Arizona Department of Environmental Quality
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# Oak Creek
# and Spring Creek

## Verde River Watershed

## Total Maximum Daily Loads

## For

## *Escherichia coliform*

Arizona Department of Environmental Quality

August 30, 2010

Open File Report 10-01

# TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| A.A.C. | Arizona Administrative Code |
| A.A.R. | Arizona Administrative Register |
| ADEQ | Arizona Department of Environmental Quality |
| ADOT | Arizona Department of Transportation |
| AFLP | Amplified Fragment Length Polymorphism |
| APP | Aquifer Protection Permit |
| A.R.S. | Arizona Revised Statutes |
| ASP | Arizona State Parks |
| AZPDES | Arizona Pollution Discharge Elimination System |
| BMP | Best Management Practices |
| cfs | cubic feet per second |
| cfu | colony forming units |
| CGP | Construction General Permit |
| CWA | Clean Water Act |
| *E. coli* | *Escherichia coliform* |
| EPA | United States Environmental Protection Agency |
| F | degrees Fahrenheit |
| FDC | Flow Duration Curve |
| FOF | Friends of the Forest |
| FBC | Full Body Contact |
| HUC | Hydrologic Unit Code |
| LA | Load Allocation |
| LDC | Load Duration Curve |
| $mi.^2$ | square miles |
| MOS | Margin of Safety |
| MGD | Million Gallons per Day |
| MS4 | Municipal Separate Storm Sewer System |
| MU | ADEQ Monitoring Unit |
| NAU | Northern Arizona University |
| NB | Natural Background |
| NMP | National Monitoring Program |
| NPS | Non Point Source |
| NTU | Nephelometric Turbidity Units |
| OAW | Outstanding Arizona Water |

| | |
|---|---|
| OCWC | Oak Creek Watershed Council |
| PBC | Partial Body Contact |
| RRSP | Red Rock State Park |
| SSM | Single Sample Maximum |
| SRSP | Slide Rock State Park |
| SWMP | Stormwater Management Plan |
| TIP | TMDL Implementation Plan |
| TMDL | Total Maximum Daily Load |
| USFS | United States Forest Service |
| USGS | United States Geological Survey |
| WIP | Watershed Improvement Plan |
| WLA | Wasteload Allocation |
| WRCC | Western Region Climate Center |
| WWTP | Wastewater Treatment Plant |

## EXECUTIVE SUMMARY

Oak Creek and the red rocks of Sedona are popular tourist destinations in central Arizona. Due to the large number of visitors, the water quality of Oak Creek has been extensively studied with concerns being raised as early as the 1970s. The Arizona Department of Environmental Quality (ADEQ) 2006/08 305(b) Assessment Report lists five segments of Oak Creek and one segment of Spring Creek as impaired for exceeding the *Escherichia coliform* (*E. coli*) water quality standard. Previous studies identified recreational users, septic systems, wildlife, and domesticated animals as potential sources of fecal contamination. Although many improvements have been implemented in the watershed, exceedances of water quality standards still occur on a regular basis.

ADEQ completed a Pathogen Total Maximum Daily Load (TMDL) in 1999 for Slide Rock State Park (SRSP) which called for a 30 percent reduction in summer recreational season *E. coli* values in order to attain the water quality standard of 580 colony forming units per 100 milliliters (cfu/100ml). Subsequently the standard was revised to its current single sample maximum (SSM) value of 235 cfu/100ml and geometric mean of 126 cfu/100ml. Continuing exceedances caused ADEQ to undertake a revision to the TMDL beginning in 2003. Sampling occurred on high visitation weekends, during stormwater runoff and snow melt events, and under baseflow conditions. The TMDLs calculated in this document supersede and replace the 1999 Pathogen (fecal coliform and *E. coli*) TMDL for SRSP.

The TMDLs are based on attaining the 235 cfu/100ml SSM and 126 cfu/100ml geometric mean water quality standards. Load Duration Curves (LDC) were developed to determine reductions necessary to attain the SSM water quality standard under different flow regimes. Based on the TMDL analysis the geometric mean standard is being attained in all of the stream segments. The LDCs provide a visual display of the relationship between stream flow, loading capacity, and water quality data. The TMDL value was arrived at by calculating the median LDC load for each flow category, then comparing the $90^{th}$ percentile value of the *E. coli* data to determine the current conditions within the flow category. If the $90^{th}$ percentile value is greater than the TMDL a reduction is needed. TMDL allocations were calculated for each flow category within the LDC where the existing load exceeds the TMDL. If the existing load is less than the

TMDL the reach is meeting the TMDL under that flow condition and no load allocation (LA) or waste load allocation (WLA) allocations were calculated. Table 1 summarizes the flow categories that require load reductions and the corresponding percent reductions necessary. Spring Creek lacked sufficient data to develop a LDC so percent reductions were calculated on a SSM concentration basis for wet (high flow) and dry conditions only. A 70 percent reduction is required under wet conditions while the TMDL is being attained under dry conditions along Spring Creek.

Table 1. Summary of Percent Load Reductions

| Segment | High Flows | Moist Conditions | Midrange flows | Dry Conditions | Low Flows |
|---|---|---|---|---|---|
| Headwaters to West Fork | 96% | - [1] | 42% | -[1] | -[1] |
| West Fork to Slide Rock | -[1] | 21% | -[1] | -[1] | -[1] |
| SRSP | -[1] | 21% | -[1] | 2% | 12% |
| SRSP to Dry Creek | 93% | 5% | 68% | -[1] | 9% |
| Dry Creek to Spring Creek | 94% | -[1] | 51% | 34% | 25% |
| Spring Creek | 70% | -[NC] | -[NC] | -[1] | -[NC] |

1 - Existing load meets TMDL
NC- Not calculated

Exceedances routinely occur seasonally during the summer recreational months (May to September). These exceedances are depicted under the dry conditions and low flow LDC regimes. Recreational use drops significantly as water temperatures decrease resulting in no observed exceedances under low flow, cool weather conditions. Stormwater runoff and spring snowmelt increase flows within the streams and may result in increased *E. coli* concentrations as fecal material is carried in to the streams via overland flow. These exceedances are typically shown under the high flow, moist conditions, and midranges flow categories on the LDCs. Critical conditions, therefore, are high recreational use and increased flows resulting from precipitation events and spring runoff.

In 2009 the Oak Creek Canyon Watershed Council (OCWC), formerly the Oak Creek Canyon Task Force, a local watershed improvement group, was awarded a Water Quality Improvement Grant by ADEQ. The main goal of the grant is to develop a Watershed Improvement Plan (WIP). Several improvement projects have been implemented over the years to improve the water quality in Oak Creek, however, the effectiveness and necessity of these projects has been questioned. Development of the WIP will include watershed and social surveys aimed at locating and prioritizing future water quality improvement projects. The document will act as a blueprint for improving water quality in Oak Creek.

# 1.0 BACKGROUND INFORMATION

## 1.1 Physiographic Setting

Oak Creek is located in the north-central portion of Arizona, with its headwaters located approximately 20 miles south of Flagstaff and its confluence with the Verde River 80 miles north of Phoenix, see Figure 1. Elevation in the watershed varies from approximately 7,500 feet in the upper watershed to 3,200 feet at the confluence of Oak Creek and the Verde River. Oak Creek Canyon formed as the uplifted Colorado Plateau was eroded. The western edge of the Mogollon Rim, which marks the transition from the Central Highlands (or Transition Zone) province to the Colorado Plateau, is seen near the City of Sedona. As Oak Creek flows south it transitions from a steep sided, narrow canyon to wide flood plain south of Sedona.

Sedona is the largest city located within the watershed. The estimated 2005 population of Sedona was 11,220 (U.S. Census Bureau, 2006). Smaller communities located within the basin include Mountainaire, 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 one-half (14 $mi^2$) of the Munds Mountain Wilderness Area is located in the east central portion of the watershed (Figure 1).

## 1.2 Climatic Setting

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 receives an average of 17.99 inches of precipitation a year (WRCC, 2003). Precipitation falls in July and August as a result of high intensity, short duration storms associated with the summer monsoon season. A second rainy season occurs during the winter months (December through March). The winter 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.

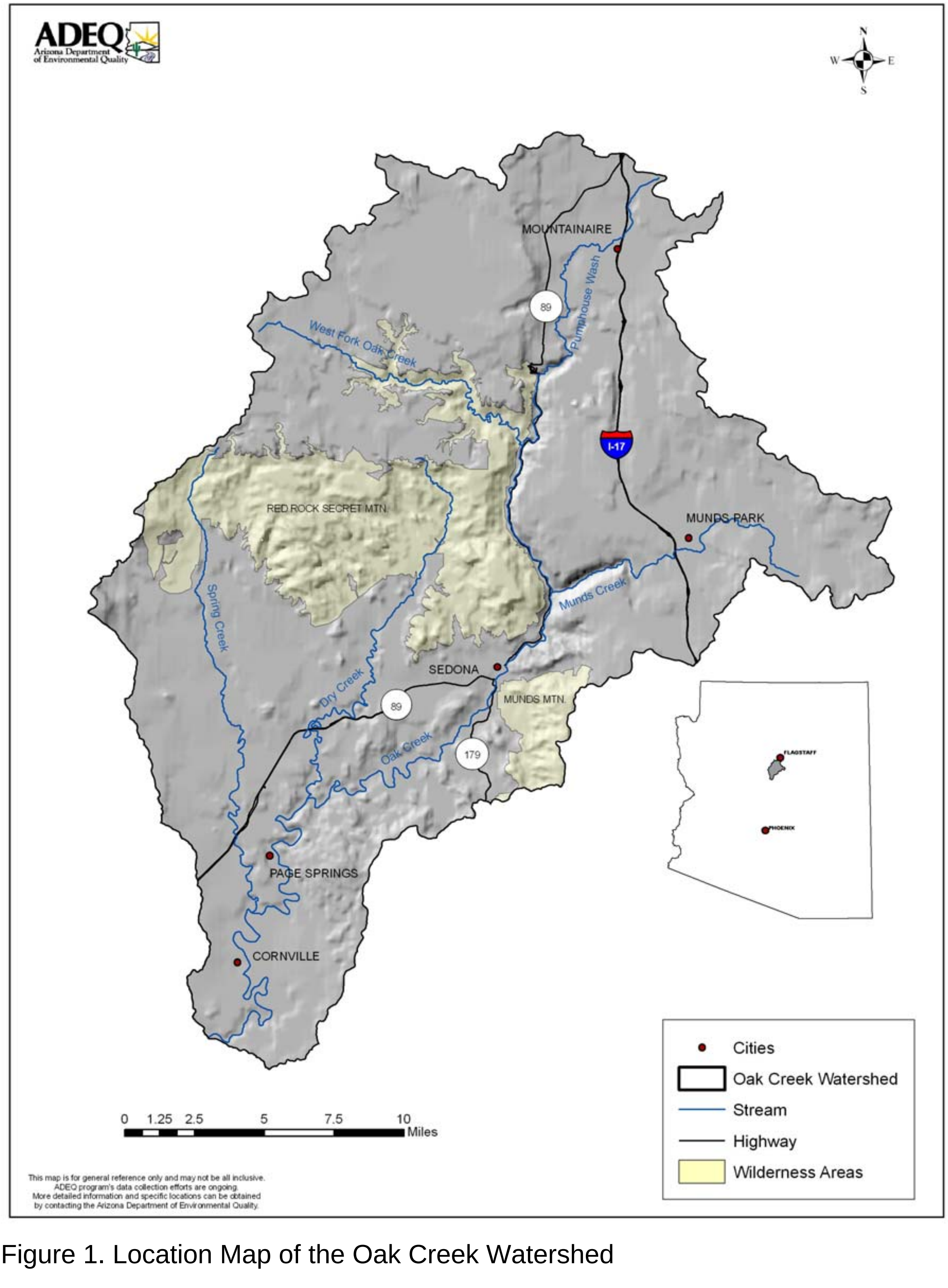


Figure 1. Location Map of the Oak Creek Watershed

## 1.3 Hydrology

The Oak Creek watershed has a drainage area of approximately 465 $mi^2$. Total stream miles within the 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 stream miles, including Dry Creek, equal approximately 344. Fry Canyon and Pumphouse Wash are ephemeral to intermittent streams that flow into Oak Creek below Sterling Springs Fish Hatchery.

Historic flow data indicate that higher than normal flows occur during two periods of the year. The first typically occurs during late February to early April; presumably in response to the winter storm season and snow melt. The second increased period of flow occurs in late July to early September as a result of the summer monsoon season.

## 1.4 Land Use and Ownership

Oak Creek Canyon is a popular area for recreational activities during the warmer months of the year. Improved campgrounds and day use areas, other than SRSP, are managed by the U.S. Forest Service (USFS). Private communities are scattered throughout the canyon. Private ownership within the watershed equals approximately 8 percent with the remaining 92 percent being managed by governmental agencies. Sample sites were selected to bracket high use areas and allow for safe access during storm events and high visitation periods via public lands. The notable exceptions include below the Rainbow Trout Farm, Munds Creek, below Dry Creek, and below Page Springs Fish Hatchery. These sites are not open to the public but access has been granted to ADEQ by the individual landowners.

## 1.5 Vegetation and Wildlife

Vegetation types within the watershed vary with elevation. The higher elevations, on the Colorado Plateau, are characterized by Ponderosa pine, Gambel oak, and Pinyon and Juniper pine. The Central Highlands, located in the center of the watershed, are primarily mixed Pinyon and Juniper pine, mixed Chaparral, and scrub brush. The southern portion of the watershed transitions into the Basin and Range province. Agricultural areas are located within the Sonoran Paloverde and mixed cacti and scrub that characterizes the Sonoran desert vegetation types.

The wildlife population found within the watershed is diverse, ranging from skunk and raccoon to deer and elk. Domesticated animals include dogs, cattle, horses, and llama.

## 2.0 EXISTING DATA SOURCES

### 2.1 Existing Water Quality Data

Water quality data has been collected from the Oak Creek watershed since the late 1960s by several entities. See Table 1 in Pathogen TMDL for SRSP for a complete listing (ADEQ, 1999a). Samples have been collected from both surface and groundwater and sediment. Analytical parameters have included bacteria, viruses, nutrients, and metals. More recent data has been collected by ADEQ, Arizona State Parks (ASP), and Friends of the Forest (FOF) on behalf of the Coconino National Forest, Northern Arizona University (NAU) and the National Monitoring Program (NMP). Sample sites are shown in Figure 2.

#### 2.1.1 ADEQ Water Quality Data

The TMDL and Monitoring (MU) units have collected data from the Oak Creek watershed. TMDL sampling efforts, until the more recent Phase II study, were conducted in 1998 to support the original pathogen and nutrient TMDL development (ADEQ, 1999a and b). Eighteen sites were sampled for fecal coliform, *E. coli*, inorganics, and nutrients. In addition physical parameters and turbidity were measured.

The MU conducts cyclical monitoring throughout the state on a three-year rotating basis, visiting one of three monitoring regions per year. The Verde River watershed, which includes Oak Creek, is located in the central monitoring region and was last sampled in fiscal year 2009 (July 1, 2008-June 30, 2009). The MU targets perennial to intermittent waters on a quarterly basis in order to characterize ambient conditions. The number of

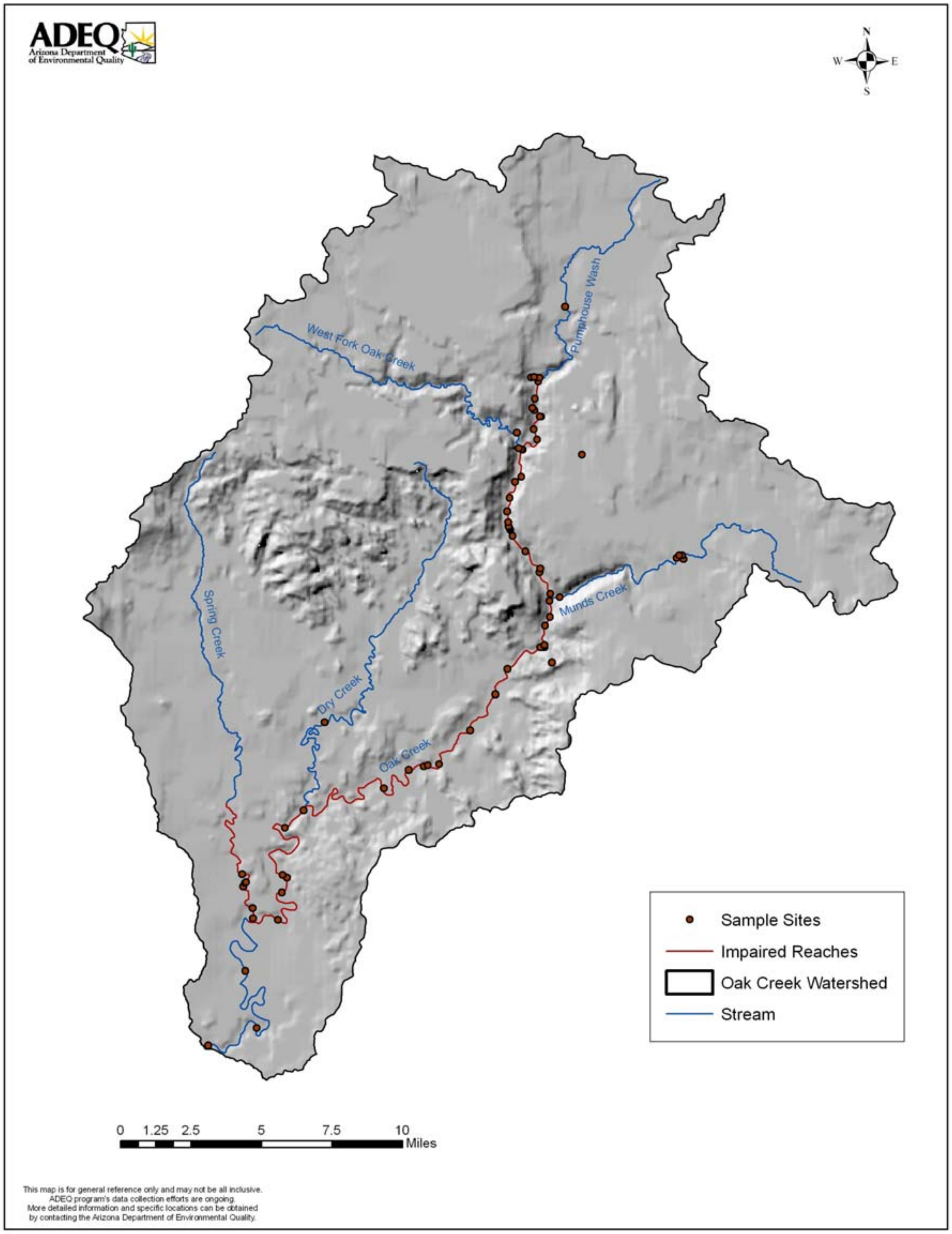


Figure 2. Water Quality Sample Locations

sample sites varies depending on workplan and available funds. Historically data collection has included *E. coli*, physical parameters, metals, nutrients, and stream flow.

### 2.1.2 ASP Water Quality Data

SRSP has been collecting bacteria samples (*E. coli*) from five sites (Upstream, Midslide, Large Pool, Foot Bridge, and Highway Bridge) within the park since 1996. Typically, samples are collected on a weekly basis during the off peak usage months (October to April) and five times a week during peak periods (May to September). During periods of water quality standard exceedances, samples are collected twice a day until levels fall below the standard. Discharge measurements are not measured during sampling; however a stage recorder is located near the Highway 89 Bridge.

### 2.1.3 FOF Water Quality Data

FOF, a volunteer group, has collected water quality samples from six sites throughout the watershed since April 1998, namely above SRSP, Grasshopper Point, Ladders, Mormon Crossing, Crescent Moon, and Spring Creek. The group collects data for the Coconino National Forest and has the samples analyzed for *E. coli* by SRSP staff. Samples are collected once a week from April to September, usually on Wednesday. No discharge measurements are made at the time of sampling; however air and water temperatures are recorded along with general observations.

### 2.1.4 NAU Water Quality Data

NAU conducted the Clean Water Act (CWA) 319 funded Oak Creek Canyon *Escherichia coli* Genotyping Project (NAU, 2000). Water and sediment samples were collected from six sites located in the upper watershed (above Sedona) in 1998 and 1999. The sample sites were located at Pumphouse Wash, Pine Flats Campground, West Fork Oak Creek, upstream and downstream of SRSP, and Grasshopper Point. In addition to *E. coli* analysis the samples were subjected to genotyping. The results show that both animal and human fecal matter impacts the water quality of Oak Creek. The study identified the contribution of animals as significant to the fecal pollution in Oak Creek. Animals are drawn to the creek by both the need for water and food litter left behind by visitors. No discharge measurements were taken during sampling events.

#### 2.1.5 NMP Water Quality Data

NAU also conducted the CWA 319 funded Oak Creek Canyon NMP from January 1994 to June 1998. Samples were collected from eight sites in the upper watershed monthly from September to May and weekly during high visitation months (May to September). Fecal coliform (water and sediment) and nutrients were the critical measurements collected. The sites included above and below Pine Flats Campground, SRSP, Manzanita Campground, and Grasshopper Point. Additional measurements included stream flow, dissolved oxygen, water temperature, and pH, among other chemical parameters. The study concluded that recreational users are not the sole source of contamination and that a sediment reservoir of fecal pollution exists in Oak Creek.

#### 2.1.6 USGS Water Quality Data

USGS has collected water quality samples from four sites within the watershed, Oak Creek near Sedona (09504420), Oak Creek at Sedona (09504430), Oak Creek at Red Rock Crossing (09504440), and Oak Creek near Cornville (09504500). The periods of records vary and are 1978 to 1980, 1987 to 1988, 1978 to 2002, and 1967 to 1978, respectively. In addition to biological data, nutrient, organic, inorganic, physical properties, stream flow and sediment data were collected.

### 2.2 Existing Discharge Data

ADEQ routinely collects instantaneous discharge measurements with each water quality sample collected. Discharge measurements are crucial when developing TMDLs as the load calculations rely upon concentration and discharge. ADEQ's discharge data is limited in its temporal expanse so additional discharge data was used.

### 2.2.1 USGS Discharge Data

The USGS currently maintains two active, real-time gauging stations on Oak Creek, Oak Creek near Sedona (09504420) and Oak Creek near Cornville (09504500). The gages have been recording daily and peak stream flow data since October 1981 and July 1940, respectively. Additional peak and daily stream flow data are available from several stations, namely Munds Canyon Tributary near Sedona (09504400), Oak Creek at Sedona (09504430), and Oak Creek Tributary near Cornville (09504800).

### 2.2.2 ASP Discharge Data

ASP historically maintained two stage loggers within SRSP. One logger was located downstream of the foot bridge and the other is upstream of the Highway 89 bridge. The lower gage was installed in April 1996. The foot bridge logger was installed to confirm irregularities seen in the lower gage. All discharge calculations are made using the data and cross-section of the lower gauge. ASP also maintains a stage logger near the foot bridge at Red Rock State Park (RRSP). The period of record for the RRSP logger is Feb. 20, 1998 to present.

### 2.2.3 Yavapai County Discharge Data

Yavapai County Flood Control District maintains five stage loggers within the watershed, Pumphouse Wash (actually on Oak Creek), West Fork Oak Creek, Munds Canyon, Tlaqapaque Bridge, and Dry Creek. Records date to 1990, except Dry Creek which dates to 2001. The data record is incomplete until 1997 when the county assumed management of the Alert Network. Current data is available real-time on-line.

## 3.0 WATER QUALITY STANDARDS AND ASSESSMENTS

### 3.1 Water Quality Standards

Water quality standards for a stream segment are based upon the designated uses assigned to it according to the Arizona Administrative Code Title 18, Chapter 11 (A.A.C.-18-11). The 2006/2008 Impaired Waters (303-(d)) list includes five segments of Oak Creek and one Spring Creek segment as impaired based upon SSM *E. coli* exceedances of the Full Body Contact (FBC) designated use. The FBC standard is intended to protect recreational users (swimmers) from potential gastrointestinal infections. Table 2 lists the impaired segments and the corresponding Hydrologic Unit Code (HUC) numbers. The impaired reaches extend the entire length of Oak Creek from its headwaters to Spring Creek and the lower segment of Spring Creek from Coffee Creek to its confluence with Oak Creek.

Table 2. Impaired Segments of Oak Creek and Spring Creek

| **Segment Description** | **HUC Number** |
|---|---|
| Oak Creek- Headwaters to West Fork Oak Creek | 15060202-019 |
| Oak Creek- West Fork to Slide Rock State Park | 15060202-18A |
| Oak Creek- At Slide Rock State Park | 15060202-18B |
| Oak Creek- Below Slide Rock State Park to Dry Creek | 15060202-18C |
| Oak Creek- Dry Creek to Spring Creek | 15060202-017 |
| Spring Creek- Coffee Creek to Oak Creek | 15060202-022 |

The applicable FBC *E. coli* standards are 126 cfu/100ml for a 30-day, four-sample minimum, geometric mean and 235 cfu/100ml for a SSM. Prior to 1996 the standard was measured as fecal coliform with a geometric mean standard of 200 cfu/100 ml and single sample maximum equal to 800 cfu/100ml. The standards for *E. coli* were originally adopted as 130 and 580 cfu/100 ml, respectively, until they were revised to their current values in 2003.

*E. coli* are part of the larger group of coliform bacteria which are very common and most are harmless to humans. Fecal coliforms, a subset of total coliforms, include *E. coli* and flourish in the digestive tracts of warm blooded animals. Fecal matter from warm blooded animals contains *E. coli* along with other pathogens including viruses, parasites, and bacteria. Although most *E. coli* are not pathogenic themselves they are used as an indicator organism meaning that its presence provides a reasonable potential that other waterborne pathogens may be present. *E. coli* is suitable as an indicator organism because it is quickly detected and quantified more readily than other pathogens. Exposure to enteric pathogens via ingestion results in gastrointestinal tract infections causing nausea, vomiting, diarrhea, and fever.

Oak Creek and West Fork Oak Creek are both designated as an Outstanding Arizona Water (OAW), formerly called a Unique Water, per A.A.C.-18-11-112. The OAW designation stipulates that site-specific standards may be adopted to maintain and protect existing water quality. Site-specific standards applicable to the main stems of Oak Creek and West Fork Oak Creek are summarized in Table 3. All of the site specific standards are currently being attained.

Table 3. Site-specific Water Quality Standards Applicable to Oak Creek and West Fork Oak Creek

| **Parameter** | **Standard** |
|---|---|
| pH (standard units) | No change due to discharge |
| Nitrogen (total- nitrate/nitrite plus total Kjeldhal nitrogen) | 1.00 mg/l (annual mean)<br>1.50 mg/L (90$^{th}$ percentile)<br>2.50 mg/L (single sample maximum) |
| Phosphorous (total) | 0.10 mg/L (annual mean)<br>0.25 mg/L (90$^{th}$ percentile)<br>0.30 mg/L (single sample maximum) |

Beginning in the late 1960's various entities have studied the water quality of Oak Creek and the potential impacts to recreational users. Investigators have studied bacteria, viruses, and nutrients in surface and groundwater and stream sediments in order to quantify them and identify potential sources.

### 3.2 Assessments

Every two years the state is required to assess the surface water quality of Arizona. The purpose of the assessment is to determine which waters are attaining and if any are impaired or not meeting the applicable standards. ADEQ produces an integrated report which contains the 305(b) Assessment Report and 303(d) List of Impaired Waters. Waters that are determined to be impaired require a TMDL to be developed. As previously mentioned, the 2006/08 305(b) report lists five segments of Oak Creek and one segment of Spring Creek as impaired for exceeding the SSM *E. coli* water quality standard intended to protect recreational users. The water quality of Oak Creek is very high with the only current impairment being exceedances of bacteria standards. The one-mile segment of SRSP has been listed as impaired for pathogens since 1994. Turbidity, arsenic, nutrients and dissolved oxygen exceedances have been observed historically but no impairments for those parameters currently exist.

## 4.0 PREVIOUS WATER QUALITY STUDIES

As mentioned previously, the water quality of Oak Creek has been extensively studied. The Arizona Department of Health Services first studied the creek in 1973 (Obr et al., 1978). Subsequent studies in the 1980s confirmed that fecal pollution was impacting the creek (Jackson, 1981; Rose et al., 1987). The studies concluded that the recreational users were the sole source of fecal contamination. However recent data have shown that the degradation of water quality is not simply a linear relationship between recreational users and *E. coli* values. Stormwater runoff (urban and undeveloped) and spring melt degrade water quality and contribute to the sediment *E. coli* reservoir which is reintroduced to the water column via recreational activities within the creek.

### 4.1 Oak Creek Canyon NMP

In 1994 NAU began a two-year baseline study of water quality to be used to compare with data collected after Best Management Practices (BMPs) were implemented in 1996 followed by another two years of monitoring. Samples were collected weekly, each Saturday, during the high recreation season and the first Saturday of each month during the winter months. Parameters collected included fecal coliform, ammonia, nitrate, phosphorus, and sediment fecal coliform. Results from the NMP included:

- Water pollution persists at SRSP and Pine Flats Campground but is not directly correlated to the number of recreational users;
- Fecal pollution at SRSP is from more than one source. Sources include loadings from upstream, park visitors, rainfall flushing the riparian area, and disturbances of the in-stream *E. coli* sediment reservoir;
- Fecal coliform levels fell quickly upon closure of the site; and
- No significant improvement in water quality was observed after BMPs were implemented. BMPs included installing one mile of permanent barricades along Highway 89A to limit access and the modernization and modification of restroom facilities at SRSP and Grasshopper Point.

## 4.2 The Oak Creek Canyon Escherichia coli Genotyping Project

Genotyping of *E. coli* isolates from human, wildlife and domesticated animal populations in the Oak Creek watershed were used to determine the sources of fecal pollution. Bacteriological sampling occurred between July 1998 and September 1999 at five sites within Oak Creek Canyon above the City of Sedona. Water column and sediment samples were collected and analyzed using the Amplified Fragment Length Polymorphism (AFLP) method. AFLP results were compared to a reference library developed from fecal samples collected from the watershed by NAU scientists.

Summer samples bracketed the high-visitation weekends but sampling did not occur on the weekends when recreational pressure was at its peak. Only four samples, two each collected at the Pine Flat and Pumphouse Wash sites, exceeded the current *E. coli* SSM water quality standard. The results indicate that humans contributed approximately 16 percent of the *E. coli* with the remaining divided among various animal populations. Raccoon (16 percent), skunk (11 percent), elk (8 percent), dogs and white-tail deer (6 percent each) were the major animal sources. However, the relative percent contributions reflect ambient conditions, not high recreational usage.

## 4.3 ADEQ TMDL Studies

### 4.3.1 Phosphorus and Total Nitrogen TMDL

In 1987 a Nutrient TMDL was completed for Oak Creek but it did not include LAs for non point sources (NPS) (ADEQ, 1987). Additional data collection and analysis led to the development of a second nutrient TMDL in 1999 which calculated contributions from both point and NPS and assigned loads accordingly. The 1999 TMDL analysis determined that there were no nitrogen or phosphorus impairments within the Oak Creek watershed.

### 4.3.2 Pathogen TMDL Slide Rock State Park

Also completed in 1999 was a Pathogen TMDL for Slide Rock State Park. Three main sources identified included recreational users, septic systems and animals. The critical loading conditions were recreational pressure, groundwater inputs impacted by septic systems and surface water runoff after storm events. At the time the 1999 TMDL was written the applicable *E. coli* standards were 130 cfu/100ml as a geometric mean and 580 cfu/100ml as the SSM. The TMDL was calculated as the reduction in the mean summer season fecal coliform values necessary to meet the single sample maximum *E. coli* sample standard. The summer season mean fecal coliform concentration equaled 823 cfu/100ml and was calculated from data collected in 1996 and 1997. A reduction of 30 percent was calculated based on the assumption that all of the fecal coliform was *E. coli*. The TMDLs calculated in this document supersede and replace the 1999 Pathogen (fecal coliform and *E. coli*) TMDL for Slide Rock State Park.

## 5.0 MODELING AND ANALYTICAL APPROACHES

Exceedances have been observed to occur under periods of high visitation and under the influence of stormwater and snow melt inputs. There is not a simple linear relationship between flow rates and *E. coli* counts, although higher *E. coli* concentrations are seen at higher flows. High concentrations have also been observed under low flow conditions and under minimal stormwater inflows. Similar to the 1999 pathogen TMDL, load reductions will be based upon percent reductions necessary to meet the applicable water quality standard but they will be estimated based on individual LDC flow regime analysis.

### 5.1 LDC Analysis

ADEQ has chosen to employ a LDC approach in order to determine TMDLs and calculate load reductions necessary to attain the concentration-based SSM water quality standard. LDCs characterize water quality standards at different flow regimes. The curves provide a visual display of the relationship between stream flow, 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. One underlying premise of the LDC approach is that impairments correlate with stream flow conditions. In Oak Creek flows and measured *E. coli* values do not form a simple linear relationship. Although higher flows typically correlate to higher *E coli* levels, water quality exceedances are also observed at low flows. In general, exceedances observed in Oak Creek under high flow conditions are stormwater or spring melt related whereas recreational users likely contribute to low flow or dry condition exceedances. Cleland (2003) provides the following discussion on the elements and merits of an LDC method:

*The percentage of time during which specified flows are equaled or exceeded may be evaluated using a flow duration curve (Leopold, 1994). Flow duration analysis looks at the cumulative frequency of historic flow data over a specified period. The duration analysis results in a curve, which relates flow values to the percent of time those values have been met or exceeded. Thus, the full range of stream flows is considered. Low flows are exceeded a majority of the time, whereas floods are exceeded infrequently. …*

*The development of a flow duration curve typically uses daily average discharge rates, which are sorted from the highest value to the lowest. Using this convention, flow duration intervals are expressed as percentages, with zero corresponding to the highest stream discharge in the record (i.e. flood conditions) and 100 to the lowest (i.e. drought conditions). Thus, a flow duration interval of sixty associated with a stream discharge of 82 cubic feet per second (cfs) implies that sixty percent of all observed stream discharge values equal or exceed 82 cfs…*

*…A duration curve framework is particularly useful in providing a simple display that describes the flow conditions under which water quality criteria are exceeded. Stiles (2002) describes the development of a load duration curve using the flow duration curve, the applicable water quality criterion, and the appropriate conversion factor. Ambient water quality data, taken with some measure or estimate of flow at the time of sampling, can be used to compute an instantaneous load. Using the relative percent exceedances from the flow duration curve that corresponds to the stream discharge at the time the water quality sample was taken, the computed load can be plotted in a duration curve format (Figure 3).*

*By displaying instantaneous loads calculated from ambient water quality data and the daily average flow on the date of the sample (expressed as a flow duration curve interval), a pattern develops, which describes the* *characteristics of the impairment. Loads that plot above the curve indicate an exceedance of the water quality criterion, while those below the load duration curve show attainment. The pattern of impairment can be examined to see if it occurs across all flow conditions, corresponds strictly to high flow events, or conversely, only to low flow conditions.*

*Duration Curve Zones*

*Flow duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: one representing high flows, another for moist conditions, one covering median or mid-range flows, another for dry conditions, and one representing low flows. Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left generally reflect potential nonpoint source contributions. This concept is illustrated in Figure 3. Data may also be separated by season (e.g. spring runoff versus summer base flow). For example, Figure 3 uses a "+" to identify those ambient samples collected during primary contact recreation season (April – October).*

*Runoff Events and Storm Flows*

*The utility of duration curve zones for pattern analysis can be further enhanced to characterize wet-weather concerns. Some measure or estimate of flow is available to develop the duration curves. As a result, stream discharge measurements on days preceding collection of the ambient water quality sample may also be examined. This concept is illustrated by comparing the flow on the day the sample was collected with the flow on the preceding day. Any one-day increase in flow (above some designated minimum threshold) is assumed to be the result of surface runoff (unless the stream is regulated by an upstream reservoir). In Figure 3, these samples are identified with a red shaded diamond.*

*Similarly, stream discharge data can also be examined using hydrograph separation techniques to identify storm flows. This is also illustrated in Figure 3. Water quality samples associated with storm flows (SF) greater* *than half of the total flow (SF>50%) are uniquely identified on the load duration curve, again with a red shaded diamond.*

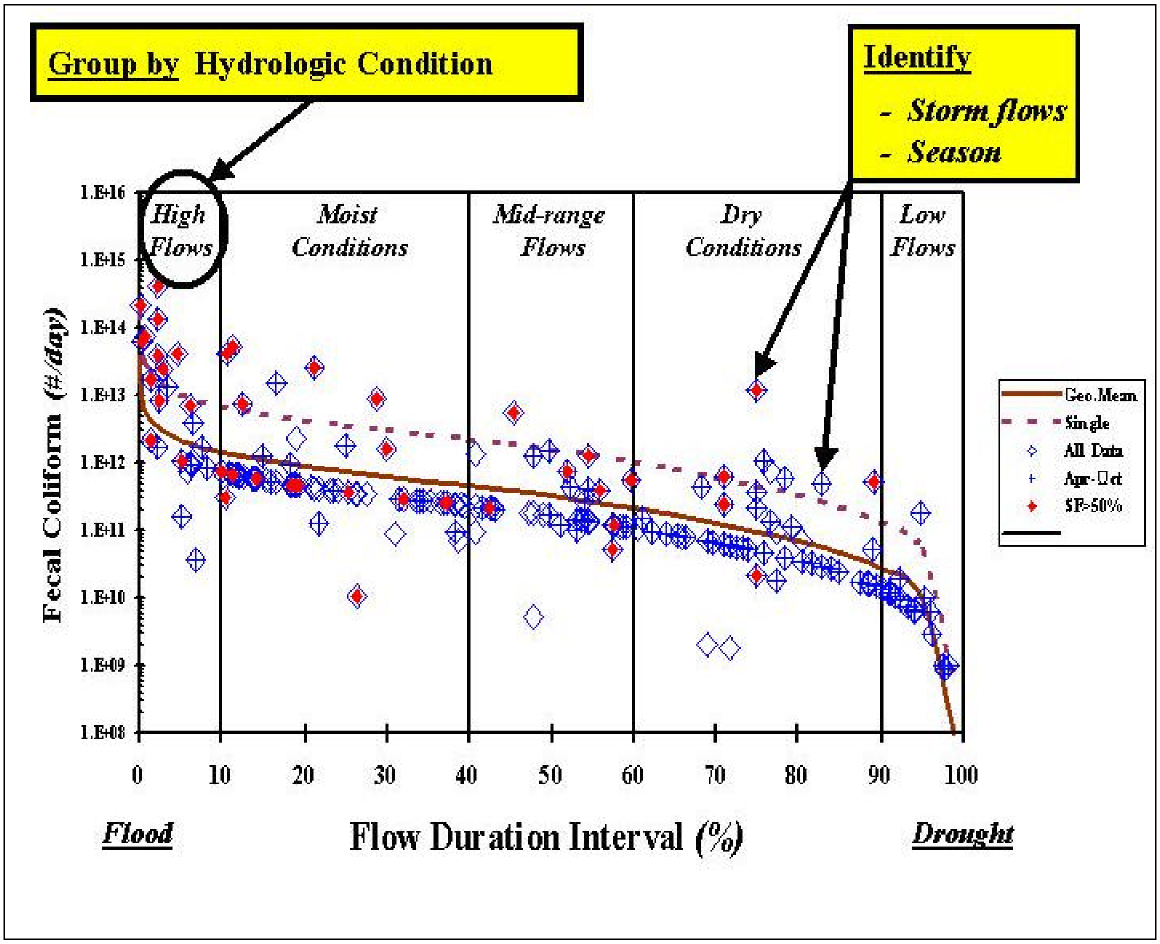


Figure 3. Sample Load Duration Curve (Cleland, 2003)

As outlined above (Cleland, 2003), the subdivision of the flow frequency curve into five zones corresponding to high flows (0-10 percent flow exceeds), moist conditions (10-40 percent flows exceeds), midrange flows (40-60 percent flows exceeds), dry conditions (60-90 percent flows exceeds), and low flows (>90 percent flows exceeds). LDCs will be developed for each segment listed as impaired in Table 2 except Spring Creek which lacks sufficient stream flow data necessary to calculate a flow duration curve (FDC). Spring Creek reductions will be calculated as percent reductions necessary to meet the applicable standard, similar to the 1999 SRSP TMDL.

### 5.2 LDC Development

As previously mentioned in Section 2.2, the USGS operates two active, real-time gauging stations along the mainstem of Oak Creek. The discharge records for these stations were used to develop LDCs for the SRSP to Dry Creek and Dry Creek to Spring Creek segments of Oak Creek. LDCs for ungauged segments were developed using USGS regression equations contained in USGS Fact Sheet 111-98 to calculate peak flows, then improved with weighted estimates (USGS, 1999). Comparisons between the regression equation discharges and actual field measurements were made and, where necessary, the regression results were adjusted to better represent actual data. The Yavapai County Alert Network data did not correspond well with measured low flows and therefore was not used to calculate FDCs or LDCs.

## 6.0 SOURCE ASSESSMENT

Potential sources of *E. coli* fall into two broad categories - point and NPS pollution. Point source pollution comes from a discrete, identifiable source, i.e. an industrial or sewage treatment plant end of pipe discharge. NPS pollution originates from many diffuse sources as a result of precipitation or snow melt moving over or through the ground. ADEQ has regulatory authority over point source via the surface water (Arizona Pollution Discharge Elimination System-AZPDES) and groundwater (Aquifer Protection- APP) permitting programs. Little regulatory authority exists over NPS within Arizona resulting in the need for voluntary efforts to control or mitigate its impacts.

### 6.1 Point sources

Point sources are typically described as end of pipe discharges. The location of these discharges are well defined and do not move. A point source discharge does not imply a continuous discharge rather a point from which a permittee may discharge. When point source discharges impair a water body they typically plot above the LDC on the low flow portion (near the right side). Point sources within the Oak Creek watershed include water treatment facilities, fish hatcheries, and stormwater related discharges.

### 6.1.1 Waste Water Treatment Plants (WWTP)

Several communities within the watershed operate small WWTPs in addition to the larger City of Sedona WWTP. Only two facilities have permit coverage for discharges to surface waters, the Pinewood Sanitary District Blackman WWTP (AZDPES Permit #AZ0023116) and Sedona Venture Sewer Company (AZ0021807). Both permits apply the SSM and geometric mean *E. coli* surface water quality standards as permit limits. The WLA for each facility will be calculated using the *E. coli* limits stated in the permit, not the average measured concentrations.

The Blackman WWTP permit authorizes regular discharge to Munds Creek only between November 15 and April 14 inclusive, with an anticipated average discharge of 0.17 MGD during this period. However, 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, as for example during wet weather. The average *E. coli* concentration measured (number of samples (N =8) is 3.6 cfu/100ml. Munds Creek carries the FBC designated use resulting in a permit limit of 235 cfu/100ml. The WLA for the Blackman WWTP is 4 G-cfu/day and is applied to all flow categories within the SRSP to Dry Creek segment.

Sedona Venture is permitted to discharge effluent to Dry Creek, a tributary to Oak Creek southwest of Sedona. There is no seasonal discharge limitation for the facility which averages 0.045 MGD. The average *E. coli* concentration measured (N=50) equals 12.5 cfu/100ml. Dry Creek carries the partial body contact (PBC) designated use resulting in an *E. coli* permit limit and surface water quality standard of 576 cfu/100ml. The Sedona Venture WLA equals 0.4 G-cfu/day and applies under all flow categories in the Dry to Spring Creek segment. Based on limited sampling of Dry Creek (N=2) no exceedances of the SSM or geometric mean standards have been observed.

### 6.1.2 Fish Hatcheries

The Arizona Game and Fish Department operates three fish hatcheries in the Oak Creek Watershed for the purpose of supporting 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 returning 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 AZDPES permit coverage because of the amount of fish raised per year (40 CFR, Chp. 1, Part 122, App. C). 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 Page Spring and Bubbling Ponds hatcheries and contains limits to protect the water quality of Oak Creek.

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 exempt from AZPDES permit coverage due to its annual use of feed.

Regardless of whether a hatchery has a permit to discharge to Oak Creek the operation, maintenance and the fish themselves are not expected to contribute any *E. coli* to the creek. Therefore the hatcheries will not be considered in TMDLs calculations resulting in a WLA equal to zero for these facilities.

#### 6.1.3 Municipal Separate Storm Sewer System (MS4) Permits

The City of Sedona was designated a Small MS4 community based upon the anticipated growth and water quality concerns in the area and, as such, has received a Small MS4 General Permit (Authorization # MS42002-32). The permit authorizes stormwater water discharges. The goal of this permit is to reduce or eliminate 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 2008 but is required to incorporate TMDL limitations or provisions as they become available. A WLA will be incorporated into the TMDL calculations for 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 percent of the TMDL within the three top flow categories (storm related discharges) based upon the area of Sedona (18.62 $mi^2$) compared to the area of the watershed

(361.73 $mi^2$). This approach is based on guidance issued by EPA in 2007 for calculating a MS4 WLA using a LDC analysis.

The Arizona Department of Transportation (ADOT) also has MS4 permit coverage within the Oak Creek watershed. The ADOT permit is a hybrid AZPDES permit that covers construction activities, industrial facilities, and stormwater runoff from highways. ADOT has completed developing its SWMP and has submitted it to ADEQ for review. Since the surface area of highways is very small (0.47 $mi^2$), approximately 0.1 percent, when compared to the larger watershed, a WLA for ADOT will not be included explicitly in the TMDL. The MS4 related WLAs only apply under the top three flow regimes which may be impacted by storm flows.

### 6.1.4 Construction General Permits (CGP)

The purpose of the CGP is to protect the quality and beneficial uses of Arizona's surface waters from pollution in stormwater runoff from construction activities. Under the Clean Water Act and Arizona Revised Statutes, it is illegal to have a point source discharge of pollutants, including stormwater runoff from construction sites, to a water of the United States that is not authorized by a permit. To protect water quality, the CGP requires operators to plan and implement appropriate pollution prevention and control practices for stormwater runoff during the construction period. The main concern with construction activities is the increased rate of erosion and sediment delivery from disturbed or cleared lands. There will be no allocation set aside for CGP activities as they are typically small in extent and duration and not expected to contribute *E. coli* to Oak Creek.

## 6.2 NPS

NPS pollution originates from both naturally occurring and anthropogenic sources causing the majority of impairments across the nation. As runoff occurs it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, and wetlands. NPS pollutants can originate from any type of land use including urban, agricultural, residential, and forest lands.

### 6.2.1 Wildlife

Other than the City of Sedona and small pockets of residential areas, the Oak Creek watershed is relatively undeveloped as reflected in the fact that 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 which were identified as sources of *E. coli* in the NAU Oak Creek Genotyping study. Precipitation events that create runoff introduce naturally occurring fecal material into the stream network but the overland flow also allows the forest floor to filter out some material. Human activities can draw wildlife closer to the waters edge or residential areas increasing the possibility of fecal contamination by increasing the number of animals present in a given area or decreasing the natural filtering ability of the forest floor.

### 6.2.2 Domesticated Animals

In addition to wildlife, domesticated animals, like pets, sheep, cattle, horses and other grazing animals raised by the ranching industry, 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 in close proximity to the stream. Open range grazing, 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 cattle or sheep 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*.

### 6.2.3 Human

Potential human sources of *E. coli* include septic systems and recreational users. Properly functioning septic systems use the leach field sediments and biological activity to eliminate bacteria from the septage. The CWA 319 funded Oak Creek Water Quality Guardian Project determined that there are approximately 164 individual onsite systems in addition to commercial and cluster systems within Oak Creek Canyon (upstream of Sedona). Many of these systems were installed prior to current regulations and/or have experienced increased demand potentially exceeding their design capacity.

Recreational pressure increases significantly during the summer season, typically 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 new public restroom adjacent to the USFS office near Indian Gardens. As a result, many visitors relieve themselves near the creek. Also, soiled diapers have been observed near the creek, at various locations, as visitors leave them behind instead of packing them out. In addition to introducing *E. coli* directly to the stream or riparian area visitors can resuspend fecal material and *E. coli* from stream sediments.

### 6.2.4 Urban/developed

The impervious surfaces introduced by urbanized and residential areas increase the amount and rate of 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 incorporating pollutants from their surfaces. Also, the alteration of native vegetation removes the filtering ability of those plants.

## 7.0 TMDL CALCULATIONS

The following sections describe how the TMDLs were calculated for each of the six individual impaired reaches. The TMDLs are based upon attaining the SSM water quality *E. coli* standard of 235 cfu/100ml. All stream segments are attaining the 126 cfu/100ml geometric mean standard, therefore, no TMDLs or load reductions based on this standard were calculated. Included within each reach discussion are the LDC and TMDL calculations necessary to attain the SSM. The TMDL value was arrived at by calculating the median LDC load for each flow category, then comparing the $90^{th}$ percentile value of the *E. coli* data to determine the current conditions within the flow category. If the $90^{th}$ percentile value is greater than the TMDL a reduction is needed. TMDL load reductions were calculated for each flow category within the LDC where the existing load exceeds the TMDL. If the existing load is less than the TMDL the reach is meeting the TMDL under that flow condition and no LA or WLA allocations were calculated.

The units for the applicable *E. coli* standards and the individual samples results are expressed as cfu/100ml. The TMDL calculations are expressed as billion cfu/day (G-cfu/day) in order to illustrate a quasi mass per time numeric TMDL target. In order to convert the concentration (cfu/100ml) to G-cfu/day it was multiplied by the discharge rate (cfs) and a conversion factor of 0.02446.

The TMDLs, allocations and load reductions calculated for the five impaired reaches of Oak Creek and the Spring Creek segment are derived from the SSM concentration-based water quality standard. Sections 7.3 to 7.7 describe the mass-based LDC approach used to estimate the reductions necessary for the Oak Creek segments to attain the SSM water quality standard. Load reductions for Spring Creek are simple percent reductions needed to attain the SSM standard.

The SSM water quality standard is routinely exceeded during the summer recreational season (May to September). The exceedances that occur under dry and low flow conditions on the LDC are typically attributed to recreational users but there are exceptions to this as discussed below. Precipitation events and spring snowmelt are also conditions that result in exceedances of the SSM water quality standard. Exceedances that are related to stormwater or snowmelt typically plot under the high flow, moist conditions, and midrange flow regimes on the LDC.

### 7.1 Natural Background

Wildlife is a source of *E. coli* and must be considered when developing TMDLs. Although wildlife contribute *E. coli* naturally the impact of human activity (trail development and clearing land around homes and riparian areas) can increase the rate and volume of runoff and pollutants entering the stream 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.

In order to develop a meaningful natural contribution of *E. coli* to Oak Creek, samples were collected in Sterling Canyon and the West Fork of Oak Creek, where the impacts of human activity could be assumed to be minimal. Samples were collected under base and storm flow conditions from both sites multiple times. The five stormwater samples averaged 43 cfu/100ml or approximately 18 percent of the 235 cfu/100ml standard. The 12 baseflow samples averaged 23 cfu/100ml or 10 percent of the standard. Therefore, 18 percent of the allowable load within the upper three flow categories will be assigned to natural background and 10 percent in the lower two flow categories.

### 7.2 Margin of Safety

The purpose of Margin of Safety (MOS) is to provide for variability in the natural system along with uncertainty in analytical results and assumptions made in the data analysis. An explicit MOS equal to 10 percent of the TMDL will be applied to each flow category calculation.

### 7.3 Oak Creek- Headwaters to West Fork Oak Creek (HUC 15060202- 019)

The headwaters to West Fork Oak Creek segment (7.4 miles) of Oak Creek was listed as impaired in the 2006/08 Assessment Report for two exceedances of the *E. coli* SSM water quality standard. Since 1998 110 *E. coli* samples have been collected from this segment. Four samples have exceeded the applicable water quality standard since 2003. Two of the exceedances were clearly related to storm flows as they plot on the left hand portion of the LDC at 0.01 percent flow, see Figure 4. Although the other two exceedances plot in the midrange and low flow portions of the LDC, field observations indicate that these samples reflect the influence of isolated, local precipitation events. The events were insufficient to significantly increase flows but were sufficient enough to raise turbidity and *E. coli* levels. To illustrate, an exceedance was measured in the morning of Sept. 4, 2004 after a minor rain event in the upper watershed. Turbidity was measured at 282 nephelometric turbidity units (NTU) and *E. coli* equaled 1203 cfu/100ml at a discharge of 0.48 cfs. Later the same day, when another sample was collected at approximately the same discharge rate, turbidity equaled 2.7 NTU and *E. coli* had fallen to 32.8 cfu.

Figure 4 and subsequent LDC figures appear to have many data points which create a vertical “bar” on the graphs. This is a reflection of the numerous data points collected at approximately the same flow value over holiday weekends. During these sampling events multiple samples were collected from the same site throughout the day. Since there were no observed stormwater inputs between sampling events the measured discharge rates were nearly identical.

Table 4 summarizes the TMDL calculations for the Headwaters to West Fork Oak Creek segment based upon the SSM standard. The segment meets the TMDL under the low flow, dry condition, and moist condition categories but exceeds under midrange and high flows. Reductions of approximately 96 percent under high flow conditions and 42 percent under midrange flows are needed to meet the TMDLs. The data indicate that recreational users are not directly impairing the creek in the upper portion of the canyon as the TMDL is only exceeded under wet conditions. Geometric mean values for each flow regime are 17 cfu/100ml under high flows, 3 cfu/100ml for moist conditions, 14 cfu/100ml under midrange flows, 5 cfu/100ml under dry conditions, and 4 cfu/100ml under low flows. The geometric means were calculated from all of the *E. coli* data within each flow category. No exceedances of the geometric mean standard were observed.

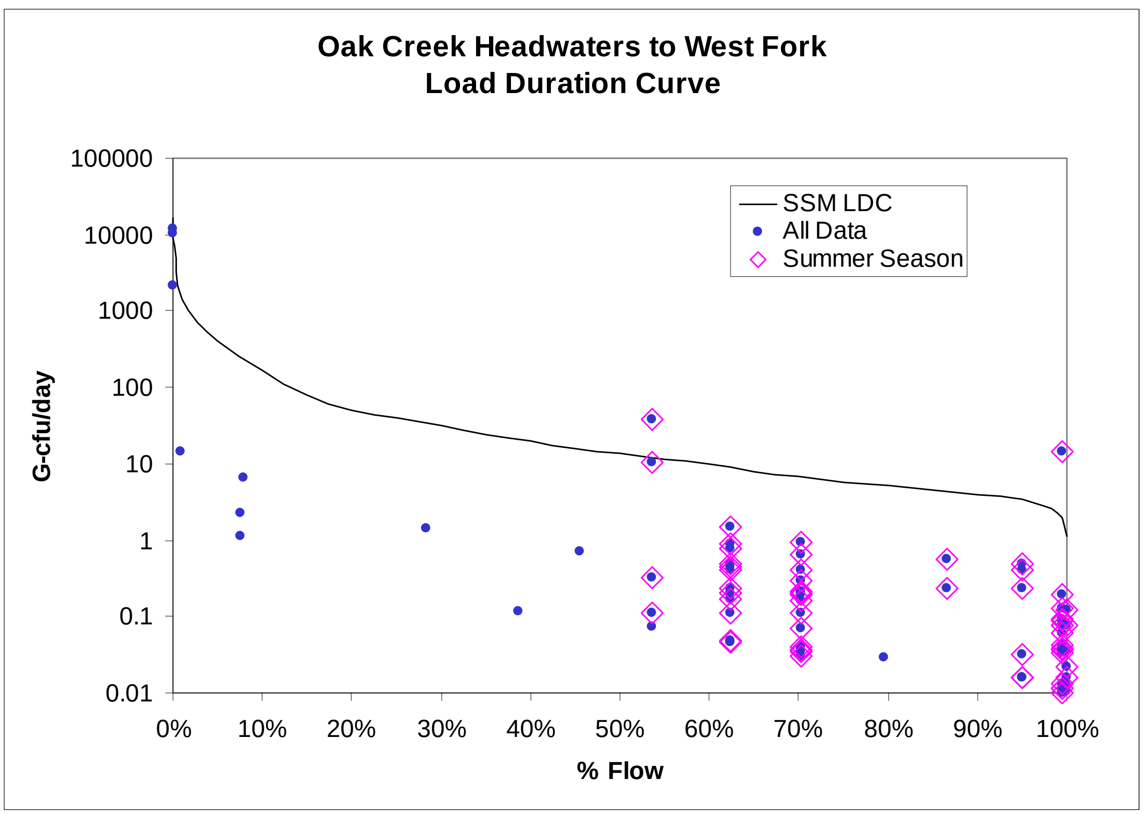


Figure 4. Headwaters to West Fork Oak Creek SSM LDC

Table 4. TMDL Summary for Headwaters to West Fork

| Flow Regime | Existing Load | TMDL | LA | WLA | NB | MOS | % reduction |
|---|---|---|---|---|---|---|---|
| 0-10% | 10855 | 405 | 292 | 0 | 73 | 41 | 96 |
| 10-40% | 1.3 | 39[1] | - | - | - | - | - |
| 40-60% | 24 | 14 | 10 | 0 | 2.5 | 1.4 | 42 |
| 60-90% | 0.77 | 5.75[1] | - | - | - | - | - |
| 90-100% | 0.20 | 3.45[1] | - | - | - | - | - |

1- Existing load meets TMDL

Units are G-cfu/day, unless otherwise noted

Although direct recreational pollution does not appear to be a consistent source of *E. coli* in the upper watershed indirect anthropogenic pollution may be a contributing factor. Several residential areas and campgrounds are located within the upper reach in close proximity to the stream. Additionally, pollutants may be introduced via Pumphouse Wash which drains portions of the watershed southeast of Flagstaff. Cattle grazing, domesticated animals and septic systems are present within the Pumphouse Wash portion of the watershed as is the Kachina Village WWTP which does not discharge to surface water. Increased access to the stream and the potential for greater runoff from these improved sites may contribute pollutants under wet conditions.

### 7.4 Oak Creek- West Fork Oak Creek to SRSP (15060202-18A)

The 5-mile segment of Oak Creek from West Fort of Oak Creek to SRSP was listed as impaired for *E. coli* in the 2006/08 Assessment Report due to three exceedances of the SSM standard within the assessment period. West Fork is a perennial tributary of Oak Creek and drains portions of the Red Rock-Secret Mountain Wilderness Area. As shown in Figure 5 the majority of the data collected for this reach was collected during the summer recreational season. Similar to the Headwaters to West Fork Creek segment, the influence of localized monsoon storms is shown in the monitoring data. On July 30, 2003, a sample was collected at the Halfway Day Use Area which measured 34 cfu/100 ml at a discharge of 9 cfs. Less than two hours later, after a local intense storm, another sample was collected that measured 1733 cfu/100 ml at a discharge of 15 cfs.

TMDL calculations based upon the SSM standard are summarized in Table 5. An insufficient number of samples were collected in order to calculate a 90$^{th}$ percentile value for the high flow category. The one sample collected in the high flow category did not exceed the SSM standard. A reduction equal to 21 percent is only required under moist conditions. The other three flow regimes currently meet the TMDL.  Similar to the SSM, the geometric mean for the high flow category could not be calculated. The geometric mean was not exceeded within any flow category and equaled 19 cfu/100ml under moist conditions, 26 cfu/100ml for midrange flows, 16 cfu/100ml under dry conditions, and 65 cfu/100ml under low flows.

Public recreational use within this reach occurs at several USFS day use areas, and various undeveloped areas of access along Highway 89A. Several small private developments and resorts are also located within this segment of Oak Creek. Septage from inadequate or failing septic systems may be contributing to water quality exceedances.

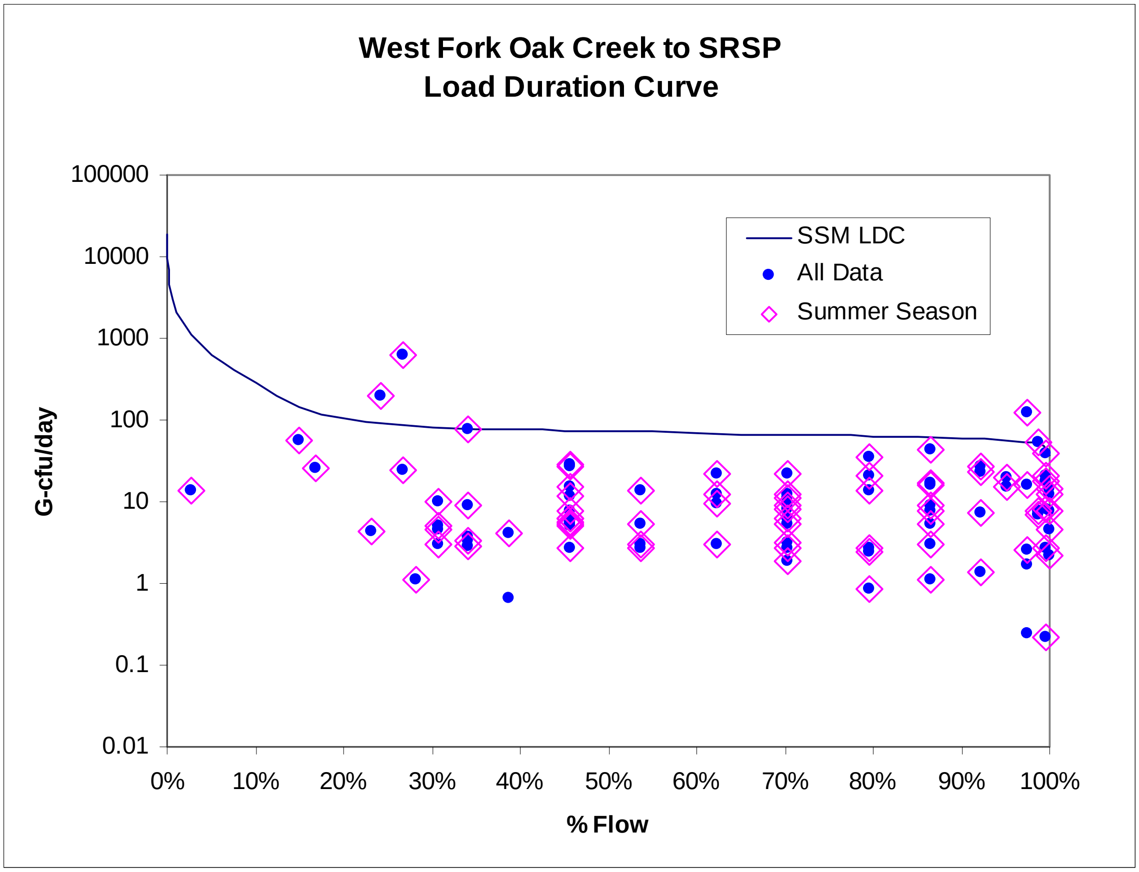


Figure 5. West Fork Oak Creek to SRSP SSM LDC

Table 5. TMDL Summary for West Fork to SRSP

| Flow Regime | Existing Load | TMDL | LA | WLA | NB | MOS | % reduction |
|---|---|---|---|---|---|---|---|
| 0-10% | NA | 628 | | | | | |
| 10-40% | 113 | 89 | 64 | 0 | 16 | 9 | 21 |
| 40-60% | 23 | 71[1] | - | - | - | - | - |
| 60-90% | 22 | 65[1] | - | - | - | - | - |
| 90-100% | 34 | 56[1] | - | - | - | - | - |

1- Existing load meets TMDL

Units are G-cfu/day, unless otherwise noted

### 7.5 Oak Creek- SRSP (15060202-18B)

As previously discussed in Section 4.3.2, a TMDL was completed in 1999 for SRSP. The TMDL called for a 30 percent reduction in mean *E. coli* concentrations during the summer recreational season. A total of 58 exceedances (aggregating all SRSP sample sites within a seven-day period) were measured during the 2006/08 assessment period. The data indicate that the SRSP segment still routinely exceeds the SSM standard. As seen in Figure 6 data collection within the park has been extensive but concentrated within the summer season reflecting the SRSP Surface Water Quality Management Plan.

Table 6 summarizes the TMDL calculations for SRSP based upon the SSM standard. Unlike the upper two Oak Creek segments discussed above, SRSP requires load reductions under low flow and dry conditions in addition to reductions under moist conditions. Percent reductions are approximately 12 percent, 2 percent, and 21 percent, respectively. The existing loads under low flow and dry conditions are approximately double the existing loads calculated for the West Fork to SRSP segment upstream of the park. This appears to indicate the conditions within or immediately upstream of the park are causing the observed exceedances observed within the park. Recreational users may be introducing contaminants themselves or resuspending *E. coli* from stream sediments. The geometric mean was not exceeded under any flow category. Calculated geometric means are 18 cfu/100ml under high flows, 17 cfu/100ml for moist conditions, 20 cfu/100ml for midrange flows, 30 cfu/100ml under dry conditions, and 41 cfu/100ml under low flows.

SRSP accommodates the highest number of recreational visitors within the Oak Creek watershed. Summer holiday weekends are especially busy when the park routinely reaches its parking capacity. Within the 1-mile stretch of the park recreational visitors and their associated activities appear to be the main source of pollution. The adverse recreational affects result from direct (i.e. dirty diapers) and indirect human pollution (i.e. trash left behind drawing wildlife to creeks edge or resuspension of *E. coli* contained in stream sediments).

### 7.6 Oak Creek- SRSP to Dry Creek (15060202-18C)

The 20 mile SRSP to Dry Creek segment was listed as impaired in the 2006/08 305(b) Assessment Report. Aggregated seven-day data resulted in 23 exceedances observed within the assessment period. The majority of exceedances were measured during the summer recreational season as shown in Figure 7.

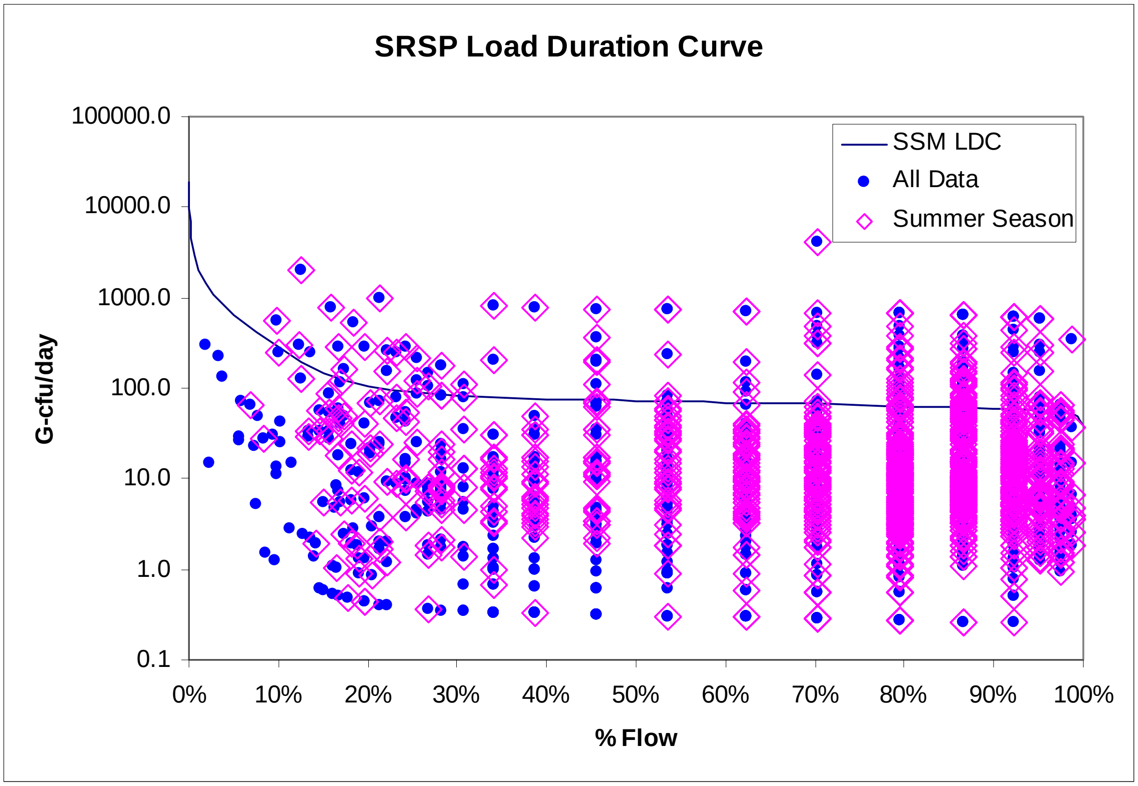


Figure 6. SRSP SSM LDC

Table 6. TMDL Summary SRSP

| Flow Regime | Existing Load | TMDL | LA | WLA | NB | MOS | % reduction |
|---|---|---|---|---|---|---|---|
| 0-10% | 242 | 628[1] | - | - | - | - | - |
| 10-40% | 112 | 89 | 64 | 0 | 16 | 9 | 21 |
| 40-60% | 70 | 71[1] | - | - | - | - | - |
| 60-90% | 66 | 65 | 52 | 0 | 6.5 | 6.5 | 2 |
| 90-100% | 64 | 56 | 45 | 0 | 6 | 6 | 12 |

1- Existing load meets TMDL

Units are G-cfu/day, unless otherwise noted

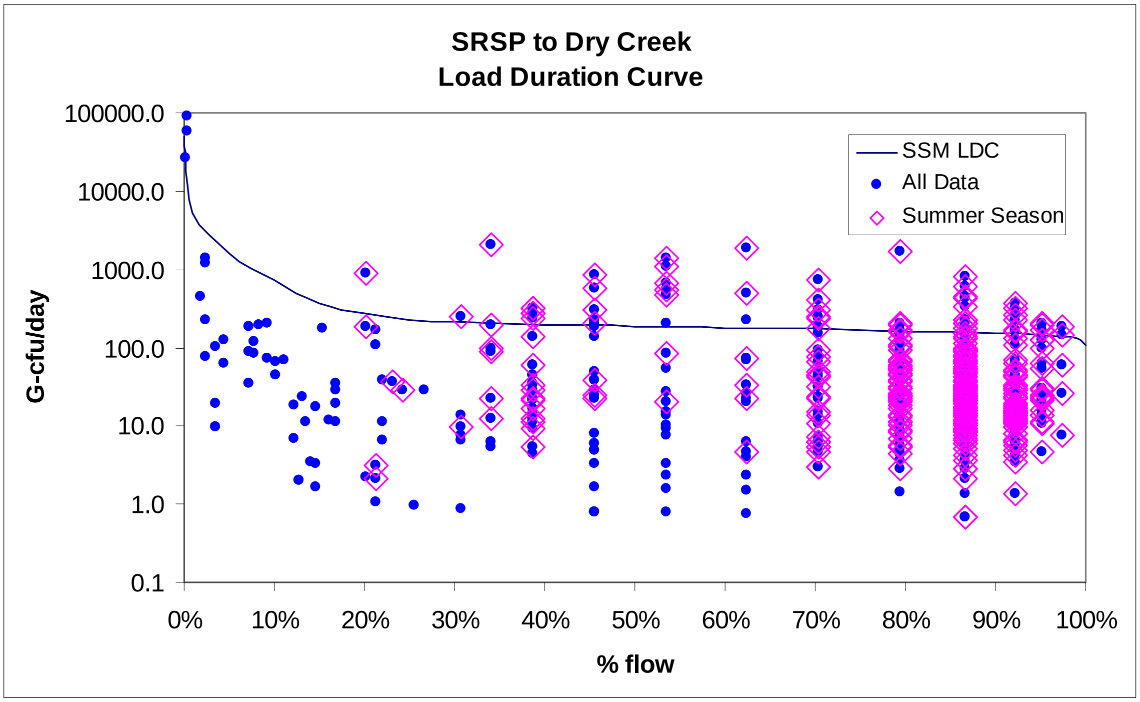


Figure 7. SRSP to Dry Creek SSM LDC

Table 7 summarizes the TMDL calculations, based upon the SSM standard, with load reductions required under all but dry conditions. Reductions equal 93 percent under high flows, 5 percent for moist conditions, 68 percent for midrange flows, and 9 percent under low flow conditions. The WLA includes loads from the Blackman WWTP (4 G-cfu/100ml) and the City of Sedona MS4 permitted discharge. The WLA for the Blackman WWTP is applied to all flow categories. The City of Sedona WLA is equal to 5 percent of the TMDL within the upper three flow categories only. This approach assigns a WLA 84 G-cfu/day for high flows, 12 G-cfu/day under moist conditions and 10 G-cfu/day under midrange flows for the City of Sedona MS4 permit. Geometric means were calculated for each flow category and equaled 26 cfu/100ml for high flows, 21 cfu/100ml under moist conditions, 32 cfu/100ml for midrange flows, 38 cfu/100ml dry conditions, and 38 cfu/100ml under low flow conditions. No exceedances of the geometric mean occurred.

This segment of Oak Creek is very diverse in regards to land use and potential sources of *E. coli*. The upper portion lies within Oak Creek Canyon and contains day use areas, a campground, private residences and commercial businesses.

Recreational pressure is significantly lower than SRSP but still a potential factor. The middle portion includes the City of Sedona, day use recreational areas, private residences along the stream channel, and permitted dischargers. Below the City of Sedona the creek flows through a relatively undeveloped, gently sloping, wide flood plain with little recreational pressure.

### 7.7 Oak Creek- Dry Creek to Spring Creek (15060202-017)

The 10-mile segment of Oak Creek from Dry Creek to Spring Creek was listed as impaired in the 2006/08 305(b) Assessment due to 12 exceedances of the SSM water quality standard. The LDC for this segment (Figure 8) shows that the majority of the exceedances occurred during the summer season although several were observed outside the recreational season.

Table 7. TMDL Summary Slide Rock State Park to Dry Creek

| Flow Regime | Existing Load | TMDL | LA | WLA | NB | MOS | % Reduction |
|---|---|---|---|---|---|---|---|
| 0-10% | 23945 | 1622 | 1080 | 88 | 292 | 162 | 93 |
| 10-40% | 242 | 230 | 150 | 16 | 41 | 23 | 5 |
| 40-60% | 582 | 184 | 118 | 14 | 33 | 18 | 68 |
| 60-90% | 163 | 167[1] | - | - | - | - | - |
| 90-100% | 158 | 144 | 111 | 4 | 14 | 14 | 9 |

1- Existing load meets TMDL

Units are G-cfu/day, unless otherwise noted

Table 8 summarizes the TMDL calculations, based upon the SSM standard, with reductions necessary under all but moist conditions. The calculations include a 0.4 G-cfu/100ml WLA for Sedona Venture applied under all flow categories. Additionally, where applicable, the WLAs from the SRSP to Dry Creek segment (Blackman WWTP and City of Sedona) have been added to the Sedona Venture WLA.  Percent reductions are 25 percent under low flow, 34 percent under dry, 51 percent under midrange, and 94 percent under high flow conditions. The geometric mean *E. coli* value was calculated for each flow category with no exceedances observed. Geometric means equaled 102 cfu/100ml, 24 cfu/100ml, 62 cfu/100ml, 82 cfu/100ml, 25 cfu/100ml ranging from high to low flows.

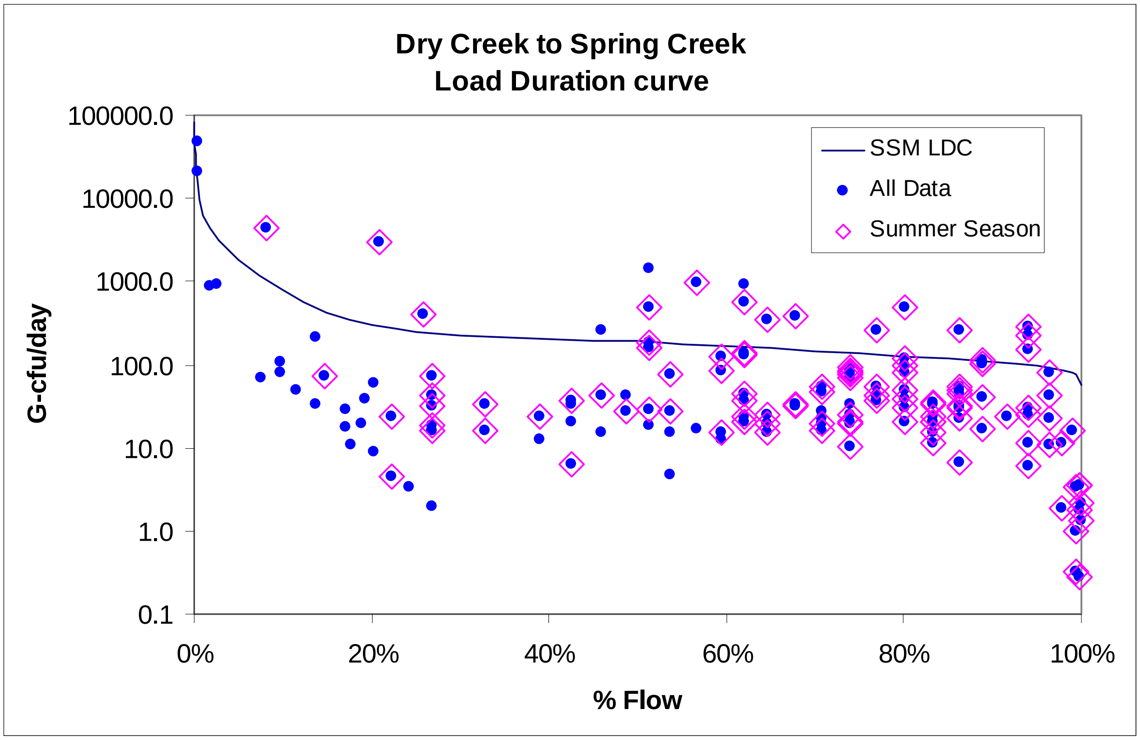


Figure 8. Dry Creek to Spring Creek SSM LDC

The majority of the land within the this portion of the watershed is undeveloped but there are several developed areas which include ranches located along Oak Creek, the service area of the Sedona Venture WWTP along Dry Creek and the area surrounding Page Springs. Excluding Sedona Venture, these areas utilize septic systems.

Table 8. TMDL Summary Dry Creek to Spring Creek

| Flow Regime | Existing Load | TMDL | LA | WLA | NB | MOS | % reduction |
|---|---|---|---|---|---|---|---|
| 0-10% | 29558 | 1794 | 1203.6 | 88.4 | 323 | 179 | 94 |
| 10-40% | 129 | 247[1] | - | - | - | - | - |
| 40-60% | 390 | 190 | 123.6 | 13.4 | 34 | 19 | 51 |
| 60-90% | 208 | 138 | 109.6 | 0.4 | 14 | 14 | 34 |
| 90-100% | 130 | 98 | 73.6 | 4.4 | 10 | 10 | 25 |

1- Existing load meets TMDL

Units are G-cfu/day, unless otherwise noted

### 7.8 Spring Creek- Coffee Creek to Oak Creek (15060202-022)

Spring Creek, a tributary of Oak Creek below Page Springs, was listed in the 2006/08 for nine exceedances of the SSM *E. coli* standard. Unfortunately insufficient stream flow data exists to develop a FDC. However, by analyzing the USGS gage station data near Page Springs (09504500) using Base Flow Recession Coefficient Statistics, the Spring Creek samples were determined to have been collected during dry or wet periods. If the analysis indicated that the flow at the gauge station was elevated it was assumed that Spring Creek was experiencing similar conditions. Once the Spring Creek data was separated into wet and dry categories, the 90$^{th}$ percentile values of each data set were calculated and compared to the 235 cfu/100ml SSM *E. coli* standard. The majority (112 samples or 88 percent) of the samples were determined to have been collected under dry conditions with the 90$^{th}$ percentile value equaling 200 cfu/100ml, therefore attaining the SSM standard. The wet condition (16 samples) 90$^{th}$ percentile value equals 779 cfu/100ml requiring a 70 percent reduction to meet the SSM standard. The TMDL for Spring Creek is summarized in Table 9. The TMDL is based on a concentration rather than a load basis due to the fact that a LDC could not be constructed. The geometric mean was calculated for each group of data, 44 cfu/100ml for dry and 69 cfu/100ml under wet conditions, indicating the standard is being attained.

Table 9. TMDL Summary Spring Creek

| Condition | Existing (cfu/100ml) | TMDL (cfu/100ml) | LA | WLA | NB | MOS | % reduction |
|---|---|---|---|---|---|---|---|
| Dry | 200 | 235[1] | - | - | - | - | - |
| Wet | 779 | 235 | 169 | 0 | 42 | 24 | 70 |

1- Existing load meets TMDL

The Spring Creek watershed is largely undeveloped containing a few small ranches. Recreational use is limited but road crossings provide opportune areas for people to enter the water. Since elevated flows require load reductions, additional information regarding land use and riparian health is needed to determine the source of *E. coli*.

## 8.0 TMDL Implementation

A.R.S 49-234, paragraphs G, H, & J requires TMDL implementation plans (TIPS) to be written for those navigable waters listed as impaired and for which a TMDL has been completed pursuant to Section 303(d) of the Clean Water Act. Implementation plans provide a strategy that explains “how the allocations in the TMDL and any reductions in existing pollutant loadings will be achieved and the time frame in which compliance with applicable surface quality standards is expected to be achieved.” Due to the nonpoint source nature of pollutants within Oak Creek, implementation of a TIP is voluntary and relies upon active stakeholders to implement projects necessary to achieve load reductions.

In 2009 the OCWC, formerly the Oak Creek Canyon Task Force, a local watershed improvement group, was awarded a Water Quality Improvement Grant by ADEQ totaling $311,000. The main goal of the grant is to develop a locally driven WIP. Several improvement projects have been implemented over the years to improve the water quality in Oak Creek but the effectiveness and necessity of these projects has been questioned as water quality exceedances are still occurring. Development of the WIP will include watershed and social surveys aimed at locating and prioritizing future water quality improvement projects. The document will act as a blueprint for improving water quality in Oak Creek. Given the level of detail and planning that the WIP will require, a detailed TIP will not be produced by ADEQ. Discussed below are some of the Best Management Practices (BMPs) suggested by various stakeholders within the watershed. These will be explored and expanded upon through the WIP development process.

The majority of the water quality exceedances occur during the high recreational use season (May to September). But recreational users are not the only source of contamination to the creek. Wildlife, domesticated animals, septic systems, and WWTP contributions must be considered. Stormwater and spring melt runoff wash in contaminants from the watershed and can result in water quality exceedances. The recreational opportunities within the canyon are wide ranging, from unimproved creekside access points to USFS managed campgrounds. The mere presence of people within the stream may lead to water quality issues but the trash and debris left behind can draw animals to the waters edge also.

Suggested BMPs have included:

- Limiting access to unimproved access points;
- Limit the number of visitors to the canyon itself;
- Provide better access to restroom facilities;
- Provide more trash receptacles for visitors to use;
- Limit domesticated animals water access;
- Provide disposal containers for dog waste;
- Children who are not potty trained are required to wear swim pants;
- Limit or regulate what can be brought to the waters edge;
- Ensure septic systems along the creek are functioning properly;
- Reduce sediment entering the stream during storm events;
- Increase public awareness of water quality and the risks associated with fecal pollution;
- Implement deferred or prescribed grazing methods in upper watershed;

All of these BMPs require land managers, property owners and stakeholder support if they are to be successful.

The OCWC is also continuing focused sampling around suspected failing or inadequate septic systems and other potential source areas. Additionally, they are working with the University of Arizona on the collection and analysis of samples to be used for bacteria source tracking to confirm and expand upon the findings of the NAU genotyping project.

## 9.0 PUBLIC PARTICIPATION

Stakeholder and public participation for the Oak Creek and Spring Creek *E. coli* TMDL has been encouraged and received throughout the development of the TMDL. ADEQ has extended opportunities for input from the watershed groups, local residents, governmental agencies, and other interested parties related to their opinions and suggestions regarding the TMDL study and findings, current and future implementation plans, data collection, and the level of involvement that they might contribute to the decision making process. ADEQ staff coordinated and communicated with the OCWC, State Parks and USFS staff on a regular basis as the TMDL was developed by attending watershed group meetings, providing training, and sharing sample results.

A 30-day public comment period was held June 23-July 23, 2010. A public notice was published in the *Red Rock News*, the local Sedona newspaper, on June 23 notifying local residents of the start of the public comment period. Additional notices were sent via email and posted on the ADEQ website. The draft report was made available via the internet and by mail, if requested. Comments were received from the USEPA Region 9, the City of Sedona, and a local resident. The TMDL allocations and summary responses to public comments were submitted to the Arizona Secretary of State's office on August 26 for publication the Arizona Administrative Register for a 45-day Notice of Public Information.

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