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San Pedro River *E. coli* TMDL
Reach #15050203-001

San Pedro Watershed
Pinal County, Arizona
August, 2013

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

A.A.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
AFO	Animal Feeding Operation
AGFD	Arizona Game and Fish Department
AgL	Agriculture-Livestock watering
A.R.S.	Arizona Revised Statutes
ASLD	Arizona State Land Department
AUM	Animal Unit Month
AZPDES	Arizona Pollution Discharge Elimination System
A&Ww	Aquatic and Wildlife-warmwater
BLM	Bureau of Land Management
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
cfs	cubic feet per second
cfu/100 ml	colony-forming units per 100 milliliters
CGP	Construction General Permit
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
ft.	feet
FC	Fish consumption
FBC	Full Body Contact
G-org	Giga –organisms (billion)
HUC	Hydrologic Unit Code; a USGS watershed division
HW	headwaters
ICE	Immigration and Customs Enforcement
LA	Load Allocation
mgd	million gallons per day
mi	miles
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
MSGP	Multi-Sector General Permit
NB	Natural background
NEMO	Nonpoint Source Education for Municipal Officials
NLCD	National Land Cover Dataset
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
RNCA	Riparian National Conservation Area
SPR	San Pedro River
sq.miles	square miles
SSM	single sample maximum
SSWMP	Statewide Stormwater Management Plan
SWPPP	Stormwater Pollution Prevention Plan
SWMP	Stormwater Management Program
TMDL	Total Maximum Daily Load
U.S.	United States

USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WLA	Waste Load Allocation
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION

In 2004, ADEQ listed Reach 15050203-001 of the San Pedro River, extending from the confluence of the Gila River upriver to its confluence with Aravaipa Creek, on the State's 303(d) Impaired Waters List as impaired for *E. coli* based on two exceedances of the water quality standard for the Full Body Contact (FBC) designated use in 2000 and 2001. The listing was confirmed in the 2006/2008 assessment with an additional three exceedances of the *E. coli* single sample maximum (SSM) portion of the water quality standard, though one of these was later discovered to be erroneous. A TMDL study initiated in 2007 collected additional samples at all points of the typical hydrograph for multiple locations within the impaired reach and for subwatersheds and tributaries feeding the impaired reach. Critical conditions for *E. coli* exceedances were determined to be exclusively stormflow conditions. Data collected during these conditions showed persistent and high-magnitude exceedances of the SSM *E. coli* standard while all data collected in baseflow conditions met the standard. This TMDL includes load and waste load allocations developed to ensure that the San Pedro will meet the water quality standard in critical conditions, and an implementation plan incorporating best management practices for land uses found within the watershed is developed.

2.0 BACKGROUND INFORMATION

2.1 Physiographic Setting

The San Pedro River watershed as defined by ADEQ begins at its confluence with the Gila River near Winkelman and extends in a south-southeasterly direction to the Mexican border. The San Pedro River has its headwaters near Cananea in the state of Sonora in Mexico and also drains a portion of northern Sonora. The river winds its way through the "sky islands" of the Coronado National Forest. "Sky islands" consist of several independent mountain ranges typical of the fault-blocked Basin and Range Province in the western United States with isolated and distinct montane environments in the higher elevations. The Huachuca Mountains, Whetstones, Rincons, Santa Catalina, Dragoons, and Galiuro mountain ranges all flank the course of the San Pedro River. The watershed drains approximately 4,500 square miles (sq.miles), 3,770 sq.miles of which are in Arizona. Elevations range from 1,920 feet at the confluence of the San Pedro and Gila rivers to 9,466 feet at Miller Peak in the Huachucas. The region in general is sparsely populated. Sierra Vista is the largest city in the San Pedro watershed, with a population of 43,888 (2010 census). Fort Huachuca, a major military base in the region, is located on the outskirts of Sierra Vista. Other towns and communities in the area include Winkelman, Palominas, Benson, St. David, and San Manuel.

Reach 15050203-001 is located in the San Pedro River Valley between Winkelman and Mammoth, Arizona (Figure 1). The defined reach extends for approximately 12 miles northward from Aravaipa Creek to the San Pedro confluence with the Gila River.

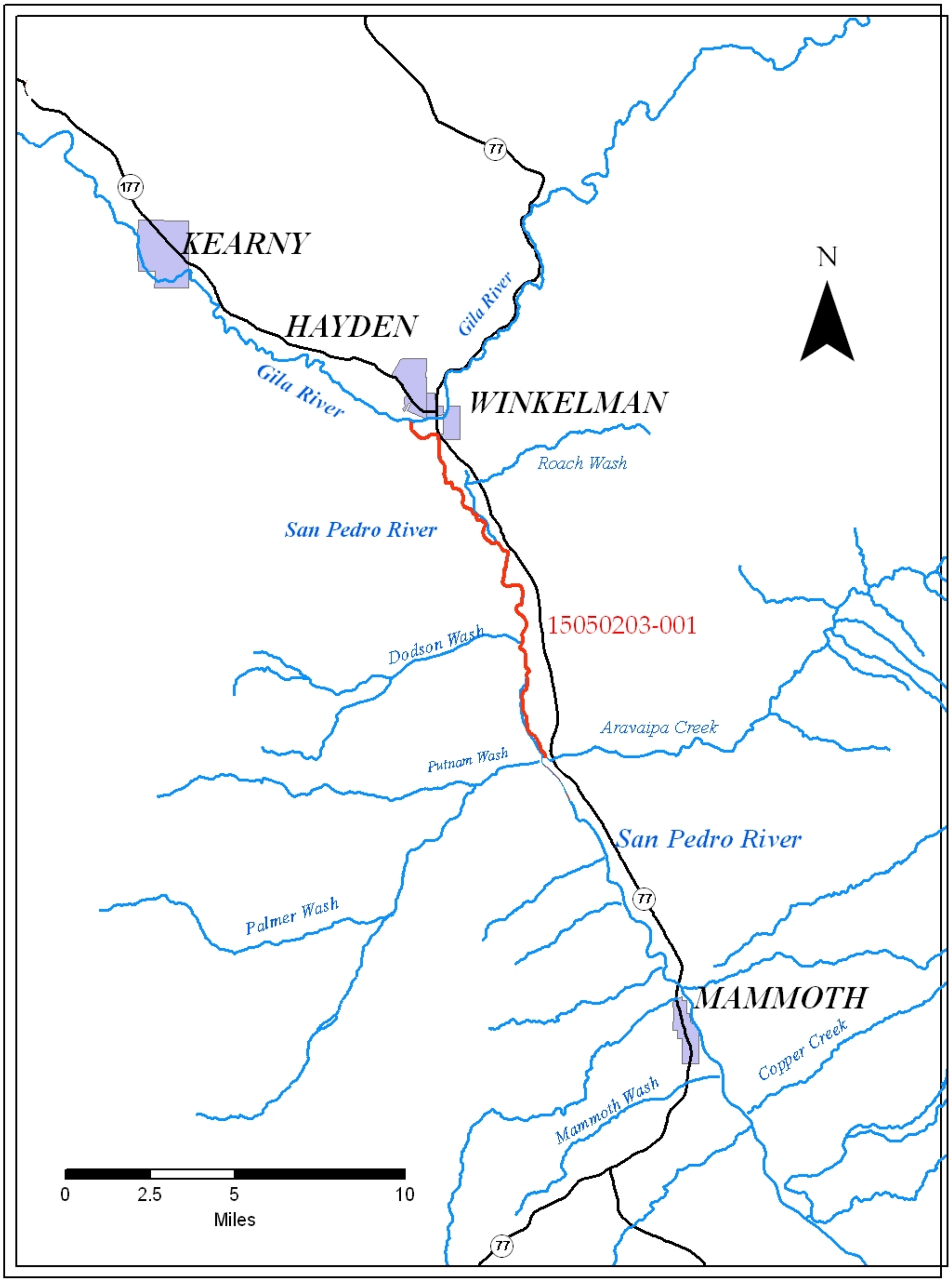

Figure 1. Location of Reach 15050203-001

2.2 Climatic Setting

Warm summers and mild winters characterize the general climate of the San Pedro River watershed. Higher elevations of the watershed experience occasional snow cover in normal years. On rare occasions, snow may cover the valley floor for a short period of time. Increased precipitation falls in July through October as a result of high intensity, short duration storms associated with the summer monsoon season. A second rainy season occurs at lower elevations during the winter months (December through March). The winter events are less intense, but longer in duration and larger in extent.

2.3 Hydrology

The San Pedro River is one of the last free-flowing stream corridors in the West and a classic example of a desert stream with excellent riparian ecological communities. These characteristics contributed to its designation in 1988 as the first Riparian National Conservation Area in the United States administered by the Bureau of Land Management. Unfortunately, drought and the continuing population growth and accompanying groundwater extractions of Sierra Vista and the Fort Huachuca area have left their imprints on the flow and hydrologic characteristics of the San Pedro River. What was once a perennial river for a majority of its length has now been reduced to largely intermittent status, with perennial stretches from approximately Hereford to Charleston and again for the reach under study in this TMDL, from Aravaipa Creek to the Gila River.

The major contributing subwatershed areas upstream of the study reach include Putnam Wash (138 sq. miles), Aravaipa Creek (564 sq. miles), and the San Pedro watershed exclusive of the study reach area (3,641 sq. miles). A number of ephemeral washes contribute to the hydrologic regime within the study reach. The largest of these, Putnam Wash, joins the San Pedro River from the west near the Aravaipa Creek confluence. Additional contributing washes in the reach include Dodson Wash (15.8 sq. miles), Eskiminzin Wash (10.3 sq. miles), Swingle Wash (9.5 sq. miles), Roach Wash (4.7 sq. miles), and Sample Wash (4.5 sq. miles).

The United States Geological Survey (USGS) maintains a station at Redington (Site # 09472050) on the San Pedro River (flow and stage only) and another on Aravaipa Creek (Site # 09473000) a few miles upstream from the mouth (flow, stage, and precipitation). Refer to Figure 2 for locations relative to the impaired reach.

The San Pedro River has an annual mean stream flow at Redington based on 14 years of record of 27.8 cubic feet per second (cfs) (USGS, 2011). For good portions of the year, no flow occurs at this site, and the mean thus reflects the extremes of high-flow monsoon flood events and winter storms with weeks to months of no recorded flow interspersed between seasons. Perennial Aravaipa Creek has a mean annual streamflow based on 51 years of record of 33.5 cfs at USGS gauging station 09473000. In the summer of 2006, Aravaipa Creek experienced two major flood events of between 20,000 and 60,000 cfs that cleared out the riparian habitat throughout the canyon and effectively reset the local geomorphic regime.

Reach 15050203-001 flows in isolation from the rest of the San Pedro's hydrologic network (excepting Aravaipa Creek) as a single perennial reach at the lower end of the San Pedro River, fed only intermittently by flow from Aravaipa Creek in baseflow conditions. It is considered a perennial or near-perennial reach due to unique hydrologic and geologic factors, while much of the rest of the San Pedro hydrologic network is now intermittent in nature. Reach 15050203-003, just above the impaired reach extending past the town of Mammoth, is dry the majority of its length absent stormflow events.

When influence from the rest of the San Pedro network is admitted in monsoon storm events, *E. coli* densities spike abruptly to many times over the standard, but the elevated flow duration is typically documented to be well less than 96 hours in duration and generally less than 24 hours duration. When the storm flow pulse passes through, the normal baseflow conditions re-establish within short order, and Reach 15050203-001 is once again isolated from the rest of the San Pedro hydrologic network. As a consequence, and in part due to the starkly contrasted dataset, it is possible to draw very definite conclusions about the sources and conditions causing exceedances in Reach 001.

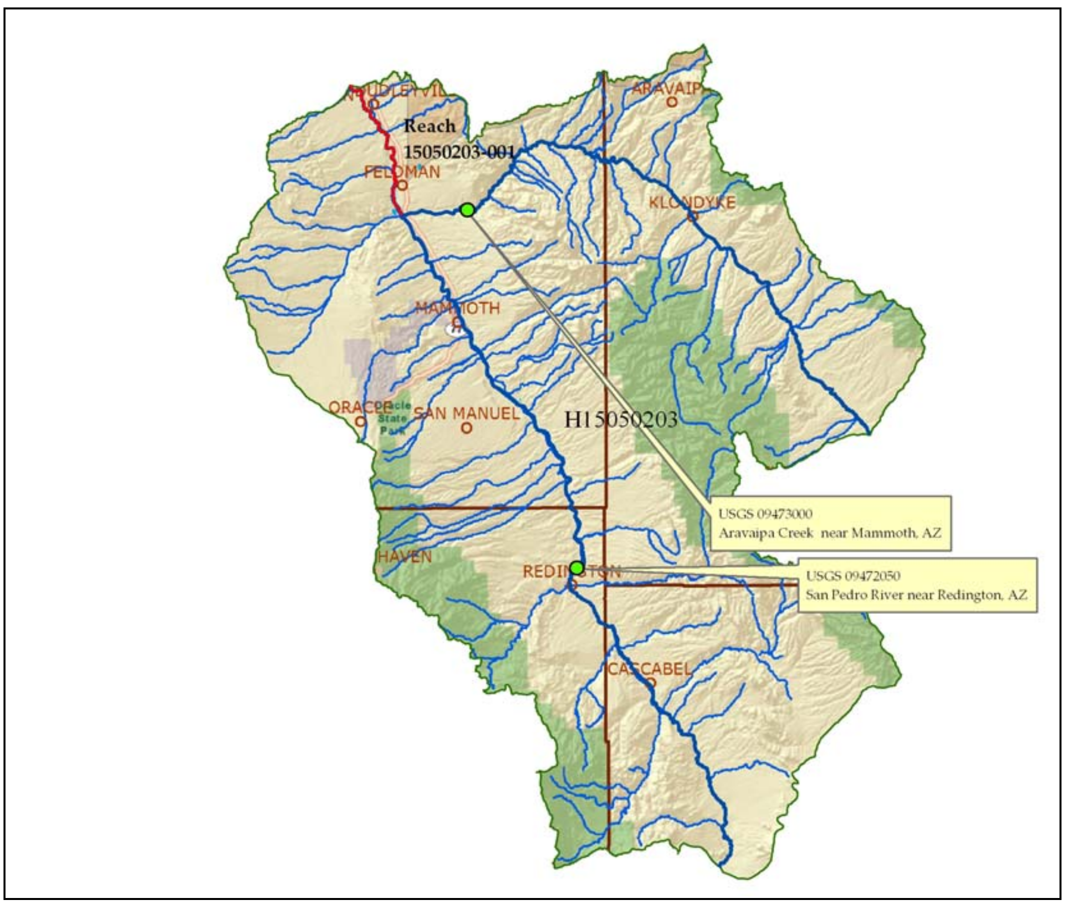

Figure 2. USGS Gauge Sites, Lower San Pedro River

2.4 Land Use and Ownership

Land ownership in the vicinity of the San Pedro impaired reach is generally split between federal, state, and private lands (Figure 3). Of the area that drains the San Pedro River proper, Arizona State Trust lands comprise the largest fraction of land in the watershed at 44.8 percent (Table 1), while private ownership ranks second at 25.9 percent. National Forest lands make up 15.6 percent of the lands in the basin, while the Bureau of Land Management administers 9 percent of San Pedro lands. Military, national park, reservation, and other land ownership classes each account for less than 3.3 percent within the watershed boundaries. Fort Huachuca accounts for the major portion of these other land ownership categories.

CATEGORY	*Area, sq mi*	*Percentage*
State Trust	1688.8	44.81%
Private	976.5	25.91%
Forest	586.6	15.57%
BLM	340.6	9.04%
Military	124.1	3.29%
Indian Reservation	31.7	0.84%
Natl. Parks	20.1	0.53%
Other	0.3	0.01%
Total:	3768.7	100.00%

Table 1. Land ownership areas and percentages

Land cover gives some further indication as to the types of anthropogenic activities occurring within the basin, and the percentages of land within the basin affected by those activities. A land cover analysis also allows for an assessment of the relative amount of development within watershed divides, thereby establishing its general character (wilderness or protected lands, rural, heavily developed, or some mix) and the associated expectations for water quality that accompany the determination. When this analysis is performed within a buffered area around the elements of the stream network and a percentage breakdown is performed, a somewhat different picture of the watershed influences arises. Differences between the percentages in comparison can be instructive and may shed light on the relative contributions that can be expected in stormflow conditions where overland flow is a consideration as juxtaposed with baseflow conditions where more immediate and adjacent influences can be expected to play a larger role.

Table 2 details percentage breakdowns of land cover from the National Land Cover Dataset (2001) for watershed lands including uplands. Table 3 presents land use/cover breakdowns within a 400 meter buffer zone around the stream network. Both analyses consider only lands within the United States. A comparison of the two tables shows that while the watershed retains its largely rural character throughout, a higher percentage of development and anthropogenic-influenced land use classes occur close to the river network than in the uplands. Notably, cultivated crops and agricultural footprints, which comprise only 2.4 percent of the total watershed area, make up more than 15 percent of lands within 400 meters of the hydrologic network. This is not surprising, as water from the San Pedro can be used for irrigation where available, and the relatively richer soils of river floodplains and terraces present a more favorable locale for agriculture. However, agricultural activities in such close proximity to the San Pedro pose a risk of nonpoint source pollution in greater degree than agriculture located away from the hydrologic network. Scrub/shrub land cover constitutes less land cover near the network (60.7 percent) than in the uplands generally (82.3 percent), but this land class is almost universally partitioned into grazing allotments on private, state, and federal lands and its majority status as a land use class in both cases suggests grazing activities are contributing to nonpoint source pollution in stormflow/runoff events. Other anthropogenic impacts are minimal in relation to these two, as demonstrated by the small percentages represented by development of four different intensity levels both near the network and in the uplands.

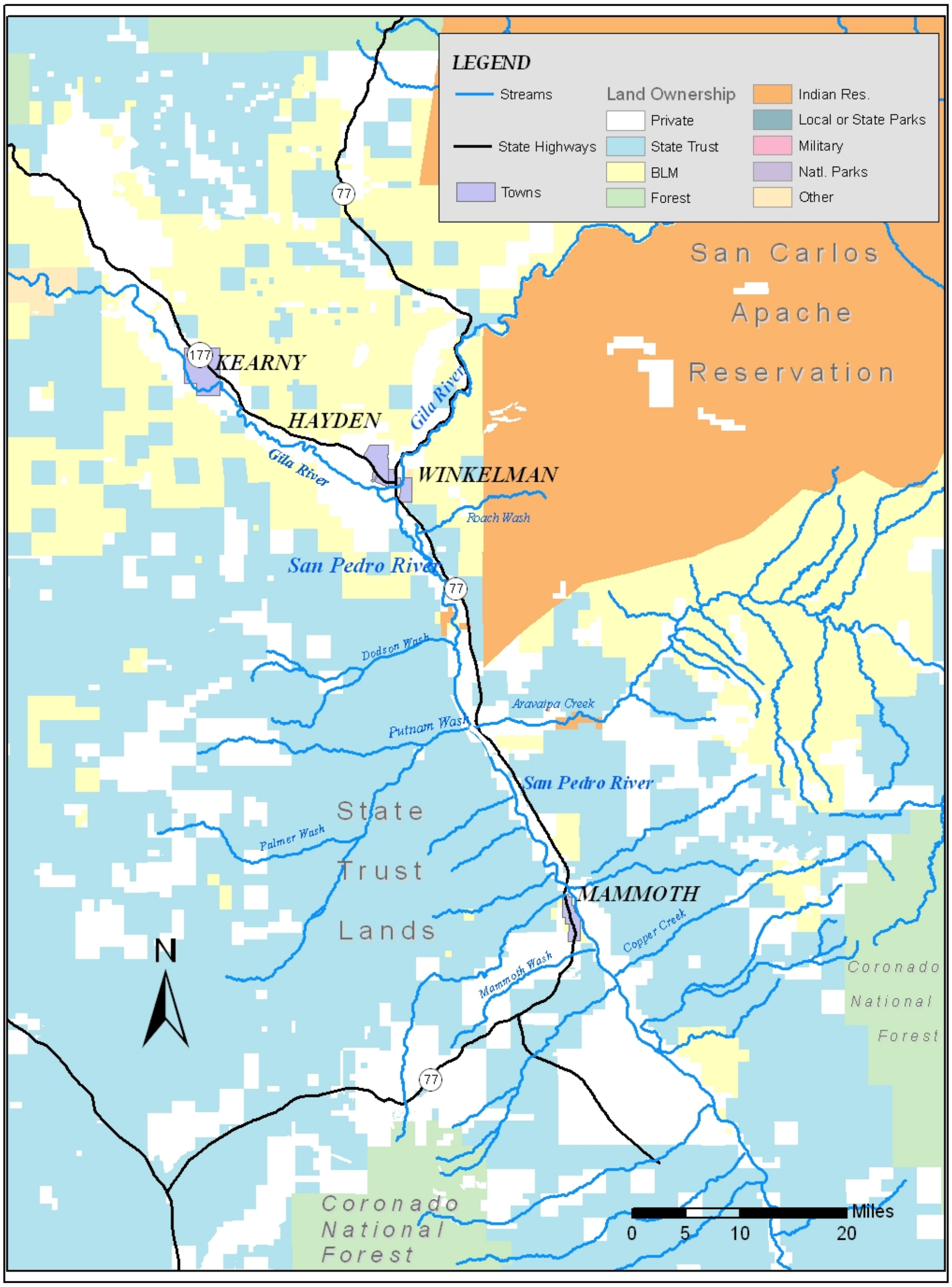

Figure 3. Land ownership, vicinity of impaired reach

Watershed Use, Total Percentage Cover	**NLCD Code/Land Cover Type**	**Class**
82.31%	52 - Scrub/Shrub	Natural
8.19%	42 - Evergreen Forest	Natural
3.82%	71 - Grassland/Herbaceous	Natural
2.43%	82 - Cultivated Crops	Anthropogenic Impact
1.36%	21 - Developed, Open Space	Anthropogenic Impact
0.87%	31 - Barren Land	Natural
0.28%	81 - Pasture/Hay	Anthropogenic Impact
0.24%	90 - Woody Wetlands	Natural
0.23%	22 - Developed, Low Intensity	Anthropogenic Impact
0.16%	43 - Mixed Forest	Natural
0.048%	11 - Open water	Natural
0.046%	23 - Developed, Medium Intensity	Anthropogenic Impact
0.010%	95 - Emergent Herbaceous Wetland	Natural
0.008%	24 - Developed, High Intensity	Anthropogenic Impact
0.002%	41 - Deciduous Forest	Natural
Natural:	**95.651%**	
Anthropogenic:	**4.348%**	

Table 2. San Pedro Watershed Land Use/Cover Breakdown, NLCD 2001

River Network Land Use/Cover, 400 meter buffer		
Percentage Cover	**NLCD Code/Land Cover Type**	**Class**
60.74%	52 - Scrub	Natural
20.54%	90 - Woody Wetlands	Natural
15.27%	82 - Cultivated Crops	Anthropogenic Impact
1.28%	21 - Developed, Open Space	Anthropogenic Impact
1.16%	81 - Pasture/Hay	Anthropogenic Impact
0.31%	95 - Emergent Herbaceous Wetlands	Natural
0.30%	11 - Open Water	Natural
0.20%	22 - Developed, Low Intensity	Anthropogenic Impact
0.13%	42 - Evergreen Forest	Natural
0.05%	43 - Mixed Forest	Natural
0.01%	71 - Grassland	Natural
0.01%	23 - Developed, Medium Intensity	Anthropogenic Impact
Natural:	**82.074%**	
Anthropogenic:	**17.926%**	

Table 3. Buffered Stream Network Land Uses/Cover

2.5 Vegetation

Vegetation types within the watershed vary with elevation. Higher elevations associated with the mountain ranges are characterized by Ponderosa Pine, spruce, and montane species, while the lower floodplain and alluvial elevations are predominately desert scrub or desert grassland. The vegetation communities within the study area exhibit Sonoran / Chihuahan deserts plant community associations. Riparian corridors near the perennial waters, including Aravaipa Canyon before the floods, consist of cottonwoods, Arizona sycamores, and other riparian vegetative communities.

3.0 NUMERIC TARGETS

All existing load calculations in the TMDL document are originally derived from the *E. coli* single sample concentration values, as expressed in data reporting. Concentrations of *E. coli* are expressed in terms of colony-forming units per 100 ml (cfu/100 ml). Loads calculated in the analysis 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.

The numeric load target values of the TMDL determined and presented in this document are based upon and calculated from the single sample maximum (235 cfu/100 ml) concentration of *E. coli* for the Full Body Contact (FBC) designated use expressed in Arizona's water quality standards. Consequently, attainment of the total maximum daily load presented will result in waters that meet concentration-based water quality standards. Conversely, waters meeting the state's water quality standard-based concentration values will be meeting the required total maximum daily load 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 8.0.

3.1 Applicable Water Quality Standards

Arizona's *E. coli* standard is used as an indicator of bacterial contamination and is designed to protect human health in the case of recreational use of waters with some possibility of small ingestion rates.

Arizona's 2009 water quality standard for *E. coli* reads:

> *The following water quality standards for Escherichia coli (E. coli) are expressed in colony forming units per 100 milliliters (cfu/100 ml) or as a Most Probable Number (MPN):*

E. coli	***FBC***	***PBC***
Geometric mean (minimum of four samples in 30 days)	*126*	*126*
Single Sample Maximum	*235*	*575*

Arizona’s former 2003 water quality standard for *E. coli*, the one in effect at the time the San Pedro reach was listed, reads:

> *The following water quality standards for Escherichia coli (E. coli), expressed in colony forming units per 100 milliliters (cfu/100 ml) of water, shall not be exceeded:*

E. coli	***FBC***	***PBC***
Geometric mean (four-sample minimum)	*126*	*126*
Single Sample Maximum	*235*	*576*

While the geometric mean is clearly listed as an integral part of the water quality standard, in practice, Arizona has lacked the data to determine the geometric mean and evaluated reaches for impairments based upon consideration of single sample maximums alone. Arizona’s *E. coli* water quality standard was derived from numbers originating in a series of freshwater beach studies undertaken in the late 1970s correlating *E. coli* bacterial densities with rates of gastroenteritis (EPA, 1986). The Arizona single sample maximum, drafted directly from the freshwater beach studies, originated as a defined point representing a particular confidence level in a cumulative frequency distribution with a geometric mean of 126 cfu/100ml. In practice, however, each incidence of single sample maximum exceedance has been treated as an episode of a violation of an acute criterion. No exemptions are currently permitted in the standard for storm flow exceedances.

Calculations, reduction determinations, and assessments of attainment status done in these TMDLs were executed according to the wording of the 2009 water quality standard which incorporated a 30 day averaging period for the geometric mean. There are no instances in the sampling record for Reach 15050203-001 where four samples were collected in a 30 day time frame after data aggregation operations were performed consistent with Arizona assessment methodology; the reach was listed solely on the basis of multiple single sample maximum exceedances. Consequently, the TMDL with its associated reduction determinations has been drafted solely for the SSM portion of the water quality standard.

3.2 Beneficial Use Designations

ADEQ codifies surface water quality regulations in Arizona Administrative Code (A.A.C.) Title 18, Chapter 11, Article 1 (ADEQ, 2009). Designated beneficial uses, such as fish consumption, recreational contact, agriculture, and aquatic biota, are described in A.A.C. R18-11-104 and are listed for specific surface waters in Appendix B of A.A.C. 18-11-1. The San Pedro River in Reach 15050203-001 is currently protected for the following designated uses: Aquatic and Wildlife-warm water fishery (A&Ww); Fish Consumption (FC); Full Body Contact (FBC); and Agriculture Livestock (AgL). *E. coli* standards are addressed under the FBC use.

3.3 Clean Water Act Section 303(d) List

The San Pedro River, from Aravaipa Creek to the Gila River (AZ15050203-001) was listed as impaired for *E. coli* on the State of Arizona's 2004 303(d) list according to the provisions of the Clean Water Act Section 303(d) (ADEQ, 2004). TMDL allocations must be developed for those waters listed on the 303(d) list. TMDLs determine the amount of given pollutant(s) that the water body can withstand without creating an impairment of that surface water's designated use(s).

Reach 15050203-001 (San Pedro River – Aravaipa Creek to Gila River) was originally listed based on two noted exceedances (n = 11) of the state's single sample maximum water quality standard (235 cfu/100 ml) in 2000 and 2001. Both exceedances were associated with stormflow samples.

4.0 SOURCE ASSESSMENT

4.1 Summary of Point Sources

4.1.1 AZPDES Permits

There are four active individual Arizona Pollutant Discharge Elimination System (AZPDES) permittees and one pending permittee in the San Pedro River basin. Refer to Table 4 for a summary of permittees and the limits of their permits. Fort Huachuca near Sierra Vista was formerly covered by a National Pollutant Discharge Elimination System (NPDES) permit administered by EPA which expired in 2006 and has not been renewed. Consequently, Fort Huachuca will not be considered for the granting of a waste load allocation in this TMDL.

The Tombstone and Mammoth Cielo wastewater treatment plants (WWTPs) are authorized to discharge to ephemeral washes tributary to the San Pedro; additionally, the Sierra Vista Water Reclamation Facility is authorized to make emergency discharges to an ephemeral wash tributary to the San Pedro when it becomes operational in late 2014. Consequently, higher permit limits apply in keeping with Arizona's ephemeral (PBC) *E. coli* water quality standard.

Permittee	*Permit Number*	*Permitting Authority*	*Design Capacity*	*Applicable Permit Limits*
City of Benson WWTP	AZ0024376	ADEQ	1.2 MGD	SSM 235 cfu/100 ml
City of Tombstone WWTP	AZ0025577	ADEQ	0.25 MGD	SSM 575 cfu/100 ml
Town of Mammoth (Cielo) WWTP	AZ0025470	ADEQ	0.65 MGD	SSM 575 cfu/100 ml
City of Bisbee (San Jose) WWTP	AZ0025275	ADEQ	1.22 MGD	SSM 235cfu/100 ml
City of Sierra Vista Tribute Reclamation Facility*	AZ0025984	ADEQ	0.5 MGD	SSM 575 cfu/100 ml

* Not yet constructed. Scheduled to come online in 2014.

Table 4. AZPDES individual permittees in the San Pedro River basin.

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). One Arizona highway (Hwy 77) covered by the permit exists upstream of the San Pedro – Gila River confluence in the vicinity of the impaired reach. 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.

Sierra Vista is classified as a small MS4 (Municipal Separate Storm Sewer System) for the purposes of stormwater discharges and is regulated under ADEQ's 2002 General Permit (AZG2002-002), which has expired but been administratively extended. In accordance with the Small MS4 General Permit, each MS4 is required to prepare and implement a Stormwater Management Program Plan (SWMP). The SWMP documents the control measures and Best Management Practices the MS4 must establish to meet the terms and conditions of the MS4 General Permit.

4.1.2 Multi-Sector General Permit and Construction General Permit

The purpose of Arizona's multi-sector general permit (MSGP) and 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 industrial and construction activities. Under the federal Clean Water Act and Arizona Revised Statutes, it is illegal to have a point source discharge of pollutants to a water of the United States that is not authorized by a permit, including stormwater runoff from construction and industrial sites. To protect water quality, the MSGP and CGP requires operators to plan and implement appropriate pollution prevention and control practices for stormwater runoff during construction or industrial activities.

There are 31 active sites covered under the MSGP in the San Pedro River watershed as of December 2012. Most are operations set away from major water courses which are not reasonably expected to generate *E. coli* by their operations. Appendix A provides details on active MSGP permittees.

There are 33 permittees covered under the state's CGP in the San Pedro River basin as of December 2012. Most are located upstream of the HUC of the impaired reach, generally around the towns of Benson, Sierra Vista and Bisbee. The number of permittees covered under the CGP fluctuates widely over short time periods; construction projects requiring coverage under the CGP are typically projects of relatively short duration covering a limited areal extent. A somewhat higher potential of bacteriological contamination exists with these sites when compared to MSGP sites due to their proximity to urban areas where stormflow runoff can contribute nonpoint source pollution from urban drainage and fecal loads associated with this process. Disturbed soils in proximity to the hydrologic process pose this higher risk factor. Wasteload allocations are addressed in Section 8.2.2.

4.1.3 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. In order to be designated as a CAFO, animal feeding operations (AFOs) must have more than designated numbers of livestock and discharge to the waters of the United States. ADEQ issues two types of water quality permits for CAFOs: AZPDES permits for potential discharges to surface waters, and Aquifer Protection Program (APP) permits for potential discharges to groundwater. ADEQ's CAFO Inspection program inspects animal facilities for the use of BMPs and unauthorized discharges of manure-contaminated wastewater. (ADEQ, 2008). Though animal feeding operations exist in the basin, none meets the operational definition of a CAFO discharging to the waters of the United States. Consequently, for the purposes of this TMDL, no consideration of CAFO load contributions is necessary.

4.1.4 Other Permitted Facilities

Some facilities discharging water to the environment opt not to discharge to a receiving water, but to reclaim and re-use their wastewater for irrigation, or dispose of it through percolation to groundwater tables or evaporation. 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 within watershed boundaries covered by APPs are detailed in Table 5. These facilities are itemized for the purpose of a comprehensive inventory of possible *E. coli* sources in the basin, but since under APP provisions they do not discharge to waters of the United States, they are not considered for the granting of waste load allocations. Where an AZPDES individual permit co-exists for a facility holding an APP, the facility is addressed separately with a wasteload allocation.

NAME	CATEGORY	LOCATION: UTM Z12 NORTHING	UTM Z12 EASTING
Naco Sanitary District WWTP	Wastewater	3468700	598431
5 Star Car Wash	Industrial	3484282	570592
Southland Sanitation - Golden Acres WWTP	Wastewater	3485712	572556
City of Sierra Vista Pilot Recharge	Wastewater	3492073	576019
Ft Huachuca WWTP	Wastewater	3493077	564756
Huachuca City WWTP	Wastewater	3501938	565094
City of Tombstone WWTP*	Wastewater	3510933	587919
Apache Nitrogen	Industrial	3528910	571586
City of Benson WWTP*	Wastewater	3539348	567229
BHP, San Manuel	Mining	3617603	529862
Town of Mammoth WWTP	Wastewater	3622730	532756
Ryland Exploration Decline - Copper Creek	Mining	3623446	545718

Table 5. APP Facilities in the SPR TMDL Study Area

* indicates AZPDES-permitted facility.

4.2 Summary of Nonpoint Sources

4.2.1 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 near the main stem in the floodplain terraces of the SPR Basin 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 or the lack of application of adequate soil conservation techniques (e.g., terracing, etc.) to agricultural acreage. *E. coli* exceedances have been noted repeatedly to be higher in conjunction with excessive sediment in the waterway. In a desktop GIS analysis, when San Pedro watershed reaches with a stream order greater than 3 are buffered to a 1.5 mile radius, agricultural land comprises 4.44 percent of the buffered area on the network. The total acreage footprint in the buffered zone is 30.6 sq. miles. Loading of the San Pedro River with *E. coli* likely occurs from agricultural runoff in storm events from these extensive fields adjacent to the watercourse.

4.2.2 Urban/Developed

Urban or developed areas can contribute to excessive *E. coli* loading by stormwater runoff from impervious areas, and by concentrations of stormflow in engineered drainage systems feeding into natural watercourses. Minimal areal coverage from lightly to moderately developed areas in the SPR watershed is tabulated according to NLCD 2001 (Table 2). The development footprint along the buffered SPR hydrologic network (within 400 meters) is 0.073 sq.miles, comprising 0.2 percent of the buffered hydrologic network area adjacent to the river course in the entire watershed. Urban stormwater contributions are considered to be negligible in the TMDL analysis.

4.2.3 Grazing

Semi-arid regions with sparse ground cover 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, including the denuding of shrubs and vegetative cover, the compacting of soil contributing to lower infiltration rates; and the direct depositing of feces within the stream courses where cattle and livestock are not managed to restrict their access to streams.

Grazing activities in the SPR basin can be largely attributed to four different sectors: U.S. Forest Service, Bureau of Land Management, Arizona State Trust Land, and private ownership. On Arizona lands, these major classes of land owners that pursue or allow grazing activities have been previously detailed in Table 2. Additional discussion on each will follow.

A large portion of watershed area is Arizona State Trust Land. Grazing allotments are delineated for all State Trust land, and grazing is actively pursued on many of these allotments by local ranchers. 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 any funding for the State Land Department to institute any agency-initiated management practices on State Trust rangeland. The agency relies on its grazing lessees to spend their own money to initiate management practices on their leases. Such management practices are water sources (such as wells and stock tanks), water distribution systems (pipelines), handling facilities (corrals), livestock control measures (fencing), and various types of land treatments to remove undesirable vegetation species or to plant desired vegetation species (prescribed fire, grubbing, agra-axe, root plowing, chaining, herbicides, reseeding) (Arizona State Land Dept., 2010).

The State Land Department offers grazing leases for up to a maximum of ten 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).

4.2.4 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 prevalent 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 and greater human population densities.

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. Areas where wildlife is the only nonpoint source contributors are candidates for use as natural background sites.

4.2.5 Septic Systems

Septic systems are encountered where residences exist outside an incorporated area where sewer service would normally be provided. Additional septic systems can be found in incorporated areas for residences that are not tied into the sewer system network. Failing septic systems 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. Septic systems require periodic maintenance to perform to their full design life capacity and efficiency, and maintenance after installation relies upon the diligence of the private citizen and homeowner. Thus, in areas where septic systems are identified as a contributing problem for bacterial water quality issues, the nature of the origin of the problem reflects a collective inadequacy and failure of many individuals to keep their septic systems in proper working order. The distributed nature of responsibility in such cases poses special difficulties in remedying the problem at a collective level.

4.2.6 Animal Feeding Operations

Unlike CAFOS, which are regulated by general permit, animal feeding operations (AFOs) are unregulated. An AFO either has fewer than the designated numbers of livestock for CAFO status, or else has not been designated as discharging directly to the waters of the United States. Many AFOs have land application areas where manure may be applied to acreage, and irrigation or stormflow runoff from those lands can constitute an unidentified nonpoint source of pollution absent specific complaints or other form of identification of the problem to the regulatory agency. If such a problem was brought to the attention of the agency, CAFO permit coverage would be required.

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 records show that one AFO exists within the boundaries of the San Pedro watershed. Cliff's Dairy outside of Benson confines approximately 335 milking cows (Hershberger, personal communication, 2011). Wastewater from the facility is confined in two wastewater ponds. The facility applies manure to approximately 15-20 acres of farmland and generates excess manure sold to local farmers as nitrogen fertilizer. The San Pedro River is located approximately one-half mile west of the facility and is dry at most times absent stormflow inputs. The facility was inspected in 2001 and 2004 with no violations issued and no problems noted in inspection reports.

4.2.7 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 SPR are generally closely tied to the San Pedro Riparian National Conservation Area administered by the BLM headquartered in the community of Fairbank.

4.2.8 Immigrant Travel Corridor

Illegal immigrant foot traffic and its attendant problems have the potential to adversely affect bacteriological water quality in the San Pedro River. In recent years, stepped-up federal enforcement efforts in the El Paso and San Diego sectors of the U.S. Border Patrol have shifted the preferred immigrant travel corridors into Arizona, and logged and estimated traffic has increased substantially. Cochise County, home of the lower San Pedro River, shares 83 miles of border with Mexico. The San Pedro River corridor heading north from the U.S. border with Mexico has become one of the major travel corridors for illegal immigrant traffic and drug smuggling entering Arizona. The milder climate, with a greater abundance of water, makes Cochise County a more attractive corridor for migrants than the harsher desert country to the west.

Apprehensions of illegal immigrants by the Border Patrol and Immigration and Customs Enforcement (ICE) fluctuate by the year; in 2008 along the Southwest border, they numbered 723,840 (DHS, 2009). Economic conditions and enhanced border enforcement efforts play a primary role in the numbers that may be recorded in any given year. It may be safely surmised that the number of apprehensions represents only a fraction of the total traffic and impact to public lands in Arizona. Numbers of total migrants estimated vary with the sources.

Ecological impacts from such activity are profound. Figures from the BLM's Southern Arizona Project, aimed at cleaning up public lands from the impacts of immigrant traffic, for FY10 for all of southern Arizona detail the following: over 255 tons of trash, 77 abandoned cars, 364 bicycles, and 787 tires removed. 2583 acres of land were remediated in FY2010 (BLM, 2010).

In addition to trash left behind by immigrant foot traffic, human waste in washes and along river floodplains is a problem. The amount of human waste and its impact on water quality is expected to be reflected in the stormwater runoff that eventually enters Reach 001.

5.0 LINKAGE ANALYSIS

One of the essential components of developing a TMDL is to establish a relationship (linkage) between source loadings and the numeric indicators chosen to measure the attainment of uses. Once this link has been established, it is possible to determine the capacity of the waterbody to assimilate fecal indicator loadings while still supporting its designated uses. Based on this analysis, allowable loads or needed load reductions can be allocated among the various pollutant sources. The link can be established through a range of techniques, from the use of qualitative assumptions backed up by sound scientific justification to the use of sophisticated modeling techniques. Ideally, the link can be based on a long-term set of monitoring data that allows the TMDL developer to associate certain waterbody responses to flow and loading conditions. More often, however, the link must be established by using a combination of monitoring data, statistical and analytical tools (including simulation models), and best professional judgment (EPA, 2001).

The location of Reach 15050203-001 at the mouth of the entire San Pedro watershed, the intermittent hydrologic flow regime through much of the main stem, and the relative scarcity of *E. coli* data elsewhere in the watershed necessitates a broad-scale approach in consideration of linkages to water quality data collected. Analysis is done through consideration of percentage areal contributions from HUCs and geographic subdivisions coupled with major land uses mentioned in the previous section. Of these, agriculture and grazing are the two most significant land uses in terms of areal percentage that contribute to excessive watershed nonpoint source loads (Table 2). Other nonpoint sources, considered to be minor in relation to these two, can be consolidated under a category of “Other” neither associated with lands that are reserved for agriculture nor grazing. The “Other” category includes development footprints (the third largest land use) with associated urban runoff and private lands not otherwise determined to be a part of grazing allotments or dedicated to agricultural activities.

Table 6 below outlines the areal percentages relative to the entire watershed applied to each subwatershed in the three categories of agriculture, grazing allotments, and other uses. Where agricultural acreage overlays a defined grazing allotment, the percentage area for the allotment is reduced to allow for the percentage available for agriculture. These percentages are applicable to the cumulative load allocation in the impaired reach to ascertain the allowable load contributions from each subwatershed, though in most cases water quality data is not available by which to measure percent reductions necessary.

As mentioned in Section 4.2.2, the urban/developed footprint accounts for only 0.2 percent of the buffered area along the San Pedro hydrologic network. This footprint is restricted to the towns of Benson in Cochise County and Mammoth in Pinal County. Sierra Vista, Tombstone, and San Manuel intermittently contribute developed area stormwater runoff to the San Pedro River through ephemeral channels on their outskirts that flow in the larger storm events. With the exception of San Manuel, these communities are several miles away from the main course of the SPR. Infiltration, predation, and first order die-off would be expected to greatly attenuate the bacterial load originating in these communities before the San Pedro would assimilate the loads. Cascabel and Redington qualify as lightly-developed rural areas with no urban infrastructure. Consequently, all urban *E. coli* loading which might be entrained by overland flow through these communities is expected to be comparatively minor as a contributing source; thus, all such uses are grouped together under a category of "Other." As land use data for the headwaters region in the State of Sonora, Mexico is unavailable, all of the San Pedro headwaters subwatershed area in Mexico and load contribution in the analysis were grouped under "Other/undifferentiated."

Area, sq mi	Watershed Use	Percentage, Whole	Percentage, Subwatershed
28.88	15050202 Agriculture Total	0.649%	1.62%
1342.02	15050202 Grazing Allotments Total	30.182%	75.17%
414.31	15050202 Other Total	9.318%	23.21%
4.34	15050203 Agriculture Total	0.098%	0.37%
1090.02	15050203 Grazing Allotments Total	24.514%	93.87%
66.81	15050203 Other Total	1.503%	5.75%
0.56	Aravaipa Creek Agriculture Total	0.013%	0.10%
546.07	Aravaipa Creek Grazing Allotments Total	12.281%	97.93%
10.95	Aravaipa Creek Other Total	0.246%	1.96%
1.30	Lower San Pedro - Impaired Reach Agriculture Total	0.029%	1.05%
89.54	Lower San Pedro - Impaired Reach Grazing Allotments Total	2.014%	72.68%
32.36	Lower San Pedro - Impaired Reach Other Total	0.728%	26.27%
681.56	San Pedro HW, Sonora, Mexico Total (Undifferentiated)	15.328%	100.00%
137.70	Putnam Wash Grazing Allotments Total	3.097%	99.96%
0.05	Putnam Wash Other Total	0.001%	0.04%
4446.47	Grand Total		

Table 6. Subwatershed land use areas and percentages

A modified load duration analysis/categorized percent reduction approach is applied as discussed in Section 6.0. Hydrologic partitioning by subwatersheds (Figure 4) feeding the impaired reach constitutes the analysis undertaken, and the summation of the respective contributions from each subwatershed analyzed will be the linkage between geographic/hydrologic sources and percent reductions called for in the impaired reach. 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 determine subwatershed/source contributions currently existing and to analyze percent reductions called for by subwatershed without resorting to stochastic methods. This analysis methodology will allow for easier and more straight-forward interpretations of data.

6.0 MODELING AND ANALYTIC APPROACHES

The approach chosen for modeling *E. coli* loads and calculating the TMDL for Reach 15050203-001 consisted of the application of a simple categorized percent reduction determination for two tiers comprised of stormflow and baseflow samples. The percent reduction approach was chosen for its ability to determine TMDL targets given the lack of any USGS gauging station or other establish flow histories within or nearby the impaired reach, for its ability to incisively and illustratively demonstrate the sharply bifurcated data set in critical conditions and non-critical conditions, and for its ease of application. Percent reductions for each of the two primary flow classes are the simplest and most demonstrative manner to determine and convey the nature of the *E. coli* impairment and the improvements needed to attain water quality standards.

Table 7 provides a comprehensive summary of the data collected over an 11-year period and used in determining percent reductions and the application of flow classes for the impaired reach of the San Pedro River. Data collected during the TMDL investigation period from May 2007 to 2010 primarily targeted stormflow events. An initial rough division was made between flow classes of baseflow and stormflow by examining the discharge values associated with sampling efforts. Flow values both above and below the category threshold (15 cfs) were examined individually by reviewing the historic records and the files associated with the events. Historic flows were classified as stormflow based upon the preponderance of evidence including consideration of the magnitude of flow, high *E. coli* counts, high turbidity values, and field notes detailing one of several conditions at the time of sampling: significant rain within 48 hours, evidence of recent flooding present at the site visit, and/or general notes about stormflow hydrographs on either ascending or receding arms. Multiple indications were necessary for historic data to be classified as a stormflow event; for sampling the analyst was personally involved with or had knowledge of, one indicator was sufficient to classify stormflow events. Three sampling events were excluded from consideration in determining stormflow reductions necessary due to reaching of an upper limit in assessing *E. coli* density. The insufficient dilution of these samples prevented the determination of an actual count. The exclusion of these events is not expected to substantially alter the percent reductions called for as the median stormflow discharge is used, a metric fairly resistant to displacement, and a number of densities are included in the dataset higher than or nearly equivalent to the upper limit reached for these samples.

An explicit margin of safety (MOS) of 10 percent was applied to each flow category’s TMDL target value before LAs and WLAs were applied. The MOS is intended to account for uncertainties and random variations associated with data collection, bacteria enumeration, equipment and method precision and accuracy limitations, and random error associated with flow measurements.

Site ID	Date	Time	Discharge, cfs	*E. coli* Density, cfu/100 ml	Flow Type	Daily Loads, G-org/day
SPSPR001.54	18-AUG-2010	0955	357	129,970	Stormflow	1,134,927
SPSPR013.29	27-JUL-2010	1015	23	41,060	Stormflow	23,100
SPSPR006.75	27-JUL-2010	0833	23	17,930	Stormflow	10,087
SPSPR006.75	11-FEB-2009	1500	8	9	Baseflow	1.761
SPSPR001.54	17-DEC-2008	0915	7.2	38	Baseflow	6.692
SPSPR006.27	17-DEC-2008	1030	6.8	35	Baseflow	5.821
SPSPR012.17	17-DEC-2008	1430	6.4	108	Baseflow	16.907
SPSPR006.75	10-DEC-2008	0900	6.6	34	Baseflow	5.489
SPSPR006.75	19-AUG-2008	1000	25	5,900	Stormflow	3,608
SPSPR001.54	31-JUL-2008	1215	9	921	Stormflow	202.705
SPSPR001.54	24-JUL-2008	1530	70	12,033	Stormflow	20,603
SPSPR001.54	16-JUL-2008	1325	18	961	Stormflow	422.933
SPSPR012.17	29-MAY-2008	1510	3.8	39	Baseflow	3.653
SPSPR012.17	29-MAY-2008	1510	3.8	38	Baseflow	3.523
SPSPR006.27	29-MAY-2008	1120	0.97	21	Baseflow	0.505
SPSPR003.85	25-FEB-2008	1220	14	6	Baseflow	2.157
SPSPR003.85	25-FEB-2008	1220	14	3	Baseflow	1.062
SPSPR012.17	24-JAN-2008	1600	6.8	17	Baseflow	2.844
SPSPR013.38	24-JAN-2008	1300	6.4	29	Baseflow	4.571
SPSPR012.17	30-MAY-2007	1400	3.4	186	Baseflow	15.469
SPSPR003.85	29-MAY-2007	1650	2.5	71	Baseflow	4.354
SPSPR005.28	06-APR-2005	1430	4.2	130	Baseflow	13.314
SPSPR005.28	07-MAR-2005	1215	6.4	27	Baseflow	4.227
SPSPR005.28	16-AUG-2004	1215	54	4,100	Stormflow	5,415
SPSPR005.28	13-APR-2004	1201	3.1	5	Baseflow	0.379
SPSPR005.28	15-JAN-2004	1430	0.74	5	Baseflow	0.091
SPSPR005.28	10-SEP-2003	1314	6.85	740	Stormflow	123.988
SPSPR003.85	31-MAR-2003	1530	2	3	Baseflow	0.147
SPSPR003.85	13-JAN-2003	1410	0.09	5	Baseflow	0.011
SPSPR003.85	26-AUG-2002	1030	0.27	139	Baseflow	0.918
SPSPR003.85	07-MAY-2002	1100	2.2	26	Baseflow	1.399
SPSPR005.28	01-MAR-2002	1030	6.6	25	Baseflow	4.036
SPSPR005.28	19-DEC-2001	0930	2.5	25	Baseflow	1.529
SPSPR005.28	17-APR-2001	1330	7.7	33	Baseflow	6.215
SPSPR005.28	10-JAN-2001	1200	29.9	2,636	Stormflow	1,928
SPSPR005.28	04-DEC-2000	1245	12.2	2	Baseflow	0.597
SPSPR005.28	21-AUG-2000	1152	15.1	600	Stormflow	221.608
SPSPR005.28	13-APR-2000	1015	6.92	50	Baseflow	8.463
SPSPR005.28	28-FEB-2000	1240	15.4	3	Baseflow	1.130
SPSPR005.28	15-DEC-1999	1500	12.1	12	Baseflow	3.552

Table 7. *E. coli* concentrations and loads for Reach 15050203-001

7.0 NATURAL BACKGROUND

ADEQ has historic data throughout the San Pedro watershed on tributaries feeding the San Pedro that give an accurate picture in most instances of expected natural background values. For baseflow conditions, when only Aravaipa Creek feeds the San Pedro River, two sites were selected within the Aravaipa Creek Wilderness Area with baseflow loads determined and applied for Reach 001 (San Pedro River). Fifteen sample events comprised the set. For these sampling events, it was possible to determine for each the flow regime (storm flow or baseflow) being characterized; only baseflow samples were employed in determining natural background for the class once the regime distinction had been applied. The average daily load for the set is 4.98 G-orgs/day.

For stormflow conditions, a total of 90 samples from 18 sites representing 11 different waterways throughout the watershed were evaluated for natural background *E. coli* values. Sites on first-order tributaries were excluded, in recognition of the fact that hydrologic process needed to be allowed to operate to yield valid *E. coli* densities. Datasets included instances of stormflow in addition to baseflow.

For many of the samples represented in the stormflow dataset, notation of the flow regime (stormflow or baseflow) was not made in the field at the time of the sample collection. Consequently, some reasonable presumptions must be employed. Observations, previous analysis, and field experience on a state-wide basis lend credence to a rule-of-thumb average percentage of 20 percent of all flows in any given site's flow history representing stormflow conditions in Arizona. A working assumption is therefore made that the 20 percent stormflow block comprises the top tier of the dataset when considering both flows and concentrations. Accordingly, the entire dataset was ordered in ascending fashion by *E. coli* concentration, and the 90th percentile value for the set, the mid-point of the stormflow class (top 20 percent), was determined as a representative stormflow concentration value. For the dataset, this 90th percentile value was 57.2 cfu/100 ml.

The median flow value in stormflow conditions for the impaired reach (23 cfs) was used as a representative flow value for the storm flow class. The product of the representative storm flow value and the 90th percentile *E. coli* concentration, along with the appropriate conversion factor, yields storm flow natural background loading of 32.18 G-orgs/day. This product is presented in Table 9, along with the figure of 4.98 G-orgs/day for baseflow natural background loading.

8.0 TMDL CALCULATIONS

8.1 Data Used for TMDL Calculations

ADEQ's TMDL program sampled at or near the sites listed (Table 8) for flow and *E. coli* concentrations a total of 12 times between 2007 and 2011. Sites listed below included two ephemeral washes where no stormflow data was gathered, and two intermittent sites on the San Pedro River and Aravaipa Creek above the impaired reach where data collection was subject to hydrologic conditions. Additional ADEQ samples were taken by the Ambient Monitoring Program at one or more of these sites in previous years (see Table 7, previously referenced). Data was collected and analyzed from both baseflow and stormflow conditions.

Site Description (previous study site ID)	Site ID	Latitude (DMS)	Longitude (DMS)
Aravaipa Creek at Hwy 77	SPARA000.28	32° 50' 21"	110° 42' 38"
Dodson Wash above SPR	SPDDW000.13	32° 53' 21.3"	110° 43' 44.5"
Putnam Wash above SPR	SPPNW000.21	32° 50' 16.9"	110° 43' 11.3"
San Pedro above Romero Wash	SPSPR001.54	32° 58' 21.7"	110° 46' 03.2"
San Pedro above Roach Wash	SPSPR003.85	32° 56' 43.3"	110° 45' 12.7"
San Pedro above Swingle Wash	SPSPR006.27	32° 55' 24.7"	110° 44' 11"
San Pedro below Dodson Wash	SPSPR006.75	32° 55' 00.7"	110° 44' 03.9"
San Pedro River on SRP Adobe Property	SPSPR012.17	32° 51' 10.2"	110° 43' 26.8"
San Pedro below Aravaipa confluence	SPSPR013.29	32° 50' 59"	110° 43' 16"
San Pedro above Aravaipa confluence	SPSPR013.38	32° 50' 13"	110° 42' 56"
San Pedro above Aravaipa Creek – SRP Stillinger	SPSPR013.99	32° 49' 52.4"	110° 42' 37.4"
San Pedro at Hwy 77 near Mammoth	SPSPR022.15	32° 44' 33"	110° 38' 53"

Table 8. TMDL sampling locations

8.2 Reach 15050203-001 TMDL Allocations

8.2.1 Load Allocations and Reductions

E. coli load reductions were determined for each of the two flow classes (baseflow, stormflow) for the entire San Pedro contributing watershed as depicted in Figure 4. Target cumulative load values and necessary reductions in the single sample maximum for the entire contributing watershed as sampled in Reach 15050203-001 are shown in Table 9. A 90th percentile value for existing conditions was selected as the threshold for comparison for each of the flow categories in keeping with Arizona's water quality binomial assessment methodology that employs the probabilities associated with a 10 percent exceedance rate to determine impairment.

San Pedro Reach 15050203-001	***Category 1: Baseflow***	***Category 2: Stormflow***
Natural Background, G-org/day	4.98	32.18
Existing Conditions (90th P-tile), G-org/day	9.43	23,100
Number of samples	29	11
Median Category Flow	6.4 cfs	23 cfs
TMDL, G-org/day	36.79	132.21
Margin of Safety	3.7	13.22
Aggregate Load Capacity, G-org/day	33.09	118.99
Aggregate Waste Load Allocations	*	51.98
Cumulative Load Allocation	28.11	34.83
Cumulative Reduction Needed	**Meets**	**99.48%**
Load Allocation Reduction Needed	**Meets**	**99.85%**

Table 9. TMDL Targets, Elements, and Reductions

***Concentration-based wasteload allocations applied in keeping with permit terms. Sum of WLAs exceeds load target in baseflow conditions. See Section 8.2.2 and Table 11 for further discussion.**

Load reductions are presented both cumulatively (in relation to the entire load capacity of the San Pedro River) and in relation to the load allocation alone. Cumulative reductions calculated in the stormflow tier of Table 9 are based upon the TMDL target and existing loads; load allocation reductions, by contrast, are based upon the load allocation and existing loads.

Though sufficient water quality data is not available to determine reductions by individual subwatershed and land use, the cumulative load allocation can be partitioned by land use to determine the allowable load allocation and percentage of the available cumulative LA each contributing subwatershed is permitted. Land uses were partitioned in grazing, agriculture, and "other" classes, and allocations were made based on the amount of land area occupied by each use for each contributing subwatershed. The subwatersheds considered for load allocation partitioning include HUCs 15050202 and 15050203 (203 considered above the Aravaipa Creek confluence), Aravaipa Creek, Putnam Wash, the SPR headwaters in the state of Sonora, Mexico, and the subwatershed of impaired reach 15050203-001, as depicted in Figure 4. Please refer to Tables 6 and 10 for load allocation breakdowns by land use and subwatershed.

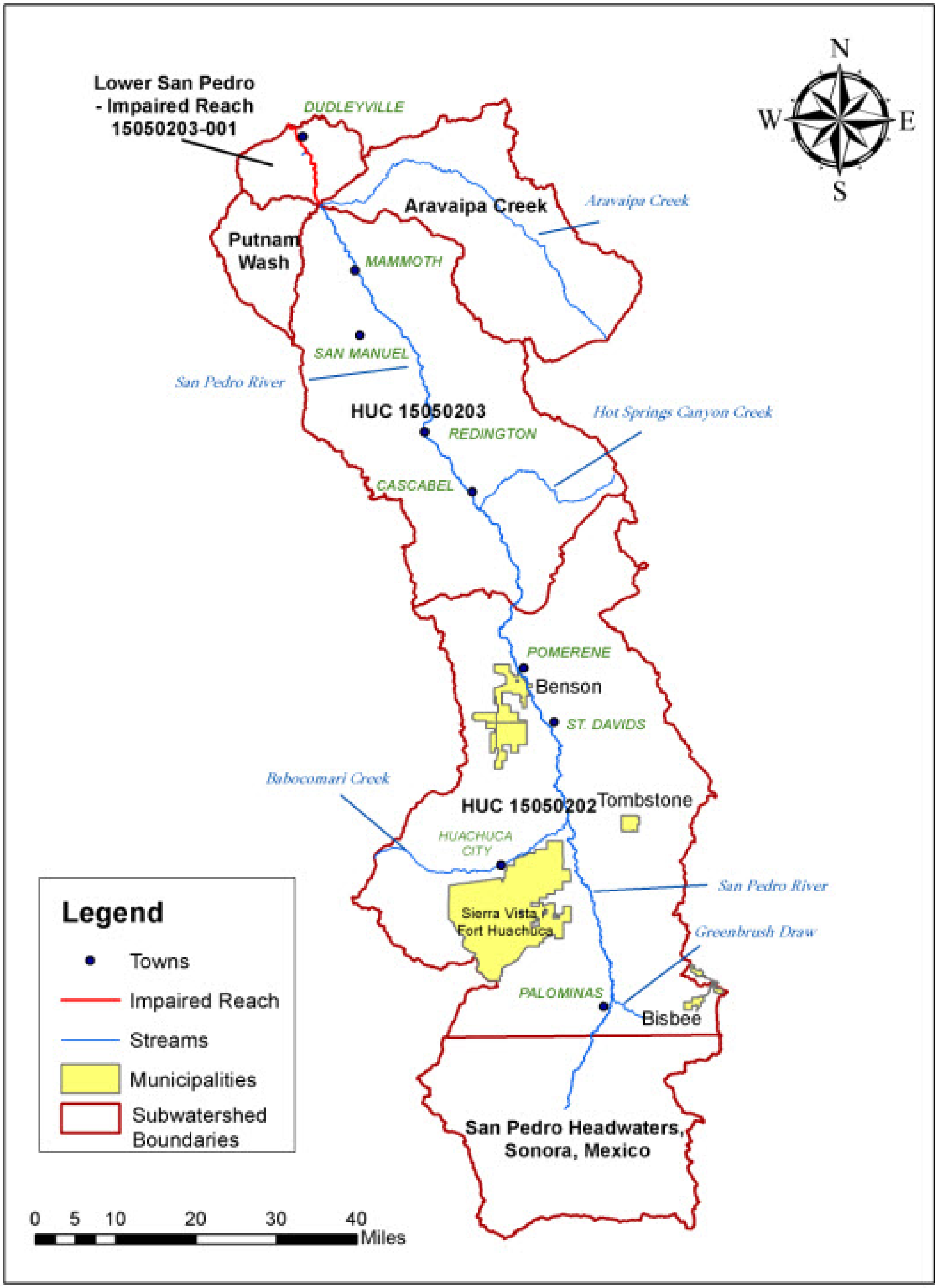

Figure 4. San Pedro Basin Subwatershed Partitioning

Load Allocations, Stormflow, by Percent Land Use (NLCD 2006)

Stormflow Cumulative Load Allocation: **34.83 G-org/day**

		Agricultural Land Use		Grazing Allotment Land Use		Other Land Use		Totals by Basin	
Area, sq m Name	**Watershed Use**	**Percentage**	**Load**	**Percentage**	**Load**	**Percentage**	**Load**	**Percentage**	**Load**
1785.21	Hydrologic Unit Code 15050202	0.649%	0.226	30.182%	10.512	9.318%	3.245	40.149%	13.984
1161.16	HUC 15050203 (abv Aravaipa confluence)	0.098%	0.034	24.514%	8.538	1.503%	0.523	26.114%	9.096
557.59	Aravaipa Creek Subwatershed	0.013%	0.004	12.281%	4.277	0.246%	0.086	12.540%	4.368
137.75	Putnam Wash Subwatershed	--	--	3.097%	1.079	0.001%	0.000	3.098%	1.079
123.20	Reach 15050203-001 Subwatershed	0.029%	0.010	2.014%	0.701	0.728%	0.253	2.771%	0.965
681.56	Mexico (Undifferentiated) Total	--	--	--	--	15.328%	5.339	15.328%	5.339
Total Area:	Subtotaled Percentages:	0.789%		72.088%		27.124%		**100.0%**	
	Subtotaled Loads:		0.275		25.108		9.447		**34.830**

Table 10. Subwatershed Load Allocations by Land Use

The “other” class comprises *E. coli* nonpoint sources discussed in Section 4.2 other than agriculture and grazing. Wildlife loading, when excessive, could be considered a nonpoint source, but in the context of this analysis, it is considered negligible and treated as natural background loading. Urban/developed stormwater runoff, failing septic systems, animal feeding operations, loading due to illegal immigrant passage in the river corridor, and recreational use are the other identified activities or sources of *E. coli* loading in the San Pedro basin. With the exception of urban/developed stormwater discharges and to a lesser extent septic system failures, the uses are generally co-mingled in the river corridor itself. They do not readily lend themselves to further breakdown in the analysis. They are of widely-dispersed and diffused origins in the river’s floodplain, or of small areal extent if not dispersed, or of comparatively minor magnitude relative to the entire nonpoint source load. These land uses and activities are grouped together under the “other” class in the analysis.

The areal footprint of development in the SPR watershed is small when considered relative to the entire watershed area. With the exceptions of Benson and Mammoth, developed areas do not occupy sizable footprints in major perennial tributary corridors or on the main-stem San Pedro. Please refer to Table 2. The summation of developed areas in the watershed from the NLCD land use breakdown (codes 21, 22, 23, and 24) is 1.644% of watershed area. Of this, 1.36% is open space development, such as parks or golf courses, leaving only a 0.284% footprint for all other classes of development. When only area within a 400 meter buffer of the hydrologic network is considered (Table 3), the development footprint is less at 1.49% and 0.21% for total development and development less open space respectively. By contrast, agriculture with a similar watershed areal footprint occupies 15.27% of riparian corridor area within 400 m of the main–stem San Pedro River. When compared to the other three land use classes in terms of percentage land area and proximity to the major watercourses, urban/development land uses did not warrant a separate category.

While urban/development stormwater discharge may constitute a distinct and ascertainable portion of the “other” class’s nonpoint source load originating from identifiable areas, it cannot be considered the primary land-use contributor in the class. No data was collected that would support this contention. At best, urban/development contributions would be co-equal in consideration with septic systems in the river corridor, AFO activities, and the problems attending to illegal immigrant traffic. This is due primarily to the distance from the main-stem the incorporated areas exhibit, as opposed to the other activities, which occur in much closer proximity to the river. It would therefore be mistaken to consider the “other” class as essentially urban/developed run-off by another name. Urban/development loading should be considered as one among several sources in the “other” category considered to be comparable in magnitude and significance.

If any sources currently assigned load allocations are later determined to be point sources requiring NPDES permits, the portion of the load allocations accruing to those sources are to be treated as wasteload allocations for the purposes of determining appropriate water quality based effluent limitations pursuant to 40 CFR 122.44(d)(1).

8.2.2 Waste Load Allocations

As of the fall of 2012, four AZPDES-permitted WWTP facilities are operational in the San Pedro watershed. Additionally, the Sierra Vista Tribute Water Reclamation Facility is scheduled to become operational in late 2014. Of the four existing facilities, only the Mammoth WWTP is in the HUC of the impaired reach. The other three are located in HUC 15050202 upstream (Figure 5). Two of these three plants discharge to ephemeral drainages. All facilities covered under AZPDES individual permits are detailed in Table 11. All entities subject to individual AZPDES permit requirements will be considered to be operating consistent with the provisions of this TMDL if they meet the effluent limits within their existing permits as expressed in *E. coli* concentrations.

For Category 1 (baseflow) conditions, it is noted that the sum of loads from all permittees assuming maximum discharge (51.98 G-orgs/day) exceeds the available load capacity to meet water quality standards of the San Pedro River at its median target flow (33.09 G-org/day). Consequently, it is not possible to establish a numeric mass-based wasteload allocation for the category compliant with its load limit in the impaired reach. Thus, for the baseflow category, it is necessary to employ a concentration-based wasteload allocation instead of a mass-based load value expressed in G-orgs/day in the TMDL summation. However, in baseflow conditions for Reach 15050203-001, wastewater from permittees is not being received in the impaired reach; infiltration of all water in the San Pedro hydrologic network above the Aravaipa Creek confluence is occurring miles upstream of the reach origin. There is no concern in using this alternative concentration-based approach that the maximum discharge of permittees in the basin would prevent the impaired reach from meeting its TMDL target due to the San Pedro's spatially intermittent hydrologic character.

Furthermore, since the category analysis is predicated on the products of discharge and concentration, it can safely be surmised that if individual permit terms are being met at all permitted locations, waste loads for the impaired San Pedro reach should be in accordance with the premises on which this TMDL is developed. Permittees would not be considered as causing or contributing to a downstream exceedance of water quality standards in such an event. For these two reasons, all AZPDES individual permittees are granted concentration-based waste load allocations equal to the terms of their permits in baseflow conditions.

For Category 2 (stormflow) conditions, AZPDES WWTP permittees are granted numeric mass-based wasteload allocations as itemized and summarized in Tables 9 (previously referenced) and 11. The sum of these allocations is 51.98 G-org/day. The loads were calculated as the products of the equivalent discharge capacity of each plant (in cfs), the permit concentration limit (in colony-forming units per 100 ml), and the conversion factor 0.02446 to arrive at a value expressed in G-orgs/day.

Facility	*Design capacity (million gallons per day)*	*Equivalent Discharge (CFS)*	*Permit Concentration Limits (cfu/100 ml)*	*Load at Max Discharge, G-org/day*
Bisbee (San Jose)	1.22	1.89	235	10.8
Benson	1.2	1.86	235	10.7
Mammoth	0.65	1.01	575	14.2
Sierra Vista Tribute	0.5	0.77	575	10.8
Tombstone	0.25	0.39	575	5.45

Table 11. Wasteload Allocations for AZPDES permittees in the San Pedro basin

Figure 5 depicts San Pedro watershed AZPDES outfalls for individual permittees granted WLAs in this TMDL.

Concentration-based WLAs are applied to all general permittees within the affected watershed for this TMDL. As mentioned in Section 4, two MS4s exist in the San Pedro River watershed. The Sierra Vista MS4 and the state-wide ADOT MS4 are both assigned concentration-based waste load allocations for this TMDL as detailed below. Existing and future permittees of the MSGP and the CGP are also assigned concentration-based wasteload allocations as addressed subsequently. For MS4, MSGP, and CGP permittees, the concentration-based WLAs apply at all times in both baseflow and stormflow conditions. The concentration-based WLA is applicable for each separate discharge that may issue from the site location.

General wasteload allocations for general permittees are established as follows: for flows originating from existing or future sites operating under MS4, CGP, or MSGP 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 direct discharges are to a stream reach carrying a PBC designated use, the concentration-based WLA shall be 575 cfu/100 ml. ADEQ recognizes certain sectors of activities and facilities covered under the general permits are not reasonably expected to add *E. coli* loading to the San Pedro River. Consequently, WLAs may be superceded by specific general permit conditions issued by the ADEQ Stormwater Program intended to more fully protect against water quality degradation where it is assessed as necessary. These additional conditions would be dependent upon site-specific factors, such as proximity to the impaired water reach or the reasonable potential to discharge *E. coli* in the course of normal general permittee operations. Additional general permit conditions may be added as a routine part of the NOI permit review process on a case-by-case basis where warranted to more adequately address either of the aforementioned conditions.

The point of compliance for WLAs for all discharges from individual AZPDES permit operations shall be the designated point(s) of discharge from the regulated facility prior to mixing with a stream reach carrying either an FBC or PBC designated use.

For MS4, MSGP, and CGP permitted operations, the point of compliance with the WLA will be determined as specified in the SWPPP or SWMP reviewed and approved by ADEQ.

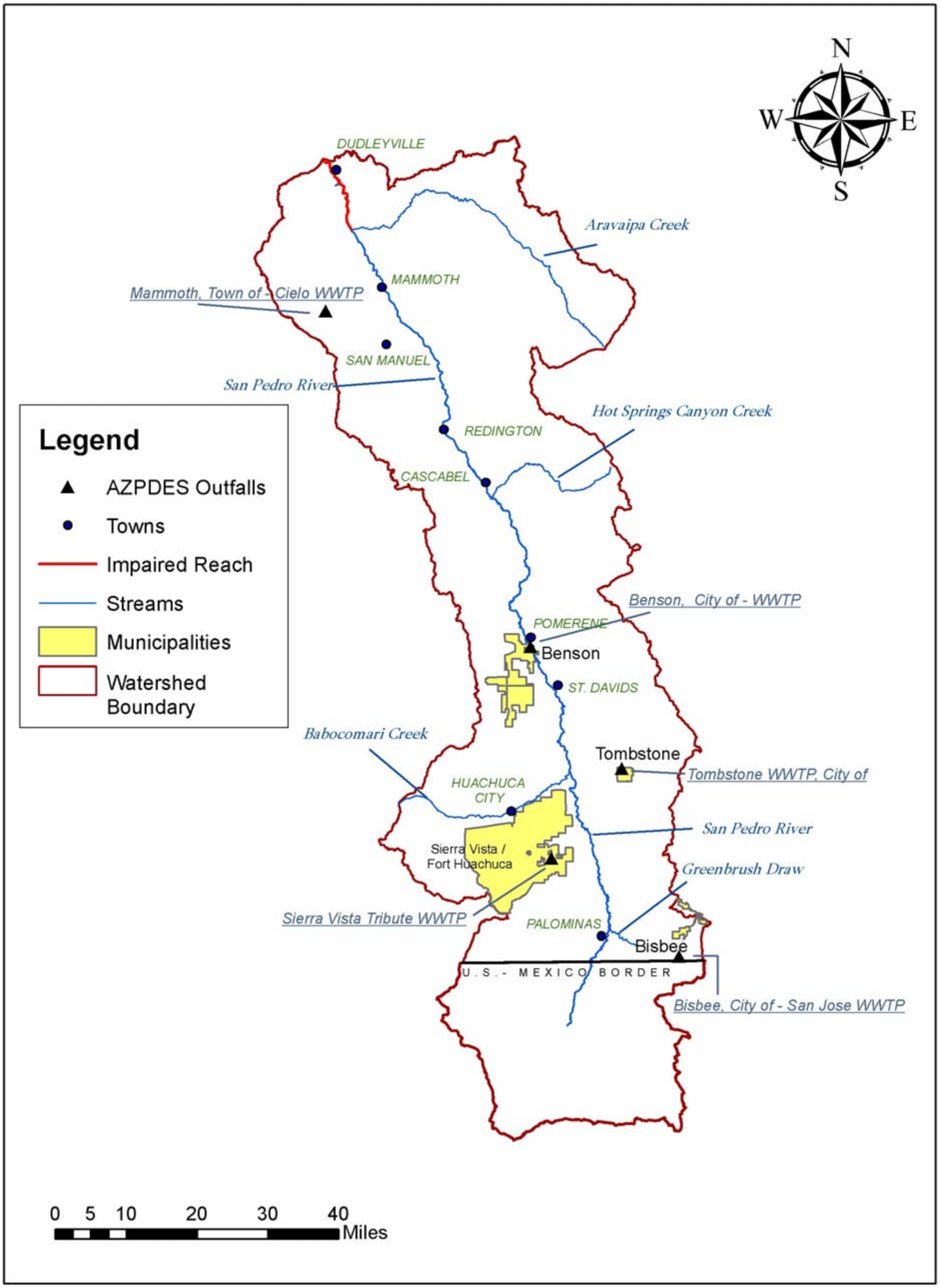

Figure 5. San Pedro watershed AZPDES outfall locations

9.0 TMDL IMPLEMENTATION

TMDL implementation plans are required by A.R.S 49-234, paragraphs G, H, & J requiring TMDL implementation plans to be written for those navigable waters listed as impaired and for which a TMDL has been completed pursuant to Section 303(d) of the Clean Water Act. This section serves as the implementation plan for the San Pedro River *E. coli* TMDLs. Implementation plans provide a strategy that explains "how the allocations in the TMDL and any reductions in existing pollutant loadings will be achieved and the time frame in which attainment of applicable surface quality standards is expected to be achieved." The following implementation plan is voluntary for the stakeholders of the region and meant to suggest possible improvements and best management practices (BMPs) that can be employed to improve water quality and guide efforts to remediate water quality on a local scale within the affected watershed.

Actual on-the-ground improvements in water quality will rely upon the voluntary initiative and actions of stakeholder groups and interested individuals employing standard best management practices (BMPs) at a local scale throughout the entire watershed. With a watershed of approximately 3,770 square miles within the U.S., 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 San Pedro River 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 and subsequently providing more focused and region-specific recommendations and guidance for the implementation of more specific improvement measures on a sub-basin scale as stakeholders and interested parties come forward with proposals.

Congress amended the Clean Water Act in 1987 to establish the Section 319 Nonpoint Source Management Program. As a result of this federal guidance, states have an improved partnership in their efforts to reduce nonpoint source pollution. The ADEQ Water Quality Improvement Grant Program allocates Section 319 grant funds from the EPA to interested parties for implementation of nonpoint source management and watershed protection. Under Section 319, state, private/public entities, and Indian tribes receive grant money which support restoration projects to implement on-the-ground water quality improvement projects to control nonpoint source pollution. Interested stakeholders may contact ADEQ's Water Quality Grants Program to propose measures and projects.

9.1 Best Management Practices

Improvements in non-point source pollutant problems are typically addressed through the implementation of BMPs. BMPs to control nonpoint source pollution problems are a combination of structural and non-structural (management or cultural) practices that landowners or land management agencies decide upon to be the most effective and economical way of controlling a specific water quality problem without disturbing the quality of the environment (NEMO, 2008). BMPs are usually tied to specific land use practices, such as agriculture, grazing, logging, construction, mining, or unimproved road crossings/maintenance, but some are directly related to managing the flow and erosive potentials of the stream course proper. Many BMPs are interdisciplinary in their application and can provide benefits for more than one type of land use or geomorphic process. Land use practices common in the watershed include all discussed in Section 4.0, such as agriculture, grazing, and light recreational and residential development. Necessarily, because of the scale of the watershed and stormwater impacts reflecting cumulative overland loading from throughout the watershed, only broad-scope BMPs can be suggested here, and suggestions are not to be construed as an all-inclusive list nor as required measures mandated by this TMDL. Refer to Appendices B, C, and D for BMPs recommended by EPA for the land uses of principal concern in the San Pedro River Valley.

BMPs for grazing activities include fencing of exclusion zones along riparian corridors to keep cattle out of streams and riparian areas, installation of troughs and watering holes away from stream courses for wildlife and cattle, management of cattle use of grazing allotment lands, primarily through rest and rotation grazing strategies, controlled stream crossings where livestock must cross streams, and establishment of riparian buffer zones and filter strips.

Where agricultural activities are concerned, water quality is benefitted through BMPs by the establishment of filter strips and riparian buffer zones, the use of contour plowing and terracing , the management of irrigation by several practices, including the control of tail water return, the engineering of irrigation water control structures such as canals, head gates, and pipelines and small-scale engineering measures such as the installation of brush layers, erosion control fabrics, and willow plantings. Non-structural (management) options can be implemented as well.

Animal Feeding Operations and agricultural enterprises may use manure-spreading on fields as a part of their routine operations. In the San Pedro watershed, agricultural fields are generally adjacent to the main stem of the river, and the potential for significant source loading from this practice is evident. During the active monsoon season, manure-spreading should be deferred until after the end of the season if possible. Likewise, during the remainder of the year, deferral of manure-spreading within five days of predicted rainfall is advisable. These two management practices are strongly recommended and hold the potential for significant bacteriological water quality improvements.

Septic system best management practices include 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.

9.2 ASARCO Mitigation Properties

In April, 2009, the Department of the Interior and the State of Arizona, acting as natural resource trustees, received three parcels of land, including water rights, along the San Pedro River near Dudleyville from ASARCO L.L.C. through the Natural Resource Damage Assessment and Restoration (NRDAR) program (a part of the CERCLA statute). The proposed sites for restoration are three parcels that comprised the former ASARCO properties (995 acres) on the lower San Pedro River, near the Aravaipa Creek confluence, which were conveyed to the Arizona Game and Fish Commission as a part of a settlement agreement. One of the parcels is located in the impaired reach; the other two are upstream of the Aravaipa Creek confluence marking the origin of the reach but within the segments of perennial baseflow. Currently, the properties consist of approximately 995 acres, of which approximately 500 acres of riparian habitat, 390 acres of uplands, and 105 acres of currently active agricultural fields exist. Approximately 20 percent of the riparian area is covered with non-native vegetation, primarily salt cedar (*Tamarix* spp.).

The Trustees considered a variety of potential restoration actions and selected the following actions to form the Preferred Alternative:

1. Fencing property boundaries to encourage re-growth of native vegetation
2. Land Acquisition/ Conservation Easements to make adjacent parcels contiguous for fencing purposes
3. Increase amount of emergent wetland habitat within the bank full area of the river by encouraging beaver colonization
4. Increase the area of native riparian vegetation along the San Pedro River by planting native tree species
5. Removal of invasive vegetation, primarily salt cedar along the river corridor in selected areas

The properties will be owned and managed by AGFD. ASLD holds large tracts of State Trust lands in the area as well as grazing leases. Both USFWS and AGFD have experience in riparian restoration and ecosystem/wildlife management. ADEQ, AGFD and BLM will conduct monitoring activities to determine baseline conditions for surface water quality and quantity, groundwater levels, stream habitat conditions, riparian resources, wildlife resources and river stability. Monitoring will be conducted regularly in order to track effectiveness of the restoration project in improving riparian and wildlife resources, water quality, aquatic life and river condition (ADEQ, 2012).

Implementation of preferred alternatives is expected to mitigate *E. coli* loads entering the San Pedro River from storm events by restricting livestock access to the watercourse, adding riparian biomass that will increase filtering capacity of the land’s surface, slow water velocities, and increase infiltration rates for overland flows, and increasing wetland habitat with its natural *E. coli* attenuation capacity.

9.3 Time Frame and Future Monitoring

A.R.S. 49-234 mandates that a time frame be established for the implementation plan by which attainment of water quality standards is expected to be achieved. A three to five year time frame after the implementation of improvement measures is expected before significant improvements will become evident for Reach 15050203-001, assuming that measures to improve *E. coli* loading are implemented expeditiously. Effectiveness monitoring by ADEQ will commence five years after implementation measures are enacted.

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 the MSGP and CGP, *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 assumption behind this provision relates to the close connection between loads and concentrations as outline in Section 3.0, with loads derived from concentrations. Waters meeting the concentration-based water quality standard are thus considered to be in compliance with associated load allocations, and these waters are not considered to be causing or contributing to actual or possible downstream impairments. 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, as this value gives the best overall view of the bacteriological water quality of the rivers over time. However, ADEQ 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. For interested stakeholders and other parties doing follow-up monitoring, ADEQ recommends the sites listed in Table 12 to best characterize subwatershed water quality conditions. Sites recommended have been considered for accessibility, suitability for project objectives, and other factors. Where private lands are involved, permission to access and sample from the landowner will be required.

ADEQ will review the status of the waterbody at least once every five years to determine if attainment of applicable surface water quality standards has been achieved. If attainment of applicable surface water quality standards has not been achieved, ADEQ will evaluate whether modification of this TMDL implementation plan is required (A.R.S. § 49-234).

Site	*ADEQ Designation*	*Arizona Associated Reach ID*	*Latitude/ Longitude (NAD27)*	*Representative USGS Site in Vicinity*	*Land Owner / Administrator*
San Pedro above confluence with Romero Wash	SPSPR001.54	15050203-001*	32° 58' 21.7", 110° 46' 03.2"	N.A.	ASARCO
San Pedro below Dodson Wash	SPSPR006.75	15050203-001	32° 55’ 00.7” 110° 44’ 03.9”	N.A.	Pinal County (access road ROW)
San Pedro below Aravaipa Creek confluence	SPSPR013.29	15050203-001	32° 50' 18.5" 110° 42' 56.7"	N.A.	Public
Aravaipa Creek above SPR confluence	SPARA000.28	15050203-004C	32° 50' 22" 110° 42' 37.9"	09473000 (upstream)	ADOT (Hwy 77 ROW)
Aravaipa Creek below Aravaipa Canyon Wilderness Boundary	SPARA010.19	15050203-004C	32° 53' 44" 110° 34' 04"	09473000 (downstream)	BLM
San Pedro at Hwy 77 Crossing, Mammoth	SPSPR022.15	15050203-003	32° 44' 33.2" 110° 38' 52.2"	09472050 (upstream)	ADOT (Hwy 77 ROW)

Table 12. Recommended Implementation Monitoring Sites

ADEQ will continue to monitor the San Pedro River and its tributaries, both as a routine part of its ambient monitoring program on a triennial basis, and for effectiveness evaluations of water quality improvement measures after water quality improvement measures have been implemented. The department will use load evaluation criteria presented in this TMDL document as opposed to the concentration-based criteria recommended to stakeholders to evaluate loading reductions and improvements in the impaired reaches and contributing subwatersheds where possible, as detailed in Section 8.2.2. As mentioned in Section 3.0, these two approaches are complementary, with loads being derived from concentrations. The more intricate nature of the loading analysis, however, makes it more suitable for application to the agency with personnel experienced in the determination, application, and interpretation of loading data in a load duration analysis.

10.0 PUBLIC PARTICIPATION

Stakeholder and public participation was encouraged and received throughout the development of this TMDL. ADEQ held two public meetings at the Central Arizona College near Winkelman, the first on Sept. 27, 2007 to introduce the San Pedro River 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 local residents, the Nature Conservancy, Safford District of the BLM, Westland Resources, the Salt River Project, and the University of Arizona Cooperative Extension Office in Maricopa. Public comment was invited for a 30-day period after the second public meeting; subsequently, the TMDL was submitted to the Arizona Administrative Review for a 45 day notice period. Copies of the final TMDL will be provided to land management agencies including the Coronado NF, and the Safford and Tucson Districts of the Bureau of Land Management.

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Appendix A – Multi-sector General Permittees

FACILITY NAME	*LONGITUDE*	*LATITUDE*	*TYPE*	*CITY*
Babacomari Ranch	31 38 45.08	110 20 25.00	Mining and Nonmining	Huachuca City
BHP Copper Inc	32 38 18.50	110 35 53.92	Mining and Nonmining	San Manuel
Cemex - Sierra Vista Plant	31 30 43	110 14 20	Mining and Nonmining	Sierra Vista
Apache Nitrogen Products Inc	31 52 49.6	110 14 25.3	Nonmining	Benson
Cochise County Highway Roadyard-Benson Area	31 57 55.93	110 1647.14	Nonmining	Benson
Cochise County Highway Roadyard-Bisbee Area	31 23 16.45	109 55 41.00	Nonmining	Bisbee
Naco Bps	31 22 37.04	109 55 36.25	Nonmining	Bisbee
Fort Huachuca	31 34 00.53	110 20 00.35	Nonmining	Fort Huachuca
M & R Auto Inc	31 26 18.909	110 14 31.9	Nonmining	Hereford
Cochise County Solid Waste Department	31 43 35.83	110 16 56.79	Nonmining	Huachuca City
Sierra Vista Hauling	31 41 23.02	110 21 36.33	Nonmining	Huachuca City
Town Of Huachuca City Muni Solid Waste Landfill	31 38 06.0	110 19 42.42	Nonmining	Huachuca City
2100 East Oracle Transfer Station Road	32 36 58.69	110 45 04.63	Nonmining	Oracle
San Manuel Airport	32 38 38.40	110 38 27.60	Nonmining	San Manuel
San Manuel Arizona Rail Road Company	32 37 22.83	110 37 31.13	Nonmining	San Manuel
UPS Sierra Vista	31 33 21.35	110 12 48.89	Nonmining	Sierra Vista
Dudleyville Landfill	32 56 56.18	110 44 13.44	Nonmining	Winkelman
Ave Del Sol Retention Site	31 32 17	110 14 16	Mining	Sierra Vista
Babacomari East & West Pit	31 38 53.01	110 19 36.41	Mining	Huachuca City
BHP Copper Inc Black Hills	32 33 18.58	110 33 12.13	Mining	San Manuel
BHP Copper Inc Camp Grant	32 50 40.23	110 43 21.96	Mining	Winkelman
BHP Copper Inc Mine Site	32 41 38.03	110 41 37.08	Mining	San Manuel
Cantera Materials LLC	31 34 03.435	110 12 24.0	Mining	Sierra Vista
Copper Creek Property	32 4 30	110 30 00	Mining	Mammoth
Copper Glance Materials Pit	31 26 32.09	110 05 30.31	Mining	Hereford
Freeport-McMoran Corp, Ricketts Property	31 51 00	110 21 40	Mining	Benson
Herford Materials Pit	31 26 03.17	110 13 04.67	Mining	Hereford
Ke&G Snyder Road Pit	31 32 17	110 14 16	Mining	Sierra Vista
Oracle Ridge Mine	32 28 35.81	110 43 48.11	Mining	Summerhaven
Pr Gypsum LLC	32 52 31.	110 41 24.	Mining	Winkelman
Samoht Rock & Sand LLC	31 33 29.2	110 14 02.0	Mining	Sierra Vista

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

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.

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.

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

[EPA excerpts concluded]

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

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.

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.

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]

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

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 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 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…]

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]*