ADEQ
Arizona Department of Environmental Quality

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Little Colorado River

Silver Creek to Carr Lake Draw
Reach # 15020002-004

Escherichia coli TMDL

Little Colorado River Watershed
Apache and Navajo Counties, Arizona

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LIST OF ABBREVIATIONS

A.A.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AgI	Agricultural-Irrigation
AgL	Agricultural-Livestock watering
APP	Aquifer Protection Permit
A.R.S.	Arizona Revised Statutes
AUM	Animal Unit Month
AZPDES	Arizona Pollution Discharge Elimination System
A-S NF	Apache-Sitgreaves National Forests
A&Wc	Aquatic and Wildlife-cold water
A&Ww	Aquatic and Wildlife-warm water
BFRC	Base flow recession coefficient
BLM	Bureau of Land Management
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
cfs	cubic feet per second
CWA	Clean Water Act
DWS	Domestic Water Source
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
FC	Fish consumption
FBC	Full Body Contact
G-org	Giga (billion)–organisms
GIS	Geographic Information System
GNIS	Geographic Names Information System
LA	Load Allocation
LCR	Little Colorado River
LN	Natural logarithm
mg/l	milligrams per liter
mgd	million gallons per day
mi.	miles
MOS	Margin of Safety
NB	Natural background
NEMO	Nonpoint Source Education for Municipal Officials
NEPA	National Environmental Policy Act
NM	New Mexico
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
TMDL	Total Maximum Daily Load
U.S.	United States
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
WLA	Waste Load Allocation
WRCC	Western Regional Climate Center
WWTP	Wastewater Treatment Plant

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1.0 EXECUTIVE SUMMARY

The Arizona Department of Environmental Quality (ADEQ) 2004 Clean Water Act (CWA) 303[d] List classified the Little Colorado River (LCR) (Reach #15020002-004: from Silver Creek to Carr Lake Draw) as impaired for the Full Body Contact (FBC) designated uses due to *Escherichia coli* (*E. coli*) exceedances (two exceedances in nine assessed events). The 2006/2008 Assessment classified the reach as remaining impaired for *E. coli* with one of seven events exceeding the single sample maximum (SSM) in the previous three years and three exceedances in the five-year assessment window. Impairment listings result in a total maximum daily load (TMDL) study and report detailing how the impaired waterbody may be brought into attainment of state water quality standards through identification of nonpoint source areas, critical conditions, and percent reductions necessary.

Sampling commenced in 2007 for this TMDL project. Sampling sites were located to take advantage of the presence of a USGS gauge on the LCR in the community of Woodruff and to isolate contributions from the two major subwatersheds feeding the LCR main-stem in the Woodruff vicinity. Seasonality was addressed through sampling at baseflow, spring runoff and storms. All sampling was done via grab sampling methods. TMDL sampling included a minimum of two baseflow, four storm, and one spring melt events. Water samples were analyzed for *E. coli* using the Colilert-18 method. Samples were processed within six hours of collection and read within 18-22 hours after processing. Where necessary, dilution of samples taken in turbid or stormflow conditions was used to quantify bacterial concentrations. Dilutions at 1:10 and 1:100 were typically used with the Colilert-18 method. Historic data employed in the TMDL analysis generally employed the mTEC plate count method.

Load duration curves were used for modeling *E. coli* loads and calculating the TMDL target values for Reach 15020002-004. The load duration curve approach was chosen for its flexibility, its capacity to identify and address flow-dependent conditions, and the ability to classify and analyze various data points individually in accordance with the requirements of Arizona's water quality standard for *E. coli*. Long-term USGS streamflow gauges in the watershed permitted an in-depth examination of flow history.

Data collected throughout the TMDL project cycle in all hydrologic flow regimes confirms that the great majority of loads exceeding the stream's assimilation capacity occur when the LCR is adding loads to the near-perennial Silver Creek. In mid-range, dry and low-flow conditions, when flow persists in the impaired reach due to the flow of Silver Creek alone, exceedances rarely occur. Storm conditions causing the LCR to flow contribute a sizable increase in both the percentage of exceedances and the density counts of *E. coli* samples in those exceedances. Silver Creek contributes to those exceedances, but LCR inputs add an order or magnitude or more to the loads measured at the Woodruff site in the upper two flow classes. Flow of the LCR above the Silver Creek confluence due to precipitation events constitutes a major critical condition identified for subsequent analysis.

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In nonstorm flow conditions, when overland flow is not occurring and the intermittent reaches of the LCR are not contributing inputs, Silver Creek is already meeting TMDL targets. No existing category load exceeded its TMDL load allocation in the two upper flow classes in which data is presented (Table 12). Though results must be considered provisional due to limited numbers of samples within each class to make definitive assertions, the high flow and moist conditions categories both met their targets under nonstorm flow conditions. Analysis was not extended into flow classes where Woodruff data shows the impaired reach is already meeting TMDL targets.

The picture changes when consideration turns to stormflows and the addition of LCR inputs. The cumulative reduction percentages outlined in Table 11 show that very high levels of existing loads have historically shown up at the Woodruff site for flows exceeding the 40th percentile flow value. While detailed source identification was not performed on data between 1993 and 2007, examination of the limited datasets for identified stormflows of both Silver Creek and the LCR show that both are contributing to class load exceedances when overland flow is occurring. For the LCR at Woodruff, load reductions of 98.9 percent (existing load 128,169 G-org/day, TMDL-MOS target value 1189 G-org/day) and 97.8 percent (existing load 5006 G-org/day, TMDL-MOS target value 96 G-org/day) for the 90th percentile values are required for the upper two flow classes respectively to attain their target values. These load reductions translate into a two orders of magnitude reduction and 1.72 order of magnitude reduction respectively. The mid-range, dry conditions, and low flow classes for flows below 9.0 cfs are meeting TMDL targets. When considering the data from each subwatershed individually in stormflow conditions, the LCR above Silver Creek shows a need for a 98.8 percent reduction in the high flow category and a 99.8 percent reduction in the moist conditions category, while Silver Creek shows a need for reductions of 98 percent in the high flow category and more moderate reductions of 55.8 percent in the moist conditions flow class based upon a limited dataset.

In summary, loads are exceeding the system's assimilation capacity when stormflow dominates the hydrologic flow regime and overland flow is occurring. Loading is greatly exacerbated by contributions from the LCR subwatershed above the Silver Creek confluence during stormflow events. Load duration analysis suggests that point sources are not an issue for the impairment, as the low flow categories show no problems. Rather, a mix of bank contributions, upland overland flows, storm water from impervious developed areas, and riparian zone/floodplain contributions are the likely stressors in descending order of significance.

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2.0 INTRODUCTION

The Arizona Department of Environmental Quality (ADEQ) 2004 Clean Water Act (CWA) 303[d] List classified the LCR (HUC #15020002-004: from Silver Creek to Carr Lake Draw) as impaired for the Full Body Contact (FBC) designated uses due to *Escherichia coli* (*E. coli*) exceedances (two exceedances in nine assessed events). The 2006/2008 Assessment classified the reach as remaining impaired for *E. coli* with one of seven events exceeding the single sample maximum (SSM) in the previous three years and three exceedances in the five year assessment window. The TMDL study resulting from these assessments was begun in 2007, with this report being drafted as a consequence.

3.0 BACKGROUND INFORMATION

3.1 Water Quality Standards

Surface water quality standards for a stream reach are based upon the designated uses assigned to it according to the Arizona Administrative Code Title 18, Chapter 11 Article 1 (18 A.A.C. 11-1). This project addresses the segment of the LCR from Silver Creek to Carr Lake Draw [15020002-004] identified as impaired on the 2004 303[d] list. Table 1 lists the segment, HUC number, and related designated uses.

Segment Description	HUC Number	Designated Uses
Silver Creek to Carr Lake Draw	15020002-004	Aquatic and Wildlife Cold, Fish Consumption, Full Body Contact, Domestic Water Source, Agriculture-Irrigation, Agriculture - Livestock Watering

Table 1. Segment of the LCR with HUC number and designated uses

The segment includes approximately six miles of the LCR from Silver Creek to Carr Lake Draw [15020002-004] listed as impaired for FBC designated uses due to *E. coli* exceedances. “Carr Lake Draw,” the GNIS name appearing on USGS 7.5’ quadrangles, has been variously referred to as “Carr Wash” and “Carr L Wash” in previous ADEQ publications including the 2004 and 2006/2008 Water Quality Assessments. The tributary will be referred to as “Carr Lake Draw” in this TMDL document in keeping with its officially registered name.

Historical listing data for the segment are provided in Appendix A.

The applicable *E. coli* standard is 126 cfu/100 ml for a four-sample minimum geometric mean and 235 cfu/100 ml for a single sample maximum. 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/100 ml. The standards for *E. coli* were originally 130 and 580 cfu/100 ml, respectively for the FBC use, until they were lowered to their current values in 2003. No data for listing and no data gathered during the TMDL investigation qualified for evaluation under the geomean clause of the standard. The reach has been listed as impaired based solely on exceedances of the single sample maximum. As a consequence, this TMDL is drafted only for single sample maximum attainments.

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3.2 Physiographic Setting

The LCR is located in Apache and Navajo counties in northeastern Arizona (Figure 1). The headwaters originate in the White Mountains along the northern and eastern slopes of Mt. Baldy. It flows to the northwest leaving the basin near Cameron, Ariz. and joining the Colorado River in the Grand Canyon. The LCR basin has a drainage area of approximately 26,459 square miles upstream from the United States Geological Survey (USGS) gauging station near Cameron (09402000), which is 42 miles upstream from its confluence with the Colorado River.

Elevations in the LCR-San Juan Basin vary from 12,600 feet at Humphreys Peak, near Flagstaff, to 4,200 feet, where the LCR flows out of the basin near Cameron (ADWR, 2006). Within the study areas, elevations range from 5,180 feet near the confluence with Silver Creek to over 9000 feet in the White Mountains. Most of the study area consists of desert highland flora and fauna, with coldwater aquatic communities in the upper reaches of Silver Creek and the LCR where perennial waters exist.

LCR basin land ownership within Arizona is divided between tribal (60 percent), private (15 percent) federal (20 percent) and state (5 percent) (Figure 2). Land use is primarily open grazing, forestry, and recreation. The largest towns in the region according to the 2010 U.S. Census are Holbrook (pop. 5,053) and Winslow (pop. 9,655).

3.3 Climatic Setting

Warm summers and mild winters characterize the general climate of the LCR. Average high temperatures range from the mid 70s to 80s with the highest temperatures starting in late June and continuing through early September. Average precipitation in the basin ranges from 8 to 12 inches (WRCC, 2003). Much of the rainfall in the basin occurs in June to September as a result of high intensity, short duration storms associated with the summer monsoon season. The basin picks up additional precipitation during the winter months from rain and snow storms.

3.4 Hydrology

Streamflow in the LCR generally is perennial upstream of Woodruff along the Silver Creek stream network and intermittent along the LCR stream network above the Silver Creek confluence. Major tributaries above the impaired reach include Silver Creek, Brown Creek, Zuni Creek and Carrizo Creek. Silver Creek is characterized by perennial flow; all other tributaries and the main stem LCR above Silver Creek flow only intermittently. Peak flows in the basin occur between March and April from snowmelt and from July to August from monsoon rainfall.

The mix of essentially perennial waters and intermittent / ephemeral waters, with a large percentage of the watershed drained by the ephemeral waters, and the spatial segregation and interruption of hydrologic continuity at Lyman Lake Dam in the upper portions of the ephemeral regions carries implications for TMDL development. Sizable proportions of stream loading occur as a result of monsoon storms and prolonged winter storms causing intermittent water courses to flow and surface water quality standards for *E. coli* to be exceeded.

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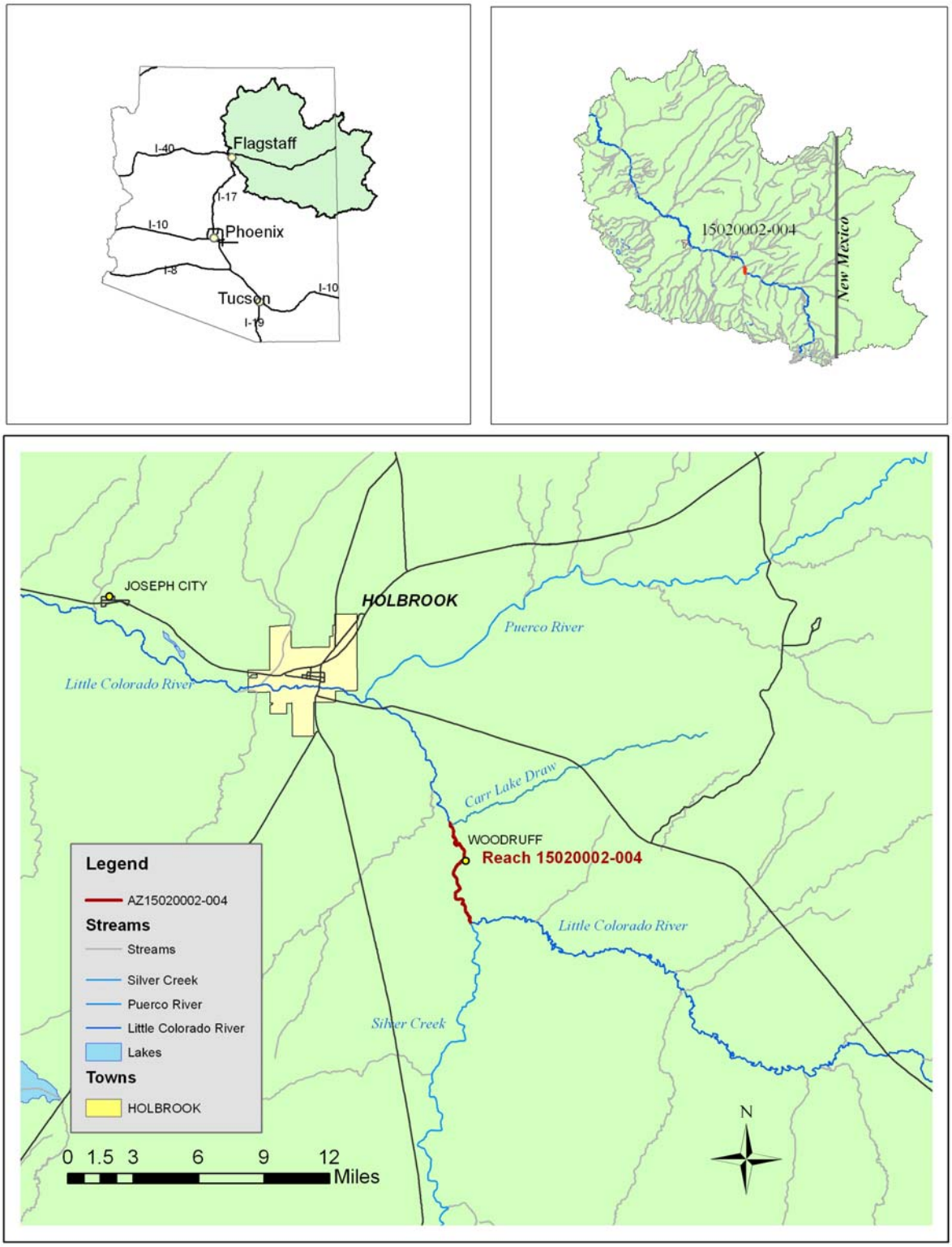

Figure 1. LCR Reach 15020002-004 Location Map

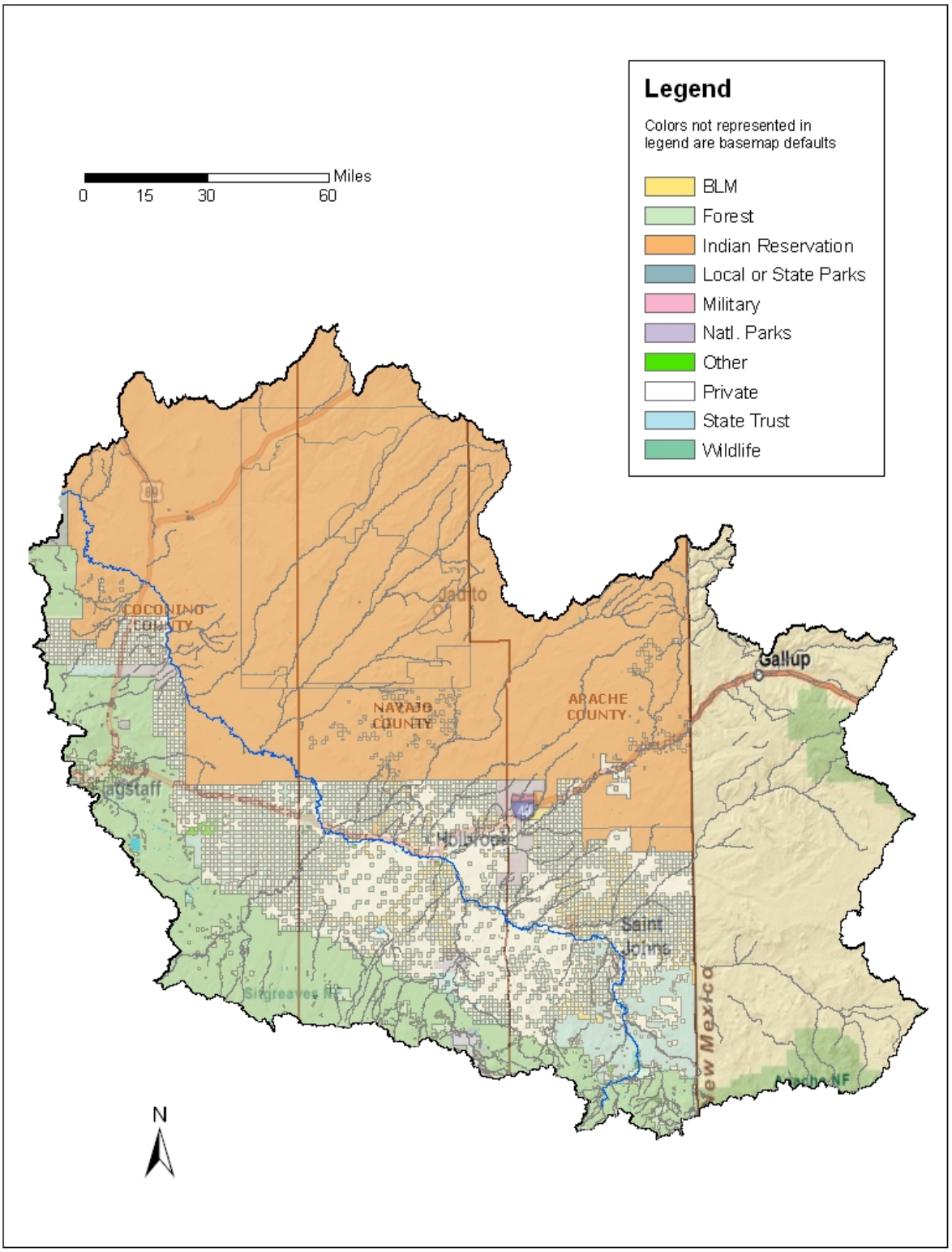

Figure 2. Land Ownership, LCR Basin

3.5 Geology and Soils

Below much of the study area are Triassic sandstone and mudstone deposits with traces of Pliocene to Mid-Miocene conglomerates and sandstones (Kamilli and Richards, 1998). The LCR and Puerco River channels are cut into older alluvium that fills valleys eroded in the Quaternary Period (Leopold and Snyder, 1951; Mann and Nemecek, 1983). The valley fill varies in thickness from zero to about 148 feet and in width from about 328 feet to about 3.7 miles (Mann and Nemecek, 1983). The headwaters of the LCR originate near Springerville in the White Mountains, and the river flows north through Quaternary and Upper Tertiary volcanic rock.

The LCR Basin is home to the Painted Desert and Petrified Forest National Park which are in the general region of the impaired reach. The landforms comprising these scenic wonders consist of badlands, buttes, and mesas in colorful arrays similar to the Grand Canyon region to the northwest. As such, these formations and landforms are largely exposed soils. Soils in the LCR Basin are highly erosive and fine-grained, with weighted erosivity values in the evaluated subwatersheds of 0.18 to 0.23 (Erosivity [K] values range from 0 to 0.72 based on a unit plot tested by the NRCS/SCS). When evaluated by 12 digit HUCs within the study area boundary, the maximum average K value rises to 0.33 (The areal average K value limit for 12 digit HUCs in Arizona is 0.44). RUSLE model results show percentages of fine-grained sediments (< 2 mm) ranging from 39 to 58 percent in the study area subwatersheds.

The high erosivity of the landscape in the study area has implications for *E. coli* loading. Previous work with *E. coli* by the ADEQ TMDL Unit has determined a strong correlation between sediment loads in stream discharge and high densities of *E. coli* in the water column. Primarily, this correlation can be attributed to the main mechanism of loading on southwestern landscapes with limited ground cover, i.e. overland flow in short and flashy pulses due to storms that wash both sediment and organic waste into watercourses. Under certain conditions, sediment reservoirs of the pathogen within the channels can also be significant contributors to impairment.

3.6 Land Cover and Vegetation

Land cover distribution in the LCR basin reflects its status as a largely rural watershed with arid climate characteristics. The range of biomes is characterized by desert scrub in the lower elevations with conifer forests comprising the higher elevations adjacent to the Mogollon Rim. Pinyon-juniper woodland communities occupy an intermediate habitat between the two. Table 2 tabulates the percentages of land cover based on the National Land Cover Dataset of 1992.

The two primary mapped vegetative communities within the LCR watershed above Woodruff are the Plains and Great Basin Grassland (41 percent of watershed area), and Great Basin Conifer Woodland (29 percent) (Figure 3). However, field reconnaissance suggests that portions of mapped units of grasslands are now more accurately characterized as desert scrub. Where grasslands exist, the grasses tend to be thinly vegetated bunch grasses, unlike the carpet grasses found in southern Arizona. The sparseness of the grasses and the arid climatic regime limiting any improvement in grassland health carries implications for heavier erosive potentials with secondary *E. coli* loading during storm events with overland flow. Literature suggests historic grazing practices contributed to the degradation of the health of LCR grasslands (Abruzzi, 1995).

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Land Cover	Area, sq, km	Percent Cover
Shrubland	11,257.54	51.32%
Evergreen Forest	8,454.99	38.55%
Grasslands/Herbaceous	1,900.68	8.67%
Bare Rock/Sand/Clay	111.11	0.51%
Pasture/hay	69.83	0.32%
Open Water	35.56	0.16%
Mixed Forest	23.92	0.11%
Commercial/Industrial	19.67	0.09%
Small Grains	17.63	0.08%
Low Intensity Residential	14.98	0.07%
Quarries/Strip Mines/ Gravel Pits	11.30	0.05%
Row Crops	5.87	0.03%
Emergent Herbaceous Wetlands	4.35	0.02%
Urban/Recreational Grasses	3.40	0.02%
Woody Wetlands	2.77	0.01%
Orchards/Vineyards/Others	0.51	<0.01%
Deciduous Forest	0.19	<0.01%

Table 2. Percentages Land Cover, LCR Basin

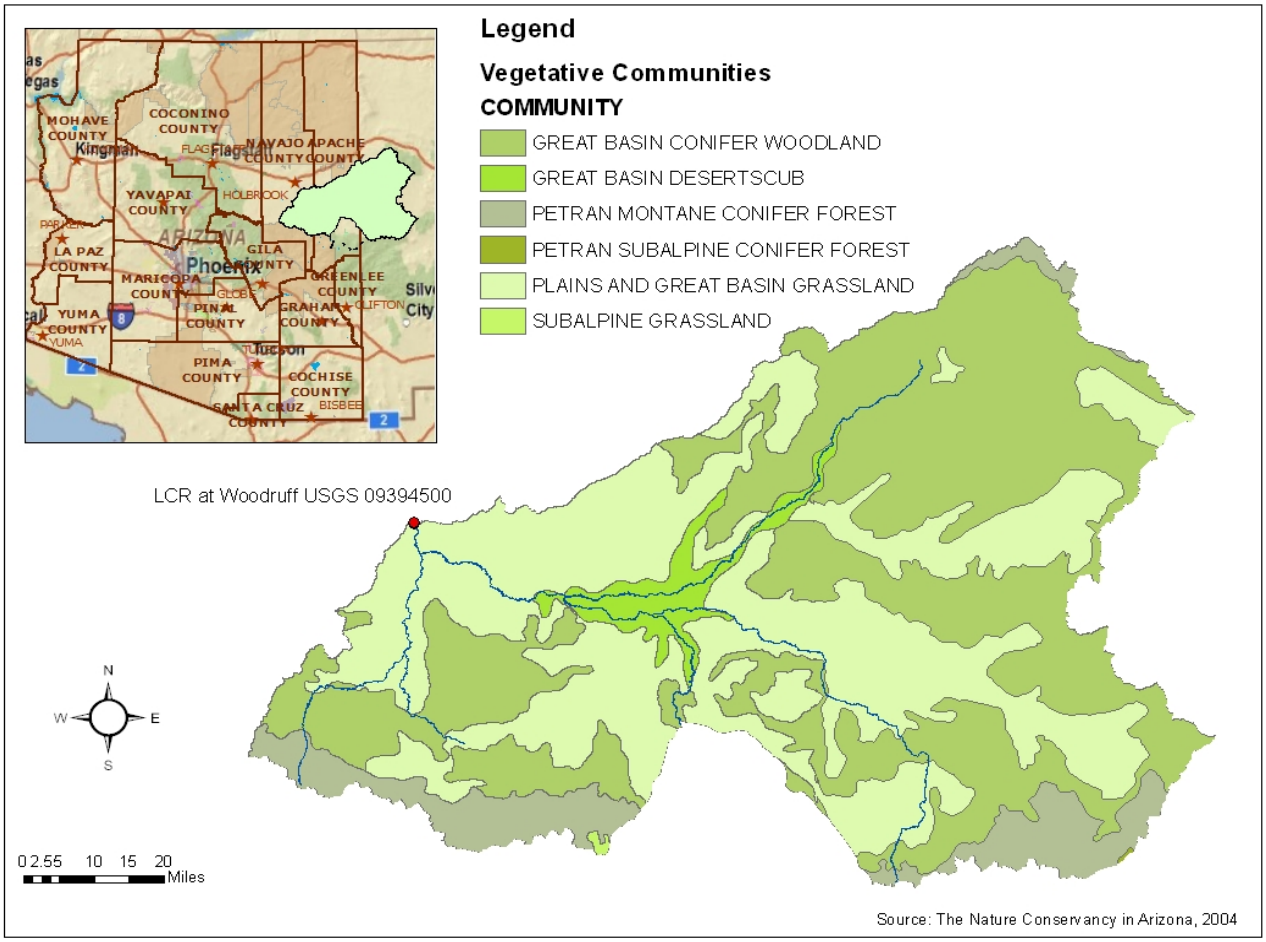

Figure 3. Southwestern Biotic Communities in the LCR Basin

4.0 EXISTING DATA SOURCES

4.1 Existing Water Quality Data and Limitations

Water quality data has been collected from sites within the study area since 1954 by the United States Geologic Survey (USGS). Additional sampling has occurred since 1993 by ADEQ. Analytical parameters have included metals, bacteria, nutrients, radiochemicals, inorganics, and suspended sediments.

4.2 Existing Discharge Data

The USGS currently maintains an active real-time gauging station within the study area. A gauge on the Woodruff Road Bridge at Woodruff (USGS Site #09394500) provides real time discharge, stage and precipitation data. It also includes historic discharge from 1906 with a continuous record starting in 1935. Some water quality data is also available for this site.

Additional gauges in the area include a gauge on Silver Creek near the confluence with the LCR (09394000), which collected discharge measurements from 1929 to 1952 before its use was discontinued. There are three additional historic gauges on Silver Creek upstream of the study area, including a gauge near Shumway, Ariz. (09390000) that includes discharge data from November 1944 to June 1955, a gauge at Snowflake, Ariz. (09393000) that includes discharge data from May 1906 to December 1906, and a second gauge below Snowflake (09393500) that includes discharge from December 1919 to February 1995 and analytical data from May 1971 to May 1974.

Several active gauges cluster on the LCR around St. Johns, Ariz. approximately 60-70 miles upstream of the LCR-Silver Creek confluence, including USGS 09386300, 09386030, 09386250, and 09385700, all of which are below Lyman Lake. These gauges are of limited utility due to the intermittent nature of the LCR below St. Johns.

4.3 Existing Precipitation Data

In addition to the precipitation data collected by the USGS, data is also available from five National Weather Service (NWS) gauging stations near the study area (Table 3) (WRCC, 2003).

Station Name	Co-op ID	Period of Record[1]
Holbrook	024089	01/01/1893-12/30/2005
Petrified Forest National Park	026468	07/01/1948-12/31/2005
Winslow	029439	10/01/1898-12/31/2005
Snowflake	028012	06/01/1897-12/31/2005
Snowflake 15W[2]	028018	05/01/1965-02/28/1998

Table 3. National Weather Service Stations in the LCR Basin

1 – Period of Record includes historical data for each station, current conditions and observations are available at http://www.wrcc.dri.edu/currentobs.html
2 – Station is no longer active.

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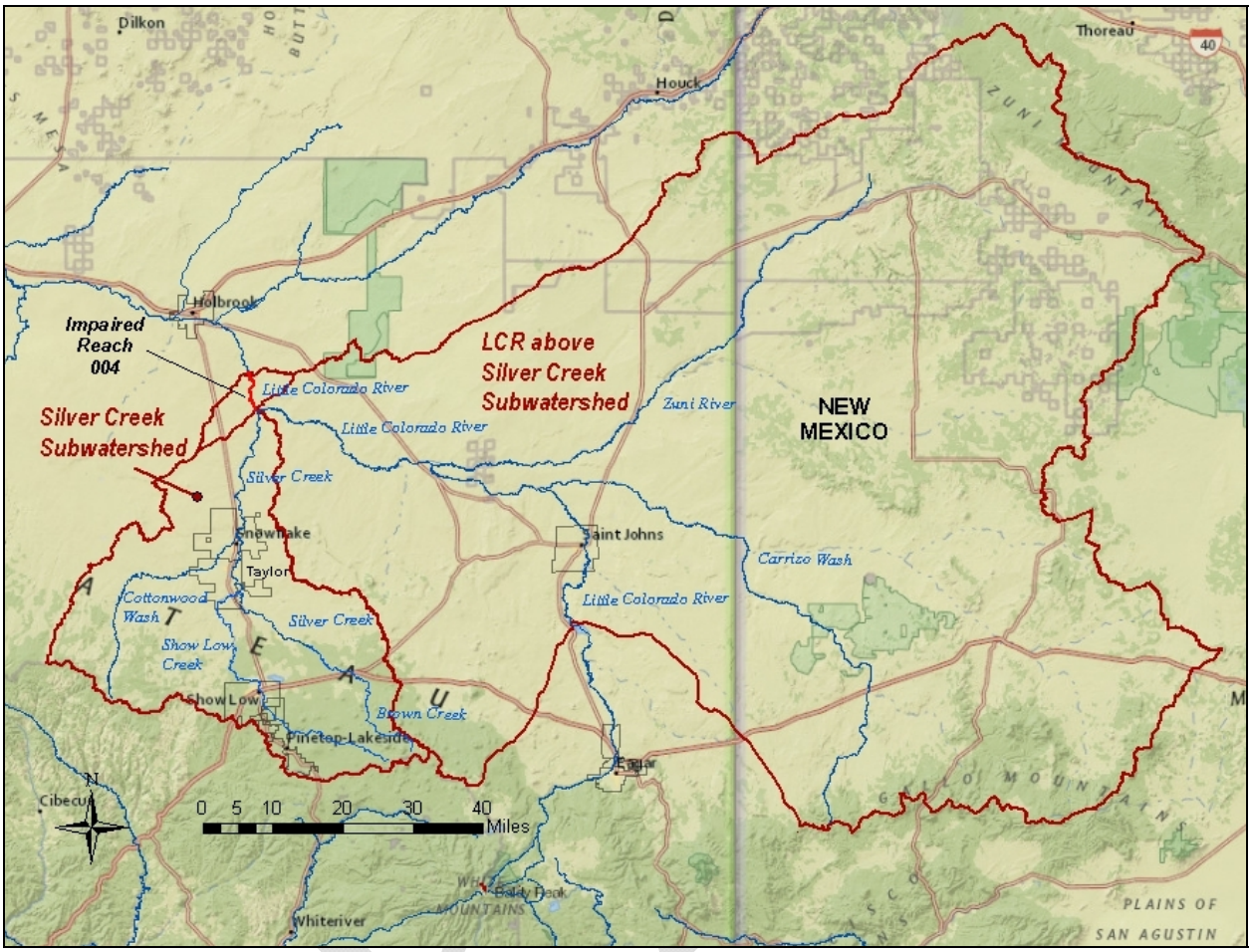

Figure 4. Subwatersheds of TMDL analysis

5.0 SOURCE ASSESSMENT

The subwatersheds for analysis addressed in this TMDL are shown in Figure 4. As mentioned in Section 6.2, the portion of the LCR watershed above a dam at the Lyman Lake Reservoir is excluded from the analysis. Discussion of the following point sources and nonpoint sources is developed from facilities and land use activities occurring within the watershed boundary.

5.1 Summary of Point Sources

5.1.1 AZPDES and NPDES Permits

The Town of Snowflake Wastewater Treatment Plant (WWTP) (Figure 5) in southern Navajo County formerly held AZPDES permit AZ0024287 allowing discharge to Silver Creek above Reach 15020002-004. The permit set a monthly concentration limit for effluent of 126 cfu/100ml and a daily maximum of 235 cfu/100 ml for *E. coli*. No mass limits were given in the terms of the permit. The monthly concentration limit was expressed as a geometric mean with a four-

sample minimum. The plant discharged through Outfall 001 to an unnamed dry wash, tributary to Cottonwood Wash, then tributary to Silver Creek. Monitoring was required four times per month, and sampling is by discrete grab samples. Permit AZ0024287 was allowed to expire in 2009, and a new permit (AZ0026034) is in the process of being drafted as of late 2011. Permit terms for effluent are expected to be the same, but a new outfall discharging directly to Cottonwood Wash is to be constructed. The design capacity of the plant will remain unchanged at 0.6 MGD (equivalent to a steady discharge of 0.93 cfs).

The AZPDES permit for the Pinetop-Lakeside WWTP, also in Navajo County (AZ0025437) sets a monthly concentration limit for effluent of 126 cfu/100ml and a daily maximum of 576 cfu/100 ml for *E. coli*. No mass limits are given in the terms of the permit. The monthly concentration limit is expressed as a geometric mean with a four-sample minimum. The plant discharges through Outfall 001 to an unnamed wash. The higher daily maximum is attributable to the nature of the receiving water as an effluent-dependent water with the Partial Body Contact designated use applied. As with Snowflake, monitoring is required four times per month, and sampling is by discrete grab samples. The design capacity of the plant is 2 MGD (equivalent to a steady discharge of 3.095 cfs).

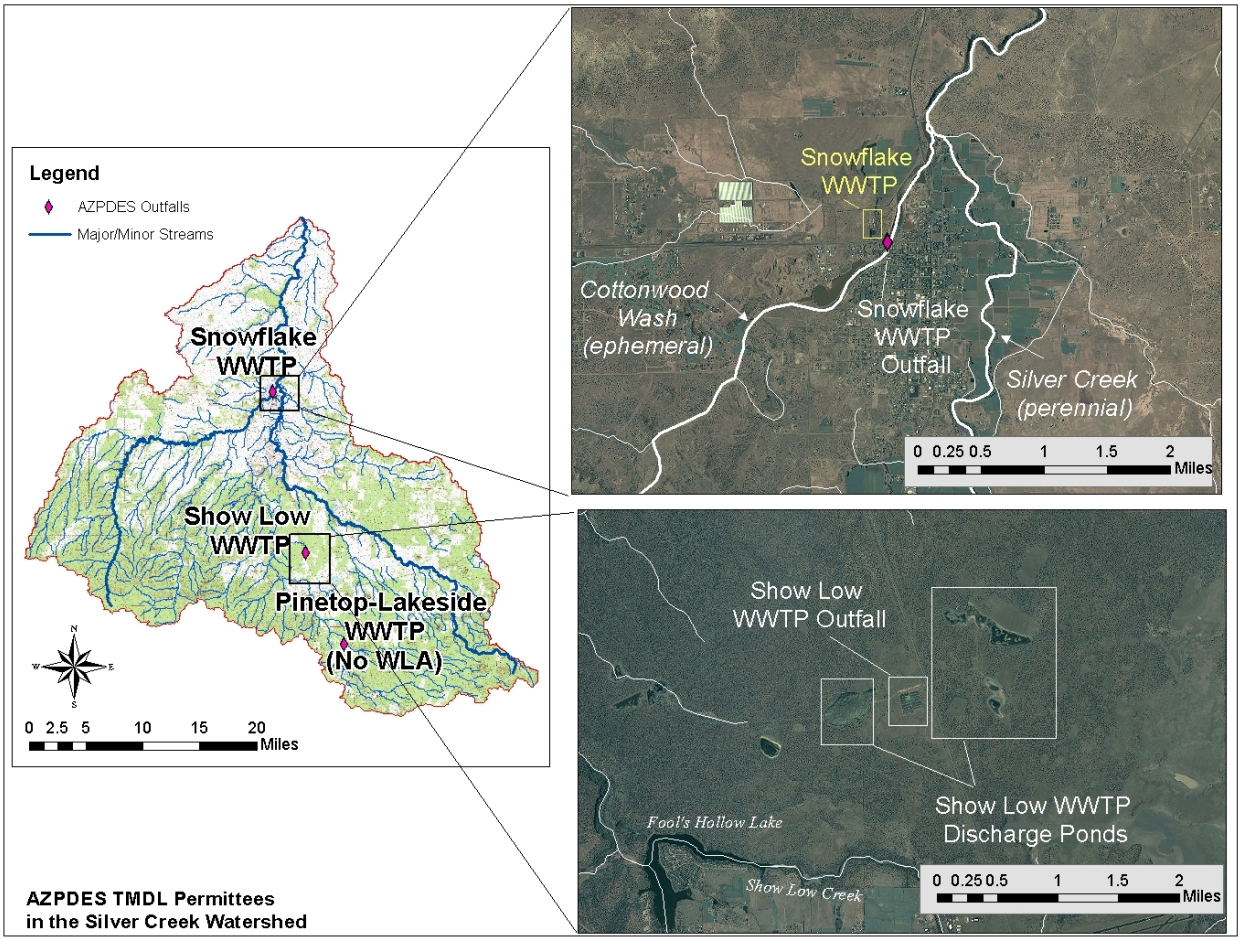

Figure 5. Locations of AZPDES individual permittees in the Silver Creek watershed

Following suit, the AZPDES permit for the Show Low Municipal WWTP (AZ0023841) sets a monthly concentration limit for effluent of 126 cfu/100ml and a daily maximum of 576 cfu/100 ml for *E. coli*. No mass limits are given in the terms of the permit. The monthly concentration limit is expressed as a geometric mean with a four-sample minimum. The plant discharges through Outfall 001 to Show Low Creek. As with the Pinetop-Lakeside WWTP, the higher daily maximum is attributable to the nature of the receiving water as an effluent-dependent water with the Partial Body Contact designated use applied. As with Snowflake and Pinetop, monitoring is required four times per month, and sampling is by discrete grab samples. The design capacity of the plant is 1.42 MGD (equivalent to a steady discharge of 2.197 cfs).

Reviews of discharge monitoring reports for the previous three years for each of the facilities addressed above showed only a single *E. coli* measurement of 10 cfu/100 ml for one facility. All other reports for the previous three years indicated either no discharges occurred or no *E. coli* colonies were detected in effluent. All three plants also hold aquifer protection permits (APPs) and generally opt to dispose of most of their effluent through reclamation and re-use whenever possible. See Section 5.1.3 for further discussion.

There are no other individual AZPDES permits discharges where *E. coli* is a constituent of concern in Navajo or Apache counties above the LCR – Carr Lake Draw confluence apart from the ones discussed in this section, and no Superfund sites within the delineated watershed in Arizona.

The Arizona Department of Transportation (ADOT) has state-wide Municipal Separate Storm Sewer System (MS4) permit coverage as a Medium-to-Large municipal operation for its facilities and infrastructure. ADOT operates its stormwater program under a separate individual permit (AZS000018-2008) and program known as the Statewide Stormwater Management Plan (SSWMP). Arizona has several state highways that transit the TMDL watershed, including Highways 77, 277, 260, 180, and 61. ADOT's SSWMP states:

ADOT is considered a large MS4 by virtue of ADOT-owned conveyances or systems of conveyances used for collecting and conveying stormwater. These include drainage systems, catch basins, curbs, gutters, ditches, man-made channels or storm drains associated with roads and highways constructed, maintained, or operated by ADOT. The Arizona Department of Environmental Quality (ADEQ) determined ADOT is required to meet the Phase II MS4 community requirements in addition to the Phase I requirements.
…
ADOT's current AZPDES Permit was issued on September 19, 2008 by ADEQ. This Permit replaces the original National Pollutant Discharge Elimination System (NPDES) Permit issued by USEPA on September 30, 1999. The scope of the current Permit includes all stormwater discharges associated with construction sites, industrial facilities, and MS4s under ADOT's control.

Wasteload allocations for MS4s are addressed in Section 8.3.

There are no NPDES facilities within the LCR watershed boundary in the state of New Mexico.

5.1.2 Concentrated Animal Feeding Operations

Concentrated Animal Feeding Operations (CAFOs) are animal feeding operations or agricultural facilities where animals (other than aquatic animals) are confined and fed for 45 days or more a year. Manure from an animal feeding operation, if not managed properly, can discharge *E. coli* and nitrogen pollutants, which can migrate and pollute surface and ground waters. ADEQ issues two types of water quality permits for CAFOs: the Arizona Pollutant Discharge Elimination System (AZPDES) permit for potential discharges to surface waters, and the Aquifer Protection Program (APP) permit for potential discharges to groundwater. ADEQ's CAFO inspection program inspects animal feeding facilities for the use of BMPs and unauthorized discharges of manure-contaminated wastewater (ADEQ, 2008b).

One CAFO exists within the study area. PFFJ Inc. northwest of Snowflake is situated in the Silver Creek watershed in Navajo County. PFFJ Inc. confines approximately 130,000 animals including 13,000 sows, 61,000 nursery/weaned swine, and 89,000 finishing swine (ADEQ, 2010b). The nearest waterway is a dry wash approximately three miles northeast of the facility which feeds Silver Creek. Pig manure is treated in a series of 29 lagoons on-site. Lagoons are generally 12 feet deep and range in capacity from 2.5 million to 74 million gallons. Freeboard for the lagoons ranged from five to 10 feet, and to date, no evidence of berm erosion or seepage bordering the lagoons has been noted. Records show inspections have been conducted in 2001, 2004, 2007, and 2011. In all four inspections, no violations of the terms of the CAFO General Permit or APP were found (Hershberger, 2012). As PFFJ Inc. has not and does not intend to discharge to waters of the U.S., it is not a factor in the calculation of this *E. coli* TMDL.

5.1.3 Wastewater Treatment Plants

WWTPs adjacent to river courses and permitted to discharge into river systems are obviously possible contributors to *E. coli* loading of a hydrologic system. Arizona facilities discharging to surface waters are regulated by permit and must comply with the appropriate permit limit for *E. coli* for the designated receiving reach of either 235 cfu/100 ml or 576 cfu/100 ml, which typically reflects the receiving water's surface water quality standard. Discussion of facilities within the watershed permitted to discharge to waters of the United States has been covered in Section 5.1.1

Some wastewater facilities opt not to discharge to a receiving water, but to reclaim and re-use their wastewater, generally for irrigation. These facilities are governed by an APP issued by ADEQ to protect the quality of groundwater. Some facilities have both an AZPDES permit and an APP where both types of use/discharge are anticipated. Facilities in Arizona's LCR watershed boundary covered by APPs are detailed in Table 4. These facilities are itemized for the purpose of a comprehensive inventory of *E. coli* sources in the basin, but since they do not discharge to waters of the United States, they are not considered for the granting of waste load allocations.

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NAME	CATEGORY	LOCATION: UTM Z12 EASTING	UTM Z12 NORTHING
Town of Springerville WWTP	Wastewater	660,557	3,779,116
Town of Eager WWTP	Wastewater	657,641	3,779,892
Pinetop-Lakeside SD*	Wastewater	593,498	3,781,553
City of Show Low WWTP*	Wastewater	589,006	3,792,079
ASPC Winslow Apache Unit WWTP	Wastewater	648,157	3,799,498
White Mountain Lakes WWTP	Wastewater	591,587	3,804,398
Town of Taylor WWTP	Wastewater	586,443	3,814,511
Concho Valley Constructed Wetlands	Wastewater	625,888	3,816,248
Town of Snowflake WWTP*	Wastewater	583,975	3,819,861
City of St. Johns WWTP	Wastewater	650,174	3,822,453

Table 4. APP Facilities in the LCR TMDL Study Area

* indicates AZPDES-permitted facility. See Sections 5.1.1 and 8.3 for further discussion.

5.1.4 Construction General Permit

The purpose of Arizona's construction general permit (CGP) is to protect the quality and beneficial uses of Arizona's surface water resources from pollution in stormwater runoff resulting 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. *E. coli* loading rates are usually directly correlated with increased sediment loading. There will be no itemized waste load allocation expressed in terms of organisms per day set aside for CGP activities in the LCR watershed that is the subject of this TMDL, as projects are expected to be small in areal extent, short in duration, and not expected to contribute *E. coli* loads to the hydrologic system in quantities large enough to be appreciable and discernible relative to the size of the LCR watershed and loads already accounted for.

As of fall 2012, 40 permittees were covered under the CGP in the Little Colorado River watershed in Navajo and Apache Counties. The CGP expires for all permittees on February 28, 2013, but it will be renewed for another term at that date. CGP permittees typically operate for short durations of time under permit coverage, and the number of permittees can fluctuate widely over any given period of time. Consequently, CGP permittees will not be itemized in this TMDL.

For flows originating from CGP sites with direct discharge(s) to a stream reach carrying an FBC designated use, a concentration-based single sample maximum waste load allocation of 235 cfu/100 ml is established consistent with the provisions governing the remainder of this TMDL. For flows from CGP sites with direct discharge(s) to a stream reach carrying a PBC designated use, a concentration-based single sample maximum waste load allocation of 576 cfu/100 ml is established unless reasonable potential for flows to reach perennial waters is assessed by the

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ADEQ Stormwater Unit in the SWPPP review and approval process. In such a case, the concentration-based WLA shall be 235 cfu/100 ml.

5.1.5 Multi-sector General Permit

The purpose of Arizona's multi-sector general permit (MSGP) is to protect the quality and beneficial uses of Arizona's surface water resources from pollution in stormwater runoff resulting from industrial activities for specific industrial sectors. Under the Clean Water Act and Arizona Revised Statutes, it is illegal to have a point source discharge of pollutants that is not authorized by a permit, including stormwater runoff from industrial sites to a water of the United States. To protect water quality, the MSGP requires operators to plan and implement appropriate pollution prevention and control practices for stormwater runoff. *E. coli* loading rates are usually directly correlated with increased sediment loading. There will be no itemized waste load allocation expressed in terms of organisms per day set aside for MSGP activities in the Little Colorado River watershed that is the subject of this TMDL, as future applicants and permittees cannot be forecast.

As of fall 2012, MSGP permittees in the LCR basin in Navajo and Apache counties numbered 17. MSGP activities and facilities are typically ongoing and of longer durations than CGP operations. Details for MSGP permittees are presented in Table 5.

For direct discharges resulting from storm events into stream reaches carrying an FBC designated use, the FBC *E. coli* single sample maximum standard of 235 cfu/100 ml is applied as a concentration-based wasteload allocation for each of the individual stormwater outfalls identified in the permittee's approved SWPPP. For direct discharges resulting from storm events into stream reaches carrying a PBC designated use, the PBC *E. coli* single sample maximum standard of 576 cfu/100 ml is applied as a concentration-based wasteload allocation for each of the individual stormwater outfalls identified in the permittee's approved SWPPP unless reasonable potential for flows to reach perennial waters is assessed by the ADEQ Stormwater Unit in the SWPPP review and approval process. In such a case, the concentration-based WLA shall be 235 cfu/100 ml. ADEQ does not expect that stormwater run-off from MSGP sites will persist long enough to determine attainment of the geometric mean portion of the *E. coli* standard, which requires a four-sample minimum collected within 30 days, with independence of samples in the set requiring only one sample per seven-day interval.

5.1.6 Future AZPDES Permittees

Future applicants and permittees in the Little Colorado River basin requesting to discharge above the impaired reach will be granted a concentration-based wasteload allocation for *E. coli* equivalent to the *E. coli* single sample maximum water quality standard for the impaired reach. Such a wasteload allocation will be considered consistent with the provisions of this TMDL and will not be considered to cause or contribute to downstream exceedances of water quality standards that lead to impairment or continued impairment assessments of Reach 15020002-004.

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FACILITY_NAME	*CITY*	*LATITUDE*	*LONGITUDE*	*TYPE*	*EXPIRATION DATE*
TAYLOR PIT	TAYLOR	34 28 50.00	110 06 40.18	MINING	JANUARY 31, 2016
CEMEX - SHOW LOW PLANT	SHOW LOW	34 15 39	110 01 13	NONMINING	JANUARY 31, 2016
COOLEY KNOLL CINDER PIT	WHITE MTN LAKE	34 19 49	109 57 48	NONMINING	JANUARY 31, 2016
ERGON ASPHALT & EMULSIONS - SNOWFLAKE	SNOWFLAKE	34 30 50	110 06 17	NONMINING	JANUARY 31, 2016
FIRST STUDENT INC #20987	SNOWFLAKE	34 30 19.69	110 05 24.46	NONMINING	JANUARY 31, 2016
GERNIMO BRIMHALL SAND MTLS	SNOWFLAKE	34 55 59	110 14 24	NONMINING	JANUARY 31, 2016
LONE PINE TRANSFER	SHOW LOW	34 21 25.45	110 03 24.44	NONMINING	JANUARY 31, 2016
SHOW LOW AUTO SALES & WRECKING, INC.	SHOW LOW	34 15 33	110 00 19	NONMINING	JANUARY 31, 2016
SHOW LOW AUTO SALES & WRECKING, INC.	SHOW LOW	34 15 33	110 00 19	NONMINING	JANUARY 31, 2016
SHOW LOW REGIONAL AIRPORT	SHOW LOW	34 15 54	110 00 02	NONMINING	JANUARY 31, 2016
SNOWFLAKE COTTONWOOD DECKER PLANT 2	SNOWFLAKE	34 30 37	110 05 45	NONMINING	JANUARY 31, 2016
SNOWFLAKE COTTONWOOD NORTH PLANT 1	SNOWFLAKE	34 31 05	110 04 49	NONMINING	JANUARY 31, 2016
WHITE MOUNTAIN REDI MIX	SHOW LOW	34 15 30.88	110 00 10.30	NONMINING	JANUARY 31, 2016
JOE'S PIT	TAYLOR	34 27 55.09	110 09 30.62	MINING AND NONMINING	JANUARY 31, 2016
PERKINS CINDERS INC - LINDEN PIT	SHOWLOW	34 17 10.03	110 07 15.52	MINING AND NONMINING	JANUARY 31, 2016
PERKINS CINDERS INC - LINDEN PIT	SHOWLOW	34 17 10.03	110 07 15.52	MINING AND NONMINING	JANUARY 31, 2016
PERKINS CINDERS INC - LINDEN PIT	SHOWLOW	34 17 10.03	110 07 15.52	MINING AND NONMINING	JANUARY 31, 2016

Table 5. MSGP permittees in the LCR TMDL watershed

5.2 Summary of Nonpoint Sources

5.2.1 Agriculture

Agriculture in the area can broadly be broken down into two classes: irrigated seasonal cropland, and pasture or forage land. Agricultural areas are generally found around the towns of the LCR Basin and along the watercourses and thus are considered possible nonpoint source contributors to *E. coli* loads. These areas have the potential to add to *E. coli* loading rates for stream networks due to injudicious applications of manure to acreage. Due to the sparse nature of rainfall and the intermittency of the LCR, agriculture is likely a minor contributor to *E. coli* problems in the basin; total area used for agricultural purposes in the basin is 93.8 square kilometers or 0.44 percent of basin area.

5.2.2 Urban/Developed

Urban or developed areas can contribute to excessive *E. coli* loading by stormwater run-off from impervious areas, and by concentrations of stormflow in engineered drainage systems feeding

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into natural watercourses. Minimal impact from lightly developed areas in the LCR watershed is observed. Development footprint in the LCR basin is 34.6 square kilometers, comprising 0.16 percent of watershed area. However, the concentration of towns along the perennial Silver Creek in the western part of the watershed, including the towns of Taylor, Snowflake, Show Low, and Pinetop-Lakeside, carries the potential of amplifying development effects on nonpoint source loadings.

5.2.3 Grazing

Semi-arid regions with sparse ground cover, such as those found along the LCR main-stem, are particularly vulnerable to increased *E. coli* loading rates due to the flashy nature of overland flow and the possibility of flash flooding in gullies and ephemeral drainages feeding into the main channel as a result of intense, short-lived monsoon storms. Overland flow and flash-flooding events in ephemeral drainages carry the potential of washing fecal material from cattle, livestock and domestic animals into major water courses. Grazing activities, where not properly managed, can add to *E. coli* problems in watercourses. This can occur due to multiple factors contributing to increased overland flow velocities and the resulting higher carrying capacity of run-off, including the reduction of vegetative cover shielding the surface from rainfall, the depletion of a litter layer acting to reduce run-off velocities, and the compaction of soil contributing to lower infiltration rates. Additionally, the direct depositing of feces within the stream courses proper, whether perennial, intermittent, or ephemeral, has a direct deleterious effect on bacteriological water quality where cattle and livestock are not managed so as to restrict their access to streams.

Grazing activities in the LCR basin above Carr Lake Draw can be largely attributed to four different land ownership classes: U.S. Forest Service, Bureau of Land Management, Arizona State Trust Land, and private ownership. Within the defined LCR watershed delineated above Carr Lake Draw, New Mexico acreage accounts for 48.7 percent of watershed area. On the remaining Arizona lands, the four classes of land owners that own or administer more than two percent of watershed area and pursue or allow grazing activities are detailed in Table 6. Additional discussion on each will follow.

Land Ownership/Administration, LCR Watershed above Carr Lake Draw	**Area, sq. mi**	**Percent**
New Mexico	3956.93	48.7%
Private Lands	1793.87	22.1%
Arizona State Trust Lands	1078.92	13.3%
Apache-Sitgreaves National Forests	847.59	10.4%
Bureau of Land Management	180.30	2.2%
Others	263.74	3.3%

Table 6. Land Ownership, LCR Watershed above Carr Lake Draw

A large portion of watershed area is Arizona State Trust Land, where grazing allotments are set aside and grazing is actively pursued. Rangeland management on Arizona's State Trust land is a mutual effort between the Land Department and its grazing lessees. Livestock grazing takes place on more acres of State Trust land than any other use. This is due to the remoteness, aridity and lack of infrastructure, such as waterlines, roads, sewers and utilities that make land attractive for development. These conditions are not expected to change to any great degree in the near future.

The Arizona Legislature does not provide funding for the Land Department to institute any agency-initiated management practices on State Trust rangeland. The Land Department relies on its grazing lessees to fund the initiation of management practices on state leases with private money. Such management practices include water sources (such as wells and stocktanks), water distribution systems (pipelines), handling facilities (corrals), livestock control measures (fencing), and various types of land treatments to remove undesirable vegetation species or plant desired vegetation species (prescribed fire, grubbing, agra-axe, root plowing, chaining, herbicides, reseeding) (Arizona State Land Department, 2010).

The State Land Department offers grazing leases for up to a maximum of 10 years. Generally, rangeland health assessments are not required on State Trust land, though a few may be associated with USFS grazing management plans if USFS lands are on adjacent parcels. Lessees can be reimbursed for the cost of range improvements, such as the installation of fences or watering tanks, if the application for such improvements is approved by the Arizona State Land Department (S. Miller, ASLD, personal communication, 6-15-09).

Private land grazing in the LCR watershed is tightly interdependent with State Trust land grazing leases and managed out of the Arizona State Land Office in many cases where grazing leases include both private and state lands (see previous paragraphs). The checkerboard land ownership pattern established from land originally deeded to railroads in the late 1800s (see Figure 2) shows today that adjacent sectional ownership alternates between state land and private lands. Much of this land has become adverse-deeded over the years as a consequence of further subdivision. Many of the subdivided parcels are either not fenced in or lived upon, thus in practice establishing open range country. Two large private companies still own and graze on a substantial amount of land in the area and sub-lease their lands out to other private parties for grazing as well. These entities are the Aztec Land and Cattle Company, with a long history in the region, and the NZ Legacy Cattle Company.

Maximum stocking rates on private lands are determined by Arizona State Trust lands grazing lease limits where State Trust land is involved. Actual grazing numbers are dependent upon the health of the lands and the abundance of forage available. Most of the area where private lands exist falls in a range of expected rainfall from six to 14 inches per year with widely differing forage conditions as a result. Forage availability fluctuates depending on annual/seasonal precipitation. Grazing rotation is the predominant method employed in the management of forage and natural resources on private lands. (R. Murph, NRCS-Holbrook, personal communication, 9-3-10).

The Apache-Sitgreaves National Forests (A-S NF) administer more than 2 million acres of National Forest land. Statistics and summaries subsequently presented from A-S NF on its grazing program accounts for all National Forest acreage, and is not specific to the portions of the National Forest within the LCR watershed boundary. There were a total of 96 active allotments on the A-S NF in 2007 (D. Jevons, Apache-Sitgreaves National Forests, Acting Forest Supervisor, written communication, 7-14-2008). The trend on numbers of active grazing allotments has been decreasing in recent years. In 1983, a total of 128 grazing allotments were actively managed and used; in 2000 the number had declined to 115. The National Forest has

concentrated in recent years on maintaining satisfactory conditions for wildlife habitat and watershed, riparian and forage vegetation, while recovering from recent major fires and still contending with ongoing drought conditions. Thirteen allotments in 2007 were not used for various reasons. The authorized total number of animal unit months (AUMs) for A-S NF in 2007 was 127,509. Recent years have seen some fluctuation of authorized numbers, ranging from a high of 187,035 in 2003 to a low of 89,603 in 2004. By rough comparison, permitted numbers (a subset of authorized numbers) in 1983 and 1985 were 233,932 and 213,819 respectively, illustrating that recent grazing usage is substantially less, with wider year-to-year variability, than in the 1980s. Active range condition and trend studies are ongoing. Six allotments were consolidated for more effective resource management under NEPA in 2007. Grazing is permitted for cattle, horse, sheep, and burros.

A small percentage of BLM land exists within the watershed boundary. These land parcels are interspersed with private lands and State Trust lands throughout the middle and lower elevations of the watershed in a checkerboard distribution where parcel boundaries date from the first days of surveyed townships, ranges, and sections and original land grants made in the 1800s (refer to Figure 2). The parcels are administered out of the Safford District BLM Office in eastern Arizona. Grazing allotments are affiliated with these parcels; in most cases, these allotments extend beyond individual parcel boundaries to include a mix of private, state, and federal lands. Coordinated land management practices in such a fragmented ownership pattern have proven to be difficult. BLM lands comprise only 2.2 percent of watershed area. The number of cattle on BLM allotments is not readily available (C. Morris, BLM-Safford, personal communication, 7-15-10).

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5.2.4 Wildlife

Wildlife in some cases can be responsible for excessive *E. coli* loading of streams and rivers. Forest and range lands largely unaffected by human activities are home to much of the wildlife population. Wildlife impacts on *E. coli* would be most commonly found in the upper elevations of the watershed, where favorable forest habitat would sustain greater populations of elk, deer, mountain lions, lynx, beavers, bears, and other species. Wildlife impacts in the arid and semi-arid provinces of the basin would be expected to be lower in keeping with the less favorable habitats available. Impacts would be further curtailed by the hydrologic characteristics of the upper reaches of the LCR above the Silver Creek confluence. Here, the LCR is intermittent / ephemeral in character, flowing only in response to localized precipitation events or snowmelt. This region is essentially spatially segregated from the upper perennial reaches of the LCR due to the existence of Lyman Lake and a dam at the lake disrupting hydrologic continuity. However, even in these stretches, arid-land mammals may be expected to be found, and the watercourse serves as a magnet for them.

While forest lands provide the habitat for wildlife sources that may contribute to *E. coli* loading problems, they may also protect against excessive *E. coli* loading rates by providing a floor layer of litter and duff covers to reduce overland flows.

5.2.5 Septic Systems

Septic systems are normally found where residences exist outside an incorporated area where sewer service would normally be provided. Failing septic systems, particularly within the floodplain of a major river like the LCR or Silver Creek, can greatly exacerbate *E. coli* problems. Septic systems can fail or underperform for a number of reasons, including overuse, lack of routine maintenance, unsuitable soils for infiltration in a septic system's leach field, clogging of perforated pipes within the leach field, chemical decimation of the normal flora within a system due to the introduction of industrial or household non-organic waste, river flooding over septic system leach fields, and infrastructure failures/disintegration.

The Navajo County Public Works Department reports that septic system failures have been documented at a fairly high rate (20 percent of installed systems) near the community of Linden west of Show Low for a recently constructed subdivision. However, it is unclear how much these failures may impact Silver Creek and LCR bacterial water quality; though Linden is in one of the subwatersheds draining to the Woodruff area, its tributary (Show Low Creek) flows only intermittently and is impounded above Lone Pine Dam above its confluence with Cottonwood Wash and Silver Creek. Navajo County also reports that the areas around White Mountain Lake on Silver Creek and Shumway, also on Silver Creek, are likely places for septic problems to be noted, though no official reports have been received in recent months and no notices of violations have been issued for the areas.

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5.2.6 Recreational Use

Where waters are used for swimming, wading, and riparian areas for recreational picnic sites, camping, and day-use recreational activities, the chance for increased *E. coli* loading is present. Locations where facilities are not provided and visitation is high carry a proportionately higher risk of *E. coli* contamination. Recreational uses of the LCR are minimal relative to the size of the watershed due to the ephemeral and unpopulated nature of a sizable portion of the watershed. Some recreational impacts occur in the Show Low/Pinetop corridor and along Silver Creek as it flows north to its confluence with the LCR.

6.0 LINKAGE ANALYSIS

The numeric target values of the TMDLs determined and presented in this document are based upon and calculated from single sample maximum concentration of *E. coli* for the Full Body Contact (FBC) designated use (235 cfu/100 ml) expressed in Arizona's surface water quality standards. Concentrations of *E. coli* are expressed in terms of colony-forming units per 100 ml (cfu/100 ml). Loads used in the load duration curve analyses are the product of concentrations and flows with an appropriate conversion factor applied. Loads are expressed in terms of giga (billion)-organisms per day (G-org/day). The conversion factor used to convert from cfu/100 ml to G-org/day is 0.02446.

All load target determinations and existing load calculations in the TMDL document are originally derived from the *E. coli* single sample concentration values, as expressed in the Arizona surface water quality standards and in data reporting. Consequently, attainment of the total maximum daily loads for the single sample maximum value presented will result in waters that meet water quality standards for concentrations. Conversely, waters meeting the state's water quality standard-based concentration values will be meeting the required total maximum daily loads set forth in this document. Suggested monitoring and effectiveness evaluation strategies pertaining to evaluations of loads and concentrations for the implementation of these TMDLs is addressed in Section 9.0.

6.1 Subwatershed Empirical Load Summations

The approach selected to meet Arizona's *E. coli* concentration standard focused upon isolating representative cumulative watershed *E. coli* load contributions at or near the mouth of the two major subwatersheds: the LCR above Silver Creek, and Silver Creek. Sampling and modeling for individual ephemeral tributary, source use, source process, or parcel contributions to the total *E. coli* load was impractical and unachievable with resource constraints. Figure 6 details the hydrologic network in the vicinity of the impaired reach and exhibits sites selected to characterize the watershed. Loadings were allocated between the two main tributaries and subwatersheds of the project area based upon ratio of each tributary's historic daily average discharge contribution (Section 7.1). From USGS flow data for Silver Creek and the LCR, a ratio of 0.471 was established for Silver Creek (24.72 cfs average daily flow, versus 52.5 cfs average

daily flow for the entire contributing source area as measured at Woodruff). Loading allocations were developed based on total run-off as opposed to contributing land area in recognition that allocating based on respective land areas would heavily bias the TMDL against the Silver Creek watershed (~86 percent land area associated with the LCR sub-basin, with only ~ 14 percent attributable to Silver Creek) and require disproportionate reductions in the perennial portions of the watershed, when sampling has demonstrated that critical conditions occur when the LCR flows and excessive loadings are largely traceable to the LCR sub-basin. The TMDL necessarily calls for allocations requiring reductions in the parts of the watershed creating the most significant problems. Calculations for both load duration analyses and TMDL reductions were made in units of giga-organisms (G-org) per day.

Arizona's *E. coli* water quality standard is expressed both as a geometric mean and a single sample maximum. However, the geometric mean was not considered in the analysis, as the impaired reach was listed on the basis of single sample maximum exceedances alone. No qualifying sets of four samples in a 30 day period were available in the water quality record to be evaluated.

E. coli concentrations were converted to their associated daily loads (i.e. multiplied by discharge and the conversion factor 0.02446) and plotted against a standard target load value in a load duration curve. As mentioned above, load allocations for subwatersheds were determined by the relative percentages of contributing tributary average daily discharge. Percentages were applied to the total *E. coli* loads, and the loads as broken down by the standard classes of a load duration analysis (<10 percent exceeds flows (high flows), 10-40 percent exceeds flows (moist conditions), 40-60 percent exceeds flows (mid-range flows), 60-90 percent exceeds flows (dry conditions), >90 percent exceeds flows (low flows)). Using this empirical linking approach, the sum of the total load allocations of the various subwatersheds is targeted to meet the load allocation necessary to attain the water quality standard at the base of the impaired reach. An additional 2 percent was added to the margin of safety to account for the small subwatershed (0.56 percent area) below the LCR-Silver Creek confluence to the lowest point in the impaired reach.

The single sample maximum value of 235 cfu/100 ml was converted into a set of corresponding load thresholds. The 90th percentile value of existing loads was compared against the threshold values for subwatersheds where such analysis was possible. The 90th percentile value of existing loads was selected in recognition of the fact that single sample maximums are not intended to be construed as values never to be exceeded (EPA, 2006), but rather represent an implied percentile or confidence level of a frequency distribution. For the original EPA studies from which Arizona *E. coli* standards were derived, the implied confidence level for a SSM of 235 cfu/100 ml is the 75th percentile as outlined in EPA guidance (EPA, 1986). However, ADEQ has elected to use the 90th percentile value of existing loads in keeping with the manner in which the agency evaluates acute exceedances of other water quality parameters using a binomial distribution based upon a 10 percent exceedance frequency. Adopting the 90th percentile confidence level for attainment evaluations adds an implicit margin of safety over the 75th percentile confidence level the single sample maximum value was originally drawn from.

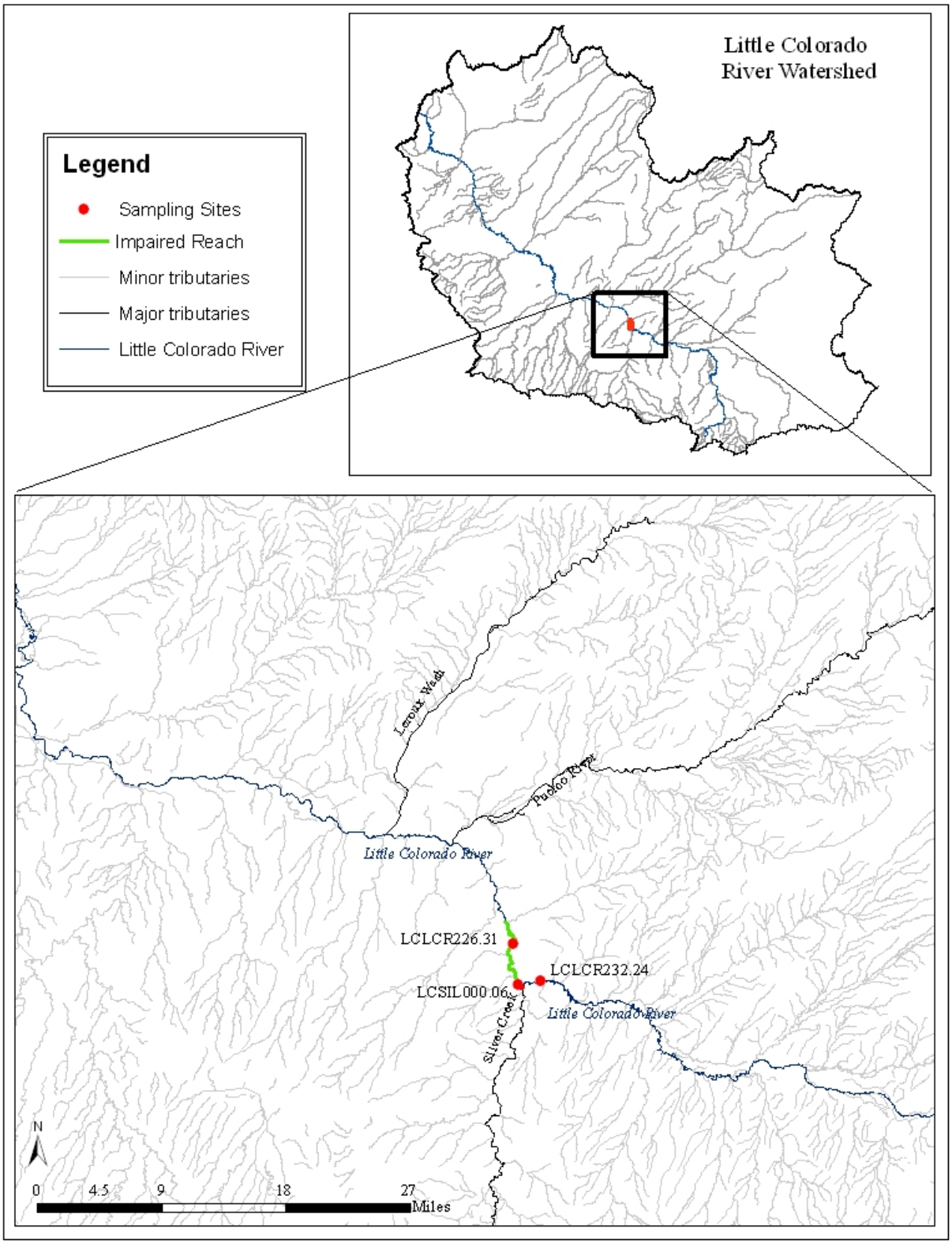


Figure 6. LCR TMDL Sample Sites

6.2 Watershed Definition and Delineation

The flow of the LCR is spatially interrupted by the existence of the Lyman Lake Dam, which creates Lyman Lake, a unit of the Arizona State Parks system used for recreation and irrigation storage. Above Lyman Lake, the LCR is perennial for its entire run to the White Mountains, where it headwaters in several significant tributaries. Water is routinely released from the dam during the irrigation season of April-October. Dam releases flow northward several miles toward the town of St. Johns, Ariz.. The river is subject to agricultural diversions for local use during its entire run below the dam; between diversions and infiltration, the LCR is typically exhausted with no flow remaining in the vicinity of the St Johns WWTP. The Lyman Lake dam is approximately 87 river miles upstream of the Silver Creek/LCR confluence. The LCR flows past the eastern edge of St. Johns near its lowest point of infiltration; this stretch of the river is 71 river miles above the LCR-Silver Creek confluence. The LCR can be considered intermittent / ephemeral below this point to the confluence with Silver Creek.

Due to the spatially interrupted nature of the river, the differing hydrologic regimes above and below the dam, the residence time in the reservoir (approximately 228 days, based on a median storage volume of 11,300 acre-feet for the previous year and the USGS discharge statistics for the LCR below Lyman), the distance of the reservoir from the project area, and the limited viability of *E. coli* in the reservoir due to predation and exposure to sunlight, the possibility of *E. coli* loading attributable to the region above Lyman Lake Dam was considered miniscule if existent at all. Contributions from the LCR watershed above Lyman Lake were not considered in the analysis. Delineations and watershed definitions were generated and developed excluding the 790 square miles above Lyman Lake Dam. Source contributions above Lyman Lake were disregarded. The watershed area excluded constitutes approximately 10 percent of total watershed area.

7.0 MODELING AND ANALYTIC APPROACHES

Load duration curves were used for modeling *E. coli* loads and calculating the TMDL for reach 15020002-004. The load duration curve approach was chosen for its flexibility, its capacity to identify and address flow-dependent conditions, and the ability to classify and analyze various data points individually in accordance with the requirements of Arizona's water quality standard for *E. coli*. Long-term USGS streamflow gauges in the watershed permitted an in-depth examination of flow history.

7.1 Flow and Load Duration Curves

ADEQ has chosen to employ a flow and load duration curve approach in order to determine total maximum daily loads and calculate necessary reductions. Cleland (2003) provides the following discussion on the elements and merits of a load duration curve 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 exceedance 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 7*).*

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

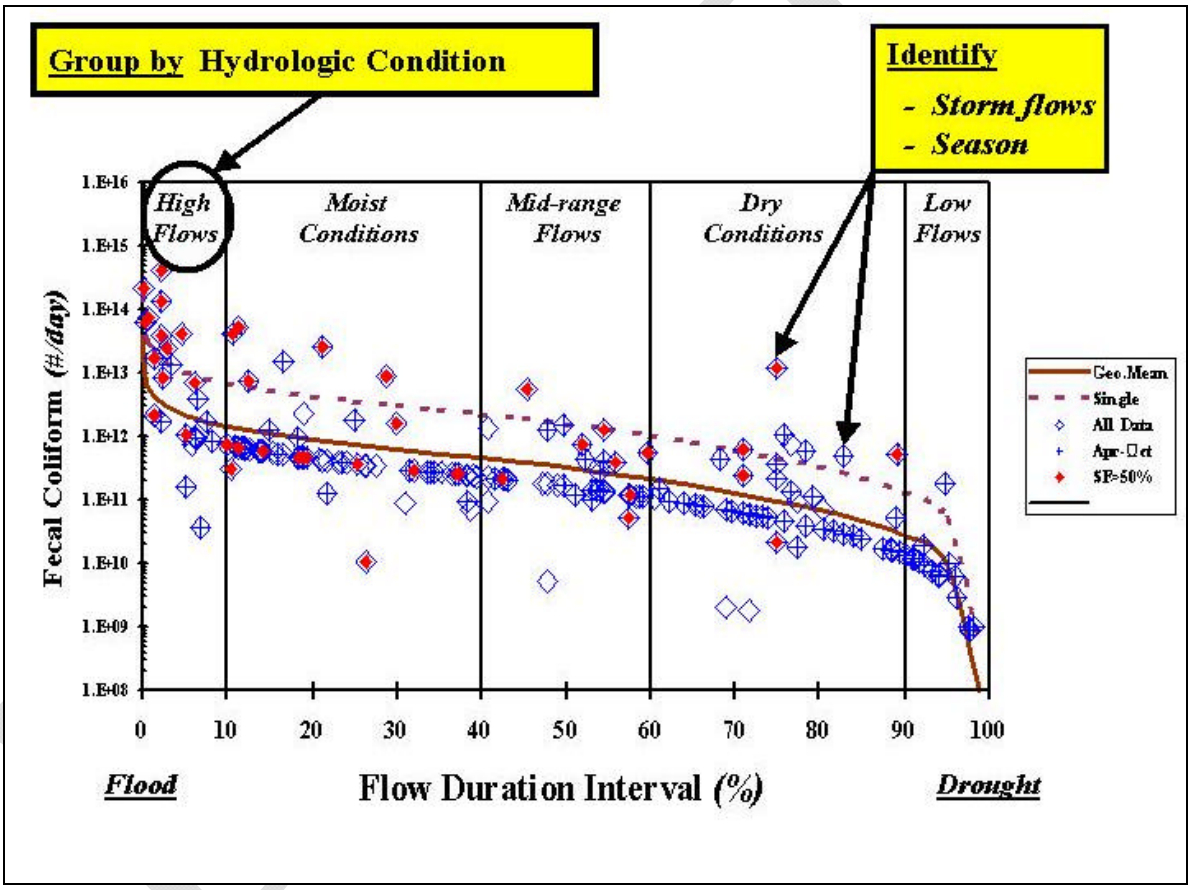
Flow duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: one representing high flows, another for moist conditions, 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 7. Data may also be separated by season (e.g. spring runoff versus summer base flow). For example, Figure 7 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 in Figure 7 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 7, 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 7. 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.



(Illustration from Cleland 2003)

Figure 7. Sample Load Duration Curve

As outlined above (Cleland, 2003), the subdivision of the flow frequency curve into five zones corresponding to high flows (0-10 percent flows exceed), moist conditions (10-40 percent flows exceed), mid-range flows (40-60 percent flows exceed), dry conditions (60-90 percent flows exceed), and low flows (>90 percent flows exceed) was executed for analysis and TMDL calculations.

Refer to Figure 8 for load duration data for the LCR at Woodruff. Flows have been graphed by percentage flow exceeded on the x-axis (the LCR at Woodruff flows approximately 95 percent of the time), and *E. coli* loads in G-org/day are graphed along the logarithmic y-axis. For the purposes of illustration, data was grouped into two categories: storm flow data by high-flow and moist-condition classes, and nonstorm flow by mid-range, dry-conditions and low-flow classes. Within these two broad groupings, the two data points falling below the target load curve in the storm flow category were both snowmelt events with steadier releases of discharge (these would not qualify as stormflow when analyzing base flow recession coefficients [BFRC] within a 48 hour period), and of the two data points above the target curve in the nonstorm flow category, one data point would qualify as storm flow when analyzed by the 48 hour BFRC method. The data clearly show the role non-steady storm flows (and by extension overland flows) plays in *E. coli* exceedances in the LCR basin. Because most of the plotted data is historic data collected before tributary contributions were sampled and analyzed, it is not possible to further classify the exceedances based upon LCR sub-basin contributions and Silver Creek sub-basin contributions. Insufficient numbers of samples were collected on the tributaries to productively plot load duration curves for each sub-basin.

7.2 Natural Background Determination

TMDL establishment includes a provision for natural background loads in the waterbody being evaluated. Load allocations and waste load allocations are reduced proportionately to accommodate natural background loading. The term “natural background” is normally applied to those areas where no effects due to human activities (urban development, mining, agriculture, ranching, heavy recreational usage, etc.) are known to occur upstream. Care must be taken in selecting natural background sites to select sites principally to eliminate or minimize anthropogenic influence. In the LCR basin, natural background conditions for *E. coli* were assessed in the headwater tributaries of the LCR in the Apache-Sitgreaves National Forests. Here, minimal human visitation and impact is paired with natural levels of bacteria loading from native fauna to present the best-case approximation of natural background contributions to *E. coli* loading.

Unlike the evaluation of naturally-inherent chemical constituents that may occur in spring water, *E. coli* requires that some degree of hydrologic process be permitted to operate in the watershed before loading can be evaluated. Natural background sites were chosen with this secondary criterion in mind. Sites were chosen on the West Fork of the LCR above the community of Greer at Government Springs, on Lee Valley Creek above Lee Valley Reservoir, and the West Fork of the LCR at the Mt. Baldy Wilderness boundary. A total of 56 sampling results from these sites were evaluated as a set; the 90th percentile value of the set was determined as 12.5 cfu/100 ml, in keeping with the method used to evaluate single sample maximums by category in the load duration analysis. The ratio of the 90th percentile to the single sample maximum was then established as a percentage value to be attributed across all flow categories in the load duration analysis. A percentage of 5.32 percent attributable to natural background relative to the water quality standard was established.

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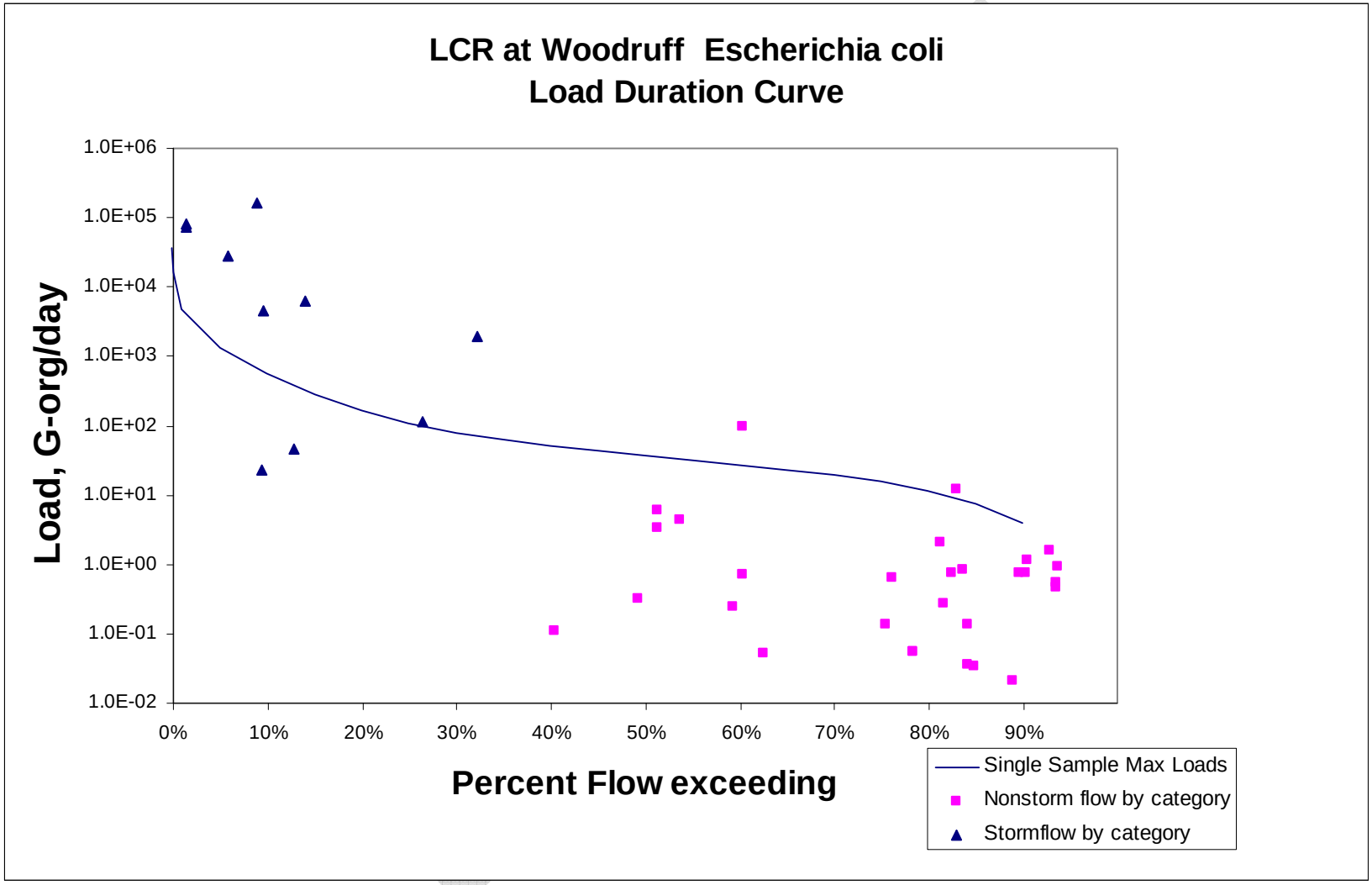

Figure 8. LCR at Woodruff Load Duration Curve

8.0 TMDL CALCULATIONS

8.1 Flow Characteristics and Critical Conditions

While flow from Silver Creek approaches true perennial status, and the USGS site at Woodruff four miles downstream of the confluence reflects this with approximately 95 percent of days showing flow, flow contributions from the LCR above the Silver Creek confluence are much more intermittent and erratic in nature. This segment of the LCR only flows in response to precipitation events or prolonged snowmelts. Some flow may persist due to interflow contributions from the water table for periods exceeding the defined storm windows ADEQ employs to characterize discharge, but all contributions from the LCR above the Silver Creek confluence are either directly or indirectly related to precipitation events.

The reach of the LCR immediately above Silver Creek has no USGS gauge to identify the proportion of time the LCR flows. Determination of amounts of runoff, and durations of time the subwatershed flows is problematic due to its relatively remote location and lack of record. The nearest upstream USGS gauge is the LCR below Zion Reservoir (USGS 09386180) located 53 miles upstream of the LCR-Silver Creek confluence. Flow history has been compiled at this site for only a little more than 10 years. An analysis of all daily mean values for 09386180 determines daily flow means of 0 cfs 82.9 percent of the time, or conversely, that there are flow contributions only 17.1 percent of the time. The average flow over this period of time is 3.01 cfs, with a maximum flow of 2140 cfs on 9-12-2002, further emphasizing the river's flashy and unpredictable nature in its intermittent reaches. It can reasonably be expected that the percentage of time flow was contributed would be somewhat higher as evaluation is carried further down the watershed, as more contributing source area amasses, potential interflow contributions grow, and persisting flow in lower reaches would have a better chance of joining Silver Creek. Evaluation of the flow history of USGS 09394500 (LCR at Woodruff) using overlapping 48 hour windows from both storm onset and storm peak after onset determines that the site exhibits stormflow influence for 20.1 percent of the daily flow history dating to 1905.

A separate analysis comparing USGS flow records from Silver Creek above the LCR and the LCR at Woodruff generally confirms this assessment, though results must be considered provisional. While Woodruff has a long flow history, Silver Creek above the LCR (USGS 09394000) was gauged only from April 1929 to September 1952. In a paired side by side analysis for the common period of record, two flow thresholds of five and 10 cfs at Woodruff were selected as the lower limits of the data comparison evaluation. Paired data from Woodruff and Silver Creek above these thresholds were then evaluated for differences of both 0.25 log normal units and 0.5 log normal units. Dependent upon the flow floor threshold considered, percentages of paired flows in the common history that exceeded the log normal criteria varied from 22.7 percent to 37.2 percent. The most probable determinations were that flows from the LCR subwatershed are estimated to occur approximately 28 to 30 percent of the time. Results are considered no more than informed estimates when extrapolated to current day conditions, due to the length of time elapsed since records were kept and the relatively short common period of record, the different hydrologic conditions during the period (average Woodruff flow of 64 cfs, compared to the entire period of record Woodruff average of 52.5 cfs), and the difficulty in

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distinguishing historic contributions of interflow and surface runoff in the small subwatershed below the confluence of Silver Creek and the LCR.

The floor flow thresholds were chosen to limit ambiguity in the analysis. With a Woodruff median flow of 6.4 cfs and a 75th percentile flow of only 2.8 cfs, small differences in daily flow means in the comparison were ambiguous, reflecting one of several possibilities:

- Differing daily means result solely from the duration of time necessary for discharges to flow four miles downstream to the second gauge;
- Additional surface runoff in the small subwatershed below the LCR and Silver Creek confluence had occurred;
- Groundwater interflow contributions within the small sub-basin were contributing to elevated Woodruff flows; or
- The LCR subwatershed was contributing small amounts of run-off (<5 cfs).

Data collected throughout the TMDL project cycle in all hydrologic flow regimes confirms that the great majority of loads exceeding the stream's assimilation capacity occur when the LCR is adding loads to the near-perennial Silver Creek. In mid-range, dry and low-flow conditions, when flow persists in the impaired reach due to the flow of Silver Creek alone, exceedances rarely occur. Storm conditions causing the LCR to flow contribute a sizable increase in both the percentage of exceedances and the density counts of *E. coli* samples in those exceedances. Silver Creek contributes to those exceedances, as subsequent tabled percent reductions will demonstrate, but LCR inputs add an order or magnitude or more to the loads measured at the Woodruff site in the upper two flow classes. Flow of the LCR due to precipitation events constitutes a major critical condition identified for subsequent analysis. Consequently TMDL analysis will be conducted on two separate classes: the first for when both Silver Creek and the LCR flow; and the second for when Silver Creek alone flows.

Though the estimated 30 percent duration LCR hydrologic influence constitutes the best reasonable estimate, analysis is not as simple as assigning the top 30 percent of flows at Woodruff to the classification of critical condition flows. Stormflows are interspersed probabilistically throughout the flow distribution at Woodruff, with a higher percentage of joint flows dominating the upper deciles, but probable joint flows occurring in some percentage throughout all deciles.

8.2 Load Allocations

A standard load duration curve analysis was applied to data from the principal site in the impaired reach and the two major tributaries above it to determine load allocations and reductions necessary to attain the TMDL values. Since the reach was listed using single sample maximums and no data aggregations in the assessment period allowed for a determination of a 30 day geomean (four sample minimum), the TMDL analysis will only be performed on the single sample maximum portion of the standard. As ADEQ treats evaluations of single sample maximums of *E. coli* in practice as stand-alone acute exceedances, a simple deterministic mass-balance approach will be employed to analyze percent reductions called for without resort to stochastic methods. This congruence of assessment practice and TMDL analysis will allow for a stronger linkage between samples collected for assessment and samples collected determining TMDL effectiveness, as well as easier and more straight-forward interpretations of data.

For the Class 1 data analysis (both Silver Creek and the LCR discharging), the load allocations were assigned based upon the ratios of average daily flows/average annual runoff in the flow record for Silver Creek when compared to LCR Woodruff. Silver Creek was assigned 47.1 percent of the total load allocation, with the remaining 52.9 percent allocated to the LCR above Silver Creek The small LCR - Silver to Carr Lake Draw subwatershed, comprising only 0.56 percent of total watershed area, was incorporated without specific numeric values into a larger margin of safety than otherwise would have been provided.

For Class 2 data analysis, where the LCR is not flowing, the entire load allocation was assigned to Silver Creek in all flow classes. As in Class 1, the LCR - Silver Creek to Carr Lake Draw subwatershed was accounted for with a larger margin of safety.

Load allocations were developed and applied both by subwatershed analyzed and cumulatively for the entire watershed. A portion of the load allocation was set aside in each subwatershed with incorporated areas to account for urban stormwater runoff. Urban runoffs from the towns of Snowflake, Taylor, Show Low, Pinetop-Lakeside, and St. Johns were allocated a portion of their respective subwatersheds' load allocation based upon urban area footprints within the subwatershed. Refer to Table 7 for details. The appropriate proportion was applied to the subwatershed load allocation and recorded as a sub-allocation in Table 10. Line items for urban load allocations in Table 10 are not considered in the larger summations within the table structure; they are simply presented as the fraction of the subwatershed's load allocation for informative purposes. It is noted that no data is available for assessing urban stormwater runoff *E. coli* loads or determining any necessary reductions in the TMDL analysis. See Table 11 and Table 12 for itemization.

Subwatershed	***Subwatershed Area (Sq. Mi)***	***Urban Areas Included***	***Urban Incorporated Area Footprint (Sq. Mi)***	***Urban Percentage Of Subwatershed Area***
Silver Creek	953.4	Snowflake, Taylor, Show Low, Pinetop-Lakeside	100.29	10.5%
Little Colorado River above Silver Creek confluence (excluding Lyman Lake subwatershed)	6347.91	St. Johns	27.06	0.43%

Table 7. Subwatershed urban incorporation footprints

8.3 Waste Load Allocations

As outlined in Section 5.1.1, three AZPDES-permitted facilities exist in the LCR basin upstream of the Carr Lake Draw confluence, with Pinetop-Lakeside's permit to discharge to waters of the U.S. expiring without renewal on January 22, 2012. Terms of Permit AZ 0026034 for the Town of Snowflake WWTP shall mandate that discharges meet surface water quality standards for the

Full Body Contact (FBC) designated use of a 30 day geomean of 126 and a single sample maximum of 235 cfu/100 ml. The terms of the permit fact sheet acknowledge that discharge may reach or affect Silver Creek, and thus the permit was written to protect Silver Creek uses. Snowflake WWTP's permit to discharge expired in October of 2009, and Snowflake applied for renewal in December 2010 upon learning this TMDL was being drafted. Based upon Snowflake WWTP's maximum daily discharge of 0.6 mgd (equivalent to 0.928 cfs), the Snowflake WWTP will be assigned a numeric waste load allocation of 5.33 G-org/day in the TMDL calculation where flow categories permit, as outlined below.

The Show Low Municipal WWTP (AZ0023841) discharges to constructed wetlands in former playa wetlands (Pintail Lake and Telephone Lake), with provisions made for excess discharges to be diverted or allowed by overland flow to an additional wetland (Ned Lake). These lakes/wetlands exist in small hydrologically closed basins. The discharges are not expected to enter the hydrologic network and impact the water quality of Silver Creek or the LCR. This is reflected in the designated uses applied to the receiving waters (Aquatic and Wildlife Effluent Dependent Water [A&Wedw], Partial Body Contact [PBC]) with a higher permitted *E. coli* density count for single samples of 576 cfu/100ml. A mass-based numeric waste load allocation will not be applied to Show Low in the TMDL calculation. Instead, a concentration-based waste load allocation of 576 cfu/100 ml, equivalent to the terms of the permit, is hereby established for the Show Low Municipal WWTP.

The Pinetop-Lakeside Sanitary District WWTP (AZ0025437) discharges to a series of constructed pond wetlands adjacent to an ephemeral tributary of Show Low Creek. Two additional wetlands (Instream Wetland A and Instream Wetland B) were planned at the previous permit renewal to be constructed within the channel of the ephemeral drainage to handle overflow conditions during storm events and to provide additional capacity during the months of April-October. The additional wetlands were designed to allow assimilation of the entire 2.0 million gallon per day capacity of the WWTP if necessary. However, the Pinetop-Lakeside Sanitary District WWTP never constructed the planned overflow wetlands. They allowed their permit to discharge to the waters of the U.S. to formally expire on January 22, 2012 (Greenbie, 2012). Consequently, no wasteload allocation for AZPDES Permit AZ0025437 is granted or assigned.

Wasteload allocations for the CGP and MSGP are discussed in Sections 5.1.4 and 5.1.5.

For flows originating from existing or future sites having reasonable potential to be a source of *E. coli* and operating under MS4 coverage, a concentration-based waste load allocation of 235 cfu/100 ml (single sample maximum) is established for direct discharge(s) to a stream reach carrying an FBC designated use consistent with the provisions governing the remainder of this TMDL, where *E. coli* is reasonably assessed as being a constituent of concern. Where direct discharge(s) are to a stream reach carrying a PBC designated use, the concentration-based WLA shall be 575 cfu/100 ml unless reasonable potential for bacteriological water quality degradation of downstream FBC reaches from such discharges is assessed by the ADEQ Stormwater Unit in the SWPPP or SWMP review and approval process. In such a case, the concentration-based WLA shall be 235 cfu/100 ml. The concentration-based WLA is applicable for each separate discharge that may issue from a site location.

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Facilities (WWTPs and constructed wetlands) identified as requiring only an APP in Table 4 are not assigned wasteload allocations, since they do not discharge nor intend to discharge to waters of the United States.

Flows in the LCR at Woodruff are generally low and pose a problem in a load duration analysis incorporating numeric mass-limit based waste load allocations in the low flow (Category 5) classification. The median flow of the low flow category at Woodruff is 0.4 cfs. With a design capacity of 0.6 MGD for the Snowflake WWTP (equivalent to a steady state flow of 0.93 cfs), a potential exists with a numeric mass limit-based WLA for a discharge impacting the impaired reach to exceed the calculated WLA in the lowest flow class at Woodruff if the Snowflake WWTP is discharging at plant capacity. Consequently, a numeric mass limit WLA will only be applied to the upper four flow classes. A concentration-based WLA equivalent to the single sample maximum water quality standard (235 cfu/100 ml) for Snowflake will be applied to the low flow class. Since the load duration curve is predicated on the product of discharge and concentration, it can safely be surmised that in these flow categories, if the *E. coli* water quality standard is being met at the Snowflake WWTP outfall, waste loads for the LCR at Woodruff should be in accordance with the TMDL.

Wasteload allocations were developed and applied for the TMDL-defined watershed as a whole. The TMDL analysis included all subwatersheds and tributaries above the confluence of Carr Lake Draw at the base of the impaired reach, with the exception of the LCR headwaters area above Lyman Lake as mentioned previously; the application of WLAs was made both separately by subwatershed and cumulatively for the watershed as a whole, as shown in Table 11 and Table 12. Since all AZPDES permittees are located in the Silver Creek watershed, WLAs show the same values for both the Silver Creek subwatershed and the entire TMDL watershed. The LCR subwatershed above the Silver Creek confluence has no individual permittees located within the TMDL watershed boundary.

The point of compliance for WLAs for all discharges from MS4, MSGP, CGP, or individual AZPDES permit operations shall be the point of discharge to a reach carrying either a PBC or FBC designated use.

8.4 Margin of Safety

A baseline margin of safety of 10 percent is subtracted from the TMDL allowance for each flow class to buffer against uncertainties in analysis, including variability of coliform densities, variability and error associated with flow measurement, variability in the Colilert incubation and enumeration process, and other uncertainties associated with sampling and enumeration. An additional two percent margin of safety is applied to account for contributions from the LCR Silver-Carr Lake Draw subwatershed that cannot be isolated from the cumulative *E. coli* densities determined at the Woodruff site. The subwatershed is being accounted for in an areal comparison relative to the size of the entire contributing watershed; its area comprises 0.56 percent of total watershed area. The additional two percent allowance permits this subwatershed's contributions to be assimilated in the TMDL value without explicit numeric values and adds an additional implicit margin of safety beyond the subwatershed's expected contribution.

8.5 Results and Discussion

Sampling for the TMDL commenced in February 2007 and covered all phases of the hydrologic regime over a three year period. The cumulative comparisons using Woodruff data included more than 15 years worth of data; however, source identification efforts with additional sampling on the tributaries did not begin until relatively late in the period. The intermittent nature of the LCR above the Silver Creek confluence coupled with the short holding time for *E. coli* samples precluded the gathering of many samples from this subwatershed. Table 8 details the number, period, and type of samples used in the analysis effort. Table 9 itemizes *E. coli* exceedances used in analysis for the three subwatersheds of this TMDL.

Subwatershed/Watershed	*Number Sampling Visits*	*Number Samples*	*Sample Data Window*	*Type*
LCR-Silver-CLD/Cumulative	37	40	16-Dec -1993 to 10-Sept-2010	Baseflow, Snowmelt, Stormflow
Silver Creek	12	10	27-Feb-2007 to 10-Sept-2010	Baseflow, Snowmelt, Stormflow
LCR above Silver Creek	12	4*	27-Feb-2007 to 10-Sept-2010	Stormflow

Table 8. Sample Population.

* Sample totals limited by intermittent nature of the watercourse

Table 10 outlines the TMDL targets, the margin of safety, load allocations, natural background and wasteload allocations for both critical and non-critical classes of analysis. Critical conditions are defined as precipitation events of sufficient duration and intensity to cause the LCR above Silver Creek to flow. Table 11 and Table 12 compare existing data for critical and non-critical conditions respectively to the TMDL targets and determine the percentage reductions necessary to attain the TMDL in each of the defined flow categories. Calculations for reductions are based on the 90th percentile value of existing data in each flow classification as compared to the SSM target load value for the mid-point of each flow category. Table 13 summarizes the percent reductions necessary for each class of conditions and presents cumulative percent reductions called for in the impaired reach. It should be noted that the tributary loads were classified according to the category of the combined flows as represented by the Woodruff flow history due to the lack of flow histories available for tributary discharges. Where flow categories of the impaired reach show that the TMDL is already being met, no breakdown or further analysis is presented, as doing so tends to give a misleading impression that reductions are necessary in the tributary analysis when the impaired reach shows attainment has already been achieved. Table 14 details the numbers of samples collected for analysis in each flow category. Where the number of samples is less than four, calculated reductions in the flow class should be considered provisional. The disparity in numbers of samples cumulatively presented for the impaired reach

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at the Woodruff site versus the tributary samples are a function of the long sampling history at Woodruff prior to the beginning of the TMDL study and the fact that some supporting samples on the tributaries are not presented in the tables when the corresponding flow class of the impaired reach shows attainment has already been achieved.

The cumulative data and the grouped data analysis for Silver Creek non-critical conditions demonstrate that critical conditions have been accurately isolated and identified. No existing class loads exceeded their TMDL load allocations in the two upper flow classes in which data is presented (Table 12). Though results must be considered provisional due to limited numbers of samples within each class to make definitive assertions, the high flow and moist conditions categories both met their targets under nonstorm flow conditions. This is a significant finding, given that the towns of Taylor and Snowflake are in the mid-reaches of Silver Creek, and Show Low and Pinetop-Lakeside occupy tributary subwatershed headwaters contributing to Silver Creek loads. In nonstorm flow conditions, when overland flow is not occurring and the intermittent reaches of the LCR are not contributing inputs, Silver Creek is already meeting TMDL targets.

The picture changes when consideration turns to stormflows and the addition of LCR inputs. The cumulative reduction percentages outlined in Table 11 show that very high levels of existing loads have historically shown up at the Woodruff site for flows exceeding the 40th percentile flow value. While detailed source identification was not performed on data between 1993 and 2007, examination of the limited datasets for identified stormflows of both Silver Creek and the LCR show that both are contributing to class load exceedances when overland flow is occurring. For the LCR at Woodruff, load reductions of 98.9 percent (existing load 128,169 G-org/day, TMDL-MOS target value 1189 G-org/day) and 97.8 percent (existing load 5006 G-org/day, TMDL-MOS target value 96 G-org/day) for the 90th percentile values are required for the upper two flow classes respectively to attain their target values. These load reductions translate into a two orders of magnitude reduction and 1.72 order of magnitude reduction respectively. The mid-range, dry conditions, and low flow classes for flows below 9.0 cfs are meeting TMDL targets. When considering the data from each subwatershed individually in stormflow conditions, the LCR above Silver Creek shows a need for a 98.8 percent reduction in the high flow category and a 99.8 percent reduction in the moist conditions category, while Silver Creek shows a need for reductions of 98 percent in the high flow category and more moderate reductions of 55.8 percent in the moist conditions flow class based upon a limited dataset.

In summary, loads are exceeding the system's assimilation capacity when stormflow dominates the hydrologic flow regime and overland flow is occurring. Loading is further exacerbated by contributions from the LCR subwatershed above the Silver Creek confluence during stormflow events. Figure 8 presents Woodruff data points plotted against the load duration curve. Load duration analysis suggests that point sources are not an issue for the impairment, as the low flow categories show no problems. Rather, a mix of bank contributions, upland overland flows, storm water from impervious developed areas, and riparian zone/floodplain contributions are the likely stressors, presented in descending order of significance.

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Site	*Description*	*Sample Date*	*E. coli concentration (cfu / 100 ml)*	*Flow (CFS)*	*Percent Flows exceeding*	*Flow Category*	*Load (G-orgs / day)*
LCLCR226.31	Little Colorado River near Woodruff, AZ	9/8/2010	4,884	669	1.4%	1	79,920.51
LCLCR226.31	Little Colorado River near Woodruff, AZ	8/6/2010	5,794	198	5.9%	1	28,060.81
LCLCR226.31	Little Colorado River near Woodruff, AZ	8/14/2000	57,000	115	8.9%	1	160,335.30
LCLCR226.31	Little Colorado River near Woodruff, AZ	8/6/2001	1,800	104	9.6%	1	4,578.91
LCLCR226.31	Little Colorado River near Woodruff, AZ	8/7/2008	4,611	56	14.1%	2	6,315.96
LCLCR226.31	Little Colorado River near Woodruff, AZ	8/12/2003	260	18	26.4%	2	114.47
LCLCR226.31	Little Colorado River near Woodruff, AZ	9/7/2009	6,131	13	32.3%	2	1,949.54
LCLCR226.31	Little Colorado River near Woodruff, AZ	8/7/2003	833*	4.8	60.3%	4*	97.80
LCLCR226.31	Little Colorado River near Woodruff, AZ	2/22/1996	300*	1.65	82.9%	4*	12.11
LCLCR232.24	Little Colorado River below Mexican Hollow Wash	9/8/2010	3,873	490	N.A.	1**	46,419.45
LCLCR232.24	Little Colorado River below Mexican Hollow Wash	8/6/2010	12,033	162	N.A.	1**	47,681.40
LCLCR232.24	Little Colorado River below Mexican Hollow Wash	9/7/2009	46,110	23	N.A.	2**	25,940.56
LCLCR232.24	Little Colorado River below Mexican Hollow Wash	8/7/2008	1,607	15	N.A.	2**	589.61
LCSIL000.06	Silver Creek above LCR Confluence	9/8/2010	4,884	246	N.A.	1**	29,387.81

* - Category data met TMDL targets; category not used to calculate reductions
** - Associated with Woodruff flow categories of the same date

Table 9. *E. coli* exceedances and loads in TMDL analysis

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Reach 15020002-004: Little Colorado River, Silver Creek - Carr Lake Draw
TMDL calculations, Single Sample Maximums, G-org/day

		Category 1	*Category 2*	*Category 3*	*Category 4*	*Category 5*
	90th percentile values	*High Flows*	*Moist Conditions*	*Mid-Range Flows*	*Dry Conditions*	*Low Flows*
Cumulative	Reach 15020002-004 Single Sample Maximum					
	TMDL (G-org/day):	**1,351**	**109**	**36.8**	**16.1**	**2.30** $
	Margin of Safety (12%)	162	13.1	4.4	1.9	0.28
	TMDL - MOS (G-org/day)	1,189	96	32.4	14.2	2.02
	Tier 1 - Critical Conditions	**Little Colorado and Silver Creek Hydrologic Inputs**				
	Natural Background*	63	5.1	1.7	0.8	0.11
	Waste Load Allocation	5.3	5.3	5.3	5.3	**
	Total Load Allocation	1120	85.5	25.3	8.1	1.92
	Silver Creek	528	40.3	11.9	3.8	0.90
	Urban areas in Silver Creek wshed^	55	4.2	1.3	0.40	0.09
	Little Colorado River Above Silver Creek	593	45.2	13.4	4.3	1.01
	Urban area in LCR subwshed^	2.5	0.19	0.06	0.02	0.004
#	**Sum**	1,189	96	32.4	14.2	2.02
	Tier 2 - Non-critical Conditions	**Silver Creek Only Hydrologic Input**				
	Natural Background*	63	5.1	1.7	0.8	0.11
	Waste Load Allocation	5.3	5.3	5.3	5.3	**
	Silver Creek	1,120	85.5	25.3	8.1	1.92
	Urban areas in Silver Creek wshed^	118	9.0	2.7	0.9	0.20
#	**Sum**	1,189	96	32.4	14.2	2.02

* Natural backgrounds are percentage extrapolations from TMDL values. NB percentage 0.0532 of SSM standard.
$ - Low flow category uses 92.5 percentile flow to determine target values; Flow class extends only to the 95th percentile before discharge is 0.
** - Concentration based WLA for Snowflake WWTP in Class 5. See discussion in Section 8.3.
# - Due to rounding, elements of summation may not equal summed value.
^ - Values for these line items are not a part of TMDL summations. Values are presented as portions of subwatershed load allocations.

Table 10. 15020002-004 TMDL Targets, Load Allocations, and Waste Load Allocations.

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Reach 15020002-004: Little Colorado, Silver Creek to Carr Lake Draw
Single Sample Maximums, G-org/day

TMDL Cumulative Reductions	*Category 1*	*Category 2*	*Category 3*	*Category 4*	*Category 5*
TMDL 90th Percentile E. coli Target Values	*High Flows*	*Moist Conditions*	*Mid-Range Flows*	*Dry Conditions*	*Low Flows*
Reach 15020002-004 Target TMDL	1351	109	36.8	16.1	2.3$
Margin of Safety	12%	12%	12%	12%	12%
Reach 15020002-004 Existing	**128,169**	**5,006**	**5.21**	**6.12**	**1.32**
Reach 15020002-004 TMDL-MOS	1,189	96	32.4	14.2	2.02
Load Allocations	**1,120**	**85.5**	**25.3**	**8.1**	**1.92**
Waste Load Allocation	5.3	5.3	5.3	5.3	**
Natural Background *	63	5.1	1.7	0.8	0.11
Load Allocation Reductions Needed	**99.1%**	**98.3%**	**Meets**	**Meets**	**Meets**
## Cumulative Reductions Needed	98.9%	97.8%	Meets	Meets	Meets
TMDL Reduction Calculations, 90th percentile G-org/day					
Tier 1: Critical Conditions Analysis					
LCR, Silver Creek to Lyman Lake Dam Existing	47,672 ^	23,405 ^	--	--	--
LCR, Silver Creek to Lyman Lake Dam L.A.	593	45	--	--	--
Waste Load Allocation	0	0	--	--	--
Reductions Needed	**98.8%** ^	**99.8%** ^	--	--	--
Silver Creek above LCR confluence Existing	26,510 ^	91 ^	--	--	--
Silver Creek above LCR confluence L.A.	528	40	--	--	--
Waste Load Allocation	5.3	5.3	--	--	--
Reductions Needed	**98.0%** ^	**55.8%** ^	--	--	--
LCR, Silver Creek - Carr Lake Draw Existing	**See cumulative values above**		--	--	--
LCR, Silver Creek - Carr Lake Draw L.A.	Implicit#	Implicit#	--	--	--
Waste Load Allocation	0	0	--	--	--
Reductions Needed	**See cumulative values above**		--	--	--

-LCR SC-CLD subwatershed comprises only 0.56% of total watershed area. Additional 2% added to MOS to account for this subwatershed.
Reductions for entire watershed are cumulative reductions; reductions for subwatershed cannot be abstracted from flow and load data.
* Natural backgrounds are percentage extrapolations from TMDL values. NB percentage 0.0532 of SSM standard.
$ - Low flow category uses 92.5 percentile flow to determine target values; Flow class extends only to the 95th percentile before discharge is 0.
** - Concentration based WLA for WWTP in Class 5. See discussion in Section 8.3. ^ Provisional reduction - fewer than four data points

Table 11. Critical Conditions Reduction Determinations

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Reach 15020002-004: Little Colorado, Silver Creek to Carr Lake Draw
TMDL Reduction Calculations, 90th percentile
Single Sample Maximums, G-org/day

Tier 2: Non-Critical Conditions Analysis	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
Reach 15020002-004 TMDL-MOS	**1,189**	**96**	**32.4**	**14.2**	**2.02**
Silver Creek above LCR confluence Existing	**10.4**	**57.5**	--	--	--
Silver Creek above LCR confluence LA	1,120	85.5	--	--	--
Waste Load Allocation	5.3	5.3	--	--	--
Reductions Needed	*	*	--	--	--
LCR, Silver Creek - Carr Lake Draw Existing	**See cumulative values above**		--	--	--
LCR, Silver Creek - Carr Lake Draw LA	Implicit#	Implicit#	--	--	--
Waste Load Allocation	0	0	--	--	--
Reductions Needed	**See cumulative values above**		--	--	--

* - Inconclusive. Insufficient data to determine 90th percentile value;
Provisionally meets TMDL - Snowmelt events with *E. coli* concentrations not approaching SSM.
-LCR SC-CLD subwatershed comprises only 0.56% of total watershed area. Additional 2% added to MOS to account for this subwatershed.

Table 12. Non-critical Conditions Reduction Determination

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Reach 15020002-004: Little Colorado River, Silver Creek - Carr Lake Draw
TMDL calculations, Single Sample Maximums Reductions Summary

Reductions Needed:		*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
	## Reach 15020002-004	**98.9%**	**97.8%**	**Meets**	**Meets**	**Meets**
Tier 1	Silver Creek	**98.0%** *	**55.8%** *	--	--	--
	Little Colorado River Above Silver Creel	**98.8%** *	**99.8%** *	--	--	--
Tier 2	Silver Creek	**INC.**	**INC.**	--	--	--

INC - Inconclusive. Insufficient samples to determine 90th percentile for evaluation in flow class. SSM WQ Std not exceeded for these events.
Reductions for entire watershed are cumulative reductions; reductions for subwatershed cannot be abstracted from flow and load data.
* Item represents evaluation made on provisional basis with less than 4 samples to assess. See Table 11.

Table 13. TMDL Reductions Summary

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Reach 15020002-004: Little Colorado River, Silver Creek - Carr Lake Draw
Numbers of samples used in analysis

Reductions Needed:	*Category 1 High Flows*	*Category 2 Moist Conditions*	*Category 3 Mid-Range Flows*	*Category 4 Dry Conditions*	*Category 5 Low Flows*
	n	**n**	**n**	**n**	**n**
Reach 15020002-004	6	4	6	17	7
Tier 1: Critical Conditions					
Silver Creek	2	2	--	--	--
Little Colorado River Above Silver Cree	2	2	--	--	--
Tier 2: Non-critical Conditions					
Silver Creek	1	1	--	--	--

Classes with n's < 4 should be considered provisional reductions.
Numbers of samples not presented where impaired reach flow class is already attaining TMDL target.

Table 14. Numbers of samples used in TMDL analysis

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9.0 IMPLEMENTATION PLAN

A basin as large as the LCR watershed, consisting of more than 8000 square miles above the USGS gauge site 09394500 near Woodruff and presenting multi-state jurisdictional issues, poses special challenges in the development of a TMDL implementation plan. Actual on-the-ground improvements in water quality will rely upon the voluntary initiative and actions of stakeholder groups and interested individuals employing standard BMPs at a local scale throughout the entire watershed. The scope of the cumulative problem is large enough that ongoing cooperation amongst many stakeholders working within the framework of this TMDL will be necessary to effect long-term improvements over several years. Water quality improvement for the LCR will ultimately come in incremental steps from many different directions and many different benefactors. Consequently, this implementation plan consists of providing a general framework in this TMDL for addressing the problem with broad-brush guidance. More focused and region-specific recommendations and guidance for the implementation of more specific improvement measures on a sub-basin scale will be provided as stakeholders and interested parties come forward with proposals.

Sample results and TMDL calculations indicate that the critical conditions causing *E. coli* exceedances in the LCR watershed are related to stormflow conditions causing elevated flows for the Silver Creek subwatershed and creating flows in the intermittent LCR channel above Silver Creek. Much of the excess loading is coming from the LCR subwatershed, where development is minimal and a mix of federal, State Trust, and private lands predominates. Broad scale and landscape-wide best management practices (BMPs) directed towards protecting water quality in these rural areas hold the most promise for mitigating *E. coli* impacts seen at Woodruff. General classes of activity identified for special consideration in the implementation plan include grazing and livestock management, urban stormwater runoff, and agricultural practices to reduce erosion and sediment transport.

For the purposes of implementation and effectiveness evaluations, stakeholders engaged in monitoring activities are encouraged to consider and evaluate monitoring results in terms of concentrations as stated in the Arizona water quality standards. As with permittees' monitoring under MSGP and CGP coverage, *E. coli* densities that meet Arizona's water quality concentration-based criteria will be considered consistent with the provisions governing the remainder of this TMDL. The State's 2009 *E. coli* standard, with a single sample maximum value of 235 cfu/100 ml and a 30 day averaging period for a geomean value of 126 cfu/100 ml is in effect for assessment of results. ADEQ encourages stakeholders to comply if possible with the monitoring requirements of the geometric mean portion of the standard with its 30 day time frame, but recognizes that in meeting the requirements of the averaging period, particular difficulties are posed, with a narrow margin of sampling time discretion available to both establish a set of minimum size four with independence of all samples in the set (samples separated by at least a seven day interval) and to meet the time limit of 30 days for the complete collection of a set. ADEQ anticipates most monitoring results from stakeholders will be evaluated under the single sample maximum provision of the standard.

Where geomean assessment cannot be reasonably performed, it is recommended that sites be sampled for *E. coli* densities quarterly at a minimum in hydrologic conditions that represent all

parts of the flow regime, including stormflow, snowmelt, and baseflow conditions, as well as in the irrigation diversion season and outside of it.

Follow-up sampling for TMDL effectiveness monitoring will depend in part on knowledge of local antecedent moisture conditions and in-field observations for both Silver Creek and the LCR above Silver Creek to determine which class of conditions is applicable to the evaluation of sampling results.

9.1 Grazing Management BMPs and Improvements

The EPA's Management Measures for NPS Pollution Manual (U.S. EPA, 1993a) offers a generally comprehensive menu of actions and best management practices applicable for grazing and livestock management to reduce the impacts of *E. coli* loading. Measures suggested include the following:

- Provide stream crossings or hardened watering access for drinking
- Provide alternative drinking water locations
- Locate salt and additional shade, if needed, away from sensitive areas, or
- Use improved grazing management (e.g., herding, rotation and rest grazing strategies) to reduce the physical disturbance and reduce direct loading of animal waste and sediment caused by livestock
- Prescribed or rotational use of riparian zones and watercourses where necessary

Excerpts from the NPS Pollution Manual pertaining to grazing are presented in Appendix B.

9.2 Urban Stormwater Runoff

Urban stormflow run-off is likely a contributing factor to excessive *E. coli* loading from the towns of Taylor, Snowflake, and Show Low. Pinetop-Lakeside may also contribute to problems in the largest hydrologic events. Urban stormflow BMPs hold promise for the amelioration of excessive *E. coli* loading originating in the Silver Creek watershed. Excerpts from EPA's Management Measures for NPS Pollution Manual with suggestions for broad scale BMPs applicable for urban stormwater mitigation to reduce the impacts of *E. coli* loading are presented in Appendix C. For the purposes of this implementation plan, urban stormwater will be treated in three separate classifications: existing development measures, septic systems, and pet waste.

Existing development measures to improve the quality of stormwater discharges include the following:

- Identify priority local and/or regional watershed pollutant reduction opportunities, e.g., improvements to existing urban runoff control structures;
- Contain a schedule for implementing appropriate controls;
- Limit destruction of natural conveyance systems; and
- Where appropriate, preserve, enhance, or establish buffers along surface waterbodies and their tributaries.

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Additional pollution prevention measures from the EPA National Management Measures manual in Appendix C address septic systems, a specific pollution source that pertains directly to pathogen impairments. Briefly, septic system best management practices include the following:

- Regular maintenance and pumping of systems,
- Siting in areas where soils are relatively permeable for infiltration from leach fields and removed from floodplains and influence from ephemeral drainages,
- Replacement of failing systems,
- Education of residents as to proper waste disposal practices (i.e., prohibition of chemicals from septic systems),
- Adequate sizing for households at construction,
- Prevention of overuse, and
- Other measures.

See Appendix C for further information.

Pet waste can be a sizable and generally publicly unrecognized contributor to urban *E. coli* loading of stormwater. Additional urban pollution prevention measures from the EPA National Management Measures manual address pet waste, a specific pollution source in developed and urban areas that pertains directly to pathogen impairments. Appendix D presents additional information pertaining to practices that can minimize the influence of pet waste on urban stormwater runoff.

9.3 Agricultural Best Management Practices

Though agriculture is limited in the LCR basin above Woodruff, the possibilities exist for nonpoint source *E. coli* loading from agricultural practices, particularly where manure is used as fertilizer on crops. Though most BMPs for agricultural practices are focused on the primary objective of reducing erosion and sediment transport, they have the secondary effect of helping to reduce *E. coli* loads transported to waterways by slowing runoff and allowing for infiltration. A high degree of correlation has been noted in Arizona between sediment loads and *E. coli* loads in historic water quality sampling; thus, there is a sound basis for adopting selected sediment control measures as BMPs to help reduce *E. coli* loading. Excerpts from EPA's *Management Measures for NPS Pollution* Manual with suggestions for broad scale BMPs applicable for agriculture to reduce the impacts of erosion and consequent *E. coli* loading are presented in Appendix D.

10.0 PUBLIC PARTICIPATION

Stakeholder and public participation was encouraged and received throughout the development of this TMDL. ADEQ held two public meetings in Holbrook, Ariz. to introduce the LCR TMDL project and subsequently to present findings and results after sampling and analysis was complete. Stakeholders and interested parties contacted throughout the project timeline included the Town of Taylor, Town of Pinetop-Lakeside, Navajo County, Natural Resource Conservation Service, Arizona Game and Fish, and Arizona NEMO. Public comment was invited for a 45 day

period after the TMDL was submitted to the Arizona Administrative Review. Copies of the final TMDL will be provided to land management agencies including the A-S NF, and the Bureau of Land Management.

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Appendix A - Summary of Listing Data

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SUMMARY OF LISTING DATA

Site ID	DEQ #	Date	Hardness (mg/l)	Flow (cfs)	Turbidity (NTUs)	TDS (mg/l)	TSS (mg/l)	*E. coli* (cfu/100mL)	Fecal Coliform (cfu/100mL)
LCLCR226.31	100334	3/27/2000	210	2.3	75.6	310	30	ND	ND
LCLCR226.31	100334	8/14/2000	630	115	12000	--	28000	**57,000**	**28,000**
LCLCR226.31	100334	12/19/2000	290	2.75	74.7	360	45	2	2
LCLCR226.31	100334	3/13/2001	240	2.3	138	350	26	ND	ND
LCLCR226.31	100334	5/21/2001	130	0.77	58	860	--	40	ND
LCLCR226.31	100334	8/6/2001	660	104	720	1600	7000	**1,800**	**3,500**
LCLCR226.31	100334	11/29/2001	210	1.6	95	330	37	22	33
LCLCR226.31	100334	3/20/2002	230	0.14	54.9	320	43	2	8
LCLCR226.31	100334	10/1/2002	135	0.7	184	320	ND	44	--
LCLCR226.31	100334	1/9/2003	200	4.8	39.1	730	15	6	--
LCLCR226.31	100334	4/1/2003	150	0.85	250	260	120	ND	--
LCLCR226.31	100334	8/7/2003	220	4.8	1000	240	600	**833**	--
LCLCR226.31	100334	8/12/2003	200	18	>1000	320	360	260	--
LCLCR226.31	100334	9/24/2003	170	1.75	245	260	99	18	--
LCLCR226.31	100334	12/28/2004	260	1.4	36	380	25	ND	--
LCLCR226.31	100334	3/23/2005	140	2.7	46.6	240	32	9.9	--

Sample results from 2001 for sample sites in the listed reach
BOLD=Sample exceeded water quality standards

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Appendix B – Grazing Management BMPs
Excerpts from EPA's Management Measures for NPS Pollution Manual

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GRAZING MANAGEMENT

Protect range, pasture and other grazing lands:

By implementing one or more of the following to protect sensitive areas (such as streambanks, wetlands, estuaries, ponds, lake shores, and riparian zones):

- Exclude livestock,
- Provide stream crossings or hardened watering access for drinking,
- Provide alternative drinking water locations,
- Locate salt and additional shade, if needed, away from sensitive areas, or
- Use improved grazing management (e.g., herding) to reduce the physical disturbance and reduce direct loading of animal waste and sediment caused by livestock; and

By achieving either of the following on all range, pasture, and other grazing lands not addressed under (1):

- Implement the range and pasture components of a Conservation Management System (CMS) as defined in the Field Office Technical Guide of the USDA-SCS (see Appendix 2A of this chapter) by applying the progressive planning approach of the USDA-Soil Conservation Service (SCS) to reduce erosion, or
- Maintain range, pasture, and other grazing lands in accordance with activity plans established by either the Bureau of Land Management of the U.S. Department of the Interior or the Forest Service of USDA.

1. Applicability

The management measure is intended to be applied by States to activities on range, irrigated and nonirrigated pasture, and other grazing lands used by domestic livestock.

[EPA discussion continues; excerpt resumed below…]

Range is those lands on which the native vegetation (climax or natural potential plant community) is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing use. Range includes natural grassland, savannas, many wetlands, some deserts, tundra, and certain forb and shrub communities. Pastures are those lands that are primarily used for the production of adapted, domesticated forage plants for livestock. Other grazing lands include woodlands, native pastures, and croplands producing forages.

The major differences between range and pasture are the kind of vegetation and level of management that each land area receives. In most cases, range supports native vegetation that is extensively managed through the control of livestock rather than by agronomy practices, such as fertilization, mowing, irrigation, etc. Range also includes areas that have been seeded to introduced species (e.g., crested wheatgrass), but

which are extensively managed like native range. Pastures are represented by those lands that have been seeded, usually to introduced species (e.g., tall fescue) or in some cases to native plants (e.g., switchgrass), and which are intensively managed using agronomy practices and control of livestock.

2. Description

The focus of the grazing management measure is on the riparian zone, yet the control of erosion from range, pasture, and other grazing lands above the riparian zone is also encouraged. Application of this management measure will reduce the physical disturbance to sensitive areas and reduce the discharge of sediment, animal waste, nutrients, and chemicals to surface waters. For information regarding potential problems caused by grazing, see Sections I.F.2 and I.F.6 of this chapter.

The key options to consider (all are not required by this management measure) when developing a comprehensive grazing management approach at a particular location include the development of one or more of the following:

Grazing management systems. These systems ensure proper grazing use through:

- Grazing frequency (includes complete rest);
- Livestock stocking rates;
- Livestock distribution;
- Timing (season of forage use) and duration of each rest and grazing period;
- Livestock kind and class; and
- Forage use allocation for livestock and wildlife.
- Proper water and salt supplement facilities.
- Livestock access control.
- Range or pasture rehabilitation.

For any grazing management system to work, it must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, and particular operation involved. For both pasture and range, areas should be provided for livestock watering, salting, and shade that are located away from streambanks and riparian zones where necessary and practical. This will be accomplished by managing livestock grazing and providing facilities for water, salt, and shade as needed. Special attention must be given to grazing management in riparian and wetland areas if management measure objectives are to be met. For purposes of this guidance, riparian areas are defined (Mitsch and Gosselink, 1986; Lowrance et al., 1988) as:

Vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent waterbody. The health of the riparian system, and thus the quality of water, is dependent on the use, management, and condition of the related uplands. Therefore, the proper management of riparian

and wetland ecosystems will involve the correct management of livestock grazing and other land uses in the total watershed.

Conservation management systems (CMS) include any combination of conservation practices and management that achieves a level of treatment of the five natural resources (i.e., soil, water, air, plants, and animals) that satisfies criteria contained in the Soil Conservation Service (SCS) Field Office Technical Guide (FOTG), such as a resource management system (RMS) or an acceptable management system (AMS). These criteria are developed at the State level, with concurrence by the appropriate SCS National Technical Center (NTC). The criteria are then applied in the provision of field office technical assistance, under the direction of the District Conservationist of SCS. In-state coordination of FOTG use is provided by the Area Conservationist and State Conservationist of SCS.

The range and pasture components of a CMS address erosion control, proper grazing, adequate pasture stand density, and range condition. National (minimum) criteria pertaining to range and pasture under an RMS are applied to achieve environmental objectives, conserve natural resources, and prevent soil degradation.

[EPA discussion continues; excerpt resumed below…]

3. Management Measure Selection

This management measure was selected based on an evaluation of available information that documents the beneficial effects of improved grazing management (see "Effectiveness Information" below). Specifically, the available information shows that (1) aquatic habitat conditions are improved with proper livestock management; (2) pollution from livestock is decreased by reducing the amount of time spent in the stream through the provision of supplemental water; and (3) sediment delivery is reduced through the proper use of vegetation, streambank protection, planned grazing systems, and livestock management.

4. Effectiveness Information

…Miner et al. (1991) showed that the provision of supplemental water facilities reduced the time each cow spent in the stream within 4 hours of feeding from 14.5 minutes to 0.17 minutes (8-day average). This pasture study in Oregon showed that the 90 cows without supplemental water spent a daily average of 25.6 minutes per cow in the stream. For the 60 cows that were provided a supplemental water tank, the average daily time in the stream was 1.6 minutes per cow, while 11.6 minutes were spent at the water tank. Based on this study, the authors expect that decreased time spent in the stream will decrease bacterial loading from the cows.

Tiedemann et al. (1988) studied the effects of four grazing strategies on bacteria levels in 13 Oregon watersheds in the summer of 1984. Results indicate that lower fecal coliform levels can be achieved at stocking rates of about 20 ac/AUM if

management for livestock distribution, fencing, and water developments are used. The study also indicates that, even with various management practices, the highest fecal coliform levels were associated with the higher stocking rates (6.9 ac/AUM) employed in strategy D.

[EPA discussion continues; excerpt resumed below…]

5. Range and Pasture Management Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.The U.S. Soil Conservation Service practice number and definition are provided for each management practice, where available. Also included in italics are SCS statements describing the effect each practice has on water quality (USDA-SCS, 1988.)

Grazing Management System Practices

Appropriate grazing management systems ensure proper grazing use by adjusting grazing intensity and duration to reflect the availability of forage and feed designated for livestock uses, and by controlling animal movement through the operating unit of range or pasture. Proper grazing use will maintain enough live vegetation and litter cover to protect the soil from erosion; will achieve riparian and other resource objectives; and will maintain or improve the quality, quantity, and age distribution of desirable vegetation. Practices that accomplish this are:

a. *Deferred grazing (352): Postponing grazing or resting grazing land for prescribed period.*

In areas with bare ground or low percent ground cover, deferred grazing will reduce sediment yield because of increased ground cover, less ground surface disturbance, improved soil bulk density characteristics, and greater infiltration rates. Areas mechanically treated will have less sediment yield when deferred to encourage re-vegetation. Animal waste would not be available to the area during the time of deferred grazing and there would be less opportunity for adverse runoff effects on surface or aquifer water quality. As vegetative cover increases, the filtering processes are enhanced, thus trapping more silt and nutrients as well as snow if climatic conditions for snow exist. Increased plant cover results in a greater uptake and utilization of plant nutrients.

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b. *Planned grazing system (556): A practice in which two or more grazing units are alternately rested and grazed in a planned sequence for a period of years, and rest periods may be throughout the year or during the growing season of key plants.*

Planned grazing systems normally reduce the system time livestock spend in each pasture. This increases quality and quantity of vegetation. As vegetation quality increases, fiber content in manure decreases which speeds manure decomposition and reduces pollution potential. Freeze-thaw, shrink-swell, and other natural soil mechanisms can reduce compacted layers during the absence of grazing animals. This increases infiltration, increases vegetative growth, slows runoff, and improves the nutrient and moisture filtering and trapping ability of the area.
Decreased runoff will reduce the rate of erosion and movement of sediment and dissolved and sediment-attached substances to downstream water courses. No increase in ground water pollution hazard would be anticipated from the use of this practice.

c. *Proper grazing use (528): Grazing at an intensity that will maintain enough cover to protect the soil and maintain or improve the quantity and quality of desirable vegetation.*

Increased vegetation slows runoff and acts as a sediment filter for sediments and sediment attached substances, uses more nutrients, and reduces raindrop splash. Adverse chemical effects should not be anticipated from the use of this practice.

d. *Proper woodland grazing (530): Grazing wooded areas at an intensity that will maintain adequate cover for soil protection and maintain or improve the quantity and quality of trees and forage vegetation.*

This practice is applicable on wooded areas producing a significant amount of forage that can be harvested without damage to other values. In these areas there should be no detrimental effects on the quality of surface and ground water. Any time this practice is applied there must be a detailed management and grazing plan.

[EPA discussion continues; excerpt resumed below…]

Alternate Water Supply Practices

Providing water and salt supplement facilities away from streams will help keep livestock away from streambanks and riparian zones. The establishment of alternate water supplies for livestock is an essential component of this measure when problems related to the distribution of livestock occur in a grazing unit. In most western states, securing water rights may be necessary. Access to a developed or natural water supply that is protective of streambank and riparian zones can be provided by using the stream crossing (interim) technology to build a watering site. In some locations, artificial shade may be constructed to encourage use of upland sites for shading and

loafing. Providing water can be accomplished through the following Soil Conservation Service practices and the stream crossing (interim) practice (practice "m") of the following section. Descriptions have been modified to meet CZM needs:

f. *Pipeline (516): Pipeline installed for conveying water for livestock or for recreation.*

Pipelines may decrease sediment, nutrient, organic, and bacteria pollution from livestock. Pipelines may afford the opportunity for alternative water sources other than streams and lakes, possibly keeping the animals away from the stream or impoundment. This will prevent bank destruction with resulting sedimentation, and will reduce animal waste deposition directly in the water. The reduction of concentrated livestock areas will reduce manure solids, nutrients, and bacteria that accompany surface runoff.

g. *Pond (378): A water impoundment made by constructing a dam or an embankment or by excavation of a pit or dugout.*

Ponds may trap nutrients and sediment which wash into the basin. This removes these substances from downstream. Chemical concentrations in the pond may be higher during the summer months. By reducing the amount of water that flows in the channel downstream, the frequency of flushing of the stream is reduced and there is a collection of substances held temporarily within the channel. A pond may cause more leachable substance to be carried into the ground water.

h. *Trough or tank (614): A trough or tank, with needed devices for water control and waste water disposal, installed to provide drinking water for livestock.*

By the installation of a trough or tank, livestock may be better distributed over the pasture, grazing can be better controlled, and surface runoff reduced, thus reducing erosion. By itself this practice will have only a minor effect on water quality; however when coupled with other conservation practices, the beneficial effects of the combined practices may be large. Each site and application should be evaluated on their own merits.

i. *Well (642): A well constructed or improved to provide water for irrigation, livestock, wildlife, or recreation.*

When water is obtained, if it has poor quality because of dissolved substances, its use in the surface environment or its discharge to downstream water courses the surface water will be degraded. The location of the well must consider the natural water quality and the hazards of its use in the potential contamination of the environment. Hazard exists during well development and its operation and maintenance to prevent aquifer quality damage from the pollutants through the well itself by back flushing, or accident, or flow down the annular spacing between the well casing and the bore hole.

j. *Spring development (574): Improving springs and seeps by excavating, cleaning, capping, or providing collection and storage facilities.*

There will be negligible long-term water quality impacts with spring developments. Erosion and sedimentation may occur from any disturbed areas during and immediately after construction, but should be short-lived. These sediments will have minor amounts of adsorbed nutrients from soil organic matter.

Livestock Access Limitation Practices

It may be necessary to minimize livestock access to streambanks, ponds or lakeshores, and riparian zones to protect these areas from physical disturbance. This could also be accomplished by establishing special use pastures to manage livestock in areas of concentration. Practices include:

k. *Fencing (382): Enclosing or dividing an area of land with a suitable permanent structure that acts as a barrier to livestock, big game, or people (does not include temporary fences).*

Fencing is a practice that can be on the contour or up and down slope. Often a fence line has grass and some shrubs in it. When a fence is built across the slope it will slow down runoff, and cause deposition of coarser grained materials reducing the amount of sediment delivered downslope. Fencing may protect riparian areas which act as sediment traps and filters along water channels and impoundments.

Livestock have a tendency to walk along fences. The paths become bare channels which concentrate and accelerate runoff causing a greater amount of erosion within the path and where the path/channel outlets into another channel. This can deliver more sediment and associated pollutants to surface waters. Fencing can have the effect of concentrating livestock in small areas, causing a concentration of manure which may wash off into the stream, thus causing surface water pollution.

l. *Livestock exclusion (472): Excluding livestock from an area not intended for grazing.*

Livestock exclusion may improve water quality by preventing livestock from being in the water or walking down the banks, and by preventing manure deposition in the stream. The amount of sediment and manure may be reduced in the surface water. This practice prevents compaction of the soil by livestock and prevents losses of vegetation and undergrowth. This may maintain or increase evapotranspiration. Increased permeability may reduce erosion and lower sediment and substance transportation to the surface waters. Shading along streams and channels resulting from the application of this practice may reduce surface water temperature.

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m. *Stream crossing (interim): A stabilized area to provide access across a stream for livestock and farm machinery.*

The purpose is to provide a controlled crossing or watering access point for livestock along with access for farm equipment, control bank and streambed erosion, reduce sediment and enhance water quality, and maintain or improve wildlife habitat.

[EPA discussion continues; excerpt resumed below…]

Selection of Practices

The selection of management practices for this measure should be based on an evaluation of current conditions, problems identified, quality criteria, and management goals. Successful resource management on range and pasture includes appropriate application of a combination of practices that will meet the needs of the range and pasture ecosystem (i.e., the soil, water, air, plant, and animal (including fish and shellfish) resources) and the objectives of the land user.

For a sound grazing land management system to function properly and to provide for a sustained level of productivity, the following should be considered:

- Know the key factors of plant species management, their growth habits, and their response to different seasons and degrees of use by various kinds and classes of livestock.
- Know the demand for, and seasons of use of, forage and browse by wildlife species.
- Know the amount of plant residue or grazing height that should be left to protect grazing land soils from wind and water erosion, provide for plant regrowth, and provide the riparian vegetation height desired to trap sediment or other pollutants.
- Know the range site production capabilities and the pasture suitability group capabilities so an initial stocking rate can be established.
- Know how to use livestock as a tool in the management of the range ecosystems and pastures to ensure the health and vigor of the plants, soil tilth, proper nutrient cycling, erosion control, and riparian area management, while at the same time meeting livestock nutritional requirements.
- Establish grazing unit sizes, watering, shade and salt locations, etc. to secure optimum livestock distribution and proper vegetation use.
- Provide for livestock herding, as needed, to protect sensitive areas from excessive use at critical times.
- Encourage proper wildlife harvesting to ensure proper population densities and forage balances.
- Know the livestock diet requirements in terms of quantity and quality to ensure that there are enough grazing units to provide adequate livestock nutrition for the season and the kind and classes of animals on the farm/ranch.

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- Maintain a flexible grazing system to adjust for unexpected environmentally and economically generated problems.

[EPA excerpts concluded]

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Appendix C – Urban Stormwater Runoff BMPs
Excerpts from EPA's Management Measures for NPS Pollution Manual

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Part A. Existing Development Management

Develop and implement watershed management programs to reduce runoff pollutant concentrations and volumes from existing development:

- Identify priority local and/or regional watershed pollutant reduction opportunities, e.g., improvements to existing urban runoff control structures;
- Contain a schedule for implementing appropriate controls;
- Limit destruction of natural conveyance systems; and
- Where appropriate, preserve, enhance, or establish buffers along surface waterbodies and their tributaries.

1. Applicability

This management measure is intended to be applied by States to all urban areas and existing development in order to reduce surface water runoff pollutant loadings from such areas. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA).

2. Description

The purpose of this management measure is to protect or improve surface water quality by the development and implementation of watershed management programs that pursue the following objectives:

1. Reduce surface water runoff pollution loadings from areas where development has already occurred;
2. Limit surface water runoff volumes in order to minimize sediment loadings resulting from the erosion of streambanks and other natural conveyance systems; and
3. Preserve, enhance, or establish buffers that provide water quality benefits along waterbodies and their tributaries.

Maintenance of water quality becomes increasingly difficult as areas of impervious surface increase and urbanization occurs. For the purpose of this guidance, urbanized areas are those areas where the presence of "man-made" impervious surfaces results in increased peak runoff volumes and pollutant loadings that permanently alter one or more of the following: stream channels, natural drainageways, and in-stream and adjacent riparian habitat so that predevelopment aquatic flora and fauna are eliminated or reduced to unsustainable levels and predevelopment water quality has been degraded. Increased bank cutting, streambed scouring, siltation damaging to

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aquatic flora and fauna, increases in water temperature, decreases in dissolved oxygen, changes to the natural structure and flow of the stream or river, and the presence of anthropogenic pollutants that are not generated from agricultural activities, in general, are indications of urbanization.

The effects of urbanization have been well described in the introduction to this chapter. Protection of water quality in urbanized areas is difficult because of a range of factors. These factors include diverse pollutant loadings, large runoff volumes, limited areas suitable for surface water runoff treatment systems, high implementation costs associated with structural controls, and the destruction or absence of buffer zones that can filter pollutants and prevent the destabilization of streambanks and shorelines.

As discussed in Section II.B of this chapter, comprehensive watershed planning facilitates integration of source reduction activities and treatment strategies to mitigate the effects of urban runoff. Through the use of watershed management, States and local governments can identify local water quality objectives and focus resources on control of specific pollutants and sources. Watershed plans typically incorporate a combination of nonstructural and structural practices.

An important nonstructural component of many watershed management plans is the identification and preservation of buffers and natural systems. These areas help to maintain and improve surface water quality by filtering and infiltrating urban runoff. In areas of existing development, natural buffers and conveyance systems may have been altered as urbanization occurred. Where possible and appropriate, additional impacts to these areas should be minimized and if degraded, the functions of these areas restored. The preservation, enhancement, or establishment of buffers along waterbodies is generally recommended throughout the section 6217 management area as an important tool for reducing NPS impacts. The establishment and protection of buffers, however, is most appropriate along surface waterbodies and their tributaries where water quality and the biological integrity of the waterbody is dependent on the presence of an adequate buffer/riparian area. Buffers may be necessary where the buffer/riparian area (1) reduces significant NPS pollutant loadings, (2) provides habitat necessary to maintain the biological integrity of the receiving water, and (3) reduces undesirable thermal impacts to the waterbody. ….

Institutional controls, such as permits, inspection, and operation and maintenance requirements, are also essential components of a watershed management program. The effectiveness of many of the practices described in this chapter is dependent on administrative controls such as inspections. Without effective compliance mechanisms and operation and maintenance requirements, many of these practices will not perform satisfactorily.

Where existing development precludes the use of effective nonstructural controls, structural practices may be the only suitable option to decrease the NPS pollution loads generated from developed areas. In such situations, a watershed plan can be

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used to integrate the construction of new surface water runoff treatment structures and the retrofit of existing surface water runoff management systems.

Retrofitting is a process that involves the modification of existing surface water runoff control structures or surface water runoff conveyance systems, which were initially designed to control flooding, not to serve a water quality improvement function. By enlarging existing surface water runoff structures, changing the inflow and outflow characteristics of the device, and increasing detention times of the runoff, sediment and associated pollutants can be removed from the runoff. Retrofit of structural controls, however, is often the only feasible alternative for improving water quality in developed areas. Where the presence of existing development or financial constraints limits treatment options, targeting may be necessary to identify priority pollutants and select the most appropriate retrofits.

Once key pollutants have been identified, an achievable water quality target for the receiving water should be set to improve current levels based on an identified objective or to prevent degradation of current water quality. Extensive site evaluations should then be performed to assess the performance of existing surface water runoff management systems and to pinpoint low-cost structural changes or maintenance programs for improving pollutant-removal efficiency. Where flooding problems exist, water quality controls should be incorporated into the design of surface water runoff controls. Available land area is often limited in urban areas, and the lack of suitable areas will frequently restrict the use of conventional pond systems. In heavily urbanized areas, sand filters or water quality inlets with oil/grit separators may be appropriate for retrofits because they do not limit land usage.

3. Management Measure Selection

Components (1) and (2) of this management measure were selected so that local communities develop and implement watershed management programs. Watershed management programs are used throughout the 6217 management area although coverage is inconsistent among States and local governments (Puget Sound Water Quality Authority, 1986).

Local conditions, availability of funding, and problem pollutants vary widely in developed communities. Watershed management programs allow these communities to select and implement practices that best address local needs. The identification of priority and/or local regional pollutant reduction opportunities and schedules for implementing appropriate controls were selected as logical starting points in the process of instituting an institutional framework to address nonpoint source pollutant reductions.

Cost was also a major factor in the selection of this management measure. EPA acknowledges the high costs and other limitations inherent in treating existing sources to levels consistent with the standards set for developing areas. Suitable areas are often unavailable for structural treatment systems that can adequately protect receiving waters. The lack of universal cost-effective treatment options was a major

factor in the selection of this management measure. EPA was also influenced by the frequent lack of funding for mandatory retrofitting and the extraordinarily high costs associated with the implementation of retention ponds and exfiltration systems in developed areas.

The use of retrofits has been encouraged because of proven water quality benefits. … Retrofits are currently being used by a number of States and local governments in the 6217 management area, including Maryland, Delaware, and South Carolina. Management measure components (3) and (4) were selected to preserve, enhance, and establish areas within existing development that provide positive water quality benefits. Refer to the New Development and Site Planning Management Measures for the rationale used in selecting components (3) and (4) of this management measure.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

a. Priority NPS pollutants should be targeted, and implementation strategies for mitigating the effects of NPS pollutants should be developed.
b. Policies, plans, and organizational structures that ensure that all surface water runoff management facilities are properly operated and maintained should be developed. Periodic monitoring and maintenance may be necessary to ensure proper operation and maintenance.
c. Remnant pervious areas in already-built areas should be subject to enforceable preservation requirements. For example, set green space goals to promote tree plantings and pavement reclamation projects.
d. Developed areas in need of local or regional structural solutions should be identified and put in priority order.
e. Regional structural solutions, retrofit opportunities, and nonstructural alternatives should be identified, inventoried, and put in priority order.
f. Where possible, modify existing surface water runoff management structures to address water quality.
g. As capital resources allow, implement [appropriate] practices.

[EPA discussion continues; excerpt resumed below…]

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Part B. Septic Systems and Pet Waste

B.1. Failing septic systems

Approximately one in four American households relies on a septic system to dispose of their wastewater. Septic systems have a failure rate of 5 to 35 percent, depending on soil conditions and other factors. When septic systems fail, the untreated or partially treated wastewater discharges to surface and ground waters. A survey conducted in the Chesapeake Bay watershed found that the average age of septic systems in the area was about 27 years, which is seven years beyond the design life of an unmaintained system. About half the owners indicated that they had not inspected or cleaned out their system in the previous three years (Schueler and Swann, 2000b).

B.2. Pet wastes

When pet waste is not properly disposed of, it can wash into nearby water bodies or be carried by runoff into storm drains. Since most urban storm drains do not connect to treatment facilities, but rather drain directly into lakes and streams, untreated animal waste can become a significant source of runoff pollution. As pet waste decays in a water body, the degradation process uses oxygen and sometimes releases ammonia. Low oxygen levels and the presence of ammonia, combined with warm temperatures, can be toxic to fish and aquatic life. Pet waste also contains nutrients that promote weed and algae growth. Perhaps most importantly, pet waste carries microbes, such as bacteria, viruses, and parasites, that can pose a health risk to humans and wildlife. For example, fatalities in sea otters off the coast of California have been traced to a protozoan, *Toxoplasma gondii*, found in cat feces. *T. gondii* can cause fatal brain infections in otters and muscle cysts in humans (Glausiusz, 2002). Pet waste can be controlled through enforcement of ordinances (e.g., warnings and citations, public education, signage, and disposal containers).

Proper disposal of pet waste

Pet owners have several options for properly managing pet waste. Collecting the waste and flushing it down the toilet, where it can be treated by a sewage treatment facility or septic tank is the preferred method. Small quantities can also be buried in the yard (when ground water is not used in the home), where the waste can decompose slowly. When buried, the waste should be at least 5 inches below the ground surface and away from water bodies and vegetable gardens. In public areas, the waste can be sealed in a plastic bag and thrown in the trash, which is legal in most areas (Water Quality Consortium, 1999).

Many communities implement pet waste management programs by posting signs in parks or other areas frequented by pet owners, sending mailings, and making public service announcements. Many communities have “pooper scooper” ordinances that govern pet waste clean-up. Some of these laws specifically require anyone who takes an animal off his or her property to carry a bag, shovel, or scoop. Any waste left by the animal must be cleaned up immediately (Hill and Johnson, 1994). In addition to postings, many communities have installed “pet waste stations” in popular dog parks. These stations contain waste receptacles as well as a supply of waste collection bags, scoops, and shovels. *[EPA excerpts concluded]*

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Appendix D – Agricultural Erosion and Sediment Control BMPs
Excerpts from EPA's Management Measures for NPS Pollution Manual

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Erosion and Sediment Control Management Measure

Combinations of the following practices can be used to satisfy the requirements of this management measure. The SCS practice number and definitions are provided for each management practice, where available. Also included in italics are SCS statements describing the effect each practice has on water quality (USDA-SCS, 1988).

a. Conservation cover (327): Establishing and maintaining perennial vegetative cover to protect soil and water resources on land retired from agricultural production.

Agricultural chemicals are usually not applied to this cover in large quantities and surface and ground water quality may improve where these material are not used. Ground cover and crop residue will be increased with this practice. Erosion and yields of sediment and sediment related stream pollutants should decrease. Temperatures of the soil surface runoff and receiving water may be reduced. Effects will vary during the establishment period and include increases in runoff, erosion and sediment yield. Due to the reduction of deep percolation, the leaching of soluble material will be reduced, as will be the potential for causing saline seeps. Long-term effects of the practice would reduce agricultural nonpoint sources of pollution to all water resources.

b. Conservation cropping sequence (328): An adapted sequence of crops designed to provide adequate organic residue for maintenance or improvement of soil tilth.

This practice reduces erosion by increasing organic matter, resulting in a reduction of sediment and associated pollutants to surface waters. Crop rotations that improve soil tilth may also disrupt disease, insect and weed reproduction cycles, reducing the need for pesticides. This removes or reduces the availability of some pollutants in the watershed. Deep percolation may carry soluble nutrients and pesticides to the ground water. Underlying soil layers, rock and unconsolidated parent material may block, delay, or enhance the delivery of these pollutants to ground water. The fate of these pollutants will be site specific, depending on the crop management, the soil and geologic conditions.

c. Conservation tillage (329): Any tillage or planting system that maintains at least 30 percent of the soil surface covered by residue after planting to reduce soil erosion by water; or, where soil erosion by wind is the primary concern, maintains at least 1,000 pounds of flat, small-grain residue equivalent on the surface during the critical erosion period.

This practice reduces soil erosion, detachment and sediment transport by providing soil cover during critical times in the cropping cycle. Surface residues reduce soil compaction from raindrops, preventing soil sealing and increasing infiltration. This action may increase the leaching of agricultural chemicals into the ground water.

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In order to maintain the crop residue on the surface it is difficult to incorporate fertilizers and pesticides. This may increase the amount of these chemicals in the runoff and cause more surface water pollution.

The additional organic material on the surface may increase the bacterial action on and near the soil surface. This may tie-up and then breakdown many pesticides which are surface applied, resulting in less pesticide leaving the field. This practice is more effective in humid regions.

With a no-till operation the only soil disturbance is the planter shoe and the compaction from the wheels. The surface applied fertilizers and chemicals are not incorporated and often are not in direct contact with the soil surface. This condition may result in a high surface runoff of pollutants (nutrient and pesticides). Macropores develop under a no-till system. They permit deep percolation and the transmittal of pollutants, both soluble and insoluble to be carried into the deeper soil horizons and into the ground water.
Reduced tillage systems disrupt or break down the macropores, incidentally incorporate some of the materials applied to the soil surface, and reduce the effects of wheeltrack compaction. The results are less runoff and less pollutants in the runoff.

d. Contour farming (330): Farming sloping land in such a way that preparing land, planting, and cultivating are done on the contour. This includes following established grades of terraces or diversions.

This practice reduces erosion and sediment production. Less sediment and related pollutants may be transported to the receiving waters.
Increased infiltration may increase the transportation potential for soluble substances to the ground water.

e. Contour orchard and other fruit area (331): Planting orchards, vineyards, or small fruits so that all cultural operations are done on the contour.

Contour orchards and fruit areas may reduce erosion, sediment yield, and pesticide concentration in the water lost. Where inward sloping benches are used, the sediment and chemicals will be trapped against the slope. With annual events, the bench may provide 100 percent trap efficiency. Outward sloping benches may allow greater sediment and chemical loss. The amount of retention depends on the slope of the bench and the amount of cover. In addition, outward sloping benches are subject to erosion form runoff from benches immediately above them. Contouring allows better access to rills, permitting maintenance that reduces additional erosion. Immediately after establishment, contour orchards may be subject to erosion and sedimentation in excess of the now contoured orchard. Contour orchards require more fertilization and pesticide application than did the native grasses that frequently covered the slopes before orchards were started. Sediment leaving the site may carry more adsorbed nutrients and pesticides than did the sediment before the benches were established from uncultivated slopes. If contoured orchards replace other crop or intensive land use, the increase or decrease in chemical transport

from the site may be determined by examining the types and amounts of chemicals used on the prior land use as compared to the contour orchard condition. Soluble pesticides and nutrients may be delivered to and possibly through the root zone in an amount proportional to the amount of soluble pesticides applied, the increase in infiltration, the chemistry of the pesticides, organic and clay content of the soil, and amounts of surface residues. Percolating water below the root zone may carry excess solutes or may dissolve potential pollutants as they move. In either case, these solutes could reach ground water supplies and/or surface downslope from the contour orchard area. The amount depends on soil type, surface water quality, and the availability of soluble material (natural or applied).

f. Cover and green manure crop (340): A crop of close-growing grasses, legumes, or small grain grown primarily for seasonal protection and soil improvement. It usually is grown for 1 year or less, except where there is permanent cover as in orchards.

Erosion, sediment and adsorbed chemical yields could be decreased in conventional tillage systems because of the increased period of vegetal cover. Plants will take up available nitrogen and prevent its undesired movement. Organic nutrients may be added to the nutrient budget reducing the need to supply more soluble forms. Overall volume of chemical application may decrease because the vegetation will supply nutrients and there may be allelopathic effects of some of the types of cover vegetation on weeds. Temperatures of ground and surface waters could slightly decrease.

g. Critical area planting (342): Planting vegetation, such as trees, shrubs, vines, grasses, or legumes, on highly erodible or critically eroding areas (does not include tree planting mainly for wood products).

This practice may reduce soil erosion and sediment delivery to surface waters. Plants may take up more of the nutrients in the soil, reducing the amount that can be washed into surface waters or leached into ground water.
During grading, seedbed preparation, seeding, and mulching, large quantities of sediment and associated chemicals may be washed into surface waters prior to plant establishment.

h. Crop residue use (344): Using plant residues to protect cultivated fields during critical erosion periods.

When this practice is employed, raindrops are intercepted by the residue reducing detachment, soil dispersion, and soil compaction. Erosion may be reduced and the delivery of sediment and associated pollutants to surface water may be reduced. Reduced soil sealing, crusting and compaction allows more water to infiltrate, resulting in an increased potential for leaching of dissolved pollutants into the ground water.
Crop residues on the surface increase the microbial and bacterial action on or near the surface. Nitrates and surface-applied pesticides may be tied-up and less available to be delivered to surface and ground water. Residues trap sediment and reduce the amount carried to surface water. Crop residues promote soil aggregation and improve soil tilth.

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i. Delayed seed bed preparation (354): Any cropping system in which all of the crop residue and volunteer vegetation are maintained on the soil surface until approximately 3 weeks before the succeeding crop is planted, thus shortening the bare seedbed period on fields during critical erosion periods.

The purpose is to reduce soil erosion by maintaining soil cover as long as practical to minimize raindrop splash and runoff during the spring erosion period. Other purposes include moisture conservation, improved water quality, increased soil infiltration, improved soil tilth, and food and cover for wildlife.

j. Diversion (362): A channel constructed across the slope with a supporting ridge on the lower side (Figure 2-3).

This practice will assist in the stabilization of a watershed, resulting in the reduction of sheet and rill erosion by reducing the length of slope. Sediment may be reduced by the elimination of ephemeral and large gullies. This may reduce the amount of sediment and related pollutants delivered to the surface waters.

k. Field border (386): A strip of perennial vegetation established at the edge of a field by planting or by converting it from trees to herbaceous vegetation or shrubs.

This practice reduces erosion by having perennial vegetation on an area of the field. Field borders serve as "anchoring points" for contour rows, terraces, diversions, and contour strip cropping. By elimination of the practice of tilling and planting the ends up and down slopes, erosion from concentrated flow in furrows and long rows may be reduced. This use may reduce the quantity of sediment and related pollutants transported to the surface waters.

l. Filter strip (393): A strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff and wastewater.

Filter strips for sediment and related pollutants meeting minimum requirements may trap the coarser grained sediment. They may not filter out soluble or suspended fine-grained materials. When a storm causes runoff in excess When the field borders are located such that runoff flows across them in sheet flow, they may cause the deposition of sediment and prevent it from entering the surface water. Where these practice are between cropland and a stream or water body, the practice may reduce the amount of pesticide application drift from entering the surface water of the design runoff, the filter may be flooded and may cause large loads of pollutants to be released to the surface water. This type of filter requires high maintenance and has a relatively short service life and is effective only as long as the flow through the filter is shallow sheet flow.

Filter strips for runoff from concentrated livestock areas may trap organic material, solids, materials which become adsorbed to the vegetation or the soil within the filter. Often they will not filter out soluble materials. This type of filter is often wet and is difficult to maintain. Filter strips for controlled overland flow treatment of liquid wastes may effectively filter out pollutants. The filter must be properly managed and maintained,

including the proper resting time. Filter strips on forest land may trap coarse sediment, timbering debris, and other deleterious material being transported by runoff. This may improve the quality of surface water and has little effect on soluble material in runoff or on the quality of ground water. All types of filters may reduce erosion on the area on which they are constructed. Filter strips trap solids from the runoff flowing in sheet flow through the filter. Coarse-grained and fibrous materials are filtered more efficiently than fine-grained and soluble substances. Filter strips work for design conditions, but when flooded or overloaded they may release a slug load of pollutants into the surface water.

m. Grade stabilization structure (410): A structure used to control the grade and head cutting in natural or artificial channels.

Where reduced stream velocities occur upstream and downstream from the structure, streambank and streambed erosion will be reduced. This will decrease the yield of sediment and sediment-attached substances. Structures that trap sediment will improve downstream water quality. The sediment yield change will be a function of the sediment yield to the structure, reservoir trap efficiency and of velocities of released water. Ground water recharge may affect aquifer quality depending on the quality of the recharging water. If the stored water contains only sediment and chemical with low water solubility, the ground water quality should not be affected.

n. Grassed waterway (412): A natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff.

This practice may reduce the erosion in a concentrated flow area, such as in a gully or in ephemeral gullies. This may result in the reduction of sediment and substances delivered to receiving waters. Vegetation may act as a filter in removing some of the sediment delivered to the waterway, although this is not the primary function of a grassed waterway.

Any chemicals applied to the waterway in the course of treatment of the adjacent cropland may wash directly into the surface waters in the case where there is a runoff event shortly after spraying.

When used as a stable outlet for another practice, waterways may increase the likelihood of dissolved and suspended pollutants being transported to surface waters when these pollutants are delivered to the waterway.

o. Grasses and legumes in rotation (411): Establishing grasses and legumes or a mixture of them and maintaining the stand for a definite number of years as part of a conservation cropping system.

Reduced runoff and increased vegetation may lower erosion rates and subsequent yields of sediment and sediment-attached substances. Less applied nitrogen may be required to grow crops because grasses and legumes will supply organic nitrogen. During the period

of the rotation when the grasses and legumes are growing, they will take up more phosphorus. Less pesticides may similarly be required with this practice. Downstream water temperatures may be lower depending on the season when this practice is applied. There will be a greater opportunity for animal waste management on grasslands because manures and other wastes may be applied for a longer part of the crop year.

p. Sediment basins (350): Basins constructed to collect and store debris or sediment.

Sediment basins will remove sediment, sediment associated materials and other debris from the water which is passed on downstream. Due to the detention of the runoff in the basin, there is an increased opportunity for soluble materials to be leached toward the ground water.

q. Contour stripcropping (585): Growing crops in a systematic arrangement of strips or bands on the contour to reduce water erosion.

The crops are arranged so that a strip of grass or close-growing crop is alternated with a strip of clean-tilled crop or fallow or a strip of grass is alternated with a close-growing crop (Figure 2-4). This practice may reduce erosion and the amount of sediment and related substances delivered to the surface waters. The practice may increase the amount of water which infiltrates into the root zone, and, at the time there is an overabundance of soil water, this water may percolate and leach soluble substances into the ground water.

r. Field strip-cropping (586): Growing crops in a systematic arrangement of strips or bands across the general slope (not on the contour) to reduce water erosion.

The crops are arranged so that a strip of grass or a close-growing crop is alternated with a clean-tilled crop or fallow. This practice may reduce erosion and the delivery of sediment and related substances to the surface waters. The practice may increase infiltration and, when there is sufficient water available, may increase the amount of leachable pollutants moved toward the ground water. Since this practice is not on the contour there will be areas of concentrated flow, from which detached sediment, adsorbed chemicals and dissolved substances will be delivered more rapidly to the receiving waters. The sod strips will not be efficient filter areas in these areas of concentrated flow.

s. Terrace (600): An earthen embankment, a channel, or combination ridge and channel constructed across the slope (Figures 2-5 and 2-6).

This practice reduces the slope length and the amount of surface runoff which passes over the area downslope from an individual terrace. This may reduce the erosion rate and production of sediment within the terrace interval. Terraces trap sediment and reduce the sediment and associated pollutant content in the runoff water which enhance surface water quality. Terraces may intercept and conduct surface runoff at a nonerosive velocity to stable outlets, thus, reducing the occurrence of ephemeral and classic gullies and the resulting sediment. Increases in infiltration can cause a greater amount of soluble nutrients and pesticides to be leached into the soil. Underground outlets may collect highly soluble nutrient and pesticide leachates and convey runoff and conveying it

directly to an outlet, terraces may increase the delivery of pollutants to surface waters. Terraces increase the opportunity to leach salts below the root zone in the soil. Terraces may have a detrimental effect on water quality if they concentrate and accelerate delivery of dissolved or suspended nutrient, salt, and pesticide pollutants to surface or ground waters.

t. Water and sediment control basin (638): An earthen embankment or a combination ridge and channel generally constructed across the slope and minor watercourses to form a sediment trap and water detention basin.

The practice traps and removes sediment and sediment-attached substances from runoff. Trap control efficiencies for sediment and total phosphorus, that are transported by runoff, may exceed 90 percent in silt loam soils. Dissolved substances, such as nitrates, may be removed from discharge to downstream areas because of the increased infiltration. Where geologic condition permit, the practice will lead to increased loadings of dissolved substances toward ground water. Water temperatures of surface runoff, released through underground outlets, may increase slightly because of longer exposure to warming during its impoundment.

u. Wetland and riparian zone protection

Wetland and riparian zone protection practices are described in Chapter 7.

[EPA excerpts concluded]

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