top 10 percent of the flow classify as High flow condition. Flow rates that are between 10.01 and 40 percent classify as Wet condition flow condition, etc.

Table 6b. Flow Condition Ranges for -018C, -017, and -016

Flow Condition	Maximum Flow Rate (cfs)	Minimum Flow Rate (cfs)
High (0 – 10%)	9330	105
Wet (10.01 – 40%)	104.9	35
Mid (40.01 – 60%)	34.9	29.5
Dry (60.01 – 90%)	29.4	21.2
Low (90.01 – 100%)	21.1	13

Insufficient streamflow data were available to develop TMDL numeric targets for the Spring Creek segment -022 using LDCs. Instead, the current SSM *E. coli* Standard was used as the TMDL numeric targets for the recreational (May – August) and off (September – April) seasons, as shown in Table 7.

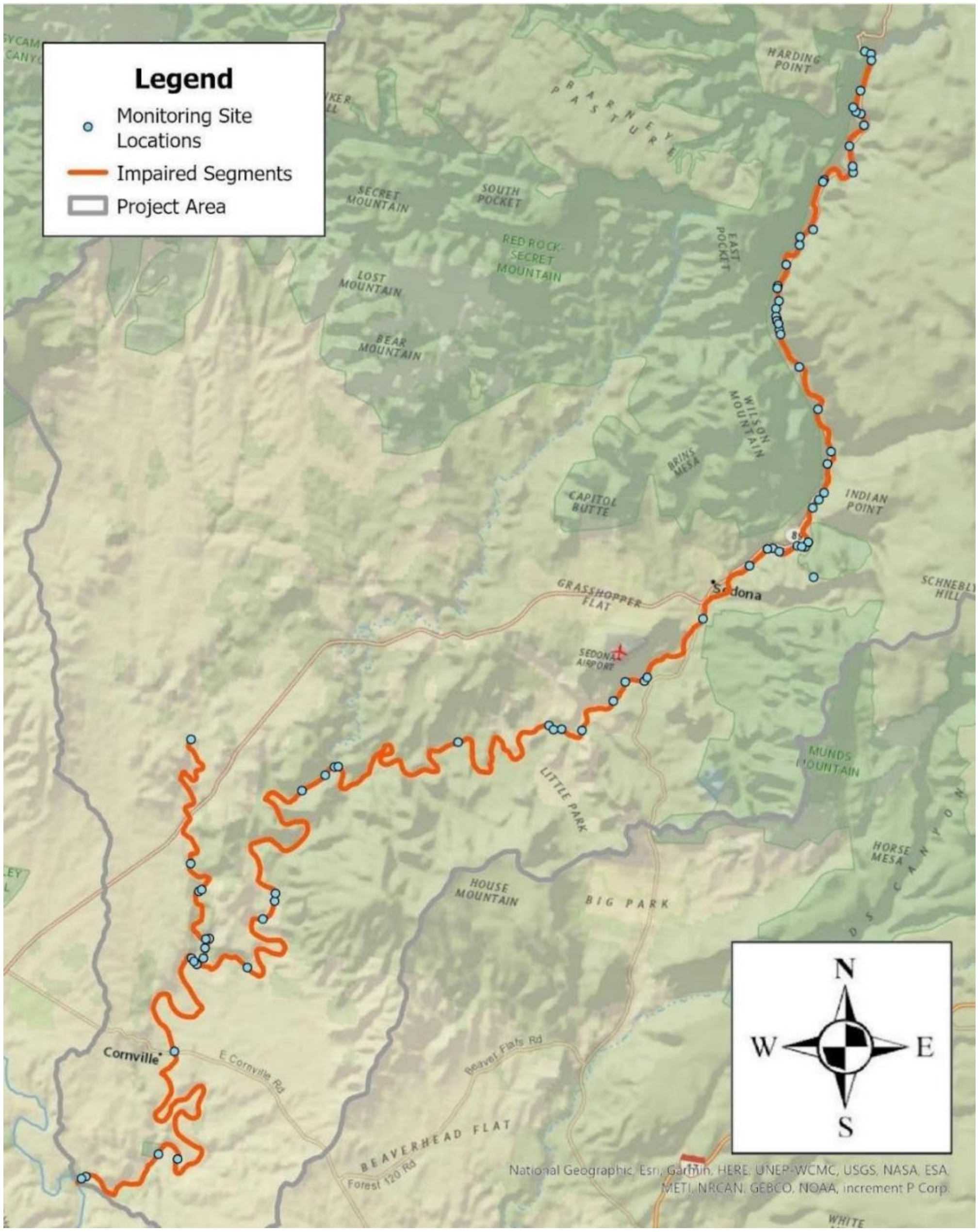
Table 7. TMDL Numeric Targets for -022

Season	TMDL Numeric Target (CFU/100 mL)
Recreational Season	235
Off Season	235

5.2 Water Quality Data

E. coli surface water quality measurements for the impaired water quality segments were obtained from EPA's Water Quality Portal (WQP) database (NWQMC, 2023). The WQP was queried for monitoring sites located within the water quality segments. Water quality sampling sites were selected based on their location (i.e., upstream and downstream of high-use areas), their accessibility (i.e., safe access during storm events and high recreational visitation periods), and their ownership (i.e., public). The notable exceptions of the ownership selection criteria include monitoring locations downstream of the Rainbow Trout Farm, Munds Creek, downstream of Dry Creek, and downstream of Page Springs Fish Hatchery. These sites are not open to the public, but access was granted to ADEQ by the individual landowners for sample collection. **Error! Reference source not found.** displays the locations of the sites with *E. coli* surface water monitoring data within the impaired waterbodies.

Figure 6. Surface Water Sampling Sites Along Oak Creek's Impaired Reaches



The WQP was queried for *E. coli* data collected from 1994 to 2023. The full record of data was pulled to compare the historical data to the post-2010 TMDL data; data from 1994 to 2009 are referred to as pre-2010 data or "past," and data from 2010 to 2023 are referred to as post-2010 or "present." The data set was filtered by removing samples with Quality Assurance flags, indicating issues with the underlying measurement (e.g., when sample holding times were exceeded, problems with the sampling procedures were indicated, etc.), and removed sample records where neither a result nor a reporting limit were reported. Duplicate samples collected at the same site on the same date were averaged together.

In total, 9,948 samples were included in the trend analysis. Sampling has been conducted in each of the impaired segments, but most of the sampling occurred in and around Slide Rock State Park, as shown in Table 8**Error! Reference source not found.**, where extensive efforts have been made to monitor and control *E. coli* in surface waters. Slide Rock State Park receives hundreds of thousands of visitors per year and park managers actively monitor water quality at high frequencies to reduce risk from waterborne pathogens to recreators. Figure 7 displays the locations of the samples taken throughout the entire watershed.

Table 8. Summary of *E. coli* Sampling in the Impaired Reaches

Waterbody	Date Range	No. of Samples
15060202-019	1998 – 2023	249
15060202-018A	2003 – 2023	275
15060202-018B	1995 – 2023	7,744
15060202-018C	1994 – 2023	1,013
15060202-017	2001 – 2023	310
15060202-022	2001 – 2023	246
15060202-016	2004 – 2023	111

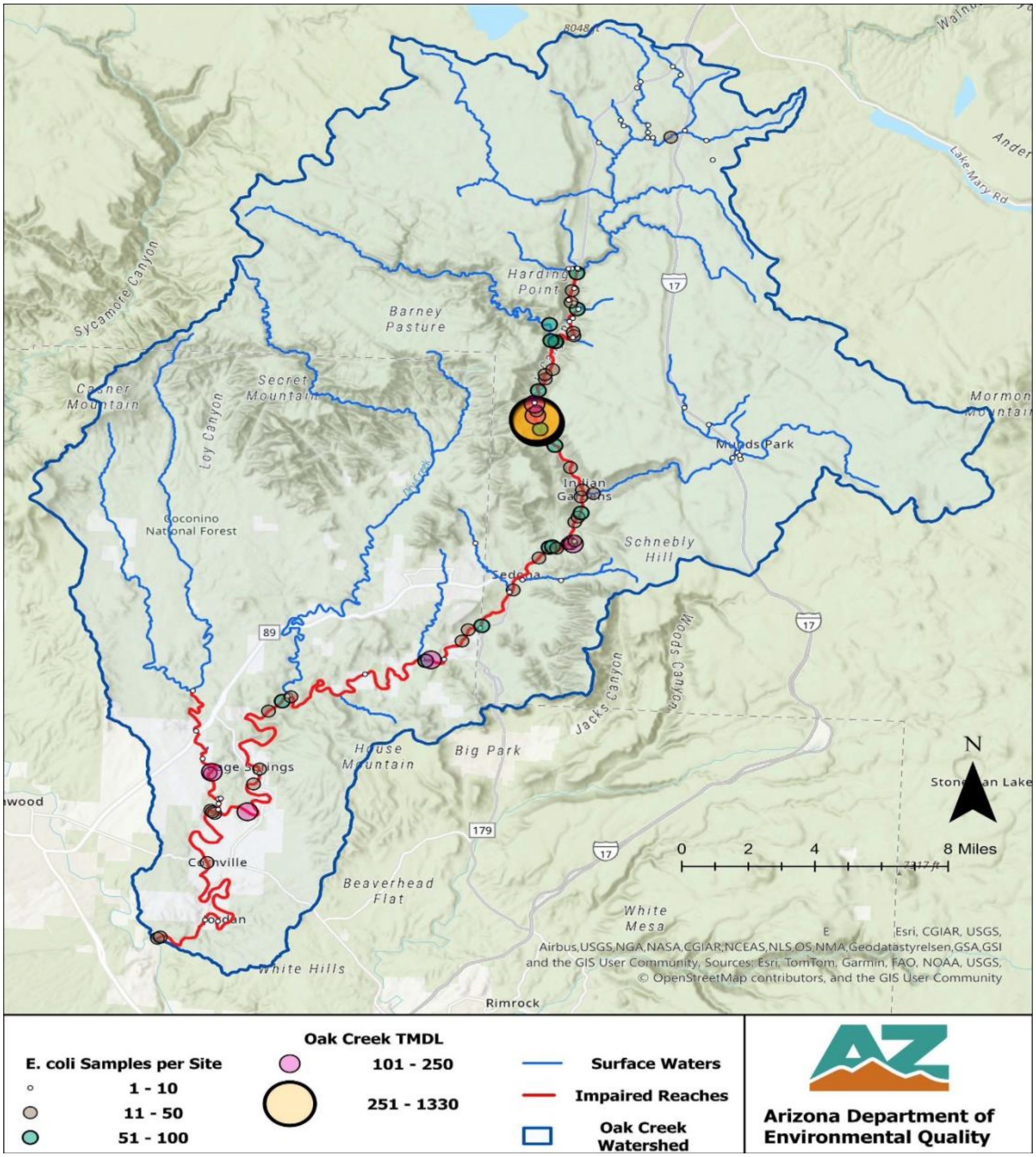


Figure 6. ***E. coli*** **Samples throughout the Oak Creek Watershed.**

General trends in the waterbody were assessed using graphical analysis of the data set. Aggregating by water quality segment, monthly geomean *E. coli* concentrations, and monthly SSM concentrations were computed for each calendar month in the period of record. The average pre- and post-2010 monthly geomean and monthly SSM value were also computed to assess whether water quality conditions had changed since the adoption of the 2010 TMDL. Trends for the recreational season and off season were assessed separately.

Recreational season monthly geomean *E. coli* concentrations generally increased or stayed the same during the post-2010 period. As shown in Figure 7, the most dramatic long-term average recreational season increase was observed at the lowest segment in the watershed (-016) though this may be an artifact of the relative lack of pre-2010 data in this segment. Concentrations tend to increase as one progresses downgradient within Oak Creek, with lowest concentrations occurring in -019 (the most upstream segment) and the highest concentrations occurring in -016 (the most downstream segment). A similar trend can be seen during the off-season data, with a decrease in *E. coli* concentrations throughout the watershed in the post-2010 period.

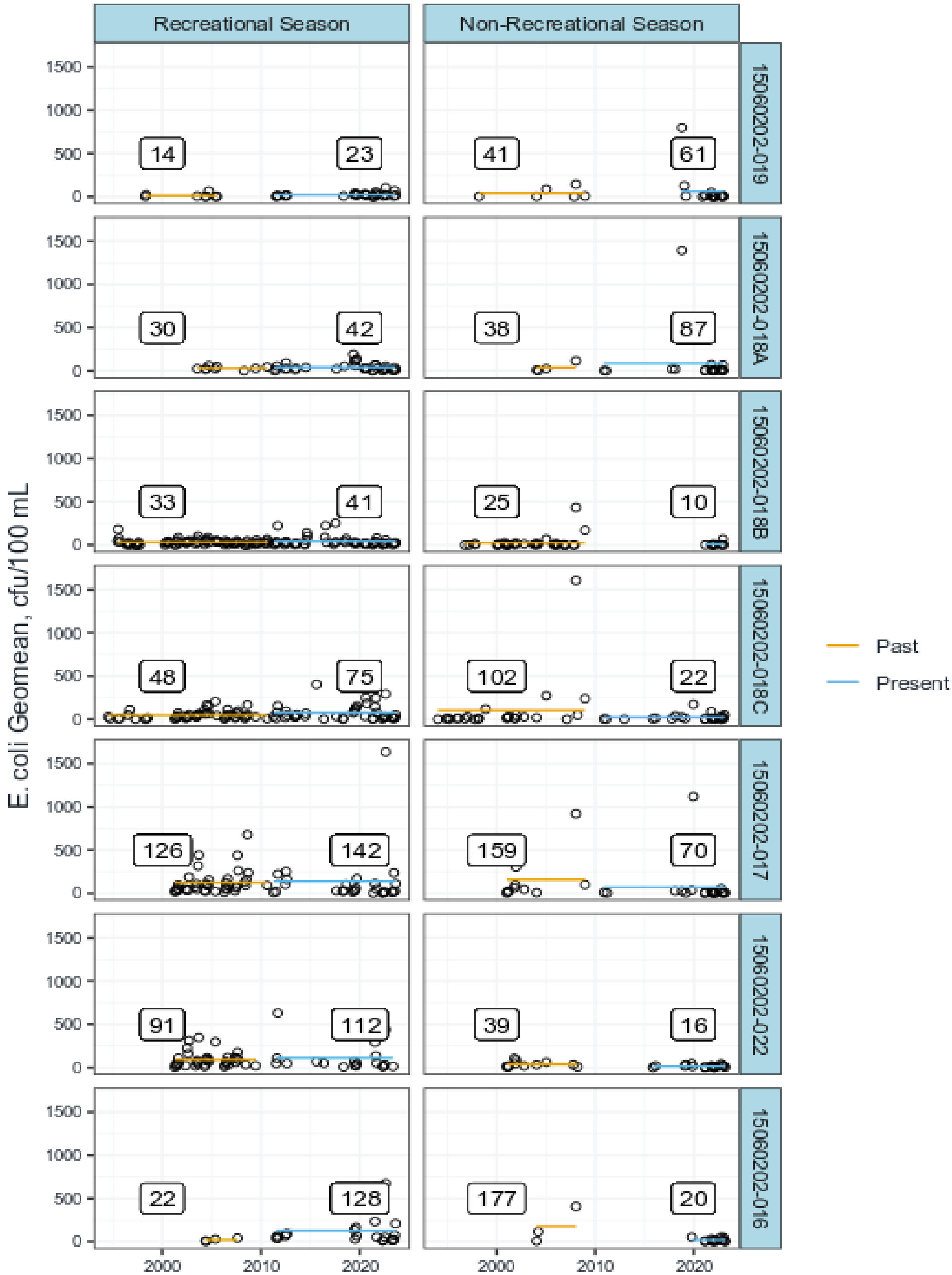


Figure 7. Monthly Geomean *E. coli* Concentrations During Recreation and Non-Recreational Seasons

Trends based on the monthly SSM concentrations show a more mixed set of trends than the monthly geomean *E. coli* concentrations during the recreational season. In the segment with the greatest number of samples, -018B, a post-2010 improvement in water quality (as measured by monthly SSM concentrations) is apparent. As displayed in Figure 8, all other segments show some level of deterioration in water quality during the recreational season in the post-2010 period. During the off-season, water quality improvements in the post-2010 period are clear throughout the watershed — apart from segment -019 due to two extreme sample results measured in October 2018.

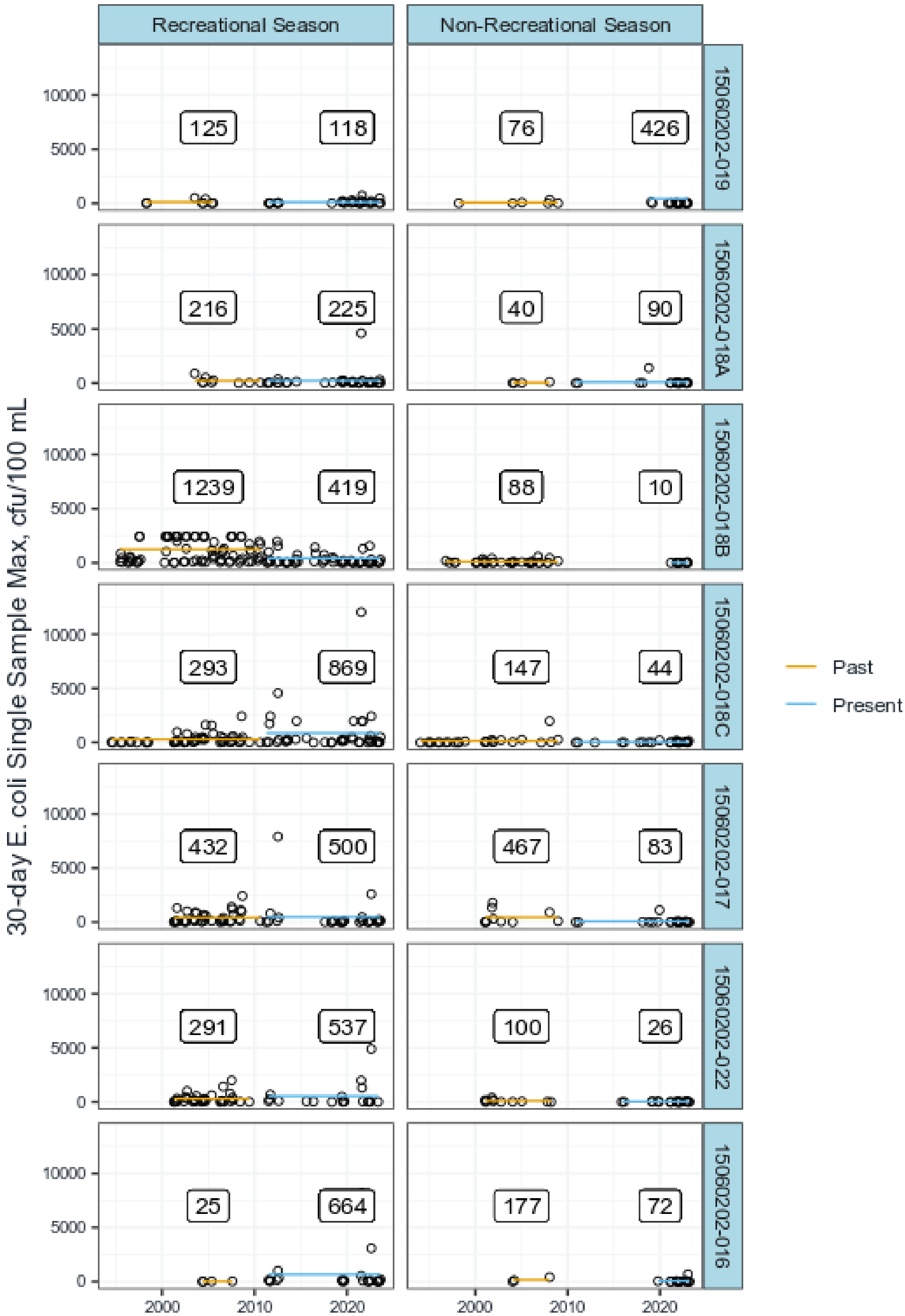


Figure 8. Monthly Single Sample Maximum *E. coli* Concentrations During Recreational and Non-Recreational Seasons

5.3 Streamflow Data

There are two USGS streamflow gauges within the Oak Creek watershed: USGS 09504500 (Oak Creek Near Cornville, AZ) and USGS 09504420 (Oak Creek Near Sedona, AZ). As shown in Figure 10, the Cornville station is located downstream on Oak Creek near the middle of the -017 segment, and the Sedona Station is located on Oak Creek near the middle of the -018C segment. Daily flow data for each station was procured using the USGS National Water Information Service (NWIS). Table 9 summarizes the information obtained for this analysis.

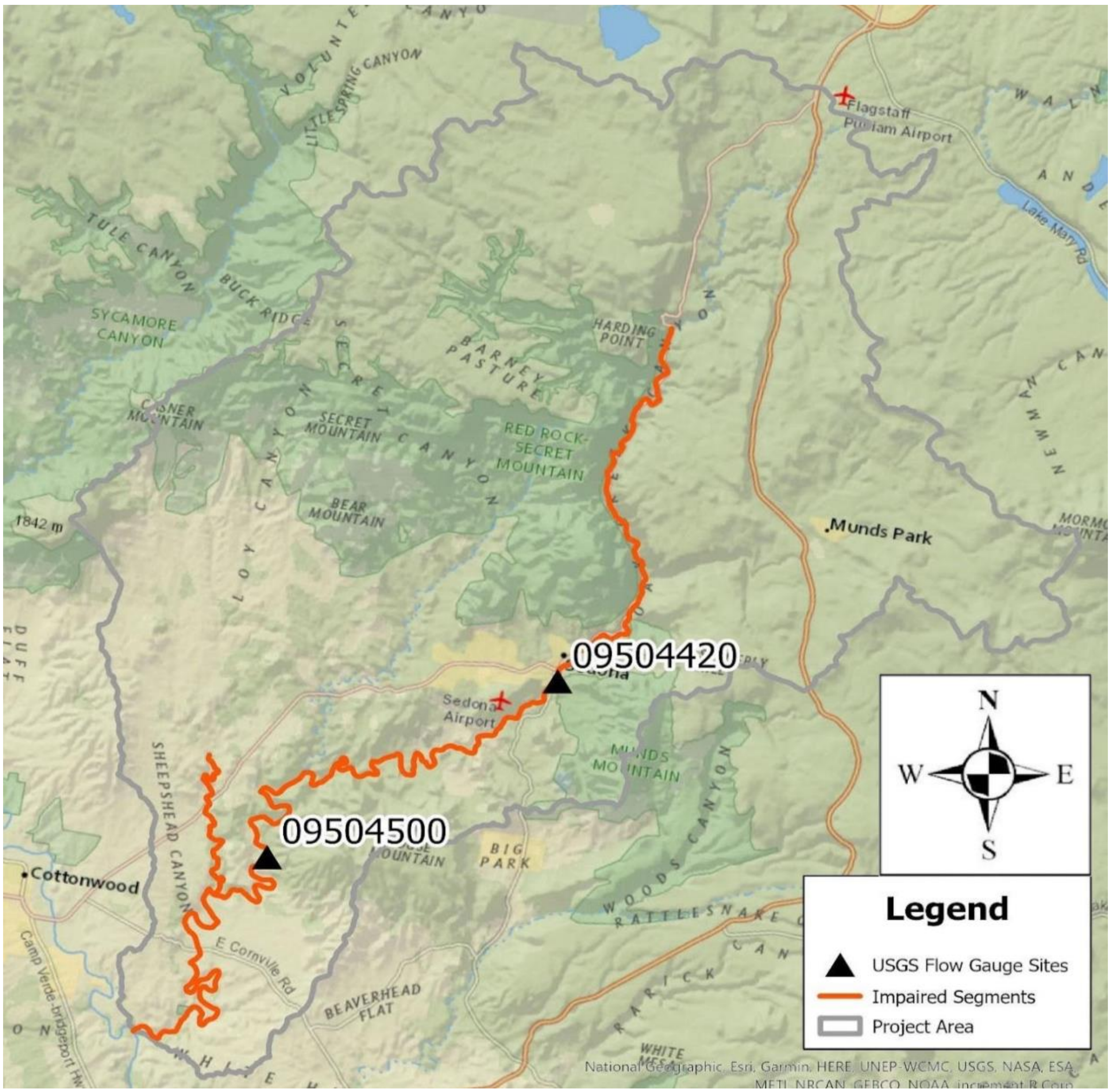


Figure 9. USGS Streamflow Gauge Locations in Watershed

Table 9. USGS Gauge Stations

Station	Description	Location	Drainage Area (km^2)	Measurement	Period of Record
09504500	OAK CREEK NEAR CORNVILLE, AZ	34.76, -111.89	919	Daily Stream Discharge	July 1940 – September 2023[1]
09504420	OAK CREEK NEAR SEDONA, AZ	34.86, -111.76	603	Daily Stream Discharge	October 1981 – September 2023

[1]Missing values from Sept. 30, 1945 to April 28, 1946, and from Sept. 29, 1946 to April 27, 1948.

Historic flow statistics were computed on each of the stream discharge datasets to characterize the flow behavior at each location over time. The analysis was based on data collected since 1980 to use data with a reasonable likelihood of representing current climatic conditions. Figure 10 displays maximum daily, mean daily, median daily, and 7-day low flow measures of the flow history at the Cornville station with points representing the annual (by water year) estimate of the statistic, and the curve representing a smoothed value of the time series (see Hirsch and De Cicco, 2015 for additional detail on smoothing methods). Annual maximum daily flows ranged approximately 4 – 331 cubic meters per second (cms) (141 – 11,689 cfs), annual mean daily flow ranged approximately 0.71 – 7.3 cms (25.1 – 257.8 cfs), and the annual 7-day average low flow ranged approximately 0.33 – 0.63 cms (11.7 – 22.2 cfs). Over this period of analysis, only relatively small changes are apparent in annual maximum daily flow, mean daily flow, and median daily flow. However, a modest increase in the 7-day low flow is shown with an approximate 30 percent increase over the period of analysis.

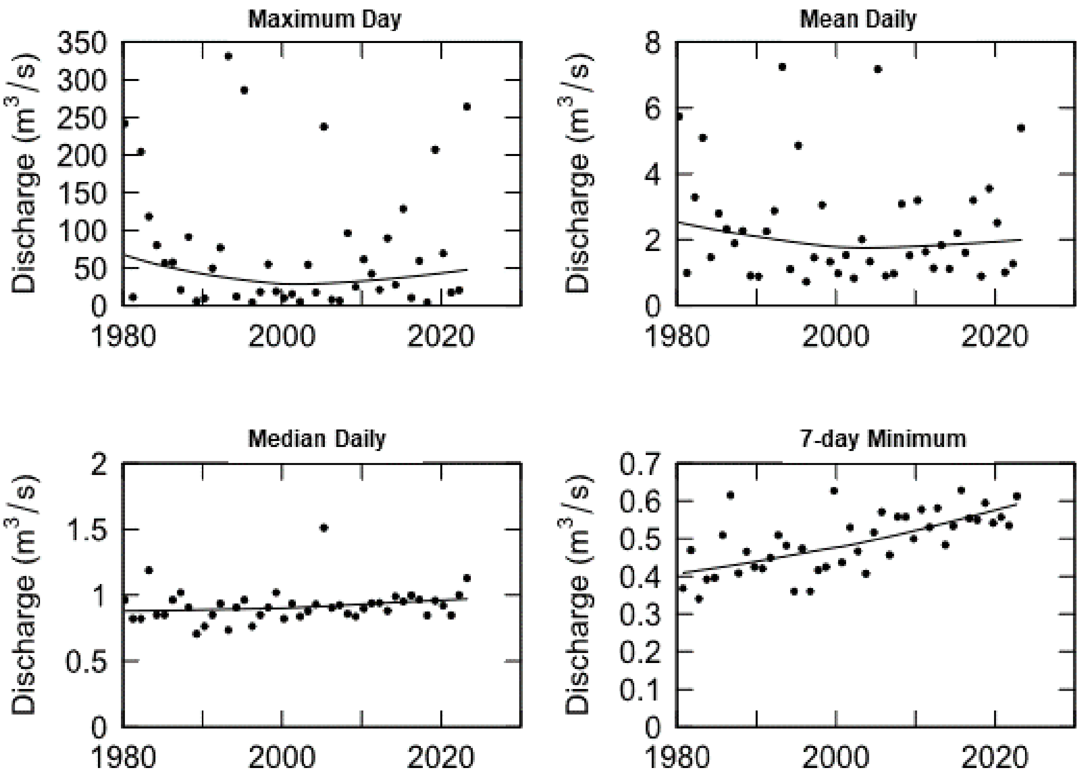


Figure 10. Streamflow Statistics by Water Year: Maximum Daily Flow, Mean Daily Flow, Median Daily Flow, and Minimum 7-Day Average Flow for USGS 09504500 (Cornville, AZ; 1980 – 2023)4

Figure 11 displays maximum daily, mean daily, median daily, and 7-day low flow measures of the flow history at the Sedona station. Annual maximum daily flows ranged approximately 1.4 – 268 cms (70 – 9571 cfs), annual mean daily flow rates ranged approximately 0.87 – 7.1 cms (31.1 – 253.6 cfs), and the annual 7-day average low flow rate ranged approximately 0.51 – 0.81 cms (18.2 – 28.9 cfs). Over this period of analysis, only relatively small changes are apparent in statistical measurements.

[4] Points represent annual statistical estimates and lines represent lowess smoothing function for the time series.

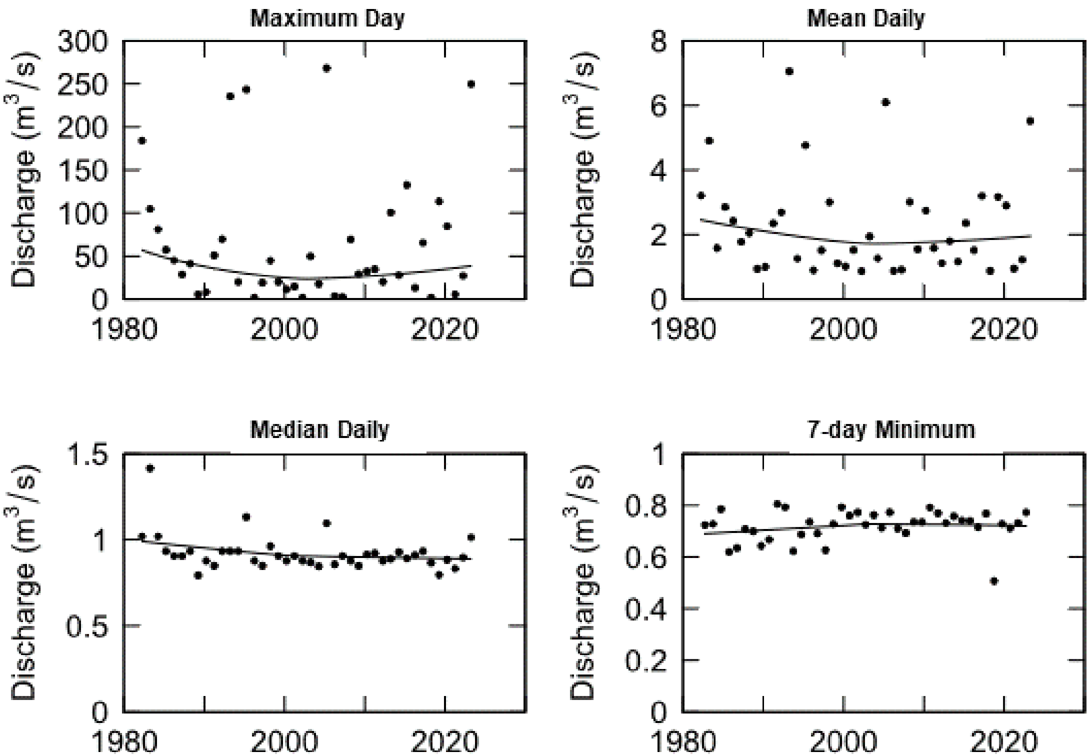


Figure 11. Streamflow Statistics by Water Year: Maximum Daily Flow, Mean Daily Flow, Median Daily Flow, and Minimum 7-Day Average Flow for USGS 09504420 (Sedona, AZ; 1982 – 2023)[5]

5.4 Summary of Findings

The previous information is included to provide a historic summary of the water quality data for Oak Creek and Spring Creek and streamflow characteristics for Oak Creek. Based on the trend analysis, water quality during the recreational season has continued to decline post-2010 for both the monthly geomean and monthly SSM statistic, with the exception of segment -018B's monthly SSM. For the off-season, generally *E. coli* concentrations have decreased for all impaired segments post-2010. For the streamflow data, there is little variation over the period of record (1980 – 2023). In general, flow rate increases between the upstream Sedona gauge station and the downstream Cornville gauge station.

Section 6 Source Assessment

A key component of a TMDL evaluation is determining the known and potential sources of contamination contributing to the watershed through a source assessment. Source assessment analyses are generally used to evaluate the type, magnitude, timing, and location of pollutant loading to a waterbody (EPA, 1999). Source assessment methods vary widely with respect to their

[5] Points represent annual statistical estimates and lines represent lowess smoothing function for the time series.

applicability, ease of use, and acceptability. This section presents potential sources of pollution throughout the Oak Creek watershed, as well as the mechanisms by which pollutants can reach the waterbody, both of which can be useful in determining applicable remediation efforts.

Contaminant sources can include point sources and NPSs. Point sources of pollutants are regulated under National Pollutant Discharge Elimination System (NPDES) permits. *E. coli* point sources for the impaired Oak and Spring Creek segments include discharges from municipal wastewater treatment plants (see Section 6.1.1) and NPDES-regulated sources of urban stormwater runoff called MS4s (see Section 6.1.3). NPSs are pollutant sources that reach the receiving water via indirect mechanisms not regulated under the NPDES program. *E. coli* NPSs for the impaired Oak and Spring Creek segments primarily include wildlife (other than waterfowl), wastes from pets, recreation and tourism (non-boating), nearby leaking septic systems, and unspecified urban stormwater.

ADEQ has regulatory authority from EPA to administer the NPDES program through the Arizona Pollution Discharge Elimination System (AZPDES) permitting program. Additionally, ADEQ regulates one category of NPS – onsite wastewater systems – under the Aquifer Protection Program (APP) and its Type 4 Aquifer Protection General Permits per A.A.C. R18-9-A301(D). Beyond this, however, ADEQ has not developed a regulatory program for other types of NPS within Arizona, resulting in the need for additional voluntary efforts to control or mitigate these sources.

6.1 Point Sources

The EPA defines point source pollution as "any discernible, confined and discrete conveyance from which pollutants are or may be discharged" (EPA, 2010). A point source discharge does not imply a continuous discharge, but rather a specific point from which a discharge can occur. When point source discharges contribute to a waterbody's impairment, exceedances typically plot in the low flow portion of the LDC (near the right side). Point sources within the Oak Creek watershed include wastewater treatment facilities, fish hatcheries, and stormwater related discharges.

Table 10 lists and describes the point sources that are permitted through AZPDES discharging to impaired segments of Oak Creek and Spring Creek. The point source discharge locations/outfalls are depicted in Figure 12. The permitted facilities identified in Table 10, excluding two of the fish hatcheries that are exempt from AZPDES permitting, will receive WLAs in the TMDL.

Table 10. Point Sources Dischargers and Individual AZPDES Permit Status

<table>
<tr><th>AZPDES ID</th><th>Facility Name</th><th>Design Flow Rate</th><th>Permittee Type</th></tr>
<tr><td colspan="4">Wastewater and Individual Permittees</td></tr>
<tr><td rowspan="2">AZ0025879</td><td rowspan="2">Pinewood Sanitary District - Kay S. Blackman Wastewater Treatment Plant (WWTP)</td><td>0.6 MGD</td><td rowspan="2">Minor WWTP</td></tr>
<tr><td>1.1 cfs</td></tr>
<tr><td rowspan="2">AZ0021807</td><td rowspan="2">Sedona Venture Sewer Company</td><td>0.075 MGD</td><td rowspan="2">Minor WWTP</td></tr>
<tr><td>0.14 cfs</td></tr>
<tr><td rowspan="2">AZ0021245</td><td rowspan="2">Arizona Game and Fish Department (AZGFD) Page Springs and Bubbling Ponds Hatchery</td><td>22.8 MGD</td><td rowspan="2">Minor Facility</td></tr>
<tr><td>42.4 cfs</td></tr>
<tr><td colspan="4">MS4 Permittees</td></tr>
<tr><td>AZS000018</td><td>Arizona Department of Transportation (ADOT)</td><td>NA</td><td>Phase I MS4</td></tr>
<tr><td>AZG2021-002</td><td>City of Sedona</td><td>NA</td><td>Phase II MS4</td></tr>
<tr><td colspan="4">Dischargers Exempt from Permitting Requirements</td></tr>
<tr><td>Not Applicable</td><td>AZGFD Sterling Springs Hatchery</td><td>Unknown</td><td>Minor Facility</td></tr>
<tr><td>Not Applicable</td><td>AZGFD Rainbow Trout Farm</td><td>Unknown</td><td>Minor Facility</td></tr>
</table>

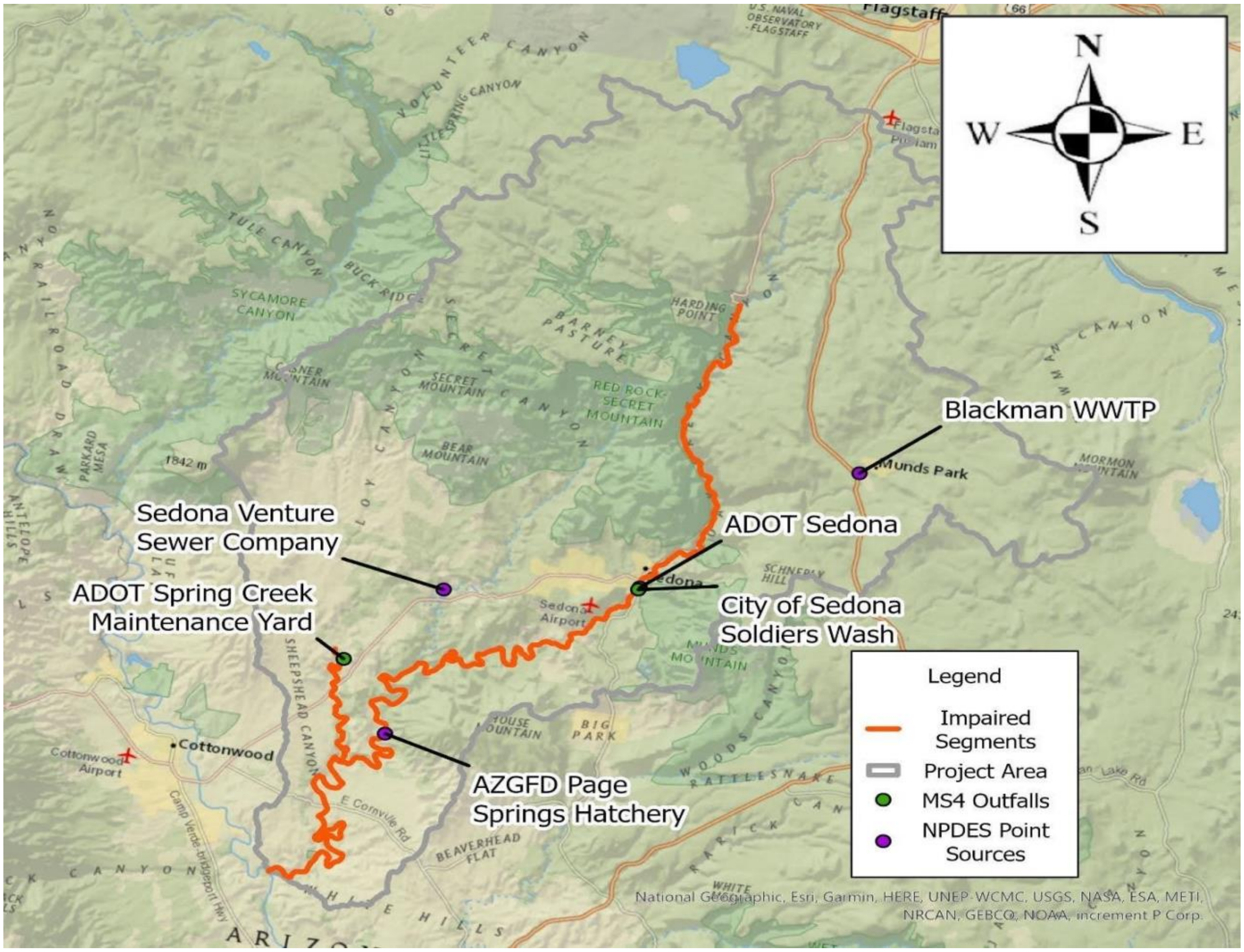


Figure 12. Locations of AZPDES Permitted Point Sources and MS4 Outfalls Within the Watershed

6.1.1 Wastewater Treatment Plants

Two wastewater treatment plant (WWTP) facilities have AZPDES permit coverage for discharges to surface waters within the Oak Creek watershed: Pinewood Sanitary District Blackman WWTP (AZPDES Permit AZ0025879) (hereafter referred to as Blackman WWTP) owned and operated by the Pinewood Sanitary District, and Sedona Venture WWTP (AZPDES Permit AZ0021807) (hereafter referred to as Sedona Venture) owned and operated by Venture Sewer Company. Both permits apply the SSM and geometric mean *E. coli* surface water quality standards as permit limits. These two WWTPs will receive WLAs that will be calculated using the *E. coli* limits stated in their respective permits, as discharge concentrations are well below the WQS (Figure 13).[6] Under median flow conditions (~31 cfs) the maximum plant discharge volume (~1.25 cfs) would account

[6]Several communities within the watershed operate small WWTPs. These facilities do not discharge to a surface water and are not permitted through AZPDES, but are regulated through other state or federal programs.

for ~4 percent of the flow in the receiving system; if these WLAs are met, then discharges from WWTPs will not be significant contributors to *E. coli* exceedances. Should water quality deteriorate or WWTP discharges increase over time, however, these limits may be modified as deemed necessary per the provisions of A.A.C. R18-9-B906, and R18-9-A905.

The Blackman WWTP permit authorizes discharge to Munds Creek between November 15 and April 14, with an anticipated average discharge of 0.17 MGD during this period. Notably, the permit also contains a provision (Part V.B.) allowing emergency discharge during the remainder of the year, if the freeboard in the storage ponds falls below three feet (for example, during wet weather). Munds Creek carries the Partial Body Contact (PBC) designated use resulting in an *E. coli* SSM permit limit of 575 CFU/100 mL. The average *E. coli* concentration measured (number of samples [N] =3) in the discharge between September 2019 and August 2023 was 4.7 CFU/100 mL and the monthly average discharge was 0.22 MGD. There were no *E. coli* exceedances measured or reported from the Blackman WWTP discharge over the specified time frame. However, Blackman WWTP has experienced periodic bypass events (Table 11) in which partially treated wastewater is discharged downstream to avoid overflow during major storm and snowmelt events. Though DMR data includes *E. coli* samples taken during these events, they only demonstrate end-of-pipe levels. ADEQ's Groundwater Protection Section filed a Consent Judgement against the WWTP in late 2024 that established a requirement to sample the discharge of any future bypass events among other enforcement actions.

Table 11. Blackman WWTP Nutrients Exceedances from Bypass Events

Bypass Event Start	Bypass Event End	Duration (hours)	Volume (million gallons)
03/11/20	03/14/20	70	0.50
12/24/21	12/25/21	15	0.50
01/01/23	01/04/23	72	1.00
03/12/23	03/22/23	249	3.75
03/17/24	3/21/24	84	0.52

Sedona Venture is permitted to discharge effluent to Dry Creek, a tributary to Oak Creek, located southwest of Sedona. There is no seasonal discharge limitation for the facility, which discharges an average of 0.045 MGD. The average *E. coli* concentration measured (N=44) in the discharge between September 2019 and August 2023 equals 3.5 CFU/100 mL and the monthly average discharge is 0.04 MGD. There was one *E. coli* SSM exceedance of 520 CFU/100 mL measured on April 30, 2021, from Sedona Venture over the specified time frame. Dry Creek carries the FBC designated use resulting in an *E. coli* SSM permit limit 235 CFU/100 mL.

EPA's ICIS-NPDES database was queried for flow and *E. coli* Discharge Monitoring Report (DMR) data for discharges from the two WWTP permittees for the period 2010 – 2023. Discharge flow rates for both facilities were generally below their design flow rates, as shown in Figure 13. *E. coli* monitoring data was available for the WWTP facilities as well (Figure 15).

Table 12 provides the maximum single sample reported *E. coli* concentrations and maximum reported average monthly *E. coli* concentrations in Most Probable Number per 100 mL (MPN/100 mL) for the two facilities.

Table 12. Maximum Single Sample and Average Monthly *E. coli* Concentrations (2010-2023)

AZPDES ID	Facility Name	Maximum Single Sample *E. coli* Concentration (MPN/100 mL)	Average Monthly *E. coli* Concentration (MPN/100 mL)
AZ0025879	Pinewood Sanitary District - Kay S. Blackman WWTP	56	12
AZ0021807	Sedona Venture Sewer Company	520	105

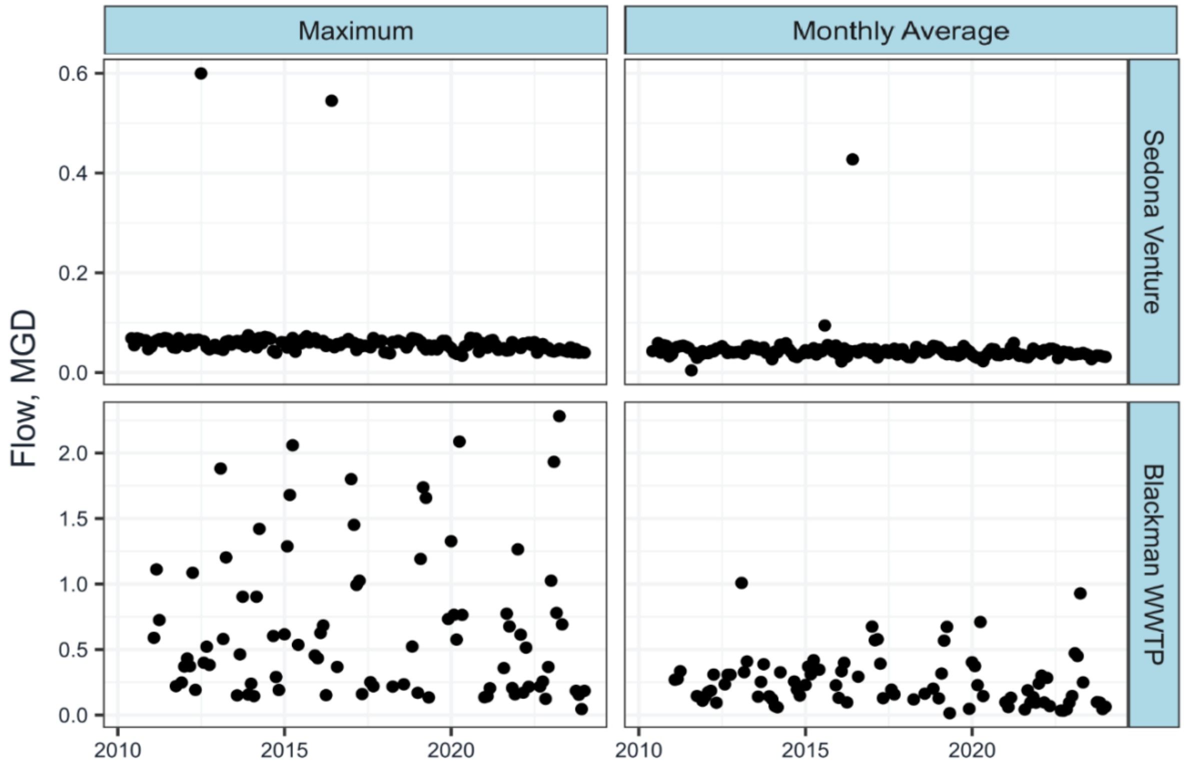


Figure 13. Available Flow Discharge Monitoring Data for WWTPs (2010-2023)

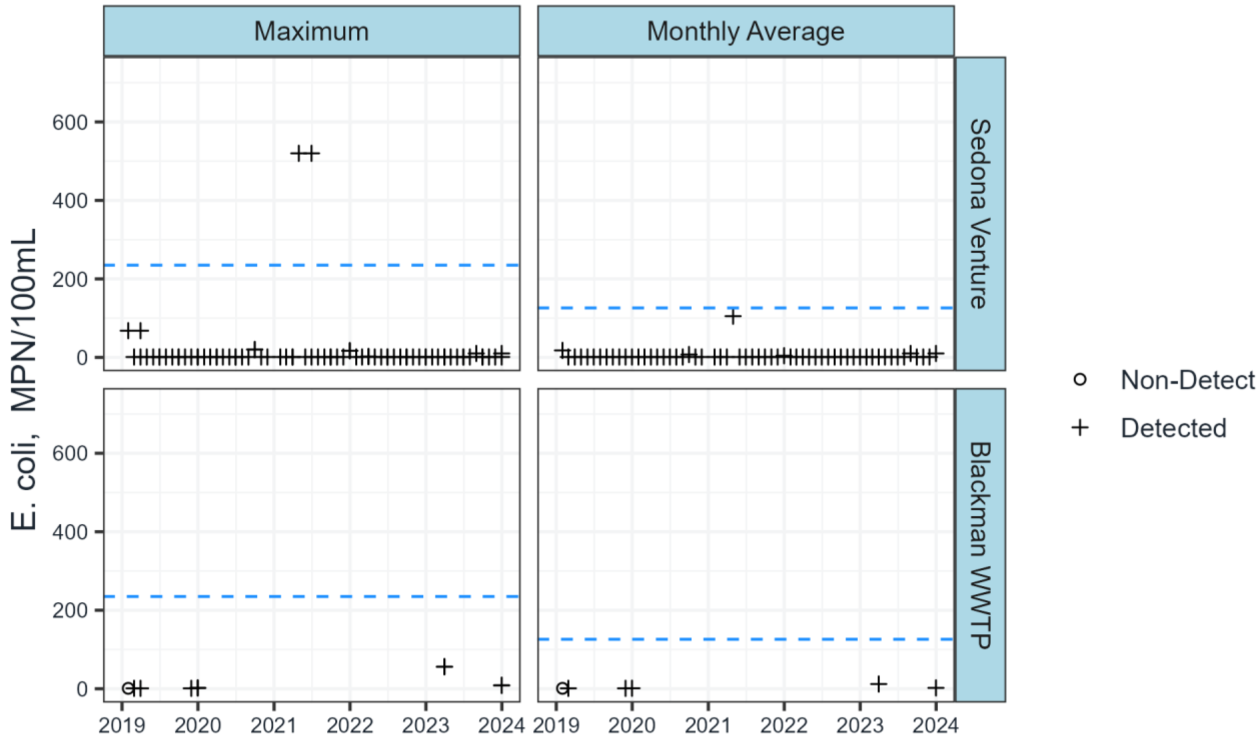


Figure 14. Available *E. coli* Effluent Monitoring Data for WWTPs (2018 – 2023)
Note: Blue dashed line indicates the magnitude of the SSM value (maximum panels) and geomean (monthly average panels) water quality criteria.

6.1.2 Fish Hatcheries

The AZGFD operates three fish hatcheries in the Oak Creek Watershed to support statewide trout fishing. The Sterling Spring Fish Hatchery is located near the top of Oak Creek Canyon. Hatchery operations capture the flow from Sterling Springs and discharge the water to Sterling Canyon after flowing through the facility. Perennial flow within Oak Creek begins below the hatchery outfall. The Sterling Spring hatchery is exempt from AZPDES permit coverage because of the number of fish raised per year (i.e., facilities that produce less than 9,090 harvest weight kilograms of coldwater aquatic animal per year, or that feed less than 2,272 kilograms of food during the calendar month of maximum feeding; see 40 C.F.R., Chapter. 1, Part 122, App. C).

Rainbow Trout Farm is a commercial "catch and take" fishing facility located approximately three miles north of Sedona. Trout are raised on site, but similar to the Sterling Spring Fish Hatchery, Rainbow Trout Farm is not regulated for *E. coli* as explained below.

The Bubbling Ponds and Page Springs Fish Hatcheries are located along Oak Creek between Sedona and Cottonwood. Page Springs is the largest trout hatchery in the state, raising more than 600,000 catchable trout per year. AZPDES Permit AZ0021245 covers discharges from both the

Bubbling Ponds and Page Springs hatcheries; it does not currently specify an *E. coli* limit (ADEQ, 2020c).

The hatcheries are expected to contribute minimal *E. coli* loading to the creek, as fish are ectotherms (cold-blooded animals), and the primary habitat for *E. coli* is in the intestines of endotherms (warm-blooded animals). Therefore, hatcheries will not receive a WLA.

6.1.3 Municipal Separate Storm Sewer System Permits

The City of Sedona is a Phase II MS4 community based upon the anticipated growth and stormwater-related water quality concerns in the area and ADEQ has issued the City a Small MS4 General Permit (AZG2021-002). The permit authorizes stormwater discharges to Oak Creek. The goal of this permit is to reduce stormwater pollution from municipal activity through development and implementation of a municipality-specific Stormwater Management Program (SWMP). The latest version of the SWMP was submitted to and deemed adequate by ADEQ in 2021 (City of Sedona, 2023). However, the City is required to revise the SWMP to incorporate TMDL limitations or provisions as they become available. A WLA will be incorporated into the TMDL calculations for Sedona's MS4 discharges into Oak Creek. Due to a lack of water quality data from the Sedona stormwater outfalls, the WLA will be equal to 5.2 percent of the TMDL within the two top flow categories (storm related discharges) based upon the area of Sedona (24.4 mi^2), compared to the total area of the watershed (465 mi^2). This approach is based on guidance issued by EPA for calculating an MS4 WLA using an LDC analysis (EPA, 2007).

The Arizona Department of Transportation (ADOT) also owns and operates areas with MS4 permit coverage within the Oak Creek watershed. The surface area of highways managed by ADOT within the watershed is very small (0.47 mi^2) or 0.1 percent of the watershed. The ADOT Phase I MS4 permit (AZS0000018) is an AZPDES permit that covers construction activities, industrial facilities, and stormwater runoff from highways and roadways maintained by ADOT across the state. Under the permit, ADOT is required to conduct pollutant monitoring during qualifying storm events at outfalls determined to be representative of the permittee's regulated MS4 area. The permit does not specify a discharge limit for *E. coli* and instead only requires monitoring and reporting. However, the permit does require the permittee to implement control measures to "minimize the discharge of any listed parameter(s) from the MS4 to protected surface waters listed on the most current version of Arizona's § 303(d) list." (ADEQ, 2021a). Since 2011, ADOT has conducted monitoring at two outfalls within the Oak Creek watershed: the ADOT Sedona monitoring location and the ADOT Spring Creek Maintenance Yard monitoring location, as shown in Figure 12. From 2011 to December 2023, 11 samples have been collected at these locations with an overall geomean concentration of 95 MPN/100 mL and a maximum concentration of 11,000 MPN/100 mL, as shown in Table 13. The full monitoring data set for these locations is displayed in Figure 15 (ADOT, 2023a).

Table 13. ADOT Discharge Monitoring Data for Monitoring Locations in the Watershed

Permittee	No. of Samples	Dates	*E. coli* (MPN/100 mL)			
			Minimum	Geomean	Median	Maximum
ADOT	11[1]	2011 - 2023	2.0	95	75	11,000

[1]Of the 11 samples collected, only a single sample was collected at the Spring Creek Maintenance Yard (2.0 MPN/100 mL on November 4, 2015). All other samples were collected at the Sedona monitoring location.

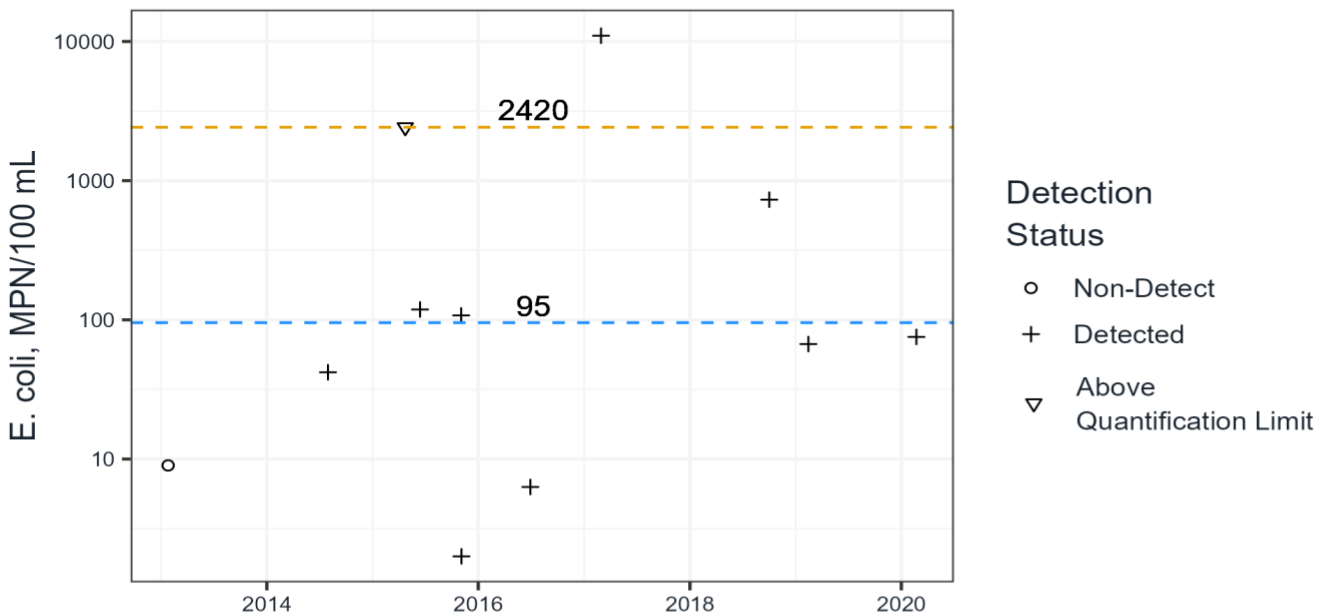


Figure 15. Discharge Monitoring Data at ADOT Monitoring Sites

Note: Blue dashed line indicates geomean of data, and orange line indicates 90th percentile. Vertical scale is on a log-scale.

ADOT completed its SWMP in 2023 (ADOT, 2023b). Because the applicable surface area of the MS4 comprises 0.1 percent of the watershed, ADOT will receive a WLA of 0.1 percent of the TMDL within the Wet flow category. This WLA only applies when the lower USGS gauge (USGS 09504500) measures flow equal to or exceeding the Minimum Flow Rate (cfs) established for Wet flow condition (see Table 5a).

6.1.4 General Permits

The purpose of Arizona's Stormwater General Permits — Construction General Permit (CGP) and Industrial Stormwater Multi-Sector General Permit (MSGP) — is to protect the quality and beneficial uses of Arizona's surface waters from pollution in stormwater runoff from construction and industrial activities. Under the Clean Water Act (33 U.S.C. §§ 1251 et seq.) and Arizona Revised Statutes (A.R.S. § 49-255.01), it is illegal to have a point source discharge of pollutants, including stormwater runoff from construction and industrial sites, to a water of the United States that is not authorized by a permit. To protect water quality, the CGP and MSGP require operators to plan and implement appropriate pollution prevention and control practices for stormwater runoff during land disturbing activities. The main concern with construction activities is the increased rate of erosion and sediment delivery from disturbed or cleared lands to receiving waters. Sites covered by these permits must specify their own control measures for sediment runoff in the Stormwater Pollution Prevention Plan (SWPPP). Because these plans will already be in place, there will be no WLA for CGP or MSGP activities, as they are typically small in extent and duration, and the nature of the operations are expected to contribute negligible *E. coli* to Oak Creek or Spring Creek.

6.2 Nonpoint Sources

NPS pollution originates from non-permitted areas and is contributed to Oak Creek and Spring Creek via surface water runoff or groundwater transport. NPSs may be intermittent and difficult to quantify, originating from both naturally occurring and anthropogenic sources. NPS pollutants can originate from any type of land use including urban, agricultural, residential, and forest lands. Identified NPSs that are known or thought to contribute pollutant loadings to the impaired waterbodies are further described in the following subsections.

6.2.1 Wildlife

Other than the City of Sedona and small pockets of residential areas, the Oak Creek watershed is relatively undeveloped, as over 90 percent of the watershed is under federal or state management. The area supports a diverse wildlife population including raccoon, skunk, deer, and elk, all of which are identified as potential sources of *E. coli* in the Northern Arizona University (NAU) Oak Creek Genotyping study (NAU, 2000). Precipitation events that create runoff introduce naturally occurring fecal material from wildlife into the stream network, although the overland flow over the forest floor may filter some pollutants. Human activities can draw wildlife closer to water sources. Additionally, residential areas increase the possibility of fecal contamination by increasing the number of animals present in a given area and/or decreasing the natural filtering ability of the forest floor.

6.2.2 Domesticated Animals

In addition to wildlife, domesticated animals such as pets, sheep, cattle, horses, and other grazing animals, are also sources of *E. coli*. Recreational users often bring their dogs to play in the creeks when they visit. If proper care is not taken to clean up the dog's fecal material, it can be left behind near the stream. Open-range grazing by domesticated animals, similar to wildlife, can produce fecal material that can be introduced to the stream under storm conditions. Additionally, streams may be the sole source of water for grazing animals, thus increasing the possibility of fecal material being introduced to the system under Low flow conditions, as the animals drink and congregate near the water. Pastures or pens that confine animals also accumulate fecal material that can be carried into the stream system under storm conditions. The NAU genotyping study identified cows, dogs, horses, and llamas as sources of *E. coli* in the Oak Creek watershed (NAU, 2000).

6.2.3 Onsite Wastewater

Onsite wastewater treatment facilities, also known as septic systems, are one potential human source of *E. coli.* Properly functioning septic systems treat septage to remove bacteria and other pollutants. A review of permitting records from ADEQ and Coconino and Yavapai counties indicate there are 1,396 unique septic systems accounted for in the watershed (Table 14). Roughly half of these systems are "aged" – that is, they were either built prior to the codification of current septic system regulation in A.A.C. R18-9-A312 (B)(1) (2001)[7] or are likely older than 20 years, the generally accepted lifespan of an onsite approval under current rule (R18-9-A312(B)(1).

Table 14. Breakdown of Total and "Aged" Septic Systems in the Watershed

Community	Relation to Oak Creek	Total Systems	# of "Aged" Systems	% of "Aged" to Total Systems
Watershed	-	1396	710	51%
Pine Del	Upstream of 15060202-019	69	30	43%
Highland Meadows	Upstream of 15060202-019	34	17	50%
Mountainaire	Upstream of 15060202-019	441	207	47%
Kachina	Upstream of 15060202-019	6	0	0%
Oak Creek Canyon	15060202-019	30	20	67%
Munds Park	East of 15060202-018C	71	48	68%
Indian Gardens	15060202-018C	41	19	46%
North Sedona	15060202-018C	180	118	66%
South Sedona	15060202-018C	237	171	72%
Page Springs	15060202-017	18	12	67%
Cornville	15060202-016	237	158	67%
Jordan	15060202-016	113	88	78%

[7] https://apps.azsos.gov/public_services/register/2001/2/final2.pdf

Such “aged” systems may experience a reduction in efficiency of treatment or fail entirely. This failure could potentially contribute *E. coli* to Oak Creek during storm events and snowmelt. However, due to a lack of direct monitoring of these systems, the true extent of this potential impact on Oak Creek is still largely unknown.

Figure 16 plots the sampling sites in each reach from upstream to downstream against their measured *E. coli* concentrations based on sampling data from 2010 – 2023. Boxes highlighted in green denote sampling sites within one mile of one of the communities from Table 14, and the red intercept line denotes the *E. coli* concentration limit for FBC. Aside from a sampling location in reach 15060202-017, these data indicate that sites near septic system communities are no more likely to see *E. coli* exceedances than those further away from them. This is further illustrated by Figure 17, as areas along the creek with a high density of aged septic systems show roughly equal or fewer *E. coli* exceedances as areas with sparse or no presence of aged systems. Based on this data, septic systems within the watershed do not currently appear to be a significant source of *E. coli* loading into Oak Creek, though contributions from individual failing systems could factor into the impairment as they continue to age over time.

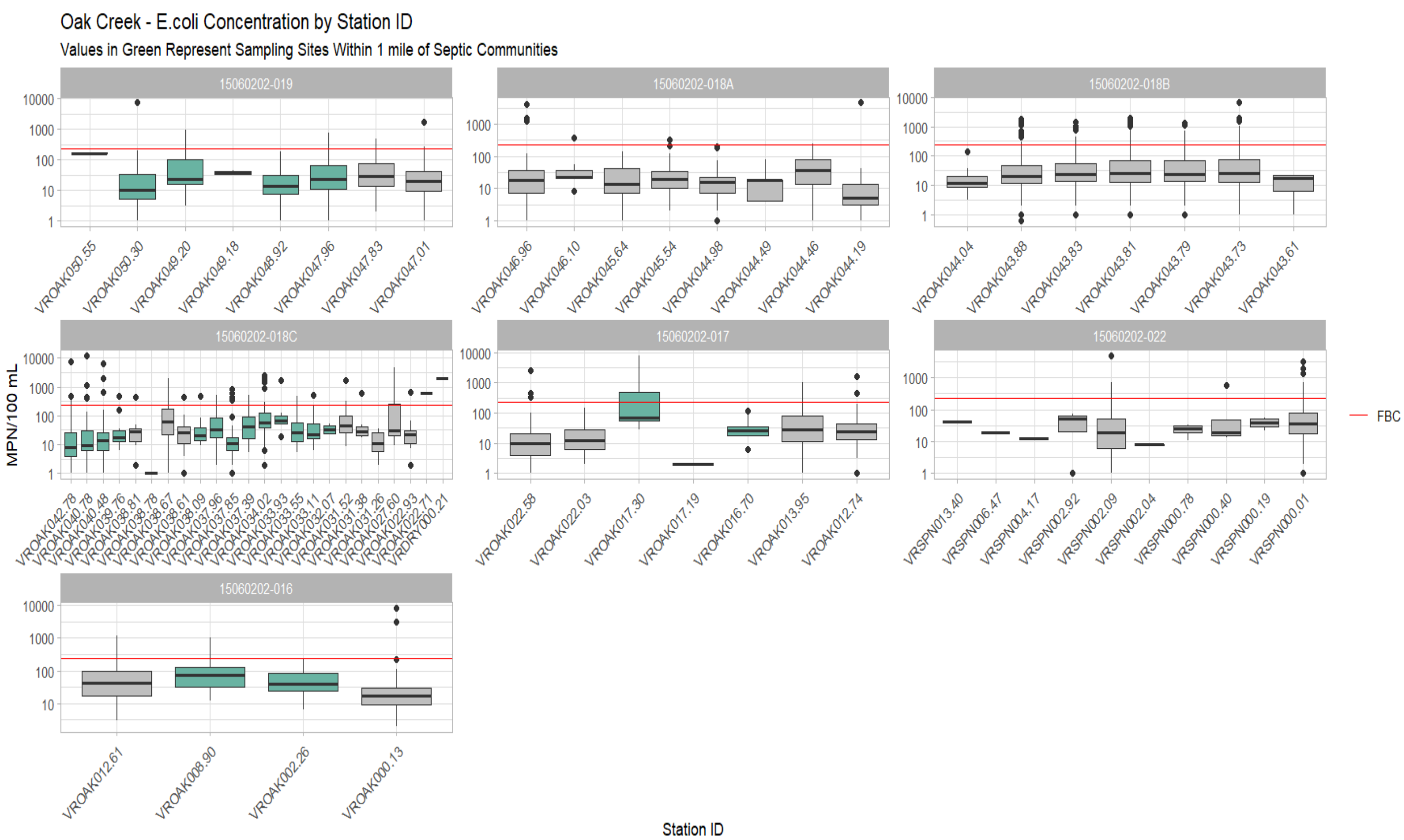


Figure 16. *E. coli* Concentrations by Sampling Site

Note: Green boxes indicate a sampling site within 1 mile of a septic system community.

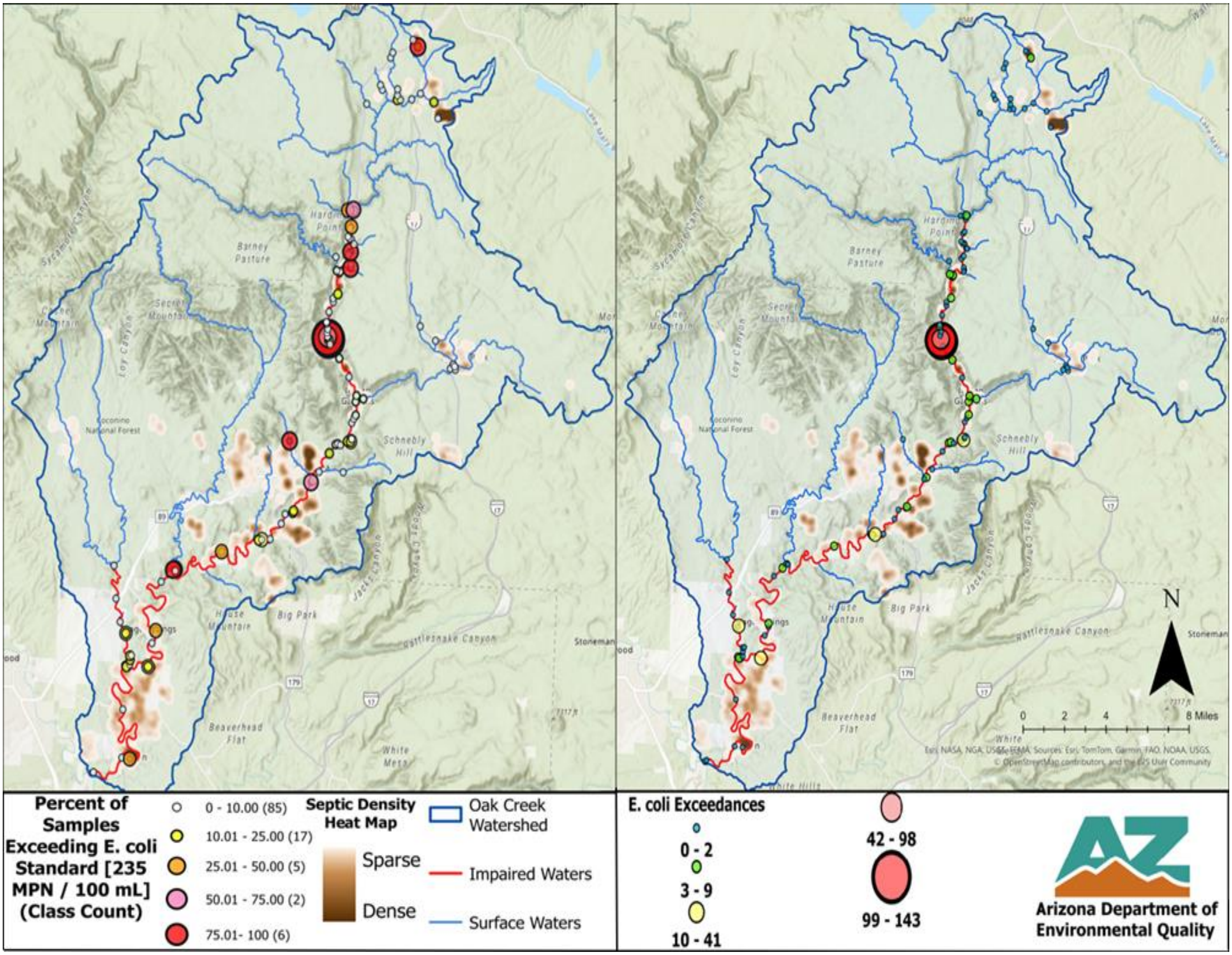


Figure 17. *E. coli* Exceedances and Aged Septic System Density Along Oak Creek

6.2.4 Recreation

Recreation is another potential human-based source of *E. coli.* Recreational activities increase significantly during the summer season — typically from May through September. Public restroom facilities and garbage receptacles within the canyon are limited to fee areas or commercial businesses, with the exception of the public restroom adjacent to the visitor center near Indian Gardens. As a result, many visitors may relieve themselves near the creek. In addition to introducing *E. coli* directly to the stream or riparian area, visitors can resuspend fecal material and *E. coli* from disturbing stream sediments during recreation.

Preliminary results from a DNA study being conducted by NAU and ADEQ and concluding in 2024 has confirmed that tributary drainages within the watershed are also important sources of human and canine fecal contamination. These can be sourced from dispersed recreation and further confirm the relevance of human sources as contributory to the waterbody impairment. Figure 18 shows the relative percent contribution of each type of host in this and the previous three sections.

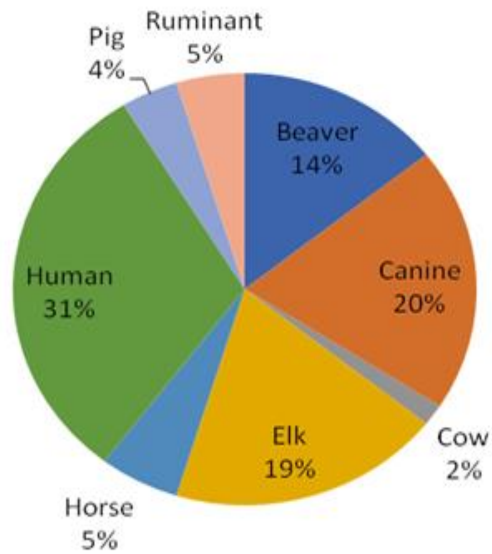


Figure 18. Preliminary Data on the Relative Contribution of Each Host to the Overall Bacteroides Positives Detected in Oak Creek and Surrounding Tributaries (NAU, 2024)

6.2.5 Urban/Developed Areas

The impervious surfaces in urbanized and residential areas increase the amount and rate of stormwater and other runoff to streams. Unlike natural soils that allow water to soak in during storm events, roofs, driveways, and patios allow water to flow over them and collect pollutants from their surfaces. Additionally, the alteration of native vegetation removes the filtering ability of those plants to mitigate pollutant impacts to water quality.

Urbanized and developed areas contain features that can contribute to surface water *E. coli* loading. These can include (but are not limited to) landfills, washdown areas, power washing, pool and hot tub maintenance, and improperly managed graywater systems. Additionally, unsecured or overflowing trash receptacles can attract “urban wildlife” — rodents, beavers, coyotes, etc. — whose waste can contribute *E. coli* to the creek via runoff (Clary et al., 2020).

Less than 5 percent of land within the Oak Creek watershed can be classified as “developed” (see Table 2) within Sedona, Munds Park, and Mountainaire, among others (see Figure 5). The lack of urbanized areas throughout the watershed relative to more natural land uses indicates that while urban sources could be contributing *E. coli* to Oak Creek, their overall impact on the watershed is not likely to be a significant contributor to loading.

Section 7 Technical Approach

The loading capacity of the six Oak Creek segments and the one Spring Creek segment is the amount of *E. coli* that can be assimilated in the waterbody without exceeding the FBC water quality standard. The flow rate within these two streams varies greatly between seasons. *E. coli* exceedances have been observed during three flow conditions — High, Wet, and Low — for the seven segments. High and Wet flow condition exceedances are typically attributed to bacterial sources such as wastes from wildlife and domesticated animals, failing onsite wastewater systems, and urban pollutants on land transported into the receiving waters by stormwater or spring snowmelt runoff, (EPA, 2007). In the previous section, all but failing onsite wastewater systems were identified as likely NPS contributors of *E. coli* to Oak Creek. The Low flow condition exceedances were observed during Oak Creek's recreational season, suggesting contributions by recreational users. Due to these flow-dependent and seasonal exceedances, EPA guidance suggests the use of LDCs to calculate the *E. coli* TMDL (EPA, 2007).

7.1 Technical Approaches Considered

Based on EPA guidance and the use of a similar approach in the 2010 *E. coli* TMDL, no other technical approaches were considered for this update.

7.2 Load Duration Curves

ADEQ chose to employ a Load Duration Curve (LDC) approach to support TMDLs and calculate load reductions necessary to attain the concentration-based SSM water quality standard. LDCs characterize water quality standards at different flow conditions. The curves provide a visual display of the relationship between streamflow, loading capacity, and water quality data. The frequency and magnitude of water quality exceedances, allowable loads, and size of load reductions are easily presented and understood using the LDC approach.

To create LDCs, a Flow Duration Curve (FDC) must be made using daily flow data. Flow data measured between Jan. 1, 2000, and Dec. 1, 2023 were used because they represent current flow conditions. Data from two USGS gauge stations were utilized in this analysis: 09504420 (Oak Creek Near Sedona, AZ) and 09504500 (Oak Creek Near Cornville, AZ). The FDCs for the upper segments (-019, -018A, -018B) used flow data from gauge station 09504420 and the lower segments (-018C, -017, -016) used flow data from gauge station 09504500. The current flow data were sorted from greatest flow rate (high flow/flood conditions) to lowest (low flow/drought conditions). Each measurement was given a rank, and the percent flow exceedance was calculated, respectively. The FDC plots the daily discharge measurements against the percent flow exceedance graphically showing the likelihood of discharge exceedance, as displayed in Figure 19 and Figure 20.

Figure 19. FDC for Gauge 09504500

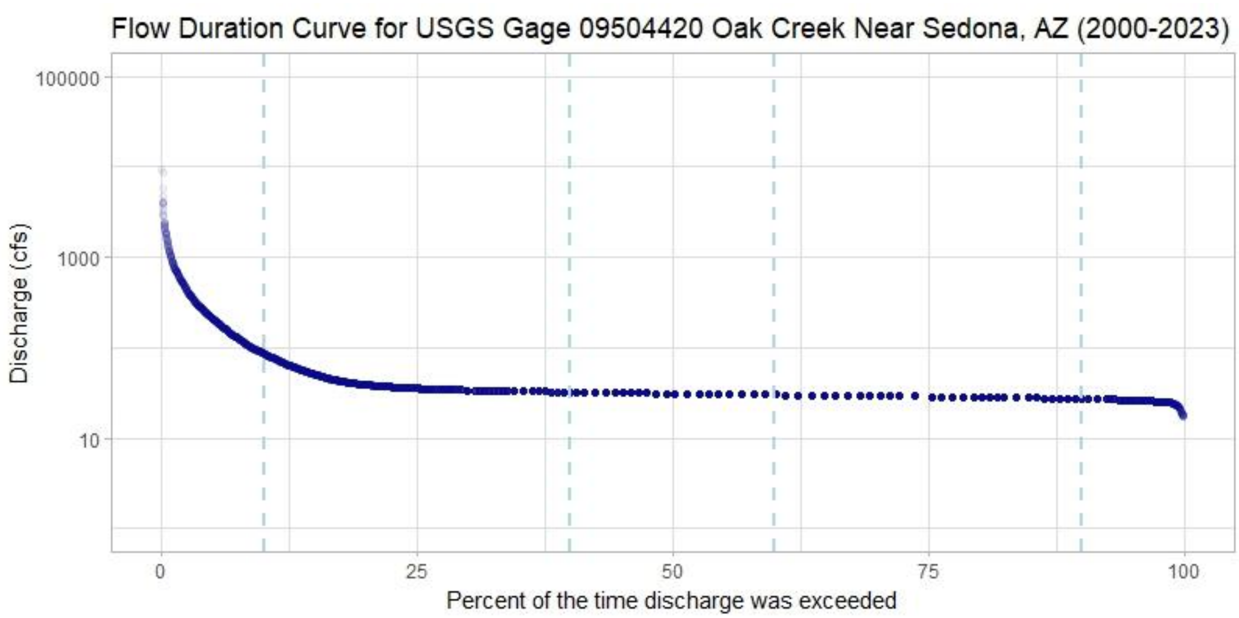


Figure 20. FDC for Gauge 09504420

To develop the LDCs, each flow measurement from the FDC is multiplied by the associated water quality standard (WQS) to calculate daily loading rates that would meet the current WQS as shown in the following equation:

$$TMDL\left(\frac{CFU}{day}\right) = WQS * Q * CF$$

Where,

WQS = 235 CFU/100 mL

Q = Flow (cfs)

CF = Conversion Factors (1 mL = 3.532e-5 ft^3, 1 day = 86400 sec)

The LDC plots the daily loading rate against the percent flow exceedance to graphically display the impairment characteristics related to flow. The LDC can be used to determine the occurrence of WQS exceedances by plotting the individual water quality samples. LDCs often correlate to flow conditions. ADEQ split each segment's LDCs into five conditions as outlined in Table 5b and
Table 6b in Section 4.2. The flow condition breakdown can highlight patterns of exceedances (e.g., occurring at all flow conditions, or only at higher or lower flow conditions). More nuances can be added to these graphs by incorporating indicators that differentiate the time of year for each water quality sample, making LDCs a robust method to represent the *E. coli* TMDL in the impaired segments (Cleland, 2003).

LDCs were developed for each segment listed as impaired in Table 1, except Spring Creek which lacks sufficient streamflow data necessary to calculate an FDC. Spring Creek reductions were calculated as percent reductions necessary to meet the applicable standard.

Section 8 Linkage Analysis

The purpose of the linkage analysis is to establish the connections or linkages between the loadings to waterbodies (i.e., the causes of impairment) and the water quality response within the receiving waters. This section describes the approach used to characterize waterbody response to pollutant loadings from the watershed.

8.1 Load Duration Curves

This section is structured in descending order from upstream segments to downstream segments. Two sets of LDCs were prepared for each Oak Creek segment: one set comparing historic (2010 – 2017) and current (2018 – 2023) data, and another set comparing samples taken during the recreational season (Rec Season) and the non-recreational season (Off Season). Rec Season was designated as the months of May through September, when tourist visitation is highest; Off Season was designated as the remaining months, October through April.

General trends observed include higher levels of exceedance during High and Wet flow conditions and more frequent exceedances during the Rec Season.

8.1.1 Oak Creek – Headwaters to West Fork (-019)

The Headwaters to West Fork Oak Creek (hereafter referred to as Headwaters) segment (3.4 miles) of Oak Creek was listed as impaired in the 2008 § 303(d) list for two exceedances of the *E. coli* SSM water quality standard. Since 2018, there have been 55 sampling days on this segment, with a total of 200 samples collected. Recent (2018 – 2023) WQP data reflective of current conditions were used to create the LDC, to determine each flow condition's existing load, TMDL, and calculate the reductions necessary to support the FBC designated use. Figure 21 shows historic (2010 – 2017) versus current (2018 – 2023) water quality measurements. The 2018 – 2023 data were used to characterize baseline conditions for each segment of the TMDL. Figure 22 includes individual water quality measurements sampled between 2018 and 2023 differentiated by season. Five samples have exceeded the applicable water quality standard since 2018. Two of the exceedances were related to storm flows, as they plot on the left-hand portion of the LDC and are within the High flow condition. The remaining three exceedances occurred during the Rec Season under Mid flow conditions. Few exceedances occurred for this upstream segment of Oak Creek; however, under Mid flow conditions, an elevated concentration of *E. coli* seems to correspond with increased recreational usage.

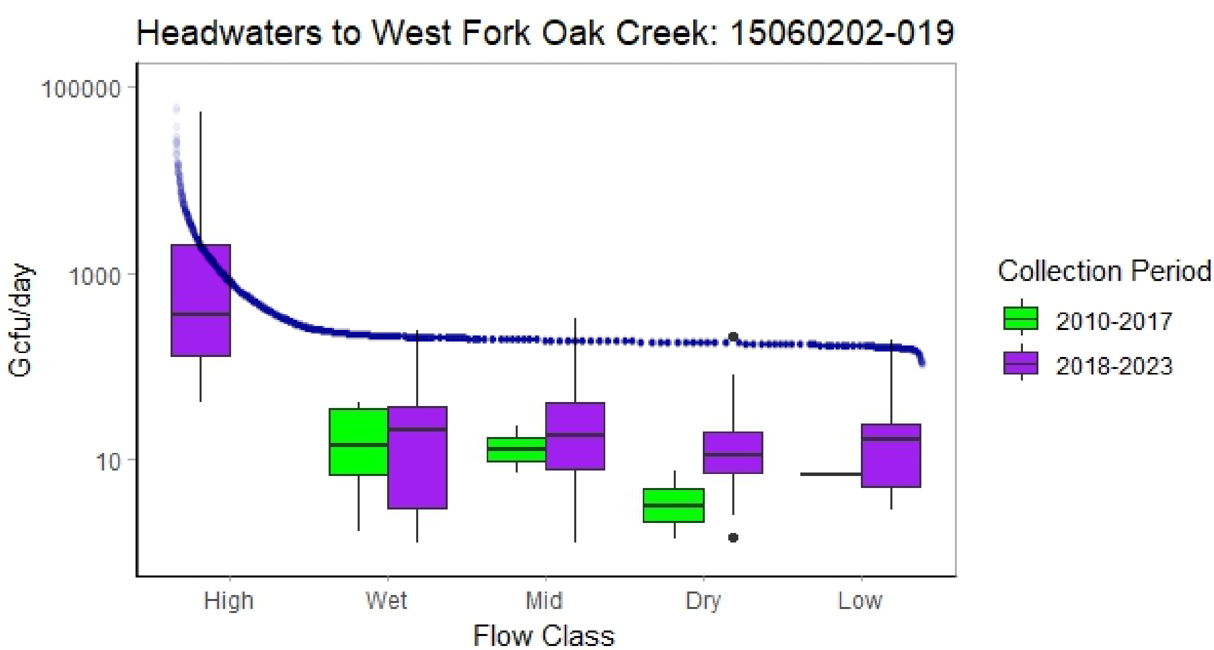


Figure 21. Headwaters LDC with Historic and Current Box and Whisker Plots

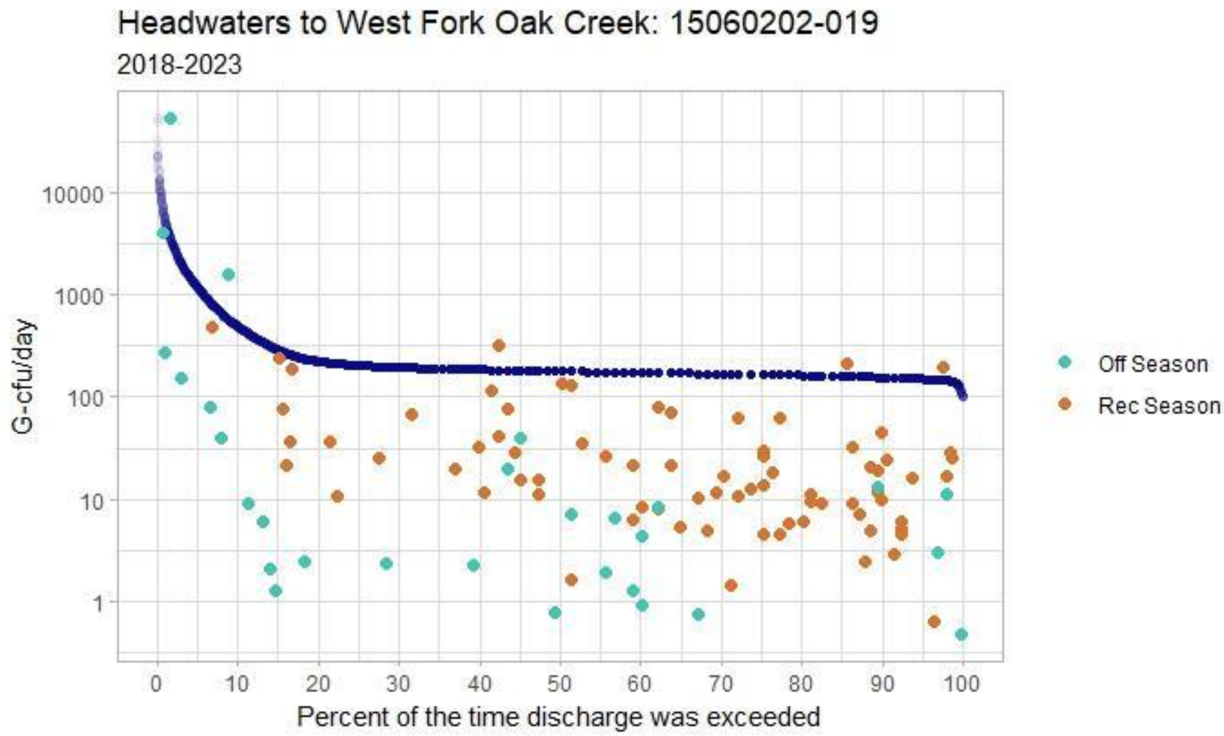


Figure 22. Headwaters LDC Differentiation of Water Quality Measurements by Season (2018 – 2023)

8.1.2 Oak Creek – West Fork to Slide Rock State Park (-018A)

The West Fork to Slide Rock State Park (hereafter referred to as West Fork) segment (2.8 miles) of Oak Creek was listed as impaired in the 2008 § 303(d) list for three exceedances of the *E. coli* SSM water quality standard. West Fork is a perennial tributary of Oak Creek and drains portions of the Red Rock-Secret Mountain Wilderness Area. Since 2018, there have been 86 sampling days on this segment, with a total of 180 samples collected. Current WQP data (2018 – 2023) were used to create the LDC, to determine each flow condition's existing load, TMDL, and calculate the reductions necessary to support the FBC designated use. Figure 23 shows historic (2010 – 2017) versus current (2018 – 2023) water quality measurements. The 2018 – 2023 data were used to characterize baseline conditions for each segment TMDL. Figure 24 includes individual water quality measurements sampled between 2018 and 2023 differentiated by season. Three samples have exceeded the applicable water quality standard since 2018. Two of the exceedances were related to storm flows, as they plot on the left-hand portion of the LDC, and are within the High flow condition. The remaining exceedance occurred during the Rec Season, under Mid flow conditions.

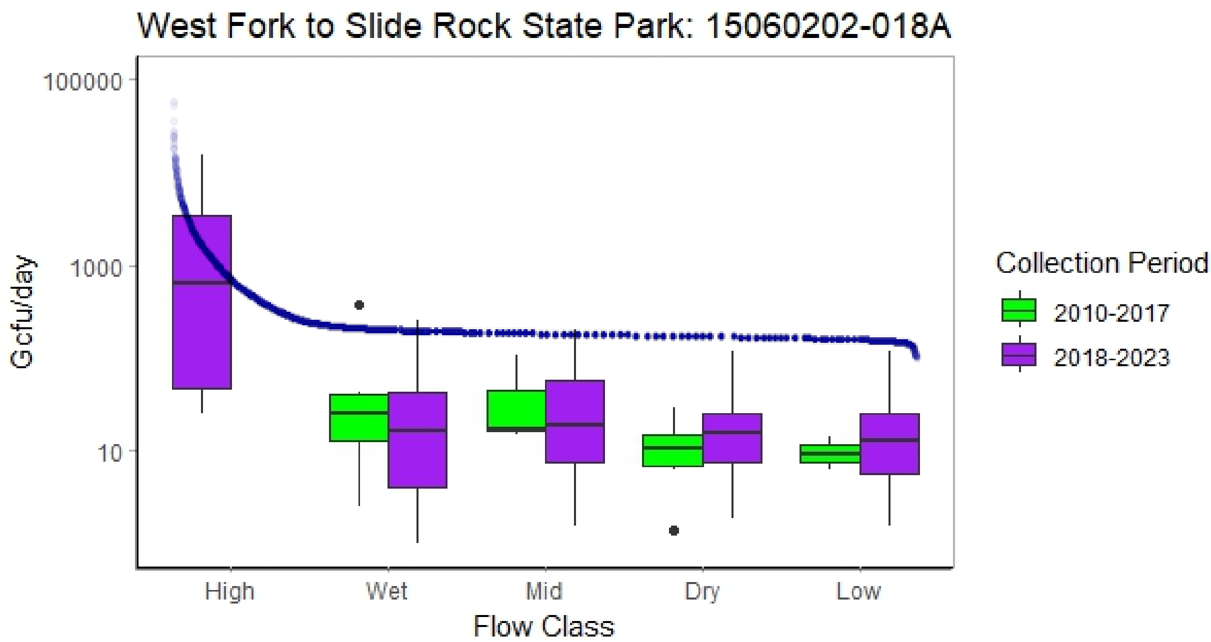


Figure 23. West Fork LDC with Historic and Current Box and Whisker Plots

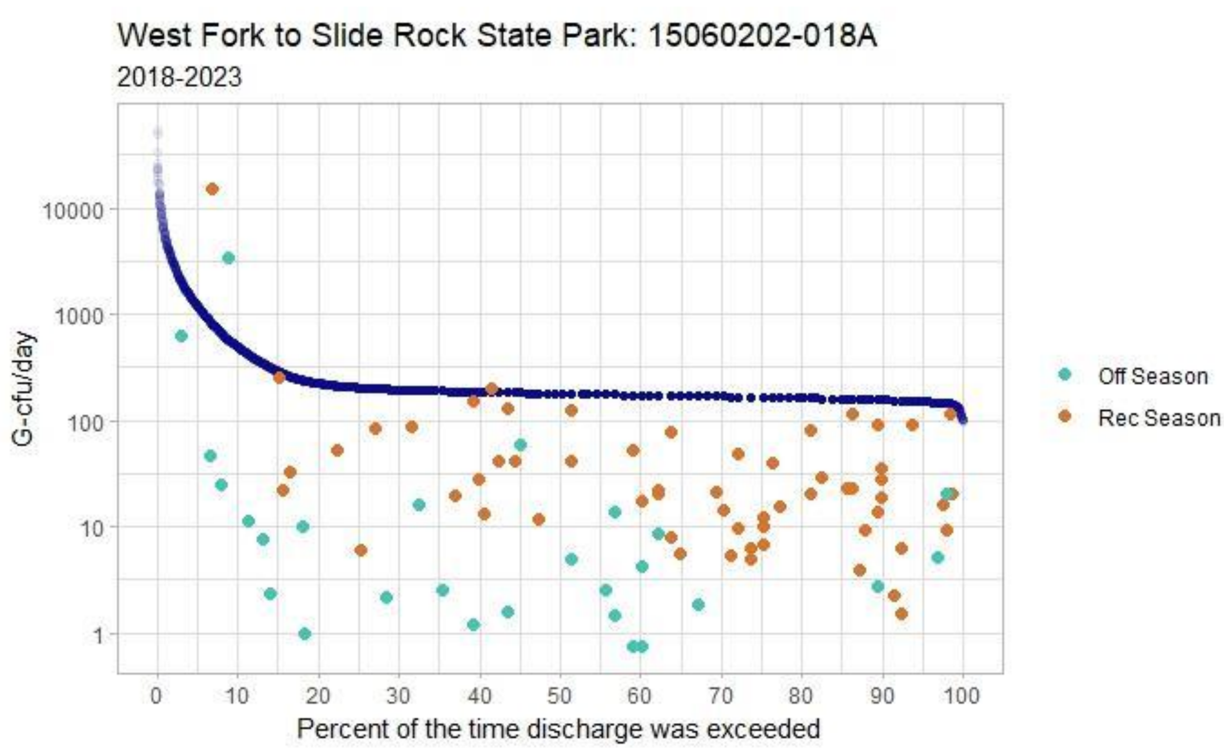


Figure 24. West Fork LDC Differentiation of Current Water Quality Measurements by Season (2018 – 2023)

8.1.3 Oak Creek – At Slide Rock State Park (-018B)

The segment at Slide Rock State Park (1.5 miles) of Oak Creek was listed as impaired in the 2008 § 303(d) list. The 2010 TMDL reported 58 exceedances (aggregating all Slide Rock State Park sample sites within a seven-day period) of the *E. coli* SSM water quality standard. Since 2018, there have been 113 sampling days on this segment, with a total of 484 samples collected. Data collection within the park has been extensive but concentrated within the Rec Season, consistent with the Slide Rock State Park Surface Water Quality Management Plan. Current WQP data (2018 – 2023) were used to create the LDC to determine each flow condition's existing load, TMDL, and calculate the reductions necessary to support the FBC designated use. Figure 25 shows historic (2010 – 2017) versus current (2018 – 2023) water quality measurements. This graph shows an *E. coli* loading decrease from historic to current measurements for almost all flow conditions. The 2018 – 2023 data were used to characterize baseline conditions for each segment TMDL. Figure 26 includes individual water quality measurements sampled between 2018 and 2023, differentiated by season. Four samples have exceeded the applicable water quality standard since 2018. Three of the exceedances were related to storm flows, as they plot on the left-hand portion of the LDC within the High and Wet flow conditions. All four exceedances occurred during the Rec Season.

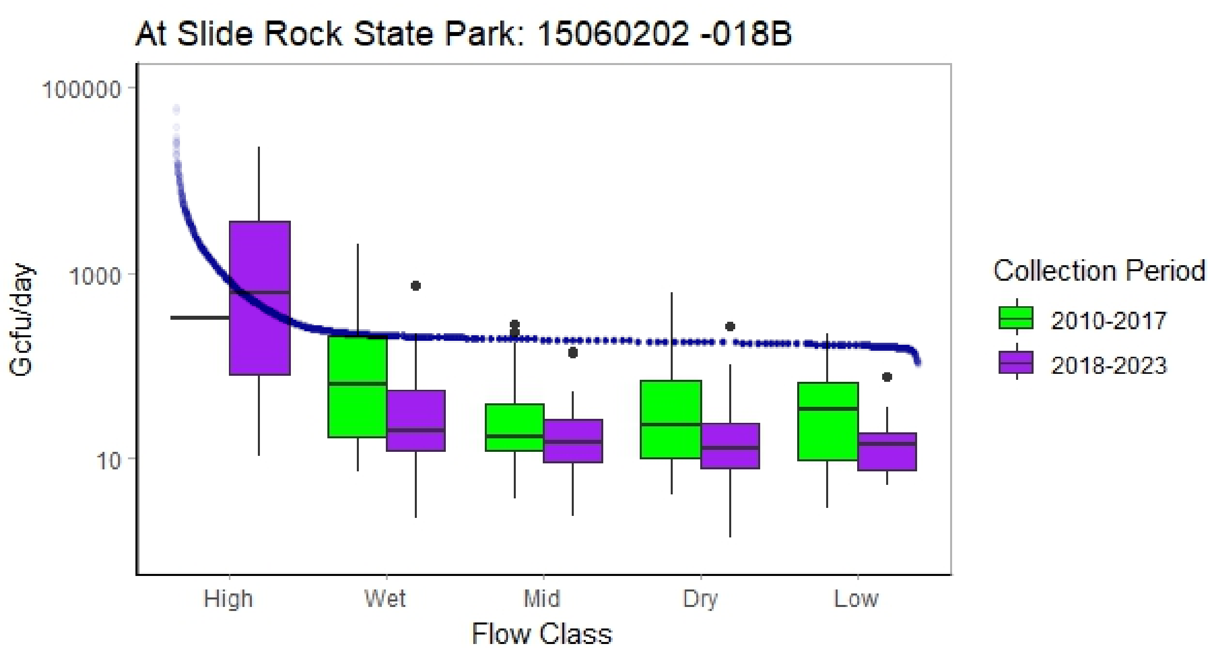


Figure 25. Slide Rock State Park LDC with Historic and Current Box and Whisker Plots

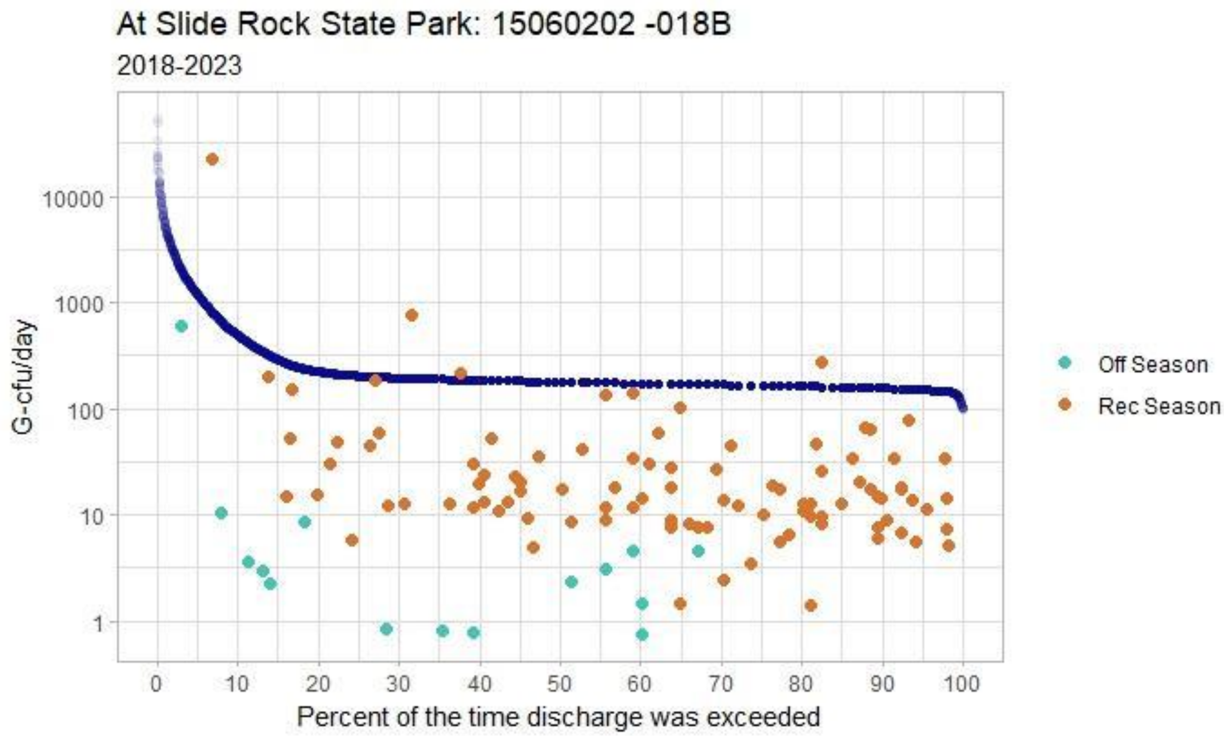


Figure 26. Slide Rock State Park LDC Differentiation of Water Quality Measurements by Season (2018 – 2023)

8.1.4 Oak Creek – Below Slide Rock State Park to Dry Creek (-018C)

The Oak Creek – Below Slide Rock State Park to Dry Creek (hereafter referred to as Below Slide Rock State Park) segment (20 miles) was listed as impaired in the 2008 § 303(d) list. The 2010 TMDL reported 23 exceedances (aggregated seven-day data) observed within the assessment period. Since 2018, there have been 117 sampling days on this segment, with a total of 364 samples collected. Current WQP data (2018 – 2023) were used to create the LDC to determine each flow condition's existing load, TMDL, and calculate the reductions necessary to support the FBC designated use. Figure 27 shows historic (2010 – 2017) versus current (2018 – 2023) water quality measurements. This graph shows both *E. coli* loading increases and decreases from historic to current measurements across the flow conditions. The 2018 – 2023 data were used to characterize baseline conditions for each segment TMDL. Figure 28 includes individual water quality measurements sampled between 2018 and 2023, differentiated by season. Eleven samples have exceeded the applicable water quality standard since 2018. Six of the exceedances were related to storm flows, as they plot on the left-hand portion of the LDC, and are within the High and Wet flow conditions. All 11 exceedances occurred during the Rec Season.

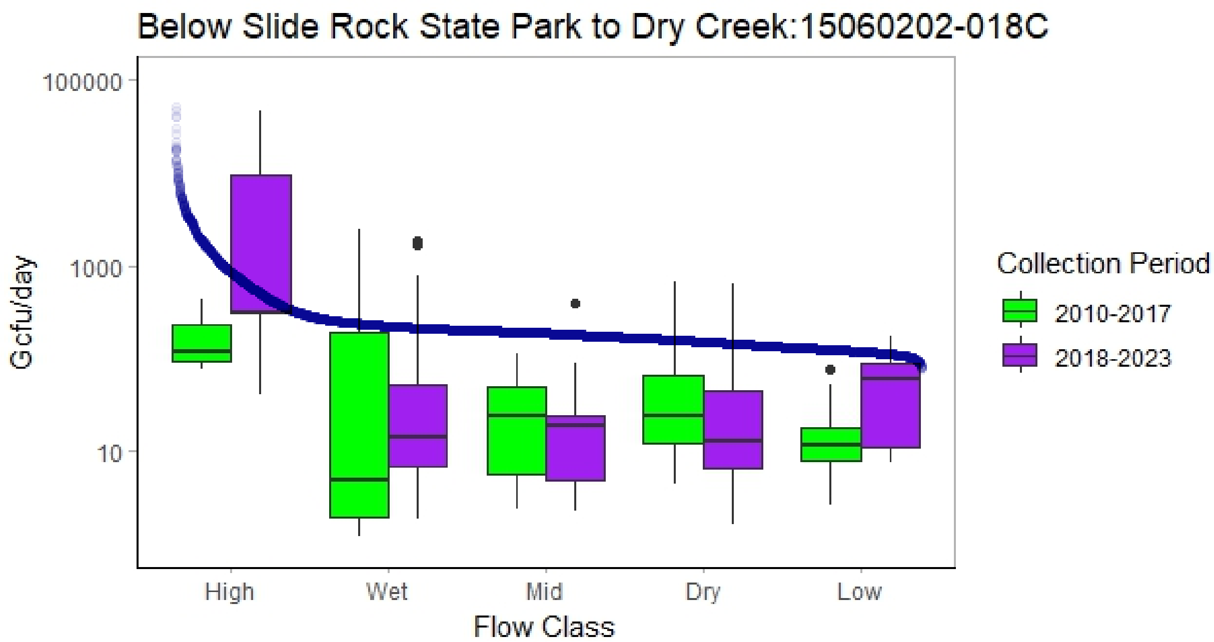


Figure 27. Below Slide Rock State Park LDC with Historic and Current Box and Whisker Plots

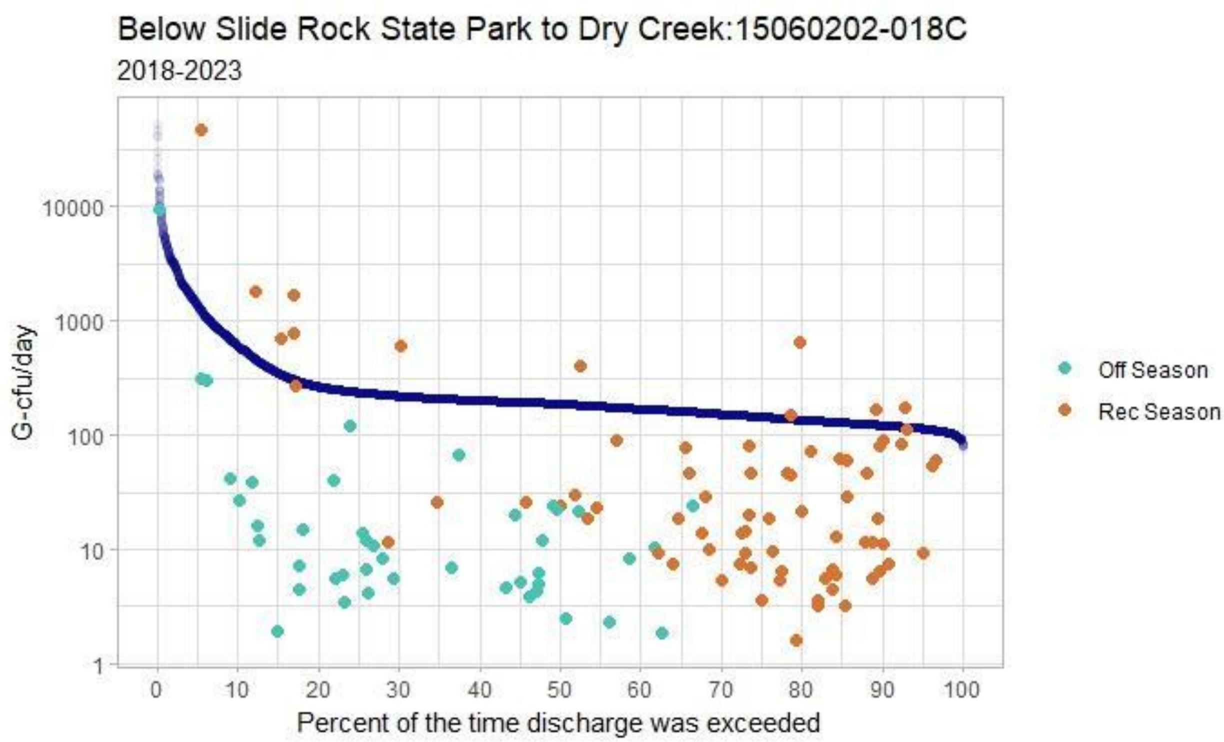


Figure 28. Below Slide Rock State Park LDC Differentiation of Water Quality Measurements by Season (2018 – 2023)

8.1.5 Oak Creek – Dry Creek to Spring Creek (-017)

The Oak Creek – Dry Creek to Spring Creek (hereafter referred to as Dry Creek) segment (10.1 miles) was listed as impaired in the 2008 § 303(d) list due to 12 exceedances of the SSM water quality standard. Since 2018, there have been 74 sampling days on this segment, with a total of 137 samples collected. Current WQP data (2018 – 2023) were used to create the LDC, determine each flow condition's existing load, TMDL, and calculate the reductions necessary to support the FBC designated use. Figure 29 shows historic (2010 – 2017) versus current (2018 – 2023) water quality measurements. This graph shows both *E. coli* loading increases and decreases from historic to current measurements across the flow conditions. The 2018 – 2023 data were used to characterize baseline conditions for each segment TMDL. Figure 30 includes individual water quality measurements sampled between 2018 and 2023, differentiated by season. Five samples have exceeded the applicable water quality standard since 2018. Four of the exceedances were related to storm flows, as they plot on the left-hand portion of the LDC, and are within the High and Wet flow conditions.

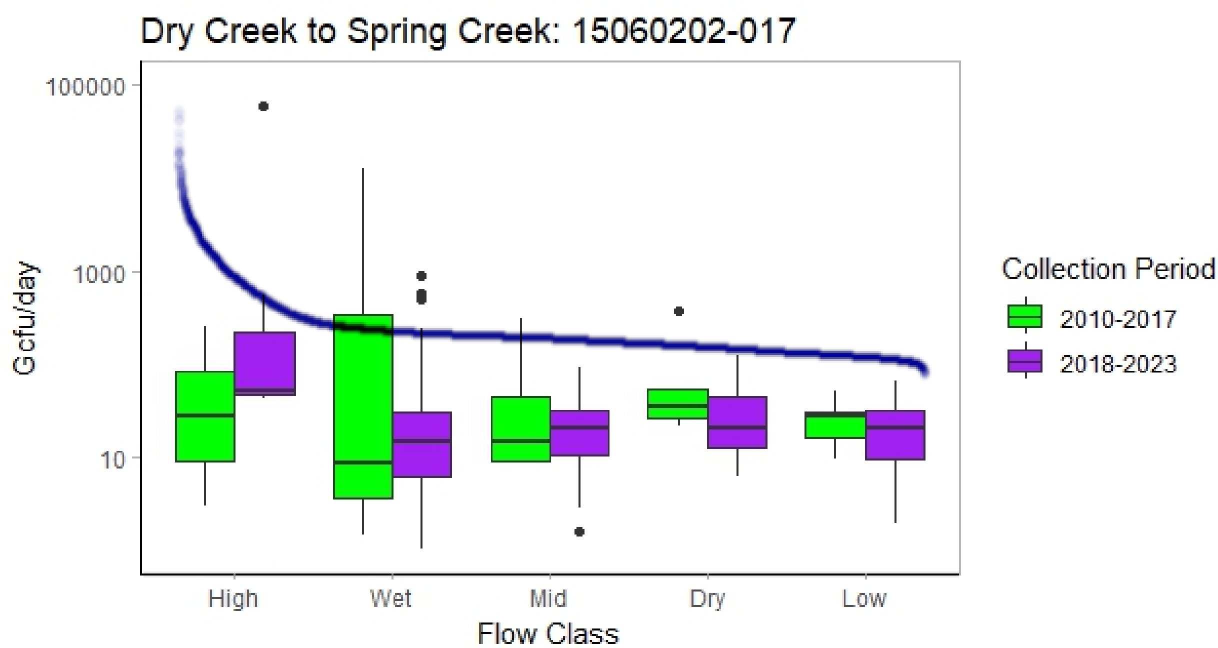


Figure 29. Dry Creek LDC with Historic and Current Box and Whisker Plots

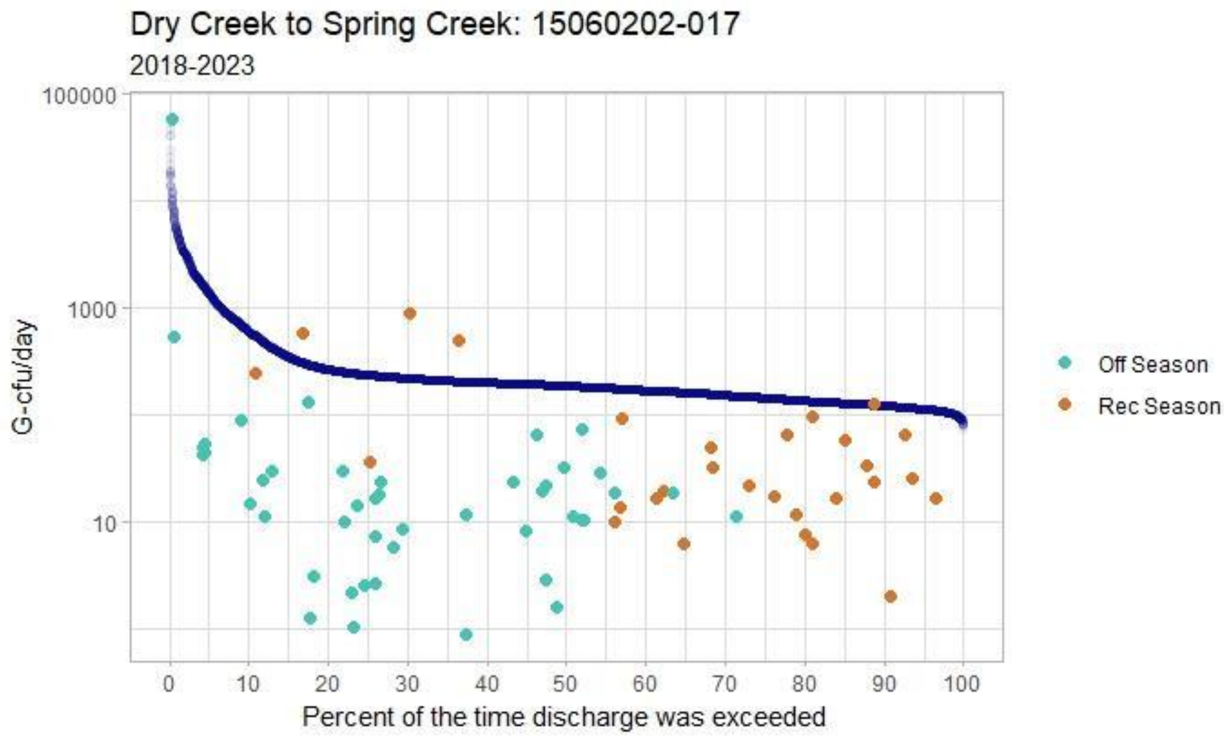


Figure 30. Dry Creek LDC Differentiation of Water Quality Measurements by Season (2018 – 2023)

8.1.6 Oak Creek – Spring Creek to Verde River (-016)

The Oak Creek – Spring Creek to Verde River (hereafter referred to as Verde River) segment (12.7 miles) was listed as impaired in the 2016 § 303(d) list due to exceedances of the SSM Water Quality Standard. Since 2018, there have been 55 sampling days on this segment, with a total of 77 samples collected. Current WQP data (2018 – 2023) were used to create the LDC to determine each flow condition's existing load, TMDL, and calculate the reductions necessary to support the FBC designated use. Figure 31 shows historic (2010 – 2017) versus current (2018 – 2023) water quality measurements. This graph shows both *E. coli* loading increases and decreases from historic to current measurements across the flow conditions. The 2018 – 2023 data were used to characterize baseline conditions for each segment TMDL. Figure 32 includes individual water quality measurements sampled between 2018 and 2023, differentiated by season. Four samples have exceeded the applicable water quality standard since 2018. Three exceedances were related to storm flows, as they plot on the left-hand portion of the LDC, and are within the High and Wet flow conditions. Few exceedances occurred for this downstream segment of Oak Creek. Most of the exceedances occurred during storm events, suggesting that *E. coli* is mostly introduced indirectly through stormwater runoff.

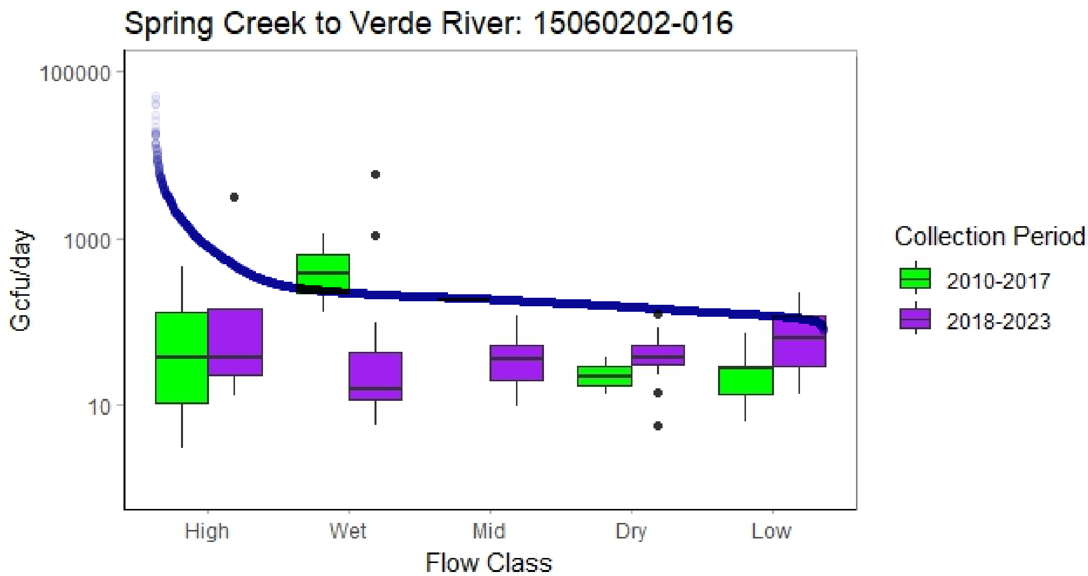


Figure 31. Verde River LDC with Historic and Current Box and Whisker Plots

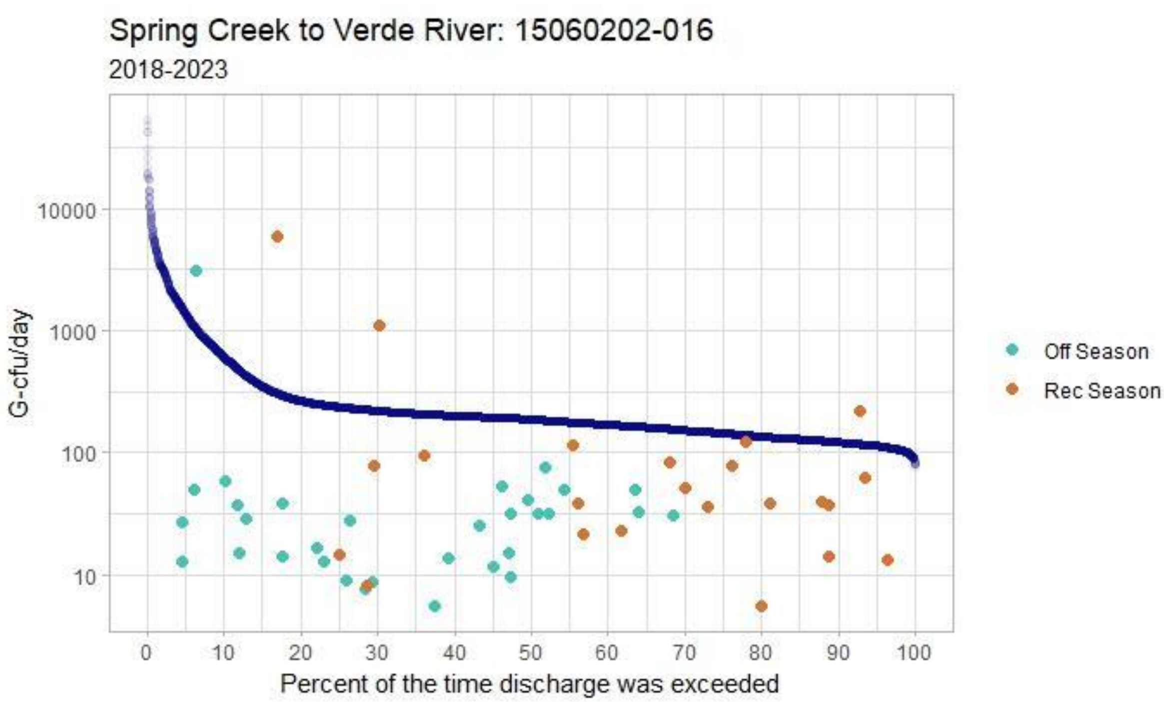


Figure 32. Verde River LDC Differentiation of Water Quality Measurements by Season (2018 – 2023)

Section 9 TMDL Development

A TMDL is defined as the sum of the WLAs for point sources, plus the sum of the LAs for nonpoint and NB sources, plus an MOS (Margin of Safety). This loading budget will result in loadings that the waterbody can process with its available assimilative loading capacity without exceeding WQS, as shown in the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

$\sum WLA$ = Sum of all individual point source WLAs
$\sum LA$ = Sum of all nonpoint source LAs and NB
MOS = Margin of safety

The TMDL documented in this section addresses *E. coli* impairments for Oak Creek and Spring Creek. It identifies allowable loadings for point sources and NPSs discharging to six Oak Creek segments and one Spring Creek segment.

9.1 Margin of Safety

The MOS is included in the TMDL to account for uncertainty regarding the relationship between pollutant loads and the water quality response of receiving waterbodies. The MOS may be formulated implicitly, using conservative assumptions or analytical techniques, or explicitly by reserving a portion of the loading capacity as an unallocated load. An explicit MOS equal to 10 percent of the TMDL was applied to each flow category calculation.

9.2 Natural Background

Wildlife is a source of *E. coli* and must be considered when developing TMDLs. Although wildlife contributes *E. coli* naturally, the impact of human activity (e.g., trail development and clearing land around homes and riparian areas) can increase the rate and volume of runoff and pollutants entering waterbodies by reducing the filtering ability of the forest floor. Also, trash left by visitors near the creek can draw wildlife closer to the water as they forage for food and increase their activity within and near the riparian area.

To estimate the NB *E. coli* contribution from wildlife in the 2010 Oak Creek TMDL, samples were collected in Sterling Canyon and the West Fork of Oak Creek, where the impacts of human activity were assumed to be minimal due to a lack of development and usage in the area. Samples were collected under base and storm flow conditions from both sites at multiple times. The five stormwater samples averaged 43 CFU/100 mL or approximately 18 percent of the 235 CFU/100 mL standard. The 12 baseflow samples averaged 23 CFU/100 mL or 10 percent of the standard. Based on this, the previous TMDL assigned 18 percent of the allowable load within the upper three flow conditions to NB and 10 percent in the lower two flow conditions (ADEQ, 2010).

There is some uncertainty in using the previous approach to NB for this TMDL. Recent data from Sterling Canyon is too limited to be truly representative of natural conditions; there are fewer than 10 recent samples for this area, and they lack distinction between base and storm flow conditions. Additionally, the presence of trailheads and recreational visitors in both Sterling Canyon and West Fork makes them potentially poor representations of NB conditions. Due to these factors, the updated TMDL will incorporate the NB values into the broader LA value.

9.3 Loading Capacity and Allocations

The loading capacity of the waterbody is defined as the quantity of a pollutant or other waterbody constituent which can be absorbed without exceeding applicable water quality standards. As discussed previously, LDCs were the selected technical approach to quantify existing loads and flow condition-related TMDLs for the impaired segments.

The TMDL value was calculated using the median LDC load for each flow category (e.g., the High flow condition *E. coli* TMDL was the load associated with a 5 percent flow probability of exceedance). Then to determine the existing load, the 90th percentile *E. coli* load was determined for each flow category. If the 90th percentile value was greater than the TMDL, a percent reduction was calculated. If the existing load was less than the TMDL, the segment is meeting the TMDL under that flow condition and no LA or WLAs were calculated. The WLA calculations in Table 15 and Table 16 are end-of-pipe without any provision for a mixing zone.

LAs from NPSs, wildlife, domesticated animals, humans, urban/developed areas, and natural background were calculated as the remainder of the TMDL once WLA, and MOS loads were allocated. The following sections describe how WLAs were calculated for each segment's flow conditions. Table 15 and Table 16 summarize the point source WLAs.

The units for the applicable *E. coli* standards and the individual samples results are expressed as CFU/100 mL. The TMDL calculations are expressed as billion (or giga) CFU/day (G-CFU/day) to illustrate a mass per time numeric TMDL target. To convert the concentration (CFU/100 mL) to G-CFU/day, the *E. coli* concentration was multiplied by the plant design flow discharge rate (cfs) and a conversion factor of 0.02446. For these WLAs the *E. coli* concentration was set at the SSM WQS of 235 CFU/100 mL for discharges into waters with FBC designated uses (i.e., Sedona Venture) and 575 CFU/100 mL for discharges into waters with PBC designated uses (i.e., Blackman WWTP).

The WLAs here reflect currently permitted facilities discharging to Oak Creek. The creek is an Outstanding Arizona Water (OAW) and a new or expanded point-source discharge directly to an OAW is prohibited under A.A.C. R18-11-107.01(C)(2).

Table 15. Waste Load Allocation Summary for Individual AZPDES Permittees

AZPDES ID	Facility Name	WLA (G-CFU/day)	Applicable Flow Conditions	Applicable Segments
AZ0021807	Sedona Venture Sewer Company	0.67	High, Wet, and Low	-017 and -016
AZ0025879	Pinewood Sanitary District - Kay S. Blackman WWTP	13.1	High, Wet, and Low	-018C, -017, and -016

Table 16. Waste Load Allocation Summary for MS4 Permittees by Segment and Flow Condition

Segment	Flow Condition	WLA (G-CFU/day)
Arizona Department of Transportation (ADOT) (AZS000018)		
-019	High	1.2
	Wet	N/A
-018A	High	1.2
	Wet	N/A
-018B	High	1.2
	Wet	N/A
-018C	High	1.4
	Wet	0.24
-017	High	1.4
	Wet	0.24
-016	High	1.4
	Wet	N/A
City of Sedona (AZG2021-002)		
-018C	High	71.3
	Wet	12.3
-017	High	71.3
	Wet	12.3
-016	High	71.3
	Wet	N/A

9.3.1 Oak Creek – Headwaters to West Fork (-019)

Table 17 summarizes the TMDL calculations for the Headwaters segment based upon the SSM standard. The segment meets the TMDL under the Wet, Mid, Dry, and Low flow conditions. Reductions of approximately 94 percent under the High flow condition are needed to meet the TMDL.

Table 17. Headwaters (-019) TMDL Summary

Flow Condition		Existing Load*	TMDL*	LA*	WLA*	MOS*	Reduction (%)
High	0-10%	19,448	1,190	1,069.8	1.2	119	94
Wet	10-40%	111	204	--	--	--	0
Mid	40-60%	128	179	--	--	--	0
Dry	60-90%	57	166	--	--	--	0
Low	90-100%	27	151	--	--	--	0

*G-CFU/day

The Headwaters segment is upstream of the Blackman WWTP, Sedona Venture WWTP, and the City of Sedona MS4. Therefore, the only point source allocated for this segment is a High flow condition WLA for the ADOT MS4. The MS4 permittees lack sufficient water quality data to determine a WLA using discharge data, so in segments where applicable, the WLA will be based on the percent area of the City of Sedona (24.4 mi^2) and highway surface area (~0.5 mi^2) within the entire watershed (456.5 mi^2). This results in the City of Sedona receiving a WLA equal to 5.2 percent of the TMDL and ADOT receiving a WLA equal to 0.1 percent of the TMDL in applicable segments. This approach is based on guidance issued by EPA for calculating WLA using LDC analyses (EPA, 2007).

9.3.2 Oak Creek – West Fork to Slide Rock State Park (-018A)

Table 18 summarizes the TMDL calculations for the West Fork segment based upon the SSM standard. The segment meets the TMDL under the Wet, Mid, Dry, and Low flow conditions. Reductions of approximately 89 percent under the High flow condition are needed to meet the TMDL.

Table 18. West Fork (-018A) TMDL Summary

Flow Condition		Existing Load*	TMDL*	LA*	WLA*	MOS*	Reduction (%)
High	0-10%	10,449	1,190	1069.8	1.2	119	89
Wet	10-40%	100	204	--	--	--	0
Mid	40-60%	127	179	--	--	--	0
Dry	60-90%	64	166	--	--	--	0
Low	90-100%	95	151	--	--	--	0

*G-CFU/day

The West Fork segment is upstream of the Blackman WWTP, Sedona Venture WWTP, and the City of Sedona MS4. As described above, the only point source designated in this segment is a High flow condition WLA for the ADOT MS4, equal to 0.1 percent of the TMDL.

9.3.3 Oak Creek – At Slide Rock State Park (-018B)

Table 19 summarizes the TMDL calculations for the Slide Rock State Park segment based upon the SSM standard. The segment meets the TMDL under the Wet, Mid, Dry, and Low flow conditions. Reductions of approximately 93 percent under the High flow condition are needed to meet the TMDL.

Table 19. Slide Rock State Park (-018B) TMDL Summary

Flow Condition		Existing Load*	TMDL*	LA*	WLA*	MOS*	Reduction (%)
High	0-10%	18,154	1,190	1069.8	1.2	119	93
Wet	10-40%	194	204	--	--	--	0
Mid	40-60%	49	179	--	--	--	0
Dry	60-90%	52	166	--	--	--	0
Low	90-100%	35	151	--	--	--	0

*G-CFU/day

The Slide Rock State Park segment is upstream of the Blackman WWTP, the Sedona Venture WWTP, and the City of Sedona MS4. As described above, the only point source designated is a High flow condition WLA for the ADOT MS4, equal to 0.1 percent of the TMDL.

9.3.4 Oak Creek – Below Slide Rock State Park to Dry Creek (-018C)

Table 20 summarizes the TMDL calculations for the Below Slide Rock State Park segment based upon the SSM standard. The segment meets the TMDL under Mid and Dry flow conditions. Reductions of approximately 96 percent under the High flow condition, 66 percent under the Wet condition flow condition, and 8 percent under the Low flow condition are needed to meet the TMDLs.

Table 20. Below Slide Rock State Park (-018C) TMDL Summary

Flow Condition		Existing Load*	TMDL*	LA*	WLA*	MOS*	Reduction (%)
High	0-10%	32,158	1,371	1148.2	85.8	137	96
Wet	10-40%	693	236	186.4	25.6	24	66
Mid	40-60%	30	188	--	--	--	0
Dry	60-90%	77	144	--	--	--	0
Low	90-100%	123	114	100.9	13.1	11	8

*G-CFU/day

The Blackman WWTP discharges to Munds Creek, a tributary of Oak Creek that converges with the Below Slide Rock State Park segment. Using the Blackman WWTP design discharge rate, discussed in Section 6.1.1, and the PBC permit limit, a 13.1 G-CFU/day WLA is applied to the High, Wet, and Low flow conditions for the Below Slide Rock State Park segment.

The City of Sedona and ADOT MS4 WLAs are only applied to the top two flow conditions because these permits are in place to regulate stormwater discharges, and the top two flow conditions are usually storm related. Therefore, for the Below Slide Rock State Park segment the 5.2 percent (for the City of Sedona MS4) and 0.1 percent (for the ADOT MS4) of the TMDL are included in the WLAs for the High and Wet flow conditions.

9.3.5 Oak Creek – Dry Creek to Spring Creek (-017)

Table 21 summarizes the TMDL calculations for the Dry Creek segment based upon the SSM standard. The segment meets the TMDL under the Mid, Dry, and Low flow conditions. Reductions of approximately 94 percent under the High flow condition and 31 percent under the Wet condition flow condition are needed to meet the TMDLs. As described above, the Blackman WWTP WLA of 13.1 G-CFU/day is included in the WLAs for segments downstream of the Dry Creek segment.

Table 21. Dry Creek (-017) TMDL Summary

Flow Condition		Existing Load*	TMDL*	LA*	WLA*	MOS*	Reduction (%)
High	0-10%	24,217	1,371	1147.5	86.5	137	94
Wet	10-40%	344	236	185.7	26.3	24	31
Mid	40-60%	71	188	--	--	--	0
Dry	60-90%	76	144	--	--	--	0
Low	90-100%	53	114	--	--	--	0

*G-CFU/day

Sedona Venture discharges directly to Dry Creek which converges with Oak Creek in the Dry Creek segment. Using the Sedona Venture plant design discharge rate, discussed in Section 6.1.1, and the FBC permit limit, a 0.67 G-CFU/day WLA is applied to all flow conditions for the Dry Creek segment and downstream segments.

As described previously, the MS4 allocations (5.2 percent and 0.1 percent of the TMDL) are included in the WLAs for the High and Wet condition flow conditions due to their relation to storm flows.

9.3.6 Oak Creek – Spring Creek to Verde River (-016)

Table 22 summarizes the TMDL calculations for the Verde River segment based upon the SSM standard. The segment meets the TMDL under Wet, Mid, and Dry flow conditions. Reductions of approximately 38 percent under the High and 39 percent under the Low flow conditions are needed to meet the TMDLs.

Table 22. Verde River (-016) TMDL Summary

Flow Condition		Existing Load*	TMDL*	LA*	WLA*	MOS*	Reduction (%)
High	0-10%	2,202	1,371	1147.5	86.5	137	38
Wet	10-40%	197	236	--	--	--	0
Mid	40-60%	73	188	--	--	--	0
Dry	60-90%	82	144	--	--	--	0
Low	90-100%	187	114	89.2	13.8	11	39

*G-CFU/day

WLAs for Sedona Venture (0.67 G-CFU/day) and Blackman WWTP (13.1 G-CFU/day) are included in both the High and Low flow conditions WLAs for the Verde River segment. As described previously, the MS4 allocations (5.2 percent and 0.1 percent of the TMDL) are included in the WLA for the High flow condition due to their relation to storm flows.

9.3.7 Spring Creek – Coffee Creek to Oak Creek (-022)

Spring Creek lacked flow data, so to determine the TMDL for the Coffee Creek to Oak Creek (hereafter referred to as Spring Creek) segment, a direct comparison of the water quality standard and collected water quality data was used. Historic values (2010 – 2017) and current values (2018 – 2023) are compared to the water quality standard in Table 23. In addition, Table 23 categorizes the current values by season, Rec Season vs. Off-Season.

Table 23. Spring Creek (-022) TMDL Summary

	Historic Average (2010 – 2017)	Current Average (2018 – 2023)	Rec Season (2018 – 2023)	Off Season (2018 – 2023)
90th Percentile *E. coli* (MPN/100 mL)	273	65*	513*	48
Standard Deviation	208	755	1,173	18
Number of Samples	9	55*	24	31
Load Reductions Needed	14%	--	54%	--

*One sample out of 55 was measured at 4884 MPN/100 mL and skews the average; without including that one outlier sample the "Current Average" (2018 – 2023) would be 62 MPN/100 mL and the "Rec Season (2018 – 2023)" would be 273 MPN/100 mL. Excluding the one outlier, the calculated load reduction during the Rec Season would be 7 percent to meet standards.

Table 23 illustrates that *E. coli* loading has decreased from the historic time frame to the current. While this segment is meeting the water quality standard on average, the recreation season's *E. coli* loading is two times the water quality standard (235 MPN/100 mL).

9.4 Seasonality and Critical Conditions

Oak Creek experiences higher than average flows twice a year. Winter storms and snowmelt typically result in higher flow rates from February to early April. The monsoon typically results in increased flow rates from late July to early September. Oak Creek most often experiences flow within the High flow condition during these indicated time periods. The existing *E. coli* loads calculated for the High flow condition for all segments of Oak Creek exceed the TMDL. Storm and snowmelt runoff transport large loads of *E. coli,* likely from wildlife sources or human recreation, from the watershed to Oak Creek.

Figure 33. Winter Snowmelt in Oak Creek (Photo from ADEQ and affiliated NGO partners)

Oak Creek, specifically the Slide Rock State Park, experiences increased visitor traffic during the summer months (May – August), with a total of around 3 million people per year. People visit this area to see the beautiful red rock terrain and to recreate in and around Oak Creek. In the TMDL analysis, the Rec Season is designated between May and August and the Off-Season is between September and April. To determine whether increased tourist traffic increased the *E. coli* load, these seasons were assessed separately.

Figure 34. Recreation at Slide Rock State Park (Photo by Richie Graham Photography, courtesy of the National Forest Foundation)

Table 24 summarizes the water quality samples from 2018 – 2023 that exceeded the LDCs, differentiated by flow condition and season. The only Off-Season exceedances occurred during the High flow condition, suggesting *E. coli* transported by storm water runoff from upland wildlife and domesticated animals is the main source outside of activity during the Rec Season. 27 out of 32 exceedances occurred during the Rec Season, suggesting humans and their domesticated animals play a large role in Oak Creek's water quality. Additionally, the greatest number of exceedances occurred within segment -018C where the Manzanita Campground is located and where substantial other creek-side recreational and residential land uses are present, further suggesting that humans and their domesticated animals are the main source of *E. coli* to Oak Creek. Segment -022, Spring Creek, does not receive water from the Slide Rock State Park segment; however, when reviewing the data, seasonal reductions are only necessary during the Rec Season, as shown in Table 24. Given these seasonal trends and the load reductions identified in

Table 17 through Table 23 high flow conditions during the Rec Season are identified as the critical conditions for this watershed.

Table 24. Water Quality Standard Exceedances by Segment, Season, and Flow Condition

Segment	Season	High Flow	Wet Condition	Mid Flow	Dry Condition	Low Flow	Total Exceedances
-019	Rec	0	0	1	1	1	3
	Off	2	0	0	0	0	2
-018A	Rec	1	0	1	0	0	2
	Off	1	0	0	0	0	1
-018B	Rec	1	2	0	1	0	4
	Off	0	0	0	0	0	0
-018C	Rec	1	5	1	3	1	11
	Off	0	0	0	0	0	0
-017	Rec	0	3	0	1	0	4
	Off	1	0	0	0	0	1
-016	Rec	0	2	0	0	1	3
	Off	1	0	0	0	0	1
-022	Rec	NA	NA	NA	NA	NA	3
	Off	NA	NA	NA	NA	NA	0
Total Rec Season Exceedances		3	12	3	6	3	30
Total Off-Season Exceedances		5	0	0	0	0	5

NA = Not Available

Section 10 Implementation Planning

The allocations (WLAs and LAs) described in this TMDL report are designed to return the targeted impaired waterbodies to attainment with their designated uses under Arizona's water quality standards. Per A.R.S. § 49-234(G), TMDLs must include an implementation plan that outlines the methods of achieving the stated load reductions. The following section identifies implementation actions that will further efforts to attain the requirements of the TMDL and associated allocations.

10.1 Point Sources

Two WWTP facilities with AZPDES individual permits discharge effluent to the Oak Creek watershed (Table 25). AZPDES MS4 permits cover two additional facilities (Table 26). ADEQ will incorporate the WLAs assigned to each permittee during their respective permit renewals if deemed necessary per the provisions of A.A.C. R18-9-B906 and R18-9-A905. Each permittee listed maintains AZPDES permit coverage and monitors their effluent for *E. coli* (Table 26).

Table 25. AZPDES Permittees and Permit Renewal Cycles

Permittee Name	AZPDES ID/Permit Type	Current Permit Effective Date	Next Permit Renewal
Blackman WWTP	AZ0025879	03/09/2021	03/08/2026
Sedona Venture WWTP	AZ0021807	12/17/2020	12/16/2025*
ADOT	Phase I MS4	07/01/2021	06/30/2026
City of Sedona	Phase II MS4	09/30/2021	09/29/2026

*Permit renewal process is ongoing

Table 26. Point Source Monitoring Plan

Point Source	Monitoring Site	Waterbody Name	Waterbody ID	Latitude and Longitude	Monitoring Frequency
Blackman WWTP	Blackman WWTP Outfall 001	Munds Creek	15060202-415	34.935833, -111.643056	Four times per month*
Sedona Venture WWTP	Confluence of Dry Creek & Oak Creek	Dry Creek	15060202-021	34.845278, -111.873889	Once per week*
City of Sedona MS4	Soldier Wash Outfall	Oak Creek - Below Slide Rock State Park to Dry Creek	15060202-018C	34.860609, -111.762574	Once per summer and winter "wet" season
ADOT MS4	ADOT Sedona	Oak Creek - Below Slide Rock State Park to Dry Creek	15060202-018C	34.862203, -111.761856	One per summer and winter "wet" season

*Applies only when the facility is actively discharging to the watershed. See the following paragraphs for more information.

The Blackman WWTP discharges to Munds Creek. The facility is required to monitor for *E. coli* four times a month if they are actively discharging to the watershed, which typically occurs between November and April; otherwise, they are only required to conduct effluent characterization monitoring once per quarter (ADEQ, 2020a). ADEQ received monitoring data that included *E. coli* samples for three months between September 2019 and August 2023. Blackman WWTP will continue to monitor their discharge for *E. coli* per the terms of their permit to ensure they are meeting their 13.1 G-CFU/day WLA; additionally, the WWTP must adhere to the monitoring and reporting requirements for any future bypass events outlined in their Consent Judgement.

Sedona Venture discharges to Dry Creek from Outfall 001 and is required to monitor for *E. coli* once per week if they are actively discharging to the watershed; otherwise, they are only required to conduct effluent characterization monitoring once per quarter (ADEQ, 2020b). At the time of TMDL development, the facility was a continuous discharger. ADEQ received monitoring data that provided monthly averages between September 2019 and August 2023. Sedona Venture will need to continue to monitor their discharge for *E. coli* weekly to ensure they are meeting their 0.67 G-CFU/day WLA (ADEQ, 2020b).

The City of Sedona MS4 has one outfall that discharges from Soldier Wash directly into Oak Creek at reach -018C. The City of Sedona's 2021 Small MS4 Annual Report states that at minimum, one storm discharge sample will be taken during each of the two wet seasons — "Summer" (June 1 – Oct 31) and "Winter" (Nov 1 – May 31) — per the terms of their permit (ADEQ, 2021b). ADEQ received monitoring data from the City of Sedona for Fiscal Year 2022 – 2023. The City of Sedona will need to continue monitoring the discharge into Soldier Wash per their permit requirements. Additionally, the City should include any newly annexed land into their updated SWMP.

The ADOT MS4 has one monitoring site in Sedona, located on reach -018C below the SR 179 bridge, that flows into Oak Creek (ADOT, 2022). ADOT will need to continue monitoring at least once during each of two wet seasons — "Summer" (June 1 – Oct 31) and "Winter" (Nov 1 – May 31) — per the terms of their permit (ADEQ, 2021a).MS4 storm water samples should be taken when the area-applicable USGS gauge meets or exceeds the Minimum Flow Rate (cfs) established for the Wet flow conditions defined in Tables 5b and 6b.

Because Oak Creek has been designated as an OAW, establishing new or expanded point source discharges is prohibited under A.A.C. R18-11-107.01(C)(2).

10.2 Nonpoint Sources

Per A.R.S. § 49-234(G), "Any reductions in loadings from nonpoint sources shall be achieved voluntarily." The proposed actions in this section and their associated schedules are provided for internal management and public information purposes.

As discussed in 6.2, nonpoint source (NPS) pollution is a potential contributor to elevated *E. coli* concentrations in aquatic environments. The deployment of Best Management Practices (BMPs) is essential for the amelioration of this prevalent environmental concern. BMPs encompass structural, vegetative, and/or managerial methodologies employed to treat, preclude, or diminish water pollution. A considerable number of BMPs have been established to curtail pollution originating from animal and human waste (Table 28).

Table 27. General BMPs for *E. coli* Reduction

Suggested BMP	Result
Secure trash receptacles from wildlife and other local animals	Prevents pollution from animal waste
Limit domesticated animal access to areas adjacent to or in the waterbody	
Clean up after pets and other domesticated animals	
Implement deferred or prescribed grazing methods in the upper watershed	
Properly maintain septic systems to minimize potential pollutant contributions over time*	Prevents pollution from human waste
Ensure visitors are aware of and have access to restroom facilities	
Encourage parents to dress their children who are not toilet trained in swim pants/swim diapers when recreating in the waterbody	
Encourage visitors to have a plan for the containment and disposal of trash and waste	

*More information can be found at https://www.epa.gov/septic/septic-system-care-and-maintenance

While many of these watershed improvement BMPs have been or will be implemented, as discussed in the following sections, the improvement on water quality is expected to occur as the management practices have time to fully establish (e.g. as rehabilitated and restored social trails re-establish vegetation cover and reduce sediment and fecal contamination transport rates). The monitoring program discussed later in this section will elaborate on how these improvements will be tracked and confirmed.

10.1.1 Historical Considerations

A previous *E. coli* TMDL for Oak Creek was developed and approved in 2010. The previous TMDL identified many of the same NPS listed in this updated TMDL, including contributions from domesticated animals and seasonal recreators.

10.1.2 Completed Actions

Efforts to restore water quality have been undertaken since the publication of the previous TMDL. These efforts primarily targeted the impacts of seasonal recreation. Table 29 summarizes restoration activity completed prior to the development of this TMDL.

Table 28. Completed Restoration Activities

Responsible Parties	Action	Result	Year Completed
ADEQ, ASPT	Reduced total parking lot capacity from 255 to 185 spaces[1]	Reduced same-time visitor capacity and associated *E. coli* loading	2020
ADEQ, ASPT	Added ½ mile of pedestrian barrier fencing[1]	Reduced volume of unauthorized visitors and associated *E. coli* loading	2020
ASPT	Stopped admitting walk-ins through Slide Rock State Park's front gate[1]		2020
ADEQ, ADOT	Closed 27 of 60 unauthorized parking areas[1]	Reduced volume of unauthorized visitors and associated *E. coli* loading	2020
City of Sedona	Established a "tourist-focused" shuttle system for popular trails[2]		2022
ADEQ, USFS	Closed or reduced erosion in 439 trails and rehabilitated 82 trails for continued public use[3]		2024

Responsible Parties	Action	Result	Year Completed
ADEQ, Oak Creek Watershed Council (OCWC)	Conducted weekly litter cleanup events in roadside parking areas and along Oak Creek Canyon[3]	As of 2024, removed 6,222 lbs. of trash — including 366 diapers and 498 lbs. of human and pet waste	2024
ADEQ, OCWC, USFS	Installed 37 pet waste stations at recreational areas along Oak Creek Canyon and around Sedona[4]	Within the first 34 months of operation, prevented 10,145 lbs. of pet waste from potentially polluting Oak Creek	2024
ADEQ, NAU	Conducted a DNA study on water quality samples to identify mammalian *E. coli* contributors[5]	Identified humans, dogs, and elk as the most common mammalian contributors of *E. coli*	2024

1. ADEQ, 2022b
2. City of Sedona, 2020
3. ADEQ, 2024a
4. ADEQ, 2024b
5. NAU, 2024

10.1.3 Ongoing Actions

ADEQ's partners will champion the ongoing sustainment of restoration, as they are well positioned in the watershed with local knowledge and mobilization of resources. Partners can leverage existing grants offered by private entities and public organizations to expand on what has been completed in Oak Creek and sustain it into the future. Several initiatives from the preceding section are being continued, and new initiatives are suggested (Table 30).

Table 29. Ongoing Restoration Activities

Responsible Parties	Action	Result
USFS	Continue improving and obscuring unauthorized "social trails"	Reduce unauthorized access by visitors and associated sediment & *E. coli* loading
OCWC, National Forest Foundation	Continue to sponsor weekly litter cleanup events	Remove trash and waste products
OCWC, USFS	Continue to maintain and monitor pet waste stations	Reduce pet waste-associated *E. coli* contributions
OCWC, Friends of the Forest, Friends of the Verde	Continue water quality monitoring per CWA section 305(b)	Obtain regular water quality data
OCWC, City of Sedona, Sedona Chamber of Commerce, National Forest Foundation	Continue education and outreach efforts via the "Leave No Trace" campaign	Spread awareness of water quality issues and solutions to visitors and the local community

10.1.4 Future Actions and Monitoring

In accordance with A.R.S. § 49-234, ADEQ will review the TMDL at least once every five years to determine if attainment of applicable surface water quality standards has been achieved. Sampling will be conducted as deemed necessary during this five-year period to obtain data for TMDL effectiveness monitoring (Table 31). If attainment of applicable surface water quality standards has not been achieved, ADEQ will evaluate whether modification of this TMDL implementation plan is required. Attainment of water quality standards is expected to take place pending the completion of an Impaired Waters Identification Rulemaking that is currently scoped in the 2026–2027 agency strategic plan and adoption of new standards for assessing *E. coli* impairments (Table 32).

Table 30. Proposed Sampling Locations

Waterbody Assessment Unit	ADEQ Site ID	Site Name	Latitude	Longitude
Oak Creek — Headwaters to West Fork 15060202-019 Length: 3.4 mi	VROAK047.96	OAK CREEK - BELOW CAVE SPRING CAMPGROUND	34.992932	-111.736965
Oak Creek — West Fork to Slide Rock State Park 15060202-018A Length: 2.8 mi	VROAK044.46	OAK CREEK - ABOVE SLIDE ROCK STATE PARK	34.955997	-111.755575
Oak Creek — Slide Rock State Park 15060202-018B Length: 1.46 mi	VROAK043.86	OAK CREEK - BELOW SLIDE ROCK STATE PARK	34.943488	-111.751853
Oak Creek — Below Slide Rock State Park to Dry Creek 15060202-018C Length: 20 mi	VROAK040.48	OAK CREEK - BELOW INDIAN GARDENS	34.91	-111.728611
	VROAK031.38	OAK CREEK - AT RED ROCK CROSSING	34.824444	-111.806389
Oak Creek — Dry Creek to Spring Creek 15060202-017	VROAK013.95	OAK CREEK - AT MORMON CROSSING	34.7449	-111.896417

Waterbody Assessment Unit	ADEQ Site ID	Site Name	Latitude	Longitude
Length: 10.05 mi				
Oak Creek — Spring Creek to Verde River 15060202-016 Length: 12.67 mi	VROAK008.90	OAK CREEK - ABOVE CORNVILLE BRIDGE	34.718508	-111.916283
Spring Creek — Coffee Creek to Oak Creek 15060202-022 Length: 6.45 mi	VRSPN013.40	SPRING CREEK - FISH BARRIER	34.75111	-111.910858

Table 31. Proposed Changes to Numeric Water Quality Standards for *E. coli*

Standard Change	2016 EPA Approved Standards	Update to Standards	Status
Replace SSM with Statistical Threshold Values	**FBC:** 235 CFU/100 ml **PBC:** 575 CFU/100 ml	**FBC:** 410 CFU/100 ml **PBC:** 576 CFU/100 ml	Implemented as of March 2025
Potential update to A.A.C § R18-11, Article 6	Two or more exceedances within a three-year sampling period results in a waterbody being listed as impaired	Determine 10% exceedance rate with 90% confidence level	Expected 2026

Potential update to A.A.C § R18-11, Article 6	Samples collected under any flow condition are applicable	Samples collected during or within 48 hours of a storm flow event are **not** applicable	Expected 2026

Currently in A.A.C § R18-11, Article 6, only two exceedances for the *E. coli* water quality standard, under any flow conditions (i.e. storm flow or base flow), are needed to list a waterbody as impaired. Under the updated rule, ten percent of a waterbody's samples will need to exceed standards to list it as impaired, and samples collected during or two days after a storm flow event will not be considered in that statistical analysis. The proposed changes to A.A.C § R18-11, Article 6 will better align with nationally accepted methodologies, and more accurately assess the bacterial contamination risk to waterbody users. Once these rules are finalized, all reaches of Oak Creek will be in attainment with water quality standards. A sample timeline for these future actions is provided (Figure 34). Actual completion dates for these actions may vary as they are subject to future cost and capacity considerations.

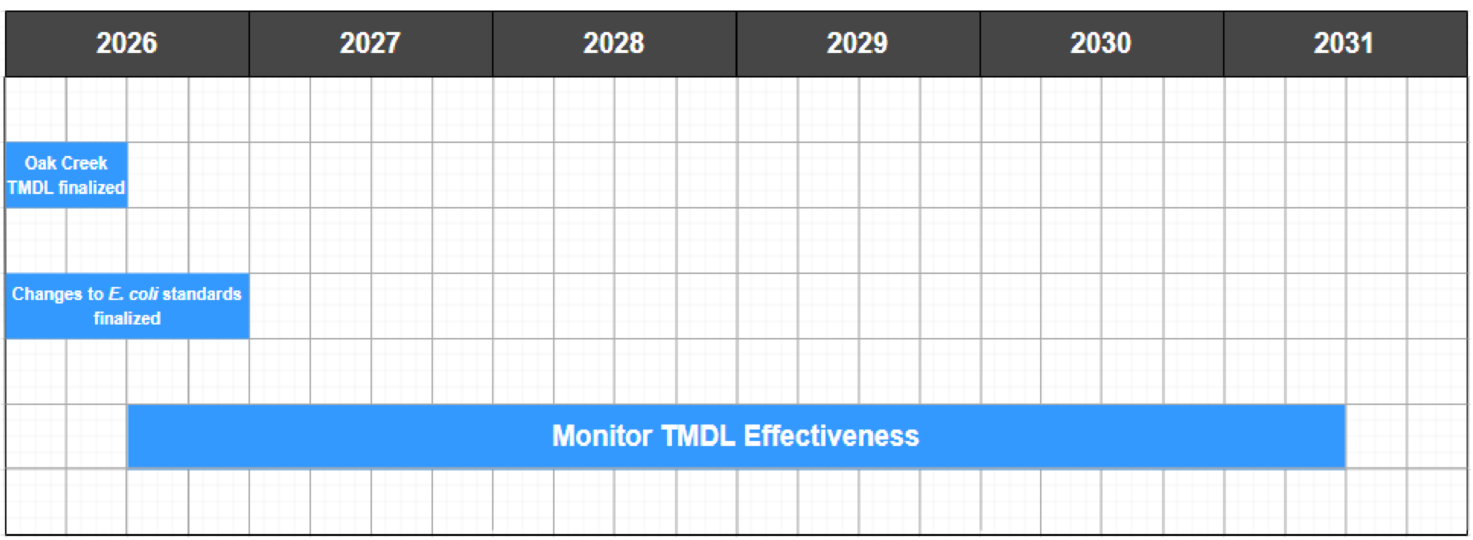


Figure 35. Sample timeline for future actions

Section 11 Public Participation

The development of the TMDL would not have been possible without the participation of the public and the engagement of local interest groups, including:

- Arizona Department of Transportation (ADOT)
- Arizona State Parks & Trails (Slide Rock State Park)
- Arizona Cross Watershed Network
- City of Sedona
- Friends of the Verde
- Sustaining Flows Council
- United States Forest Service (Coconino National Forest)
- Yavapai County Flood Control District

The following is a summary of the public engagement efforts for this TMDL:

- **Initial Stakeholder Engagement:** From Aug. 2023 to the end of Dec. 2023, local stakeholders and interest groups were invited to provide input and their desired level of engagement for the development of this TMDL. Many of these groups expressed interest in receiving updates and opportunities to comment on data when available.

- **Data Update — Load Duration Curves and Load Reductions:** On Jan. 3, 2024, stakeholders and local interest groups were provided the finalized Load Duration Curves and Load Reduction data for review and comment.

- **Arizona Cross Watershed Network Lunch 'n Learn:** On March 5, 2024, members of ADEQ's Sampling & Source Identification Unit gave a presentation about ongoing and upcoming TMDL projects — including the Oak Creek TMDL — to members of the AZ Cross Watershed Network as part of their monthly "Lunch 'n Learn" series.

- **Sedona World Water Day:** On March 23, 2024, members of ADEQ's Surface Water Quality Improvement Section set up a booth to engage the public at the Sedona World Water Day event by distributing education materials including an Oak Creek TMDL Fact Sheet and providing an opportunity to discuss the project and ask further questions.

- **Arizona Game and Fish Expo:** On March 23 and 24, 2024, members of ADEQ's Sampling & Source Identification Unit set up a booth to engage the public at the Arizona Game and Fish Expo by distributing educational materials including an Oak Creek TMDL Fact Sheet and providing an opportunity to discuss the project and ask further questions.

- **Verde Valley Updates Presentation:** On April 16, 2024, members of ADEQ's Surface and Groundwater teams briefly presented about ongoing projects in the Verde watershed

— including the Oak Creek TMDL — to local leadership and interest groups.

- **Earth Day Celebration at Red Rock State Park:** On April 20, 2024, members of ADEQ's Surface Water Quality Improvement Section set up a booth to engage the public at the Earth Day Celebration at Red Rock State Park by distributing educational materials including an Oak Creek TMDL Fact Sheet and providing an opportunity to discuss the project and ask further questions.

- **Verde Valley Birding and Nature Festival (Family Nature Day):** On April 27, 2024, members of ADEQ's Surface Water Quality Improvement Section participated in the Verde Valley Birding and Nature Festival, distributed an Oak Creek TMDL Fact Sheet, and provided an opportunity to discuss the project and ask further questions.

Prior to the TMDL formal comment period, an opportunity for informal feedback on the draft TMDL was presented to community stakeholders starting April 5, 2024 and concluding April 19, 2024. The TMDL was also reviewed informally by applicable members of the EPA and ADEQ prior to formal comment.

The draft TMDL will be published on ADEQ's website for 45 days, and will include a public notice of publication. During the public notice period, public comments will be collected and included with response from ADEQ in the final publish of the TMDL.

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