PUBLIC COMMENT DRAFT

TOTAL MAXIMUM DAILY LOADS

FOR THE

GILA/MIMBRES/SAN FRANCISCO RIVER AND LOWER RIO GRANDE BASINS

AUGUST 8, 2023

Prepared by

New Mexico Environment Department, Surface Water Quality Bureau

Monitoring, Assessments, and Standards Section

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For Additional Information please visit:

https://www.env.nm.gov/surface-water-quality/

~or~

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Cover photo: The Whitewater Creek Catwalk

Photo: SWQB staff

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List of Abbreviations

4Q3	4-Day, 3-year low-flow frequency
6T3	Temperature not to be exceeded for 6 or more consecutive hours on more than 3 consecutive days
AU	Assessment Unit
BMP	Best management practices
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony forming units
CGP	Construction general storm water permit
CoolWAL	Cool Water Aquatic Life
CWA	Clean Water Act
^{o}C	Degrees Celsius
DMR	Discharge Monitoring Report
HQCWAL	High Quality Coldwater Aquatic Life
^{o}F	Degrees Fahrenheit
HUC	Hydrologic Unit Code
$j/m^2/s$	Joules per square meter per second
km^2	Square kilometers
LA	Load allocation
lb/day	Pounds per day
mgd	Million gallons per day
mg/L	Milligrams per Liter
mi^2	Square miles
mL	Milliliters
MOS	Margin of safety
MOU	Memorandum of Understanding
MS4	Municipal separate storm sewer system
MSGP	Multi-sector general storm water permit
NM	New Mexico
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
QAPP	Quality Assurance Project Plan
SSTEMP	Stream Segment Temperature Model
SWPPP	Storm water pollution prevention plan
SWQB	Surface Water Quality Bureau
TMDL	Total Maximum Daily Load
UAA	Use Attainability Analysis
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WBP	Watershed-based plan
WLA	Waste load allocation
WQCC	Water Quality Control Commission
WQS	Water quality standards (20.6.4 NMAC as amended through 5/22/2020)

EXECUTIVE SUMMARY

Section 303(d), or 33 U.S.C. § 1313(d), of the Federal Water Pollution Control Act, also known as the Clean Water Act (CWA), 33 U.S.C. § 1251 *et seq*., requires states to develop Total Maximum Daily Load (TMDL) management plans for water bodies determined to be water quality limited. A TMDL is defined as "*a written plan and analysis established to ensure that a water body will attain and maintain water quality standards including consideration of existing pollutant loads and reasonably foreseeable increases in pollutant loads*" (USEPA, 1999). A TMDL defines the amount of a pollutant a water body can assimilate without violating a state's water quality standards (WQS). It also allocates that load capacity to known point sources and nonpoint sources at a given flow. It further identifies potential methods, actions, or limitations that could be implemented to achieve water quality standards. TMDLs are defined in 40 Code of Federal Regulations Part 130 (40 C.F.R. § 130.2(i)) as the sum of individual Waste Load Allocations (WLAs) for point sources, and Load Allocations (LAs) for nonpoint source and background conditions, and a Margin of Safety (MOS) in acknowledgement of various sources of uncertainty in the analysis.

The New Mexico Environment Department (NMED) Surface Water Quality Bureau (SWQB) conducted a water quality survey of the Gila/Mimbres/San Francisco and Lower Rio Grande basins in 2019-20. Water quality monitoring stations were located to evaluate the impact of tributary streams and ambient water quality conditions. Impairments addressed in this TMDL document, as well as existing approved TMDLs, are shown on Tables ES-1 to ES-11, below. Additional information regarding these impairments is available in the 2022-2024 Clean Water Act §303(d)/§305(b) Integrated Report and List (IR) (NMED/SWQB, 2022). This TMDL does not address all water quality impairments in the project area, only new listings based on 2019-2020 data, plus one older impairment which did not yet have a TMDL. Previous TMDLs were developed for other impairments in these watersheds; those TMDLs are available online at: https://www.env.nm.gov/surface-water-quality/tmdl/. Information regarding all impairments is available in the 2022-2024 Clean Water Act §303(d)/§305(b) Integrated Report and List (IR) (NMED/SWQB, 2022). The SWQB interactive Mapper (https://gis.web.env.nm.gov/oem/?map=swqb) provides a convenient interface to see where impairments exist, and to search for information about water bodies of interest using the Identify Features tool.

The next water quality monitoring survey of the Gila/Mimbres/San Francisco and Lower Rio Grande basins is scheduled for 2029-2030, at which time TMDL targets will be re-examined and potentially revised, as this document is considered to be an evolving management plan. In the event that new data indicate that the targets used in this analysis are not appropriate and/or if new standards are adopted, the TMDL will be adjusted accordingly. When water quality standards have been achieved, the reaches will be moved to the appropriate category in the IR.

Table ES-1. TMDL for Gilita Creek (Middle Fork Gila R to Willow Creek)	
New Mexico Standards Segment	20.6.4.503
Assessment Unit Identifier	NM-2503_45
NPDES Permit(s)	None
Segment Length	6.35 miles
Parameters of Concern	Temperature
Designated Uses Affected	High quality coldwater aquatic life
USGS Hydrologic Unit Code	15040001 - Upper Gila
Scope/size of Watershed	39.4 square miles
Land Type	23c – Montane Conifer Forests
Land Use/Cover	62.6% shrub/scrub, 35.0% forest, 1.3% grassland, 1.1% developed
Land Management	99.2% Forest Service, 0.8% Private
Geology	98.0% Igneous, 2.0% Igneous and Sedimentary
Probable Sources	Dam/impoundment; Forest fire; Other recreation (hiking trails)
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	None
	MOS + WLA + LA = TMDL
Temperature (kJ/day)	3.04×10^8 + 0 + 1.22×10^9 = 1.52×10^9

Table ES-2. TMDL for Las Animas Ck (perennial prt R Grande to Animas Gulch)	
New Mexico Standards Segment	20.6.4.103
Assessment Unit Identifier	NM-2103.A_51
NPDES Permit(s)	None
Segment Length	12.9 square miles
Parameters of Concern	Temperature
Designated Uses Affected	Marginal coldwater aquatic life
USGS Hydrologic Unit Code	13030101 - Caballo
Scope/size of Watershed	131 square miles
Land Type	23d – Arizona/New Mexico Subalpine; 23c – Montane Conifer Forests; 23e – Conifer Woodlands and Savannas; 24b – Chihuahuan Desert Grasslands
Land Use/Cover	67.0% shrub/scrub, 29.4% forest, 2.6% grassland
Land Management	47.7% Private, 42.1% Forest Service, 5.6% State Land Office, 4.6% Bureau of Land Management
Geology	69.5% Igneous, 18.9% Unconsolidated and Sedimentary, 6.8% Sedimentary, 4.7% Unconsolidated
Probable Sources	Crop production; Dam/impoundment; Forest fire; Highway/Road/Bridge runoff; Low water crossing; Rural residential area; Water diversion
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	None
	MOS + WLA + LA = TMDL
Temperature (kJ/day)	1.78×10^7 + 0 + 8.01×10^7 = 8.90×10^7

Table ES-3. TMDL for Mangas Creek (Gila River to Mangas Springs)	
New Mexico Standards Segment	20.6.4.502
Assessment Unit Identifier	NM-2502.A_21
NPDES Permit(s)	None
Segment Length	6.9 miles
Parameters of Concern	*E. coli,* Temperature
Designated Uses Affected	Primary contact
USGS Hydrologic Unit Code	15040002 – Upper Gila-Mangas
Scope/size of Watershed	204 square miles
Land Type	23b – Madrean Lower Montane Woodlands
Land Use/Cover	52.9% shrub/scrub, 31.2% forest, 10.6% grassland, 4.6% barren
Land Management	44.2% Private, 39.4% Forest Service, 13.1% State Land Office, 0.3% Bureau of Land Management
Geology	49.4% Igneous, 38.0% Igneous and Sedimentary, 4.4% Sedimentary, 4.2% Metamorphic, 3.9% Unconsolidated
Probable Sources	Crop production; Dam/impoundment; Highway/Road/Bridge runoff; Low water crossing; Natural sources; Rangeland grazing
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	Plant nutrients
	MOS + WLA + LA = TMDL
E. coli (cfu/100mL)	2.24×10^{8} + 0 + 2.02×10^{9} = 2.24×10^{9}
Temperature (kJ/day)	4.18×10^{7} + 0 + 1.67×10^{8} = 2.09×10^{8}

Table ES-4. Mimbres R (Perennial reaches Cooney Cyn to headwaters)	
New Mexico Standards Segment	20.6.4.807
Assessment Unit Identifier	NM-2804_40
NPDES Permit(s)	None
Segment Length	12.6 miles
Parameters of Concern	Temperature
Designated Uses Affected	High quality coldwater aquatic life
USGS Hydrologic Unit Code	13030202 - Mimbres
Scope/size of Watershed	30.4 sq mi
Land Type	23d – Arizona/New Mexico Subalpine; 23c – Montane Conifer Forests
Land Use/Cover	52.6% shrub/scrub, 45.1% forest, 2.3% grassland
Land Management	99.2% Forest Service, 0.8% Private
Geology	86.8% Igneous, 13.2% Igneous and Sedimentary
Probable Sources	Forest fire; Highway/Road/Bridge runoff; Low water crossing
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	*E. coli*
	MOS + WLA + LA = TMDL
Temperature (kJ/day)	3.72×10^7 + 0 + 1.49×10^8 = 1.86×10^8

Table ES-5. TMDL for Mule Creek (San Francisco R to Mule Springs)	
New Mexico Standards Segment	20.6.4.601 and 20.6.4.13(E)
Assessment Unit Identifier	NM-2601_01
NPDES Permit(s)	None
Segment Length	11.7 miles
Parameters of Concern	Plant nutrients
Designated Uses Affected	Marginal warmwater and marginal coldwater aquatic life
USGS Hydrologic Unit Code	15040004 – San Francisco
Scope/size of Watershed	93.9 square miles
Land Type	23b – Madrean Lower Montane Woodlands
Land Use/Cover	51.2% shrub/scrub, 37.2% forest, 11.0% grassland
Land Management	55.0% Forest Service, 45.0% Private
Geology	62.5% Igneous, 37.5% Igneous and Sedimentary
Probable Sources	Grazing in the riparian zone; Loss of riparian habitat; On-site treatment systems; Rangeland grazing; Rural residential area; Wildlife other than waterfowl
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	None
	MOS + WLA + LA = TMDL
TP (lb/day) TN (lb/day)	0.016 + 0 + 0.144 = 0.16 0.109 + 0 + 0.981 = 1.09

Table ES-6. TMDL for Rio Grande (International Mexico bnd to TX border)	
New Mexico Standards Segment	20.6.4.101
Assessment Unit Identifier	NM-2101_00
NPDES Permit(s)	NM0000108 - El Paso Electric Company/Rio Grande Power Plant; NM0029483 CRRUA - Sunland Park WWTP; NM0031178 – CRRUA - Sunland Park North WWTP; NMR040000 - New Mexico statewide general sMS4 permit
Segment Length	8.7 miles
Parameters of Concern	Dissolved boron
Designated Uses Affected	Irrigation
USGS Hydrologic Unit Code	13030102 – El Paso-Las Cruces
Scope/size of Watershed	28,014 square miles
Land Type	24f – Rio Grande Floodplain; 24a – Chihuahuan Basins and Playas
Land Use/Cover	45.6% shrub/scrub; 42.1% developed; 5.4% cultivated; 5.1% grassland; 1.0% barren
Land Management (US portion)	93.8% Private, 6.1% State Land Office, 0.1% Bureau of Land Management
Geology (US portion)	59.9% Unconsolidated, 32.3% Unconsolidated and Sedimentary, 5.2% Sedimentary, 2.6% Igneous
Probable Sources	Animal shows and racetracks; Channelization; Crop Production; Golf courses; Highway/Road/Bridge runoff; Inappropriate waste disposal; Industrial point source discharge; Municipal point source discharge; Off-road vehicles; Pavement/impervious surface; Urban runoff/storm sewers; Urbanized area
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	*E. coli*
	MOS + WLA + LA = TMDL
Dissolved boron (lb/day) Dry conditions Low Flow	30.3 + 62.3 + 210.4 = 303 11.4 + 35.2 + 67.4 = 114

Table ES-7. TMDL for San Francisco River (Box Canyon to Whitewater Creek)	
New Mexico Standards Segment	20.6.4.601
Assessment Unit Identifier	NM-2601_10
NPDES Permit(s)	None
Segment Length	6.2 miles
Parameters of Concern	*E. coli*
Designated Uses Affected	Primary contact
USGS Hydrologic Unit Code	15040004 – San Francisco
Scope/size of Watershed	1600 square miles
Land Type	23b – Madrean Lower Montane Woodlands
Land Use/Cover	69.1% forest, 23.7% shrub/scrub, 6.3% grassland
Land Management	94.8% Forest Service, 5.1% Private, 0.1% Bureau of Land Management
Geology	51.2% Igneous, 22.0% Igneous and Sedimentary, 13.7% Unconsolidated and Sedimentary, 10.1% Unconsolidated, 3.0% Sedimentary
Probable Sources	Crop production; Forest fire; Highway/Road/Bridge runoff; On-site treatment systems; Other recreation (hot springs soaking); Rangeland grazing; Rural residential area; Water diversion
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	None
	MOS + WLA + LA = TMDL
E. coli (cfu/100mL)	2.00×10^{9} + 0 + 3.81×10^{10} = 4.01×10^{10}

Table ES-8. TMDL for San Francisco River (Centerfire Creek to AZ border)*	
New Mexico Standards Segment	20.6.4.602 and 20.6.4.13(A)
Assessment Unit Identifier	NM-2602_20
NPDES Permit(s)	None
Segment Length	15.2 miles
Parameters of Concern	Sedimentation/siltation
Designated Uses Affected	Coldwater aquatic life
USGS Hydrologic Unit Code	15040004 – San Francisco
Scope/size of Watershed	150 square miles
Land Type	23c – Montane Conifer Forests
Land Use/Cover	79.1% forest, 12.3% shrub/scrub, 6.0% grassland, 1.5% developed
Land Management	90.8% Forest Service, 9.2% Private
Geology	39.5% Igneous, 32.4% Sedimentary, 18.4% Unconsolidated and Sedimentary, 5.6% Igneous and Sedimentary, 4.1% Unconsolidated
Probable Sources	Forest fire; Grazing in the riparian zone; Highway/Road/Bridge runoff; Low water crossing; Other recreation (campground); Rangeland grazing; Rural residential area; Silviculture; Water diversions
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	Plant nutrients, Temperature
	MOS + WLA + LA = TMDL
TSS (lb/day)	13.1 + 0 + 52.6 = 65.7

** protective TMDL*

Table ES-9. TMDL for San Francisco River (NM 12 at Reserve to Centerfire Creek)	
New Mexico Standards Segment	20.6.4.602
Assessment Unit Identifier	NM-2602_10
NPDES Permit(s)	None
Segment Length	16.3 miles
Parameters of Concern	Temperature
Designated Uses Affected	Coldwater aquatic life
USGS Hydrologic Unit Code	15040004 - San Francisco
Scope/size of Watershed	336 sq mi
Land Type	23c – Montane Conifer Forests; 23e – Conifer Woodlands and Savannas
Land Use/Cover	74.1% forest, 16.7% shrub/scrub, 7.6% grassland
Land Management	91.0% Forest Service, 9.0% Private
Geology	32.8% Unconsolidated and Sedimentary, 32.6% Igneous, 14.5% Sedimentary, 10.8% Unconsolidated, 9.4% Igneous and Sedimentary
Probable Sources	Crop production (irrigated); Dam/impoundment; Forest fire; Grazing in the riparian zone; Highway/Road/Bridge runoff; Low water crossing; Natural sources; Rangeland grazing;
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	*E. coli*, Turbidity
	MOS + WLA + LA = TMDL
Temperature (kJ/day)	4.38×10^7 + 0 + 2.48×10^8 = 2.92×10^8

*

Table ES-10. TMDL for Whitewater Creek (Whitewater Campgrd to headwaters)	
New Mexico Standards Segment	20.6.4.603
Assessment Unit Identifier	NM-2603.A_12
NPDES Permit(s)	None
Segment Length	14.0 miles
Parameters of Concern	Temperature
Designated Uses Affected	High quality coldwater aquatic life
USGS Hydrologic Unit Code	15040004 - San Francisco
Scope/size of Watershed	36.2 sq mi
Land Type	23d – Arizona/New Mexico Subalpine; 23c – Montane Conifer Forests; 23b – Madrean Lower Montane
Land Use/Cover	61.8% shrub/scrub, 36.9% forest, 1.3% grassland
Land Management	100% Forest Service
Geology	98.7% Igneous, 1.0% Unconsolidated, 0.2% Igneous and Sedimentary
Probable Sources	Forest fire; Other recreation (hiking trails);
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	Turbidity
	MOS + WLA + LA = TMDL
Temperature (kJ/day)	7.66×10^8 + 0 + 3.06×10^9 = 3.83×10^9

Table ES-11. TMDL for Willow Creek (Gilita Creek to headwaters)	
New Mexico Standards Segment	20.6.4.503
Assessment Unit Identifier	NM-2503_47
NPDES Permit(s)	None
Segment Length	7.34 miles
Parameters of Concern	Temperature
Designated Uses Affected	High quality coldwater aquatic life
USGS Hydrologic Unit Code	15040001 - Upper Gila
Scope/size of Watershed	15 square miles
Land Type	23d – Arizona/New Mexico Subalpine; 23c – Montane Conifer Forests
Land Use/Cover	82.0% shrub/scrub, 15.3% forest, 1.4% grassland, 1.2% developed
Land Management	99.2% Forest Service, 0.8% Private
Geology	99.8% Igneous, 0.2% Igneous and Sedimentary
Probable Sources	Forest fire; Highway/Road/Bridge runoff; Low water crossing; Other recreation (angling, campgrounds, hiking trails)
IR Category	5/5A
Priority Ranking	High
Existing TMDLs	Chronic aluminum
	MOS + WLA + LA = TMDL
Temperature (kJ/day)	2.70×10^8 + 0 + 1.08×10^9 = 1.35×10^9

1.0 BACKGROUND

This document establishes TMDLs for 11 Assessment Units (AUs) in the Gila/Mimbres/San Francisco, and Lower Rio Grande basins (**Figures 1.1** - **1.4**). Assessments of impairment were based on data collected during the 2019-2020 SWQB water quality survey.

1.1 Watershed Description

1.1.1 Gila/San Francisco/Mimbres

The project area for the Gila/San Francisco/Mimbres TMDLs is the 8-digit HUC 15040001 (Upper Gila), the portions of 8-digit HUCs 15040004 (San Francisco) and 15040002 (Upper Gila-Mangas) located within the state of New Mexico, and the 12-digit HUC 130302020101 (Powderhorn Canyon-Mimbres River) (**Figures 1.1** - **1.3**).

Table 1.1 Gila/San Francisco/Mimbres TMDL Assessment Units and monitoring stations. Locations are shown on Figure 1.3.

Map Point	Assessment Unit	Station name
1	Gilita Creek (Middle Fork Gila R to Willow Creek)	Gilita abv M Fk Gila-77Gilita000.1
2	Mangas Creek (Gila River to Mangas Springs)	Mangas Cr abv Gila R-78Mangas000.7
3	Mimbres R (Perennial reaches Cooney Cyn to headwaters)	Mimbres R @ Cooney Campground Crossing 150A-45Mimbre127.8
4	Mule Creek (San Francisco R to Mule Springs)	Mule Cr blw NM 78-80MuleCr014.5
5	San Francisco River (Box Canyon to Whitewater Creek)	San Francisco R @ USGS gauge nr Glenwood-80SanFra028.6
6	San Francisco River (Centerfire Creek to AZ border)	San Francisco R blw Luna-80SanFra144.9
7	San Francisco River (Centerfire Creek to AZ border)	San Francisco River above Luna-80SanFra154.1
8	San Francisco River (NM 12 at Reserve to Centerfire Creek)	SFR @ Cienega Cyn-80SanFra117.9
9	Whitewater Creek (Whitewater Campgrd to headwaters)	Whitewater Cr abv CG-80Whitew008.8
10	Willow Creek (Gilita Creek to headwaters)	Willow Cr abv Gilita-77Willow000.1

The Gila River is a major tributary to the Colorado River Basin, with its headwaters located in the Gila Wilderness and Gila National Forest of southwestern New Mexico. The greater Gila River Basin encompasses portions of New Mexico and Arizona. The New Mexico portion of the basin extends into Grant, Catron, and Hidalgo counties, and includes the main stem of the Gila River, the NM portion of the San Francisco River, and several tributaries. Major tributaries to the Gila

River include the East, Middle, and West forks of the Gila, Sapillo Creek, Mogollon Creek, and Mangas Creek. The San Francisco River is another major tributary to the Gila River with the confluence located in Arizona. Major tributaries to the San Francisco River in New Mexico include the Tularosa River and Whitewater Creek. The main population center in the Gila/San Francisco/Mimbres survey area is Silver City, NM.

Most of the greater Gila River watershed occurs within the southeastern portion of the Transition Zone Physiographic Province. The Transition Zone is an extensive area of extrusive and intrusive volcanic rocks that lies between the Paleozoic and Mesozoic sediments of the Colorado Plateau to the north and the Tertiary alluvial sediments of the Basin and Range to the south (NRCS, undated). The lower elevation areas in the southern part of the Gila watershed are located within the Basin and Range province. Surface geology of the project area is 56.6% Igneous, 31.5% Igneous and Sedimentary, 6.1% Unconsolidated, and 4.7% Unconsolidated and Sedimentary. The greater Gila River watershed within the Transition Zone is dominated by alumino-silicate igneous rocks including rhyolite, tuff, dacite, andesite and basalt that formed as part of the Mogollon-Datil volcanic field. Eruptions of lava and ash flows covered approximately 40,000 km^2 of southwestern New Mexico and southeastern Arizona between 40-24 million years ago (NMBGMR, undated). The volcanic field in the greater Gila River Basin is bounded on the east by the Rio Grande Rift. In addition to igneous rocks, Tertiary and Quaternary sedimentary deposits are widespread, including valley fill, pediment gravels, talus, and alluvial deposits. The portion of the watershed that lies in the Basin and Range province is dominated by younger Tertiary and Quaternary sedimentary deposits of sand, gravel, and conglomerate, interbedded with basalts in the basins, and volcanic rocks that are present in the parallel ranges (NRCS, undated) (**Figure 1.1**).

The region's complex geologic history has resulted in numerous economically viable ore deposits. There are many mining districts, mostly of metals (McLemore et al., 2021). The three major mining districts in the greater Gila River Basin are the Mogollon Mining District, located in the Mineral Creek and Silver Creek watersheds; the Tyrone, in the Mangas Creek watershed; and the NM portion of the Steeple Rock Mining District, located in Carlisle Creek watershed. While mining activity has decreased, there is active copper production and ongoing exploration.

The Mimbres watershed is classified in 20.6.4.803 NMAC as an endorheic, or closed, watershed. An endorheic basin is one in which there is no outflow from the basin. The closed basin that includes the Mimbres River watershed reaches from the northeast portions of Luna and Sierra counties into Grant and Doña Ana counties, and into northern Chihuahua, Mexico. It is located in the Mexican Highlands section of the Basin and Range physiographic province, and is characterized by high relief in the northern portion and moderate to low relief in the central and southern portions (NRCS, undated). Tributaries to the Mimbres River in New Mexico include San Vicente Arroyo, Gallinas River, East Fork Mimbres (McKnight Canyon), and Hot Springs Creek.

The geology of the Mimbres watershed in the north is similar to that of the greater Gila River Basin, with elevations ranging from nearly 10,000 ft above mean sea level at the headwaters to below 4,000 ft above mean sea level in the lower desert. The basin within New Mexico is dominated by the Mogollon-Datil volcanic field in the northern Transition Zone and the deep sedimentary deposits associated with the Basin and Range province in the southern watershed (**Figure 1.1**). Neogene volcanics dominate the headwaters of the Mimbres watershed, including basaltic andesites and tuffs. Other geologic materials in the watershed include Quaternary-aged conglomerates, piedmont alluvium and basin fill, and recent alluvial sediments. A wide variety of bedrock is present in the area, ranging from sedimentary rocks including limestone, sandstone, and shale, to igneous rock s of granite, granodiorite, and monzonite and metamorphic rocks including gneiss, schist, and quartzite (NRCS, undated).

Project area land cover is 51.4% forest, 38.0% shrub/scrub and 9.7% grassland (**Figure 1.2**). The Gila region is a center of biodiversity. Species listed by the federal Fish & Wildlife Service and/or the New Mexico Department of Game & Fish as Threatened or Endangered, which are known to occur in the Gila/San Francisco/Mimbres project area, are represented by county records for Catron and Grant Counties (Biota Information System of New Mexico, https://www.bison-m.org, accessed December 12, 2022). The list is shown in **Appendix A**. Whitewater Creek, Willow Creek and Gilita Creek are locations of species recovery efforts for the state and federally Threatened Gila trout. Those efforts are coordinated by the Gila Trout Recovery Team. State and federally listed Threatened and Endangered plant species are also listed in **Appendix A**.

Gilita Creek (Middle Fork Gila R to Willow Creek) and most of the Whitewater Creek (Whitewater Campgrd to headwaters) are located within the Congressionally designated Gila Wilderness. The Mimbres R (Perennial reaches Cooney Cyn to headwaters) AU is located within the Congressionally designated Aldo Leopold Wilderness. These water bodies are designated Outstanding National Resource Waters (ONRWs; 20.6.4.9 NMAC). ONRWs are streams, lakes and wetlands that receive additional protection against degradation under the State of New Mexico's Standards for Interstate and Intrastate Surface Waters and the federal Clean Water Act. An ONRW designation is the highest level of protection against degradation that can be afforded a waterbody under the State of New Mexico's Water Quality Standards.

From 800 to 1100 years ago, various native people (Clovis, Mogollon, Mimbres, and others) lived in the Gila and Mimbres river valleys. These people grew corn and beans, and were also hunters and gatherers. The Mimbres people disappeared from the area between the 1100s and 1300s. Spaniards arrived in the area around 1540 AD (NRCS, undated).

During colonial times, bands of Apache travelled the area and were led by historically significant chiefs such as Chato, Cochise, Geronimo, Mangas Coloradas, Nana, Natchez and Victorio. The rough terrain and strategic points on the landscape made the Gila Wilderness a well-fortified area where the Apaches felt safe from U.S. and Mexican Army pursuit. Frustrated with the appointed Spanish rulers, Mexican revolutionaries overthrew the Spanish and established the republic of Mexico in 1821. Twenty-five years after the Mexican Revolution, the expansion of America westward promoted a war against Mexico for the same piece of ground. The Treaty of Guadalupe Hidalgo (1821) and the Gadsden Purchase of 1854 claimed much of Mexico's northern lands (California, Arizona, New Mexico, Utah, Nevada and parts of Wyoming and Colorado) as part of the United States (NRCS, undated).

Present land ownership in the Gila/San Francisco/Mimbres project area is 69.4% Forest Service, 15.9% private, 9.6% Bureau of Land Management, and 5.1% State Land Office (**Figure 1.3**). The project area also includes the Gila Cliff Dwellings National Monument, managed by the National Park Service.

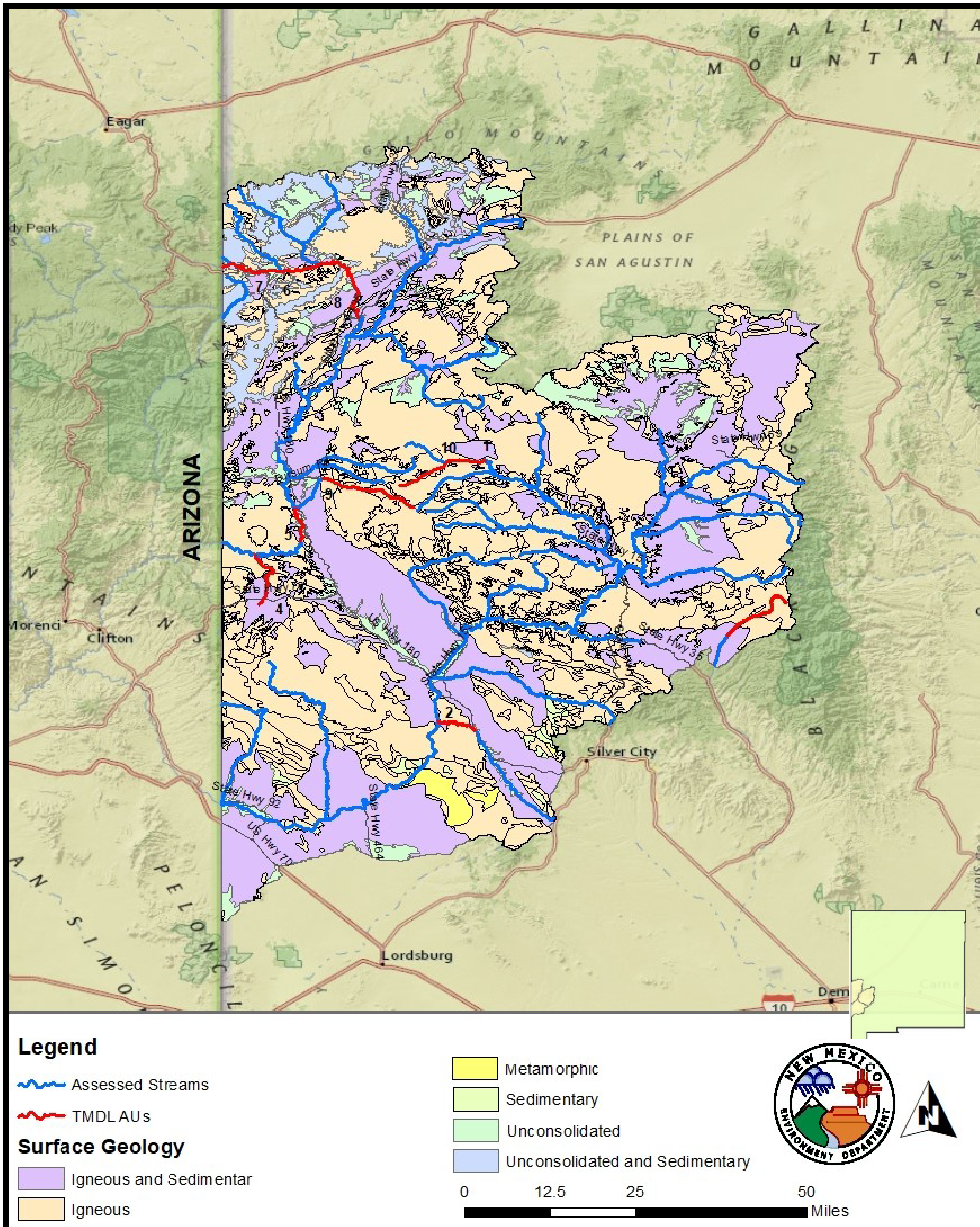

Figure 1.1 Surface geology of the Gila/San Francisco/Mimbres project area

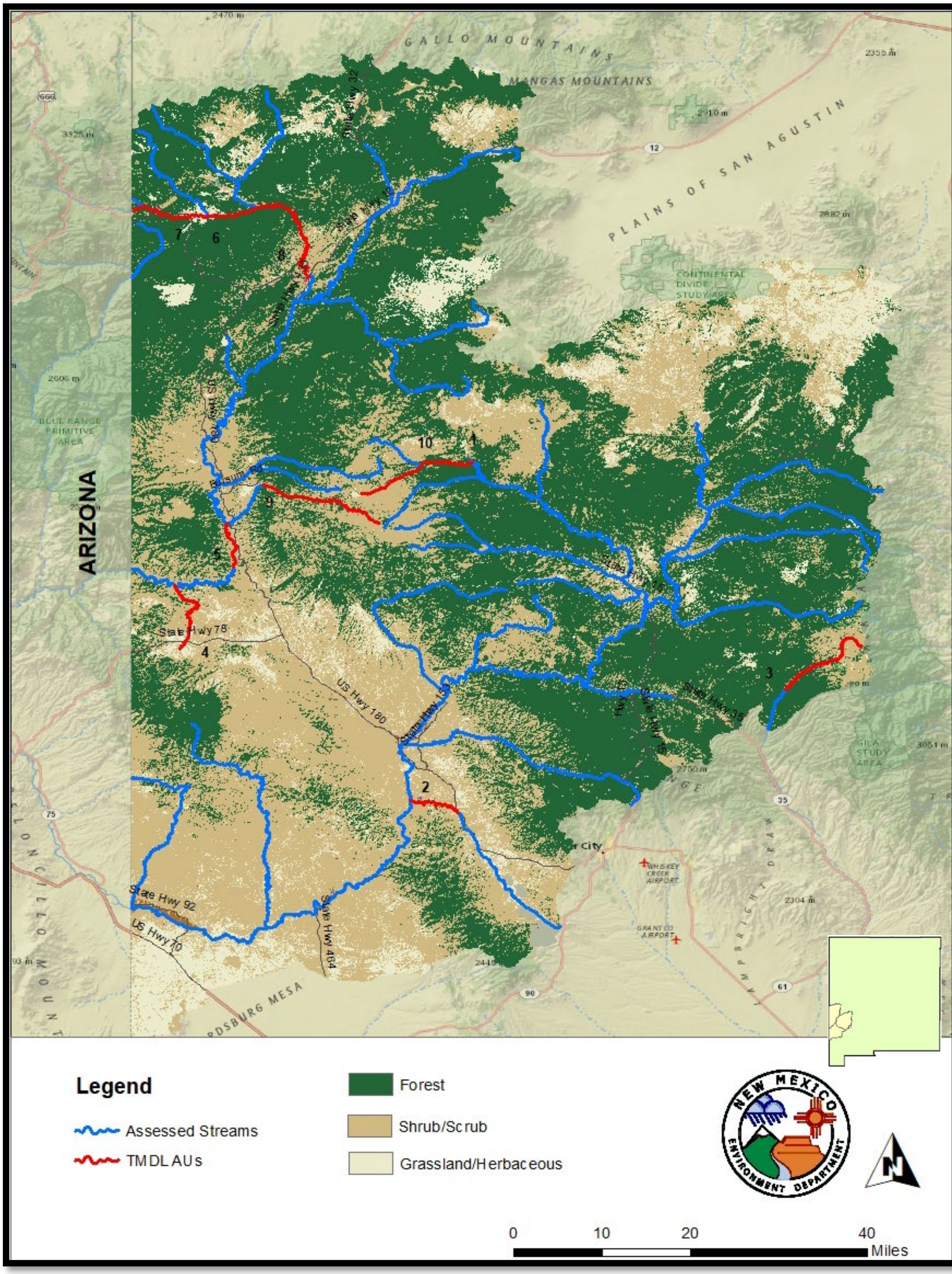

Figure 1.2 Land cover in the Gila/San Francisco/Mimbres survey area

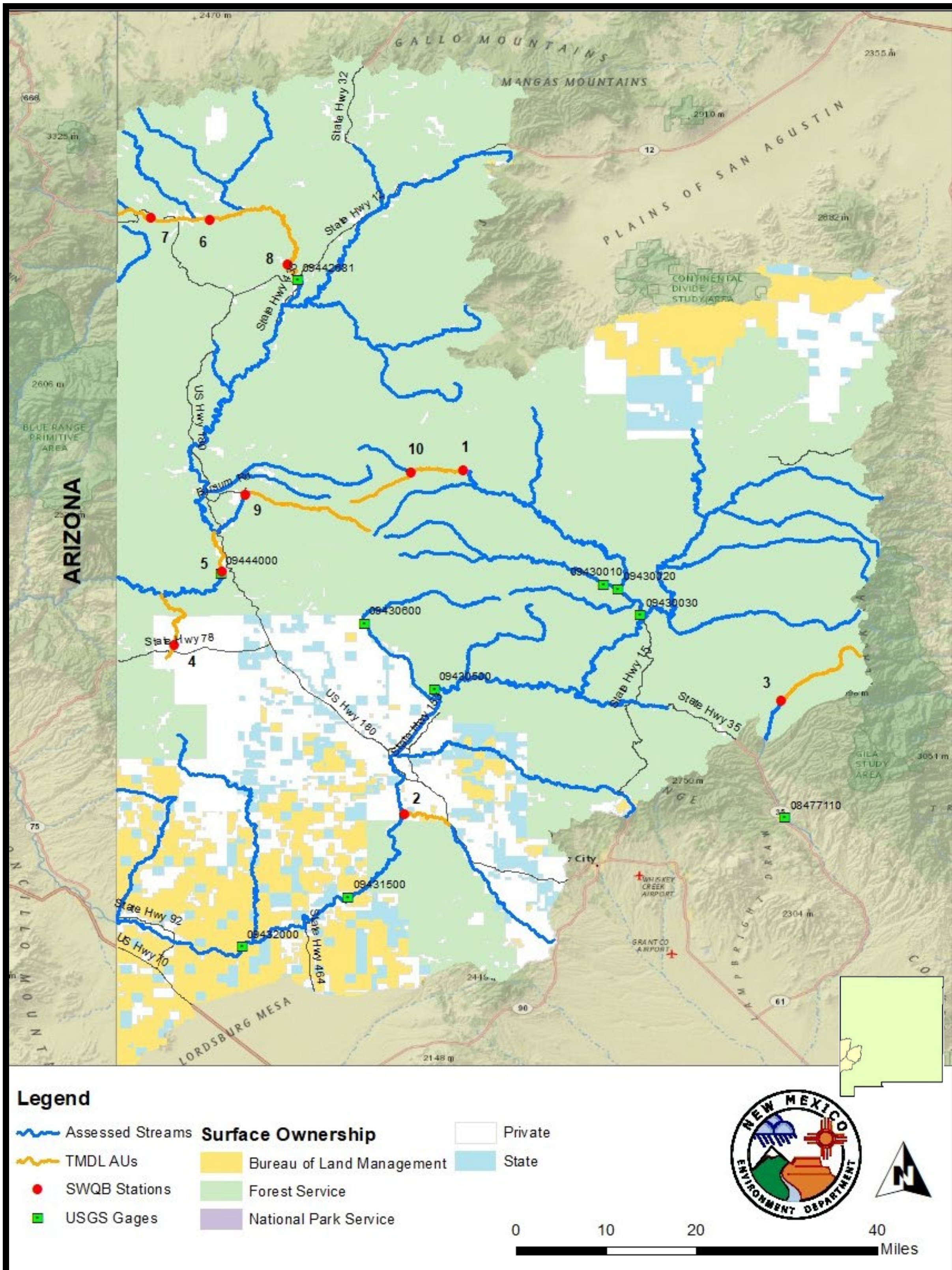

Figure 1.3 Land ownership in the Gila/San Francisco/Mimbres survey area

1.1.2 Lower Rio Grande

The Lower Rio Grande basin is located in Doña Ana, Sierra, and Socorro Counties in south-central New Mexico. The Lower Rio Grande Basin includes the Rio Grande from the boundary with Mexico to Elephant Butte Dam, as well as tributaries that enter the Rio Grande. At the international boundary, the Rio Grande drains approximately 29,267 square miles. The main population centers in the basin are Las Cruces, NM and El Paso, TX.

Table 1.2 Lower Rio Grande TMDL Assessment Units and monitoring stations. Locations are shown on Figure 1.4.

Map Point	Assessment Unit	Monitoring Station
1	Las Animas Ck (perennial prt R Grande to Animas Gulch)	Las Animas Cr @ Animas Rd-41LAnima009.0
2	(International Mexico bnd to TX border)	Rio Grande at Corchesne Bridge-42RGrand002.7

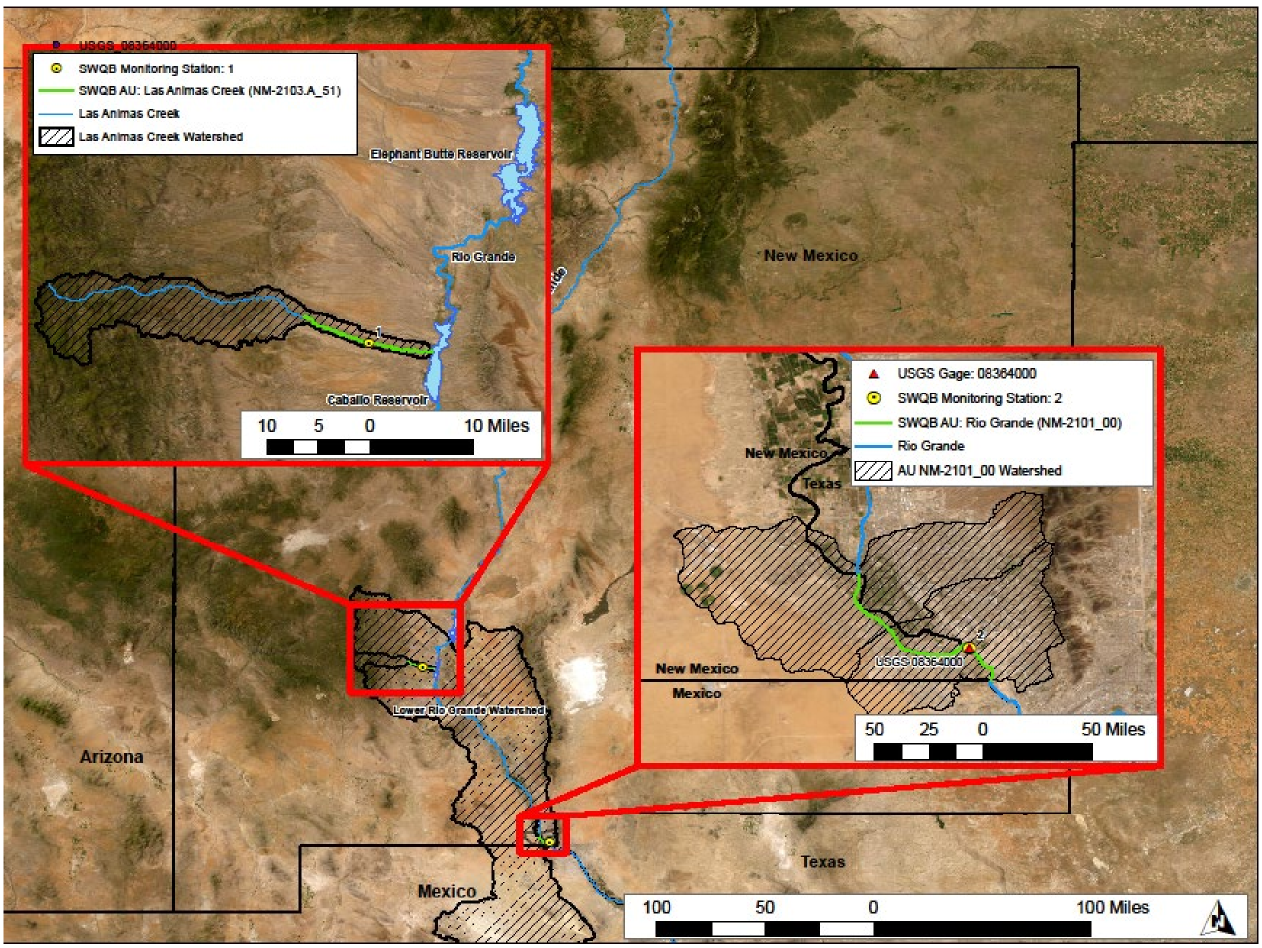

Figure 1.4 Location of the Lower Rio Grande TMDL watersheds

The surrounding geology was shaped by the Rio Grande Rift system, a series of grabens (fault-bounded basins) that extend from central Colorado southward through New Mexico and into western Texas and Mexico. Continental rifting was associated with crustal stretching and uplift of the southwestern United States. Grabens dropped down thousands of meters relative to adjacent uplifts, and alluvial sediment accumulated to great thickness in the basins. Intrusions and volcanic eruptions also took place within the rift valleys and throughout the surrounding region (NRCS, undated).

In this mostly arid to semiarid region, many of the Rio Grande tributaries are intermittent streams and mainstem flow is dominated by dam operations. Throughout the basin, an extensive system of structures captures and controls the flow of water in the subbasins to meet regional needs for flood control, power generation, and storage for domestic, agricultural, and industrial purposes. Ranching and irrigated agriculture is a major component of the economy in the basin. The Lower Rio Grande offers a 247-day growing season where temperatures can soar to 111 °F and plummet to –16 °F (Autobee, 1994). State parks and reservoirs located along the river support recreational sports such as hiking, mountain biking, camping, fishing, and water-skiing.

The Spanish Empire's entradas for colonization and conversion first made their way up the Rio Grande led by explorer Alvar Nuñez Cabeza de Vaca in 1536. Wandering inland in search of the mythic "Seven Cities of Cibola," Cabeza de Vaca and his band never found gold. The conquistadors and priests came upon Pueblo Indians irrigating and cultivating maize, beans, and squash. The Spanish arrival instigated a hundred-year struggle between the Europeans and the Pueblos. At the beginning of the seventeenth century, a Catholic mission established at El Paso del Norte (modern Juarez, Mexico) began teaching the Indians more advanced methods of growing crops, using water carried by the Acequia Madre (Main Canal).

Around 1890, extensive settlement and irrigation development in southern Colorado, in addition to that which had already taken place in central New Mexico, depleted the normal summer flow of the Rio Grande, causing the river to dry up at El Paso for more frequent and longer periods. Following a federal water claims agreement with Mexico, the Rio Grande Project was first appropriated funds in 1907. The Rio Grande Project water system features the Elephant Butte and Caballo Dams and reservoirs, six diversion dams, 141 miles of canals, 462 miles of laterals, 457 miles of drains, and a hydroelectric plant (Autobee, 1994).

Historic and current land uses in the watershed include agriculture, recreation, and municipal areas. Much of the land adjacent to the river is privately owned, with the exception of state parks near Elephant Butte Lake, Caballo Lake, Percha Dam, and Leasburg Dam. The Bureau of Land Management and the State of New Mexico also own and manage sizable tracts of public land in the upland portions of the watershed. The Lower Rio Grande watershed is located in Omernick Level III Ecoregion 24 - Chihuahuan Deserts.

Animal species listed by the federal Fish & Wildlife Service and/or the New Mexico Department of Game & Fish as Threatened or Endangered, which are known to occur in the Rio Grande (International Mexico bnd to TX border) and Las Animas Ck (perennial prt R Grande to Animas Gulch) watersheds are represented by county records for Sierra and Dona Ana Counties, respectively (Biota Information System of New Mexico, https://www.bison-m.org, accessed July 11, 2022). The lists are shown in **Appendix A**. State and federally listed Threatened and Endangered plant species are also listed in **Appendix A**.

The drainage areas of the two TMDL AUs in the Lower Rio Grande basin are distant and quite distinct from each other (**Figure 1.4**). Las Animas Creek heads in the Black Range mountains of the Gila National Forest, and flows eastward into Caballo Lake, an impoundment of the Rio Grande. The AU drainage area coincides with the HUC-12 130301010408 (Outlet Las Animas Creek). The Rio Grande (International Mexico bnd to TX border) AU is located in the outskirts of the city of El Paso, TX. The AU drainage area coincides with the HUC-12s 130301020905 (Mulberry Dam-Rio Grande) and 130301020906 (City of Coronado Hills-Rio Grande). The portion of the drainage area in the state of Texas lies entirely within the incorporated limits of the city of El Paso.

1.2 Water Quality Standards

Water quality standards for the **Rio Grande (International Mexico bnd to TX border)** are set forth in the following sections of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 New Mexico Administrative Code [NMAC], effective 9/24/22, https://www.env.nm.gov/surface-water-quality/wqs/):

20.6.4.101 RIO GRANDE BASIN: The main stem of the Rio Grande from the international boundary with Mexico upstream to one mile downstream of Percha dam.

A. Designated uses: irrigation, marginal warmwater aquatic life, livestock watering, wildlife habitat and primary contact.

B. Criteria:
(1) The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses except that the following segment-specific criterion applies: temperature 34°C (93.2°F) or less.
(2) At mean monthly flows above 350 cfs, the monthly average concentration for: TDS 2,000 mg/L or less, sulfate 500 mg/L or less and chloride 400 mg/L or less.

C. Remarks: sustained flow in the Rio Grande below Caballo reservoir is dependent on release from Caballo reservoir during the irrigation season; at other times of the year, there may be little or no flow.

[20.6.4.101 NMAC - Rp 20 NMAC 6.1.2101, 10/12/2010; A, 12/15/2001; A, 5/23/2005; A, 12/1/2010; A, 3/2/2017]

Water quality standards for **Las Animas Ck (perennial prt Animas Gulch to headwaters)** are set forth in the following sections of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 New Mexico Administrative Code [NMAC], 2018, https://www.env.nm.gov/surface-water-quality/wqs/):

20.6.4.103 RIO GRANDE BASIN: - The main stem of the Rio Grande from the headwaters of Caballo reservoir upstream to Elephant Butte dam and perennial reaches of tributaries to the Rio Grande in Sierra and Socorro counties, excluding waters on tribal lands.

A. Designated uses: irrigation, livestock watering, wildlife habitat, marginal coldwater aquatic life, secondary contact and warmwater aquatic life.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses.

C. Remarks: flow in this reach of the Rio Grande main stem is dependent upon release from Elephant Butte dam.
[20.6.4.103 NMAC - Rp 20 NMAC 6.1.2103, 10/12/2000; A, 5/23/2005; A, 12/1/2010]

Water quality standards for **Mangas Creek (Gila River to Mangas Springs)** are set forth in the following sections of New Mexico Standards for Interstate and Intrastate Surface Waters(20.6.4 New Mexico Administrative Code [NMAC], 2018, https://www.env.nm.gov/surface-water-quality/wqs/):

20.6.4.502 GILA RIVER BASIN: The main stem of the Gila river from Redrock canyon upstream to the confluence of the West Fork Gila river and East Fork Gila river and perennial reaches of tributaries to the Gila river downstream of Mogollon creek.

A. Designated uses: industrial water supply, irrigation, livestock watering, wildlife habitat, marginal coldwater aquatic life, primary contact and warmwater aquatic life.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses, except that the following segment-specific criterion applies: 28°C (82.4°F) or less.

[20.6.4.502 NMAC - Rp 20 NMAC 6.1.2502, 10/12/2010; A, 5/23/2005; A, 12/1/2010; A, 3/2/2017]

Water quality standards for **Gilita Creek** (Middle Fork Gila R to Willow Creek) and **Willow Creek** (Gilita Creek to headwaters) are set forth in the following sections of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 New Mexico Administrative Code [NMAC], 2018, https://www.env.nm.gov/surface-water-quality/wqs/):

20.6.4.503 GILA RIVER BASIN: All perennial tributaries to the Gila river upstream of and including Mogollon creek.

A. Designated uses: domestic water supply, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and primary contact.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses, except that the following segment-specific criteria apply: specific conductance of 400 µS/cm or less for all perennial tributaries except West Fork Gila and tributaries thereto, specific conductance of 300 µS/cm or less; 32.2°C (90°F) or less in the east fork of the Gila river and Sapillo creek downstream of Lake Roberts; the monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less, single sample 235 cfu/100 mL or less.

[20.6.4.503 NMAC - Rp 20 NMAC 6.1.2503, 10/12/2010; A, 5/23/2005; A, 12/1/2010; A, 3/2/2017]

Water quality standards for **Mule Creek (San Francisco R to Mule Springs)** and **San Francisco River (Box Canyon to Whitewater Creek)** are set forth in the following sections of New Mexico Standards for Interstate and Intrastate Surface Waters(20.6.4 New Mexico Administrative Code [NMAC], 2018, https://www.env.nm.gov/surface-water-quality/wqs/):

20.6.4.601 SAN FRANCISCO RIVER BASIN: - The main stem of the San Francisco river from the New Mexico-Arizona line upstream to state highway 12 at Reserve and perennial reaches of Mule creek.

A. Designated uses: irrigation, marginal warmwater and marginal coldwater aquatic life, livestock watering, wildlife habitat and primary contact.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses.

[20.6.4.601 NMAC - Rp 20 NMAC 6.1.2601, 10/12/2000; A, 5/23/2005; A, 12/1/2010]

Water quality standards for the **San Francisco River (Centerfire Creek to AZ border),** and **San Francisco River (NM 12 at Reserve to Centerfire Creek)** are set forth in the following sections of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 New Mexico Administrative Code [NMAC], 2018, https://www.env.nm.gov/surface-water-quality/wqs/):

20.6.4.602 SAN FRANCISCO RIVER BASIN: - The main stem of the San Francisco river from state highway 12 at Reserve upstream to the New Mexico-Arizona line.

A. Designated uses: coldwater aquatic life, irrigation, livestock watering, wildlife habitat and primary contact.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses, except that the following segment-specific criterion applies: temperature 25°C (77°F) or less.

[20.6.4.602 NMAC - Rp 20 NMAC 6.1.2602, 10/12/2000; A, 5/23/2005; A, 12/1/2010]

Water quality standards for **Whitewater Creek (Whitewater Campgrd to headwaters)** are set forth in the following sections of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 New Mexico Administrative Code [NMAC], 2018, https://www.env.nm.gov/surface-water-quality/wqs/):

20.6.4.603 SAN FRANCISCO RIVER BASIN: - All perennial reaches of tributaries to the San Francisco river above the confluence of Whitewater creek and including Whitewater creek.

A. Designated uses: domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and primary contact.

B. Criteria: the use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses, except that the following segment-specific criteria apply: specific conductance 400 µS/cm or less; the monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less, single sample 235 cfu/100 mL or less; and temperature 25°C (77°F) or less in Tularosa creek.

[20.6.4.603 NMAC - Rp 20 NMAC 6.1.2603, 10/12/2000; A, 5/23/2005; A, 12/1/2010]

Water quality standards for the **Mimbres R (Perennial reaches Cooney Cyn to headwaters)** are set forth in the following sections of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 New Mexico Administrative Code [NMAC], 2018, https://www.env.nm.gov/surface-water-quality/wqs/):

20.6.4.807 CLOSED BASINS: Perennial reaches of the Mimbres river upstream of Cooney canyon and all perennial reaches thereto, including perennial reaches of East Fork Mimbres river (McKnight canyon) upstream of the fish barrier.

A. Designated uses: Irrigation, domestic water supply, high quality coldwater aquatic life, livestock watering, wildlife habitat and primary contact.

B. Criteria: The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses, except that the following segment-specific criteria apply: specific conductance 300 µS/cm or less; the monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less, single sample 235 cfu/100 mL or less.

[20.6.4.807 NMAC - N, 3/2/2017]

1.3 Antidegradation and TMDLs

New Mexico's antidegradation policy, found at 20.6.4.8(A) NMAC and required under 40 C.F.R. § 131.12, describes how waters are to be protected from degradation. At a minimum, the policy mandates that "the level of water quality necessary to protect the existing uses shall be maintained and protected in all surface waters of the state." Furthermore, the policy's requirements must be met whether or not a segment is impaired. TMDLs are consistent with this policy because implementation of a TMDL restores water quality so that existing uses (defined as the highest quality of water that has been attained since 1975) are protected and water quality criteria are achieved.

The Antidegradation Policy Implementation Procedure establishes the process for implementing the antidegradation policy (Appendix A of NMED/SWQB, 2020b, https://www.env.nm.gov/surface-water-quality/wqmp-cpp/). However, certain specific requirements in the Antidegradation Policy Implementation Procedure do not apply to the Water Quality Control Commission's (WQCC) establishment of TMDLs because these types of water quality-related actions already are subject to extensive requirements for review and public participation, as well as various limitations on degradation imposed by state and federal law (NMED/SWQB, 2020b).

1.4 Water Quality Monitoring Survey

In 2019-20 SWQB surveyed the Gila River, Mimbres River, San Francisco River and Lower Rio Grande basins. The survey included the 8-digit HUCs 13030101 (Caballo), 13030102 (El Paso-Las Cruces), 13030202 (Mimbres), 15040001 (Upper Gila), 15040002 (Upper Gila-Mangas), and 15040004 (San Francisco) (**Figures 1.1-1.4**).

The SWQB divides rivers and streams into AUs based on differing geological and hydrological properties, and each AU was assessed individually using data from one or more monitoring sites located within the AU. Based on a variety of factors, selected monitoring locations were sampled for water quality constituents several times over the two years. Major reductions in the implementation of the 2019-2020 Upper Pecos River, San Francisco River, Gila River, Mimbres River, and Lower Rio Grande Field Sampling Plans, were necessary as a result of dry conditions, resource limitations, and COVID-19 restrictions.

Geomorphology and continuously logged data were collected at least once for as many as possible of the perennial AUs. Geomorphology parameters were measured following the then-current revision of the SWQB Standard Operating Procedure 5.0, Physical Habitat Measurements (https://www.env.nm.gov/surface-water-quality/sop/). Data-logged parameters may include temperature, turbidity, dissolved oxygen, pH, and/or conductivity, and were measured following the then-current revision of the SWQB Standard Operating Procedures 6.1-6.4, Sondes and Thermographs (https://www.env.nm.gov/surface-water-quality/sop/). Impaired AUs addressed in this TMDL report, and the associated monitoring stations, are shown on **Figures 1.3 and 1.4**.

Monitoring occurs during the non-winter months (March through November); focuses on physical, chemical, and biological conditions in perennial waters; and includes sampling for most pollutants that have numeric and/or narrative criteria in the WQS. More detail about the 2019-20 water quality survey can be found in the survey summary reports (NMED/SWQB, 2020b and 2020c, https://www.env.nm.gov/surface-water-quality/water-quality-monitoring/).

1.5 Hydrologic Conditions

In order to characterize streamflow conditions in which the thermograph and water chemistry data were collected, discharge data were obtained for 2019 and 2020 from USGS gages on the major rivers in the basins. Gage locations are shown on **Figures 1.3** and **1.4**. Discharge data (**Figures 1.5** and **1.6**) shows that the San Francisco River experienced much higher than normal spring runoff flow during both survey years, but was much drier than normal through the late summer and fall of both years. The Gila River had near-normal flow through most of the survey period, with brief drier-than-normal spells in late summer of both years. Las Animas Creek is ungaged and data were not available for the survey period from USGS Gage 08364000 – Rio Grande at El Paso, TX. There are no active discharge gages between USGS Gage 08364000 and the Leasburg Dam.

The U.S. Drought Monitor (https://droughtmonitor.unl.edu/Maps/MapArchive.aspx) classifies drought intensity into six condition classes, ranging from None to Exceptional. Parts of both project areas were in drought levels from None to Moderate through most of the TMDL project area in the spring and summer of 2019, becoming drier as the year progressed, up to conditions considered Severe in the San Francisco watershed that fall. Only the Mimbres watershed experienced conditions exceeding Moderate drought in the spring of 2020, but conditions were again in the Severe to Exceptional drought range in parts of the project area by fall of that year.

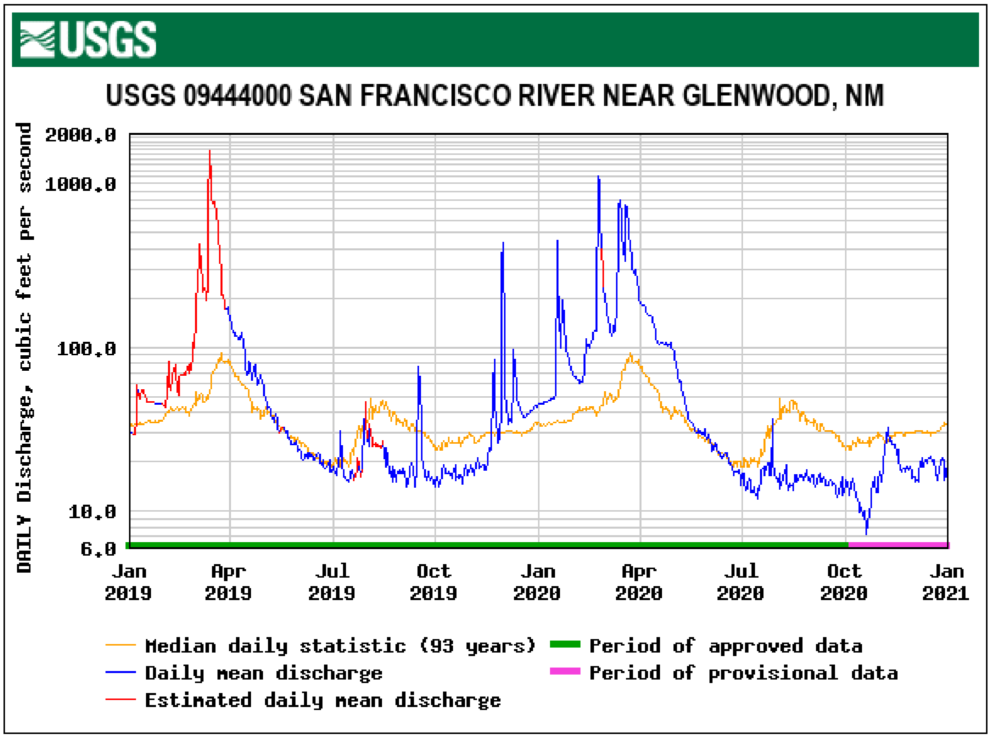

Figure 1.5 Daily discharge in 2019 and 2020 for the San Francisco River near Glenwood, NM.

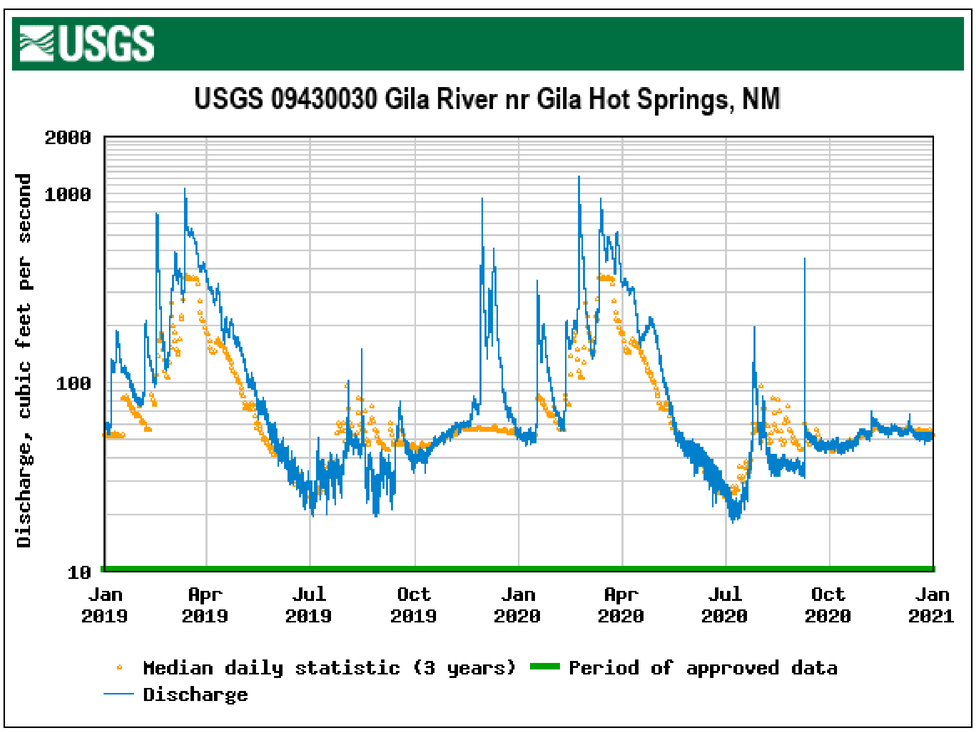

Figure 1.6 Daily discharge in 2019 and 2020 for the Gila River near Gila Hot Springs, NM.

1.6 TMDL Uncertainties

Pursuant to EPA guidance (EPA, 2002), TMDLs "should contain documentation supporting the TMDL analysis, including the basis for any assumptions; a discussion of strengths and weaknesses in the analytical process; and results from any water quality modeling." Uncertainties and assumptions in the TMDL process are detailed in the individual Margin of Safety subsections for each TMDL parameter. Uncertainties and assumptions related to the size of the available datasets and/or flow are detailed in the Target Loading Capacity and Flow subsections for each TMDL parameter. When modeling is used to develop a TMDL, water quality modeling results are summarized in the individual TMDL parameter sections and detailed in an appendix to the TMDL. In general, weaknesses in the TMDL analytical process include the limited availability of water quality data during the assessment process, limited flow and habitat measurements for TMDL development, and limited flow and water quality long-term gaging sites to be used during both the assessment and TMDL processes. Strengths in the TMDL analytical process include the robust assessment processes outlined in the Comprehensive Assessment and Listing Methodology (CALM; NMED/SWQB, 2021) especially related to assessments of narrative water quality standards, such as nutrients, sedimentation, and turbidity. Additional strengths include the use of regression equations to calculate TMDLs such as turbidity and specific conductance as well as the collection and subsequent discussion of NPDES permit effluent data as part of the TMDL development process.

2.0 BORON

Boron is a naturally occurring element widely distributed in the earth's crust, soils, and minerals. In water boron is usually found as boric acid. High concentrations of boron are common for some volcanic spring waters and boron may also enter the air, water, and land from wind-blown dust or runoff and leaching.

Boron is an essential micronutrient for plants, but different plant species require different boron levels for optimum growth. Boron plays several roles within the plant cell: in cell division, in the metabolism, and in the cell membrane. As a result, boron (in the form of borates) occurs naturally in fruits, nuts, and vegetables. Boron enters the environment mainly through natural processes such as weathering and, to a lesser extent, through anthropogenic sources such as urban stormwater, borate-containing fertilizers and the burning of domestic waste and wood fuel since boron is present in many plants. Additionally, sodium perborate serves as a source of active oxygen in many detergents, laundry detergents, cleaning products, laundry bleaches, and some tooth bleaching formulas.

In plants, there is only a narrow margin between boron deficiency and excess boron uptake leading to toxicity. Boron excesses usually occur in soil solution, i.e. the water found in the soil containing soluble material, from geologically young deposits, arid soils and soils derived from marine sediments. It also occurs in soils contaminated by human activities, such as releases from sewage outfalls. Irrigation water containing boron is one of the main sources of high boron levels leading to toxicity on agricultural land.

2.1 Target Loading Capacity

Assessment of data collected from 2010-12 identified exceedances of the New Mexico water quality standards for dissolved boron in the AU NM-2101_00 Rio Grande International Mexico bnd to TX border), formerly a part of Rio Grande (International Mexico bnd to Anthony Bridge) (**Figure 2.1**). The impairment was confirmed by monitoring results of the 2019-20 Lower Rio Grande water quality survey. Data supporting the assessments is shown in **Appendix B**. Consequently, this waterbody is listed on the Integrated CWA §303(d)/§305(b) list as impaired for boron (NMED/SWQB, 2022).

According to the New Mexico water quality standards (20.6.4.900 NMAC), the dissolved boron criteria are 750 µg/L for irrigation and 5,000 µg/L for livestock watering. No samples exceeded the livestock watering criterion. Exceedance ratios of the irrigation criterion are presented in **Table 2.1**.

Table 2.1 Exceedances of the dissolved boron irrigation criterion

Assessment Unit	2010-12	2019
Rio Grande (International Mexico bnd to TX border)	2/8	1/4

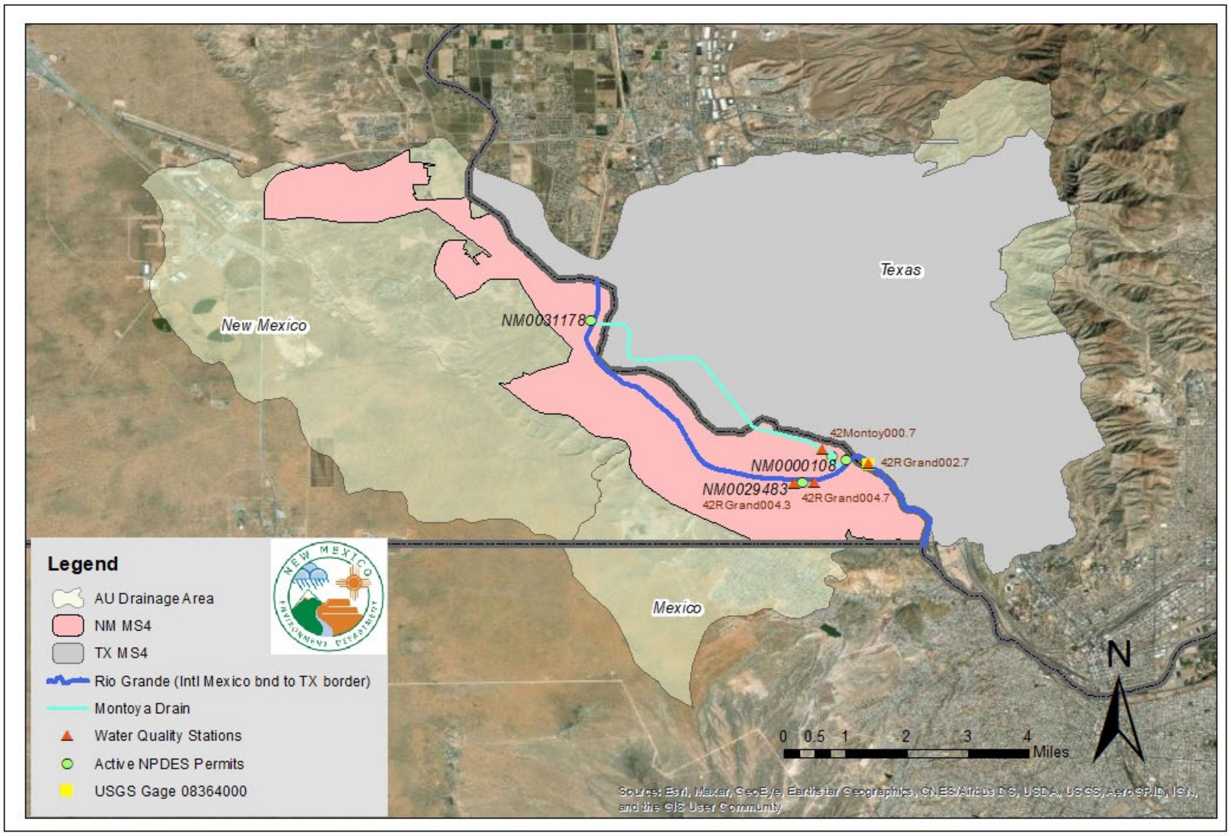

Figure 2.1 Drainage area of the dissolved boron impaired AU Rio Grande (Intl Mexico bnd to TX border)

2.2 Flow

Flow in the Lower Rio Grande is dam-controlled and follows a bimodal pattern wherein water is conserved behind a series of dams, to be released in the summer months for purposes of irrigation and contracted deliveries to Texas. Exceedances of the dissolved boron WQS were documented only at lower flows. When water quality impairments are correlated to flow conditions, a duration curve approach is appropriate (USEPA, 2007). Therefore, the boron loading target for the Rio Grande (International Mexico bnd to TX border) is evaluated using a flow duration curve, which looks at the cumulative frequency of historic flow data over a specified period. A flow duration curve relates flow values to the percent of time those values have been met or exceeded. The use of *"percent of time"* provides a uniform scale ranging between 0 and 100. Thus, the full range of stream flows is considered. Low flows are exceeded most of the time, while floods are exceeded infrequently (USEPA, 2007).

A basic flow duration curve runs from high to low along the x-axis. The x-axis represents the duration, or percent of time, as in a cumulative frequency distribution. The y-axis represents the flow value (e.g., cubic feet per second) associated with that percent of time, or duration. The flow duration analysis presented here uses daily average discharge rates, which are sorted from the highest value to the lowest. Using this convention, flow duration intervals are expressed as a percentage, with zero corresponding to the highest stream discharge in the record (i.e., flood conditions) and 100 to the lowest (i.e., drought conditions).

Thus, a flow duration interval of sixty associated with a specific stream discharge means that sixty percent of all observed daily average stream discharge values equal or exceed that discharge value.

Flow for the Rio Grande (International Mexico bnd to TX border) is recorded by daily discharge data of USGS Gage 08364000 – Rio Grande at El Paso, TX (USGS gage location shown on **Figures 1.4** and **2.1**). The Caballo Dam was completed in 1938, and substantially altered water management in the Lower Rio Grande. Gage flow from 1939 through 2017 (the latest available record) was used to develop the flow duration curve (**Figure 2.2**).

Duration curve analysis may include the identification of intervals which can be used as a general indicator of hydrologic condition (i.e., wet versus dry and to what degree). Flow duration curve intervals can be grouped into broad categories or zones in order to provide additional insight about conditions and patterns associated with the impairment. In this case we have divided the curve into five zones, as illustrated in **Figures 2.2** and **2.3**: one representing *high flows (0-10%)*, another for *moist conditions (10-40%)*, one covering *mid-range flows (40-60%)*, another for *dry conditions (60-90%)*, and one representing *low (or no) flows (90-100%)* (Cleland, 2003). This particular approach places the midpoints of the moist, mid-range, and dry zones at the 25th, 50th, and 75th percentiles respectively (i.e., the quartiles). The high zone is centered at the 5th percentile, while the low zone is centered at the 95th percentile.

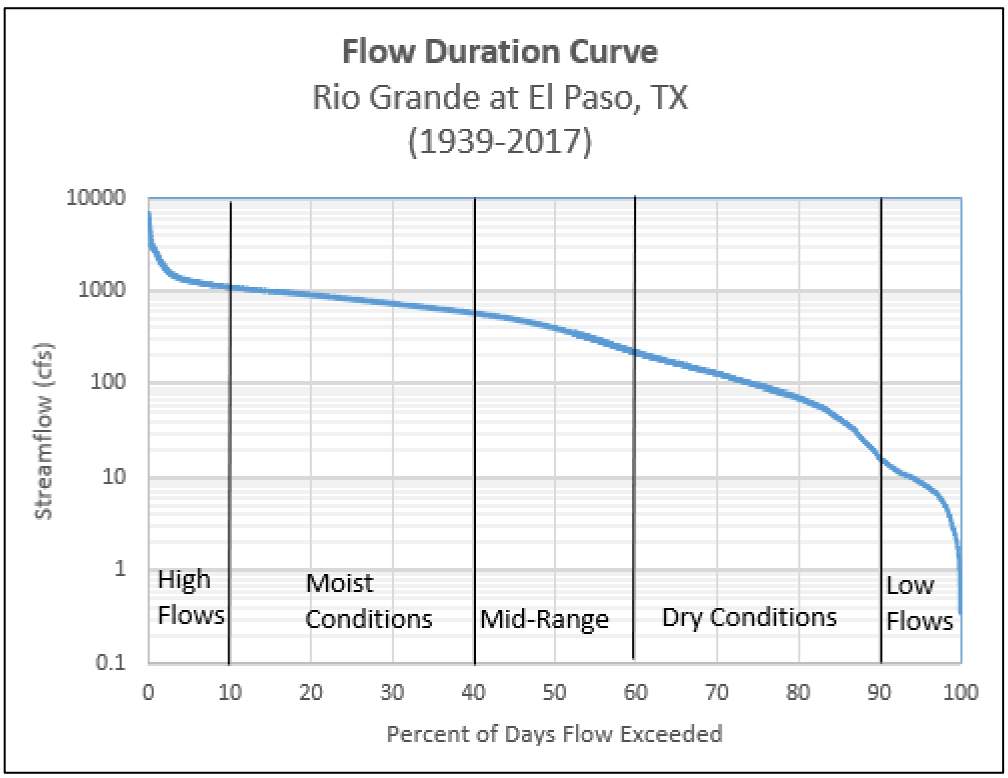

Figure 2.2 Flow duration curve for the USGS Gage 08364000 – Rio Grande at El Paso, TX

2.3 TMDL Calculations

The use of duration curves provides a technical framework for identifying daily loads in TMDL development, which accounts for the variable nature of water quality associated with different stream flow rates. Specifically, a maximum daily concentration limit can be used with basic hydrology and a duration curve to identify a TMDL that covers the full range of flow conditions. With this approach, ambient water quality data, taken with some measure or estimate of flow at the time of sampling, can be used to compute an instantaneous load. Using the relative percent exceedance from the flow duration curve that corresponds to the stream discharge at the time the water quality sample was taken, the computed load can be plotted in a duration curve format (**Figure 2.3**).

By displaying instantaneous loads calculated from ambient water quality data and the daily average flow on the date of the sample (expressed as a flow duration curve interval), a pattern develops which describes the characteristics of the water quality impairment. Loads that plot above the curve indicate an exceedance of the water quality criterion (dissolved boron in this case), while those below the load duration curve show achievement of the standard. The pattern of impairment can be examined to see if it occurs across all flow conditions, corresponds strictly to high flow events, or conversely, only to low flows. Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left generally reflect probable nonpoint source contributions.

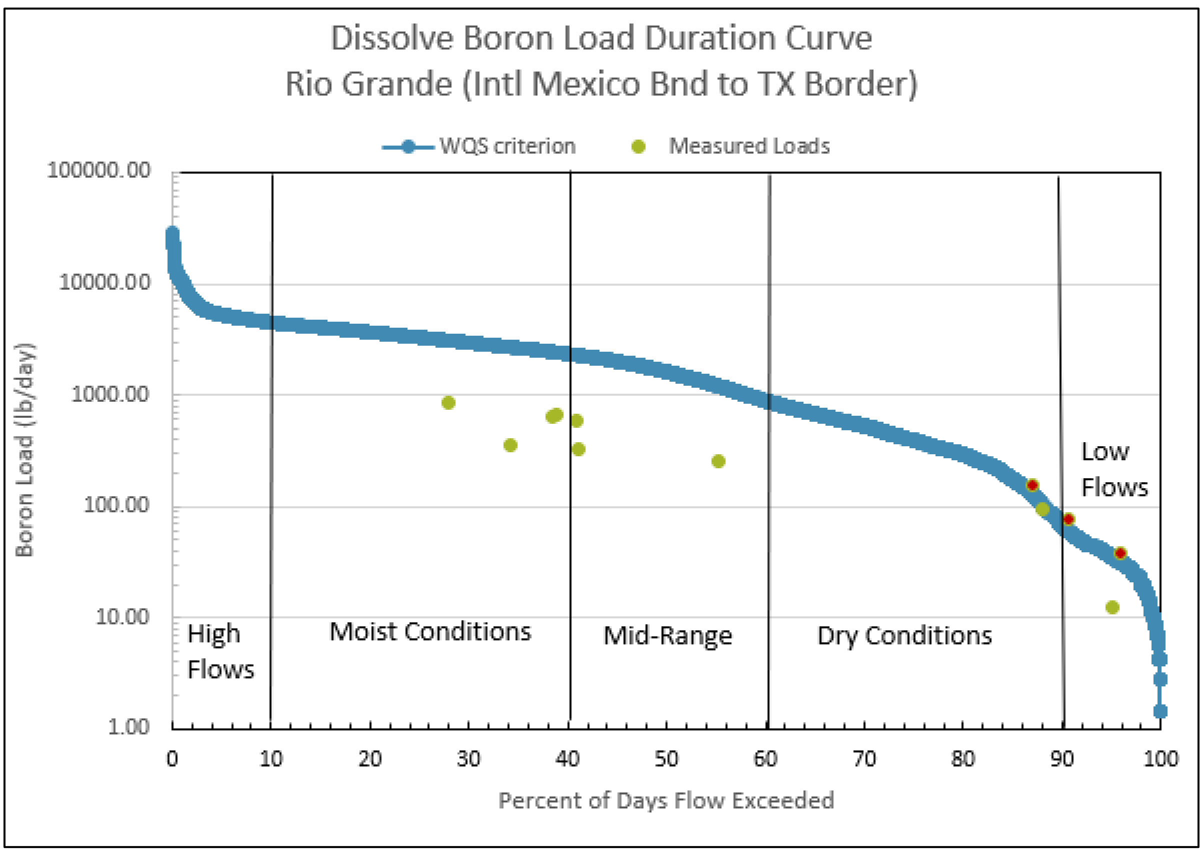

Figure 2.3 Dissolved boron load duration curve – Rio Grande (International Mexico bnd to TX border). Measured loads exceeding the WQS are filled in red.

Under the duration curve framework, the loading capacity is essentially the curve itself. The loading capacity, which sets the target load on any given day, is determined by the flow on the particular day of interest. However, a continuous curve that represents the loading capacity has some logistical drawbacks. It is often easier to communicate information with a set of fixed targets. Critical points along the curve can be used as an alternative method to quantify the loading capacity, such as the mid-point of each hydrologic zone (e.g., the 5th, 25th, 50th, 75th, and 95th percentiles). A unique loading capacity for each hydrologic zone allows the TMDL to reflect changes in dominant watershed processes that may occur under different flow regimes. This TMDL presents values for the dry (90 to 219 cfs) and low flow (0 to 90 cfs) zones, since those were the prevailing conditions at the time that exceedances were documented in 2011, 2012 and 2019. The TMDL values are presented on **Table 2.2**.

Flow was converted from cfs to million gallons per day (mgd) using a conversion factor of 0.646. The target loading capacity is calculated using the following equation: *WQS criterion (mg/L) x Flow (mgd) x 8.34 (a unit conversion factor)*.

The TMDL is a planning tool to be used to achieve water quality standards. Since flows vary throughout the year in these systems the target load will vary based on the changing flow. Management of the load to improve stream water quality and meet water quality criteria is the goal. The TMDL is further allocated to a MOS, WLA (permitted point sources), and LA (nonpoint sources), according to the formula: WLA + LA + MOS = TMDL.

Table 2. 2 Calculation of Target Loads: Rio Grande (International Mexico bnd to TX border)

	FLOW CONDITIONS	
	Dry Conditions	**Low Flow**
Dissolved boron criterion (mg/l)	0.75	0.75
Mid-point Flow (mgd)	48.5	23.0
Conversion Factor	8.34	8.34
TMDL (lb/day)	303	114

2.3.1 Margin of Safety

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS can be expressed either implicitly or explicitly. An implicit MOS is incorporated by making conservative assumptions in the TMDL analysis, such as allocating a conservative load to background sources. An explicit MOS is applied by reserving a portion of the TMDL and not allocating it to any other sources. For this boron TMDL, the margin of safety was developed using a combination of conservative assumptions and explicit recognition of potential errors. Therefore, this margin of safety is the sum of the following two elements:

- *Conservative Assumptions*
    - Treating boron as a pollutant that does not readily degrade in the environment.

- *Explicit Recognition of Potential Errors*
    - There is inherent error in flow estimation, both measured and calculated; a conservative MOS for this element in gaged streams is 5%. Another 5% explicit MOS is assigned due to the complexity of flow engineering in the Lower Rio Grande.

Therefore, based on the potential errors described above **an explicit MOS of 10%** was assigned to the boron TMDL.

2.3.2 Waste Load Allocation

Point Source

There are three facilities with active individual NPDES permits discharging to the Rio Grande (International Mexico bnd to TX border) (**Table 2.3**). All three permits have reporting requirements for boron, but no permit limits.

Table 2.3 Point source permits discharging to the Rio Grande (International Mexico bnd to TX border). Locations are shown on Figure 2.1.

NPDES Permit Number	Permittee	Expiration Date
NM0031178	Camino Real Regional Utility Authority/Sunland Park North WWTP	December 29,2023
NM0029483	Camino Real Regional Utility Authority/Sunland Park WWTP	October 31, 2025
NM0000108	El Paso Electric Company/Rio Grande Power Plant	December 31, 2023

WLAs are calculated based on the permitted design flow. Since NPDES Permit NM0000108 does not specify a facility design flow, the WLA is calculated using the 85th percentile daily maximum flow for the most recent available reporting period (Jan 2019 to Mar 2022), which is 0.594 mgd. Individual waste load allocations are shown on **Table 2.4**. They are calculated using the equation: *WQS criterion x Flow x 8.34.*

Table 2.4 Dissolved boron Waste Load Allocations for individual NPDES permits discharging to the Rio Grande (International Mexico bnd to TX border)

Permit	Design Flow (mgd)	WLA (lb/day)
NM0031178 - SPN	1.0	6.26
NM0029483 - SP	2.0	12.52
NM0000108 - EPE	0.594*	3.72
Total Individual Permit WLA	3.6	22.5

** 85th percentile of reported flow value*

Over the period January 2019 to December 2020, the Sunland Park North WWTP discharged an average of 0.72 mgd. For the DMR reporting period January 2019 to May 2022, daily maximum total recoverable boron concentration of the NM0031178 Outfall 001A effluent exceeded the WQS in all but two months, or 95% of the time. Boron loading was also reported for Permit NM0031178. The daily maximum load of total recoverable boron in lb/day exceeded the calculated WLA in **Table 2.4** in 10 of 39 months, or 26% of the time. For permit reporting purposes, total or total recoverable concentration is considered the same as dissolved concentration, except where the permittee has conducted a partitioning study.

Over the reporting period November 2020 to May 2022, the Sunland Park WWTP discharged an average of 0.63 mgd. For the DMR reporting period Nov 2020 to June 2022, daily maximum total boron concentration of the NM0029483 Outfall 001A effluent equaled the WQS on one month, and exceeded it once (5% of the time). Boron loading was not reported for Permit NM0029483.

For the DMR reporting period Mar 2019 to Mar 2022, daily maximum dissolved boron concentration of the NM0000108 Outfall 002 effluent was greater than the WQS on 10 of 13 calendar quarters, or 77% of the time. Boron loading was not reported for Permit NM0000108.

Stormwater discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the USEPA NPDES Construction General Permit (CGP) for construction sites of one or more acres, or smaller if part of a common plan of development, requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. The current CGP also includes state-specific requirements to implement site-specific interim and permanent stabilization, managerial, and structural solids, erosion, and sediment control Best Management Practices (BMPs), and/or other controls. BMPs are designed to prevent to the maximum extent practicable an increase in sediment load to the water body or an increase in a sediment-related parameter, such as total suspended solids, turbidity, siltation, stream bottom deposits, etc. BMPs also include measures to reduce flow velocity during and after construction compared to pre-construction conditions to assure that waste load allocations and/or applicable water quality standards, including the antidegradation policy, are met. Compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Stormwater discharges from industrial activities and facilities, based on industrial classification codes, may be eligible for coverage under the current NPDES Multi-Sector General Permit (MSGP). The MSGP also requires preparation of a SWPPP. Some of the industrial facilities and activities covered under the MSGP have technology based effluent limitation and/or benchmark monitoring for pollutants. The current MSGP includes state-specific requirements that the benchmark values be protective of State of New Mexico WQS.

It is not possible to calculate individual WLAs for facilities covered by the General Permits at this time using the available tools. The discharges from these permits are typically transitory as the activities are temporary. Loads that are in compliance with the General Permits are therefore currently included as part of the Load Allocation (LA). While these sources are not given individual allocations, they are addressed through other means, including BMPs, stormwater pollution prevention conditions, and other requirements.

Municipal Stormwater

Dissolved boron may be a component of some stormwater discharges, so these discharges should be addressed. On September 29, 2006, EPA Region 6 issued general permits for discharges from regulated small municipal separate storm sewer system (sMS4s) in New Mexico and on Indian Country lands in New Mexico and Oklahoma. The general permits offer coverage for discharges of storm water from sMS4s that are regulated under Phase II of the National Pollutant Discharge Elimination System (NPDES) Storm Water Program to various waters of the United States in New Mexico and Oklahoma. In New Mexico, some of the major impacts to small MS4s are as follows: operators of MS4s located in urbanized areas must develop, implement, and enforce a storm water management program to reduce the discharge of pollutants from its MS4 to the "maximum extent practicable" and protect water quality; operators of "regulated" MS4s must obtain NPDES permit coverage; the permit application (Notice of Intent [NOI]) must include six "minimum control measures" (using Best Management Practices, or BMPs) and measurable goals; the BMPs must be fully implemented within 5 years of permit issuance; and, operators must submit yearly progress reports to EPA.

Boron concentration data from March 13, 2019, the same day that the dissolved boron impairment was confirmed by SWQB sampling, indicate that the majority of the load was entering the Rio Grande via the Montoya Drain (data presented in **Appendix B**). Stormwater from much of the AU drainage area east of the Rio Grande runs off to the Montoya Drain, which also receives the effluent from the El Paso Electric permitted discharge. The drain was originally constructed to lower the water table, so as to increase the area of dry land available for agriculture and urban development, and hence is likely in contact with the shallow groundwater table.

The TMDL AU is within the Census-designated El Paso Urbanized Area. There are three entities along the Rio Grande (International Mexico Boundary to TX border) AU that are eligible for coverage under the New Mexico statewide, general sMS4 permit (#NMR040000). They are Doña Ana County, City of Sunland Park, and the NM Department of Transportation. The WLA for sMS4s was based on the percent jurisdictional area approach. For each flow duration zone, the amount available for nonpoint source load allocations (LAs) and the sMS4 WLA was the TMDL for that zone minus the margin of safety (MOS) and the WLAs for individual NPDES permitted facilities. In the case of the Rio Grande (International Mexico Boundary to TX border), 15.9% of the drainage area falls within the jurisdiction of New Mexico sMS4 communities. Thus, the sMS4 WLA is 15.9% of the available allocation for each flow zone. The remaining 84.1% was designated as the LA for each zone.

This analysis assumes that flow in the AU upstream of Montoya Drain all comes from the permitted sources and from local overland flow. Implementation practitioners should conduct further investigation of relative contribution to flow at various points in the drainage area during dry and low flow conditions. Calculated waste load allocations for all NPDES permits in the impaired assessment unit are shown in **Table 2.5**.

Table 2.5 Dissolved boron Waste Load Allocations for the Rio Grande (International Mexico Boundary to TX border). Units are in lb/day.

	Flow Condition	
	Dry	**Low Flow**
TMDL minus MOS	272.7	102.6
Total Individual NPDES WLA	22.5	22.5
sMS4 WLA	39.8 (15.9% of 250.2)	12.7 (15.9% of 80.1)
Total WLA	62.3	35.2

In contrast to discharges from other industrial storm water and individual process wastewater permitted facilities, stormwater discharges are transient because they occur during storm events. Coverage under Phase II of the NPDES Storm Water Program requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with urban activities to minimize impacts to water quality. If a TMDL is approved for any waterbody into which the permittee discharges after the date that the permittee submits an NOI, EPA may require revisions to the SWMP to ensure that the Waste Load Allocation, Load Allocation and/or the TMDL's associated implementation plan will be met within any timeframes established in the TMDL. Monitoring of the discharges may also be required, as appropriate, to ensure compliance with the TMDL.

40 CFR 122.44 (d)(1)(vii) requires that NPDES permit conditions be consistent with State and Tribal water quality standards and available WLAs in an approved TMDL. The requirements in the MS4 General Permit are designed to implement the requirements of the TMDL. The TMDL requires the use of controls to meet water quality standards in stormwater through a combination of source reductions and structural controls. Where stormwater has the potential to cause or contribute to the impairment, the permittee shall include in the SWMP controls targeting the pollutant(s) of concern along with their corresponding measurable goals. Discharges of pollutant(s) of concern to impaired water bodies for which there is an EPA approved TMDL are not eligible for this general permit unless they are consistent with the approved TMDL (NM040000 Fact Sheet).

If the permittee discharges directly into an impaired water body without an approved TMDL, the permit requires the permittee to determine whether the MS4 may be a source of the pollutant(s) of concern by referring to the CWA §303(d) list and then determining if discharges from the MS4 would be likely to contain the pollutant(s) of concern at levels of concern. The permit requires the permittees to implement BMPs, to reduce, the discharge of pollutant(s) of concern that contribute to the impairment of the water body.

2.3.3 Load Allocation

To calculate the load allocation (LA), the WLA and margin of safety (MOS) were subtracted from the TMDL. Results are presented in **Table 2.6.** Additional details on the MOS are presented in **Section 2.3.1.**

Table 2.6 TMDL allocation for dissolved boron in the Rio Grande (International Mexico bnd to Anthony Bridge). Units are (lb/day)

Flow Condition	TMDL	10% MOS	Total WLA	LA
Dry Conditions	303	30.3	62.3	210.4
Low Flow	114	11.4	35.2	67.4

That portion of the TMDL drainage area which lies within the state of Texas is part of the incorporated City of El Paso, an MS4 permitted entity. The City of El Paso permitted area constitutes 45.7% of the drainage area. 6.8% of the drainage area is within the nation of Mexico, where there are potential pollutant sources in and around the town of Puerto de Anapra. The LA includes background overland flow, shallow groundwater intercepted by the Montoya Drain, and stormwater from the City of El Paso that flows directly into the TMDL AU. The extensive data collection and analyses necessary to determine background boron loads were beyond the resources available for this study. It is therefore assumed that a portion of the LA comes from natural sources.

2.3.4 Load Reduction

Table 2.7 Calculation of load reductions for dissolved boron in the Rio Grande (International Mexico bnd to TX border). Units are in lb/day.

Flow Condition	Target Load[a]	Measured Load[b]	Load Reduction	Percent Reduction[c]
Dry	272.7	329.7	57.0	17.3%
Low	102.6	134.5	31.9	23.7%

(a) Target Load = TMDL – MOS. The MOS is not included in the load reduction calculations because it is a set aside value, which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured load.

(b) The measured load is the magnitude of point and nonpoint sources. It is calculated using mean measured concentration values in the respective flow duration zone, at the midpoint flow for that zone.

(c) Percent reduction is the percent the existing measured load must be reduced to achieve the target load and is calculated as follows: ((Measured Load – Target Load) / Measured Load) x 100.

2.4 Identification and Description of Pollutant Source(s)

SWQB fieldwork includes an assessment of the probable sources of impairment in the AU drainage area, according to Standard Operating Procedure 4.1, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/; **Appendix C**). Probable Source Sheets are filled out by SWQB monitoring staff during watershed surveys. The sheets are then reviewed by watershed protection staff familiar with the location, and the TMDL writer conducts a search of aerial imagery, GIS files, and other available resources. The list of probable sources (**Table 2.8**) is not intended to single out any particular landowner or land management activity and generally includes several sources per pollutant. Impairments observed in the low flow zone typically indicate the influence of point sources (USEPA, 2007).

Probable sources of the boron impairment will be evaluated, refined, and changed as necessary through the Watershed Based Plan.

Table 2.8 Probable Sources for dissolved boron

Assessment Unit	Probable Sources	
Rio Grande (International Mexico bnd to TX border)	Animal shows and racetracks Channelization Crop Production Golf courses Highway/Road/Bridge runoff Inappropriate waste disposal	Industrial point source discharge Municipal point source discharge Off-road vehicles Pavement/impervious surface Urban runoff/storm sewers Urbanized area

Urban runoff containing metals in the TMDL drainage area could include stormwater from a golf course and a horse-racing track, as well as standard urban contaminants like used motor oil and tire fragments.

2.5 Consideration of Seasonal Variation

Federal regulations (40 CFR §130.7 (c)(1)) require that TMDLs take into consideration seasonal variation in watershed conditions and pollutant loading. Data used in the calculation of this TMDL were collected year-round in 2010-12 and during the spring and summer of 2019, to ensure coverage of any potential seasonal variation in the system. No samples were taken in 2020, as the survey schedule was disrupted by the COVID-19 pandemic.

Sustained flow in the Rio Grande below Caballo reservoir is dependent on release from Caballo reservoir during the irrigation season; at other times of the year, there may be little or no flow. During both the 2010-12 and 2019-20 water quality surveys, boron exceedances and elevated boron concentrations occurred only during lower flows in the winter months (November-March; **Appendix B**).

2.6 Future Growth

The Rio Grande (International Mexico Boundary to TX border) drainage area is located in Doña Ana County, NM, El Paso County, TX, and the Mexican state of Chihuahua.

Growth estimates by county are available from the University of New Mexico Geospatial and Population Studies (https://gps.unm.edu/pru/projections, accessed 7/18/23). These estimates project growth to the year 2040. Due to delays in UNM receiving Census Bureau and other data, projections updated to include the 2020 Census findings are not yet available. Updated projections are expected to be available by the end of 2023. Watershed Based Plan writers and TMDL implementation practitioners should use the latest available information, if future growth is applicable to their project.

Growth estimates by Texas county are available from the Texas Demographic Center (https://demographics.texas.gov/data/TPEPP/Projections/, accessed 7/18/23). These estimates project growth to the year 2050. As with NM, projections updated to include the 2020 Census findings are not yet available. Population projections for Mexico are not available.

Table 2.9 Population projections for the dissolved boron TMDL

County	2020	2030	2040	2050	Increase
Doña Ana, NM	218,971	226,879	231,331	NA	5.6% (2020-2040)
El Paso, TX	865,657	909,933	942,242	953,007	10.1% (2020-2050)

3.0 *E. COLI*

Escherichia coli (E. coli) is a species of coliform bacteria that is present in the intestinal tracts and feces of warm-blooded animals. Most *E. coli* are harmless and are an important part of a healthy human intestinal tract. However, some strains of *E. coli* are pathogenic, meaning they can cause illness, either diarrhea or illness outside of the intestinal tract. It is also used as an indicator of the potential presence of other pathogens that may present human health concerns.

Bacterial data collected from the impaired AUs during the 2019-20 SWQB water quality survey are shown in **Appendix B** and summarized on **Table 3.1**, below. Samples were assessed by comparing the *E. coli* results to the applicable single sample criterion. Assessment of the data identified exceedances of the New Mexico water quality standards for *E. coli* bacteria. As a result, these AUs are listed on the Integrated CWA §303(d)/ §305(b) List with *E. coli* as an impairment of the primary contact designated use (NMED/SWQB, 2020).

Table 3.1 Exceedances of *E. coli* criteria documented during the 2017-18 SWQB survey.

Assessment Unit	Water Quality Criterion (single sample, cfu/100mL)	Number of Exceedances
Mangas Creek (Gila River to Mangas Springs)	410	3/4
San Francisco River (Box Canyon to Whitewater Creek)	410	2/5

3.1 Target Loading Capacity

The TMDL is a value calculated at a defined critical flow condition as part of a planning process designed to achieve water quality standards. For these *E. coli* TMDLs, the appropriate critical flow condition is at low flow, to be protective when the assimilative capacity of a stream is at its lowest. For this TMDL document, target values for *E. coli* bacteria are based on achievement of the monthly geometric mean numeric criterion of 126 cfu/100 mL as value not to be exceeded rather than a monthly geometric mean, to provide a conservative protective value. If the single sample criterion was used and achieved as a target, the geometric mean criterion may still not be achieved.

3.2 Flow

According to the New Mexico Water Quality Standards, the low flow critical condition for numeric criteria (excluding human health-organism only criteria) set in 20.6.4.97 through 20.6.4.900 NMAC and 20.6.4.13(F) NMAC is defined as the 4-day, 3-year low-flow frequency (4Q3, 20.6.4.11(B)(2) NMAC). The 4Q3 is the annual lowest four (4) consecutive day flow that occurs with a frequency of at least once every three (3) years.

Critical flow for the San Francisco River (Box Canyon to Whitewater Creek) was determined from daily discharge data of USGS Gage 09444000 San Francisco River near Glenwood, NM, using the DFLOW software program (USGS gage locations are shown on **Figure 1.3**). The calculated 4Q3 is 8.398 mgd. Because Mangas Creek (Gila River to Mangas Springs) is ungaged, an analysis method developed by Waltemeyer (2002) was used to estimate the critical low flow. In Waltemeyer's analysis, two regression equations for estimating 4Q3 were developed based on physiographic regions of New Mexico (i.e., statewide and mountainous regions above 7,500 ft in elevation). The average elevation of the Mangas Creek (Gila River to Mangas Springs) watershed is below 7,500 ft, so the statewide regression equation was used. The following regression equation is based on data from 50 gaging stations with non-zero discharge (Waltemeyer, 2002):

Equation 3.1: $4Q3 = 1.2856 \times 10^{-4}\ DA^{0.42}\ Pw^{3.16}$

Where:

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = drainage area (mi^2)
Pw = average basin mean winter precipitation (inches)

The 4Q3 value calculated using Waltemeyer's method are presented in **Table 3.2**. Parameters used in the calculation were obtained using the StreamStats online GIS application developed by the USGS (https://streamstats.usgs.gov/ss/). The flow was converted from cfs to million gallons per day (mgd) using a conversion factor of 0.646. The TMDL itself is a value calculated at a defined critical condition as part of a planning process designed to achieve water quality standards. Since flows vary throughout the year in these systems, the actual load at any given time will vary based on the changing flow. Management of the load to improve instream water quality is the goal of SWQB efforts.

Table 3.2 Calculation of 4Q3 for Mangas Creek (Gila River to Mangas Springs)

Average Elevation (ft)	Drainage Area (mi^2)	Average Basin Slope (ft/ft)	Mean Winter Precipitation (in)	4Q3 (cfs)	4Q3 (mgd)
5745	204	0.18	6.8	0.51	0.33

Mangas Springs discharge has been measured at 0.22 cfs (Trauger, 1972; White and Kues, 1992), which is unlikely to vary significantly, so that amount was added to the 4Q3 derived from the Waltemeyer equation, for a critical low flow value of 0.73 cfs, or 0.47 mgd.

3.3 TMDL Calculations

The WQS for bacteria are expressed as colony forming units (cfu) per unit volume. TMDLs for bacteria (**Table 3.3**) were calculated based on critical flow values (**Table 3.2**), water quality standards, and a conversion factor, using **Equation 3.2**.

Equation 3.2 $$C\ as\ \frac{cfu}{100mL} * 1000\,\frac{mL}{L} * \frac{L}{0.264\ gallons} * Q\ in\ 1{,}000{,}000\,\frac{gallons}{day} = cfu/day$$

Where C = water quality criterion for bacteria
Q = the critical stream flow in million gallons per day (MGD)

Table 3.3 Calculation of TMDLs

Assessment Unit	Geometric Mean *E. coli* criterion (cfu/100 mL)	Critical Flow (mgd)	Conversion Factor	TMDL (cfu/day)
Mangas Creek (Gila River to Mangas Springs)	126	0.47	3.79×10^{7}	2.24×10^{9}
San Francisco River (Box Canyon to Whitewater Creek)	126	8.40	3.79×10^{7}	4.01×10^{10}

3.3.1 Margin of Safety (MOS)

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. For these bacteria TMDLs, the MOS was developed using a combination of conservative assumptions and inputs and explicit recognition of potential errors in flow calculations. Therefore, the MOS is the sum of the following:

- *Conservative Assumptions:*

  E. coli bacteria do not readily degrade in the environment; and,

  Basing the target load capacity on the geometric mean criterion rather than the higher-concentration single sample criterion; and

- *Explicit recognition of potential errors:*

  There is inherent error in all flow estimations; a conservative **explicit MOS for this element in gaged streams is 5%;** a conservative **explicit MOS for this element in ungaged streams is 10%.**

3.3.2 Waste Load Allocation (WLA)

There are no National Pollutant Discharge Elimination System (NPDES) individual permits that discharge to the *E. coli* impaired TMDL drainages. Therefore no WLA is assigned for this TMDL.

Stormwater discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the USEPA NPDES Construction General Permit (CGP) for construction sites of one or more acres, or smaller if part of a common plan of development, requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. The current CGP also includes state-specific requirements to implement site-specific interim and permanent stabilization, managerial, and structural solids, erosion, and sediment control Best Management Practices (BMPs), and/or other controls. BMPs are designed to prevent to the maximum extent practicable an increase in sediment load to the water body or an increase in a sediment-related parameter, such as total suspended solids, turbidity, siltation, stream bottom deposits, etc. BMPs also include measures to reduce flow velocity during and after construction compared to pre-construction conditions to assure that waste load allocations and/or applicable water quality standards, including the antidegradation policy, are met. Compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Stormwater discharges from industrial activities and facilities, based on industrial classification codes, may be eligible for coverage under the current NPDES Multi-Sector General Permit (MSGP). The MSGP also requires preparation of a SWPPP. Some of the industrial facilities and activities covered under the MSGP have technology based effluent limitation and/or benchmark monitoring for pollutants. The current MSGP includes state-specific requirements that the benchmark values be protective of State of New Mexico WQS.

It is not possible to calculate individual WLAs for facilities covered by the General Permits at this time using the available tools. The discharges from these permits are typically transitory as the activities are temporary. Loads that are in compliance with the General Permits are therefore currently included as part of the Load Allocation (LA). While these sources are not given individual allocations, they are addressed through other means, including BMPs, stormwater pollution prevention conditions, and other requirements.

3.3.4 Load Allocation (LA)

In order to calculate the LA, the WLA and MOS are subtracted from the TMDL using the equation below.

$$WLA + LA + MOS = TMDL$$

Since there is no WLA, the LA is equal to the TMDL minus the MOS. Results of the load calculations are presented in **Table 3.4**. The extensive data collection and analyses necessary to determine background *E. coli* loads are beyond the resources available for this study. It is assumed that a portion of the LA is made up of natural background loads. It is important to note that WLAs and LAs are estimates based on a specific flow condition. Under differing hydrologic conditions, the loads will change. Successful implementation of this TMDL will be determined based on achievement of the *E. coli* standards under all flow conditions.

Table 3.4 Load allocations for *E. coli* (units are in cfu/day)

Assessment Unit	WLA	LA	MOS	TMDL
Mangas Creek (Gila River to Mangas Springs)	0	2.02×10^{9}	2.24×10^{8}	2.24×10^{9}
San Francisco River (Box Canyon to Whitewater Creek)	0	3.81×10^{10}	2.00×10^{9}	4.01×10^{10}

E. coli impairment determinations were based on exceedances of the State's single sample criteria and the TMDL is written to address the monthly geometric mean standard. As such, a simple comparison of the numbers would not necessarily represent an amount of contaminant reduction that would result in removing the impairment, and would instead result in an overestimation of the actual reduction necessary. Neither Section 303 of the Clean Water Act nor 40 C.F.R. Part 130.7 requires states to include discussions of percent reductions in TMDL documents. Although NMED believes that it is often useful to discuss the magnitude of water quality exceedances in the TMDL report, the "percent reduction" value can be calculated in multiple ways and as a result is often misinterpreted. Therefore, a percent reduction value is not provided for *E. coli* TMDLs.

3.4 Identification and Description of Pollutant Sources

SWQB fieldwork includes an assessment of the probable sources of impairment in the AU drainage area, according to Standard Operating Procedure 4.1, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/; **Appendix B**). Probable Source Sheets are filled out by SWQB monitoring staff during watershed surveys. The sheets are then reviewed by watershed protection staff familiar with the location, and the TMDL writer conducts a search of aerial imagery, GIS files, and other available resources. The list of probable sources is not intended to single out any particular landowner or land management activity and generally includes several sources per pollutant. Pollutant sources that may contribute to each impairment were determined by field reconnaissance and evaluation (**Table 3.5**). Probable sources of bacteria impairments will be evaluated, refined, and changed as necessary through the Watershed Based Plans.

Table 3.5 Probable Sources for *E. coli*

Assessment Unit	Probable Source(s)
Mangas Creek (Gila River to Mangas Springs)	Crop production; Dam/impoundment; Highway/Road/Bridge runoff; Low water crossing; Rangeland grazing
San Francisco River (Box Canyon to Whitewater Creek)	Crop production; Forest fire; Highway/Road/Bridge runoff; On-site treatment systems; Other recreation (hot springs soaking); Rangeland grazing; Rural residential area; Water diversion

Among the potential sources of coliform bacteria are municipal point source discharges such as wastewater treatment facilities, septic tanks which are poorly maintained, improperly installed, or missing, livestock grazing of uplands and riparian areas, and waste from pets and wildlife. Howell et al. (1996) found that bacteria concentrations in underlying sediment increase when cattle have direct access to streams. Natural sources of *E. coli* are also present in the form of wildlife such as elk, deer, waterfowl and other warm-blooded animals.

In addition to the initial loading, several ambient parameters have been documented to influence coliform bacteria survival and, potentially, regrowth, in freshwater bodies (Howell et al., 1996; Wcislo and Chrost, 2000). Abiotic factors include visible light, ultraviolet light, temperature, organic and metal pollutants, dissolved organic matter, suspended sediment concentration and particle size, and pH. Biotic, or ecological, factors include viral parasites and protozoan predators. Bacterial concentrations may become elevated when bacteria-laden sediment is re-suspended during storm events or by other subsequent disturbance such as trampling by livestock (Howell et al., 1996) or wildlife.

Wildfires can affect the physical, chemical, and biological quality of streams, rivers, and lakes. After a fire, increased runoff provides the pathway for the transport of chemical-laden sediment to surface water, which may have substantial water quality impacts. Forest fires can result in increased water temperature due to reduced infiltration and loss of shading vegetation. Potential wildfire impacts to water quality are discussed on the SWQB website at https://www.env.nm.gov/surface-water-quality/wildfire-impacts-on-surface-water-quality/. Most watershed effects will naturally recover within 5 to 10 years after the fire, but some aspects of watershed structure and function, as well as areas of most severe fire intensity, may continue to recover for 15-20 years (Bixby et al., 2015). Therefore, runoff following forest fire has been added to the Probable Source list (**Table 3.5**) for those TMDL AUs where fires occurred during the 20 years preceding the 2019-20 water quality survey.

Further study would be needed to determine exact sources of *E. coli* and their relative contributions. One method of characterizing sources of bacteria is Bacterial, or Microbial, Source Tracking (BST or MST). The extensive data collection and analyses necessary to determine bacterial sources are beyond the resources available for this TMDL. While sufficient data currently exist to support development of *E. coli* TMDLs to address the stream standards exceedances, a BST dataset would likely be useful to better identify the sources of *E. coli* impacting the stream.

3.5 Consideration of Seasonal Variation

Federal regulations (40 C.F.R. § 130.7(c)(1)) require that TMDLs take into consideration seasonal variation in watershed conditions and pollutant loading. Data used in the calculation of these TMDLs were collected during the spring, summer, and fall of 2019, plus one additional sample in early fall 2020, to ensure coverage of potential seasonal variation in the system. In Mangas Creek, exceedances of the WQS were documented in summer through early fall. In the San Francisco River, exceedances were documented in June and August. This pattern is consistent with the findings of Hulvey et al. (2021) that *E. coli* peaked in midsummer in Utah streams running through grazed or ungrazed grasslands, with higher peaks in the grazed meadows.

3.6 Future Growth

Mangas Creek (Gila River to Mangas Springs) is located in Grant County and San Francisco River (Box Canyon to Whitewater Creek) is located in Catron County.

Growth estimates by county are available from the University of New Mexico Geospatial and Population Studies (https://gps.unm.edu/pru/projections, accessed 7/18/23). These estimates project growth to the year 2040. Due to delays in UNM receiving Census Bureau and other data, projections updated to include the 2020 Census findings are not yet available. Updated projections are expected to be available by the end of 2023. Watershed Based Plan writers and TMDL implementation practitioners should use the latest available information, if future growth is applicable to their project.

Table 3.6 Population projections for the *E. coli* TMDLs

County	2020	2030	2040	Increase (2020-2040)
Catron	3,491	3,221	2,897	-17.0%
Grant	29,475	25,585	23,092	-21.7%

Estimates of future growth are not anticipated to lead to a significant increase in *E. coli* that cannot be controlled with BMP implementation. BMPs should be utilized and improved upon while continuing to improve watershed conditions and adhering to SWPPP requirements related to construction and industrial activities covered under the general permit.

4.0 PLANT NUTRIENTS

Phosphorus and nitrogen are essential for proper functioning of ecosystems. However, excess nutrients cause conditions unfavorable for the proper functioning of aquatic ecosystems. Nuisance levels of algae and other aquatic vegetation (macrophytes) can develop rapidly in response to nutrient enrichment when other factors (e.g., light, temperature, substrate) are not limiting (**Figure 4.1**). However, the magnitude of nutrient concentration that constitutes an "excess" is difficult to determine and varies by ecoregion.

Phosphorus and nitrogen generally drive the productivity of algae and macrophytes in aquatic ecosystems, therefore they are regarded as the primary limiting nutrients in freshwaters. The main reservoirs of natural phosphorus are rocks and natural phosphate deposits. Weathering, leaching, and erosion are all processes that breakdown rock and mineral deposits allowing phosphorus to be transported to aquatic systems via water or wind. The breakdown of mineral phosphorus produces inorganic phosphate ions ($H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}) that can be absorbed by plants from soil or water (USEPA, 1999). Phosphorus primarily moves through the food web as organic phosphorus (after it has been incorporated into plant or algal tissue) where it may be released as phosphate in urine or other waste by heterotrophic consumers and reabsorbed by plants or algae to start another cycle (Nebel and Wright, 2000).

The largest global reservoir of nitrogen is the atmosphere. About 80% of the atmosphere by volume consists of nitrogen gas (N_2). Although nitrogen is plentiful in the environment, it is not readily available for biological uptake. Nitrogen gas must be converted to other forms, such as ammonia (NH_3 and NH_4^+), nitrate (NO_3^-), or nitrite (NO_2^-) before plants and animals can use it. Conversion of gaseous nitrogen into usable mineral forms occurs through three biologically mediated processes of the nitrogen cycle: nitrogen fixation, nitrification, and ammonification (USEPA, 1999). Mineral forms of nitrogen can be taken up by plants and algae and incorporated into their tissue. Nitrogen follows the same pattern of food web incorporation as phosphorus and is released in waste primarily as ammonium compounds. The ammonium compounds are usually converted to nitrates by nitrifying bacteria, making it available again for uptake, starting the cycle anew (Nebel and Wright, 2000).

Rain, overland runoff, groundwater, drainage networks, and industrial and residential waste effluents transport nutrients to receiving waterbodies. Once nutrients have been transported into a waterbody they can be taken up by algae, macrophytes, and microorganisms either in the water column or in the benthos; they can sorb to organic or inorganic particles in the water column and/or sediment; they can accumulate or be recycled in the sediment; or they can be transformed and released as a gas from the waterbody (**Figure 4.1**).

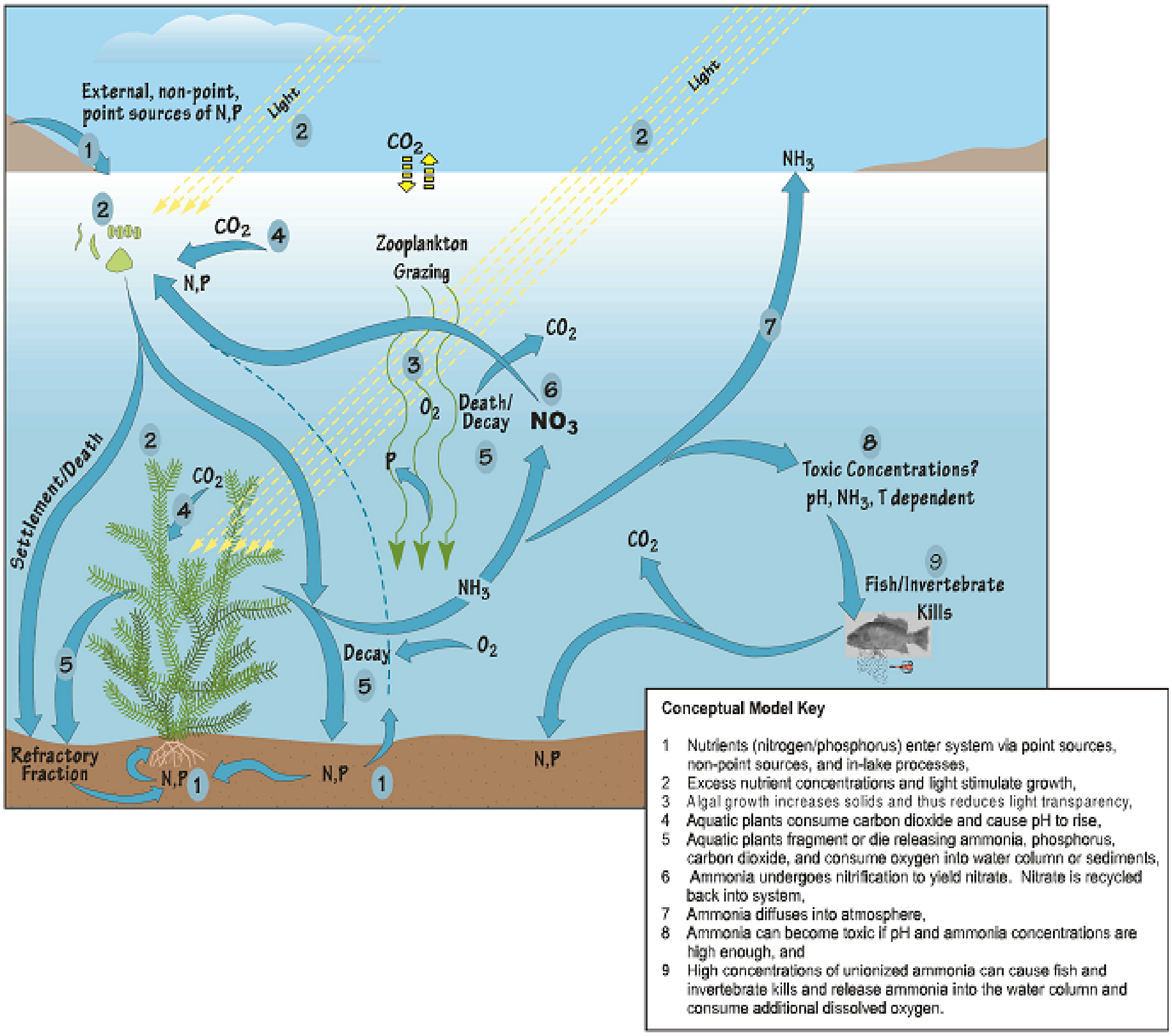

Figure 4.1 Nutrient conceptual model (USEPA 1999)

4.1 Target Loading Capacity

The intent of nutrient criteria, whether numeric or narrative, is to limit nutrient inputs in order to control the excessive growth of attached algae and higher aquatic plants. Controlling algae and plant growth preserves aesthetic and ecologic characteristics along the waterway. While conceptually there may be a number of possible combinations of total nitrogen (TN) and total phosphorus (TP) concentrations that are protective of water quality, the application of simple chemical limitation concepts to a complex biologic system to determine these combinations is challenging. One of the primary reasons for this is that different species of algae and higher aquatic plants will have different nutritional needs. Some species will thrive in nitrogen limited environments while others will thrive in phosphorous limited environments. Because of the diversity of nutritional needs amongst organisms, numeric thresholds for both TN and TP are required to preserve the aesthetic and ecologic characteristics along a waterway. Focusing on one nutrient or trading a decrease in one for an increase in the other may simply favor a particular species without achieving water quality standards.

New Mexico has a narrative criterion for plant nutrients set forth in Subsection E of 20.6.4.13 NMAC:

> ***Plant Nutrients:*** *Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in the dominance of nuisance species in surface waters of the state.*

This narrative criterion can be challenging to assess because the relationships between nutrient levels and impairment of designated uses are not defined, and distinguishing nutrients from "other than natural causes" is difficult. Numeric thresholds are necessary to establish targets for TMDLs, to develop water quality-based permit limits and source control plans, and to support designated uses within the watershed.

In 2015 and 2016, SWQB collaborated with Tetra Tech, Inc., the EPA Region 6, and EPA's National Nutrient Criteria Program Nutrient Scientific Technical Exchange Partnership and Support (N-STEPS) program on a project to revise nutrient impairment thresholds in New Mexico. This project follows EPA's nutrient criteria guidance (EPA, 2010) and Empirical Approaches for Nutrient Criteria Derivation (EPA, 2009). Statistical analyses of available state and regional data were conducted to refine nutrient thresholds using defined reference conditions, relationships between cause and response variables and a verified classification system. TN and TP candidate thresholds were derived for each site class using frequency distributions of nutrient conditions, defined as the median site value (Jessup et al. 2015), in least disturbed sites. Comparing site medians rather than individual sampling events to numeric thresholds is better aligned with the intention of identifying chronic excessive nutrients conditions. The resultant candidate thresholds were evaluated by SWQB staff, and the selected thresholds were used to revise this nutrient listing methodology. The 100+ page report (Jessup et al., 2015) detailing the N-STEPS effort is available at https://www.env.nm.gov/surface-water-quality/nutrients/. SWQB also generated and posted a shorter document which summarizes the steps taken to determine the candidate thresholds, and SWQB's logic regarding final threshold selection (NMED/SWQB, 2016).

Nutrient assessments were conducted on data collected during the 2019-20 water quality survey. Detailed assessment of water quality parameters indicated plant nutrient impairment in the Mule Creek (San Francisco R to Mule Springs) AU. Data contributing to the impairment determination are shown in **Appendix B**. Mule Creek flows into the San Francisco River a few miles east of the Arizona state border. The San Francisco River at the confluence of Mule Creek is not impaired.

Table 4.1 Causal and response variable thresholds for plant nutrients TMDL. Units are in mg/L.

AU	Site Class	TN	TP	Delta DO
Mule Creek (San Francisco R to Mule Springs)	TN (Moderate) TP (Flat Moderate)	0.42	0.061	4.08

Phosphorous is found in water primarily as orthophosphate. In contrast nitrogen may be found as several dissolved species, all of which must be considered in nutrient loading. Total nitrogen is defined by SWQB as the sum of nitrate+nitrite (N+N), and Total Kjeldahl Nitrogen (TKN) (NMED/SWQB, 2017). At the present time, there is no USEPA-approved method to test for total nitrogen, however adding the results of USEPA methods 351.2 (TKN) and 353.2 (N+N) is appropriate for estimating total nitrogen. While not an EPA-approved method, Method SM4500-N for Total Nitrogen using a persulfate digest, is an approved method in the SWQB QAPP (NMED/SWQB, 2018) and is used in cases where a lower detection limit is needed. Daily delta DO, a response variable, is defined as the difference between the maximum and minimum DO concentration within a 24-hour period. The applicable threshold values for this TMDL are shown on **Table 4.1**. These threshold values were used for water quality assessments and TMDL development.

4.2 Flow

According to the New Mexico Water Quality Standards, the low flow critical condition for numeric criteria (excluding human health-organism only criteria) set in NMAC 20.6.4.97 through 20.6.4.900 and NMAC 20.6.4.13(F) is defined as the 4-day, 3-year low-flow frequency (4Q3, NMAC 20.6.4.11(B)(2)). The 4Q3 is the annual lowest four (4) consecutive day flow that occurs with a frequency of at least once every three (3) years.

Because Mule Creek is ungaged, an analysis method developed by Waltemeyer (2002) was used to estimate the critical low flow. In Waltemeyer's analysis, two regression equations for estimating 4Q3 were developed based on physiographic regions of New Mexico (i.e., statewide and mountainous regions above 7,500 ft in elevation). The average elevation of the Mule Creek watershed is less than 7,500 ft, so the statewide regression equation was used. The following regression equation is based on data from 50 gaging stations with non-zero discharge (Waltemeyer 2002):

$$4Q3 = 1.2856 \times 10^{-4}\ DA^{0.42}\ Pw^{3.16}$$

Where:
4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = drainage area (mi^2)
Pw = average basin mean winter precipitation (inches)

The 4Q3 value calculated using Waltemeyer's method is presented in **Table 4.2**. Parameters used in the calculation were obtained using the StreamStats online GIS application developed by the USGS (https://streamstats.usgs.gov/ss/). The critical flow was converted from cfs to million gallons per day (mgd) using a conversion factor of 0.646.

Table 4.2 Flow summary for Mule Creek (San Francisco R to Mule Springs)

Average Elevation (ft)	Drainage Area (mi^2)	Winter Precip (in)	4Q3 Flow
5735	93.9	7.37	0.48 cfs 0.31 mgd

The TMDL itself is a value calculated at a defined critical condition as part of a planning process designed to achieve water quality standards. Since flows vary throughout the year, the actual load at any given time will vary based on the changing flow. Management of the load to improve stream water quality is the goal of SWQB efforts.

4.3 TMDL Calculation

As a river flows downstream it has a specific loading capacity for nutrients. This loading capacity, or TMDL, is defined as the mass of pollutant that can be carried under critical flow conditions without violating the target concentration for that constituent. These TMDLs were developed based on simple dilution calculations using critical flows, the numeric target, and a conversion factor used to convert the resulting TMDL to lb/day units. The specific loading capacity of a receiving water for a given pollutant was estimated using **Equation 4.2**. The calculated daily loading capacities (i.e., TMDLs) for TP and TN are summarized in **Table 4.3**.

Eq. 4.2: *Critical flow (4Q3) x WQS (mg/L) x Conversion Factor = TMDL (lb/day)*

Table 4.3 TMDLs for TP & TN in Mule Creek (San Francisco R to Mule Springs)

Parameter	Critical Flow (mgd)	In-Stream Target (mg/L)	Conversion Factor	TMDL (lbs/day)
Total Phosphorus	0.31	0.061	8.34	0.16
Total Nitrogen		0.42		1.09

The TMDL is further allocated to a MOS, WLA (permitted point sources), and LA (nonpoint sources), according to the formula: *WLA + LA + MOS = TMDL.*

4.3.1 Margin of Safety

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS can be expressed either implicitly or explicitly. An implicit MOS is incorporated by making conservative assumptions in the TMDL analysis, such as allocating a conservative load to background sources. An explicit MOS is applied by reserving a portion of the TMDL and not allocating it to any other sources.

For this nutrient TMDL, the margin of safety was developed using a combination of conservative assumptions and explicit recognition of potential errors. Therefore, this margin of safety is the sum of the following two elements:

- *Conservative Assumptions*
    - Treating phosphorus and nitrogen as pollutants that do not readily degrade in the environment.
    - An implicit margin of safety is added by setting a TMDL that, if achieved, would not exceed the threshold at any time, whereas the WQS thresholds are based on the median measured concentration.
- *Explicit Recognition of Potential Errors*
    - There is inherent error in flow estimation, both measured and calculated; a conservative MOS for this element in ungaged streams is **10 %**.

4.3.2 Waste Load Allocation

There are no active National Pollutant Discharge Elimination System (NPDES) permits that discharge to Mule Creek, therefore the WLA for this TMDL is zero.

Stormwater discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the USEPA NPDES Construction General Permit (CGP) for construction sites of one or more acres, or smaller if part of a common plan of development, requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. The current CGP also includes state-specific requirements to implement site-specific interim and permanent stabilization, managerial, and structural solids, erosion, and sediment control Best Management Practices (BMPs), and/or other controls. BMPs are designed to prevent to the maximum extent practicable an increase in sediment load to the water body or an increase in a sediment-related parameter, such as total suspended solids, turbidity, siltation, stream bottom deposits, etc. BMPs also include measures to reduce flow velocity during and after construction compared to pre-construction conditions to assure that waste load allocations and/or applicable water quality standards, including the antidegradation policy, are met. Compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Stormwater discharges from industrial activities and facilities, based on industrial classification codes, may be eligible for coverage under the current NPDES Multi-Sector General Permit (MSGP). The MSGP also requires preparation of a SWPPP. Some of the industrial facilities and activities covered under the MSGP have technology based effluent limitation and/or benchmark monitoring for pollutants. The current MSGP includes state-specific requirements that the benchmark values be protective of State of New Mexico WQS.

It is not possible to calculate individual WLAs for facilities covered by the General Permits at this time using the available tools. The discharges from these permits are typically transitory as the activities are temporary. Loads that are in compliance with the General Permits are therefore currently included as part of the Load Allocation (LA). While these sources are not given individual allocations, they are addressed through other means, including BMPs, stormwater pollution prevention conditions, and other requirements.

4.3.3 Load Allocation

To calculate the LA, the WLA and the MOS were subtracted from the TMDL, as shown on **Table 4.4**. The MOS was developed using a combination of conservative assumptions and explicit recognition of potential errors (see **Section 4.3.1** for details).

Table 4.4 Plant nutrient Load Allocation for Mule Creek (San Francisco R to Mule Springs). Units are in lb/day.

Parameter	WLA	LA	MOS	TMDL
Total Phosphorus	0	0.144	0.016	0.16
Total Nitrogen	0	0.981	0.109	1.09

4.3.4 Load Reduction

The extensive data collection and analysis necessary to determine background nutrient loads were beyond the resources available for this study. It is therefore assumed that a portion of the load allocation is made up of natural background loads.

Table 4.5 Calculation of load reductions for TP and TN in Mule Creek (San Francisco R to Mule Springs). Units are in lb/day.

Parameter	Target Load[a]	Measured Load[b]	Load Reduction	Percent Reduction[c]
Total Phosphorus	0.144	0.328	0.184	56%
Total Nitrogen	0.981	0.838	None	None

(a) Target Load = TMDL – MOS. The MOS is not included in the load reduction calculations because it is a set aside value, which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured load.

(b) The measured load is the magnitude of point and nonpoint sources. It is calculated using the median measured concentration value at the TMDL critical flow.

(c) Percent reduction is the percent the existing measured load must be reduced to achieve the target load and is calculated as follows: ((Measured Load – Target Load) / Measured Load) x 100.

4.4 Identification and Description of Pollutant Sources

SWQB fieldwork includes an assessment of the probable sources of impairment in the AU drainage area, according to Standard Operating Procedure 4.1, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/; **Appendix C**). Probable Source Sheets are filled out by SWQB monitoring staff during watershed surveys. The sheets are then reviewed by watershed protection staff familiar with the location, and the TMDL writer conducts a search of aerial imagery, GIS files, and other available resources. The list of probable sources is not intended to single out any particular landowner or land management activity and generally includes several sources per pollutant.

Table 4.6 displays probable pollutant sources that have the potential to contribute to nutrient impairment within the TMDL AU, as determined by field reconnaissance and knowledge of watershed activities. The draft probable source list will be reviewed and modified as necessary, with watershed group/stakeholder input during the TMDL public meeting and comment period. Probable sources of impairment will be further evaluated, refined, and changed as necessary through the Watershed-Based Plan (WBP).

Table 4.6 Probable Sources for Plant Nutrients

Assessment Unit	Probable Sources	
Mule Creek (San Francisco R to Mule Springs)	Grazing in the riparian zone Loss of riparian habitat On-site treatment systems	Rangeland grazing Rural residential area Wildlife other than waterfowl

As described in **Section 4.2**, the presence of plant nutrients in a stream can vary as a function of flow. As flow decreases through water diversions and/or drought-related stressors, the stream cannot effectively dilute its constituents, which causes the concentration of plant nutrients to increase. Nutrients generally reach a waterbody from land uses that are in close proximity to the stream because the hydrological pathways are shorter and have fewer obstacles than land uses located away from the riparian corridor. During the growing season (i.e., in agricultural return flow) and in storm water runoff, distant land uses can become hydrologically connected to the stream, thus transporting nutrients from the hillslopes to the stream during these time periods.

In addition to agriculture, there are several other human-related activities that influence nutrient concentrations in rivers and streams. Residential areas contribute nutrients from septic tanks, landscape maintenance, as well as backyard livestock (e.g., cattle, horses) and pet wastes. Urban development contributes nutrients by disturbing the land and consequently increasing soil erosion, by increasing the impervious area within the watershed, and by directly applying nutrients to the landscape. Recreational activities such as hiking and biking can also contribute nutrients to the stream by reducing plant cover and increasing soil erosion (e.g., trail network, streambank destabilization), direct application of human waste, campfires and/or wildfires, and dumping trash near the riparian corridor.

Undeveloped, or natural, landscapes also can deliver nutrients to a waterbody through decaying plant material, soil erosion, and wild animal waste. Another nutrient source is atmospheric deposition, which adds nutrients directly to the waterbody through dryfall and precipitation. Atmospheric phosphorus and nitrogen can be found in both organic and inorganic particles, such as pollen and dust, as well as anthropogenic sources such as fuel combustion and agriculture. The contributions from natural sources are generally considered to represent background levels.

4.5 Consideration of Seasonal Variability

Section 303(d)(1) of the CWA requires TMDLs to be "established at a level necessary to implement the applicable WQS with seasonal variation." Data used in the calculation of the Mule Creek TMDL were collected during the spring and summer of 2019. All sampling events documented exceedances of the median TP threshold. Although there are very few data points, there does not appear to be any seasonal trend in TP concentration. The spring (April) sample was much higher in TN than the samples taken later in the year.

The critical condition used for calculating the TMDL is considered to be conservative and protective of the water quality standard under all flow conditions. Calculations made at the critical flow, in addition to using other conservative assumptions as described in the previous section on MOS, should be protective of the water quality standards designed to preserve aquatic life in the stream. It was assumed that if critical conditions were met during this time, coverage of any potential seasonal variation would also be met.

4.6 Future Growth

Mule Creek (San Francisco R to Mule Springs) is located in Grant County.

Growth estimates by county are available from the University of New Mexico Geospatial and Population Studies (https://gps.unm.edu/pru/projections, accessed 7/18/23). These estimates project growth to the year 2040. Due to delays in UNM receiving Census Bureau and other data, projections updated to include the 2020 Census findings are not yet available. Updated projections are expected to be available by the end of 2023. Watershed Based Plan writers and TMDL implementation practitioners should use the latest available information, if future growth is applicable to their project.

Table 4.7 Population projections for the plant nutrients TMDL

County	2020	2030	2040	Increase (2020-2040)
Grant	29,475	25,585	23,092	-21.7%

Estimates of future growth are not anticipated to lead to a significant increase in plant nutrients that cannot be controlled with BMP implementation. BMPs should be utilized and improved upon while continuing to improve watershed conditions and adhering to SWPPP requirements related to construction and industrial activities covered under the general permit.

5.0 SEDIMENTATION

Stream bottom substrate provides optimum habitat for many fish and aquatic insect communities when it does not include excessive fine sediment filling the interstitial spaces. Excessive fine sediment occurs when biologically important habitat components such as spawning gravels and cobble surfaces are physically covered by fines (Chapman and McLeod, 1987). Substrate fining decreases intergravel oxygen and results in reduced or eliminated quality and quantity of habitat for fish, macroinvertebrates, and algae (Lisle, 1989; Waters, 1995). Chapman and Mcleod (1987) found that bed material size is related to habitat suitability for fish and macroinvertebrates and that excess fine sediment decreased both density and diversity of aquatic insects.

Sediment loads that exceed a stream's sediment transport capacity often trigger changes in stream morphology (Leopold et al., 1964). Streams that become overwhelmed with sediment often go through a period of accelerated channel widening and streambank erosion before returning to a stable form (Rosgen, 1996). These morphological changes can accelerate erosion, reduce habitat diversity (pools, riffles, etc.) and place additional stress on the designated aquatic life use.

5.1 Target Loading Capacity

The New Mexico WQS include a general narrative standard at 20.6.4.13(A)(1) NMAC for "bottom deposits and suspended or settleable solids", which reads:

> *"Surface waters of the state shall be free of water contaminants including fine sediment particles (less than two millimeters in diameter), precipitates or organic or inorganic solids from other than natural causes that have settled to form layers on or fill the interstices of the natural or dominant substrate in quantities that damage or impair the normal growth, function or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom."*

The assessment approach used to determine these sedimentation impairments is described in detail in Appendix G of the SWQB Comprehensive Assessment and Listing Methodology (CALM; NMED/SWQB, 2021; https://www.env.nm.gov/surface-water-quality/calm/). Target values for this TMDL were based on the numeric thresholds identified in the CALM. The CALM establishes a procedure for determining impairment due to excessive sedimentation/siltation in perennial, wadeable streams. Bedded sediments cannot be treated as introduced pollutants such as pesticides because they are not uniquely generated through human input or disturbance. Rather, bedded sediments are components of natural systems that are present even in pristine settings and to which stream organisms have evolved and adapted. Therefore, the detection of a sediment imbalance is more complicated than detecting an absolute concentration or percentage that represents a clear biological impact.

The SWQB and USEPA Region 6 contracted with Tetra Tech, Inc., to develop sediment translators or thresholds. The contractor generally followed the steps provided in USEPA's Framework for developing suspended and bedded sediment water quality criteria (USEPA, 2006). This effort included the identification of sediment characteristics that are expected under the range of environmental settings in New Mexico, especially in undisturbed or best available reference streams. Examining the relationships between biological measures and sediment indicators helped to identify where disturbance had caused sediment imbalance and biologically relevant habitat degradation. The analysis resulted in threshold recommendations for two bedded sediment indicators for New Mexico perennial streams (**Table 5.1**) – percent Sand & Fines (%SaFN) and log Relative Bed Stability calculated without bedrock (LRBS_NOR) -- for three different site classes, Mountains, Foothills, and Xeric. The site classes are defined by Level 3 and 4 ecoregions (Griffith et al.., 2006) and distinguish sediment expectations across New Mexico. The report detailing this effort (Jessup et al., 2010) is available at https://www.env.nm.gov/surface-water-quality/sedimentation/.

Table 5.1. Bedded sediment indicators (from Jessup et al., 2010)

Sediment Indicator	Description
Percent Sand & Fines (%SaFN)	**The percentage of systematically selected streambed substrate particles that are ≤2.0 mm in diameter from reach-wide pebble count.**
Log Relative Bed Stability (LRBS)	**A measure of the relationship of the median particle size in a stream reach compared to the critical particle size calculated to be mobilized by standardized fluvial stresses in the reach.** Median particle size is determined using a reach-wide pebble count (Peck et al.. 2006). Critical particle size is calculated from channel dimensions, flow characteristics, and channel roughness factors (Kaufmann et al.. 2008). The measure is expressed as a logarithm of the ratio of geometric mean to critical particle size.
LRBS_NOR	**RBS without bedrock or hardpan (log10).** This measure regards only the potentially mobile streambed particles in determining the geometric mean particle size, and improved associations between the bedded sediment measure and biological responses in the TetraTech analyses (Jessup et al.. 2010)

To determine if there is excessive sedimentation/siltation in the study stream reach, two levels of assessment are performed in sequential order. The first level considers the simpler indicator of biological impairment, and then refines the assessment with the second indicator of geomorphic impairment as needed when the first level threshold is exceeded. The % SaFN sediment indicator is used in the Level One assessment because it is easily measured and related strongly with biological metrics. If the %SaFN indicates excessive fine sediment in the stream bed, a Level Two survey is performed to collect data used to calculate the LRBS_NOR value.

In minimally disturbed streams, the measured geometric mean particle size should trend towards the expected particle size (i.e., the size the stream is capable of moving as bedload at bankfull flow). The LRBS_NOR indicator considers site-specific hydraulic potential for moving bed sediments, so that the observed amount of fine sediments is considered impaired only when the streambed is more easily mobilized and transported than expected. It incorporates stream channel, shape, slope, flow, and sediment supply. The LRBS_NOR measure is appropriate as a second-tier indicator because it is scaled to hydro-geomorphic factors of the individual sites, as well as to the broader site classes, thus allowing evaluation of the potential of the specific site in terms of retaining or flushing fine sediments.

Table 5.2 Sedimentation indicator thresholds based on biological responses and reference distributions (Jessup et al., 2010)

Site Class	% Sand and Fines	LRBS_NOR Units
Mountain	< 20	> -1.1
Foothill	< 37	> -1.3
Xeric	< 74	> -2.5

If the calculated LRBS_NOR is greater than the applicable site class threshold in **Table 5.2**, the AU is regarded as **Full Support** with respect to New Mexico's narrative sedimentation/siltation standard found at NMAC 20.6.4.13 NMAC. If the calculated LRBS_NOR is less than or equal to the applicable site class threshold, the AU is considered **Non Support.** The LRBS_NOR threshold for the San Francisco River (Centerfire Creek to AZ border) AU is -1.1 and the calculated LRBS_NOR is -1.03, thus indicating that the stream is trending toward sedimentation impairment. Therefore, to be protective of the AU, the following sedimentation TMDL is included as a protective TMDL.

Table 5.3 Numeric thresholds applied to San Francisco River (Centerfire Creek to AZ border)

Ecoregion/Site Class	**% Sand and Fines Threshold**	**% Sand and Fines Observed**	**LRBS_NOR Threshold**	**Calculated LRBS_NOR**
23c/Mountain	20	31.4	-1.1	-1.03

A load-based indicator is needed to generate a TMDL based on mass balance. Turbidity is correlated with TSS for a given water body. Jessup et al. (2010) suggests an interpretation of the indicator value distributions for sites which fully support their designated uses, using the 90th percentile value for Mountain and Foothills sites and the 75th percentile value for Xeric sites (**Table 5.4**). Therefore the target Total Suspended Solids (TSS) value for the sedimentation TMDL will be 8.75 mg/L. Monitoring data for flow, TSS and turbidity are presented in **Appendix B**.

Table 5.4 Suspended sediment indicator percentiles for fully supporting sites and all sites in three site classes

		Fully Supporting Sites			All Sites		
		Valid N	75th	90th	Valid N	25th	Median
Mountains	Turbidity (ntu)	68	4.88	9.50	217	1.25	3.10
	TSS (mg/L)	70	5.05	8.75	221	3.00	3.89
FootHills	Turbidity (ntu)	24	12.18	19.30	136	2.33	5.99
	TSS (mg/L)	24	9.88	16.12	138	3.71	6.71
Xeric	Turbidity (ntu)	83	68.50	191.76	289	5.60	16.00
	TSS (mg/L)	85	60.23	262.80	295	7.00	17.00

5.2 Flow

The TMDL is a value calculated at a defined critical flow condition as part of a planning process designed to achieve water quality standards. For this sedimentation TMDL, the appropriate critical flow condition is at low flow in order to be protective when the assimilative capacity of a stream is at its lowest. According to the New Mexico Water Quality Standards, the low flow critical condition for numeric criteria (excluding human health-organism only criteria) set in 20.6.4.97 through 20.6.4.900 NMAC and Subsection F of 20.6.4.13 NMAC is defined as the 4-day, 3-year low-flow frequency (4Q3, 20.6.4.11(B)(2) NMAC). The 4Q3 is the annual lowest four (4) consecutive day flow that occurs with a frequency of at least once every three (3) years.

Critical flow values used to calculate the sedimentation/siltation TMDLs were obtained using a regression model. Because these streams are ungaged, an analysis method developed by Waltemeyer (2002) was used to estimate the critical low flow. In Waltemeyer's analysis, two regression equations for estimating 4Q3 were developed based on physiographic regions of New Mexico (i.e., statewide and mountainous regions above 7,500 ft in elevation). The average elevation of each of the San Francisco River (Centerfire Creek to AZ border) watershed is above 7,500 ft, so the mountainous regions regression equation was used. The following mountainous regions regression equation (**Equation 5.1**) is based on data from 40 gaging stations located above 7,500 ft in elevation with non-zero discharge (Waltemeyer, 2002):

Equation 5.1 $4Q3 = 7.3287 \times 10^{-5} DA^{0.70} {P_w}^{3.58} S^{1.35}$

Where:

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = Drainage area (mi^2)
P_w = Average basin mean winter precipitation (inches)
S = Average basin slope (ft/ft)

The 4Q3 values calculated using Waltemeyer's method are presented on **Table 5.5**. Parameters used in the calculation were determined using the StreamStats online GIS application developed by the USGS (https://streamstats.usgs.gov/ss/). The critical flow was converted from cfs to million gallons per day (mgd) using a conversion factor of 0.646. The TMDL itself is a value calculated at a defined critical condition as part of a planning process designed to achieve water quality standards. Since flows vary throughout the year in these systems, the actual load at any given time will vary based on the changing flow. Management of the load to improve instream water quality is the goal of SWQB efforts.

Table 5.5 Calculation of Critical Flow for the San Francisco River (Centerfire Creek to AZ border)

Average Elevation (ft)	Drainage Area (mi^2)	Average Basin Slope (ft/ft)	Mean Winter Precipitation (in)	4Q3 (cfs)	4Q3 (mgd)
8149	150	0.2	10.8	1.39	0.90

5.3 TMDL Calculations

The TMDL is defined as the mass of pollutant that can be carried under critical flow conditions without violating the target concentration for that constituent. The TMDL is calculated based on simple dilution using critical flow, the numeric target, and a conversion factor to correct the units of measure, according to the formula:

Critical flow (4Q3) x WQS x Conversion Factor = TMDL

The TSS TMDL concentration is presented on **Table 5.6** for the critical low flow condition.

Table 5.6 Calculation of TMDL for San Francisco River (Centerfire Creek to AZ border)

TSS Indicator Value (mg/l)	Critical Flow (mgd)	Conversion Factor	TMDL (lb/day)
8.75 [a]	0.90	8.34	65.7

[a] *See Table 5.4*

The TMDL is a planning tool to be used to achieve water quality standards. Since flows vary throughout the year in these systems the target load will vary based on the changing flow. Management of the load to improve stream water quality and meet water quality criteria is the goal of SWQB efforts. The TMDL is further allocated to a MOS, WLA (permitted point sources), and LA (nonpoint sources), according to the formula: *WLA + LA + MOS = TMDL.*

5.3.1 Margin of Safety (MOS)

The CWA requires that each TMDL be calculated with a MOS. This statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A MOS may be expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions). The MOS may be implicit, utilizing conservative assumptions for calculation of the loading capacity, WLAs, and LAs. The MOS may also be explicitly stated as an added separate quantity in the TMDL calculation. For this TMDL, the MOS was developed using explicit allocations. Therefore, this MOS is the sum of the following two elements:

- Explicit Recognition of Potential Errors:
    - Uncertainty exists in the relationship between TSS and deposition of excess sediment. A conservative MOS for this element is **10%**.
    - There is error inherent in flow estimation. A conservative MOS for this element in is **10%**.

Total MOS for this TMDL is **20%**.

5.3.2 Waste Load Allocation (WLA)

There are no active individual National Pollutant Discharge Elimination System (NPDES) permits that discharge to the sedimentation impaired AU, therefore the WLA for this TMDL is zero.

Stormwater discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the USEPA NPDES Construction General Permit (CGP) for construction sites of one or more acres, or smaller if part of a common plan of development, requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. The current CGP also includes state-specific requirements to implement site-specific interim and permanent stabilization, managerial, and structural solids, erosion, and sediment control Best Management Practices (BMPs), and/or other controls. BMPs are designed to prevent to the maximum extent practicable an increase in sediment load to the water body or an increase in a sediment-related parameter, such as total suspended solids, turbidity, siltation, stream bottom deposits, etc. BMPs also include measures to reduce flow velocity during and after construction compared to pre-construction conditions to assure that waste load allocations and/or applicable water quality standards, including the antidegradation policy, are met. Compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Stormwater discharges from industrial activities and facilities, based on industrial classification codes, may be eligible for coverage under the current NPDES Multi-Sector General Permit (MSGP). The MSGP also requires preparation of a SWPPP. Some of the industrial facilities and activities covered under the MSGP have technology based effluent limitation and/or benchmark monitoring for pollutants. The current MSGP includes state-specific requirements that the benchmark values be protective of State of New Mexico WQS.

It is not possible to calculate individual WLAs for facilities covered by the General Permits at this time using the available tools. The discharges from these permits are typically transitory as the activities are temporary. Loads that are in compliance with the General Permits are therefore currently included as part of the Load Allocation (LA). While these sources are not given individual allocations, they are addressed through other means, including BMPs, stormwater pollution prevention conditions, and other requirements.

5.3.3 Load Allocation (LA)

In order to calculate the LA, the WLA and the MOS were subtracted from the target capacity (TMDL), as shown on **Table 5.7**. The MOS was developed using a combination of conservative assumptions and explicit recognition of potential errors (see **Section 5.3.1** for details).

Table 5.7 TMDL allocations for Total Suspended Solids in San Francisco River (Centerfire Creek to AZ border) as an indicator for sedimentation/siltation. Units are in lb/day.

WLA	LA	20% MOS	TMDL
0	52.6	13.1	65.7

The extensive data collection and analyses necessary to determine background sediment loads were beyond the resources available for this study. It is therefore assumed that a portion of the load allocation is made up of natural background loads. The target load for TSS is the TMDL minus the MOS, in this case equal to the LA. Because the relationship of stream bottom sediment to instantaneous TSS loads is complex and includes a temporal element, a measured load cannot be calculated from available data, so TSS load reduction estimates are not presented for sedimentation/siltation impairments. One indicator of implementation progress could be achievement of the % SaFN threshold indicator (**Table 5.8**).

Table 5.8 Reduction of % Sand and Fines needed to fall below the % Sand and Fines threshold indicator value for sedimentation/siltation in the San Francisco River (Centerfire Creek to AZ border).

Ecoregion/Site Class	% Sand and Fines Threshold	% Sand and Fines Observed	Percent Reduction [a]
23c/Mountain	20	31.4	36%

[a] *Percent reduction is the percent the existing measured load must be reduced to achieve the target load and is calculated as follows: ((Measured Load – Target Load) / Measured Load) x 100*

5.4 Identification and Description of Pollutant Sources

SWQB fieldwork includes an assessment of the probable sources of impairment in the AU drainage area, according to Standard Operating Procedure 4.1, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/; **Appendix C**). Probable Source Sheets are filled out by SWQB monitoring staff during watershed surveys. The sheets are then reviewed by watershed protection staff familiar with the location, and the TMDL writer conducts a search of aerial imagery, GIS files, and other available resources. The list of probable sources is not intended to single out any particular landowner or land management activity and generally includes several sources per pollutant.

Table 5.9 displays probable pollutant sources that have the potential to contribute to sedimentation impairment in the San Francisco River (Centerfire Creek to AZ border). The draft probable source list will be reviewed and modified as necessary, with watershed group/stakeholder input during the TMDL public meeting and comment period. Probable sources of impairment will be further evaluated, refined, and changed as necessary through the Watershed-Based Plan (WBP).

Table 5.9 Probable Sources for Sedimentation/Siltation

Assessment Unit	Probable Sources	
San Francisco River (Centerfire Creek to AZ border)	Forest fire Grazing in the riparian zone Highway/Road/Bridge runoff Low water crossing Other recreation (campground)	Rangeland grazing Rural residential area Silviculture Water diversions

Although natural rates of sediment input vary among and within regions, human activities can alter these inputs. Excessive watershed erosion from these activities can transport large amounts of fine sediments into streams, leading to frequent bed mobility and poor instream habitat. Conversely, some human alterations like dredging, channelization or upstream impoundments, may lead to a lack of fine sediments in some parts of the channel, but an excess in other places. Clearing vegetation from banks and riparian areas may increase siltation and reduce large woody debris in streams. Logging or farming up to the stream banks, building roads across or along streams, dredging and straightening the stream channel, and building dams or other diversion structures in the stream channel may destabilize stream banks and change bottom substrate size and composition. Even in streams draining relatively pristine watersheds that are at equilibrium between sediment supply and transport, one might expect different characteristic values of Relative Bed Stability that are dependent upon the natural rates of erosion. In the absence of human activities, these natural erosion rates would depend upon climate, basin geology, geomorphology, channel position within the watershed, and related features such as glaciers and natural landslide frequency (Kaufman et al., 2008).

Wildfires can affect the physical, chemical, and biological quality of streams, rivers, and lakes. After a fire, increased runoff provides a pathway for the transport of chemical-laden sediment to surface water, which may have substantial water quality impacts. Forest fires can result in increased water temperature due to reduced infiltration and loss of shading vegetation. Potential wildfire impacts to water quality are discussed on the SWQB website at https://www.env.nm.gov/surface-water-quality/wildfire-impacts-on-surface-water-quality/. Most watershed effects will naturally recover within 5 to 10 years after the fire, but some aspects of watershed structure and function, as well as areas of most severe fire intensity, may continue to recover for 15-20 years (Bixby et al., 2015). Therefore, runoff following forest fire has been added to the Probable Source list (**Table 5.9**) for those TMDL AUs where fires occurred during the 20 years preceding the 2019-20 water quality survey.

5.5 Consideration of Seasonal Variation

The sediment moving capacity of a stream is exponentially related to flow velocity and discharge. Therefore, most of the work of streams is accomplished during floods, when stream velocity and discharge (and therefore capacity) are many times their level during low flow conditions. This work is in the form of bed scouring (erosion), sediment transport (bed and suspended loads), and sediment deposition. It is likely that the excess fine sediment loading and deposition occur during periods of higher flow, which in New Mexico are most likely to occur during spring snowmelt and summer monsoon storms. TSS samples were collected from June to September of 2019, and in September and October of 2020, capturing the summer and fall seasons. There was no evident seasonal pattern to turbidity and TSS results. Only one sampling event documented TSS above the sedimentation indicator value, in September of 2019.

5.6 Future Growth

San Francisco River (Centerfire Creek to AZ border) is located in Catron County.

Growth estimates by county are available from the University of New Mexico Geospatial and Population Studies (https://gps.unm.edu/pru/projections, accessed 7/18/23). These estimates project growth to the year 2040. Due to delays in UNM receiving Census Bureau and other data, projections updated to include the 2020 Census findings are not yet available. Updated projections are expected to be available by the end of 2023. Watershed Based Plan writers and TMDL implementation practitioners should use the latest available information, if future growth is applicable to their project.

Table 5.10 Population projections for the sedimentation/siltation TMDL

County	2020	2030	2040	Increase (2020-2040)
Catron	3,491	3,221	2,897	-17.0%

Estimates of future growth are not anticipated to lead to a significant increase in sedimentation that cannot be controlled with BMP implementation. BMPs should be utilized and improved upon while continuing to improve watershed conditions and adhering to SWPPP requirements related to construction and industrial activities covered under the general permit.

6.0 TEMPERATURE

Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms. Natural temperatures of a water body fluctuate daily and seasonally. These natural fluctuations do not eliminate indigenous populations, but may affect existing community structure and geographical distribution of species. Anthropogenic impacts such as thermal pollution, deforestation, flow modification and climate change can modify these natural temperature cycles, often leading to deleterious impacts on aquatic life communities. Such modifications may contribute to changes in geographical distribution of species and their ability to persist in the presence of additional stressors such as introduced species. One mechanism by which temperature affects fish is that warmer water has a lower capacity for dissolved oxygen. Water temperature within the stream substrate can influence the growth of insects and salmon eggs. In addition to direct effects, the toxicity of many chemical contaminants increases with temperature (Caissie, 2006).

6.1 Target Loading Capacity

Fish and other aquatic organisms have specific ranges of temperature tolerance and preference. Cold water fish such as salmonids (salmon and trout) are especially vulnerable to increased water temperature. For that reason, coldwater criteria are typically designed primarily to support reproducing populations of salmonids. A coolwater Aquatic Life Use (ALU) was approved by the WQCC in October 2010, to support aquatic life whose physiologic tolerances are intermediate between those of warmwater and coldwater aquatic life (NMED/SWQB, 2009). Acute temperature criteria (such as New Mexico's T_{MAX}) are intended to protect aquatic life from lethal exposures, whereas chronic criteria (the 4T3 or 6T3) protect from sub-lethal exposures sufficient to cause long-term detrimental effects (Todd et al., 2008). The acute and chronic criteria are established to protect the most sensitive members of fish communities, based on laboratory studies of the upper thermal limits of individual species.

For this TMDL document, target values for temperature are based on the reduction in thermal loading necessary to achieve numeric criteria. Temperature criteria for ALUs in New Mexico are shown on **Table 6.1**. New Mexico's aquatic life temperature criteria are expressed as $T_{MAX,}$ 4T3 and 6T3. T_{MAX} is the maximum recorded temperature, 4T3 means the temperature not to be exceeded for four or more consecutive hours in a 24-hour period on more than three consecutive days, and 6T3 means the temperature not to be exceeded for six or more consecutive hours in a 24-hour period on more than three consecutive days.

Table 6.1 Aquatic Life Use Temperature (°C) Water Quality Criteria

Criterion	*High Quality Coldwater*	*Coldwater*	*Marginal Coldwater*	*Coolwater*	*Warmwater*	*Marginal Warmwater*
4T3	20	---	---	---	---	---
6T3	---	20	25	---	---	---
T_{MAX}	23	24	29	29	32.2	32.2

TMDLs were calculated for six Gila/Mimbres/San Francisco and Lower Rio Grande watershed AUs that exceeded the T_{MAX} for their designated ALU. All of those which have chronic standards also exceeded the applicable chronic standard, except for the Mimbres River. In addition, one AU, Whitewater Creek (Whitewater Campgrd to headwaters) exceeded its chronic standard but not the WQS T_{MAX}. Thermograph records are available for Gilita Creek (Middle Fork Gila R to Willow Creek) and Willow Creek (Gilita Creek to headwaters) from both survey years, and both AUs exceeded their acute and chronic standards in both 2019 and 2020. Thermograph data are presented in **Appendix B**.

Table 6.2 Aquatic Life Use designations of the temperature TMDL AUs

Assessment Unit	Designated ALU
Gilita Creek (Middle Fork Gila R to Willow Creek)	High Quality Coldwater
Las Animas Ck (perennial prt R Grande to Animas Gulch)	Marginal Coldwater/Warmwater
Mangas Creek (Gila River to Mangas Springs)	Marginal Coldwater/Warmwater
Mimbres R (Perennial reaches Cooney Cyn to headwaters)	High Quality Coldwater
San Francisco River (NM 12 at Reserve to Centerfire Creek)	Marginal Coldwater/Marginal Warmwater
Whitewater Creek (Whitewater Campgrd to headwaters)	High Quality Coldwater
Willow Creek (Gilita Creek to headwaters)	High Quality Coldwater

6.2 Flow

The TMDL is a value calculated at a defined critical flow condition as part of a planning process designed to achieve water quality standards. For this temperature TMDL, the appropriate critical flow condition is at low flow in order to be protective when the assimilative capacity of a stream is at its lowest. According to the New Mexico Water Quality Standards, the low flow critical condition for numeric criteria (excluding human health-organism only criteria) set in 20.6.4.97 through NMAC 20.6.4.900 and Subsection F of NMAC 20.6.4.13 is defined as the 4-day, 3-year low-flow frequency (4Q3, NMAC 20.6.4.11(B)(2)). The 4Q3 is the annual lowest four consecutive day flow that occurs with a frequency of at least once every three years.

A regression model developed by Waltemeyer (2002) was used to estimate critical low flow in the ungaged TMDL AUs. In Waltemeyer's analysis, two regression equations for estimating 4Q3 were developed based on physiographic regions of New Mexico (i.e., statewide and mountainous regions above 7,500 ft in elevation). The following mountainous regions regression equation (**Equation 6.1**) is based on data from 40 gaging stations located above 7,500 ft in elevation with non-zero discharge (Waltemeyer, 2002):

Equation 6.1 $4Q3 = 7.3287 \times 10^{-5} DA^{0.70} {P_w}^{3.58} S^{1.35}$

Where:

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = Drainage area (mi^2)
P_w = Average basin mean winter precipitation (inches)
S = Average basin slope (ft/ft)

The following the statewide regression equation (**Equation 6.2**) was used for those AUs with average watershed elevation below 7,500 ft. The following statewide regression equation is based on data from 50 gaging stations with non-zero discharge (Waltemeyer 2002):

Equation 6.2 $4Q3 = 1.2856 \times 10^{-4}\ DA^{0.42}\ P_w^{3.16}$

Where:

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = drainage area (mi^2)
Pw = average basin mean winter precipitation (inches)

The 4Q3 values calculated using Waltemeyer's method are presented in **Table 6.3**. Parameters used in the calculation were obtained using the StreamStats online GIS application developed by the USGS (https://streamstats.usgs.gov/ss/).

Table 6.3 Variables used in Waltemeyer's regression estimation of critical flow value for Gila/Mimbres/San Francisco and Lower Rio Grande temperature TMDLs

Assessment Unit	Average Elevation (ft)	Drainage Area (mi^2)	Average Basin Slope (ft/ft)	Mean Winter Precipita tion (in)	4Q3 (cfs)
Gilita Creek (Middle Fork Gila R to Willow Creek)	8720	39.4	0.24	20.1	6.47
Las Animas Ck (perennial prt R Grande to Animas Gulch)	6572	131	NA	6.1	0.30
Mangas Creek (Gila River to Mangas Springs)	5745	204	NA	6.8	0.51
Mimbres R (Perennial reaches Cooney Cyn to headwaters)	8388	30.4	0.4	9.68	0.79
Whitewater Creek (Whitewater Campgrd to headwaters)	8210	36.2	0.55	18.9	14.97
Willow Creek (Gilita Creek to headwaters)	9068	15	0.3	21.6	5.75

Mangas Springs discharge has been measured at 0.22 cfs (Trauger, 1972; White and Kues, 1992), which is unlikely to vary significantly, so that amount was added to the 4Q3 derived from the Waltemeyer equation for Mangas Creek, for a critical low flow value of 0.73 cfs.

USGS gage data was available to estimate critical flow for the San Francisco River (NM 12 at Reserve to Centerfire Creek), using the DFLOW software program, applied to daily discharge at the USGS gage

09442680 - San Francisco River near Reserve, NM, from 1990 through 2017. The estimated critical flow for the San Francisco River (NM 12 at Reserve to Centerfire Creek) is 1.14 cfs.

The TMDL is a value calculated at a defined critical condition as part of a planning process designed to achieve water quality standards. Since flows vary throughout the year in these systems, the actual load at any given time will vary based on the changing flow. Management of the load to improve stream water quality is the goal of SWQB efforts.

6.3 TMDL Calculations

The calculation of a TMDL is governed by the basic equation,

WQS criterion x flow x conversion factor = TMDL target capacity

For temperature TMDLs, the WQS criterion is a temperature specified either by the designated ALU or segment-specific criteria, and it can be either a maximum temperature or time-duration temperature such as the 4T3 or 6T3. The 4Q3 low-flow is generally used for the critical flow unless another flow statistic or multiple flow conditions are more appropriate for the situation. The conversion factor is a variable needed to convert units used by SWQB for temperature (in Celsius) and flow (in cfs) to units needed to balance the thermal energy equation. Substituting the appropriate unit conversion factors, the equation used for temperature is the following:

$$WQS\ (^{o}C)\ x\ Flow\ (cfs)\ x\ (1.023\ x\ 10^{7}) = TMDL\ (kJ/day)$$

Details of the derivation of the temperature TMDL equation are presented in **Appendix D**. **Table 6.4** shows the TMDL calculation values for each TMDL AU.

Table 6.4 Temperature TMDL calculations

Assessment Unit Name	Target temperature (°C)	4Q3 critical flow (cfs)	Conversion factor	TMDL (kJ/day)
Gilita Creek (Middle Fork Gila R to Willow Creek)	23	6.47	1.023×10^{7}	1.52×10^{9}
Las Animas Ck (perennial prt R Grande to Animas Gulch)	29	0.30	1.023×10^{7}	8.90×10^{7}
Mangas Creek (Gila River to Mangas Springs)	28	0.73	1.023×10^{7}	2.09×10^{8}
Mimbres R (Perennial reaches Cooney Cyn to headwaters)	23	0.79	1.023×10^{7}	1.86×10^{8}
San Francisco River (NM 12 at Reserve to Centerfire Creek)	25	1.14	1.023×10^{7}	2.92×10^{8}
Whitewater Creek (Whitewater Campgrd to headwaters)	20*	14.97	1.023×10^{7}	3.83×10^{9}
Willow Creek (Gilita Creek to headwaters)	23	5.75	1.023×10^{7}	1.35×10^{9}

** 4T3 chronic standard used as target because the T_{MAX} was not exceeded*

The TMDL is further allocated to a Margin of Safety (MOS), Waste Load Allocation (WLA; permitted point sources), and Load Allocation (LA; nonpoint sources), according to the formula:

$$WLA + LA + MOS = TMDL$$

6.3.1 Margin of Safety (MOS)

The CWA requires that each TMDL be calculated with a MOS, intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A MOS may be expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions). The MOS may be implicit, utilizing conservative assumptions for calculation of the loading capacity, WLAs, and LAs. The MOS may also be explicitly stated as an added separate quantity in the TMDL calculation.

- An **implicit MOS** for the Whitewater Creek (Whitewater Campgrd to headwaters) TMDL is introduced by using the chronic criterion as the target for maximum water temperature.

- Because of the uncertainty in determining critical low flow, an **explicit MOS of 5%** is assigned to the TMDL where gage data was available. An **explicit MOS of 10%** is assigned to the TMDLs where the critical flow was estimated using the Waltemeyer regression.

- In recognition of the likelihood of future increases in air temperature and evaporative demand, an **additional explicit 10% MOS** is added to each AU for climate change.

6.3.2 Waste Load Allocation (WLA)

There are no active individual National Pollutant Discharge Elimination System (NPDES) permits that discharge to the temperature TMDL AUs. There are no Municipal Separate Storm Sewer System (MS4) permits in these AUs. Therefore, no WLA is assigned.

There may be storm water discharges from industrial, including construction, activities covered under the National Pollutant Discharge Elimination System (NPDES) Construction General Permit (CGP) or Multi-Sector General Permit (MSGP). Excess temperature loading may be a component of some storm water discharges covered under general NPDES permits. Stormwater discharges from industrial, including construction, activities are generally considered transient because they occur mainly during the construction itself and/or only during storm events.

Coverage under the USEPA NPDES CGP for construction sites one acre or greater or smaller if part of a common plan of development require preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of pollutants associated with the construction activities to minimize impacts to water quality. The current CGP also includes state-specific requirements to implement site-specific interim and permanent stabilization, managerial, and structural solids, erosion, and sediment control Best Management Practices (BMPs), and/or other controls. BMPs are designed to prevent to the maximum extent practicable an increase in sediment load to the water body or an increase in a sediment-related parameter, such as total suspended solids, turbidity, siltation, stream bottom deposits, etc. BMPs also include measures to reduce flow velocity during and after construction compared to pre-construction conditions. Stormwater discharges from industrial activities and facilities, based on industrial classification codes, may be eligible for coverage under the current NPDES MSGP. The MSGP also requires preparation of a SWPPP. Some of the industrial facilities and activities covered under the MSGP have technology based effluent limitation and/or benchmark monitoring for pollutants. The current MSGP includes state-specific requirements that the benchmark values reflect State of New Mexico WQS.

It is not possible to calculate individual WLAs for facilities covered by the General Permits at this time using the available tools. Loads that are in compliance with the General Permits are therefore currently included as part of the Load Allocation (LA). While these sources are not given individual allocations, they are addressed through other means, including BMPs, stormwater pollution prevention conditions, and other requirements. State certification of federal permits ensure that applicable water quality standards, including the antidegradation policy, are met. Compliance with a CGP or MSGP SWPPP that meets the requirements of the general permits is generally assumed to be consistent with this TMDL.

6.3.3 Load Allocation (LA)

Load Allocation is pollution from any nonpoint source(s) or natural background and is addressed through Best Management Practices (BMPs). Since there are no WLAs for these AUs, the LA is equal to the TMDL value minus the MOS.

Table 6.5 Temperature TMDL load allocations. Units are kilojoules per day.

Assessment Unit	MOS	WLA	LA	TMDL
Gilita Creek (Middle Fork Gila R to Willow Creek)	3.04×10^8	0	1.22×10^9	1.52×10^9
Las Animas Ck (perennial prt R Grande to Animas Gulch)	1.78×10^7	0	7.12×10^7	8.90×10^7
Mangas Creek (Gila River to Mangas Springs)	4.18×10^7	0	1.67×10^8	2.09×10^8
Mimbres R (Perennial reaches Cooney Cyn to headwaters)	3.72×10^7	0	1.49×10^8	1.86×10^8
San Francisco River (NM 12 at Reserve to Centerfire Creek)	4.38×10^7	0	2.48×10^8	2.92×10^8
Whitewater Creek (Whitewater Campgrd to headwaters)	7.66×10^8	0	3.06×10^9	3.83×10^9
Willow Creek (Gilita Creek to headwaters)	2.70×10^8	0	1.08×10^9	1.35×10^9

6.4 Identification and Description of Pollutant Source(s)

SWQB fieldwork includes an assessment of the probable sources of impairment in the AU drainage area, according to Standard Operating Procedure 4.1, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/; **Appendix C**). Probable Source Sheets are filled out by SWQB monitoring staff during watershed surveys. The sheets are then reviewed by watershed protection staff familiar with the location, and the TMDL writer conducts a search of aerial imagery, GIS files, and other available resources. The list of probable sources is not intended to single out any particular landowner or land management activity and generally includes several sources per pollutant.

Table 6.6 displays probable pollutant sources that have the potential to contribute to temperature impairments. The draft probable source list will be reviewed and modified, as necessary, with watershed group/stakeholder input during the TMDL public meeting and comment period. Probable sources of temperature impairments can be further evaluated, refined, and changed as necessary through the Watershed-Based Plan (WBP).

Table 6.6 Probable Sources for Temperature

Assessment Unit	Probable Source(s)
Gilita Creek (Middle Fork Gila R to Willow Creek)	Dam/impoundment; Forest fire; Other recreation (hiking trails)
Las Animas Ck (perennial prt R Grande to Animas Gulch)	Crop production; Dam/impoundment; Forest fire; Highway/Road/Bridge runoff; Low water crossing; Rural residential area; Water diversion
Mangas Creek (Gila River to Mangas Springs)	Crop production; Dam/impoundment; Highway/Road/Bridge runoff; Low water crossing; Natural sources; Rangeland grazing
Mimbres R (Perennial reaches Cooney Cyn to headwaters)	Forest fire; Highway/Road/Bridge runoff; Low water crossing
San Francisco River (NM 12 at Reserve to Centerfire Creek)	Crop production (irrigated); Dam/impoundment; Forest fire; Grazing in the riparian zone; Highway/Road/Bridge runoff; Low water crossing; Natural sources; Rangeland grazing;
Whitewater Creek (Whitewater Campgrd to headwaters)	Forest fire; Other recreation (hiking trails);
Willow Creek (Gilita Creek to headwaters)	Forest fire; Highway/Road/Bridge runoff; Low water crossing; Other recreation (angling, campgrounds, hiking trails)

A variety of factors can impact stream temperature (**Figure 6.1**). Decreased effective shade levels may result from reduction of riparian vegetation. When canopy densities are reduced, thermal loading increases in response to the increase in incident solar radiation. Likewise, it is well documented that past hydromodification activities have led to channel incision and widening. Wider stream channels also increase the stream surface area exposed to sunlight, thereby increasing heat transfer. Riparian area and channel morphology disturbances may also be attributed to past or current rangeland grazing practices that have resulted in reduction of riparian vegetation and streambank destabilization. These nonpoint sources of pollution primarily affect the water temperature through increased solar loading by: (1) increasing stream surface solar radiation influx, and (2) increasing stream surface area exposed to solar radiation.

Riparian vegetation, stream morphology, hydrology, climate, geographic location, and aspect all influence stream temperature. Although climate, geographic location, and aspect are outside of human control, the condition of the riparian area, channel morphology, and hydrology can be affected by land use activities. Specifically, elevated summertime stream temperatures attributable to anthropogenic causes may result from the following conditions:

1. Channel widening (i.e., increased width to depth ratios) that has increased the stream surface area exposed to incident solar radiation;
2. Riparian vegetation disturbance that has reduced stream surface shading, riparian vegetation height and density;
3. Reduced summertime base flows that result from instream impoundments and withdrawals and/or inadequate riparian vegetation; and,
4. Inflow from heated surfaces, such as road pavement, buildings, bare land, etc. and the flow of water over hardened channel bottoms and walls.

Loss of a functioning riparian system may lower and sometimes eliminate baseflows. Although removal of upland vegetation has been shown, in some cases, to increase water yield, studies show that removal of riparian vegetation along the stream channel subjects the water surface and adjacent soil surfaces to wind and solar radiation, partially offsetting the reduction in transpiration with evaporation. In losing reaches, where the stream loses water through infiltration to the surrounding ground as it flows downstream, increased temperatures can result in increased streambed infiltration, which can result in lower base flow (Constrantz et al., 1994).

Vegetation density increases will provide necessary shading, as well as encourage bank-building processes in severe hydrologic events (see **Section 8.3** of this report for modeling of shade increases to reduce water temperature). However shade is only one avenue which may be pursued to decrease water temperature and ultimately meet WQS. Changes in geomorphological parameters might also prove useful. For example, unstable channels may be characterized by excess sedimentation. Many aquatic organisms respond to high temperature by seeking thermal refuge, moving into cooler tributaries or small cold patches within the stream. Creation of thermal refuges, or enhanced connectivity, may mitigate the effects of increased water temperature (Caissie, 2006).

Wildfires can affect the physical, chemical, and biological quality of streams, rivers, and lakes. After a fire, increased runoff provides the pathway for the transport of chemical-laden sediment to surface water, which may have substantial water quality impacts. Forest fires can result in increased water temperature due to reduced infiltration and loss of shading vegetation. Potential wildfire impacts to water quality are discussed on the SWQB website at https://www.env.nm.gov/surface-water-quality/wildfire-impacts-on-surface-water-quality/. Most watershed effects will naturally recover within 5 to 10 years after the fire, but some aspects of watershed structure and function, as well as areas of most severe fire intensity, may continue to recover for 15-20 years (Bixby et al., 2015). Therefore, runoff following forest fire has been added to the Probable Source list (**Table 6.6**) for those TMDL AUs where fires occurred during the 20 years preceding the 2019-20 water quality survey. The Mimbres R (Perennial reaches Cooney Cyn to headwaters) AU, and the headwaters of Las Animas Creek, were burned over by the Black Fire in 2022.

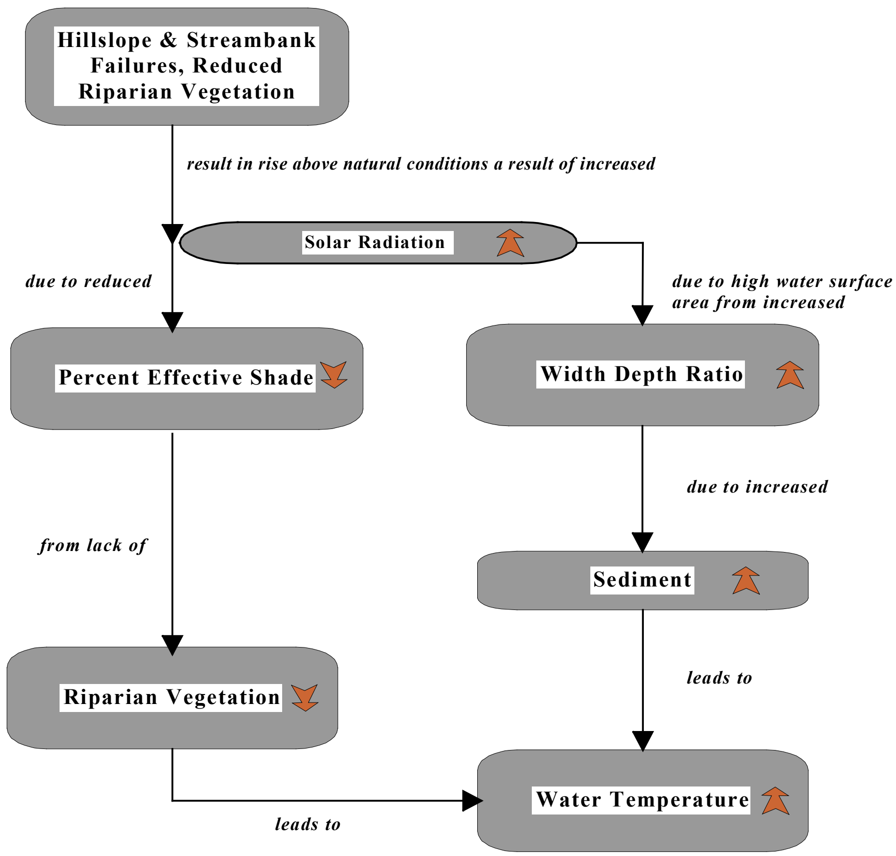

Figure 6.1 Factors Impacting Stream Temperature

An unnamed ephemeral side canyon enters the San Francisco River (NM 12 at Reserve to Centerfire Creek) immediately upstream of the thermograph location. The side canyon is impounded in a series of ponds, downstream of which it receives water from Hudson Spring, before entering the San Francisco. The ponds and the spring are located on the privately-owned Hudson Ranch. The volume and seasonality of the side canyon runoff is unknown, as is the volume and temperature of the spring water. Mangas Creek (Gila River to Mangas Springs) is influenced by hot spring flow. Estimated total discharge into Mangas Creek from the hot springs 0.22 cfs (approximately 1/3 of the critical flow used for TMDL calculation) at 27.2 °C (White and Kues, 1992).

Six thermographs were placed along Willow Creek and its tributary Little Turkey Creek in 2018, by Natural Channel Design (Tucson, AZ), in the course of developing a Watershed Based Plan. All of the thermograph records show that the maximum water temperature occurred on the same day that summer near the end of July. From the North Fork above South Fork, downstream as far as the NMDGF Cabin, the T_{max} fluctuated narrowly around 24 °C. The Above Barrier thermograph station is located towards the bottom of the AU, near the SWQB monitoring location used during the 2019-20 water quality survey. The T_{max} on that day in July 2018 at Above Barrier was 26.0 °C. Little Turkey Creek (which was not monitored by SWQB) flows into Willow Creek just below the NMDGF Cabin, and the T_{max} recorded that day in Little Turkey Creek was 26.7 °C. From this information it appears that, while the entire length of Willow Creek exceeds the temperature WQS, Little Turkey Creek contributes disproportionately to water temperature at the bottom of the AU. Fortunately, the WBP includes proposed actions which are intended to lower the temperature of both water bodies. A current River Stewardship funded project is intended to address post-fire restoration of Little Turkey Creek.

Centerfire Creek, which is tributary to the San Francisco River (NM 12 at Reserve to Centerfire Creek) AU, has TMDLs for conductivity, plant nutrients, *E. coli* and temperature. A current River Stewardship funded project is intended to address these impairments, and may be expected to contribute to improved water quality in the San Francisco River downstream of Centerfire Creek.

6.5 Consideration of Seasonal Variation

Section 303(d)(1) of the CWA requires TMDLs to be "established at a level necessary to implement the applicable WQS with seasonal variations." Both stream temperature and flow vary seasonally and from year to year. Water temperatures are coolest in the winter and early spring months. Future climate change is expected to increase air temperatures and decrease streamflow, potentially causing increases in maximum water temperature.

The warmest stream temperatures correspond to prolonged solar radiation exposure, warmer air temperature, and low flow conditions. Maximum temperatures were recorded in the TMDL AUs from late June to early August, in both 2019 and 2020.

6.6 Future Growth

SWQB acknowledges the projected impact of climate change on the state's water resources. Climate change will put additional stress on New Mexico's water resources and make attainment of water quality standards more difficult to achieve. In addition, shifting temperature and precipitation patterns affect vegetative composition and density and increase wildfire intensity and the propensity for wildfire in non-fire adapted ecosystems. In 2019, Governor Lujan Grisham signed Executive Order 2019-003 on Addressing Climate Change and Energy Waste Prevention. Executive order 2019-003 directs all State agencies to evaluate the impacts of climate change on their programs and operations and integrate climate change mitigation and adaptation practices into their programs and operations.

In general, the strongest influence on in-stream water temperature is the ambient air temperature. Stakeholders should explore options to determine the most appropriate approach for each particular watershed or project, with the ultimate goal being that the stream meets the WQS. The SWQB encourages implementation practitioners to design projects to reduce water temperature well below the WQS, such that currently impaired AUs will be likely to meet WQS standards in the future with sufficient resiliency to warmer air temperatures and potentially lower flows.

Las Animas Ck (perennial prt R Grande to Animas Gulch) is located in Sierra County, Mangas Creek (Gila River to Mangas Springs) and Mimbres R (Perennial reaches Cooney Cyn to headwaters) are located in Grant County, and the remaining temperature TMDL AUs are located in Catron County.

Growth estimates by county are available from the University of New Mexico Geospatial and Population Studies (https://gps.unm.edu/pru/projections, accessed 7/18/23). These estimates project growth to the year 2040. Due to delays in UNM receiving Census Bureau and other data, projections updated to include the 2020 Census findings are not yet available. Updated projections are expected to be available by the end of 2023. Watershed Based Plan writers and TMDL implementation practitioners should use the latest available information, if future growth is applicable to their project.

Table 6.8 Population projections for the temperature TMDLs

County	2020	2030	2040	Increase (2020-2040)
Catron	3,491	3,221	2,897	-17.0%
Grant	29,475	25,585	23,092	-21.7%
Sierra	10,898	9,733	8,400	-22.9%

Estimates of future growth are not anticipated to lead to a significant increase in in-stream temperatures that cannot be controlled with BMP implementation. BMPs should be utilized and improved upon while continuing to improve watershed conditions and adhering to SWPPP requirements related to construction and industrial activities covered under the general permit.

7.0 MONITORING PLAN

Pursuant to CWA Section 106(e)(1), 33 U.S.C. Section 1251, the SWQB has established appropriate monitoring methods, systems and procedures in order to compile and analyze data on the quality of the surface waters of New Mexico. In accordance with the New Mexico Water Quality Act, NMSA 1978, Sections 74-6-1 to -17, the SWQB has developed and implemented a comprehensive water quality monitoring strategy for the surface waters of the State.

The monitoring strategy establishes the methods of identifying and prioritizing water quality data needs, specifies procedures for acquiring and managing water quality data, and describes how these data are used to progress toward three basic monitoring objectives: to develop water quality-based controls, to evaluate the effectiveness of such controls, and to conduct water quality assessments. The SWQB revised its 10-year monitoring and assessment strategy (NMED/SWQB, 2016a) and submitted it to USEPA Region 6 for review in June of 2016. The strategy details both the extent of monitoring that can be accomplished with existing resources plus expanded monitoring strategies that could be implemented given additional resources. The SWQB utilizes a rotating basin approach to water quality monitoring. In this approach, a select number of watersheds are intensively monitored each year with an established return frequency of approximately every eight to ten years. The next scheduled monitoring date for the Gila/Mimbres/San Francisco and Lower Rio Grande watersheds is 2029-2030.

The SWQB maintains current quality assurance and quality control plans to cover all monitoring activities. This document, called the Quality Assurance Project Plan (NMED/SWQB, 2018b), is updated regularly and approved by USEPA Region 6. In addition, the SWQB identifies the data quality objectives required to provide information of sufficient quality to meet the established goals of the program. Current priorities for monitoring in the SWQB are driven by the CWA Section 303(d) list of streams requiring TMDLs or TMDL alternatives; water bodies identified as needing ALU verification; the need to monitor unassessed perennial waters; and water bodies receiving point source discharge(s).

Once assessment monitoring is completed, those reaches showing impairment and requiring a TMDL will be targeted for more intensive monitoring. The methods of data acquisition include fixed-station monitoring, intensive surveys of priority assessment units (including biological assessments), and compliance monitoring of industrial, federal, and municipal dischargers, as specified in the SWQB Standard Operating Procedures.

Long-term monitoring for assessments will be accomplished through the establishment of sampling sites that are representative of the water body and which can be revisited approximately every eight years. This information will provide time relevant information for use in CWA Section 303(d) listing and 305(b) report assessments and to support the need for developing TMDLs. The approach provides:

- a systematic, detailed review of water quality data which allows for a more efficient use of valuable monitoring resources;
- information at a scale where implementation of corrective activities is feasible;
- an established order of rotation and predictable sampling in each basin which allows for enhanced coordinated efforts with other programs; and
- program efficiency and improvements in the basis for management decisions.

A watershed would not be ignored during the years in between water quality surveys. The rotating basin program will be supplemented with other data collection efforts such as on-going studies being performed by the USGS and USEPA. Data will be analyzed and field studies will be conducted to further characterize acknowledged problems and TMDLs will be developed and implemented accordingly. Both long-term and intensive field studies can contribute to the State's Integrated 303(d)/§305(b) listing process for waters requiring TMDLs.

8.0 IMPLEMENTATION OF TMDLs

When approving TMDL documents, USEPA takes action on the TMDL, LA, WLA, and other components of the TMDL as needed (e.g., MOS and future growth). USEPA does not take action on the implementation section of the TMDL, and USEPA is not bound to implement any recommendations found in this section, in particular if they are found to be inconsistent with CWA and NPDES regulations, guidance, or policy.

8.1 Point Sources

8.1.1 Individual NPDES Permits

There are three individual NPDES permits that discharge to the dissolved boron-impaired Rio Grande (International Mexico bnd to TX border), as shown on **Table 2.3**. Calculation of Waste Load Allocations for the point sources is shown in **Section 2.3.2** of this report. Implementation of permit limits is discussed below.

Wastewater flows by gravity and with the aid of 20 lift stations for Sunland Park and the Sunland Park North (Santa Teresa) WWTPs. The flow is through the entrance works which consists of an automatic bar screen with a manual backup and a grit removal chamber. The wastewater flow then enters an aeration basin, then two circular final clarifiers from the aeration basin. Contents of the final clarifier are discharged to an ultraviolet disinfection unit. The treated water flows through a flume, with a Drexelbrook instantaneous flow meter and totalizer. Samples for NPDES permit monitoring are collected from this unit. The flow is then discharged through an underground pipe to the Rio Grande in Segment 20.6.4.101 NMAC of the Rio Grande Basin.

El Paso Electric Company Rio Grande Power Plant is authorized under NPDES Permit No. NM0000108 to discharge stormwater runoff, reverse osmosis reject, and emergency overflows at Outfall 001 to Rio Grande, and primarily cooling tower blowdown and/or storm water at Outfall 002 to Montoya Drain, a tributary to the Rio Grande. Outfall 001 has not discharged since 2010. EPE maintains this outfall in their permit for emergency purposes only, such as times of extreme flooding conditions within the plant. Such discharges are to be monitored for dissolved boron and reported. Source waters for industrial uses at the power plant include municipal water supply and groundwater, as well as stormwater that collects in two canals (upper and lower) at the facility.

8.1.2 MS4 Permit

The National Pollutant Discharge Elimination System (NPDES) permitting program for stormwater discharges was established under the Clean Water Act as the result of a 1987 amendment. The Act specifies the level of control to be incorporated into the NPDES stormwater permitting program depending on the source (industrial versus municipal). These programs contain specific requirements for the regulated communities/facilities to establish a comprehensive stormwater management program (SWMP) or storm water pollution prevention plan (SWPPP) to implement any requirements of the total maximum daily load (TMDL) allocation. [See 40 CFR §130.]

Storm water discharges are highly variable both in terms of flow and pollutant concentration, and the relationships between discharges and water quality can be complex. For municipal stormwater discharges in particular, the current use of system-wide permits and a variety of jurisdiction-wide BMPs, including educational and programmatic BMPs, does not easily lend itself to the existing methodologies for deriving numeric water quality-based effluent limitations. These methodologies were designed primarily for process wastewater discharges which occur at predictable rates with predictable pollutant loadings under low flow conditions in receiving waters. EPA has recognized these problems and developed permitting guidance for stormwater permits (USEPA, 1996).

Due to the nature of storm water discharges, and the typical lack of information on which to base numeric water quality-based effluent limitations (expressed as concentration and mass), EPA recommends an interim permitting approach for NPDES storm water permits which is based on BMPs. “The interim permitting approach uses best management practices (BMPs) in first-round storm water permits, and expanded or better-tailored BMPs in subsequent permits, where necessary, to provide for the attainment of water quality standards.”

A monitoring component is also included in the recommended BMP approach. “Each storm water permit should include a coordinated and cost-effective monitoring program to gather necessary information to determine the extent to which the permit provides for attainment of applicable water quality standards and to determine the appropriate conditions or limitations for subsequent permits.” (USEPA, 1996). This approach was further elaborated in an EPA guidance memo (USEPA, 2002): “The policy outlined in this memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and nonstructural BMPs) that address storm water discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality. …… If it is determined that a BMP approach (including an iterative BMP approach) is appropriate to meet the storm water component of the TMDL, EPA recommends that the TMDL reflect this.” This BMP-based approach to stormwater sources in TMDLs is also recognized and described in the most recent EPA guidance (USEPA, 2008).

This TMDL adopts the EPA recommended approach and relies on appropriate BMPs for implementation. No numeric effluent limitations are required or anticipated for municipal stormwater discharge permits.

8.2 Nonpoint Sources

8.2.1 WBP and BMP Coordination

Public awareness and involvement will be crucial to the successful implementation of these plans and improved water quality. A Watershed Based Plan (WBP) is a written plan intended to provide a long-range vision for various activities and management of resources in a watershed. It includes opportunities for private landowners and public agencies in reducing and preventing nonpoint source impacts to water quality. This long-range strategy will become instrumental in coordinating efforts to achieve water quality standards in the watershed. The WBP is essentially the Implementation Plan, or Phase Two of the TMDL process. The completion of the TMDLs and WBP leads directly to the development of on-the-ground projects to address surface water impairments in the watershed. BMPs to be considered as part of on-the ground-projects to address temperature include establishment of additional woody riparian vegetation for shade and/or stream channel restoration work, particularly at road crossings. Additional information about the reduction of nonpoint source pollution can be found online at: https://www.epa.gov/polluted-runoff-nonpoint-source-pollution.

In the Gila/Mimbres/San Francisco project area, currently active watershed groups include the San Francisco River Association and the Upper Gila Watershed Alliance. WBPs have been approved for Black Canyon and Willow Creek. In the Lower Rio Grande project area, the active watershed group is the Paseo del Norte Watershed Council, and there is an approved Paseo del Norte WBP focused on bacterial impairments. SWQB staff will continue to conduct outreach related to the CWA Section 319(h) funding program.

8.2.2 Clean Water Act Section 319(h) Funding

The Watershed Protection Section of the SWQB may potentially be able to provide USEPA Section 319(h) funding to assist in implementation of BMPs to address water quality problems on reaches listed as category 4 or 5 waters on the Integrated 303(d)/§305(b) list. These monies are available to all private, for-profit, and nonprofit organizations that are authenticated legal entities, or governmental jurisdictions including: cities, counties, tribal entities, federal agencies, or agencies of the state. Proposals are submitted through a Request for Proposal (RFP) process. Selected projects require a non-federal match of 40% of the total project cost consisting of funds and/or in-kind services. Funding is potentially available, generally annually, for both watershed-based planning and on-the-ground projects to improve surface water quality and associated habitat. Further information on funding from the CWA Section 319(h) can be found at the SWQB website: https://www.env.nm.gov/surface-water-quality/.

8.2.3 Other Funding Opportunities and Restoration Efforts

Several other sources of funding exist to address impairments discussed in this TMDL document. NMED's Construction Programs Bureau assists communities in need of funding for WWTP upgrades and improvements to septic tank configurations. They can also provide matching funds for appropriate CWA Section 319(h) projects using state revolving fund monies. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Environmental Quality Incentive Program (EQIP) program can provide assistance to private landowners in the basin. The USDA Forest Service aligns their mission to protect lands they manage with the TMDL process, and are another source of assistance. The US Bureau of Land Management (BLM) has several programs in place to provide assistance to improve unpaved roads and grazing allotments.

The SWQB annually makes available CWA Section 604(b) funds through a Request for Quotes (RFQ) process. The SWQB requests quotes from regional public comprehensive planning organizations to conduct water quality management planning as defined under Sections 205(j) and 303(e) and the CWA. The SWQB seeks proposals to conduct water quality management planning with a focus on projects that clearly address the State's water quality goals to preserve, protect and improve the water quality in New Mexico. The SWQB encourages proposals focused on TMDLs and UAAs or other water quality management planning activities that will directly address identified water quality impairments. The SWQB 604(b) RFQ is released annually in September.

The New Mexico Legislature appropriated $1,250,000 in state funds for the River Stewardship Program during the 2020 Legislative Session. The River Stewardship Program has the overall goal of addressing the root causes of poor water quality and stream habitat. Objectives of the River Stewardship Program include: "restoring or maintaining hydrology of streams and rivers to better handle overbank flows and thus reduce flooding downstream; enhancing economic benefits of healthy river systems such as improved opportunities to hunt, fish, float or view wildlife; and providing state matching funds required for federal CWA grants." A competitive Request for Proposals will be conducted to select projects for the 2020 funding. Responsibility for the program is assigned to NMED, and SWQB staff administer the projects. Additional funding sources for watershed protection and improvement projects are listed in Appendix C of the New Mexico Nonpoint Source Management Plan, available at https://www.env.nm.gov/surface-water-quality/nps-plan.

Information on additional watershed restoration funding resources is available on the SWQB website at- https://www.env.nm.gov/surface-water-quality/watershed-protection-section/.

8.3 Temperature Modeling

Freshwater systems have interrelated biotic and abiotic parameters that drive the temperature of the waterbody. For a stream, these parameters can be generalized into simple categories that include: vegetation and land cover, channel morphology, and hydrology. Parameters such as channel width, meteorological measurements and microclimates, and solar irradiance, can exhibit considerable spatial variability. Together these parameters affect heat transfer and mass transfer processes to varying degrees. Due to the complexity of these systems, temperature modeling techniques are useful to facilitate the computation and prediction of the extent to which different parameters can affect a freshwater system. Temperature models can also identify the sensitivity of water temperature to individual parameters, to inform understanding of actions most likely to succeed in TMDL implementation. BMPs to be considered as part of on-the ground-projects to address temperature include establishment of additional woody riparian vegetation for shade and/or stream channel restoration work, particularly at road crossings.

The SSTEMP Model, Version 2.0.8, developed by the USGS Biological Resource Division (Bartholow, 2002) was used to predict stream temperatures of the impaired AUs based on watershed geometry, hydrology, and meteorology. The model predicts mean, minimum, and maximum daily water temperatures throughout a stream reach by estimating the heat gained or lost from a parcel of water as it passes through a stream segment during a single day (Bartholow, 2002). Each AU was modeled on the date of the maximum recorded water temperature on the thermograph record which was used to assess impairment. The model is calibrated by comparing predicted temperature values with actual thermograph readings measured in the field. SSTEMP is useful to inform TMDL implementation practices for temperature impaired AUs. The model analysis focuses mainly on changes in the riparian shade percentage and/or modification to channel dimensions. Total percent shade was chosen as a first-step analysis for TMDL implementation since it is easily translated into quantifiable management objectives.

SWQB collects physical habitat data using Standard Operating Procedure 5.0 (https://www.env.nm.gov/surface-water-quality/sop/). Sufficient physical habitat data was available to conduct SSTEMP modeling for the AUs Gilita Creek (Middle Fork Gila R to Willow Creek) and San Francisco River (NM 12 at Reserve to Centerfire Creek).

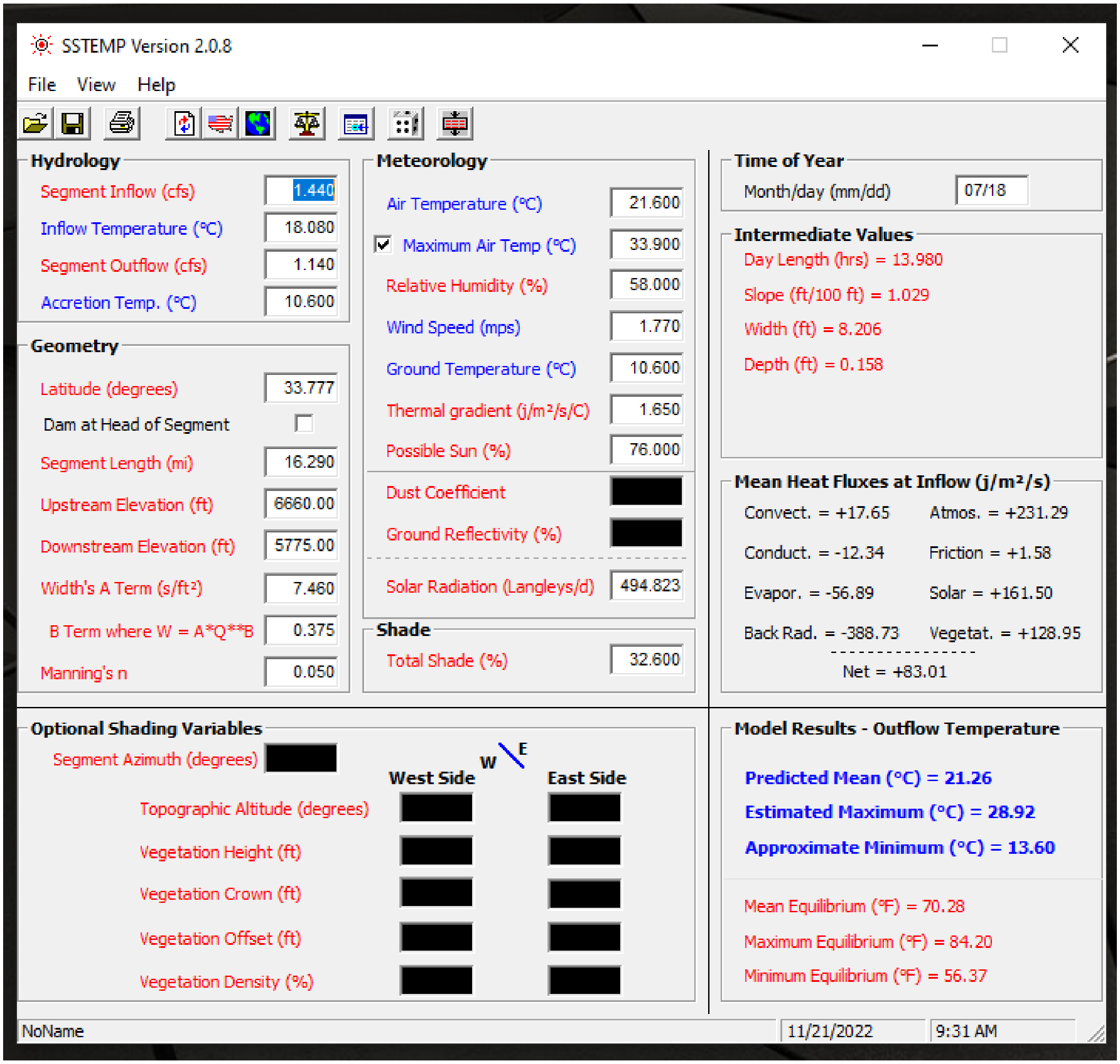

Figure 8.1 Example of SSTEMP output for San Francisco River (NM 12 at Reserve to Centerfire Creek)

A series of assumptions are associated with the SSTEMP model run conditions. Running the model outside of these assumptions may result in inaccuracies or model instability. The assumptions used in the development of SSTEMP that are most relevant to the present TMDLs are listed below. A complete list of assumptions and model deficiencies is presented in the SSTEMP user manual (Bartholow, 2002).

- Water in the system is instantaneously and thoroughly mixed at all times; there is no lateral temperature distribution across channel OR vertical gradients in pools.
- Stream geometry is characterized by mean conditions.
- Solar radiation and other meteorological and hydrological variables are 24-hour means.
- Distribution of lateral inflow is uniformly apportioned throughout the segment length

- Manning's n and travel time do not vary as functions of flow.
- Modeled/representative time periods must be long enough for water to flow the full length of the segment.
- SSTEMP is not able to model cumulative effects; for example, adding or deleting vegetation mathematically is not the same as in real life.

Water temperature can be expressed as heat energy per unit volume. SSTEMP provides an estimate of heat energy expressed in joules per square meter per second ($j/m^2/s$). The program will predict the minimum, mean, and maximum daily water temperature for the set of variables input into the model. The theoretical basis for the model is strongest for the mean daily temperature. The predicted maximum is largely an estimate and likely to vary widely with the maximum daily air temperature. The predicted minimum is computed by subtracting the difference between maximum and mean, from the mean; but the predicted minimum is always above 0 degrees Celsius (Bartholow, 2002).

Sources for the SSTEMP input variables are shown in **Appendix E**. The SSTEMP predicted maximum temperature was calibrated against thermograph data. **Table E.1** show input values for the calibrated model. Percent total shade was then increased until the maximum 24-hour temperature decreased to the applicable temperature criterion. Width's A term (a measure of relative width-to-depth ratio) was then decreased, at the calibrated percent shade, until the criterion was reached. **Table 8.1** details model outputs for the TMDL AUs.

Table 8.1 SSTEMP model results for Gila/San Franciso watershed temperature impaired AUs

Assessment Unit	Estimated % Shade [(a)]	WQS % Shade [(b)]	Shade Increase [(c)]	Width's A	WQS Width's A [(d)]
Gilita Creek (Middle Fork Gila R to Willow Creek)	29.0	65	124%	8.8	2.2
San Francisco River (NM 12 at Reserve to Centerfire Creek)	13.6	52	282%	7.46	NA[e]

[(a)] *Estimates of AU vegetative canopy were generated using the attribute table of the USDA NorWest Stream Temperature Modeled Stream Temperature Scenario map for New Mexico (see Appendix E).*
[(b)] *% shade at which the SSTEMP predicted maximum temperature is held below the applicable WQS, all other variables being held the same.*
[(c)] *% by which SSTEMP predicts that shade must be increased to hold maximum water temperature below the applicable WQS, all other variables being held the same.*
[(d)] *Width's A term at which the SSTEMP predicted maximum temperature is held below the applicable WQS, all other variables being held the same.*
[(e)] *Width's A term cannot be less than 1.0. Setting Width's A at 1.0 did not bring the SSTEMP predicted maximum temperature below the applicable WQS.*

For the San Francisco River AU, the shade value obtained from USDA NorWest Stream Temperature Modeled Stream Temperature Scenario map for New Mexico (https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html) was adjusted upward from 13.6% to 32.6% for model calibration. The adjustment is justified by observing that a short distance above the thermograph location, the river flows through two steep-sided canyons that block sunlight from the south.

A rough calculation is that the effect of vegetative shade over the entire AU is increased by an additional absolute 19% because of the topographic shade near the thermograph location. If this assumption holds true, vegetative shade should increase from 13.6% to 52% in order to achieve the WQS T_{MAX}.

SSTEMP may be used to compute, one at a time, the sensitivity to input values. This analysis varies most active input by 10% in both directions and displays a screen showing the resulting changes to estimated maximum temperature. The “Relative Sensitivity” schematic graph that accompanies the display gives an indication of which variables most strongly influence the results (Bartholow, 2002). Sensitivity analysis outputs are shown in **Figure 8.2**. Meteorological variables will always have the greatest impact on predicted maximum temperature. For the San Francisco River, the sensitivity analysis indicates that maximum water temperature is relatively insensitive to variables other than the meteorological conditions.

Sensitivity Analysis - SSTEMP (2.0.8)

```
Sensitivity for maximum temperature values (10% varaition)     SSTEMP (2.0.8)
Original maximum temperature = 27.09°C
                                  Temperature change (°C)
                                      if variable is:
Variable                            Decreased Increased   Relative Sensitivity
--------------------------------------------------------------------------------
Segment Inflow (cfs)                  +0.03     -0.03 *
Inflow Temperature (°C)               -0.37     +0.38 ****************
Segment Outflow (cfs)                 +0.21     -0.23 *********
Accretion Temp. (°C)                  +0.00     +0.00
Width's A Term (s/ft²)                -0.28     +0.31 *************
  B Term where W = A*Q**B             -0.09     +0.09 ****
Manning's n                           +0.17     -0.18 *******
Air Temperature (°C)                  -0.59     +0.54 ************************
Relative Humidity (%)                 -0.33     +0.33 **************
Wind Speed (mps)                      +0.16     -0.17 *******
Ground Temperature (°C)               -0.04     +0.04 **
Thermal gradient (j/m²/s/C)           +0.06     -0.06 **
Possible Sun (%)                      -0.39     +0.45 ******************
Dust Coefficient                      +0.06     -0.06 ***
Ground Reflectivity (%)               -0.03     +0.03 *
Total Shade (%)                       +0.33     -0.32 *************
 Maximum Air Temp (°C)                -0.74     +0.73 *******************************
```

A

Sensitivity Analysis - SSTEMP (2.0.8)

```
Sensitivity for maximum temperature values (10% varaition)     SSTEMP (2.0.8)
Original maximum temperature = 28.92°C
                                  Temperature change (°C)
                                      if variable is:
Variable                            Decreased Increased   Relative Sensitivity
--------------------------------------------------------------------------------
Segment Inflow (cfs)                  -0.01     +0.01
Inflow Temperature (°C)                0.00     +0.00
Segment Outflow (cfs)                 +0.02     -0.02 *
Accretion Temp. (°C)                  +0.00     +0.00
Width's A Term (s/ft²)                -0.01     +0.02 *
  B Term where W = A*Q**B              0.00     +0.00
Manning's n                           +0.02     -0.02 *
Air Temperature (°C)                  -0.67     +0.62 ********************
Relative Humidity (%)                 -0.50     +0.51 ***************
Wind Speed (mps)                      +0.22     -0.24 *******
Ground Temperature (°C)               -0.05     +0.05 *
Thermal gradient (j/m²/s/C)           +0.08     -0.08 **
Possible Sun (%)                      +0.08     -0.09 ***
Solar Radiation (Langleys/d)          -0.73     +0.76 **********************
Total Shade (%)                       +0.31     -0.31 *********
 Maximum Air Temp (°C)                -1.00     +1.03 ******************************
```

B

Figure 8.2 SSTEMP sensitivity analyses for Gilita Creek (Middle Fork Gila R to Willow Creek) (A) and San Francisco River (NM 12 at Reserve to Centerfire Creek) (B)

For Gilita Creek, the model predicts that a large increase in shade would be needed to result in support of the designated ALU. Other non-meteorological variables, besides shade, to which the maximum temperature is sensitive include inflow temperature and Width's A. A large, and probably unrealistic, decrease in Width's A would be needed to result in support of the designated ALU. This result indicates that implementation of the Willow Creek WBP is likely to decrease water temperature in Gilita Creek. Revegetation, natural or otherwise, of the burn scars in the watershed may also help to achieve the WQS, by shading the ground and hence lowering the temperature of shallow groundwater inputs to the stream.

For the San Francisco River, the first step in implementation should be to determine the influence of Hudson spring and the large ponds along the unnamed drainage a short distance upstream of the thermograph location. A thermograph record from a point upstream of this confluence would help to fill this data gap. The SSTEMP model predicts that a large increase in shade would be needed to result in support of the designated ALU. Morphological changes which decrease channel width would not be expected to result in attainment of the WQS T_{MAX} criterion. The maximum temperature is not sensitive to other non-meteorological variables.

The SSTEMP model does not consider any impacts of climate change. SWQB encourages implementation practitioners to design projects to decrease water temperatures beyond simply meeting the applicable WQS, such that currently impaired AUs will be likely to meet WQS standards well into the future with some resiliency to climate change. Another example of designing for resiliency would be the creation of habitat refugia wherein water temperatures would be expected to remain cooler than the average for that water body.

9.0 APPLICABLE REGULATIONS AND REASONABLE ASSURANCES

New Mexico's Water Quality Act, NMSA 1978 §§ 74-6-1 to -17 (Act), authorizes the WQCC to "promulgate and publish regulation to prevent or abate water pollution in the state" and to require permits. The Act authorizes a constituent agency, such as NMED, to take enforcement action against any person who violates a water quality standard. Several statutory provisions on nuisance law could also be applied to NPS water pollution. The Act also states in Section 74-6-12(a):

> *The Water Quality Act does not grant to the commission or to any other entity the power to take away or modify the property rights in water, nor is it the intention of the Water Quality Act to take away or modify such rights.*

In addition, the State of New Mexico Standards for Interstate and Intrastate Surface Waters at 20.6.4.6(C) NMAC state:

> *Pursuant to Subsection A of Section 74-6-12 NMSA 1978, this part does not grant to the water quality control commission or to any other entity the power to take away or modify property rights in water.*

New Mexico policies are in accordance with the federal CWA Section 101(g):

> *It is the policy of Congress that the authority of each State to allocate quantities of water within its jurisdiction shall not be superseded, abrogated or otherwise impaired by this Act. It is the further policy of Congress that nothing in this Act shall be construed to supersede or abrogate rights to quantities of water which have been established by any State. Federal agencies shall co-operate with State and local agencies to develop comprehensive solutions to prevent, reduce and eliminate pollution in concert with programs for managing water resources.*

New Mexico's CWA Section 319 Program has been developed in a coordinated manner with the State's CWA Section 303(d) process. All watersheds that are targeted in the annual §319 request for proposal process coincide with the State's biennial impaired waters list as approved by USEPA. The State has given a high priority for funding, assessment, and restoration activities to these watersheds.

As a constituent agency, NMED has the authority under NMSA 1978, Section 74-6-10 to issue a compliance order or commence civil action in district court for appropriate relief if NMED determines that actions of a "person" (as defined in the Act) have resulted in a violation of a water quality standard including a violation caused by a NPS. The NMED NPS water quality management program has historically strived for and will continue to promote voluntary compliance to NPS water pollution concerns by utilizing a voluntary, cooperative approach. The State provides technical support and grant monies for implementation of BMPs and other NPS prevention mechanisms through Section 319 of the CWA. Since portions of this TMDL will be implemented through NPS control mechanisms, the New Mexico Watershed Protection Program will target efforts to this and other watersheds with TMDLs.

In order to obtain reasonable assurances for implementation in watersheds with multiple landowners, including federal, state, and private land, NMED has established Memoranda of Understanding (MOUs) with various federal agencies, in particular the U.S. Forest Service and the BLM. MOUs have also been developed with other state agencies, such as the New Mexico Department of Transportation. These MOUs provide for coordination and consistency in dealing with NPS issues.

The time required to attain standards for all reaches is estimated to be approximately 10-20 years. This estimate is based on a five-year time frame implementing several watershed projects that may not be starting immediately or may be in response to earlier projects. Stakeholders in this process will include SWQB, and other parties identified in the WBP. The cooperation of watershed stakeholders will be pivotal in the implementation of these TMDLs as well.

10.0 PUBLIC PARTICIPATION

Public participation will be solicited in development of this TMDL, pursuant to CWA §303(d) and Section XIV of the New Mexico Statewide Water Quality Management Plan and Continuing Planning Process. The draft TMDL will be made available for a 30-day comment period beginning August 8, 2023 and ending on September 8, 2023. The draft document Notice of Availability will be advertised via email distribution lists and webpage postings. A public meeting will be held using virtual meeting technology. A response to public comments will be added to the TMDL document as **Appendix F**.

Once the TMDL is approved by the EPA, the next step for public participation will be development of WBPs and watershed protection projects, including those that may be funded by CWA Section 319(h) grants managed by SWQB.

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APPENDIX A

THREATENED AND ENDANGERED SPECIES KNOWN TO OCCUR IN THE PROJECT AREAS

Federal or State Threatened/Endangered Species

Catron, Grant

Taxonomic Group	# Species	Taxonomic Group	# Species
Amphibians	2	Birds	26
Fish	7	Lepidoptera; moths and butterflies	1
Mammals	5	Molluscs	2
Reptiles	3		

TOTAL SPECIES: 46

Common Name	Scientific Name	NMGF	US FWS	Critical Habitat	SGCN	Photo
Lesser Long-nosed Bat	Leptonycteris yerbabuenae	T			Y	View
Spotted Bat	Euderma maculatum	T			Y	View
Mexican Gray Wolf	Canis lupus baileyi	E	E		Y	View
Arizona Montane Vole	Microtus montanus arizonensis	E			Y	No Photo
Meadow Jumping Mouse	Zapus luteus luteus	E	E	Y	Y	View
Common Ground Dove	Columbina passerina	E			Y	View
Yellow-billed Cuckoo (western pop)	Coccyzus americanus occidentalis		T	Y	Y	View
Buff-collared Nightjar	Antrostomus ridgwayi	E				No Photo
Lucifer Hummingbird	Calothorax lucifer	T			Y	View
Costa's Hummingbird	Calypte costae	T			Y	View
Broad-billed Hummingbird	Cynanthus latirostris	T			Y	View
White-eared Hummingbird	Basilinna leucotis	T				View
Least Tern	Sternula antillarum	E			Y	View
Neotropic Cormorant	Phalacrocorax brasilianus	T			Y	View
Brown Pelican	Pelecanus occidentalis	E				View
Bald Eagle	Haliaeetus leucocephalus	T			Y	View
Common Black Hawk	Buteogallus anthracinus	T			Y	View
Mexican Spotted Owl	Strix occidentalis lucida		T	Y	Y	View
Elegant Trogon	Trogon elegans	E			Y	View
Gila Woodpecker	Melanerpes uropygialis	T			Y	View
Aplomado Falcon	Falco femoralis	E	E		Y	View
Peregrine Falcon	Falco peregrinus	T			Y	View
Northern Beardless-Tyrannulet	Camptostoma imberbe	E			Y	View

Federal or State Threatened/Endangered Species

Catron, Grant

Common Name	Scientific Name	NMGF	US FWS	Critical Habitat	SGCN	Photo
Thick-billed Kingbird	Tyrannus crassirostris	E			Y	View
Southwestern Willow Flycatcher	Empidonax traillii extimus	E	E	Y	Y	View
Bell's Vireo	Vireo bellii	T			Y	View
Gray Vireo	Vireo vicinior	T			Y	View
Yellow-eyed Junco	Junco phaeonotus	T			Y	View
Baird's Sparrow	Centronyx bairdii	T			Y	View
Abert's Towhee	Melozone aberti	T			Y	View
Varied Bunting	Passerina versicolor	T			Y	View
Reticulate Gila Monster	Heloderma suspectum suspectum	E			Y	View
Mexican Gartersnake	Thamnophis eques	E	T	Y	Y	View
Narrow-headed Gartersnake	Thamnophis rufipunctatus	E	T	Y	Y	View
Chiricahua Leopard Frog	Lithobates chiricahuensis		T	Y	Y	View
Lowland Leopard Frog	Lithobates yavapaiensis	E			Y	View
Gila Chub	Gila intermedia	E	E	Y	Y	View
Chihuahua Chub	Gila nigrescens	E	T		Y	View
Roundtail Chub (lower Colorado River populations)	Gila robusta	E			Y	View
Spikedace	Meda fulgida	E	E	Y	Y	View
Loach Minnow	Rhinichthys cobitis	E	E	Y	Y	View
Gila Trout	Oncorhynchus gilae	T	T		Y	View
Gila Topminnow	Poeciliopsis occidentalis occidentalis	T	E		Y	View
Gila Springsnail	Pyrgulopsis gilae	T			Y	No Photo
New Mexico Hot Springsnail	Pyrgulopsis thermalis	T			Y	No Photo
Monarch Butterfly	Danaus plexippus		C			View

Biota Information System of New Mexico — NATURAL HERITAGE NEW MEXICO

Federal or State Threatened/Endangered Species
Sierra

Taxonomic Group	# Species	Taxonomic Group	# Species
Amphibians	1	Birds	20
Fish	3	Lepidoptera; moths and butterflies	1
Mammals	2	Molluscs	1
Reptiles	1		

TOTAL SPECIES: 29

Common Name	Scientific Name	NMGF	US FWS	Critical Habitat	SGCN	Photo
Mexican Gray Wolf	Canis lupus baileyi	E	E		Y	View
Penasco Least Chipmunk	Neotamias minimus atristriatus	E	P		Y	View
Common Ground Dove	Columbina passerina	E			Y	View
Yellow-billed Cuckoo (western pop)	Coccyzus americanus occidentalis		T	Y	Y	View
Lucifer Hummingbird	Calothorax lucifer	T			Y	View
Costa's Hummingbird	Calypte costae	T			Y	View
Broad-billed Hummingbird	Cynanthus latirostris	T			Y	View
Least Tern	Sternula antillarum	E			Y	View
Neotropic Cormorant	Phalacrocorax brasilianus	T			Y	View
Brown Pelican	Pelecanus occidentalis	E				View
Bald Eagle	Haliaeetus leucocephalus	T			Y	View
Common Black Hawk	Buteogallus anthracinus	T			Y	View
Mexican Spotted Owl	Strix occidentalis lucida		T	Y	Y	View
Elegant Trogon	Trogon elegans	E			Y	View
Aplomado Falcon	Falco femoralis	E	E		Y	View
Peregrine Falcon	Falco peregrinus	T			Y	View
Thick-billed Kingbird	Tyrannus crassirostris	E			Y	View
Southwestern Willow Flycatcher	Empidonax traillii extimus	E	E	Y	Y	View
Bell's Vireo	Vireo bellii	T			Y	View
Gray Vireo	Vireo vicinior	T			Y	View
Baird's Sparrow	Centronyx bairdii	T			Y	View
Varied Bunting	Passerina versicolor	T			Y	View
Mottled Rock Rattlesnake	Crotalus lepidus lepidus	T			Y	View

Federal or State Threatened/Endangered Species
Sierra

Common Name	Scientific Name	NMGF	US FWS	Critical Habitat	SGCN	Photo
Chiricahua Leopard Frog	Lithobates chiricahuensis		T	Y	Y	View
Roundtail Chub (lower Colorado River populations)	Gila robusta	E			Y	View
Gila Trout	Oncorhynchus gilae	T	T		Y	View
White Sands Pupfish	Cyprinodon tularosa	T			Y	View
Mineral Creek Mountainsnail	Oreohelix pilsbryi	T			Y	No Photo
Monarch Butterfly	Danaus plexippus		C			View

Federal or State Threatened/Endangered Species

Dona Ana

Taxonomic Group	# Species	Taxonomic Group	# Species
Birds	19	Lepidoptera; moths and butterflies	1
Mammals	4	Molluscs	1
Reptiles	2		

TOTAL SPECIES: 27

Common Name	Scientific Name	NMGF	US FWS	Critical Habitat	SGCN	Photo
Western Yellow Bat	Dasypterus xanthinus	T			Y	View
Spotted Bat	Euderma maculatum	T			Y	View
Penasco Least Chipmunk	Neotamias minimus atristriatus	E	P		Y	View
Organ Mountains Colorado Chipmunk	Neotamias quadrivittatus australis	T			Y	View
Common Ground Dove	Columbina passerina	E			Y	View
Yellow-billed Cuckoo (western pop)	Coccyzus americanus occidentalis		T	Y	Y	View
Buff-collared Nightjar	Antrostomus ridgwayi	E				No Photo
Costa's Hummingbird	Calypte costae	T			Y	View
Broad-billed Hummingbird	Cynanthus latirostris	T			Y	View
Violet-crowned Hummingbird	Leucolia violiceps	T			Y	View
Least Tern	Sternula antillarum	E			Y	View
Neotropic Cormorant	Phalacrocorax brasilianus	T			Y	View
Brown Pelican	Pelecanus occidentalis	E				View
Bald Eagle	Haliaeetus leucocephalus	T			Y	View
Common Black Hawk	Buteogallus anthracinus	T			Y	View
Mexican Spotted Owl	Strix occidentalis lucida		T	Y	Y	View
Aplomado Falcon	Falco femoralis	E	E		Y	View
Peregrine Falcon	Falco peregrinus	T			Y	View
Southwestern Willow Flycatcher	Empidonax traillii extimus	E	E	Y	Y	View
Bell's Vireo	Vireo bellii	T			Y	View
Gray Vireo	Vireo vicinior	T			Y	View
Baird's Sparrow	Centronyx bairdii	T			Y	View
Varied Bunting	Passerina versicolor	T			Y	View
Reticulate Gila Monster	Heloderma suspectum suspectum	E			Y	No Photo

Federal or State Threatened/Endangered Species
Dona Ana

Common Name	Scientific Name	NMGF	US FWS	Critical Habitat	SGCN	Photo
Mottled Rock Rattlesnake	Crotalus lepidus lepidus	T			Y	View
Dona Ana Talussnail	Sonorella todseni	T			Y	No Photo
Monarch Butterfly	Danaus plexippus		C			View

T and E Plant Species	FWS status	NM status	County Occurrence			
			Sierra	Dona Ana	Catron	Grant
Allium gooddingii		E			x	
Cypripedium parviflorum var. pubescens		E			x	x
Erigeron hessii		E			x	
Erigeron rhizomatus	T	E			x	
Escobaria duncanii		E	x			
Escobaria organensis		E		x		
Escobaria sneedii var. sneedii	E	E		x		
Escobaria villardii		E		x		
Hedeoma todsenii	E	E	x			
Hexalectris arizonica		E	x			
Opuntia arenaria		E		x		
Peniocereus greggii		E				x
Penstemon metcalfei		E	x			
Peritoma multicaulis		E				x
Polygala rimulicola var. mescalerorum		E		x		
Puccinellia parishii		E			x	x

T-Threatened; E-Endangered

APPENDIX B

WATER QUALITY DATA

Exceedances of the applicable thresholds are shown in bold red font.

Boron data

Rio Grande (International Mexico bnd to TX border), formerly known as Rio Grande (International Mexico bnd to Anthony Bridge)

Monitoring stations: Rio Grande abv Sunland Park WWTF outfall - 42RGrand004.7
Rio Grande blw Sunland Park WWTP outfall - 42RGrand004.3
Rio Grande at Corchesne Bridge - 42RGrand002.7

All units in mg/L.

WQS: 0.75 mg/L

Date	Above Sunland Park WWTF Outfall	Below Sunland Park WWTF Outfall	Corchesne Bridge	Flow (cfs)
12/15/10	NS	NS	0.71	25
4/27/11	NS	NS	0.19	565
6/16/11	NS	NS	0.20	604
8/18/11	NS	NS	0.21	597
11/9/11	NS	NS	**0.90**	8
12/8/11	NS	NS	0.26	9
2/22/12	NS	NS	**0.92**	32
4/10/12	NS	NS	0.21	766
3/13/19	NS	0.34	**0.95**	15
6/19/19	0.16	0.16	0.16	298
7/31/19	0.11	0.11	0.11	560
9/11/19	0.10	0.10	0.10	667

NS – not sampled

Monitoring station: Montoya Drain at Racetrack Dr. - 42Montoy000.7 (upstream of EPEC outfalls)

For comparison purposes only, the assessment protocol does not apply.

Location	Date	Dissolved Boron (mg/L)
Montoya Drain	3/13/19	0.91
Montoya Drain	6/19/19	0.84
Montoya Drain	7/31/19	0.41
Montoya Drain	9/11/19	0.57

Monitoring station: El Paso Electric Co. Outfall No. 2 - NM0000108-2

For comparison purposes only, the assessment protocol does not apply.

Location	Date	Dissolved Boron (mg/L)
NM0000108-2	6/16/11	1.74
NM0000108-2	12/8/11	1.53

E. coli data

Mangas Creek (Gila River to Mangas Springs)
Monitoring station: Mangas Creek above Gila River (Forest Road 809) - 78Mangas000.7

WQS Acute standard: 410 mpn/100 ml

Date	E. coli (mpn/100ml)	Flow (cfs)
4/10/19	11.87	1.5
6/6/19	**2419.57**	0.52
8/1/19	**770.1**	0.3
9/24/19	**> 2419.6**	1.15

San Francisco River (Box Canyon to Whitewater Creek)
Monitoring station: San Francisco R @ USGS gauge nr Glenwood - 80SanFra028.6

WQS Acute standard: 410 mpn/100 ml

Date	E. coli (mpn/100ml)	Flow (cfs)
4/10/19	193.49	139
6/5/19	**> 2419.6**	60.9
8/20/19	**686.67**	17.5
9/24/19	76.65	17.2
9/30/20	242.44	15.2

Plant nutrients data

Mule Creek (San Francisco R to Mule Springs)
Monitoring station: Mule Cr blw NM 78 - 80MuleCr014.5

Applicable thresholds: TN (Moderate) 0.42 mg/L, TP (Flat-Moderate) 0.061 mg/L, delta DO 4.08 mg/L

Date	TN (mg/L)	TP (mg/L)	Flow (cfs)
4/10/19	1.190	0.108	0.2
6/6/19	0.284	0.083	0.33
8/14/19	0.269	0.149	0.3
9/24/19	0.379	0.146	0.2
Max Delta DO = 4.77 mg/L, deployed 5/30/19 to 9/24/19			

Median TN = 0.324 Median TP = **0.127**

Sedimentation/Siltation data

San Francisco River (Centerfire Creek to AZ border)
Monitoring station: San Francisco River above Luna - 80SanFra154.1
San Francisco R blw Luna - 80SanFra144.9

Applicable TSS indicator threshold: 8.75 mg/L

Date	TSS (mg/L)	Turbidity (NTU)	Flow (cfs)
6/5/19*	< 1	1.1	0.51
8/20/19	5	2.2	1
9/25/19	14	5.8	1.22
9/10/20	5	0	0.64
10/1/20	< 1	0	0.68

** this sample was taken at San Francisco River above Luna - 80SanFra154.1; all other samples were taken at San Francisco R blw Luna - 80SanFra144.9*

Temperature data

Exceedances of the applicable criteria are shown in bold red font.

AU Name – Thermograph Location	Designated ALU	Chronic Criterion (°C)	Measured Chronic (°C)	T_{MAX} Criterion (°C)	Date of Measured T_{MAX}	Measured T_{MAX} (°C)
Gilita Creek (Middle Fork Gila R to Willow Creek) - 77Gilita000.1 Gilita abv M Fk Gila	High Quality Coldwater	(4T3) 20	**23.2** **24.1**	23	7/28/19 7/8/20	**26.8** **27.1**
Las Animas Ck (perennial prt R Grande to Animas Gulch) - 41LAnima009.0 Las Animas Cr @ Animas Rd	Marginal Coldwater/Warmwater	(6T3) 25	**26.0**	29	6/20/19**	**31.1**
Mangas Creek (Gila River to Mangas Springs) - 78Mangas000.7 Mangas Cr abv Gila R	Marginal Coldwater/Warmwater	None	NA	28*	6/23/19** 8/5/19	**33.9** **37.2**
Mimbres R (Perennial reaches Cooney Cyn to headwaters) - 45Mimbre127.8 Mimbres R @ Cooney Campground Crossing 150A	High Quality Coldwater	(4T3) 20	20.0	23	7/1/20**	**24.1**
San Francisco River (NM 12 at Reserve to Centerfire Creek) - 80SanFra117.9 SFR @ Cienega Cyn	Marginal Coldwater/Marginal Warmwater	None	NA	25*	7/18/19**	**28.92**
Whitewater Creek (Whitewater Campgrd to headwaters) - 80Whitew008.8 Whitewater Cr abv CG	High Quality Coldwater	(4T3) 20	**20.6**	25	7/28/19	22.5
Willow Creek (Gilita Creek to headwaters) - 77Willow000.1 Willow Cr abv Gilita	High Quality Coldwater	(4T3) 20	**21.0** **21.5**	23	7/28/19 7/9/20	**25.2** **25.9**

** segment-specific criterion; ** partial data set*

APPENDIX C
SOURCE DOCUMENTATION

The approach for identifying probable sources of impairment is documented in SWQB Standard Operating Procedure (SOP) 4.1, Probable Source(s) Determination (https://www.env.nm.gov/surface-water-quality/sop/). "Sources" are defined as activities that may contribute pollutants or stressors to a water body (USEPA, 1997). The list of "Probable Sources of Impairment" in the Integrated 303(d)/305(b) List, Total Maximum Daily Load documents (TMDLs), and Watershed-Based Plans (WBPs) is intended to include any and all activities that could be contributing to the identified cause of impairment, which are supported by evidence strong enough to establish presumption but not proof. Probable Source categories are selected from Appendix A of SOP 4.1, which was adapted from the EPA ATTAINS database.

USEPA, through guidance documents, strongly encourages states to include a list of Probable Sources for each listed impairment. According to the 1998 Section 305(b) report guidance, *"…, states must always provide aggregate source category totals…"* in the biennial submittal that fulfills CWA section 305(b)(1)(C) through (E) (USEPA, 1997). The list of "Probable Sources" is not intended to single out any particular landowner or single land management activity and has therefore been labeled "Probable" and generally includes several sources for each known impairment.

Any new impairment listing will be assigned a Probable Source of "Source Unknown." During sampling events, Monitoring Team staff select applicable Probable Sources from a drop-down menu on the Stream/River Field Data Form. Information gathered by the Monitoring Team is used to generate a draft Probable Source list in consequent TMDL planning documents. The TMDL writer then revises the list using aerial imagery, Geographic Information System data, and other available records. The list is also reviewed by Watershed Protection Section staff with knowledge of the AU and watershed. These draft Probable Source lists will be finalized with watershed group/stakeholder input during the pre-survey public meeting, TMDL public meeting, WBP development, and various public comment periods. The Probable Source list in the approved TMDL will be used to update the subsequent Integrated List.

Data on Probable Sources gathered by Monitoring and Assessment Section staff and Watershed Protection Section staff during water quality surveys and watershed restoration projects is housed in the NMED Surface Water Quality Information Database (SQUID). More specific information on Probable Sources of Impairment is provided in individual watershed planning documents (e.g., TMDLs, WBPs, etc.) as they are prepared to address individual impairments by AU.

Literature Cited:

USEPA. 1997. Guidelines for preparation of the comprehensive state water quality assessments (305(b) reports) and electronic uptakes. EPA-841-B-97-002A. Washington, D.C.

APPENDIX D

CALCULATION OF TEMPERATURE TMDL

Calculation of Temperature TMDL

Problem Statement: Convert Temperature Criteria into a Daily Load

Background

The temperature of water is essential for proper metabolic regulation in the aquatic community. Water at a given temperature has a thermal mass that can be represented in units of energy (thermal energy). There are a variety of sources of temperature loading to a waterbody, including air temperature, solar radiation and point source discharge (if present). In addition, how the temperature loading to a stream is translated to the thermal mass of the stream is dependent on its hydrologic characteristics and condition of riparian area (i.e., shading).

The calculation of a TMDL target is governed by the basic equation,

Eq1. *WQS criterion * flow * conversion factor = TMDL target capacity*

For Temperature TMDLs, the WQS criterion is a temperature specified either by the designated Aquatic Life Use (ALU) or site-specific criteria and can be either a maximum temperature or time-duration temperature such as the 4T3 or 6T3.

Flow will generally use the 4Q3 low-flow for the critical flow unless another flow statistic or multiple flow conditions are more appropriate for the situation.

The conversion factor is a variable needed to 1) convert units used by SWQB for flow (in cfs) to cubic meters (m^3) and 2) convert change in water temperature (C) to a volumetric heat capacity (kJ/(m^3*C).

Calculation of Thermal Energy

The thermal loading capacity of a volume is governed by the following equation,

Eq2. *thermal energy = specific heat capacity * mass * change in temperature*

Specific heat capacity is the amount of energy needed to raise the temperature of one kilogram of a substance by 1 degree Celsius.

Mass can be replaced by volume via density.

Accepted Scientific Units for the variables above are:

thermal energy = kilojoule (kJ) (calories are less common and considered archaic)

specific heat capacity = kJ/(kg*C)

mass = kilograms (kg)

change in temperature = Celsius (C)

The specific heat capacity of water at 25^{o}C = 4.182 kJ/(kg*C). This is the isobaric (under constant pressure) value for heat capacity at an absolute atmospheric pressure of 585 mmHg. Note: varying water temperature and absolute pressure to minimum and maximum ambient values has negligible effect on the resulting heat capacity.

Calculation of Conversion Factor

Flow (cfs) to (m^3/day)

Eq3. 1 cf/s * 86,400 s/day * 0.0283 m^3/cf = 2445.12 m^3/day

Heat Capacity to Volumetric Heat Capacity

Eq4. 4.182 kJ/(kg*C) * 1000 kg/m^3 = 4,182 kJ/(m^3*C)

Note: water density varies with temperature but only by a fraction of a percent.

Conversion Factor = 2445.12 m^3/day * 4,182 kJ/(m^3*C) = 1.023E+07 kJ/(day*C)

Form of TMDL Equation

Eq5. Δ [**^{o}C**] x [**cfs]** x 1.023E+07 = TMDL (kJ/day)

Input variables in **bold**, Δ**^{o}C** = (WQC - 0**^{o}C)** and **cfs** = critical flow

The resulting value is the increase in kJ/day above 0^{o} Celsius.

APPENDIX E
SSTEMP INPUT DATA

E 1.0 INTRODUCTION

This appendix provides site-specific hydrology, geometry, and meteorological data for input into the Stream Segment Temperature (SSTEMP) Model (Bartholow, 2002). Hydrology variables include segment inflow, inflow temperature, segment outflow, and accretion temperature. Geometry variables are latitude, segment length, upstream and downstream elevation, Width's A-term, Width's B-term, and Manning's n. Meteorological inputs to SSTEMP Model include maximum air temperature, air temperature, relative humidity, windspeed, ground temperature, thermal gradient, possible sun, dust coefficient, ground reflectivity, and solar radiation. In the following sections, data sources for these parameters are discussed in detail for each Assessment Unit (AU) to be modeled using SSTEMP Model. Input values of the calibrated models are shown on **Table E.1**, following the discussion of data sources. Each AU was modeled on the date of the maximum recorded water temperature on the thermograph record which was used to assess impairment.

E 2.0 HYDROLOGY

E 2.1 Segment Inflow and Outflow

This parameter is the streamflow at the top and bottom of the stream segment. To be conservative, the lowest four-consecutive-day discharge that has a recurrence interval of three years, but that does not necessarily occur every three years (4Q3), was used instead of the mean daily flow. These critical low flows were used to reflect the decreased assimilative capacity of the stream to absorb and disperse solar energy.

The 4Q3 inflow and outflow were determined for the Gilita Creek AU using the Waltemeyer regression equation. The 4Q3 inflow was determined for the San Francisco River AU using the Waltemeyer regression equation. The 4Q3 outflow was determined for the San Francisco River AU using the DFLOW software program applied to flow data from USGS Gage 09442680 - San Francisco River Near Reserve, NM, from 1990 through 2017.

E 2.2 Inflow Temperature

This parameter represents the mean water temperature at the top of the segment on the modeled date.

To obtain inflow temperature for the Gilita Creek (Middle Fork Gila to Willow Creek), thermograph mean temperatures on the modeled date were obtained from Gilita Creek (Willow Creek to hdwtrs) and Willow Creek (Gilita Creek to hdwtrs), and averaged together based on relative 4Q3 flow from each contributing stream.

The San Francisco River AU begins at the confluence with Centerfire Creek. Thermograph data from the next upstream monitoring station were disqualified by SWQB quality control procedures, so an alternative method was used to estimate inflow temperature. Mean air temperature for the modeled date was queried from the PRISM database (http://www.prism.oregonstate.edu/), and an assumption was made that the ratio between air temperature and water temperature is the same at the top and bottom of the reach.

E 2.3 Accretion Temperature

The temperature of the lateral inflow, barring tributaries, generally should be the same as groundwater temperature. In turn, groundwater temperature may be approximated by the mean annual air temperature. Mean annual air temperatures for 2019 and 2020, obtained from the PRISM database (http://www.prism.oregonstate.edu/), were used in the absence of measured data. PRISM was queried using a 4 km grid cell covering a central portion of each AU, with the interpolation function switched on in cases where the AU spanned a number of grid cells.

E 3.0 GEOMETRY

E 3.1 Latitude

Latitude refers to the position of the stream segment on the earth's surface. Latitude was obtained from the SWQB Mapper, a GIS application, by taking the mean average between the highest and lowest values for the stream corridor for each AU.

E 3.2 Dam at Head of Segment

Neither of the TMDL AUs has a dam at the upstream end of the segment.

E 3.3 Segment Length

Segment length was obtained from the SWQB Surface Water Quality Database.

E 3.4 Upstream and Downstream Elevation

Elevations were obtained from Google Earth.

E 3.5 Width's A and Width's B Term

Field measurements of particle size distribution, water surface slope, and bankfull cross-section were collected following the SWQB Standard Operating Procedure for Physical Habitat Measurements (https://www.env.nm.gov/surface-water-quality/sop/). These field data were entered into the Windows-Based Stream Channel Cross-Section Analysis (WinXSPro 3.0) Program (USDA, 2005), to generate values for width, discharge, and Manning's n coefficient at various stages up to bankfull. Width's B Term was calculated as the slope of the regression of the natural log of width and the natural log of flow. Theoretically, the Width's A Term is the untransformed Y-intercept. However, because the width versus discharge relationship tends to break down at very low flows, Width's A Term was estimated by solving for the following equation:

$$W = A \times Q^B$$

Where,

W =Known width (feet)
A =Width's A Term (seconds per square foot)
Q =Known discharge (cfs)
B =Width's B Term (unitless)

It should be noted that the physical habitat monitoring on Gilita Creek was conducted as part of a probabilistic water quality survey. As such, the exact monitoring locations were chosen at random, rather than having been selected as representative of the AU, and therefore may not meet all of the SOP requirements for site selection. There were two probabilistic monitoring sites in Gilita Creek (Middle Fork Gila to Willow Creek) during the 2019 survey. Data from site NM19-10465 was used as input to WinXSPro, rather than site NM19-10331, because that site was considered more representative of the AU (personal communication, John Money, SWQB). Also note that the monitored flow (1.2 cfs) was significantly lower than the estimated 4Q3 being modeled.

E 3.6 Manning's n or Travel Time

Site- and stage-specific geometry was modeled by the WinXSPro program described above. WinXSPro uses Thorne and Zevenbergen's equation as the default Manning's n estimator. Manning's n is a measure of channel roughness which varies with depth of flow, increasing in value at shallower stages. The Manning's n coefficient associated with the flow being modelled was selected.

In the case of Gilita Creek (Middle Fork Gila to Willow Creek), the initial WinXSPro model was not consistent with data observed in the field. Therefore, the "User Supplied Manning's n" option was used. That procedure requires the user to put in at least two values for the program to interpolate. Manning's n was calculated at low flow using the observed variables from the monitoring event, and was estimated using Jarrett's equation for a higher stage. The variables that go into Jarrett's equation are slope and hydraulic radius. This adjustment to the roughness coefficient was likely necessary because the stream was flowing well below the 4Q3 discharge at the time of the monitoring event.

E 4.0 METEOROLOGICAL PARAMETERS

E 4.1 Air Temperature

In the absence of measured air temperature at the thermograph stations, 24 hour mean temperature on the modelled date was obtained from the nearest available weather station posted on the New Mexico Climate Center website (https://wrcc.dri.edu/wraws/nmF.html). Air temperature for the San Francisco River AU was the temperature at the Remote Automatic Weather Station (RAWS) at Reserve New Mexico. Air temperature for the Gilita Creek AU was the average between the RAWS stations Beaverhead New Mexico and Mogollon New Mexico. The Beaverhead and Mogollon RAWS stations are equidistant from Gilita Creek, in opposite directions. The Beaverhead station is at a similar elevation to the bottom of the modeled AU and the Mogollon station is at a similar elevation to the top of the AU.

E 4.2 Maximum Air Temperature

The maximum daily air temperature in SSTEMP overrides a calculated value only if the check box is checked. Since the WQS standard of concern is the T_{MAX}, which is particularly sensitive to the maximum air temperature (Bartholow, 2002), an empirical value was entered in this field. In the absence of measured air temperature at the thermograph stations, maximum temperature on the modelled date was obtained from the same weather stations used for mean daily air temperature, above.

E 4.3 Relative Humidity

Mean relative humidity on the modelled date was obtained from the same weather stations used for mean and maximum daily air temperature, above.

E 4.4 Wind Speed

Mean wind speed on the modelled date was obtained from the same weather stations used for mean and maximum daily air temperature, above.

For the Gilita Creek AU, wind speed was adjusted downward from 2.55 to 2.00 mps in order to help calibrate the model. This adjustment is justified because wind speed is likely to be lower at the water surface than it is at an exposed weather station.

E 4.5 Ground Temperature

Same as Accretion Temperature, above.

E 4.6 Thermal Gradient

The software default value is 1.65 joules/meter^2/second/°C.

E 4.7 Possible Sun

This variable is an indirect and inverse measure of cloud cover. Percent possible sun was obtained from the Western Regional Climate Center (https://www.ncei.noaa.gov/pub/data/ccd-data/pctpos20.dat). The nearest location with monthly possible sun data is Albuquerque. Bartholow (2002) recommends using possible sun as a calibration parameter.

For the Gilita Creek AU, possible sun was adjusted from 76% to 88% to help calibrate the model.

E 4.8 Dust Coefficient

For the Gilita Creek AU, this variable was adjusted from the default value of 5 to 13, to help calibrate the model. Thirteen is the upper end of the range suggested by Bartholow (2002). This adjustment is justified because lingering effects from a series of wildfires, most recently in 2017 and 2018, make it likely that there would be more than expected dust in the air on a day with some wind.

The software default value of 5 was used for the San Francisco River AU.

E 4.9 Ground Reflectivity

The software default value of 25% was used.

E 4.10 Solar Radiation

SSTEMP calculates solar radiation internally when a dust coefficient is entered, as it was for the Gilita Creek AU. Weather station values may not represent the on-site solar radiation since the stations are remote from the AU.

For the San Francisco River AU, solar radiation values were obtained from the same weather station used for mean and maximum daily air temperature, above, then multiplied by 0.9, as instructed in the SSTEMP manual.

E 5.0 SHADE

Estimates of vegetative canopy were generated using the attribute table of the USDA NorWest Stream Temperature Modeled Stream Temperature Scenario map for New Mexico (https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html).

For the San Francisco River AU, the shade value obtained from NorWest was adjusted upward from 13.6% to 32.6% for model calibration. The adjustment is justified by observing that a short distance above the thermograph location, the river flows through two steep-sided canyons that block sunlight from the south.

Table E.1 SSTEMP input data values by Assessment Unit (calibrated model)

VARIABLE	Gilita Creek (Middle Fork Gila R to Willow Creek)	San Francisco River (NM 12 at Reserve to Centerfire Creek)
Segment Inflow (cfs)	7.3	1.44
Inflow Temperature (C)	17.87	18.08
Segment Outflow (cfs)	6.47	1.4
Accretion Temp (C)	10.5	10.6
Latitude (deg)	33.413	33.777
Dam?	No	No
Segment Length (mi)	6.35	16.29
Upstream Elevation (ft)	7869	6660
Downstream Elevation (ft)	7283	5775
With's A Term (s/sqft)	8.8	7.46
B Term	0.1566	0.3745
Manning's n	0.2	0.05
Air Temperature (C)	24.2	21.6
Max Air Temp (C)	32.5	33.9
Relative Humidity	39	58
Wind Speed (mps)	2.00*	1.77
Ground Temp (C)	10.5	10.6
Thermal Gradient (j/sqm/s/C)	1.65	1.65
Possible Sun %	88*	76

VARIABLE	Gilita Creek (Middle Fork Gila R to Willow Creek)	San Francisco River (NM 12 at Reserve to Centerfire Creek)
Dust Coefficient	13*	5
Ground Reflectivity (%)	25	25
Solar Radiation (Langleys/day)	NA	494.82
Total Shade (%)	29.0	32.6*
Time of year	7/8/2020	7/18/2019

** variable was adjusted to calibrate the model*

D 6.0 REFERENCES

Bartholow, J.M. 2002. SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0). U.S. Geological Survey computer model and documentation. Available on the internet at https://www.sciencebase.gov/catalog/item/53ea4091e4b008eaa4f4c457. Revised August 2002.

New Mexico Environment Department/Surface Water Quality Bureau (NMED/SWQB). 2013. Standard Operating Procedure for Physical Habitat Measurements, Revision 5. June 26, 2019.

New Mexico Environment Department/Surface Water Quality Bureau (NMED/SWQB). 2013. Standard Operating Procedure for Physical Habitat Measurements, Revision 6. September 17, 2019.

U.S. Department of Agriculture (USDA). 2005. WinXSPRO 3.0. A Channel Cross Section Analyzer. WEST Consultants Inc. San Diego, CA & Utah State University.

APPENDIX F
RESPONSE TO COMMENTS

SWQB will host a virtual public meeting via webex on August 30, 2023 from 1-2 pm. Notes from the public meeting will be available in the SWQB TMDL files in Santa Fe. Written comments received during the public comment period, and SWQB responses, will be added to this document as **Appendix F.**