TOTAL MAXIMUM DAILY LOAD (TMDL)

FOR THE

PECOS HEADWATERS WATERSHED

FT. SUMNER RESERVOIR TO HEADWATERS

JUNE 14, 2005

This page left intentionally blank.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

LIST OF APPENDICES

LIST OF ABBREVIATIONS

4Q3	4-Day, 3-year low-flow frequency
BLM	Bureau of Land Management
BMP	Best management practices
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CGP	Construction general storm water permit
cms	Cubic meters per second
CWA	Clean Water Act
CWF	Coldwater Fishery
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera/Plecoptera/Tricoptera
FISRWG	Federal Interagency Stream Restoration Working Group
FR	Forest Road
GIS	Geographic Information Systems
GPS	Global Positioning System
HBI	Hilsenhoff's Biotic Index
HQCWF	High quality cold water fishery
HUC	Hydrologic unit code
IOWDM	Input and Output for Watershed Data Management
$j/m^2/s$	Joules per square meter per second
LA	Load allocation
lb/day	Pounds per Day
mg/L	Milligrams per Liter
mi^2	Square miles
mL	Milliliters
mm	Millimeters
MOS	Margin of safety
MOU	Memoranda of Understanding
MS4	Municipal Separate Storm Sewer System
MSGP	Multi Sector Genral Storm Water Permit
NM	New Mexico
NMAC	New Mexico Administrative Code
NMDG&F	New Mexico Department of Game and Fish
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NTU	Nephelometric turbidity units
^oC	Degrees Celcius
^oF	Degrees Farenheit
QAPP	Quality Assurance Project Plan
RBP	Rapid Bioassessment Protocol
RFP	Request for proposal
SBD	Stream bottom deposits
SC	Specific Conductance

SEE	Standard Error of the Estimate
SSTEMP	Stream Segment Temperature Model
SWPPP	Storm Water Pollution Prevention Plan
SWQB	Surface Water Quality Bureau
SWSTAT	Surface Water Statistics
TDS	Total Dissolved Solids
TMDL	Total maximum daily load
TSS	Total suspended solids
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WLA	Waste load allocation
WQCC	Water Quality Control Commission
WQS	Water quality standards (NMAC 20.6.4 as amended through October 11, 2002)
WRAS	Watershed Restoration Action Strategy
WTP	Water treatment plant
WWTP	Waste water treatment plant
µmhos	Micromhos
µmhos/cm	Micromhos per centimeter

EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to develop Total Maximum Daily Load management plans for water bodies determined to be water quality limited. A total maximum daily load documents the amount of a pollutant a water body can assimilate without violating a state's water quality standards. It also allocates that load capacity to known point sources and nonpoint sources at a given flow. Total maximum daily loads are defined in 40 Code of Federal Regulations Part 130 as the sum of the individual Waste Load Allocations for point sources and Load Allocations for nonpoint source and background conditions, and includes a margin of safety.

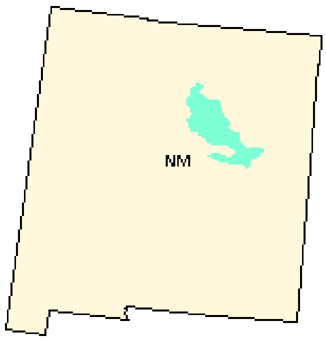
The Pecos Headwaters watershed is located in north central New Mexico. Stations were located throughout the Pecos Headwaters watershed during an intensive watershed survey performed by the New Mexico Environment Department Surface Water Quality Bureau in 2001 to evaluate the impact of tributary streams. Exceedences of the turbidity criterion were documented on Cow Creek (Pecos River to Bull Creek), Cow Creek (Bull Creek to headwaters), Pecos River (Canon de Manzanita to Alamitos Canyon), and Pecos River (Alamitos Canyon to Willow Creek). Bull Creek (Cow Creek to headwaters), Cow Creek (Pecos River to Bull Creek), Cow Creek (Bull Creek to headwaters), Gallinas River (Las Vegas diversion to headwaters), and Pecos River (Canon de Manzanita to Alamitos Canyon) did not meet the temperature criterion. This total maximum daily load document addresses the above noted impairments.

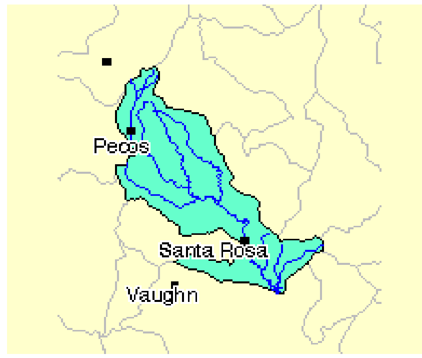
A number of assessment units were not able to be assessed in this document due to insufficient data. These impairments will remain on the Clean Water Act Integrated §303(d)/§305(b) list of waters until additional data are available. Additionally, assessment units whose designated uses are not existing or attainable and those that will be de-listed are detailed in this document.

Additional water quality data will be collected by New Mexico Environment Department during the standard rotational period for intensive stream surveys. As a result, 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 load capacity will be adjusted accordingly. When water quality standards have been achieved, the reach will be moved to the appropriate category on the Clean Water Act Integrated §303(d)/§305(b) list of waters.

The Surface Water Quality Bureau's Watershed Protection Section has and will continue to work with watershed groups to develop Watershed Restoration Action Strategies to develop and implement strategies to attempt to correct the water quality impairments detailed in this document. Implementation of items detailed in Watershed Restoration Action Strategies will be done with participation of all interested and affected parties.

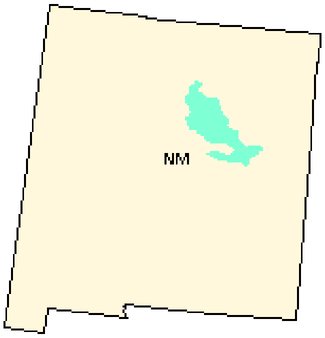
TOTAL MAXIMUM DAILY LOAD FOR TEMPERATURE
BULL CREEK (COW CREEK TO HEADWATERS)

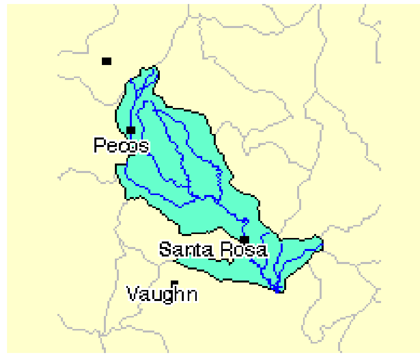




New Mexico Standards Segment	Pecos River Basin 20.6.4.217
Assessment Unit (AU) Identifier	Bull Creek (Cow Creek to headwaters) NM-2214.A 091 (formerly NM-PR1-20210)
Assessment Unit Length	15.28 miles
Parameters of Concern	Temperature
Uses Affected	High Quality Coldwater Fishery
Geographic Location	Pecos Headwaters USGS Hydrologic Unit Code 13060001
Scope/size of Watershed	27.314 mi^2
Land Type	Southern Rockies Ecoregion (21)
Land Use/Cover	Forest (91%), Rangeland (7%), Barren (2%), Agriculture (<1%), Tundra (<1%)
Identified Sources	Loss of riparian habitat, rangeland grazing, watershed runoff following Forest Fire.
Land Management	U.S. Forest Service (87%), Private (13%)
Priority Ranking	High
TMDL for: Temperature	**WLA (0) + LA (137.93) + MOS (15.33) = 153.26 j/m²/sec/day**

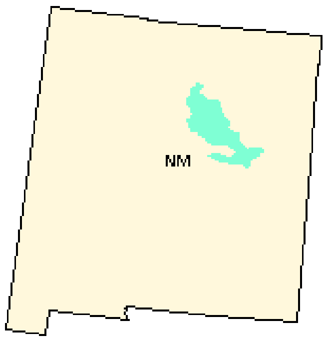
TOTAL MAXIMUM DAILY LOAD FOR TURBIDITY AND TEMPERATURE
COW CREEK (BULL CREEK TO HEADWATERS)

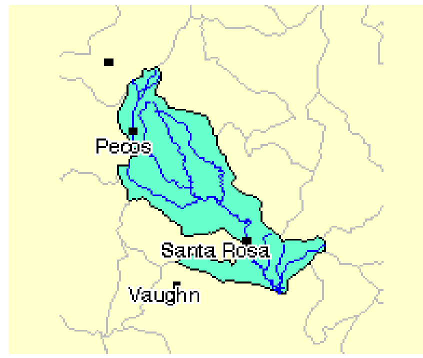




New Mexico Standards Segment	Pecos River Basin 20.6.4.217
Assessment Unit (AU) Identifier	Cow Creek (Bull Creek to headwaters) NM-2214.A_102 (formerly NM-PR1-20200 split)
Assessment Unit Length	22.3 miles
Parameters of Concern	Turbidity, temperature
Uses Affected	High Quality Coldwater Fishery
Geographic Location	Pecos Headwaters USGS Hydrologic Unit Code 13060001
Scope/size of Watershed	52.436 mi^2
Land Type	Southern Rockies Ecoregion (21)
Land Use/Cover	Forest (93%), Tundra (4%), Rangeland (3%), Barren (<1%)
Identified Sources	Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modifications/destabilization, watershed runoff following Forest Fire.
Land Management	U.S. Forest Service (78%), Private (22%)
Priority Ranking	High
TMDL for: Turbidity Temperature	 **WLA (0) + LA (795) + MOS (268) = 1,063 lbs/day** **WLA (0) + LA (138.44) + MOS (15.38) = 153.82 j/m²/sec/day**

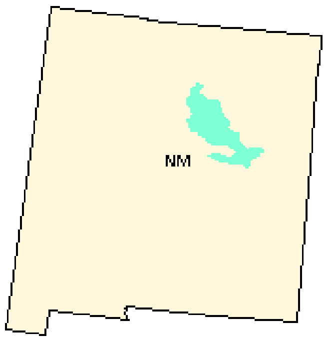
TOTAL MAXIMUM DAILY LOAD FOR TURBIDITY AND TEMPERATURE COW CREEK (PECOS RIVER TO BULL CREEK)

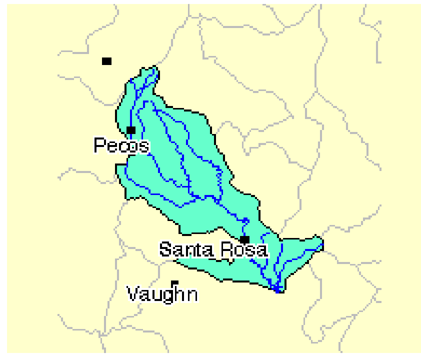




New Mexico Standards Segment	Pecos River Basin 20.6.4.217
Assessment Unit (AU) Identifier	Cow Creek (Pecos River to Bull Creek) NM-2214.A 090 (formerly NM-PR1-20200 split)
Assessment Unit Length	15.6 miles
Parameters of Concern	Turbidity, temperature
Uses Affected	High Quality Coldwater Fishery
Geographic Location	Pecos Headwaters USGS Hydrologic Unit Code 13060001
Scope/size of Watershed	126.314 mi^2
Land Type	Southern Rockies Ecoregion (21)
Land Use/Cover	Forest (95%), Rangeland (4%), Tundra (1%), Agriculture (<1%), Barren (<1%)
Identified Sources	Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modifications/destabilization, watershed runoff following Forest Fire.
Land Management	U.S. Forest Service (80%), Private (18%), BLM (2%)
Priority Ranking	High
TMDL for: Turbidity Temperature	 **WLA (0) + LA (311) + MOS (104) = 415 lbs/day** **WLA (0) + LA (73.04) + MOS (8.12) = 81.16 j/m²/sec/day**

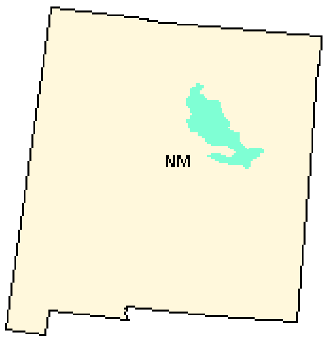
TOTAL MAXIMUM DAILY LOAD FOR TEMPERATURE GALLINAS RIVER (LAS VEGAS DIVERSION TO HEADWATERS)

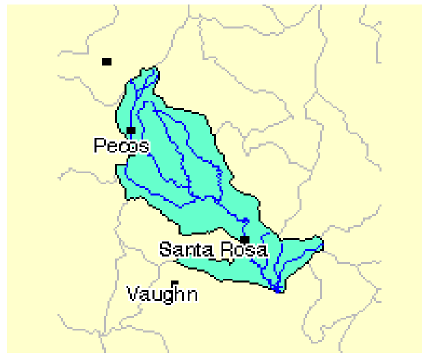




New Mexico Standards Segment	Pecos River Basin 20.6.4.215
Assessment Unit (AU) Identifier	Gallinas River (Las Vegas Diversion to headwaters) NM-2212_00 (formerly NM-UPR1-10300)
Assessment Unit Length	24.21 miles
Parameters of Concern	Temperature
Uses Affected	High Quality Coldwater Fishery
Geographic Location	Pecos Headwaters USGS Hydrologic Unit Code 13060001
Scope/size of Watershed	87.5 mi^2
Land Type	Southern Rockies Ecoregion (21)
Land Use/Cover	Forest (92%), Rangeland (6%), Barren (2%), Agriculture (<1%), Built-up (<1%), Tundra (<1%)
Identified Sources	Highway/road/bridge runoff (non-construction related), livestock (grazing or feeding operations), loss of riparian habitat, rangeland grazing, streambank modifications/destabilization.
Land Management	U.S. Forest Service (52%), Private (48%)
Priority Ranking	High
TMDL for: Temperature	**WLA (0) + LA (99.30) + MOS (11.03) = 110.33 j/m^2/sec/day**

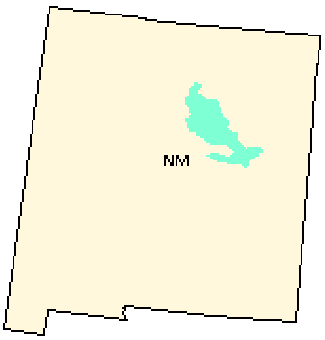
TOTAL MAXIMUMM DAILY LOAD FOR TURBIDITY
PECOS RIVER (ALAMITOS CANYON TO WILLOW CREEK)

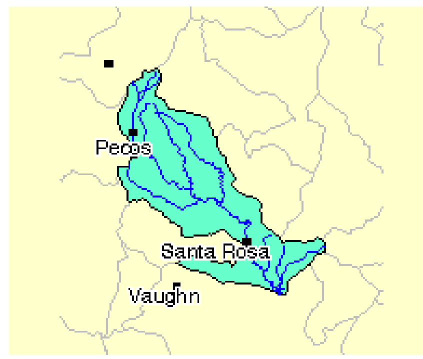




New Mexico Standards Segment	Pecos River Basin 20.6.4.217
Assessment Unit (AU) Identifier	Pecos River (Alamitos Canyon to Willow Creek) NM-2214A_002 (formerly NM-PR11-30000 or UPR1-30000)
Assessment Unit Length	16.17 miles
Parameters of Concern	Turbidity
Uses Affected	High Quality Coldwater Fishery
Geographic Location	Pecos Headwaters USGS Hydrologic Unit Code 13060001
Scope/size of Watershed	234.695 mi^2
Land Type	Southern Rockies Ecoregion (21)
Land Use/Cover	Forest (94%), Tundra (4%), Rangeland (2%), Agriculture (<1%), Barren (<1%), Built-up (<1%)
Identified Sources	Aquaculture (permitted), highway/road/bridge runoff (non-construction related), natural sources, other recreational pollution sources, reclamation on inactive mining.
Land Management	U.S. Forest Service (93%), Private (7%)
Priority Ranking	High
TMDL for: Turbidity	**WLA (721) + LA (22,360) + MOS (7,694) = 30,775 lbs/day**

TOTAL MAXIMUMM DAILY LOAD FOR TURBIDITY AND TEMPERATURE
PECOS RIVER (CANON DE MANZANITA TO ALAMITOS CANYON)





New Mexico Standards Segment	Pecos River Basin 20.6.4.217
Assessment Unit (AU) Identifier	Pecos River (Canon de Manzanita to Alamitos Canyon) NM-2214.A_003 (no WBS identifier)
Assessment Unit Length	5.7 miles
Parameters of Concern	Turbidity, temperature
Uses Affected	High Quality Coldwater Fishery
Geographic Location	Pecos Headwaters USGS Hydrologic Unit Code 13060001
Scope/size of Watershed	294.322 mi^2
Land Type	Southern Rockies Ecoregion (21)
Land Use/Cover	Forest (94%), Rangeland (3%), Tundra (3%), Agriculture (<1%), Built-up (<1%)
Identified Sources	Flow alterations from water diversions, loss of riparian habitat, natural sources, rangeland grazing.
Land Management	U.S. Forest Service (86%), Private (14%)
Priority Ranking	High
TMDL for: Turbidity Temperature	 **WLA (160) + LA (21,488) + MOS (7,216) = 28,864 lbs/day** **WLA (0) + LA (53.11) + MOS (5.9) = 59.01 j/m^2/sec/day**

1.0 INTRODUCTION

Under Section 303 of the Clean Water Act (CWA), states establish water quality standards, which are submitted and subject to the approval of the U.S. Environmental Protection Agency (EPA). Under Section 303(d)(1) of the CWA, states are required to develop a list of waters within a state that are impaired and establish a total maximum daily load (TMDL) for each pollutant. A TMDL is defined as "*a written plan and analysis established to ensure that a waterbody will attain and maintain water quality standard including consideration of existing pollutant loads and reasonably foreseeable increases in pollutant loads*" (EPA 1999). A TMDL documents the amount of a pollutant a waterbody can assimilate without violating a state's water quality standards. It also allocates that load capacity to known point sources and nonpoint sources at a given flow. TMDLs are defined in 40 Code of Federal Regulations (CFR) Part 130 as the sum of the individual Waste Load Allocations (WLAs) for point sources and Load Allocations (LAs) for nonpoint sources and backtground conditions, and include a margin of safety (MOS) and natural background conditions. This document provides TMDLs for assessment units within the Pecos Headwaters that have been determined to be impaired based on a comparison of measured concentrations and conditions with water quality criteria and numeric translators for narrative standards.

In addition to this introductory Section 1.0, this document is divided into eleven main sections. Section 2.0 provides background information on the location and history of the Pecos Headwaters watershed, provides applicable water quality standards for the assessment units addressed in this document, and briefly discusses the intensive water quality survey that was conducted in the Pecos Headwaters watershed in 2001. Section 3.0 provides a detailed description of the individual watersheds for which TMDLs were developed. Section 4.0 presents the TMDLs developed for turbidity in the Pecos Headwaters. Section 5.0 provides temperature TMDLs. Pursuant to Section 106(e)(1) of the Federal CWA, Section 6.0 provides a monitoring plan in which methods, systems, and procedures for data collection and analysis are discussed. Section 7.0 discusses implementation of TMDLs (phase two) and the relationship with Watershed Restoration Action Strategies. Section 8.0 discusses assurance, section 9.0 public participation in the TMDL process, and Section 10.0 provides references.

2.0 PECOS HEADWATERS BACKGROUND

For practical purposes, the Pecos Headwaters watershed was divided into three investigations (i.e., Upper Pecos Parts 1, 2, and 3). The Pecos Headwaters was intensively sampled by the New Mexico Environment Department/Surface Water Quality Bureau (NMED/SWQB) from March to November, 2001 and is addressed in this document. Surface water quality monitoring stations were selected to characterize water quality of the stream reaches (Table 2.1, Figure 2.1). Assessment units that will have a TMDL prepared in this document and those receiving de-list letters are discussed in their respective individual watershed sections. A number of assessment units were not able to be assessed due to insufficient data. These impairments will remain on the Clean Water Act Integrated §303(d)/§305(b) list of waters until additional data are available. Additionally, assessment units that will be de-listed are detailed in this document in their respective individual watershed descriptions.

2.1 Location Description and History

The Pecos Headwaters watershed (US Geological Survey [USGS] Hydrologic Unit Code [HUC] 13060001) is located in north central NM and originates in the Sangre de Cristo Mountains. The entire Pecos Headwaters watershed encompasses approximately 4,276 square miles (mi^2) and extends over portions of six counties including Guadalupe, San Miguel, Santa Fe, Mora, Quay, and De Baca. The Pecos Headwaters includes the main stem of the Pecos River between Ft Sumner Reservoir and the headwaters, as well as tributaries that enter the Pecos River in that reach. As presented in Figure 2.1, land use is 55% rangeland and 44% forest. Figure 2.2 shows ownership as 74% private, 18% US Forest Service, 6% State, 1% BLM, and less than 1% National Park Service and U.S. Fish and Wildlife.

The first known sedentary community in the Pecos Headwaters valley was around A.D. 800 near the present-day Pecos Pueblo (USDA 2003). When Coronado visited the area in 1540 in search of the Seven Cities of Gold, the Pecos Pueblo was the most populous and thriving of the Pueblos with 3,000 inhabitants. However, after illness and Commanche attacks, the 180 remaining survivors migrated to the Jemez Pueblo where they spoke the same language (Montgomery and Sutherland 1967). The upper Pecos Valley has had three sovereigns- the colonial Spanish Empire, the Mexican Republic, and the United States (Hall 1984). For example, the Village of Pecos has been a Spanish settlement since about 1700 (Montgomery and Sutherland 1967). Glorieta Pass, west of the Village of Pecos, was crossed by Coronado's expedition in 1540-1541 and became part of the Santa Fe Trail in 1821 (Chronic 1987). Many Spanish grants existed in the watershed (Hall 1984). Until the mid-nineteenth century, the upper Pecos Valley was mainly populated by small, fiercely independent Hispanic subsistence communities (Hall 2002) that were decendents of these early Spanish settlements. Settlement was initiated in the Gallinas watershed with the establishment of San Miguel del Bado in 1794. The grant of Las Vegas was founded in 1823. (NMED/SWQB 2002a)

The geology of the Pecos Headwaters watershed consists of a complex distribution of Precambrian metamorphic rocks, Mesozoic sedimentary rocks, and Tertiary basalts (Table 2.2, Figure 2.3). The Precambrian rocks (dark amphibolites, granite, gneiss, and mica schist) form the core of the Sangre de Cristo Mountains. However, the region is dominated by the sedimentary deposits that chronicle the uplift of mountains during the Pennsylvannian, the subsequent erosion of these mountains, and the influx of a warm, shallow sea. These events explain the presence of the grey limestone of the San Andres formation, the light-tan Glorieta sandstone, and the brick-red siltstone and sandstone of the Yeso Formation. Pennsylvannian deposits are documented in the exposed layers of Dalton Bluff, near the Village of Pecos, where paleontologists have been able to study the fossiliferous layers and construct a reference assemblage for the region. The Cretaceous Dakota Sandstone serves as an aquifer in the eastern portion of the watershed. The Chinle Formation is composed of red Triassic sandstone, siltstone, and conglomerate that contains petrified wood and fossils of plants, invertebrates, and vertebrates. Pecos National Monument contains ruins of a mission church and pueblo that use the surrounding clear gypsum from the Bernal Formation as windowpanes (Chronic 1987). The Permian gypsum and salt solutions in underlying rocks have created sinkholes in the Santa Rosa area and account for the snaking path of the Pecos River as it follows the curving line of collapsed caverns. The highway near Santa Rosa abruptly drops into the Santa Rosa Sink, one of the area's notable karst features, along with Blue Hole, a 60-foot diameter sink in the town of Santa Rosa. Additionally, near Santa Rosa Lake, the Santa Rosa sandstone includes tar sands that contain an estimated 90 million barrels of oil (Chronic, 1987). The Ogallala Formation consists of Miocene-Pliocene gravel washed eastward from the various mountain ranges, including the Rocky Mountains. Placer gold was mined in the Sangre de Cristos as well as lead, zinc, and copper. Early attempts were also made to extract Early Pennsylvannian bituminous coal near the Village of Pecos.

Several species within this watershed are listed as either threatened or endangered by both State and Federal agencies. Federally listed endangered species include the holy ghost ipomopsis (*Ipomopsis sanctispiritus*), Rio Grande silvery minnow (*Hybognathus amarus*), brown pelican (*Pelecanus occidentalis*), and the southwestern willow flycatcher (*Empidonax traillii extimus*). Federally listed threatened species include the puzzle sunflower (*Helianthus paradoxus*), Pecos bluntnose shiner (*Notropis simus pecosenis*), piping plover (*Charadrius melodus*), and the Mexican spotted owl (*Strix occidentalis lucida*). Additional species listed by the State as endangered include the mountain lily (*Lilium philadelphicum var andinum*), yellow lady's slipper (*Cypripedium parviflorum var pubescens*), and the white-tailed ptarmigan (*Lagopus leucurus*). Additional species listed by the State as threatened include the Mexican tetra (Astyanax mexicanus), suckermouth minnow (*Phenacobius mirabilis*), bigscale logperch (*Percina macrolepida*), American peregrine falcon (*Falco peregrinus anatum*), least shrew (*Cryptotis parva*), and the American marten (*Martes americana*).

Table 2.1 SWQB 2001 Pecos Headwaters Sampling Stations

Station	Latitude, decimal degrees	Longitude, decimal degrees	Elevation, feet	Station Location
1	35.58840	-105.21850	6,500	12th St runoff drain abv Independence Ave in Las Vegas
2	**35.69880**	**-105.42300**	**7,450**	**2-05 Gallinas River at National Forest boundary**
3	35.566111	-105.205556	6,397	Aqua Olympia
4	35.59470	-105.22400	6,400	Arroyo Hermanos
5	**35.76150**	**-105.44840**	**8,209**	**Beaver Creek abv El Porvenir Creek**
6	35.65000	-105.44000	7,300	Blue Creek abv Tecolote Creek
7	**35.53820**	**-105.58000**	**6,903**	**Bull Creek above confluence with Cow Creek**
8	35.72610	-105.49460	8,504	Burro Creek abv Gallinas Creek
9	35.566393	-105.21167	6,382	City of Las Vegas, NM WWTP Outfall Pipe
10	**35.53820**	**-105.5810**	**6,889**	**Cow Creek above confluence with Bull Creek**
11	**35.53800**	**-105.5810**	**6,898**	**Cow Creek below confluence with Bull Creek @ Forest Road 83**
12	35.76000	-105.44900	8,180	El Porvenir Creek @ headwaters
13	35.710837	-105.415559	7,559	El Porvenir Creek at Christian Camp, USGS 08380075
14	35.689685	-105.375883	7,254	El Porvenir Creek at Hwy 65 above the Gallinas
15	34.925559	-104.68306	4,540	El Rito Creek downstream of the Santa Rosa WWTF
16	34.926115	-104.681115	4,550	El Rito Creek upstream of Santa Rosa WWTF
17	35.595600	-105.40400	6,860	Falls Creek @ CR A 19A
18	35.621631	-105.245518	6,540	Gallinas River above Las Vegas @ County Road A-11C
19	35.58820	-105.21810	6,500	Gallinas River abv Independence Ave
20	35.46470	-105.15720	5,945	Gallinas River @ San Augustin
21	35.565003	-105.211949	6,417	Gallinas River 0.25 mile below Las Vegas WWTF
22	35.56667	-105.210837	6,427	Gallinas River above Las Vegas WWTP
23	35.16690	-104.92400	4,925	Gallinas River above Pecos at Park Springs
24	**35.722139**	**-105.497333**	**8,435**	**Gallinas River at end of FR 263 above Burro Creek**
25	**35.651948**	**-105.318338**	**6,867**	**Gallinas River at Montezuma, USGS gage 08380500**
26	35.584870	-105.764756	7,379	Glorieta Baptist Conf Center WWTP
27	35.539789	-105.682598	6,823	Glorieta Creek above confluence with Pecos River
28	35.760800	-105.44950	8,186	Hollinger Creek above El Porvenir Creek
29	35.741235	-105.679033	7,674	Holy Ghost Cr 300m upstream Hwy 63 bridge over Pecos River
30	35.707671	-105.683254	7,490	Indian Creek 3m west of Hwy 63 bridge
31	35.824837	-105.654158	8,272	Jack's Creek above confluence with Pecos River
32	**35.609343**	**-105.676992**	**6,997**	**Lisboa Springs Fish Hatchery effluent discharge**
33	35.675754	-105.692531	7,350	Macho Canyon Creek 10m west of Hwy 63 bridge
34	34.91010	-104.6630	4,500	Ortega Ditch below Rock Lake Fish Hatchery
35	35.831558	-105.664061	8,402	Panchuela Creek 100m abv campground
36	35.62950	-105.20600	6,466	Pecos Arroyo @ Harris Lake abv Spring Arroyo
37	35.5738	-105.206000	6,427	Pecos Arroyo above the Gallinas River
38	**35.53520**	**-105.66800**	**6,750**	**Pecos River @ Pecos National Historical Park**
39	35.446285	-105.580794	6,320	Pecos River @ South San Ysidro
40	35.825774	-105.651538	8,302	Pecos River @ wilderness boundary
41	35.762904	-105.67006	7,822	Pecos River 400m above confluence with Willow Creek

Station	Latitude, decimal degrees	Longitude, decimal degrees	Elevation, feet	Station Location
42	**35.609343**	**-105.676992**	**6,997**	**Pecos River above Lisboa Springs Fish Hatchery**
43	**35.567248**	**-105.667464**	**6,883**	**Pecos River above Village of Pecos WWTP effluent discharge**
44	35.09140	-104.7998	4,800	Pecos River at gage above Santa Rosa Reservoir
45	34.730004	-104.524449	4,445	Pecos River at Puerta de Luna Bridge
46	35.397226	-105.470282	6,080	Pecos River at San Jose
47	35.268002	-105.334275	5,744	Pecos River at Villanueva State Park
48	34.92480	-104.6830	4,530	Pecos River below confluence with El Rito Creek
49	35.23810	-105.16200	5,290	Pecos River below confluence with Tecolote Creek
50	35.82280	-105.65400	8,395	Pecos River below Jack's Creek
51	**35.606327**	**-105.677138**	**7,016**	**Pecos River below Lisboa Springs Fish Hatchery**
52	35.02417	-104.688893	4,606	Pecos River below Santa Rosa Dam
53	**35.744788**	**-105.674963**	**7,683**	**Pecos River below Terrero mine**
54	**35.566011**	**-105.667489**	**6,880**	**Pecos River below Village of Pecos WWTP**
55	35.057226	-104.755559	5,000	Pecos River near Colonias, NM
56	34.925281	-104.68417	5,000	Pecos River upstream of El Rito Creek
57	35.777226	-105.657503	7,926	Rio Mora at USGS gage 08377900 abv Pecos campground
58	34.925900	-104.682000	5,000	Santa Rosa Wastewater Plant
59	35.581670	-105.394448	6,758	Tecolote Creek at bridge near San Geronimo
60	35.65240	-105.44610	7,415	Tecolote Creek below SFNF boundary
61	35.23830	-105.16300	5,500	Tecolote Creek above confluence with Pecos River
62	35.689000	-105.480000	8,583	Tecolote Creek above Wright Canyon above FR 291
63	35.457469	-105.277584	6,286	Tecolote Creek at I-25 near Tecolote
64	**35.567268**	**-105.668593**	**6,861**	**Village of Pecos WWTP**
65	35.758205	-105.670446	7,791	Willow Creek below White Drain
66	35.81180	-105.65930	9,000	Winsor Creek at Pecos River
67	35.693900	-105.47900	8,470	Wright Creek above Tecolote Creek

Bold indicates stations used in TMDL determination.

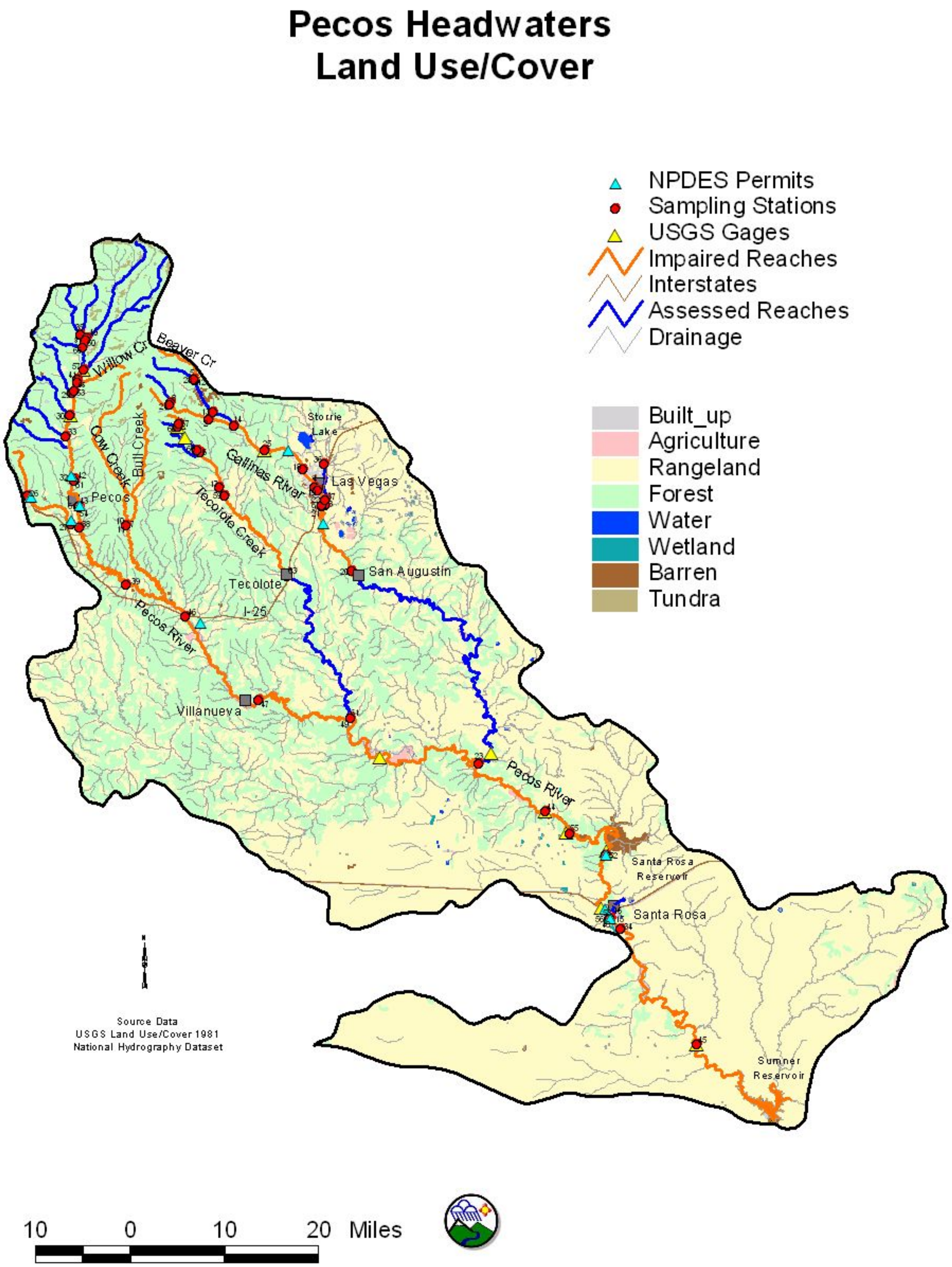


Figure 2.1 Pecos Headwaters Land Use and 2001 Sampling Stations

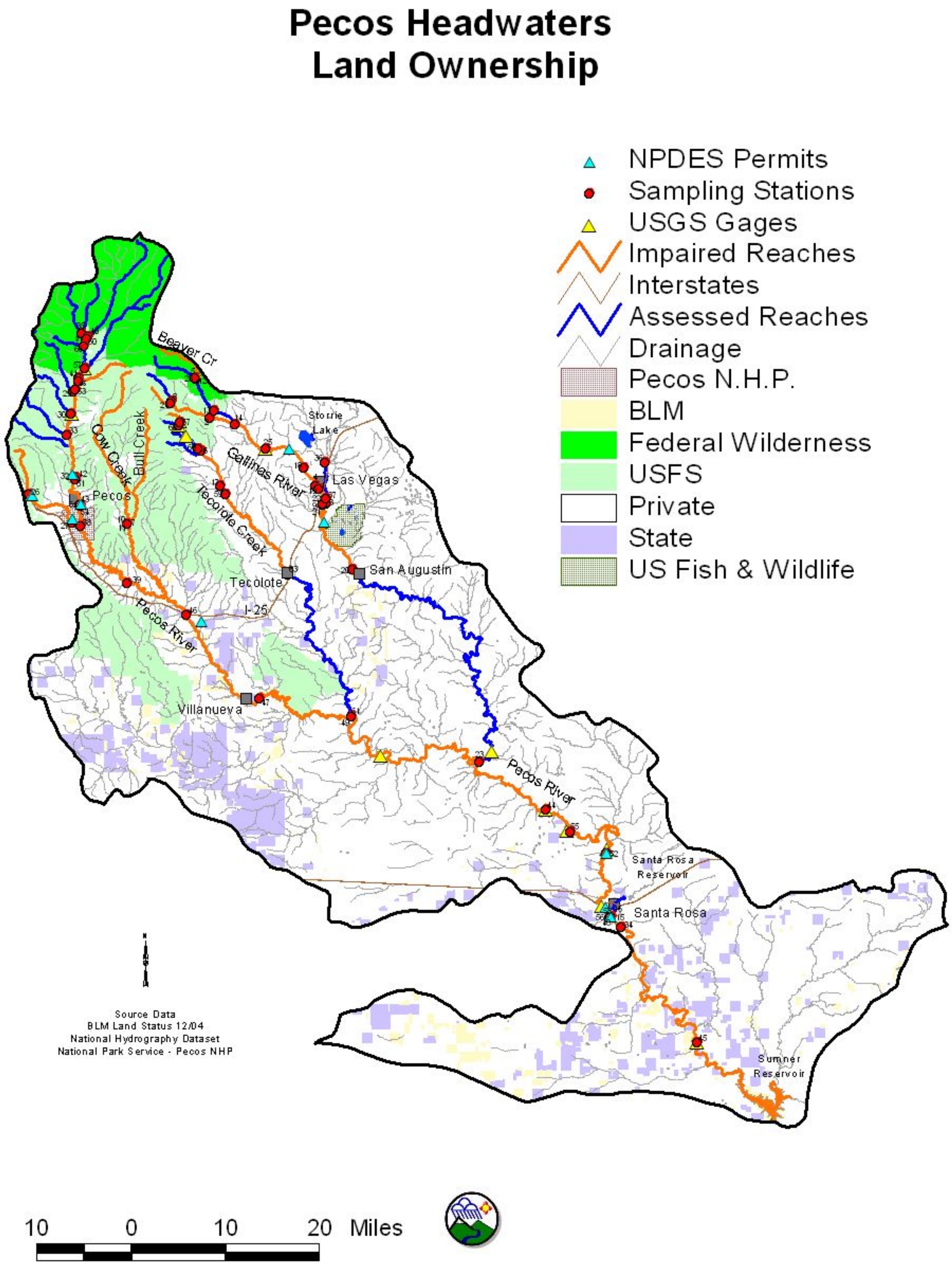


Figure 2.2 Pecos Headwaters Land Ownership

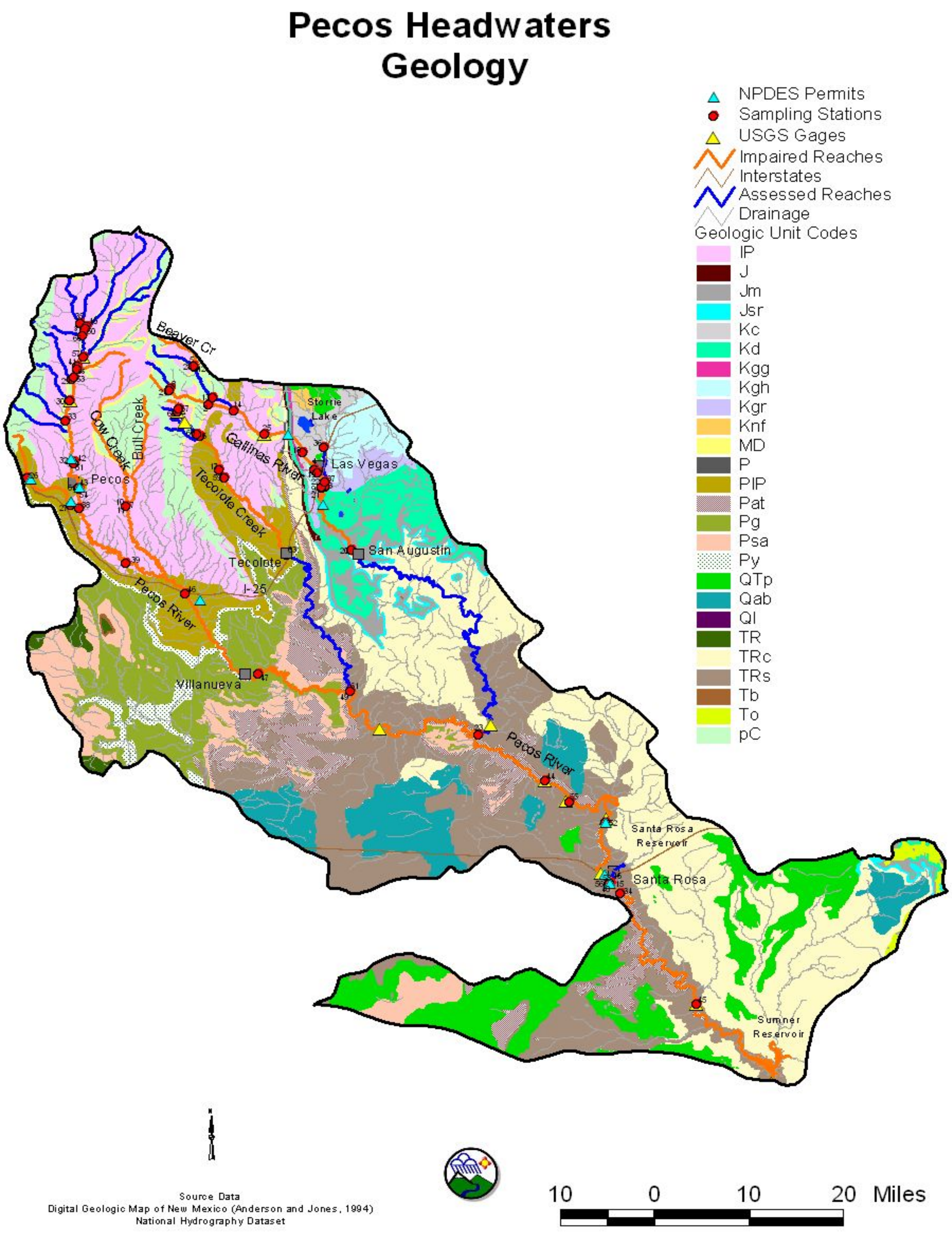


Figure 2.3 Pecos Headwaters Geology

Table 2.2 Geologic Unit Definitions for the Pecos Headwaters

Geologic Unit Code	Definition
IP	Pennsylvanian (age) rocks
J	Jurassic rocks, Middle and Upper, undivided
Jm	Morrison Formation, Upper Jurassic nonmarine rocks present only in northern one-third of state
Jsr	San Rafael Group; consists of Entrada Sandstone, Todilto and Summerville Formations
Kc	Carlile Shale, limited to northeastern area
Kd	Dakota Sandstone; includes Oak Canyon, Cubero, and Paguate Tongues plus Clay Mesa Tongue of Mancos Shale
Kgg	Graneros Shale and Greenhorn Formation, limited to northeastern area
Kgh	Greenhorn Formation, limited to northeastern area
Kgr	Graneros Shale, limited to northeastern area
Knf	Fort Hays Limestone Member of Niobrara Formation
MD	Mississippian and Devonian rocks, undivided; includes the Lake Valley Limestone
P	Permian rocks, undivided
PIP	Combination of Permian and Pennsylvanian (age) rock units
Pat	Artesia Group, shelf facies forming broad south-southeast trending outcrop
Pg	Glorieta Sandstone; texturally and mineralogically mature, high-silica quartz sandstone
Psa	San Andres Formation; limestone and dolomite with minor shale; Guadalupian in south, in part Leonardian to north
Py	Yeso Formation; sandstones, siltstones, anhydrite, gypsum, halite, and dolomite; Leonardian
QTp	Older piedmont alluvial deposits and shallow basin fill
Qab	Alluvium; upper and middle Quaternary; Basalt and andesite flows and locally vent deposits
QI	Landslide deposits and colluvium
TR	Triassic rocks, general
TRc	Triassic Chinle Group
TRs	Triassic sediments
Tb	Tertiary basalt
To	Ogallala Formation, alluvial and eolian deposits, and petrocalcic soils of the southern High Plains
pC	Precambrian rocks, undifferentiated

2.2 Water Quality Standards

Water quality standards (WQS) for all assessment units in this document are set forth in sections, 20.6.4.215, 20.6.4.217, 20.6.4.12, and 20.6.4.900 of the 2002 NM Standards for Interstate and

Intrastate Surface Waters (NM Administrative Code [NMAC] 20.6.4). NMAC 20.6.4.215 reads as follows:

> **PECOS RIVER BASIN**-The Gallinas river and all its tributaries above the diversion for the Las Vegas municipal reservoir and perennial reaches of Tecolote creek and its perennial tributaries.
>
> **A. Designated Uses**: domestic water supply, high quality coldwater fishery, irrigation, livestock watering, wildlife habitat, municipal and industrial water supply, and secondary contact.
>
> **B. Standards**:
>
> (1) In any single sample: conductivity[1] shall not exceed 300 µmhos except conductivity shall not exceed 450 µmhos in Wright Canyon Creek, pH shall be within the range of 6.6 to 8.8, temperature shall not exceed 20°C (68°F), and turbidity shall not exceed 10 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.
>
> (2) The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100 mL; no single sample shall exceed 200/100 mL (see Subsection B of 20.6.4.13 NMAC).

NMAC 20.6.4.217 reads as follows:

> **PECOS RIVER BASIN**-Cow creek and all its tributaries and the main stem of the Pecos river from the southern boundary of the Pecos national historical park upstream to its headwaters, including all tributaries thereto.
>
> **A. Designated Uses**: domestic water supply, fish culture, high quality coldwater fishery, irrigation, livestock watering, wildlife habitat, and secondary contact.
>
> **B. Standards**:
>
> (1) In any single sample: conductivity shall not exceed 300 umhos, pH shall be within the range of 6.6 to 8.8, temperature shall not exceed 20°C (68°F), and turbidity shall not exceed 10 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.
>
> (2) The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100 mL; no single sample shall exceed 200/100 mL (see Subsection B of 20.6.4.13 NMAC).

NMAC 20.6.4.12 lists general standards that apply to all surface waters of the state at all times, unless a specified standard is provided elsewhere in NMAC. NMAC 20.6.4.900 provides standards applicable to attainable or designated uses unless otherwise specified in 20.6.4.101 through 20.6.4.899.

1 The current water quality standards erroneously refer to "conductivity" when the intention was "specific conductance." Specific conductance means conductivity adjusted to 25 degrees C. SWQB proposed changing all references from conductivity to specific conductance at the recent (February 2004) trienniel review hearing. This proposal is expected to be accepted by the WQCC and EPA. Therefore, the term specific conductance is used throughout this TMDL document.

2.3 Intensive Water Quality Sampling

The Pecos Headwaters watershed was intensively sampled by the SWQB in 2001. A brief summary of the survey and the hydrologic conditions during the sampling events is provided in the following subsections.

2.3.1 Survey Design

Water quality samples were collected during three seasons (spring, summer, and fall) in 2001. Follow-up data collection was conducted in 2004. Temperature data were collected in 2001. Follow-up monitoring for temperature was completed in July to September, 2003. Surface water quality monitoring stations were selected to characterize water quality of the stream reaches. Table 2.1 and Figure 2.1 present the SWQB water quality monitoring station locations sampled in 2001. Figure 5.1 shows thermograph locations from the monitoring in both 2001 and 2003. Stations were located to evaluate the impact of tributary streams and to determine ambient water quality conditions. The results of the survey were summarized in three water quality survey reports (NMED/SWQB 2002a, 2004c, 2004d).

All temperature and chemical/physical sampling and assessment techniques are detailed in the *Quality Assurance Project Plan* (QAPP, NMED/SWQB 2001, and the SWQB assessment protocols (NMED/SWQB 2004b). As a result of the 2001 monitoring effort and subsequent assessment of results, several exceedences of NM WQS for several streams were documented. Accordingly, these impairments were added to NM’s 2004-2006 Integrated §303(d)/305(b) list (NMED/SWQB 2004a).

2.3.2 Hydrologic Conditions

There are two USGS gaging stations in the Pecos Headwaters watershed that are associated with reaches presented in this document. All USGS gage locations are presented in Figure 2.1. Daily streamflow for the pertinent gages are presented graphically in Figures 2.4 and 2.5 for the 2001 calendar year.

Figure 2.4 USGS Average Daily Streamflow, Pecos River near Pecos, NM (2001)

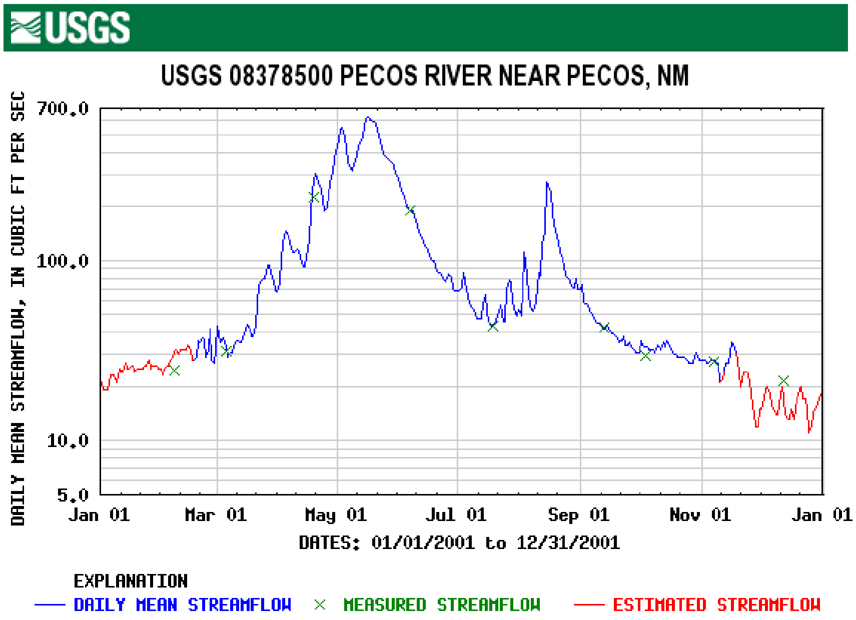
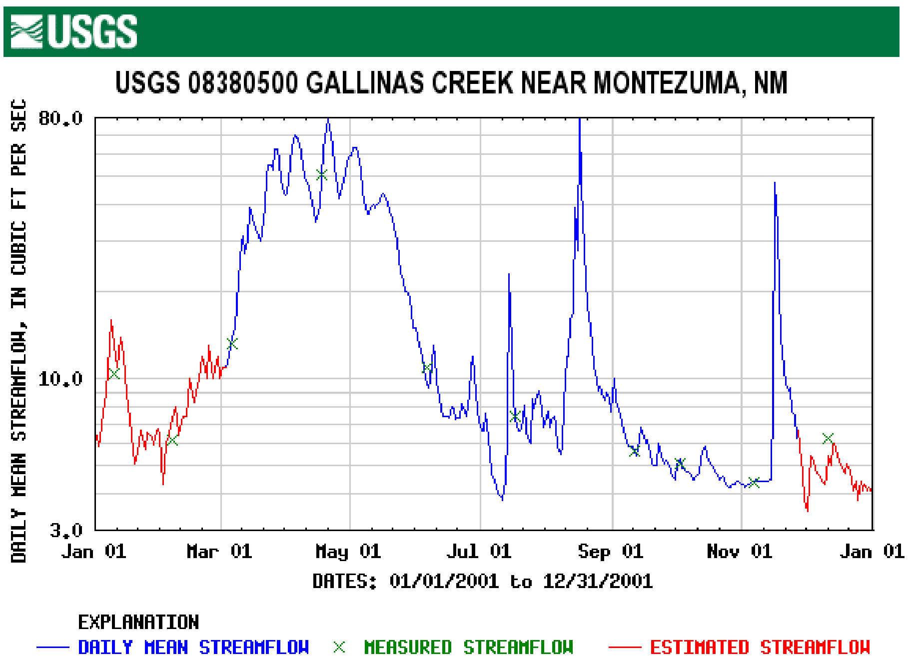


Figure 2.5 USGS Average Daily Streamflow, Gallinas Creek near Montezuma, NM (2001)



3.0 PECOS HEADWATERS-NORTHERN PORTION

TMDLs were developed for several assessment units for which constituent (or pollutant) concentrations measured during the 2001 water quality survey indicated impairment. Because characteristics of each sub-watershed, such as geology, land use, and land ownership provide insight into probable sources of impairment, they are presented together in this section as the northern portion of the Pecos Headwaters watershed. In addition, the listings on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) within the Pecos Headwaters river/stream reaches are discussed. Assessment units that will have de-list letters prepared are discussed in their respective individual watershed sections.

As presented in Figure 3.1, land use in the northern portion of the Pecos Headwaters is 65% forest and 34% rangeland. Figure 3.2 shows ownership as 56% private, 41% U.S. Forest Service, 2% State, 1% U.S. Fish and Wildlife, and less than 1% National Park Service and BLM.

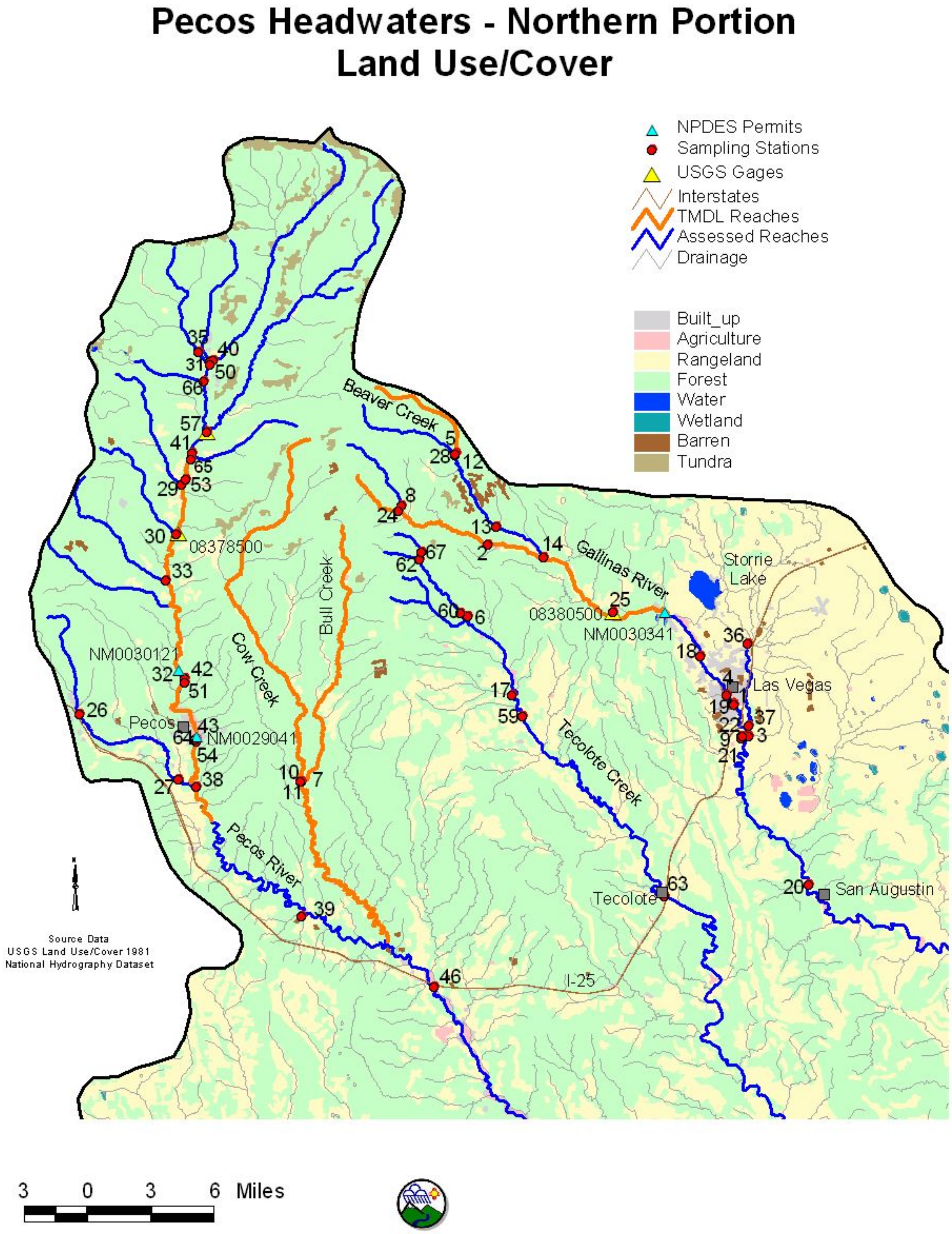


Figure 3.1 Pecos Headwaters -Northern Portion Land Use

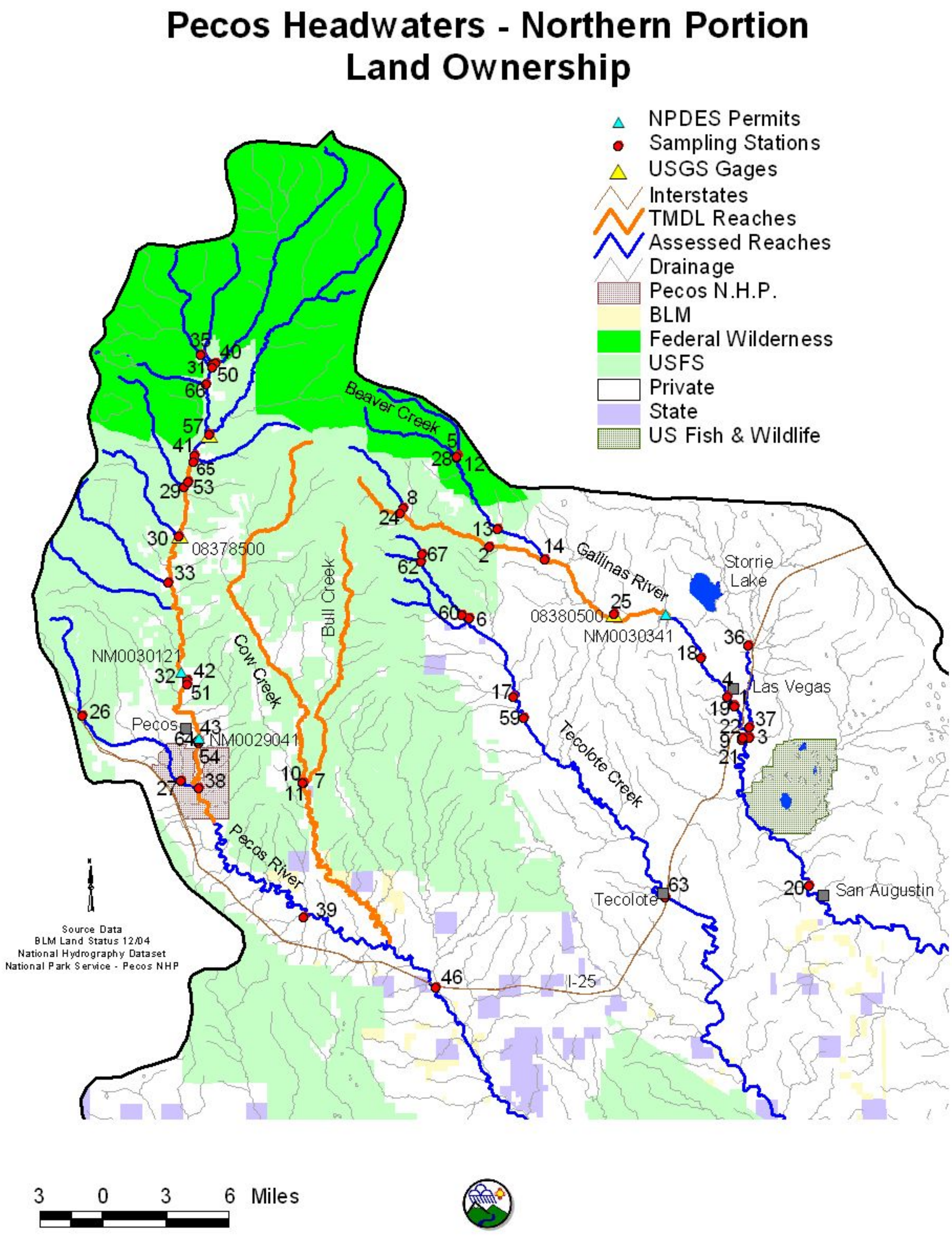


Figure 3.2 Pecos Headwaters-Northern Portion Land Ownership

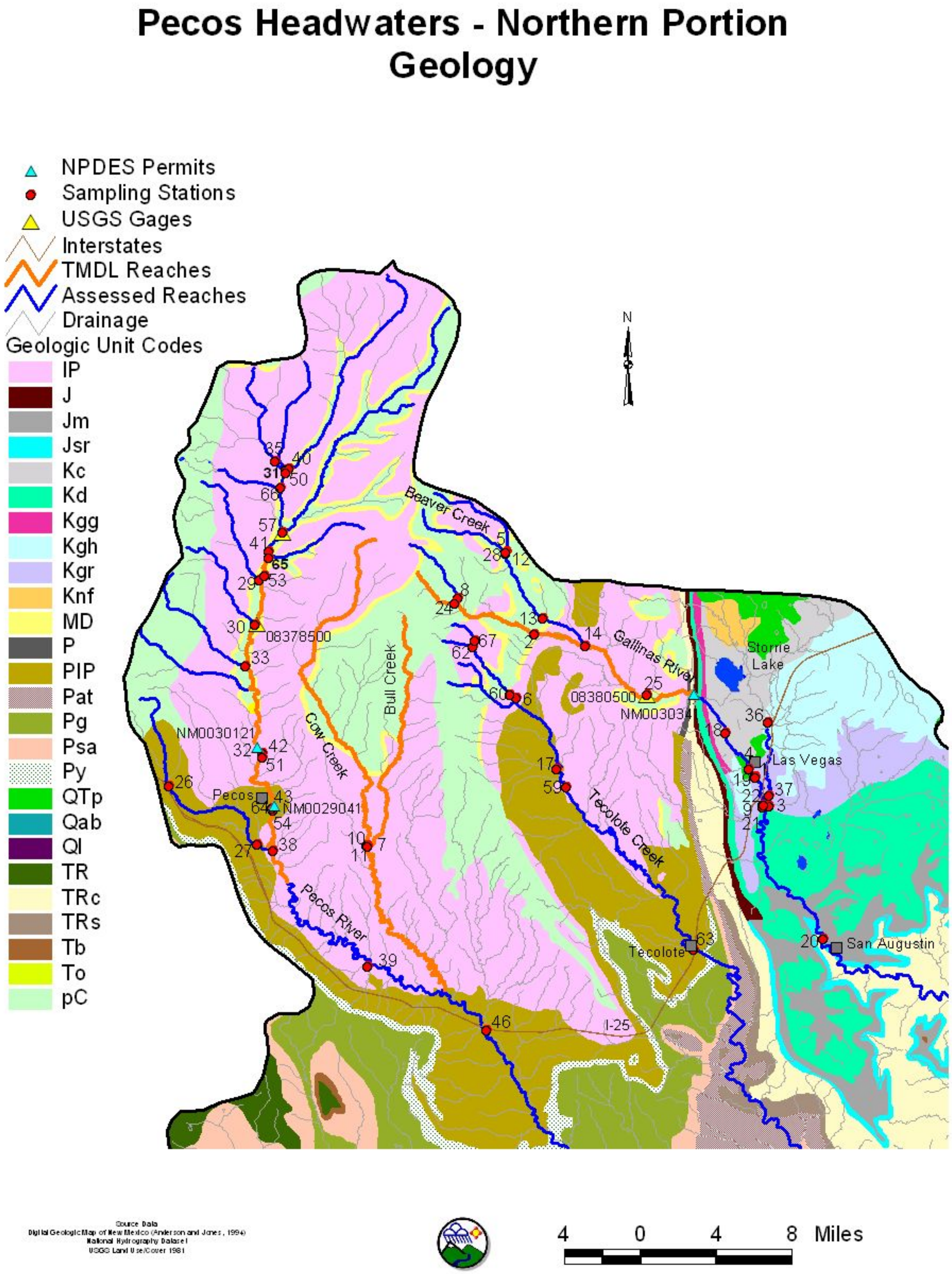


Figure 3.3 Pecos Headwaters -Northern Portion Geology

3.1 Bull Creek

Bull Creek originates on Elk Mountain in the Sangre de Cristo Mountains. Bull Creek watershed is approximately 27 mi^2 and is a tributary to Cow Creek, which then joins the Pecos River. As presented in Figure 3.1, land use is 91% forest, 7% rangeland, 2% barren, and less than 1% agriculture and tundra. Land ownership is 87% U.S. Forest Service and 13% private (Figure 3.2). Bull Creek was largely unaffected by the Viveash fire of May 2000 (USDA 2003).

The geology of the Bull Creek watershed consists of undiferentiated Precambrian rocks, dominantly crystalline granitic, plutonic rocks (granites, schists, quartzites, and other metavolcanic or metamorphics) and a combination of Pennsylvannian sedimentary rock units. This watershed is dominated by the Pennsylvanian-Permian rocks of the Sangre de Cristo Formation (Chronic 1987). The Sangre de Cristo formation consists of as much as 2,500 feet of alternating arkose, siltstone, and shale with colors that vary from brown or gray to red (New Mexico Geological Society 1956).

Bull Creek (Cow Creek to headwaters) is approximately 15.28 miles in length. One station was established (Table 2.1, Figure 3.1) and one thermograph was deployed (Figure 5.1) in this assessment unit during the 2001 intensive survey. Bull Creek was listed on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for temperature impairment and requires a TMDL. No previous TMDLs have been written for this assessment unit. The following TMDL was developed for this watershed:

- ***Temperature-*** Bull Creek (Cow Creek to headwaters)

Photo 3.1 Bull Creek above Cow Creek (May 15, 2001)

3.2 Cow Creek

Cow Creek originates on Elk Mountain in the Sangre de Cristo Mountains. Cow Creek watershed is approximately 126 mi^2 and includes Bull Creek before it joins the Pecos River one mile north of Sands, New Mexico. As presented in Figure 3.1, land use is 95% forest, 4% rangeland, 1% tundra, and less than 1% agriculture and barren. Land ownership is 80% U.S. Forest Service, 18% private, and 2% BLM (Figure 3.2).

The geology of the Cow Creek watershed consists of undiferentiated Precambrian rocks, dominantly crystalline granitic, plutonic rocks (granites, schists, quartzites, and other metavolcanic or metamorphics) and a combination of Pennsylvannian, Mississipian, and Devonian sedimentary rocks. This watershed is dominated by the Pennsylvanian-Permian rocks of the Sangre de Cristo Formation (Chronic 1987). The Sangre de Cristo formation consists of as much as 2,500 feet of alternating arkose, siltstone, and shale with colors that vary from brown or gray to red (New Mexico Geological Society 1956).

The 29,000 acre Viveash wildfire of May 2000 severely impacted the Cow Creek watershed. Cow Creek has become a very flashy stream since the Viveash Fire and generally lacks large woody debris and pool habitat (USDA 2003). During a special water quality survey in August 2000, Cow Creek was found to have incised approximately two feet and deposits of ash and sediment were one to two meters deep in low gradient areas below the burned area (NMED/SWQB 2001b). Stream surveys in 2001 failed to find any fish in Cow Creek (USDA 2003) and an initial examination of the benthic-macroinvertebrate community found the invertebrates to have been completely extirpated (NMED/SWQB 2001b).

Cow Creek (Bull Creek to headwaters) is approximately 22.3 miles in length. One station was established (Table 2.1, Figure 3.1) and one thermograph was deployed (Figure 5.1) in this assessment unit during the 2001 intensive survey. Cow Creek (Bull Creek to headwaters) was listed on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for temperature and turbidity impairments and requires a TMDL. No previous TMDLs have been written for this assessment unit.

Cow Creek (Pecos River to Bull Creek) is approximately 15.6 miles in length. One station was established (Table 2.1, Figure 3.1) and three thermographs were deployed (Figure 5.1) in this assessment unit during the 2001 intensive survey and 2003 thermograph redeployments. Cow Creek (Pecos River to Bull Creek) was listed on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for temperature and turbidity impairments and requires a TMDL. No previous TMDLs have been written for this assessment unit. The following TMDLs were developed for this watershed:

- ***Temperature, turbidity***- Cow Creek (Bull Creek to headwaters)
- ***Temperature, turbidity***- Cow Creek (Pecos River to Bull Creek)

Cow Creek (Bull Creek to headwaters) was included on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for sedimentation/siltation. Data collected during 2004 indicate that Cow Creek (Bull Creek to headwaters) supports a healthy benthic macroinvertebrate community and 8% fines. Based on application of this data to the assessment protocols (NMED/SWQB 2004b), Cow Creek (Bull Creek to headwaters) was delisted for sedimentation/siltation. Likewise, Cow Creek (Pecos River to Bull Creek) was included on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for sedimentation/siltation. A 2001 survey indicated that Cow Creek (Pecos River to Bull Creek) had 27% fines, but data collected during 2004 indicated that Cow Creek (Pecos River to Bull Creek) supports a healthy benthic macroinvertebrate community and 10% fines. Based on application of this data to the assessment protocols (NMED/SWQB 2004b), Cow Creek (Pecos River to Bull Creek) was delisted for sedimentation/siltation.

Photo 3.2 Cow Creek above Bull Creek (March 28, 2001)

Photo 3.3 Cow Creek below Bull Creek @ FR 83 (July 17, 2003)

3.3 Gallinas River

The Gallinas River originates on Elk Mountain in the Sangre de Cristo Mountains. The Gallinas River watershed (Las Vegas Diversion to headwaters) is approximately 88 mi^2 and includes Beaver Creek, Hollinger Creek, Porvenir Creek, and Burro Canyon before it reaches the City of Las Vegas, NM. As presented in Figure 3.1, land use is 92% forest, 6% rangeland, 2% barren, and less than 1% agriculture and tundra. Land ownership is 52% U.S. Forest Service and 48% private (Figure 3.2). The 29,000 acre Viveash wildfire of May 2000 impacted the Gallinas River watershed. There may have been increases of turbidity in the Gallinas River due to the fire's encrochment into the upper watershed, but not to the extent as in the Cow Creek watershed (NMED/SWQB 2001b).

The geology of the upper Gallinas River watershed consists of undiferentiated Precambrian rocks, dominantly crystalline granitic, plutonic rocks (granites, schists, quartzites, and other metavolcanic or metamorphics) and a combination of Pennsylvannian, Mississipian, and Devonian sedimentary rocks. A flat-topped mesa just north of Las Vegas is a remnant of a Pleistocene alluvial fan (Chronic 1987). This area is also dominated by the hogbacks along the mountain front.

The Las Vegas Water Treatment Plant (WTP) (NPDES permit NM 0030341) discharges into an unnamed arroyo and thence into the Gallinas River (Las Vegas Diversion to headwaters). However, this is a no discharge permit that only under emergency conditions would discharge backwash and filter-to-waste water into the arroyo.

Gallinas River (Las Vegas diversion to headwaters) is approximately 24.21 miles in length. One station was established (Table 2.1, Figure 3.1) and two thermographs were deployed (Figure 5.1) in this assessment unit during the 2001 intensive survey and 2003 thermograph redeployments. Gallinas River (Las Vegas diversion to headwaters) was listed on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for temperature impairment and requires a TMDL. No previous TMDLs have been written for this assessment unit. The following TMDL was developed for this watershed:

- ***Temperature***- Gallinas River (Las Vegas diversion to headwaters)

Gallinas River (Las Vegas diversion to headwaters) was also included on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for sedimentation/siltation. During the analysis of benthic macroinvertebrate samples collected in 2001 from Gallinas River (Las Vegas diversion to headwaters), a site in this assessment unit was used as a reference site. It was deemed as being in the top three least-impaired sites available for analysis. The associated pebble count indicates 23% fines. Based on application of this data to the assessment protocols (NMED/SWQB 2004b), Gallinas River (Las Vegas diversion to headwaters) was delisted for sedimentation/siltation. Addtionally, Beaver Creek (Porvenir Creek to headwaters) was included on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for sedimentation/siltation. Data gathered in 2001 indicated 31% fines and a total biotic score of 90% of the reference site. Based on application of these data to the assessment protocols (NMED/SWQB 2004b), Beaver Creek (Porvenir Creek to headwaters) was delisted for sedimentation/siltation.

Photo 3.4 Gallinas River above Las Vegas Diversion (July 16, 2003)

3.4 Pecos River

The Pecos River originates at the Santa Barbara Divide in the Sangre de Cristo Mountains. The Pecos River watershed (Canon de Manzanita to headwaters) is approximately 294 mi^2 and includes Rio Mora, Rito del Oso, Willow Creek, Jack's Creek, Panchuela Creek, Winsor Creek, Holy Ghost Creek, Indian Creek, Macho Canyon, Dalton Canyon, and Glorieta Creek. As presented in Figure 3.1, land use in the Pecos River (Canon de Manzanita to Alamitos Canyon) assessment unit is 94% forest, 3% rangeland, 3% tundra, and less than 1% agriculture and built-up. Land use in the Pecos River (Alamitos Canyon to Willow Creek) assessment unit is 94% forest, 4% tundra, 2% rangeland, and less than 1% agriculture, barren, and built-up. Land ownership is 86% U.S. Forest Service and 14% private in the Pecos River (Canon de Manzanita to Alamitos Canyon) assessment unit and 93% U.S. Forest Service and 7% private in the Pecos River (Alamitos Canyon to Willow Creek) assessment unit (Figure 3.2). The Pecos River flows through the Santa Fe National Forest and the Pecos National Historical Park.

The geology of the upper Pecos River watershed consists of undiferentiated Precambrian rocks, dominantly crystalline granitic, plutonic rocks (granites, schists, quartzites, and other metavolcanic or metamorphics) and a combination of Permian, Pennsylvannian, Mississipian, and Devonian sedimentary rocks. Sharp bluffs of resistant limestone and sandstone of Late Pennsylvanian age hem in the Pecos River just north of the Village of Pecos, while the hills surrounding the Village are composed of red and maroon shales and sandstones of Permian age (Montgomery and Sutherland 1967). The prominent bluff behind the Lisboa Springs State Fish Hatchery is composed of Middle Pennsylvanian chert and limestone (Montgomery and

Sutherland 1967). Pecos Falls, near the headwaters, is capped by glassy-white Precambrian quartzite overlying flat Pennsylvanian shales and sandstones (Montgomery and Sutherland 1967).
The Village of Pecos Wastewater Treatment Plant (WWTP) (NPDES permit NM 0029041) discharges into the Pecos River (Canon de Manzanita to Alamitos Canyon) and the Lisboa Springs Fish Hatchery (NPDES permit NM 0030121) discharges into the Pecos River (Alamitos Canyon to Willow Creek). Additionally, reclamation assessment continues at the Terrereo mine (Pecos mine) site on Willow Creek immediately upstream of its confluence with the Pecos River.

Pecos River (Alamitos Canyon to Willow Creek) is approximately 16.17 miles in length. Four stations were established (Table 2.1, Figure 3.1) in this assessment unit during the 2001 intensive survey. Pecos River (Alamitos Canyon to Willow Creek) was listed on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for turbidity impairment and requires a TMDL. No previous TMDLs have been written for this assessment unit.

Pecos River (Canon de Manzanita to Alamitos Canyon) is approximately 5.7 miles in length. Four stations were established (Table 2.1, Figure 3.1) in this assessment unit during the 2001 intensive survey and two thermographs were deployed (Figure 5.1) in this assessment unit during the 2001 intensive survey and 2003 thermograph redeployments. Pecos River (Canon de Manzanita to Alamitos Canyon) was listed on the 2004-2006 Integrated §303(d)/305(b) List of Impaired Waters (NMED/SWQB 2004a) for turbidity and temperature impairments and requires a TMDL. No previous TMDLs have been written for this assessment unit. The following TMDLs were developed for this watershed:

- ***Turbidity***- Pecos River (Alamitos Canyon to Willow Creek)
- ***Temperature, turbidity***- Pecos River (Canon de Manzanita to Alamitos Canyon)

Photo 3.5 Pecos River @ Pecos National Historical Park (July 16, 2003)

4.0 TURBIDITY

During the 2001 SWQB intensive water quality survey in the Pecos Headwaters Watershed, several exceedences of the NM water quality criteria for turbidity were documented in the following assessment units:

- Cow Creek (Pecos River to Bull Creek) (20.6.4.217 NMAC)
- Cow Creek (Bull Creek to headwaters) (20.6.4.217 NMAC)
- Pecos River (Alamitos Canyon to Willow Creek) (20.6.4.217 NMAC)
- Pecos River (Canon de Manzanita to Alamitos Canyon) (20.6.4.217 NMAC)

According to the NM WQS the segment specific standard for turbidity reads:

> *20.6.4.217 NMAC: In any single sample: turbidity shall not exceed 10 NTU.*

The following subsections present the turbidity TMDLs for these assessment units.

4.1 Target Loading Capacity

Target values for this turbidity TMDL will be determined based on 1) the presence of numeric criteria, 2) the degree of experience in applying the indicator, and 3) the ability to easily monitor and produce quantifiable and reproducible results. For this TMDL document, target values for turbidity are based on numeric criteria. This TMDL is also consistent with New Mexico's antidegradation policy.

According to the New Mexico Water Quality Standards (20.6.4 NMAC), the general narrative standard for turbidity reads:

> Turbidity: Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

The total suspended solids (TSS) analytical method is a commonly used measurement of suspended material in surface water. This method was originally developed for use on wastewater samples, but has widely been used as a measure of suspended materials in stream samples because it is acceptable for regulatory purposes and is an inexpensive laboratory procedure. This analytic method does not discern between solids produced from erosional activities versus biosolids when instream samples are collected and analyzed. Since there are no WWTPs discharging into Cow Creek, it is assumed that TSS measurements in these ambient stream samples are representative of erosional activities and thus comprised primarily of suspended sediment vs. any potential biosolids from WWTP effluent. However, the Lisboa Springs Fish Hatchery discharges into the Pecos River (Alamitos Canyon to Willow Creek) and the Village of Pecos WWTP discharges into the Pecos River (Canon de Manzanita to Alamitos

Canyon). Both facilities potentially contribute biosolids as a portion of turbidity in these reaches.

Turbidity levels can be inferred from studies that monitor suspended sediment concentrations. Extrapolation from these studies is possible when a site-specific relationship between concentrations of suspended sediments and turbidity is confirmed. Activities that generate varying amounts of suspended sediment will proportionally change or affect turbidity (USEPA 1991). The impacts of suspended sediment and turbidity are well documented in the literature. An increased sediment load is often the most important adverse effect of activities on streams, according to a monitoring guidelines report (USEPA 1991). This impact is largely a mechanical action that severely reduces the available habitat for macroinvertebrates and fish species that utilize the streambed in various life stages. An increase in suspended sediment concentration will reduce the penetration of light, decreases the ability of fish or fingerlings to capture prey, and reduce primary production (USEPA 1991). Research presented by Relyea *et al* (2000) states, "increased turbidity by sediments can reduce stream primary production by reducing photosynthesis, physically abrading algae and other plants, and preventing attachment of autotrouphs to substrate surfaces."

TSS and turbidity were measured in Cow Creek and Pecos River during the 2001 survey (Tables 4.1-4.4). The TSS target was derived using a regression equation developed using measured turbidity as the independent variable and measured TSS dependent variable. The equation and regression statistics are displayed below in Figures 4.1–4.4. Correlations of r^2=0.99 and r^2=0.96 were found between TSS and turbidity for the reaches of Cow Creek. For the two Cow Creek assessment units, the exceedences on July 31 were considered outliers and were not included in the regression analysis. Increased turbidity in Cow Creek is likely due to the 2000 Viveash fire (NMED/SWQB 2001b).

A correlation of r^2=0.59 was found between TSS and turbidity for Pecos River (Alamitos Canyon to Willow Creek). This indicates that TSS is not the sole contributor to turbidity in this assessment unit. Turbidity exceedences only occurred during the spring and are likely due to snowmelt runoff.

A good correlation of r^2=0.83 exists between TSS and turbidity for Pecos River (Canon de Manzanita to Alamitos Canyon). Turbidity exceedences primarily occurred during the spring and are likely due to snowmelt runoff.

Table 4.1 TSS and turbidity data for Cow Creek (Pecos River to Bull Creek)

Sample Date	TSS (mg/L)	Turbidity (NTU)
Cow Creek -below confluence with Bull Creek @ FR 83		
5/15/01	164	133.7*
5/16/01	52	82.2*
5/17/01	66	62.7*
7/31/01	4,660	1,490.7*(a)
8/1/01	524	550*
10/9/01	8	18.7*
10/10/01	4	17.1*
10/11/01	5	22.9*

Table 4.2 TSS and turbidity data for Cow Creek (Bull Creek to headwaters)

Sample Date	TSS (mg/L)	Turbidity (NTU)
Cow Creek above confluence with Bull Creek		
3/28/01	375	301*
5/15/01	172	105.3*
5/16/01	118	119.3*
5/17/01	94	77.5*
7/31/01	3,250	1,483.5*(a)
8/1/01	610	650*
10/9/01	10	24.6*
10/10/01	7	22.6*
10/11/01	7	27.7*

(a) The turbidity data collected from both Cow Creek assessment units on July 31, 2001 were considered outliers and therefore not included in the regression analysis and TSS arithmetric mean calculations (Table 4.6).

Table 4.3 TSS and turbidity data for Pecos River (Alamitos Canyon to Willow Creek)

Sample Date	TSS (mg/L)	Turbidity (NTU)
Pecos River above Lisboa Springs fish hatchery		
5/15/01	21	11.1*
5/16/01	26	27.4*
5/17/01	21	34.2*
7/31/01	4	2.5
8/1/01	3	1
10/9/01	3	1
10/10/01	3	1
10/11/01	3	1

Sample Date	TSS (mg/L)	Turbidity (NTU)
Pecos River below Lisboa Springs fish hatchery		
5/15/01	19	7.6
5/16/01	8	21.5*
5/17/01	21	30*
10/9/01	3	1.4
10/10/01	3	1
10/11/01	3	1
Pecos River below Terrero mine		
3/28/01	3	6.24
5/15/01	15	6.7
5/16/01	12	19.2*
5/17/01	8	25*
7/31/01	3	2.4
8/1/01	3	1
10/9/01	3	1
10/10/01	3	1
10/11/01	3	1

Table 4.4 TSS and turbidity data for Pecos River (Canon de Manzanita to Alamitos Canyon)

Sample Date	TSS (mg/L)	Turbidity (NTU)
Pecos River above Village of Pecos WWTP effluent discharge		
5/15/01	47	51*
5/16/01	32	65.2*
5/17/01	25	32.1*
7/31/01	3	3.1
8/1/01	5	13.7*
10/9/01	3	0.7
10/10/01	3	0.4
Pecos River below Village of Pecos WWTP		
5/15/01	41	37.2*
5/16/01	-	62.8*
5/17/01	23	26*
7/31/01	5	3.2
8/1/01	5	4.7
10/9/01	3	1.2
10/10/01	3	2

Notes: *Exceedence of appropriate turbidity water quality criterion.
NTU = Nephelometric turbidity units

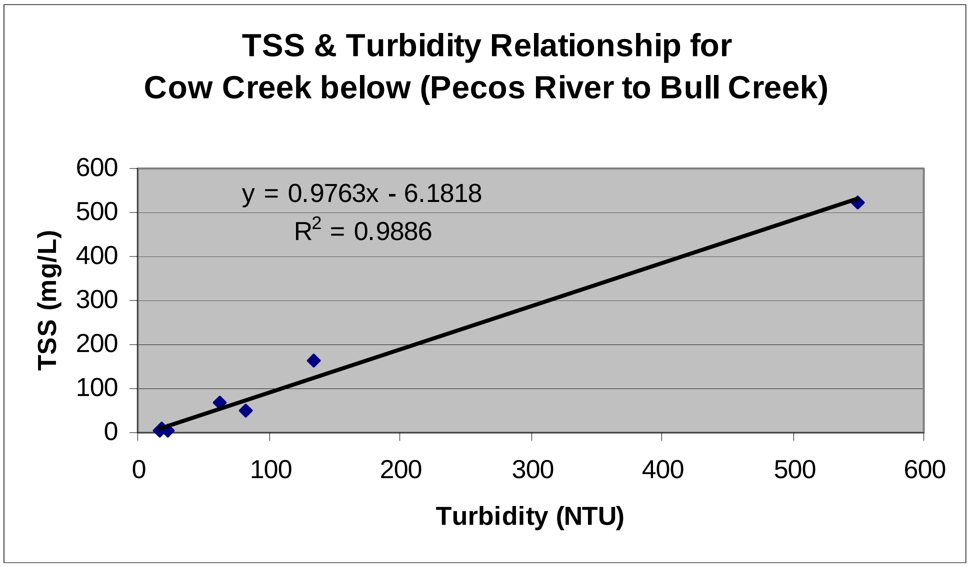


Figure 4.1 Relationship between TSS and Turbidity at Cow Creek below confluence with Bull Creek at FR 83

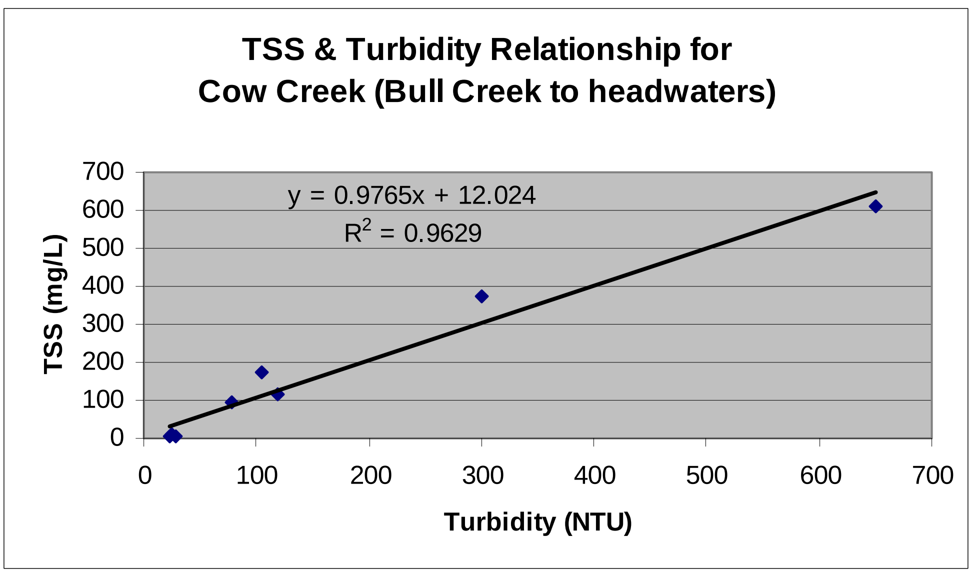


Figure 4.2 Relationship between TSS and Turbidity at Cow Creek above confluence with Bull Creek

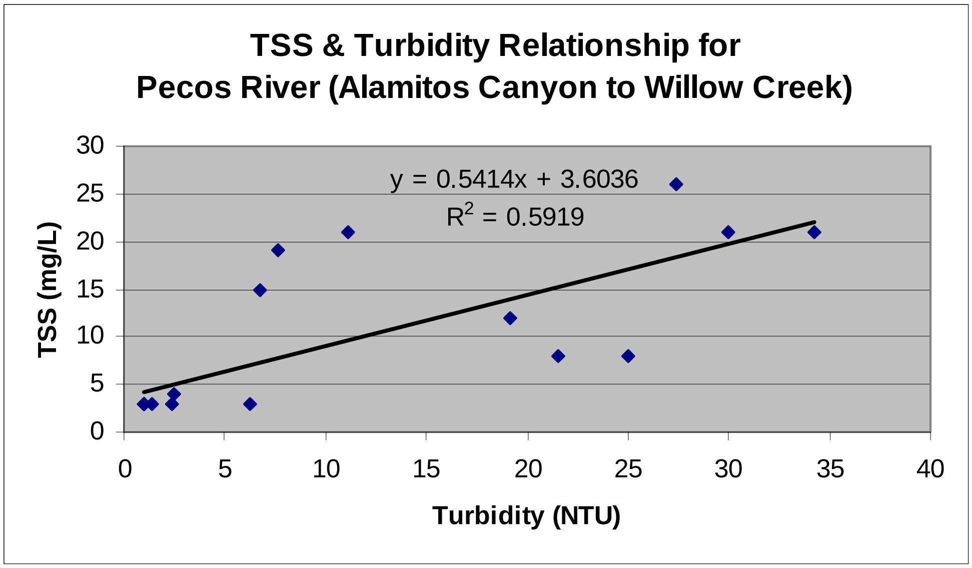


Figure 4.3 Relationship between TSS and Turbidity at Pecos River (Alamitos Canyon to Willow Creek)

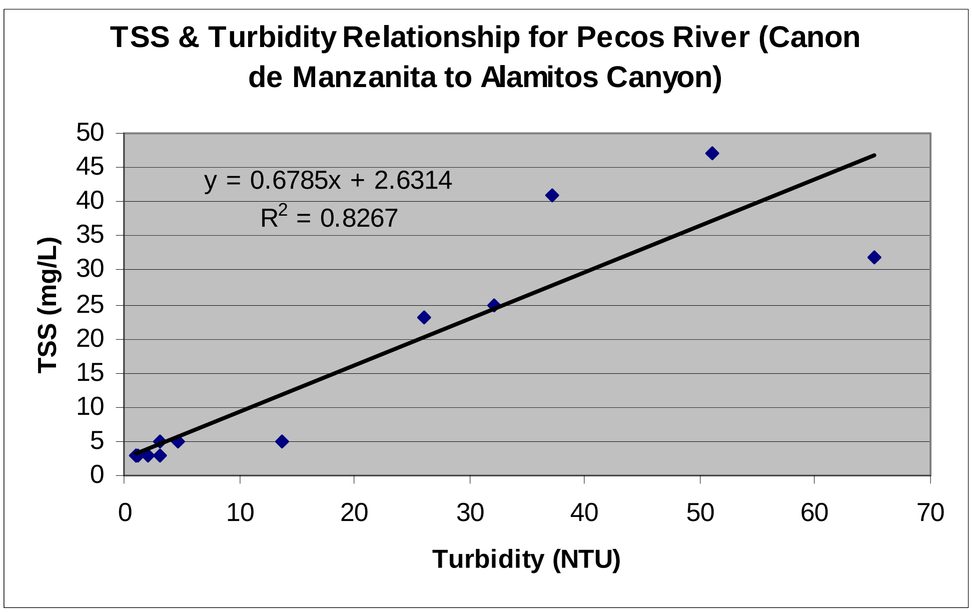


Figure 4.4 Relationship between TSS and Turbidity at Pecos River (Canon de Manzanita to Alamitos Canyon)

4.2 Flow

Sediment transport in a stream varies as a function of flow. As flow increases, the amount of sediment being transported increases. These TMDLs are calculated for each reach at specific flows. When available, USGS gages are used to estimate flow. Where gages are absent, geomorphologic cross sectional information is taken at each site and the flows are modeled. Gaged streamflow data are not available for Cow Creek. For this reach, flow was measured by SWQB during the 2001 sampling runs using standard USGS procedures (NMED/SWQB 2001a). Flows were measured at Cow Creek below the confluence with Bull Creek at Forest Road 83 on May 16, May 17, August 1, and October 10, 2001 with flows of 31.86 cfs, 34.85 cfs, 14 cfs, and 5.02 cfs respectively. Flows were measured at Cow Creek above the confluence with Bull Creek on the same dates with flows of 21.29 cfs, 24.65 cfs, 11.84 cfs, and 3.91 cfs respectively. WQS exceedences occurred frequently throughout this entire range of sampling dates, both during low and high flows. Due to the fact that there are no gages on Cow Creek, exceedences occurred in both low and high flows, and only limited flow measurements were taken, the critical flow was determined to be the average of all measured flows during the 2001 sampling year.

Gaged streamflow data are available for Pecos River (Alamitos Canyon to Willow Creek). Therefore, USGS gage data was used to determine the average flow when the turbidity water quality criterion was exceeded in the river. Exceedences were observed on 5/15/2001, 5/16/2001, and 5/17/2001 and discharge at USGS gage 08378500 (Pecos River near Pecos, NM) was recorded on these three days at 611 cfs, 621 cfs, and 605 cfs respectively, with an average discharge of 612 cfs. Since no flow measuremnt were taken at any of the three sampling sites in this assessment unit, the following equation was used to estimate flow at these locations: (Thomas et al 1997).

$$Q_u = Q_g \left(\frac{A_u}{A_g} \right)^{0.5}$$

where,

Q_u = discharge at ungaged site, cfs
Q_g = discharge at gaged site, cfs
A_u = Drainage area at the ungaged site, (square miles [mi^2])
A_g = Drainage area at the gaged site, (mi^2)

Using this equation, a flow of 566 cfs was calculated at the Pecos River below Terrero mine station and 700 cfs at the Pecos River above Lisboa Fish Hatchery station. The flow is essentially the same above and below the Hatchery as the water is diverted and not consumptively used by the Hatchery. The water is then discharged back to the Pecos River. These two flows were averaged to get a flow of 633 cfs for the Pecos River (Alamitos Canyon to Willow Creek) reach.

Similiarly, gaged streamflow data are available for Pecos River (Canon de Manzanita to Alamitos Canyon). Turbidity exceedences were observed on May 15-17 at stations both above and below the Village of Pecos WWTP and on August 1 above the WWTP. Discharge at USGS gage 08378500 (Pecos River near Pecos, NM) was recorded on May 15-17 at 611 cfs, 621 cfs, and 605 cfs respectively, and at 49 cfs on August 1. The average discharge is 472 cfs. Since no flow measuremnts were taken at the sampling sites in this assessment unit, the above equation was again used. A flow of 568.5 cfs was calculated at the Pecos River above the Village of Pecos WWTP. The Village of Pecos WWTP reported 30-day average flows for May 2001 in their discharge monitoring reports as 0.0753 mgd (0.117 cfs). Therefore, the flows above and below the WWTP are considered essentially equilvalent and the average discharge remains 568.5 cfs.

Therefore the critical flows for these TMDLs were:

- Cow Creek (Pecos River to Bull Creek) = 21.43 cfs
- Cow Creek (Bull Creek to headwaters) = 15.42 cfs
- Pecos River (Alamitos Canyon to Willow Creek) = 633 cfs
- Pecos River (Canon de Manzanita to Alamitos Canyon) = 568.5 cfs

The flow value for Cow Creek (Pecos River to Bull Creek)was converted from cfs to units of mgd as follows:

$$21.43\frac{ft^3}{\sec}\times 1{,}728\frac{in^3}{ft^3}\times 0.004329\frac{gal}{in^3}\times 86{,}400\frac{\sec}{day}\times 10^{-6} = 13.9\,mgd$$

Using the above equation, the flow value for Cow Creek (Bull Creek to headwaters) was converted from 15.42 cfs to 9.8 mgd, the flow value for the Pecos River (Alamitos Canyon to Willow Creek) was converted from 633 cfs to 409.1 mgd, and the flow value for the Pecos River (Canon de Manzanita to Alamitos Canyon) was converted from 568.5 cfs to 367.4 mgd.

4.3 Calculations

Target loads for turbidity (expressed as TSS) are calculated based on a flow, the current water quality standards, and a conversion factor (8.34) that is a used to convert mg/L units to lbs/day (see Appendix A for Conversion Factor Derivation). The target loading capacity is calculated using **Equation 2**. The results are shown in Table 4.5.

Critical Flow (mgd) x Standard (mg/L) x 8.34 = Target Loading Capacity (Eq. 2)

Table 4.5 Calculation of target loads for turbidity (expressed as TSS)

Location	Flow (mgd)	TSS (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
Cow Creek (Pecos River to Bull Creek)	13.9	3.58+	8.34	415
Cow Creek (Bull Creek to headwaters)	9.8	13.00*	8.34	1,063
Pecos River (Alamitos Canyon to Willow Creek)	409.1	9.02++	8.34	30,775
Pecos River (Canon de Manzanita to Alamitos Canyon)	367.4	9.42**	8.34	28,864

Notes:
+ The TSS value was calculated using the relationship established between TSS and turbidity in Figure 4.1 (y=0.9763x - 6.1818, R^2=0.99) using the turbidity standard of 10 NTU for the X variable.
*The TSS value was calculated using the relationship established between TSS and turbidity in Figure 4.2 (y=0.9765x + 12.024, R^2=0.96) using the turbidity standard of 10 NTU for the X variable.
++The TSS value was calculated using the relationship established between TSS and turbidity in Figure 4.3 (y=0.5414x+ 3.6036, R^2=0.59) using the turbidity standard of 10 NTU for the X variable.
** The TSS value was calculated using the relationship established between TSS and turbidity in Figure 4.4 (y=0.6785x+ 2.6314, R^2=0.83) using the turbidity standard of 10 NTU for the X variable.

It is important to remember that 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 should be a goal to be attained. Meeting the calculated TMDL may be a difficult objective.

The measured loads for turbidity (expressed as TSS) were similarly calculated. In order to achieve comparability between the target and measured loads, the flows used were the same for both calculations. The arithmetic mean of corresponding TSS values when turbidity exceeded the standard was substituted for the standard in **Equation 2**. The same conversion factor of 8.34 was used. Results are presented in Table 4.6.

Table 4.6 Calculation of measured loads for turbidity (expressed as TSS)

Location	Flow (mgd)	TSS Arithmetic Mean* (mg/L)	Conversion Factor	Measured Load Capacity (lbs/day)
Cow Creek (Pecos River to Bull Creek)	13.9	117.57	8.34	13,629
Cow Creek (Bull Creek to headwaters)	9.8	174.13	8.34	14,232
Pecos River (Alamitos Canyon to Willow Creek)	409.1	8.43	8.34	28,762
Pecos River (Canon de Manzanita to Alamitos Canyon)	367.4	15.23	8.34	46,666

Notes: *Arithmetic mean of TSS values for the Cow Creek assessment units does not included the outlier data collected on July 31, 2001(see Tables 4.1 and 4.2).

4.4 Waste Load Allocations and Load Allocations

4.4.1 Waste Load Allocation

There are no individually permitted point source facilities on Cow Creek. However, both Pecos River (Alamitos Canyon to Willow Creek) and Pecos River (Canon de Manzanita to Alamitos Canyon) have permitted point source facilites. The Lisboa Springs Fish Hatchery discharges into the Pecos River (Alamitos Canyon to Willow Creek). The NPDES permit (Permit No. NM 0030121) for Lisboa Springs Fish Hatchery has total suspended solids (TSS) limits of 15 mg/L (daily maximum) and a 30-day average of 10 mg/L (480 lbs/day). The design flow is 5.76 mgd. The waste load allocation is 721 lbs/day (5.76 mgd design flow x 15 mg/L TSS daily max x 8.34 conversion factor). The daily maximum of 15 mg/L was used to calculate the WLA. This limit will allow the TMDL to be met under both low flow and high flow conditions. Limitations on TSS are in accordance with EPA Best Available Technology Economically Feasible for the animal aquaculture industry.

Also, the Village of Pecos WWTP discharges into the Pecos River (Canon de Manzanita to Alamitos Canyon). The NPDES permit (Permit No. NM 0029041) has TSS limits of 135 mg/L (7-day average) and a 30-day average of 90 mg/L (107 lbs/day) that are based on secondary treatment as defined by 40 CFR part 133. The design flow is 0.142 mgd. The waste load allocation is 160 lbs/day (0.142 mgd design flow x 135 mg/L TSS daily maximum x 8.34 conversion factor). The 7-day average of 135 mg/L was used to calculate the WLA. This limit will allow the TMDL to be met under both low flow and high flow conditions.

There are no MS4 storm water permits in these assessment units. Turbidity may be a component of some (primarily construction) storm water discharges that contribute to suspended sediment impacts, and should be addressed.

In contrast to discharges from other industrial storm water and individual process wastewater permitted facilities, storm water discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the National Pollutant Discharge Elimination System (NPDES) construction general storm water permit (CGP) 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. In addition, the current CGP also includes state specific requirements to implement best management practices (BMPs) that are designed to prevent to the maximum extent practicable, an increase in sediment, or a parameter that addresses sediment (e.g., total suspended solids, turbidity, siltation, stream bottom deposits, etc.) and flow velocity during and after construction compared to pre-construction conditions. In this case, compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Other industrial storm water facilities are generally covered under the current NPDES Multi Sector General Storm Water Permit (MSGP). This permit also requires preparation of an SWPPP that includes identification and control of all pollutants associated with the industrial activities to minimize impacts to water quality. In addition, the current MSGP also includes state specific requirements to further limit (or eliminate) pollutant loading to water quality impaired/water quality limited waters from facilities where there is a reasonable potential to contain pollutants for which the receiving water is impaired. In this case, compliance with a SWPPP that meets the requirements of the MSGP is generally assumed to be consistent with this TMDL.

Individual WLAs for any General Permits were not possible to calculate at this time in this watershed using available tools. Loads that are in compliance with the General Permits from facilities covered are therefore currently calculated as part on the watershed load allocation.

4.4.2 Load Allocation

In order to calculate the LA, the WLA and MOS were subtracted from the target capacity (TMDL) following **Equation 2**.

$$WLA + LA + MOS = TMDL \qquad \text{(Eq. 2)}$$

The MOS is estimated to be 25% of the target load calculated in Table 4.5. Results are presented in Table 4.7. Additional details on the MOS chosen are presented in Section 4.7 below.

Table 4.7 Calculation of TMDL for turbidity

Location	WLA (lbs/day)	LA (lbs/day)	MOS (25%) (lbs/day)	TMDL (lbs/day)
Cow Creek (Pecos River to Bull Creek)	0	311	104	415
Cow Creek (Bull Creek to headwaters)	0	795	268	1,063
Pecos River (Alamitos Canyon to Willow Creek)	721	22,360	7,694	30,775
Pecos River (Canon de Manzanita to Alamitos Canyon)	160	21,488	7,216	28,864

The extensive data collection and analyses necessary to determine background turbidity loads for the Cow Creek and Pecos River watersheds was 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 NPS and background load reductions that would be necessary to meet the target loads were calculated to be the difference between the target load allocation (Table 4.7) and the measured load (Table 4.6), and are shown in Table 4.8.

Table 4.8 Calculation of load reduction for turbidity (expressed as TSS)

Location	LA (lbs/day)	Measured Load (lbs/day)	Load Reduction (lb/day)
Cow Creek (Pecos River to Bull Creek)	311	13,629	13,318
Cow Creek (Bull Creek to headwaters)	795	14,232	13,437
Pecos River (Alamitos Canyon to Willow Creek)	22,360	28,762	6,402
Pecos River (Canon de Manzanita to Alamitos Canyon)	21,488	46,666	25,178

4.5 Identification and Description of pollutant source(s)

Pollutant sources that could contribute to each segment are listed in Tables 4.9 and 4.10.

Table 4.9 Pollutant source summary for turbidity on Cow Creek

Pollutant Sources	**Magnitude (lbs/day)**	**Location**	**Potential Sources** (% from each)
Point: None	0	--------	0%
Nonpoint: Turbidity (expressed as TSS in lbs/day)	15,679	Cow Creek (Pecos River to Bull Creek)	100% Agriculture, rangeland, removal of riparian vegetation, streambank modification or destabilization, natural causes
	12,955	Cow Creek (Bull Creek to headwaters)	100% Agriculture, rangeland, removal of riparian vegetation, streambank modification or destabilization, natural causes

Table 4.10 Pollutant source summary for turbidity on Pecos River

Pollutant Sources	**Magnitude (lbs/day)**	**Location**	**Potential Sources** (% from each)
Point: NPDES facilities	721	Pecos River (Alamitos Canyon to Willow Creek)	<1% Lisboa Springs Fish Hatchery
	160	Pecos River (Canon de Manzanita to Alamitos)	<1% Village of Pecos WWTP
Nonpoint: Turbidity (expressed as TSS in lbs/day)	28,041*	Pecos River (Alamitos Canyon to Willow Creek)	99% Natural sources
	46,506*	Pecos River (Canon de Manzanita to Alamitos)	99% Agriculture, pastureland, rangeland, removal of riparian vegetation, and streambank modification or destabilization

*Measured load minues WLA

4.6 Linkage of Water Quality and Pollutant Sources

Turbidity is an expression of the optical property in water that causes incident light to be scattered or absorbed rather than transmitted in straight lines. It is the condition resulting from suspended solids in the water, including silts, clays, and plankton. Such particles absorb heat in the sunlight, thus raising water temperature, which in turn lowers dissolved oxygen levels. It also prevents sunlight from reaching plants below the surface. This decreases the rate of photosynthesis, so less oxygen is produced by plants. Turbidity may harm fish and their larvae. Turbidity exceedences, historically, are generally attributable to soil erosion, excess nutrients, various wastes and pollutants, and the stirring of sediments up into the water column during high flow events. Turbidity increases, as observed in SWQB monitoring data, show turbidity values along these reaches that exceed the State Standards for the protection of aquatic habitat, High Quality Coldwater Fishery (HQCWF) designed uses. Through monitoring, and pollutant source documentation, it has been observed that the most probable cause for these exceedences are due to the alteration of the stream's hydrograph and natural causes. Alterations can be historical or current in nature.

The components of a watershed continually change through natural ecological processes such as vegetation succession, erosion, and evolution of stream channels. Intrusive human activity often affects watershed function in ways that are inconsistent with the natural balance. These changes, often rapid and sometimes irreversible, occur when people:

- cut forests
- clear and cultivate land
- remove stream-side vegetation
- alter the drainage of the land
- channelize watercourses
- withdraw water for irrigation
- build towns and cities
- discharge pollutants into waterways.

Possible effects of these practices on aquatic ecosystems include:

1. Increased amount of sediment carried into water by soil erosion which may

    - increase turbidity of the water
    - reduce transmission of sunlight needed for photosynthesis
    - interfere with animal behaviors dependent on sight (foraging, mating, and escape from predators)
    - impede respiration (e.g., by gill abrasion in fish) and digestion
    - reduce oxygen in the water
    - cover bottom gravel and degrade spawning habitat cover eggs, which may suffocate or develop abnormally; fry may be unable to emerge from the buried gravel bed

2. Clearing of trees and shrubs from shorelines which may

- destabilize banks and promote erosion
- increase sedimentation and turbidity
- reduce shade and increase water temperature which could disrupt fish metabolism
- cause channels to widen and become more shallow

3. Land clearing, constructing drainage ditches, straightening natural water channels which may

    - create an obstacle to upstream movement of fish and suspend more sediment in the water due to increased flow
    - strand fish upstream and dry out recently spawned eggs due to subsequent low flows
    - reduce baseflows

Where data gaps exist or the level of uncertainty in the characterization of sources is large, the recommended approach to TMDL assignments requires the development of allocations based on estimates utilizing the best available information.

SWQB fieldwork includes an assessment of the potential sources of impairment (NMED/SWQB 1999). The completed *Pollutant Source(s) Documentation Protocol* forms in **Appendix B** provide documentation of a visual analysis of probable sources along an impaired reach. Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of potential sources of impairment in this watershed. Staff completing these forms identify and quantify potential sources of NPS impairments along each reach as determined by field reconnaissance and assessment. It is important to consider not only the land directly adjacent to the stream but also to consider upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

The main sources of impairment along both reaches of Cow Creek appear to be from natural sources, such as the 2000 Viveash fire (NMED/SWQB 2001b), disturbances from agriculture and grazing, streambank modifications, and the removal of riparian vegetation.

The main sources of impairment to the Pecos River (Alamitos Canyon to Willow Creek) appear to be a combination of natural and point source contributions. Turbidity exceedences during the 2001 survey only occurred in the spring and were likely due to snowmelt runoff. However, New Mexico Department of Game and Fish (NMG&F) Lisboa Springs Fish Hatchery discharges solids, stagnant water, algae, scum, debris, and other waste material daily from the surface of the main settling pond (NMED/SWQB 2004e). This pond and two other settling ponds are periodically cleaned out by discharging into the Pecos River. Discharges from the settling ponds at the Lisboa Hatchery are likely to contribute to turbidity levels within this impaired reach of the Pecos River (NMED/SWQB 2004e). Although the Hatchery was closed in 1999 due to whirling disease and reopened in March 2003, it seems the Hatchery has the potential to be a contributor of biosolids to this system.

The main sources of impairment to the Pecos River (Canon de Manzanita to Alamitos Canyon) appear to be a combination of both point and nonpoint source contributions. Turbidity exceedences during the 2001 survey occurred primarily in the spring and were likely due to snowmelt runoff. However, the Village of Pecos WWTP discharges into this reach of the Pecos River. Since 1998, TSS exceedences of the effluent limits have been reported by the WWTP (NMED/SWQB 2002). During a 2002 inspection, the effluent was a turbid, cloudy green color and the river substrate was coated with solids, silt, and had a coating of algal growth (NMED/SWQB 2002). Additionally, a small amount of foam and floating solids were noted in the effluent (NMED/SWQB 2002). The Village of Pecos WWTP does have the potential to increase TSS loads in the Pecos River, although there is some debate as to the level at which TSS discharged from WWTP directly contributes to turbidity impairment. The TSS contribution from the WWTP is minimal compared to the non-point source contribution (0.18% and 99.8% respectively).

There are TSS limitation and monitoring requirement in the approved NPDES permits along with a re-opener clause, which will be utilized if changes to the TMDL or WQS will result in changes to the conditions of the permits. Any elevated levels of TSS beyond the permitted limits for the effluents are considered a violation of the permit, and are subject to enforcement action.

4.7 Margin of Safety (MOS)

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and NPS load estimates, and the modeling analysis. For the Cow Creek TMDLs, there will be no MOS for point sources since there are none in either assessment unit. However, for the NPS in all of the TMDLs, the MOS is estimated to be an addition of **25%** of the TMDL. This MOS incorporates several factors:

- Errors in calculating NPS loads

  A level of uncertainty does exist in the relationship between TSS and turbidity. In this case, the TSS measure does not include bedload and therefore does not account for a complete measure of sediment load. This does not influence the MOS because we need only be concerned with the turbidity portion of the sediment load, which is the basis for the standard. However, there is a potential to have errors in measurements of NPS loads due to equipment accuracy, time of sampling, etc. Accordingly, a conservative MOS increases the TMDL by **15%**.

- Errors in calculating flow

  Flow estimates were based on USGS gages and field measurements on each of the reaches. There is a potential to have errors in measurements of flow due to equipment accuracy, time of sampling, etc. To be conservative, an additional MOS of **10%** will be included to account for accuracy of flow computations.

The MOS for the point sources in the Pecos River TMDLs is implicit because permitted flows were used to calculate the waste loads.

4.8 Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during spring, summer, and fall in order to ensure coverage of any potential seasonal variation in the system. Critical condtions were estimated to be the average flow during exceedences and only data that exceeded the water quality criterion were used in determining the target capacities. Therefore, it is assumed that if critical conditions are met, coverage of any potential seasonal variation will also be met.

4.9 Future Growth

Estimations of future growth are not anticipated to lead to a significant increase for turbidity that cannot be controlled with best management practice implementation in this watershed

5.0 TEMPERATURE

Monitoring for temperature was conducted in 2001. Follow-up monitoring for temperature was conducted in 2003. Based on available data, several exceedences of the NM WQS for temperature were noted throughout the watershed (Figure 5.1). Thermographs were set to record once every hour (occasionally a thermograph was set to record once every 15 minutes) for several months during the warmest time of the year (generally June through September). Thermograph data are assessed using Appendix C of the *State of New Mexico Procedures for Assessing Standards Attainment for the Integrated §303(d)/§305(b) Water Quality Monitoring and Assessment Report* (NMED/SWQB 2004b). Based on 2001 data, Bull Creek (Cow Creek to headwaters), Cow Creek (Pecos River to Bull Creek), Cow Creek (Bull Creek to headwaters), Gallinas River (Las Vegas Diversion to headwaters), and Pecos River (Canon de Manzanita to Alamitos Canyon) were included on the 2002-2004 CWA §303(d) list for temperature. Temperature data from 2001 and 2003 were used to develop TMDLs.

5.1 Target Loading Capacity

Target values for these temperature TMDLs will be determined based on 1) the presence of numeric criteria, 2) the degree of experience in applying the indicator, and 3) the ability to easily monitor and produce quantifiable and reproducible results. For this TMDL document, target values for temperature are based on the reduction in solar radiation necessary to achieve numeric criteria as predicted by a temperature model. This TMDL is also consistent with New Mexico's antidegradation policy.

The NM WQCC has adopted numeric water quality criteria for temperature to protect the designated use of HQCWF (20.6.4.900.C NMAC). These WQS have been set at a level to protect cold-water aquatic life such as trout. The HQCWF use designation requires that a stream reach must have water quality, streambed characteristics, and other attributes of habitat sufficient to protect and maintain a propagating coldwater fishery (i.e., a population of reproducing salmonids). The primary standard leading to an assessment of use impairment is the numeric criterion for temperature of 20 °C (68°F). The following TMDLs address the following reaches where temperatures exceeded the criterion (**Appendix C** of this document provides a graphical representation of thermograph data):

Bull Creek (Cow Creek to headwaters): One thermograph was deployed on this reach in 2001 at thermograph site 1. Recorded temperatures from June 12 (12:51) through November 5, 2001 exceeded the HQCWF criterion 350 of 3,504 times (10%) with a maximum temperature of 26.56°C. There were no thermograph deployments in 2003.

Cow Creek (Pecos River to Bull Creek): One thermograph was deployed on this reach in 2001 at thermograph site 4. Recorded temperatures from July 11 (18:52) through October 10, 2001 exceeded the HQCWF criterion 1044 of 8,254 times (13%) with a maximum temperature of 27.15°C. In 2003, two thermographs were deployed in Cow Creek below Bull Creek for verification and model calibration purposes. One thermograph was deployed in Cow Creek at North San Ysidro (site 3), recorded temperatures from July 16 (16:37) through September 29, 2003 exceeded the HQCWF criterion 344 of 1797 times (19%) with a maximum temperature of 27.43°C. Another thermograph was deployed in Cow Creek near Lower Colonias (site 4), recorded temperatures from July 16 (16:44) through September 29, 2003 exceeded the HQCWF criterion 376 of 1799 times (21%) with a maximum temperature of 29.09°C.

Cow Creek (Bull Creek to headwaters):-- One thermograph was deployed on this reach in 2001 at themograph site 2. Recorded temperatures from June 12 (11:50) through November 5, 2001 exceeded the HQCWF criterion 285 of 3505 times (8%) with a maximum temperature of 26.31°C. In 2003, a thermograph was deployed on Cow Creek at the FR 82 bridge (site 2) on July 17, 2003. However, the streambank collapsed and the thermograph is currently inaccessible. No data was retrieved from this 2003 thermograph.

Gallinas River (Las Vegas Diversion to headwaters):-- In 2001, grab data at three stations (2, 24, 25) on the Gallinas River indicated 2 of 24 temperature exceedences with a maximum temperature of 22.4°C. A thermograph deployed in the Gallinas River at the end of FR 263 in 2001 indicated 0 exceedences of the criterion. In 2003, one thermograph was deployed in Gallinas River at the Forest Service boundary (site 5) for verification and model calibration purposes. Recorded temperatures from July 16 (16:37) through September 29, 2003 exceeded the HQCWF criterion 250 of 1795 times (14%) with a maximum temperature of 30.4°C. Also in 2003, one thermograph was deployed in Gallinas River at the USGS gage above the Las Vegas diversion (site 6), recorded temperatures from July 16 (16:30) through September 29, 2003 exceeded the HQCWF criterion 461 of 1794 times (26%) with a maximum temperatue of 28.1°C.

Pecos River (Canon de Manzanita to Alamitos Canyon): In 2001, one thermograph was deployed on this reach at thermograph site 7. Recorded temperatures from June 12 (14:52) through November 5, 2001 exceeded the HQCWF criterion 295 of 3503 times (8%) with a maximum temperature of 24.86°C. In 2003, one thermograph was deployed in Pecos River near the Pecos National Historical Park (site 7) for verification and model calibration purposes. Recorded temperatures from July 17 (10:15) through September 29, 2003 exceeded the HQCWF criterion 286 of 1779 times (16%) with a maximum temperature of 26.6°C.

Table 5.1 Pecos Headwaters Thermograph Sites

Site Number	Site Name	Deployment Date
1	Bull Creek above confluence with Cow Creek	2001
2	Cow Creek above confluence with Bull Creek	2001
3	Cow Creek at North San Ysidro	2003
4	Cow Creek near Lower Colonias	2001, 2003
5	Gallinas R. at National Forest boundary	2003
6	Gallinas River at Montezuma, USGS Gage 08380500	2003
7	Pecos River @ Pecos National Historical Park	2001,2003

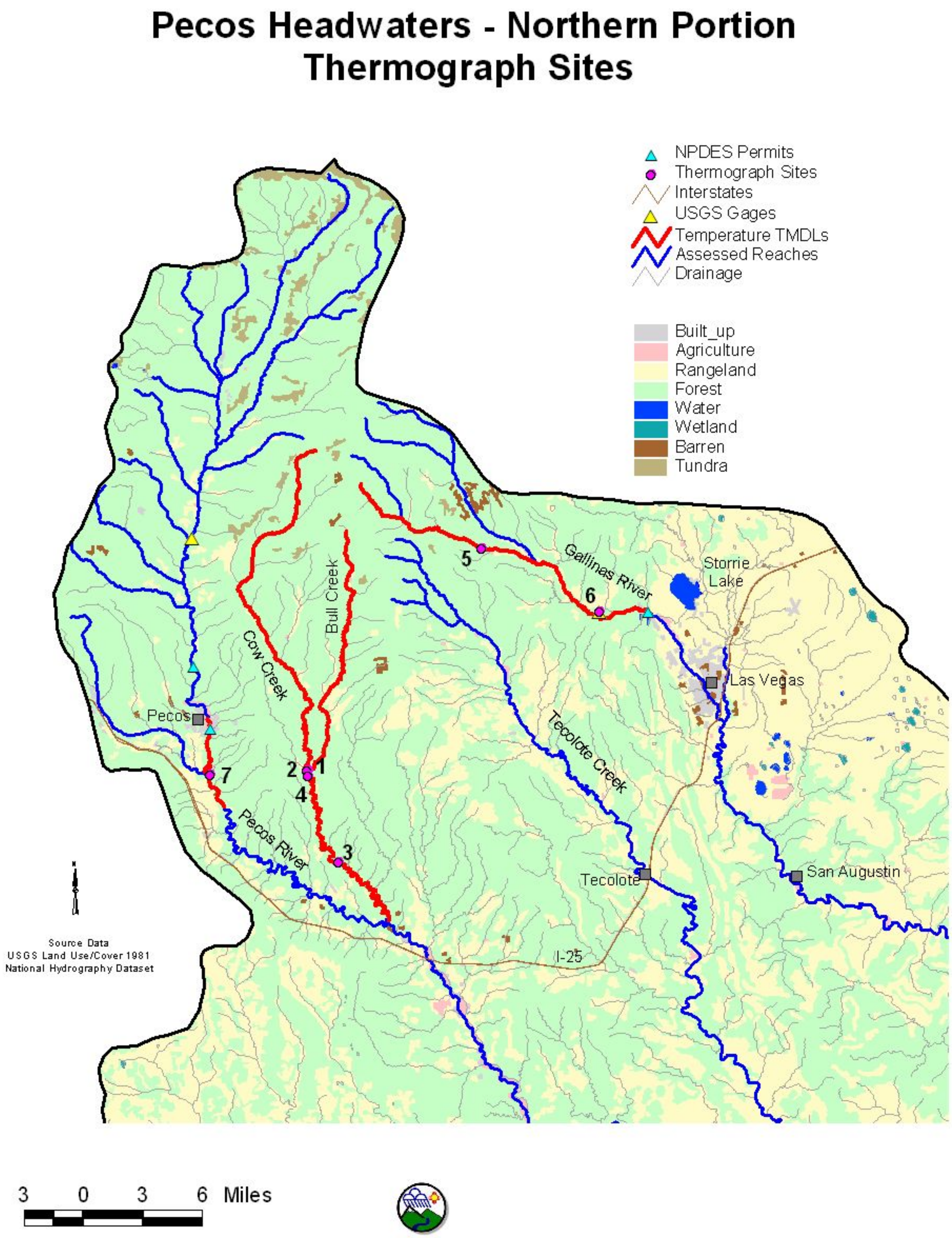


Figure 5.1 Pecos Headwaters Thermograph sites

5.2 Calculations

The Stream Segment Temperature (SSTEMP) Model, Version 2.0 (Bartholow 2002) was used to predict stream temperatures based on watershed geometry, hydrology, and meteorology. This model was developed by the USGS Biological Resource Division (Bartholow 2002). 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 (Bartholow 2002). The predicted temperature values are compared to actual thermograph readings measured in the field in order to calibrate the model. The SSTEMP model identifies current stream and/or watershed characteristics that control stream temperatures. The model also quantifies the maximum loading capacity of the stream to meet water quality criteria for temperature. This model is important for estimating the effect of changing controls or factors (such as riparian grazing, stream channel alteration, and reduced streamflow) on stream temperature. The model can also be used to help identify possible implementation activities to improve stream temperature by targeting those factors causing impairment to the stream.

5.3 Waste Load Allocations and Load Allocations

5.3.1 Waste Load Allocation

With the exception of Gallinas River (Las Vegas Diversion to headwaters) and Pecos River (Canon de Manzanita to Alamitos Canyon), there are no point source contributions associated with these TMDLs.

The Las Vegas WTP (NPDES permit NM 0030341) discharges into assessment unit Gallinas River (Las Vegas Diversion to headwaters). The permit is a "no discharge" permit, but, if under emergency conditions the facility must discharge backwash and filter-to-waste water, the discharge must be monitored. The NPDES permit does not have limitations or monitoring requirements for temperature. Data indicate that the WTP is not contributing to elevated temperature in the Gallinas River. Field temperatures taken during the 2001 sampling season (May 29-October 18) at SWQB sites 2 and 24 show no exceedences of the WQS. At site 25, field temperatures taken during the same sampling season indicate 1 of 8 temperature exceedences with a maximum temperature of 20.33 ºC. Therefore, the WLA for this reach is zero.

The Village of Pecos WWTP (NPDES permit NM 0029041) discharges into assessment unit Pecos River (Canon de Manzanita to Alamitos Canyon). The NPDES permit does not have limitations or monitoring requirements for temperature. WWTP effluent has never been noted to be a significant source contributor of temperature impairment. Data indicate that the WWTP is not contributing to elevated temperature in the Pecos River. Field temperatures taken during the 2001 sampling season (May 15-November 1) at site 43 (above WWTP) and 54 (below WWTP) indicate no WQS exceedences. At site 64 (Village of Pecos WWTP), field measurements of the WWTP effluent taken during the same sampling season indicated 4 of 7 temperature exceedences with a maximum temperature of 23.83 ºC. It seems that, although the effluent has a slightly elevated temperature, the reach itself does not experience any long-term effects since the station below the treatment plant shows no exceedences. Therefore, the WLA in this reach is zero.

5.3.2 Load Allocation

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 ($j/m^2/s$) and Langley's per day. The following information relevant to the model runs used to determine temperature TMDLs is taken from the SSTEMP documentation (Bartholow 2002). Please refer to the SSTEMP User's Manual for complete text. Various notes have been added below in brackets to clarify local sources of input data.

Description of Logic:
In general terms, SSTEMP calculates the heat gained or lost from a parcel of water as it passes through a stream segment. This is accomplished by simulating the various heat flux processes that determine that temperature change. . . These physical processes include convection, conduction, evaporation, as well as heat to or from the air (long wave radiation), direct solar radiation (short wave), and radiation back from the water. SSTEMP first calculates the solar radiation and how much is intercepted by (optional) shading. This is followed by calculations of the remaining heat flux components for the stream segment. The details are just that: To calculate solar radiation, SSTEMP computes the radiation at the outer edge of the earth's atmosphere. This radiation is passed through the attenuating effects of the atmosphere and finally reflects off the water's surface depending on the angle of the sun. For shading, SSTEMP computes the day length for the level plain case, i.e., as if there were no local topographic influence. Next, sunrise and sunset times are computed by factoring in local east and west-side topography. Thus, the local topography results in a percentage decrease in the level plain daylight hours. From this local sunrise/sunset, the program computes the percentage of light that is filtered out by the riparian vegetation. This filtering is the result of the size, position and density of the shadow-casting vegetation on both sides of the stream. . .

HYDROLOGY VARIABLES

. . . 1. Segment Inflow (cfs or cms [cubic meters per second]) -- Enter the mean daily flow at the top of the stream segment. If the segment begins at an effective headwater, the flow may be entered as zero so that all accumulated flow will accrue from accretions, both surface water and groundwater. If the segment begins at a reservoir, the flow will be the outflow from that reservoir. Remember that this model assumes steady-state flow conditions.

If the inflow to the segment is the result of mixing two streams, you may use the mixing equation to compute the combined temperature:

$$T_j = \frac{(Q_1 \times T_1) + (Q_2 \times T_2)}{Q_1 + Q_2}$$

where

T_j = Temperature below the junction
Q_n = Discharge of source n
T_n = Temperature of source n

2. Inflow Temperature (°F or °C) -- Enter the mean daily water temperature at the top of the segment. If the segment begins at a true headwater, you may enter any water temperature, because zero flow has zero heat. If there is a reservoir at the inflow, use the reservoir release temperature. Otherwise, use the outflow from the next upstream segment.

3. Segment Outflow (cfs or cms) -- The program calculates the lateral discharge accretion rate by knowing the flow at the head and tail of the segment, subtracting to obtain the net difference, and dividing by segment length. The program assumes that lateral inflow (or outflow) is uniformly apportioned through the length of the segment. If any "major" tributaries enter the segment, you should divide the segment into two or more subsections. "Major" is defined as any stream contributing greater than 10% of the mainstem flow, particularly if there are major discontinuities in stream temperature.

[NOTE: To be conservative, 4Q3 low flow values were used as the segment outflow. These critical low flows were used to decrease assimilative capacity of the stream to adsorb and disperse solar energy. See **Appendix D** for calculations.]

4. Accretion Temperature (°F or °C) -- 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. You can verify this by checking United States Geological Survey (USGS) well log temperatures. Exceptions may arise in areas of geothermal activity. If irrigation return flow makes up most of the lateral flow, it may be warmer than mean annual air temperature. Return flow may be approximated by equilibrium temperatures.

GEOMETRY VARIABLES

. . . 1. Latitude (decimal degrees or radians) -- Latitude refers to the position of the stream segment on the earth's surface. It may be read off of any standard topographic map.

[NOTE: Latitude is generally determined in the field with a global positioning system (GPS) unit.]

2. Dam at Head of Segment (checked or unchecked) -- If there is a dam at the upstream end of the segment with a constant, or nearly constant diel release temperature, check the box, otherwise leave it unchecked . . . Maximum daily water temperature is calculated by following a water parcel from solar noon to the end of the segment, allowing it to heat towards the maximum equilibrium temperature. If there is an upstream dam within a half-day's travel time from the end of the segment, a parcel of water should only be allowed to heat for a shorter time/distance. By telling SSTEMP that there is a dam at the top, it will know to heat the water only from the dam downstream. . . Just to confuse the issue, be aware that if there is no dam SSTEMP will assume that the stream segment’s meterology and geometry also apply upstream from that point a half-day’s travel time from the end of the segment. If conditions are vastly different upstream, this is one reason that the maximum temperature estimate can be inaccurate.

3. Segment Length (miles or kilometers) -- Enter the length of the segment for which you want to predict the outflowing temperature. Remember that all variables will be assumed to remain constant for the entire segment. Length may be estimated from a topographic map, but a true measurement is best.

[NOTE: Segment length is determined with National Hydrographic Dataset Reach Indexing Geographic Information System (GIS) tool.]

4. Upstream Elevation (feet or meters) -- Enter elevation as taken from a 7 ½ minute quadrangle map.

[NOTE: Upstream elevation is generally determined in the field with a GPS unit or GIS tool.]

5. Downstream Elevation (feet or meters) -- Enter elevation as taken from a 7 ½ minute quadrangle map. Do not enter a downstream elevation that is higher than the upstream elevation. . .

[NOTE: Downstream elevation is generally determined in the field with a GPS unit or GIS tool.]

6. Width's A Term (seconds/foot^2 or seconds/meter^2) -- This parameter may be derived by calculating the wetted width-discharge relationship. . . To conceptualize this, plot the width of the segment on the Y-axis and discharge on the X-axis of log-log paper. . . The relationship should approximate a straight line, the slope of which is the B term (the next variable). Theoretically, the A term is the untransformed Y-intercept. However, the width vs. discharge relationship tends to break down at very low flows. Thus, it is best to calculate B as the slope and then solve for A in the equation:

$$W = A * Q^B$$

where Q is a known discharge
W is a known width
B is the power relationship

Regression analysis also may be used to develop this relationship. First transform the flow to natural log (flow) and width to natural log (width). Log (width) will be the dependent variable. The resulting X coefficient will be the B term and the (non-zero) constant will be the A term when exponentiated. That is:

A = e^constant from regression

where ^ represents exponentiation

As you can see from the width equation, width equals A if B is zero. Thus, substitution of the stream's actual wetted width for the A term will result if the B term is equal to zero. This is satisfactory if you will not be varying the flow, and thus the stream width, very much in your simulations. If, however, you will be changing the flow by a factor of 10 or so, you should go to the trouble of calculating the A and B terms more precisely. Width can be a sensitive factor under many circumstances.

[NOTE: After Width's B Term is determined (see note below), Width's A Term is calculated as displayed above.]

7. Width's B Term (essentially dimensionless) -- From the above discussion, you can see how to calculate the B term from the log-log plot. This plot may be in either English or international units. The B term is calculated by linear measurements from this plot. Leopold et al. (1964, p.244) report a variety of B values from around the world. A good default in the absence of anything better is 0.20; you may then calculate A if you know the width at a particular flow.

[NOTE: Width's B Term is calculated at the slope of the regression of the natural log of width and the natural log of flow. Width vs. flow data sets are determined by entering cross-section field data into WINXSPRO (USDA 1998). See **Appendix D** for details.]

8. Manning's n or Travel Time (seconds/mile or seconds/kilometer) -- Manning's n is an empirical measure of the segment's "roughness. . ." A generally acceptable default value is 0.035. This parameter is necessary only if you are interested in predicting the minimum and maximum daily fluctuation in temperatures. It is not used in the prediction of the mean daily water temperature.

[NOTE: Rosgen stream type is also taken into account when estimating Manning's n (Rosgen 1996).]

TIME OF YEAR

Month/Day (mm/dd) -- Enter the number of the month and day to be modeled. January is month 1, etc. This program's output is for a single day. To compute an average value for a longer period (up to one month), simply use the middle day of that period, e.g., July 15. The error encountered in so doing will usually be minimal. Note that any month in SSTEMP can contain 31 days.

METEOROLOGICAL PARAMETERS

1. Air Temperature (°F or °C) -- Enter the mean daily air temperature. This information may of course be measured (in the shade), and should be for truly accurate results; however, this and the other (following) meteorological parameters may come from the Local Climatological Data (LCD) reports which can be obtained from the National Oceanic and Atmospheric Administration for a weather station near your site. The LCD Annual Summary contains monthly values, whereas the Monthly Summary contains daily values. The Internet is another obvious source of data today. If only scooping-level analyses are required, you may refer to sources of general meterology for the United States, such as USDA (1941) or USDC (1968).

Use the adiabatic lapse rate to correct for elevational differences from the met station:

$$Ta = To + Ct * (Z - Zo)$$

where Ta = air temperature at elevation E (°C)
To = air temperature at elevation Eo (°C)
Z = mean elevation of segment (m)
Zo = elevation of station (m)
Ct = moist-air adiabatic lapse rate (-0.00656 °C/m)

NOTE: Air temperature will usually be the single most important factor in determining mean daily water temperature. . .

[NOTE: Mean daily air temperature data were determined from air thermographs deployed in the shade near the instream thermograph locations or found at the New Mexico Climate Center web site (http://weather.nmsu.edu/data/data.htm). Regardless of the source, air temperatures are corrected for elevation using the above equation.]

2. Maximum Air Temperature (°F or °C) -- The maximum air temperature is a special case. Unlike the other variables where simply typing a value influences which variables "take effect", the maximum daily air temperature overrides only if the check box is checked. If the box is not checked, the program continues to estimate the maximum daily air temperature from a set of empirical coefficients (Theurer et al., 1984) and will print the result in the grayed data entry box. You cannot enter a value in that box unless the box is checked.

3. Relative Humidity (percent) -- Obtain the mean daily relative humidity for your area by measurement or from LCD reports by averaging the four daily values given in the report. Correct for elevational differences by:

$$Rh = Ro \times [1.0640**(To - Ta)] \times \left(\frac{Ta + 273.16}{To + 273.16}\right)$$

where Rh = relative humidity for temperature Ta (decimal)
Ro = relative humidity at station (decimal)
Ta = air temperature at segment (°C)
To = air temperature at station (°C)
** = exponentation
0 <= Rh <= 1.0

[NOTE: Relative humidity data are found at the New Mexico Climate Center web site (http://weather.nmsu.edu/data/data.htm). Regardless of the source, relative humidity data are corrected for elevation and temperature using the above equation.]

4. Wind Speed (miles per hour or meters/second) -- Obtainable from the LCD. Wind speed also may be useful in calibrating the program to known outflow temperatures by varying it within some reasonable range. In the best of all worlds, wind speed should be measured right above the water's surface.

[NOTE: Wind speed data are found at the New Mexico Climate Center web site (http://weather.nmsu.edu/data/data.htm).]

5. Ground Temperature (°F or °C) – In the absence of measured data, use mean annual air temperature from the LCD.

[NOTE: Mean annual air temperature is found at the New Mexico Climate Center web site (http://weather.nmsu.edu/data/data.htm).]

6. Thermal Gradient (Joules/Meter^2/Second/°C) -- This elusive quantity is a measure of rate of thermal input (or outgo) from the streambed to the water. It is not a particularly sensitive parameter within a narrow range. This variable may prove useful in calibration, particularly for the maximum temperature of small, shallow streams where it may be expected that surface waters interact with either the streambed or subsurface flows. In the absence of anything better, simply use the 1.65 default. **Note** that this parameter is measured in the same units regardless of the system of measurement used.

7. Possible Sun (percent) -- This parameter is an indirect and inverse measure of cloud cover. Measure with a pyrometer or use the LCD for historical data. Unfortunately, cloud cover is no longer routinely measured by NOAA weather stations. That means that one must "back calculate" this value or use it as a calibration parameter.

[NOTE: Percent possible sun is found at the New Mexico Climate Center web site (http://weather.nmsu.edu/data/data.htm).]

8. Dust Coefficient (dimensionless) -- This value represents the amount of dust in the air. If you enter a value for the dust coefficient, SSTEMP will calculate the solar radiation.

Representative values look like the following (TVA 1972):

Winter	6 to 13
Spring	5 to 13
Summer	3 to 10
Fall	4 to 11

If all other parameters are well known for a given event, the dust coefficient may be calibrated by using known ground-level solar radiation data.

9. Ground Reflectivity (percent) -- The ground reflectivity is a measure of the amount of short-wave radiation reflected back from the earth into the atmosphere. If you enter a value for the ground reflectivity, SSTEMP will calculate the solar radiation.

Representative values look like the following (TVA, 1972, and Gray, 1970):

Meadows and fields	14
Leaf and needle forest	5 to 20
Dark, extended mixed forest	4 to 5
Heath	10
Flat ground, grass covered	15 to 33
Flat ground, rock	12 to 15
Flat ground, tilled soil	15 to 30
Sand	10 to 20
Vegetation, early summer	19
Vegetation, late summer	29
Fresh snow	80 to 90
Old snow	60 to 80
Melting snow	40 to 60
Ice	40 to 50
Water	5 to 15

10. Solar Radiation (Langley's/day or Joules/meter^2/second) -- Measure with a pyrometer, or refer to Cinquemani et al. (1978) for reported values of solar radiation. If you do not calculate solar radiation within SSTEMP, but instead rely on an external source of ground level radiation, you should assume that about 90% of the ground-level solar radiation actually enters the water. Thus, multiply the recorded solar measurements by 0.90 to get the number to be entered. If you enter a value for solar radiation, SSTEMP will ignore the dust coefficient and ground reflectivity and "override' the internal calculation of solar radiation, graying out the unused input boxes.

[NOTE: Solar radiation data are found at the New Mexico Climate Center web site (http://weather.nmsu.edu/data/data.htm).]

SHADE PARAMETER

Total Shade (percent) -- This parameter refers to how much of the segment is shaded by vegetation, cliffs, etc. If 10% of the water surface is shaded through the day, enter 10. As a shortcut, you may think of the shade factor as being the percent of water surface shaded at noon on a sunny day. In actuality however, shade represents the percent of the incoming solar radiation that does not reach the water. If you enter a value for total shade, the optional shading parameters will be grayed out and ignored. You may find it to your advantage to use the Optional Shading Variables to more accurately calculate stream shading. . .

[NOTE: In a 2002 study, Optional Shading Parameters and concurrent densiometer readings were measured at seventeen stations in order to compare modeling results from the use of these more extensive data sets to modeling results using densiometer readings as an estimate of Total Shade. The estimated value for Total Shade was within 15% of the calculated value in all cases. Estimated values for Maximum Temperatures differed by less than 0.5% in all cases. The Optional Shading Parameters are dependent on the exact vegetation at each cross section, thus requiring multiple cross sections to determine an accurate estimate for vegetation at a reach scale. Densiometer readings are less variable and less inclined to measurement error in the field. Aerial photos are examined and considered whenever available.]

OUTPUT

The program will predict the minimum, mean, and maximum daily water temperature for the set of variables you provide. . . The theoretical basis for the model is strongest for the mean daily temperature. The maximum is largely an estimate and likely to vary widely with the maximum daily air temperature. The minimum is computed by subtracting the difference between maximum and mean from the mean; but the minimum is always positive. The mean daily equilibrium temperature is that temperature that the daily mean water temperature will approach, but never reach, if all conditions remain the same (forever) as you go downstream. (Of course, all conditions cannot remain the same, e.g., the elevation changes immediately.) The maximum daily equilibrium temperature is that temperature that the daily maximum water temperature will approach. . . Other output includes the intermediate parameters average width, and average depth and slope (all calculated from the input variables), and the mean daily heat flux components.

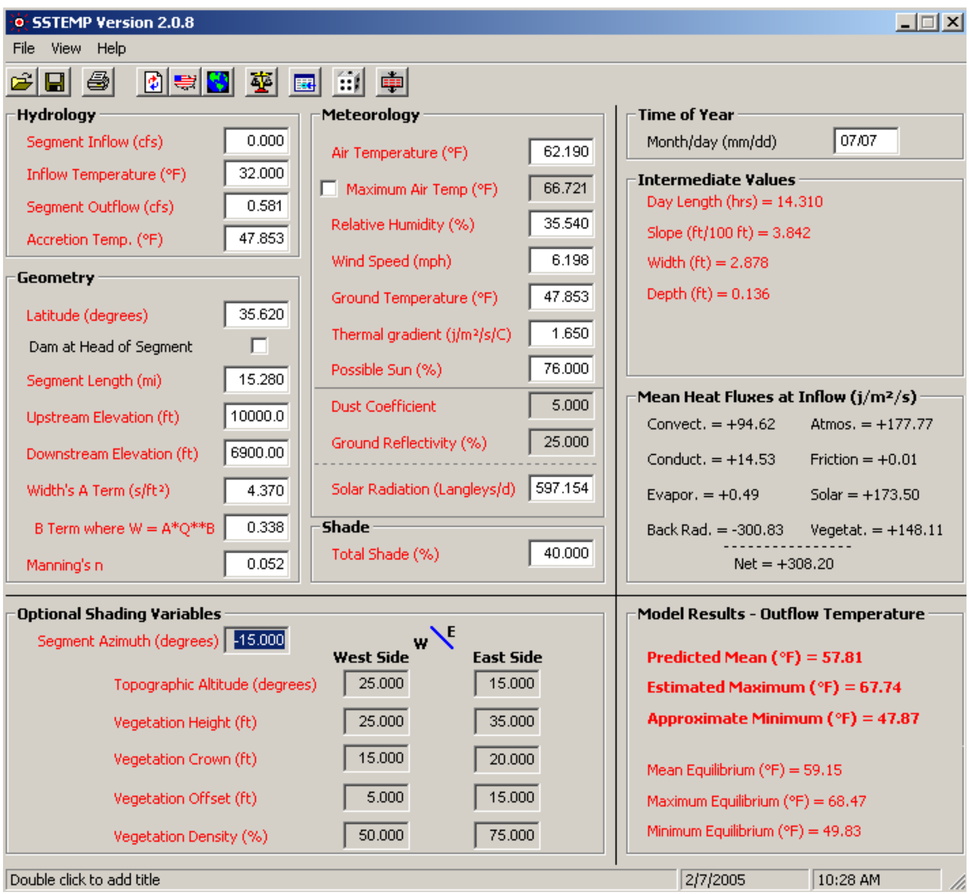


Figure 5.2 Example of SSTEMP input and output for Bull Creek

. . . The mean heat flux components are abbreviated as follows:

Convect. = convection component
Conduct. = conduction component
Evapor. = evaporation component
Back Rad. = water's back radiation component

Atmos. = atmospheric radiation component
Friction = friction component
Solar = solar radiation component
Vegetat. = vegetative and topographic radiation component
Net = sum of all the above flux values

The sign of these flux components indicates whether or not heat is entering (+) or exiting (-) the water. The units are in joules/meter^2/second. In essence, these flux components are the best indicator of the relative importance of the driving forces in heating and cooling the water from inflow to outflow. SSTEMP produces two sets of values, one based on the inflow to the segment and one based on the outflow. You may toggle from one to the other by double clicking on the frame containing the values. In doing so, you will find that the first four flux values change as a function of water temperature which varies along the segment. In contrast, the last four flux values do not change because they are not a function of water temperature but of constant air temperature and channel attributes. For a more complete discussion of heat flux, please refer to Theurer et al. (1984). . .

The program will predict the total segment shading for the set of variables you provide. The program will also display how much of the total shade is a result of topography and how much is a result of vegetation. The topographic shade and vegetative shade are merely added to get the total shade. Use the knowledge that the two shade components are additive to improve your understanding about how SSTEMP deals with shade in toto.

SENSITIVITY ANALYSIS

SSTEMP may be used to compute a one-at-a-time sensitivity of a set of input values. Use **View|Sensitivity Analysis** or the scale toolbar button to initiate the computation. This simply increases and decreases most active input (i.e., non-grayed out values) by 10% and displays a screen for changes to mean and maximum temperatures. The schematic graph that accompanies the display. . . gives an indication of which variables most strongly influence the results. This version does not compute any interactions between input values.

FLOW/DISTANCE MATRIX

The **View|Flow/DistanceMatrix** option allows you to look at a variety of flow and distance combinations from your stream segment. You may enter up to five flows and five distances for further examination. The program will supply a default set of each, with flows ranging from 33% to 166% of that given on the main screen, and distances regularly spaced along the segment. After making any changes you may need, you may choose to view the results in simple graphs either as a function of distance (X) or discharge (Q). The units for discharge, distance and temperature used on the matrix and the graph are a function of those from the main form. The graph is discrete, i.e., does not attempt to smooth between points, and does not currently scale the X-axis realistically.

Note that changing the flow only changes the flow <u>through</u> the segment. That is, the accretion rate per unit distance will remain the same. Flow does impact shading (if active) and all other dependent calculations. . .

Note that you may enter distances beyond your segment length, but if you do so you are assuming that everything remains homogeneous farther downstream, just as you have assumed for the segment itself. *If you try to look at distances very close to the top of the segment, you may get mathematical instability*. . .

UNCERTAINTY ANALYSIS

SNTEMP and previous versions of SSTEMP were deterministic; you supplied the "most likely" estimate of input variables and the model predicted the "most likely" thermal response. This approach was comforting and easy to understand. But choosing this "most likely" approach is like putting on blinders. We know there is variability in the natural system and inherent inaccuracy in the model. The previous model did not reflect variance in measured or estimated input variables (e.g., air temperature, streamflow, stream width) or parameter values (e.g., Bowen ratio, specific gravity of water); therefore they could not be used to estimate the uncertainty in the predicted temperatures. This version (2.0) adds an uncertainty feature that may be useful in estimating uncertainty in the water temperature estimates, given certain caveats.

The built-in uncertainty routine uses Monte Carlo analysis, a technique that gets its name from the seventeenth century study of the casino games of chance. The basic idea behind Monte Carlo analysis is that model input values are randomly selected from a distribution that describes the set of values composing the input. That is, instead of choosing one value for mean daily air temperature, the model is repeatedly run with several randomly selected estimates for air temperature in combination with random selections for all other relevant input values. The distribution of input values may be thought of as representing the variability in measurement and extrapolation error, estimation error, and a degree of spatial and temporal variability throughout the landscape. In other words, we may measure a single value for an input variable, but we know that our instruments are inaccurate to a degree. . . and we also know that the values we measure might have been different if we had measured in a different location along or across the stream, or on a different day. . .

SSTEMP is fairly crude in its method of creating a distribution for each input variable. There are two approaches in this software: a percentage deviation and an absolute deviation. The percentage deviation is useful for variables commonly considered to be reliable only within a percentage difference. For example, USGS commonly describes stream flow as being accurate plus or minus 10%. The absolute deviation, as the name implies, allows entry of deviation values in the same units as the variable (*and always in international units*). A common example would be water temperature where we estimate our ability to measure temperature plus or minus maybe 0.2 degrees. Do not be fooled with input variables whose units are themselves percent, like shade. In this case, if you are in the percentage mode and shade is 50% as an example, entering a value of 5% would impose a deviation of ±2.5 percent (47.5-52.5%), but if you were in the absolute mode, the same 5% value would impose a deviation of ±5 percent (45-55%). Ultimately, SSTEMP converts all of the deviation values you enter to the percent representation before it computes a sample value in the range. No attempt is made to allow for deviations of the date, but all others are fair game, with three exceptions. First, the deviation on stream width is applied only to the A-value, not the B-term. If you want to be thorough, set the width to a constant by setting the B-term to zero. Second, if after sampling, the upstream elevation is lower than the downstream elevation, the upstream elevation is adjusted to be slightly above the downstream elevation. Third, you may enter deviations only for the values being used on the main screen.

The sampled value is chosen from either 1) a uniform (rectangular) distribution plus or minus the percent deviation, or 2) a normal (bell-shaped) distribution with its mean equal to the original value and its standard deviation equal to 1.96 times the deviation so that it represents 95% of the samples drawn from that distribution. If in the process of sampling from either of these two distributions, a value is drawn that is either above or below the "legal" limits set in SSTEMP, a new value is drawn from the distribution. For example, lets assume that you had a relative humidity of 99% and a deviation of 5 percent. If you were using a uniform distribution, the sample range would be 94.05 to 103.95; but you cannot have a relative humidity greater than 100%. Rather than prune the distribution at 100%, SSTEMP resamples to avoid over-specifying 100% values. No attempt has been made to account for correlation among variables, even though we know there is some. I have found little difference in using the uniform versus normal distributions, except that the normal method produces somewhat tighter confidence intervals.

SSTEMP's random sampling is used to estimate the average temperature response, both for mean daily and maximum daily temperature, and to estimate the entire dispersion in predicted temperatures. You tell the program how many trials to run (minimum of 11) and how many samples per trial (minimum of two). Although it would be satisfactory to simply run many individual samples, the advantage to this trial-sample method is twofold. First, by computing the average of the trial means, it allows a better, tighter estimate of that mean value. This is analogous to performing numerous "experiments" each with the same number of data points used for calibration. Each "experiment" produces an estimate of the mean. Second, one can gain insight as to the narrowness of the confidence interval around the mean depending on how many samples there are per trial. This is analogous to knowing how many data points you have to calibrate the model with and the influence of that. For example, if you have only a few days' worth of measurements, your confidence interval will be far broader than if you had several months' worth of daily values. But this technique does little to reduce the overall spread of the resulting predicted temperatures. . .

ASSUMPTIONS

a. Water in the system is instantaneously and thoroughly mixed at all times. Thus there is no lateral temperature distribution across the stream channel, nor is there any vertical gradient in pools.

b. All stream geometry (e.g., slope, shade, friction coefficient) is characterized by mean conditions. This applies to the full travel distance upstream to solar noon, unless there is a dam at the upstream end.

c. Distribution of lateral inflow is uniformly apportioned throughout the segment length.

d. Solar radiation and the other meteorological and hydrological parameters are 24-hour means. You may lean away from them for an extreme case analysis, but you risk violating some of the principles involved. For example, you may alter the relative humidity to be more representative of the early morning hours. If you do, the mean water temperature may better approximate the early morning temperature, but the maximum and minimum temperatures would be meaningless.

e. Each variable has certain built-in upper and lower bounds to prevent outlandish input errors. These limits are not unreasonable; however, the user should look to see that what he or she types actually shows up on the screen. The screen image will always contain the values that the program is using.

f. This model does not allow either Manning's n or travel time to vary as a function of flow.

g. The program should be considered valid only for the Northern Hemisphere below the Arctic Circle. One could theoretically "fast forward" six months for the Southern Hemisphere's shade calculations, but this has not been tested. The solar radiation calculations would likely be invalid due to the asymmetrical elliptical nature of the earth's orbit around the sun.

h. The representative time period must be long enough for water to flow the full length of the segment. . . Remember that SSTEMP, like SNTEMP, is a model that simulates the mean (and maximum) water temperature for some period of days. (One day is the minimum time period, and theoretically, there is no maximum, although a month is likely the upper pragmatic limit.) SSTEMP looks at the world as if all the inputs represent an average day for the time period. For this reason, SSTEMP also assumes that a parcel of water entering the top of the study segment will have the opportunity to be exposed to a full day's worth of heat flux by the time it exits the downstream end. If this is not true, the time period must be lengthened.

. . . suppose your stream has an average velocity of 0.5 meters per second and you want to simulate a 10 km segment. With 86,400 seconds in a day, that water would travel 43 km in a day's time. As this far exceeds your 10 km segment length, you can simulate a single day if you wish. But if your stream's velocity were only 0.05 mps, the water would only travel 4.3 km, so the averaging period for your simulation must be at least 3 days to allow that water to be fully influenced by the average conditions over that period. If, however, most conditions (flow, meteorology) are really relatively stable over the 3 days, you can get by with simulating a single day. Just be aware of the theoretical limitation.

i. Remember that SSTEMP does not and cannot deal with cumulative effects. For example, suppose you are gaming with the riparian vegetation shade's effect on stream temperature. Mathematically adding or deleting vegetation is not the same as doing so in real life, where such vegetation may have subtle or not so subtle effects on channel width or length, air temperature, relative humidity, wind speed, and so on. . .

5.3.2.1 Temperature Allocations as Determined by % Total Shade and Width-to-Depth Ratios

Tables 5.2 through 5.6 detail model run outputs for segments on Bull Creek, Cow Creek, Gallinas River, and Pecos River. SSTEMP was first calibrated against thermograph data to determine the standard error of the model. Initial conditions were determined. As the percent total shade was increased and the Width's A term was decreased, the maximum 24-hour temperature decreased until the segment-specific standard of 20ºC was achieved. The calculated 24-hour solar radiation component is the maximum solar load that can occur in order to meet the WQS (i.e., the target capacity). In order to calculate the actual LA, the WLA and MOS were subtracted from the target capacity (TMDL) following **Equation 1**.

$$WLA + LA + MOS = TMDL \qquad \text{(Eq. 1)}$$

The allocations for each assessment unit requiring a temperature TMDL are provided in the following tables.

Temperature Load Allocation for Bull Creek (Cow Creek to headwaters)

For Bull Creek, the WQS for temperature is achieved when the percent total shade is increased to 47%. According to the SSTEMP model, the actual LA of 137.93 j/m^2/s is achieved when the shade is further increased to 47.58% (Table 5.2).

Table 5.2 SSTEMP Model Results for Bull Creek (Cow Creek to headwaters)

<table>
<tr><th>Rosgen Channel Type</th><th>WQS (HQCWF)</th><th>Model Run Dates</th><th>Segment Length (miles)</th><th>Solar Radiation Component per 24-Hours (+/-)</th><th>% Total Shade</th><th>Width's A Term</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>BC4</td><td>20°C (68°F)</td><td>7/7/01</td><td>15.28</td><td>Current Field Condition
+173.50
joules/m^2/s</td><td>40</td><td>4.37</td><td>Minimum: 9.91
Mean: 15.08
Maximum: 20.26</td></tr>
<tr><td colspan="4" rowspan="3">TEMPERATURE ALLOCATIONS FOR Bull Creek (Cow Creek to headwaters)

[a] 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

[b] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

Actual reduction in solar radiation necessary to meet surface WQS for temperature:

Current Condition – Load Allocation =

173.50 joules/m^2/s – 137.93 joules/m^2/s

= 35.6 joules/m^2/s</td><td>Run 1
+170.61
joules/m^2/s</td><td>41</td><td>4.37</td><td>Minimum: 9.87
Mean: 15.0
Maximum: 20.12</td></tr>
<tr><td>Run 2
+153.26[a]
joules/m^2/s</td><td>47</td><td>4.37</td><td>Minimum: 8.79
Mean: 14.36
Maximum: 19.9</td></tr>
<tr><td>Actual LA
+137.93 [b]
joules/m^2/s</td><td>52</td><td>4.37</td><td>Minimum: 8.68
Mean: 13.93
Maximum: 19.2</td></tr>
</table>

Temperature Load Allocation for Cow Creek (Pecos River to Bull Creek)

For Cow Creek (Pecos River to Bull Creek), the WQS for temperature is achieved when the percent total shade is increased to 60.1%. According to the SSTEMP model, the actual LA of 72.86 j/m^2/s is achieved when the shade is further increased to 64% (Table 5.3).

Table 5.3 SSTEMP Model Results for Cow Creek (Pecos River to Bull Creek)

<table>
<tr><th>Rosgen Channel Type</th><th>WQS (HQCWF)</th><th>Model Run Dates</th><th>Segment Length (miles)</th><th>Solar Radiation Component per 24-Hours (+/-)</th><th>% Total Shade</th><th>Width's A Term</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>C4</td><td>20°C (68°F)</td><td>7/19/03</td><td>15.6</td><td>Current Field Condition
+121.75
joules/m²/s</td><td>40</td><td>7.0</td><td>Minimum: 14.12
Mean: 17.97
Maximum: 22.03</td></tr>
<tr><td colspan="4" rowspan="3">TEMPERATURE ALLOCATIONS FOR Cow Creek (Pecos River to Bull Creek)

(a) 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

(b) 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

Actual reduction in solar radiation necessary to meet surface WQS for temperature:

Current Condition – Load Allocation =

121.75 joules/m²/s – 73.04 joules/m²/s

=48.71 joules/m²/s</td><td>Run 1
+101.45
joules/m²/s</td><td>50</td><td>7.0</td><td>Minimum: 13.74
Mean: 17.34
Maximum: 21.00</td></tr>
<tr><td>Run 2
+81.16 (a)
joules/m²/s</td><td>61</td><td>7.0</td><td>Minimum: 13.60
Mean: 16.79
Maximum: 20.0</td></tr>
<tr><td>Actual LA
73.04 (b)
joules/m²/s</td><td>64.5</td><td>7.0</td><td>Minimum: 13.56
Mean: 16.54
Maximum: 19.54</td></tr>
</table>

Temperature Load Allocation for Cow Creek (Bull Creek to headwaters)

For Cow Creek (Bull Creek to headwaters), the WQS for temperature is achieved when the percent total shade is increased to 31%. According to the SSTEMP model, the actual LA of 138.44j/m^2/s is achieved when the shade is further increased to 38% (Table 5.4).

Table 5.4 SSTEMP Model Results for Cow Creek (Bull Creek to headwaters)

<table>
<tr><th>Rosgen Channel Type[1]</th><th>WQS (HQCWF)</th><th>Model Run Dates</th><th>Segment Length (miles)</th><th>Solar Radiation Component per 24-Hours (+/-)</th><th>% Total Shade</th><th>Width's A Term[2]</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>A4</td><td>20°C (68°F)</td><td>7/22/01</td><td>22.3</td><td>Current Field Condition
+156.05
joules/m^2/s</td><td>30</td><td>4.370</td><td>Minimum: 9.99
Mean: 15.04
Maximum: 20.09</td></tr>
<tr><td colspan="4" rowspan="3">TEMPERATURE ALLOCATIONS FOR Cow Creek (Bull Creek to headwaters)

(a) 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

(b) 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

Actual reduction in solar radiation necessary to meet surface WQS for temperature:

Current Condition – Load Allocation =

153.82 joules/m^2/s – 138.44 joules/m^2/s

= 15.38 joules/m^2/s</td><td>Run 1
+154.94
joules/m^2/s</td><td>30.5</td><td>4.370</td><td>Minimum: 9.98
Mean: 15.01
Maximum: 20.03</td></tr>
<tr><td>Run 2
+153.82 (a)
joules/m^2/s</td><td>31</td><td>4.370</td><td>Minimum: 9.41
Mean: 14.97
Maximum: 20.0</td></tr>
<tr><td>Actual LA

+138.44 (b)
joules/m^2/s</td><td>38</td><td>4.370</td><td>Minimum: 9.8
Mean: 14.5
Maximum: 19.17</td></tr>
</table>

[1]*No NMED/SWQB cross-section data available for this assessment unit, used data from Santa Fe National Forest report (USDA 2003).*

[2]*No NMED/SWQB cross-section data available for this assessment unit, used data from NM-2214.A_091.*

Temperature Load Allocation for Gallinas River (Las Vegas Diversion to headwaters)

For Gallinas River (Las Vegas Diversion to headwaters), the WQS for temperature is achieved when the percent total shade is increased to 56.22%. According to the SSTEMP model, the actual LA of 100.33 j/m^2/s is achieved when the shade is further increased to 60.895% (Table 5.5).

Table 5.5 SSTEMP Model Results for Gallinas River (Las Vegas Diversion to headwaters)

<table>
<tr><th>Rosgen Channel Type</th><th>WQS (HQCWF)</th><th>Model Run Dates</th><th>Segment Length (miles)</th><th>Solar Radiation Component per 24-Hours (+/-)</th><th>% Total Shade</th><th>Width's A Term</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>B4</td><td>20°C (68°F)</td><td>7/18/03</td><td>24.21</td><td>Current Field Condition
+153.95
joules/m^2/s</td><td>40</td><td>18.38</td><td>Minimum: 14.57
Mean: 18.04
Maximum: 21.51</td></tr>
<tr><td colspan="4" rowspan="3">TEMPERATURE ALLOCATIONS FOR
Gallinas River (Las Vegas Diversion to headwaters)
(a) 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

(b) 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

Actual reduction in solar radiation necessary to meet surface WQS for temperature:

Current Condition – Load Allocation =

153.95 joules/m^2/s – 99.30 joules/m^2/s

= 54.65 joules/m^2/s</td><td>Run 1
+128.29
joules/m^2/s</td><td>50</td><td>18.38</td><td>Minimum: 14.40
Mean: 17.51
Maximum: 20.61</td></tr>
<tr><td>Run 2
+110.33 (a)
joules/m^2/s</td><td>57</td><td>18.38</td><td>Minimum: 14.28
Mean: 17.12
Maximum: 20.0</td></tr>
<tr><td>Actual LA
+99.30 (b)
joules/m^2/s</td><td>61.5</td><td>18.38</td><td>Minimum: 14.21
Mean: 16.88
Maximum: 19.54</td></tr>
</table>

Temperature Load Allocation for Pecos River (Canon de Manzanita to Alamitos Canyon)

For Pecos River (Canon de Manzanita to Alamitos Canyon), the WQS for temperature is achieved when the percent total shade is increased to 77%. According to the SSTEMP model, the actual LA of 53.11 j/m^2/s is achieved when the shade is further increased to 79.3% (Table 5.6).

Table 5.6 SSTEMP Model Results for Pecos River (Canon de Manzanita to Alamitos Canyon)

<table>
<tr><th>Rosgen Channel Type</th><th>WQS (HQCWF)</th><th>Model Run Dates</th><th>Segment Length (miles)</th><th>Solar Radiation Component per 24-Hours (+/-)</th><th>% Total Shade</th><th>Width's A Term</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>F4</td><td>20°C (68°F)</td><td>7/18/03</td><td>5.7</td><td>Current Field Condition
+153.95
joules/m²/s</td><td>40</td><td>52.2</td><td>Minimum: 15.66
Mean: 20.4
Maximum: 25.14</td></tr>
<tr><td colspan="4" rowspan="3">TEMPERATURE ALLOCATIONS FOR Pecos River (Canon de Manzanita to Alamitos Canyon)
(a) 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

(b) 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

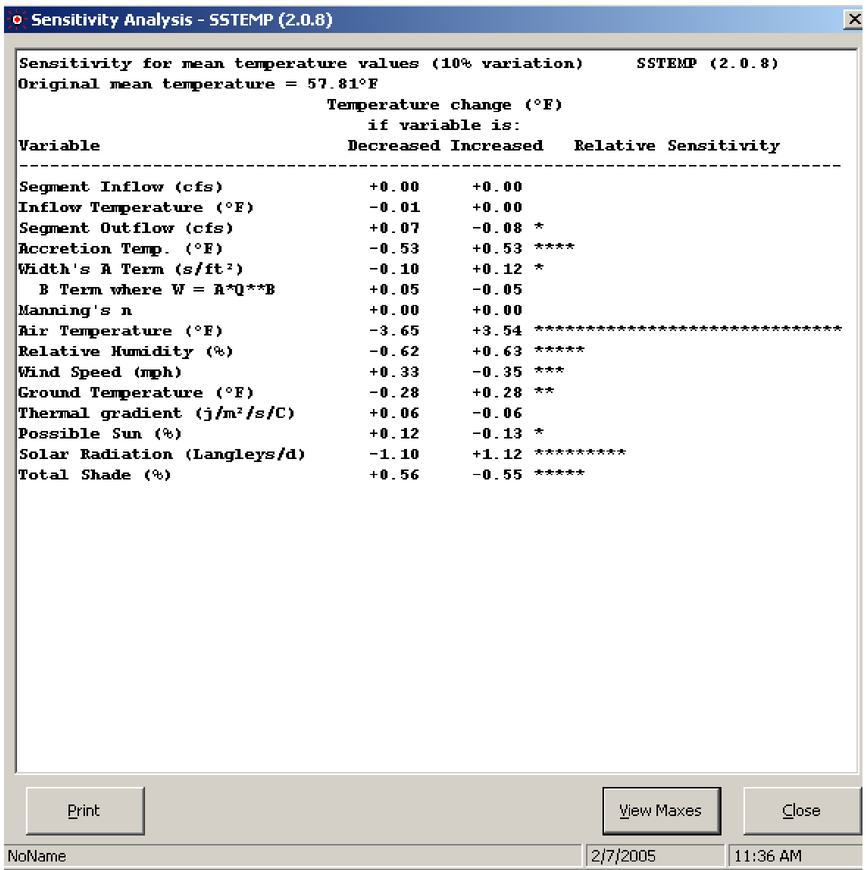
Actual reduction in solar radiation necessary to meet surface WQS for temperature:

Current Condition – Load Allocation =

153.95 joules/m²/s – 53.11 joules/m²/s

= 100.84 joules/m²/s</td><td>Run 1
+128.29
joules/m²/s</td><td>50</td><td>52.2</td><td>Minimum: 15.34
Mean: 19.60
Maximum: 23.86</td></tr>
<tr><td>Run 2
+59.01 (a)
joules/m²/s</td><td>77</td><td>52.2</td><td>Minimum: 14.60
Mean: 17.32
Maximum: 20.0</td></tr>
<tr><td>Actual LA
+53.11 (b)
joules/m²/s</td><td>79.3</td><td>52.2</td><td>Minimum: 14.54
Mean: 17.12
Maximum: 19.69</td></tr>
</table>

According to the Sensitivity Analysis feature of the model runs, mean daily air temperature had the greatest influence on the predicted outflow temperatures and total shade values have the greatest influence on temperature reduction. However, reducing Width's A term had an insignificant effect on the predicted maximum temperature. The estimate of total shade used in the model calibration was based on densiometer readings and examination of aerial photographs (see **Appendix D**). Target loads as determined by the modeling runs are summarized in Tables 5.2 through 5.6. The MOS is estimated to be 10% of the target load calculated by the modeling runs. Results are summarized in Table 5.7. Additional details on the MOS chosen are presented in Section 5.7 below.



Variable	Temperature change (°F) if variable is: Decreased	Increased	Relative Sensitivity
Segment Inflow (cfs)	+0.00	+0.00	
Inflow Temperature (°F)	-0.01	+0.00	
Segment Outflow (cfs)	+0.07	-0.08	*
Accretion Temp. (°F)	-0.53	+0.53	****
Width's A Term (s/ft^2)	-0.10	+0.12	*
B Term where W = A*Q**B	+0.05	-0.05	
Manning's n	+0.00	+0.00	
Air Temperature (°F)	-3.65	+3.54	******************************
Relative Humidity (%)	-0.62	+0.63	*****
Wind Speed (mph)	+0.33	-0.35	***
Ground Temperature (°F)	-0.28	+0.28	**
Thermal gradient (j/m^2/s/C)	+0.06	-0.06	
Possible Sun (%)	+0.12	-0.13	*
Solar Radiation (Langleys/d)	-1.10	+1.12	*********
Total Shade (%)	+0.56	-0.55	*****

Figure 5.3 Example of SSTEMP sensitivity analysis for Bull Creek

Table 5.7 Calculation of TMDLs for Temperature

Assessment Unit	WLA ($j/m^2/s$)	LA ($j/m^2/s$)	MOS (10%)[(a)] ($j/m^2/s$)	TMDL ($j/m^2/s$)
Bull Creek (Cow Creek to headwaters)	0	137.93	15.33	153.26
Cow Creek (Pecos River to Bull Creek)	0	73.04	8.12	81.16
Cow Creek (Bull Creek to headwaters)	0	138.44	15.38	153.82
Gallinas River (Las Vegas Diversion to headwaters)	0	99.30	11.03	110.33
Pecos River (Canon de Manzanita to Alamitos Canyon)	0	53.11	5.9	59.01

Notes:
[(a)] Actual MOS values may be slightly greater than 10% because the final MOS is back calculated after the Total Shade value is increased enough to reduce the modeled solar radiation component to a value less than the target load minus 10%.

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the calculated target LA and the measured load (i.e., current field condition in Tables 5.2 through 5.6), and are shown in Table 5.8.

Table 5.8 Calculation of Load Reduction for Temperature

Location	LA ($j/m^2/s$)	Measured Load ($j/m^2/s$)	Load Reduction ($j/m^2/s$)
Bull Creek (Cow Creek to headwaters)	137.93	173.50	35.57
Cow Creek (Pecos River to Bull Creek)	73.04	121.75	48.71
Cow Creek (Bull Creek to headwaters)	138.44	156.05	17.61
Gallinas River (Las Vegas Diversion to headwaters)	99.30	153.95	54.65
Pecos River (Canon de Manzanita to Alamitos Canyon)	53.11	153.95	100.84

5.4 Identification and Description of pollutant source(s)

Pollutant sources that could contribute to each segment are listed in Table 6.9.

Table 5.9 Pollutant source summary for Temperature

Pollutant Sources	Magnitude[(a)]	Location	Potential Sources[(b)] (% from each)
Point:			
None or NA	0	--------	0%
Nonpoint:			
Temperature[(c)]	173.50	Bull Creek	100% Loss of riparian habitat Rangeland grazing Watershed runoff following forest fire Agriculture (field sheet notes) Streambank modification/destabilization (field notes)
	121.75	Cow Creek (Pecos River to Bull Creek)	100% Highway/road/bridge runoff (non-construction related) Loss of riparian habitat Rangeland grazing Streambank modification/destabilization Watershed runoff following forest fire Agriculture (field notes)
	156.05	Cow Creek (Bull Creek to headwaters)	100% Highway/road/bridge runoff (non-construction related) Loss of riparian habitat Rangeland grazing Streambank modification/destabilization Watershed runoff following forest fire
	153.95	Gallinas River	100% Highway/road/bridge runoff (non-construction related) Livestock (grazing or feeding operations) Loss of riparian habitat Rangeland grazing Streambank modification/destabilization Natural (field notes)
	153.95	Pecos River	100% Flow alterations from water diversions Loss of riparian habitat Natual sources Rangeland grazing Agriculture, pastureland (field notes) Streambank modification/destabilization (field notes)

Notes:
NA = Not applicable
[(a)] Measured Load as j/m^2/s
[(b)] From the 2004-2006 Integrated §303(d)/305(b) list unless otherwise noted. [(c)] Expressed as solar radiation.

5.5 Linkage of Water Quality and Pollutant Sources

Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms that affect fish. Natural temperatures of a waterbody fluctuate daily and seasonally. These natural fluctuations do not eliminate indigenous populations, but may affect existing community structure and geographical distribution of species. In fact, such temperature cycles are often necessary to induce reproductive cycles and may regulate other aspects of life history (Mount 1969). Behnke and Zarn (1976) in a discussion of temperature requirements for endangered western native trout recognized that populations cannot persist in waters where maximum temperatures consistently exceed 21-22°C, but they may survive brief daily periods of higher temperatures (25.5-26.7°C). Anthropogenic impacts can lead to modifications of these natural temperature cycles, often leading to deleterious impacts on the fishery. Such modifications may contribute to changes in geographical distribution of species and their ability to persist in the presence of introduced species. Of all the environmental factors affecting aquatic organisms in a waterbody, many either present or not present, temperature is always a factor. Heat, which is a quantitative measure of energy of molecular motion that is dependent on the mass of an object or body of water is fundamentally different than temperature, which is a measure (unrelated to mass) of energy intensity. Organisms respond to temperature, not heat.

Temperature increases, as observed in SWQB thermograph data, show temperatures that exceed the State Standards for the protection of aquatic habitat, namely the HQCWF designed uses. Through monitoring, and pollutant source documentation, it has been observed that the most probable cause for these temperature exceedences are due to the alteration of the stream's hydrograph, removal of riparian vegetation, livestock grazing, and natural causes. Alterations can be historical or current in nature.

A variety of factors impact stream temperature (Figure 5.2). Decreased effective shade levels result from reduction of riparian vegetation. When canopy densities are compromised, thermal loading increases in response to the increase in incident solar radiation. Likewise, it is well documented that many past hydromodification activities have lead to channel widening. Wider stream channels also increase the stream surface area exposed to sunlight and heat transfer. Riparian area and channel morphology disturbances are attributed to past and to some extent 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 and (2) increasing stream surface area exposed to solar radiation.

Riparian vegetation, stream morphology, hydrology, climate, geographic location, and aspect 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, the elevated summertime stream temperatures attributable to anthropogenic causes in the Pecos Headwaters watershed 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, and

3. Reduced summertime base flows that result from instream withdrawals and/or inadequate riparian vegetation. Base flows are maintained with a functioning riparian system so that loss of a functioning riparian system may lower and sometimes eliminate baseflows. Although removal of upland vegetation has been shown 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 stream reaches, increased temperatures can result in increased streambed infiltration which can result in lower base flow (Constantz et al. 1994).

Analyses presented in these TMDLs demonstrate that defined loading capacities will ensure attainment of NM WQS. Specifically, the relationship between shade, channel dimensions, solar radiation, and water quality attainment was demonstrated. Vegetation density increases will provide necessary shading, as well as encourage bank-building processes in severe hydrologic events.

Where available data are incomplete or where the level of uncertainty in the characterization of sources is large, the recommended approach to TMDL assignments requires the development of allocations based on estimates utilizing the best available information.

SWQB fieldwork includes an assessment of the potential sources of impairment (NMED/SWQB 1999). The completed Pollutant Source(s) Documentation Protocol forms in **Appendix B** provide documentation of a visual analysis of probable sources along an impaired reach. Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of potential sources of impairment in this watershed. Table 5.9 identifies and quantifies potential sources of nonpoint source impairments along each reach as determined by field reconnaissance and assessment. It is important to consider not only the land directly adjacent to the stream, but also to consider upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

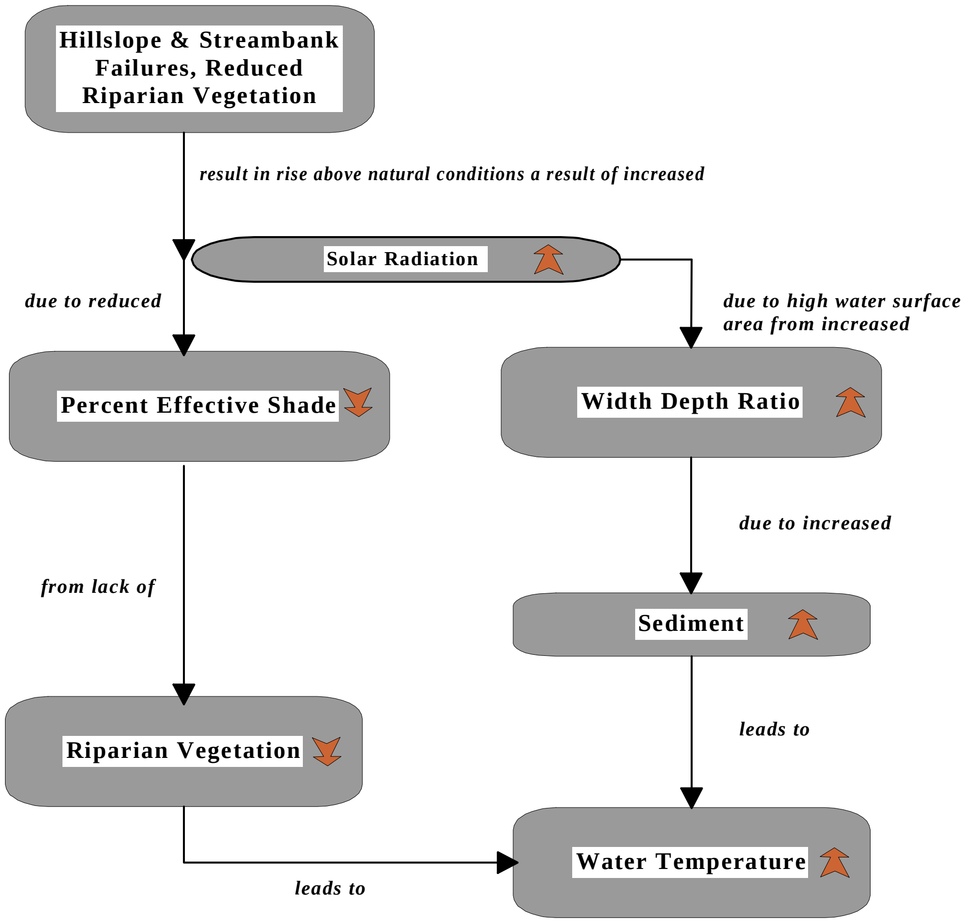


Figure 5.4 Factors That Impact Water Temperature

5.6 Margin of Safety (MOS)

The Federal 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, there were no MOS adjustments for point sources since there are none.

In order to develop this temperature TMDL, the following conservative assumptions were used to parameterize the model:

- Data from the warmest time of the year were used in order to capture the seasonality of temperature exceedences.

- Critical upstream and downstream low flows were used because assimilative capacity of the stream to absorb and disperse solar heat is decreased during these flow conditions.

- Low flow was modeled using formulas developed by the USGS. One formula (Thomas et al. 1997) is recommended when the ratio between the gaged watershed area and the ungaged watershed area is between 0.5 and 1.5. When the ratio is outside of this range, a different regression formula is used (Waltemeyer 2002). See **Appendix D** for details.

As detailed in **Appendix D,** a variety of high quality hydrologic, geomorphologic, and meteorological data were used to parameterize the SSTEMP model. Because of the high quality of data and information that was put into this model and the continuous field monitoring data used to verify these model outputs, an explicit MOS of 10% is assigned to this TMDL.

5.7 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 variation." Both stream temperature and flow vary seasonally and from year to year. Water temperatures are coolest in winter and early spring months.

Thermograph records show that temperatures exceed State of NM WQS in summer and early fall. Warmest stream temperatures corresponded to prolonged solar radiation exposure, warmer air temperature, and low flow conditions. These conditions occur during late summer and early fall and promote the warmest seasonal instream temperatures. It is assumed that if critical conditions are met, coverage of any potential seasonal variation will also be met.

5.8 Future Growth

Estimations of future growth are not anticipated to lead to a significant increase for temperature that cannot be controlled with BMP implementation in this watershed.

6.0 MONITORING PLAN

Pursuant to Section 106(e)(1) of the Federal CWA, 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 NM. In accordance with the NM Water Quality Act, 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 utilizes a rotating basin system approach to water quality monitoring. In this system, a select number of watersheds are intensively monitored each year with an established return frequency of approximately every seven years. The next scheduled monitoring date for the Pecos Headwaters watershed is 2009. The SWQB maintains current quality assurance and quality control plans to cover all monitoring activities. This document, called the QAPP, is updated and certified annually by EPA Region 6 (NMED/SWQB 2001a). 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. Short-term efforts will be directed toward those waters that are on the EPA TMDL consent decree list (U.S. District Court for the District of New Mexico 1997).

Once assessment monitoring is completed, those reaches showing impacts 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 Assessment Protocols (NMED/SWQB 2004b).

Long-term monitoring for assessments will be accomplished through the establishment of sampling sites that are representative of the waterbody and which can be revisited approximately every seven 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.

SWQB recently developed a 10-year monitoring strategy on September 30, 2004. Once the 10-year monitoring plan is approved by the USEPA, it will be available at the SWQB website: http://www.nmenv.state.nm.us/swqb/swqb.html. The strategy will detail both the extent of monitoring that can be accomplished with existing resources plus expanded monitoring strategies that could be implemented given additional resources. According to the draft proposed 8-year rotational cycle, which assumes the existing level of resources, the next time SWQB will intensive sample the Pecos Headwaters watershed is the year 2009.

It should be noted that a watershed would not be ignored during the years in between intensive sampling. The rotating basin program will be supplemented with other data collection efforts such as the funding of long-term USGS water quality gaging stations for long-term trend data. 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.

7.0 IMPLEMENTATION OF TMDLS

7.1 Coordination

In this watershed public awareness and involvement will be crucial to the successful implementation of these plans and improved water quality. Staff from the SWQB will work with stakeholders to provide the guidance in developing the Watershed Restoration Action Strategy (WRAS). The WRAS 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 impacts to water quality. This long-range strategy will become instrumental in coordinating and achieving constituent levels consistent with the New Mexico State Standards, and will be used to prevent water quality impacts in the watershed. The WRAS is essentially the Implementation Plan, or Phase Two of the TMDL process.

SWQB staff will assist with any technical assistance such as selection and application of BMPs needed to meet WRAS goals. Stakeholder public outreach and involvement in the implementation of this TMDL will be ongoing. Stakeholders in this process will include SWQB, and other members of the WRAS.

Implementation of BMPs within the watershed to reduce pollutant loading from nonpoint sources will be encouraged. Reductions from point sources will be addressed in revisions to discharge permits.

7.2 Time Line

The following table details the proposed implementation timeline (**Table 7.1**).

7.3 Clean Water Act §319(h) Funding Opportunities

The Watershed Protection Section of the SWQB provides USEPA §319(h) funding to assist in implementation of BMPs to address water quality problems on reaches listed on the §303(d) list or which are located within Category I Watersheds as identified under the Unified Watershed Assessment of the Clean Water Action Plan. 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 by applicants two times a year through a Request for Proposal (RFP) process and require a non-federal match of 40% of the total project cost consisting of funds and/or in-kind services. Funding is available for both watershed group formation (which includes WRAS development) and on-the-ground projects to improve surface water quality and associated habitat. Further information on funding from the CWA §319 (h) can be found at the NMED website: http://www.nmenv.state.nm.us.

Table 7.1 Proposed Implementation Timeline

Implementation Actions	Year 1	Year 2	Year 3	Year 4	Year 5
Public Outreach and Involvement	X	X	X	X	X
Form watershed groups	X	X			
WRAS Development		X	X	X	
Establish Performance Targets		X			
Secure Funding		X	X		
Implement Management Measures (BMPs)		X	X	X	
Monitor BMPs		X	X	X	
Determine BMP Effectiveness				X	X
Re-evaluate Performance Targets				X	X

8.0 ASSURANCES

New Mexico's Water Quality Act (Act) does authorize the Water Quality Control Commission to "promulgate and publish regulation to prevent or abate water pollution in the state" and to require permits. The Act authorizes a constituent agency to take enforcement action against any person who violates a water quality standard. Several statutory provisions on nuisance law could also be applied to nonpoint source water pollution. The Water Quality Act also states in §74-6-12(a):

> *The Water Quality Act (this article) 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 Surface Water Quality Standards (see NMAC 20.6.4.10.C) (NMAC 2002) states:

> *These water quality standards do not grant the Commission or any other entity the power to create, take away or modify property rights in water.*

New Mexico policies are in accordance with the federal Clean Water Act §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 319 Program has been developed in a coordinated manner with the State's 303(d) process. All 319 watersheds that are targeted in the annual (RFP) process coincide with the State's biennial impaired waters list as approved by EPA. 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 Chapter 74, Article 6-10 NMSA 1978 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. NMED nonpoint source water quality management program has historically strived for and will continue to promote voluntary compliance to nonpoint source 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 §319 of the Clean Water Act. 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 Forest Service and the Bureau of Land Management. MOUs have also been developed with other State agencies, such as the New Mexico State Highway and Transportation Department. These MOUs provide for coordination and consistency in dealing with nonpoint source 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 members of the WRAS. The cooperation of watershed stakeholders will be pivotal in the implementation of these TMDLs as well.

9.0 PUBLIC PARTICIPATION

Public participation was solicited in development of this TMDL (see **Appendix E**). The draft TMDL was made available for a 30-day comment period March 15, 2005. Response to comments are attached as **Appendix F** of this document. The draft document notice of availability was extensively advertised via newsletters, email distribution lists, webpage postings (http://www.nmenv.state.nm.us), and press releases to area newspapers.

10.0 REFERENCES

Barbour, Michael T., Jeroen Gerritsen, Blaine D. Snyder, and James B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*. Second Edition. EPA 841/B-99/002. Office of Water, Washington, DC.

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 http://www.fort.usgs.gov. Revised August 2002.

Behnke, R.J. and M. Zarn. 1976. *Biology and management of threatened and endangered western trouts*. USDA Forest Service, General Technical Report RM-28. Fort Collins, CO. 45 pp.

Chronic, Halka. 1987. Roadside Geology of New Mexico. Mountain Press Publishing Company, Missoula.

Constantz, J, C.L. Thomas, and G. Zellweger. 1994. *Influence of diurnal variations in stream temperature on streamflow loss and groundwater recharge*. Water Resources Research 30:3253-3264.

Energy, Minerals, and Natural Resources Department (EMNRD), New Mexico. 1983. *Water Quality Protection Guidelines for Forestry Operations in New Mexico*. New Mexico State Forestry (NMSF) Division.

Hall, G.E. 1984. Four Leagues of Pecos. New Mexico Land Grant Series, John R. Van Ness (ed.). University of New Mexico Press, Albuquerque.

———. 2002. High and Dry-The Texas-New Mexico Struggle for the Pecos River. University of New Mexico Press, Albuquerque.

Minshall, G.W. 1984. *Aquatic insect-substratum relationships*. *In* The Ecology of Aquatic Insects, Resh and Rosenberg (eds.) Praeger Publishers, New York, NY.

Montgomery, Arthur and Patrick K. Sutherland. 1967. Trail Guide to the Upper Pecos. University of New Mexico Publishing Plant-New Mexico State Bureau of Mines and Mineral Resources, Albuquerque.

Mount, D.I. 1969. *Developing thermal requirements for freshwater fishes*. *In* Biological Aspects of Thermal Pollution. Krenkel and Parker (eds.), Vanderbilit University Press, Nashville, TN.

New Mexico Administrative Code (NMAC). 2002. *State of New Mexico Standards for Interstate and Intrastate Streams*. 20.6.4. New Mexico Water Quality Control Commission. As amended through October 11, 2002.

New Mexico Environment Department/Surface Water Quality Bureau (NMED/SWQB). 1999. *Draft pollutant source documentation protocol*. Available on the internet at http://www.nmenv.state.nm.us/swqb/links.html.

———. 2001a. *Quality Assurance Project Plan for Water Quality Management Programs*. Surface Water Quality Bureau. Santa Fe, NM.

———. 2001b. *Special Water Quality Survey of the Pecos and Gallinas Rivers below the Viveash and Manuelitas Fires.* Santa Fe, NM.

———. 2002a. *Water Quality Assessment of the Gallinas River and Tecolote Creek (Part II) 2001*. Santa Fe, NM.

———. 2002b. *Village of Pecos Wastewater Treatment Plant Compliance Evaluation Inspection report.* March 26.

———. 2004a. Integrated §303(d)/§305(b) list.

———. 2004b. *State of New Mexico Procedures for Assessing Standards Attainment for the Integrated §303(d)/§305(b) Water Quality Monitoring and Assessment Report.* January. Available online at http://www.nmenv.state.nm.us/swqb/links.html.

———. 2004c. *Water Quality Survey Summary for the Upper Pecos River Watershed, Part I (Between Headwaters and Villanueva State Park) 2001.* Santa Fe, NM.

———. 2004d. *Water Quality Survey Summary for the Upper Pecos River Watershed, Part III (Between Tecolote Creek and Sumner Reservoir) 2001*. Santa Fe, NM.

———. 2004e. *New Mexico Department of Game and Fish-Lisboa State Fish Hatchery Compliance Evaluation Inspection report.* May 26.

New Mexico Geological Society. 1956. *Guidebook of Southeastern Sangre de Cristo Mountains*
New Mexico-Seventh Field Conference.

Relyea, C.D., C. W. Marshall, and R.J. Danehy. 2000. *Stream insects as indicators of fine sediment.* Stream Ecology Center, Idaho State University, Pocatello, ID. Presented at WEF 2000 Watershed Management Conference.

Rosgen, D. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

Thomas, Blakemore E., H.W. Hjalmarson, and S.D. Waltemeyer. 1997. *Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States*. USGS Water-Supply Paper 2433.

U.S. Department of Agriculture (USDA). 1998. *WinXSPRO A Channel Cross Section Analyzer*. West Consultants Inc. San Diego, CA.

———. 2003. Santa Fe National Forest. *Cow Creek Stream Inventory Report.*

U.S. District Court for the District of New Mexico. 1997. *Forest Guardians and Southwest Environmental Center (Plaintiffs) v. Carol Browner, in her official capacity as Administrator, EPA (Defendant): Joint Motion for Entry of Consent Decree*. April 29. Online at www.nmenv.state.nm.us/swqb/CDNM.html.

U.S. Environmental Protection Agency (EPA). 1991. *Monitoring Guidelines to Evaluate Effects of Forestry Activities Activities on Streams in the Pacific Northwest and Alaska*. EPA 910/9-91/001. Seattle, WA.

———. 1999. *Draft Guidance for Water Quality-based Decisions: The TMDL Process (Second Edition)*. EPA 841-D-99-001. Office of Water, Washington, D.C. August.

U.S. Geological Survey (USGS). 2002a. *Input and Output to a Watershed Data Management File (Version 4.1)*. Hydrologic Analysis Software Support Program. Available on the internet at http://water.usgs.gov/software/surface_water.html .

———. 2002b. *Surface-Water Statistics (Version 4.1)*. Hydrologic Analysis Software Support Program. Available on the internet at http://water.usgs.gov/software/surface_water.html.

Waltemeyer, Scott D. 2002. *Analysis of the Magnitude and Frequency of the 4-Day Annual Low Flow and Regression Equations for Estimating the 4-Day, 3-Year Low-Flow Frequency at Ungaged Sites on Unregulated Streams in New Mexico*. USGS Water-Resources Investigations Report 01-4271. Albuquerque, New Mexico.

Wohlman, M.G. 1954. *A method of sampling coarse riverbed material*. Transactions of American Geophysical Union. Vol. 35, pp. 951-956.

APPENDIX A
CONVERSION FACTOR DERIVATION

This page left intentionally blank.

Flow (as million gallons per day [MGD]) and concentration values (milligrams per liter [mg/L]) must be multiplied by a conversion factor in order to express the load in units "pounds per day." The following expressions detail how the conversion factor was determined:

TMDL Calculation:

$$Flow\,(MGD) \times Concentration\left(\frac{mg}{L}\right) \times CF\left(\frac{L-lb}{gal-mg}\right) = Load\left(\frac{lb}{day}\right)$$

Conversion Factor Derivation:

$$CF = 10^6 \times \frac{3.785\,L}{gal} \times \frac{1\,lb}{454{,}000\,mg} = 8.34\,\frac{L-lb}{gal-mg}$$

APPENDIX B
POLLUTANT SOURCE(S) DOCUMENTATION PROTOCOL

This page left intentionally blank.

This protocol was designed to support federal regulations and guidance requiring states to document and include probable source(s) of pollutant(s) in their §303(d) Lists as well as the States §305(b) Report to Congress.

The following procedure should be used when sampling crews are in the field conducting water quality surveys or at any other time field staff are collecting data.

Pollutant Source Documentation Steps:

1). Obtain a copy of the most current §303(d) List.

2). Obtain copies of the ***Field Sheet for Assessing Designated Uses and Nonpoint Sources of Pollution***.

3). Obtain 35mm camera that has time/date photo stamp on it. **DO NOT USE A DIGITAL CAMERA FOR THIS PHOTODOCUMENTATION**

4). Identify the reach(s) and probable source(s) of pollutant in the §303(d) List associated with the project that you will be working on.

5). Verify if current source(s) listed in the §303(d) List are accurate.

6). Check the appropriate box(s) on the field sheet for source(s) of nonsupport and estimate percent contribution of each source.

7). Photodocument probable source(s) of pollutant.

8). Create a folder for the TMDL files, insert field sheet and photodocumentation into the file.

This information will be used to update §303(d) Lists and the States §305(b) Report to Congress.

FIELD SHEET FOR ASSESSING DESIGNATED USES AND NONPOINT SOURCES OF POLLUTION

ODES FOR USES NOT FULLY SUPPORTED

☒	HQCWF =	HIGH QUALITY COLDWATER FISHERY	☐	DWS	=	DOMESTIC WATER SUPPLY
☐	CWF =	COLDWATER FISHERY	☐	PC	=	PRIMARY CONTACT
☐	MCWF =	MARGINAL COLDWATER FISHERY	☐	IRR	=	IRRIGATION
☐	WWF =	WARMWATER FISHERY	☐	LW	=	LIVESTOCK WATERING
☐	LWWF =	LIMITED WARMWATER FISHERY	☐	WH	=	WILDLIFE HABITAT

ish culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these ses are actually being realized. However, no numeric standards apply uniquely to these uses.

REACH NAME: Beaver Creek (Porvenir Creek to headwaters)

SEGMENT NUMBER: NM 2212-04

BASIN: Pecos

PARAMETER: SBD

STAFF MAKING ASSESSMENT: SH, HH

DATE: 11-2-04

ODES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

☐	0100	INDUSTRIAL POINT SOURCES	☐	4000	URBAN RUNOFF/STORM SEWERS	☐	7400	FLOW REGULATION/MODIFICATION
						☐	7500	BRIDGE CONSTRUCTION
☐	0200	MUNICIPAL POINT SOURCES	☐	5000	RESOURCES EXTRACTION	☐	7600	REMOVAL OF RIPARIAN VEGETATION
☐	0201	DOMESTIC POINT SOURCES	☐	5100	SURFACE MINING	☒	7700	STREAMBANK MODIFICATION OI DESTABILIZATION
			☐	5200	SUBSURFACE MINING	☐	7800	DRAINING/FILLING OF WETLANDS
☐	0400	COMBINED SEWER OVERFLOWS	☐	5300	PLACER MINING			
			☐	5400	DREDGE MINING	☐	8000	OTHER
☐	1000	AGRICULTURE	☐	5500	PETROLEUM ACTIVITIES	☐	8010	VECTOR CONTROL ACTIVITIES
☐	1100	NONIRRIGATED CROP PRODUCTION	☐	5501	PIPELINES	☐	8100	ATMOSPHERIC DEPOSITION
☐	1200	IRRIGATED CROP PRODUCTION	☐	5600	MILL TAILINGS	☐	8200	WASTE STORAGE/STORAGE TANK LEAKS
☐	1201	IRRIGATED RETURN FLOWS	☐	5700	MINE TAILINGS	☐	8300	ROAD MAINTENANCE or RUNOFF
☐	1300	SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)	☐	5800	ROAD CONSTRUCTION/MAINTENANCE	☐	8400	SPILLS
			☐	5900	SPILLS	☐	8500	IN-PLACE CONTAMINANTS
☐	1400	PASTURELAND				☐	8600	NATURAL
☒	1500	RANGELAND	☐	6000	LAND DISPOSAL	☒	8700	RECREATIONAL ACTIVITIES
☐	1600	FEEDLOTS - ALL TYPES	☐	6100	SLUDGE	☐	8701	ROAD/PARKING LOT RUNOFF
☐	1700	AQUACULTURE	☐	6200	WASTEWATER	☐	8702	OFF-ROAD VEHICLES
☐	1800	ANIMAL HOLDING/MANAGEMENT AREAS	☐	6300	LANDFILLS	☐	8703	REFUSE DISPOSAL
☐	1900	MANURE LAGOONS	☐	6400	INDUSTRIAL LAND TREATMENT	☒	8704	WILDLIFE IMPACTS
			☐	6500	ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)	☐	8705	SKI SLOPE RUNOFF
☐	2000	SILVICULTURE				☐	8800	UPSTREAM IMPOUNDMENT
☐	2100	HARVESTING, RESTORATION, RESIDUE MANAGEMENT	☐	6600	HAZARDOUS WASTE	☐	8900	SALT STORAGE SITES
			☐	6700	SEPTAGE DISPOSAL			
☒	2200	FOREST MANAGEMENT	☐	6800	UST LEAKS	☐	9000	SOURCE UNKNOWN
☐	2300	ROAD CONSTRUCTION or MAINTENANCE						
			☐	7000	HYDROMODIFICATION			
☐	3000	CONSTRUCTION	☐	7100	CHANNELIZATION			
☐	3100	HIGHWAY/ROAD/BRIDGE	☐	7200	DREDGING			
☐	3200	LAND DEVELOPMENT	☐	7300	DAM CONSTRUCTION/REPAIR			
☐	3201	RESORT DEVELOPMENT						
☐	3300	HYDROELECTRIC						

FIELD SHEET FOR ASSESSING DESIGNATED USES AND NONPOINT SOURCES OF POLLUTION

:ODES FOR USES NOT FULLY SUPPORTED

☒	HQCWF =	HIGH QUALITY COLDWATER FISHERY	☐	DWS	=	DOMESTIC WATER SUPPLY
☐	CWF =	COLDWATER FISHERY	☐	PC	=	PRIMARY CONTACT
☐	MCWF =	MARGINAL COLDWATER FISHERY	☐	IRR	=	IRRIGATION
☐	WWF =	WARMWATER FISHERY	☐	LW	=	LIVESTOCK WATERING
☐	LWWF =	LIMITED WARMWATER FISHERY	☐	WH	=	WILDLIFE HABITAT

'ish culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these ıses are actually being realized. However, no numeric standards apply uniquely to these uses.

REACH NAME: Bull Creek (Cow Creek to headwaters)

SEGMENT NUMBER: 20.6.4.217
BASIN: Upper Pecos
PARAMETER: temp

STAFF MAKING ASSESSMENT: Schiffmiller
DATE: 6 Dec 04

:ODES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

☐	0100	INDUSTRIAL POINT SOURCES
☐	0200	MUNICIPAL POINT SOURCES
☐	0201	DOMESTIC POINT SOURCES
☐	0400	COMBINED SEWER OVERFLOWS
☒	1000	AGRICULTURE
☐	1100	NONIRRIGATED CROP PRODUCTION
☐	1200	IRRIGATED CROP PRODUCTION
☐	1201	IRRIGATED RETURN FLOWS
☐	1300	SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)
☐	1400	PASTURELAND
☒	1500	RANGELAND
☐	1600	FEEDLOTS - ALL TYPES
☐	1700	AQUACULTURE
☐	1800	ANIMAL HOLDING/MANAGEMENT AREAS
☐	1900	MANURE LAGOONS
☐	2000	SILVICULTURE
☐	2100	HARVESTING, RESTORATION, RESIDUE MANAGEMENT
☐	2200	FOREST MANAGEMENT
☐	2300	ROAD CONSTRUCTION or MAINTENANCE
☐	3000	CONSTRUCTION
☐	3100	HIGHWAY/ROAD/BRIDGE
☐	3200	LAND DEVELOPMENT
☐	3201	RESORT DEVELOPMENT
☐	3300	HYDROELECTRIC
☐	4000	URBAN RUNOFF/STORM SEWERS
☐	5000	RESOURCES EXTRACTION
☐	5100	SURFACE MINING
☐	5200	SUBSURFACE MINING
☐	5300	PLACER MINING
☐	5400	DREDGE MINING
☐	5500	PETROLEUM ACTIVITIES
☐	5501	PIPELINES
☐	5600	MILL TAILINGS
☐	5700	MINE TAILINGS
☐	5800	ROAD CONSTRUCTION/MAINTENANCE
☐	5900	SPILLS
☐	6000	LAND DISPOSAL
☐	6100	SLUDGE
☐	6200	WASTEWATER
☐	6300	LANDFILLS
☐	6400	INDUSTRIAL LAND TREATMENT
☐	6500	ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)
☐	6600	HAZARDOUS WASTE
☐	6700	SEPTAGE DISPOSAL
☐	6800	UST LEAKS
☐	7000	HYDROMODIFICATION
☐	7100	CHANNELIZATION
☐	7200	DREDGING
☐	7300	DAM CONSTRUCTION/REPAIR
☐	7400	FLOW REGULATION/MODIFICATION
☐	7500	BRIDGE CONSTRUCTION
☒	7600	REMOVAL OF RIPARIAN VEGETATION
☒	7700	STREAMBANK MODIFICATION OI DESTABILIZATION
☐	7800	DRAINING/FILLING OF WETLANDS
☐	8000	OTHER
☐	8010	VECTOR CONTROL ACTIVITIES
☐	8100	ATMOSPHERIC DEPOSITION
☐	8200	WASTE STORAGE/STORAGE TANK LEAKS
☐	8300	ROAD MAINTENANCE or RUNOFF
☐	8400	SPILLS
☐	8500	IN-PLACE CONTAMINANTS
☐	8600	NATURAL
☐	8700	RECREATIONAL ACTIVITIES
☐	8701	ROAD/PARKING LOT RUNOFF
☐	8702	OFF-ROAD VEHICLES
☐	8703	REFUSE DISPOSAL
☐	8704	WILDLIFE IMPACTS
☐	8705	SKI SLOPE RUNOFF
☐	8800	UPSTREAM IMPOUNDMENT
☐	8900	SALT STORAGE SITES
☐	9000	SOURCE UNKNOWN

FIELD SHEET FOR ASSESSING DESIGNATED USES AND NONPOINT SOURCES OF POLLUTION

:ODES FOR USES NOT FULLY SUPPORTED

☒	HQCWF =	HIGH QUALITY COLDWATER FISHERY	☐	DWS	=	DOMESTIC WATER SUPPLY
☐	CWF =	COLDWATER FISHERY	☐	PC	=	PRIMARY CONTACT
☐	MCWF =	MARGINAL COLDWATER FISHERY	☐	IRR	=	IRRIGATION
☐	WWF =	WARMWATER FISHERY	☐	LW	=	LIVESTOCK WATERING
☐	LWWF =	LIMITED WARMWATER FISHERY	☐	WH	=	WILDLIFE HABITAT

'ish culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these ises are actually being realized. However, no numeric standards apply uniquely to these uses.

REACH NAME: Cow Creek (Bull Creek to headwaters)

SEGMENT NUMBER: 20.6.4.217

BASIN: Upper Pecos

PARAMETER: temp

STAFF MAKING ASSESSMENT: Schiffmiller

DATE: 6 Dec 04

:ODES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

☐	0100	INDUSTRIAL POINT SOURCES
☐	0200	MUNICIPAL POINT SOURCES
☐	0201	DOMESTIC POINT SOURCES
☐	0400	COMBINED SEWER OVERFLOWS
☒	1000	AGRICULTURE
☐	1100	NONIRRIGATED CROP PRODUCTION
☐	1200	IRRIGATED CROP PRODUCTION
☐	1201	IRRIGATED RETURN FLOWS
☐	1300	SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)
☐	1400	PASTURELAND
☒	1500	RANGELAND
☐	1600	FEEDLOTS - ALL TYPES
☐	1700	AQUACULTURE
☐	1800	ANIMAL HOLDING/MANAGEMENT AREAS
☐	1900	MANURE LAGOONS
☐	2000	SILVICULTURE
☐	2100	HARVESTING, RESTORATION, RESIDUE MANAGEMENT
☐	2200	FOREST MANAGEMENT
☐	2300	ROAD CONSTRUCTION or MAINTENANCE
☐	3000	CONSTRUCTION
☐	3100	HIGHWAY/ROAD/BRIDGE
☐	3200	LAND DEVELOPMENT
☐	3201	RESORT DEVELOPMENT
☐	3300	HYDROELECTRIC

☐	4000	URBAN RUNOFF/STORM SEWERS
☐	5000	RESOURCES EXTRACTION
☐	5100	SURFACE MINING
☐	5200	SUBSURFACE MINING
☐	5300	PLACER MINING
☐	5400	DREDGE MINING
☐	5500	PETROLEUM ACTIVITIES
☐	5501	PIPELINES
☐	5600	MILL TAILINGS
☐	5700	MINE TAILINGS
☐	5800	ROAD CONSTRUCTION/MAINTENANCE
☐	5900	SPILLS
☐	6000	LAND DISPOSAL
☐	6100	SLUDGE
☐	6200	WASTEWATER
☐	6300	LANDFILLS
☐	6400	INDUSTRIAL LAND TREATMENT
☐	6500	ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)
☐	6600	HAZARDOUS WASTE
☐	6700	SEPTAGE DISPOSAL
☐	6800	UST LEAKS
☐	7000	HYDROMODIFICATION
☐	7100	CHANNELIZATION
☐	7200	DREDGING
☐	7300	DAM CONSTRUCTION/REPAIR

☐	7400	FLOW REGULATION/MODIFICATION
☐	7500	BRIDGE CONSTRUCTION
☒	7600	REMOVAL OF RIPARIAN VEGETATION
☒	7700	STREAMBANK MODIFICATION OI DESTABILIZATION
☐	7800	DRAINING/FILLING OF WETLANDS
☐	8000	OTHER
☐	8010	VECTOR CONTROL ACTIVITIES
☐	8100	ATMOSPHERIC DEPOSITION
☐	8200	WASTE STORAGE/STORAGE TANK LEAKS
☐	8300	ROAD MAINTENANCE or RUNOFF
☐	8400	SPILLS
☐	8500	IN-PLACE CONTAMINANTS
☒	8600	NATURAL
☐	8700	RECREATIONAL ACTIVITIES
☐	8701	ROAD/PARKING LOT RUNOFF
☐	8702	OFF-ROAD VEHICLES
☐	8703	REFUSE DISPOSAL
☐	8704	WILDLIFE IMPACTS
☐	8705	SKI SLOPE RUNOFF
☐	8800	UPSTREAM IMPOUNDMENT
☐	8900	SALT STORAGE SITES
☐	9000	SOURCE UNKNOWN

Viveash fire (2000) probably major contributing factor

FIELD SHEET FOR ASSESSING DESIGNATED USES AND NONPOINT SOURCES OF POLLUTION

CODES FOR USES NOT FULLY SUPPORTED

- ☒ HQCWF = HIGH QUALITY COLDWATER FISHERY
- ☐ CWF = COLDWATER FISHERY
- ☐ MCWF = MARGINAL COLDWATER FISHERY
- ☐ WWF = WARMWATER FISHERY
- ☐ LWWF = LIMITED WARMWATER FISHERY
- ☐ DWS = DOMESTIC WATER SUPPLY
- ☐ PC = PRIMARY CONTACT
- ☐ IRR = IRRIGATION
- ☐ LW = LIVESTOCK WATERING
- ☐ WH = WILDLIFE HABITAT

Fish culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these uses are actually being realized. However, no numeric standards apply uniquely to these uses.

REACH NAME: Cow Creek (Pecos R to Bull Creek)

SEGMENT NUMBER: 20.6.4.217

BASIN: Upper Pecos

PARAMETER: temp

STAFF MAKING ASSESSMENT: Schiffmiller

DATE: 6 Dec 04

CODES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

- ☐ 0100 INDUSTRIAL POINT SOURCES
- ☐ 0200 MUNICIPAL POINT SOURCES
- ☐ 0201 DOMESTIC POINT SOURCES
- ☐ 0400 COMBINED SEWER OVERFLOWS
- ☒ 1000 AGRICULTURE
- ☐ 1100 NONIRRIGATED CROP PRODUCTION
- ☐ 1200 IRRIGATED CROP PRODUCTION
- ☐ 1201 IRRIGATED RETURN FLOWS
- ☐ 1300 SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)
- ☐ 1400 PASTURELAND
- ☒ 1500 RANGELAND
- ☐ 1600 FEEDLOTS - ALL TYPES
- ☐ 1700 AQUACULTURE
- ☐ 1800 ANIMAL HOLDING/MANAGEMENT AREAS
- ☐ 1900 MANURE LAGOONS
- ☐ 2000 SILVICULTURE
- ☐ 2100 HARVESTING, RESTORATION, RESIDUE MANAGEMENT
- ☐ 2200 FOREST MANAGEMENT
- ☐ 2300 ROAD CONSTRUCTION or MAINTENANCE
- ☐ 3000 CONSTRUCTION
- ☐ 3100 HIGHWAY/ROAD/BRIDGE
- ☐ 3200 LAND DEVELOPMENT
- ☐ 3201 RESORT DEVELOPMENT
- ☐ 3300 HYDROELECTRIC
- ☐ 4000 URBAN RUNOFF/STORM SEWERS
- ☐ 5000 RESOURCES EXTRACTION
- ☐ 5100 SURFACE MINING
- ☐ 5200 SUBSURFACE MINING
- ☐ 5300 PLACER MINING
- ☐ 5400 DREDGE MINING
- ☐ 5500 PETROLEUM ACTIVITIES
- ☐ 5501 PIPELINES
- ☐ 5600 MILL TAILINGS
- ☐ 5700 MINE TAILINGS
- ☐ 5800 ROAD CONSTRUCTION/MAINTENANCE
- ☐ 5900 SPILLS
- ☐ 6000 LAND DISPOSAL
- ☐ 6100 SLUDGE
- ☐ 6200 WASTEWATER
- ☐ 6300 LANDFILLS
- ☐ 6400 INDUSTRIAL LAND TREATMENT
- ☐ 6500 ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)
- ☐ 6600 HAZARDOUS WASTE
- ☐ 6700 SEPTAGE DISPOSAL
- ☐ 6800 UST LEAKS
- ☐ 7000 HYDROMODIFICATION
- ☐ 7100 CHANNELIZATION
- ☐ 7200 DREDGING
- ☐ 7300 DAM CONSTRUCTION/REPAIR
- ☐ 7400 FLOW REGULATION/MODIFICATION
- ☐ 7500 BRIDGE CONSTRUCTION
- ☒ 7600 REMOVAL OF RIPARIAN VEGETATION
- ☒ 7700 STREAMBANK MODIFICATION OI DESTABILIZATION
- ☐ 7800 DRAINING/FILLING OF WETLANDS
- ☐ 8000 OTHER
- ☐ 8010 VECTOR CONTROL ACTIVITIES
- ☐ 8100 ATMOSPHERIC DEPOSITION
- ☐ 8200 WASTE STORAGE/STORAGE TANK LEAKS
- ☐ 8300 ROAD MAINTENANCE or RUNOFF
- ☐ 8400 SPILLS
- ☐ 8500 IN-PLACE CONTAMINANTS
- ☒ 8600 NATURAL
- ☐ 8700 RECREATIONAL ACTIVITIES
- ☐ 8701 ROAD/PARKING LOT RUNOFF
- ☐ 8702 OFF-ROAD VEHICLES
- ☐ 8703 REFUSE DISPOSAL
- ☐ 8704 WILDLIFE IMPACTS
- ☐ 8705 SKI SLOPE RUNOFF
- ☐ 8800 UPSTREAM IMPOUNDMENT
- ☐ 8900 SALT STORAGE SITES
- ☐ 9000 SOURCE UNKNOWN

Viveash fire (2000) probably major contributing factor

FIELD SHEET FOR ASSESSING DESIGNATED USES AND NONPOINT SOURCES OF POLLUTION

REACH NAME: Gallinas R, LV div to hdwtr
SEGMENT NUMBER: 20.6.4.215
BASIN: Pecos
PARAMETER: Temp.
STAFF MAKING ASSESSMENT: JSH
DATE: 12-03-04

CODES FOR USES NOT FULLY SUPPORTED

☑	HQCWF =	HIGH QUALITY COLDWATER FISHERY	☐	DWS	=	DOMESTIC WATER SUPPLY
☐	CWF =	COLDWATER FISHERY	☐	PC	=	PRIMARY CONTACT
☐	MCWF =	MARGINAL COLDWATER FISHERY	☐	IRR	=	IRRIGATION
☐	WWF =	WARMWATER FISHERY	☐	LW	=	LIVESTOCK WATERING
☐	LWWF =	LIMITED WARMWATER FISHERY	☐	WH	=	WILDLIFE HABITAT

Fish culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these uses are actually being realized. However, no numeric standards apply uniquely to these uses.

CODES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

- ☐ <u>0100</u> <u>INDUSTRIAL POINT SOURCES</u>
- ☐ <u>0200</u> <u>MUNICIPAL POINT SOURCES</u>
- ☐ 0201 DOMESTIC POINT SOURCES
- ☐ <u>0400</u> <u>COMBINED SEWER OVERFLOWS</u>
- ☐ <u>1000</u> AGRICULTURE
- ☐ 1100 NONIRRIGATED CROP PRODUCTION
- ☐ 1200 IRRIGATED CROP PRODUCTION
- ☐ 1201 IRRIGATED RETURN FLOWS
- ☐ 1300 SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)
- ☐ 1400 PASTURELAND
- ☐ 1500 RANGELAND
- ☐ 1600 FEEDLOTS - ALL TYPES
- ☐ 1700 AQUACULTURE
- ☐ 1800 ANIMAL HOLDING/MANAGEMENT AREAS
- ☐ 1900 MANURE LAGOONS
- ☐ <u>2000</u> <u>SILVICULTURE</u>
- ☐ 2100 HARVESTING, RESTORATION, RESIDUE MANAGEMENT
- ☐ 2200 FOREST MANAGEMENT
- ☐ 2300 ROAD CONSTRUCTION or MAINTENANCE
- ☐ <u>3000</u> <u>CONSTRUCTION</u>
- ☐ 3100 HIGHWAY/ROAD/BRIDGE
- ☐ 3200 LAND DEVELOPMENT
- ☐ 3201 RESORT DEVELOPMENT
- ☐ 3300 HYDROELECTRIC
- ☐ <u>4000</u> <u>URBAN RUNOFF/STORM SEWERS</u>
- ☐ 5000 <u>RESOURCES EXTRACTION</u>
- ☐ 5100 SURFACE MINING
- ☐ 5200 SUBSURFACE MINING
- ☐ 5300 PLACER MINING
- ☐ 5400 DREDGE MINING
- ☐ 5500 PETROLEUM ACTIVITIES
- ☐ 5501 PIPELINES
- ☐ 5600 MILL TAILINGS
- ☐ 5700 MINE TAILINGS
- ☐ 5800 ROAD CONSTRUCTION/MAINTENANCE
- ☐ 5900 SPILLS
- ☐ <u>6000</u> <u>LAND DISPOSAL</u>
- ☐ 6100 SLUDGE
- ☐ 6200 WASTEWATER
- ☐ 6300 LANDFILLS
- ☐ 6400 INDUSTRIAL LAND TREATMENT
- ☐ 6500 ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)
- ☐ 6600 HAZARDOUS WASTE
- ☐ 6700 SEPTAGE DISPOSAL
- ☐ 6800 UST LEAKS
- ☐ <u>7000</u> <u>HYDROMODIFICATION</u>
- ☐ 7100 CHANNELIZATION
- ☐ 7200 DREDGING
- ☐ 7300 DAM CONSTRUCTION/REPAIR
- ☐ 7400 FLOW REGULATION/MODIFICATION
- ☐ 7500 BRIDGE CONSTRUCTION
- ☑ 7600 REMOVAL OF RIPARIAN VEGETATION
- ☐ 7700 STREAMBANK MODIFICATION OI DESTABILIZATION
- ☐ 7800 DRAINING/FILLING OF WETLANDS
- ☐ <u>8000</u> <u>OTHER</u>
- ☐ 8010 VECTOR CONTROL ACTIVITIES
- ☐ 8100 ATMOSPHERIC DEPOSITION
- ☐ 8200 WASTE STORAGE/STORAGE TANK LEAKS
- ☐ 8300 ROAD MAINTENANCE or RUNOFF
- ☐ 8400 SPILLS
- ☐ 8500 IN-PLACE CONTAMINANTS
- ☑ 8600 NATURAL
- ☐ 8700 RECREATIONAL ACTIVITIES
- ☐ 8701 ROAD/PARKING LOT RUNOFF
- ☐ 8702 OFF-ROAD VEHICLES
- ☐ 8703 REFUSE DISPOSAL
- ☐ 8704 WILDLIFE IMPACTS
- ☐ 8705 SKI SLOPE RUNOFF
- ☐ 8800 UPSTREAM IMPOUNDMENT
- ☐ 8900 SALT STORAGE SITES
- ☐ <u>9000</u> <u>SOURCE UNKNOWN</u>

FIELD SHEET FOR ASSESSING DESIGNATED USES AND NONPOINT SOURCES OF POLLUTION

CODES FOR USES NOT FULLY SUPPORTED

- ☒ HQCWF = HIGH QUALITY COLDWATER FISHERY
- ☐ CWF = COLDWATER FISHERY
- ☐ MCWF = MARGINAL COLDWATER FISHERY
- ☐ WWF = WARMWATER FISHERY
- ☐ LWWF = LIMITED WARMWATER FISHERY
- ☐ DWS = DOMESTIC WATER SUPPLY
- ☐ PC = PRIMARY CONTACT
- ☐ IRR = IRRIGATION
- ☐ LW = LIVESTOCK WATERING
- ☐ WH = WILDLIFE HABITAT

Fish culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these uses are actually being realized. However, no numeric standards apply uniquely to these uses.

REACH NAME: Pecos R (Alamitos Canyon to Willow Cr)

SEGMENT NUMBER: 20.6.4.217

BASIN: Upper Pecos

PARAMETER: turbidity

STAFF MAKING ASSESSMENT: Schiffmiller

DATE: 6 Dec 04

CODES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

- ☐ 0100 INDUSTRIAL POINT SOURCES
- ☐ 0200 MUNICIPAL POINT SOURCES
- ☐ 0201 DOMESTIC POINT SOURCES
- ☐ 0400 COMBINED SEWER OVERFLOWS
- ☐ 1000 AGRICULTURE
- ☐ 1100 NONIRRIGATED CROP PRODUCTION
- ☐ 1200 IRRIGATED CROP PRODUCTION
- ☐ 1201 IRRIGATED RETURN FLOWS
- ☐ 1300 SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)
- ☐ 1400 PASTURELAND
- ☐ 1500 RANGELAND
- ☐ 1600 FEEDLOTS - ALL TYPES
- ☐ 1700 AQUACULTURE
- ☐ 1800 ANIMAL HOLDING/MANAGEMENT AREAS
- ☐ 1900 MANURE LAGOONS
- ☐ 2000 SILVICULTURE
- ☐ 2100 HARVESTING, RESTORATION, RESIDUE MANAGEMENT
- ☐ 2200 FOREST MANAGEMENT
- ☐ 2300 ROAD CONSTRUCTION or MAINTENANCE
- ☐ 3000 CONSTRUCTION
- ☐ 3100 HIGHWAY/ROAD/BRIDGE
- ☐ 3200 LAND DEVELOPMENT
- ☐ 3201 RESORT DEVELOPMENT
- ☐ 3300 HYDROELECTRIC
- ☐ 4000 URBAN RUNOFF/STORM SEWERS
- ☐ 5000 RESOURCES EXTRACTION
- ☐ 5100 SURFACE MINING
- ☐ 5200 SUBSURFACE MINING
- ☐ 5300 PLACER MINING
- ☐ 5400 DREDGE MINING
- ☐ 5500 PETROLEUM ACTIVITIES
- ☐ 5501 PIPELINES
- ☐ 5600 MILL TAILINGS
- ☐ 5700 MINE TAILINGS
- ☐ 5800 ROAD CONSTRUCTION/MAINTENANCE
- ☐ 5900 SPILLS
- ☐ 6000 LAND DISPOSAL
- ☐ 6100 SLUDGE
- ☐ 6200 WASTEWATER
- ☐ 6300 LANDFILLS
- ☐ 6400 INDUSTRIAL LAND TREATMENT
- ☐ 6500 ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)
- ☐ 6600 HAZARDOUS WASTE
- ☐ 6700 SEPTAGE DISPOSAL
- ☐ 6800 UST LEAKS
- ☐ 7000 HYDROMODIFICATION
- ☐ 7100 CHANNELIZATION
- ☐ 7200 DREDGING
- ☐ 7300 DAM CONSTRUCTION/REPAIR
- ☐ 7400 FLOW REGULATION/MODIFICATION
- ☐ 7500 BRIDGE CONSTRUCTION
- ☐ 7600 REMOVAL OF RIPARIAN VEGETATION
- ☐ 7700 STREAMBANK MODIFICATION OR DESTABILIZATION
- ☐ 7800 DRAINING/FILLING OF WETLANDS
- ☐ 8000 OTHER
- ☐ 8010 VECTOR CONTROL ACTIVITIES
- ☐ 8100 ATMOSPHERIC DEPOSITION
- ☐ 8200 WASTE STORAGE/STORAGE TANK LEAKS
- ☐ 8300 ROAD MAINTENANCE or RUNOFF
- ☐ 8400 SPILLS
- ☐ 8500 IN-PLACE CONTAMINANTS
- ☒ 8600 NATURAL
- ☐ 8700 RECREATIONAL ACTIVITIES
- ☐ 8701 ROAD/PARKING LOT RUNOFF
- ☐ 8702 OFF-ROAD VEHICLES
- ☐ 8703 REFUSE DISPOSAL
- ☐ 8704 WILDLIFE IMPACTS
- ☐ 8705 SKI SLOPE RUNOFF
- ☐ 8800 UPSTREAM IMPOUNDMENT
- ☐ 8900 SALT STORAGE SITES
- ☐ 9000 SOURCE UNKNOWN

FIELD SHEET FOR ASSESSING DESIGNATED USES AND NONPOINT SOURCES OF POLLUTION

CODES FOR USES NOT FULLY SUPPORTED

- [x] HQCWF = HIGH QUALITY COLDWATER FISHERY
- [ ] CWF = COLDWATER FISHERY
- [ ] MCWF = MARGINAL COLDWATER FISHERY
- [ ] WWF = WARMWATER FISHERY
- [ ] LWWF = LIMITED WARMWATER FISHERY
- [ ] DWS = DOMESTIC WATER SUPPLY
- [ ] PC = PRIMARY CONTACT
- [ ] IRR = IRRIGATION
- [ ] LW = LIVESTOCK WATERING
- [ ] WH = WILDLIFE HABITAT

Fish culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these uses are actually being realized. However, no numeric standards apply uniquely to these uses.

REACH NAME: Pecos R (Cañon de Manzanitas to Alamitos Canyon)
SEGMENT NUMBER: 20.6.4.217
BASIN: Upper Pecos
PARAMETER: temp
STAFF MAKING ASSESSMENT: Schiffmiller
DATE: 6 Dec 04

CODES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

- [ ] 0100 INDUSTRIAL POINT SOURCES
- [ ] 0200 MUNICIPAL POINT SOURCES
- [ ] 0201 DOMESTIC POINT SOURCES
- [ ] 0400 COMBINED SEWER OVERFLOWS
- [x] 1000 AGRICULTURE
- [ ] 1100 NONIRRIGATED CROP PRODUCTION
- [ ] 1200 IRRIGATED CROP PRODUCTION
- [ ] 1201 IRRIGATED RETURN FLOWS
- [ ] 1300 SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)
- [x] 1400 PASTURELAND
- [x] 1500 RANGELAND
- [ ] 1600 FEEDLOTS - ALL TYPES
- [ ] 1700 AQUACULTURE
- [ ] 1800 ANIMAL HOLDING/MANAGEMENT AREAS
- [ ] 1900 MANURE LAGOONS
- [ ] 2000 SILVICULTURE
- [ ] 2100 HARVESTING, RESTORATION, RESIDUE MANAGEMENT
- [ ] 2200 FOREST MANAGEMENT
- [ ] 2300 ROAD CONSTRUCTION or MAINTENANCE
- [ ] 3000 CONSTRUCTION
- [ ] 3100 HIGHWAY/ROAD/BRIDGE
- [ ] 3200 LAND DEVELOPMENT
- [ ] 3201 RESORT DEVELOPMENT
- [ ] 3300 HYDROELECTRIC
- [ ] 4000 URBAN RUNOFF/STORM SEWERS
- [ ] 5000 RESOURCES EXTRACTION
- [ ] 5100 SURFACE MINING
- [ ] 5200 SUBSURFACE MINING
- [ ] 5300 PLACER MINING
- [ ] 5400 DREDGE MINING
- [ ] 5500 PETROLEUM ACTIVITIES
- [ ] 5501 PIPELINES
- [ ] 5600 MILL TAILINGS
- [ ] 5700 MINE TAILINGS
- [ ] 5800 ROAD CONSTRUCTION/MAINTENANCE
- [ ] 5900 SPILLS
- [ ] 6000 LAND DISPOSAL
- [ ] 6100 SLUDGE
- [ ] 6200 WASTEWATER
- [ ] 6300 LANDFILLS
- [ ] 6400 INDUSTRIAL LAND TREATMENT
- [ ] 6500 ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)
- [ ] 6600 HAZARDOUS WASTE
- [ ] 6700 SEPTAGE DISPOSAL
- [ ] 6800 UST LEAKS
- [ ] 7000 HYDROMODIFICATION
- [ ] 7100 CHANNELIZATION
- [ ] 7200 DREDGING
- [ ] 7300 DAM CONSTRUCTION/REPAIR
- [ ] 7400 FLOW REGULATION/MODIFICATION
- [ ] 7500 BRIDGE CONSTRUCTION
- [x] 7600 REMOVAL OF RIPARIAN VEGETATION
- [x] 7700 STREAMBANK MODIFICATION OI DESTABILIZATION
- [ ] 7800 DRAINING/FILLING OF WETLANDS
- [ ] 8000 OTHER
- [ ] 8010 VECTOR CONTROL ACTIVITIES
- [ ] 8100 ATMOSPHERIC DEPOSITION
- [ ] 8200 WASTE STORAGE/STORAGE TANK LEAKS
- [ ] 8300 ROAD MAINTENANCE or RUNOFF
- [ ] 8400 SPILLS
- [ ] 8500 IN-PLACE CONTAMINANTS
- [ ] 8600 NATURAL
- [ ] 8700 RECREATIONAL ACTIVITIES
- [ ] 8701 ROAD/PARKING LOT RUNOFF
- [ ] 8702 OFF-ROAD VEHICLES
- [ ] 8703 REFUSE DISPOSAL
- [ ] 8704 WILDLIFE IMPACTS
- [ ] 8705 SKI SLOPE RUNOFF
- [ ] 8800 UPSTREAM IMPOUNDMENT
- [ ] 8900 SALT STORAGE SITES
- [ ] 9000 SOURCE UNKNOWN

This page left intentionally blank.

APPENDIX C
THERMOGRAPH SUMMARY DATA AND GRAPHICS

This page left intentionally blank.

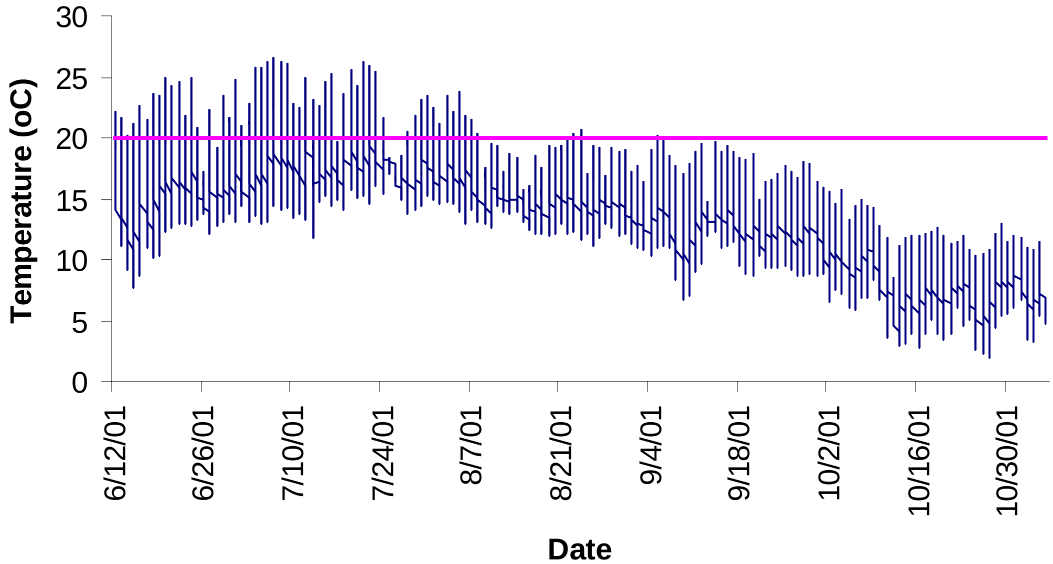
TABLE OF CONTENTS

This page left intentionally blank.

C1.0 Bull Creek (Cow Creek to headwaters)

June 12, 2001 (12:51) through November 5, 2001:

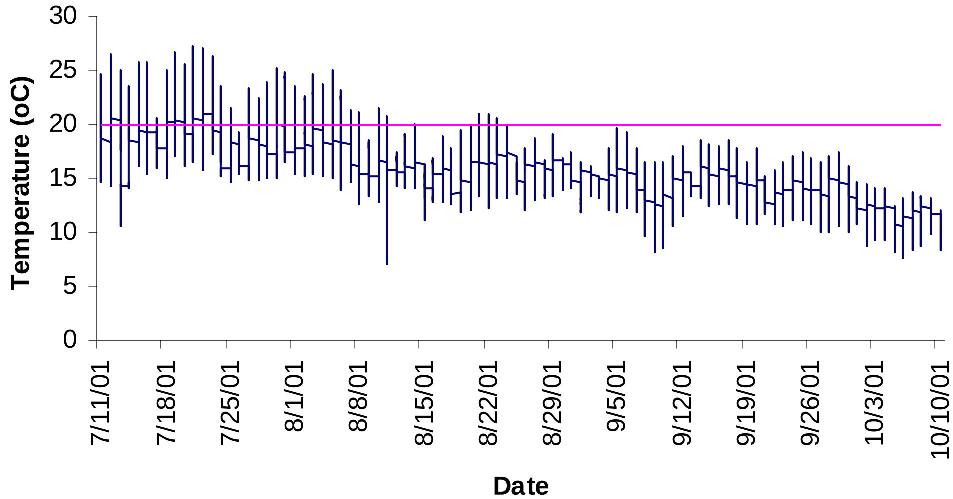
Number of Data Points:	3,504
Number of Measurements >20°C:	350
Percentage Data Points >20°C:	10%
Minimum Temperature (°C):	1.95
Maximum Temperature (°C):	26.56



No photo available

C2.0 Cow Creek (Pecos River to Bull Creek)

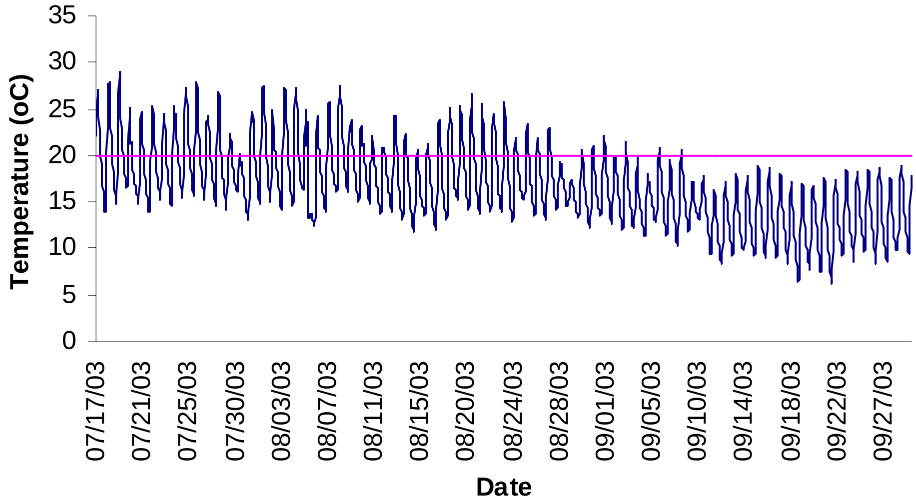
July 11, 2001 (18:52) through October 10, 2001:	
Number of Data Points:	8,254
Number of Measurements >20^{o}C:	1,044
Percentage Data Points >20^{o}C:	13%
Minimum Temperature (^{o}C):	7.04
Maximum Temperature (^{o}C):	27.15



No photo available

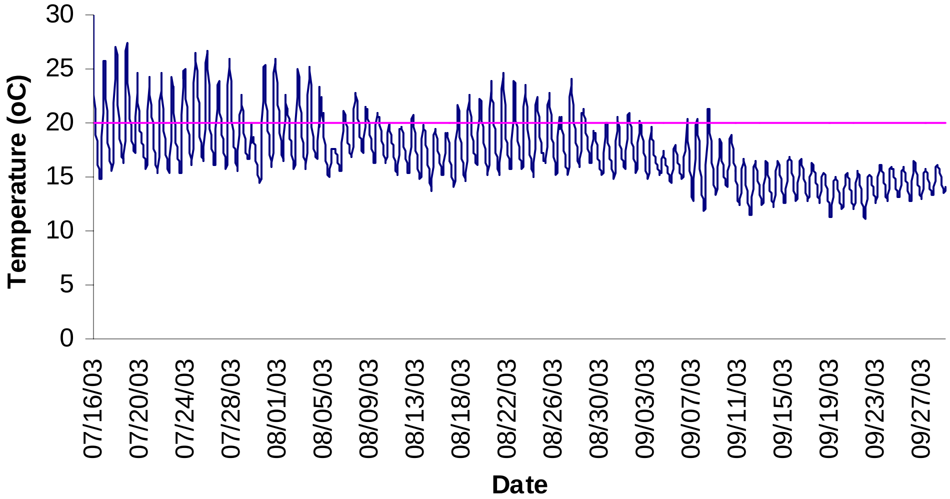
July 17, 2003 (11:37) through September 29, 2003:

Number of Data Points:	1,779
Number of Measurements >20°C:	377
Percentage Data Points >20°C:	21%
Minimum Temperature (°C):	6.1
Maximum Temperature (°C):	29.09



No photo available

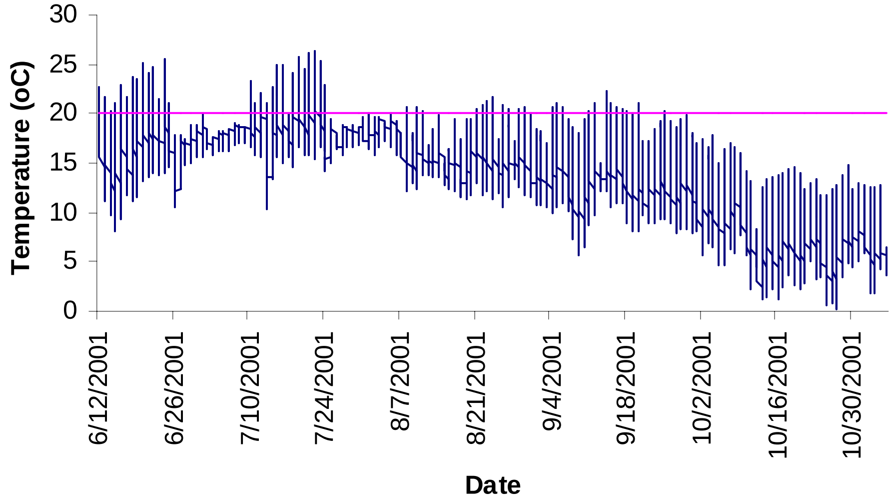
July 16, 2003 (16:37) through September 29, 2003:	
Number of Data Points:	1,796
Number of Measurements >20°C:	343
Percentage Data Points >20°C:	19%
Minimum Temperature (°C):	11.1
Maximum Temperature (°C):	27.4



Cow Creek at North San Ysidro, 2003

C3.0 Cow Creek (Bull Creek to headwaters)

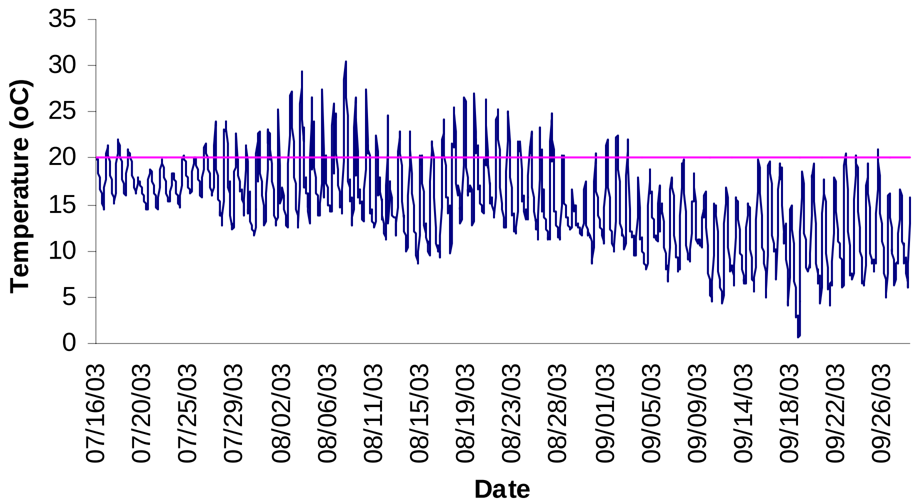
June 12, 2001 (11:50) through November 5, 2001:	
Number of Data Points:	3,505
Number of Measurements >20°C:	285
Percentage Data Points >20°C:	8%
Minimum Temperature (°C):	0.25
Maximum Temperature (°C):	26.31

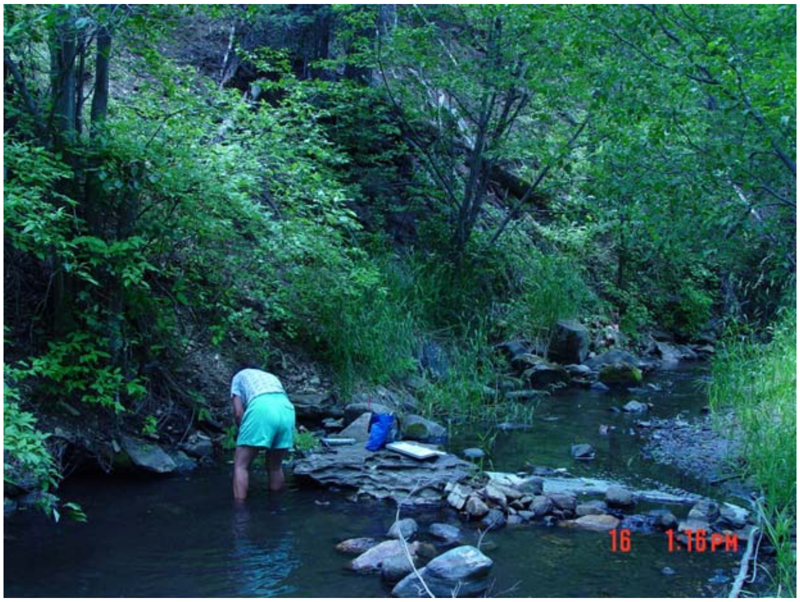


Cow Creek above Bull Creek, 2001

C4.0 Gallinas River (Las Vegas Diversion to headwaters)

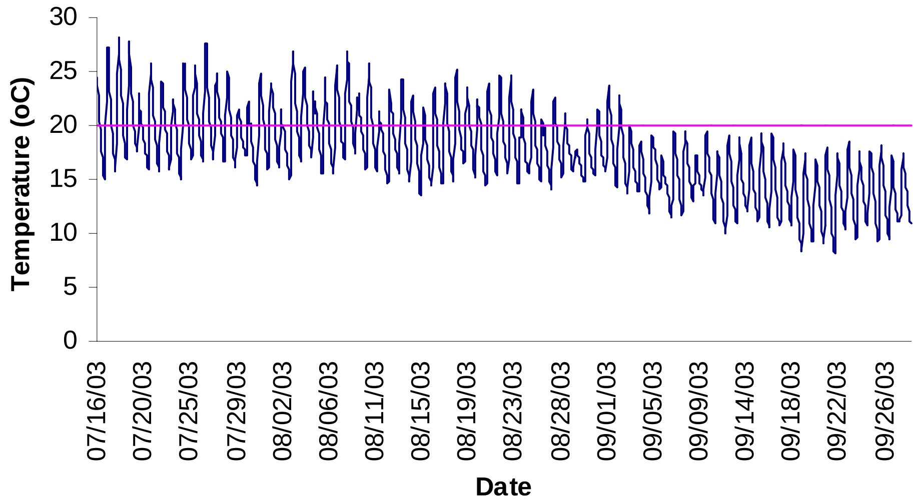
July 16, 2003 (16:37) through September 29, 2003:	
Number of Data Points:	1795
Number of Measurements >20°C:	250
Percentage Data Points >20°C:	14%
Minimum Temperature (°C):	0.74
Maximum Temperature (°C):	30.4





Gallinas River @ Forest Service Boundary

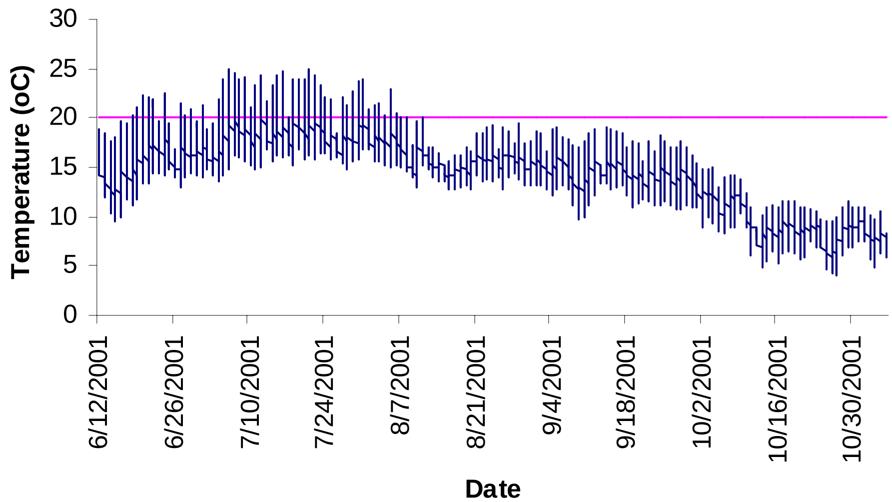
July 16, 2003 (16:30) through September 29, 2003:	
Number of Data Points:	1794
Number of Measurements >20°C:	461
Percentage Data Points >20°C:	26%
Minimum Temperature (°C):	8.1
Maximum Temperature (°C):	28.1



See Photo 3.5 in Section 3.3

C5.0 Pecos River (Canon de Manzanita to Alamitos Canyon)

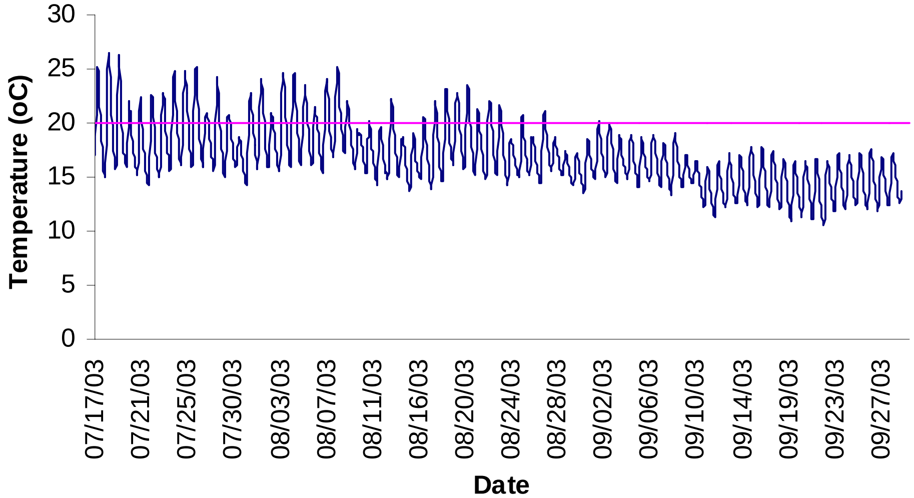
June 12, 2003 (14:52) through November 5, 2001:	
Number of Data Points:	3503
Number of Measurements >20^{o}C:	295
Percentage Data Points >20^{o}C:	8%
Minimum Temperature (^{o}C):	4.02
Maximum Temperature (^{o}C):	24.86



No photo available

July 17, 2003 (10:15) through September 29, 2003:

Number of Data Points:	1779
Number of Measurements >20^{o}C:	286
Percentage Data Points >20^{o}C:	16%
Minimum Temperature (^{o}C):	10.47
Maximum Temperature (^{o}C):	26.6



Pecos River @ Pecos NHP, 2003

APPENDIX D
HYDROLOGY, GEOMETRY, AND METEROLOGICAL INPUT DATA FOR SSTEMP

This page left intentionally blank.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

4Q3	Four-consecutive day discharge that has a recurrence interval of three years
cfs	Cubic Feet per Second
GIS	Geographic Information Systems
GPS	Global Positioning System
IOWDM	Input and Output for Watershed Data Management
mi^2	Square Miles
^{o}C	Degrees Celcius
SEE	Standard Error of Estimate
SSTEMP	Stream Segment Temperature
SWSTAT	Surface-Water Statistics
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WinXSPRO	Windows-Based Stream Channel Cross-Section Analysis

This page left intentionally blank.

D 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. Meterological inputs to SSTEMP Model include air temperature, relative humidity, windspeed, ground temperature, thermal gradient, possible sun, dust coefficient, ground reflectivity, and solar radiation. In the following sections, these parameters are discussed in detail for each assessment unit to be modeled using SSTEMP Model. The assessment units were modeled on the day of the maximum recorded thermograph measurement. The assessment units and modeled dates are defined as follows:

Table D.1 Assessment Units and Modeled Dates

Assessment Unit ID	Assessment Unit Description	Modeled Date
NM-2214.A_091	Bull Creek (Cow Creek to headwaters)	7-7-2001
NM-2214.A_090	Cow Creek (Pecos River to Bull Creek)	7-19-2003
NM-2214.A_102	Cow Creek (Bull Creek to headwaters)	7-22-2001
NM-2212_00	Gallinas River (Las Vegas Diversion to headwaters)	7-18-2003
NM-2214.A_003	Pecos River (Canon de Manzanita to Alamitos Canyon)	7-18-2003

D 2.0 HYDROLOGY

D2.1 Segment Inflow

This parameter is the *mean daily* flow at the top of the stream segment. If the segment begins at an effective headwater, the flow is entered into SSTEMP Model as zero. Flow data from USGS gages were used when available. 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 as the inflow instead of the mean daily flow. These critical low flows were used to decrease assimilative capacity of the stream to adsorb and disperse solar energy. The 4Q3 was determined for gaged sites using a log Pearson Type III distribution through "*Input and Output for Watershed Data Management*" (IOWDM) software, Version 4.1 (USGS 2002a) and "*Surface-Water Statistics*" (SWSTAT) software, Version 4.1 (USGS 2002b).

Discharges for ungaged sites on gaged streams were estimated based on methods published by Thomas and others (1997). If the drainage area of the ungaged site is between 50 and 150 percent of the drainage area of the gaged site, the following equation is used:

$$Q_u = Q_g \left(\frac{A_u}{A_g} \right)^{0.5}$$

where,

Q_u = Area weighted 4Q3 at the ungaged site (cubic feet per second [cfs])
Q_g = 4Q3 at the gaged site (cfs)
A_u = Drainage area at the ungaged site (square miles [mi^2])
A_g = Drainage area at the gaged site (mi^2)

Drainage areas for assessment units to which this method was applied are summarized in the following table:

Table D.2 Drainage Areas for Estimating Flow by Drainage Area Ratios

Assessment Unit	USGS Gage	Drainage Area from Gage (mi^2)	Drainage Area from Top of AU (mi^2)	Drainage Area from Bottom of AU (mi^2)	Ratio of DA of Ungaged (upstream) to Gaged Site	Ratio of DA of Ungaged (downstream) to Gaged Site
NM-2214.A_091	—[(a)]	—	—[(b)]	27.314	—	—
NM-2214.A_090	—[(a)]	—	79.768	126.314	—	—
NM-2214.A_102	—[(a)]	—	—[(b)]	52.436	—	—
NM-2212_00	08380500	75.949	—[(b)]	87.5	—[(b)]	115%
NM-2214.A_003	08378500	170.31	234.695	294.322	138%	**173%**[(c)]

Notes:
[(a)]Regression method developed by Waltemeyer (2002) was used to estimate flows since this is an ungaged stream.
[(b)]Assessment unit begins at headwaters.
[(c)] The method developed by Thomas et al. (1997) is not applicable because the drainage area of the ungaged site is greater than 150 percent of the drainage area of the gaged site. Therefore, the method developed by Waltemeyer (2002) was used to estimate flows for this assessment unit.

mi^2 = Square miles
USGS = U.S. Geological Survey
AU = Assessment Unit

4Q3 derivations for ungaged streams were based on analysis methods described by Waltemeyer (2002). Two regression equations for estimating 4Q3 were developed based on physiographic regions of New Mexico (i.e., statewide and mountainous regions above 7,500 feet in elevation). The following statewide regression equation is based on data from 50 gaging stations with non-zero discharge (Waltemeyer 2002):

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

where,

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

The average standard error of estimate (SEE) and coefficient of determination are 126 and 48 percent, respectively, for this regression equation (Waltemeyer 2002). The following regression equation for mountainous regions above 7,500 feet in elevation is based on data from 40 gaging stations with non-zero discharge (Waltemeyer 2002):

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

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 (percent)

The average SEE and coefficient of determination are 94 and 66 percent, respectively, for this regression equation (Waltemeyer 2002). The drainage areas, average basin mean winter precipitation, and average basin slope for assessment units where this regression method was used are presented in the following table:

Table D.3 Parameters for Estimating Flow using USGS Regression Model

Assessment Unit	Regression Model[a]	Average Elevation for Assessment Unit (feet)	Mean Basin Winter Precipitation (inches)	Average Basin Slope (unitless)
NM-2214.A_091	Mountainous	8,450	10.72	0.258
NM-2214.A_090	Statewide	6,600	9.85	0.243
NM-2214.A_102	Mountainous	8,950	12.44	0.277
NM-2212_00	Mountainous	8,350	10.18	0.307
NM-2214.A_003	Statewide	6,795	13.12	0.293

Notes:
mi^2 = Square miles
[a] Waltemeyer (2002)

Based on the methods described above, the following values were estimated for inflow:

Table D.4 Inflow

Assessment Unit	Ref.	4Q3[1] (cfs)	DAt (mi^2)	DAg (mi^2)	Pw (in)	S unitless	Inflow (cfs)
NM-2214.A_091	N/A	—	—	—	10.72	0.258	0.000[2]
NM-2214.A_090	(a)	—	79.768	—	9.85	0.243	1.115
NM-2214.A_102	N/A	—	—	—	12.44	0.277	0.000[2]
NM-2212_00	N/A	1.943	—	75.949	10.18	0.307	0.000[2]
NM-2214.A_003	(a)	15.89	234.695	170.31	13.12	0.293	4.339

Notes:
N/A = Not applicable, assessment unit begins at headwaters.
Ref. = Reference
(a) Waltemeyer 2002, statewide
cfs = cubic feet per second
mi^2 = Square miles
in = Inches
Pw = Mean winter precipitation
DAt = Drainage area from top of segment
DAb = Drainage area from bottom of segment
DAg = Drainage area from USGS gage
S = Average basin slope

(1) Based on period of record for USGS gage.
(2) Inflow is zero because assessment unit begins at headwaters.

D2.2 Inflow Temperature

This parameter represents the *mean daily* water temperature at the top of the segment. 2001 and 2003 data from thermographs positioned at the top of the assessment unit were used when possible. If the segment began at a true headwater, the temperature entered was zero degrees Celcius (°C) (zero flow has zero heat). The following inflow temperatures for impaired assessment units were modeled in SSTEMP:

Table D.5 Mean Daily Water Temperature

Assessment Unit	Upstream Thermograph Location	Inflow Temp. (°C)	Inflow Temp. (°F)
NM-2214.A_091	None (headwaters)	0	32.0
NM-2214.A_090	Cow Creek near Lower Colonias[(a)]	16.8	62.24
NM-2214.A_102	None (headwaters)	0	32.0
NM-2212_00	None (headwaters)	0	32.0
NM-2214.A_003	Gallinas River at National Forest Service boundary[(b)]	14.99	58.98

Notes:
°C = Degrees Celcius
°F = Degrees Farenheit
(a) Uppermost Cow Creek (Pecos River to Bull Creek) thermograph, 2003
(b) Uppermost Gallinas River (Las Vegas Diversion to headwaters) thermograph, 2003

D2.3 Segment Outflow

Flow data from USGS gages were used when available. To be conservative, the 4Q3 was used as the segment outflow. These critical low flows were used to decrease assimilative capacity of the stream to adsorb and disperse solar energy. Outflow was estimated using the methods described in Section 2.1. The following table summarizes 4Q3s used in the SSTEMP Model:

Table D.6 Segment Outflow

Assessment Unit	Ref.	4Q3[(1)] (cfs)	DAb (mi^2)	DAg (mi^2)	Pw (in)	S unitless	Outflow (cfs)
NM-2214.A_091	(a)	—	27.314	—	10.72	0.258	0.581
NM-2214.A_090	(a)	—	126.314	—	9.85	0.243	1.35
NM-2214.A_102	(a)	—	52.436	—	12.44	0.277	1.720
NM-2212_00	(b)	1.943	87.5	75.949	10.18	0.307	1.81
NM-2214.A_003	(a)	15.89	294.322	170.31	13.12	0.293	4.77

Notes:
Ref. = Reference
(a) Waltemeyer 2002
(b) Thomas et al. 1997
(c) From USGS gage data

cfs = cubic feet per second
mi^2 = Square miles
in = Inches
Pw = Mean winter precipitation
DAb = Drainage area from bottom of segment
DAg = Drainage area from USGS gage
S = Average basin slope
(1) Based on period of record for USGS gage.

D2.4 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 temperature for 2003 was used in the absence of measured data. The following table presents the mean annual air temperature for each assessment unit:

Table D.7 Mean Annual Air Temperature as an Estimate for Accretion Temperature

Assessment Unit	Ref.	Mean Annual Air Temperature (°C)	Mean Annual Air Temperature (°F)
NM-2214.A_091	(a)	8.81	47.853
NM-2214.A_090	(b)	8.88	47.982
NM-2214.A_102	(a)	8.81	47.853
NM-2212_00	(c)	10.69	51.250
NM-2214.A_003	(b)	8.88	47.982

Notes:
Ref. = References for Weather Station Data are as follows:

*(a) New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)****, 2001***

*(b) New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)****, 2003***

*(c) New Mexico State University Climate Network (Las Vegas METAR Station, Elevation 2,091 meters; Latitude 35° 39' N, Longitude 105° 08' W)****, 2003***

ºF = Degrees Farenheit
ºC = Degrees Celcius

D 3.0 GEOMETRY

D3.1 Latitude

Latitude refers to the position of the stream segment on the earth's surface. Latitude is generally determined in the field with a global positioning system (GPS) unit. Latitude for each assessment unit is summarized below:

Table D.8 Assessment Unit Latitude

Assessment Unit	Latitude (decimal degrees)
NM-2214.A_091	35.62
NM-2214.A_090	35.48
NM-2214.A_102	35.53
NM-2212_00	35.70
NM-2214.A_003	35.54

D3.2 Dam at Head of Segment

The following assessment units have a dam at the upstream end of the segment with a constant, or nearly constant diel release temperature:

Table D.9 Presence of Dam at Head of Segment

Assessment Unit	Dam?
NM-2214.A_091	No
NM-2214.A_090	No
NM-2214.A_102	No
NM-2212_00	No
NM-2214.A_003	No

D3.3 Segment Length

Segment length was determined with National Hydrographic Dataset Reach Indexing GIS tool. The segment lengths are as follows:

Table D.10 Segment Length

Assessment Unit	Length (miles)
NM-2214.A_091	15.28
NM-2214.A_090	15.6
NM-2214.A_102	22.3
NM-2212_00	24.21
NM-2214.A_003	5.7

D3.4 Upstream Elevation

The following upstream elevations were determined with National Hydrographic Dataset Reach Indexing GIS tool.

Table D.11 Upstream Elevations

Assessment Unit	Upstream Elevation (feet)
NM-2214.A_091	10,000
NM-2214.A_090	6,900
NM-2214.A_102	11,000
NM-2212_00	10,000
NM-2214.A_003	6,890

D3.5 Downstream Elevation

The following downstream elevations were determined with National Hydrographic Dataset Reach Indexing GIS tool.

Table D.12 Downstream Elevations

Assessment Unit	Downstream Elevation (feet)
NM-2214.A_091	6,900
NM-2214.A_090	6,300
NM-2214.A_102	6,900
NM-2212_00	6,700
NM-2214.A_003	6,700

D3.6 Width's A and Width’s B Term

Width’s B Term was calculated as the slope of the regression of the natural log of width and the natural log of flow. Width-versus-flow regression analyses were prepared by entering cross-section field data into a Windows-Based Stream Channel Cross-Section Analysis (WINXSPRO) Program (U.S. Department of Agriculture [USDA] 1998). 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, the Width’s B-Term was first calculated as the slope and 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)

The following table summarizes Width's A- and B-Terms for assessment units requiring temperature TMDLs:

Table D.13 Width's A and Width's B Terms

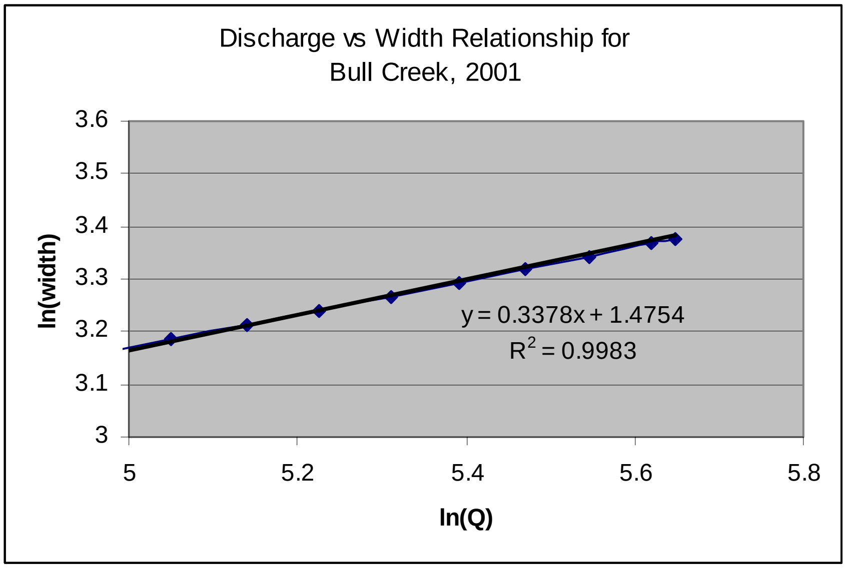
Assessment Unit	**Width's B-Term**	**Width's A-Term**[(1)]
NM-2214.A_091	0.338	4.37
NM-2214.A_090	0.227	7.00
NM-2214.A_102	0.338[(2)]	4.37[(2)]
NM-2212_00	1.40	18.38
NM-2214.A_003	0.045	52.20

[(1)] A = e^constant from regression.
[(2)] No cross-section data available-estimated values to be that of NM-2214.A_091

The following figures present the detailed calculations for the Width's B-Term.

Measurements were collected at one site within these assessment units. The regression of natural log of width and natural log of flow for each location is as follows:

Figure D.1 Wetted Width versus Flow for Assessment Unit NM-2214.A_091



SUMMARY OUTPUT

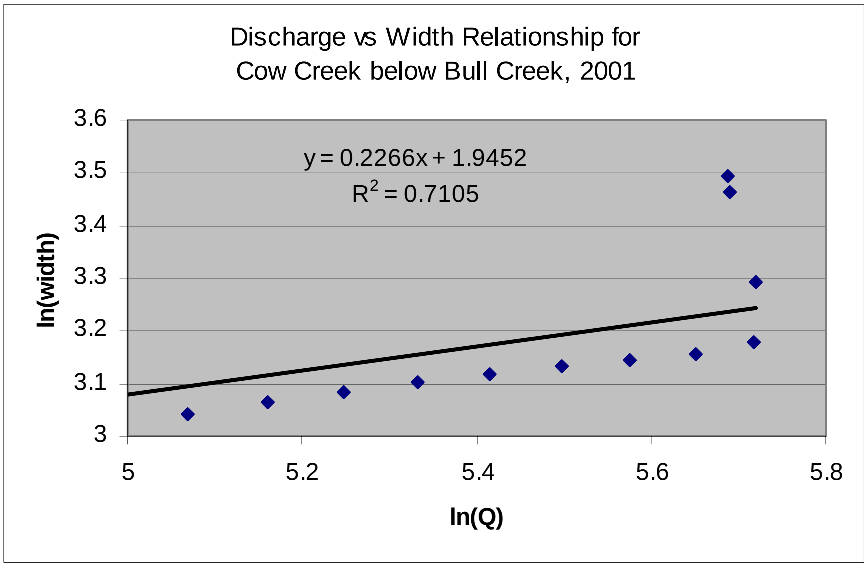
Regression Statistics	
Multiple R	0.999155912
R Square	0.998312537
Adjusted R Square	0.998213274
Standard Error	0.007609021
Observations	19

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.582289096	0.582289096	10057.293	5.1541E-25
Residual	17	0.000984252	5.78972E-05		
Total	18	0.583273348			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.475375719	0.016627714	88.72992176	4.115E-24	1.440294261	1.510457177	1.440294261	1.510457177
X Variable 1	0.337823164	0.003368596	100.2860576	5.154E-25	0.330716039	0.344930289	0.330716039	0.344930289

Figure D.2 Wetted Width versus Flow for Assessment Unit NM-2214.A_090



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.84
R Square	0.71
Adjusted R Square	0.70
Standard Error	0.09
Observations	22.00

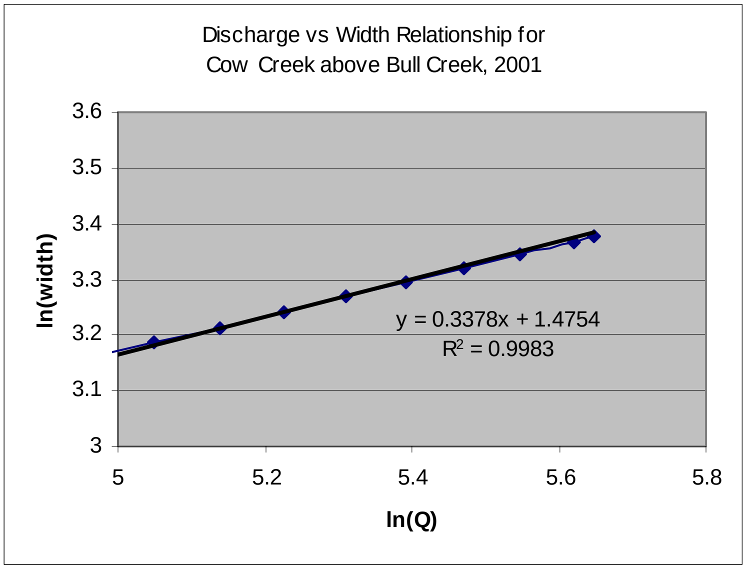
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.42	0.42	49.08	0.00
Residual	20.00	0.17	0.01		
Total	21.00	0.60			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95%*	*Upper 95%*
Intercept	1.95	0.16	11.94	0.00	1.61	2.29	1.61	2.29
X Variable 1	0.23	0.03	7.01	0.00	0.16	0.29	0.16	0.29

Figure D.3 Wetted Width versus Flow for Assessment Unit NM-2214.A_102

Note: no cross-section data was available for this assessment unit; data from NM-2214.A_091 was used.



SUMMARY OUTPUT

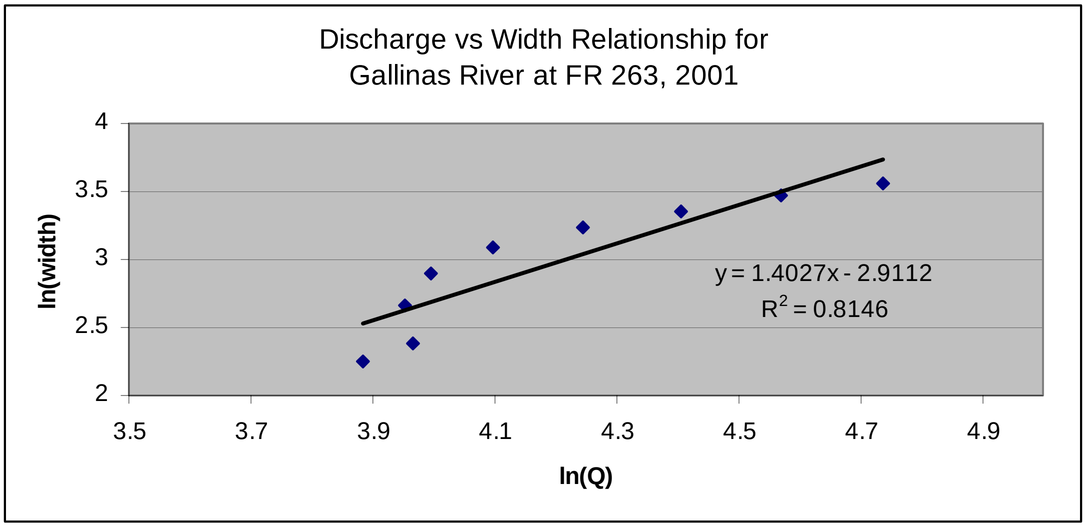
Regression Statistics	
Multiple R	0.999155912
R Square	0.998312537
Adjusted R Square	0.998213274
Standard Error	0.007609021
Observations	19

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.582289096	0.582289096	10057.293	5.1541E-25
Residual	17	0.000984252	5.78972E-05		
Total	18	0.583273348			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.475375719	0.016627714	88.72992176	4.115E-24	1.440294261	1.510457177	1.440294261	1.510457177
X Variable 1	0.337823164	0.003368596	100.2860576	5.154E-25	0.330716039	0.344930289	0.330716039	0.344930289

Figure D.4 Wetted Width versus Flow for Assessment Unit NM-2212_00



SUMMARY OUTPUT

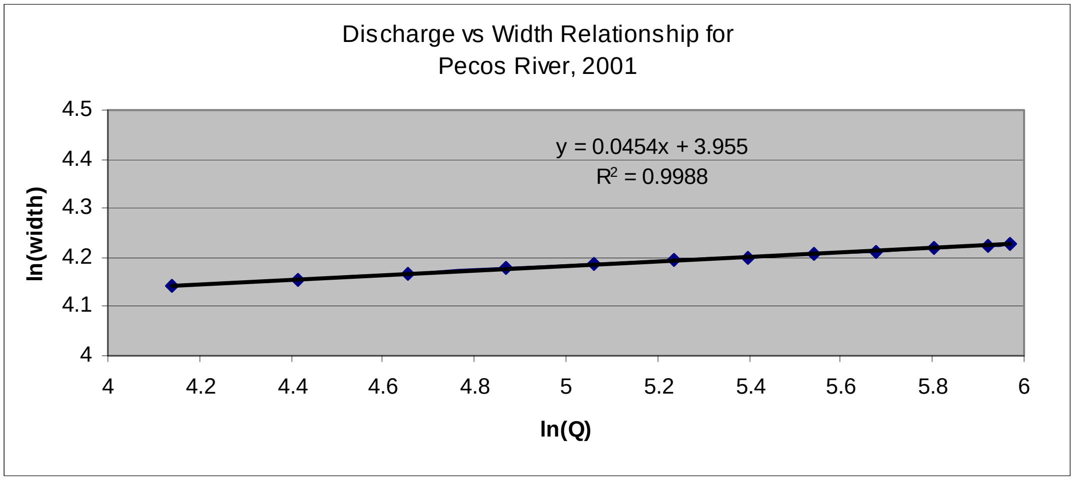
Regression Statistics	
Multiple R	0.90
R Square	0.81
Adjusted R Square	0.79
Standard Error	0.22
Observations	9.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	1.45	1.45	30.76	0.00
Residual	7.00	0.33	0.05		
Total	8.00	1.78			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95%*	*Upper 95%*
Intercept	-2.91	1.07	-2.73	0.03	-5.43	-0.39	-5.43	-0.39
X Variable 1	1.40	0.25	5.55	0.00	0.80	2.00	0.80	2.00

Figure D.5 Wetted Width versus Flow for Assessment Unit NM-2214.A_003



SUMMARY OUTPUT

Regression Statistics	
Multiple R	1.00
R Square	1.00
Adjusted R Square	1.00
Standard Error	0.00
Observations	12.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.01	0.01	8068.90	0.00
Residual	10.00	0.00	0.00		
Total	11.00	0.01			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95%*	*Upper 95%*
Intercept	3.95	0.00	1487.47	0.00	3.95	3.96	3.95	3.96
X Variable 1	0.05	0.00	89.83	0.00	0.04	0.05	0.04	0.05

D3.7 Manning's n or Travel Time

Site-specific values generated from WINXSPRO were used for Manning's n. The following table summarizes the input values:

Table D.14 Manning's n Values

Assessment Unit	Manning's n
NM-2214.A_091	0.052
NM-2214.A_090	0.055
NM-2214.A_102	0.052 [(1)]
NM-2212_00	0.066 [(2)]
NM-2214.A_003	0.051

[(1)] no data available-used value for site NM-2214.A_091
[(2)] average of upstream and downstream sites

D 4.0 METEOROLOGICAL PARAMETERS

D4.1 Air Temperature

This parameter is the mean daily air temperature for the assessment unit (or average daily temperature at the mean elevation of the assessment unit). Air temperature will usually be the single most important factor in determining mean daily water temperature. Air temperature was measured directly (in the shade) using air thermographs and adjusted to what the temperature would be at the mean elevation of the assessment unit. The following table summarizes mean daily air temperatures for each assessment unit (for its modeled date) requiring a temperature Total Maximum Daily Load (TMDL):

Table D.15 Mean Daily Air Temperature

Assessment Unit	Elevation at Air Thermograph Location (meters)	Measured Mean Daily Air Temperature (°C)	Mean Elevation for Assessment Unit (meters)	Adjusted Mean Daily Air Temperature (°C)	Adjusted Mean Daily Air Temperature (°F)
NM-2214.A_091	2,621[(a)]	16.47[(a)]	2,576	16.77	62.19
NM-2214.A_090	2,071	21.86	2,012	22.25	72.05
NM-2214.A_102	2,621[(b)]	14.22[(b)]	2,728	13.52	56.34
NM-2212_00	2,093	20.73	2,545	17.76	63.97
NM-2214.A_003	2,057	21.59	2,071	21.50	70.70

Notes:
[(a)] Mean daily temperature for **July 7, 2001** from New Mexico State University Climate Network (Pecos RAWS Station at 2,621 meters elevation).
[(b)] Mean daily temperature for **July 22, 2001** from New Mexico State University Climate Network (Pecos RAWS Station at 2,621 meters elevation).

ºF = Degrees Farenheit
ºC = Degrees Celcius

The adiabatic lapse rate was used to correct for elevational differences from the met station:

$$T_a = T_o + C_t \times (Z - Z_o)$$

where,

T_a = air temperature at elevation E (°C)
T_o = air temperature at elevation E_o (°C)
Z = mean elevation of segment (meters)
Z_o = elevation of station (meters)
C_t = moist-air adiabatic lapse rate (-0.00656 °C/meter)

D4.2 Maximum Air Temperature

Unlike the other variables, the maximum daily air temperature overrides only if the check box is checked. If the box is not checked, the SSTEMP Model estimates the maximum daily air temperature from a set of empirical coefficients (Theurer et al., 1984 as cited in Bartholow 2002) and will print the result in the grayed data entry box. A value cannot be entered unless the box is checked.

D4.3 Relative Humidity

Relative humidity data were obtained from the Western Regional Climate Center web site (www.wrcc.dri.edu) or the New Mexico State University Climate Network (http://weather.nmsu.edu/data/data.htm). The data were corrected for elevation and temperature using the following equation:

$$R_h = R_o \times \left(1.0640^{(To-Ta)}\right) \times \left(\frac{T_a + 273.16}{T_o + 273.16}\right)$$

where,

R_h = relative humidity for temperature T_a (decimal)
R_o = relative humidity at station (decimal)
T_a = air temperature at segment (°C)
T_o = air temperature at station (°C)

The following table presents the adjusted mean daily relative humidity for each assessment unit:

Table D.16 Mean Daily Relative Humidity

Assessment Unit	Ref.	Mean Daily Air Temp. at Weather Station (°C)	Mean Daily Air Temperature at AU (°C)	Mean Daily Relative Humidity at Weather Station (percent)	Mean Daily Relative Humidity for AU (percent)
NM-2214.A_091	(a)	16.47	16.77	36.166	35.54
NM-2214.A_090	(b)	22.78	22.25	38.750	39.97
NM-2214.A_102	(c)	14.22	13.52	62.729	65.35
NM-2212_00	(d)	20.73	17.76	45.161	53.75
NM-2214.A_003	(e)	21.99	21.50	49.292	50.73

Notes:
Ref. = References for Weather Station Data are as follows:
(a) *New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)* ***July 7, 2001***
(b) *New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)* ***July 19, 2003***
(c) *New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)* ***July 22, 2001***

(d) *New Mexico State University Climate Network (Las Vegas METAR Station, Elevation 2,091 meters; Latitude 35° 39' N, Longitude 105° 08' W)* ***July 31, 2003***
(e) *New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)* ***July 18, 2003***

AU = Assessment Unit
ºC = Degrees Celcius

D4.4 Wind Speed

Average daily wind speed data were obtained from the New Mexico State University Climate Network (http://weather.nmsu.edu/data/data.htm). The following table presents the mean daily wind speed for each assessment unit:

Table D.17 Mean Daily Wind Speed

Assessment Unit	Ref.	Mean Daily Wind Speed (miles per hour)
NM-2214.A_091	(a)	6.198
NM-2214.A_090	(b)	4.750
NM-2214.A_102	(c)	5.280
NM-2212_00	(d)	11.316
NM-2214.A_003	(e)	3.208

Notes:
Ref. = References for Weather Station Data are as follows:
(a) *New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)* ***July 7, 2001***
(b) *New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)* ***July 19, 2003***
(c) *New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)* ***July 22, 2001***
(d) *New Mexico State University Climate Network (Las Vegas METAR Station, Elevation 2,091 meters; Latitude 35° 39' N, Longitude 105° 08' W)* ***July 18, 2003***
(e) *New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W)* ***July 18, 2003***

D4.5 Ground Temperature

Mean annual air temperature for 2001 and 2003 were used in the absence of measured data. The following table presents the mean annual air temperature for each assessment unit:

Table D.18 Mean Annual Air Temperature as an Estimate for Ground Temperature

Assessment Unit	Ref.	Mean Annual Air Temperature (°C)	Mean Annual Air Temperature (°F)
NM-2214.A_091	(a)	8.81	47.853
NM-2214.A_090	(b)	8.88	47.982
NM-2214.A_102	(a)	8.81	47.853
NM-2212_00	(c)	10.69	51.250
NM-2214.A_003	(b)	8.88	47.982

Notes:
Ref. = References for Weather Station Data are as follows:
(a) New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W) ***2001***
(b) New Mexico State University Climate Network (Pecos RAWS, Elevation 2,621 meters; Latitude 35° 34' N, Longitude 105° 29' W) ***2003***
(c) *New Mexico State University Climate Network (Las Vegas METAR Station, Elevation 2,091 meters; Latitude 35° 39' N, Longitude 105° 08' W)* **2003**
ºF = Degrees Farenheit
ºC = Degrees Celcius

D4.6 Thermal Gradient

The default value of 1.65 was used in the absence of measured data.

D4.7 Possible Sun

Percent possible sun for Albuquerque is found at the Western Regional Climate Center web site http://www.wrcc.dri.edu/htmlfiles/westcomp.sun.html#NEW%20MEXICO. The percent possible sun is 76 percent for July.

D4.8 Dust Coefficient

If a value is entered for solar radiation, SSTEMP Model will ignore the dust coefficient and ground reflectivity and "override' the internal calculation of solar radiation. Solar radiation data are available from the New Mexico State University Climate Network (see Section 4.10).

D4.9 Ground Reflectivity

If a value is entered for solar radiation, SSTEMP Model will ignore the dust coefficient and ground reflectivity and "override' the internal calculation of solar radiation. Solar radiation data are available from the New Mexico State University Climate Network (see Section 4.10).

D4.10 Solar Radiation

Because solar radiation data were obtained from an external source of ground level radiation, it was assumed that about 90% of the ground-level solar radiation actually enters the water. Thus, the recorded solar measurements were multiplied by 0.90 to get the number to be entered into the SSTEMP Model. Solar radiation data were not available for either the Pecos RAWS or Las Vegas METAR stations, so the nearest station with solar radiation was used. The following table presents the measured solar radiation at Mora station for 2001 and 2003:

Table E.19 Mean Daily Solar Radiation

Assessment Unit	Ref.	Date	Mean Solar Radiation (L/day)	Mean Solar Radiation x 0.90 (L/day)
NM-2214.A_091	(a)	7-7-2001	663.504	597.154
NM-2214.A_090	(a)	7-19-2003	465.576	419.018
NM-2214.A_102	(a)	7-22-2001	511.512	460.361
NM-2212_00	(a)	7-18-2003	588.720	529.848
NM-2214.A_003	(a)	7-18-2003	588.720	529.848

Ref. = References for Weather Station Data are as follows:

(a) New Mexico State University Climate Network (Mora, Elevation 2,195 meters; Latitude 35° 58' N, Longitude 105° 21' W)

D 5.0 SHADE

Percent shade was estimated for the assessment units using densiometer readings taken in 2001 and 2004. The measurements were averaged along with visual estimates using USGS digital orthophoto quarter quadrangles downloaded from New Mexico Resource Geographic Information System Program (RGIS), online at http://rgis.unm.edu/. This parameter refers to how much of the segment is shaded by vegetation, cliffs, etc. The following table summarizes percent shade for each assessment unit:

Table D.20 Percent Shade

Assessment Unit	Percent Shade
NM-2214.A_091	40%
NM-2214.A_090	40%
NM-2214.A_102	30%
NM-2212_00	40%
NM-2214.A_003	40%

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 http://www.fort.usgs.gov. Revised August 2002.

U.S. Department of Agriculture (USDA). 1998. WinXSPRO A Channel Cross Section Analyzer. West Consultants Inc. San Diego, CA.

U.S. Geological Survey (USGS). 2002a. Input and Output to a Watershed Data Management File (Version 4.1). Hydrologic Analysis Software Support Program. Available on the internet at http://water.usgs.gov/software/surface_water.html .

U.S. Geological Survey (USGS). 2002b. Surface-Water Statistics (Version 4.1). Hydrologic Analysis Software Support Program. Available on the internet at http://water.usgs.gov/software/surface_water.html .

Theurer, Fred D., Kenneth A. Voos, and William J. Miller. 1984. Instream Water Temperature Model. Instream Flow Inf. Pap. 16 Coop. Instream Flow and Aquatic System Group. U.S. Fish & Wildlife Service, Fort Collins, CO.

Thomas, Blakemore E., H.W. Hjalmarson, and S.D. Waltemeyer. 1997. Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States. USGS Water-Supply Paper 2433.

Viger, R.J., S.L. Markstrom, G.H. Leavesley and D.W. Stewart. 2000. The GIS Weasel: An Interface for the Development of Spatial Parameters for Physical Process Modeling. Lakewood, CO. Available on the internet at http://wwwbrr.cr.usgs.gov/weasel/.

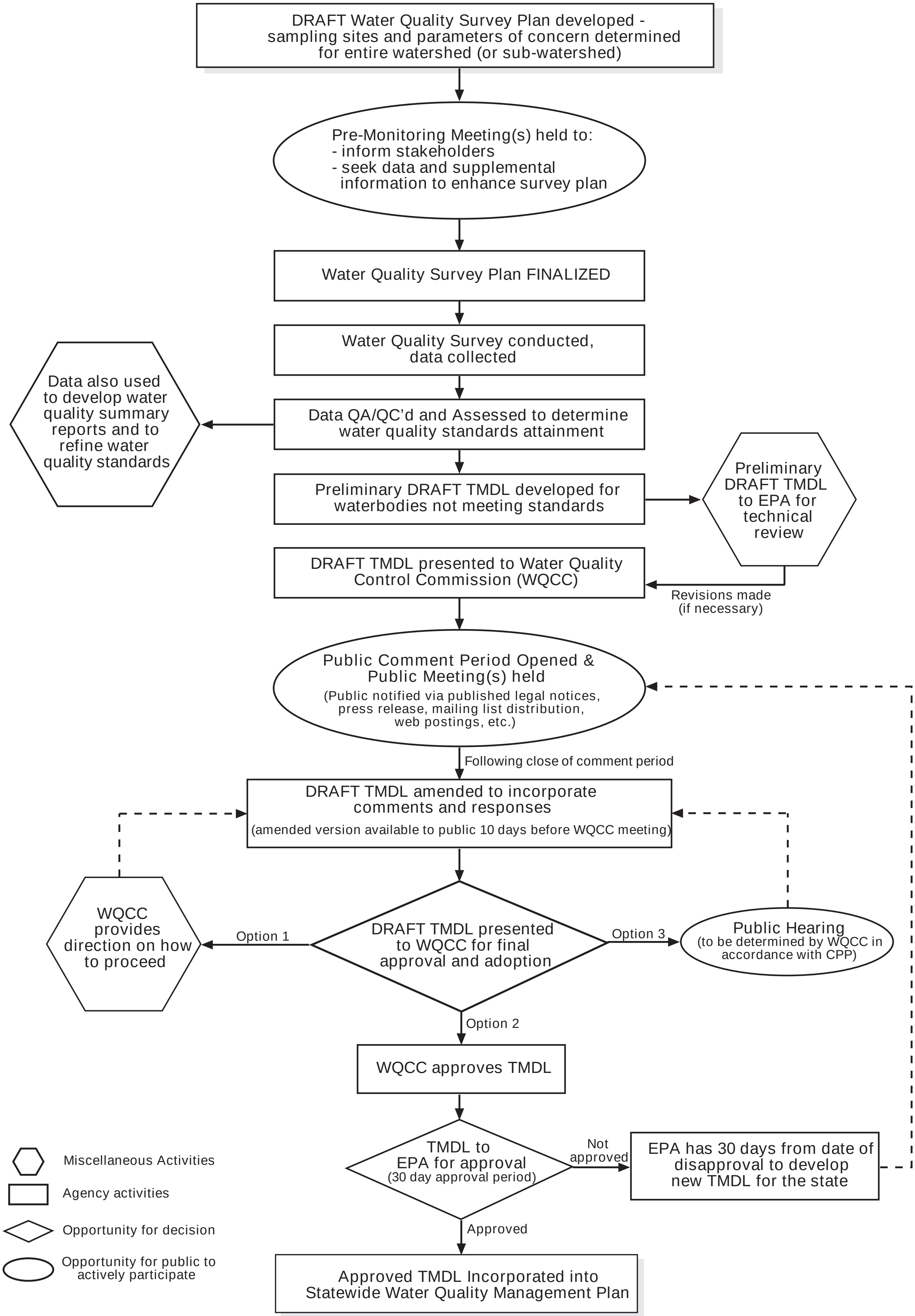
Waltemeyer, Scott D. 2002. Analysis of the Magnitude and Frequency of the 4-Day Annual Low Flow and Regression Equations for Estimating the 4-Day, 3-Year Low-Flow Frequency at Ungaged Sites on Unregulated Streams in New Mexico. USGS Water-Resources Investigations Report 01-4271. Albuquerque, New Mexico.

This page left intentionally blank.

APPENDIX E
PUBLIC PARTICIPATION PROCESS FLOWCHART

This page left intentionally blank.

Appendix E: Public Participation Process Flowchart



This page left intentionally blank.

APPENDIX F
RESPONSES TO COMMENTS

This page left intentionally blank.

Comments on Pecos Headwaters TMDL

Sent via Email, April 13, 2005 18:45

Janice Varela and Pancho Adelo
La Gente del Rio Pecos
H.C. 70 Box 12-A
Pecos, N M 87552

April 13, 2005

RE: Draft TMDL for the Upper Rio Pecos

On behalf of La Gente del Rio Pecos, a 100 member grassroots organization, we wish to submit the following comments regarding the TMDL study for the Upper Pecos.

COMMENT: We would like to begin with comments regarding the public meeting held in Pecos and lack of community residents at the meeting. While we appreciate the community meeting, one could not help but notice, there were only two citizens/non agency people at the meeting. We believe better notice of meetings like this is essential to the public participation process. Notice was not posted in the usual places such as the local stores and post office. Additionally, for future meetings, it is helpful to post notice in the Pecos weekly section of the Santa Fe New Mexican.

NMED/SWQB Response: Thank you for your comment. Notices of the Pecos Headwaters TMDL public meeting were posted at the Pecos Post Office, Town & Country General Store, and the Rowe Post Office & General Store. Notices were also published in the legal sections of the Albuquerque Journal North & Las Vegas Optic. Public service announcements were sent to the local radio stations KBAC and KEDP. Announcements were also sent to 109 individuals on our mailing list in Santa Fe & San Miguel Counties & 190 individuals on our statewide email list. Though we are often dealing with limited resources, we are interested in finding creative and effective ways to communicate with the public. We often rely on local governments and organizations, such as active watershed groups, to help spread the word about public meetings. Your suggestion of publishing meeting announcements in the Pecos weekly section of the Santa Fe New Mexican is helpful and we will keep that in mind for future announcements.

COMMENT: No sampling was done immediately bellow the waste water treatment plant, yet on page 38 you state there are serious violations upon your inspection, the report further states that this is a minimal contribution of the total pollution. Since 1998 there have been permit violations for turbidity and if you are not sampling immediately bellow how do you know the contribution to the total?

NMED/SWQB Response: Physical, chemical, and biological water quality sampling occurred during the 2001 survey below the Village of Pecos WWTP (page 5, site 54) and at the Village of Pecos WWTP (page 5, site 64). Turbidity and TSS data from the site below the Village of

Pecos WWTP were used in the turbidity TMDL calculations (page 26, Table 4.4). The WWTP effluent is not used in the TMDL calculation as the calculation is based on sampling stations within the mixing zone, thus characterizing the assessment unit as a whole rather than effluent discharge alone. The Village of Pecos WWTP contributes minimal flow to the Pecos River, and therefore only a small percentage of the turbidity load.

COMMENT: The next issue is the increase in target pollution for turbidity in the river in the section from Alamitos Canyon to Willow Creek, page 31, the measured load capacity is less than the target load (28,762 lbs/day v. 30,775 lbs/day). Why would you allow for more pollution in an already impaired river? If you are increasing the amount of allowable pollution then an antidegradation review should be conducted to evaluate the impact of increased pollution in this stretch.

NMED/SWQB Response: Thank you for your comment. Your comment prompted the recalculation of the measured loads for the four assessment units listed for turbidity and an error was found. There had been an earlier adjustment to the TSS arithmetic mean calculation (that would not include the July 31, 2001 outliers) in Tables 4.1 and 4.2; however, the subsequent tables in the original document did not reflect this change. The measured loads and load reductions in Tables 4.6 and 4.8 have been changed in the final document.

However, the measured load and load reductions for Pecos River (Alamitos Canyon to Willow Creek) are correct. The SWQB is not suggesting that more pollution be allowed in the river; in fact, the TMDL is showing the necessity for a significant load reduction from the measured load to the load allocation (Table 4.8). In the case of antidegradation, a study could be introduced during the review process for permit renewal.

COMMENT: The target load capacity for point sources is based on what is presently assumed to be discharged based on effluent limits of the permit. Our understanding of the TMDL process is that it is supposed to reduce pollution. Why is the waste load allocation not reduced for point sources? This is especially pertinent taking into consideration the contributions from the waste water treatment plant and the trout hatchery could be greater than reported (see comment above). Reducing the amount of pollution from these point sources seems to be one of the easiest way to reduce the total amount of pollution.

NMED/SWQB Response: Thank you for your comment. Both the Village of Pecos WWTP and the Lisboa Springs Fish Hatchery contribute less than 1% of the turbidity load to the Pecos River. The USEPA and the Point Source Regulation Section of the SWQB are aware of the discharge activities of these point sources. In the case of point sources, the 7-day average permit limit is used to calculate the waste load allocations, not reported values. The water quality parameters in the permits are written to ensure that a facility will not cause or contribute to an impaired stream. In the Pecos Headwaters watershed, non-point sources are the most significant contributor to water quality exceedences; therefore, the best avenue to restore watershed health is to focus community efforts on a holistic approach to watershed protection.

COMMENT: Pollution from construction sites should be taken into account because they collectively contribute to turbidity. Future growth will impact turbidity levels in the watershed and should be addressed by the TMDL. New homes mean new roads. Our close proximity to Santa Fe guarantees substantial growth. One only needs to go to Construction industries Division of the State of NM (NMCID) to see the amount of new building permits for this area, this can directly lead to more pollution from construction sites. The present stance of the TMDL that pollution from construction sites is controlled by storm water prevention plans (SWPPPs) is inadequate, especially for construction sites in close proximity to the river. Waste load allocations should be allocated to construction sites covered under a general storm water permit and construction sites not covered under a general permit should be assigned a load allocation.

NMED/SWQB Response: Thank you for your comment. SWQB agrees that construction activities in a watershed can adversely affect water quality. As stated in the TMDL, individual wasteload allocations for construction activities covered under general permits were not possible to calculate at this time using available data and analysis tools. Loads that are in compliance with the general permits are therefore currently calculated as part of the load allocation. SWQB does not have the tools, site-specific data, and/or resources to conduct the necessary detailed studies to be able to accurately determine waste load allocations from construction activities covered under general permits. Storm water discharges from construction activities are transient because they occur mainly during the construction itself, and often only during storm events. Therefore, protection of the receiving water is best addressed through individual SWPPPs that are required as part of the construction process.

SWQB has previously discussed this issue with EPA Region 6, and both parties performed research to determine if there are any examples from other states on how to approach this issue with construction activities covered under general permits. There are no good examples at this time, but several states are developing methods of including stormwater runoff from construction activities in their TMDLs; the SWQB will continue to review these approaches for possible use in future TMDLs.

COMMENT: Where are the guarantees that this TMDL document is not merely a paper exercise? La Gente del Rio Pecos holds that TMDLS, including their implementation plans, should be written as enforceable documents. On page 69 the TMDL states "Implementation of BMPs within the watershed to reduce pollutant loading from NPS will be encouraged." How will the Environment Department encourage BMPs? The implementation plan should include detailed plans as to what types of BMPs will be encouraged, and ideally required, to meet water quality standards. TMDLs, should be written with equal focus on presenting data on current conditions *and* implementing plans to clean up the river. Most TMDL documents are heavy on data on the current conditions and the target conditions but lack detail on how to get to that target. One and half pages out of seventy-six is not giving TMDL implementation adequate attention. This is especially of concern as the TMDL states on page 31 that "Meeting the calculated TMDL may be a difficult objective." The complexity and difficulty of meeting the calculated TMDL is all the more reason to focus the attention of the TMDL document towards implementation to provide a concrete plan as to how the TMDL will be realized.

Groups such as la Gente would support the department in TMDL implementation.

NMED/SWQB Response: Thank you for your comment. SWQB concurs that TMDLs may be more effective if they could be written as 100% enforceable documents. The final "TMDL Rule" published in the Federal Register July 13, 2000, would have given states the authority to regulate non point source discharge under the TMDL program. This rule was subsequently withdrawn by the USEPA due to intense pressure from the regulated community. As such, SWQB does not have the authority other than those noted in the Assurances section of the document to regulate non point sources.

Even so, SWQB believes TMDLs are not merely paper exercises. There are several required elements in TMDLs, per EPA guidance, which is why the TMDL itself is heavy on current conditions and target conditions. TMDLs are the guiding document for development of Watershed Restoration Action Strategies (WRAS) or Watershed Implementation Plans (WIP) by local stakeholders with assistance from the SWQB Watershed Protection Section (WPS). The WRAS or WIP is in essence the TMDL Implementation Plan, or phase 2 of the TMDL process. The WRAS provides details on the type and location of BMPs based on local stakeholder knowledge, individual stakeholder interest, and the technical restoration expertise of WPS staff that will best address the impairments detailed in the TMDL. Development of the TMDL and WRAS opens up funding opportunities through the Clean Water Act 319 program to implement these BMPs in the watershed. The WPS issued a Request for Proposal (RFP) in August 2004 for the Pecos Headwaters; watershed groups funded by these monies are currently forming in the watershed. SWQB has and will continue to encourage BMP implementation through technical assistance during the development of the WRAS, as well as technical assistance during development, implementation, and monitoring of CWA 319 projects.

Thank you in advance for your attention to these issues.

Sincerely,

Pancho Adelo